NCDP Scientific Advisory Council Agenda

10:00am – 3:30pm
July 19, 2018
Triangle J COG, Large Conference Room
4307 Emperor Blvd, Suite 110, Durham, NC 27703

Desired Outcomes:

- Shared understanding of the comments and questions from the CIC on the pH Proposal.
- Shared understanding of fisheries data for HRL.
- Shared understanding of the workflow proposal for Chlorophyll *a* criteria for HRL.
- Shared understanding of the continuing discussions on Chlorophyll *a*.

Time	Topic	Speaker(s)
10:00	Convene • *Introductions* • *Approval/Comments on meeting minutes – May* • *Administrative Business*	Andy Sachs (facilitator)
10:20	CIC Update	Brian Wrenn
10:50	Workflow Proposal for Chla • Alternatives and Decisions Document • Chla-Use Linkages • Chla Proposal Framework	Jim Bowen, Clifton Bell
11:20	Break	
11:30	Continued Discussions: Workflow Proposal for Chla	Andy Sachs (facilitator)
12:30	**Lunch**	
1:00	Chlorophyll *a* Discussions	Clifton Bell, Lauren Petter, Andy Sachs (facilitator)
2:15	Break	
2:30	Continue Chlorophyll *a* Discussions	Andy Sachs (facilitator)
3:15	Wrap-up, closing remarks, and adjourn	Andy Sachs (facilitator)
3:30	Adjourn	

Action Items and Questions for SAC from June 2018 CIC Meeting

Action Items

- Guidance on establishing assessment units – multiple criteria proposals include language addressing assessment units. Where changes to assessment units are made or directly referenced in a proposal, there needs to be some reference to an official method or guidance for the establishment of assessment units. - SAC
- The CIC would like the SAC to explain how statewide implementation of site specific criteria would occur. - SAC
- The pH proposal document from the SAC should be edited to include the most recent changes by the EMC to the assessment method. – SAC/DWR
- Analyze the overlay within the water column of photic zone v. zone of DO >= 4.0 mg/L. Where is the highest pH. – DWR (delivered)
- Provide range of areas where a pH standard would be applied to regulated entities (e.g., NPDES permits, Stormwater, etc.) - DWR

Questions for SAC regarding pH proposals

- *Option #1*
    - If 1-hour median is scientifically defensible, why allow instantaneous reading? Should proposal read median or instantaneous?
- *Option #2*
    - Could Option #2 be implemented under existing pH criteria?
    - What is criteria for water column where DO <4.0 mg/L?
- *General*
    - What is the difference between the ammonia toxicity analyses conducted for the pH proposals and the minority report?
    - Why did proposals use different metrics for determining general tendency (median v. arithmetic mean)?
    - Proposal "assumes that North Carolina will apply its current practice of evaluating compliance using the 90_{th} percentile and the 90-percent confidence level." Shouldn't this be explicitly stated in the proposal?

Alternatives and decisions to be made in writing a numeric nutrient criteria for chlorophyll-a for High Rock Lake, NC

By Jim Bowen, July 2018, for consideration by the Nutrient Criteria Science Advisory Council

Assumptions:

- Samples used for assessment are taken from a designated portion of the water column at a given sampling station
- Only growing season samples are used for assessment (see question below on the growing season)
- One or more sampling stations within the water body are used for assessment
- One or more samples are used for assessment within the growing season (see question 4 below on minimum numbers)
- Sets of samples from multiple years are used when available for the assessment

Other questions that must be answered in all cases:

1. How will stations be aggregated regionally within a waterbody for purposes of assessment?
2. What portion of the water column will be included in the sample?
3. When is the start and end of the growing season?
4. What is the minimum data requirement for an assessment? (e.g. is there a minimum total number of samples? a minimum number per year? a minimum number of years?)

Alternatives (A1 …) and Questions (Q1 …) - Start Here

A1 Is the criteria evaluation based upon the number of samples exceeding the numeric criteria (exceedance based) or a growing season average of the samples (average based)?

For exceedance-based assessments, answer the following:

Q1 What fraction of samples may exceed the criteria?

A2 Is there a confidence level that need be met when the number of exceedances is above the threshold? (e.g. 10% exceedance with 90% confidence)

Q2 What is the confidence level that need be met when the number of exceedances is above the threshold level?

For average-based assessments, answer the following

A3 Will multiple samples for a particular assessment, taken at different times and/or at different stations be averaged arithmetically or geometrically?

A4 Is the decision on how to average multiple samples (arithmetically vs. geometrically) done based upon the distribution of sample values (e.g., chl-a concentrations were found to be log-normally distributed, therefore a geometric mean growing season, assessment unit average was used)

If no, answer the following

Q3 What other bases will be used to decide how the growing season is calculated?

A5 When multiple samples are averaged, will a confidence level need be met that the growing season average is less than the numeric criteria? (e.g. will there be at least an XX% confidence that the growing season, assessment unit (arithmetic/geometric) mean chl-a conc. is less than YY ug/L)

If yes, answer the following

Q4 What is the confidence level (i.e. quantify XX%)

If no, answer the following

A6 Will the numeric criteria be set based upon a multi-year monitoring data set that quantifies the fraction of growing season average values that would be expected to exceed a designated use impairment concentration in the waterbody. Note: This method would be similar to the Florida chl-a numeric criteria where a minimum of seven years of data were used to establish the distribution of growing season averages for multiple years. The chl-a criteria for these cases was based upon inter-year variability of average chl-a concentrations, a use impairment concentration, and a confidence level (in this case 80%) that the growing season average chl-a concentration would be less than the use impairment concentration.

If yes, answer the following two questions

Q5 and Q6 What is the maximum fraction of averages that may exceed the use impairment concentration and what is that concentration?

Note:

If no answers are given for A5 and A6, then the numeric water quality criteria will be considered a not-to-exceed concentration with respect to the calculated growing season average for the given assessment unit.

In all cases, continue on to Q7.

Q7 What is the numeric criteria for chlorophyll-a?

Considering Data from Multiple Years

A7 When data for an assessment unit are available for multiple years, may those data be pooled to calculate a single average concentration for purposes of assessment?

If no, answer the following

A8 When growing season averages for multiple years are available for an assessment unit, is there an acceptable frequency of exceedances of the numeric chl-a criteria as specified in the answer to Q7?

If yes, answer the following

Q8 When multiple growing season averages are available for the water body, at what frequency may these averages exceed the numeric chl-a criteria?

If no, answer the following

Q9 How are growing season averages from multiple years considered in performing the assessment?

Working Title: Recommended Framework for Deriving Site-Specific Criteria for Warmwater Lakes and Reservoirs in NC

Section No.	Name	Notes on Content
	Abstract	
1	**Introduction**	Provide background on NCDP and the reservoir pilot (HRL). Explain SAC goals of deriving site-specific criteria for HRL, but also developing framework for other lakes/reservoirs.
1.1	Existing Chlorophyll-*a* Criterion	Describe existing criterion and how it is used for assessment of NC lakes. Provide background on how it was derived.
1.2	Overview of SAC Approach	Brief, high-level overview of the SAC's thinking; e.g., using both lit and HRL-specific observations, balance fishing with other uses, manage risk at reasonable level, etc.
2	**Literature Review of Chlorophyll-a and Use Attainment**	Each subsection identifies ranges of CHLa at which other lakes/reservoirs have either met uses or experienced problems.
2.1	Aquatic Life	
2.2	Potable Water Supply	
2.3	Recreation	
2.4	Other Uses	
3	**Chlorophyll-a in High Rock Lake**	Each section would utilize graphics/tables developed from HRL datasets, and associated interpretation.
3.1	Spatial patterns	
3.2	Temporal patterns	
3.3	Relation with other Indicators	
3.1.1	Dissolved oxygen	
3.1.2	pH	
3.1.3	Water clarity	
3.1.4	Algal taxonomy	
3.1.5	Algal toxins	
4	**Narrative Use Attainment in High Rock Lake**	Summarize available information on each sub-topic; e.g., fishery status, other aquatic life present, existing water supply use & impacts, recreational use, etc.
4.1	Aquatic Life	
4.2	Potable Water Supply	
4.3	Recreation	
4.4	Other Uses	
5	**Recommended Framework for Site-Specific Criteria**	Building on previous sections, the SAC would lay out an approach for deriving site-specific criteria. The following section (6) would apply that approach to High Rock Lake to recommend a specific magnitude. Section 5 would provide rationale for recommended elements of the criteria that would not be expected to change between lakes/reservoirs (e.g., averaging period & statistic, frequency/allowable exceedance). As currently organized, this section uses elements of one proposal discussed by the SAC (screening range + narrative evaluation + antideg. policy ➔ site specific criterion). If SAC does not reach consensus on that, it could be reorganized based on whatever else the SAC comes up with re. a general framework for deriving site-specific criteria.

Section No.	Name	Notes on Content
5.1	Temporal Averaging Period and Statistic	Present rationale for how the CHla value would be calculated. This would address topics such as type of mean, months to include, individual year vs. multi-year, minimum data requirements.
5.2	Spatial Considerations	Includes recommendations on spatial aggregation of data, should the SAC reach consensus on this topic.
5.3	Statistical Test for Assessment	If the SAC chooses to recommend a statistical test for use with the CHLa criteria, describe it here.
5.4	Chlorophyll-a Screening Range	Synthesize literature and HRL-specific observations to identify range of CHLa values for initial assessment step. Literature can inform the both the upper and lower end of the range, especially the lower. The HRL-specific observations can inform the upper end of the range, because HRL is representative of a high-CHLa reservoir that does not necessarily experience many of the impairments reported in the literature.
5.5	Narrative Use Evaluation	Describe elements of a narrative use evaluation for lakes with mid-range CHLa values. What types of information should DEQ consider (e.g., fishery status, nuisance blooms, algal toxins, fish kills, taste and odor problems, etc.)
5.6	Antidegradation	Describe how lakes with CHLa less than screening values would be protected from degradation.
5.7	Summary of Proposed Framework	Synthesize previous subsections to describe the recommended approach for expressing criteria and deriving site-specific magnitudes.
6	**Proposed Site-Specific Criteria for High Rock Lake**	Apply the framework described in section 5 to derive a site-specific criterion for HRL. Content will represent SAC consensus on magnitude.
6.1	Application of CHLa Screening Range	
6.2	Summary of Narrative Use Evaluation	
6.3	Antidegradation Considerations	
6.4	Summary of Recommended Criterion	
7	**References**	

