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Nutrient Criteria Technical Guidance Manual

Wetlands

Full Guidance Document available in full at:
http://www.epa.gov/waterscience/criteria/nutrient/guidance/

Chapter 1 Introduction

1.1 INTRODUCTION

PURPOSE

The purpose of this document is to provide technical guidance to assist States in assessing the nutrient status of their wetlands by considering water, vegetation, and soil conditions, and to provide technical assistance for developing regionally-based, scientifically defensible, numeric nutrient criteria for wetlands. In this document, the term "wetlands" or "wetland systems" refers to wetlands that are considered as "waters of the United States." However, States may, at their discretion, use this document to develop water quality criteria and standards for wetlands that are considered waters of the State.

EPA's development of recommended nutrient criteria is part of an initiative by the U.S. Environmental Protection Agency (USEPA) to address the problem of cultural eutrophication. In 1998, the EPA published a report entitled, *National Strategy for the Development of Regional Nutrient Criteria* (USEPA 1998a). The report outlines a framework for EPA's development of waterbody-specific technical guidance that can be used to assess nutrient status and develop region-specific numeric nutrient criteria. This document is the technical guidance for developing numeric nutrient criteria for wetlands. Approaches to nutrient criteria development are similar for freshwater and tidal wetlands, however, this document has a freshwater emphasis. EPA recognizes that wetlands are different from the other types of waters of the U.S. in that they frequently do not have standing or flowing water, and the soils and vegetation components are more dominant in these systems than in the other waterbody types (lakes, streams, estuaries). Additional, more specific information on sampling wetlands is available at: www.epa.gov/waterscience/criteria/nutrient/guidance/index.html.

BACKGROUND

Cultural eutrophication (human-caused inputs of excess nutrients in waterbodies) is one of the primary causal factors that impair surface waters in the U.S. (USEPA 1998a). Both point and nonpoint sources of nutrients contribute to impairment of water quality. Point source discharges of nutrients are relatively constant and are controlled by the National Pollutant Discharge Elimination System (NPDES) permitting program. Nonpoint source pollutant inputs have increased in recent decades, resulting in degraded water quality in many aquatic systems. Nonpoint sources of nutrients are most commonly intermittent and are usually linked to runoff, atmospheric deposition, seasonal agricultural activity, and other irregularly occurring events such as silvicultural activities. Control of nonpoint source pollutants typically focuses on land management activities and regulation of pollutants released to the atmosphere (Kronvang et al., 2005; Howarth et al., 2002; Carpenter et al., 1998).

The term eutrophication was coined in reference to lake systems. The use of the term for wetlands can be problematic due to the confounding nature of hydrodynamics, light, and the differences in the responses of algae and vegetation. Eutrophication in this document refers to human-caused inputs of excess nutrients and is not intended to indicate the same scale or responses to eutrophication found in lake systems and codified in the trophic state index for lakes (Carlson 1977). This manual is intended to provide guidance for identifying deviance from natural conditions with respect to cultural eutrophication in wetland systems. Hydrologic alteration and pollutants other than excess nutrients may amplify or reduce the effects of nutrient pollution, making specific responses to nutrient pollution difficult to quantify. EPA recognizes these issues, and presents recommendations for analyzing wetland systems with respect to nutrient condition for development of nutrient criteria in spite of these confounding factors.

Cultural eutrophication is not new; however, traditional efforts at nutrient control have been only moderately successful. Specifically, efforts to control nutrients in waterbodies that have multiple nutrient sources (point and nonpoint sources) have been less effective in providing satisfactory, timely remedies for enrichment-related problems (Azzellino et al., 2006; Merseburger et al., 2005; Carpenter et al., 1998). Development and adoption of numeric nutrient criteria into water quality standards aid State nutrient pollution control efforts by providing clear numeric goals for nutrient concentrations. Furthermore, numeric nutrient criteria provide specific water quality goals that will assist researchers in designing improved best management practices.

