TECHNICAL EVALUATION OF COLORADO NUTRIENT CRITERIA DERIVATION METHODOLOGY AND DRAFT CRITERIA FOR LAKES AND STREAMS

PREPARED FOR COLORADO NUTRIENTS COALITION

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The Water Quality Control Division ("WQCD" or the "Division") has indicated that it plans to adopt statewide nutrient criteria for lakes and streams in mid-2011. Draft criteria that establish stringent requirements on both nitrogen and phosphorus have been released to the public for consideration. The purpose of this Technical Report is to review the scientific bases for the draft nutrient criteria and to determine whether the presently recommended lake and stream numeric criteria are necessary and appropriate to address nutrient impairments, where they exist. To complete this analysis the report provides (1) an overview of the draft standards approach (pages 2-10); (2) presents the available federal guidance and Science Advisory Board recommendations on the factors and mechanisms to consider in the development of numeric nutrient criteria (pages 10 -18); (3) assesses the factors and mechanisms considered in the draft criteria derivation and the technical support for the general structure of the draft criteria (pages 18-32), and (4) evaluates whether the derivation techniques used to select the specific numeric criteria are scientifically justified (pages 33- 45). This document also provides general recommendations on changes to the preliminary criteria to ensure that the development and application of nutrient criteria is scientifically defensible and will result in discernable environmental benefits for the resources expended.

I. BACKGROUND

Nitrogen and phosphorus are essential nutrients for life on earth. Nutrients are not toxic substances that have a threshold above which adverse impacts are certain to occur. Rather, nutrients may contribute to excessive plant growth that may contribute to "designated use" impairments, depending upon the physical setting. These designated use impairments may include water quality criteria exceedances (*e.g.*, reduced dissolved oxygen) or other adverse effects on aquatic life due to significant habitat alteration. Excessive algal growth may also contribute to taste and odor problems in drinking water. Physical factors, such as sunlight, wind, water velocity, depth, temperature, turbidity, substrate, presence of zooplankton and other biological factors may prevent excessive plant growth even when high nutrient concentrations occur. These complex interactions are what make setting and applying uniform nutrients standards a very difficult process.

Due to the many factors affecting whether or not nutrient levels will trigger excessive plant growth, the Association of State and Interstate Water Pollution Control Administrators ("ASIWPCA"), in June 2007, informed EPA that attempting to establish statewide nutrient objectives (particularly for stream environments) was not technically defensible:

> *During their considerable development processes, many States are failing to find a strong linkage between the EPA recommended cause variables (N and P) and response variables of chlorophyll 'a' and transparency, but are finding wide variations in parameters that seem unrelated to professional assessments of ''trophic health'' status. In many cases, a relationship cannot be demonstrated between causal variables N and P, and factors such as turbidity, light limitation, canopy cover, substrate, aquatic community structure, bioavailability, reservoir sequestration, micronutrient limitations and other ''response'' variables. These*

> *problems can only lead to mis-cues in impairment identification and mis-direction of scarce management and implementation resources.*
>
> Letter from ASIWPCA to Ben Grumbles (EPA, AA Water) (July 18, 2007); *http://www.asiwpca.org/home/docs/Ltr2EPANutrients.pd*

Notwithstanding these reservations, the US EPA has directed the states to develop state-specific criteria for nutrients and recommended that the proposed criteria include response variables, such as chlorophyll 'a' level and transparency, as well as the presumed causal variables – nitrogen and phosphorus. The response variables recommended by EPA may be appropriate as nutrient criteria provided that the linkage between the response variable and the designated use impairment can be demonstrated and flexibility is provided to alter the allowable nutrient level considering site-specific conditions. Since both nitrogen and phosphorus are necessary to sustain plant growth, it is commonly recognized that controlling only one of these parameters is sufficient to prevent excessive growth. In freshwater systems, such as that in Colorado, phosphorus is typically the nutrient in limiting supply and it is usually unnecessary to limit the amount of nitrogen.[1] Moreover, it is generally more cost effective to control phosphorus, even if nitrogen was the limiting nutrient. Nitrogen reductions can trigger other harmful ecological shifts to occur that favor blue green algae dominance – a toxic form of algae. Consequently, the need to establish nutrient criteria for both phosphorus and nitrogen requires carefully developed scientific documentation. Without such documentation, local resources will be wasted and more harm than good may result.

II. OVERVIEW OF THE WATER QUALITY CONTROL DIVISION'S INITIAL PROPOSALS

A. <u>The Draft Nutrient Criteria Proposals</u>

The Division has suggested the nutrient criteria for Lakes and Reservoirs in a presentation by the Standards Framework Work Group on August 19, 2009. Suggested nutrient criteria for Rivers and Streams were presented in a Work Group meeting on February 9, 2010. These suggested criteria, for the protection of aquatic life, are summarized below in Table 1.

[1] See, CDPHE PowerPoint presentation "Colorado Lake Nutrient Criteria – A Proposal," which concluded TP control was appropriate to address excessive plant growth in state waters, asserting that it was the 'Linchpin among factors regulating chl'. (Slide 19)

Table 1
Suggested Nutrient Criteria for the Protection of Aquatic Life

Receiving Water Type	Use Classification	TP (mg/L)	TN (mg/L)	Biological Metric
Lakes and Reservoirs [1]	Cold Water	0.024	0.490	8 µg Chl-a/L
	Warm Water	0.082	0.960	20 µg Chl-a/L
Rivers and Streams	Cold Water	0.090	0.824	*
	Warm Water	0.135	1.316	*

1. Lake criteria are the 80th percentile of the summer average, with a once-in-five-year exceedance frequency.

* The nutrient standards for rivers and streams do not include a biological metric that signifies use impairment, however the TP and TN criteria were developed based on a 5% reduction in multi metric index (MMI) score from a reference condition.

The primary purpose of the lake objectives is to protect aquatic life uses. These values would apply to all standing surface waters regardless of size (*e.g.*, golf course ponds and watering holes are also covered) or actual usage (*e.g.*, agricultural water supply, primary drinking water source). The stream standards are intended to protect aquatic macroinvertebrates, as measured by the MMI. A more detailed discussion of how these numeric criteria were derived follows.

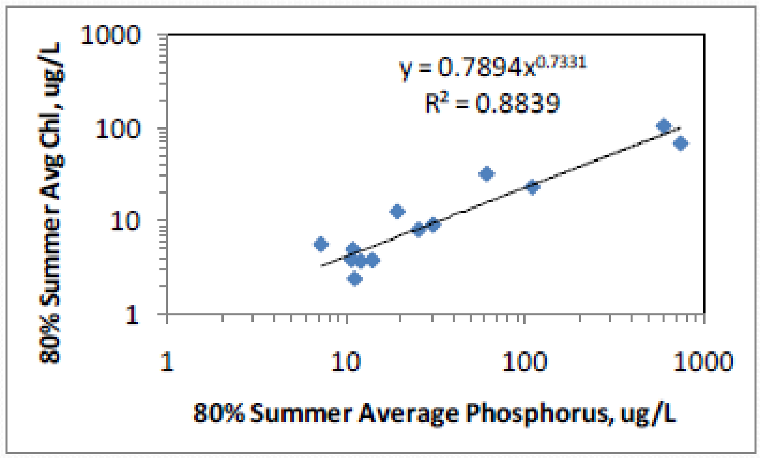
B. <u>Review of Scientific Basis for Proposed Nutrient Criteria</u>

The basis for the proposed nutrient criteria was presented by the Colorado Water Quality Control Division in a PowerPoint presentation on August 19, 2009. The draft nutrient criteria for lakes and reservoirs were developed for two broad categories of lakes: cold lakes and warm lakes. The criteria include the establishment of summer average impairment thresholds for chlorophyll deemed necessary to support the appropriate fisheries.

1. Lakes and Reservoirs

The Division established a chlorophyll 'a' concentration of 8 µg/L as the impairment threshold for Cold Water Lakes. The Initial Table Value is identified in the August 19, 2009 presentation as the 80th percentile of the summer average with an allowable exceedance frequency of once in five years. This concentration is also described in the August 19, 2009 presentation as the summer average "optimal for most salmonids," although alternate criteria may be required for lake trout. The Division also noted that this summer average criterion would limit the bloom threshold to 20 µg/L (<1% exceedance frequency) and there would be no risk from cyano-toxins (*e.g.*, no measurable risk of chlorophyll 'a' greater than 50 µg/L). The impairment threshold for Warm Water Lakes was set at 20 µg/L (80th percentile of summer average); a summer average of 20 µg/L is described as optimal for warm water game fish. Blooms in excess of 30 µg/L would occur less than 15% of the time when this summer average was achieved, and the risk from cyano-toxins would be acceptable (*e.g.*, >50 µg/L once in 6 weeks). The criteria for total phosphorus (TP) and total nitrogen (TN) were established using empirical regressions between the nutrient parameter and chlorophyll 'a'. Figure 1 illustrates the regression analysis presented for chlorophyll 'a' and TP that was used to derive the allowable numeric criteria values.

Figure 1



In the case of phosphorus, the regression analysis presented in the figure was based on an assessment of 13 lakes with sufficient data (multiple years) to determine the 80th percentile summer average chlorophyll 'a' and TP concentrations. The independently derived 80th percentile concentrations were presumed to coincide in the database regardless of actual measurements. This approach presumes that high chlorophyll levels occur when phosphorus concentrations are high, but this is not always the case (as will be discussed later in this evaluation of the Division's approach to nutrient criteria development).

The regression in Figure 1 includes a very high regression coefficient, suggesting an excellent fit to the data. As noted herein, this statistical manipulation of the long term data sets is inappropriate.[2] Most lake data sets do not show this degree of correlation, as illustrated in Figure 12 from "EPA's Draft Empirical Approaches for Nutrient Criteria Derivation" (August 17, 2009) (presented in Figure 2), which was the subject of a peer review by the Science Advisory Board.

[2] In simplest terms, by ordering the data to independently select the 80th percentile reading from each data set, it was a foregone conclusion that a high correlation coefficient would be created by this methodology. It is an improper manipulation of the data base and violates principles of data analyses by using the data processing method to create a correlation where none may actually exist.

Figure 2

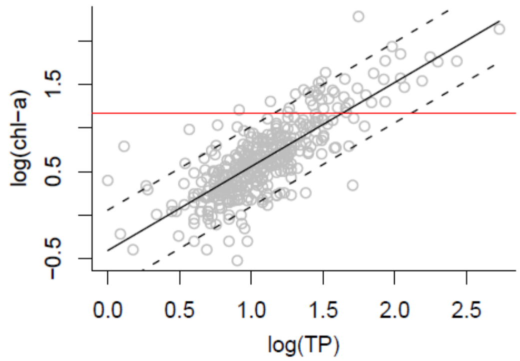
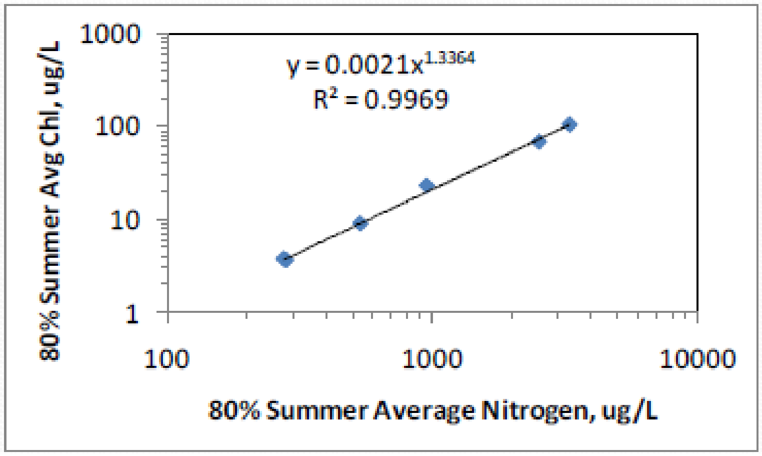


Figure 12. Log(TP) versus log(chl *a*) using EMAP Northeast Lakes Survey data. Solid line: mean regression relationship, dashed lines: 90% prediction intervals. Red horizontal line indicates chlorophyll *a* = 15 µg/L. Units are in µg/L. Regression Equation: Log(chl *a*) = -0.41 + 0.97[log(TP)]; R^2=0.61, p<0.001.

Figure 2 illustrates a typical regression for lake data, with a regression coefficient of 0.61. The difference in the regression coefficients is related to the manner in which the data were processed and plotted. Figure 1 presents data for thirteen lakes that were processed into a single data point for each lake while Figure 2 presents actual paired measurements of algae and TP**.** The Division's methodology for processing the voluminous amount of lake data into a single point created new paired data points. These are not the actual measured data. The 80th percentile summer (July – September) average chlorophyll 'a' concentration was calculated independently from the 80th percentile summer average TP concentration and these values were paired together. This approach presumes that these percentiles occur simultaneously, which they do [or did] not.

With regard to nitrogen, the regression was based on six lakes with sufficient data as illustrated in Figure 3. The regression coefficient for these data is nearly perfect. Such a relationship is too good to be true. State Agencies across the country have informed EPA that relationships between causal variables (*e.g.*, TN) and response variables (*e.g.*, chlorophyll 'a') cannot be demonstrated (See, Letter from ASIWPCA to Ben Grumbles, July 18, 2007). Yet, the Division has presented a nearly perfect relationship between algal growth in lakes and TN, a parameter that is not generally associated with algal growth in lakes. As with TP, the goodness of fit has more to do with the way the lake data were processed and less to do with a cause and effect response.

Figure 3

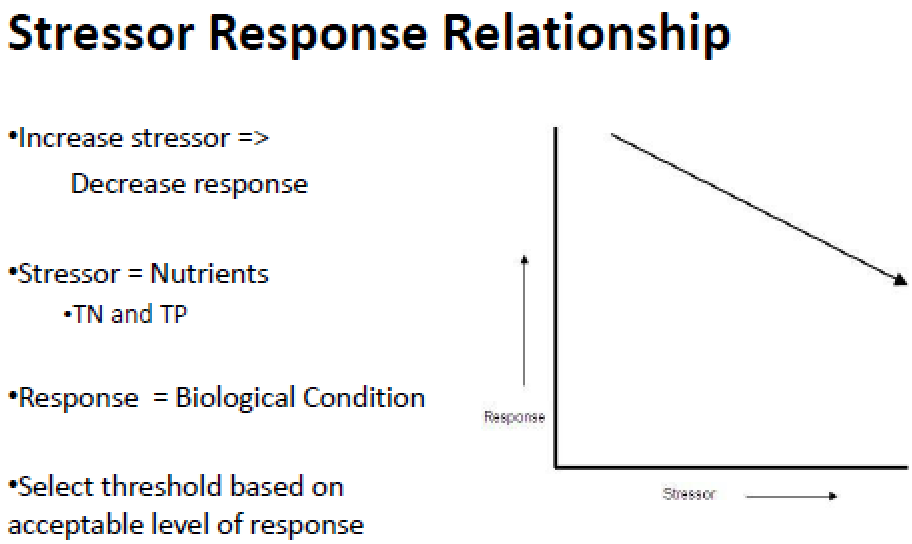


Acceptable statistical and cause and effect assessments were not completed for the lakes database. The Division's method of data processing and TP/TN criteria selection for lakes is not a scientifically or statistically defensible approach. By reducing the database for each lake to a single point, the natural variability that occurs in lentic systems is obscured and the resulting analysis gives the impression that the regression explains most of the variability in the data when, in fact, it does not. If the individual summer average concentrations are considered for each lake, rather than the 80th percentile data pair, a more realistic analysis is obtained.

2. Rivers and Streams

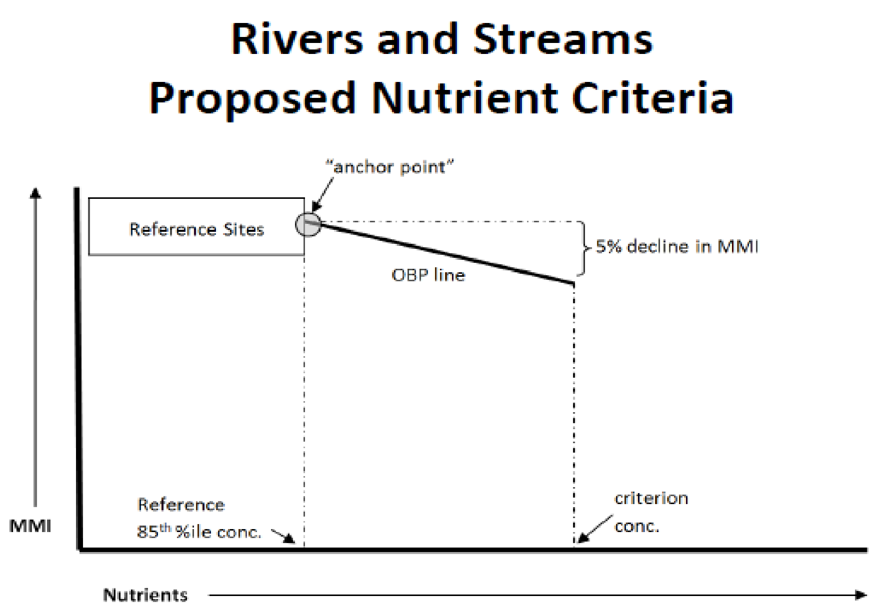
The draft nutrient criteria for rivers and stream were also developed for two broad categories: cold water biota and warm water biota. The criteria include numeric values for TP and TN based on empirical relationships between the nutrient and a multi metric index (MMI) value under the presumption that nutrient concentrations "cause" the response variable to change in the direction of use impairment. The presumed stressor-response relationship is illustrated below (Figure 4).

Figure 4 (February 9, 2010 CWQCD Presentation Slide)



Numeric criteria for TP and TN were set equal to the nutrient concentration (*i.e.*, the presumed stressor) at which a 5% reduction in MMI (*i.e.*, the response) was predicted from an "anchor" value. Criteria for TP and TN were established using empirical regressions between the nutrient parameter and the stressor. The hypothetical analysis presented in the figure below was included in the February 9, 2010 presentation by the WQCD.

Figure 5 (February 9, 2010 Presentation Slide)



In this plot, the slope of the Observable Biological Potential (OBP) must be determined. This analysis is based on evaluation of the data in the Wedge Plot illustrated below. The Wedge Plot presents the multi-metric index score as a response to total phosphorus concentration measured in the stream. The OBP line is determined using Quantile Regression. A 5% reduction in the anchor point MMI was assigned as the basis for establishing the nutrient criterion in consideration of how water quality standards for toxics are established. The chronic and acute standards are defined as a "level that protects 95% of the genera from chronic (or acute) effects." In an analogous approach, the nutrient criteria were set at a level that does not permit a decrease of more than 5% in the anchor point biological condition. But, this is a purely arbitrary choice, and not supported by references, experimentation, or empirical data. In fact, many aquatic systems do not respond measurably to reductions in nutrient loading (and the subsequent concentration reductions) because a number of other factors may actually control the response at the site. In the case of whole effluent toxicity testing, which is conducted under controlled conditions, a minimum 25% change is considered necessary to demonstrate a pollutant related impact as opposed to natural variation.

