Technical Manual for Phosphorus Evaluations

N.J.A.C. 7:9B-1.14(c)

For

NJPDES Discharge to Surface Water Permits

March 2003

New Jersey Department of Environmental Protection
Division of Water Quality

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Foreword

The New Jersey Department of Environmental Protection is taking steps to fully implement the numeric water quality criteria for total phosphorus as necessary to insure that surface water quality standards (N.J.A.C. 7:9B) are achieved.

This guidance manual is for use by NJPDES Discharge to Surface Water (DSW) Permittees, consultants and other interested parties who may be conducting a limiting nutrient analysis and a "render unsuitable for uses" analysis for total phosphorus, when offered these options as part of a compliance schedule contained in a Final NJPDES DSW Permit. The guidance provided herein is in addition to any other guidance or requirements for NJPDES DSW renewal permits provided in the NJPDES regulations at N.J.A.C. 7:14A. New dischargers, if choosing to conduct these analysis, must complete the analysis and submit to the Department as part of their NJPDES application for discharge, as a compliance schedule for phosphorus will not be contained in a permit for a new discharger.

To the extent feasible, the Department supports efforts by dischargers on common waterbodies to coordinate their efforts and resources when conducting these analyses.

This guidance manual is intended to address only the optional phosphorus evaluations that are specified in applicable NJPDES permits. This guidance does not address the studies necessary to develop or implement site-specific water quality criteria pursuant to N.J.A.C. 7:9B-1.5(g)3, or other evaluations a permittee may elect to pursue outside the scope of the permit, including the studies and modeling analyses necessary to develop a third party TMDL (total max daily load).

In addition, and regardless of the status or results of any optional studies undertaken in accordance with this guidance, if the Department in a future action adopts a TMDL for total phosphorus for the receiving water of a subject discharger, the Department will develop and propose a draft NJPDES permit consistent with any wasteload allocation derived from the TMDL.

Please note that any data submitted to the Department in relation to the phosphorus evaluation study shall be submitted in the format specified at www.state.nj.us/dep/dsr/watershed/datasolicitation.htm, and may be utilized by the Department for evaluation of waterbodies in the development of the 303(d) Impaired Waterbody List.

PART 1:

OVERVIEW

Purpose of this document

This manual provides the Department's technical guidance for conducting certain evaluations concerning total phosphorus (TP). These analyses are in accordance with the allowable demonstrations provided for in the Surface Water Quality Standards (SWQS) at N.J.A.C. 7:9(B)-1.14(c) to demonstrate whether or not TP is the limiting nutrient and whether or not TP otherwise renders the waters unsuitable for the designated uses. The results of such demonstrations shall be submitted to the Department for a final determination of the applicability of the TP stream criteria and a Water Quality Based Effluent Limitation (WQBEL) in accordance with the compliance schedule provided in a final NJPDES discharge permit. This document also describes the thresholds the Department will use for making the limiting nutrient and "render unsuitable" determinations, based on the data submitted by the permittees.

SWQS for Phosphorus

The New Jersey Surface Water Quality Standards (SWQS) include both numeric and narrative water quality criteria for Total Phosphorus (N.J.A.C. 7:9B-1.14(c)). In FW2 freshwater lakes and streams, the SWQS state:

a) Lakes: Phosphorus as total P shall not exceed 0.05 (mg/L) in any lake, pond or reservoir, or in a tributary at the point where it enters such bodies or water, except where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3.

b) Streams: Except as necessary to satisfy the more stringent criteria in the paragraph above or where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3, phosphorus as total P shall not exceed 0.1 (mg/L) in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.

In addition, at N.J.A.C. 7:9B-1.5(g)2, the SWQS state:

- Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, abnormal diurnal fluctuations in dissolved oxygen or pH, changes to the composition of aquatic ecosystems, or otherwise render the waters unsuitable for the designated uses.

- The Department shall establish water quality based effluent limits for nutrients, in addition to or more stringent than, the effluent standard in N.J.A.C. 7:9-5.7, as necessary to meet water quality criteria.

- Activities resulting in the non-point discharge of nutrients shall implement the best management practices determined by the Department to be necessary to protect the existing or designated uses.

