New Jersey Nutrient Criteria Enhancement Plan 2013

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OVERVIEW

The New Jersey Department of Environmental Protection (Department) has prepared a plan for developing and enhancing nutrient criteria for all waters of the State. This Nutrient Criteria Enhancement Plan (Plan), as well as its predecessor in 2009, was developed in conformance with a United States Environmental Protection Agency (USEPA) requirement that states develop nutrient criteria plans to outline a process for adopting nutrient criteria into state water quality standards. USEPA has encouraged all states to accelerate their efforts and give priority to adopting numeric nutrient standards or numeric translators for narrative standards for all waterbody types. The New Jersey Plan was prepared with the input of a multi-disciplinary team, that included a representative from the U.S. Geological Survey.

New Jersey's SWQS establish designated uses and the water quality criteria designed to protect those uses. Each stream is assigned a surface water classification that specifies the uses to be protected. Designated uses of New Jersey waters are categorized as aquatic life, recreation, drinking water supply, industrial and agricultural water supply, and fish and shellfish consumption. Designated uses potentially affected by excessive nutrients are aquatic life, recreation (aesthetics), and drinking water supply. For recreation and drinking water supply uses, the threshold for "excessive" nutrients can be subjective and may be related more to personal preference than science. For instance, while some amount of vegetation in a lake is necessary to support a healthy recreational fishery, that same amount of vegetation may be perceived as a nuisance to bathers and boaters. Similarly, any change in the taste of drinking water, whether caused by algae or simply different source waters, may be perceived as "bad" or unacceptable. The Department must balance the competing demands of uses and criteria and may need to establish a "primary use" and corresponding response indicators or thresholds to objectively assess use attainment. Therefore, the Nutrient Criteria Enhancement Plan initially focuses on addressing the impacts of nutrients on the aquatic life use. The Department will evaluate whether the aquatic life criteria are protective of all other uses. If necessary, the Nutrient Criteria Enhancement Plan will be revised to incorporate projects to develop criteria for other uses.

Early on USEPA had developed nutrient criteria on an ecoregion basis and gave states the option of adopting these criteria or developing their own criteria based on USEPA guidance. New Jersey's Surface Water Quality Standards at N.J.A.C. 7:9B (SWQS) already contain narrative nutrient criteria for all waters and numeric criteria for freshwaters. Since these criteria were promulgated, significant data and research developments have expanded the knowledge base about the general and site-specific factors that cause or contribute to nutrient impairment in New Jersey's waterways.

Nutrient criteria development requires an understanding of the complex causal relationships between nutrient over-enrichment, response variables, and documented impacts on attainment of

designated and existing uses. This Plan provides a detailed description of the Department's strategy for enhancing the existing nutrient criteria for freshwaters and developing new nutrient criteria for coastal waters through an assessment of these relationships. Nutrient criteria (which may include numeric criteria and numeric translators of narrative criteria) will be developed to address existing and future nutrient-related impairment in New Jersey waters. New Jersey's current Plan provides information on the following steps to support and enhance this effort:

1. Continued enhanced monitoring in rivers and coastal regions on nutrients and response variables;
2. The assessment of causal relationships for nutrients and response variables;
3. The methodology for developing ecoregional nutrient reference levels;
4. The development of new assessment methodologies to define thresholds of use impairment based on ecosystem response variables;
5. The development of new/enhanced criteria; and
6. The promulgation of the new and revised criteria through amendments to the Surface Water Quality Standards and implementation of the new assessment methodology through the Integrated Monitoring and Assessment Reporting process.

This Plan explains the details of each of these steps by waterbody type, including priorities, milestones, and where possible, timelines for nutrient criteria development and further study. The Department intends to employ a comprehensive approach with a regional perspective, under the paradigm of comprehensive water resource management, in selecting priority areas. Barnegat Bay has already been identified as a priority area and will serve as the model under the Estuaries waterbody type, with "Adopt more rigorous water quality standards" being component 7 of the Barnegat Bay 10-Point Action Plan. The approach for this area is set forth in the section on Estuaries. The Department expects to utilize this model approach, which relies heavily on extensive partner involvement in developing the scientific basis for nutrient management findings, including target nutrient levels or loadings, as part of a regional watershed approach for monitoring and assessment. The Plan should be viewed as a "living" document that will be modified as we learn from the Barnegat Bay model, as well as in response to developing program priorities and resource limitations.

The Department intends on updating this Plan every three years or as needed to address substantive changes. In addition, the Department expects to publish annual progress reports. These reports will provide information and status on individual projects identified in the Plan. For more information go to: http://www.state.nj.us/dep/wms/bwqsa/nutrient_criteria.htm.

BACKGROUND

USEPA's *National Water Quality Inventory: 1996 Report to Congress Executive Summary* cites nutrients (nitrogen and phosphorus) as one of the leading causes of water quality impairment in U.S. rivers, lakes, and estuaries. The report stated that forty percent of the U.S. rivers were impaired due to nutrient enrichment; fifty-one percent of the surveyed lakes and fifty-seven percent of the surveyed estuaries were similarly adversely affected. More recently, the USEPA National Aquatic Resources Surveys (NARS) program reports that 72 percent of streams in the lower 48 states exhibited impaired biota for which the most important stressors were *nutrients* and excess sedimentation. In the same study, 44 percent of lakes showed impaired biology largely brought about from poor lakeshore habitat and *nutrients*. Nutrients have also been implicated with respect to the large hypoxic zone in the Gulf of Mexico, hypoxia observed in several East Coast States, and *Pfiesteria*-induced fish kills and human health problems in the coastal waters of several East Coast and Gulf States. A single national approach to nutrient criteria development was determined by USEPA to be inappropriate due to regional variations in geology, vegetation, climate, and soil types that exist and the lack of a clear technical understanding of the relationship between nutrients, algal growth, and other factors such as flow, light, and substrata.