The actual stream data used to derive the nutrient criterion concentration are illustrated in wedge plots for TP (Figure 6) and TN (Figure 7). A cursory review of these plots indicates significant variability in the response, particularly within the reference zone and within the range of nutrient concentrations that may influence plant growth (< 0.1mg/l TP and < 0.5 mg/l TN). This analysis presumes that TP or TN is responsible for the MMI score but does not present any mechanistic basis to explain why such a relationship exists. The analysis also presumes that a 5% reduction in the median MMI from reference sites constitutes an impairment that is equivalent to a chronic water quality standard as if nutrients act like toxics. The analysis also includes an assumption that other stress factors are responsible for low MMI scores associated with low nutrient levels, but not with those associated with higher nutrient levels. None of these presumptions are scientifically defensible and the Division presents no analyses to justify their reasonableness.

Figure 6

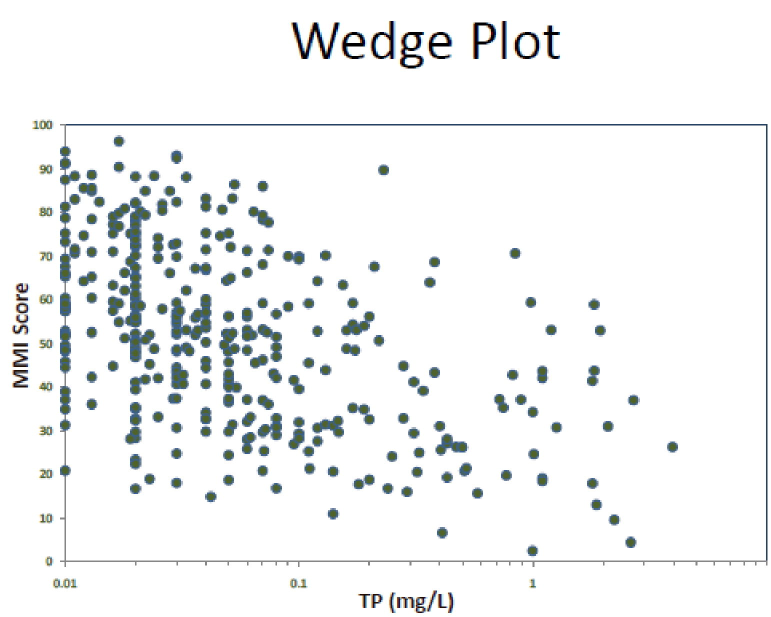
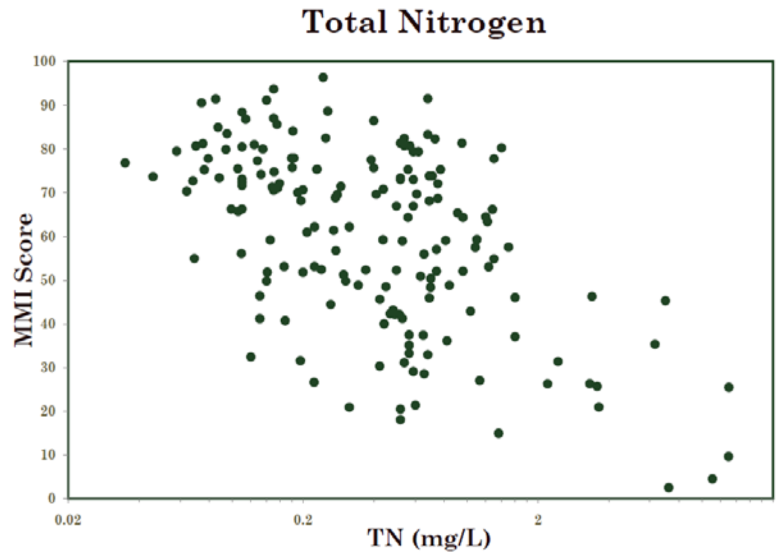


Figure 7



These data plots and the analyses used by the Division bear a striking resemblance to the data and analyses presented by EPA in its Draft "Empirical Approaches for Nutrient Criteria Derivation" (August 17, 2009). Figure 16 from the draft report is illustrated below for comparison (Figure 8). The EPA guidance document was the subject of a Science Advisory Board peer review. The SAB found that the methods used in the document to derive numeric nutrient criteria were not scientifically defensible because those methods, like the ones used by the Division, do not demonstrate cause and effect. The other relevant SAB report conclusions will be discussed further, herein.

Figure 8

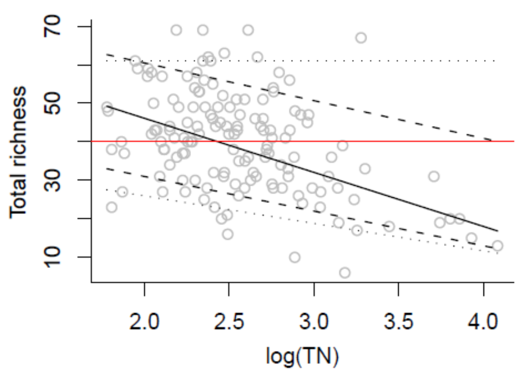


Figure 16. Log(TN) vs. total species richness for EMAP-West Xeric region streams. Dashed lines indicate 10th and 90th quantiles estimated with quantile regression, dotted lines indicate the 5th and 95th quantiles, and the solid line indicates the 50th quantile. Units are μg/L for log(TN). Red line indicates where total species richness = 40.

In summary, the analyses used to support both the lake and stream criteria derivation were fundamentally flawed and used methods for selection of nutrient criteria that are not scientifically defensible. The following reviews the regulatory and technical issues with the proposed approach, and suggests more appropriate methods of data analysis and nutrient impact assessment.

III. TECHNICAL GUIDANCE ON NUTRIENT CRITERIA DEVELOPMENT

A. Applicable Rules and General Guidance on Criteria Derivation

Water quality standards are required to be set at the level "necessary to protect uses." 40 CFR 131.2. In general this requires that a clear "cause and effect" relationship between the pollutant of concern and the use impairment be documented for different classes of waters and various uses. As noted earlier, many state programs have encountered severe problems in making this demonstration for nutrients, and, at EPA's suggestion, have begun to use more simplified statistical methods to identify numeric standards. These simplified methods presume, *but do not demonstrate*, that elevated levels of nutrients are the cause of impairments in any water where they may occur. This assumption is directly at odds with decades of nutrient research and EPA-published technical guidance which has repeatedly affirmed that nutrients do not cause impairments in many situations, since other important factors may also control plant growth (*e.g.*, light availability, habitat, time for growth, etc.).

EPA's National Guidelines establish the threshold principles that all aquatic life water quality criteria must meet. First, the purpose of criteria is to protect aquatic organisms and their uses from unacceptable effects. *See* National Guidelines, at vi. "Criteria should attempt to provide a reasonable and adequate amount of protection with only a small possibility of considerable overprotection or under-protection." National Guidelines, at 5. Proper criteria derivation requires the establishment of a cause-and-effect relationship to ensure that regulation of the pollutant is necessary and will produce the desired effect. National Guidelines at 15- 16, 21. Thus, "[t]he concentrations, durations, and frequencies specified in criteria are based on biological, ecological, and toxicological data, and are designed to protect aquatic organisms and their uses from unacceptable effects." *Id.* at 16. To develop such criteria, adequate data must be available or the criteria should not be developed. *Id.* at 5-6. Specifically, there must be adequate data on pollutant levels that cause an unacceptable adverse effect on any of the specified biological measurements. *Id.* at 39. For materials that have a threshold effect (like nutrients), the threshold of unacceptable effect must be determined. *Id.* at 8. In addition, "[c]riterion must be used in a manner that is consistent with the way in which they were derived…." *Id*. at 7.

Based on the National Guidelines, it is well established that criteria must be based on a defined cause and effect relationship to be scientifically defensible.

B. EPA Technical Guidance on Nutrient Criteria Development

EPA has issued a variety of guidance documents relating to the development of numeric nutrient criteria. Technical guidance documents include EPA's 1985 *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Use* (USEPA 1985) (hereinafter National Guidelines), the *Nutrient Criteria Technical Guidance Manual – Rivers and Streams (*USEPA 2000) (hereinafter Rivers and Streams Technical Guidance Manual), and the *Nutrient Criteria Technical*

Guidance Manual – Lakes and Reservoirs (USEPA 2000) (hereinafter Lakes and Reservoirs Technical Guidance Manual). In 2001 and 2003, EPA published recommended water quality criteria for nutrients based on an ecoregion approach under section 304(a) of the Clean Water Act. *See* 66 *Fed. Reg.* 1671 (Jan. 9, 2001); 68 *Fed. Reg.* 557 (Jan. 6, 2003). More recently, EPA developed draft guidance called *Empirical Approaches for Nutrient Criteria Derivation* (draft 2009), which was subject to peer review by EPA's Science Advisory Board.

EPA also has issued various policy documents, including the *National Strategy for the Development of Regional Nutrient Criteria* (USEPA June 1998) (noticed in the *Federal Register* on June 25, 1998 at 63 *Fed. Reg*. 34648) and the 2001 memorandum from Geoffrey Grubbs to states on the *Development and Adoption of Nutrient Criteria into Water Quality Standards* (hereinafter Grubbs 2001).

Although EPA has developed recommended nutrient criteria under Section 304(a) using an "ecoregional" approach, EPA has made it clear that its criteria are merely a starting point and states should use EPA's technical guidance to develop water body specific criteria. *See*, 68 *Fed. Reg*. at 558 ("It is not mandatory or expected that the reference condition so derived [using the 75th percentile of all reference data] be translated directly into a criterion."). In fact, nutrient criteria that fully reflect localized conditions and protect specific designated uses, using the process outlined in the technical guidance manuals, are preferred:

> *EPA strongly encourages states, territories and authorized tribes to refine these recommendations based on the key elements of nutrient criteria development (historical information, reference conditions, models, consideration of downstream effects, and expert judgment) discussed in EPA's published Technical Guidance Manuals (Lakes and Reservoirs: EPA-822-B00-001; Rivers and Streams: EPA-822-B-00- 002). EPA recognizes that states and authorized tribes have several options available to them and recommends the following approaches, in order of preference: (1) Wherever possible, develop nutrient criteria that fully reflect localized conditions and protect specific designated uses using the process described in EPA's Technical Guidance Manuals for nutrient criteria development. Such criteria may be expressed either as numeric criteria or as procedures to translate a state or tribal narrative criterion into a quantified endpoint in state or tribal water quality standards.*

Grubbs 2001, at 15.

EPA's Rivers and Streams Technical Guidance Manual discusses three general approaches for criteria setting: (1) identification of reference reaches for each stream class based on best professional judgment or percentile selections of data plotted as frequency distributions, (2) use of predictive relationships (*e.g*., trophic state classifications, models, biocriteria), and (3) application and/or modification of established nutrient/algal thresholds (*e.g*., nutrient concentration thresholds or algal limits from published literature). Rivers and Streams Technical Guidance Manual, at 13. Whatever approach is used, however, the Rivers and Streams Technical Guidance Manual makes it clear that establishing a cause-and-effect relationship between nutrients and an adverse response is critical:

> *When evaluating the relationships among nutrients and algal response within stream systems, it is important to first understand which nutrient is limiting. Once the limiting nutrient is defined, critical nutrient concentrations can be specified and nutrient and algal biomass relationships can be examined to identify potential criteria to avoid nuisance algal levels.*

EPA. 2000. Nutrient Criteria Technical Guidance Manual – Rivers and Streams, at 74.

Given the complexity of nutrient criteria development, EPA has begun to suggest that a "weight of evidence" approach using field data be used to generate scientifically defensible numeric objectives. There is no formally issued EPA criteria development guidance on what constitutes an acceptable "weight of evidence" demonstration. However, EPA's Office of Research and Development has also provided additional background documentation regarding what should constitute an acceptable "weight of evidence" approach used in criteria development. ("*Using Field Data and Weight of Evidence to Develop Water Quality Criteria,*" Cormier et al, 2008 SETAC). That document specifies the following with respect to criteria derivation:

> *Development of numeric WQC is based on 3 basic assumptions: First, causal relationships exist between agents and environmental effects. Second, these causal relationships can be quantitatively modeled. Finally, if exposures to the causal agent remain within a range predicted by the quantitative model, unacceptable affects will not occur and designated uses will be safeguarded. Therefore, for criteria to be valid there must be evidence that the criteria are based on reasonably consistent and scientifically defensible causal relationships*.

C. Science Advisory Board Recommendations Applicable to the Division's Proposal

Most recently, EPA has indicated that empirical methods could be used to establish numeric nutrient criteria. These empirical methods include various types of regressions that correlate a biological metric (*e.g.*, a macroinvertebrate index) with nutrient concentrations. A criterion value is then determined based on the correlation and selection of an aquatic life impairment threshold for the particular metric. These methods were applied in several draft TMDLs issued by EPA Region 3 for Pennsylvania and promoted in EPA's N-STEPS website. The use of those methods was challenged and became the subject of a detailed peer review by the Science Advisory Board (SAB) Ecological Processes and Effects Committee in September 2009. In anticipation of the peer review, EPA issued draft guidance that described how to utilize the empirical methods. On April 27, 2010, EPA's SAB issued a report highly critical of the "statistical" methods being used to generate nutrient criteria and found these procedures inadequate for developing scientifically defensible criteria because they lack a "cause and effect" demonstration.[3] Key findings of the SAB relevant to the Division's rulemaking activity include the following:

1. Cause and Effect Demonstration Necessary

> *[T]he final document should clearly state that statistical associations may not be biologically relevant and do not prove cause and effect. (at 2, italicized text in last paragraph) Without a mechanistic understanding and a clear causative link between nutrient levels and impairment, there is no assurance that managing for particular nutrient levels will lead to the desired outcome. (at 6, first paragraph); The Guidance needs to clearly indicate that the empirical stressor-response approach does* ***not result in cause-effect relationships; it only indicates correlations that need to be explored further****. (at 41, bullet #1)(emphasis supplied)*

This finding is particularly significant with regard to the derivation of numeric nutrient criteria for streams. As discussed below, the Division used an empirical analysis to assess the relationship between nutrients and a biological metric, the Multimetric Index (MMI). The empirical analysis shows there is a very large amount of variability in MMI score at any nutrient concentration and the analysis framework presumes, but does not demonstrate, that nutrients are responsible for the decreasing MMI score at elevated nutrient concentrations. Without a mechanistic understanding of the relationship between a nutrient and the biological metric and a means of accounting for covarying factors that directly impact this metric, there is no way of knowing whether the presumed relationship is correct or if it merely reflects some other factor that co-varies with nutrient concentration. As the Division has presented no scientific analysis showing that elevated nutrient levels cause MMI reductions, this is just a preliminary correlation that requires further investigation as noted by the SAB.

2. Biological Significance/Use Impairment Threshold Relationship

> *The Committee emphasizes the importance of choosing the biological endpoints (i.e., response variables) that respond specifically to nutrients. We note that responses of benthic indices can be related to many types of stress. We question why periphyton would not be a better receptor to measure. (at 16, second bullet from bottom)*

For lakes, the Division has chosen a response metric (chlorophyll 'a') that may specifically and directly respond to increasing phosphorus levels. For streams, however, the MMI does not. The Division's use of MMI to define acceptable nutrient levels in the stream proposal is based on a key, unsupported assumption – invertebrate community

[3] See, SAB Ecological Processes and Effects Committee Review of Empirical Approaches for Nutrient Criteria Derivation. (April 27, 2010).

impacts (as indicated by the MMI score) are adversely affected by nutrient concentrations in excess of a reference threshold concentration. As noted by the SAB (and EPA's own guidance), there is no direct mechanistic relationship between nutrient impairment and invertebrate community integrity.

> *[F]ish and macroinvertebrates do not directly respond to nutrients, and therefore may not be as sensitive to changes in nutrient concentrations as algal assemblages. It is recommended that relations between biotic integrity of algal assemblages and nutrients be defined and then related to biotic integrity of macroinvertebrate and fish assemblages in a stepwise, mechanistic fashion.*

(EPA. 2000. Nutrient Criteria Technical Guidance Manual - Rivers and Streams at 85).

The strength and advantage of using an MMI (*i.e.*, bioassessment of benthic macroinvertebrates) is that it can integrate and detect the effects of multiple stressors over time. But the MMI was not developed to detect the effects of a single potential stressor, or to be regressed against an instantaneous measurement of that stressor at a particular site. It is a screening tool to detect general impairment, not to detect impairment specifically due to nutrients.

For nutrients to cause invertebrate community impairment they must first cause excessive plant (*e.g.*, periphyton) growth that in turn causes a change in habitat or water quality that subsequently impairs or adversely influences certain community constituents (*e.g.*, low DO, habitat, food supply) such that the community metrics that make up the MMI are negatively affected. The Division's proposal, as with EPA's discredited empirical relationship guidance, would regulate nutrients even where plant growth is not excessive and other relevant criteria (*e.g.*, DO) are achieved. In such circumstances, nutrient regulation is not demonstrated to be necessary. The SAB repeatedly underscored that multiple stressors influence metrics such as MMI. Failing to account for those factors will, in most situations, lead to mis-regulation and to continued environmental impairment, as the wrong parameter will be regulated. This occurred in a series of Pennsylvania TMDLs where EPA's streamlined methods were applied. ("*Critical Evaluation of EPA Stream Nutrient Standard Initiative*," W. Hall *et al*., BNA Environment Reporter, July 3, 2009). In those situations, both unimpaired waters and impaired waters received stringent nutrient limits. However, in none of the cases were nutrients actually the cause of the invertebrate impairments. The only reasonable way to avoid this situation is to require confirmation that nutrients are actually the cause of an alleged impairment via a demonstration that some type of excessive plant growth is altering the habitat, water quality, or community integrity.

In ASIWPCA's most recent letter to EPA regarding the stream numeric criteria (Attachment), this organization reiterated that use impacts must be <u>confirmed</u>, not presumed to exist:

> *Especially in view of the complex interactions by which nutrients exert their adverse impacts, and the lack of a dose-response relationship, ASIWPCA recommends that nutrient standards be applied only when there*

is biological confirmation of an impact related to nutrient loads from human sources that exceeds stressor identification and nutrient susceptibility determinations for the waterbody and that there is confidence that nutrient control is key to use attainment.

ASIWPCA to USEPA dated April 28, 2010.

The Division has established MMI thresholds that it considers thresholds of impairment for specific water body types. These thresholds may be appropriate response thresholds, but the empirical relationship used by the Division does not establish the necessary linkage between MMI and nutrient concentration. Without such a linkage as noted by both ASIWPCA and the SAB, nutrient regulation may result in no improvement of the MMI. Consequently, the proposed approach for developing stream nutrient criteria is not scientifically defensible.

