Report from June 2015 Meeting of Nutrient Science Advisory Panel for California Wadeable Streams

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The California Stream Nutrient Science Advisory Panel (NSAP) met with State Water Board staff, the Stakeholder Advisory Group, and multiple stakeholders on June 2-3, 2015. The NSAP was charged with addressing two questions:

1. What refinements or additional elements to the Science Plan does the Panel suggest to improve scientific support for the State Water Board staff's work plan (SWRCB 2014)?
2. What specific refinements or elements would aid in directly addressing stakeholder concerns or issues?

Prior to the meeting, the NSAP reviewed the Wadeable Streams Science Plan (Science Plan, Sutula et al. 2014), the State Water Board Work Plan for Nutrient Objectives (Work Plan, SWRCB 2014), stakeholder comments on both those plans, and the Tetra Tech 2006 Report. In addition, we reviewed at least the executive summary of the Fetscher et al. (2014) ORD report.

We address the two charge questions in this report with an overview of our findings at the beginning and a stakeholder-oriented recap at the end of the report. We have two appendices at the end that resulted from more detailed discussions on specific topics.

We applaud the Water Board staff for designing a thorough, state-of-the-science approach for developing stream nutrient targets for protecting beneficial uses. The Work Plan and Science Plan provide an approach, the numeric nutrient endpoint approach, to generate the information that will be needed to support a variety of different management options, including accounting for natural variation and restoration potential of sites. A key element of the Science Plan is developing relationships among nutrient concentrations, algal responses, biological condition, and beneficial uses, which can inform the application of science to a variety of policies, including: accounting for natural variation among streams and accounting for management potential with the the Biological Condition Gradient (BCG) and translation of relationships between the BCG, tiered aquatic life uses, and other tiered beneficial uses. The statistical methods used by the Technical Team are state-of-the-art and designed to control for interactions among variables and non-linear relationships among variables. In addition, engaging stakeholders throughout the scientific and policy development stages of nutrient criteria development was recognized as important.

The NSAP developed a number of recommendations for the Water Board staff and Technical Team to consider, which we have organized in this report by Tasks in the Science Plan.

Implementation

Policy and policy implementation options should be detailed to provide guidance for the science that will be needed to support those options. We think policy options can be listed with a discussion about how they would be integrated and implemented to protect CA waters without making commitments for policy decisions. For example, one policy option is to have one nutrient concentration target for all streams. Another policy option is to have different nutrient targets for different natural "classes" of streams (see Appendix A) and different "tiers" of beneficial uses designated for streams. Examples of implementation questions include, "How will nutrient targets be established for streams?" "How will it be determined whether a stream meets or fails to meet those targets?" Different research is needed to support different policies and approaches for implementation.

Clarifying terms associated with policy options to provide for consistent and clear communication with all stakeholders. For example, "classification" can be used as shorthand for a plan to account for natural variability in stream nutrient concentrations (or watershed loading), versus tiering, which is related to the Biological Condition Gradient (BCG) and Tiered Aquatic Life Uses (TALU). "Tiering" can be used as shorthand for protecting different levels of beneficial uses, including but not limited to aquatic life use.

Engage a more diverse set of stakeholders to provide input on policy options, implementation strategies, and concerns about science underpinning policy and implementation. The stakeholders involved with the June 2015 meeting did not include a balance of stakeholders from the environmental and regulated communities.

Conceptual Approach, Waterbody Definition, Classification and Status

Given the diversity of management options that are possible, consider the science that will be needed for implementing those policies, end-to-end, i.e. from altering expectations based on natural potential (classification), determining nutrient targets needed to support possible beneficial uses, altering beneficial use expectations for restoration potential (tiering, TALU, and BCG), determining whether beneficial use and nutrient targets are being met, and planning effective management and protection strategies based on current status.

Emphasize to stakeholders and science planners, that the BCG conceptual framework can be used to establish management goals at multiple levels of biological condition. The BCG enables protection (preservation/conservation) of high quality waters as well as those with less than highest quality biological condition, thereby allowing for management of tradeoffs among multiple in-stream and watershed-scale beneficial uses (Davies and Jackson 2006, Stevenson and Sabater 2010, Stevenson 2011). The BCG can also be used to establish incremental goals for restoration.

