Outline of Methodology to Establish Scientifically Defensible Nutrient Water Quality Standards.

Impetus for Nutrient Criteria

The USEPA mandates the adoption of nutrient criteria into state water quality standards by 2004. The deadline may be extended if states prepare a plan for development of nutrient criteria and demonstrate significant progress toward setting nutrient standards consistent with the plan. However, USEPA may promulgate standards if a State fails to develop and adopt criteria according to the State's plan. The push for nutrient criteria adoption is driven by state water quality inventories repeatedly citing nutrients as a major cause of ambient water quality use impairments. EPA's section 305(b) reports consistently identify excessive nutrients as one of the top three leading causes of impairments of the nation's waters (along with siltation and pathogens). Under section 303(d), states identify waters that are not attaining water quality standards and submit a list of those impaired waters to EPA. These lists also consistently identify excessive nutrients as a leading cause of impairments. These 303(d) lists also frequently cite impairments such as reduced dissolved oxygen, growth of noxious plants, and increased turbidity (or decreased water clarity) that are related to nutrients. Section 303(c) of the Clean Water Act requires states and authorized tribes to adopt criteria as necessary to protect designated uses where those uses may be adversely affected by the presence of a pollutant.

According to Geoff Grubb's memo (4 December 2001), USEPA's preference is that States adopt nutrient standards by 2004. However, since the process for developing standards may differ significantly between states, some may not have to adopt standards by 2004 as long as evaluations of progress show that standards development is well underway and the State's efforts are consistent with its plan for developing and adopting nutrient criteria. If USEPA feels a State's plan is not appropriate or if a State has not adopted standards by 2004, the USEPA Administrator may exercise her authority under section 303(c)(4)(B) of the Clean Water Act and find that promulgation of nutrient criteria for the State is necessary to meet the requirements of the Clean Water Act.

Should the USEPA promulgate standards, the criteria promulgated will be based on EPA's published recommendations derived using a reference site approach. For level III ecoregions 55 and 57 (ECBP and HELP) the target values for TP are 0.0625 mg/l and 0.0700 mg/l, respectively, and would be applied to all streams regardless of drainage area or designated aquatic life use. In contrast, target values identified by analyses of Ohio EPA's ECOS databases suggest that a tiered approach based on stream size and designated aquatic life use will be equally protective while offering less stringent criteria in most circumstances. For example, the TP targets identified by Ohio EPA for a WWH designated headwater stream in the ECBP is 0.07 mg/l, approximately the same as the level III target, but that for a small river is 0.17 mg/l, an order of magnitude difference.

States developing their own standards will have the advantage of added flexibility in how standards are applied toward making 303d listing decisions, such that a measured nutrient concentration exceeding the numeric target would not necessarily demonstrate impairment. For this to occur, in the words of Geoff Grubbs, "States should quantify response variables to know what it is they're trying to attain." Those response variables can be a combination of factors including chlorophyll a, turbidity, and, in the case of Ohio, biological criteria. The trick is to scientifically demonstrate the relationship between the causal elements and the response variables. Because the ECOS databases lack information on chlorophyll *a*, a cause-and-effect relationship between nutrients and biological criteria can only be inferred (though rather compellingly - see Miltner and Rankin 1998).

A direct positive relationship between nutrient concentration and periphytic biomass, as measured by chlorophyll *a*, has been abundantly demonstrated for temperate, boreal and arctic streams (Biggs 2000, Scrimgeour and Chambers 2000, Van Nieuwenhuyse and Jones 1996, Deegan and Peterson 1992, Lohman et al. 1992, Bothwell 1989). However, few studies have examined the effects of that relationship on higher trophic levels or indirect effects on water quality. Ohio EPA has demonstrated secondary effects of excessive algal abundance on diel dissolved oxygen concentrations and higher trophic levels by measuring dissolved oxygen hourly with synoptically collected biological samples. Again, however, chlorophyll *a* was not concurrently measured. Closing this gap would give a definitive, scientifically defensible basis for developing nutrient water quality standards using response variables as indicators of impairment.