3. Consideration of Factors Influencing Nutrient Dynamics/Impairment Metric

The examples provided in the Guidance generally do not demonstrate a strong nutrient stressor linkage to beneficial use impairment. The stream examples show very weak correlations that have high levels of uncertainty, and the examples lump data from distinctly different ecosystems where multiple factors in addition to nutrients will contribute to biotic responses. (at 16, fourth bullet)

In order to be scientifically defensible, empirical methods must take into consideration the influence of other variables. (at 24, 2nd bullet from bottom)…The statistical methods in the Guidance require careful consideration of confounding variables before being used as predictive tools. … Without such information, nutrient criteria developed using bivariate methods may be highly inaccurate. (at 24, first complete bullet)

For criteria that meet EPA's stated goal of "protecting against environmental degradation by nutrients," the underlying causal models must be correct. Habitat condition is a crucial consideration in this regard (e.g., light [for example, canopy cover], hydrology, grazer abundance, velocity, sediment type) that is not adequately addressed in the Guidance. Thus, a major uncertainty inherent in the Guidance is accounting for factors that influence biological responses to nutrient inputs. Addressing this uncertainty requires adequately accounting for these factors in different types of water bodies. (at 38, first bullet) Numeric nutrient criteria developed and implemented without consideration of system specific conditions (e.g., from a classification based on site types) can lead to management actions that may have negative social and economic and unintended environmental consequences without additional environmental protection. (at 38, third bullet).

Stream environments are highly variable, subject to numerous stressors and facilitate a great range of aquatic life due to habitat influences. Some of this is natural, but some is human-induced. (See, 16th Annual Meeting of the California Aquatic Bioassessment Workgroup (October, 2009) for research on habitat factors influencing stream macroinvertebrates) Unless the confounding factors are assessed, mis-regulation will, to a certainty, occur. For example, invertebrate community integrity/diversity is low in several areas of the Platte River, where only sandy substrate exists. These same conditions do not favor plant growth. In this circumstance, elevated nutrient levels do not cause adverse impacts. However, since the MMI approach does not inquire as to the cause of reduced invertebrate integrity/diversity, these sites would be improperly regulated as nutrient impaired. Likewise, merely plotting plant growth versus TN or TP concentration for a lake does not provide the necessary information for establishing a nutrient reduction program. It is well recognized that the standing crop of algae is a function of loading and nutrient availability, *not the ambient nutrient concentration measured at the time of the chlorophyll 'a' measurement.* Depending upon physical and biological factors, the conditions that lead to an unacceptable algal condition could be transient and not related to the current water column concentration. That is why most algal/nutrient relationships for lakes vary by at least a factor of four. This was clearly documented before the SAB and in EPA's recent nutrient criteria proposal for the State of Florida.[4] Understanding why the plant growth varies to this degree requires more careful consideration of lake morphology and biology to assess the necessary level of nutrient control required to address impairment.

4. Stream Considerations

> *Single variable stressor-response relationships (e.g., those derived using the simple linear regression approach discussed in the Guidance) that explain a substantial amount of variation are likely to be uncommon for most aquatic ecosystems (in particular, streams). (at 12, second bullet); As previously discussed, relationships for streams may be more complex than for lakes and must account for multiple stressors/conditions and/or stream 'types' or conditions, and then be applied appropriately. (at 25, first bullet)*

A key factor addressed by the SAB was the need to assess uncertainties associated with generating nutrient standards based on simplified regression analyses. Such uncertainties are considerably greater for variable stream environments where the nutrient plant response is governed by a host of physical factors. However, none of the relevant physical factors were considered by the Division in developing the proposed draft criteria. This is a major oversight that will lead to both over and under regulation. This deficiency can only be corrected by developing a criteria implementation approach that accounts for the critical physical factors that make a water body more or less sensitive to nutrient inputs. By establishing a procedure to assess actual impairment causes, more appropriate application of nutrient objectives is ensured. This procedure is particularly

[4] See, Technical Support Document for U.S.E.P.A.'s "Proposed Rule for Numeric Nutrient Criteria for Florida's Inland Surface Fresh Waters" (USEPA 2009)

important where man-made waters are at issue. In those cases, there is no preconceived notion of the degree of water quality that could or should be attained. Where large reservoirs are established with a major contributing watershed, higher algal growth would "naturally" be expected because one has turned a stream/river environment to a lake environment. In these cases, the desired uses should control decision-making. In Minnesota's recent lake criteria adoption, application of lake standards to reservoirs was excluded because there was no direct way to establish the water quality that would be expected to exist in such waters absent significant human influences. All such waters are addressed on a case-by-case basis considering watershed and use factors.

5. Loading versus Concentration Approach

> *A basic conceptual problem concerning selection of nutrient concentrations as stressor variables (as illustrated in the Guidance) is that nutrient concentrations directly control only point-in-time, point-in-space kinetics, not peak or standing stock plant biomass. Plant biomass is driven by nutrient supply rates (i.e., nutrient mass loads). Ambient nutrient concentrations are not necessarily good surrogates for nutrient mass loads. Relationships between nutrient mass loads and ambient nutrient concentrations are highly system-specific and depend on many factors including inflows, hydrology, bathymetry, sediment-water exchanges and chemical-biological processes. Consequently, there may be many systems for which nutrient concentrations will not be appropriate stressor variables. For such systems it may be more appropriate, and scientifically defensible, to use site-specific mechanistic models incorporating loading to determine the nutrient controls required to attain designated uses. (at 13, first bullet*)

This concern pertains particularly to lakes, where the relationship between phosphorus loading and eutrophic state is well established. However, even this relationship cannot be expressed as a simple correlation between in-lake concentration and chlorophyll 'a' concentration. Rather, phytoplankton growth also depends upon the loading distribution and hydraulic characteristics of the lake that affect nutrient cycling and the ability of grazers to reduce phytoplankton growth. Failure to consider these well known factors governing lake response to nutrients will lead to arbitrary and inappropriate nutrient regulation. In particular, for reservoirs, the volume and detention time of such waters may be highly variable and artificially altered. These conditions may greatly impact the degree of plant growth occurring.

6. Summary

The SAB findings provide a roadmap for developing water quality criteria for nutrients as well as a checklist to assess whether nutrient criteria are being developed in a scientifically defensible manner. Perhaps the most important aspect for criteria development is a demonstration of cause and effect. This demonstration requires a mechanistic understanding and a clear causative link between a stressor and a use impairment. This requires that the relevant physical factors influencing nutrient impacts be accounted for when empirical approaches are used in setting the criteria.

With respect to lakes, the SAB cautioned that factors influencing nutrient dynamics and the impairment metric must be considered in developing numeric nutrient criteria. In this regard, a shallow lake dominated by macrophytes will not respond in the same way as a deep lake, and an impounded river (*e.g*., a reservoir) will respond in a different manner than a natural lake. Lake algal dynamics are controlled primarily by phosphorus. Empirical relationships between algal growth and nitrogen are likely to be unreliable and misleading in regulating excessive plant growth. Moreover, the nutrient concentration may not be the best stressor to consider, since plant biomass is driven by nutrient supply rates (*i.e*., nutrient mass loads). Lake chlorophyll 'a' concentration observed during the summer months may be determined by spring runoff loads, but the Division's approach only considers summer nutrient concentration.

The SAB provided extensive advice regarding scientifically defensible approaches for developing nutrient criteria for streams. First and foremost, the biological endpoint of concern must specifically respond to nutrients. The Division is using the MMI as its biological endpoint of concern. The MMI is a benthic macroinvertebrate index that does not respond directly to nutrients. The SAB specifically noted that benthic indices can be related to many different types of stress. These different stressors must be considered because is it unlikely that nutrients, alone, will be able to explain a significant amount of the variation present in the data. However, the Division's approach is a single stressor regression analysis that ignores all other stressors. This type of analysis is the same analysis that the SAB evaluated and determined to be without scientific merit.

IV. EVALUATION OF SCIENTIFIC APPROACH

The approach taken by the Division has several major scientific deficiencies that must be addressed before the criteria should be considered for adoption. The primary deficiency with the greatest potential to misdirect resources is the decision by the Division to include numeric criteria for total nitrogen. Nutrient impacts are mediated through plant growth, which depends upon adequate levels of both nitrogen and phosphorus to cause excessive plant growth. Only one parameter requires control. In freshwater systems, phosphorus is typically the limiting nutrient and control of TP is usually sufficient to restore impaired uses. Regulating nitrogen in addition to phosphorus can promote blue green algae dominance which is very detrimental to a healthy lake ecology.

The criteria for lakes are proposed in two broad categories - cold water and warm water biota - that will result in unnecessary control for uses or impairments that may not exist. These two categories ignore other critical physical characterizations that significantly influence the attainable use of the lakes under consideration (*e.g*., depth, residence time, etc.). The empirically-derived nutrient criteria are a function of the physical characteristics of the waters from which the measurements were taken. Applying a performance characteristic for a deep lake to a shallow lake is not scientifically defensible. Such waters do not respond similarly to nutrient loadings. To ensure proper nutrient criteria derivation and allow consideration of actual uses, the Division should categorize lakes in terms of shallow versus deep lakes, natural versus man-made lakes, and recreational/aquatic life-use lakes versus agricultural-use lakes and primary drinking water supply lakes. These different categories of lakes support different types of fisheries and different quality attainment needs. For example, many shallow lakes and agricultural ponds may only be able to support a rough fishery consisting of bullheads and carp. The existence of such a fishery will prevent low chlorophyll 'a' levels from being attained. (Heiskary, S.; Lindon, M. *Interrelationships among water quality, lake morphometry, rooted plants and related factors for selected shallow lakes of West-Central Minnesota*, Minnesota Pollution Control Agency, St. Paul, Minnesota (2005)).

Finally, the river and stream standards presume that nutrients are stressors that drive the MMI score, and ignore all the other critical physical factors that play a more significant role influencing macroinvertebrate communities. Streams and rivers form complex ecosystems that require a mechanistic model to characterize the relationship between macroinvertebrates and abiotic factors. Without such a model, the relationship between nutrients and MMI is tenuous. (See, Nutrient Criteria Technical Guidance Manual – Rivers and Streams (EPA, 2000) at 85) The procedures used to develop candidate criteria make several presumptions that require demonstration before these methods can be applied. Primary among these is the presumption that nutrient concentrations greater than the anchor point "cause" a reduction in MMI. This is not a scientifically accepted position as underscored by the recent SAB review.

The following presents specific concerns that should be addressed before the numeric criteria are presented for adoption:

A. <u>Regulating Non-Limiting Nutrients (TN Control)</u>

Perhaps the single greatest concern with the proposed criteria is the recommendation that both TN and TP must be regulated in all waters. This proposal is made even though there is no information or analyses presented showing that TN control will provide any additional benefits beyond phosphorus control. It is widely recognized in the literature that lowering nitrogen levels, particularly in lakes, may promote harmful blooms of nitrogen-fixing blue-green algae and cause major adverse ecological impacts. Nitrogen removal may also be an energy intensive process and is extremely difficult to implement from a stormwater perspective. Dissolved forms of nitrogen must be converted into plant biomass or denitrified to be removed from the environment. BMPs are generally not capable of achieving significant TN reduction beyond that achieved by removing the nitrogen associated with particulate matter. The suggested TN criteria, approximately 1 mg/l, cannot be achieved in practically any water that receives a municipal or agricultural loading. Consequently, virtually all point sources would need to be eliminated and the associated water would not be available for downstream users, even though there is no objective ecological basis to justify such stringent controls.

1. TN limits are not justified by any demonstration of cause-and-effect

As part of the proposed criteria for lakes, the CWQCD has established both TN and TP requirements that must be achieved, regardless of the actual effect of nitrogen on chlorophyll 'a' levels. While it is generally accepted that TP levels may be effectively regulated in fresh waters to control excessive plant growth, it is not generally accepted that limitations on TN are required, or even beneficial, in many circumstances. Hundreds of TMDLs and other water quality-based limitations have been established by states and approved by EPA with this technical understanding. All of the lake TMDLs completed by the Division focused solely on TP control also. CWQCD now seeks to justify TN limitations by presenting a simplified correlation between chlorophyll 'a' levels and TN concentrations based on six paired data points. This analysis, however, does not provide a demonstration that TN levels are, in fact, controlling the chlorophyll 'a' levels in these lakes and the statistical approach does not justify the need for TN criteria. Nitrogen is a component of algal biomass and, therefore, increasing algal level would be expected to be accompanied by increasing TN levels. A mechanistic understanding of which nutrient is controlling plant growth in a lake is essential for identifying whether TN will have any impact on controlling plant growth. The EPA Science Advisory Board cautioned against the use of simplified correlation analyses, without a mechanistic understanding of the situation. SAB Report, at 6. Such an analysis supporting the need for TN control is not presented anywhere in CWQCD's presentation materials; however, considerable guidance, data and analysis to the contrary are available. For example:

> *When evaluating the relationships among nutrients and algal response within stream systems, <u>it is important to first understand which nutrient is limiting</u>. Once the limiting nutrient is defined, critical nutrient concentrations can be specified and nutrient and algal biomass relationships can be examined to identify potential criteria to avoid nuisance algal levels.*

EPA. 2000. Nutrient Criteria Technical Guidance Manual – Rivers and Streams, at 74. (Emphasis added).

> *Many natural factors combine to determine rates of plant growth in a waterbody. First of these is whether sufficient phosphorus and nitrogen exist to support plant growth. The absence of one of these nutrients generally will restrict plant growth. <u>In inland waters, typically phosphorus is the limiting nutrient</u> of the two, because blue-green algae can "fix" elemental nitrogen from the water as a nutrient source.*

EPA. 1999. Protocol for Developing Nutrient TMDLs First Edition at t 2-4. EPA 841-B-99-007 (Emphasis added).

> *The causal variables such as phosphorus and nitrogen are essential criteria because they will be the limits necessary to establish management objectives and are usually directly related to discharge runoff abatement*

efforts. Although phosphorus is the limiting factor for most lakes and reservoirs, in some regions the nutrient paradigm centers on nitrogen rather than phosphorus, especially where sewage treatment plant effluent is involved (Canfield, 1983; Pridmore, 1985; Jones et al., 1989). These regions are often in the subtropics or at high latitude or altitude (Wurtsbaugh et al., 1985; Morris and Lewis, 1988) but are also found in parts of Britain.

USEPA. 2000. Nutrient Criteria Technical Guidance Manual Lakes and Reservoirs at 2-3. EPA-822-B00-001 (Emphasis added).

The Division has previously concurred that nutrient regulation in lakes should focus on phosphorus, not nitrogen control. Supra at n.1.

As discussed above, eutrophication in freshwater lakes is controlled by phosphorus in the majority of instances. While nitrogen may be the limiting nutrient in certain cases, this is typically not the case and nitrogen limitation should be documented on a case-by-case basis. Under these circumstances, it is inappropriate to establish a criterion for TN that presumes all lakes require limits on nitrogen. Water quality criteria must be "necessary" to protect use, and a simplified regression certainly does not provide this proof.

The U.S. EPA employs a series of models that use TP as the proper nutrient for controlling plant growth in lakes. These assessments include the Vollenweider model and the State of Florida's MEI model. 75 *Fed. Reg.* at 4186, 4188. Both of these models have been used and documented to predict the ability to control chlorophyll 'a' levels through TP reductions. None of these analyses show that effective reductions can be achieved through TN control and it is widely recognized that reduced TN levels may promote harmful algal blooms

The U.S. EPA has issued numerous nutrient TMDLs for lakes in other states based on the technical conclusion that TP control is sufficient to protect uses and limit excessive plant growth. EPA's efforts to control plant growth in the Great Lakes and Potomac River have all focused on TP not TN control. In five different Pennsylvania stream TMDLs developed by EPA in June 2008, EPA concluded that TN regulation was not appropriate because TN was not the limiting nutrient in these waters.[5] Similarly, EPA's efforts in the Everglades have focused on TP, not TN control. If adopted, the latest CWQCD approach would force additional nitrogen reduction for state waters when the new criteria become effective, even where the TMDL actions have determined that TP control will be sufficient to produce the desired plant growth level. Such a result would be wasteful of local and state resources, and not consistent with the requirements of either state or federal law. Applicable laws only require implementation of those pollution reduction measures that are necessary to protect uses.

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[5] See, *e.g.*, Nutrient and Sediment TMDLs for the Indian Creek Watershed, Pennsylvania, established by the U.S. Environmental Protection Agency, June 30, 2008. Similar TMDLs were established for Goose and Paxton Creeks.

The Department's own watershed protection control requirements confirm that TN control is not necessary to achieve chlorophyll 'a' objectives in most lakes and reservoirs. The Water Quality Control Commission established site-specific regulations for several reservoirs to protect them from excessive algal growth. These include Dillon Reservoir (5 CCR 1002-71), Cherry Creek Reservoir (5 CCR 1002-72), Chatfield Reservoir (5 CCR 1002-73), and Bear Creek Reservoir (5 CCR 1002-74). In each case, the regulations establish limits on the load of phosphorus entering the reservoir, but not the load of nitrogen. Additional detail on the basis for regulating phosphorus in these reservoirs is presented in Appendix A.

Based on the foregoing, the basis for regulating TN in all Colorado surface waters is inadequate because there is no analysis showing TN control is generally necessary to regulate plant growth in fresh waters. Consequently, the CWQCD should withdraw the TN criteria or, at a minimum, only require control of that nutrient where it is documented that it will effectively limit plant growth <u>and</u> avoid promoting toxic algal blooms. This decision must be based on site-specific analysis in order to avoid causing adverse environmental effects and avoid wasting energy and local resources. Site-specific information is essential for making an informed decision on this issue.

2. No objective scientific basis provided for regulating nitrogen to prevent excessive plant growth in streams.

As with lakes, the CWQCD is recommending that both nitrogen and phosphorus be controlled to very low levels to avoid adverse impacts in streams and rivers. This approach is directly at odds with earlier Division presentations that specified TP control would be sufficient in most cases. Supra at n.1. There are no data in the record indicating that regulating nitrogen levels in streams is a generally required action or that it is an approach accepted by the scientific community to control excessive plant growth in streams. As with lakes, EPA's prior TMDL activities for streams have focused on TP reduction. Hundreds if not thousands of stream water quality analyses approved by EPA have focused on phosphorus as the parameter of concern in regulating plant growth in streams. In recently issued stream TMDLs for five Pennsylvania watersheds, EPA concluded TN control was not required because the parameter did not limit plant growth. Supra at n.5. The Division has failed to demonstrate why statewide TN controls are appropriate where numerous site-specific analyses have concluded TN controls are not necessary.

It has not been documented that there will be any discernable benefit from TN reduction, beyond that obtained through TP reduction (where excessive plant growth actually exists). For the reasons previously explained under the lake's comments, the TN reduction requirements should be withdrawn. TN reduction should be a site-specific determination only made after careful analysis of the data and confirmation that TN reduction is required to prevent excessive plant growth.

B. <u>Lake and Reservoir Approach</u>

CWQCD has presented preliminary summer average nutrient (TN and TP) and chlorophyll 'a' numeric criteria for two broad categories of lakes (cold water and warm water). The Division is recommending that these criteria should not be exceeded more frequently than once in five years. This would require compliance with <u>all three</u> numeric criteria (TP, TN and chlorophyll 'a') for the waters to be considered non-impaired. The impairment indicator (response variable) intended to be controlled is phytoplankton (floating algae) as measured by the degree of chlorophyll 'a' present in the waters. This is the indicator of nutrient impairment that is generally accepted by the scientific community.

