Overview of Nutrient Criteria Development and Relationship to TMDLs

This document provides background information on approaches being taken by Tetra Tech to provide technical support to the SWRCB Nutrient TMDL Work Group and the EPA Region IX Regional Technical Advisory Group (RTAG). The RTAG is the primary stakeholder group for the development of nutrient criteria. There are substantial areas of overlap between the technical requirements / needs of a TMDL and the development of regional nutrient criteria. Because numeric criteria are often used as endpoints in TMDL analyses, the results of this study have an important bearing on future nutrient TMDLs that will be conducted in the state. There are also substantial distinctions that must be made between the two. In this overview document, we describe how the two processes are related, and lay out a roadmap for ongoing and future work on the criteria development efforts. Also attached to this package are a series of white papers that provide considerable technical detail into various aspects of the criteria development approach. These include papers on: (i) a risk-based approach to nutrient criteria, including generalized conceptual models for nutrient impacts on beneficial uses, (ii) review of peer-reviewed scientific literature since the publication of the US EPA guidance documents, (iii) review of recently completed nutrient TMDLs in the Western US, (iv) methods by which to make independent estimates of nutrient loads from various sources, including WWTPs, septic systems, animal feeding operations, (v) use of the SWAT model to evaluate watershed loads, including loads from the atmosphere and groundwater, (vi) use of HSPF/LSPC to estimate existing and allowable loads, (vii) advantages and disadvantages of using load duration curves to estimate existing and allowable loads, and (viii) discussion of other models that can be used for calculating nutrient loads from watersheds. The goal of these white papers is not necessarily to provide final answers, but to stimulate discussion and provide the various stakeholders in this process an opportunity to influence and improve the nutrient criteria development efforts in California.

Basic Assumption

It is generally understood that nutrients loads have complex, and often indirect, effects on aquatic ecosystems that may lead to impairment of beneficial uses of water bodies. In many instances, these effects are also influenced by non-nutrient factors that may act differently in individual water bodies to mitigate or worsen problems caused by excess nutrients. Because nutrients have the potential to alter entire ecosystems, it is difficult to reproduce these effects in controlled laboratory studies. In this regard, nutrients are a class of chemicals distinct from toxicants where controlled studies can be used to identify endpoints of adverse impacts on specific organisms of interest, and where these endpoints may be translated into criteria. Of necessity therefore, efforts to obtain nutrient criteria must follow approaches that are different from those that have been widely applied for developing criteria for toxicants.

Approach

As a first and critical step, it is proposed in this study that nutrient criteria not be defined solely in terms of the concentrations of various nitrogen and phosphorus species, but also include consideration of primary biological responses to nutrients. It is these biological responses that correlate to support or impairment of uses. It is proposed that the consideration of biological responses be **in addition to** chemical concentrations in the final form of the nutrient criteria.

Further, the development of chemical concentration criteria should be closely linked to the evaluation of biological responses.

Although the definition of the term primary biological responses can be somewhat arbitrary, for the purpose of this discussion, it includes measurements such as chlorophyll a (Chl a) in the plankton and periphyton, dissolved oxygen (DO), and benthic indices of biological integrity (IBI). Other choices for biological response may also be included as and when suitable data become available. The basis for this approach is explored more thoroughly in White Paper (i), where it is shown that elevated nutrient concentrations and impairment of beneficial uses consists of multiple interactions between different components of the aquatic ecosystem, and nutrient concentrations alone cannot be used to predict the likelihood of impairment. For example, a stream with elevated nutrient concentrations may not exhibit excessive algal growth and consequent impairment if it has a good canopy cover. If criteria were defined only in terms of nutrient concentrations, and excluded other considerations, this stream could be thought of as nutrient impaired, an inappropriate designation in the absence of excessive algal growth.

The proposed approach for criteria development above is broadly consistent with the approach that has been recommended for performing TMDLs by US EPA. To perform a TMDL, loads must be related to concentrations in water bodies that are often the numerical criteria against which the success of the TMDL will be measured. In the absence of numeric criteria in water, other numeric criteria may apply, such as concentration in fish tissue. However, if no numeric criteria are applicable, EPA recommends identification of potential indicators of impairment, selecting a numeric target for the indicator that protects designated uses, and developing the TMDL on this numeric target.

In our proposed methodology for nutrient criteria development, we propose to take the above TMDL-type approach, where both chemical concentrations as well as biological responses will be part of the criteria. Figure 1 illustrates in a simplified form the relationship between the loads and beneficial uses, and identifies the interactions that are the typical focus of TMDL analyses and the subset of interactions that will be studied in the nutrient criteria development process. The role of exogenous factors such as flow, sediment load, habitat quality, temperature, and shade, on biological responses is also shown. Because TMDL analyses are focused on an individual water body, as opposed to groups of water bodies in the criteria development process, it is possible to do a much more detailed analysis of the connections between initial biological responses and beneficial uses in that water body. For practical purposes, therefore, we have chosen to limit our analysis to those types of primary biological responses for which data are more likely to be available, either now or in future, such as Chla, DO, and IBI. Aside from being one step closer to the actual impairment, a significant benefit of including some form of biological response in the criteria is the automatic consideration of some of the hard-to-measure exogenous factors that affect the likelihood of impairment. To take the example of the stream with elevated nutrient levels but low algal biomass, this approach would clearly indicate no nutrient impairment without requiring specific data on canopy cover. The inclusion of chemical concentrations in the criteria is also important. For example, a stream could have an unacceptable IBI, caused by poor habitat quality, where lowering of nutrient concentrations may provide no ecological benefit. In such cases, a nutrient concentration criterion should identify when an observed impairment is unlikely to be due to nutrients.

