California Environmental Flows Framework:

Implementation Workplan

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Introduction and Goals of Workplan

The California Environmental Flows Framework (Framework) is an approach for establishing ecological flow criteria and environmental flow recommendations statewide. The Framework was developed over the course of several years by a diverse technical team in close coordination with agency partners and other stakeholders. The technical workgroup includes scientists and engineers from academia, agencies, and NGOs who have a broad range of expertise and experience in modeling and assessing environmental flows. The key objectives of the Framework are to standardize, streamline, and improve transparency of environmental flow assessments; provide flexibility to accommodate diverse management goals and priorities; and improve coordination and data sharing among management agencies. The Framework uses a functional flows approach for developing scientifically defensible environmental flow recommendations that balance human and ecosystem needs for water. The Framework is described in a detailed technical report available at https://ceff.ucdavis.edu/tech-report.

The purpose of this workplan is to identify additional efforts necessary to support statewide implementation of the Framework, including improvements in technical tools, tracking and standardizing the documentation of case studies, and establishing mechanisms for ongoing data and information sharing. The workplan is organized around major needs and expected products. This workplan should help to guide and organize efforts to advance implementation of the Framework by the parties involved in the Environmental Flows Workgroup. This plan is intended to be a “living document” and should be periodically reviewed and updated.

Overarching technical needs for supporting the Framework:

1. Targeted case studies across diversity of stream types and management contexts

Initial efforts to implement the Framework are in early stages of development and have been focused on a small subset of watersheds in California. There is a need to apply the Framework across a diversity of stream types, including systems in drier parts of the state, systems with strong groundwater contributions, and systems where environmental management priorities are not focused on threatened fish species. The Framework should also be tested in places where different approaches are needed to implement environmental flow recommendations. These may include large, regulated rivers that require changes in dam operations; smaller, unregulated rivers that require changes in the timing, volume, and location of diversions; and urban rivers that require changes in effluent discharges from wastewater treatment plants, as well as stormwater management. The goal of implementing the Framework through pilot case studies in diverse contexts is to assess the generalizability of the approach and identify where additional guidance or tools may be necessary to support development of environmental flow recommendations. The products of this effort would be recommendations for enhancing the Framework and examples/templates that could be used in other areas in the future.

2. Coordination with SGMA, Flood-MAR, and other programs

In many systems in California, implementation of environmental flow recommendations will require consideration of the interactions between surface water and groundwater, particularly in systems where groundwater inputs are a key contributor to summer baseflows. The Sustainable

Groundwater Management Act (SGMA) was enacted to limit groundwater overdraft and promote sustainable groundwater use. Under SGMA, groundwater use and management plans must limit “depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.” The Framework can be used to assess the potential impacts of surface flow depletions that may arise from lowered groundwater levels in locations where relationships between surface flow and groundwater conditions are understood. Improved coordination between implementation efforts for the Framework, SGMA, Flood-MAR, and other local groundwater management programs is particularly needed in heavily groundwater-dominated systems. Additional case studies of the Framework are needed in basins where SGMA is being implemented and will help illustrate how these two programs can coordinate and be mutually informative. Similarly, in basins where managed aquifer recharge efforts are proposed or underway (such as Flood-MAR), understanding the relationships between ecological flow criteria and management of groundwater conditions can lead to potentially more functional outcomes from both efforts. For example, ecological flow criteria for high flow pulses and wet season baseflows can provide guidance for determining whether and how much water may be available for aquifer recharge.

3. Guidance around design and evaluation of non-flow interventions (section B and C)

The Framework is structured around the scientific concept of functional flows - components of a river’s flow that sustain the biological, chemical, and physical processes upon which native freshwater species depend. A functional flows approach recognizes that the ecosystem functions are supported through the interaction of flowing water with physical habitat, including channel beds, banks, and floodplains. The condition of physical habitat is recognized as a mediating factor in influencing ecological-flow relationships and is considered in the development of ecological flow criteria in Sections A and B . However, the Framework does not provide guidance on how to evaluate potential interventions that modify physical habitat - such as gravel augmentation, large woody debris enhancement, or floodplain restoration - and will affect ecosystem functions and associated environmental water needs (i.e., ecological flow criteria). This guidance is also lacking in Section C, where physical habitat interventions could play an important role in navigating tradeoffs between ecological and human needs in the development of environmental flow recommendations. The Framework could be improved by providing more specific guidance and examples of how non-flow interventions can be evaluated in the development of ecological flow criteria and environmental flow recommendations. These additions could make the Framework better suited to a wider range of contexts, especially those in which water supplies are over-allocated.