Study Design for Support of Nutrient Criteria for Rivers and Streams

The data quality objective of the study is to establish a link between average seasonal nutrient concentration, algal biomass as measured by chlorophyll *a*, and the health of higher trophic levels as measured by IBI and ICI . This study also will consider the variation in nutrient effects explained by flow and habitat (solar irradiance being one aspect of habitat). The outcome of the study will be a data set that has the following variables: IBI scores and attendant information, ICI scores and attendant information, QHEI scores and attendant information, including riparian width, as a measure of habitat quality, hourly dissolved oxygen concentrations, routine water quality parameters (dissolved oxygen, pH, conductivity, temperature, arsenic, cadmium, chromium, copper, iron, lead, nickel, zinc, chemical oxygen demand, alkalinity, chloride, nitrate-nitrite nitrogen, total Kjeldahl nitrogen (TKN), ammonia nitrogen, oil and grease, low-level detection of total phosphorus, dissolved phosphorus, total non-filtrable residue, and total filtrable residue), measures of chlorophyll *a* from the water column and periphyton, seasonal flow or rainfall, and a qualitative measure of the percent of daylight hours where direct sunlight can reach the wetted channel. This latter measure will be accomplished using a densitometer-transect as an estimate of canopy cover. In larger streams with an obvious canopy gap, a clinometer reading from the center of the stream to the top of the canopy on both banks, and a compass reading of channel direction will also be taken. The only two aforementioned parameters not routinely collected in present biological and water quality studies are chlorophyll *a* and irradiance. See Table 1 for a matrix of existing parameters and parameters to be collected during the proposed study. Also, see http://www.epa.state.oh.us/dsw/document_index/docindx.html for a detailed description of existing data. Total inorganic nitrogen (TIN) will be expressed as the sum of nitrate, nitrite and ammonia nitrogen.

Temporal variation will be measured, but the temporal scope will be determined by resources. At a minimum, two years information will be collected at a subset of sampling locations to address inter-annual variation. Intra-seasonal variation can be minimized by collecting chlorophyll *a* samples no sooner than two weeks following any significant rainfall or high flow event (Biggs 2000, Lohman et al. 1992). Spatial variation within a stream reach can be minimized by collecting periphyton from cobble-sized substrates in riffles (Cattaneo et al. 1997).

Methodology for collecting periphyton samples and determining chlorophyll *a* concentration is discussed in detail in Hambrook (2001), Scrimgeour and Chambers (2000), Cattaneo (1997), Lohman et al. (1992) and Parsons et al. (1984), to name a few. All follow the same general methodology as described here briefly: scrape a known area of periphyton from several rocks (five rocks for this study) within a representative reach of stream, typically a riffle, filter the sample on glass fiber filters in the field (filters can then be frozen on dry ice for no more than 30 days), and extract the chlorophyll *a* using a known quantity (10-15 ml) of either 95 percent ethanol or 90 percent acetone. The amount of chlorophyll *a* in a sample will be determined using EPA Method 445 (USEPA 1997b). Initial calibration of the fluorometer will be against a know standard.

Sampling sites will be chosen to reflect a range of stream sizes, habitat quality and anthropogenic enrichment, and should optimally, but not necessarily, be located on streams with USGS gauging stations. The number of sites used to characterize periphytic biomass within a region varies greatly in the literature, ranging from 33 sites in a watershed of over 20,000 mi^2 (Scrimgeour and Chambers 2000) - the Scioto River at Portsmouth is 6,500 mi^2 for comparison - to 22 sites to characterize streams within a 500 mi^2 area (Lohman et al. 1992). Samples will be collected 2 times during the summer season as that is when stream flows in Ohio are lowest and temperatures highest, hence any secondary effects from excessive algal abundance (*e.g.*, wide D.O. swings) are likely to be most pronounced.

Table 1. Matrix of causal and response variables for nutrient criteria for rivers and streams.

