EPA 822-B-00-023

AMBIENT WATER QUALITY CRITERIA RECOMMENDATIONS

INFORMATION SUPPORTING THE DEVELOPMENT OF STATE AND TRIBAL NUTRIENT CRITERIA

FOR

WETLANDS IN NUTRIENT ECOREGION XIII

Southern Florida Coastal Plain

including all or parts of the State of:

Florida

and the authorized Tribes within the Ecoregion

U.S. ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF WATER
OFFICE OF SCIENCE AND TECHNOLOGY
HEALTH AND ECOLOGICAL CRITERIA DIVISION
WASHINGTON, D.C.

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FOREWORD

This document presents EPA's nutrient criteria for **Wetlands in Nutrient Ecoregion XIII.** These criteria provide EPA's recommendations to States and authorized Tribes for use in establishing their water quality standards consistent with section 303(c) of CWA. Under section 303(c) of the CWA, States and authorized Tribes have the primary responsibility for adopting water quality standards as State or Tribal law or regulation. The standards must contain scientifically defensible water quality criteria that are protective of designated uses. EPA's recommended section 304(a) criteria are not laws or regulations – they are guidance that States and Tribes may use as a starting point for the criteria for their water quality standards.

The term "water quality criteria" is used in two sections of the Clean Water Act, Section 304(a)(1) and Section 303(c)(2). The term has a different impact in each section. In Section 304, the term represents a scientific assessment of ecological and human health effects that EPA recommends to States and authorized Tribes for establishing water quality standards that ultimately provide a basis for controlling discharges or releases of pollutants or related parameters. Ambient water quality criteria associated with specific waterbody uses when adopted as State or Tribal water quality standards under Section 303 define the level of a pollutant (or, in the case of nutrients, a condition) necessary to protect designated uses in ambient waters. Quantified water quality criteria contained within State or Tribal water quality standards are essential to a water quality-based approach to pollution control. Whether expressed as numeric criteria or quantified translations of narrative criteria within State or Tribal water quality standards, quantified criteria serve as a critical basis for assessing attainment of designated uses and measuring progress toward meeting the water quality goals of the Clean Water Act.

EPA is developing section 304(a) water quality criteria for nutrients because States and Tribes consistently identify excessive levels of nutrients are a major reason why as much as half of the surface waters surveyed in this country do not meet water quality objectives, such as full support of aquatic life. EPA expects to develop nutrient criteria that cover four major types of waterbodies – lakes and reservoirs, rivers and streams, estuarine and coastal areas, and wetlands – across fourteen major ecoregions of the United States. EPA's section 304(a) criteria are intended to provide for the protection and propagation of aquatic life and recreation. To support the development of nutrient criteria, EPA is publishing Technical Guidance Manuals that describe a process for assessing nutrient conditions in the four waterbody types.

EPA's section 304(a) water quality criteria for nutrients provide numeric water quality criteria, as well as procedures by which to translate narrative criteria within State or Tribal water quality standards. In the case of nutrients, EPA section 304(a) criteria establish values for causal variables (e.g., total nitrogen and total phosphorus) and response variables (e.g., turbidity and chlorophyll *a*). EPA believes that State and Tribal water quality standards need to include quantified endpoints for causal and response variables to provide sufficient protection of uses and to maintain downstream uses. These quantified endpoints will most often be expressed as numeric water quality criteria or as procedures to translate a State or Tribal narrative criterion into a quantified endpoint.

EPA will work with States and authorized Tribes as they adopt water quality criteria for nutrients into their water quality standards. EPA recognizes that States and authorized Tribes require flexibility in adopting numeric nutrient criteria into State and Tribal water quality standards. States and authorized Tribes have several options available to them. EPA recommends the following approaches, in order of preference:

(1) Wherever possible, develop nutrient criteria that fully reflect localized conditions and protect specific designated uses using the process described in EPA's Technical Guidance Manuals for nutrient criteria development. Such criteria may be expressed either as numeric criteria or as procedures to translate a State or Tribal narrative criterion into a quantified endpoint in State or Tribal water quality standards.

(2) Adopt EPA's section 304(a) water quality criteria for nutrients, either as numeric criteria or as procedures to translate a State or Tribal narrative nutrient criterion into a quantified endpoint.

(3) Develop nutrient criteria protective of designated uses using other scientifically defensible methods and appropriate water quality data.

Geoffrey H. Grubbs, Director
Office of Science and Technology

DISCLAIMER

This document provides technical guidance and recommendations to States, authorized Tribes, and other authorized jurisdictions to develop water quality criteria and water quality standards under the Clean Water Act (CWA) to protect against the adverse effects of nutrient overenrichment. Under the CWA, States and authorized Tribes are to establish water quality criteria to protect designated uses. State and Tribal decision-makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance when appropriate and scientifically defensible. While this document contains EPA's scientific recommendations regarding ambient concentrations of nutrients that protect aquatic resource quality, it does not substitute for the CWA or EPA regulations; nor is it a regulation itself. Thus it cannot impose legally binding requirements on EPA, States, authorized Tribes, or the regulated community, and it might not apply to a particular situation or circumstance. EPA may change this guidance in the future.

EXECUTIVE SUMMARY

Nutrient Program Goals

EPA developed the National Strategy for the Development of Regional Nutrient Criteria (National Strategy) in June 1998. The strategy presents EPA's intentions to develop technical guidance manuals for four types of waters (lakes and reservoirs, rivers and streams, estuaries and coastal waters, and wetlands) and produce section 304(a) criteria for specific nutrient ecoregions by the end of 2000. In addition, the Agency formed Regional Technical Assistance Groups (RTAGs) which include State and Tribal representatives working to develop more refined and more localized nutrient criteria based on approaches described in the waterbody guidance manuals. This document presents EPA's current recommended criteria for total phosphorus for wetlands in Nutrient Ecoregion XIII - Southern Florida Coastal Plain which were derived using peer-reviewed publications of research conducted in the Everglades and the findings and information associated with the EPA approval of the Miccosukee Tribe of Indians of Florida standard for phosphorus for the Federal Reservation within the Everglades.

EPA's ecoregional nutrient criteria are intended to address cultural eutrophication – the adverse effects of excess inputs of nutrients. The criteria are empirically derived to represent conditions of surface waters that are minimally impacted by human activities and are protective of aquatic life and recreational uses. The information contained in this document represent starting points for States and Tribes to develop (with assistance from EPA) more refined nutrient criteria.

In developing these criteria recommendations, EPA followed a process which included, to the extent they were readily available, the following elements critical to criterion derivation:

- **Historical and recent nutrient data in Nutrient Ecoregion XIII.**
  Historical and recent data used in the development of the nutrient criteria for this ecoregion include information from more than 300 scientific publications and reports were reviewed and summarized; the *Everglades Interim Report* (1999) published by the South Florida Water Management District; *Phosphorus Biogeochemistry in Subtropical Ecosystems* (1999) a compilation of papers from a symposium, and a comparison of soil phosphorus concentrations in 1990 and 1998 by DeBusk *et al*. (1994) and DeBusk *et al*. (in press).

- **Reference sites/reference conditions in Nutrient Ecoregion XIII.**
  Reference conditions presented in this document were summarized from peer-reviewed literature and the primary source documents listed above. The water column phosphorus number for reference condition and criteria recommendations is based on long-term (at least three months) average values. Hydrologic variability can result in variable concentrations of water column total phosphorus, therefore, a long-term or rolling average, or geometric mean (as required by the Everglades Forever Act; Section 373.4592 Florida Statutes) is most appropriate to identify reference conditions and evaluate excursions from numeric criteria in this system. In developing reference conditions, the natural, seasonal/annual hydrologic variability should be considered. Periphyton reference condition and criterion recommendations are based on relative species abundance, which has been found to be an integrative measure of nutrient condition. for the previous three months. The oligotrophic Everglades marsh system contains a mosaic of wetland community types, such as sloughs, wet prairies and sawgrass marshes, all of which are adapted to low nutrient conditions. The mosaic character of the South Florida Coastal Plain Nutrient Ecoregion, which provides a diverse array of habitats for animals, is an important defining characteristic of the Everglades and was recognized in developing reference conditions for the ecoregion. States and Tribes are urged to determine their own reference sites for wetlands within the ecoregion at different geographic scales and to

compare them to EPA's reference conditions.

- **Models employed for prediction or validation.**
Several models have been developed for the Everglades. Summaries and detailed descriptions of models developed for the Everglades can be found in McCormick *et al*. (1999) and *Phosphorus Biogeochemistry in Subtropical Ecosystems* (1999), respectively. States and Tribes are encouraged to identify and apply appropriate models to support nutrient criteria development.

- **RTAG expert review and consensus.**
EPA recommends that when States and Tribes prepare their nutrient criteria, they obtain the expert review and consent of the RTAG.

- **Downstream effects of criteria.**
EPA encourages the RTAG to assess the potential effects of the proposed criteria on downstream water quality and uses.

A summary of reference conditions for the Aggregate nutrient ecoregion for water column TP and vegetation are presented below. These were chosen because they constitute early warning indicators of eutrophication within the Everglades systems.

BASED ON LITERATURE VALUES

Aggregate Ecoregion XIII-Southern Florida Coastal Plain	**Reference Conditions**
Total Water Column Phosphorus (µg/L)	10
Periphyton	No significant change in relative species abundance

EPA also recommends that States and Tribes develop reference conditions and criteria for soil phosphorus levels since it is considered a necessary indicator of eutrophication and phosphorus condition within the Everglades. Studies have indicated that 300-600 mg P/kg soil is the preferred range for organic soils. However, these same levels may not be appropriate for mineral soils in some regions of the Everglades.

NOTICE OF DOCUMENT AVAILABILITY

This document is available electronically to the public through the INTERNET at: (http://www.epa.gov/OST/standards/nutrient.html). Requests for hard copies of the document should be made to EPA's National Service Center for Environmental Publications (NSCEP), 11029 Kenwood Road, Cincinnati, OH 45242 or (513) 489-8190, or toll free (800) 490-9198. Please refer to EPA document number **EPA-822-B-00-023**.

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1.0 INTRODUCTION

Background

Nutrients are essential to the health and diversity of our surface waters. However, in excessive amounts, nutrients cause hypereutrophication, which results in overgrowth of plant life and decline of the biological community. Excessive nutrients can also result in potential human health risks, such as the growth of harmful algal blooms - most recently manifested in the *Pfiesteria* outbreaks of the Gulf and East Coasts. Chronic nutrient overenrichment of a waterbody can lead to the following consequences: low dissolved oxygen, fish kills, algal blooms, overabundance of macrophytes, likely increased sediment accumulation rates, and species shifts of both flora and fauna.

Historically, National Water Quality Inventories have repeatedly shown that nutrients are a major cause of ambient water quality use impairments. EPA's 1996 National Water Quality Inventory report identifies excessive nutrients as the leading cause of impairment in lakes and the second leading cause of impairment in rivers (behind siltation). In addition, nutrients were the second leading cause of impairments reported by the States in their 1998 lists of impaired waters. Where use impairment is documented, nutrients contribute roughly 25-50% of the impairment nationally. The Clean Water Act establishes a national goal to achieve, wherever attainable, water quality which provides for the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water. In adopting water quality standards, States and Tribes designate uses for their waters in consideration of the Clean Water Act goals, and establish water quality criteria that contain sufficient parameters to protect those uses. To date, EPA has not published information and recommendations under section 304(a) for nutrients to assist States and Tribes in establishing numeric nutrient criteria to protect uses when adopting water quality standards.

In 1995, EPA gathered a set of national experts and asked the experts how to best deal with the national nutrient problem. The experts recommended that the Agency not develop single criteria values for phosphorus or nitrogen applicable to all water bodies and regions of the country. Rather, the experts recommended that EPA put a premium on regionalization, develop guidance (assessment tools and control measures) for specific waterbodies and ecological regions across the country, and use reference conditions (conditions that reflect pristine or minimally impacted waters) as a basis for developing nutrient criteria.

With these suggestions as starting points, EPA developed the National Strategy for the Development of Regional Nutrient Criteria (National Strategy), published in June 1998. This strategy presented EPA's intentions to develop technical guidance manuals for four types of waters (lakes and reservoirs, rivers and streams, estuaries and coastal waters, and wetlands) and, thereafter, to publish section 304(a) criteria recommendations for specific nutrient ecoregions. Technical guidance manuals for lakes/reservoirs and rivers/streams were published in April 2000 and July 2000, respectively. The technical guidance manual for estuaries/coastal waters will be published in spring 2000 and the draft wetlands technical guidance manual will be published by December 2001. Each manual presents EPA's recommended approach for developing nutrient criteria values for a specific waterbody type. In addition, EPA is committed to working with States and Tribes to develop more refined and more localized nutrient criteria based on approaches described in the waterbody guidance manuals and this document.

Overview of the Nutrient Criteria Development Process

For each Nutrient Ecoregion, EPA developed a set of recommendations for two causal variables (total nitrogen and total phosphorus) and two early indicator response variables (chlorophyll *a* and some measure of turbidity). Other indicators such as dissolved oxygen and macrophyte growth or speciation, and other fauna and flora changes are also deemed useful. However, the first four are considered to be the best suited for protecting designated uses. This basic set of indicators clearly must be modified for wetlands to accommodate the complexity of these aquatic environments. The parameters of concern for the Southern Florida Coastal Plain are water column total phosphorus (TP) concentration; soil phosphorus concentration, and change in vegetation communities. Parameters of concern for the Everglades will also be used in other wetland systems, if appropriate.