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1.1	Existing Chlorophyll-*a* Criterion (Clifton?)	Describe existing criterion and how it is used for assessment of NC lakes. Provide background on how it was derived.
1.2	Overview of SAC Approach	Brief, high-level overview of the SAC's thinking; e.g., using both lit and HRL-specific observations, balance fishing with other uses, manage risk at reasonable level, etc.
2	**Literature Review of Chlorophyll-a and Use Attainment**	Each subsection identifies ranges of CHLa at which other lakes/reservoirs have either met uses or experienced problems.
2.1	Aquatic Life (Marcelo/Nathan/Hans?)	
2.2	Potable Water Supply (Bill H.?)	
2.3	Recreation	
2.4	Other Uses	
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3.1	Spatial patterns	
3.2	Temporal patterns (Marcelo?)	
3.3	Relation with other Indicators	
3.1.1	Dissolved oxygen (Clifton, others?)	
3.1.2	pH (Marty?)	
3.1.3	Water clarity (Michael O'?)	
3.1.4	Algal taxonomy (Linda?)	
3.1.5	Algal toxins (Astrid?)	
4	**Narrative Use Attainment in High Rock Lake**	Summarize available information on each sub-topic; e.g., fishery status, other aquatic life present, existing water supply use & impacts, recreational use, etc.
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Working Table: Using High Rock Lake-Specific Information to Inform CHLa Criterion Magnitude

Use Category	Indicator	Primary or Secondary Indicator[1]	Narrative or Numeric Indicator	Threshold(s) or Bases for Evaluation	Indicator Status under HRL's Existing CHLa Conditions[2]	Potential Use of HRL Data to Inform CHLa Target	
						Examine Existing CHLa Condition	Explore CHLa-Indicator Relation
Aquatic Life	DO concentration	Primary	Numeric	4-5 mg/L (NC criteria)	HRL not impaired for DO. Surface DO favorable. Bottom DO strongly affected by stratification.	X	
	DO saturation	Secondary	Numeric	250-300% (based on sci. lit. of O_2-only gas bubble disease)	2016 monitoring showed 90th percentiles of 98% -188% with instant. max. values of 148%-265% depending on station.		X
	pH	Primary	Numeric	9.0 – 9.5 (from pH criteria proposal)	HRL currently impaired for pH. Proposed adjustments to pH criteria would lessen impairment but some stations (e.g., YAD152C) would still be marginal.		X
	Algal toxins	Primary	Numeric	Various thresholds	Algal toxins present but in low concentrations. General concern over toxin potential.		
	%Cyanobact.	Secondary	Numeric	% biovolume, % count (%biovolume more useful for judging zooplankton support)	%Counts high but %biovolume adequate to support high trophic levels.		
	Fishery status	Primary	Narrative	Characterization based on NC WRC sampling	One of NC's best fisheries.	X	
	Fish kills	Primary	Narrative	Occurrence & frequency	No nutrient-related fish kills on record.	X	
	Fish abnormalities	Secondary	Narrative	Some might be related to nutrients (e.g., signs of gas bubble disease)	NC WRC: No signs of gas bubble disease in HRL fish.	X	
Public water supply	Algal toxins	Primary	Numeric	Various thresholds	Algal toxins present but in low concentrations. General concern over toxin potential.		
	T&O-causing compounds	Secondary	Numeric	Various thresholds	No info for HRL		
	Treatability challenges	Primary	Narrative	Occurrence & frequency	Town of Denton does not report algae-related treatability problems.	X	
Recreation	Algal toxins	Primary	Numeric	Various thresholds	Algal toxins present but in low concentrations. General concern over toxin potential.		
	Secchi depth	Secondary	Numeric	0.6 – 1.0 m	CHLa sufficiently high to reduce SD < 1.0 m and impart green color to water. Unclear how this relates to regional user expectations or actual use.		X
	Nuisance blooms; mats or extensive scums	Primary	Narrative	Occurrence & frequency	Algae in HRL tends to be dispersed in water column.	X	

[1]Primary indicators would be direct measures of impacts or use attainment. Secondary indicators would be indirect measures that might correlate with other risks but are not direct measures of use attainment.

[2]Color coding as follows:

Indicator supports finding of use attainment.
Indicator does not clearly show use not met, but raises concerns.
Indicator shows use clearly **not** met.

Narrative to Accompany Table: The table above is intended to demonstrate how different types of High Rock Lake-specific information could inform the magnitude of a site-specific chlorophyll-a criterion. It does not (yet) represent an SAC consensus on the content, and could be refined based on SAC discussion. But it is offered as a template to help increase the scientific defensibility of a multiple-lines-of evidence approach to setting the criterion magnitude.

The table attempts to list the major numeric and narrative indicators that would inform whether HRL is currently meeting designated uses. For favorable indicators, HRL's existing CHLa condition would be relevant to the magnitude discussion. For mixed or unfavorable indicators, additional data analysis would be performed to determine if that indicator correlates with CHLa, and if so, to what degree the indicator could be improved by reducing CHLa from current levels.

As an example, High Rock Lake's existing fishery status is a narrative indicator that supports a finding of attainment relevant to both aquatic life and recreational uses. Quantitatively, this indicator can be linked with HRL's existing chlorophyll-a condition. Conversely, Secchi depth and pH might be considered indicators of concern for HRL. Lake specific data can be used to quantify how different CHLa levels would affect Secchi depth (Figure 1) and pH (Figure 2) at various locations in the reservoir. The balanced considered of information for all indicators—in conjunction with insights from the literature—could be used to support professional judgments on criteria magnitude.

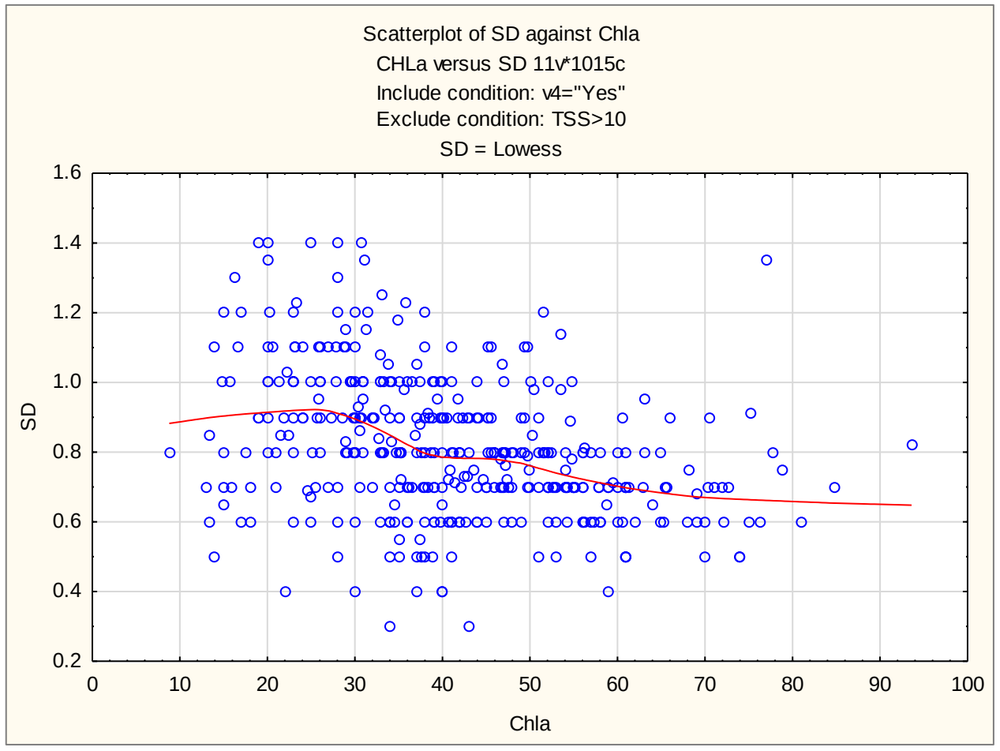


Figure 1 – Secchi depth (m) vs. chlorophyll-a (ug/L) in High Rock Lake, 1981-2016, Apr- Oct. Samples with >10 mg/L total suspended solids were removed.

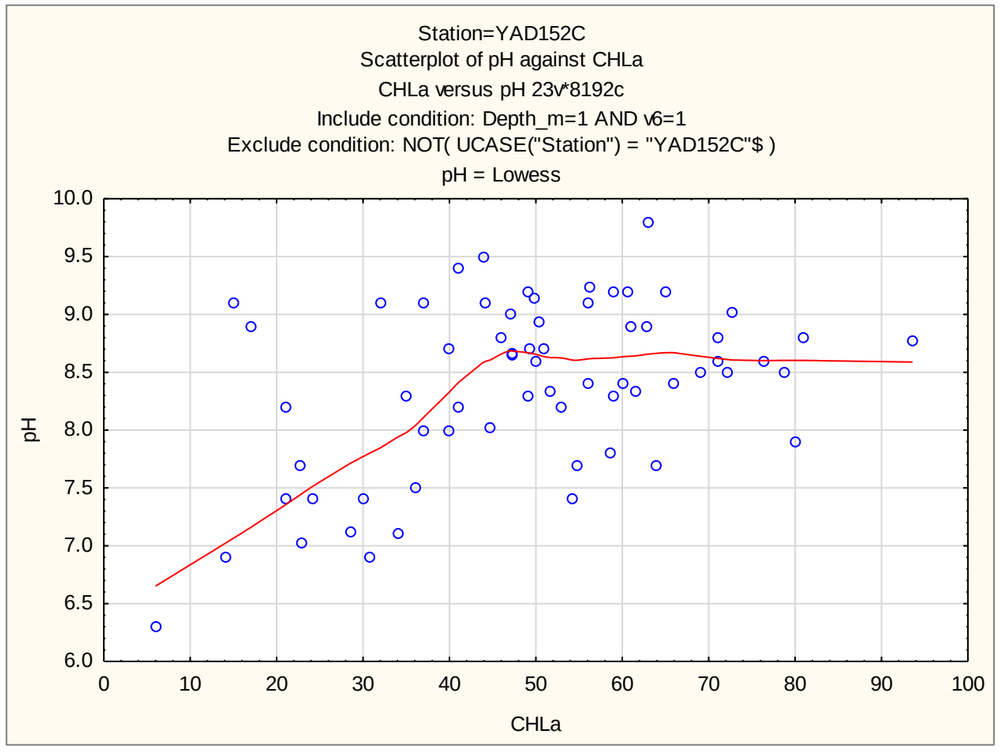


Figure 2 – Surface pH (<1 m) versus chlorophyll-a (ug/L) at station YAD152C, 1981-2016, Apr-Oct.

Date: July 6, 2018

Subject: Comments from Clifton Bell on Lauren Petter (EPA) proposal entitled "Updated Chlorophyll a Criteria Considerations for High Rock Lake date June 2018"

I appreciate the opportunity to comment on the proposal. The comments below start with observations on some general areas of agreement, and then areas of disagreement.

1. Agreement on some concepts. One of the concepts implicit if not explicit in the EPA proposal is a continuum of risk of CHLa- related impairment. This is a useful concept, and the challenge is to apply in a quantitative manner. I also agree with the concept that—as expressed in the embedded Mike Pace quote—that increased eutrophication of a water body like High Rock Lake could lead to undesirable consequences, and that these consequences would not be completely predictable. General agreement on these principles is a reason that my separate proposal would also set CHLa criteria at a level lower than observed in HRL, and lead to substantial nutrient load reductions.

