Narrative Nutrient Standard Implementation Procedures for Lakes and Reservoirs

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Arizona Department of Environmental Quality

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Acknowledgements

This implementation procedures document was written by Susan Fitch, Lakes Program Coordinator within the Surface Water Monitoring and Standards Unit, Hydrologic Support & Assessment Section, Water Quality Division, at the Arizona Department of Environmental Quality. The document is based on a two-year contract with Malcolm Pirnie to develop a lake classification system and associated narrative nutrient endpoints. This work partially satisfies the EPA requirement for state development of nutrient criteria. Thanks to all internal and external reviewers for their assistance in organizing and presenting the material, particularly, Clifton Bell, P.E., Dr. David Walker, Diana Marsh, Melanie Diroll, Steve Pawlowski, Sam Rector, Jennifer Hickman, Jason Sutter, and Linda Taunt.

1.0 EXECUTIVE SUMMARY

This document sets forth implementation procedures as applied to lakes and reservoirs for the narrative nutrient water quality standard found in Arizona Administrative Code (A.A.C.) R18-11-108(A)(6) and associated implementation procedures rule at A.A.C. R18-11-108.03. This document explains how ADEQ developed the implementation procedures for the narrative nutrient standard as applied to lakes and reservoirs and how ADEQ will determine compliance with the narrative nutrient standard in an objective way.

The narrative nutrient standard at R18-11-108(A)(6) states:

> *"A surface water shall not contain pollutants in amounts or combination that…cause the growth of algae or aquatic plants that inhibit or prohibit the habitation, growth, or propagation of other aquatic life or that impair recreational uses…"*

This standard is often condensed into: "no excess algal and plant growth." The growth of algae or plants depends on the presence of light and nutrients, primarily nitrogen, phosphorus, and carbon, though trace elements are also necessary. "Excess growth" of algae or plants naturally implies the presence of "excess nutrients," given sufficient light and the availability of trace elements. However, in practice, plant and algal growth, respiration, and decay are continual processes. This means that nutrient uptake, assimilation, and transformation are also in a continual state of flux and difficult to measure. The tradition in limnology, the study of lakes, has been to use the measure of chlorophyll-*a* as a surrogate measure of plant or algal biomass. Chlorophyll-*a* is the primary pigment in plants and algae and is required for photosynthesis, the production of plant sugars necessary for growth and reproduction. Thus, the narrative nutrient standard refers to a complex ecological process and must consider differences in space and time.

As a result of the national mandate for states to develop nutrient criteria, ADEQ submitted a Nutrient Criteria Development Plan to EPA in 2002. The plan focused on the development of nutrient criteria for lakes and reservoirs as a first priority. In keeping with national guidance, ADEQ suggested the development of a matrix of lake endpoints that, taken together in a weight-of-evidence approach, would provide the basis for interpretation of the narrative nutrient standard. In conjunction with this proposal, ADEQ proposed to establish lake and reservoir categories or classes, such that individual water bodies would be evaluated within a context of watershed attributes, land uses, climatology, morphology, and management practices. A two-year study was undertaken to first derive lake classes and second the associated matrix of water quality endpoints for interpretation of the narrative nutrient standard. This document is based on the results of this study and lays out the expectations by lake class for compliance with the narrative nutrient standard as applied to a lake or reservoir system. This document will be used for both water quality assessment and compliance purposes.

ADEQ has created five functional lake classes: deep, shallow, igneous-based, sedimentary-based, and urban. For each class and each applicable designated use, ADEQ developed a matrix of threshold values expressed as ranges for chlorophyll-*a*, Secchi depth, total nitrogen, total Kjeldahl nitrogen (TKN), total phosphorus, percent blue-green algae, and total count of blue-green algae. Lake classes were derived using statistical analysis of lake and watershed characteristics from 70 lakes and reservoirs in Arizona. A subset of 50 lakes and reservoirs was used to derive threshold ranges, evaluated through the lens of scientific literature review and policies adopted by other states. Dissolved oxygen (DO) and pH standards have been added as relevant and supportive endpoints.

A lake or reservoir is attaining the narrative nutrient standard if the mean of *all* parameters fall below respective threshold ranges in Table 1 (except for Secchi depth, in which case, the result must all be above the threshold range).

