Recommendations for High Rock Lake Criteria—Chlorophyll-*a*

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1.0   Overview of Proposed Chlorophyll-a Criterion

- Magnitude: 40 ug/L (High Rock Lake), derived from range of 25 – 40 ug/L for warmwater fishery reservoirs.
- Temporal averaging: Seasonal (April – October) geometric mean, based on samples from at least five months within the warm weather season.
- Spatial averaging: Aggregate surface samples from all stations within major reservoir segments (riverine, transitional, lacustrine).
- Frequency: Criterion to be attained as three-year rolling average.

2.0   Background

Over 2015-17, the discussions of the SAC have pointed to two different approaches for deriving chlorophyll-a (CHLa) criteria in High Rock Lake (HRL). In this document, these two approaches are described as the "maintain existing use support" approach and a "balanced uses" approach. Prior to discussing the proposed criterion elements in detail, it is useful to review these two fundamentally different approaches.

2.1   "Maintain Existing Use Support" Approach

One approach for deriving CHLa criteria would be predicated on the conclusion that the reservoir is meeting all designated uses, and would essentially seek to maintain CHLa concentrations at current levels or lower. The concept that HRL is currently meeting all designated uses would be supported by the following observations:

- HRL supports an excellent warmwater fishery and is a popular recreational resource for this reason. This shows that the existing CHLa concentrations are supportive of both fish and their food sources at lower trophic levels.

- The algae in HRL tends to be relatively dispersed in the water column rather than occurring in obvious nuisance forms (mats/scums). There is little record of user complaints regarding algal levels, and many existing users likely consider the existing condition to be an acceptable prevailing condition of a productive reservoir.

- Monitoring data collected to date indicates that algal toxin concentrations are relatively low.

- While cell counts show a dominance of cyanobacteria taxa during the summer, biovolume estimates show that green and other (more desirable) algae maintain a relatively high proportion of the algal biomass (equal to or exceeding biomass of cyanobacteria) during these months.

- Any effects of CHLa concentrations on public water supplies can be addressed through normal water treatment processes. There is no suggestion of major impacts on water treatment plants downstream of HRL.

For reference, the current CHLa levels in HRL are mostly in the 30-55 ug/L range, depending on location, expressed as a growing season geometric mean (see W.T. Hall slides from April 2016 SAC meting). Criteria derived using the "maintain existing use support" approach would prompt nutrient reductions to prevent increases in CHLa from future development, new/expanded discharges, and natural reservoir aging processes.

2.2   "Balanced Uses" Approach

The "balanced uses" approach would acknowledge that HRL supports an excellent fishery under existing CHLa concentrations, but would recommend more conservative (lower) CHLa criteria to potentially benefit other uses and provide a margin of safety against future impairment. Many of the designated use-CHLa relationships are gradational rather than step functions with sharp thresholds of impairment. The literature confirms that warmwater fisheries can be supported at HRL's current CHLa levels, but also indicates a common tension between CHLa levels that are necessary to support sport fisheries with lower levels that can be preferred for primary recreation use. Other potential benefits of lower CHLa values relate to algal toxins, diel variations in DO/pH, hypoxic volume, and drinking water treatment costs. Although none of these considerations would easily lead to specific CHLa criteria by themselves, a weight-of-evidence approach might indicate that the combined uses of HRL would be better supported by lower CHLa concentrations than the reservoir currently experiences. This evaluation would be undertaken with the backdrop that the current CHLa concentrations in HRL are higher than in most other Piedmont lakes/reservoirs in NC (Tetra Tech, 2015).

The primary argument for the "balanced uses" approach is that it is more environmentally conservative than simply maintaining existing condition and accounts for some uncertainty and natural variability. However, this approach still requires a large degree of professional judgment regarding what CHLa level—within a relatively large range—should be the recommended criterion. It is also based on a somewhat blurry definition of use attainment—related to subjective risk levels along a CHLa continuum—rather than the clear presence or absence of certain effects above and below specific CHLa thresholds.