USEPA determined that, to better protect water quality from the adverse impacts of nutrient over-enrichment, ecoregional variations must be taken into account when setting water quality criteria for a particular waterbody. Therefore, in January 2001, the USEPA announced publication of recommended water quality criteria for nutrients under Section 304(a) of the federal Clean Water Act (see 66 F.R. 1671). USEPA's recommended ecoregion nutrient criteria were developed based on water quality conditions that are minimally impacted by human activities. Section 304(a) directs USEPA to develop and publish criteria guidance to assist states and authorized tribes in developing water quality standards that are protective of designated uses. Water quality criteria developed under Section 304(a) are based solely on data and scientific judgments and do not consider economic impacts or the technological feasibility of meeting any specific level of water quality in ambient water. Establishing water quality criteria based on the concentrations measured at these minimally impacted locations is protective of existing and designated uses. The USEPA intended for states to use the recommended 304(a) criteria to support the development of more localized, waterbody-specific state and tribal nutrient criteria that would provide a basis for controlling discharges or releases of pollutants and ultimately result in the protection of aquatic life and recreational uses.

The USEPA also provided two other options for states to develop and adopt nutrient criteria: 1) develop criteria that reflect localized conditions and protect specific designated uses, pursuant to the USEPA technical guidance documents other than those supplied in Section 304; 2) use other scientifically defensible methods and water quality data to develop criteria protective of designated uses.

The Department is developing nutrient criteria using a multiple line of evidence approach. Much of the work will focus on relationships between nutrient levels in state waters and indicators for detrimental changes to aquatic ecosystems, as well as undesirable levels in DO and/or pH. The goal is to determine nutrients levels that result in a high likelihood that desirable biological communities will be maintained over time, and the allowable frequency and duration above this concentration that may occur while not impairing the biological community. In lakes and wadeable streams, this approach will be supplemented by assessments of reference nutrient levels in waters characterized by minimal cultural disturbance. For rivers, streams, and coastal waters the Department will use representative biota (algae, fish, benthic invertebrates, shellfish, chlorophyll a, diatoms) as indicators of the aquatic ecosystem. Because methodologies for fish, and benthic invertebrates assessments have not yet been developed for New Jersey lakes, the Department will use chlorophyll 'a' and diatoms as the representative biota. Data collection and analysis are ongoing in the Barnegat Bay, which will be used as a model to develop assessment approaches applicable to other estuaries in the State. Ocean assessments will soon begin once an invertebrate macroinvertebrate index is validated. Discussions still are needed to formulate an approach for some non-wadeable, non-tidal rivers not covered by a TMDL.

New Jersey's Surface Water Quality Standards (SWQS) contain narrative nutrient criteria as well as a numeric phosphorus criteria for freshwater lakes/ponds and rivers/streams and a numeric nitrate criteria for PL waters. These provisions were promulgated in 1981.

In 2010, the Department developed an assessment method for wadeable non-tidal freshwater streams to evaluate the narrative criteria. A waterbody can be listed on the 303(d) list as impaired by phosphorus even if the numeric criteria are met if it can be demonstrated that the concentrations of phosphorus are rendering the waters unsuitable for its designated uses. Conversely, if phosphorus concentrations exceed 0.1 mg/l, but the designated uses are supported, the waterbody would not be listed as impaired. The approach for this assessment method is described in the 2010 Progress Report on page 11 and in both the 2010 and 2012 Integrated Report Method Documents.

The goal of New Jersey's Nutrient Criteria Enhancement Plan is to develop numeric translators based upon the narrative nutrient criteria for all waterbody types. For example, a translator of objectionable algal densities could be based upon the average summer chlorophyll a

concentration. Chlorophyll concentrations are known to increase positively along a nutrient gradient and can reach undesirable levels if nutrients are in abundance.

Nutrient ranges within reference conditions represent the nutrient ranges associated with undisturbed or minimally disturbed conditions. These concentrations can be useful in determining whether the nutrient levels derived from stressor-response studies are realistic for the ecoregion. Once protective magnitudes are established for a nutrient, the frequency at which nutrient concentrations can be exceeded and for what duration these exceedences can occur and still support uses need to be determined.

Since 2009, when the initial Nutrient Criteria Enhancement Plan was developed, the Department has developed a significant database of nutrient and nutrient response data from freshwater lakes and wadeable streams to support this effort. Extensive monitoring and biological indicator development have been ongoing in coastal waters, rivers/ streams, and lakes. However, tools to assess the aquatic life conditions (benthic indexes) are not yet available for lakes, tidal rivers, nearshore ocean waters, and most of our coastal waters with the exception of the NY/NJ Harbor which was developed by the USEPA.

To improve our understanding of the impacts of nutrients on the aquatic life conditions, diatom-based nutrient inference models were developed for northern and southern New Jersey streams, (exclusive of the Pinelands waters) and northern New Jersey lakes. These models form the basis of a Trophic Diatom Index (TDI) which estimates Total Phosphorus (TP) and Total Nitrogen (TN) levels in wadeable streams based upon resident diatom populations. These same data form the basis for the development of a diatom-based Biological Condition Gradient (BCG) intended to identify diatom communities. These communities, and their position on the BCG, can identify the use attainment and assessment status of waters as mandated by the goals of the Federal Clean Water Act. Upon review of the TDI and BCG by DEP it was determined that these models would benefit significantly from additional data, especially from the extreme ends of an anthropological disturbance gradient. Current projects will enhance the database supporting the nutrient-diatom relationships described in the TDI and BCG and to determine if the “stressor-response” relationships initially observed can be confirmed (validated). Until we can evaluate the health of the ecosystem we cannot evaluate whether nutrients cause impairment.