ADEQ will determine compliance with the narrative nutrient standard in lakes by one of the following four ways:

1. The mean chlorophyll-*a* result is at or above the upper value in the target range for chlorophyll-*a* for the lake category prescribed in Table ES-1.

2. The mean chlorophyll-*a* result is within the target range for chlorophyll-*a* for the lake category prescribed in Table 1, and the mean blue-green algae result is at or above 20,000 per milliliter or the mean blue-green algae count is 50 percent or more of the total algae count.

3. The mean chlorophyll-*a* result is within the prescribed range for the lake category and there is other evidence of nutrient-related impairments. ADEQ will consider the following factors when applying this weight-of-evidence approach:
   a. Exceedances of dissolved oxygen or pH standards;
   b. Fish kills or other aquatic organism mortality attributed to exceedances of dissolved oxygen or pH, or to ammonia or algal toxicity;
   c. Secchi depth is below the lower threshold value for the lake category;
   d. The concentration of total phosphorus, total nitrogen, or TKN exceed the upper value in the range prescribed for the lake category in Table 1.

4. The lake is a shallow lake with a mean depth of less than 4 meters and submerged aquatic vegetation covers more than 50% of the aerial extent of the lake bottom and there is a greater than 5 milligram per liter swing in diel (24-hr) dissolved oxygen concentration measured within the photic zone.

Table ES-1. Matrix for Implementation of the Narrative Nutrient Standard in Lakes and Reservoirs

<table>
<tr><td colspan="11"></td></tr>
<tr><th>Designated Use</th><th>Lake Category</th><th>Chl-a (µg/L)</th><th>Secchi Depth (m)</th><th>Blue-Green Algae (per mL)</th><th>Blue-Green Algae (% of total count)</th><th>Tot. Phos. (mg/L)</th><th>Tot. Nit. (mg/L)</th><th>TKN (mg/L)</th><th>Dissolved Oxygen (mg/L)</th><th>pH (SU)</th></tr>
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</table>

NOTES: Threshold ranges apply during "peak season" for lake productivity.
Peak season for cold water lakes is May – September
Peak season for warm water lakes is April – October.
"NA" means not applicable

2.0. INTRODUCTION:

EPA published the *National Nutrient Strategy* in 1998, with the stated intent of compiling technical information on nutrients and working with states and tribes to adopt nutrient criteria as part of their water quality standards. The major focus of this strategy was the development of water body- and region-specific technical guidance for nutrient criteria. EPA published the *Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs* in 2000, followed by regional summaries of lake and reservoir data in 2000 and 2001. Each of these documents corresponded to an aggregate Level III *ecoregion* that share broadly similar geographic and ecological characteristics. The EPA-recommended nutrient criteria were derived from calculating either the 75^{th} percentile of available data from reference water bodies in an ecoregion, or the 25^{th} percentile of data from all water bodies in an ecoregion.

Many Arizona "lakes" are man-made impoundments, with the exception of a few shallow ephemeral systems. Most of the impoundments were constructed originally for irrigation purposes, but many are now popular recreational resources. Until recently, the Arizona Department of Environmental Quality (ADEQ) applied one set of water quality standards to both perennial streams and lakes. EPA's national nutrient criteria recommendations did not include the broad diversity of Arizona lakes and reservoirs. In addition, Arizona only contains two Level III ecoregions: the Western Forested Mountains and the Xeric West, two broad divisions that do not capture the inherent variability of Arizona lakes and reservoirs.

ADEQ's approach for deriving nutrient targets relies on the best scientific knowledge available while also considering the distinctive characteristics of Arizona's lakes. The first step was to perform a thorough review of the scientific and lake / reservoir management literature, with a focus on identifying nutrient-related targets associated with specific designated uses. The observed water quality of Arizona's lakes and reservoirs was characterized, leading to the classification of Arizona's lakes into management categories based on similar characteristics. The development of an Arizona-specific trophic state index has allowed ADEQ to set appropriate nutrient concentration targets for attainment of different chlorophyll-*a* targets.