Process

As shown on the flow chart on page 7, a permittee, if they elect to do so, might need to conduct several types of assessments to provide information to the Department relative to the applicability of the Water Quality Based Effluent Limitation (WQBEL) derived from the 0.1 mg/L TP stream criterion contained in the Surface Water Quality Standards (SWQS) (N.J.A.C. 7:9B). Please note that this figure does not address other possible options which may be pursued outside the scope of the subject permit. Also note that these evaluations would not apply if the WQBEL contained in a permit was based upon the 0.05 mg/L lakes criteria.

The first task in a phosphorus evaluation demonstration is to determine the spatial extent of the monitoring and assessment required. For purposes of this phosphorus evaluation manual, spatial extent is defined as the length of the waterbody segment using the methodology included in the 2002 303(d) Impaired Waterbody List. This list, including segment descriptions, may be accessed at: www.state.nj.us/dep/dsr/watershed/integratedlist/integratedlist-report.pdf select the link in the left column, "Integrated Water Quality Monitoring and Assessment Methods Report." The description of the spatial extent method begins on page 34 of 81. For waterways that are not contained in the 2002 303(d) Impaired Waterbody List, the spatial extent shall be determined in conjunction with the Department using the same methodology as used in the 2002 303(d) Impaired Waterbody List.

- Should the spatial extent of the segment include or terminate at a downstream lake or impoundment, additional sampling must be conducted at the point where the tributary reaches the lake or impoundment. Phosphorus levels in excess of 0.05 mg/L at this point will prevent the use of this phosphorus evaluation manual for any additional assessments (as the SWQS do not allow for demonstrations for lakes) and the WQBEL is applicable. Please note that for the purpose of this assessment and in accordance with N.J.A.C. 7:9(B)1.5(d)8, "a waterway or waterbody from which raw water is transferred to another waterway or waterbody shall be treated as a tributary to the waterway or waterbody receiving the transferred water." In addition, the Department may require or allow the use of a hydraulic analysis of the waterbody to determine whether the waterbody behaves in a manner typical of a lake, consistent with the definition of a "Lake, pond, or reservoir" (N.J.A.C. 7:9-1.4). A waterbody more than 2 acres in surface area will be considered to be a lake unless it can be demonstrated through a hydraulic analysis of the waterbody that it does not behave in the manner typical of a lake or impoundment. A waterbody 2 acres or less in surface area will not be considered a lake or impoundment, although the Department may require on a case by case basis a hydraulic analysis of the waterbody to verify that it does not behave in the manner typical of a lake or impoundment. For the purpose of determining surface area, the Department's published shapefile for lakes may be used: NJDEP Statewide Lakes (Shapefile) with Name Attributes (from 95/97 Land Use/Land Cover) in New Jersey, published 7/13/2001 by NJDEP - Bureau of Freshwater and Biological Monitoring, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njlakes.zip.

If there are no lakes or impoundments (as defined above) within the spatial extent, or if the sampling at the confluence of the tributary to the lake or impoundment (or the point of diversion) shows phosphorus levels are less than 0.05 mg/l, then the permittee may proceed to the next level of assessment, to determine whether or not phosphorus is the limiting nutrient and whether or not total phosphorus does not otherwise render the waters unsuitable for designated uses.

Please note: A Quality Assurance/Work Plan, descriptive of the proposed monitoring program, must be submitted to the Department and be approved prior to commencement of any monitoring. Only monitoring conducted in accordance with an approved workplan will be considered. In addition, the submitted workplan must address all areas of analysis, as identified herein. For submission of completed workplans, or guidance in designing a detailed workplan, please contact the Department's Division of Water Quality, Bureaus of Point Source Permitting.

After the permittee has obtained the Department's written concurrence with their proposed workplan, sampling and assessment may commence. Completed studies, analysis and all associated data should be submitted to the NJDEP, Division of Water Quality, Bureaus of Point Source Permitting. The Department will review the submittal and make a determination that one of the following applies:

a) The information submitted is incomplete/incorrect and additional information is needed;

b) The information submitted supports the allowable demonstrations under N.J.A.C. 7:9(B)1.14(c), the 0.1mg/l water quality criteria for phosphorus is not applicable, and the Department will consider a major modification of the NJPDES permit to remove the TP limitation; or

c) The information submitted does not support the demonstrations under N.J.A.C. 7:9(B)1.14(c), the 0.1 mg/l water quality criteria limit for phosphorus is applicable, and the Department will confirm that the WQBEL compliance schedule contained in the previously issued NJPDES permit is applicable and effective, absent any other analysis.