The technical guidance manuals describe a process for developing nutrient criteria that involves consideration of five factors. The first of these is the Regional Technical Assistance Group (RTAG), which is a body of qualified regional specialists able to objectively evaluate all of the available evidence and select the value(s) appropriate to nutrient control in the water bodies of concern. These specialists may come from such disciplines as limnology, biology, natural resources management-- especially water resource management, chemistry, and ecology. The RTAG evaluates and recommends appropriate classification techniques for criteria determination, usually physical within an ecoregional construct.

The second factor is the historical information available to establish a perspective of the resource base. This is usually data and anecdotal information available within the past ten to twenty-five years. This information gives evidence about the background and enrichment trend of the resource.

The third factor is the present reference condition. A selection of reference sites chosen to represent the least culturally impacted waters of the class existing at the present time. The data from these sites are combined and a value from the distribution of these observations is selected to represent the reference condition, or best attainable, most natural condition of the resource base at this time.

A fourth factor often employed is theoretical or empirical models of the historical and reference condition data to better understand the condition of the resource. It is recognized that, distinct from ambient monitoring or empirical efforts, field and laboratory experiments can elucidate specific processes and establish cause and effect. These studies (such as field nutrient dosing studies, mesocosm studies, or laboratory mesocosm or microcosm experiments) can facilitate causal interpretation of data. (Lean, *et al*., 1992; Hopkinson, *et la*., 1998).

The RTAG comprehensively evaluates the other three elements to propose a candidate criterion (initially one each for TP, TN, chl *a*, and some measure of turbidity).

The last and final element of the criteria development process is the assessment by the RTAG of the likely downstream effects of the criterion. Will there be a negative, positive, or neutral effect on the downstream waterbody? If the RTAG judges that a negative effect is likely, then the proposed State/Tribal water quality criteria should be revised to ameliorate the potential for any adverse downstream effects.

While States and authorized Tribes would not necessarily need to incorporate all five elements into their water quality criteria setting process (e.g., modeling may be significant in only some instances), the best assurance of a representative and effective criterion for nutrient management decision making is the balanced incorporation of all five elements, or at least all elements except modeling.

Because some parts of the country have naturally higher soil and parent material enrichment, and different precipitation regimes, the application of the criterion development process has to be adjusted by region. Therefore, an ecoregional approach was chosen to develop nutrient criteria appropriate to each of the different geographical and climatological areas of the country. Initially, the continental U.S. was divided into 14 separate ecoregions of similar geographical characteristics. Ecoregions are defined as regions of relative homogeneity in ecological systems; they depict areas within which the mosaic of ecosystem components (biotic and abiotic as well as terrestrial and aquatic) is different than adjacent areas in a holistic sense. Geographic phenomena such as soils, vegetation, climate, geology, land cover, and physiology that are associated with spatial differences in the quantity and quality of ecosystem components are relatively similar within each ecoregion.

The Nutrient ecoregions are aggregates of U.S. EPA:s hierarchal level III ecoregions (Omernik, 1995, 1998). As such, they are more generalized and less defined than level III ecoregions. EPA determined that setting ecoregional criteria for the large scale aggregates is not without its drawbacks - variability is high due to the lumping of many waterbody classes, seasons, and years worth of multipurpose data over a large geographic area. For these reasons, the Agency recommends that States and Tribes develop nutrient criteria at the level III ecoregional scale and at the waterbody class scale where those data are readily available. Data analyses and recommendations on both the large aggregate ecoregion scale as well as more refined scales (level III ecoregions and waterbody classes), where data were available to make such assessments, are presented for comparison purposes and completeness of analysis.

Relationship of Nutrient Criteria to Biological Criteria

Biological criteria are quantitative expressions of the desired condition of the aquatic community. Such criteria can be based on an aggregation of data from sites that represent the least-impacted and attainable condition for a particular waterbody type in an ecoregion, subecoregion, or watershed. EPA’s nutrient criteria recommendations and biological criteria recommendations have many similarities in the basic approach to their development and data requirements. Both are empirically derived from statistical analysis of field collected data and expert evaluation of current reference conditions and historical information. Both utilize direct measurements from the environment to integrate the effects of complex processes that vary according to type and location of waterbody. The resulting criteria recommendations, in both cases, are efficient and holistic indicators of water quality necessary to protect uses.

States and authorized Tribes can develop and apply nutrient criteria and biological criteria in tandem, with each providing important and useful information to interpret both the nutrient enrichment levels and the biological condition of sampled waterbodies. For example, using the same reference sites for both types of criteria can lead to efficiencies in both sample design and data analysis. In one effort, environmental managers can obtain information to support assessment of biological and nutrient condition, either through evaluating existing data sets or through designing and conducting a common sampling program. The traditional biological criteria variables of benthic invertebrate and fish sampling can be readily incorporated to supplement a nutrient assessment. To demonstrate the effectiveness of this tandem approach, EPA has initiated pilot projects in both freshwater and marine environments to investigate the relationship between nutrient overenrichment and apparent declines in diversity indices of benthic invertebrates and fish.

2.0 BEST USE OF THIS INFORMATION

EPA recommendations published under section 304(a) of the CWA serve several purposes, including providing guidance to States and Tribes in adopting water quality standards for nutrients that ultimately provide a basis for controlling discharges or releases of pollutants. The recommendations also provide guidance to EPA when promulgating Federal water quality standards under section 303(c) when such action is necessary. Other uses include identification of overenrichment problems, management planning, project evaluation, and determination of status and trends of water resources.

State water quality inventories and listings of impaired waters consistently rank nutrient overenrichment as a top contributor to use impairments. EPA’s water quality standards regulations at 40 CFR §131.11(a) require States and Tribes to adopt criteria that contain sufficient parameters and constituents to protect the designated uses of their waters. In addition, States and Tribes need quantifiable targets for nutrients in their standards to assess attainment of uses, develop water quality-based permit limits and source control plans, and establish targets for total maximum daily loads (TMDLs).

EPA expects States and Tribes to address nutrient overenrichment in their water quality standards, and to build on existing State and Tribal initiated efforts where possible. States and Tribes can address nutrient overenrichment through establishment of numerical criteria or through use of new or existing narrative criteria statements (e.g., free from excess nutrients that cause or contribute to undesirable or nuisance aquatic life or produce adverse physiological response in humans, animals, or plants). In the case of narrative criteria, EPA expects that States and Tribes establish procedures to quantitatively translate these statements for both assessment and source control purposes.

The intent of developing ecoregional nutrient criteria is to represent conditions of surface waters that are minimally impacted by human activities and thus protect against the adverse effects of nutrient overenrichment from cultural eutrophication. EPA's recommended process for developing such criteria includes physical classification of waterbodies, determination of current reference conditions, evaluation of historical data and other information (such as published literature), use of models to simulate physical and ecological processes or determine empirical relationships among causal and response variables (if necessary), expert judgement, and evaluation of downstream effects. To the extent allowed by the information available, EPA has used elements of this process to produce the information contained in this document. The values for both causal (total nitrogen, total phosphorus) and biological and physical response (chlorophyll *a*, turbidity) variables represent a set of starting points for States and Tribes to use in establishing their own criteria in standards to protect uses.

In its water quality standards regulations, EPA recommends that States and Tribes establish numerical criteria based on section 304(a) guidance, section 304(a) guidance modified to reflect site-specific conditions, or other scientifically defensible methods. For many pollutants, such as toxic chemicals, EPA expects that section 304(a) guidance will provide an appropriate level of protection without further modification in most cases. EPA has also published methods for modifying 304(a) criteria on a site-specific basis, such as the water effect ratio, where site-specific conditions warrant modification to achieve the intended level of protection. For nutrients, however, EPA expects that, in most cases, it will be necessary for States and authorized Tribes to identify with greater precision the nutrient levels that protect aquatic life and recreational uses. This can be achieved through development of criteria modified to reflect conditions at a smaller geographic scale than an ecoregion such as a subecoregion, the State or Tribe level, or specific class of waterbodies. Criteria refinement can occur by grouping data or performing data analyses at these smaller geographic scales. Refinement can also occur through further consideration of other elements of criteria development, such as published literature or models.

The values presented in this document generally represent nutrient levels that protect against the adverse effects of nutrient overenrichment and are based on information available to the Agency at the time of this publication. However, States and Tribes should critically evaluate this information in light of the specific designated uses that need to be protected. For example, more sensitive uses may require more stringent values as criteria to ensure adequate protection. On the other hand, overly stringent levels of protection against the adverse effects of cultural eutrophication may actually fall below levels that represent the natural load of nutrients for certain waterbodies. In cases such as these, the level of nutrients specified may not be sufficient to support a productive fishery. In the criteria derivation process, it is important to distinguish between the natural load associated with a specific waterbody and current reference conditions, using historical data and expert judgement. These elements of the nutrient criteria derivation process are best addressed by States and Tribes with access to information and local expertise. Therefore, EPA strongly encourages States and Tribes to use the information contained in this document and to develop more refined criteria according to the methods described in EPA's technical guidance manuals for specific waterbody types.

To assist in the process of further refinement of nutrient criteria, EPA has established ten

Regional Technical Advisory Groups (experts from EPA Regional Offices and States/Tribes). In the process of refining criteria, States and authorized Tribes need to provide documentation of data and analyses, along with a defensible rationale, for any new or revised nutrient criteria they submit to EPA for review and approval. As part of EPA's review of State and Tribal standards, EPA intends to seek assurance from the RTAG that proposed criteria are sufficient to protect uses.

In the process of using the information and recommendations contained in this document, as well as additional information, to develop numerical criteria or procedures to translate narrative criteria, EPA encourages States and Tribes to:

- Address both chemical causal variables and early indicator response variables. Causal variables are necessary to provide sufficient protection of uses before impairment occurs and to maintain downstream uses. Early response variables are necessary to provide warning signs of possible impairment and to integrate the effects of variable and potentially unmeasured nutrient loads.
- Include variables that can be measured to determine if standards are met, and variables that can be related to the ultimate sources of excess nutrients.
- Identify appropriate periods of duration (i.e., how long) and frequency (i.e., how often) of occurrence in addition to magnitude (i.e., how much). EPA does not recommend identifying nutrient concentrations that must be met at all times, rather a seasonal or annual averaging period (e.g.,based on weekly measurements) is considered appropriate. However, these seasonal or annual central tendency measures (i.e., geometric mean or median) should apply each season or each year, except under the most extraordinary of conditions (e.g., a 100 year flood).

3.0 AREA COVERED BY THIS DOCUMENT

The following sections provide a general description of the aggregate ecoregion and its geographical boundaries. A descriptions of the level III ecoregion contained within the aggregate ecoregion is also provided.

3.1 Description of Aggregate Ecoregion XIII – Southern Florida Coastal Plain

The Southern Florida Coastal Plain is nearly level and subtropical to tropical (U.S. EPA, 2000). It is characterized by wildlife-rich fresh water marshes, wet prairies, sloughs, swamps, and coastal wetlands; only about 10% is used as cropland. Canals, ditches, and broad, poorly-defined stream channels are common. Lakes are generally rare but one large, shallow, regulated lake is found in the region, Lake Okeechobee; it links the waters of the Kissimmee Basin to the Everglades. Elevations are low and range from sea level to less than 50 feet; only hummocks, limestone ridges, beach ridges, and dunes relieve the flatness of the region. Poorly- and very poorly-drained, organic soils (peat and muck) are common and overlie carbonate-rich bedrock. Much of the Southern Florida Coastal Plain (XIII) has been set aside as parks, game refuges, water conservation areas, and Indian reservations. However, extensive areas have also been urbanized or drained for agriculture, resulting in the widespread alteration of hydrological and biological systems, depletion of peat deposits, and reduction of regional water quality. Canals draining developed areas generally have higher nutrient concentrations than those flowing through undeveloped areas. Lake Okeechobee is one of the largest lakes in the United States and has been significantly impacted by agricultural runoff. Cattle and dairy farms have contributed a large amount of phosphorus to the lake and the Everglades Agricultural Area has pumped nitrogen-rich water into the lake to control flooding. During the 1970s, lake concentrations of phosphorus and nitrogen more than doubled and bottom sediments accumulated a massive quantity of phosphorus. By the mid-1980s, large algal blooms had occurred.

3.2 Geographic Boundaries of Aggregate Ecoregion XIII

Ecoregion XIII is small compared to the other ecoregions; encompassing only the southern quarter of Florida (Figure 1).

3.3 Level III Ecoregion Within Aggregate Ecoregion XIII

76. Southern Florida Coastal Plain

The frost-free climate of the Southern Florida Coastal Plain makes it distinct from other ecoregions in the conterminous United States (Figure 2). This region is characterized by flat plains with wet soils, marshland and swamp land cover with Everglades and palmetto prairie vegetation types. Although portions of this region are in parks, game refuges, and Indian reservations, a large part of the region has undergone extensive hydrological and biological alteration.