1. Comment on Chlorophyll 'a' targets

As indicated in the August 2009 presentation materials, the chlorophyll 'a' concentrations were established to protect specific types of fisheries. This approach seems reasonable provided that appropriate justification is provided demonstrating a need for nutrient reduction to achieve this target. As noted above, certain waterbody types cannot be reasonably expected to support the two fishery types upon which the chlorophyll 'a' criteria are based. Lakes that experience fill and draw-down cycles or those intended to be agricultural water sources may only support a rough fishery (carp and bullheads), and this fishery type does not require as restrictive chlorophyll 'a' criterion.

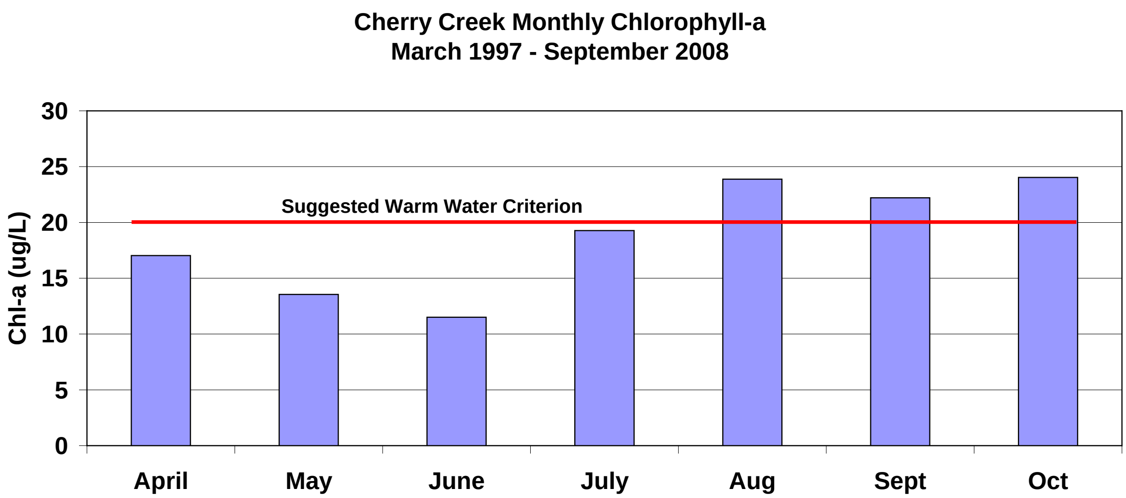
2. Return Frequency of Criteria

The Division has proposed that the selected mesotrophic chlorophyll 'a' target be achieved as an 80^{th} percentile concentration once in five years. This is far more restrictive than necessary to protect warm water fishery objectives. Mesotrophic targets are considered long term average trophic conditions, not short term infrequent conditions. (See, USEPA TSD Florida WQS proposal.) Given the joint probabilities used by the Division to apply the 20 µg/l chlorophyll 'a' target, the selected value will occur 4% of the time or less. (*e.g.,* once in 5 years – 20% occurrence, 80^{th} percentile concentration – a 20^{th} percentile occurrence). To achieve the 20 µg/l target this infrequently, the actually long term average summer concentration will need to be less than 8 – 10 µg/l – a concentration bordering on oligotrophic (assuming a CV of 1.0). It is not appropriate to mandate that all lakes and reservoirs in the state achieve this very low level of chlorophyll 'a' growth. There are no data in the record showing this level of plant growth is necessary to protect fishery uses in all standing waters or that it is necessary to protect high quality warm water fisheries.

3. Growing Season

The Division calculated growing season averages for the period from July – September as the basis for assessing compliance with the aquatic life chlorophyll 'a' targets. Other northern-tier states (*e.g.,* Minnesota) use a growing season average of April – October as the basis for assessing compliance with chlorophyll 'a' lake criteria for aquatic life protection. EPA has recommended application of this 20 µg/L chlorophyll 'a' objective as an annual average in Florida. This difference in the specification of the growing season is significant because the Colorado approach excludes periods of reduced algal growth that occur earlier in the growing season. The resulting long-term summer average algal level is elevated with respect to the typical growing season average chlorophyll 'a' level as illustrated in Figure 9 for Cherry Creek. The long-term average chlorophyll 'a' level[6], calculated for a summer period of July – September (21.8 µg/L), exceeds the suggested warm water criterion (20 µg/L). However, the long-term average for the April – October growing season (18.8 µg/L) does not.

Figure 9



Because of the more restrictive averaging approach proposed by the Division, the actual long term average must be well below the 20 µg/L level that is considered protective of fishery resources. Based on EPA-approved actions in other states, the Division approach is more restrictive than necessary to protect lake uses. Therefore, it is recommended that the 20 µg/L chlorophyll 'a' target be applied as an April – October growing season average.

4. Identification of Nutrient Concentrations

The chlorophyll 'a' targets were related to specific levels of TP and TN using empirical relationships under the assumption that, if the TP/TN level did not rise above the threshold value (as an 80^{th} percentile summer average), then the chlorophyll 'a' level would not exceed its fisheries-based target. This approach presumes a specific cause and effect relationship between the 80^{th} percentile nutrient concentration and the 80^{th} percentile chlorophyll 'a' level that has not been demonstrated to be generally applicable to all standing waters regardless of their actual physical characteristics and use.

[6] The long term summer average was calculated as the average of each month in the period, with all months given equal weighting.

Moreover, the specific measured concentration of chlorophyll ‘a’ is not a direct result of the present ambient nutrient concentration. An alternative, and generally accepted model of lake trophic state, is that of Vollenweider, which evaluates trophic state as a function of the areal loading rate and average depth of a lake.

a. Division’s classification system should include additional categories.

Criteria are supposed to be designed to reflect the water quality parameters necessary to protect the beneficial uses of the waters. Rather than focusing on use protection needs, the Division has focused on waterbody type. The Division determined that there are only two basic types of lakes in Colorado: cold water and warm water. Within these classifications, the Division did not further consider whether any other physical characteristic of the lake (depth, prevalence of emergent plant growth, degree of freshwater inflow, local geology, type of warm water fishery, *etc*.) would influence the lakes’ algal response to nutrient level or whether the proposed chlorophyll ‘a’ levels are necessary to protect the designated use. For example, lakes (both natural and man-made) that experience significant draw-down cycles cannot support the same fisheries envisioned by the proposed criteria but readily meet their intended agricultural use. Moreover, lakes with a predominant rough warm water fishery cannot maintain lower algal levels because of bio-perturbation that mobilizes sediment bed nutrients.

It is well recognized in the literature and EPA nutrient criteria guidance manuals that the physical characteristics of lakes dramatically impact the type of response that may occur to nutrient inputs. *Nutrient Criteria Technical Guidance Manual – Lakes and Reservoirs*, (USEPA April 2000). EPA’s Science Advisory Board recently informed EPA that attempts to establish defensible nutrient criteria for water body types will require more refined classification approaches that reflect the important physical factors and characteristics that control plant growth. *SAB Review of Empirical Approaches for Nutrient Criteria Derivation* (April 27, 2010) (SAB-10-006) at 12, 17, 38 (hereinafter SAB Report). Thus, failure to account appropriately for these factors will produce criteria that are likely to be dramatically overprotective, in violation of National Guidelines principles and applicable regulatory requirements. The limited information presented by the Division in support of these preliminary criteria confirm that the proposed approach will mis-regulate and unnecessarily regulate most lakes because the proposal does not differentiate lakes based on the appropriate physical characteristics. The database, however, reflects a limited set of characteristics and only provides an indication of similar potential response if the physical characteristics are the same.

For shallow lakes, EPA recognizes that the prevalence of emergent plant growth impacts how nutrients will affect the lake. (*See* TSD for EPA’s Proposed Numeric Nutrient Criteria for Florida Inland Surface Fresh Waters, at 1-7.) In its Florida nutrient criteria proposal, EPA referenced various Minnesota studies that confirm the same influence of emergent plant growth where very high nutrient levels may exist with relatively low chlorophyll ‘a’ levels. These data confirm that macrophyte growth is a critical factor prevalent in shallow lakes that must be accounted for in deriving appropriate nutrient criteria. The National Guidelines require that criteria properly reflect the important factors that influence their impact on the environment. The Division's approach does not meet this requirement for proper criteria derivation. The following classification refinements are necessary to ensure the criteria do not significantly over- or under-regulate nutrient levels.

b. Lakes influenced by streams (watershed size dependence).

In addition to the physical characteristics of the lake, the physical characteristics of the watershed influence the nutrient concentration and loading that a water body will naturally receive. EPA's analysis of the effect of stream flow on lake response for the recently proposed Florida nutrient standards confirms that the greater the watershed size feeding the lake (even from pristine areas), the greater the chlorophyll 'a' level expected to occur naturally.

This assessment confirmed that the Division's categorization approach to lake nutrient criteria selection is misplaced, because it failed to account for a critical physical factor influencing the degree of plant growth that would naturally be expected to occur in lakes – watershed size feeding into the lake. In Minnesota's recent lake criteria adoption the lakes with a significant watershed (*i.e.*, run-of-the- river lakes or reservoirs) were determined to be distinct from other lake types. Because these waters naturally receive higher loadings, Minnesota is establishing higher water quality criteria for these waters. Minn. R. ch. 7050.0222. Based on the National Guidelines the critical factors influencing the expected impact of a pollutant are to be included in deriving criteria. The degree of stream flow entering a lake has been documented to be such a factor and, therefore, a separate category of lakes needs to be established reflecting the influence of this factor on the nutrient and chlorophyll 'a' level that may reasonably be obtained for such waters.

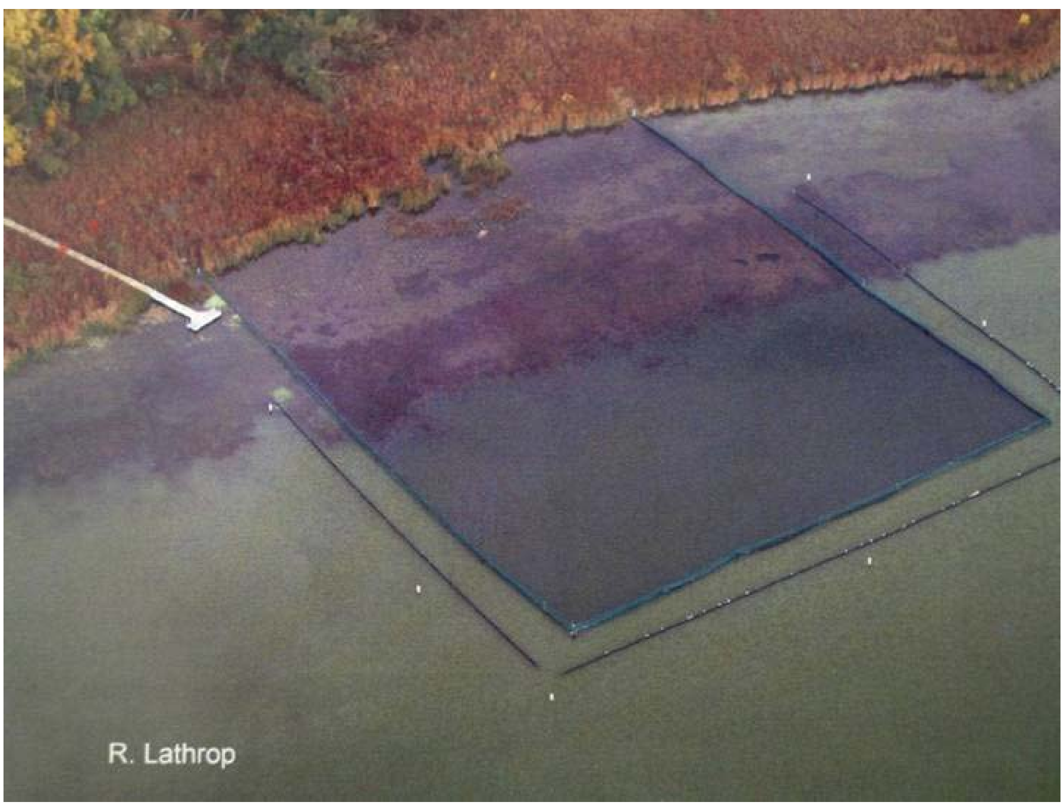
c. Long versus short detention time.

EPA's published guidance on lake response to varying nutrient levels and loadings indicates that detention time is a critical factor influencing the expected chlorophyll 'a' response. Lakes with very long detention time may produce much lower chlorophyll 'a' levels for a given concentration/loading because resuspension is minimal. Likewise, very <u>short</u> detention time limits plant growth hydraulically. Although detention time is widely recognized as a critical factor influencing a lake's response to nutrient inputs, the Division did not consider this factor in assessing the appropriate chlorophyll 'a' and nutrient concentration objectives for cold water or warm water lakes. Based on the well-published literature, appropriate nutrient criteria should be a function of lake detention time. Higher (relaxed) standards should apply to shorter detention time waters and very deep lakes. The Division's failure to account for this factor in establishing the lake criteria was a serious oversight that needs to be corrected.

d. Lakes influenced by the type of fishery present.

In assessing appropriate lake criteria, the Division also failed to account for the influence the type of fishery may have on the water quality that is reasonably attainable. Numerous studies have shown that lakes dominated by carp and catfish typically have much higher chlorophyll 'a' levels because such fish graze on the macrophytes and stir up sediments. Heiskary, S.; Lindon, M. *Interrelationships among water quality, lake morphometry, rooted plants and related factors for selected shallow lakes of West-Central Minnesota*, Minnesota Pollution Control Agency, St. Paul, Minnesota (2005). Where this occurs chlorophyll 'a' levels can become extremely high, well above eutrophic levels, even where nutrient inputs to the lake are minimal (Figure 10). Under this circumstance the "natural" condition would be well above the Division's proposed nutrient and chlorophyll 'a' criteria. Failure to account for this factor that is well recognized by limnologists was a significant technical oversight that needs to be corrected. A separate classification for waters identified as dominated by these species of fish needs to be developed to avoid improperly regulating such waters.

Figure 10 Effect of Carp Exclusion on Chlorophyll in Lake Wingra, MN



e. Man-made Lakes and Reservoirs.

The Division intends that the developed nutrient objectives protect natural lakes as well as man-made lakes and reservoirs. Man-made lakes, however, may have distinctly different characteristics than natural lakes and may not exhibit all of the uses the Division presumes are applicable in natural lakes. These lakes, including quarries, golf course and farm ponds, may not have diverse aquatic life and may not allow swimming uses. These waters should be given their own category and controlled only to the degree the uses are consistent with the original purpose for developing the waters. Reservoirs, as discussed earlier, are created for specific uses that may clash with the state-wide requirements specified for all lakes. Moreover, their physical attributes and management may preclude the attainment of certain uses otherwise desired for natural lakes.

For example, EPA's Technical Guidance Manual for Lakes and Reservoirs notes that no natural reservoir reference conditions exist, so reservoirs should be classified according to hydrology, morphometry, management objectives, and other factors. Lakes and Reservoirs Technical Guidance Manual, at 3-5. Water control structures can create significant seasonal fluctuations in water column depth, storage volume, and retention time that must be considered when developing nutrient criteria. *Id.* at 3-6. In response to comments on its 304(a) criteria for Lakes and Reservoirs, EPA agreed that reservoirs should not be grouped with lakes and criteria for reservoir and lakes should be developed separately. 68 *Fed. Reg.* 557, 559 (Jan. 6, 2003). Similarly, man-made lakes in Colorado should have their own classification and should not be classified with natural lakes. These waters need to be assessed on a case-by-case basis.

Conclusions regarding the Division's proposed criteria for lakes

Although the Division has attempted to establish lake criteria based on a stressor/response relationship, its proposed criteria for lakes are technically deficient. As a result, the criteria also are legally deficient.

First, this approach is too simplistic, placing lakes in only two overly broad categories: cold water lakes and warm water lakes. This failure to properly classify lakes means that the Division is proposing criteria for lakes that fail to account for natural nutrient levels and natural plant growth; fail to consider critical factors such as depth, size and type of watershed feeding the lake, detention time, and fishery present; and fail to take into account different uses. As a result, the proposed criteria for lakes are not based on the levels of nutrients needed to protect designated uses, contravening 40 C.F.R. 131.2. The Division's decision to establish a uniform chlorophyll 'a' threshold for cold water lakes and one for warm water lakes is not scientifically defensible, contravening 40 C.F.R. 131.11(a) and will lead to criteria that are not necessary to protect designated uses, contravening 40 C.F.R. 131.2.

For warm and cold water fisheries, the proposed chlorophyll 'a' targets are being applied in an unduly stringent manner. Applying a long term trophic state target (*e.g.*, 20 µg/L chlorophyll 'a') as a once-in-five-year, peak summer (July – September) average essentially doubles the stringency of the requirement. It is recommended that the target be applied as a growing season (April – October) average not to be exceeded more frequently than once in three years.

Finally, by proposing criteria for TN without establishing whether or not nitrogen is causing impairment, the Division is proposing criteria that are not necessary to protect designated uses, again contravening 40 C.F.R. 131.2. As noted above, EPA guidance requires nutrient criteria to be developed based on adequate data on water body condition, establishment of the threshold level of a nutrient that causes impairment, and a mechanistic understanding and a clear causative link between nutrient levels and impairment. The approach used by the Division also runs counter to the recommendations of the SAB.

Due to these deficiencies, Colorado's approach to nutrient criteria for lakes does not meet the technical or regulatory requirements of the Clean Water Act. To correct these deficiencies, the Division needs to (1) refine its classification of lakes, as recommended above, (2) identify an impairment threshold using chlorophyll 'a' for each class of lakes, (3) select a range of acceptable TP levels for each class of lakes, (4) only apply the limits on TP if the criterion for chlorophyll 'a' is exceeded, and (5) determine whether TN must also be controlled to meet the chlorophyll 'a' criterion, based on site-specific information.

C. <u>Stream and River Approach</u>

The approach for developing nutrient criteria for streams and rivers has been included in several presentations by the CWQCD, dating back at least to August 19, 2009. That approach is based on an empirical analysis wherein nutrient concentrations greater than the anchor point are presumed to cause a decrease in the MMI. (See, CWQCD presentation, Nutrients in Rivers and Streams, Part II. February 9, 2010 at 39). The "anchor point" is defined as the 85th percentile of grab sample concentrations observed at reference sites. The draft criterion is determined as the nutrient concentration corresponding to a 5% decline in the median MMI for the reference sites, as predicted using the OBP slope. The median MMI for cold water reference sites is 70 and the median MMI for warm water reference sites is 60. (See, CWQCD presentation, Nutrients in Rivers and Streams, Part II. February 9, 2010 at 41). Consequently, the nutrient impairment threshold MMI for cold water streams is 66.5 (*e.g.*, a 5% reduction from the median for reference sites). The nutrient impairment threshold MMI for warm water streams is 57.