3.0   Justification for Recommended Criterion

The proposed criterion was derived using the "balanced uses" approach, primarily due to the higher degree of conservatism, and with acknowledgement of uncertainties in CHLa-related effects. However, concepts from the "maintain existing use support" approach were applied to select the criterion magnitude along the potential range. The result is the recommendation of a seasonal average criterion of 40 ug/L for High Rock Lake, drawn from the working CHLa threshold range of 25-40 ug/L for warmwater fishery reservoirs. This section describes the technical basis for the criterion magnitude, duration (averaging period), and frequency components. Looking beyond HRL, section 4.0 describes an

approach by which the 25-40 ug/L CHLa range could be combined with narrative information to assess other warm water fishery reservoirs.

3.1   Averaging Period

The criterion is proposed as an average for the warm weather or growing season (April -October), for the following reasons:

- Use of a seasonal average would clarify the original intention of NC's existing CHLa criterion. To this point, the chair of the advisory group that recommended NC's existing criterion has provided original meeting notes, and summarizes by stating "It is clear in those documents that the technical basis, derivation, and intent of the 40/15 standards were based on 'growing season averages'…and not an any time/any place standard." (Mike McGhee, elec. comm., 10 May 2009).
- A temporally-averaged metric is appropriate for an indicator of reservoir trophic status and the general potential for various algal-related effects over different time scales. This is in contrast to toxics criteria, which are set based on specific effects over short durations.
- The use of seasonal average has many precedents in CHLa criteria from other states, and this a common manner to express CHLa criteria for lakes and reservoirs.
- Many of the potential use-CHLa linkages are better characterized using the central tendency of CHLa rather than "instantaneous" concentrations; for example, many of the literature citations of target CHLa values considered by the SAC are averages.
- Laboratory round-robin testing for CHLa conducted by DWR show significant variability in results between labs, which supports an averaging approach rather basing attainment on individual measurements.
- Water quality models used for management are better at predicting seasonal average CHLa values than short-duration CHLa values, which is the case for the HRL EFDC model.

The term "average" is ambiguous in that it could be interpreted as an arithmetic mean, geometric mean, or some other measure of central tendency. This proposal includes the recommendation of a geometric mean, because this statistic is the best measure of central tendency for log-normally distributed parameters such as CHLa, as stated by USEPA (2010). Examples of states that have adopted geometric mean CHLa criteria include Florida, Virginia, Arkansas, and Texas. The calculation of the geometric mean would require samples from at least five different months within a growing season, and preferably would utilize samples from all seven months.

3.2   Magnitude

After setting the duration component, the next step was to derive a range of CHLa concentrations that were deemed to be represent balanced uses attainment in HRL. In prior meetings, the SAC and DWR compiled tables of CHLa values associated with attainment of uses, in other water bodies (e.g., see slides from April 2016 SAC meeting). The value of 25 ug/L was selected as the bottom of the range, primarily due to concerns over impacts to HRL's warmwater fishery at lower values.

The value of 40 ug/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 ug/L value could be interpreted as a short-duration target in some systems, it is used herein as a longer-term geometric mean, partly drawing upon the concepts discussed under the "maintain existing use support" approach. That is, the algae in HRL tends 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 CHLa values higher than 40 ug/L (up to the mid-50s ug/L) under current conditions. Other favorable indicators in HRL—low algal toxin levels, excellent fishery, etc.—provide additional evidence that a value of 40 ug/L would be supportive of designated uses.

3.3   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 CHLa 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 CHLa targets might be practically unattainable. Virginia also uses a version of a 1-in-3 year approach for CHLa criteria in lakes and reservoirs (9VAC25-260-187), and Minnesota deems lakes and reservoirs to be in compliance if CHLa 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.

3.3   Spatial Averaging

For calculating the seasonal geometric mean CHLa, 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.

