RECOMMENDED NUTRIENT CRITERIA FOR WEST VIRGINIA LAKES AND RESERVOIRS

Submitted to:

Division of Water and Waste Management
West Virginia Department of Environmental Protection

Submitted by:

West Virginia Coal Association
West Virginia Manufacturers Association
West Virginia Chamber of Commerce
West Virginia Farm Bureau
West Virginia Forestry Association

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1.0 INTRODUCTION

This document is being provided pursuant to the discussions and conclusions reached during the April 7, 2006, teleconference of the Nutrient Criteria Committee (NCC). During that teleconference, it was determined that the members of the NCC would be unable to reach consensus on recommendations for nutrient criteria for West Virginia's lakes and reservoirs. It was agreed that members would submit "position papers" with recommendations for the criteria and their basis for those recommendations to the West Virginia Department of Environmental Protection (DEP).

While it is regrettable that the NCC was unable to reach a consensus, the members of the NCC should be commended for their time, hard work and sincere efforts to arrive at mutually agreeable recommended criteria. We hope that this document will provide information that the DEP will find useful in establishing criteria for lakes and reservoirs.

The West Virginia Coal Association is submitting this position paper on behalf of the NCC members representing the following organizations: the West Virginia Coal Association, the West Virginia Manufacturers Association, the West Virginia Chamber of Commerce, the West Virginia Farm Bureau, and the West Virginia Forestry Association.

In addition, the West Virginia Municipal Water Quality Association supports the position paper methodology and criteria recommendations.

2.0 BACKGROUND INFORMATION ON NCC DECISIONS

The NCC's updated "Nutrient Criteria Development Plan for West Virginia," dated January 12, 2006, contains the following information on West Virginia's approach for developing nutrient criteria:

> "Depending on the availability of data of sufficient quality and quantity, and funds for research and model development, the state will consider the following methods, in the following order of preference:
>
> - Empirical and/or cause and effect analyses based on West Virginia data.
> - Empirical and/or cause and effect analyses based on other data.
> - Alternatives to the first two approaches are to define when and under what circumstances reference-based or other methods might be appropriate."

Early in its process, the NCC agreed not to use the United States Environmental Protection Agency's (USEPA) reference-based method for setting nutrient criteria. This was because the

USEPA's eco-regional data set is not representative of the conditions found in West Virginia. Use of the method would define an unacceptable percentage of West Virginia's lakes as "impaired," whether or not they really are impaired, resulting in the unnecessary expenditure of limited resources to address such "impairments." In fact, we believe the adoption and subsequent attainment of the USEPA criteria would actually prevent the attainment of designated uses of West Virginia's lakes, particularly with regard to fishing.

3.0 REVIEW OF STATISTICAL CAUSE AND EFFECT APPROACH

The NCC put considerable effort into attempting to establish criteria based on a cause and effect approach using statistical analysis of both West Virginia data alone, and combined data from West Virginia and that portion of Virginia's data from the shared Nutrient Ecoregion XI. The results of these efforts were set forth in various draft documents provided for discussion by the NCC.

Several simple regressions were performed using the data sets from the Clean Lakes Program (CLP), the US Army Corps of Engineers (USACE) and NCC's 2004 (NCC04) sample collection. Criteria parameter concentrations were then selected based on the regression line's intercept with a target variable concentration. The following is a table summarizing some of the results from the statistical analyses (simple regression) performed.