4. Integration of climate change forecasts

Climate change is expected to affect streamflow patterns through changes in the timing and magnitude of precipitation and snowmelt as well as higher temperatures, which may affect evapotranspiration rates, alter plant communities, and directly affect aquatic organisms. Advances in our ability to have readily available daily streamflow estimates from different emission scenarios and Global Climate models provide opportunities to incorporate future climate projections into the Framework. Consideration of climate change can occur in all three sections of the Framework:

- ❖ Section A - natural flow estimates can be revisited to determine how climate change may affect the ranges for natural FFM and associated ecological flow criteria under future climate scenarios.
- ❖ Section B - changing flow conditions may affect sediment transport and channel morphology and changing temperatures may exacerbate potential adverse effects on species and habitats of management concerns. These interactions can be explored in Section B through revised flow - ecology relationships and ecological flow criteria that consider potential impacts of changes in climate.
- ❖ Section C - climate induced changes in flow will affect non-ecological as well as ecological water needs and availability. Tradeoff analyses under Section C should account for climate change scenarios and uncertainty when developing environmental flow recommendations that are practical and effectively balance multiple demands on water supplies. In addition, alteration analyses in Section C may compare natural flow estimates predicted for historical conditions with natural flow estimates predicted under climate change scenarios to consider how climate change may alter functional flow metrics and flow components.

5. Further development of functional flows calculator

The functional flows calculator quantifies functional flows for use in the Framework. The algorithm uses reference gages to calculate natural functional flow metrics that then form the training dataset for the predicted statewide natural functional flow metrics described in Section A. Several metric additions to the functional flows calculator have been identified that would help capture additional ecologically-relevant flow features and help managers implement reference-based functional flows.

- Three additional flow metrics could include: fall pulse frequency (% of years in which a fall pulse occurs), number of no-flow days in the dry season, and dry-season baseflow recession rate. These metrics are all easily calculated by the user for gage data, but would be a helpful addition to the statewide set of predicted (reference-based) metrics. Fall pulse frequency can vary widely between streams and, particularly in regulated streams, managers need to know how often a fall pulse should naturally occur. Similarly, the number of no-flow days provides a complement to the existing dry-season baseflow and can help managers understand how flows may change through the dry season and when to expect intermittent flows under natural conditions.
- To fully assess alteration, the functional flows calculator would need to be expanded to manage a broader array of highly altered stream types. The calculator was developed to accurately identify functional flow metrics from the reference gage set. However, flow patterns in some streams are so altered that the algorithm is unable to compute key flow metrics, and as a result the alteration assessment (Section C) cannot be performed. Changes in the algorithm to either incorporate a seasonality metric to screen for this type of problem or to identify metrics on more highly altered streams would improve user ability to assess alteration.

Section A Needs

6. Additional models/tools to address groundwater-dependent ecosystems and intermittent streams and improve modeling of specific flow components

Hydrologic models have been developed to predict natural functional flow metrics at all streams in the state (https://rivers.codefornature.org/). The natural range of functional flow metrics are estimated using a statistical modeling approach, which quantifies the relationships between observed flows at reference-quality gages and catchment characteristics. The models generally perform well in predicting functional flow metrics, but improvements in predictive accuracy would be helpful in supporting the analyses and implementation steps in the Framework. Improvements in the performance of low-flow metric models, in particular, would be helpful for understanding natural, baseline conditions in relation to observed, current conditions, for assessing ecosystem needs, and for quantifying the influence of human activities. There is also a need to improve predictions of functional flow metrics in intermittent and ephemeral streams that experience periods of zero-flow and in streams strongly influenced by groundwater interactions. Efforts to improve model predictions would help support implementation of the Framework, particularly in more arid regions of the state and those subject to requirements of the Sustainable Groundwater Management Act.