In reviewing lake data collected since 1990, it became increasingly clear that Arizona lake systems not only behaved significantly different from streams, but also differed from one another. Shallow lakes naturally tend toward heavy growth of macrophytes (submerged or emergent vegetation) and display a typical set of water quality problems that can be mitigated but not entirely remedied. Urban impoundments, for which setting plays a huge role, require attention to political boundaries and often aggressive and cooperative management practices. Large reservoirs with huge watersheds do not behave like small high-elevation lakes nestled in undeveloped forest land. Arizona has interpreted the need for refined nutrient criteria in a broader context than numeric criteria alone. The narrative nutrient implementation matrix is an example of a "translator approach,"which is supported by EPA in the *Guidance for Development of Nutrient Criteria for Lakes and Reservoirs, 2000*. ADEQ has developed five lake classes with associated endpoints for interpretation of the narrative nutrient standard. These classifications more accurately reflect the diversity of geography and lake setting, as well as specific levels of designated use protection.

3.0 NARRATIVE NUTRIENT STANDARD [A.A.C. R18-11-108 (A)(6)]

3.1 Purpose of the Narrative Nutrient Standard Applied to Lakes & Reservoirs

Arizona's narrative nutrient standard states: "A surface water shall be free from pollutants in amounts or combination that…cause the growth of algae or aquatic plants that inhibit or prohibit the habitation, growth, or propagation of other aquatic life or that impair recreational uses." This standard is often condensed into: "no excess algal and plant growth." The growth of algae or plants depends on the presence of light and nutrients, primarily nitrogen, phosphorus, and carbon, though trace elements are also necessary. "Excess growth" of algae or plants naturally implies the presence of "excess nutrients," given sufficient light and availability of trace elements. However, in practice, plant and algal growth, respiration, and decay are continual processes. This means that nutrient uptake, assimilation, and transformation are also in a continual state of flux. For this reason, grab samples for nutrients alone are not good indicators of the level of productivity. The tradition in limnology (the study of lakes) has been to use the measure of chlorophyll-*a* as a surrogate measure of plant or algal biomass. Chlorophyll-*a* is the primary pigment in plants and algae and is required for photosynthesis, the production of plant sugars necessary for growth and reproduction. Thus, the narrative nutrient standard refers to a complex ecological process with many compartments and factors influencing differences in space and time. In lakes, the best indirect way to measure "excess" is to sample chlorophyll-*a* in plankton-dominated systems, and percent plant cover in very shallow systems.

3.2 Adverse Effects of Excess Algae and Aquatic Plant Growth

The adverse effects of excess nutrients, translated into excess algae and plant growth in lakes, include several aspects cited in the narrative standards, A.A.C. R18-11-108, as well as some that are not cited:

- Objectionable odor
- Off-taste or odor in drinking water
- Off-flavor in aquatic organisms
- Changes in water color (noxious blooms of algae)
- Accelerated production of bottom deposits
- Low dissolved oxygen (DO)
- Radical swings in DO on a daily basis
- Very low or very high pH
- Fish mortality due to low DO, ammonia toxicity, or algal toxins
- Mortality of invertebrates from algal toxins
- Imbalances in the energy structure (trophic levels)
- Lack of biotic diversity
- Habitat changes
- Sub-lethal stress to organisms
- Visual impairment (swimming; boating)

- Mechanical interference (clogging boat motors; paint-fouling; expensive filtration)
- Production of hydrogen sulfide

This list is not exhaustive, but it does illustrate the point that assessment and remediation of excess plant and algal growth may require consideration of multiple variables.

3.3 Applicability of Narrative Nutrient Standard

These implementation procedures for the narrative nutrients standard apply only to lakes and reservoirs because the existing research to develop the procedures is based on lake and reservoir data.

4.0 DEVELOPMENT of the IMPLEMENTATION PROCEDURES

4.1 Lake Classification

From 2002 to 2004, ADEQ worked with a contractor to develop a statistically robust method of categorizing Arizona lakes into classes, based on similar attributes and functionality. Data were compiled from a cross-section of approximately 75 impoundments in Arizona. These data reflect monitoring efforts by several state and federal entities and span a twenty year period. Data were screened to meet quality objectives and placed in an Access database. A Geographic Information System was constructed to include spatial data on watershed and lake attributes. The databases were linked to allow relational queries and the application of various statistical tests. Statistical analyses included descriptive methods such as box and whisker plots, the multivariate method, Principle Components Analysis (PCA), and the multiple regression method, Classification and Regressions Tree (CART). A complete review of the tests applied can be found in the *Data Summary and Statistical Modeling Report* produced by Malcolm Pirnie (2004). The resulting classes are listed in Table 4-1. Each lake or reservoir in Arizona will be assigned a primary classification. In practice, some lakes may exhibit secondary class attributes that may also be considered in narrative nutrient evaluation.