Consider using continuous models, versus categorical models, for establishing stream expectations related to natural potential (classification) and restoration potential (tiering and BCG). This will enable establishment of site (segment or watershed) specific goals for management.

The threshold analysis was good, but the difference in how resilience vs. exhaustive thresholds relate to policy should be thought through and integrated into future research.

The expert-elicited BCG is a thoughtful way to express stream response to nutrients and other forcings as well as an assessment of current status.

- If the result of this elicitation is a “crunched BCG” (e.g., tiers 3-5, with few 1's and 6's), the experts could be asked to describe conditions that would result in a 1 or 6 class.
- The Bayesian CART can be used to define stream tiers. The CART portion of the analysis would yield the set of physical conditions (e.g., habitat, substrate, temperature) that define each class. The remaining unexplained variance at the end nodes would be used to yield regression models for the effect of nitrogen and phosphorus.
- The expert-elicited BCG could serve as the response variable for CART/regression modeling with stream physical, chemical, and biological variables as predictors. This would yield a quantitative characterization of the experts' mental models and also indicate the relative importance of TN and TP as predictors of BCG.

Science

More explicitly link nutrient sources (e.g. land use and point-sources) to in-stream nutrient concentrations in the conceptual approach, thereby linking human activities to nutrients, algal responses, and beneficial uses, while accounting for natural variability.

Gather information to aid in planning success for different restoration strategies, early indicators of restoration, and legacy effects that can slow progress of restoration efforts.

Develop more thorough understanding of how algal responses to nutrients are related to DO, pH, and fecal indicator bacteria, as well as beneficial uses. This could be done in more targeted, opportunistic studies that complement ongoing monitoring programs.

- DO, pH, and fecal indicator bacteria are notoriously variable in streams, and are therefore difficult to assess in traditional stream monitoring programs. With more intensive temporal sampling with probes and repeated visits, this variation could be reduced.
- Use targeted study designs with selected sites along nutrient gradients in selected classes of sites to determine the natural variability in relationships among algal responses to nutrients, DO, pH, fecal indicator bacteria, and beneficial uses.

Evaluate tradeoffs among beneficial uses more explicitly, and consider the socioeconomic importance of those tradeoffs. This may extend to a broad suite of ecosystem services when and where appropriate.

Conduct causal analyses to confirm cause-effect relationships among variables. Surveys are powerful sources of information about ecological relationships for application in ecological assessment; however, they require careful evaluation of underlying causality for effective management. The EPA has written extensively about causal analysis. Frequentist (structural equation models) and Bayesian approaches (Bayesian networks) for causal modeling with observational data do exist, and they are accepted in the statistics community.

Consider risk and uncertainty in ecological relationships, and how they relate to policy as the science is applied end-to-end. An important feature of the statistical models is that uncertainty in predictions can be estimated and applied both proactively for planning to preserve healthy conditions as well as to assign priorities for management in threatened and impaired waters. A remaining challenge is how to use the uncertainty to improve decision making. As uncertainty becomes more and more tied to beneficial uses, higher uncertainty leads to greater caution to protect beneficial uses or make restoration investments more cost effective. However, overprotection can harm the regulated community and services they provide. Investment in reducing key sources of uncertainty in relationships linking human activities to nutrients, and causal relationships for nutrients to beneficial uses, has the potential for important payoffs for all stakeholders by increasing effectiveness of conservation as well as restorative measures.

Compare uncertainty in state-wide models and models from the southern California coastal region, where sampling has been most intensive, to provide guidance on investments in research in other parts of the state where model uncertainty is relatively high compared to the beneficial uses that are threatened.

Stakeholders should feel confident that the scientific approach planned by Water Board staff will address many of their concerns about implementation of nutrient management policy, including both conservation and restoration management. Numeric nutrient endpoints are intended to causally link nutrients to beneficial uses. The data gathered according to the Science Plan includes information that will enable application of numerical nutrient endpoints that account for natural variability and restoration potential among sites, and thereby effectively guide conservation and management. See Appendix B for more detail.