Even in the event the Department determines it is appropriate, as a result of the studies described herein, to remove the current WQBEL for TP, the permit may be revised in a future permit action to incorporate a new or revised WQBEL based on a waste load allocation established through a TMDL. The Department reserves the right to modify the subject NJPDES permit at any time to reflect current rules, regulations, policies or establishment of a TMDL and such an action may result in an equivalent or more stringent phosphorus limitation.

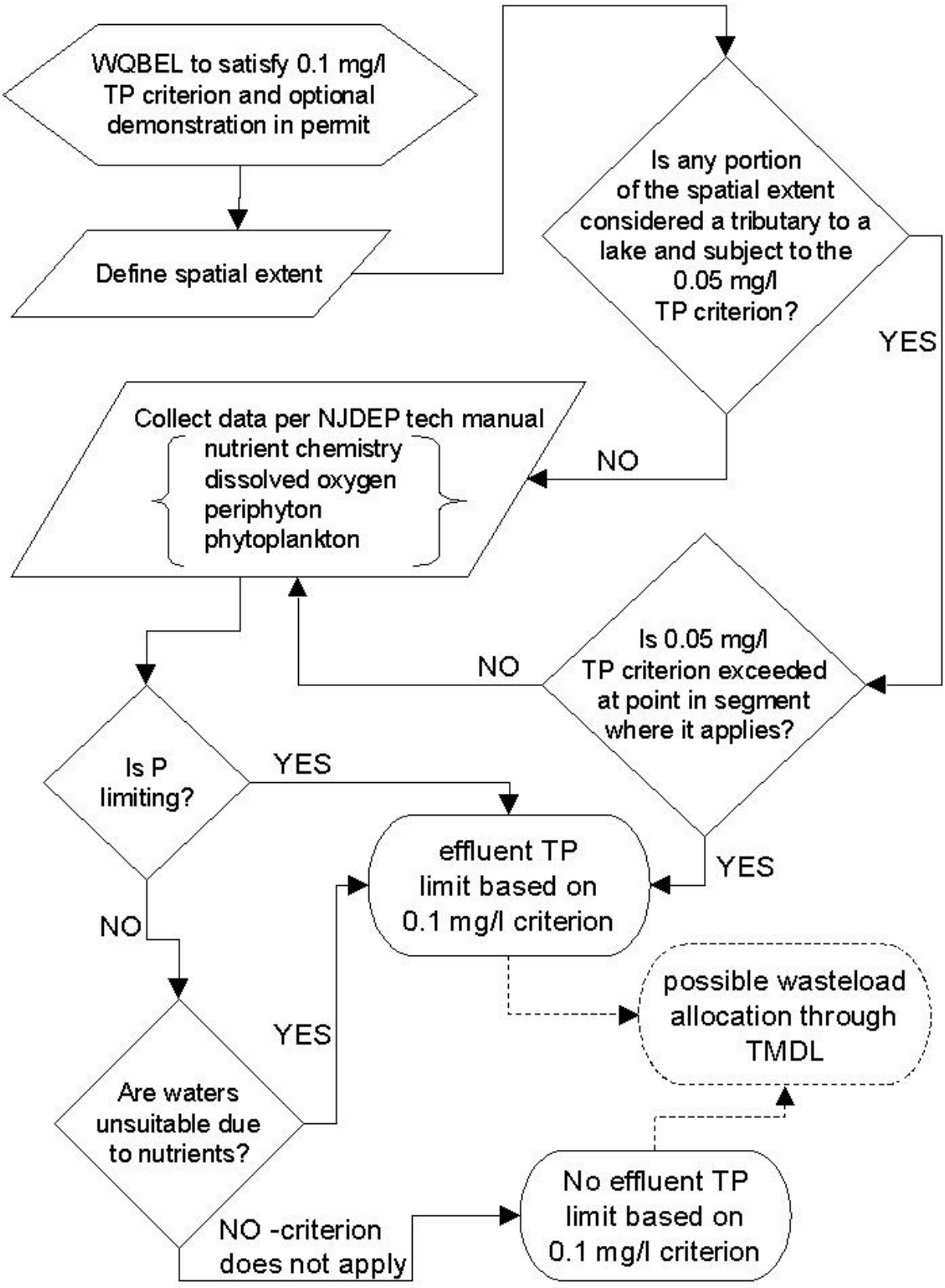


Figure 1 NJPDES Phosphorus Evaluations

Part 2:

Monitoring and Workplan Requirements for Limiting Nutrient Analysis Determination

The limiting nutrient concept refers to the reduction of the growth rate of primary producers due to the limited supply of one or more of its required nutrients. Primary producers are those organisms that convert light to energy and thereby form the base of the food web, primarily algae and plants. Biologically-available nitrogen includes dissolved nitrite, nitrate and ammonia. The biologically-available form of phosphorus is dissolved reactive phosphorus. Two properties of primary producers make it possible to use available nutrients in the water column to evaluate the limiting nutrient:

1. Algal cells only require a small concentration of biologically-available phosphorus to maintain their maximum growth rate. If the concentration of biologically-available phosphorus is 0.05 mg/l or greater, then growth is limited by some factor(s) other than phosphorus.
2. Algal cells require nitrogen and phosphorus in relatively fixed proportions. If there is less available nitrogen than phosphorus relative to the algal stoichiometric requirements, then it is not possible for phosphorus to be limiting growth. If the ratio of biologically-available nitrogen to biologically-available phosphorus is 5 or less, then phosphorus limitation can be ruled out.

1. Workplan Requirements - Limiting Nutrient Analysis

The focus of the following monitoring protocol is to apply the results of available nutrient concentrations in the water column and/or algal stimulation assays to evaluate the limiting nutrient. The monitoring protocol includes conditions, frequency, sites, and number of data points and parameters. This monitoring protocol will also require the collection of chlorophyll a data for use in the biomass measurement of phytoplankton. The protocol for collecting attached algae or periphyton is included later in this document.

Study Area Delineation: The delineation of the study area is defined by the methodology used in the 2002 303(d) Impaired Waterbody List. The focus must be directed to investigating impacts of phosphorus on the segment in which the discharge is located.

MonitoringPeriod/Conditions: normal, summer flow conditions (May 1 through September 30), and low flow conditions. The goal should be to sample during the lowest flows possible under the prevailing conditions.

Duration: Five months (May through September), during which a minimum of twenty (20) samples per station must be collected over the monitoring period.

Maps and Figures: A listing of all monitoring sites, with map showing locations, must be provided in the Quality Assurance/Work Plan with associated GPS information.

Parameters to be analyzed: Flow, ammonia, dissolved nitrite and nitrate, total phosphorus, total dissolved phosphorus, dissolved reactive phosphorus, dissolved oxygen, chlorophyll a, turbidity, total suspended solids, and total recoverable iron (particulate fractions of phosphorus from, for example, bank erosion, are often bound to iron).

Number of monitoring stations: Sampling sites must be selected based on the hydrodynamic characteristics of the receiving waters; specifically, they must be located in pool areas with lower velocity than that of the main flow of the stream. Note: A complete listing of all monitoring sites, with maps showing locations, must be GPSed and provided in the Quality Assurance/Work Plan, and a rationale for selecting the particular monitoring site. The number of monitoring sites is determined on a site-specific basis. At a minimum, the workplan must include the following:

> Three or more stations: one at the upstream end of the waterbody segment, one below the discharge, representative of the critical conditions conducive to eutrophication, and one at the downstream end of the segment under study.

Should the spatial extent of the segment terminate at a downstream lake or impoundment, additional sampling must be conducted at the point where the tributary reaches the lake or impoundment (or at the point of diversion). Phosphorus levels in excess of 0.05 mg/L at this point will prevent the use of this approach and will require that the WQBEL based upon the 0.1mg/L total phosphorus stream criterion in the NJPDES permit be applicable, or that taking into consideration the data collected as part of these evaluations, a different WQBEL based upon the 0.05 mg/l lakes criteria be applicable (which would require a permit modification).

The submitted workplan must contain all normally required quality assurance/quality control information as well as a section addressing final report content. A duplicate copy of the proposed work plan must be supplied to the Department and will be forwarded to our Office of Quality Assurance for review. Please note, a field inspection, by Department personnel, may be required to verify suitability of the sampling stations prior to workplan approval.

PART 3:

Monitoring and Workplan Requirements for Render Unsuitable for Designated Uses Determination

Designated water uses may include aquatic life, recreation and water supply. The focus of these tests is to apply response indicators to determine whether any of the designated uses are being rendered unsuitable by phosphorus (or by excessive algae caused by nutrients).