2. Lack of useful linkages between CHL and impairment risk for High Rock Lake. These areas of agreement notwithstanding, I do not believe the EPA proposal makes meaningful linkages between chlorophyll-a and impairment risk in High Rock Lake. Much of the proposal's content emphasizes speculative effects over actual observations, or bases CHLa recommendations on indicators that are not in themselves impairments. It makes very little use of High Rock Lake-specific information. I do not believe that Table 1 of the EPA proposal accurately characterizes the relations between CHLa and impairment risk for High Rock Lake. The information sources cited in this table are as follows:

a) DEQ's August 2015 presentation on the relation between CHLa and % cyanobacteria by count. Although cyanobacteria prevalence is a relevant scientific consideration, it must be emphasized that high cyanobacteria counts themselves are not an impairment of designated uses. Cyanobacteria impair designated uses if they cause high toxin concentrations, frequent nuisance blooms, insufficient non-cyanobacteria biovolume to support higher trophic levels, etc. None of these effects have been demonstrated to occur in HRL. But even if they did, it would be important to tie CHLa to the actual impairment rather than merely the cyanobacteria count.
b) My tabulated literature survey from April 2016. The literature is another relevant source of information, but should not be emphasized over actual reservoir-specific observations. The literature is most useful for identifying the lower end of the CHLa range at which some water bodies—many of which are very different from NC's Piedmont reservoirs—have experienced problems. It is less useful for identifying the upper end of the range below which some reservoirs will not experience impairments.
c) WHO guidance values: As described in Chorus and Bartram (1999)[1], the WHO CHLa thresholds are based on the assumption that microcystin-producing cyanobacteria are dominant. For example, the 10 ug/L CHLa threshold is based on the assumption of 2-10 ug/L microcystins at this CHLa level. High Rock Lake, in contrast, commonly experiences much higher CHLa concentrations, but lower microcystin concentrations. There is no evidence that correlations between CHLa and microcystins assumed by the WHO guidance hold true for HRL.

[1] Chorus, I. and Bartram, J. 2009. Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring and management. Publication of the World Health Organization. 400 p.

3. *There is little indication that the EPA proposal has considered actual use attainment in High Rock Lake*. The only direct use of High Rock Lake data was the correlation with cyanobacteria counts. Information on High Rock Lake's many favorable indicators—excellent fishery status, rarity of nuisance blooms, lack of drinking water impacts, lack of user complaints, sufficient non-cyanobacteria biovolume, etc.—does not appear to have been factored into the EPA criteria recommendation.

4. T*he EPA CHLa recommendation (30 ug/L as an arithmetic mean) is unreasonably low*. The recommended seasonal arithmetic mean of 30 ug/L equates to a seasonal geometric mean of perhaps ~27 ug/L. This would require more than 50% reduction in CHLa for a reservoir that has many favorable indicators and does not show obvious impairments. In fact, considering that the highest-CHLa station would control implementation under NC's existing methods, model predictions (Figure 1 of EPA proposal) indicate that the EPA-recommended criteria is only slightly higher than a "natural conditions" scenario with no point sources in the basin (!). Despite the statement that the intent is "not to select something that is infeasible", the proposed criterion may be just that. A "natural conditions" scenario is interesting for examining the sensitivity of CHLa to nutrient reductions, but is not a viable management scenario.

   I would concur that IF an extremely stringent CHLA value was shown to be necessary to attain designated uses in High Rock Lake, this would be a matter for the CIC to work out the implementation implications and possibly pursue a use attainability analysis. But no such demonstration has been made, for reasons discussed under comment #2.

5. *The need to develop a more transferable framework for deriving site-specific criteria*. The SAC is tasked with deriving site-specific criteria for High Rock Lake, but also for considering how site-specific criteria could be derived for other lakes and reservoirs in NC. It is unlikely that DWR could afford to repeat the SAC High Rock Lake-like deliberations for every reservoir. It is also unlikely that the criterion magnitude derived for High Rock Lake is the appropriate criterion for every other warmwater reservoir. I do not believe the EPA proposal is very useful as general framework for deriving site-specific criteria because: (1) it does not provide a range of CHLa screening values for warmwater reservoirs; and (2) it does not describe how narrative attainment should be considered in conjunction with CHLa values. My recommendation—as shown in the separate proposal—is that the SAC first derive a transferable framework for deriving site-specific criteria, and then use High Rock Lake as the pilot to show how it would work.

Having offered the criticisms above, I will say that the proposal that I offered could also be improved with an expanded technical justification of the magnitude, and better explanation of how the High Rock Lake-specific factors into the decision on magnitude. My hope is that the SAC can come to consensus on an outline for a joint CHLa proposal, and then share the responsibilities of completing different subsections. Some of these subsections should include more detailed examination of the relation between CHLa and use indicators in High Rock Lake.

Evaluation of
Updated Chlorophyll-a Criteria for High Rock Lake by Lauren Petter (June 2018)

By
William T. Hall
Hall & Associates
July 13, 2018

Introduction

A numeric nutrient criterion proposal for chlorophyll-a was prepared by SAC member Lauren Petter, and is documented in a written proposal titled, Updated Chlorophyll a Criteria Considerations for High Rock Lake, March 2018. As described in the write-up, this proposal is based on a consideration of "balanced risk". Following the SAC meeting on May 31, 2018, Lauren sent out an email asking for comments on a revised version of the proposal (date, June 2018). The comments presented below are presented to identify areas of the proposal that need to be strengthened to make it more scientifically defensible.

Overview

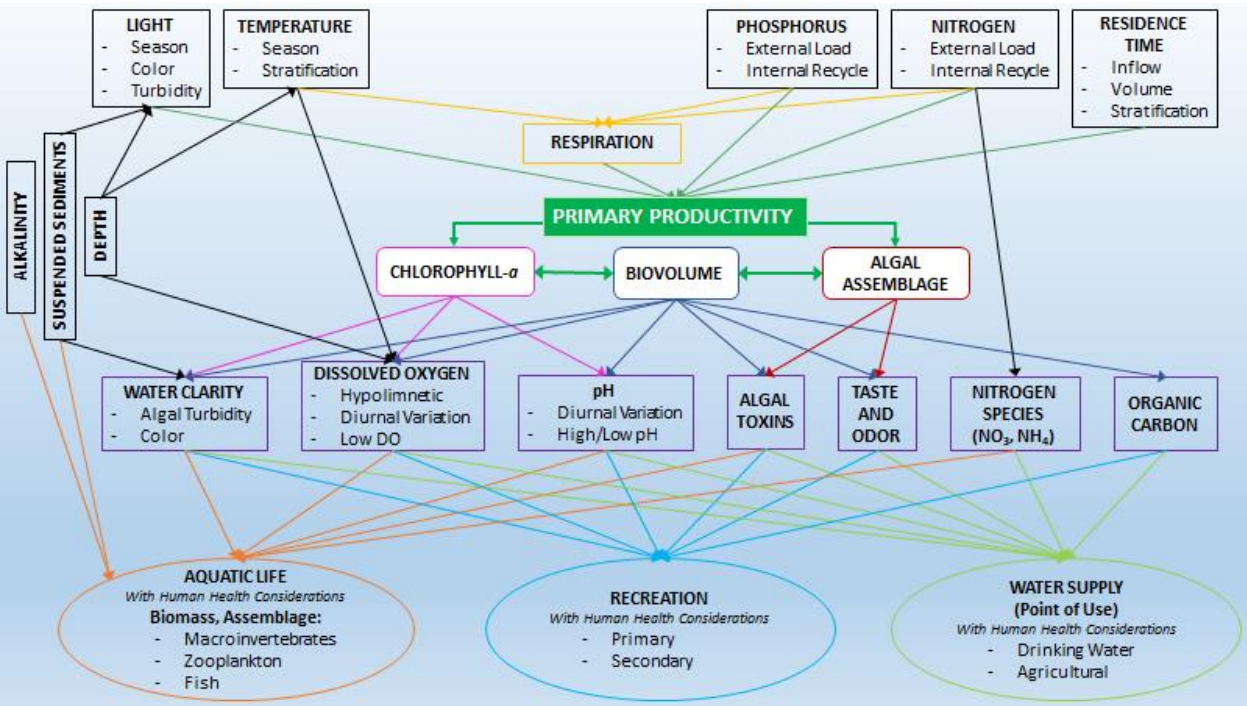
High Rock Lake is a run-of-river reservoir with designated uses including aquatic life, recreation (primary, secondary), drinking water supply, and other uses (fishing, fish consumption, wildlife, and agricultural uses). A review of the North Carolina 2016 303(d) List shows that several segments of High Rock Lake are listed as impaired. The listed impairments include aquatic life impairment due to turbidity, chlorophyll-a, and pH. In addition, there is a fish tissue advisory for PCBs. Of these, the fish tissue advisory for PCBs is not considered a nutrient-related impairment. The turbidity impairment is based on exceedance of the existing criterion for turbidity (25 NTU). This impairment is caused by algal and non-algal particles and soluble colored organic compounds. As such the exceedance of this parameter can be attributed to multiple causes, including nutrients. The impairment for pH is based on exceedance of the existing upper pH criterion (9.0 su). The SAC has considered this criterion and made recommendations for revising the upper pH criterion. If the recommended pH criterion is adopted, the aquatic life pH impairment will need to be reassessed. The impairment for chlorophyll-a is based on exceedance of the existing chlorophyll-a criterion, 40 µg/L. The NC DWQ has indicated that this criterion needs updating. The chlorophyll-a criterion is the subject of this proposal.

The impairment listings for turbidity, pH and chlorophyll-a are presumed impairments to aquatic life. Alternative narrative evaluations of aquatic life use in High Rock Lake do not suggest use impairment. For example, the lake supports an excellent warm water fishery and is a popular recreational resource for this reason. Thus, it is not apparent at this time whether nutrients are causing use impairment. No other evidence of aquatic life impairment has been presented to the SAC. The Balanced Risk chlorophyll-a proposal for High Rock Lake provides a criterion value of 30 µg/L as a growing season arithmetic average to protect recreation and drinking water uses of the lake. Performance data for High Rock Lake shows that chlorophyll-a concentrations in the lake can average over 60 µg/L in specific assessment units (i.e., YAD152). Compliance with the proposed criterion is likely to require a 50% reduction in nutrient loads to the lake at a cost likely exceeding hundreds of millions of dollars. Given these potential costs, it is imperative that the recommended chlorophyll-a criterion is necessary to protect designated

uses in the lake. The following comments address specific areas of the proposal that should be strengthened to ensure that the proposed chlorophyll-a criterion is linked to designated use attainment in a way that is scientifically defensible.