Regression Performed	Parameter & Concentration (ug/l)	p value	r^2 value	Data set
Minimum DO versus Average TP (DO target – 6 mg/l)	TP = 33	0.05	0.1526	WV
TP versus Chlorophyll *a* [Chl-a] (TP target – 33 ug/l)	Chl-a = 7.1	<0.0001	0.1608	WV
Minimum DO versus Average TP (DO target – 6 mg/l)	TP = 44	0.006	0.1766	WV/VA
TP versus Chl-a (TP target 44 ug/l)	Chl-a = 8.7	<0.0001	0.1917	WV/VA

In some cases, the analysis of the data showed statistically significant correlations between parameters. However, in no case was both a statistically significant correlation (p value <0.05) and a strong coefficient of determination (r^2) observed.[1] An r^2 value of 0.1526 indicates that approximately 15 percent of the variability observed in the data can be explained by the relationship between the two variables. **The remaining 85% of variability comes from unknown causes.** If only a small percentage of the variability in the data can be explained by the relationship between the two parameters, the relationship is not strong enough to use as a predictor for a specific value (i.e. nutrient criteria concentration). Since the coefficient of determination is necessary to interpret the strength and magnitude of the observed correlations, weak r^2 values cannot be ignored.

There are likely several reasons for the lack of predictive relationships here:

[1] In our previous paper, we stated that the only value generated from this analysis that had statistical significance was the 145 ug/l value for total phosphorus, based on VA data. By this statement, we meant that none of the other values had both statistically significant correlations and strong coefficients of determination.

- When following EPA's suggested protocol (as was done for the regressions for DO and TP) each lake is considered a single data point, which greatly reduces the volume of data available and their resulting value as a predictor.
- Dissolved oxygen was used as the response variable to select total phosphorus and it is not an appropriate response variable by which to measure nutrient impacts. While nutrients do impact dissolved oxygen concentrations, other variables including temperature and sample time have even greater effects that were not accounted for in the regression analysis.
- The total phosphorus data contain many values less than the method detection level, which skews the data set.
- The data are too variable and there is not enough information available to remove outliers reliably.

The West Virginia Coal Association conducted some additional statistical analysis in the form of multiple regressions. The purpose of this analysis was to develop more predictive models of the relationship between nutrients and response parameters by including additional available data and variables.

Two different multiple regressions were performed using the CLP and NCC04 data sets (the USACE data set was not used as it required significant reformatting before it could be used and this work was done in a short time frame). Criteria parameter concentrations were not selected due to the weak r^2 values that were observed. The results of this analysis were provided to the group for discussion and are summarized in the table below.

Multiple Regression Performed	**p value**	**r^2 value**
TP, Temperature, and Total Suspended Solids versus Chl-a		
Overall model	<0.0001	0.2972
TP	<0.0001	0.1588
Temperature	<0.0001	0.1218
Total Suspended Solids	0.9536	<0.0000
TP, Temperature, Total Suspended Solids versus DO		
Overall model	0.1135	0.0352
TP	0.0240	0.0302
Temperature	0.4115	0.0039
Total Suspended Solids	0.3460	0.0052

As with the single regression analysis, this analysis shows statistically significant correlations (p value <0.05) between some of the parameters, particularly in the regression using chlorophyll *a* (chl-a) as the response variable. However, all of the causal parameters taken together only explain 29.7 percent of the variability observed in the data, indicating 70 % of the observed variability comes from unknown causes. Further, the model that uses DO as the response variable does not show statistically significant correlations, except in the case of TP. However, only 3 percent of the observed variability can be explained by TP, indicating **97% of the observed variability comes from unknown causes**.

Based on a review of the various statistical analyses conducted to date, and the quantity and the quality of the available data, it is not appropriate to select nutrient criteria using these methods.

4.0 REVIEW OF TROPHIC STATE INDEX APPROACH

Because West Virginia's preferred method of setting criteria using cause and effect analyses based on statistical analysis of the available data is not appropriate, a possible alternative method that was reviewed was the use of Trophic State Index. This method has historically been used by the DEP to determine nutrient impairments. However, all of West Virginia's lakes are constructed impoundments, and the following excerpt from Virginia Academic Advisory Committee's January 2005 report (VAAC 2005a), explains why the TSI is inappropriate for use man-made impoundments:

> "The Trophic State Index (TSI) indicator was developed for application in natural lakes (Carlson 1977). The TSI is a good tool for communicating trophic state condition to the public because it is an index. Total phosphorus, chlorophyll-a, and Secchi depth are all on a common, understandable scale. The problem with using the TSI to express nutrient criteria is the lack of spatial and temporal homogeneity among trophic state parameters in a reservoir. Suspended sediments delivered to impoundments lead to levels of non-algal turbidity that interfere with algal production, especially in the upper channel, and thus distort the assumed correspondence between the TSI components. As documented in Appendix B for Smith Mountain and Claytor Lakes, sediment-related non-algal turbidity varies spatially within reservoirs. Suspended sediment delivery from the watershed to impoundments varies temporally in response to weather conditions and seasonal cycles, as suggested by the seasonality analysis in Section I-A, Preliminary Analyses. The extent to which reservoirs vary in dissolved components that affect water clarity (such as tannins) is not known.
>
> Virginia's impoundments are highly variable in morphometric characteristics, watershed area, retention time, and other factors that can be expected to influence both their capability to sustain designated uses at various levels of nutrient enrichment and potential correspondence between TSI measures. Given that Virginia impoundments are being treated collectively for the purpose of nutrient criteria development, the AAC recommends that nutrient criteria be implemented by monitoring nutrient variables directly and not through use of TSI, which would add yet another source of variability to criteria implementation."

West Virginia's impoundments share these characteristics and it would therefore be inappropriate to use TSI values to set nutrient criteria.

5.0 LITERATURE REVIEW APPROACH

Based on the existing data, a cause and effect analyses cannot be used to develop nutrient criteria for lakes and reservoirs. In addition, as discussed above, use of either the TSI or USEPA's reference methods for establishing nutrient criteria would be inappropriate for West Virginia. Given that, West Virginia's nutrient criteria for lakes and reservoirs are best developed based on a review of the applicable scientific literature.

To narrow the literature to be considered, one must first define the resource that is being protected. West Virginia has no natural lakes; all of the state's lakes are constructed impoundments. These impoundments were constructed for a variety of purposes, including flood control, navigation, hydroelectric power generation, water storage, recreation and game fish production. Many of these impoundments are intensely managed for fisheries and are also used for other recreation, including the release of water from some of these structures as part of West Virginia's white water rafting industry.

Constructed impoundments do not behave like natural lakes. They tend to have characteristics of both rivers and lakes, with three distinctive zones: (1) riverine – flowing riverlike conditions; (2) transitional – transition to lake conditions; and (3) lacustrine – non-flowing lakelike conditions near the dam. Impoundments differ from natural lakes in the form or shape of the basin and watershed, age, turbidity, and loading and management. While natural lakes may move through a range of trophic states, beginning as oligotrophic and moving towards eutrophic over the course of thousands of years, an impoundment's natural lifespan may be only 50 to 100 years. The reason an impoundment was created and the purposes for which it is operated and managed will dictate the resultant water quality (USEPA 2000).

As many of West Virginia's impoundments are managed for fishing and recreation, it is appropriate to select criteria that will protect these uses.

With regard to the fitness of fisheries, the general conclusion in the literature is that higher nutrient concentrations typically result in more productive fisheries. The optimal nutrient concentrations vary in accordance with the type of fishery. According to VAAC (2005a), warmwater Centrarchid species (sunfish, crappie, bass) in Minnesota, Alabama and Florida thrive in lakes and reservoirs with nutrient concentrations ranging from 60 to 100 ug/l of TP and 20 to 60 ug/l chl-a. In Virginia impoundments rated as high quality fisheries, the nutrient concentration ranges were 40 to 50 ug/l median TP, 10 to 30 ug/l median chl-a, and 35 to 60 ug/l chl-a at the 90^{th} percentile. A TP concentration below 40 ug/l was reported as counterproductive to fisheries (VAAC 2005a, 2005b).