Activities Leading Up To Nutrient Criteria Development

Lakes: New Jersey has about 870 named lake/impoundments that are at least five acres in size. Lakes that are monitored through a probabilistic network (see Progress Report, page 2) are required by the sampling design to be at least one meter in depth, nontidal and not be water supply reservoirs being actively managed for potable water supply, i.e. subject to various pumping and water exchange operations. Many New Jersey lakes are shallow, run-of-the-river constructed impoundments which renders them highly susceptible to accelerated eutrophication.

As a result, many New Jersey lakes have exhibited water quality problems for decades, primarily with respect to nutrient over-enrichment. This predisposition is enhanced in lakes with large watersheds. The Department has developed phosphorus TMDLs for the 48 lakes in New Jersey where water quality data indicated eutrophic condition. In developing these lake TMDLs, water quality models predicted that some lakes could never attain the numeric TP criterion of 0.05 mg/l, even if there were no anthropogenic inputs, because of the large size of the contributing drainage area relative to the impounded volume. For these lakes, reference conditions[1] were used as "end points" for calculating phosphorus reductions consistent with the SWQS provision that allows naturally occurring conditions to prevail over numeric criteria.

Reservoirs: There are twenty-six Water Supply Reservoirs in New Jersey, totaling approximately 15,700 acres. These water supply reservoirs are owned and operated by purveyors. While, purveyors conduct limited water quality monitoring, it is primarily focused on water treatment needs. As a result, these waterbodies are not part of any regular statewide monitoring program. The current Ambient Lake Monitoring Network is intended to characterize the statewide ecological health of lakes meeting the design criteria. It was determined that since reservoirs are subject to various pumping and water exchange operations, they were atypical of common New Jersey lake conditions and including data on these reservoirs would bias statewide condition estimate. This data gap has been identified in the Department's Long Term Monitoring & Assessment Strategy. Once the Department has successfully developed a nutrient assessment methodology for lakes, the Department will consider developing a similar methodology for assessing nutrient impairment in reservoirs for which TMDLs have not been developed.

Freshwater Streams: There are roughly 18,000 miles of rivers and streams in New Jersey (at 1:24,000 scale of resolution), of which approximately 12,000 miles are non-tidal. For the purposes of this Plan, streams are considered "wadeable" and rivers are considered "non-wadeable". "Wadeable" means that the waters are conducive to monitoring on foot, rather than by boat or bridge. Most of New Jersey's non-tidal waterbodies are wadeable. Wadeable streams may exhibit a variety of habitats including shallow, weed-dominated areas and deeper pools where floating algae may occur. Rivers (non-wadeable), on contrast, are larger and deeper than streams and must be monitored via bridges and/or by boat. There are another 6,000 stream miles that are tidal and are addressed as large rivers and estuaries.

Since streams comprise the majority of New Jersey's freshwaters, enhancing the existing numeric phosphorus criteria and assessing nutrient impacts based on the narrative nutrient

[1] Reference conditions were determined by assuming that 100% of the land use within the lakeshed was either forest or water.

criteria remains a priority. As stated earlier, the Department's current nutrient assessment methodology has been modified to be more consistent with the narrative nutrient criteria and employs multiple lines of evidence to determine if phosphorus is the cause of use impairment (see page 11 of the 2010 Progress report). Identifying waters as impaired based solely on the concentrations of phosphorus has resulted in listing 160 out of 952 assessment units as impaired. However, many waters listed based on TP have healthy biological conditions, while others with acceptable levels of phosphorus have degraded aquatic life conditions and are not listed for phosphorus. Biological confirmation using benthic invertebrates and periphyton chlorophyll a in concert with dissolved oxygen data is necessary to determine if phosphorus is actually contributing to conditions consistent with the narrative criteria and in so doing, impairing the aquatic life use.

Larger rivers and estuaries: This section includes the more downstream portions of wadeable streams of the State, representing a transition from freshwater non-tidal, freshwater tidal to saline/estuarine conditions. From the perspective of the Nutrient Enhancement Plan, the fresh water portions of these rivers have been a low priority since there are few if any river miles in this category that have not been addressed through the TMDL program. The lower tidal portion of the Passaic, Raritan, Hackensack Rivers and other tributaries to the NY-NJ Harbor are under the spatial extent of a nutrient/DO TMDL overseen by the NY/NJ Harbor Estuary Program (See Progress Report, page 17). The lower Toms River and other tributaries to Barnegat Bay are being addressed under the Barnegat Bay Ten Point Plan. There has been extensive work assessing the potential impacts of nutrients to Barnegat Bay. Barnegat Bay has been the focus of extensive monitoring and assessment which is discussed in the Progress Report beginning on page 13. For non-wadeable rivers not being addressed by TMDL development, the actions taken to reduce nutrient impacts in wadeable streams is expected that the reduction will have a positive impact on the conditions in the non-wadeable segments.

The Delaware River Basin Commission (DRBC) is developing nutrient criteria for the Delaware River Estuary. This will address the non-tidal reach above Trenton as well as all the tributaries below the head of tide including the Cooper, Rancocas, Pennsauken, etc. In the tidal Delaware River, current efforts are evaluating the causes behind persistent depressed summertime dissolved oxygen in the River's urban corridor. The DRBC has initiated a monitoring program to quantify current nutrient loads to the tidal river from both point and nonpoint sources. Additional information on DRBC's nutrient criteria program can be obtained at http://www.state.nj.us/drbc/quality/conventional/nutrients.

Freshwater tidal waters, coastal bays and non-tidal rivers were historically assessed for aquatic life use attainment based on grab sample measurements of dissolved oxygen because benthic indicators or other biological measures were not available for assessment. USEPA has developed a biological index specifically for the New York/New Jersey Harbor waters which is currently in

use. Still needed are similar indices suitable for the more southerly estuarine waters. A benthic index to evaluate aquatic life use in Barnegat Bay is expected to be completed by 2015 and will be evaluated for applicability in other coastal waters.