While the Department's numerical criteria are based on a "causative" indicator, namely total phosphorus, the applicability of the criterion in lakes and streams as well as the interpretation of the narrative criteria require the evaluation of "response" indicators to determine whether uses are being rendered unsuitable. USEPA recommends the use of chemical response indicators, such as dissolved oxygen and turbidity, as well as biological response indicators, such as algal biomass (i.e. measured as Chlorophyl a (Chl a)) (U.S. EPA, 1996 and USEPA 1999a). The purpose of a water quality indicator is to provide a quantitative estimate of where ambient water quality supports the designated uses. Different indicators may be needed for different uses (e.g., dissolved oxygen concentration for aquatic life support and extent of algae for recreational uses).

The mechanism for phosphorus to cause use impairment is excessive primary productivity leading to cultural (i.e. human caused) eutrophication. Phosphorus is a required nutrient for plants and algae but is considered a pollutant when it stimulates excessive primary production. Cultural eutrophication has been described as the acceleration of the natural aging process of surface waters. Symptoms of cultural eutrophication (primary impacts) include oxygen super-saturation during the day, oxygen depletion during the night, and high sedimentation rate. Algae are the catalysts for these processes. Secondary biological impacts can include loss of biodiversity and structural changes to communities.

It is also important to consider that excessive primary production may occur primarily in depositional areas such as impoundments and under summer low flow conditions. Excessive primary production may be manifested as blooms of floating algae (seston), attached algae (periphyton) or dense aquatic vegetation, which in turn affect diurnal oxygen dynamics.

In order to determine whether total phosphorus has not otherwise rendered the waters unsuitable for the designated uses, the Department will evaluate data from two areas of analysis:

1. Diurnal dissolved oxygen measurements
2. Biomass Measurement Phytoplankton and Periphyton (measured as Chl a)

Workplan Requirements:

A Quality Assurance/Work Plan, descriptive of the proposed monitoring program, must be submitted to the Department for approval prior to commencement of monitoring. Only monitoring conducted in accordance with an approved workplan will be considered. In addition, the submitted workplan must address both areas of analysis, as identified above. For submission of completed workplans, or guidance in designing a workplan please contact the Department's Division of Water Quality, Bureaus of Point Source Permitting.

1. **Workplan Requirements**
Intensive Diurnal Dissolved Oxygen Monitoring Survey

The focus of diurnal dissolved oxygen (DO) monitoring is to examine aquatic life impacts resulting from eutrophication, for which the major indicator is inadequate DO concentrations. The monitoring program is designed to determine whether DO criteria are being met and whether any DO violations are due to excessive primary productivity.

Study Area Delineation: The delineation of the study area is defined by the 303(d) Impaired Waterbody List. The focus must be directed to investigating impacts on the segment in which the discharge is located.

Period/Conditions: Data shall be gathered during warm weather months (May-Sept.) and low flow conditions (that flow frequency which is exceeded at least 70% of the time). If wet weather conditions are encountered, the goal should be to sample during the lowest flows possible under the prevailing conditions.

Duration: A minimum of three sampling surveys will be conducted during this period. Each must be a three consecutive day intensive survey. In an attempt to capture peak algal growth periods, the first 3-day survey must occur early in the growing season (May-June). The second and third 3-day surveys must be conducted later in the growing season (July through September).

Number and Location of Monitoring Stations: For streams, stations should coincide with the limiting nutrient stations (See Part 2, Section 1). Note: A complete listing of all monitoring sites, with maps showing locations, must be GPSed and provided in the Quality Assurance/Work Plan.

Monitoring frequency: Diurnal sampling shall consist of at least six water chemistry samples during each day of the 3-day sampling events. At least four of the measurements will be taken during the nighttime between four and one hours before sunrise, with a minimum of thirty minutes elapsed between samples. At least two measurements will be taken during the daytime hours between 11:00am and 3:00pm, with a minimum of one hour elapsed between samples. Stream flows shall be obtained at each station once per day.

Parameters: temperature, dissolved oxygen, pH, turbidity and atmospheric pressure at each station.

NOTE: The Department will allow the use of a properly calibrated, automatic sampling device as an alternative to a grab sample.