Appendix A. Stream Classification – Accounting for Natural Variability

Setting nutrient objectives for wadeable streams throughout California is a challenging undertaking. One important reason why this is a difficult task is the extreme climatic variability found within the State of California. California has the most variable precipitation regime of any state in the United States (Dettinger et al. 2011, Figure 1). Dettinger et al. (2011) characterized the coefficients of variation for total annual precipitation throughout the continental United States. The bull's-eye for precipitation variability occurs in southern California with very high variability extending throughout central California. Variability is high throughout all of California, when compared to the rest of the United States, except the far north of California. This annual precipitation variability leads to extremely high streamflow variability throughout most of California (Dettinger et al. 2011). Nutrient concentrations respond to the variability in flows and to the antecedent dry periods between flows. This variability argues for a stream classification protocol that differentiates between the multiple classes of streams that exist within California due to the extreme climatic variability along with the high degree of human modification of wadeable streams within California.

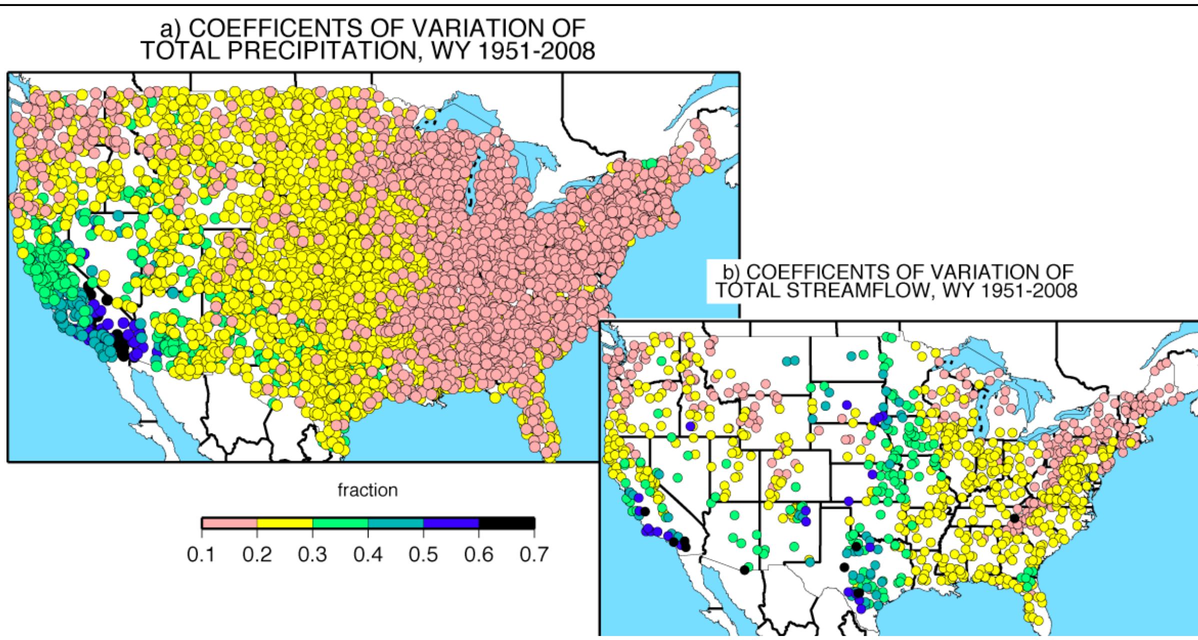

Figure 1. Coefficients of variation in total precipitation and total stream flow in the continental US (Dettinger et al. 2011).

There are multiple criteria upon which a stream classification scheme can be based. Attributes that can be the basis for stream classification include climate, hydrology, geomorphology, geology, or soils. A hybrid scheme that includes multiple criteria will likely work best in a state like California. Examples of stream classification schemes include hydrologically-based classes (e.g. Poff and Ward 1989), geomorphology-based classes (e.g. Frissell et al. 1986; Rosgen 1994), and reference-condition derived classes (e.g. Stoddard et al. 2006). The extreme climatological