Nearshore Ocean: Historically, USEPA grab samples collected via helicopter through the coastal monitoring program have found low benthic DO conditions off the New Jersey Coast for most of its length during the quiescent periods of the summer and early fall. These low DO conditions are brought about by natural thermal stratification that establishes during this period. These conditions are further exacerbated by the presence of summer upwelling nodes which are associated with recurrent seasonal hypoxia. Storms and the onset of autumn bring about surface to bottom mixing resulting in a breakup of these low DO conditions until the onset of warmer temperatures again in June. The impacts to benthic aquatic life and the possible anthropogenic contributions to these benthic conditions are currently unknown. To better understand the resulting biological impacts, the Department is working with Rutgers, USEPA Region 2, USEPA Office of Research and Development (Narraganset), and NOAA to develop indicators of ecosystem health for the benthic communities in near-shore ocean (marine) waters. Benthic samples were collected in 2007, 2009, and 2010 in support of this effort (see page 24 in this document for current progress). A benthic index for nearshore ocean waters is expected by the end of 2013.

As a separate effort, a slocum glider has been deployed that provides continuous DO, salinity, and temperature along a transect showing values at various depths. This should provide a better evaluation of the nature and spatial extent of the low DO regions in near-shore ocean waters. More information on this project is available at: http://rucool.marine.rutgers.edu/ The Department plans to reassess aquatic life use in ocean waters using the new benthic index and continuous DO data.

II. CRITERIA DEVELOPMENT PROCESS

To support states in their effort to develop numerical nutrient criteria, USEPA published ecoregional reference values in January 2001 as 304(a) criteria recommendations upon which states could base nutrient criteria. USEPA also provided states the option to generate state specific reference values reflecting local conditions using two different approaches. In regions that are minimally developed, USEPA suggests establishing the 75th percentile of a cumulative frequency distribution of minimally disturbed sites as a potential reference value. In regions with more extensive development, USEPA has suggested that the 25th percentile of a distribution of sites throughout the region in question would provide a reference. The Department has concerns regarding both approaches as targets supporting criteria. Using the 25th percentile approach is seen as arbitrary and not directly tied to a designated use. The use of the 75th percentile approach can be confounded by such questions as what constitutes “minimally

disturbed" conditions which can vary significantly from ecoregion to ecoregion and can be defined in varying ways.

In contrast to the reference condition approach, nutrient–response variable assessments explore the relationship between nutrient levels and indicators of ecosystem health such as a biological index or other biologically relevant response indicators such as DO, pH, chlorophyll a. These assessments suggest the likelihood of obtaining a desired biological community if nutrients are maintained at certain levels. The advantage of this approach is that it allows the development of numeric nutrient criteria based on and directly tied to desired outcomes (i.e. healthy biota) reflecting specific designated uses. This process first seeks to determine if there is in fact a relationship between nutrient levels and the response indicator(s) of concern. If a relationship exists, the approach explores whether altering the nutrient levels will result in a corresponding change in the response variable in a preferred direction.

Our goal is to determine what nutrient levels will result in a high likelihood that desirable biological communities will be maintained over time, and at what frequency and duration can excursions above this concentration occur and not impair the biological community. The development of a criterion can begin with either ecoregional reference levels, or effects-based thresholds established through stressor-response relationships. These levels (thresholds) then inform what magnitude the criterion should be. The Department must then establish what frequency and duration should apply.

Once all data are analyzed, the Department will review what has been learned from nutrient response relationships in the light of natural ecoregional nutrient levels. We intend to review how other states have developed their numeric nutrient criteria and what thresholds their research recommended and what additional information (data, research, and literature) contributed to their final criteria. The Department will determine if clear thresholds were uncovered having sufficient robustness to support the development of scientifically defensible criteria. If sufficiently robust, these thresholds will form the basis to establish final criteria to protect aquatic life uses. If assessments lack sufficient robustness, recommendations will be made as to additional research or datasets necessary to enhance the information base.

In moving from simple thresholds to final criteria, decisions will be made as to where or in what specific waterbodies these criteria will apply. Factors such as waterbody size, retention time (lakes), stream order, location, specific uses, all may influence these decisions.

The next section provides an overview and a description of the projects planned by waterbody type including the purpose of the project, the data used, and how each project fits into the overall Nutrient Plan. Table 1 delineates the anticipated schedules for this Nutrient Plan and the 2013

Progress Report. Tables 2 through 5 provide anticipated completion dates for projects in support of criteria development in lakes, streams, estuaries and the near-shore ocean respectively.

Table 1. General and Administrative Tasks and Anticipated Completion Goals

Description	Completion Goal *
Complete Draft 2012 Plan, Deliver to EPA	completed
Finalize Nutrient Plan	July 2013
2013 Progress Report	December 2013
Updated Nutrient Criteria Plan	December 2016

* All dates are targets based upon available resources and staff workloads; dates are subject to change

LAKES:

The following individual projects are necessary to complete nutrient criteria enhancement for lakes. This section provides descriptions and justifications for each effort. Anticipated completion dates are included in Table 2.

L1. Project Title: Explore ecoregional nutrient ranges.
Description: Box and whisker plot TN and TP ranges within the state's 6 ecoregions from data collected by the Department's lake monitoring network [2]. Determine if ecoregions should be assessed separately or combined. Ecoregions showing similar nutrient ranges will be combined to enhance the statistical sample size. Ecoregions showing notably dissimilar nutrient ranges are to be analyzed separately as this impacts the assessment of what nutrient levels are present in each ecoregion. This assessment forms the basis for all subsequent ecoregional analyses.

L2. Project Title: Lakes Stratification Options: Lake size and Retention Time
Description: Lake size, morphology and watershed drainage area affect lake retention time. Lakes with relatively short retention times are less sensitive to the effects of phosphorus and may function more like riverine systems. The intent here is to review literature and decisions of other states regarding the significance of retention time in lake assessments and recommend thresholds for stratifying lakes based on size and retention time.