Table 4-1. Arizona Lake and Reservoir Classes

Lake/Reservoir Class	Primary characteristic	Class Description
Deep	Avg. lake depth	Lakes w/mean depth > 18 m
Shallow	Avg. lake depth	Lakes w/mean depth < 4 m
Igneous	Dominant geology/soils	Lakes in volcanic/granitic lithology
Sedimentary	Dominant geology/soils	Lakes in alluvial, sedimentary and metamorphic lithology
Urban	Land use/setting/source water	Lakes in urban landscape

4.2 Development of Arizona's Trophic State Index (TSI)

The approach for deriving a TSI in Arizona was similar to that of Brezonik (1984) in that the sub-index for chlorophyll-*a* was based on the criteria that (1) doubling chlorophyll-*a* would increase the sub-index by 10 units; and (2) a sub-index value of 50 corresponds to a chlorophyll-*a* value of 10 µg/L. The resulting sub-index is: $TSI_{CHLA} = 16.8 + 14.4 \ln(chla)$. Least-squares linear regression analysis was used to develop separate sub-indices for Secchi depth, total phosphorus, total nitrogen, and TKN based on their correlation with chlorophyll-*a*. All data used in the regressions were expressed as the natural logarithms of growing season mean values for individual water bodies. Resulting sub-indices were as follows: $TSI_{SD} = 63.0 - 38.1 \ln(SD)$; $TSI_{TP} = 127.1 + 29.5 \ln(TP)$; $TSI_{TKN} = 51.4 + 39.1 \ln(TKN)$

The Arizona TSI (Table 4-2*)* will be used to track lake productivity. For lakes with sufficient data, both sub-index and primary index TSI values will be calculated for each assessment period. The index for TKN will be used based on the fact that TKN was shown to be statistically more significant than total nitrogen in relation to chlorophyll-*a* in Arizona lakes and reservoirs. The TSI scores will be used to track changes in nutrient-related conditions and set management endpoints.

Table 4-2. Arizona's Trophic State Index (TSI)*

Trophic State	TSI	Chlor-*a* (*u*g/L)	Secchi (m)	Total-P mg/L)	TKN (mg/L)
Oligotrophy	**0**	0.3	5.2	0.013	0.3
	10	0.6	4.0	0.019	0.3
	20	1.2	3.1	0.027	0.4
Mesotrophy	**30**	2.5	2.4	0.037	0.6
	40	5.0	1.8	0.052	0.7
Eutrophy	**50**	10	1.4	0.074	1.0
	60	20	1.1	0.103	1.2
	70	40	0.8	0.145	1.6
Hypereutrophy	**80**	81	0.6	0.203	2.1
	90	161	0.5	0.285	2.7
	100	323	0.4	0.400	3.5

* Derivation of TSI scoring and associated water quality values can be found in the document entitled *Potential Nutrient-Related Targets for Lakes and Reservoirs in Arizona* (Malcolm Pirnie, 2005). The literature cites the following *descriptive* thresholds, the first three relate to nutrient limitation:

Oligotrophic: clear lakes w/low productivity
Mesotrophic: moderately productive lakes
Eutrophic: productive ("greener") lakes
Hypereutrophic: highly productive; light limited
Dystrophic: distinguished by suspended solids or humic acids causing color; light limited

4.3 Narrative Nutrient Implementation Matrix for Lakes & Reservoirs

Of the 75 lakes used to establish lake classes, data from a subset of fifty lakes collected within at least three peak seasons was used to develop the Arizona Trophic State Index (TSI) and to inform a matrix of numeric thresholds for interpretation of the narrative nutrient standard. The water quality endpoints in the matrix have been derived in association with lake classes and designated uses. These numeric targets, both causative variables (numeric nutrient thresholds) and response variables (chlorophyll-a, Secchi depth, and blue-green algae thresholds) were established using the following types of information:

- Arizona's existing numeric nutrient water quality criteria
- Numeric ranges from watershed and in-lake loading models/methods
- EPA proposed ecoregional numeric nutrient criteria
- Trophic state indices developed for Arizona lakes and reservoirs
- Numeric targets derived from the scientific and lake management literature
- Effects-based targets adopted by other states