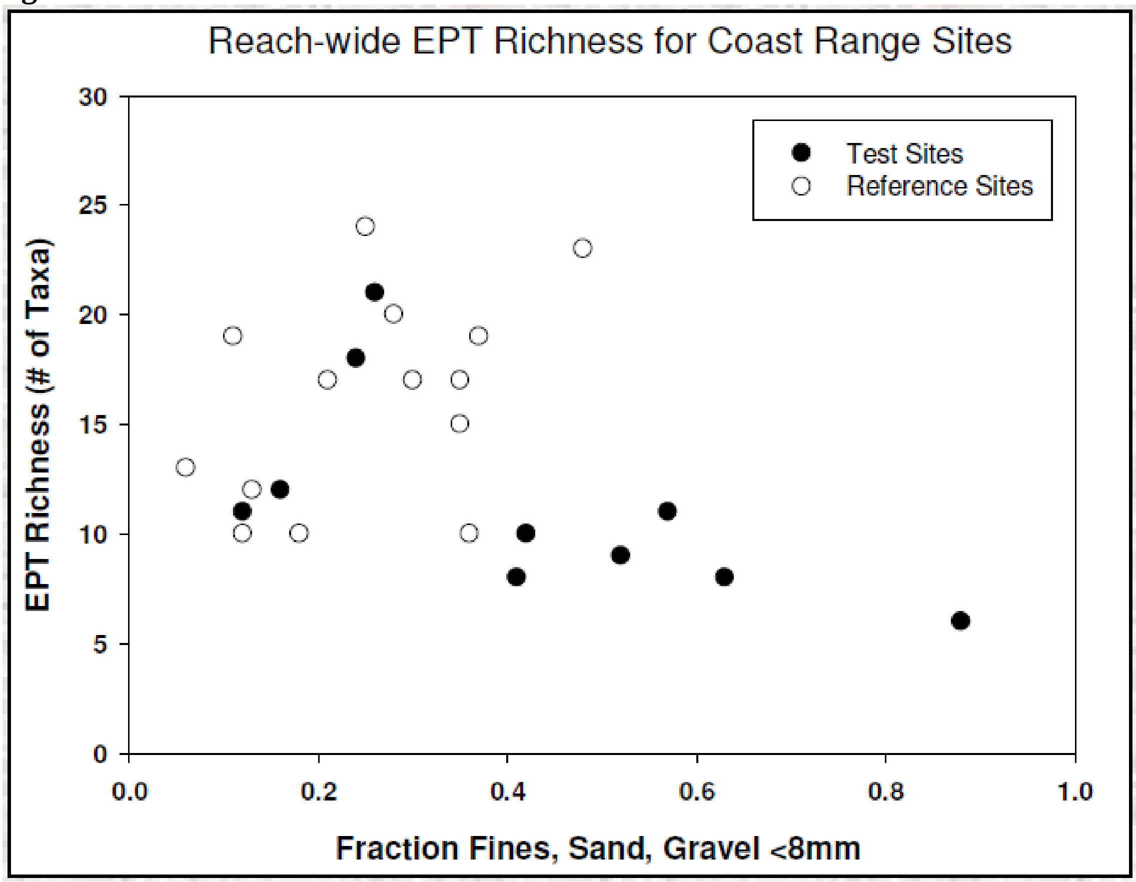
This approach is technically deficient and is internally inconsistent with other approaches used by the Division to assess use impairment and develop nutrient criteria. The SAB recently informed EPA that stream nutrient criteria, in particular, must account for the numerous physical/habitat factors that control whether or not excessive plant growth will adversely impact macroinvertebrate populations. SAB Report, at 16, 24. Likewise, the National Guidelines require that criteria derivation reflect the critical factors that influence the effect that the pollutant may have on aquatic life. National Guidelines, at 5, 18. The basic purpose of these requirements is to avoid significantly over or under regulating the pollutant. *Id.* However, The Division's approach ignores all physical factors that influence nutrient dynamics in streams under the assumption that simple empirical relationships can elucidate impairments to macroinvertebrate communities directly caused by nutrient concentrations. This approach is not generally accepted by the scientific community as demonstrated by the recent SAB report and, therefore, as a matter of law, cannot be used for criteria derivation.

The approach used by the Division to generate numeric nutrient criteria for TP/TN is an empirical analysis that is, for all practical purposes, *identical* to the methods proposed in EPA's draft guidance that was the subject of a SAB peer review. The SAB found that this approach is not sufficient to develop scientifically defensible numeric nutrient criteria. The SAB specifically noted that single stressor-response relationships, such as those used in the CWQCD approach, are unlikely to yield appropriate stream criteria and the response of benthic indices, such as MMI, can be related to many types of stress. Consequently, a mechanistic understanding and a clear causative link between nutrient level and impairment is necessary.

For example, research conducted by the State of California indicates that urban stressors, such as road density, result in decreasing biological metrics. It is well known that sediment deposition/substrate quality adversely affects benthic invertebrates. Information presented by researchers[7] from the University of California, at the *16th Annual Meeting of the California Aquatic Bioassessment Workgroup* (October, 2009) illustrate this relationship (Figure 11). These data show that as fines increase, invertebrate populations drop dramatically.

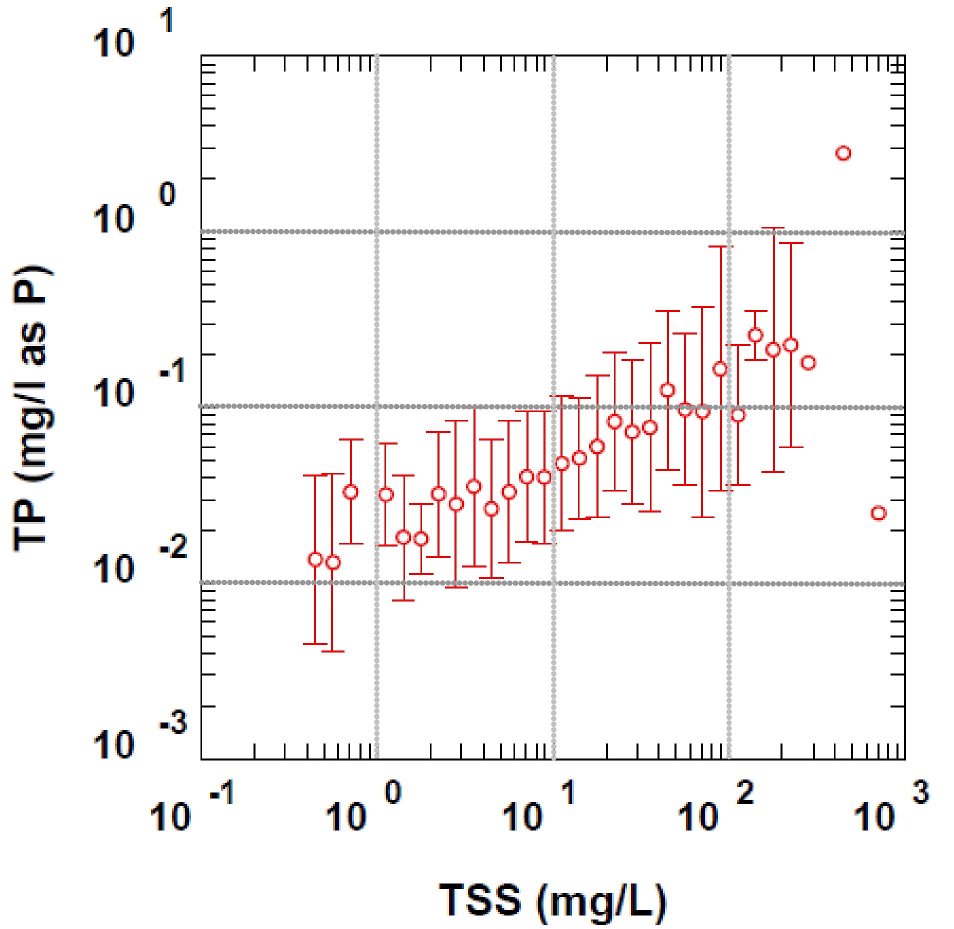
[7] Herbst, D, S. Roberts, B. Medhurst, and N. Hayden. Benthic invertebrate responses to patch and reach-scale deposition and the relation of land use and roads to sedimentation. http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/cabw2009/invertrespseddepos.pdf

Figure 11



Consequently, it is appropriate to consider whether nutrient levels covary with any of the known invertebrate stressors. For example, information collected in the panhandle region of Florida shows that stream TP is positively correlated with suspended solids, as illustrated in Figure 12. If similar relationships exist in Colorado, as would be expected, it is incumbent upon the CWQCD to demonstrate that the observed MMI reductions are not caused by suspended solids, with elevated TP (or TN) levels only along for the ride.

Figure 12 Relationship between TSS and TP in the Florida Panhandle Region



In the case of sediment, there is a well known mechanistic understanding of the relationship between this factor and macroinvertebrates. Macroinvertebrates have specific habitat requirements and these habitat requirements are adversely affected by sedimentation. No such relationship directly links TP to MMI. EPA made this observation in its guidance document[8] on developing nutrient criteria for rivers and streams:

> *[F]ish and macroinvertebrates do not directly respond to nutrients, and therefore may not be as sensitive to changes in nutrient concentrations as algal assemblages. It is recommended that relations between biotic integrity of algal assemblages and nutrients be defined and then related to biotic integrity of macroinvertebrate and fish assemblages in a stepwise, mechanistic fashion.*

(EPA. 2000. Nutrient Criteria Technical Guidance Manual – Rivers and Streams at 85).

[8] Nutrient Criteria Technical Guidance Manual – Rivers and Streams. USEPA 2000. EPA-822-B-00-002

With this in mind, again consider the wedge plots presented in Figure 6 and Figure 7 that are relied upon to generate the numeric stream criteria. CWQCD presumes that reference sites with low MMI scores must be impaired by factors other than nutrient concentration and that at higher nutrient concentrations, the reduction in the MMI is due to nutrients. There is, however, no objective basis for this position. Suppose, however, that sedimentation is responsible for the low MMI scores seen at higher nutrient concentrations. Since TP increases as TSS increases, one would expect to see the same wedge shape as that presented in Figure 6, but nutrient control would not restore the MMI score. As stated by the SAB, the Division needs to identify the impairment factors causing a reduction in the MMI under low nutrient concentrations and verify that those factors are not responsible for MMI reductions associated with elevated nutrient concentrations. If this evaluation is not done, the Division will arbitrarily regulate nutrients without resolving the underlying conditions that actually cause reductions in the MMI score.

1. "Anchor Point" Method Produces a Misplaced Impairment Threshold.

As a practical matter, the TP/TN criteria established, with the "anchor point" method, are equivalent to impairment thresholds of MMI = 66.5 (cold water) and MMI = 57 (warm water). However, the Division's proposed MMI impairment threshold policy uses a cold water MMI threshold of 46 and a warm water threshold of 25 to make use impairment listing determinations. (See March 8, 2010 CWQCD presentation at 37) More recently, the impairment thresholds have been revised to 52/50 (cold water transition and mountain biotypes) and 37 (warm water plains biotype), but even these revised thresholds of impairment are less than the 5% reduction values used to derive the TP/TN endpoints. Consequently, a stream could be assessed as meeting water quality objectives based on a measure of its MMI score while at the same time assessed as impaired for MMI based on a measure of nutrient concentration. Such an approach gives greater weight to the MMI score implied from the nutrient measurement than to the actual measure of the MMI score.

The proposed approach would establish impairment listing inconsistent with those concurrently proposed for aquatic life. Moreover, using this new definition for the MMI impairment threshold, many reference sites would be considered impaired. However, CWQCD does not consider reference sites to be impaired. (See March 8, 2010 CWQCD presentation at 23) If reference sites are not impaired, it does not make sense to set the anchor point equal to the 85^{th} percentile of the reference station nutrient concentrations. This approach fails to relate nutrient concentrations to environmental needs.

V. REVIEW OF DATA AND CALCULATIONS SUPPORTING PROPOSED NUTRIENT CRITERIA

The data and calibration method used by the Division to develop its draft nutrient criteria were provided to the Coalition. Based on the descriptions provided in the various presentations by the Division, the data were assessed to determine whether the draft nutrient criteria are supported. A key consideration in this regard was an assessment to determine whether a cause-and-effect relationship exists between the nutrient and the response variable. It is apparent that the approach used highly flawed methods for predicting cause and effect relationships for all waters.

A. Lakes and Reservoirs

The chlorophyll 'a' criteria were specified based on a determination of which type of fishery could be supported by a given algal level. The summer average chlorophyll 'a' concentration of 8 µg/L is intended to provide optimal conditions for most salmonids in cold water lakes. The summer average chlorophyll 'a' concentration of 20 µg/L is intended to provide optimal conditions for warm water game fish in warm water lakes. As noted previously in these comments, two lake classifications are insufficient to physically characterize the needs of lentic ecosystems and establish nutrient criteria. While the proposed chlorophyll 'a' criteria may be appropriate for deep cold water and deep warm water lakes, those criteria are not appropriate for other types of fisheries or shallow, lower detention time systems. The Division needs to develop proposed chlorophyll 'a' criteria for these other fisheries and lake types.

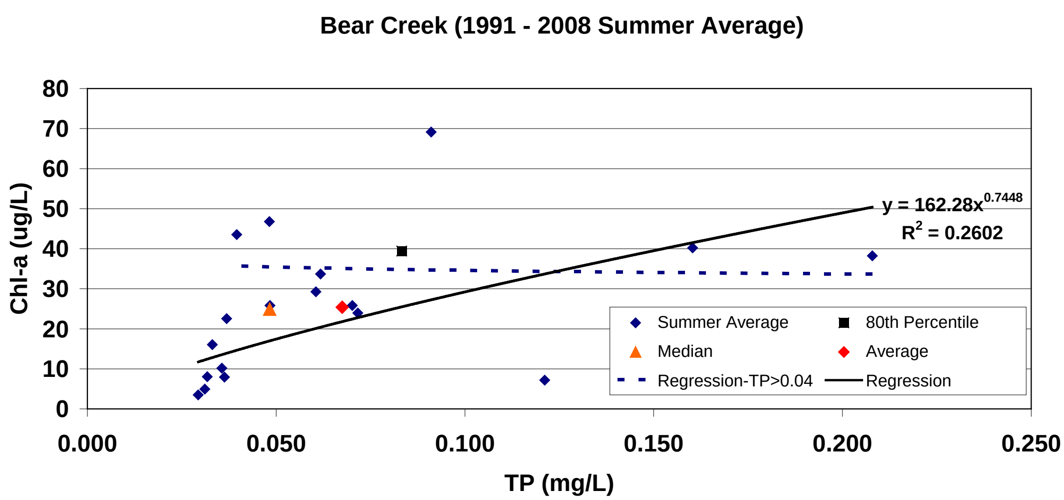
The TP and TN criteria were developed using empirical regressions to calculate the nutrient concentration corresponding with the chlorophyll 'a' criteria. For this analysis, the Division used one regression to derive the warm water and cold water criteria, using a procedure wherein all the summer data for each lake was condensed into a single chlorophyll 'a' and nutrient concentration pair (as illustrated above in Figure 1 and Figure 3). The analysis pairs the 80^{th} percentile concentration of each parameter under the assumption that summer average chlorophyll 'a' concentration increases in response to increasing summer average nutrient concentration. The following reviews several of the individual lake data sets used to generate the numeric criteria and confirms that the Division's proposed relationship does not reflect individual lake nutrient responses.

1. Cold Lakes

Four cold water lakes were evaluated to assess whether regressions using the 80^{th} percentile concentrations are appropriate for assigning the TP criterion. These include: Bear Creek, Dillon, Granby, and Shadow Mountain. These lakes were selected because the available data extended over at least 15 years, providing a sufficient number of data points for trend analysis. For each lake, the summertime (July – September) average chlorophyll 'a' and TP concentrations were calculated for each year of record. Those data pairs were then plotted for each lake in comparison with the 80^{th} percentile, median, and average concentrations for the data set. The results are illustrated below.

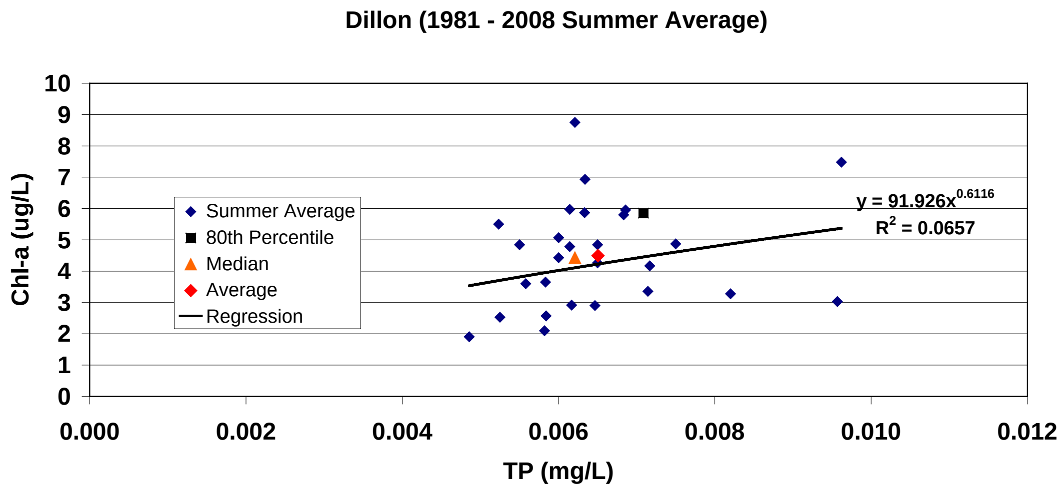
Bear Creek (Figure 13) is a deep, cold water lake with elevated phytoplankton and TP concentrations. The database included 18 years of data, with all observations in excess of the draft TP criterion of 24 µg/L, and 72% of the observations exceeding the algal criterion (8 µg/L). The data suggest that chlorophyll 'a' concentration increases with increasing TP concentration, but the regression coefficient is low (R^2 = 0.26). The regression also suggests that the 80th percentile point exceeds the regression estimate by about 50%. The data also include a data point that meets the algal target even though the TP concentration exceeds the criterion by a factor of 5. In actuality, TP values > 0.04 mg/l appear to have no clear effect on plant growth in this lake. Other factors appear to limit chlorophyll 'a' to < 50 µg/l regardless of TP present. These physical factors need to be assessed to produce a defensible target for this lake (*e.g.*, turbidity occurring with elevated TP loading).