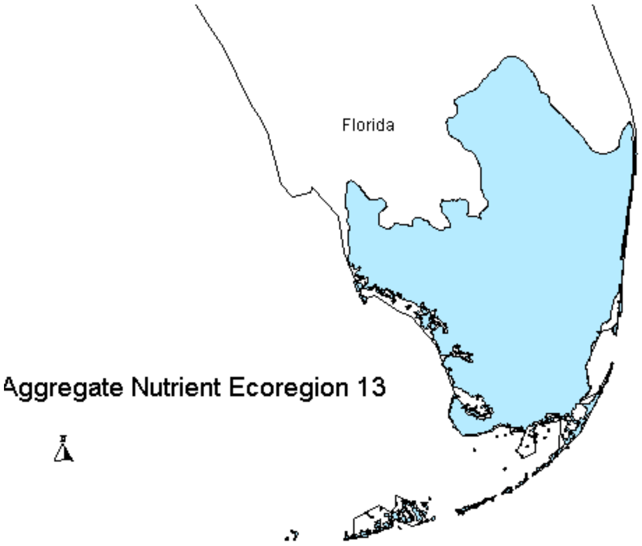

Figure 1. **Aggregate Ecoregion XIII**

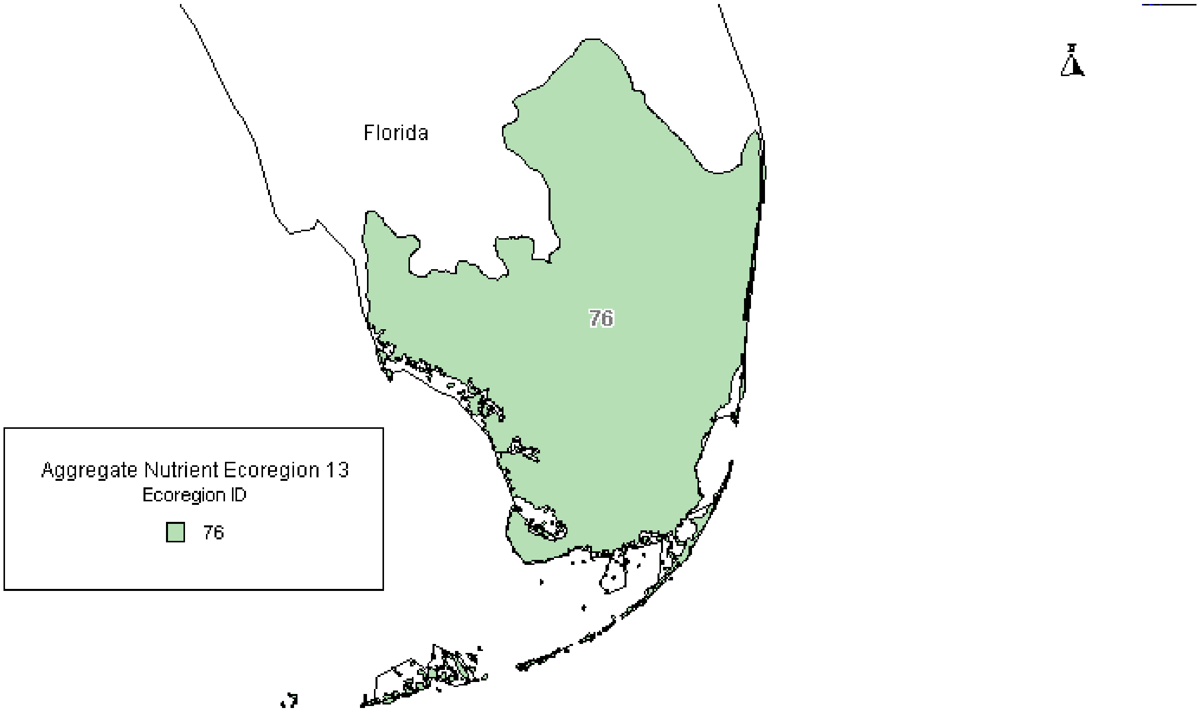

Figure 2. **Aggregate Ecoregion XIII with level III ecoregion shown**

4.0 DATA REVIEW FOR WETLANDS IN AGGREGATE ECOREGION XIII

The following section describes the nutrient data information that EPA reviewed for this Ecoregion. They include data for the causal parameters-- total water column phosphorus and soil phosphorus and the primary response variable-- periphyton- relative species abundance. These are the parameters which EPA considers essential to nutrient assessment in wetlands because the first two are the measurements of the main causative agents of phosphorus enrichment and the response variable is the early indicator of system enrichment for the Everglades ecosystem (Ecoregion XIII).

4.1 Data Sources

Relevant scientific information used in determining the phosphorus criterion range in this document has been summarized from the EPA finding in support of the criterion proposed for Miccosukee tribal lands in Nutrient Ecoregion XIII (EPA 1999), from the Everglades Interim Report (SFWMD 1999), from Phosphorus Biogeochemistry in Subtropical Ecosystems (1999), and from DeBusk *et al.*, 1994, and DeBusk *et al.*, in press.

4.2 Historical Data from Aggregate Ecoregion XIII (water column TP, soil P and vegetation):

EPA recommends that States/Tribes assess long-term trends observed over the past 50 years. This information may be obtained from scientific literature or documentation of historical trends. To gain additional perspective on more recent trends, it is recommended that States and Tribes assess nutrient trends over the last 10 years (e.g., what do seasonal trends indicate?)

- long term trends over past 50 years.

Historical descriptions of the Everglades ecosystem are relatively scarce, and those that are available are largely descriptive and qualitative, rather than quantitative in nature. Information on historical large-scale vegetation patterns is available, but water quality information is sparse prior to the 1970s (McCormick *et al.*, 1999). Phosphorus inputs to the Everglades historically came largely from atmospheric deposition. Current estimates indicate that the total phosphorus concentration in rainfall is typically less than 10 μg/L and that total atmospheric inputs average between 22 and 36 mg TP/m^2/yr; it is assumed that historical inputs were not greater than current estimates (McCormick *et al*, 1999). Historically, the Everglades also received periodic inflows from Lake Okeechobee, but these inputs were likely small relative to atmospheric inputs. The more remote interior areas of the Everglades still exhibit the low P concentrations that once prevailed throughout the Everglades system. Measurements of soluble reactive phosphorus (SRP) and orthophosphate in some interior marsh sites in the 1970s and 1980s indicate that background concentrations of 2 to 5 ppb were not uncommon (Scheidt 1999). More recent studies in the Everglades National Park (ENP) note the low concentrations of phosphorus in the interior sites. Scheidt, *et al.* (1989) summarized water quality characteristics of the ENP from 1984-1986, and found typical orthophosphate concentrations of 4 ppb in the interior marsh sites, with P concentration values from 10 to 35 times higher from sites in and around the Everglades Agricultural Area (EAA) and Lake Okeechobee.

The majority of soils data collected from the Everglades in the early 1900s were descriptive. The few soil data from the 1900s that are quantitative are summarized in McCormick *et al.* (1999), and indicate that soil P concentrations near Okeechobee were much higher than those in more interior Everglades sites. Early studies found that soil P concentrations in the top 30 cm of organic soil at sites adjacent to Lake Okeechobee (in what is now the EAA) averaged (1,800 to 2,000 mg P/kg), and soil P concentrations at interior Everglades sites near Tamiami trail averaged (~400 mg P/kg) (McCormick et al. 1999). More recent studies of soil P have indicated an increase in surficial soil phosphorus concentrations of up to three-fold since the 1970s (Davis 1989; Reddy *et al.* 1991; DeBusk *et al.* 1994; Reddy *et al.* 1998; DeBusk *et al.*, in press) in those areas receiving inflows from canals draining the EAA.

Periphyton is the most widely distributed plant community in the Everglades. Periphyton exhibits three growth forms in the Everglades: benthic (growing on the soil surface), epiphytic (growing attached to rooted vegetation) and floating (growing on the water surface sometimes in association with other floating vegetation such as *Utricularia purpurea*) (McCormick *et al.*, 1999). Periphyton mat communities are found throughout the unimpacted Everglades marsh, especially in open water areas, sloughs and wet prairies, and are particularly well adapted to the low P conditions historically found in the Everglades ecosystem. The first visible changes caused by P enrichment are seen in the periphyton mat communities. As the P-limited areas of the Everglades are enriched, the calcareous blue-green algae and diatoms are replaced by soft-bodied green and blue-green algae, and the soft-water periphyton communities show increased relative abundance of pollution-tolerant species. Swift (1984) found that marsh water TP was the controlling factor regulating periphyton growth. Elevated water TP increased periphyton biomass, increased periphyton phosphorus content, and altered community species composition toward pollution-tolerant species. The continued flow of nutrient enriched waters into the Everglades from the EAA has also resulted in more profound changes in the vegetation community. Increased macrophyte growth has decreased periphyton productivity due to reduced light availability, and has caused a change in macrophyte community composition. The historically dominant marsh macrophyte, *Cladium jamaicense*, is being displaced with the high P-adapted species, *Typha domingensis*, in those areas enriched by EAA outflows (McCormick *et al*. 1999; Bechtel *et al*. 1999; DeBusk, *et al*., in press). This also includes the loss of open water wet prairies plant communities.

-trends over the last 10 years

Recent trends in the Everglades reflect the continued enrichment of the Everglades. Phosphorus concentrations in those areas closest to the Everglades Agricultural Area (EAA) outflows show the greatest levels of enrichment in both the water column and soil phosphorus concentrations. The increasing loss of native periphyton, and continued spread of *Typha latifolia* into the more interior areas of the Everglades further support the conclusion that nutrient enrichment is affecting the Everglades ecosystem.

Water column total phosphorus concentrations in remote interior sites currently average between 4 and 10 µg/L (McCormick *et al*. 1999); contemporary measurements of soil porewater concentrations are consistently below 50 µg/L soluble reactive phosphorus (SRP), and are often at or below 4 µg/L, and total phosphorus concentrations in surface soils range between 200 and 500mg/kg (McCormick *et al*. 1999). Chronic inputs of P from the EAA has lead to increased P in the water and soil in areas receiving inflows from canals draining the EAA, and a forward moving front of P-enriched surficial soil (McCormick *et al*. 1999; DeBusk *et al*, in press).

Water column phosphorus concentrations within the Everglades fluctuate naturally with water conditions. Marsh phosphorus concentrations have been shown to vary with water depth, with higher concentration excursions occurring during periods of low water or marsh drying (McCormick, *et al*. 1999). McCormick *et al*. (1999) summarized the impact of increased P loading to the Everglades on microbial and biogeochemical processes. P loading has been shown to affect the quality and quantity of organic matter, rates of nutrient accumulation, microbial biomass and community composition, and biogeochemical cycling. Moreover, P enrichment has been shown to initiate a series of effects on the cycling of carbon and nitrogen, as well as a shift in the system from an aerobic environment where oxygen is readily available to an anaerobic environment where oxygen is lacking.

4.3 Data for all Wetlands Within Aggregate Ecoregion XIII

The Everglades predominate in Ecoregion XIII. The information presented in this document is from studies performed in the Everglades.

4.4. Classification of Wetland Type:

The Everglades ecosystem is a large, unique wetland mosaic in the tropical and sub-tropical southern peninsula of Florida. Classification of the Everglades system into sub-types based on chemical, physical and biological differences can help decrease variability in monitoring data. In addition, nutrient gradients are evident in the Everglades system, and comparisons of data along the spatial gradient may be of use in further refining nutrient criteria for this system.

5.0 REFERENCE SITES AND CONDITIONS IN AGGREGATE ECOREGION XIII

The Everglades is a nutrient poor (oligotrophic) wetland, with natural populations of plants and animals adapted to extremely low nutrient conditions. Scheidt (1999) summarized and reviewed approximately 300 scientific journal articles, state, and federal reports relevant to nutrients in the Everglades. The literature summarized indicate long-term average water column phosphorus concentrations of less than 10 µg/L. Data supporting this number span three decades and were analyzed by independent laboratories (see Appendix A). For the purposes of reducing these data to a single value which represents an appropriate characterization of reference condition, EPA recommends a central tendency value such as the long-term geometric mean or median because of the large amount of data available, the relatively long length of time represented by the data, and the effects of hydrologic variability on water column concentration of phosphorus in this system.

Unenriched portions of the Everglades are reported to have some of the lowest rates of phosphorus accumulation in peatlands in North America. Increased surface water phosphorus from EAA canal inflows has caused elevated soil phosphorus concentrations. Studies conducted in the last decade by DeBusk *et al*. (1994; in press) indicate that chronic dosing has lead to increased soil P in Water Conservation Area 2A (WCA2A), the primary recipient of EAA inflows, and the front of P-enriched soils is moving south and encompassing increasingly larger areas.

Periphyton mat communities are found throughout the unimpacted Everglades marsh, especially in open water areas, sloughs and wet prairies. These mats, often referred to as calcareous mats, are known to be extremely sensitive to P enrichment. The calcareous algal mats in the hardwater calcium rich portions of the Everglades exhibit the first visible changes as a result of increased phosphorus when the dominant periphyton, calcareous blue-green algae, is replaced by soft-bodied green and blue-green algae (McCormick *et al*. 1999). The soft-water habitats of the Everglades also have periphyton adapted to low-nutrient conditions. These periphyton communities are comprised primarily of a type of green algae (desmids) and diatoms. Shifts in relative species abundance and an increase in pollution-tolerant species also occur as a response to nutrient enrichment in the soft-water periphyton community (McCormick *et al* 1999).

Reference conditions in the Everglades are defined by the native periphyton and macrophyte communities. Everglades periphyton provides multiple functions in the ecosystem. These functions include: accounts for much of the primary productivity in wet prairies and sloughs; provides habitat for aquatic animals such as invertebrates; along with macrophyte detritus, forms forming the base of the Everglades aquatic food web; is the major source of oxygenating the water for fish and other animal life in sloughs and wet prairies; maintaining low water TP concentrations; plays a role in cycling of nitrogen, phosphorus, carbon and oxygen; and contributes to the formation of marl soils.

The oligotrophic Everglades marsh system contains a mosaic of macrophyte communities, such as sloughs, wet prairies and sawgrass marshes, all of which are adapted to low nutrient conditions. This mosaic, which provides a diverse array of habitats for animals, is an important defining characteristic of the Everglades. Wet prairies encompass a group of plant communities generally described by soil type and dominant plant species. Wet prairies on peat soil are generally characterized by spikerush (*Eleocharis cellulosa*), beak rush (*Rhynchospora tracyi*), or maidencane (*Panicum hemitomon*), although dozens of plant species exist. Sloughs generally refer to deeper water areas, often dominated by white water lily (*Nymphaea odorata*), floating hearts (*Nymphoides aquatica*), and spatterdock. Bladderworts (*Utricularia purpurea* or *Utricularia foliosa*) are common submerged aquatic plants that provide a substrate for dense periphyton mats. Wet prairies and sloughs in particular provide critical habitat for animals and provide cover, nesting, and feeding sites for all animal groups. The wet prairie/slough habitat is also the major feeding area in the Everglades for both wintering and nesting wading birds, especially during the dry season when fish concentrations provide food for their nestlings (Scheidt 1999).