Background

Under the North Carolina Nutrient Criteria Development Plan (NCDP; June 2014), the Scientific Advisory Council (SAC) was established to assist the DWR with development of nutrient criteria. Under the Plan, the SAC is tasked with the development of nutrient criteria, based primarily on the linkage between nutrient concentrations and protection of designated uses in accordance with federal regulations (40 CFR 131). The linkage referenced in the NCDP is illustrated in the conceptual model that describes how nutrients are related to use impairments. This Conceptual Model was adopted by the SAC at its February 17, 2016 meeting and is illustrated below.



As illustrated in the Conceptual Model, the designated uses are not directly affected by chlorophyll-a concentration. Rather, chlorophyll-a concentration is a measure of primary productivity. Chlorophyll-a concentration exerts a direct or indirect effect on several primary stressors of the lake, which in turn have the potential to affect use attainment for the various uses defined for the water body. These primary stressors include:

- Water Clarity

  Chlorophyll-a affects water clarity based on the color it imparts to the water and light scattering caused by algal cells. Water clarity is also influenced by non-algal particulates and water color

unrelated to primary productivity. Water clarity potentially affects all primary uses (aquatic life, recreation, water supply) of High Rock Lake. The most sensitive use is probably recreation.

- Dissolved Oxygen

  Chlorophyll-a affects dissolved oxygen through algal photosynthesis (increases DO) and respiration (decreases DO). It also influences DO in benthic waters through settling and cellular decomposition. DO is also influenced by biochemical oxygen demand unrelated to primary production. DO affects all primary uses of High Rock Lake. The most sensitive use is probably aquatic life. DWQ has water quality criteria for DO, but these criteria do not apply to the stratified bottom waters of the lake.

- pH

  Chlorophyll-a affects pH through algal photosynthesis (increases pH) and respiration (decreases pH). Ambient pH is also influenced by factors unrelated to primary production (e.g., external loads, geology, alkalinity). Ambient pH affects all primary uses of High Rock Lake. The most sensitive use is probably aquatic life. DWQ has water quality criteria for pH and the SAC has proposed revised criteria for pH.

- Algal Toxins

  Chlorophyll-a affects the concentration of algal toxins indirectly. Algal toxins, such as microcystin, are produced by certain cyanobacteria under certain conditions that are not well defined. If certain toxin-forming cyanobacteria are present, they contribute to the overall chlorophyll-a concentration in the water column. Those cyanobacteria may also produce cyanotoxins that have the potential to affect all primary uses of High Rock Lake. The most sensitive use is probably recreation, where incidental ingestion of untreated water may occur.

- Taste & Odor

  Chlorophyll-a affects taste and odor indirectly. Taste and odor problems are caused by certain algal species by the production of cellular products (e.g., geosmin) and when elevated concentrations of algae decompose. If certain taste and odor-causing algae are present, they contribute to the overall chlorophyll-a concentration in the water column. Taste and odor problems have the potential to affect the recreational and drinking water uses of High Rock Lake. The most sensitive use is probably drinking water, although this issue can be addressed through treatment and should be assessed at the point of potable water intake (downstream of High Rock Lake).

- Organic Carbon

  Chlorophyll-a affects organic carbon indirectly. Organic carbon is a constituent of algal cells and increases with cell growth. As chlorophyll-a concentration increases, the amount of organic carbon present also increases, but the proportion of organic carbon to chlorophyll varies by species. Organic carbon is primarily a drinking water concern due to the formation of disinfection byproducts when drinking water is chlorinated in the presence of organic carbon and should be assessed at the point of potable water intake (downstream of High Rock Lake). The Safe Drinking Water Act establishes treatment requirements to control organic carbon in potable water systems.

If scientifically defensible numeric nutrient criteria are to be developed for chlorophyll-a, data illustrating the linkage between the use that is being protected and the direct stressor causing the use impairment must be presented. Typically, this would yield a numeric criterion for the direct stressor. Then, the linkage between the direct stressor and chlorophyll-a could be developed using guidance available from USEPA.[1]

Summarization of Balanced Risk Approach

The Balanced Risk approach is characterized as a weight of evidence approach based on the risk of use impairment using information from other comparable reservoir systems, modeling results, and system resilience. The proposed chlorophyll-a criterion reflects the following considerations:

- Designated Uses – balanced consideration, including a decision to allow a "medium" risk of recreation and drinking water impacts, while not resulting in a chlorophyll-a concentration that would be detrimental to the recreational fishing populations.
- Water Quality Characteristics – a reduced chlorophyll-a concentration designed to lessen super saturated DO conditions and increased pH concentrations typical of a highly eutrophic system.
- Resiliency – a provision for future development and/or changing environmental or lake management conditions.

The first step in this analysis was to consider chlorophyll-a criteria development for lakes in Alabama and Georgia, as these states use a seasonal average most similar to the duration being discussed by the SAC for North Carolina. Based on this analysis, the range of criteria concentration values associated with multiple designated use lakes (i.e., swimming, fish and wildlife, public water supply) falls within the range of 5 – 24 µg/L. However, modeling of High Rock Lake indicates that the average chlorophyll-a concentration would not be less than ~25 µg/L for mid-lake stations (YAD152, YAD152A, and YAD152C) even if all point sources were removed and the watershed was restored to "natural" conditions. Consequently, the selected chlorophyll-a criterion for High Rock Lake would need to be higher than the criteria recommendations used in other southeastern states.

The second step in this analysis includes a consideration of system resilience with regard to recreational and drinking water uses. Given the amount of development happening across North Carolina, the growing knowledge of algal communities, and the difficulty in determining every "switch" which can cause an algal group to create toxins, criteria development warrants careful consideration to ensure the resulting recommendation is protective. In this regard, the Balanced Risk approach cites Touchette et al. (2007) stating that cyanotoxin production can be stimulated by nutrient enrichment as eutrophication progresses. It also cites a presentation by Pace (2015) on determining early warning signs of resilience loss: "There may be no advance warning for some kinds of abrupt change, reinforcing the need to enhance resilience by managing ecosystems to reduce the possibility of crossing thresholds of change."

The final step in this analysis presented a consideration of existing cyanobacteria dominance and cell counts in High Rock Lake, and toxin ranges relative to chlorophyll-a concentrations from literature. Using these data, three risk level categories were developed. These are summarized below.

[1] USEPA. 2010. Using Stressor-response Relationships to Derive Numeric Nutrient Criteria. EPA-820-S-10-001. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100IK1N.PDF?Dockey=P100IK1N.PDF.

Risk Category	Chlorophyll-a Range	Cyanobacteria Dominance	Cyanobacteria Cell Count	Microcystin Level	Average Chlorophyll-a
Low	9 - <30 μg/L	9.3%	<20,000/mL	<10 μg/L	16.5 μg/L
Medium	10 – 50 μg/L	46.4%	20-100,000/mL	10 – 20 μg/L	30.6 μg/L
High	20 – 80 μg/L	61.5%	>100,000/mL	> 20 μg/L	47.5 μg/L

Based on the assumption that the information contained in the medium risk category represents the best approximation of what would be considered a protective chlorophyll-a concentration for High Rock Lake, the following criterion is proposed.

Magnitude: 30 μg/L

Duration: seasonal arithmetic mean (May – October)

Frequency: once in three-year excursion.

Feedback on Approach

Although multiple considerations were identified as the basis for the recommended criterion, the proposed criterion appears to be primarily based on theoretical risk associated with the formation of cyanotoxins by cyanobacteria (See, Template for Chlorophyll-a Proposals). There are multiple concerns with the manner in which the proposed criterion was developed if risk associated with cyanotoxin formation is the primary basis. These include the following:

- Chlorophyll-a Risk Categories Overlap – The risk categories include chlorophyll-a concentrations with a significant amount of overlap (e.g., the high end (< 30 μg/L) of the low risk category is higher than the low end (20 μg/L) of the high risk category). Given the large amount of overlap, the distinction between the risk categories is tenuous.
- Cyanobacteria Dominance is not an appropriate Use Impairment Metric – Cyanobacteria percent dominance, based on cell counts, is not an impairment metric in the Conceptual Model and should not serve as the basis for establishing chlorophyll-a criteria to protect designated uses. Moreover, dominance expressed as a percentage of cell counts does not distinguish between low overall biomass (low risk) and high biomass (higher risk). Consequently, this metric is not appropriate for criteria development without more information linking it to use impairment.
- Cyanobacteria Cell Count is not an appropriate Use Impairment Metric – Cyanobacteria cell counts are a better indicator than percent dominance, but the relationship between this metric and the factors directly causing use impairment is weak, resulting in a very large confidence interval or a high probability of obtaining an erroneous result (e.g., a type-1 error). If this metric is used as a basis for establishing a chlorophyll-a criterion, data showing how cell count is related to use impairment needs to be presented so that the strength of the relationship can be assessed.
- Cyanotoxin Impairment Threshold – The cyanotoxin threshold associated with use impairment has not been identified. In order to develop a scientifically defensible chlorophyll-a criterion to protect against cyanotoxins, the impairment threshold for cyanotoxin must be identified for each use to be protected and the chlorophyll-a concentration associated with an exceedance of that threshold must be developed using scientifically defensible methods, such as those

presented in EPA's stressor-response guidance document. This information was not presented in the proposal.

- Cyanotoxin-based Use Attainment Threatened Under All Proposed Risk Categories – the cyanotoxin concentrations identified with each risk category are likely sufficient to impair recreational uses. USEPA has proposed a microcystin water quality standard of 4 μg/L to protect recreational[2] uses, but the low risk category suggests it would allow microcystin concentrations up to 10 μg/L. It is not apparent that any of the risk categories would protect uses if these cyanotoxin concentrations occur at the referenced chlorophyll-a concentrations.
- Chlorophyll Averaging Inappropriate – The chlorophyll-a concentration associated with each risk category was calculated by averaging the various data ranges identified for each risk metric. For example, the Medium Risk category with an arithmetic average chlorophyll-a concentration of 30.6 μg/L was based on an average of the following ranges:
    - 30 – 40 μg/L (46.4% blue green dominance)
    - 30 – 50 μg/L (moderate risk of health effects)
    - 15 – 20 μg/L (water supply use impairment)
    - 10 - 50 μg/L (microcystin concentrations of 10 – 20 μg/L)

  This approach is inappropriate for multiple reasons. Blue green dominance is not a stressor identified in the Conceptual Model. Moderate risk of health effects is unspecified as to cause and should not be used or its basis should be further defined for consideration by the SAC. The information presented suggests that water supply uses would be impaired at a concentration well below the target value of 30 μg/L (water quality standards must protect the most sensitive use). And, the "expected" cyanotoxin concentration is well above EPA's proposed threshold for recreational use impairment. Moreover, no justification is provided as to why a simple average of these disparate metrics is appropriate for setting a water quality standard or how the proposed standard protects individual uses.