Measures of biological responses can be used directly to assess attainment of uses in a waterbody. They are more difficult to apply for planning and management, for instance to determine the appropriate level of nutrient loading that should be allowed in a NPDES wasteload allocation. In a TMDL analysis, this problem is addressed by establishing a quantitative linkage between chemical concentrations and biological responses. A chemical criterion target should implicitly recognize the same linkage. That is, a chemical criterion (e.g., phosphorus concentration) should be established at a particular level that protects against occurrence of a biological response sufficient to impair a designated use.

Based on our experience in working with available biological data, we realize that the proposed approach, although scientifically defensible, is not a quick solution to obtain nutrient criteria, in large part because it is difficult to obtain adequate data where the biological parameter in question was consistently sampled and measured. To consider some examples: algal cover and Chl a on stream bottoms may be obtained using different techniques, DO measurements may be affected by the time of day when the sampling was done, and samples for IBI evaluations may have been obtained from different substrates. The major finding of our work with biological data is that it is unlikely that a rational database appropriate for nutrient criteria can be put together simply by collecting all previously collected data. Data collection must be geared toward the planned end use of the data. In the absence of such a data collection program over large parts of the state, we must make use of available data, albeit within a framework of uncertainty.

The linkage between the primary biological responses and the impairment of beneficial use is also uncertain. Specific levels of a response parameter may be related to beneficial use in an individual water body, but it is more difficult to identify a specific level that will apply to a group of water bodies.

A practical solution to the uncertainty discussed above is to define nutrient criteria (for chemistry and biological responses) in a region not as individual numbers, but as ranges that can be used to classify water bodies into one of three categories: Tier I (unlikely to be impaired), Tier II (impairment possible), and Tier III (definitely impaired). One or more concentrations or biological responses could be expressed as ranges that correspond to each of the three tiers. This is shown schematically in Figure 2. In this example, Concentration 1 could represent the total nitrogen concentration, Concentration 2 could represent the total phosphorus concentration, Primary Biological Response 1 could represent the periphyton Chl a concentration, and Primary Biological Response 2 could represent the IBI. Data from a specific water body could be used rapidly to place the water body in one of the three tiers. If the nutrient concentrations indicated a lower tier than the others, the water body would be placed in the lower tier, in consideration of the possibility that the impacted biological responses are a consequence of non-nutrient factors. Following the classification above, some predefined actions could follow, such as no action for Tier I, further monitoring and study for Tier II, and impairment assessment or TMDLs for Tier III.

Next Steps

The above discussion provides a summary and a roadmap of the approach being taken to derive nutrient criteria for California. Ongoing work (modeling and empirical data analysis, and review of the scientific literature) will provide first cut numbers for the some of the metrics shown in shown in Figure 2. These initial numbers will be refined following input from regional experts (RTAGs, academic researchers, and other stakeholders) and, in future years, will be modified as a greater quantity of biological response data becomes available.