An important characteristic of unimpacted wet prairies and sloughs is their diversity and the large number of native plant species (Scheidt 1999). Multiple factors are responsible for the alteration and maintenance of plant community structure in the Everglades, including nutrients, fire, disturbance, and hydroperiod. Elevated water phosphorus concentrations or elevated soil phosphorus concentrations in the Everglades are associated with elimination of submerged vegetation species including the *Utricularia*-periphyton complex and expansion of nutrient-tolerant macrophytes such as cattail or *Sagittaria lancifolia* (Arrowhead) into areas previously dominated by sawgrass, sloughs or wet prairies. Historically, cattail was a minor component of the Everglades landscape.

The table below (Table 1) shows the reference condition recommendations for the Aggregate nutrient ecoregion for water column TP and vegetation. The recommendations are based on literature values.

Table 1: Reference Conditions for Aggregate Ecoregion XIII.

Aggregate Ecoregion XIII-Southern Florida Coastal Plain	Reference Conditions
Total Water Column Phosphorus (µg/L)	10
Periphyton	No significant change in relative species abundance

These recommendations were derived based on data from the over 300 peer-reviewed publications from Everglades research. They may not be appropriate for all the wetlands within the Everglades because the mosaic character of the system may result in site-specific conditions that do not reflect the characteristics were used to derive these reference values. EPA encourages the State and Tribes of Florida to apply this approach in other wetlands within the ecoregion.

EPA also recommends that States and Tribes develop reference conditions and criteria for soil phosphorus levels since it is considered a necessary indicator of eutrophication and phosphorus condition within the Everglades. Studies have indicated that 300-600 mg P/kg soil is the preferred range for organic soils. However, these same levels may not be appropriate for mineral soils in other parts of the Everglades.

6.0 MODELS USED

No models were directly used in the preparation of this document. However, many models have been produced to model nutrient effects in the Everglades. An overview of the models used in the Everglades is provided in the *Everglades Interim Report* (1999). Summaries and detailed descriptions of models developed for the Everglades can be found in McCormick *et al*. (1999) and *Phosphorus Biogeochemistry in Subtropical Ecosystems* (1999), respectively.

It is recognized that, distinct from ambient monitoring or empirical efforts, field and laboratory experiments can elucidate specific processes and establish cause and effect. These studies (such as field nutrient dosing studies, mesocosm studies, or laboratory mesocosm or microcosm experiments) can facilitate causal interpretation of data. (Lean, *et al*., 1992; Hopkinson, *et la.*, 1998).

7.0 FRAMEWORK FOR REFINING RECOMMENDED NUTRIENT CRITERIA FOR AGGREGATE ECOREGION XIII

Information on each of the following six weight of evidence factors is important to refine the criteria presented in this document. All elements should be addressed in developing criteria. It is our expectation that EPA Regions and States (as RTAGs) will consider these information elements as States/Tribes develop their criteria. This section should be viewed as a work sheet to assist in the completion of the nutrient criteria assessment. For example, States and Tribes should address factors that have the potential to impact downstream receiving waters, particularly

Florida Bay and the Keys. If these elements are ultimately unaddressed, EPA may rely on the proposed reference conditions and criteria recommendations presented in this document, and other literature and information readily available to the HQ nutrient team to develop nutrient water quality recommendations for this ecoregion.

7.1 Example Worksheet for Developing Aggregate Ecoregion and Subecoregion Nutrient Criteria

- *Literature sources*

- *Historical data and trends*

- *Reference condition*

- *Models*

- *RTAG expert review and consensus*

- *Downstream effects*

7.2 Setting Seasonal Criteria

States/Tribes may choose to develop criteria which reflect each particular season or a given year when there is significant variability between seasons/years or designated uses that are specifically tied to one or more seasons of the year (e.g., recreation, fishing). Obviously, this option is season-specific and would also require increased monitoring within each season to assess compliance.

7.3 Site-specific Criteria Development

Criteria may be refined in a number of ways. The best way to refine criteria is to follow the critical elements of criteria development as well as to refer to the Wetlands technical guidance manual (due out for publication in 2001).

The Technical Guidance Manual presents sections on each of the following factors to consider in setting criteria

- refinements to ecoregions
- classification of waterbodies
- setting seasonal criteria to reflect major seasonal climate differences
- accounting for significant or cyclical rainfall events - high flow/low flow conditions
- Wetland types

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9.0 APPENDICES

Appendix A: Scheidt, D. J. 1999. EPA Memorandum. Numeric phosphorus water quality criterion for the Everglades as adopted by the Miccosukee Tribe of Indians of Florida for Class III-A Waters. May 20, 1999.

Appendix B: EVERGLADES NUTRIENT-RELEVANT REFERENCES. Compiled by D. Scheidt, USEPA, May 1999.

APPENDIX A

Memorandum

To: Robert F. McGhee
Director, Water Management Division

Through: Richard Harvey
Director, South Florida Office

From: Dan Scheidt
Senior Scientist
South Florida Initiative

Subject: Numeric phosphorus water quality criterion for the Everglades as adopted by the Miccosukee Tribe of Indians of Florida for Class III-A Waters

Date: May 20, 1999

The Miccosukee Tribe of Indians of Florida (the Tribe) has submitted to the United States Environmental Protection Agency (USEPA) a numeric criterion for total phosphorus of 10 parts per billion (ppb, or micrograms per liter). The Tribe adopted this numeric criterion for Class III-A waters of the Miccosukee Tribe's Federal Reservation in the Everglades on December 19, 1997. The Tribe has defined Class III-A waters within the Federal Reservation as: "Those Tribal water bodies which are used for fishing, frogging, recreation (including airboating), and the propagation and maintenance of a healthy, well-balanced population of fish and other aquatic life and wildlife. These waters have been primarily designated for preservation of native plants and animals of the natural Everglades ecosystem." (page 23 of the Final Miccosukee Environmental Protection Code, Subtitle B, dated December 19,1997). The Tribal water quality standard for nutrients includes the narrative statement: "In no case shall nutrient concentrations of Tribal Class I or Class III-A surface waters be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." (page 11). The areas which the Tribe has designated as Class III-A waters include the north grass, south grass and gap areas (Everglades habitat within western Water Conservation Area 3A) (Figures 1 and 2).

PROBLEM STATEMENT

The determination that USEPA must make in approving or disapproving the Miccosukee 10 ppb phosphorus criterion is whether it is protective of the Class III-A designated use.

The Everglades marsh is extremely oligotrophic (nutrient poor). The mosaic of native plant communities and associated animals developed under, and are adapted to, very low phosphorus conditions. Phosphorus enrichment in the Everglades has caused a series of well-documented impacts (see below) such as loss of water column dissolved oxygen, loss of native plant life (periphyton (micro-algae) and macrophytes), and loss of preferred foraging habitat for wading birds.

As summarized by the external peer-review panel to the Florida Department of Environmental Protection (Hopkinson et al. 1998), in phosphorus-limited aquatic systems such as the Everglades, concentrations of total phosphorus in the water column are very low, and a small pool of dissolved phosphorus cycles or turns over very rapidly.

> Added phosphorus is assimilated rapidly into biomass or adsorbed by particulate matter. Phosphorus concentrations in the water will begin to increase only when a number of other living and non-living pools begin to saturate with excess P. For this reason, measurements of the standing stocks of total P in Everglades water are a relatively insensitive measure of significant changes of the system. By the time the concentration of total P in water has increased significantly, the system has already begun to approach P saturation in other components of the system (periphyton, macrophytes, sediments) and species succession may well be underway. In terms of time, the microbial components will be the first to change, followed much later by changes in macro-organisms, such as sawgrass to cattails. The stages in this succession can be seen in the present-day Everglades.

(Hopkinson et al.1998, page 11).

Phosphorus condition in the "Natural Everglades Ecosystem" is depicted in Figure 3. In contrast, Figure 4 depicts the phosphorus-impacted Everglades system. Figure 5, "Cultural Eutrophication", depicts the succession of changes caused by phosphorus enrichment in the Everglades, proceeding from those that are not visible to the naked eye (such as decreased alkaline phosphatase activity or increased soil phosphorus content) to those that are visible (such as changes in periphyton communities and macrophyte species composition).

Ultimately, determining whether a numeric TP criterion will protect Class III-A Everglades plant and animal communities appears to revolve around three issues: 1) selecting appropriate indicators of some change in the marsh ecosystem (sensitive indicators such as alkaline phosphatase activity or periphyton species versus less sensitive indicators such as macrophyte species); 2) determining what constitutes an imbalance in natural populations of aquatic flora or fauna: 3) determining what spatial extent of phosphorus impact, if any, is acceptable. These issues are not solely scientific ones.

The numeric phosphorus water quality criterion adopted by the Tribe must be sufficiently stringent to protect the Class III-A designated use, including preservation of native plants (periphyton and macrophytes) and animals of the natural oligotrophic Everglades ecosystem for decades or centuries. "This issue, obviously, is what amount of input of phosphorus to the Everglades will result in system change after several decades or a century..." (Hopkinson et al.1998, page 14). Phosphorus impacts in the Everglades are well-documented. This documentation includes observational studies as well as controlled experimental manipulations. Some of the observed phosphorus impacts have been based on short-term phosphorus addition or dosing experiments, with the nutrient addition taking place for a duration of a few weeks up to a few (less than five) years. With this type of study although it is possible to observe the phosphorus impacts that occur within the short-term duration of dosing, it is not possible to observe or infer what other indirect effects may occur later as the added phosphorus continues to cycle. Nor is it possible to infer what effects may have occurred later had dosing at the same concentration continued for a much longer period of time, such as decades or even centuries. It is not possible to identify all final long-term direct and indirect ecological impacts from short-term nutrient addition studies. Thus, there is a risk that a numeric criterion based solely on short-term (less than 5 years) dosing without also considering long-term observational studies would not be protective of the Class III-A designated use.

SUMMARY

Extent of the Review

A very extensive body of peer-reviewed scientific literature and data has been assembled during the last three decades concerning Everglades water quality, periphyton communities, macrophyte communities, and the impacts of phosphorus enrichment on Everglades plants and animals. USEPA received 110 documents from the Tribe in support of their adoption of the numeric phosphorus criterion. These documents have been reviewed by USEPA. In addition, an effort was made to identify and review other equally relevant scientific literature specific to the Everglades. A listing (attached) of the published reports identified numbers about 300 scientific documents. All of this literature is specific to the Everglades and is relevant to eutrophication. No other wetland system and few, if any, other bodies of water in the world have been the subject of so much scientific information concerning phosphorus conditions and the ecological impacts of phosphorus enrichment.

A brief review is presented of the scientific documentation about Everglades natural background phosphorus conditions and the impacts of phosphorus enrichment. This review relied on published scientific literature (peer-reviewed publications in scientific journals as well as technical publications by agencies such as the South Florida Water Management District, United States Geological Survey or USEPA). The reviewed literature included publications about Everglades:

- phosphorus conditions including the Everglades Agricultural Area,
- periphyton communities,
- macrophyte communities,
- cycling of oxygen, carbon, sulfur, and nitrogen, and
- wading bird foraging habitat.

The literature review excluded hundreds of additional scientific publications that primarily concern Everglades:

- hydrology,
- Phase II phosphorus treatment technology,
- water management,
- mercury contamination,
- pesticides,
- botany, and
- soils.

An extensive additional body of scientific information and opinion exists that was not included: published abstracts, memoranda, depositions, various legal documents, court exhibits, and public meetings and conferences.

Summary of conclusions

Based on the best available scientific information and the review that follows, the Tribe's 10 ppb criterion for phosphorus meets the requirements of 40 CFR §131.11 as it is protective of the Class III-A designated use, and review of published available information and data shows that the value is scientifically defensible.

This review has identified the following major points, which are expanded upon in the text that follows:

- The Everglades marsh system is naturally extremely oligotrophic. Un-impacted interior portions of the Everglades marsh have long-term average water column phosphorus concentrations of approximately 10 ppb or even less.

- The native plant and animal communities in the Everglades marsh developed under and are adapted to these very low phosphorus conditions.

- Phosphorus is the primary limiting nutrient in the oligotrophic Everglades marsh system.

- Microbial processes are important in controlling nutrient cycling in wetlands and they play an important role in determining water quality and maintaining an ecosystem's normal productivity. Elevated water column or soil phosphorus concentrations in the Everglades have been implicated as cause for disruption of various microbial processes.

- Periphyton communities are an important defining characteristic of the Everglades marsh ecosystem. According to the scientific literature, Everglades periphyton accounts for much of marsh primary productivity in wet prairies and sloughs; provides habitat for aquatic animals such as invertebrates; along with macrophyte detritus, forms the base of the Everglades aquatic food web; is the major source of oxygen for fish and other animal life in sloughs and wet prairies; maintains low water TP concentrations; plays a role in cycling of nitrogen, phosphorus, carbon and oxygen; and affects formation of marl soils. Periphyton communities are extremely sensitive to phosphorus enrichment. Phosphorus enrichment at levels above 10 ppb TP has been shown to cause a loss of Everglades native periphyton communities.

- Surface water dissolved oxygen in pristine Everglades wet prairie and slough communities often exhibits a strong diel cycle, with concentration at a particular location ranging from 0 mg/l in early morning to over 12 mg/l in late afternoon. Everglades fish are adapted to these conditions. In contrast, oxygen levels in nutrient-rich locations within WCA2A have been shown to often be undetectable and rarely exceed 2 mg/l, with protracted periods of oxygen depletion.