The complete explanation of method development can be found in *Potential Nutrient-Related Targets for Lakes and Reservoirs in Arizona*, Malcolm Pirnie, 2005. Within the matrix, thresholds are expressed as ranges to account for spatial / temporal heterogeneity in the data and statistical uncertainty. As such, the threshold range represents data values below which there is *no* narrative nutrient problem. Data that fall within a range *may* indicate a problem, whereas, data above the upper value of the range *will* be interpreted as indicative of a narrative nutrient problem. The matrix will be incorporated into Arizona Surface Water Standards rules at A.A.C. R18-11-108.03.

4.4 Applicability of Matrix

The matrix of numeric thresholds found in Table 4-3 is intended for use in assessing lakes and reservoirs as a translator for the narrative nutrient standard. Table 4-3 includes chlorophyll-*a*, blue-green algae, and Secchi depth as response variables. Nutrient thresholds are included in the matrix as those ranges found to be statistically associated with the primary response variables, chlorophyll-*a* and blue-green algae. Blue-green algae, or Cyanophytes (similar to bacteria), are the type of algae most often associated with taste and odor problems, scums, and toxicity. An abundance of blue-green algae correlates with the probability that one or more of these issues may be present. Ammonia production is another parameter reflected in plant and algal growth. Ammonia toxicity has a separate standard which is pH and temperature-dependent (A.A.C. R18-11-Appendix A). Although ammonia is not included in the matrix, where data are available, ammonia results will be considered as part of the weight-of-evidence in evaluation of narrative nutrient compliance. The DO and pH standards have been appended to the matrix because they are both ecologically relevant and more straightforward to display.

The narrative nutrient standard matrix will be applied to lakes listed in Appendix B of the Surface Water Quality Standards (A.A.C. R18-11) using a "weight of evidence" approach to interpretation. "Weight of evidence" in this context refers to the application of matrix thresholds taken together as a set of parameters that inform "excess plant and algae growth" (A.A.C. R18-11-108). In application of the matrix, chlorophyll-*a* will carry the greatest weight. The measure of chlorophyll-*a* indicates the relative biomass in a lake or reservoir as well as nutrient availability. Blue-green algae thresholds will carry the second-highest weight in matrix application. Secchi depth may be influenced by non-algal turbidity, therefore, Secchi depth thresholds must be applied with evaluation of turbidity and suspended sediment data, as well as chlorophyll-*a*.

Arizona recognizes the following designated uses to which the narrative nutrient implementation matrix applies in lakes and reservoirs:

- Domestic Water Source (DWS)
- Aquatic & Wildlife cold water (A&Wc)
- Aquatic and Wildlife warm water (A&Ww)
- Aquatic and Wildlife effluent dependent water(A&Wedw)
- Full Body Contact (FBC)

Because the DWS use relates to surface waters that may be treated for human consumption, this use carries the most restrictive water quality thresholds. The next most stringent use is recreation, synonymous with the FBC designated use. The A&W use is associated with fisheries. Matrix A&W thresholds are less restrictive than those for DWS or FBC, reflecting the fact that *relatively* higher nutrients and productivity are favored to promote a healthy fishery.

The lake classification study introduced a new sub-category of aquatic life protection, the "urban" lake category, in which thresholds have been set to reflect a level of protection particular to a "put and take fishery" in an urban setting with a variety of source water from groundwater to reclaimed water. Urban lakes may or may not carry the FBC beneficial use, though typically they do not. Lakes with reclaimed water carry only the partial body contact (PBC) designated use.

EDW lakes and ephemeral lakes must be identified as such in Appendix B; they will be evaluated using the matrix but may ultimately require development of either site-specific or refined seasonal narrative nutrient criteria. The matrix will not apply to ephemeral lakes with an average depth of less than one meter. Note that matrix thresholds apply during "peak season" only, or during the period of highest productivity.

Table 4-3. Numeric Thresholds for Implementation of the Narrative Nutrient Standard in Arizona’s Lakes and Reservoirs

<table>
<tr><th>Designated Use</th><th>Lake Category</th><th>Chl-a (μg/L)</th><th>Secchi Depth (m)</th><th>Blue-Green Algae (per mL)</th><th>Blue-Green Algae (% of total count)</th><th>Tot. Phos. (μg/L)</th><th>Tot. Nit. (mg/L)</th><th>TKN (mg/L)</th><th>Dissolved Oxygen (mg/L)</th><th>pH (SU)</th></tr>
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</table>

NOTES:

“ NA”: the threshold does not apply to that particular designated use.