The Department's experience with lake TMDL development has encountered scenarios where the natural phosphorus concentration was higher than the existing numeric phosphorus criteria

[2] The Lake Monitoring Network is based upon a 200 lake network randomly selected from a universe of 869 named New Jersey lakes of 5 acres or greater, excluding water supply reservoirs. The randomized site selection design creates an unbiased "snapshot" of lake conditions statewide representing a continuous disturbance gradient from pristine to degraded. As a result, the design supports an unbiased calculation of cumulative frequency distributions of lake water quality. The network provides nutrient data and response variables such as chlorophyll a, DO, pH, and secchi transparency.

due simply to the large watershed size, assuming the entire watershed was undeveloped (forest and wetlands). Moving forward, the Department will explore how lake retention time and watershed size might affect criteria decisions.

L3. Project Title: Northern New Jersey Lake Diatom Trophic Index

Identification and enumeration of lake sediment diatoms to species level which are collected by WM&S during NJDEP's routine monitoring of lakes for the Ambient Lakes Monitoring Network. The current project is intended to enhance the database supporting the nutrient-diatom relationships described in the NJ Lake Trophic Diatom Index and to determine if the "stressor-response" relationships initially observed can be confirmed (validated).

L4. Project Title: Explore stressor-response relationships between nutrients and response variables (chlorophyll a, in-lake DO and pH).

Description Using data from the Department's Lake Monitoring Network, graph and statistically explore in-lake nutrient species individually against the response variables chlorophyll a, DO and pH to determine if there are predictable relationships between one or more nutrient parameters and response indicators. Evaluate whether the information can be used to enhance our Carlson Trophic Index to better classify lake conditions. Based on the strength of the stressor-response relationship, determine what nutrient forms, and possibly the ratio of these nutrients, are most important to manage these response variables. All subsequent nutrient analyses will focus on those nutrient species determined most promising for effectively predicting changes in the identified response variables. The goal is to assess what nutrient levels correspond to the most desirable chlorophyll, DO and pH targets for New Jersey lakes.

L5. Project Title: Identify chlorophyll levels protective of various aquatic life uses.

Description: The Department's goal is to maximize the lake's recreational fisheries (both cold and warmwater) whenever appropriate. To achieve this, the Department's target is to keep water column phytoplankton production relatively low and center primary production in submerged macrophytes (natural to the region, not invasive species). Macrophytes provide habitat for grazing zooplankton, forage fish, fry, and predatory game fish. These, in concert with a clear water column, combine to create the conditions favorable to stable populations of sport fish. In contrast, excessive phytoplankton production can lead to a clouding of the water, possible nuisance blooms, loss of submerged macrophytes, and a decline in the quality of the fishery from piscivorous species to one dominated by bottom feeders tolerant of high turbidity and low DO. Although very low nutrient levels are more likely to maintain clear water conditions, some level of productivity is necessary to maintain the forage base needed to support high trophic level predators (most sport fish). Hence, a balance must be struck with nutrient inputs between water clarity and maintaining sufficient productivity to maximize recreational fishing potential, be it cold or warm-water. The goal will be to select a chlorophyll concentration that is appropriate for the type of fish community desired.

Review lake criteria development in other states to determine what criteria (nutrients and chlorophyll) levels are recommended to sustain healthy fish communities for recreational fishing including cold, cool and warm water fisheries. Work with the NJ Bureau of Freshwater Fisheries (BFF) to assess recreational fishery quality using a scale similar to Virginia's and determine the nutrient/chlorophyll concentrations in lakes with excellent/good recreational fisheries and fair/poor recreational fisheries. Evaluate lakes in the probabilistically designed Ambient Lake Monitoring Network for which BFF has fishery assessments. These data can suggest target values to guide the balancing of recreational fish productivity with lake stability and balance competing uses. The goals are to assess what nutrient levels correspond with desirable chlorophyll, DO and pH targets for New Jersey lakes based on the intended aquatic life use (bass vs cold water fisheries), the ecoregion and the other physical characteristics such as lake types (natural, impounded run of the river), lake size and depth.

L6. Project Title: Identify in-lake N:P ratios and other factors that render lakes susceptible to cyanobacterial blooms.
Description: Low N:P ratios may create favorable conditions for cyanobacteria. The presence of cyanobacteria can threaten a healthy recreational fishery and the impoundment's drinking water use through cyanotoxin release. Review literature to determine if N:P ratios and other factors related to nutrients have been identified that increase the likelihood of cyanobacteria growth and blooms. In addition to a literature review, the Department has initiated a monitoring project as part of the probabilistic Ambient Lake Monitoring Network to determine the occurrence, extent, and relative exposure risk of microcystin toxins in lakes statewide. Based on data collected from this project a determination will be made to revise and/ or extend statewide microcystin monitoring and reporting of exposure risk.

L7. Project Title: Paleo-limnology Investigations.
Description: Diatoms in lakes and streams have long been regarded as sensitive indicators of nutrient levels as well as other disturbance factors in waterways. The Academy of Natural Sciences of Drexel University is exploring the use of diatom frustules taken from lake sediment cores to infer nutrient levels in lakes going potentially as far back as pre-European settlement. Additional information concerning this effort is on page 3 of the 2010 Progress Report under "Paleo-limnology Investigations."

Examining evidence of historical algal communities can infer historical in-lake nutrient levels providing an alternative method to explore lake reference conditions that reflect pre-European settlement nutrient profiles. This is accomplished by comparing sediment diatom frustules in the upper sediment layer, representing current conditions, with those contained within deeper core layers, reflecting historical conditions. Layer dating can be accomplished by isotope dating or more economically by the presence/absence of ragweed pollen indicating the boundary line of

European settlement. A significant limitation of this effort is it only applies to natural lakes (approx. 60) and a limited number of manmade lakes in the state.

L8. Project Title Recommend nutrient criteria to protect aquatic life uses or identify additional research needs.