- Unenriched portions of the Everglades are reported to have some of the lowest rates of phosphorus accumulation in peatlands in North America. Increased surface water phosphorus has caused elevated soil phosphorus concentrations. Over 51% of WCA2A has been reported as having increased soil phosphorus.

- The oligotrophic Everglades marsh system contains a mosaic of macrophyte communities, such as sloughs, wet prairies and sawgrass marshes, all of which are adapted to low nutrient conditions. This mosaic is an important defining characteristic of the Everglades. Wet prairies and sloughs in particular provide critical habitat for animals and provide cover, nesting, and feeding sites for all animal groups. Elevated water phosphorus concentrations or elevated soil phosphorus concentrations in the Everglades are associated with elimination of submerged vegetation species including the important *Utricularia*-periphyton complex and expansion of nutrient-tolerant macrophytes such as cattail or *Sagittaria* into areas previously dominated by sawgrass, sloughs or wet prairies.

- Shallow, open water areas with scattered to moderately dense emergent macrophytes are the preferred foraging habitat for Everglades wading birds. Conversion of these areas to dense emergent macrophytes due to phosphorus enrichment constitutes a loss of wading bird foraging habitat.

- Phosphorus enrichment initiates a succession of changes within the marsh system. Initial changes, such as those that occur at the microbial level, are not visible. Visible impacts eventually occur, such as loss of native flora or fauna.

- The oligotrophic Everglades marsh system has very low assimilative capacity, or tolerance, for phosphorus before changes in ecosystem structure and function occur.

- The well-documented phosphorus impacts in WCA2A have taken place since the discharge of phosphorus-rich water through the S-10 structures beginning about 1960 (a period of about four decades). There is no information available concerning low-level additions of excess phosphorus for a century or more.

- The nutrient dosing studies and observational studies described below indicate that total phosphorus concentrations above 10 ppb have been shown to cause impacts to native Everglades periphyton and macrophytes such as *Utricularia purpurea* that are adapted to low phosphorus conditions. The best available scientific information indicates that average TP concentrations greater than 10 ppb, in general, can be expected to be inadequate for long-term protection of the Class III-A designated use. Therefore the Tribe's adopted numeric phosphorus criterion of 10 ppb is not overly protective.

- Currently available scientific information reviewed also indicates that the Tribe's proposed numeric criterion of 10 ppb is protective of the Class III-A use and the native Everglades periphyton and macrophytes. Although some data have identified long-term phosphorus concentrations within the Everglades as low as 5.0 ppb, EPA's review identified no currently available published scientific information documenting changes in the natural flora or fauna resulting from total phosphorus concentrations in the 5 ppb to 10 ppb range. If new data or information are presented in the future that demonstrate that 10 ppb is not protective of the Class III-A use, the Tribe should revise the criterion accordingly.

Therefore, USEPA has determined that the 10 ppb total phosphorus criterion is protective of the Class III-A designated use, is reasonable, and is scientifically defensible.

REVIEW OF RELEVANT SCIENTIFIC INFORMATION

Phosphorus is a nutrient that is essential to the growth of organisms and is often the nutrient that limits primary productivity in a water body. Phosphorus can exist in a water body as organic and inorganic forms. Phosphorus cycles in aquatic environments from the organic and inorganic state, and vice versa, with microorganisms playing a key role (Jones, 1996). Phosphorus data from water bodies is typically reported as total phosphorus and inorganic soluble phosphate (orthophosphate). The citations that follow include mention of these two forms. Phosphate is the form that is considered to be readily available for biological uptake.

In the summary that follows, the term "Everglades" is used to refer to the freshwater marsh habitats, such as sawgrass marsh, wet prairies and sloughs, in the greater Everglades system. The geographic area includes Loxahatchee National Wildlife Refuge (the Refuge), Everglades National Park (the Park), the Holeyland, the Rotenberger Tract, and all of the Water Conservation Areas (2A, 2B, 3A and 3B). The water quality and ecology of the Tribe's Class III-A waters are generally consistent with the water quality and ecology found in the greater Everglades system.

1- Reference conditions in the Everglades marsh ecosystem.

The Everglades is a nutrient poor (oligotrophic) wetland, with natural populations of plants and animals adapted to extremely low nutrient conditions. A reasonable approximation of long-term average surface water total phosphorus concentration is 10 ppb. The smallest but most widely distributed plant community in the Everglades is an assemblage of micro-algae referred to collectively as periphyton. Everglades periphyton generally is comprised of three major divisions or groups: diatoms, blue-green algae and green algae (Browder et al., 1994). Periphyton exhibits three growth forms in the Everglades: benthic (growing on the soil surface), epiphytic (growing attached to rooted vegetation) and floating (growing on the water surface sometimes in association with other floating vegetation such as *Utricularia purpurea*) (McCormick et al. 1999). These periphyton mat communities are found throughout the unimpacted Everglades marsh, especially in open water areas, sloughs and wet prairies. These mats, often referred to as calcareous mats, are known to be extremely sensitive to phosphorus enrichment. The widespread distribution of floating periphyton mats throughout the Everglades as observed during 1995-1996 is presented by Stober et al. (1998).

Periphyton provides multiple functions in the marsh ecosystem. These have been summarized by Browder et al. (1994), McCormick et al. (1998) and McCormick et al. (1999). Everglades periphyton: accounts for much of marsh primary productivity in wet prairies and sloughs; provides habitat for aquatic animals such as invertebrates; along with macrophyte detritus, forms the base of the Everglades aquatic food web; is the major source of oxygen for fish and other animal life in sloughs and wet prairies; maintains low water TP concentrations; plays a role in cycling of nitrogen, phosphorus, carbon and oxygen; and affects formation of marl soils.

Everglades plant communities, along with the factors contributing to plant community distribution and change, have been studied extensively. Recent vegetation classification maps have been published for Loxahatchee National Wildlife Refuge, WCA2A, and the Shark River Slough portion of Everglades National Park. The oligotrophic Everglades marsh system contains a mosaic of macrophyte communities, such as sloughs, wet prairies and sawgrass marshes, all of which are adapted to low nutrient conditions. This mosaic, which provides a diverse array of habitats for animals, is an important defining characteristic of the Everglades. Wet prairies encompass a group of plant communities generally described by soil type and dominant plant species. Wet prairies on peat soil are generally characterized by spikerush (*Eleocharis cellulosa*), beak rush (*Rhynchospora tracyi*), or maidencane (*Panicum hemitomon*), although dozens of plant species exist. Sloughs generally refer to deeper water areas, often dominated by white water lilly (*Nymphaea odorata*), floating hearts (*Nymphoides aquatica*), and spatterdock. Bladderwort (*Utricularia purpurea* or *Utricularia foliosa*) are common submerged aquatic plants that provide a substrate for dense periphyton mats. Wet prairies and sloughs in particular provide critical habitat for animals and provide cover, nesting, and feeding sites for all animal groups. The wet prairie/slough habitat is also the major feeding area in the Everglades for both wintering and nesting wading birds, especially during the dry season when fish concentrations provide food for their nestlings (Gunderson and Loftus, 1993). An important characteristic of unimpacted wet prairies and sloughs is their diversity and the large number of native plant species (Olmstead et al, 1980; Olmstead and Loope, 1984; Goodrick, 1974; Gunderson and Loftus, 1993). Multiple factors are responsible for the alteration and maintenance of plant community structure in the Everglades, including nutrients, fire, disturbance, and hydroperiod. Elevated water phosphorus concentrations or elevated soil phosphorus concentrations in the Everglades are associated with elimination of submerged vegetation species including the *Utricularia*-periphyton complex and expansion of nutrient-tolerant macrophytes such as cattail or *Sagittaria lancifolia* (Arrowhead) into areas previously dominated by sawgrass, sloughs or wet prairies. Historically, cattail was a minor component of the Everglades landscape.

The following discussion of Everglades animals is taken largely from McCormick et al. (1999). Aquatic invertebrates such as insects, snails and crayfish play an important role in the Everglades food web. Most invertebrates feed directly on periphyton and/or plant detritus and are then consumed by other animals. Invertebrates tend to be concentrated in periphyton-rich habitats such as sloughs or wet prairies where dissolved oxygen is plentiful and food is more readily available. Fish are a key link between invertebrates and predators, such the wading birds for which the Everglades is widely renown. Fish biomass in the natural (oligotrophic) Everglades is low relative to other wetlands. Turner et al. (in press) report that the natural condition in the oligotrophic Everglades is one of a high periphyton standing stock, but low invertebrate and fish standing stock.

The conditions described above are representative of unimpaired Miccosukee Tribal Waters. SFWMD has produced a classified vegetation map of northern WCA3A dated 1 July 1997. This map was based on September 1994 and June 1995 color infrared aerial photographs, and involved extensive ground-truthing (see Doren et al., 1999 for methods). The vegetation communities within the Tribal Waters indicative of unimpaired conditions include a mosaic of sawgrass marsh and wet prairies dominated by maidencane or spikerush. In addition, USEPA made visual observations of the Tribal Waters by airboat on July 30, 1998 and by helicopter on November 13, 1998.

2- The Everglades marsh system is extremely oligotrophic. Un-impacted interior portions of the Everglades marsh have long-term average water column phosphorus concentrations of approximately 10 ppb or less.

Relevant scientific literature: Gleason et al., 1974b; Gleason et al., 1975a; Millar, 1981; Swift and Nicholas, 1987; Flora et al., 1988; Scheidt et al., 1989; Davis, 1991; Walker, 1991; SFWMD, 1992; Reddy et al., 1993; Richardson et al., 1994; Walker, 1995; McCormick et al., 1996; Walker, 1997a; Richardson et al., 1997; Vaithiyanathan et al., 1997; Stober et al., 1998; McCormick et al., 1999.

Long-term average concentrations of 10 ppb or less have been documented repeatedly throughout the Everglades system, including Loxahatchee National Wildlife Refuge, Water Conservation Area 2 (WCA2), Water Conservation Area 3 (WCA3), and Everglades National Park. These complementary and corroborative data come from several independent studies conducted by different investigators spanning a time-frame of three decades. These data come from several independent analytical laboratories, including South Florida Water Management District (SFWMD), Florida Department of Environmental Protection (FDEP), Duke University, the National Park Service, and the Florida International University Southeast Environmental Research Program (FIU SERP).

Surface water phosphorus concentrations within the Everglades fluctuate naturally with water conditions. Marsh phosphorus concentrations have been shown to vary with water depth, with higher concentration excursions occurring during periods of low water or marsh drying (Walker, 1997a; McCormick et al., 1999). McCormick et al. (1999) reported that occasional high P concentrations at Everglades reference stations can be attributed to difficulty in collecting water samples that are not contaminated by flocculent sediment when water depths are low (a few inches), P released as a result of oxidation of exposed soils, or mobilization of P with fires. This represents recycling within the marsh internal phosphorus pool, as opposed to marsh exposure to additional phosphorus from external sources. In spite of this internal cycling, 10 ppb is a reasonable approximation of long-term average or median phosphorus concentrations at Everglades reference stations.

Some water samples from the Everglades marsh that are analyzed for phosphorus are below the limits of analytical detection. For example, the phosphorus analytical limit is 4 ppb for the SFWMD laboratory and varies across laboratories. In these cases, the low end of the distribution of phosphorus concentration at a sampling location is artificially truncated, and the actual median or average phosphorus concentration at a location would in reality be even lower than the reported median or average.

In a study of nutrient uptake and rates of nutrient deposition in WCA2A from 1973-1974, Gleason et al. (1974b) documented phosphorus gradients downstream of the S-10 structures, with background orthophosphate concentrations of 2 ppb.

During 1974 Gleason et al. (1975a) studied the effect of agricultural runoff on algal communities at 5 wet prairie marsh stations within the Loxahatchee National Wildlife Refuge. The orthophosphate phosphorus concentration reported for all of the 57 water samples collected was less than 2 ppb.

Swift and Nicholas (1987) summarized 1977-1983 water quality throughout LNWR, WCA2A and WCA3A interior marsh sites. They reported mean total phosphate concentrations of 14 ppb for LNWR, 11 ppb for WCA2A and 9 ppb for WCA3A, with a grand mean of 11 ppb.

Swift (1981) summarized average total dissolved phosphate concentration at these same interior marsh sites from 1978-1979. The average total dissolved phosphate concentration at interior marsh sites within LNWR, WCA2A and WCA3A was 2 to 5 ppb.

Walker (1995, figure 1) presented surface water mean TP concentration at water control structures and marsh locations throughout the Everglades system. Mean TP concentration at remote marsh stations away from alligator ponds within Everglades National Park ranged from 5.2 ppb at P-37 to 10.8 ppb at P-35 (statistical summary used for preparation of Figure 1 received from the author). The grand mean of the eight station means was 8.3 ppb.

Grimshaw et al. (1997) reported 8 ppb as the 1994-1995 mean surface water TP concentration at an unenriched slough site within WCA2A.

In a 1991-1996 study of WCA2A sloughs, Vaithiyanathan et al. (1997) found an average water column dissolved phosphate concentration of 5 ppb (n=2557) and total phosphorus (TP) concentration of 9 ppb (n=1659), with individual TP concentration measurements ranging from 2 to 20 ppb.

In a summary of a 1992-1996 nutrient dosing study in WCA2A, Richardson et al. (1997, pages 15-32 and 15-44) reported mean 1993-1996 surface water TP concentrations at 16 locations in the control area ranging from 8.8 ppb to 12.1 ppb, with a grand median of 9.1 ppb and a grand mean of 10.9 ppb.