  A more appropriate method to develop a criterion would be to present a regression relating cyanotoxin concentration to chlorophyll-a concentration on a continuous scale, showing confidence intervals for the regression, and accounting for confounding factors as discussed in EPA's guidance on stressor-response evaluations.

The medium risk category is based on information that includes use impairments to drinking water and recreational uses. As such, it would be inappropriate as the basis for chlorophyll-a criteria if these uses are actually impaired at the proposed concentration. Similarly, it would be inappropriate if use attainment actually occurred at these chlorophyll-a concentrations. High Rock Lake experiences growing season average chlorophyll-a concentrations in excess of 60 μg/L, but there is no information showing elevated levels of cyanotoxins, which is the basis for the proposed chlorophyll-a criterion. Consequently, the proposed criterion does not appear to be necessary to protect uses in High Rock Lake.

[2] See, Federal Register notice 81 FR 243: 91929. Request for Scientific Views: Draft Human Health Recreational Ambient Water Quality Criteria and/or Swimming Advisories for Microcycstins and Cylindrospermopsin.

Additional Comments

In addition to these specific concerns with the basis for the proposed criterion, the Balanced Risk write-up includes several statements that appear unfounded or are undefined and need further explanation. These include the following:

> Comparable Reservoir Systems: The background section on page 1 indicates that criteria from comparable reservoir systems were identified for potential application to High Rock Lake. No information is presented to show that the other reservoir systems cited are comparable to High Rock Lake other than geography. If they are comparable, the information presented would suggest that the chlorophyll-a criterion necessary to protect aquatic life, recreation, and drinking water uses would be in the 5 – 24 μg/L range. Information on the specific factors associated with the chlorophyll-a criteria for the other reservoir systems (i.e., cyanotoxins, taste & odor, transparency) would help identify whether these systems are comparable or whether High Rock Lake is unlike these other systems.
>
> Super Saturated Dissolved Oxygen: The summary section on page 1 indicates that the proposed criterion for High Rock Lake reflects lessening super saturated DO conditions. This is not an impairment metric. Dissolved oxygen concentrations above saturation do not cause use impairments. Consequently, super-saturated DO conditions should not be cited as a basis of consideration with regard to criteria development.
>
> Increased pH concentration: The summary section on page 1 indicates that the proposed criterion for High Rock Lake reflects lessening increased pH concentrations. For this metric to be used as the basis for a chlorophyll-a criterion, a relationship between chlorophyll-a and pH must be presented to show the chlorophyll-a threshold at which pH will exceed the pH criterion and the confidence around this level of chlorophyll-a. This has not been presented.
>
> Resiliency: This term is used a number of times in the presentation but is not defined.

These terms need to be defined and the write-up needs to identify how these considerations factored into the proposed criterion. Without this, their relationship to the proposed criterion is uncertain.

Summary

The Balanced Risk Approach needs to ensure that all uses are protected by the proposed chlorophyll-a criterion. To do this in a scientifically defensible manner, chlorophyll-a concentration must be linked to use impairment in a manner that can be validated. In this particular case, it appears that the risk is based on formation of cyanotoxins. Consequently, use impairment thresholds for cyanotoxin must first be identified. Then, the relationship between chlorophyll-a concentration and cyanotoxin concentration should be established, accounting for confounding factors that influence the occurrence of cyanotoxins in accordance with EPA's Stressor-response guidance.[3] Then, based on this relationship, a chlorophyll-a criterion can be proposed. Moreover, because the actual cause of impairment is defined (i.e., a concentration of microcystin with an averaging period and a return frequency), the criterion is amenable

[3] It is not necessary to determine every switch which can cause an algal group to start forming cyanotoxins, but you cannot ignore all of these factors because this will result in criteria with a very low coefficient of determination that is not suitable for criteria development.

to site-specific adjustment if the assumptions made in developing the chlorophyll-a criterion are not appropriate for a particular lake. This is particularly important for numeric nutrient criteria because many of the designated use-chlorophyll-a relationships are gradational rather than step functions with sharp thresholds of impairment, and the linkage we are trying to establish is highly variable.

A less rigorous alternative would be to propose a chlorophyll-a concentration based on weight of evidence without the detailed supporting information suggested above. In this case it is still important to identify the specific use being protected, the direct stressor of concern, and what factors were considered in proposing the criterion. Since this approach lacks the information necessary to assess the error around the proposed criterion, it must allow for site-specific adjustment where it can be demonstrated that the criterion is inappropriate for a specific situation.

Evaluation of
Recommendations for High Rock Lake Criteria – Chlorophyll-a by Clifton Bell (March 13, 2018)

By
William T. Hall
Hall & Associates
July 13, 2018

Introduction

A numeric nutrient criterion proposal for chlorophyll-a was prepared by SAC member Clifton Bell, and is documented in a written proposal titled, Recommendations for High Rock Lake Criteria – Chlorophyll-a, March 13, 2018. As described in the write-up, this proposal is based on a consideration of "balanced uses". The comments presented below are presented to identify areas of the proposal that need to be strengthened to make it more scientifically defensible.

Overview

High Rock Lake is a run-of-river reservoir with designated uses including aquatic life, recreation (primary, secondary), drinking water supply, and other uses (fishing, fish consumption, wildlife, and agricultural uses). A review of the North Carolina 2016 303(d) List shows that several segments of High Rock Lake are listed as impaired. The listed impairments include aquatic life impairment due to turbidity, chlorophyll-a, and pH. In addition, there is a fish tissue advisory for PCBs. Of these, the fish tissue advisory for PCBs is not considered a nutrient-related impairment. The turbidity impairment is based on exceedance of the existing criterion for turbidity (25 NTU). This impairment is caused by algal and non-algal particles and soluble colored organic compounds. As such the exceedance of this parameter can be attributed to multiple causes, including nutrients. The impairment for pH is based on exceedance of the existing upper pH criterion (9.0 su). The SAC has considered this criterion and made recommendations for revising the upper pH criterion. If the recommended pH criterion is adopted, the aquatic life pH impairment will need to be reassessed. The impairment for chlorophyll-a is based on exceedance of the existing chlorophyll-a criterion, 40 µg/L. The NC DWQ has indicated that this criterion needs updating. The chlorophyll-a criterion is the subject of this proposal.

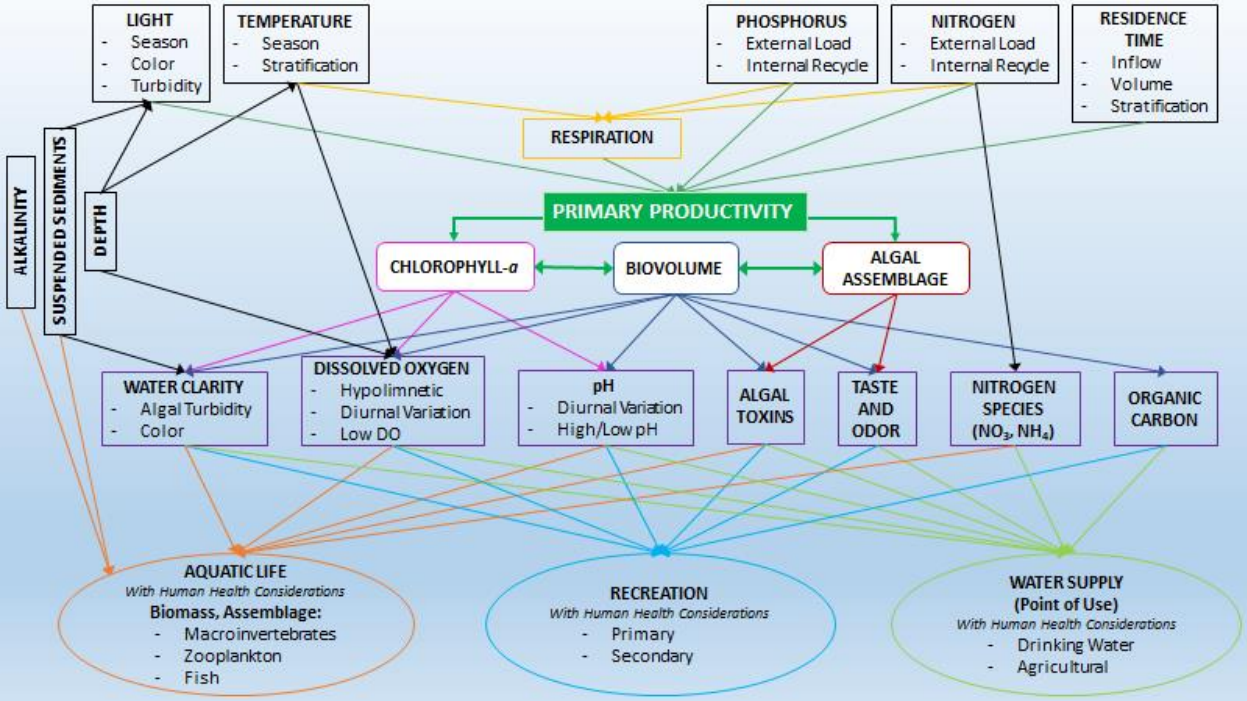
The impairment listings for turbidity, pH and chlorophyll-a are presumed impairments to aquatic life. Alternative narrative evaluations of aquatic life use do not suggest use impairment. For example, the lake supports an excellent warm water fishery and is a popular recreational resource for this reason. Thus, it is not apparent at this time whether nutrients are causing use impairment. No other evidence of aquatic life impairment has been presented to the SAC. The Balanced Use chlorophyll-a proposal for High Rock Lake provides a criterion value of 40 µg/L as a growing season geometric average to protect recreation and drinking water uses of the lake. Performance data for High Rock Lake shows that chlorophyll-a concentrations in the lake can average over 60 µg/L in specific assessment units (i.e., YAD152). Compliance with the proposed criterion is likely to require a >25% reduction in nutrient loads to the lake at a cost in the hundreds of millions of dollars. Given these potential costs, it is imperative that the recommended chlorophyll-a criterion is necessary to protect designated uses in the lake. The following comments address specific areas of the proposal that should be strengthened to ensure that

the proposed chlorophyll-a criterion is linked to designated use attainment in a way that is scientifically defensible.

Background

Under the North Carolina Nutrient Criteria Development Plan (NCDP; June 2014), the Scientific Advisory Council (SAC) was established to assist the DWR with development of nutrient criteria. Under the Plan, the SAC is tasked with the development of nutrient criteria, based primarily on the linkage between nutrient concentrations and protection of designated uses in accordance with federal regulations (40 CFR 131). The linkage referenced in the NCDP is illustrated in the conceptual model that describes how nutrients are related to use impairments. This Conceptual Model was adopted by the SAC at its February 17, 2016 meeting and is illustrated below (Figure 1).