Figure 13



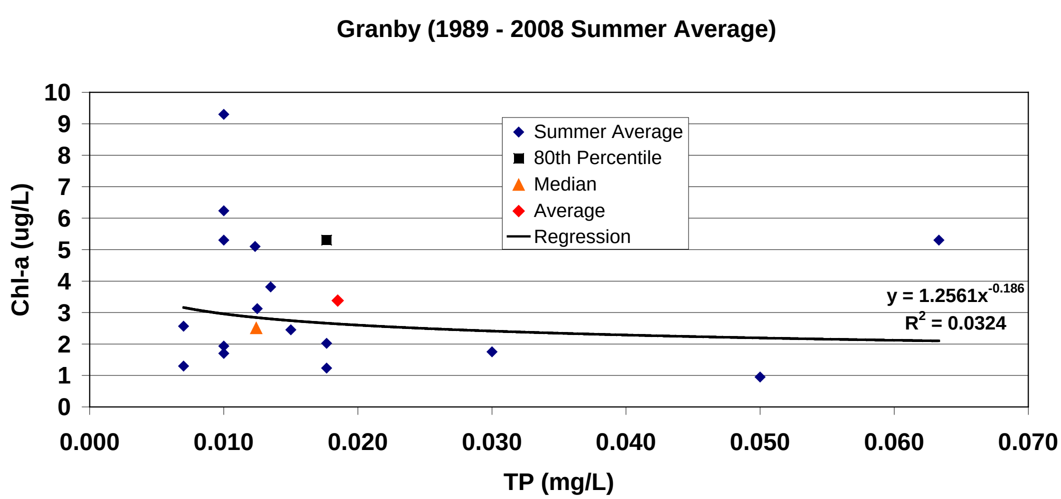
Dillon (Figure 14) is a deep, cold water lake with low phytoplankton and TP concentrations. The database included 27 years of data, with all observations significantly less than the draft TP criterion. The data suggest that variations in the chlorophyll 'a' concentration are unrelated to TP concentration (R^2 = 0.07), though the range of TP is too small (0.005-0.009 mg/l) to reliably reach any conclusion regarding these data.

Figure 14



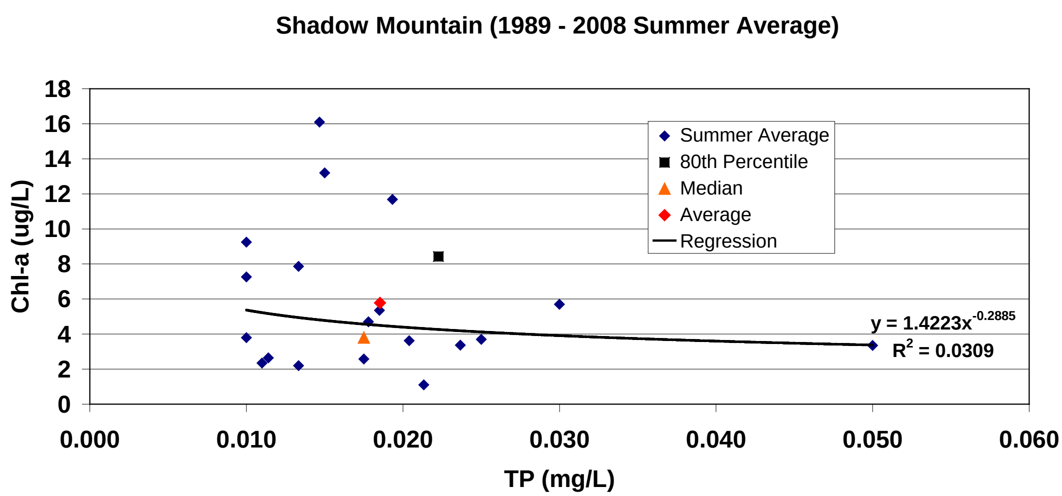
Granby (Figure 15) is a deep, cold water lake with low phytoplankton and TP concentrations. The database included 16 years of data, with about 80% of the observations significantly less than the draft TP criterion. Of the three summer averages that exceed the draft TP criterion, one value is nearly triple the target, but the corresponding summer average chlorophyll 'a' concentration is well below the proposed criterion. The data suggest that variations in the chlorophyll 'a' concentration are unrelated to TP concentration (R^2 = 0.03). Although the regression does not explain much of the variation in the data, it trends <u>downward</u> (*i.e.*, chlorophyll 'a' decreases as TP increases). Regression analyses of this data set would imply (improperly) that <u>increasing</u> TP levels will produce <u>lower</u> chlorophyll 'a' levels.

Figure 15



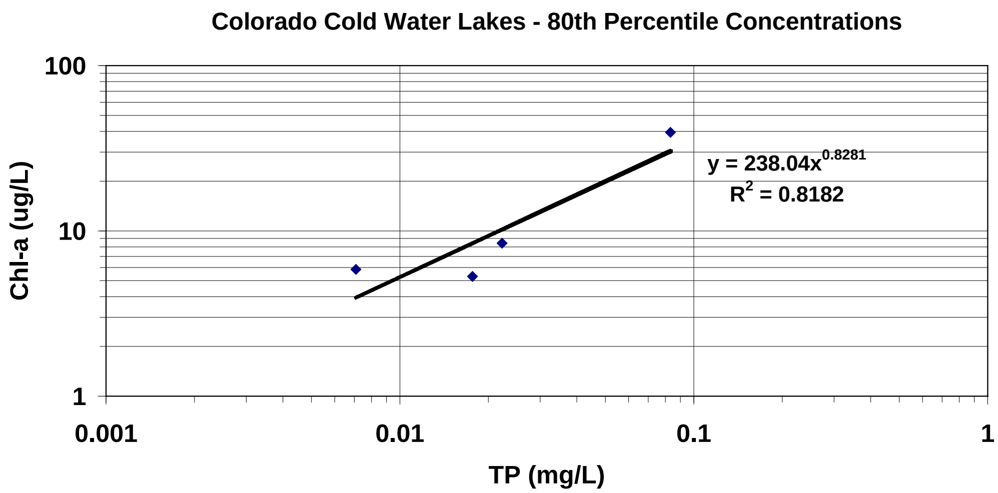
Shadow Mountain (Figure 16) is a cold water lake, with moderate phytoplankton and TP concentrations. The database included 19 years of data, with 3 observations greater than the draft TP criterion, and 4 algal measurements in excess of the criterion. The data suggest that variations in the chlorophyll 'a' concentration are unrelated to TP concentration (R^2 = 0.03). Although the regression does not explain much of the variation in the data, it trends downward (*i.e.*, chlorophyll 'a' decreases as TP increases). Again, simplified regression analyses, such as those proposed by the Division, would improperly come to the conclusion that increasing TP level will produce lower chlorophyll 'a' levels.

Figure 16



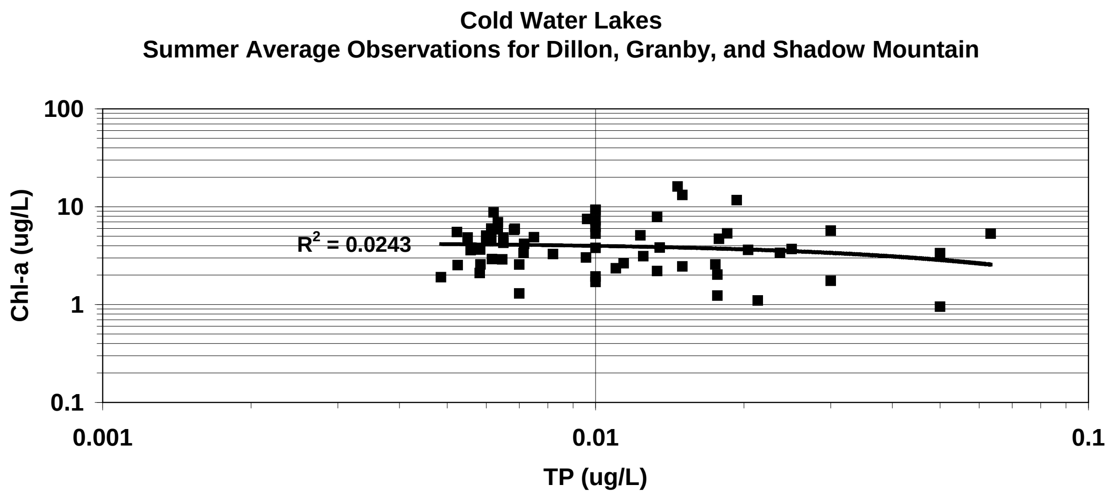
The data for the individual lakes were evaluated to determine the 80th percentile chlorophyll 'a' and TP concentrations (using the EXCEL "percentile" function). These results are illustrated in Figure 17.

Figure 17



The regression illustrated in Figure 16 suggests a very strong positive relationship between TP and chlorophyll ‘a’. However, the data from which the individual data points in Figure 16 were derived do not support this conclusion. Three of the four lakes show no response of chlorophyll ‘a’ to TP over a concentration range of 5 – 63 µg/L (Figure 18).

Figure 18

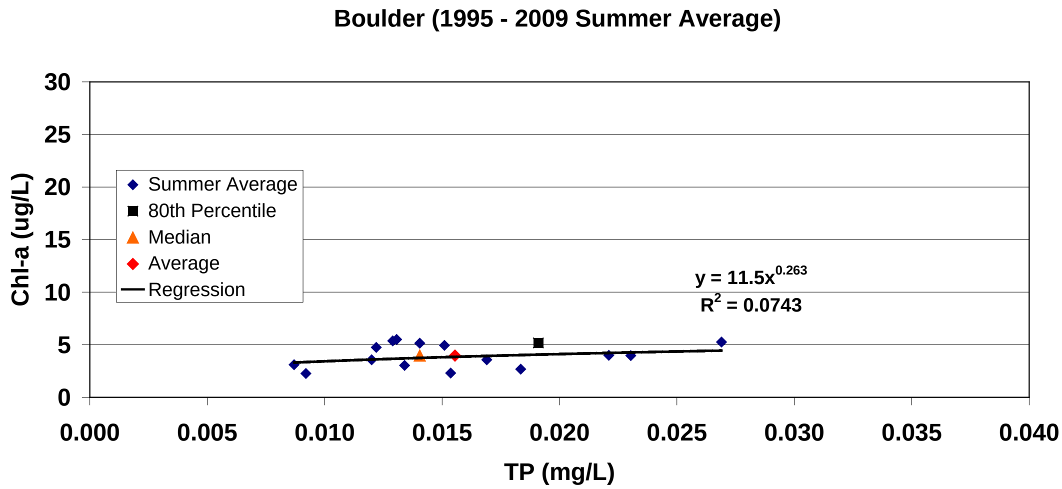


It is readily apparent that the algae-TP relationship in Figure 17 differs significantly from the relationship illustrated in Figure 10 for Bear Creek. These data clearly indicate that these lakes respond differently and, therefore, need to be treated differently, not lumped together into a single class. Moreover, it is incorrect to combine the independently generated 80th percentile concentration and assume that the 80th percentile TP concentration caused the specific 80th percentile chlorophyll ‘a’ reading.

2. Warm Lakes

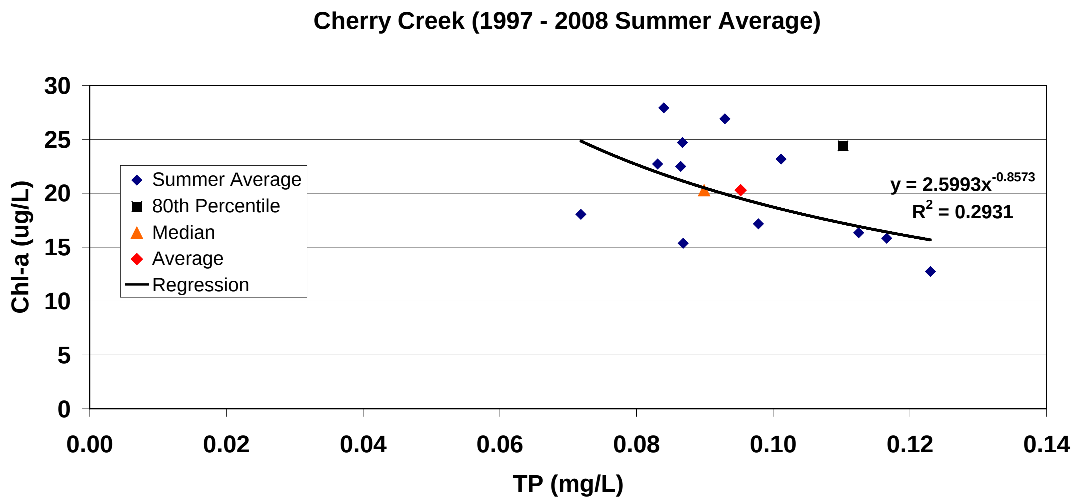
Four warm water lakes were evaluated to assess whether regressions using the 80th percentile concentrations are appropriate for assigning the TP criterion. These include: Boulder, Cherry Creek, Quincy, and Standley. For each lake, the summertime (July – September) average chlorophyll ‘a’ and TP concentrations were calculated for each year of record. Those data pairs were then plotted for each lake. Boulder (Figure 19) is a deep, warm water lake with low phytoplankton and TP concentrations. The database included 15 years of data, with all observations well below the draft chlorophyll ‘a’ criterion of 20 µg/L and the TP criterion of 82 µg/L. The data suggest that variations in the chlorophyll ‘a’ concentration are unrelated to TP concentration (R^2 = 0.07). These data indicate no relationship at all between chlorophyll ‘a’ growth and TP concentration.

Figure 19



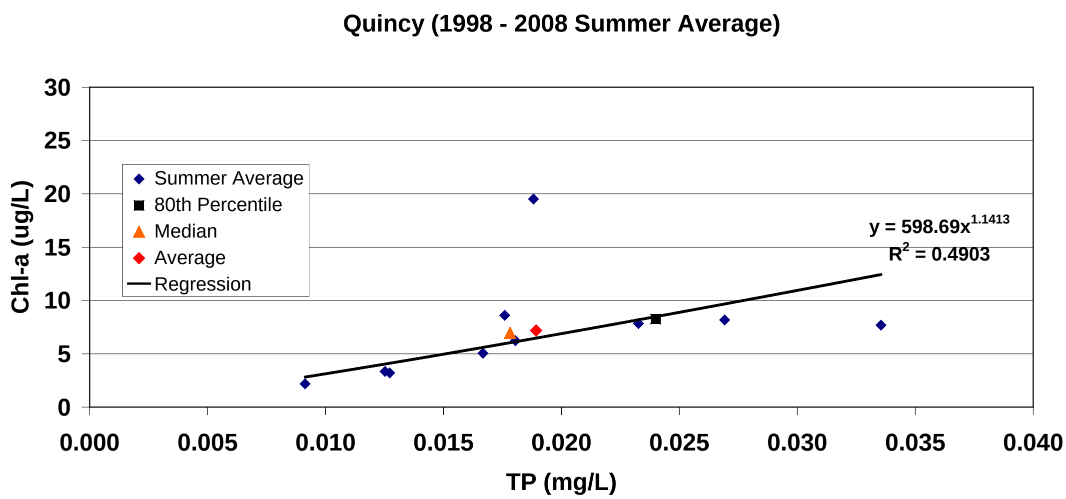
Cherry Creek (Figure 20) is a deep, warm water lake with elevated phytoplankton and TP concentrations. The database included twelve years of data; half of the chlorophyll 'a' observations exceed the draft criterion (20 µg/L) and all but one of the TP values is less than the TP criterion (82 µg/L). The data suggest that variations in the chlorophyll 'a' concentration are <u>inversely</u> related to TP concentration (R^2 = 0.29). This conclusion cannot be correct; however, it underscores that other significant factors (*e.g.*, grazers) are probably influencing lake response to algal growth.

Figure 20



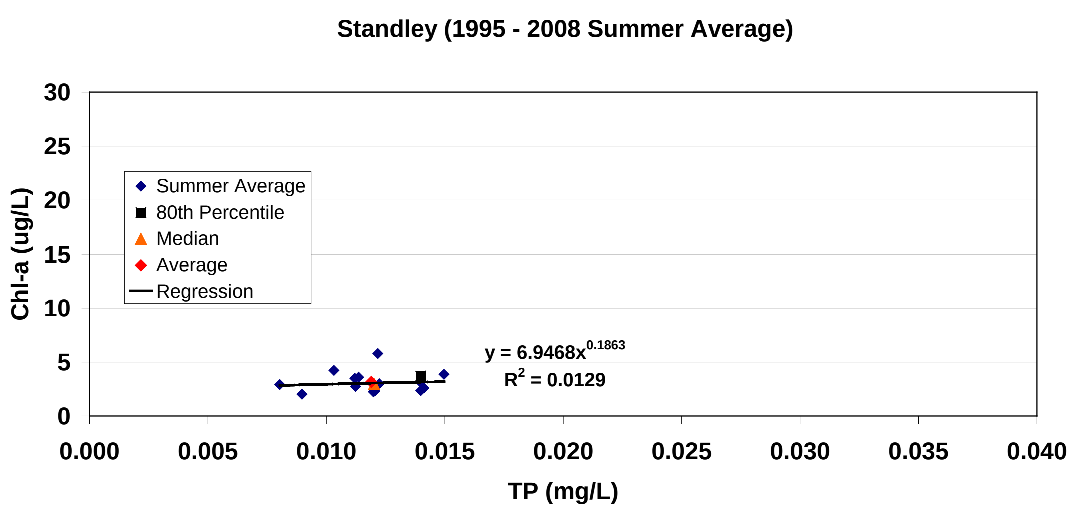
Quincy (Figure 21) is a deep, warm water lake with low phytoplankton and relatively low TP concentrations (0.010-0.035 mg/l). The database included 10 years of data, with all observations significantly less than the draft TP criterion. The data show a positive correlation between chlorophyll ‘a’ and TP concentration (R^2 = 0.49), though the response is quite flat.

Figure 21



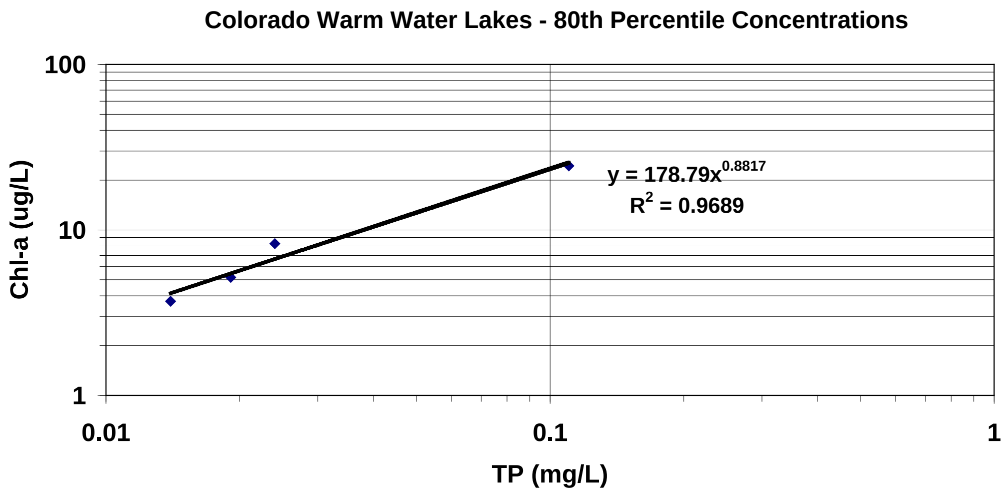
Standley (Figure 22) is a deep, warm water lake, with very low phytoplankton and TP concentrations. The database included 14 years of data. The data suggest that variations in the chlorophyll ‘a’ concentration are unrelated to TP concentration (R^2 = 0.01), though the range of in-lake TP concentrations are too narrow to reach any meaningful conclusions.