Waterbody Type	Available Data	Data Set Information	Causal variables			Response variables				
			NOx, NH_3, TKN	TP	Habitat*	Turbidity (as TSS for existing data)	Hourly D.O.	Chl_a	Fish	Macro-invert-ebrates
Rivers and Streams	Existing data: the number of sites where all parameters were collected is indicated for each.	State-wide for streams and rivers, period of coverage 1981-1998. Data from 1999 - 2001 yet to be linked in the database.	1,788	1,788	1,788	1,788	<100	0	1,788	1,448
	Planned data collection: two field seasons, the total number of sites and samples per site for each parameter is indicated; see Table 2 for a breakdown of sampling sites by stream size.	See Table 2 for breakdown of sampling protocol for chl_a	61 sites, 6 samples per site	61 sites, 6 samples per site	61 sites, 1 sample per site	61 sites, 6 samples per site	33 sites (head-waters and wadeable - see Table 2), 1 sample per site	See Table 2	61 sites, 1 sample per site	61 sites, 1 sample per site
Lakes and Reservoirs	Ohio EPA to adopt the Ambient Water Quality Criteria Recommendations for Lakes and Reservoirs applicable to Ohio's ecoregions.									

* Habitat includes physical stream habitat, riparian width and quality, solar irradiance, and flow regime.

Table 2. Proposed number of periphyton or water column samples for chlorophyll *a* analysis.

	Sites*			Yearly Chla samples for analysis
	Total	Year 1	Year 2	
Headwaters	20(10)	15	15	15 x 3 replicates x 2 months† + 5 splits† = 95
Wadeable	24(12)	18	18	15 x 3 replicates x 2 months† + 5 splits† = 95
Small and Large Rivers	20(10)	15	15	15 x 3 replicates x 2 months† + 5 splits† + 15 water column x 2 months + 5 splits = 130
	77(45)	61	61	Total by year = 320
*Number of sites sampled in both years are listed in parentheses. † Number is pending DES input for their QA/QC requirements				

Quality Assurance

The level of precision and accuracy of the fluorometric method used to estimate chlorophyll *a* concentrations will follow methods outlined in USEPA (1997); however, the requirement of an initial calibration to an extraction that has been spectrophotometrically quantified will be done against a calibration standard. Phytoplankton grab samples and periphyton composites will be split to determine the precision and reproducibility of sample handling and the analytical method (*i.e.*, the same chlorophyll *a* concentration should exist in a split sample). Replicate periphyton samples (n = 3) from a particular location will estimate the mean chlorophyll *a* concentration and a confidence interval or standard error of the mean. Spatial variation within stratification levels will be examined to determine if additional levels of stratification are needed. Possible additional stratification levels include ecoregion, stream gradient, and a measure of the central tendancy of substrate size from the Wolman pebble count. The relationship between chlorophyll *a* concentration and nutrient concentration, as modified by habitat quality, will be tested using linear statistical models.

Fall-back

If the proposed study is not carried out, the fall-back approach will be to adopt USEPA's recommended criteria based on ecoregional reference ranges.

Nutrient Criteria Development

The proposed study will be piloted in 2003 with full field seasons planned in 2004 and 2005. Data will be analyzed during the winter following each field year, including the pilot season, and revisions to the plan will be made, if necessary, based on the variation in the data and the level of resolution suggested by the results. If warranted, more levels of stratification, increased number of samples and refinement of sampling techniques will be added to the plan. Four levels of stratification by stream size are currently proposed. Pending results, ecoregions may be added as a stratification level. The geographic scope of nutrient criteria will depend on stratification levels. Currently, statewide criteria stratified by stream size are planned. If ecoregions explain a significant proportion of variation in the data, criteria will be additionally stratified by ecoregion.

Progress reports and amendments to the initial plan indicated by the results, including results of pilot work, will be sent to Region V. A study timetable with milestones and outcomes is shown in Table 3.