Description: Review assessment results from the preceding work in the context of a multiple line of evidence approach. Based on these results, determine if assessment results are sufficiently robust to support scientifically defensible criteria and if so, recommend numeric nutrient criteria for lakes to protect aquatic life use and minimize exposures to cyanobacteria. The recommended criteria will specify frequency, magnitude, and duration and where applicable. If analysis results lack sufficient robustness, recommendations for additional data gathering and analysis to enhance the database will be provided.

Table 2. Projects Associated with Lake Criteria Development

Project	Description	Start Date	Completion Goal*
L1	Explore ecoregional nutrient ranges	July 2013	Dec. 2013
L2	Lake Stratification: Lake size & Retention Time	Not determined	Beyond 2015
L3	NJ Northern Lake Diatom Trophic Index	March 2013	Jan. 2015
L4	Explore Lake stressor-response relationships	Not determined	Beyond 2015
L5	Chlorophyll levels protective of fisheries	July 2013	Dec. 2013
L6	N:P Ratios and cyanobacterial bloom	June 2013	Dec. 2014
L7	Paleo-limnology Investigations	2010	July 2015
L8	Recommend nutrient criteria/additional research needs for lakes	Not determined	Beyond 2015

* All dates are targets based upon available resources and staff workloads; dates are subject to change

WADEABLE STREAMS:

The Department collects a rich assortment of biological data including benthic invertebrates and finfish in streams (see pages 8 and 9 in the 2010 Progress Report for description of the networks) with which to assess the aquatic life use. These data have been recently supplemented with limited diatom data in non-tidal wadeable streams outside the Pinelands (see Progress Report, pg. 9). These biological data are often collocated at existing stations with chemistry data allowing the Department to assess nutrient–response relationships between nutrients and all three biological communities as well as with chemical responses such as DO and pH. This supports calculating cumulative frequency distributions reflective of the distribution of chemical and biological conditions within the wadeable streams of the state, allowing the assessment of reference conditions in a manner consistent with USEPA.

New Jersey's ecoregions represent physiographic regions which differ in geology, soils, and climate sufficient to influence the resident water quality as these factors can also influence the resident biota. Our nutrient assessment will start with these six ecoregions but based upon findings several ecoregions may ultimately be combined. A similar approach has been used to develop our biological indicators. For benthic macroinvertebrates which are used to assess biological conditions in wadeable streams, the Department was able to collapse these ecoregions into three. The HGMI index encompasses the Highlands, Ridge and Valley, and Piedmont provinces, and is designed to assess high gradient waters with fast flow and rocky bottoms. The CPMI applies to the inner and outer coastal Plain while the PMI is limited to Pinelands streams and waters in the inner and outer coastal plain with naturally low pH. Both the CPMI and the PMI are calibrated for more low gradient streams with sand/silt bottoms and slower flows. The two Fish IBI indices follow the same pattern; the northern IBI is applied to the same waters as the HGMI and the southern IBI is used in much of the same waters as the CPMI. There is currently no fish IBI for the Pinelands region.

The following projects are designed to collectedly provide the information necessary to enhance wadeable stream nutrient criteria; anticipated completion dates are provided in Table 3.

S1. Project Title: Explore ecoregional nutrient ranges.
Description: For the purpose of nutrient assessment, the Department will explore the nutrient ranges within each of the six ecoregions to determine if any can be combined or need to be assessed separately. Preliminary data suggest that the nutrient rich Northern Piedmont may require an assessment separate from the other two northern ecoregions. As with lakes, stream nutrient data from the Ridge and Valley and Highlands ecoregions will be reviewed to see if these two ecoregions should be treated as a single entity or kept separate. A similar assessment

will be performed to see if portions of the coastal plains (as discussed in the lake section) also require separate assessments.

Graphically review TN and TP ranges within the state's 6 ecoregions from the data collected by the randomly-sampled portion of the ambient monitoring program. Ecoregions showing similar ranges should be combined to enhance the statistical sample size while ecoregions possessing dissimilar ranges should be analyzed separately as this impacts what nutrient levels are determined to be attainable within each ecoregion. This assessment forms the basis for all subsequent ecoregional analyses.

S2. Project Title: Explore stressor-response relationships between nutrients and response variables (in-stream biological condition, DO and pH).

Description: The biological condition as measured using the index scores recorded by the biomonitoring program for fish (IBI) and benthic invertebrates (HGMI, CPMI, PMI, etc.) represent a response variable in the context of nutrient-response analyses. These indices are not calibrated to nutrient levels alone but to an overall anthropogenic footprint that includes a wide range of environmental degradation. The Department will explore whether there nutrient levels below which biological impairment is unlikely with the understanding that nutrient levels do correlate to other anthropogenic stressors that negatively impact biota and whether there are nutrient thresholds above which the biological condition and nutrient relationship abruptly change. The Department will explore the individual biometrics for both invertebrates and fish (e.g. Hilsenhoff Biotic Index, number of scraper genera, etc.) to determine whether these metrics provide a strong nutrient response relationship.

The Department will initially review cause-response relationships with nutrients using scatter plots possibly followed up by regression and/or classification/ordination techniques. Using scatter plots, graph the nutrient species (TP, NO3, NH4, TKN, etc.) individually against the response variables including individual biological metrics and indices, DO and pH to determine if there are predictable relationships between one or more nutrient parameters and response indicators. This analysis is limited to those sites that have both chemical and biological data.

Therefore, to enhance diversity of sites with both biological data and physical/chemical data, additional monitoring will be conducted over the next three summers. The Department will collect biological samples at the newly established a statewide probabilistic rivers and stream network. This network consists of 50 sites scheduled for quarterly sampling for physical/chemical parameters from July 2013- June 2015.

S3. Project Title: Determine what nutrient levels were determined to be protective of aquatic life uses in other states.
Description: Review information from other states to inform establishing nutrient target values (criteria or translators) that protect aquatic life uses.