2. **Workplan Requirements**
Biomass Measurements (Phytoplankton and Periphyton as Chl a)

Chlorophyll a, the dominant pigment in algal cells, is fairly easy to measure and is a valuable surrogate for algal biomass. Chlorophyll a is desirable as an indicator because algae are either the direct (e.g., nuisance algal blooms) or indirect (e.g., high/low dissolved oxygen and pH and high turbidity) cause of most problems related to excessive nutrient enrichment. USEPA has offered guidance for monitoring algal biomass and nutrients in streams and rivers (USEPA, 1998a) and lakes (USEPA, 1990). More detailed monitoring methods are summarized in "Protocol for Developing Nutrient Criteria" (USEPA 1999a) and "Rapid Bioassessment Protocols" (USEPA 1999b).

It should be noted that chlorophyll-a data in phytoplankton are collected concurrently with the Limiting Nutrient Analysis data collection.

Monitoring Locations: Algal biomass can vary greatly in time and space within the same stream; so to reduce variability, the focus should be on algal sampling in a representative sections of the stream (i.e., riffles). Locations should be as close as possible to the limiting nutrient (i.e., pool) stations (See Part 2, Section 1). To ensure that a representative portion of the reach is covered, samples must be distributed over a reach of at least 100 meters and chosen in a stratified random approach as delineated in USGS NAWQA protocols. NAWQA field protocols for periphyton sampling can be downloaded on the World Wide Web at http://water.usgs.gov/nawqa/protocols/OFR02-150.pdf. Prior to determining the monitoring location, a distance of at least a few hundred meters must be examined upstream and downstream of the proposed monitoring location to ensure that the selected sampling point is typical of the reach being characterized. Minimum extent of sampling shall be defined as three monitoring locations, one at the most upstream location of the listed water segment; one just below the outfall of the facility in question but outside the mixing zone; and one at the most downstream segment of the listed segment as listed by the Department.

Duration: Four-months (June through September).

Number of Samples: A minimum of twelve (12) samples must be collected comprised of four (4) sampling events (monthly); with triplicate samples per event/site.

Monitoring frequency: For Phytoplankton in water column see Limited Nutrient Protocol (Part 2: Section 1). Periphyton attached algal biomass does not change as rapidly as water column parameters, however samples should be taken under low flow conditions and at least fourteen days after significant (scouring) rain or flooding event, which may scour rocks of available periphyton. Therefore, one sample a month will be required to assess algal biomass (i.e., Chlorophyll a).

Parameters: Chlorophyll a. Methods for collecting and analyzing benthic algae (periphyton) and phytoplankton biomass for Chl a are characterized in both standard methods (APHA 1995) and USEPA procedures (USEPA 1992).

Part 4

Phosphorus Criterion Applicability Determination

Each area of the segment should be evaluated independently, making the following determinations.

A. Is Phosphorus Limiting?

The limiting nutrient can be evaluated using available nutrient concentrations by using the following thresholds to exclude phosphorus as the limiting nutrient (The acronyms TIN and DRP refer to biologically-available forms of nitrogen and phosphorus, respectively: TIN = dissolved nitrite, nitrate and ammonia; DRP = dissolved reactive phosphorus):

IF	[DRP] $\geq$ 0.05 mg/l
OR	TIN/DRP $\leq$ 5
THEN	phosphorus can be excluded as the limiting nutrient

Figures 2 and 3 show examples of how to plot pairs of TP and DRP data along a TIN/DRP axis to visually evaluate the phosphorus limitation thresholds at a particular location. By making the TP range twice the DRP range, the thresholds of 0.1 mg/l TP and 0.05 mg/l DRP coincide, simplifying the interpretation. Episodes when TP > 0.1 mg/l AND DRP $\leq$ 0.05 mg/l and TIN/DRP $\geq$ 5 can be identified by seeing TP in the upper right quadrant while DRP is in the lower right quadrant. If phosphorus cannot be excluded as the limiting nutrient for more than 10% of the samples that exceed the 0.1 mg/l threshold (a minimum of 2 samples), then the 0.1 mg/l criterion is applicable.