7. Comparisons of statewide functional flow modeling and site-specific/regional models

The statistically based hydrologic models developed to predict functional flow metrics provide a consistent approach to evaluating natural flow ranges across diverse regions of the state. However, several regional hydrologic models exist in various locations that provide higher spatial and temporal resolution than the statistical hydrologic models developed for the Framework. For example, the Department of Water Resources has unimpaired flow models for the Sierra Nevada watersheds, many integrated surface-groundwater models have been developed in support of SGMA implementation, the State Water Resources Control Board has hydrologic models for several watersheds assessed in the California Water Action Plan, and several utilities and local water agencies have watershed-scale hydrologic models for basins in southern California. Comparisons between these locally-calibrated, physically-based models and the statewide statistical models would help to elucidate the advantages and disadvantages of each approach, highlight uncertainties inherent in each of the different modeling approaches, and inform the conditions when one modeling approach may be preferred over another for determining and evaluating ecological flow criteria. Additional guidance is needed to navigate the strengths and weaknesses of different modeling approaches within the Framework. Detailed comparisons between various modeling approaches in basins or regions where multiple models exist can also improve our understanding of the range of natural flow conditions, the degree of interannual flow variability, and the importance of groundwater contributions in various systems.

8. Natural flows database modeling updates (post-2015)

The Framework relies on predictions of functional flow metrics that are representative of natural hydrology as a starting point for developing ecological flow criteria. These flow metric predictions are publicly available on a web app (https://rivers.codefornature.org/) for visualization and download, along with predictions of monthly natural flows. Both datasets (functional flow metrics and monthly natural flows) represent the time period from 1950-2015 and need to be updated over time to represent current hydrology. The original monthly flow modeling was completed as a static product, without the ability to incorporate updated input data or to integrate model components to efficiently produce updated model results. Modifications to enable these tools to be updated more regularly will be increasingly important as local weather conditions shift under climate change. Updated predictions will enable comparison of current and natural conditions to better highlight flow alteration. There is also a need to update and streamline the modeling process, including translating various model languages into python, validating the updated model with current training data from reference gages, and documenting the modeling updates.

Section B Needs

9. Tools to support Section B (i.e. interactions with temperature, geomorph, etc.)

A variety of tools were developed for Section B of the Framework to help support additional site specific analysis of channel morphology considerations and flow-ecology relationships. These include development of geomorphic steam classifications (Appendix F), umbrella fish species life history requirements that serve to represent the full fish community assemblage (Appendix H), an analysis of the relationships between the degree of flow alteration and the benthic macroinvertebrate community (Appendix I), and an altered streamflow classification (Appendix N). However, further analysis is needed to improve our understanding of the interactions between changes in flow and changes in stream temperature or channel morphology, which directly impact habitat suitability conditions for aquatic species. Enhanced development of relationships between channel morphology and various functional flow metrics via hydraulic models will help to inform relationships between flow, habitat suitability, and aquatic species needs that can then be assessed in relation to ecological functions identified in Section A. Additional consideration of the impacts of flow alteration on umbrella species and other focal species, including fish, benthic macroinvertebrates, and algal communities, will help to further understanding of how flow criteria can best support various ecological functions in stream systems. Analysis of the interacting effects of flow alteration and temperature, and the resulting effects on aquatic species would also support more comprehensive application of the steps in Section B.

Section C Needs

10. **Development of a monitoring and adaptive management strategy** that's specific to the Framework and an associated data repository. As environmental flows developed using the Framework are implemented throughout California, monitoring data should be collected in a way that allows the data to be compiled and compared. A functional flows approach has not yet been adapted for management at a statewide scale, and careful data collection at a variety of sites will be an important piece of the development of the Framework, enabling practitioners to assess how well the selected functional flow metrics support stream condition. It will be important over time to evaluate whether streams are responding as expected relative to our assumptions of functional flows and what methods can best be used

to demonstrate function. To enable this assessment, a focused effort is needed to 1) develop consistent methods, protocols, and data structures and 2) develop consistent performance standards that support a process to track and assess outcomes of flow management actions across projects, It will also be important to develop relationships with existing monitoring programs and identify opportunities to partner/leverage efforts.