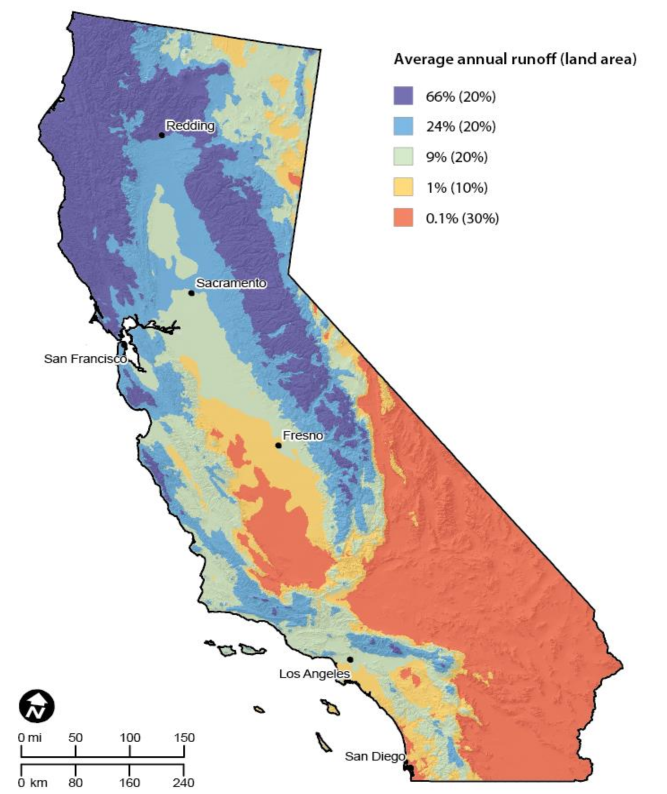

Figure 2. Stream classes related to average annual runoff is an example of an approach for accounting for natural variation for one factor in a stream classification approach (Figure from Jay Lund, University of California-Davis).

and hydrological variability within California points to a potential methodology for stream classification (Figure 2). Annual runoff is extremely variable throughout California with nearly two-thirds of stream runoff linked to the north coast and the Sierra Nevada. Annual stream runoff integrates precipitation, climate, geology, and soils, and provides a basis for a statewide classification scheme.

The highly variable climate and precipitation patterns in California coupled with a predictable Mediterranean climate in much of the state leads to major parts of the stream network being intermittent. Intermittency is commonly spatially variable with segments of perennial flow embedded thin regions of intermittent flows. These patterns are often linked to stream geomorphology. A California stream classification scheme should consider the role of intermittent streams and segments of perennial flow within largely intermittent river networks when developing stream classification schemes and nutrient objectives (Datry et al. 2014). In addition, channelized, human-built, and highly modified streams should be classified separately as nutrient dynamics and loading are distinctly different in such ecosystems when compared to less modified streams.

Appendix B. Stakeholder Concerns

Stakeholder concerns were provided by individual Stakeholder Advisory Group representatives as well as in a summary interview. They were categorized into five issues presented by Brock Bernstein, Stakeholder Advisory Group facilitator:

- Overall scope and focus of the policy
- Linking science and policy implementation
- Nature of the watershed/site-specific implementation
- Connecting indicators to beneficial uses
- Dealing with stream modification

These issues appeared to be very consistent with the direction and intent of the California State Water Resources Control Board workplan (SWRCB, 2014), the Wadeable Streams Science Plan and the scientific underpinning of the Nutrient Numeric Endpoint (NNE) approach. A brief summary of Nutrient Science Advisory Panel responses to each stakeholder issue category concludes:

<u>Overall Scope and Focus of the Policy:</u> The Biological Condition Gradient (BCG) approach will help overcome concerns about numeric objectives that focus too heavily on single criterion standards and subsequent loss of management flexibility and outcomes suitable to local conditions. Both the Science Plan and the stakeholders seem to concur that suitable endpoints will yield better water quality outcomes and accommodate the flexibility necessary for an effective transition to policy. This will inevitably involve some tradeoffs between human and environmental goals that will need to be acknowledged in setting endpoints.

<u>Linking Science and Policy Implementation:</u> This is necessary and supportive for an effective BCG approach that provides relevant management options for aquatic life endpoint setting. It will necessarily have to be designed in the context of stream classifications based on in-stream attributes and watershed assessments, which also appears to be a point of concurrence between the stakeholders and the Science Plan. Points of regionalization, e.g., integrated watershed management, will have to be explored more fully in future discussions to see how endpoints might best accommodate the tiered aquatic life use (TALU) concept raised at the meeting and how beneficial use classifications and their attributes will support TALU.