Nutrient Criteria - Rules Package

The objective of the study is to establish a link between average seasonal nutrient concentration (either TP, TN, or both), algal biomass as measured by chlorophyll *a*, habitat quality, and the health of higher trophic levels as measured by IBI and ICI scores. Application of the ensuing results into a water quality rule package will take the form of a hierarchical decision tree as conceptualized in Figure 1. Entry into the decision tree occurs at two points, one assumes the status of aquatic life use attainment is known through biological monitoring, the other assumes some data for causal and response variables are available. Entry at either point can result in a waterbody being listed as impaired by nutrients if certain conditions are met; however, the later entry point carries a high error rate for falsely concluding that a waterbody is impaired when it is not. The more variation that can be explained between causal and response variables, the lower this error rate will be. Entry at either point carries a low chance of error in the opposite direction, that is, of falsely concluding that a waterbody is neither impaired nor threatened when it is. Individual criterion for causal or response variables, stratified by stream size, will form the conditional statement for determining whether the aquatic life use of a waterbody is either impaired or threatened, and will be selected pending the outcome of the study. Because existing data for Ohio indicates that TP is more strongly associated with biological quality than is total inorganic nitrogen, criteria development will be focused on TP as a causal variable, with habitat quality as a continuous covariable. Data will be collected for nitrogen and criteria developed as the results warrant. Potential downstream effects of nutrient enrichment caused by nitrogen will also be assessed through biological and water quality surveys, and subsequent determinations of causes and sources of impairment. Because Ohio uses numeric biological criteria to judge attainment/non-attainment of aquatic life uses, every waterbody that is genuinely impaired due to nutrient enrichment from nitrogen will be identified, listed, and have TMDL developed for nitrogen as a pollutant. Criteria for response variables will be developed for dissolved oxygen variation and sestonic and periphytic chlorophyll *a* for headwaters and wadeable streams, and dissolved oxygen variation and either periphytic or sestonic chlorophyll *a* or both for larger rivers. The utility of turbidity to serve as a surrogate for algal biomass will be examined and criteria developed accordingly. Criteria for biological response variables already exist in Ohio water quality standards.

Ohio EPA plans to adopt USEPA's ecoregional recommendations for all lakes and reservoirs. A rule package will be developed in 2005.

Table 3. A timetable with milestones and anticipated outcomes of the proposed study and nutrient criteria development process.

Activity	Milestone or Outcome				
	2003	2004	2005	2006	2007
Pilot methods	Establish validity of methods to achieve objectives.				
Full field study		Populate database with chlorophyll_a, TP, TN, Habitat, et al. information	Augment database	*Augment database if needed*	*Augment database if needed*
Data analysis and action based on results	Determine reproducibility of split samples: validate analytical methods. Examine variation between samples: refine sampling technique and/or increase sample size for 2003	Initial results used to amend plan for 2004 as necessary (i.e., stratification levels)	Initial results used to amend plan for 2005 if needed	Analyze all data collected to date; determine if results support rule making decisions	
Reporting	Report result of pilot to Region V	Progress report to Region V	Progress report to Region V	Prepare technical report, submit for publication	
Rule Making		Initiate rule-making process for Lakes and Reservoirs based on USEPA recommended nutrient criteria.	Submit rule-making process for Lakes and Reservoirs based on USEPA recommended nutrient criteria.	Initiate rule-making process for Rivers and Streams based on study results.	Submit rule-making package for Rivers and Streams.