1.2 WATER QUALITY STANDARDS AND CRITERIA

States are responsible for setting water quality standards to protect the physical, biological, and chemical integrity of their waters. “Water quality standards (WQS) are provisions of State or Federal law which consist of a designated use or uses and water quality criteria for such waters to protect such uses.[2] Water quality standards are to protect public health or welfare, enhance the quality of the water, and serve the purposes of the Act (40 CFR 131.2 and 131.3(i))” (USEPA 1994). A water quality standard defines the goals for a wetland by: 1) designating its specific uses, 2) setting criteria to protect those uses, and, 3) establishing an antidegradation policy to protect existing water quality.

Designated uses are a State’s concise statements of its goals and expectations for each of the individual surface waters under its jurisdiction. With designated uses, States can work with their publics to identify a collective goal for their waters that they intend to strive for as they manage water quality. EPA encourages States to evaluate the attainability of these goals and expectations

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[2] EPA published guidance on water quality standards for wetlands in 1990 (USEPA, 1990c). Examples of different state approaches for standards can be found at: http://www.epa.gov/owow/wetlands/initiatives/.

to ensure they have designated the appropriate uses. Generally, the effectiveness of designated uses in guiding water quality management programs is greater if they:

- Identify specific expectations based on as much data as possible to reduce ambiguity.
- Recognize and accommodate inherent natural differences among surface water types.
- Acknowledge certain human caused conditions that limit the potential to support uses.

Designated uses may involve a spectrum of expectations, depending on the type of wetland and associated hydropatterns, where the wetland is situated with respect to natural landscape features and human activity, and the historical and anticipated future functions that the wetland provides. Criteria to protect specific uses, in turn, should reflect these differing expectations where appropriate. The information used in developing the technical approaches in this document was drawn from references about studies of wetlands in a wide range of conditions, but not wetlands with a high degree of modification (e.g., wetlands that are considered “prior converted cropland” or artificial wetlands specifically engineered to protect or improve downstream water quality).

Water quality criteria may be expressed as numeric values or narrative statements. As of this writing, most of the Nation’s waterbodies do not have numeric nutrient criteria, but instead rely on narrative criteria that describe the desired condition. Narrative criteria are descriptions of conditions necessary for a water to attain the designated uses. An example of a narrative criterion for nutrients is shown below:

> In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna.

Numeric criteria, on the other hand, are values assigned to measurable components of water quality to protect designated uses, such as the concentration of a specific constituent that is present in the water column. An example of a numeric criterion for specific waters is shown below:

> (4) Phosphorus Criterion.
> (a) The numeric phosphorus criterion for Class III waters shall be a long-term geometric mean of 10 ppb, but shall not be lower than the natural conditions of the Class II waters, and shall take into account spatial and temporal variability. Achievement of the criterion shall be determined by the methods in this subsection. Exceedences of the provisions of the subsection shall not be considered deviations from the criterion if they are attributable to the full range of natural spatial and temporal variability, statistical variability inherent in sampling and testing procedures, or higher natural background conditions.

In addition to narrative and numeric criteria, some States use numeric translator mechanisms—mechanisms that translate narrative (qualitative) standards into numeric (quantitative) values for use in evaluating water quality data. Translator mechanisms may be useful internally by the State agency for water assessment and management and serve as an intermediate step between numeric and narrative criteria.

Numeric criteria provide distinct interpretations of acceptable and unacceptable conditions, form the foundation for measurement of environmental quality, and reduce ambiguity for management and enforcement decisions. The lack of numeric nutrient criteria in State water quality standards for most of the Nation's waterbodies makes it difficult to assess the condition of waters of the U.S. with respect to nutrients, and thus hampers the water quality manager's ability to protect designated uses and improve water quality. EPA encourages States to adopt numeric nutrient criteria into their water quality standards (USEPA 2007b).

Many States have adopted some form of nutrient criteria for surface waters related to maintaining natural conditions and avoiding nutrient enrichment. Most States with nutrient criteria in their water quality standards have broad narrative criteria for most waterbodies and may also have site-specific numeric criteria for certain waters of the State. Established criteria most commonly pertain to phosphorus (P) concentrations in lakes. Nitrogen (N) criteria, where they have been established, are usually protective of human health effects or relate to toxic effects of ammonia and nitrates. In general, levels of nitrate (10 ppm [mg/L] for drinking water) and ammonia high enough to be problematic for human health or toxic to aquatic life (1.24 mg N/L at pH = 8 and 25°C) will also cause problems of enhanced algal growth (USEPA 1986).