Threshold ranges apply during “peak season” for lake productivity:
Peak season for cold water lakes is May – September (inclusive)
Peak season for warm water lakes is April – October (inclusive)

5.0 INTERPRETATION OF STANDARD for LAKE/RESERVOIR

5.1 *Attainment of the Narrative Nutrient Standard*

Attainment of the narrative nutrient standard will be based on representative lake data reflecting a complete set of matrix variables from two independent sampling events. All results, calculated as seasonal means, must fall below the threshold or within the appropriate threshold range for that particular class of lake or reservoir (unless otherwise specified under exceedance criteria in Table 5-1). Samples must be collected during the appropriate peak season (based on cold or warm water designation) as defined in the previous section.

5.2 *Violation of the Narrative Nutrient Standard*

A violation of the narrative nutrient standard applied to lakes will be determined by *any one* of the four criteria found in Table 5-1.

Table 5-1 Violation of the Narrative Nutrient Standard for Lakes/Reservoirs

	Primary Decision Criteria	**Weight of Evidence Supporting Criteria**
1	The mean[1] chlorophyll-*a* result is above the upper value in the threshold range	None needed
2	The mean[1] chlorophyll-*a* result is within the range, **and**	The mean[1] blue-green result is at or above either blue-green threshold
3	The mean[1] chlorophyll-*a* result is within the threshold range, and there is additional evidence of nutrient-related impairments **such as**	Exceedances of DO or pH, **or** Fish kills attributed to DO or pH exceedances or ammonia toxicity, **or** Fish kills or other aquatic organism mortality attributed to algal toxicity, **or** Secchi depth below the lower threshold value, **or** Nuisance algal blooms present in the lacustrine[2] portion of the lake or reservoir, **or** The upper threshold for TKN, Total Phosphorus, or Total Nitrogen is exceeded
4	The mean[1] chlorophyll-*a* result is within or below the range, but the lake is a shallow lake (mean depth less than 4 m), **and**	Submerged aquatic vegetation is greater than 50% of the aerial extent of the lake bottom, **and** There is greater than 5 mg/L swing in diel (24-hr) DO measured within the photic zone (depth of light penetration supporting algal or plant growth)

[1]"mean" refers to the average value of the parameter collected from a lake based on a minimum of two sample events within one peak season
[2] "lacustrine" refers to the shallow shoreline areas

6.0 IMPLEMENTATION OF NARRATIVE NUTRIENT STANDARD IN AZPDES PERMITS

6.1 AZPDES Permit Nutrient Discharge Limits

Target nutrient limits for point source discharges of nutrients to a lake or reservoir will be set not to exceed applicable matrix nutrient threshold ranges, unless assimilative capacity can be demonstrated such that the applicable chlorophyll-*a* threshold is met within an acceptable zone of influence*, not to exceed 2 ug/L above background for that lake or reservoir.

* The zone of influence must meet the rule requirements for a *mixing zone* (A.A.C. R18-11-114) applied to a discharge of nutrients.

6.2 Narrative Nutrient Compliance for Permits with Nutrient Discharges

Permit compliance for narrative nutrients in a lake or reservoir will be based on sampling that shows:

- End of pipe nutrient values meet and do not exceed the matrix threshold range(s) as determined by lake class and designated uses, **or**
- There is demonstration of sufficient nutrient assimilative capacity to meet the chlorophyll-*a* threshold range, not to exceed 2 ug/L above background, **and**
- There is no ammonia toxicity

7.0 USE OF NARRATIVE NUTRIENT WATER QUALITY STANDARD FOR §303(d) LISTING PURPOSES

7.1 Impaired

ADEQ will determine that a lake or reservoir is an impaired water for §303(d) listing purposes if there are a minimum of two violations, as determined in Section 5.2, within a five-year assessment period. A §303(d) listing because of narrative nutrient standard violations will result in the development of a TMDL unless a suitable lake management plan for mitigation can show attainment of the narrative nutrient standard within three years.