The VAAC also reported that walleye (coolwater species) in Minnesota and Lake Erie were reported to do well in lakes with TP concentrations of 15 to 25 ug/l and chl-a concentrations ranging from 5 to 15 ug/l. Striped bass (coolwater species) in Lake Mead, Nevada became stunted and emaciated when TP levels dropped below 10 ug/l. High quality coolwater fisheries in Virginia were reported to have nutrient concentrations ranging from 20 to 30 ug/l median TP, 10 to 15 ug/l median chl-a, and 21 to 25 ug/l chl-a at the 90^{th} percentile (VAAC 2005a, 2005b).

The VAAC's final recommendations considered both the values in the literature and specific data on nutrient concentrations in individual lakes with high quality fisheries. The recommended criteria for warmwater fisheries were a median TP concentration of 40 ug/l and a 90^{th} percentile chl-a concentration of 35 to 60 ug/l. The recommended criteria for coolwater fisheries were a

median TP concentration of 20 ug/l and a 90th percentile chl-a concentration of 25 ug/l (VAAC 2005a, 2005b).

There is substantially less information in the available literature on contact recreational uses. Other than user surveys, which are very subjective, there is little available information in the literature as to what constitutes a "clean" lake with regard to nutrient-associated effects on contact recreation, i.e. swimming. In any given survey, user responses vary in their ratings of lakes depending on a variety of factors including water depth, color, clarity, temperatures, and the presence of associated facilities. Some users do not find greenish water (indicative of algal growth) objective in a lake, while others do. Further, it is difficult to correlate user ratings accurately with associated nutrient-related parameters. While it is expected that the DEP will take the protection of contact recreation into account when setting nutrient criteria, it is important to note that the relationship between nutrient criteria and contact recreation is aesthetic only. West Virginia has other water quality criteria in place to protect public safety and concerns regarding public perception may be best left to the discretion of the lake managers.

6.0 RECOMMENDED CRITERIA

6.1 Definition of Lakes Subject to Nutrient Criteria

In establishing nutrient criteria, the first step needs to be a definition of lakes that will be subject to those criteria. The USEPA (2005) recommends that states establish a regulatory size threshold that specifies what should be considered a lake from the management perspective. "The goal is to eliminate small water bodies that, because of their size (and resulting hydrology) or uses (small agricultural impoundments), do not accurately represent typical lake conditions or do not exhibit expected responses to stressors."

The USEPA (2000) defines lakes as "natural and artificial impoundments with a surface area greater than 10 acres and a mean water residence time of 14 or more days." . We believe this definition is appropriate for use in West Virginia.

In addition, certain lakes in West Virginia "do not accurately represent typical lake conditions." Mount Storm is a constructed impoundment created for industrial use. Further, Beech Fork Lake is a man-made impoundment that must be mechanically aerated to behave like a lake. Neither of these water bodies should be included in the definition of lakes subject to nutrient criteria.

Finally, the West Virginia Division of Natural Resources (DNR) and USACE should be consulted to determine if they manage lakes by fertilization or other methods that would cause them to be removed from the definition. Appendix A contains a list of West Virginia's known impoundments, with information assembled by the NCC. This list includes many impoundments that should not meet the definition of "lake" and is provided for informational purposes only.

6.2 Fisheries Classifications

As previously stated, West Virginia's impoundments are largely managed as recreational fisheries. According to a survey completed for the NCC by DNR fisheries biologists, West Virginia's impoundments are mostly warmwater fisheries, with several larger impoundments also capable of supporting coolwater species such as walleye and yellow perch. It is generally believed that these impoundments are capable of supporting coolwater species due to the presence of deep water areas that remain cooler throughout the year. Given the dichotomy in nutrient levels that are optimal to support a thriving warmwater or coolwater fishery, most members of the NCC agreed that it would be useful to consider the development of separate coolwater and warmwater criteria for lakes based on their fisheries classification.[2]

We believe that the DEP should consult with the DNR and USACE to determine which impoundments are or will be managed as coolwater fisheries. These decisions need to be made thoughtfully, with consideration given to the balance of nutrients necessary to protect the habitat of coolwater species, while supporting sufficient primary production for the co-habiting warmwater species. As noted in the literature TP concentrations of less than 40 ug/l are counterproductive to warmwater fisheries. The fisheries status of each lake should be listed in the rule, with a justification for the classification.