Numeric nutrient criteria can provide a variety of benefits and may be used in conjunction with State and Federal biological assessments, Nonpoint Source Programs, Watershed Implementation Plans, and in development of Total Maximum Daily Loads (TMDLs) to improve resource management and support watershed protection activities at local, State, and national levels. Information obtained from compiling existing data and conducting new surveys can provide water quality managers and the public a better perspective on the condition of State waters. The compiled information can be used to most effectively budget personnel and financial resources for the protection and restoration of State waters. In a similar manner, data collected in the criteria development and implementation process can be compared before, during, and after specific management actions. Analyses of these data can determine the response of the wetland and the effectiveness of management endeavors.

1.3 NUTRIENT ENRICHMENT PROBLEMS

Water quality can be affected when watersheds are modified by alterations in vegetation, sediment transport, fertilizer use, industrialization, urbanization, or conversion of native forests and grasslands to agriculture and silviculture (Turner and Rabalais 1991; Vitousek et al., 1997; Carpenter et al., 1998). Cultural eutrophication, one of the primary factors causing impairment of U.S. surface waters (USEPA 1998a), results from point and nonpoint sources of nutrient pollution. Nonpoint source pollutant inputs have increased in recent decades and have degraded water quality in many aquatic systems (Carpenter et al., 1998). Control of nonpoint source pollutants focuses on land management activities and regulation of pollutants released to the atmosphere (Carpenter et al., 1998).

Nutrient enrichment frequently ranks as one of the top causes of water resource impairment. EPA reported to Congress that of the waterbodies surveyed and reported impaired, 20 percent of rivers and 50 percent of lakes were listed with nutrients as the primary cause of impairment (USEPA 2000c). Few States currently include wetland monitoring in their routine water quality monitoring programs (only eleven States reported attainment of designated uses for wetlands in the *National Water Quality Inventory 1998 Report to Congress* (USEPA 1998b) and only three States used monitoring data as a basis for determining attainment of water quality standards for wetlands); thus, the extent of nutrient enrichment and impairment of wetland systems is largely undocumented. Increased wetland monitoring by States will help define the extent of nutrient enrichment problems in wetland systems.

The best-documented case of cultural eutrophication in wetlands is the Everglades ecosystem. The Everglades ecosystem is a wetland mosaic that is composed primarily of oligotrophic freshwater marsh. Historically, the greater Everglades ecosystem included vast acreage of freshwater marsh, small stands of custard apple and some cattail south of Lake Okeechobee, and Big Cypress Swamp, which eventually drains into Florida Bay. Lake Okeechobee was diked to reduce flooding. The area directly south of Lake Okeechobee was then converted into agricultural lands for cattle grazing and row crop production. The cultivation and use of commercial fertilizers in the area now known as the “Everglades Agricultural Area” have resulted in release of nutrient-rich waters into the Everglades for more than thirty years. The effects of the nutrient-rich water, combined with coastal development and channeling to supply water to communities on the southern Florida coast, have significantly increased soil and water column phosphorus levels in naturally oligotrophic areas. In particular, nutrient enrichment of the freshwater marsh has resulted in an imbalance in the native vegetation. Cattail is now encroaching in areas that were historically primarily sawgrass; calcareous algal mats are being replaced by non-calcareous algae, changing the balance of native flora that is needed to support vast quantities of wildlife. Nutrient enriched water is also reaching Florida Bay, suffocating the native turtle grass as periphyton covers the blades (Davis and Ogden 1994; Everglades Interim Report 1999, 2003; Everglades Consolidated Report 2003). Current efforts to restore the Everglades are focusing on nutrient reduction and better hydrologic management (Everglades Consolidated Report 2003).