Figure 22



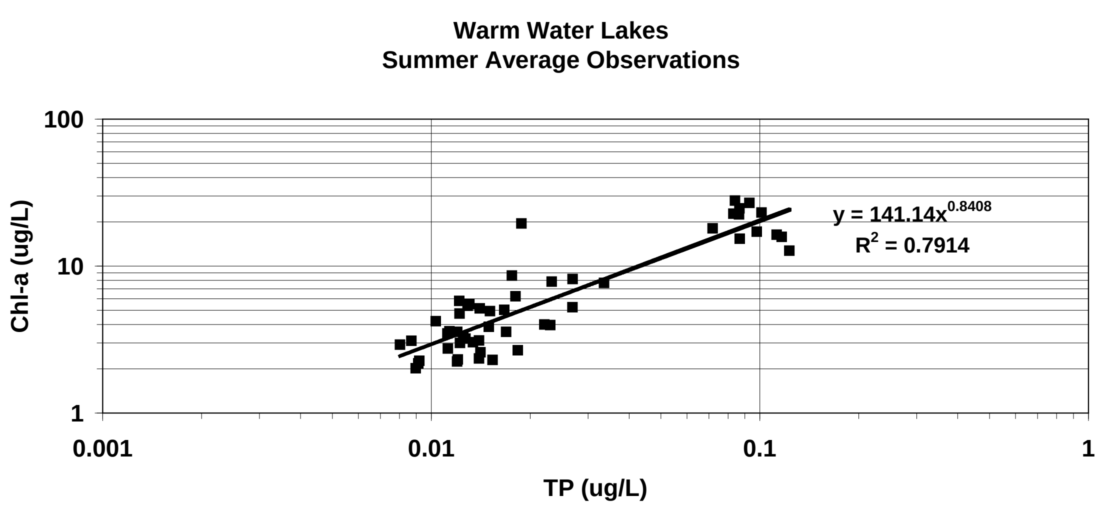
All of these lakes appear to meet long-term average mesotrophic target levels for protection of warm water fisheries. The data for the individual lakes was evaluated to determine the 80th percentile chlorophyll 'a' and TP concentrations (using the EXCEL "percentile" function). These results are illustrated in Figure 23.

Figure 23



The regression illustrated in Figure 22 suggests a very strong relationship between TP and chlorophyll 'a' when the 80th percentile concentrations for each lake are paired. However, the data from which the individual data points in Figure 22 were derived do not support this conclusion. This occurs, in part, because the data sets grouped as two points (three low points, one elevated point). However, three of the four lakes show no response of chlorophyll 'a' to TP over a concentration range of 7 – 28 µg/L and the actual data for the "high" response showed a negative relationship with chlorophyll 'a'. If all the warm water lake data are put together, the distribution in Figure 24 is obtained.

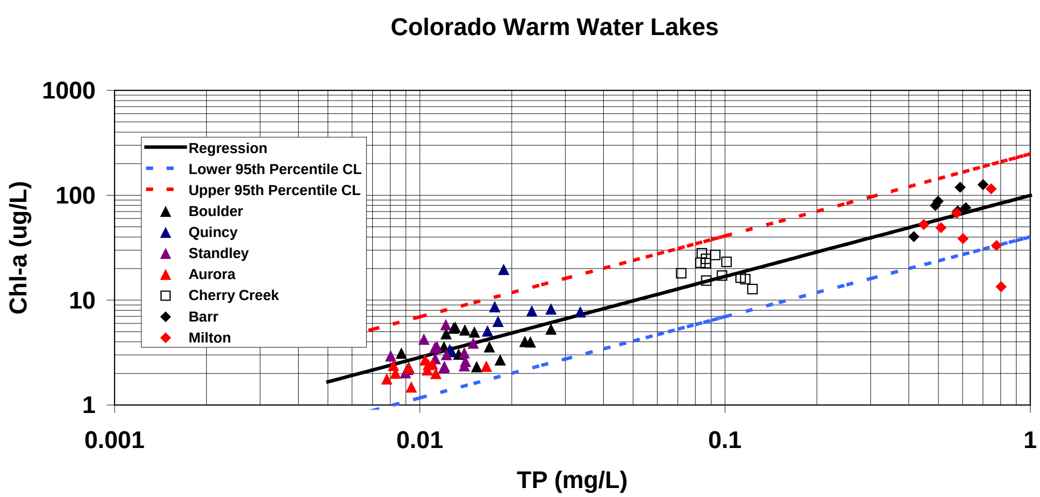
Figure 24



The relationships presented above for the warm water lakes suggest that, in this case, the 80th percentile regression (Figure 23) provides a similar relationship as the individual summer average data (Figure 24). This agreement suggests that the lakes included in the analysis are all of a similar type and the lake performance is similar over the range of nutrient level, as one would expect. The pertinent characteristics of these lakes (*e.g.*, depth, detention time, drainage area, etc.) need to be assessed to confirm this supposition. If these lakes share similar characteristics, then other warm water lakes with different characteristics need to be evaluated to determine whether the relationships illustrated above also apply to those lakes.

One concern with this type of analysis, however, is the variability in response to a given amount of nutrient. To assess this variability, the summer average data for all the warm water lakes included in the Division's regression analysis (see Figure 1) were evaluated. This evaluation is presented in Figure 25. The individual summer (July – September) average chlorophyll 'a' and TP values were assessed for each of the seven warm water lakes. The data were then evaluated to determine the regression line for the log-transformed data, and the confidence interval for an individual summer average.

Figure 25



The confidence limits (95th percentile) around the regression line show that a given chlorophyll 'a' response concentration can result from TP concentrations spanning an order of magnitude. For example, the 20 µg/L chlorophyll 'a' criterion for warm water lakes would be expected to occur for TP concentrations between 40 – 400 µg/L. Similarly, at a TP concentration of 40 µg/L, the chlorophyll 'a' response is expected to range from 3.4 – 20 µg/L, about a factor of 6.

3. Summary

The Division's statistical methods create data sets that do not properly reflect the underlying data base. There is no meaningful connection between a multi-year, 80th percentile TP average and an 80th percentile chlorophyll 'a' concentration. However, plotting all data from lakes with similar physical characteristics may result in reasonable relationships between nutrient levels and plant growth on a median, long-term basis that is useful in guiding regulatory decision-making.

B. Rivers and Streams

The TP and TN criteria were developed using quantile regressions to calculate the nutrient concentration corresponding with a 5% decrease in the MMI score from the median reference site condition. For this analysis, the Division used one regression to derive the slope of the Observable Biological Potential (OBP) that was applied to both the warm water and cold water criteria to calculate either the TP or TN criteria. This approach is premised on the concept that increasing nutrient concentrations exert a negative influence on MMI score. The evidence provided for this relationship is the wedge plot illustrated in Figure 6 and Figure 7. Nutrient concentrations up to an anchor point (*e.g.*, the nutrient concentration corresponding to the 85th percentile concentration for reference streams) do not influence the MMI score, but above the anchor point the MMI decreases along the OBP slope. Absent other stressors, streams exposed to nutrient concentrations equal to or less than the anchor point should exhibit MMI scores characterized by the median MMI for reference streams.

1. Mechanistic Model Considerations

As noted earlier, the EPA Science Advisory Board cautioned that "any" criteria derivation must be based on a mechanistic understanding and a clear causative link between nutrient levels and impairment. Mechanistically, nutrients do not directly influence macroinvertebrates (*i.e.*, MMI score). Rather, nutrients influence plant growth and the altered plant growth affects the macroinvertebrates. One consequence of this mechanistic understanding is that there should be no further influence on macroinvertebrates when nutrient levels exceed the concentration that has the potential to limit plant growth. With regard to TP, this growth saturation concentration is not greater than 0.1 mg/L and probably much lower as suggested in the literature.

> *Relationships between periphytic biomass in streams and nutrient concentrations are ill-defined, compared to those in lakes. Accrual of periphytic diatom biomass on flattened rock substrates in six western Washington streams showed a strong interaction between velocity and soluble reactive phosphorus (SRP) with more biomass resulting, as velocity increased to 50 cm s^{-1}, at high (35 µg L^{-1}) compared to low (8 µg L^{-1}) SRP (Horner & Welch, 1981). Subsequently, continuous flow laboratory channel experiments were conducted in order to quantify more accurately the relationship between biomass and SRP, as well as the velocity interaction with more nuisance-prone filamentous green and blue-green algae (Horner et al., 1983). Those experiments showed an average inflow SRP concentration of about 15-25 µg L^{-1} to provide an apparent saturation to chlorophyll a (chl a) accrual at high and medium velocities alike. Recent experimental work with filamentous species has shown that the in situ concentration of SRP above which growth is saturated may be*

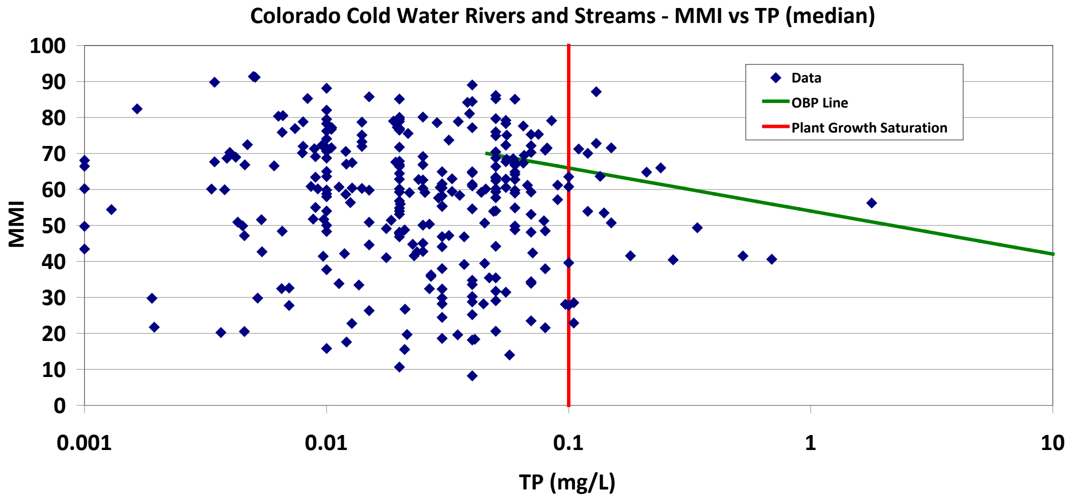
around 7 µg L^{-1} (Seeley, 1986). Bothwell (1985), working with in situ levels and diatoms, suggested that the saturation point may be even lower (3 -4 µg L^{-1}).

(Welch et al. 1988. Nuisance biomass levels of periphytic algae in streams. Hydrobiologia 157: 161 – 168).

This growth saturation effect was also documented in the Clark Fork River, Montana. In those waters, it was demonstrated that the green, filamentous algae *Cladophora* reached "very abundant" levels, even at low TP (10 µg/L) and TN (150 µg/L) concentrations (Dodds *et al*. (1997) *Developing nutrient targets to control benthic chlorophyll levels in streams: a case study of the Clark Fork River*. Water Resources 31(7):1738-1750). The documentation for several water quality models (*i.e.*, WASP, U.S. Army Corps of Engineers) recommends a phosphorus half-saturation coefficient of 1 – 5 µg/L for predicting algal growth. The Michaelis-Menten expression is then evaluated to determine the effect of nutrient concentration on the saturated growth rate. At a half-saturation coefficient of 1 µg/L, growth reduction becomes significant only when the phosphorus concentration is less than 8 µg/L. This level is consistent with the growth saturation values referenced by Welch et al. (1988). In consideration for the low plant growth saturation concentration for periphyton, EPA withdrew a proposed nutrient TMDL in Pennsylvania (*See* Zou *et al*. (2006) *Integrated Hydrodynamic and Water Quality Modeling System to Support Nutrient Total Maximum Daily Load Development for Wissahickon Creek, Pennsylvania*. J. Env. Eng. 132(4): 555-566). This factor was also presented by Professor Emeritus, Dominic DiToro to the EPA SAB as part of the review of EPA's empirical methods (Slide Presentation: "Review of Empirical Approaches for Nutrient Criteria Derivation," Slide 8) to show there was no mechanistic relationship between invertebrate indices and nutrient concentration.

If the wedge plot for TP is reconsidered with respect to ability to influence plant growth, it is apparent that the OBP line used to derive the preliminary criterion value is at a level where nutrients no longer influence plant growth (Figure 26). From this perspective, it is highly improbable that TP is responsible for the decrease in MMI suggested by the wedge plot. Rather, unidentified confounding factors cause reductions in MMI that are evident above and below the anchor concentration, and a factor that co-varies with phosphorus is the likely factor controlling MMI changes at high TP concentrations. Consequently, regulating TP at the preliminary criterion value (90 µg/L) will not restore use impairments indicated by low MMI scores above the "anchor" point.

Figure 26



2. Stressor-Response Relationship

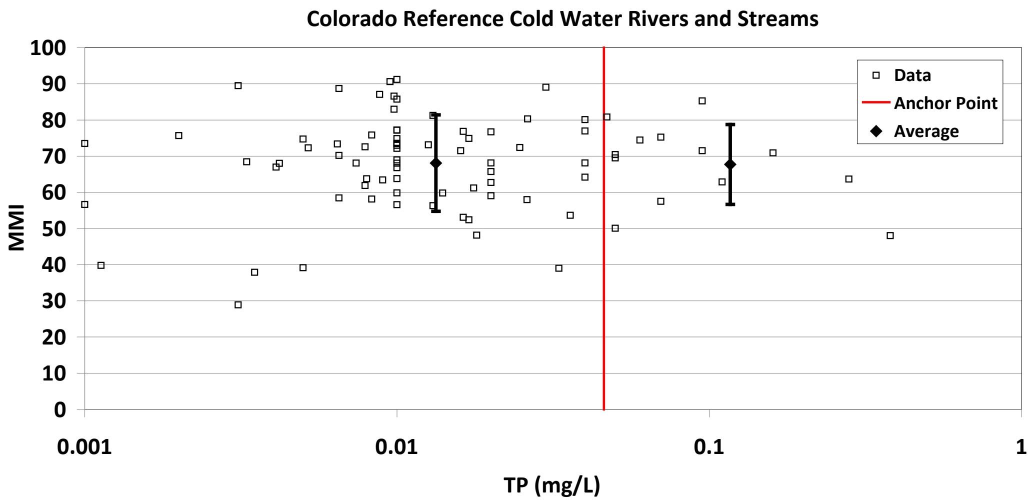
The preliminary criteria were derived from an evaluation of reference stream data to assess the nutrient concentration anchor point and the median MMI response when the nutrient concentration was below the anchor point. Further evaluation of the reference data indicates that TP is not a stressor for MMI score. Due to the limited number of reference streams with TN data, it was not possible to conduct a similar assessment with regard to TN. However, as noted earlier in this report, there is no reason to believe that TN limits plant growth. Consequently, TN is not expected to affect MMI score.

The reference stream data were evaluated by separating the MMI scores into two groups: 1) those scores associated with TP concentration below the anchor point, and 2) those scores with TP concentration above the anchor point. The two groups were then statistically evaluated using Analysis of Variance to determine whether the MMI scores were significantly different. TP can only be considered a stressor if these differences are significant and the MMI score above the anchor point is reduced relative to the control.

a. Cold Water Streams

The cold water reference streams database included 82 paired observations of MMI and TP, with 69 observations below the anchor point (0.046 mg/L) for cold water streams, and the remaining 13 observations above the anchor point (Figure 27). The two groups of MMI scores were evaluated using Analysis of Variance to see whether differences in the response were significant. The ANOVA gave a probability of 92% that the null hyposthesis (no difference between the two groups) was true. This result indicates there is no difference in the response of the MMI score to TP above or below the anchor point. Consequently, TP is not a stressor for MMI score.

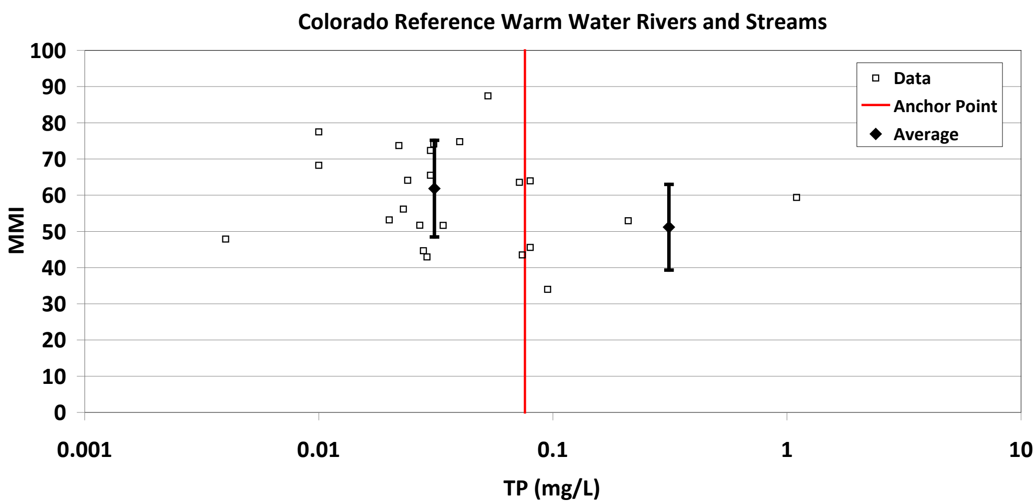
Figure 27



b. Warm Water Streams

The warm water reference streams database included 23 paired observations of MMI and TP, with 18 observations below the anchor point (0.076 mg/L) for warm water streams, and only 5 observations above the anchor point (Figure 28). The two groups of MMI scores were evaluated using Analysis of Variance to see whether differences in the response were significant. The ANOVA gave a probability of 12% that the null hypothesis (no difference between the two groups) was true. This result is not significant but suggests there may be a difference in the response of the MMI score to TP above and below the anchor point.

Figure 28



This response is, in part, due to the fact that there are only five observations in the high TP category. We note, however, that one observation yields an MMI of 59.4 with a corresponding *TP of 1.1 mg/L*. This result is noteworthy because the TP concentration exceeds the anchor point by over an *order of magnitude*, but the corresponding MMI score is nearly identical to the anchor point MMI (60). Again, this indicates there is no dose-response/cause-effect relationship between TP and MMI score. The probability of obtaining an MMI = 60 at a TP concentration of 1.1 mg/L is unlikely if TP is a stressor as assumed by the Division's analysis.