S4. Project Title: Continue exploring relationships between instream nutrient levels and diatom community condition measurements (Biological Condition Gradient or BCG).
Description: Nutrient to diatom BCG relationships show the relationship between instream nutrient levels and the presence or absence of desirable diatom communities. Details are contained in the 2010 Progress Report under "Biological Condition Gradient" (page 11). Preliminary work using a selected number of stations in northern New Jersey identified nutrient thresholds above which diatom communities significantly degrade. The researcher recommended that additional monitoring be conducted to expand the range of stations sampled to improve the model. Diatom/nutrient data from an additional 40 to 80 sites will be assigned to their respective BCG categories and used to supplement existing data to enhance the exploration of nutrient-BCG relationships.

S5. Project Title: Determine the natural variability of phosphorus concentration at selected diatom sites.
Description: The Department will develop a Quality Assurance Project Plan to collect weekly phosphorus samples for an extended period at diatom sites exhibiting low to moderate BCG categories. The Department will seek support from monitoring partners to collect and analyze samples for phosphorus concentrates at these targeted sites. Data will be used to establish the frequency and duration for the recommended phosphorus criterion.

S6. Project Title: Recommend numeric nutrient criteria for wadeable streams to protect aquatic life use or identify additional research needs.
Description: Review assessment results from the preceding work in the context of a multiple line of evidence approach. Based on these results determine if assessment results are sufficiently robust to support a scientifically defensible approach to criteria development and if so, recommend numeric nutrient criteria for streams in NJ to protect and enhance aquatic life. The recommended criteria will specify frequency, magnitude, and duration and where applicable. If analysis results lack sufficient robustness, recommendations are made regarding additional data gathering and analysis necessary to enhance the database needed to develop scientifically defensible criteria.

Table 3. Projects Associated with Stream Criteria Development

Project	Description	Start Date	Completion Goal*
S1	Explore ecoregional nutrient ranges	July 2013	June 2014
S2	Explore stream stressor-response relationships	July 2013	Dec. 2015
S3	Nutrient levels protective of fisheries	July 2013	Dec. 2013
S4	Continue diatom collection and enhancement to TDI and BCG	July 2013	June 2015
S5	Evaluate natural variability in phosphorus	July 2013	Dec. 2014
S6	Recommend nutrient criteria/additional research needs for streams	Not determined	Beyond 2015

* All dates are targets based upon available resources and staff workloads; dates are subject to change

ESTUARIES (BARNEGAT BAY AS MODEL)

As stated in the 2010 Progress Report, New Jersey has approximately 6,000 miles of tidal waters and 260 square miles of estuaries. All these contribute significantly to the state's recreational and commercial wellbeing. As a result of the Governor's focus on restoring the Barnegat Bay, a significant component of the nutrient criteria enhancement effort will take place in the context of the Governor's overall ten point plan for the Bay. Comprehensive information on the Department's efforts in the Bay are described at http://www.nj.gov/dep/barnegatbay/. The development of nutrient criteria for the Bay, either as numeric criteria, load limits or surrogates in the form of response indicators, is part of a broad management strategy which will address a suite of problems including sea level rising, overfishing, sea nettles, shellfish population loss, boating impacts, concerns surrounding aquatic vegetation, and other issues. The concerns regarding use support in the Bay are described on page 13 of the 2010 Progress Report.

On a national scale, estuaries within the United States can vary significantly from one another in terms of benthic substrates, fresh and salt water hydrology, climate as well as other factors making each one unique. In view of this, USEPA has yet to develop 304(a) ecoregional nutrient criteria recommendations as they have for freshwaters. Reference condition approaches may not be practical here because few if any estuaries in the eastern US share features and climate sufficient to serve as reference conditions that are applicable to other neighboring estuaries. As a result, the Department is taking a waterbody specific approach to nutrient criteria development that contrasts with the ecoregional approach used in fresh waters.

Developing a water quality based management plan for the Barnegat Bay involves a multi-faceted approach. The Department along with numerous partners are conducting a comprehensive water monitoring program. The study is described in the QAPP, which can be

found at http://www.nj.gov/dep/barnegatbay/. The Department has contracted with USGS to conduct the modeling and other related work like determining the bathymetry of the Bay. Once the monitoring is complete, the hydrodynamic and water quality models can be developed and linked together so that the Department can simulate the fate and transport of nutrients and the water quality responses related to nutrient levels and other relevant parameters.

Concurrently, the Department oversees ten research projects intended to fill information gaps regarding issues of concern in Barnegat Bay that may or may not be primarily affected by water quality. If successful, the research will provide the basis for the Department to determine the locations and extent of water quality impairments as well as help with establishing ambient thresholds for nutrient concentrations and/or loads that are associated with support of healthy aquatic systems where physical conditions are or would be supportive. All ten projects are discussed at http://www.nj.gov/dep/barnegatbay/plan-research.htm

The Department will integrate all that is learned about the Bay through the preceding studies, determine the extent and cause of impairments, the relationship between pollutant loads and water quality response using the linked hydrodynamic and water quality models, and determine the suite of measures that need to be implemented to achieve aquatic life support in the Bay. It is hoped that the intensive effort in Barnegat Bay and the projects funded in support of this effort will provide tools to utilize in other estuaries in the state.

The following Barnegat Bay projects are designed to provide the information necessary to evaluate the need for and establish nutrient criteria for Barnegat Bay. Anticipated completion dates for these projects are provided in Table 4.

B1. Project Title: Development of Hydrodynamic Model
Description: Using data collected from the Barnegat Bay Comprehensive Monitoring Project's flow gages, chemical monitoring and bathymetric measurements, develop a hydrodynamic model of the Barnegat Bay. This model will simulate the movement of water and particles throughout the system. It will be linked with a water quality model to allow simulation of what happens to nutrients, sediment, and other inputs to the Bay as a result of the physical, chemical and biological processes that occur in that system.