Walker (website:“http://www2.shore.net/~wwwalker/clearwtr/maps/sld010.htm, 04/04/98) depicted TP in marsh surface water sites and water control structures throughout the Everglades from 1992-1996. Geometric mean TP concentration for 1992-1996 was 10 ppb or less at all 14 marsh stations within LNWR, all 9 marsh stations within ENP, and all 12 marsh stations within WCA2A or WCA3A that are away from sources of phosphorus enrichment.

McCormick et al. (1999) summarized surface water TP at interior marsh locations throughout LNWR, WCA2A, WCA3A, and ENP. The median for each of the eight stations ranged from about 4 to 10 ppb. The lowest median of about 5 ppb (n=100) was for WCA3A station CA3-15.

In 1991 the best available surface water TP data (data source: SFWMD) were used to determine the surface water TP condition that existed from 1979-1988 at water structures discharging into Everglades National Park and at interior marsh stations within Loxahatchee National Wildlife Refuge. These data became the basis for phosphorus limits or levels intended to maintain the water quality condition that existed from 1979-1988 in order to protect the oligotrophic marsh system including the associated plants and animals within the Refuge and the Park. The development of and scientific basis for these water column phosphorus limits or levels is described in SFWMD (1992) and Walker (1997), and is summarized in the next two paragraphs.

Phosphorus limits for inflows to Everglades National Park were derived in 1991. Attaining these concentrations would continue to provide the Park with the quality of water that existed from 1979-1988. These apply to the annual flow-weighted mean TP concentration of inflows composited across the five water delivery structures to Shark River Slough (the S-12 structures and S-333). Although the required phosphorus limits vary from a flow-weighted mean of about 13 ppb during dry years to about 8 ppb during wet years, if attained these limits would provide Shark River Slough a long-term average flow-weighted mean inflow TP concentration of approximately 8 ppb. Phosphorus limits were also established for water delivered to the Taylor Slough and Coastal Basin portion of the Park. Attaining these limits is expected to provide these portions of the Park with a long-term average flow-weighted mean inflow TP concentration of 6 ppb.

In addition, separate marsh water column phosphorus levels were derived in 1991 for Loxahatchee National Wildlife Refuge based on historic data from SFWMD at 14 interior marsh stations. To account for the observed correlation between marsh total phosphorus concentration and water depth (as determined by stage) the phosphorus concentration levels (determined monthly) vary with the average interior water level on the date of sample collection. Although the required phosphorus levels vary from 17 ppb at low water depth to 7 ppb at high water depth, attaining these concentrations would be expected to provide the Refuge with a long-term geometric mean concentration of approximately 7 ppb TP at the 14 interior marsh stations.

3- *Phosphorus is the primary limiting nutrient in the oligotrophic Everglades marsh system.*

Relevant scientific literature: Stewart and Ornes, 1975; Stewart and Ornes, 1983; Swift, 1984; Swift and Nicholas, 1987; Flora et al., 1988; Hall and Rice, 1990; Davis, 1991; Koch and Reddy, 1992; Grimshaw et al., 1993; Vymazal et al., 1994; Craft et al., 1995; Craft and Richardson, 1997; Vymazal and Richardson, 1995; McCormick and O’Dell, 1996; Vaithiyanathan et al., 1997a; Daoust and Childers, 1999.

Investigators have used two approaches to conclude that phosphorus is the limiting nutrient in unenriched portions of the marsh system. The first approach is identifying nutrient ratios within water, periphyton tissue and macrophyte tissue (Swift, 1984; Swift and Nicholas, 1987; Davis, 1991; Koch and Reddy, 1992; Grimshaw et al., 1993; Daoust and Childers, 1999). For example, in a 1991-1996 study of WCA2A sloughs, Vaithiyanathan et al. (1997a) concluded that nutrient ratios in surface water and in the periphyton and macrophyte tissues suggest strong P-limitation in the Everglades sloughs. (Page 5-21).

Daoust and Childers (1999) studied the relationships between tissue nutrient content, species productivity, and species abundance for seven plant species in sawgrass marsh or wet prairies. They found that the dominant plants in both communities (*Cladium jamaicense* in the sawgrass community, and *Eleocharis* spp. and *Sagittaria lancifolia* in the wet prairie) are strongly limited by phosphorus availability. They concluded that although no single environmental factor is responsible for controlling all species that occur, a majority of the plant species within this system are limited by phosphorus availability.

The second approach is nutrient dosing experiments (Stewart and Ornes, 1975; Stewart and Ornes, 1983; Flora et al., 1988; Hall and Rice, 1990; McCormick and O'Dell, 1996). In a 1983-1984 nutrient dosing study in an Everglades National Park wet prairie dominated by *Eleocharis* spp. and *Utricularia* spp. (Flora et al., 1988; Hall and Rice, 1990), one flow-through channel was dosed with phosphate only for one year at an average concentration of 27 ppb while a second channel was dosed with nitrate only at an average of 85 ppb. The background concentrations in the adjacent reference sites averaged 6 ppb phosphate and 11 ppb nitrate. In the phosphate only channel, plant tissue phosphorus was increased, *Utricularia* was eliminated, *Panicum* and *Sagittaria* became the dominant macrophytes, plant biomass was increased, periphyton phosphorus content changed and the native periphyton community was lost. These changes were not observed in the channel dosed with nitrate only or the reference sites. All treatments and the reference site were exposed to the same hydroperiod and water depth.

4- Impacts of phosphorus enrichment: microbial processes.

Relevant scientific literature: Maltby, 1985; Amador et al., 1992; Lean et al., 1992; Amador and Jones, 1993; Koch-Rose et al., 1994; Stober et al., 1996; Stober et al., 1998; McCormick et al., 1999; Newman et al., in press.

McCormick et al. (1999 page 3-13) summarized the importance of microbes in wetland systems as follows: "Wetlands host complex microbial communities including bacteria, fungi, protozoa and viruses. The size and diversity of microbial communities are related directly to the quality and quantity of the resources (i.e., nutrients, energy sources) available in the system. Microbial biomass and activity is highest in habitats where these resources are concentrated, including periphyton mats, plant litter, and surface soils. Microbial processes regulate major nutrient cycles in wetlands and, therefore, play an important role in determining water quality and ecosystem productivity." Microbial populations regulate the decomposition of organic matter and the cycling of nutrients, including carbon, nitrogen, and phosphorus. Increasing water column phosphorus or soil phosphorus has been implicated as cause for the disruption of various microbial processes within the Everglades system. Lean et al. (1992) in an Everglades nutrient threshold research plan, stated that “Sufficient data from the Everglades and other wetland ecosystems exist to indicate that microorganisms (algae, bacteria) and their metabolic influences on organic detrital and soil components are critical to the retention, cycling, and biological impacts of phosphorus. Organisms with the fastest turnover rates respond most rapidly to P enrichments. Their growth rates and composition provide initial indicators of imbalance.” (page 7).

In a nutrient dosing study performed in a wet prairie within Everglades National Park during 1983 and 1984, Maltby (1985) deployed cellulose strips to observe the effects of nutrient loadings on decomposition profiles in the water column and peat. He observed that cellulose decomposition within the water column was accelerated by nitrate and phosphate dosed together and by phosphate alone but not by nitrate alone, and that the decomposition profile increased sharply in the peat within areas where P had been added. He stated that nutrient addition “may elicit marked acceleration of decomposition not only of litter but also of organic matter stored in the sedimentary peat system. It is impossible to be certain that this will not result in further release of nutrients previously fixed by the peat and a progressive instability developed in the ecosystem” (page 457).

In studies of phosphate and phosphorus removal by peat soils from Everglades National Park, Amador et al. (1992), Jones and Amador (1992), and Amador and Jones (1992) found that microbial processes play a role in determining how much phosphorus Everglades peat can store, continued exposure to water containing high P concentrations significantly decreased the available P storage capacity of Everglades soils, these soils have a finite ability to remove and store phosphorus, and P pollution may have a marked, long-term effect on microbial respiration in organic soils with low P content.

Phosphatase enzymes, such as alkaline phosphatase, have been used as a sensitive indicator of phosphorus enrichment in aquatic systems (Jones, 1996; Newman et al., in press). Stober et al. (1998) used alkaline phosphatase activity in surface water as a sensitive indicator of phosphorus condition. During 1995 and 1996 marked gradients were observed throughout the Everglades marsh, with the interior of LNWR and ENP having the highest alkaline phosphatase activity (indicative of a condition void of readily available phosphorus). The area that consistently had the lowest alkaline phosphatase activity (indicating that phosphorus within the water column was in a readily available form) was the northern portion of WCA3A and WCA2A adjacent to canals delivering water of high phosphorus content.

McCormick et al. (1999) summarized the impact of increased P loading to the Everglades on microbial and biogeochemical processes. P loading has been shown to affect the quality and quantity of organic matter, rates of nutrient accumulation, microbial biomass and community composition, and biogeochemical cycling. Moreover, P enrichment has been shown to initiate a series of effects on the cycling of carbon and nitrogen, as well as a shift in the system from an aerobic environment where oxygen is readily available to an anaerobic environment where oxygen is lacking.

5- Impacts of phosphorus enrichment: periphyton community impacts.

Scientific literature describing Everglades periphyton communities, their function and the impacts of phosphorus include the following: Hunt, 1961; Brock, 1970; Gleason and Spackman, 1974; Wilson, 1974; Wood and Maynard, 1974; Gleason et al., 1975b; Swift and Nicholas, 1987; Flora et al., 1988; Hall and Rice, 1989; Belanger et al., 1989; Grimshaw et al., 1993; Raschke, 1993; Browder et al., 1994; Craft and Richardson, 1994; Craft et al., 1995; McCormick et al., 1996; McCormick and O'Dell, 1996; McCormick et al., 1997; Vaithiyanathan et al., 1997; Vaithiyanithan and Richardson, 1998; McCormick et al., 1999.

Periphyton is an important defining characteristic of the Everglades ecosystem.

The smallest but most widely distributed plant community in the Everglades is an assemblage of micro-algae referred to collectively as periphyton. Everglades periphyton generally is comprised of three major divisions or groups: diatoms, blue-green algae and green algae (Browder et al., 1994). Periphyton exhibits three growth forms in the Everglades: benthic (growing on the soil surface), epiphytic (growing attached to rooted vegetation) and floating (growing on the water surface sometimes in association with other floating vegetation such as *Utricularia purpurea*) (McCormick et al., 1999). These periphyton mat communities are found throughout the unimpacted Everglades marsh, especially in open water areas, sloughs and wet prairies. The widespread distribution of floating periphyton mats throughout the Everglades as observed during 1995-1996 is presented by Stober et al. (1998).

The designated use for Class III-A Waters of the Tribe is “preservation of native plants and animals of the natural Everglades ecosystem”. This clearly includes preservation of natural periphyton communities, in so far as periphyton are native plants.

Periphyton provides multiple functions in the marsh ecosystem. These have been summarized by Browder et al. (1994), McCormick et al. (1998) and McCormick et al. (1999). Everglades periphyton: accounts for much of marsh primary productivity in wet prairies and sloughs; provides habitat for aquatic animals such as invertebrates; along with macrophyte detritus, forms the base of the Everglades aquatic food web; is the major source of oxygen for fish and other animal life in sloughs and wet prairies; maintains low water TP concentrations; plays a role in cycling of nitrogen, phosphorus, carbon and oxygen; and affects formation of marl soils.

Periphyton photosynthesis and respiration play an important role in controlling surface water dissolved oxygen concentrations. (Hunt, 1961; Gleason and Spackman, 1974, Wilson, 1974, Belanger et al., 1989; McCormick et al., 1997; Vaithiyanathan et al., 1997).

Vymazal et al. (1994) stated that “Highly calcified periphyton, dominated by blue-green algae, is the primary source of oxygen in open water habitats and for most of the Everglades ecosystem” (page 76).

Vaithiyanathan et al. (1997a) in a 1991-1996 study of WCA2A sloughs found that the dissolved oxygen concentration on the surface of the periphyton mat was substantially higher than the water column concentration, reflecting the intense photosynthetic activity of the *Utricularia*-periphyton complex. They concluded that: periphyton photosynthesis is a major source of oxygen production in Everglades sloughs, periphyton regulate water column TP concentrations, nutrient ratios in surface water and in the periphyton and macrophyte tissues suggest strong P-limitation, and "preservation of the Everglades sloughs is strongly related to the integrity of the periphyton mat" (page 5-22).

Belanger et al. (1989) described a 1985 oxygen budget study in enriched and unenriched marsh habitats with WCA2A. They found strong surface water diurnal oxygen variations in slough and sawgrass areas, with extremely low surface water dissolved oxygen and frequent anoxia in the enriched cattail area. The periphyton mat was the major source of oxygen at the slough site. They stated that pristine slough areas are essential for oxygen production, and loss of these areas due to phosphorus enrichment could have serious ecological consequences, such as lost feeding areas for fishes and birds.

Numerous scientists have stated that periphyton is an integral component of the oligotrophic marsh system. In their external panel peer-review report to FDEP, Hopkinson et al. (1998, page 20) stated that "The periphyton community is a particularly important component of sloughs in the Everglades, and is often associated closely with floating macrophytes (e. g., *Utricularia* spp.) which serve as physical substrata for growth. Periphyton contributes a substantial portion of the primary production in the Everglades and appears to be the primary food resource for many macroinvertebrates. Periphyton may be of higher importance in Everglades food webs than macrophytes because of its high rate of production and turnover. While organic matter derived from sawgrass and other macrophytes is consumed primarily after it dies and becomes the basis of a relatively inefficient detritus-based food web, periphyton is consumed while living, providing a richer, more direct, and probably more efficient, transfer of organic matter and energy to invertebrate and vertebrate consumers. Loss of periphyton or shifts in species composition toward forms that are less palatable to consumers are likely to create a significant change in Everglades food webs".