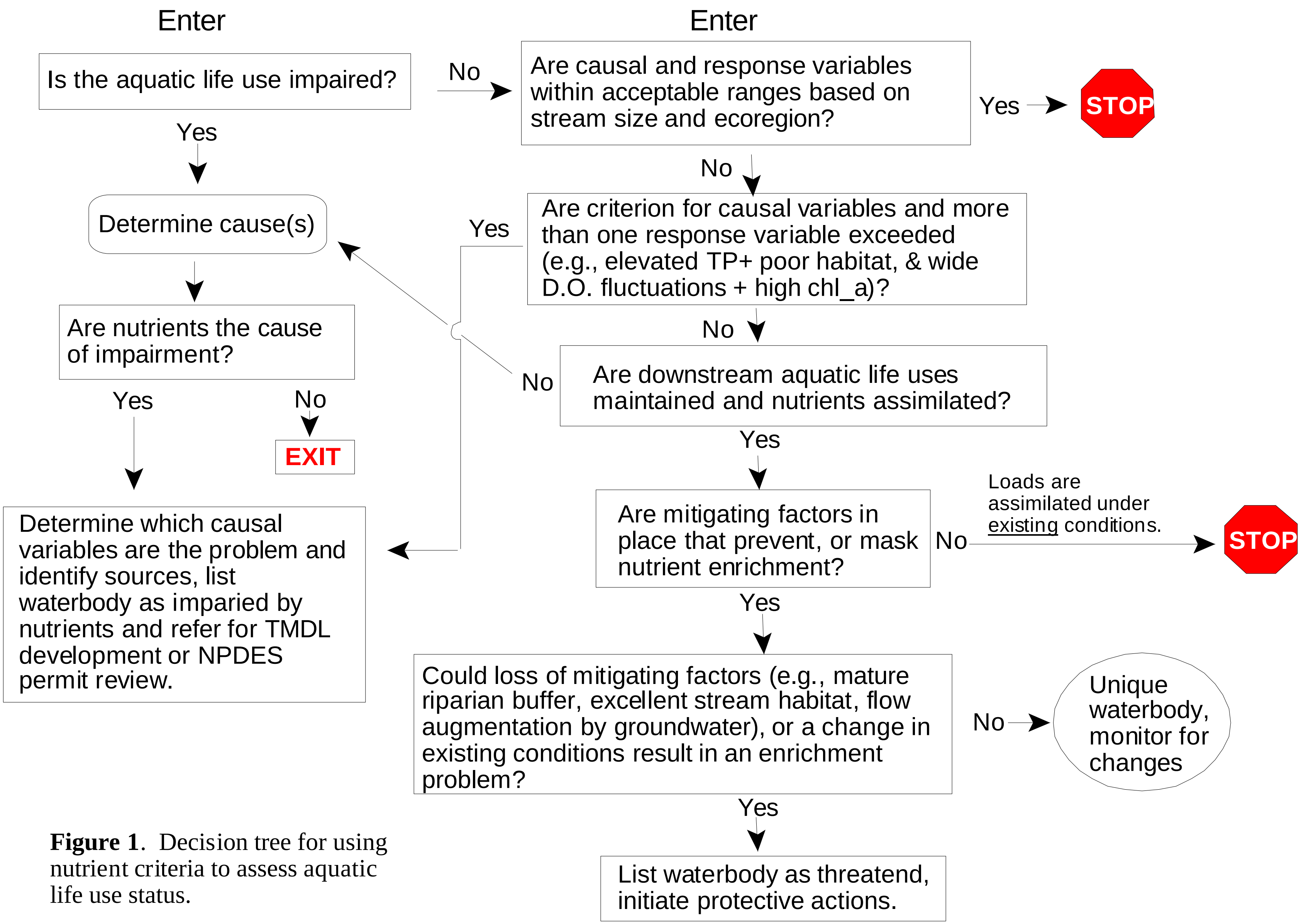

Figure 1. Decision tree for using nutrient criteria to assess aquatic life use status.

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Appendix 1

TMDL Guidelines for Choosing Nutrient Targets for the Restoration of Aquatic Life Uses

<table>
<tr><td rowspan="2">Water Quality Standard Guidance
4
Final</td><td colspan="2">Legal and Technical Basis for
Nutrient Target Values Used in TMDL Projects</td></tr>
<tr><td>Statutory references: ORC Sections 6111.03, 6111.041
Rule references: OAC rules 3745-1-04 (E), 3745-1-07(A)(6), 3745-1-07 Table 7-10, 3745-2-12</td><td>Ohio EPA, Division of Surface Water
Revision 0, November 27, 2000</td></tr>
<tr><td colspan="3">This internal guidance does not affect the requirements found in the referenced rules or statutes.</td></tr>
</table>

Note: The user of this guidance should be familiar with the Ohio EPA technical report *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA 1999). Familiarity with this technical report is important when selecting nutrient targets.

Background

The establishment of instream numeric targets is a significant component of the total maximum daily load (TMDL) process. The numeric targets serve as measures of comparison between observed instream conditions and conditions that are expected to restore the designated uses of the water body. The TMDL identifies the load reductions and other actions that are necessary to meet the target, thus resulting in the attainment of applicable water quality standards. Numeric targets are derived directly or indirectly from narrative or numeric water quality standards contained in Chapter 3745-1 of the Ohio Administrative Code (OAC).

This guidance summarizes Ohio EPA's authority for regulating the discharge of nutrients and developing TMDL implementation plans for nutrients, focusing on nitrogen and phosphorus in river/stream environments. This guidance was written at this time to address the immediate need to regulate discharges of nutrients through the TMDL program.

