**Comments on**
**US EPA "Empirical Approaches for Nutrient Criteria Derivation"**
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Comments submitted
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The US EPA Office of Water is attempting to gain support for the development of nutrient criteria based on a statistical approach that is supposed to relate nutrient concentrations to a water quality impact. The US EPA Science Advisory Board's (SAB) draft executive summary for its discussion of "Empirical Approaches for Nutrient Criteria Derivation" states:

> "*Step 1 reviews techniques for selecting the variables that appropriately quantify the stressor (i.e., excess nutrients) and the response (e.g., chlorophyll a (chl a), dissolved oxygen, or a biological index). Selecting response variables that relate directly to measures of designated use are most appropriate since criteria must ensure protection of the designated uses. This step then describes data exploration, visualization, and summary. Exploratory techniques include histograms, box and whisker plots, Quantile-Quantile plots, cumulative distribution plots, scatter diagrams, and spatial mapping. The visualization step helps the analyst understand how variables change across space and time, general relationships among variables and how one or more variables co-vary. Conditional probability analysis, a more quantitative statistical approach for summarizing the data can also be used for data exploration.*"

Lee and Jones-Lee commented on the unreliability of the US EPA's conditional probability approach for establishing phosphorus nutrient criteria in the report:

> Lee, G. F., and Jones-Lee, A., "Comments on US EPA's Conditional Probability Approach for Developing Phosphorus Nutrient Criteria," Report of G. Fred Lee & Associates, El Macero, CA, September 26 (2008).
> http://www.gfredlee.com/Nutrients/PCriterionCondProb.pdf

As Lee and Jones-Lee discussed in that report, "conditional probability" as being advanced by the US EPA is not a technically valid approach for establishing phosphorus nutrient criteria for use in establishing and regulating allowable phosphorus discharges to a waterbody. Because those Lee and Jones-Lee (2008) comments on technical aspects of the unreliability of the conditional probability approach have considerable applicability to this review of the US EPA proposed statistical approach for developing nutrient criteria, they are appended to these comments as a source of additional information on the problems with the proposed statistical approach, and should become part of the record of the SAB review of the statistical approach for establishing nutrient criteria.

Dr. G. Fred Lee has had more than 40 years of experience in developing water quality criteria and using such criteria in water quality management, as well as in the aqueous environmental chemistry of nutrients, including their behavior, fate, and water quality impacts. In the early 1970s Dr. Lee was a National Academies of Sciences and Engineering-invited peer reviewer of Academies' Bluebook of Water Quality Criteria-1972. In the early 1980s Dr. Lee served as a US EPA-invited peer reviewer of the then-proposed water quality criteria development approach and of several criteria documents. The approach that was developed is still being used today. Additional information on the authors' qualifications to submit these comments is provided on their website, www.gfredlee.com. Based on this experience, it is clear that statistical approaches of the type proposed are not reliable for the development of nutrient criteria. Criteria developed through that approach cannot be relied upon to provide technically valid assessments of potential water quality impacts of nutrient inputs or to provide appropriate regulation of nutrient discharges.

*"Step 1"* of the proposed approach, quoted above, states that a "*biological index"* can be used as a "*stressor response."* That claim is without technical merit. The factors that influence the various "biological indexes" are poorly understood; relationships between "biological indexes" and water quality are coincidental. Nutrient loads/concentrations do not even necessarily influence, much less control, such "indexes." Biological indexes are not reliable stressor responses to nutrient enrichment.

While it is of interest to examine the relationships between nutrient loads/concentrations to/within a waterbody and nutrient-related water quality characteristics of the waterbody, great caution must be exercised in using statistical relationships developed from such exercises to establish regulatory requirements enacted for the purpose of achieving desired nutrient-related water quality characteristics. Employment of technically inappropriate statistical relationships can readily lead to arbitrary nutrient discharge restrictions that can trigger large expenditures for "nutrient control" from domestic wastewaters, urban and agricultural runoff/discharges, and others without the expectation or achievement of the desired water quality.

The SAB's draft Executive Summary stated,

> "*Step 2 is assessing the strength of the cause-effect relationship represented in the stressor-response linkage. When stressor-response relationships are used to establish nutrient criteria, it is important to assess the degree to which changes in nutrient concentration are likely to cause changes in the chosen response variable. This can be accomplished using conceptual models, existing literature, and empirical models."*

Beginning in the 1960s G. F. Lee became highly involved in examining the relationships between nutrient loads to waterbodies and the associated resultant nutrient concentrations and nutrient-related water quality characteristics/responses within those waterbodies. Beginning in the 1970s, with support from the US EPA nutrient management water quality program, he held contracts to examine and quantify relationships between nutrient loads to waterbodies and associated fertilization water quality responses. In the 1970s he, Dr. Anne Jones-Lee, and several colleagues, especially Dr. Walter Rast, became involved in the US and the international OECD Eutrophication Study program. They developed a series of reports on nutrient load–

fertilization response relationships for several hundred waterbodies located throughout the US, in Western Europe, North America, Japan and Australia. That work included investigation of predictive capabilities of empirical models based comparison of predicted and measured changes in water quality response resulting from nutrient load alterations. Many of their papers and reports on that past and ongoing effort are located on the Lee/Jones-Lee website, www.gfredlee.com in the Excessive Fertilization Section http://www.gfredlee.com/pexfert2.htm.