Monitoring to establish trends in nutrient levels and associated changes in biology has been infrequent for most wetland types as compared to studies in the Everglades or examination of other surface waters such as lakes. Noe et.al., (2001) have argued that phosphorus biogeochemistry and the extreme oligotrophy observed in the Everglades in the absence of anthropogenic inputs represents a unique case. Effects of cultural eutrophication, however, have been documented in a range of different wetland types. Existing studies are available to document potential impacts of anthropogenic nutrient additions to a wide variety of wetland types, including bogs, fens, Great Lakes coastal emergent marshes, and cypress swamps. The evidence of nutrient effects in wetlands ranges from controlled experimental manipulations, to trend or empirical gradient analysis, to anecdotal observations. Consequences of cultural eutrophication have been observed at both community and ecosystem-level scales (Table 1). Changes in wetland vegetation composition resulting from cultural eutrophication of these systems have been demonstrated in bogs (Kadlec and Bevis 1990), fens (Guesewell et.al., 1998, Bollens and Ramseier 2001, Pauli et.al., 2002), meadows (Finlayson et.al., 1986), marshes (Bedford et.al., 1999) and cypress domes (Ewel 1976). Specific effects on higher trophic levels in marshes seem to depend on trophic structure (e.g., presence/absence of minnows, benthivores, and/or piscivores, Jude and Pappas 1992, Angeler et.al., 2003) and timing/frequency of nutrient additions (pulse vs. press; Gabor et.al., 1994, Murkin et.al., 1994, Hann and Goldsborough 1997, Sandilands et.al., 2000, Hann et.al., 2001, Zrum and Hann 2002).

Table 1. Observed consequences of cultural eutrophication in freshwater wetlands.[3]

Observed impact	References
Loss of submerged aquatic plants that have high light compensation points	Phillips et.al., 1978 Stephenson et.al., 1980 Galatowitsch and van der Valk 1996
Shifts in vascular plant species composition due to shifts in competitive advantage	Wentz 1976 Verhoeven et.al., 1988 Ehrenfeld and Schneider 1993 Gaudet and Keddy 1995 Koerselman and Verhoeven 1995
Increases in above-ground production	Barko 1983 Bayley et.al., 1985 Barko and Smart 1986 Vermeer 1986
Decreases in local or regional biodiversity	Mudroch and Capobianco 1979 Guntenspergen et al., 1980 Lougheed et.al., 2001 Balla and Davis 1995 VanGroenendael et.al., 1993 Bedford et.al., 1999
Increased competitive advantage of aggressive/invasive species (e.g., *Typha glauca*, *T. latifolia* and *Phalaris arundinacea)*	Woo and Zedler 2002 Svengsouk and Mitsch 2001 Green and Galatowitsch 2002 Maurer and Zedler 2002
Loss of nutrient retention capacity (e.g., carbon and	Nichols 1983

[3] Similar impacts in tidal and estuarine wetlands have been documented, but are not included in this table.

nitrogen storage, changes in plant litter decomposition)	Davis and van der Valk 1983 Rybczyk et.al., 1996
Major structural shifts between "clear water" macrophyte dominated systems to turbid phytoplankton dominated systems or metaphyton-dominated systems with reduced macrophyte coverage	McDougal et.al., 1997 Angeler et.al., 2003
Shifts in macroinvertebrate composition along a cultural eutrophication gradient	Chessman et.al., 2002

The cycling of nitrogen (N) and phosphorus (P) in aquatic systems should be considered when managing nutrient enrichment. The hydroperiod of wetland systems significantly affects nutrient transformations, availability, transport, and loss of gaseous forms to the atmosphere (Mitsch and Gosselink, 2000). Nutrients can be re-introduced into a wetland from the sediment, or by microbial transformation, potentially resulting in a long recovery period even after pollutant sources have been reduced. In open wetland systems, nutrients may also be rapidly transported downstream, uncoupling the effects of nutrient inputs from the nutrient source, and further complicating nutrient source control (Mitsch and Gosselink, 2000; Wetzel 2001). Recognizing relationships between nutrient input and wetland response is the first step in mitigating the effects of cultural eutrophication. When relationships are established, nutrient criteria can be developed to manage nutrient pollution and protect wetlands from eutrophication.