Figure 2: Example of site where 0.1 mg/l criterion is applicable and exceeded

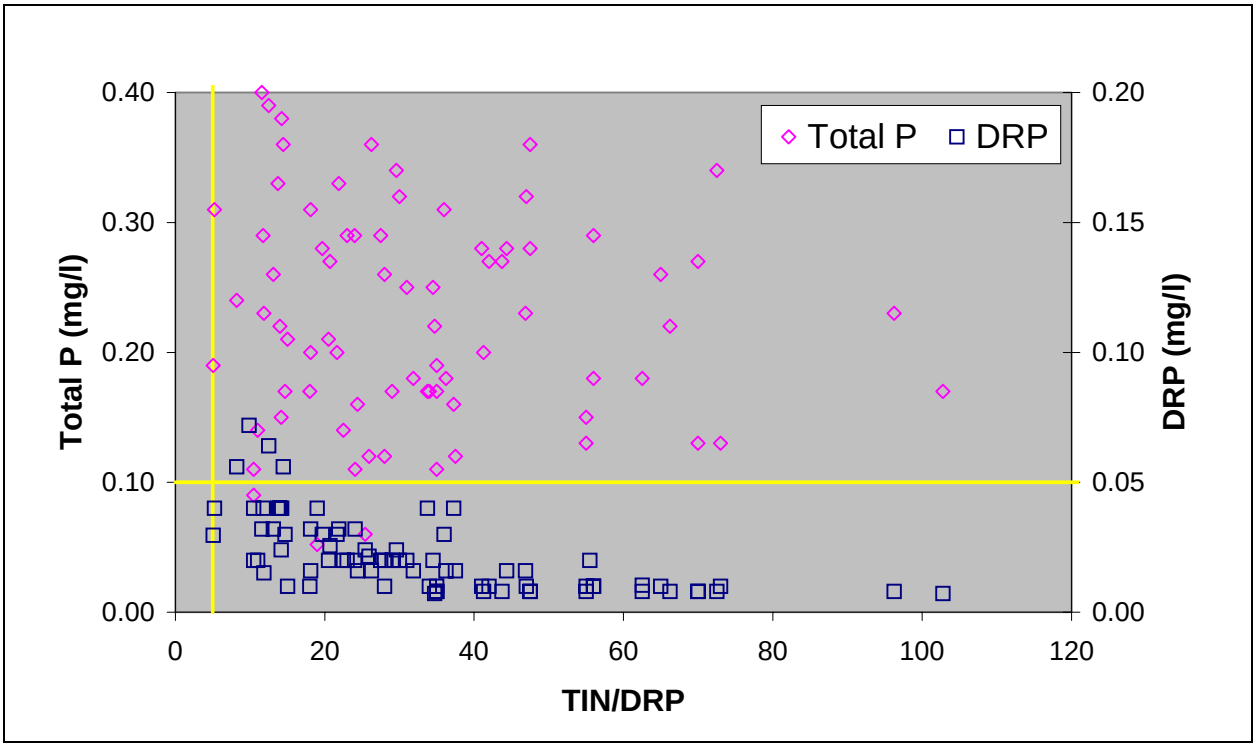
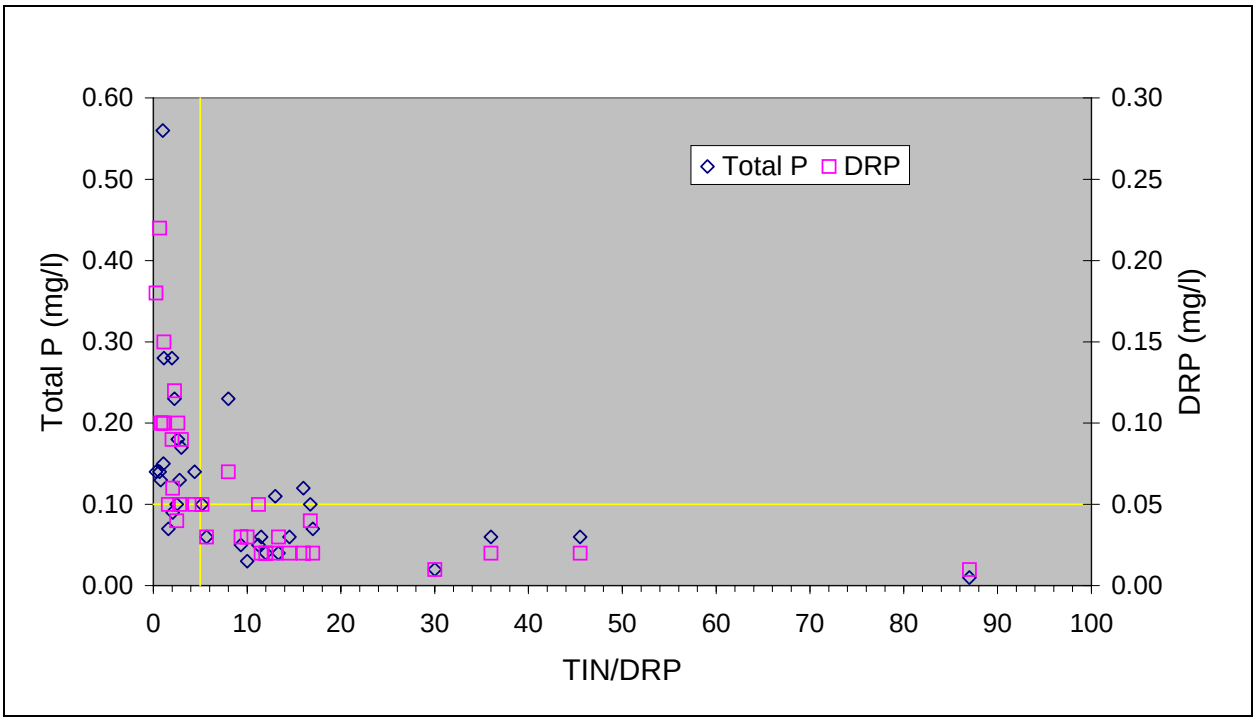