U.S. EPA has identified state adoption of numeric water quality standards for nutrients as a priority and is in the process of developing recommendations. The recommendations under development address phosphorus, nitrogen, chlorophyll a and turbidity in rivers/streams, lakes/reservoirs, estuarine/coastal and wetlands. Adoption of specific numeric water quality standards for nutrients in Ohio rules is probably two to four years away. In the meantime, the existing water quality standards provisions can be used to regulate the discharge of nutrients. The existing rule requirements for nutrients are general in nature and, therefore, must be applied on a case-by-case basis.

The following sections summarize the existing Ohio rule provisions that should be considered when developing TMDLs for nutrients and offer guidance on the selection of nutrient targets in TMDLs.

Ohio Administrative Code (OAC) Rule Requirements

Paragraph (A) of OAC 3745-2-12 requires that TMDLs be established and implemented through TMDL implementation plans that address attainment of applicable water quality standards. Water quality standards are contained in OAC Chapter 3745-1. The water quality standards for nutrients can be grouped into two categories: 1) prevention of nuisance conditions; and 2) prevention of biological community impairment. These categories are explained below.

<u>Prevention of Nuisance Conditions</u>

OAC 3745-1-04 prohibits, where practical and possible as determined by the director, discharges of nutrients in concentrations that create nuisance growths of aquatic weeds and algae. The term nuisance growth is not defined in Chapter 3745-1. Growths of aquatic weeds and algae are commonly considered nuisances when they interfere with the use of a water body. Nuisance growths that interfere with the use of a water body are those that directly inhibit recreational uses like fishing or swimming, or produce a noxious odor or taste in drinking water. The concentrations of nutrients that result in nuisance growths of aquatic weeds and algae vary from water body to water body due to physical and hydrological factors including the flow volume, the amount of direct sunlight reaching the water body, the quality of the physical stream habitat, and the mode of nutrient delivery to the water body.

Table 7-10 of rule 3745-1-07 specifically limits phosphorus "to the extent necessary to prevent nuisance growths of algae, weeds, and slimes that result in a violation of the water quality criteria set forth in paragraph (E) of rule 3745-1-04 of the Administrative Code or, for public water supplies, that result in taste or odor problems. In areas where such nuisance growths exist, phosphorus discharges from point sources determined significant by the director shall not exceed a daily average of one milligram per liter as total P, or such stricter requirements as may be imposed by the director in accordance with the international joint commission (United States-Canada agreement)." The limit for phosphorus currently established by the International Joint Commission for municipal waste treatment facilities discharging more than one million gallons per day within the Lake Erie drainage basin is 0.5 mg/l (IJC 1987, Annex 3).

Prevention of Biological Community Impairment

Nutrients can interfere with an aquatic life use by lowering the quality of the biological communities through the process commonly known as eutrophication. Determination of current use attainment is based on a comparison of biological scores to the appropriate numeric biological criteria in OAC 3745-1-07. Likewise, the success of any implementation actions resulting from the TMDLs will be evaluated by observed improvements in biological scores. OAC 3745-1-07(A)(6) states that the biological criteria in Table 7-14 of rule 3745-1-07 are used to determine attainment of the warmwater habitat, exceptional warmwater habitat and modified warmwater habitat aquatic life uses. When the biological criteria are not met in a water body, the Agency has the responsibility to identify the causes of nonattainment and implement regulatory approaches to allow the water body to come into attainment.

Selection of Nutrient Targets

Nutrient targets used in the TMDL process are determined on a case-by-case basis. The TMDL project team should consider stream survey results and other available information to determine if nuisance conditions and aquatic life use impairment exist. Options available include the following:

Option 1

The nuisance provisions of rule 3745-1-04 and Table 7-10 of rule 3745-1-07 can be applied alone or in combination with the other provisions of rule 3745-1-07 described under Option 2.

Phosphorus

For situations in which a nuisance condition has been identified (which in Table 7-10 means a nuisance growth of algae, weeds and slimes or, for public water supplies, taste or odor problems), phosphorus limits for dischargers determined to be significant must not exceed a daily average of 1.0 mg/l. For significant dischargers in the Lake Erie drainage basin, phosphorus limits of 0.5 mg/l may be imposed. Table 7-10 and rule 3745-1-04 allow the imposition of more restrictive phosphorus limits on a case-by-case basis if determined to be necessary to prevent nuisance conditions.