1.4 THE CRITERIA DEVELOPMENT PROCESS

The *National Strategy for the Development of Regional Nutrient Criteria* (USEPA 1998a) describes the principal elements of numeric nutrient criteria development. This document can be downloaded in PDF format at the Web site: http://www.epa.gov/waterscience/criteria/nutrient/strategy.html. The Strategy recognizes that a prescriptive, one-size-fits-all approach is not appropriate due to regional differences that exist and the scientific community's current technical understanding of the relationship between nutrients, algal and macrophyte growth, and other factors (e.g., flow, light, substrata). The approach chosen for criteria development therefore may be tailored to meet the specific needs of each State. The

EPA Strategy envisions a process by which State waters are initially monitored, reference conditions are established, individual waterbodies are compared to known reference waterbodies, and appropriate management measures are implemented. These measurements can be used to document change and monitor the progress of nutrient reduction activities and protection of water quality.

The National Nutrient Program represents an effort and approach to criteria development that, in conjunction with efforts made by State water quality managers, will ultimately result in a heightened understanding of nutrient-response relationships. As the proposed process is put into use to set criteria, program success will be gauged over time through evaluation of management and monitoring efforts. A more comprehensive knowledge-base pertaining to nutrient, and vegetation and/or algal relationships will be expanded as new information is gained and obstacles overcome, justifying potential refinements to the criteria development process.

The overarching goal of developing and adopting nutrient criteria is to protect and maintain the quality of our national waters. Protecting and maintaining water quality may include restoration of impaired systems, conservation of high quality waters, and protection of systems at high risk for future impairment. The specific goals of a State water quality program may be defined differently based on the needs of each State, but should, at a minimum, be established to protect the designated uses for the waterbodies within State lands. In addition, as numeric nutrient criteria are developed for the nation's waters, States should revisit their goals for water quality and revise their water quality standards as needed.

1.5 ROADMAP TO THE DOCUMENT

As set out in Figure 1.1, the process of developing numeric nutrient criteria begins with defining the goals of criteria development and water quality standards adoption. Those goals are pertinent to the classification of systems, the development of a monitoring program, and the application of numeric nutrient criteria to permit limits and water quality protection. These goals therefore should be determined with the intent of revising and adapting them as new information is obtained and the paths to achieving those goals are clarified. Defining the goals for criteria development is the first step in the process. The summaries below describe each chapter in this document. The document is written to provide recommendations for a stepwise procedure for criteria development. Some chapters contain information that is not needed by some readers; the descriptions below should serve as a guide to the most relevant information for each reader.

Chapter Two describes many of the functions of wetland systems and their role in the landscape with respect to nutrients. This chapter is intended to familiarize the reader with some basic scientific information about wetlands that will provide a better understanding of how nutrients move within a wetland and the importance of wetland systems in the landscape.

Chapter Three discusses wetland classification and presents the reader with options for classifying wetlands based on system characteristics. This chapter introduces the scientific rationale for classifying wetlands, reviews some common classification schemes, and discusses their role in establishing nutrient criteria for wetlands. The classification of these systems is important to identifying their nutrient status and their condition in relation to similar wetlands.

Chapter Four provides technical guidance on designing effective sampling programs for State wetland water quality monitoring programs. Most States should begin wetland monitoring programs to collect water quality and biological data in order to develop nutrient criteria protective of wetland systems. The best monitoring programs are designed to assess wetland condition with statistical rigor and maximize effective use of available resources. The sampling protocol selected, therefore, should be determined based on the goals of the monitoring program, and the resources available.

Chapter Five gives an overview of candidate variables that could be used to establish nutrient criteria for wetlands. Primary variables are expected to be most broadly useful in characterizing wetland conditions with respect to nutrients, and include nutrient loading rates, soil nutrient concentrations, and nutrient content of wetland vegetation. Supporting variables provide information useful for normalizing causal and response variables. The candidate variables suggested here are not the only parameters that can be used to determine wetland nutrient condition, but rather identify those variables that are thought to be most likely to identify the current nutrient condition and of the greatest utility in determining a change in nutrient status.

A database of relevant water quality information can be an invaluable tool to States as they develop nutrient criteria. If little or no data are available for most regions or parameters, it may be necessary for States to create a database of newly gathered data. Chapter Six provides the basic information on how to develop a database of nutrient information for wetlands, and supplies links to ongoing database development efforts at the State and national levels.