3. MMI Response to Increasing TP

The nutrient criteria derivation presumes that the nutrient is the stressor that causes the MMI to decrease. This assumption was tested using the entire dataset provided by the Division. The data for all the streams within a given class (*i.e.*, cold water or warm water) were sorted according to nutrient concentration and aggregated into concentration bins such that the number of observations in each bin was equalized. The MMI response in each bin was evaluated using an Analysis of Variance to determine whether significant differences exist among the various bins. If the differences were significant, the data were further evaluated using the Student-Newman-Keuls (SNK) test (Sokal and Rohlf, 1969) to identify which groups were significantly different at the 0.05 level. The analysis results presented below confirm that the Division's approach is unsupported and that there is no apparent relationship between nutrient level and MMI score.

a. Cold Water Streams

The cold water streams dataset included 818 paired observations of MMI and TP. These pairs were segregated into concentration bins with the distribution of observations illustrated in Figure 29. Most of the bins ranged from 40 – 60 observations. One of the bins, with a TP range of 9–11 µg/L, included 171 observations due to a preponderance of measured TP concentrations at 10 µg/L (162 observations). This grouping did not affect the results of the analysis.

Figure 29

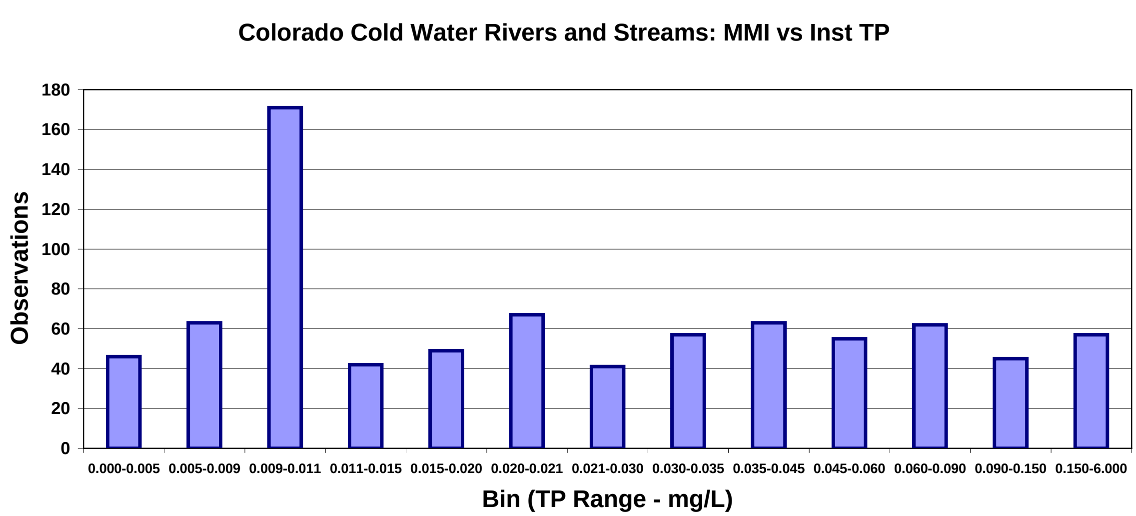
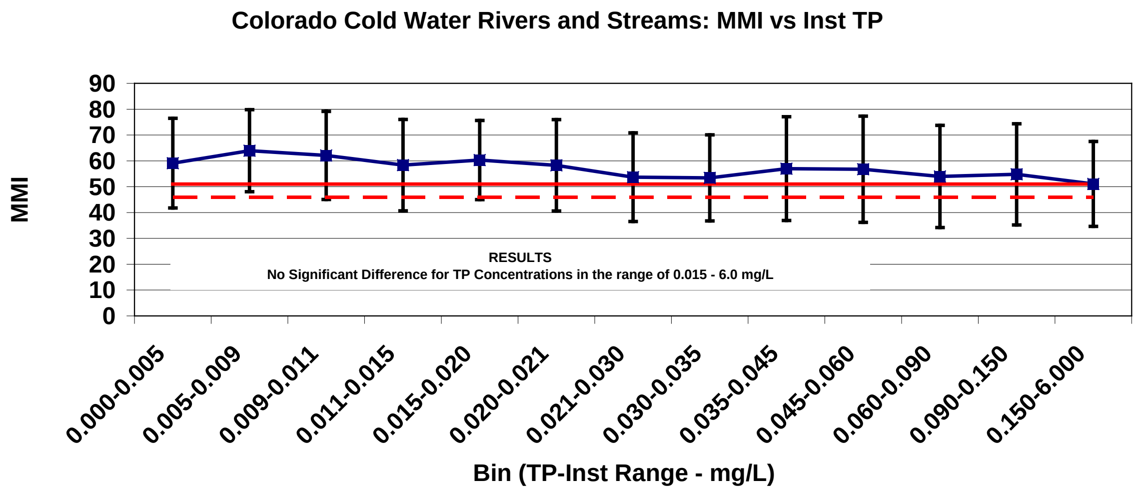


Figure 30 presents the average MMI results for each bin along with a whisker plot illustrating one standard deviation about the mean. The MMI attainment thresholds identified for Transitional (biotype 1; solid red line in figure) and Mountain (biotype 2; dashed red line in figure) streams, as presented by the Division in its March 8, 2010 presentation, are superimposed on the cold water stream MMI results (solid blue line with black whiskers). The ANOVA was very significant, but the SNK test indicated that the significant differences were restricted to the highest concentration bin (0.15 – 6 mg/L) and the two highest-performing brackets (0.005 – 0.009 mg/L and 0.009 – 0.011 mg/L). The remaining concentration brackets were not significantly different. No significant differences exist from 0.000 – 0.150 mg/L and differences in performance were not significant from 0.011 – 6.0 mg/L.

Figure 30



This analysis indicates that these data cannot support any TP criterion and suggests that TP is not a stressor with regard to the MMI score. Moreover, the average performance of every category exceeds the MMI attainment threshold suggested by the Division.

b. Warm Water

The warm water streams dataset included 325 paired observations of MMI and TP. These pairs were segregated into concentration bins with the distribution of observations illustrated in Figure 31. The bins generally ranged from 20 – 30 observations.

Figure 31

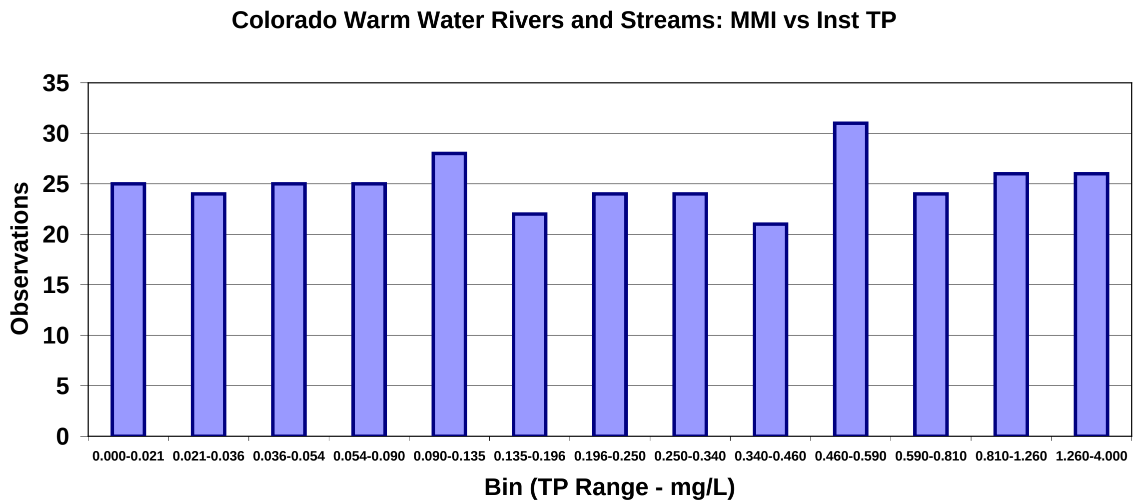
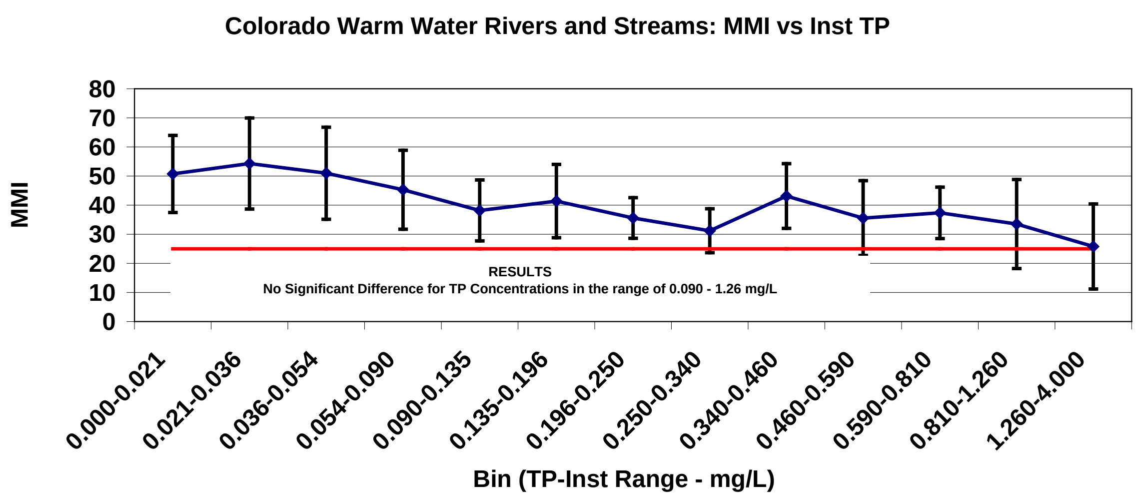


Figure 32 presents the average MMI results for each bin along with a whisker plot illustrating one standard deviation about the mean. The MMI attainment thresholds identified for Plains (biotype 3; solid red line in the figure) streams, as presented by the Division in its March 8, 2010 presentation, is superimposed on the warm water stream MMI results. The ANOVA was very significant. The SNK test indicates there are multiple, overlapping significant differences among the various bins. Differences were not significant for TP concentrations ranging from 0 – 90 µg/L. In addition, there is no significant difference in MMI score between the 0 – 21 µg/L bin and the 135 – 196 µg/L bin.

Figure 32



While the analysis shows significant differences among the groups, this analysis confirms that these data cannot support any TP criterion. The MMI scores show insignificant differences for TP concentrations from 0 – 90 µg/L, but 90 µg/L is a concentration that does not limit plant growth. Thus, any changes in MMI above this TP level cannot be caused by the increased TP level as TP concentrations greater than 90 µg/L do not limit plant growth. If plant growth is not limited, the linkage between nutrient concentration and the macroinvertebrate response is eliminated and some other, undefined stressor must be responsible for the observed significant differences as the TP level increases. This information indicates that TP covaries with other major stressors (*e.g.*, urban development, sediment load). Failure to account for these co-occurring causes of reduced invertebrate population is a major oversight of the analyses.

4. Summary

The analyses presented above demonstrate that TP is not a likely stressor for MMI score and the MMI data do not support any TP criterion for cold water or warm water streams. In both cases, there are no significant differences in MMI response within the range of TP concentrations that might influence plant growth in the stream. Without such a linkage, it should be apparent that nutrients cannot be responsible for changes in MMI. It is further noted that the Division has assigned anchor values of 46 µg/L and 76 µg/L to cold water and warm water reference streams, respectively. By definition, reference streams are not impaired. These anchor values are at a level that does not inhibit plant growth. EPA guidance dictates that nutrient impairments first influence algal biotic integrity, which then influences macroinvertebrates. If nutrient levels that sustain unrestricted algal growth do not impair the stream MMI, nutrients cannot be the stressor causing stream impairments measured by the MMI. Analyses of Variance demonstrates that there is no consistent relationship between MMI and nutrient levels, as one might expect since nutrients do not directly impact invertebrate populations.

VI. CONCLUSIONS AND RECOMMENDATIONS

1. Given the significant questions regarding need for a TN criterion for fresh waters and the enormous cost associated with reducing TN in wastewater, the adoption of TN requirements should be deferred pending a demonstration of actual environmental need and confirmation that attainment of stringent TN objectives would not cause more overall harm than good. The Division has proposed to delay the effective date for adoption of the TN criteria, but this approach is unacceptable because it retains a criterion for a parameter that has not been shown to cause use impairment.

2. Stream water quality objectives on a stream segment specific basis should be tied to a demonstration that the nutrient of concern is causing a documented use impairment (*e.g.*, excessive plant growth beyond what would be expected under natural conditions that would adversely impact stream uses). SAB recommendations on the factors to consider in setting scientifically defensible nutrient objectives need to be addressed. This should involve the development of a specific protocol that may be used for such assessments by the Division and regulated community.

3. Reservoir standards need to be evaluated on a case-by-case basis given the existing and planned uses of such waters. Plains reservoirs should not be forced to attain plant growth objectives applicable to foothill/mountain reservoirs given the dramatically different watershed and climactic conditions occurring at these sites. As with streams, a specific protocol needs to be established that will inform the public how impairment indicators will be derived and the methods for determining what nutrient parameters need to be regulated.

4. The lake classification and nutrient relationships should be refined. Lakes with similar critical characteristics that influence plant growth should be grouped. Preliminary nutrient chlorophyll ‘a’ relationships from such refined grouping should be based on long-term lake performance, not 80^{th} percentile concentrations.

Appendix A

Overview of Nutrient Regulation in Various Lakes and Reservoirs

Chatfield Reservoir: Initial standards were adopted in 1984 to preserve existing uses close to 1982 conditions (total phosphorus at 14.6 ug/l). A Clean Lakes Study with little sampling data in November 1981 and October 1982 resulted in a goal for chlorophyll 'a' of 17 ug/l (within an acceptable range of 15-25 ug/l) and a site-specific total phosphorus standard of 27 ug/l to protect that chlorophyll 'a' goal, considering economic reasonableness.

The November 2009 rulemaking hearing changed the chlorophyll goal of 17 ug/l to a standard of 10 ug/l and changed the phosphorus standard from 0.027 mg/l to 0.030 mg/l, as measured by samples in the mixed layer during summer months of July, August, and September, with an exceedance frequency of once in five years. These revisions were due to measured exceedances of the phosphorus standard but not the chlorophyll goal. This demonstrated that where a mismatch between the two parameters occurs, the chlorophyll 'a' criteria should control decision-making.

"The Commission agreed that the linkages between the in-lake chlorophyll and total phosphorus concentrations and between total phosphorus concentrations and total phosphorus load to the reservoir are critical to the basis of the Control Regulation and the TMDL and that these linkages should be reviewed." (Reg # 73.17: 2009 Statement of Basis and Purpose.) The review found that median chlorophyll 'a' at 6 ug/l was much lower than anticipated from the typical phosphorous concentrations of 0.022 mg/l. The conventional regression (modified Jones-Bachmann equation) analysis used to originally set the standard and the goal was a weak linkage. Summer chlorophyll had greater variability than could be explained on the basis of summer phosphorus alone. A better linkage was created using a simple ratio of chlorophyll 'a' to phosphorus, which records the net responsiveness of the resident algal community to the amount of phosphorus present in the lake. It is a "net" value because it reflects the balance of growth (nutrients, light, temperature) and loss (grazing, washout, settling) processes.[9] The measured ratios offer an empirical basis for defining expectations for chlorophyll given the available phosphorus. The total phosphorus loading limit was reduced to 19,600 lbs/yr under a median inflow of 100,860 ac-ft/yr. Revisions to the wasteload allocations and load allocations have not yet occurred.

[9] "[A] simulation model was used to develop exceedance probabilities for chlorophyll; a simulation model, rather than a regression approach, was necessary because chlorophyll is dependent on the phosphorus concentration, although there is considerable noise in the relationship. The simulation model yields a chlorophyll 'a' concentration of 9.7 ug/l for a one-in-five exceedance probability…The benefit of the simulation model resides largely in its capacity to unite chlorophyll 'a' and phosphorus in a common view of current trophic condition."(page 17) As shown in Figure 12 at page 16, that simulation model had an R^2 of 0.9995.

<u>Cherry Creek Reservoir</u>: The March 2009 rulemaking hearing changed the chlorophyll 'a' standard from 15 µg/l to a seasonal standard of 18 ug/l to be attained four out of five years. (The Basin Authority sought a new standard of 25 ug/l.) The prior standard of 15 ug/l was previously adopted in 2000 as a compromise between competing aquatic and recreational uses, pending significant data collection in recognition of the uncertainty of the relationship between chlorophyll 'a' and total phosphorus.

In 2009, the Commission concluded that the 15 ug/l standard could not feasibly be attained nine out of ten years. It was infeasible because the long term average of 10 ug/l which is necessary to attain the 15 ug/l would require a 30% reduction from the background levels of phosphorus monitored entering the reservoir. In light of the natural background phosphorus levels, which greatly exceeded the amounts necessary to attain 15 ug/l of chlorophyll 'a', it was infeasible to attain the 15 ug/l. Any additional practices to reduce total phosphorus would be exorbitantly expensive and it was unclear when and to what extent further reductions in phosphorus could be realized.

Meanwhile, the Cherry Creek Basin Authority continues watershed improvements. Since the 15 ug/l chlorophyll 'a' standard is not attainable, a standard of 18 ug/l is set as the maximum degree practicable standard. This is an interim standard that retains the goal of full protection of the Reservoir's uses. The 18 ug/l is a long-term average based upon the prediction that 16.2 ug/l is the "most likely" chlorophyll concentration resulting from input of flow weighted phosphorus concentrations of 0.177 mg/l. This 16.2 ug/l is the 80^{th} percentile of a long term mean of the last five years.

<u>Bear Creek Reservoir</u>: On May 11, 2009, the Commission revised the site-specific narrative nutrient criteria to include numeric standards for chlorophyll 'a' and total phosphorus. Significant data has been collected since 1987 at the reservoir. The target condition to attain is between mesotrophic and eutrophic, but the reservoir is more productive than intended (eutrophic to hypereutrophic). This is despite significant reductions in external phosphorus loading since 1994, which includes effluent limits of 1.0 mg/l total phosphorus. Rather, the internal loading from past phosphorus discharges appear to have accumulated in the reservoir sediment and continue to increase during the summer months from 20 ug/l to 100 ug/l. It is anticipated that internal release will diminish over 10-15 years as sediment is flushed out.

Using a simple ratio of chlorophyll 'a' to phosphorus defines the site-specific responsiveness of the resident algal community to the availability of phosphorus. It is a "net" value, because it reflects the balance of growth (nutrients, light, temperature) and loss (grazing, washout, settling) processes. The chlorophyll standard of 10 ug/l is based upon the 80^{th} percentile of data related to the typical summer chlorophyll of 8 ug/l, as derived from a set of twelve Colorado lakes, each of which had been sampled in at least six years. The 10 ug/l chlorophyll 'a' standard is maintained by a standard of 32 ug/l of total phosphorus, with a one-in-five exceedance permitted. Testimony (EPA) for a larger ratio and thus a smaller phosphorus standard was found by the Commission to be unsupported by either statistical argument or mechanistic explanation.[10]

[10] Because the internal loading prevents attainment of the new numeric standards and it is uncertain how the new standards might be translated into point source permit limits, a Temporary Modification was adopted pending disappearance of the internal loading over time. Note that the reservoir's accumulated sediment reduced depth of the reservoir from 55 to 35 feet. Dredging is not an acceptable solution to Corps of Engineers.