Vaithiyanathan et al. (1997, page 5-1) summarized the multiple functions of periphyton and concluded that "The integrity of the periphyton mat is crucial to the protection of the Everglades slough community".

Richardson et al. (1997, page 17-28) stated that "Any changes in *Eleocharis* spp. may be the most significant ecological change in the slough community since it is the dominant plant and an important substrate for periphyton."

Grimshaw et al. (1997, page 19) stated that "Periphyton communities are critical structural and functional components of the Florida Everglade wetland ecosystem."

McCormick and Stevenson (1998, page 730) stated that "...the loss of the oligotrophic periphyton assemblage represents a significant ecological change because periphyton represents a habitat and food source for other species as well as an important part of major biogeochemical cycles."

The South Florida Ecosystem Restoration Task Force adopted a series of success indices in order to define ecosystem restoration goals, track ecosystem health, and measure the effectiveness of restoration efforts. The Science Sub-Group of the Task Force (1997) established 14 ecologic or precursor success criteria for ecosystem protection and restoration. These specific success criteria were selected based on several years of collaborative scientific effort, representing the distillation of the best professional judgement of dozens of scientists. One of the adopted ecologic success criteria is “restored natural taxonomic composition of periphyton communities”.

McCormick and O’Dell (1996, page 465) concluded: “Periphyton is an important biological component of the Everglades ecosystem and may represent one of the most sensitive indicators of eutrophication in the marsh. The periphyton assemblage that dominates oligotrophic areas of the Everglades was replaced by a taxonomically distinct assemblage in response to relatively small increases in water column phosphorus concentration above background levels, which ranged between 5 and 10 ug/L in WCA2A during this and previous work (McCormick et al., 1996). Because of its ubiquity and significance to fundamental ecosystem processes (i.e., energy fixation, nutrient cycling, and soils formation) in the Everglades, the native periphyton assemblage represents an important indicator of ecosystem condition, and its loss has several implications for the success of ecosystem restoration and management efforts in this wetland. Most importantly, our findings indicate that restoration measures must reduce and maintain phosphorus concentrations in the marsh close to background levels to preserve the oligotrophic characteristic of the Everglades.”

McCormick et al. (1998) studied periphyton biomass and productivity in WCA2A during 1994-1995. They noted many functions that periphyton communities provide, and that periphyton appears to play a critical role in sequestering phosphorus from the water column and maintaining the oligotrophic status of this wetland. They noted that eutrophication has caused a decline in Everglades periphyton biomass, productivity, and nutrient retention, and a shift in species composition. They hypothesized that functional changes resulting from this decline may affect other biotic and abiotic components of the marsh including changes in the food web, reduced suitability of eutrophic habitats for some native species, and a reduction in the capacity of the marsh to assimilate added phosphorus without causing further biological changes. They stated that (page 206) “...it is increasingly clear that the maintenance of the native periphyton assemblage is essential to the normal functioning of the Everglades and, thus, is critical to the success of efforts to restore and manage this wetland in a sustainable manner.”

Vaithiyanithan and Richardson (1998) studied the biogeochemical characteristics of two WCA-2A sloughs. They noted that the decline in periphyton mat cover reported in parts of the Everglades subjected to eutrophication will result in a decrease in the water column dissolved oxygen concentration and may also lead to other ecosystem changes by enhancing light availability to the slough bottom. They stated that increased light availability may also lead to the establishment of other macrophyte species uncharacteristic of the oligotrophic sloughs. They concluded (page 1449): “Preservation of the Everglades sloughs is thus strongly related to the integrity of the periphyton mat”.

Phosphorus enrichment changes or eliminates the native Everglades periphyton communities.

Increasing water column phosphorus has been repeatedly shown to cause numerous changes to the periphyton community, including changed phosphorus content, changed biomass, loss of native species such as diatoms that are indicators of oligotrophic conditions, or establishment of a different community with changed spatial extent and species composition.

Gleason et al. (1975a) investigated the effect of agricultural runoff on the periphyton communities observed at five Refuge wet prairie marsh sites during the spring of 1974. The two marsh stations in contact with agricultural runoff were distinct from the other stations with respect to diatoms, green algae, blue-green algae, and periphyton biomass and phosphorus content. They stated that the "correlation between high biomass, high phosphorus and close proximity to the peripheral canal suggests that the high biomass and high phosphorus concentrations are probably, in part, a response to higher nutrient concentrations near the rim canal." (page 63).

Swift (1984) reported on water quality and periphyton relationships observed during 1978-1979 throughout Loxahatchee National Wildlife Refuge and WCAs 2A and 3A. He found that periphyton growth on glass slides was significantly affected by site differences in marsh water major ion content, pH, alkalinity and phosphorus concentration. Marsh water TP was the controlling factor regulating periphyton growth. Elevated water TP increased periphyton biomass, increased periphyton phosphorus content, and altered community species composition toward pollution-tolerant species.

In an analysis of periphyton data collected by Swift from 1978-1983 in WCA2A, WCA3A, and WCA3B, Grimshaw et al. (1993) found strong statistically significant correlations between mean dissolved phosphorus concentrations in the marsh water column and the mean phosphorus content and mean relative abundance of eutrophic algae in periphyton communities within WCA2A. They also found statistically strong significant correlations between total, dissolved and inorganic phosphorus in the water column with the mean phosphorus content of periphyton communities when WCA3A and WCA3B were included.

A 1983-1984 nutrient dosing study in an Everglades National Park wet prairie (Flora et al., 1988; Hall and Rice, 1990) documented changes in the algal community in response to phosphorus enrichment. An average addition of 14 ppb phosphate over a 63-day period resulted in the elimination of the native periphyton mat, which continued to remain at the adjacent reference sites that were not subjected to nutrient addition. Continued dosing caused an increase in periphyton biomass and a succession of changes in periphyton community composition. The average background phosphate concentration for the study duration was 6 ppb.

Raschke (1993) reported the results of a 1990-1991 study of diatom community response along a soil phosphorus gradient within Everglades National Park downstream of water control structure S-12C. A strong correlation was found between sediment phosphorus concentration and diatom community mean diversity. He concluded that the periphyton diatom community was responding to sediment phosphorus increases as evidenced by changes in the number of diatom species, mean diversity, and occurrence of periphyton species that are indicators of phosphorus enrichment. The TP concentration of water discharged to the marsh through the S-12C structure had an annual median ranging from 7 ppb to 14 ppb during the previous 12 years. From 1978 to 1989 water TP at S-12C had increased from about 7 ppb to 12 ppb.

McCormick and O'Dell (1996) quantified periphyton responses to phosphorus in WCA2A. During 1995 they sampled transect stations along a phosphorus gradient while simultaneously performing a phosphorus enrichment experiment in a pristine slough. Phosphorus content of periphyton mats was strongly correlated with surface water TP, and periphyton mat species composition changed along the phosphorus gradient. They concluded that these changes were caused by phosphorus concentrations. McCormick and O'Dell also stated that:

> "The cyanobacterial-diatom assemblage characteristic of oligotrophic conditions in the Everglades was replaced by filamentous green algae at marsh stations where water-column phosphorus concentrations exceeded 10 ug/L TP." (page 464).
>
> "Our study provides strong experimental evidence to support previous evidence that relatively small increases in marsh phosphorus concentration are associated with substantial changes in the Everglades periphyton assemblage." (page 464).
>
> "The loss of the calcareous cyanobacterial mat in response to phosphorus enrichment has ramifications for several ecosystem processes in the Everglades. This mat can account for more than 50% of the vegetative biomass in sloughs (Wood and Maynard, 1974, Browder, et al. 1982) and represents an important substrate for invertebrate populations in the marsh (Reark, 1961)." (page 465).

McCormick and O'Dell also mentioned: the role that this periphyton mat plays in maintaining surface water oxygen in the marsh, with mat absence associated with protracted periods of low dissolved oxygen or anoxia; its role in affecting availability of phosphorus and nitrogen; and its role in forming marl soils in portions of the Everglades. They stated that changes in the periphyton assemblage may have important implications for the Everglades food web.

Pan et al. (1997, page 2-13) sampled 32 sloughs in WCA2A along a phosphorus enrichment gradient during 1995 and found that diatom species composition, periphyton biomass, and physico-chemical structure of periphyton assemblages all shifted relative to native assemblages as P loading increased. "Changes in periphyton assemblages along the P gradients were evident at the community, functional, and population levels". They also stated that changes in algal species composition are much more sensitive and predictable than algal biomass (chlorophyll *a* and biovolume) in response to P loading. Cluster analysis of data separated the 32 sites along the P gradient into 3 groups based on diatom species composition. Periphyton biomass and ash weight decreased and the TP content of periphyton increased as water column TP increased from group I (surface water TP mean 11.54 ppb) to group II (surface water TP mean 16.37 ppb).

McCormick and Stevenson (1998) reported data from an experiment in which several different concentrations of phosphate were added to nutrient dosing flumes as described in Richardson et al. (1994). They stated that calcareous periphyton was reduced in waters averaging 5 ug/l soluble reactive phosphorus (SRP) above the background concentration of about 4 ug/L SRP. They noted that the observed periphyton mat cover varied over time taxonomically and chemically, and the common characteristic of the phosphorus environment in which the calcareous mat did not exist was that SRP was at least 5 ug/L greater than the concentration in the control treatment.

In their 1999 Everglades Interim Report, SFWMD (McCormick et al., 1999) found that controlled dosing studies combined with sampling along marsh phosphorus gradients in WCA-2A indicate that periphyton species changes begin to occur at water column total phosphorus concentrations of about 10 ppb.

6- Impacts of phosphorus enrichment: water column dissolved oxygen.

Relevant scientific literature: Hunt, 1961; Gleason and Spackman, 1974; Gleason et al., 1975a; McPherson et al., 1976; Scheidt et al., 1985; Belanger and Platko, 1986; Belanger et al., 1989; McCormick et al., 1997.

Dissolved oxygen in pristine Everglades wet prairie and slough communities often exhibits a strong diel cycle, with concentration at a particular location ranging from 0 mg/l in early morning to over 12 mg/l in late afternoon. In contrast, oxygen levels in nutrient-rich locations within WCA2A have been shown to often be undetectable and rarely exceed 2 mg/l, with protracted periods of oxygen depletion. Although wetland plant and animal species are well adapted to the natural diel cycle of anoxia that often characterizes pristine marsh ecosystems, it is improbable that many native Everglades fish species are tolerant of prolonged oxygen depletion.

McCormick et al. (1997) summarized marsh diel dissolved oxygen data at minimally nutrient-impacted sites (reference sites) in WCA1, WCA2A, and WCA3A and at a phosphorus-impacted site in WCA2A. They found that all reference sites were characterized by a strong diel variation in water column oxygen (0-12 mg/L) while oxygen concentration at the phosphorus-impacted site rarely exceeded 2 mg/L and were often undetectable. Rates of gross primary productivity and aerobic respiration were higher, with average P/R ratios near unity (1.0) at reference sites, as compared to the enriched site (P/R<0.5). Nutrient enrichment was associated with reduced primary productivity, a shift towards increasing community heterotrophy and protracted periods of oxygen depletion. They also state that the "intense photosynthetic activity of the periphyton-*Utricularia* mats represents the major source of aquatic O_2 production in the Everglades,..."(page 124) and the "loss of the native periphyton-*Utricularia* mat from enriched sloughs corresponds with a shift towards a heterotrophic system (P/R<1) and prolonged periods of O_2 depletion (<2 mg/L) in the water column." (page 127).

7- Impacts of phosphorus enrichment: soil.

Relevant scientific literature: Koch, 1991; Reddy et al., 1991; Koch and Reddy, 1992; Jones and Amador, 1992; Reddy et al., 1993; Craft and Richardson, 1993; Debusk et al., 1994; Qualls and Richardson, 1995; Doren et al., 1996; Walker and Kadlec, 1996; Newman et al., 1997; Craft and Richardson, 1997; Richardson et al., 1997; Vaithiyanithan and Richardson, 1997; Stober et al., 1998; Reddy et al., 1998.

Increasing water column phosphorus concentration over sufficient duration has increased

Everglades soil phosphorus concentrations. Soil TP gradients have been documented throughout the Everglades system with the highest concentrations observed at soils downstream of structures discharging high phosphorus water. This soil enrichment phenomenon has been documented within:

LNWR- [Richardson et al., 1990; Doren et al., 1996; Newman et al., 1997; Stober et al., 1998]; *WCA2A*- [Koch, 1991; Reddy et al., 1991; Koch and Reddy, 1992; Craft and Richardson, 1993; Debusk et al., 1994; Qualls and Richardson, 1995; Doren et al., 1996; Craft and Richardson, 1997; Richardson et al., 1997; Craft and Richardson, 1998; Vaithiyanithan and Richardson, 1997; Stober et al., 1998)]; WCA3A- [Doren et al., 1996; Stober et al., 1998]; and ENP- [Raschke, 1993; Doren et al., 1996; Stober et al., 1998].

Craft and Richardson (1998) studied peat soil accretion and accumulation throughout the Everglades. They found that unenriched areas of the Everglades possess some of the lowest rates of P accumulation of peatlands in North America. In enriched areas of WCA2A, phosphorus accumulation was eight times higher and soil accretion was three to five times higher than in unenriched areas. They stated that even small anthropogenic P loadings may alter organic soil accretion and nutrient accumulation. “Successful restoration of the Everglades will have to include the elimination of anthropogenic nutrient loadings to limit the P enrichment zone from expanding into existing unenriched interior areas and areas downstream of WCA2A.” (abstract)

Richardson et al. (1997) noted that the most nutrient-impacted area of the Everglades is WCA2A, with 51% of the area showing increased soil P (page 14-3).