Figure 3: Example of site where phosphorus is not limiting algal growth when 0.1 mg/l threshold is exceeded



B. Are the Designated Uses Rendered Unsuitable Due to Phosphorus?

Phosphorus is not rendering a river or stream unsuitable for the designated uses if:

1) Diurnal Dissolved oxygen (DO) is not in violation of applicable DO criteria due to excessive primary productivity; AND
2) Periphyton concentration is not excessive; AND
3) Phytoplankton concentration is not excessive;

These three conditions are discussed in detail below.

1. Diurnal Dissolved Oxygen

Diurnal dissolved oxygen indicates that phosphorus is rendering the water unsuitable for aquatic life use if, of the below three conditions, both 1 and 2 or both 1 and 3 occur in any single 3-day sampling event:

1) *Condition 1:* The daytime average is 3 mg/L or more higher than the nighttime average.

2) *Condition 2:* The minimum DO threshold is violated in greater than 10% of the samples taken during the night.

3) *Condition 3:* The DO daily average violates the applicable 24-hour average criteria.

2. Periphyton Concentration (Chl a)*

The following thresholds are used to determine that periphyton density is excessive due to phosphorus:

- seasonal mean > 150 mg/m^2; or
- individual sample > 200 mg/m^2

3. Phytoplankton Concentration (Chl a)*

The following thresholds are to determine that phytoplankton density is excessive due to phosphorus:

- seasonal mean > 24 µg/l; or
- 2 week mean > 32 µg/l

(1000 µg/l = 1 mg/l)

*source: *USEPA.2000. Nutrient Criteria Technical Manual; Rivers and Streams, United States Environmental Protection Agency, Office of Water, Office of Science and Technology, July 2000, EPA-822-B-00-002. (See: Chapter 7, Table 4; and Chapter 2, Table 2).*

C. SUMMARY:

Each area of the segment must be evaluated independently. In order to successfully demonstrate that the 0.1 mg/L phosphorus criterion does not apply, it must be demonstrated that phosphorus is not the limiting nutrient AND the designated uses would not otherwise be impaired for each area of the segment. In this regard, the two tables below summarize the standards that must be met:

USE IMPAIRMENTS DETERMINATION TRIGGERS

NUTRIENT PARAMETERS	IMPAIRMENT TRIGGERS

Diurnal Dissolved Oxygen	Applicable DO conditions (see pg. 14)
Periphyton Concentration (Chl a)	> 150 mg/m^2 Seasonal Mean > 200 mg/m^2 Individual Sample
Phytoplankton Concentration (Chl a)	>24 µg/l Seasonal Mean > 32 µg/l 2 week mean

LIMITING NUTRIENT DETERMINATION TRIGGERS

IF [DRP] $\geq$ 0.05 mg/l

OR TIN/DRP $\leq$ 5

THEN phosphorus can be excluded as the limiting nutrient

Upon successful demonstration of compliance with both determinations noted above, a permittee may request a modification of the NJPDES permit to remove the current phosphorus limitation derived from the 0.1mg/L TP criteria, since that criteria does not apply. However, please note that the permit may be revised, again, in a future permit action to reflect a new or modified WQBEL based on a waste load allocation established through a TMDL, or reflective of any new rule or regulation.

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