Figure 1 – Conceptual Model Relating Nutrients to Use Impairment



As illustrated in the Conceptual Model, the designated uses are not directly affected by chlorophyll-a concentration. Rather, chlorophyll-a concentration is a measure of primary productivity. Chlorophyll-a concentration exerts a direct or indirect effect on several primary stressors of the lake, which in turn have the potential to affect use attainment for the various uses defined for the water body. These primary stressors include:

- Water Clarity

  Chlorophyll-a affects water clarity based on the color it imparts to the water and light scattering caused by algal cells. Water clarity is also influenced by non-algal particulates and water color

unrelated to primary productivity. Water clarity potentially affects all primary uses (aquatic life, recreation, water supply) of High Rock Lake. The most sensitive use is probably recreation.

- Dissolved Oxygen

  Chlorophyll-a affects dissolved oxygen through algal photosynthesis (increases DO) and respiration (decreases DO). It also influences DO in benthic waters through settling and cellular decomposition. DO is also influenced by biochemical oxygen demand unrelated to primary production. DO affects all primary uses of High Rock Lake. The most sensitive use is probably aquatic life. DWQ has water quality criteria for DO, but these criteria do not apply to the stratified bottom waters of the lake.

- pH

  Chlorophyll-a affects pH through algal photosynthesis (increases pH) and respiration (decreases pH). Ambient pH is also influenced by factors unrelated to primary production (e.g., external loads, geology, alkalinity). Ambient pH affects all primary uses of High Rock Lake. The most sensitive use is probably aquatic life. DWQ has water quality criteria for pH and the SAC has proposed revised criteria for pH.

- Algal Toxins

  Chlorophyll-a affects the concentration of algal toxins indirectly. Algal toxins, such as microcystin, are produced by certain cyanobacteria under certain conditions that are not well defined. If certain toxin-forming cyanobacteria are present, they contribute to the overall chlorophyll-a concentration in the water column. Those cyanobacteria may also produce cyanotoxins that have the potential to affect all primary uses of High Rock Lake. The most sensitive use is probably recreation, where incidental ingestion of untreated water may occur.

- Taste & Odor

  Chlorophyll-a affects taste and odor indirectly. Taste and odor problems are caused by certain algal species by the production of cellular products (e.g., geosmin) and when elevated concentrations of algae decompose. If certain taste and odor-causing algae are present, they contribute to the overall chlorophyll-a concentration in the water column. Taste and odor problems have the potential to affect the recreational and drinking water uses of High Rock Lake. The most sensitive use is probably drinking water, although this issue can be addressed through treatment and should be assessed at the point of potable water intake (downstream of High Rock Lake).

- Organic Carbon

  Chlorophyll-a affects organic carbon indirectly. Organic carbon is a constituent of algal cells and increases with cell growth. As chlorophyll-a concentration increases, the amount of organic carbon present also increases, but the proportion of organic carbon to chlorophyll varies by species. Organic carbon is primarily a drinking water concern due to the formation of disinfection byproducts when drinking water is chlorinated in the presence of organic carbon and should be assessed at the point of potable water intake (downstream of High Rock Lake). The Safe Drinking Water Act establishes treatment requirements to control organic carbon in potable water systems.

If scientifically defensible numeric nutrient criteria are to be developed for chlorophyll-a, data illustrating the linkage between the use that is being protected and the direct stressor causing the use impairment must be presented. Typically, this would yield a numeric criterion for the direct stressor. Then, the linkage between the direct stressor and chlorophyll-a could be developed using guidance available from USEPA.[1]

Summarization of Balanced Uses Approach

The Balanced Uses approach is based on the observation that the designated uses for High Rock Lake (i.e., aquatic life protection, recreation, drinking water supply) respond differently to the concentration of chlorophyll-a in the lake.

- Aquatic Life Protection – increasing levels of chlorophyll-a do not appear to impair aquatic life uses and support a very productive warmwater fishery. But, the productivity of the fishery is expected to decrease as the chlorophyll-a concentration decreases.
- Recreation – decreasing levels of chlorophyll-a are preferred for primary and secondary contact recreation. However, there is little record of user complaints and many existing users likely consider the existing condition to be an acceptable prevailing condition of a productive reservoir.
- Drinking Water Supply – decreasing levels of chlorophyll-a are preferred for use as a potable water supply. However, any effects of chlorophyll-a concentrations on public water supplies can be addressed through normal water treatment processes and there is no suggestion of major impacts on water treatment plants downstream of High Rock Lake.

Because many of the designated use-chlorophyll-a relationships are gradational rather than step functions with sharp thresholds of impairment, this approach recommends a more conservative chlorophyll-a criterion to potentially benefit other uses and provide a margin of safety against future impairment. A seasonal average criterion of 40 μg/L is proposed, which is drawn from a working chlorophyll-a threshold range of 25 – 40 μg/L for warmwater fishery reservoirs. The technical basis for the magnitude, frequency, and duration components of the proposed criterion are as follows.

Averaging Period

The criterion is presented as a geometric average for the warm weather or growing season (April – October) based on: 1) the original intent behind the current chlorophyll-a standard; 2) A temporally-averaged metric is appropriate as an indicator of reservoir trophic status and the general potential for various algal-related effects over different time scales (as opposed to criteria for toxics); 3) use of a seasonal average has many precedents from other states; 4) many of the potential use-chlorophyll-a linkages are better characterized using the central tendency rather than an instantaneous concentration; 5) laboratory round-robin testing for chlorophyll-a, conducted by DWR, shows significant variability in results between laboratories, which supports an averaging approach; and, 6) water quality models used to management are better at predicting seasonal average chlorophyll-a concentrations than short duration values.

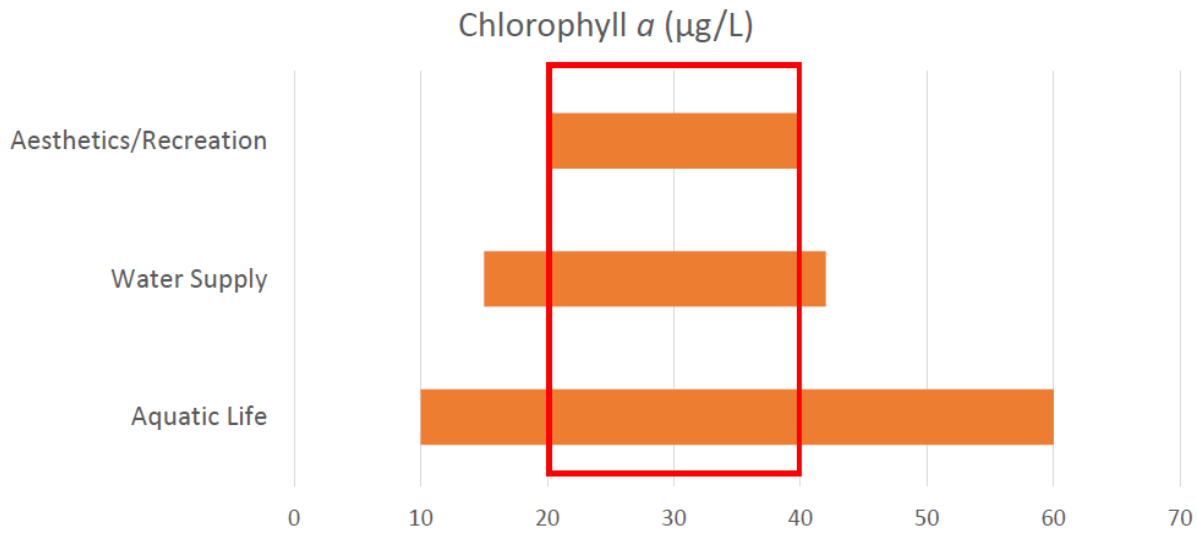
[1] USEPA. 2010. Using Stressor-response Relationships to Derive Numeric Nutrient Criteria. EPA-820-S-10-001. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100IK1N.PDF?Dockey=P100IK1N.PDF.

A geometric mean is recommended because this is the best measure of central tendency for log-normally distributed parameters such as chlorophyll-a, as noted by USEPA. The calculation of a geometric mean would require samples from at least five different months within a growing season, and preferably would utilize samples from all seven months.

Magnitude

In prior meetings, the SAC and DWR compiled tables of chlorophyll-a values associated with attainment of uses, in other water bodies (see Figure 2 below from April 2016 SAC meeting). The value of 25 µg/L was selected as the bottom of the range, primarily due to concerns over impacts to HRL's warmwater fishery at lower values.

Figure 2 – Chlorophyll-a Use Impairment Range



The value of 40 µg/L was selected as the high end of the range, consistent with the April 2016 SAC tabulation of the upper end of support for aesthetics and recreation, and within the range presented for support of water supply and aquatic life. Although the 40 µg/L value could be interpreted as a short-duration target in some systems, it is used as a longer-term geometric mean because the algae in HRL tend to be relatively dispersed and there is little to no record of user complaints regarding algal levels, even though some parts of HRL experiences season geometric mean chlorophyll-a values higher than 40 µg/L (up to the mid-50s µg/L) under current conditions. Other favorable indicators in HRL—low algal toxin levels, excellent fishery, etc.—provide additional evidence that a value of 40 µg/L would be supportive of designated uses.

Frequency

The frequency component of water quality criteria identifies the number of exceedances that would be allowed with a certain time period. In recent years, the state of Florida underwent a rigorous nutrient criteria derivation process that resulted in the recommendation of geometric mean chlorophyll-a criteria for lakes, reservoirs, and estuaries. The associated frequency component was that the criteria should be exceeded in no more than 1 year in 3. Florida DEP (2012) demonstrated that this frequency would result in an acceptable rate of Type I error (e.g., false findings of

impairments) and Type II errors (false findings of attainment) for assessment. The 1-in-3 approach also addresses the possibility of unusual climatic years, whereby chlorophyll-a targets might be practically unattainable. Virginia also uses a version of a 1-in-3 year approach for chlorophyll-a criteria in lakes and reservoirs (9VAC25-260-187), and Minnesota deems lakes and reservoirs to be in compliance if chlorophyll-a criteria are met in the majority of assessment years or as long-term averages (MAR 7050). Both Missouri and USEPA have proposed the use of a three-year rolling average (geometric mean) for Missouri lakes and reservoirs (82 FR 61213).

For many lakes and reservoirs in NC, only a single year of monitoring data is available for a given 5-year assessment period. This presents an obvious challenge to a 1-in-3 year frequency component. One year of monitoring data would be insufficient to list a water body, but it is unlikely that resources will be available to greatly expand the monitoring frequency of most lakes. For this reason, it is recommended that frequency component be addressed by expressing the criterion as a three-year rolling average, similar to what Missouri and USEPA have proposed for Missouri lakes and reservoirs. A minimum of one year of data would be recommended for calculation of the average. For reservoirs with annual data, assessment would be based on the "worst" three-year average within the five-year assessment period.