<u>Nature of Watershed/Site Specific Implementation:</u> One of the more difficult hurdles is providing regional or waterbody-type endpoints that behave like site-specific criteria or endpoints. While site-specific endpoints are the ideal, endpoints for streams grouped in different classes and tiers, relevant to converging biogeophysical and beneficial use classifications, also provide a pragmatic approach with more balance than the "one size fits all" approach proposed in some EPA guidance.- As the NNE approach evolves, guidance and procedures should be developed for considering local setting, current condition, recovery potential, and relationship to land attributes and loading of nutrients.

<u>Connecting Indicators to Beneficial Uses:</u> As noted and emphasized throughout this report, both the stakeholders and the Science Plan will require added attention to this issue. It is fundamental

to a BCG-TALU approach and setting effective endpoints consistent with beneficial use goals. NNE provides consistency with the intent of the Clean Water Act and could incorporate allowances for natural factors that consider both recovery potential for goal setting, and conservation for a preventative mix of attributes that would work well in an integrated watershed management approach.

Physical Stream Modification: Highly-modified streams and diversions that alter stream flows interfere significantly with the beneficial uses that streams have and for which they are managed. Therefore, they should be assessed and classified in that context. There appears to be a consistency of possibilities between the Science Plan and the stakeholder position that these streams will require special treatment and endpoints reflective of their status.

In sum, the Nutrient Science Advisory Panel appreciates the good thoughts and direction provided in the Science Plan and in stakeholder comments. We anticipate that most of the stakeholder issues can be addressed with the science produced, and they will benefit from a continued dialogue and formulation of the NNE approach that will support good policy. We look forward to the outcomes of those discussions.

References

Davies, S.P. and S.K. Jackson. 2006. The biological condition gradient: a descriptive model for interpreting change in aquatic ecosystems. Ecological Applications 16:121-126.

Datry T., T.S. Larned, and K. Tockner. 2014. Intermittent rivers: a challenge for freshwater ecology. BioScience 64 (3): 229–235.

Dettinger, M.D., F.M. Ralph, T. Das, P. J. Neiman, and D.R. Cayan. 2011. Atmospheric rivers, floods and the water resources of California. Water 3:445-478.

Fetscher, A.E., M.A. Sutula, A. Sengupta, and N. Detenbeck. 2014. Linking nutrients to alterations in aquatic life in California wadeable streams. U.S. Environmental Protection Agency EPA/600/R-14/043, Washington, D.C.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. Environmental Management 10 (2): 199-214.

National Research Council. 2001. Assessing the TMDL Approach for Water Quality Management. National Academy Press.

Pearl. J. 2009. Causality: Modeling, Reasoning, and Inference. Cambridge University Press.

Poff, N.L., and J.V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: A regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46:1805-1818.

Reckhow, K.H. G.B. Arhonditsis, M.A. Kenney, L. Hauser, J. Tribo, C. Wu, K.J. Elcock, L.J. Steinberg, C.A. Stow, S.J. McBride. 2005. A Predictive Approach to Nutrient Criteria. Environmental Science and Technology. 39:2913-2919.

Reckhow, K.H. 2010. Bayesian Networks for the Assessment of the Effect of Urbanization on Stream Macroinvertebrates. Proceedings IEEE Computer Society Press. HICSS-43. Kauai, Hawaii.

Reckhow, K.H. 1994. The Importance of Scientific Information in Decision Making. Environmental Management. 18:161-166.

Rosgen, D.L. 1994. A classification of natural rivers. Catena 22:169-199.

State Water Resources Control Board. 2014. Proposed workplan for development of a nutrient control program.

Stevenson, R. J. 2011. A revised framework for coupled human and natural systems, propagating thresholds, and managing environmental problems. Physics and Chemistry of the Earth 36:342-351.

Stevenson, R. J., and S. Sabater. 2010. Understanding effects of global change on river ecosystems: science to support policy in a changing world. Hydrobiologia 657:3-18.

Stoddard, J.L., D.P. Larsen, C.P. Hawkins, R.K. Johnson, and R.H. Norris. 2006. Setting expectations for the ecological condition of stream: The concept of reference condition. Ecological Applications 16: 1267-1276.

Sutula, M., E. Fetscher, E. Stein, M. Paul, J. Butcher, and N. Detenbeck. 2014. Science Plan to Support the Development of a Nutrient Control Program for California Wdeable Streams.

Tetra Tech, Inc. 2006. Technical approach to develop nutrient numeric endpoints for California.