The DNR survey lists only one coldwater fishery (trout species). It is uncertain if that impoundment is actually Rockcliff Lake on Trout Pond Run or Trout Pond Impoundment, which is a spring-fed impoundment that is too small to meet the proposed lake definition. Based upon our knowledge of West Virginia impoundments, as well as input from the DNR (as communicated by the DEP during NCC conference calls), we do not believe that West Virginia has other impoundments that qualify as coldwater fisheries. West Virginia's impoundments do not maintain year-round temperatures capable of supporting coldwater species. Even if the lakes were managed with very low levels of nutrients, it is unlikely that summer temperature and oxygen regimes would support salmonid survival, growth and reproduction. Additionally, the low level of nutrients that may be considered optimal for coldwater fisheries would impair the growth and survival of both coolwater and warmwater species.

The current version of the West Virginia's Requirements Governing Water Quality Standards (47 CSR 2) lists several impoundments on the Category B-2 list of Trout Waters. Due to the release of cold water from the bottom of the dam, the tailwaters of some of these impoundments are put-and-take fisheries that are stocked by the DNR, and this may be the reason these impoundments appear on the list. Additionally, some of the impoundments themselves may be stocked put-and-take trout fisheries. However, it is not believed, and likely not documented, that any of these impoundments can support year-round trout populations. This error in the

[2] In our previous paper, we suggested that this classification be developed based on temperature regime. Further review and discussion has convinced us that West Virginia's impoundments are probably predominantly warmwater with regard to temperature regime, but have deep, cool areas that can support coolwater species when appropriately managed.

regulation needs to be corrected so that it is clear that there are no impoundments managed as coldwater fisheries or limited as such with regard to nutrient criteria.

6.3 Criteria concentrations for TP and Chl-a

As set forth above, development of West Virginia's nutrient criteria based upon the available literature seems to be the most appropriate method of those examined by the NCC. We believe that criteria should be selected that, according to the available literature, will support healthy fisheries populations.

Of the lakes described in the literature, the artificial impoundments in Virginia seem to be most like the artificial impoundments in West Virginia. Accordingly, selecting criteria based upon those ranges would be appropriate. As West Virginia currently lacks the data necessary to confirm the selection of an optimal number as was done in Virginia, we recommend the adoption of criteria at the upper end of the referenced ranges. This should allow for the protection of West Virginia's lakes, without unnecessarily taxing the limited resources available to perform detailed pre-TMDL assessments on healthy lakes that might be improperly listed as impaired. Based upon the information reviewed, we recommend the values in the following table.

Fishery classification	Chronic Category B Criteria		Chronic Category C Criteria	
	Average TP (ug/l)	90th Percentile Chl-a (ug/l)	Average TP (ug/l)	90th Percentile Chl-a (ug./l)
Coolwater	30	25	30	25
Warmwater	50	35-60[3]	50	35-60

While we believe that the recommended criteria for chl-a are optimally based on the 90th percentile of values, we understand that it may be impractical for the DEP to routinely obtain a sufficient number of samples to calculate this value. The available literature also contains supportable average chl-a values.

Appendix B contains a list of impoundments for which there are available data and their associated estimated pollutant concentrations. The supporting data analysis is shown in Appendix C. We do not believe that these data are of sufficient quality to make impairment decisions and they are being provided for informational purposes only. It should also be noted that, for illustration purposes only, an impoundment listed by DNR fisheries biologists as supporting coolwater species is listed in Appendix B as a coolwater fishery.

[3] In our previous paper, we suggested chl-a criteria of 20 –40 ug/l. Those values were based on median concentrations from VAAC's literature review (2005a). A review of the VAAC's addendum (2005b) suggests the use of 90th percentile values for chl-a and provides a correspondingly higher concentration range. We believe that this method is appropriate.