The work by Drs. Lee and Jones-Lee on these issues continues today including on issues of the excessive fertilization of the Sacramento San Joaquin Delta. They continue to closely follow work on these issues in other areas including the California State Water Resources Control Board's work to develop nutrient criteria for enclosed bay and estuaries, and the Mississippi River watershed. They also periodically discuss emergent and recurring nutrient-related water quality issues in their Stormwater Runoff Water Quality Newsletter, an email-based newsletter distributed at no cost to more than 10,400 professionals and other interested individuals. Past issues are available online at http://www.gfredlee.com/newsindex.htm. The most recent issue (Volume 12, Number 5) is devoted to nutrient water quality issues. Newsletters 1-2, 1-3, 1-5, 4-3/4, 5-1, 6-1, 6-2, 7-6/7, 9-1/2, 9-7, 9-8, 9-10, 10-4, 10-5, 10-6, 10-7, 10-13, 11-2, 11-5, 11-9, 12-3, 12-5, 11-7/8, 11-9, 11-10, and 12-3 have discussed nutrient-related water quality issues. Many of the topics discussed in those issues need to be considered in developing water quality criteria for nutrients, but were not reliably considered in the draft approach outlined by the US EPA.

Over the past four decades that Dr. G. Fred Lee has been active in examining nutrient load – response relationships, he has repeated observed the unreliability of statistical correlations developed between nutrient concentrations and assumed responses. It has been his experience that the current "Empirical Approach" can readily lead to unreliable approaches for developing nutrient criteria for the management of excessive fertilization of waterbodies. It is not a matter of the approaches' yielding overly protective, or under-protective regulation and management. The problem is that they are not technically sound; a technically unsound approach cannot be expected to render reliable criteria/standards, or conclusions regarding the necessity for or water quality impacts of nutrient loads or management steps that could be required to achieve arbitrary criteria/standards.

*Steps 3 though 5 (Step 3 – Analyzing Data, Step 4 – Evaluating estimated stressor response relationships, Step 5 – Evaluating candidate stressor response criteria).* Basically these steps direct the use of the statistical relationships to develop nutrient criteria. One of the fundamental flaws in the US EPA's empirical approach is that statistical "relationships" can be developed without there being a mechanistic (cause-effect) foundation that relates how nutrients impact water quality. An example is seen in the situation that occurred when a national US university professor conducted a multi-variant analysis of data that were available on nutrient concentrations and algal biomass without including information on the hydrologic and morphologic characteristics of the waterbodies in the statistical analysis. As was demonstrated in the authors'(Lee and Jones-Lee) evaluation and quantification of nutrient load–response relationships based on data from more than 750 waterbodies world-wide noted above, waterbody mean depth and hydraulic residence time are key parameters controlling the nutrient concentrations and nutrient-related water quality characteristics that result from nutrient input to waterbodies.

There are many other "statistical approach" relationships reported in the literature that are not valid for relating nutrient loads/concentrations to fertilization response. Statistical "relationships" can be developed that have little or no capability to reliably predict changes in nutrient-related water quality characteristics that would result from changes in nutrient loads. Such a demonstration is of paramount importance for the development of nutrient criteria developed for the purpose of controlling nutrient-related water quality. Any statistical relationship between nutrient load and waterbody response must be solidly grounded in fundamental mechanisms (cause-effect) that influence how a nutrient could impact a fertilization response. Without such a foundation, the statistical relationship is simply game playing.

The draft proposed approach contains a number of log-log plots of total nutrient concentrations vs some "indicator response." Critical examination of those plots shows that there is no defensible relationship between the concentrations and the "indicator." Such plots cannot be used to develop a meaningful criterion or defend a management practice for the control of nutrient-related water quality characteristics of a waterbody.

Overall, the US EPA should abandon it present efforts to develop nutrient criteria based on "statistical approaches" and focus on supporting research to reliably define the adverse and beneficial impacts caused by addition of nutrients to waterbodies.

Appendix

Lee, G. F., and Jones-Lee, A., "Comments on US EPA's Conditional Probability Approach for Developing Phosphorus Nutrient Criteria," Report of G. Fred Lee & Associates, El Macero, CA, September 26 (2008).
This report is available as a downloadable file from,
http://www.gfredlee.com/Nutrients/PCriterionCondProb.pdf, and should be incorporated as part of these comments.