Nitrogen
There are no numerical nitrogen criteria in OAC 3745-1 that address the prevention of nuisance conditions. Rule 3745-1-04 limits nitrogen to the extent necessary to prevent nuisance growths of aquatic weeds and algae. Nitrogen limits necessary to prevent nuisance conditions must be determined on a case-by-case basis.

OAC 3745-1 contains several numerical water quality criteria for nitrogen based on toxicity effects. They are summarized in Table 1. These criteria, however, may not be restrictive enough to prevent nuisance conditions.

Table 1. Numeric water quality criteria for nitrogen in OAC 3745-1

Water Body	Chemical	Criterion	OAC 3745-1 Citation
Aquatic life habitats	Ammonia-nitrogen	varies with temp. and pH	Tables 7-2 to 7-8
Public water supplies	Nitrate-nitrogen	10 mg/l	Table 7-9
Agricultural water supplies	Nitrates + nitrites	100 mg/l	Table 7-11
Ohio River	Nitrate-N + nitrite-N	10 mg/l	Table 32-1
Ohio River	Nitrite-nitrogen	1.0 mg/l	Table 32-1
Ohio River	Ammonia-nitrogen	varies with temp. and pH	Table 32-2

Option 2
The use of specially developed nutrient targets may be appropriate under the biological criteria provisions in OAC 3745-1-07 in the following situation, taken from OAC 3745-1-07(A)(6)(b):

> "Where the designated use is attainable and the cause of the nonattainment has been established, the director shall, wherever necessary and appropriate, implement regulatory controls or make other recommendations regarding water resource management to restore the designated use. Additional regulatory controls shall not be imposed on point sources that are meeting all applicable chemical-specific and whole-effluent criteria unless:
>
> (i) The point sources are shown to be the primary contributing cause of the nonattainment;
>
> (ii) The application of additional or alternate treatment or technology can reasonably be expected to lead to attainment of the designated use; and
>
> (iii) The director has given due consideration to the factors specified in division (J) of section 6111.03 of the Revised Code."

Division (J) of section 6111.03 of the Revised Code requires that, when establishing water quality based permit limits, the director "shall give consideration to, and base the determination on, evidence relating to the technical feasibility and economic reasonableness of removing the polluting properties from those wastes and to evidence relating to conditions calculated to result from that action and their relation to benefits to the people of the state and to accomplishment of the purposes of this chapter."

Intermediate nutrient targets are available to complement the biological criteria and to help evaluate the impact of nutrient loadings. These target concentrations are identified in a technical report (Ohio EPA 1999). The values in the technical report represent "no affect or no impact" based concentrations that have been associated with measured biological criteria and aquatic life use attainment. In most situations, higher concentrations can reasonably be expected to carry an increasing risk of impaired biological communities and failure to attain the respective aquatic life use. However, the values in the technical report are only suggested guidelines, and a variety of factors must be considered in selecting a specific nutrient target used in the TMDL process. These factors include:

Some waters attain aquatic life criteria at higher concentrations - this fact is evident in the technical report (Ohio EPA 1999) and requires that a variety of physical and hydrological factors be evaluated on a case-by-case basis prior to setting a target level.

Location of project with respect to ecoregion - consult the technical report (Ohio EPA 1999) and assess if higher of lower targets may be appropriate.

Stream habitat conditions - unusually low or high physical habitat quality will influence nutrient impacts on aquatic life; adjust the targets accordingly.

Stream flow conditions - impairment of the aquatic life use caused by nutrients is exacerbated on wastewater effluent dominated streams (high percentage of wastewater during low flow periods).

Because the values in the technical report are initial target concentrations only and are not codified in regulations, there is a certain degree of flexibility as to how they can be used in a TMDL setting. A TMDL must be flexible in its consideration of load reduction, habitat improvements, the degree of wastewater effluent flow predominance, and other features that determine attainment of biological criteria. As provided in paragraph (E) of rule at 3745-2-12, TMDL nutrient targets may allow for a phased reduction towards the selected target in recognition of such factors as habitat restoration efforts, technical feasibility, treatment costs, and the possibility of achieving aquatic life use attainment at concentrations in excess of the target value.

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