4.0 Generalized Application to Reservoirs

Although this criterion proposal is only for HRL, NC's nutrient criteria development plan (NC DWR, 2014) calls for the development of statewide, site-specific criteria for lakes and reservoirs. For this reason, it is helpful to consider the HRL pilot concepts could be extended to other lakes and reservoirs. Simple application of the HRL CHLa criterion to other all other warm water fisheries would not be recommended. Such an approach would not be consistent with the NCDP's call for site-specific criteria, and potentially not be protective of water bodies that experience impairments at different CHLa concentrations. Rather, the proposed statewide model is to combined a working CHLa threshold range of 25-40 ug/L with lake/reservoir-specific narrative information to assess each of NC's warmwater fishery reservoirs. This approach would balance the advantages of simple application of numeric CHLa thresholds with the need to consider water body-specific characteristics.

Under the proposed approach, reservoirs with chlorophyll-*a* below the 25-40 ug/L range would be considered in attainment (Figure 1). Reservoirs with CHLa concentration higher than the upper end of the range—such as HRL—would be considered in non-attainment and managed to bring CHLa down to the upper end of the range (40 ug/L). Reservoirs with CHLa within the 25-40 ug/L 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 CHLa criteria would be set at values within the 25-40 ug/L range, but lower than the CHLa values that coincided with the impairment conditions. For reservoirs without algal-related impairments, site-specific CHLa criteria would also be set at values within the 25-40 ug/L range, but higher than the prevailing CHLa values. The latter approach would be bolstered by State and federal antidegradation rules.
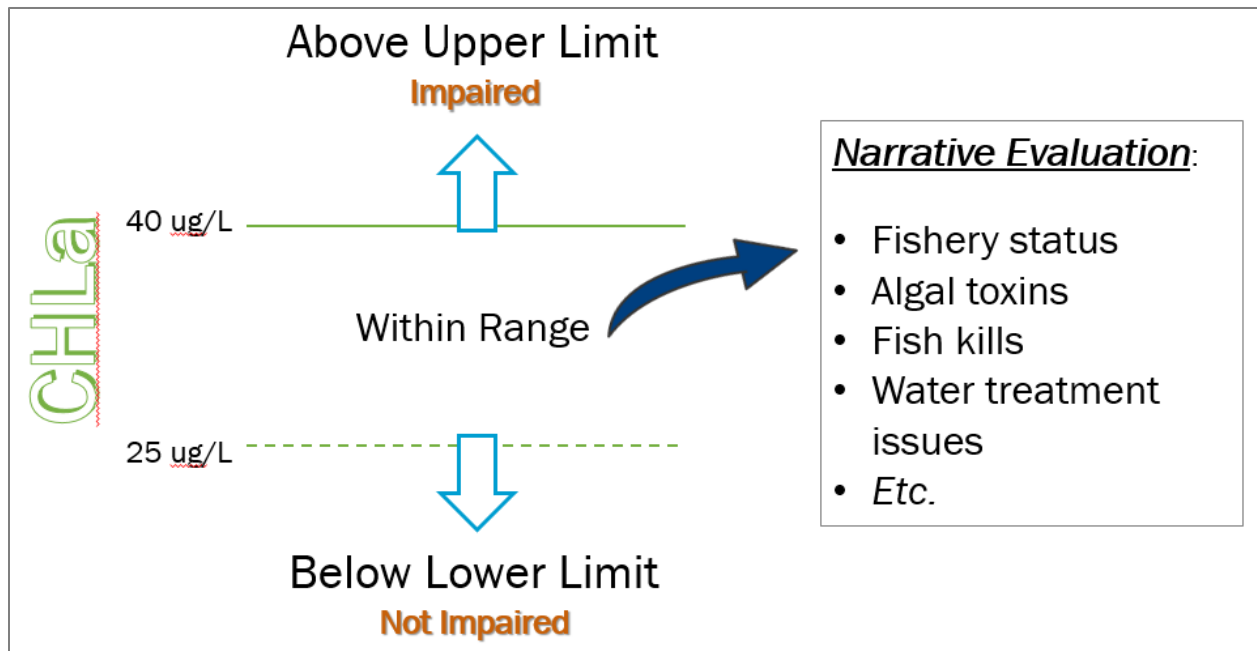
Figure 1 – Illustration of use of a CHLa threshold range in conjunction with narrative assessments.

References

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