Spatial Averaging

For calculating the seasonal geometric mean chlorophyll-a concentration, it is recommended to aggregate surface samples from all stations within each individual reservoir segment. A related caution is to avoid delineating small segments around individual stations simply based on station location. In this regard, it appears that the current segmentation of HRL could be simplified by the aggregation of the current segments into two (upper and lower reservoir) or three (upper, transitional, and lower) segments. This would recognize the different nature of the riverine and lacustrine portions of the reservoirs, without excessive segmentation around individual stations.

- Application to Other Reservoirs

A proposed statewide model combines a working chlorophyll-a threshold range of 25 – 40 µg/L with lake/reservoir-specific narrative information to assess each of North Carolina's warmwater fishery reservoirs (Figure 3). This approach would balance the advantages of simple application of numeric chlorophyll-a thresholds with the need to consider waterbody-specific characteristics. Under the proposed approach, reservoirs with a chlorophyll-a concentration below 25 µg/L would be considered in attainment. Reservoirs with chlorophyll-a concentrations higher than 40 µg/L would be considered in non-attainment and be managed to meet the 40 µg/L upper level of the working threshold range. Reservoirs within the working threshold range would undergo a narrative assessment for evidence of algal-related issues such as algal toxins, nuisance blooms, fish kills, etc. A weight-of-evidence approach would be used to determine impairment status, following guidance to be developed. For reservoirs exhibiting evidence of algal-related impairments, site-specific chlorophyll-a criteria would be set at values within the 25-40 µg/L range, but lower than the Chlorophyll-a values that coincided with the impairment conditions. For reservoirs without algal-related impairments, site-specific Chlorophyll-a criteria would also be set at values within the 25-40 µg/L range, but higher than the prevailing Chlorophyll-a values. The latter approach would be bolstered by State and federal antidegradation rules.

Figure 3 – Generalized Approach for other Reservoirs

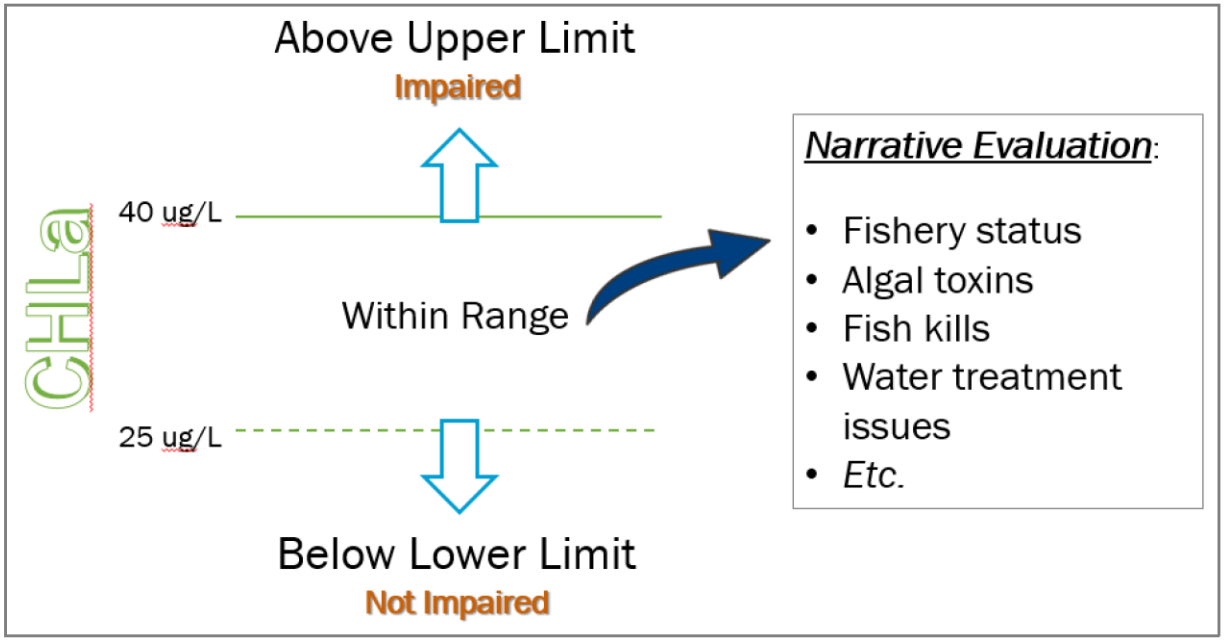


Figure 1 – Illustration of use of a CHLa threshold range in conjunction with narrative assessments.

Feedback on Approach

- Proposed Criterion for High Rock Lake

The proposed chlorophyll-a criterion for High Rock Lake, 40 µg/L, is based on meeting aesthetic and recreational use requirements. However, chlorophyll-a is not directly linked to recreational/aesthetic use impairment, as illustrated in the Conceptual Model. The factors most likely to cause aesthetic/recreational use impairment include water clarity and algal toxins. How these factors influence the range presented in Figure 2 has not been delineated so there is uncertainty regarding which factors are actually responsible for the range presented in the figure. Without knowing which factors drive the criteria values in Figure 2, it is not possible to assign a chlorophyll-a use impairment threshold with any degree of confidence that the proposed threshold is necessary.

For example, if the recreational impairment range was primarily derived from water clarity considerations, it is pertinent to know whether the assessments that form the basis for Figure 2 were based on clarity in beach areas (primary contact) or open waters (secondary contact), were the ranges developed for similar populations of users (chlorophyll-a targets greatly depend on the level of clarity the public is used to), or did other factors such as scum formation drive the thresholds (algal species in High Rock Lake tend to be dispersed forms of algae). Alternatively, if the impairment range was based on algal toxins, what cyanotoxin was responsible and what was the concentration of algal toxin the target was meant to prevent. Without this background, the linkage between the proposed chlorophyll-a criterion and protection of designated uses in High Rock Lake is not scientifically defensible.

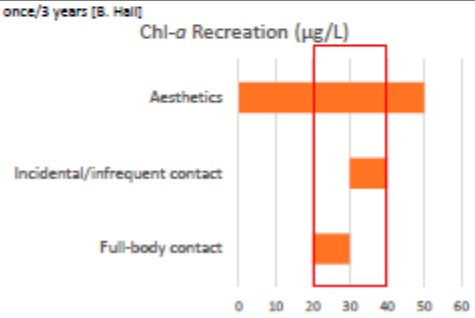
The basis for the proposed range was discussed at the April 20, 2016 SAC meeting. The Presentation Slides supporting the chlorophyll-a criteria range for the protection of recreational uses are summarized below.

Compiled Indicator Ranges for Recreation

Indicator: Chlorophyll *a* (µg/L)						
Water Quality Goal: Recreation	Low	High	Range	Duration	Frequency	Special Considerations
Full-body contact	20		10			Low value derived from reservoirs that experience higher level of algal toxins. Use attainment status serves as basis for criteria implementation. [C. Bell]
Incidental/infrequent contact	30		10			[C. Bell]
Aesthetics	30		10			[C. Bell]
Aesthetics	0	50	50	inst.	<10% summer	ref: Lake Pepin, MN (Wasley and Heiskary, 2009) [J. Bowen]
Aesthetics	0	30	30	inst.	max	ref: MN WCP shallow (Heiskary & Wilson, 2008) [J. Bowen]
Aesthetics	0	16	16	inst.	max	NY users rated as awful (Smith et al. 2009) [J. Bowen]
Aesthetics TX	0	25	25	inst.	max	TX users rated w/ significant impairment (Glass 2006) [J. Bowen]
Main body 1	42.67			see notes	see notes	Sample at HRL051, YAD152A & C, YAD169B & F [B. Hall]
Main body 2	45.59			see notes	see notes	Sample as above, minus HRL051 (due to turbidity) [B. Hall]
Abbotts Creek	37.34			see notes	see notes	Sample at HRL052, YAD169A [B. Hall]
Town Creek	36.28			see notes	see notes	Sample at YAD152 [B. Hall]
Second Creek	35.39			see notes	see notes	Sample at YAD156A, YAD1561A [B. Hall]
Arm	35.95			see notes	see notes	Sample at YAD169E [B. Hall]

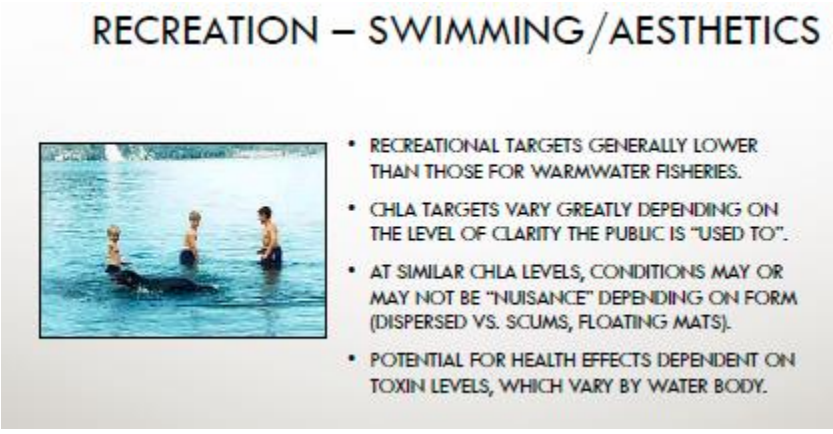
Growing season (May-Sept) geomean; ≥ 1 sample/month; allowable exceedance return frequency once/3 years [B. Hall]

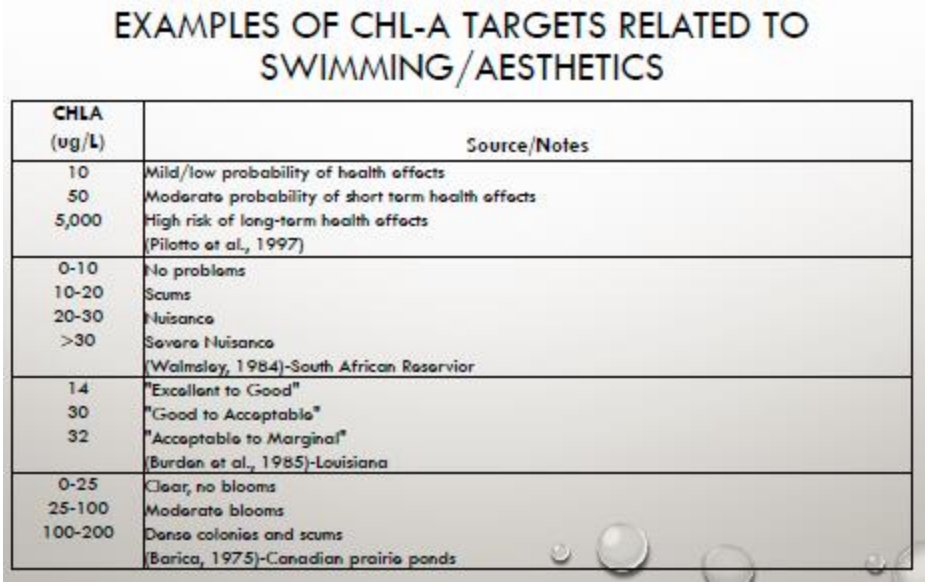
No max or range included. Range of 10 added for graphing purposes.