11. Additional Section C guidance and examples around decision-support/ decision-analysis

Section C provides general guidance on balancing ecological flow criteria with competing management objectives through tradeoff analyses to develop a final set of environmental flow recommendations. However, the guidance is less prescriptive than that in sections A and B due to the numerous sociopolitical, site-specific, and non-flow based considerations in this process. For example, tradeoffs can be between human and environmental objectives (i.e. flow balancing), or a decision of which ecological metrics to support with a given amount of water (e.g. frequency vs. duration of peak flows). Numerous tools and frameworks are available or could be adapted to perform trade-off analyses and provide decision-support for balancing. A literature survey or meta analysis of tradeoffs from other states and countries would facilitate user implementation. This analysis should include approaches for evaluating ecological and social tradeoffs between various competing objectives. The analysis could produce a set of available tools and resources that CEFF users could explore to support their Section C process. Additional CEFF case studies including trade-off analyses and decision-support systems in the context of specific ecological and non-ecological management goals, scenarios and regulations would also support effective implementation of Section C steps and the larger Framework.

12. Modeling of actual flows and/or actual functional flow metrics to enable alteration analyses (all Section C work) with Upstream tech

The Framework provides predictions of natural functional flow metrics for all NHD+ stream segments in California. However, data on actual flows are limited. Actual flow data (observed or modeled) are needed to assess flow alteration and estimate flow volumes necessary to achieve ecological flow criteria. The Nature Conservancy is working with Upstream Tech (https://upstream.tech/) to predict a 20-year record of daily actual flows at 300 USGS stream gages across California using a machine learning approach. Results from this pilot study can be used to develop models to predict actual daily flows at ungaged stream reaches across the state. Ideally, actual flows could be modeled at all NHD+ stream segments in California for at least the most recent 20-year time period, uploaded to the functional flows calculator to calculate actual functional flow metrics, and compared with Framework predictions of natural functional flow metrics to assess flow alteration. Actual functional flow metrics and alteration status could be added to the Natural flows web tool (https://rivers.codefornature.org/) to provide alteration assessments for streams across the state.

Components that need longer-term maintenance and development

The Framework is supported by various tools, websites, and other resources. These resources need to be maintained and updated over time to ensure their continued accessibility, relevancy, and utility in supporting Framework implementation. These include:

- **Ongoing FAQs** and process for soliciting and responding to common questions
- **Maintenance and support of eflows website**. The functional flows calculator is currently hosted on the eflow.ucdavis.edu website. Resources to maintain functionality of the calculator and website are needed.
- **Maintenance and support of The Nature Conservancy's Natural Flows web tool.** The Natural Flows web tool provides public access (data visualization and download) to functional flow metrics predicted for all stream segments in the NHD+ hydrography, as well as other data such as predictions of monthly natural flows from 1950-2015. The web tool requires ongoing maintenance, modifications, and improvements as datasets are updated, issues in the NHD+ stream hydrography are identified and corrected, and other issues arise.
- **Development and maintenance of Framework R package and associated documentation.** For users that are familiar with R, a package has been developed to complete the steps needed to download natural functional flow metrics for any gage or stream location, compare observed metrics (from modeled or gaged data) versus predicted metrics to determine potential flow alteration, and create a series of plots illustrating the metric comparisons. This package needs added functionality to visualize flow metrics on the annual hydrograph, compare two user-defined flow time series, and generate additional interpretive plots. The package could be made widely accessible by translating it into a user-friendly shiny app with an associated user's guide and documentation.
- **Case study documentation webportal and tracking of outcomes.** A variety of case studies are and will be implemented across the state. A metadata and case study documentation template has been developed (Appendix M) to help users document, catalogue, and track these case studies and associated data, products, and reports in a clear and consistent manner. However, a webportal/geodatabase is needed to inventory the case studies and associated documentation. Ongoing webportal maintenance and tracking of outcomes will also be necessary to inform future case studies implementing the Framework.
- **Data management infrastructure** (for data generated through implementation and monitoring of the Framework). As case studies are developed, a system that would enable monitoring data to be compiled and compared across projects would support continued development and improvement of Framework tools. Ideally practitioners would also be able to learn from similar projects.
- **Development of a strategic communications plan** that includes statewide roll-out of Framework materials (e.g. fact sheet, press release, website) to agencies, stakeholders, and other interested groups. This should include agency briefings, workshops with training materials, recorded presentations, and coordination with other agency program training as appropriate.