The purpose of Chapter Seven is to explore methods for analyzing data that can be used to develop nutrient criteria. The quality of the analysis and interpretation of data generally determines whether the criteria will be scientifically defensible and effective. This chapter describes recommended approaches to data analysis for developing numeric nutrient criteria for wetlands. Included are techniques to evaluate metrics, to examine or compare distributions of nutrient exposure or response variables, and to examine nutrient exposure-response relationships.

Chapter Eight describes the details of establishing scientifically defensible criteria in wetlands. Several approaches are presented that water quality managers can use to derive numeric criteria for wetland systems in their State waters. They include: (1) the use of the reference conditions concept to characterize natural or minimally impaired wetland systems with respect to causal and response variables; (2) applying predictive relationships to select nutrient concentrations that will protect wetland function; and, (3) developing criteria from established nutrient exposure-response relationships (as in the peer-reviewed, published literature). This chapter provides recommendations regarding how to determine the appropriate numeric criterion based on the data collected and analyzed.

The appendices include a glossary of terms and acronyms and case study examples of wetland nutrient enrichment and management.

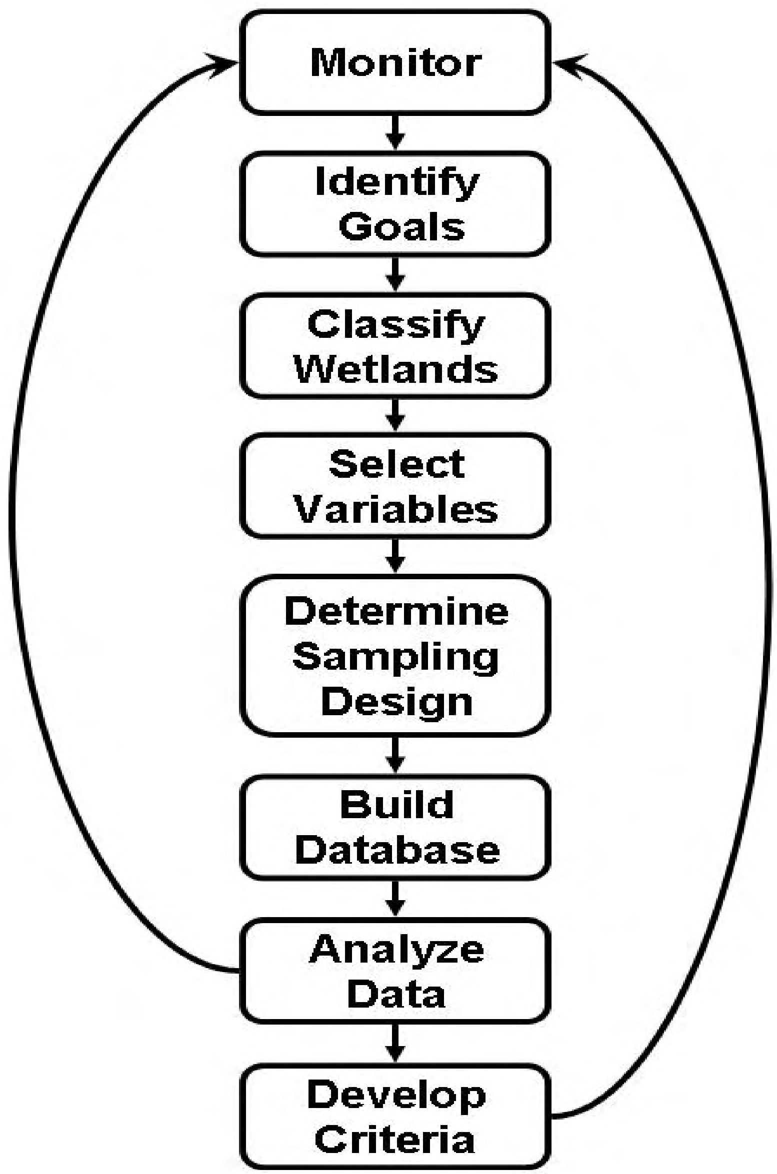

Figure 1.1 Flowchart identifying the steps of the recommended process to develop wetland nutrient criteria.