Several investigators have documented a correlation between elevated soil TP and the expansion of cattail into sawgrass or wet prairies (see below). Walker and Kadlec (1996) developed a mass balance model to simulate phosphorus concentrations in waters and soils downstream of Everglades Stormwater Treatment Areas. They proposed a soil threshold phosphorus criteria of 540 to 990 milligrams per kilogram (mg/kg) as a surrogate for impacts on ecosystem components which respond primarily to soil P, such as cattail expansion.

8- Impacts of phosphorus enrichment: macrophyte impacts.

Relevant scientific literature: Steward and Ornes, 1975a; Steward and Ornes, 1975b; Gleason et al., 1975b; Davis, 1989; Flora et al., 1988; Walker et al., 1989; Richardson et al., 1990; Davis, 1991; Koch, 1992; Urban et al., 1993; Rutchey and Vilchek, 1994; Davis, 1994; DeBusk et al., 1994; Jensen et al., 1995; Doren et al., 1996; Walker and Kadlec, 1996; Craft and Richardson, 1997; Newman et al., 1997; Stewart et al., 1997; Stober et al., 1998; Daoust and Childers, 1999.

The oligotrophic Everglades marsh system contains a mosaic of macrophyte communities, such as sloughs, wet prairies and sawgrass marshes, all of which are adapted to low nutrient conditions. This mosaic is an important defining characteristic of the Everglades. Wet prairies and sloughs in particular provide critical habitat for animals and provide cover, nesting, and feeding sites for all animal groups. The wet prairie/slough habitat is also the major feeding area in the Everglades for both wintering and nesting wading birds, especially during the dry season when fish concentrations provide food for their nestlings (Gunderson and Loftus, 1993). An important characteristic of unimpacted wet prairies and sloughs is their diversity and the large number of native plant species (Olmstead et al, 1980; Olmstead and Loope, 1984; Goodrick, 1974; Gunderson and Loftus, 1993). Multiple factors are responsible for the alteration and maintenance of plant community structure in the Everglades, including nutrients, fire, disturbance, and hydroperiod. Elevated water phosphorus concentrations or elevated soil phosphorus concentrations in the Everglades are associated with elimination of submerged vegetation species including the *Utricularia*-periphyton complex and expansion of nutrient-tolerant macrophytes such as cattail or *Sagittaria* into areas previously dominated by sawgrass, sloughs or wet prairies.

Ornes and Steward (1973) added phosphorus (10 milligrams per liter) and potassium to a WCA3B sawgrass marsh for 22 weeks in order to simulate sewage effluent discharge. They reported algal blooms and macrophyte community changes, including elimination of native submerged aquatic vegetation such as *Utricularia* spp.

Gleason et al. (1975b) investigated the effect of agricultural runoff on the Everglades marsh. They looked at the effect of nutrient inputs on biomass and phosphorus concentrations in cattail and sawgrass downstream of the S-10 structures within WCA2A. They noted that the two species respond differently to added nutrients and concluded that “The differential growth response of the two plant species to phosphorus enrichment offers an explanation for the invasion of sawgrass by cattail in Area 2A below the S-10 structures.” (page 115).

A 1983-1984 nutrient dosing study in an Everglades National Park wet prairie (Flora et al., 1988; Hall and Rice, 1990) documented changes in periphyton and emergent plant communities in response to phosphorus enrichment. Within one year of phosphate addition at an average concentration of 27 ppb the native *Utricularia*-periphyton assemblage had been eliminated and the open water marsh which was previously dominated by *Eleocharis* spp. became dominated by dense emergent stands of *Sagittaria* and *Panicum.* Plant tissue concentrations, biomass and community composition were all changed within several months. The background phosphate concentration for the study duration was 6 ppb.

From 1985 to 1990, Richardson et al. (1990) conducted a study of vegetation and habitats within Loxahatchee National Wildlife Refuge and their relationships to water quality, quantity and hydroperiod. Multi-variate analysis indicated that soil phosphorus rather than hydroperiod was the primary factor controlling cattail distribution in the Refuge.

Craft and Richardson (1997) studied relationships between soil nutrients and plant species (sawgrass, cattail and other species) in WCA2A during 1989. They found that plant species composition along a P enrichment gradient was highly correlated with soil P content, but not with sodium or calcium. They concluded that “P, not Na, is the primary determinant of the observed changes in macrophyte community composition in enriched areas of WCA2A” (page 231) and “These findings support previous studies, which indicate that cattail encroachment into sawgrass communities in northern WCA2A is caused, to a large extent, by P enrichment of the peat (Urban et al., 1993; DeBusk et al., 1994)” (page 232).

Newman et al. (1997) observed the spatial distribution of soil nutrients and plant species in Loxahatchee National Wildlife Refuge during 1991. Of the 90 sites sampled, 66 sites consisted of sloughs and sawgrass, while 24 were either cattail-dominated or had a significant cattail presence. "These 24 cattail sites were closest to the nutrient inflow areas and had the highest soil nutrient concentrations" (page 1275).

From 1991-1993 Newman et al., (1996) studied the effects of nutrients (P and nitrate) and hydroperiod on cattail, sawgrass and *Eleocharis* in controlled outdoor tanks. Their high treatment consisted of nutrient additions to adjust ambient marsh water concentrations to 100 ppb phosphorus and 1 milligram per liter (1000 ppb) nitrogen. Their low treatment increased the ambient P concentration to 50 ppb with no adjustment made to the nitrate concentration. They observed that cattail was enhanced by both elevated nutrient concentration and increased depth of flooding. Increased nutrients led to a significant dominance of cattail over sawgrass and *Eleocharis*, and this dominance was further enhanced by increased flooding levels. They noted that the interaction between nutrients and hydrology is important, and that restoration of Everglades vegetation requires more natural hydroperiods as well as reduced nutrient inputs.

Grimshaw et al. (1997) compared the relative net primary productivity of periphyton communities within WCA2A under emergent plant canopies typical of enriched and unenriched Everglades habitats. The amount of photosynthetically active radiation reaching periphyton communities was reduced only by 35% in sawgrass habitats but was reduced by 85% or more in dense stands of cattail. The net primary productivity of periphyton in nutrient-rich cattail habitats was severely reduced (by about 80%) as compared to open water habitats. The plant shading effect suppressed periphyton photosynthesis.

A 1990-1996 study of WCA2A found a significant positive correlation between cattail and *Sagittaria* and several indicators of increased P, including soil TP (Richardson et al., 1997, page 14-28). They also found a significant negative correlation between sawgrass and soil TP as well as surface water TP. As phosphorus enrichment increased, the number of macrophyte species typical of the oligotrophic area showed a progressive decline, and nearly half of the macrophyte species widespread throughout the unenriched Everglades were absent from the two most enriched sites (page 14-44).

In a nutrient dosing study in WCA2A, Richardson et al (1997, chapter 17) found that: *Utricularia* is generally not found at TP concentrations greater than 30 ppb; maximum densities of *Eleocharis elongata* were reached in the un-walled control channel where TP averaged close to 10 ppb; a significant relationship was found between *Eleocharis cellulosa* and surface water TP concentration with a significant decrease in density above 30 ppb after four years of P dosing; "elevated TP concentrations above 20 ug/L demonstrates direct or indirect effects of elevated PO4 concentrations, which inhibits the survival of *U. purpurea*." (Page 17-27); "Any changes in *Eleocharis* spp. may be the most significant ecological change in the slough community since it is the dominant plant and an important substrate for periphyton" (Page 17-28).

Walker and Kadlec (1996) developed a mass balance model to simulate phosphorus concentrations in waters and soils downstream of Everglades Stormwater Treatment Areas. They proposed a 0 to 10 centimeter soil threshold phosphorus criteria of 540 to 990 milligrams per kilogram (mg/kg) as a surrogate for impacts on ecosystem components which respond primarily to soil P, such as cattail expansion.

Wu et al. (1997) developed a probability model to test the effect of water depth and soil TP concentration on the cattail invasion of WCA2A. They proposed a soil TP concentration of 650 milligrams per kilogram as a threshold above which accelerated cattail invasion occurs.

9- Impacts of phosphorus enrichment: food web changes and loss of wading bird foraging habitat.

Relevant scientific literature: Bancroft et al., 1992; Hoffman, 1994; Gunderson and Loftus, 1993; Fleming et al., 1994; Turner et al., in press.

Shallow, open water areas with low to moderate density emergent macrophytes are the preferred foraging habitat for Everglades wading birds. Bancroft et al. (1992) documented the importance of the Water Conservation Areas as foraging habitat for the wood stork, an endangered species. They noted that the habitats used by wood storks generally are drying ponds, wet prairies, and sloughs. The storks feed in these more open areas, where their foraging habitats are least affected by submerged or emergent vegetation.

Hoffman et al. (1994) studied wading bird foraging habitat in the Water Conservation Areas from 1985-1988. They reported that great egrets, great blue herons, white ibises and wood storks all avoided dense grass habitats, defined as continuous coverage of sawgrass, cattail, sedges, reeds or grasses. They noted the importance of perpetuating slough and wet prairie habitats for wading birds. Conversion of these open water or wet prairie plant communities to dense stands of emergent nutrient-tolerant macrophyte species such as cattail constitutes a loss of preferred wading bird foraging habitat.

Turner et al. (in press) reported that the natural condition in the Everglades is one of high periphyton standing stock, but low standing stocks of invertebrates and fish. They also reported that: enriched areas have a higher fish standing stock; “The data we present also suggest the possibility of a trophic cascade that may lead to unanticipated changes in community structure where nutrients are added” (page 20); and “Anthropogenic eutrophication in Everglades marshes will lead to the loss of distinctive ecosystem features.” (abstract).

Gunderson and Loftus (1993) presented food web diagrams for known trophic relationships among the characteristic Everglades animals with a macrophyte base (*Utricularia, Eleocharis*, sawgrass, beak rush, and *Panicum*) and a detritus/periphyton base. Macrophytes, periphyton and detritus are at the bottom or base of both food webs. Invertebrates, insects, fish, birds, amphibians, reptiles and mammals are found at higher trophic levels. Everglades phosphorus enrichment has been shown to change detrital formation processes, and change periphyton and macrophyte communities. Such changes at the food web base can be expected to change inter-relationships among species across higher trophic levels.

CONCLUSION

The Tribe has defined Class III-A waters within the Federal Reservation as "Those Tribal water bodies which are used for fishing, frogging, recreation (including airboating), and the propagation and maintenance of a healthy, well-balanced population of fish and other aquatic life and wildlife. These waters have been primarily designated for preservation of native plants and animals of the natural Everglades ecosystem." (page 19 of the Final Miccosukee Environmental Protection Code, Subtitle B, dated December 19, 1997). In the section on water quality standards for nutrients the Tribe states: “Nutrients: In no case shall nutrient concentrations of Tribal Class I or Class III-A surface waters be altered so as to cause an imbalance in natural populations of aquatic flora or fauna.” (page 9).

There is no single scientific study or publication that provides a complete synthesis of the data and information regarding background Everglades phosphorus conditions and phosphorus enrichment impacts. Rather, a great number of scientific publications and efforts provide relevant pieces of information, which when considered collectively, provide a generally consistent and more complete understanding.

The scientific information summarized above has been independently developed by different scientists, in different studies, over different time frames, using different methods, in different areas of the Everglades system. These scientists include consultants and individuals employed by but not limited to SFWMD, USDA, NPS, USFWS, USEPA, USGS, Florida International University, University of Florida, and Duke University. Generally, the results are complementary and corroborative. There is no question that phosphorus enrichment in the Everglades causes direct and indirect changes within this marsh ecosystem. Taken as a whole, these collective changes must be reasonably viewed as systemic. That is, phosphorus enrichment at a marsh location changes not only surface water phosphorus concentrations, but eventually also impacts plants and animals at that location. The natural structure and function of the Everglades system becomes lost. Such changes are directly contrary to the intent of the Class III-A designated use adopted by the Tribe.

The nutrient dosing studies and observational studies reviewed indicate that total phosphorus concentrations above 10 ppb have been shown to cause impacts to native Everglades periphyton and macrophytes such as *Utricularia purpurea* that are adapted to low phosphorus conditions. The best available scientific information indicates that average TP concentrations greater than 10 ppb, in general, can be expected to be inadequate for long-term protection of the designated use defined by the Tribe. Therefore the Tribe’s adopted numeric phosphorus criterion of 10 ppb is not overly protective.

The currently available data and information also indicates that the Tribe’s adopted numeric phosphorus criterion of 10 ppb is protective of the Class III-A designated use. While in certain portions of the Everglades system, long-term phosphorus concentrations are less than 10 ppb, the scientific information reviewed did not demonstrate that a numeric phosphorus criterion of 10 ppb would not be protective of the Class III-A designated use. For example, as summarized by Walker (1995), the long-term phosphorus concentration at wet prairie marsh station P-37 with Everglades National Park was 5.2 ppb. For WCA-3A, the SFWMD identified a total phosphorus median concentration of 5 ppb of phosphorus (McCormick et al., 1999). However, EPA’s review identified no currently available published scientific information documenting changes in the natural flora or fauna of the Everglades System as a result of changes in the phosphorus concentrations in the 5 ppb to 10 ppb range. If new data or scientific information are presented that demonstrate that 10 ppb is not protective of the Class III-A designated use, then the Tribe should revise the 10 ppb standard accordingly.

In conclusion, the Miccosukee Tribe's 10 ppb criterion for phosphorus meets the requirements of 40 CFR §131.11 as it is protective of the Class III-A designated use and review of available data shows that this value is scientifically defensible.

APPENDIX B

EVERGLADES NUTRIENT-RELEVANT REFERENCES

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