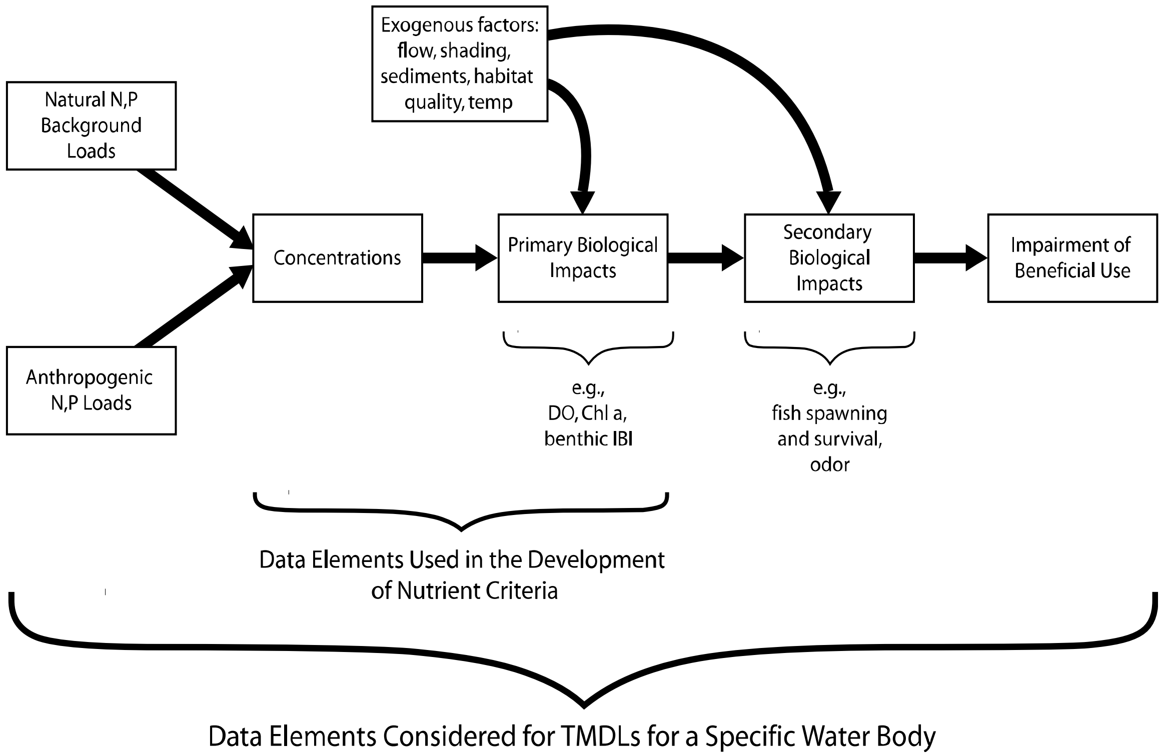

Figure 1. Schematic showing the relationship between nutrient loads and impairment of beneficial uses, including data elements used for nutrient criteria development and for development of TMDLs. Impairment of beneficial use will be considered in both cases, but because criteria development deals with groups of water bodies the linkage will be more uncertain than in a single water body TMDL analysis.

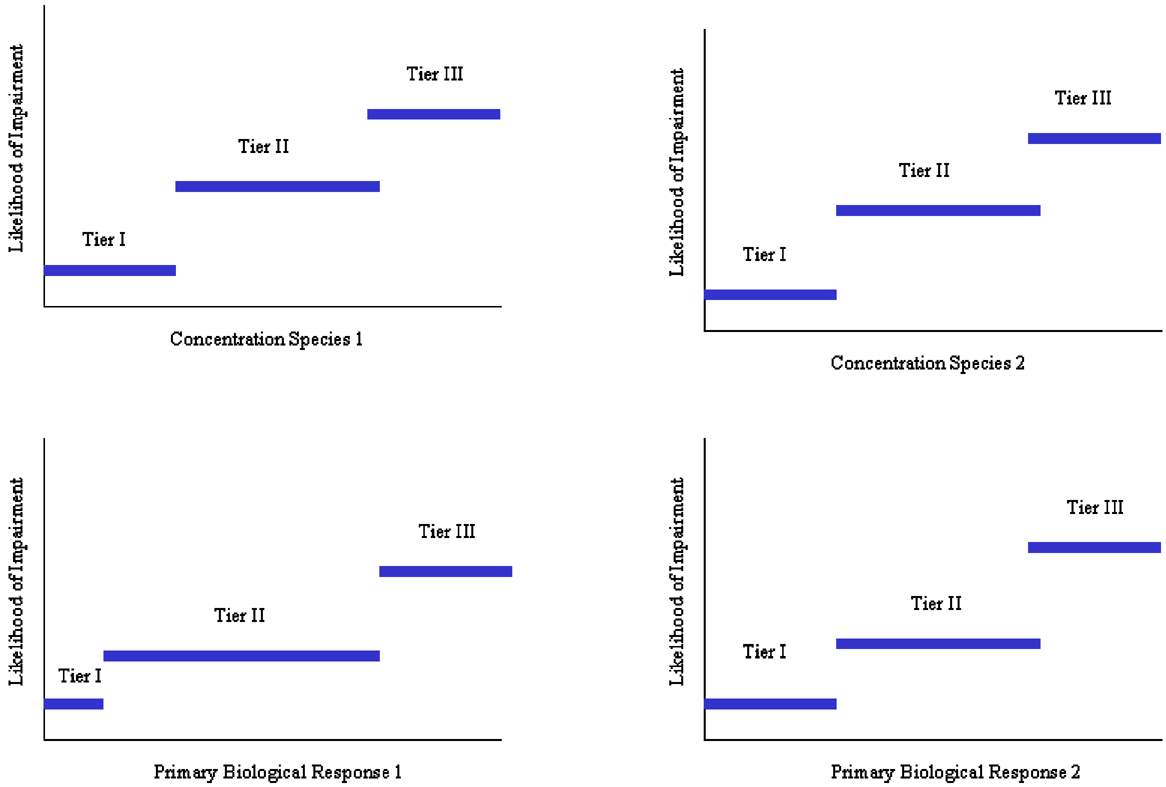

Figure 2. Schematic representation of the nutrient criteria framework, with chemical and biological measures being used to classify water bodies into one of three tiers; Tier I = impairment unlikely; Tier II = impairment possible; and Tier III = impairment likely.