The final selected range of 20 – 40 µg/L was attributed to literature provided by Clifton Bell. That information is summarized in the slides below from the April 2016 meeting.

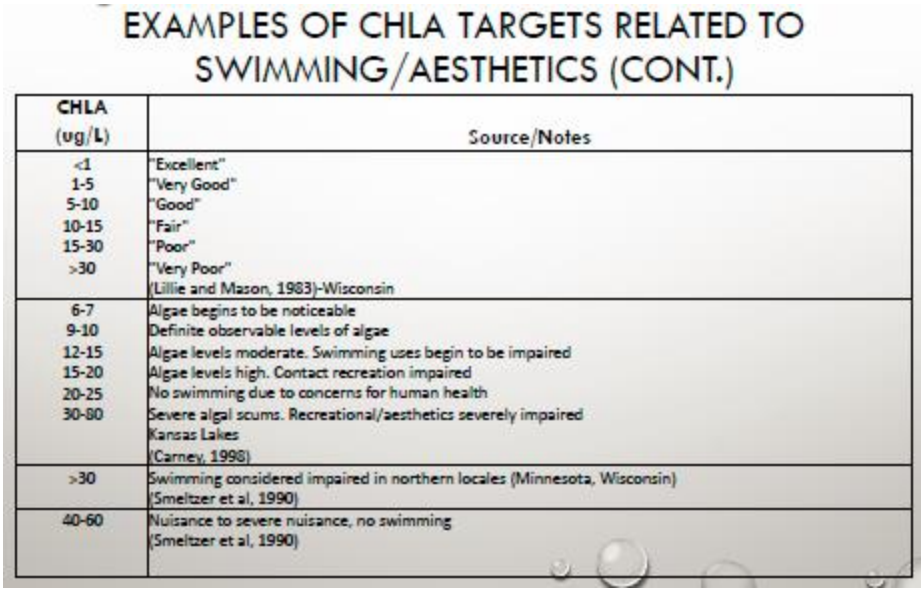
Literature Survey by Clifton Bell





EXAMPLES OF CHL-A TARGETS RELATED TO SWIMMING/AESTHETICS

CHLA (ug/L)	Source/Notes
10 50 5,000	Mild/low probability of health effects Moderate probability of short term health effects High risk of long-term health effects (Pilotto et al., 1997)
0-10 10-20 20-30 >30	No problems Scums Nuisance Severe Nuisance (Walmsley, 1984)-South African Reservior
14 30 32	"Excellent to Good" "Good to Acceptable" "Acceptable to Marginal" (Burden et al., 1985)-Louisiana
0-25 25-100 100-200	Clear, no blooms Moderate blooms Dense colonies and scums (Barica, 1975)-Canadian prairie ponds



EXAMPLES OF CHLA TARGETS RELATED TO SWIMMING/AESTHETICS (CONT.)

CHLA (ug/L)	Source/Notes
<1 1-5 5-10 10-15 15-30 >30	"Excellent" "Very Good" "Good" "Fair" "Poor" "Very Poor" (Lillie and Mason, 1983)-Wisconsin
6-7 9-10 12-15 15-20 20-25 30-80	Algae begins to be noticeable Definite observable levels of algae Algae levels moderate. Swimming uses begin to be impaired Algae levels high. Contact recreation impaired No swimming due to concerns for human health Severe algal scums. Recreational/aesthetics severely impaired Kansas Lakes (Carney, 1998)
>30	Swimming considered impaired in northern locales (Minnesota, Wisconsin) (Smeltzer et al, 1990)
40-60	Nuisance to severe nuisance, no swimming (Smeltzer et al, 1990)

The information presented in the slides suggests that the low end of the range (20 – 30 µg/L) is based on primary contact recreational exposure to cyanotoxins. The upper end of the range (30 – 40 µg/L) appears to be based on aesthetic considerations from northern states such as Minnesota and Wisconsin related to swimming or the formation of algal scums. Thus, the proposed criterion of 40 µg/L is based on meeting aesthetic requirements for Minnesota in North Carolina. This can only be justified with a determination that the Minnesota standards are appropriate for North Carolina.

If this is the intent of the proposed criterion (to prevent swimming impairments or the formation of nuisance algal scums), the proposal needs to explicitly identify the causes of impairment that the proposed chlorophyll-a criterion is intended to address. The inclusion of this information will make the proposal more defensible because it provides the linkage between the criterion, the primary stressor,

and the use being protected. Without such a statement, we are left without the ability to determine whether the criterion is necessary to protect uses, is overly protective, or is insufficient.

Under the Clean Water Act, criteria are independently developed to protect aquatic life, recreation, drinking water uses, and other adopted uses. This proposal has not presented information showing that the 40 μg/L concentration is a threshold for use impairment using the linkage identified in the North Carolina Nutrient Criteria Development Plan and it does not explicitly define which uses are being protected. As shown in the conceptual model, chlorophyll-a is a step removed from the use that is being protected. Recreational uses are not directly affected by chlorophyll concentration but may be impaired by reduced visibility, the formation of nuisance algal mats, or the presence of elevated levels of cyanotoxins. An appropriate linkage to justify a threshold value of 40 μg/L would need to relate recreational use to these primary stressors and then relate the parameter causing the impairment to chlorophyll concentration. However, we do not have these linkages so the fixed threshold value of 40 μg/L is tenuous at best.

With specific regard to High Rock Lake, the Balanced Uses proposal acknowledges that the lake appears to be meeting all of its designated uses, with the following observations:

- Current chlorophyll-a levels in the lake are up to 55 μg/L as a growing season geometric mean in the center of the lake.
- The lake supports an excellent warmwater fishery and is a popular recreational resource for this reason.
- The algae present in the lake tend to be relatively dispersed rather than occurring in obvious nuisance forms (mats/scums).
- There is little record of user complaints regarding algae levels and many existing users consider the existing condition to be an acceptable condition of a productive reservoir.
- Monitoring data indicate that algal toxin concentrations are relatively low.
- While cell counts show a dominance of cyanobacteria cells during the summer, biovolume estimates show that other more desirable algae maintain a relatively high proportion of the algal biomass.
- There is no suggestion of major impacts caused by chlorophyll-a concentrations on downstream water treatment plants.

If the lake is meeting all its designated uses and there is no evidence that any uses are threatened or impaired, it is not reasonable to propose a criterion for chlorophyll-a that immediately assumes a use is impaired. In fact, this proposed criterion is contrary to the Clean Water Act (which allows a demonstration to show that a site-specific criterion is warranted where uses are not impaired) and is internally inconsistent. As proposed, the Balanced Uses approach allows a narrative evaluation of use attainment when the chlorophyll-a concentration is within the range of 25 – 40 μg/L but presumes use impairment when chlorophyll-a concentrations exceed 40 μg/L, even if the same narrative evaluation confirms no uses are impaired.

This deficiency can be remedied by adding a clarification to the proposed criterion. The clarification would note that the use impairment threshold may be modified to reflect existing conditions when a detailed, scientifically defensible study demonstrates that all designated uses are being achieved at the

higher concentration or that any existing use impairments are not caused by the level of chlorophyll in the lake.

As proposed, impairment assessments based on chlorophyll-a concentration would be evaluated for the riverine, transitional, and lacustrine areas of the lake. This is an improvement over the current assessment methodology which assesses impairment at each station. However, it can also result in an overly stringent application of the proposed criteria. For example, the riverine section of the lake may not be suitable for primary contact recreation. Consequently, a criterion intended to protect contact recreation would not be appropriate in this section of the lake. Similarly, protection of the drinking water standard is typically applied at the point of potable water use, which is located in downstream waters. The chlorophyll-a concentration in the riverine and transitional portions of the lake should not be evaluated against a potable water use chlorophyll-a standard.

- Application to Other Reservoirs

The proposed approach to evaluate other reservoirs does not appear to provide a workable solution to address nutrient related impairments. If a reservoir has chlorophyll-a concentrations higher than 40 μg/L, it is considered impaired and would be managed to comply with the 40 μg/L upper level of the working threshold range. We have no way of knowing whether this is sufficient to achieve designated uses or if designated uses are already being achieved because the direct causes of use impairment have not been considered in setting the chlorophyll-a threshold.

If a reservoir has a chlorophyll-a concentration below 25 μg/L, it is assumed to be in attainment, but again, we have no way of knowing whether uses are being attained because the direct causes of use impairment have not been considered in setting the chlorophyll-a threshold. In fact, if the chlorophyll-a ranges presented at the June 2016 SAC meeting are reasonably accurate, there is a reasonable probability that uses are not being met at this level.

Within the range of 25 - 40 μg/L, a narrative assessment would be required to determine impairment status, using guidance to be developed. If algal-related impairments are observed, a site-specific criterion would need to be developed. Under this approach, site specific criteria will need to be developed over and over again as individual reservoirs are evaluated, including for lakes that were originally above 40 μg/L, as these would now fall into the narrative assessment range.

The site-specific assessments that need to be developed will likely require consideration of the primary factors identified in the Conceptual Model. If this consideration must be done to implement the proposal, it should be done now as a way to confirm that the proposed chlorophyll-a criteria are necessary by developing the relationships between chlorophyll-a concentration and the stressor causing use impairment.

Summary

The Balanced Use Approach needs to ensure that all uses are protected by the proposed chlorophyll-a criterion. To do this in a scientifically defensible manner, chlorophyll-a concentration must be linked to use impairment in a manner that can be validated. In this particular case, it appears that the risk is based on aesthetics affecting recreational uses. The primary factors influencing aesthetics need to be

identified (i.e., water clarity, scum formation) and impairment threshold values need to be identified. Then, the relationship between chlorophyll-a concentration and the primary stressors can be evaluated, accounting for confounding factors that influence these stressors in accordance with EPA's Stressor-response guidance.[2] Based on this relationship, a chlorophyll-a criterion can be proposed. Moreover, because the actual cause of impairment is defined (i.e., minimum water clarity, scum cover), the criterion is amenable to site-specific adjustment if the assumptions made in developing the chlorophyll-a criterion are not appropriate for a particular lake. A similar approach should also be used to develop criteria to protect the other uses of the lake.

A less rigorous alternative would be to propose a chlorophyll-a concentration without the detailed supporting information suggested above. In this case it is still important to identify the specific use being protected, the direct stressor of concern, and what factors were considered in proposing the criterion. Since this approach lacks the information necessary to assess the error around the proposed criterion, it must allow for site-specific adjustment where it can be demonstrated that the criterion is inappropriate for a specific situation.

[2] It is not necessary to determine every switch which can cause an algal group to start forming cyanotoxins, but you cannot ignore all of these factors because this will result in criteria with a very low coefficient of determination that is not suitable for criteria development.