6.4 Acute Criteria

The effects of nutrient enrichment are not acute in nature. Therefore, only chronic criteria are recommended.

6.5 Secchi Depth and Nitrogen

Secchi depth is not recommended as an appropriate criterion for West Virginia's impoundments. As previously stated, constructed impoundments tend to receive sediment loading from their watersheds that prohibit Secchi depth readings from accurately representing algal growth.

Nitrogen is not recommended as an appropriate criterion for West Virginia impoundments. Primary production (algal growth) in lakes can be limited by nitrogen but would be primarily affected by phosphorus. While some subtropical and high altitude/latitude lakes are limited by nitrogen (USEPA 2000), West Virginia's impoundments would not be expected to fall into those categories.

6.6 Criteria Implementation

Criteria should be listed for each lake individually, rather than by definition or classification. This method will allow special circumstances to be taken into account as appropriate, for individual impoundments.

The unique nature of nutrients and their impacts require implementation that differs from most other water quality criteria. As nutrient impacts are observed in the warmer, lower flow months, criteria should only apply seasonally. The NCC had preliminarily discussed an April to October monitoring period.

TP should be expressed as an average value and chl-a should be expressed as 90^{th} percentile value. We recognize, however, that the DEP may find use of a 90^{th} percentile value problematic, in which case we suggest that the DEP review available literature values based upon averages.

For criteria expressed as averages and 90^{th} percentile values, it is necessary to establish a minimum number of samples to be obtained. We believe that a minimum number of four samples would be appropriate.

Additionally, as the hypolimnion is the area that is targeted for protection, it should be specified that these samples are obtained in the hypolimnion (< 1 meter depth) of the lacustrine zone (non-flowing, lakelike areas near the dam) of the impoundment.

It should also be specified that samples taken from multiple locations on an impoundment in one day should be averaged into a single result.

The rule should clearly state that chlorophyll *a* criteria will not be used for permitting purposes, and instead will only be used for assessment purposes.

With regard to these various issues, the VDEQ's draft regulations read:

> "Whether or not algicide treatments are used, the chlorophyll *a* criteria apply to all waters on the list… The 90^{th} percentile of the chlorophyll *a* data collected at one meter or less within the lacustrine portion of the man-made lake or reservoir between April 1 and October 31 in any given year shall not exceed the

chlorophyll *a* criterion for that water body for two consecutive assessments. The median of the total phosphorus data collected at one meter or less within the lacustrine portion of a man-made lake or reservoir between April 1 and October 31 in any given year shall not exceed the total phosphorus criterion for that water body for two consecutive assessments for a water body that received algicide treatments."

7.0 CONCLUSIONS

We appreciate the opportunity to participate in the NCC process and to provide information to the DEP to assist in its development of nutrient criteria for lakes and reservoirs. After significant technical review, and based upon the information currently available, have recommended technically supported criteria for the DEP's consideration. The literature reviewed would support even higher total phosphorus numbers in certain circumstances, and we would encourage the DEP to consider assignment of such criteria on a lake-specific basis in the future. To the extent the DEP plans to adopt a single total phosphorus value for lakes and reservoirs, however, or specific values for lakes managed as warm water fisheries and cool water fisheries, we have recommended numbers that are in our view both protective and technically supported by the relevant literature.

We also urge the DEP to fully consider the many issues addressed herein in addition to numeric values, such as a definition of lakes, the number and location of samples, and listing of lakes, as it prepares to propose nutrient criteria for West Virginia's lakes and reservoirs. All of these issues are important to the successful development and implementation of nutrient criteria.

8.0 LITERATURE CITED

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VAAC. 2005a. January 2005 Report of the Academic Advisory Committee to the Virginia Department of Environmental Quality: Freshwater Nutrient Criteria. January 2005.

VAAC. 2005b. Report of the Academic Advisory Committee to the Virginia Department of Environmental Quality: Freshwater Nutrient Criteria, Addendum to January 2005 Report. May 2005.