7.2 *Inconclusive*

Using the weight of evidence approach, a lake or reservoir may not be clearly "attaining" or "impaired" with regard to the narrative nutrient standard . A finding of "inconclusive" does not result in an identification of the lake as an impaired water. ADEQ will continue to monitor water quality conditions to determine the attainment status of the narrative nutrient water quality standard.

7.3 De-listing

Within three years following completion of an EPA-approved TMDL, attainment of the narrative nutrient standard is demonstrated over two *consecutive* peak seasons.

8.0 REFERENCES

Arizona Department of Environmental Quality, 2000. ADEQ Lakes Program Quality Assurance Project Plan.

ADEQ, 2001. Lakes Program Procedures Manual.

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Brezonik, P.L. 1984. Trophic state indices: rationale for multivariate approaches. Lake and Reservoir Management; Proc. 3rd An. Conf. NALMS, Oct 18-20, 1983, Knoxville, TN. EPA 440/5/84-001 p. 441-5.

EPA, 2000. Guidance for Development of Nutrient Criteria for Lakes and Reservoirs.

EPA, 2000/2001. Ambient Water Quality Criteria Recommendations: Lakes and Reservoirs in Nutrient Ecoregions II and III.

Malcolm Pirnie, 2005. Data Summary and Statistical Modeling Report and Appendices (Lakes Classification Study)

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APPENDIX A: SAMPLING FOR COMPLIANCE with the NARRATIVE NUTRIENT STANDARD for LAKES/RESERVOIRS

Sample Site(s)

A lake or reservoir sample site is chosen based on lake size, shape, and depth. "Simple" lake shape is round to oblong with a bowl-like topography, and usually relatively shallow. The deepest and most representative location on a simple lake is either the middle or close to the dam (if present). "Complex" lake shape refers to multiple arms or tributary inputs such that the lake may have characteristics peculiar to each arm. The most overall representative location in this type of lake is also the deepest site or close to the dam (if present). However, separate samples should be collected from any arms that display a depth profile differing from the main part of the lake. "Linear" lake shape refers to a reservoir that is fed by one main tributary and has three sections: riverine, transition, and bay (by the dam). This type of lake is best sampled at a minimum of three separate sites unless very small. Table 5-1 shows a general guideline for determining the number of sample sites on a lake based on size and shape.

Table A-1 Guideline for Number of Lake Sampling Locations*

Lake Size (acres)	Lake Shape (descriptive)	Mean Lake Depth (m)	Min. No. Sample Sites
Less than or equal to 1,000	Simple Complex Linear	< 4m (> 4m) < 4m (> 4m) < 18m (> 18m)	1 (2) 1 (2) 2 (3)
>1,000 - < 10,000	Simple Complex Linear	> 4 m > 18m (> 1 arm) > 18m	2 2 (3) 3
10,000 - < 100,000	Complex Linear	> 18m (> 2 arms) > 18m	3 (4) 4
100,000 or greater	Linear/Complex	> 18m	5

* Sample sites must be at least 200 meters apart

Sample Depth

Matrix thresholds shall apply to samples collected within the lake photic zone only. The "photic zone" is defined as the zone of the water column contained within a depth profile from lake surface down to 1.5 X the Secchi depth. For example, if the Secchi depth is 1.5 m, the photic zone would be 2.25 m. Samples for nutrients, chlorophyll-a, DO, pH, and algae identification would all be collected within this depth zone in order to assess compliance with the narrative nutrient standard. DO and pH shall be measured using a depth-compensated probe or multi-probe and recorded at a minimum of 1.0 m increments within a photic zone > 2 m, or at a minimum of 0.5 m within a photic zone of less than 2 m. Lake samples shall be collected using a depth-specific sampler such as a Beta Bottle or similar device (*Lakes Program Procedures Manual*, 2001).

Sample QC

Samples must be collected according to standard QA/QC protocols: use of appropriate and clean containers and preservatives, maintenance of samples at 4 degrees C, adherence to holding times, adequate lab detection limits to meet the threshold targets, etc.(*Lakes Program Quality Assurance Project Plan*, 2000)

Sample Frequency

In order to assess compliance with the narrative nutrient standard, there must be a minimum of two independent sample events (more than 7 days apart) within the appropriate peak season: May-Sept for cold water lakes and reservoirs; April-October for warm water lakes and reservoirs, or two sample events within two peak seasons.