B2. Project Title: Development of the Water Quality Model
Description: As a concurrent and follow-on project to the hydrodynamic model, develop a water quality model to simulate the fate and transport of key parameters related to water quality standards and designated use attainment. This model will be used, along with the findings from the scientific projects described below, to establish water quality or pollutant load thresholds that are consistent with restoring the health of the Bay, with respect to water quality. It is recognized that other stressors, not related to nutrients, play an important role in the observed condition of the Bay.

B3. Project Title: Complete research projects designed to collect necessary data on various ecosystem variables (phytoplankton, zooplankton, fish, crabs and other benthic invertebrates).
Description: This represents the ten selected research projects overseen by the Department's Office of Science. Complete research projects focused on biological properties of the Bay designed to fill in information gaps.

B4. Project Title: Identify stressors and develop stressor response relationships.
Description: Based upon results of the OS research projects described above and using the hydrodynamic/water quality model, identify relationships between anthropogenic stressors to the Bay and resulting biological condition, as relates to water quality. Develop a method to evaluate attainment of the narrative nutrient criteria and use this information to establish numeric criteria and/or loading thresholds.

B5. Project Title: Assess current conditions, identify problems areas and evaluate actions to restore conditions.
Description: Based upon acquired information, assess the current level of attainment, identify the sources of non-attainment and develop a restoration plan for the Bay.

B6. Project Title: Evaluate the applicability of the Barnegat Bay recommendations to other estuaries.
Description: The Department will evaluate the appropriateness of using the benthic macroinvertebrate index and other thresholds developed through the intensive research and monitoring conducted in Barnegat Bay to evaluate aquatic life conditions in other bays. Additional data collection, research and analysis may be needed to refine the Barnegat Bay metrics to other coastal waters.

Table 4. Projects Associated with Estuarine Criteria Development

Project	Description	Start Date	Completion Goal*
B1	Develop Hydrodynamic Model	2012	June 2014
B2	Develop Water Quality Model	2012	June 2015
B3	Complete research projects designed to collect necessary data on various ecosystem variables	2011	Dec. 2015
B4	Identify stressors and develop stressor response relationships.	2012	Beyond 2015
B5	Assess current conditions, identify problems areas and evaluate actions to restore conditions	2012	Beyond 2015
B6	Evaluate the applicability of the Barnegat Bay recommendations to other estuaries	Not determined	Beyond 2015

* All dates are targets based upon available resources and staff workloads; dates are subject to change

OCEAN:

Overview: Low dissolved oxygen has been reported in the ocean off the New Jersey coast. No information was available to evaluate the duration and frequency of these event or whether the reported low DO impacted the biota. The Department listed the ocean as impaired for aquatic life use based on reported low DO in 2002.

New Jersey's nutrient enhancement in ocean waters is focused on three aspects: 1) developing a biological indicator for near ocean waters; 2) reviewing USEPA's recommended dissolved oxygen criteria for marine waters; and 3) enhancing our monitoring capabilities to better evaluate the frequency and duration of low DO. The biological index is being developed by Rutgers University and will be based upon benthic invertebrates (see "Biotic Index for Nearshore Ocean Waters," page 18 of the 2010 Progress Report). Once an index is developed, the Department will assess the aquatic life conditions in the near shore ocean waters. If biological impairments are observed, we will attempt to determine if the impairment is due to nutrients or some other stressor. Having the means to assess the biological condition in concert with a strong database of dissolved oxygen recorded by submerged mobile continuous data recorders will allow the Department to determine if periods of low DO are natural and whether it affects the health of the aquatic ecosystem. Until this assessment is completed, the Department has no plans to develop nutrient criteria for the ocean waters under New Jersey's jurisdiction.

Ocean Nutrient Assessment Projects

What follows are the individual projects necessary to complete nutrient criteria enhancement for New Jersey's Coastal Ocean. Anticipated completion dates are provided in Table 5.

O1. Project Title: Finalize benthic biological index

Description: Samples collected in 2010 need to be analyzed and the index further calibrated. Additional benthic samples will be collected in 2013. These results will be used to validate the index. The completed index must be then reviewed by the Department in terms of what constitutes full and nonsupport of the aquatic life use and decide how the index will be used for assessment purposes. If these communities exhibit impairment, then the Department will work to determine if excess nutrients might be a contributor.

O2. Project Title: Evaluate continuous DO conditions and recommend revisions to the EPA marine DO criteria.

Description: Using DO data from glider transects, evaluate the current DO condition and recommend revisions to implement the EPA marine DO criteria.

O3. Project Title: Assess ocean aquatic conditions and determine if additional work is needed

Description: Apply the nearshore ocean benthic index to biological samples collected in 2010 and 2011 to assess the aquatic life status. Use this information along with findings on the DO condition to delist DO from the 303(d) List. If sufficient, and the results do not indicate impaired aquatic life condition, no future work will be conducted. If not sufficient, determine what information is needed to fill the data gaps.

O4. Project Title: Recommend nutrient criteria

Description: The outcome of the previous projects will be evaluated to determine if a need exists to develop nutrient criteria for ocean waters. Based on preliminary results, it does not appear that there would be a need as the biological condition is generally unimpaired. The only real use of criteria would be to regulate discharges to the ocean. However, because of the significant amount of dilution available it is unlikely that the discharges would cause the criteria to be exceeded.

Table 5. Projects Associated with Near Shore Ocean Criteria Development

Project	Description	Start Date	Completion Goal*
O1	Complete ocean biological index	January 2013	December 2013
O2	Evaluate continuous DO conditions and recommend criteria revisions	July 2013	December 2013
O3	Assess aquatic conditions, determine if additional work is needed	December 2013	April 2014
O4	Recommend Ocean nutrient criteria if needed	Not Determined	Beyond 2015

* All dates are targets based upon available resources and staff workloads; dates are subject to change