Interim Phosphorus Reduction Strategy for Connecticut Freshwater Non-Tidal Waste-Receiving Rivers and Streams

Mary E. Becker
CT Department of Environmental Protection
Bureau of Water Protection and Land Reuse
Planning and Standards Division
mary.becker@ct.gov

Draft: April 21, 2011

Introduction

Macro nutrients, such as nitrogen and phosphorus, are an essential component of plant and animal nutrition and are naturally occurring in aquatic systems. However, excessive inputs of nutrients from human sources can alter primary productivity in aquatic systems, which can result in impairment to both recreational and aquatic life uses in Connecticut's water resources. Excessive loading of phosphorus to surface waters as a result of discharges from industrial and municipal water pollution control facilities (WPCF) or non point sources such as runoff from urban and agricultural lands, can lead to algal blooms, including blooms of noxious blue green algae, reduction in water clarity, and in extreme cases depletion of oxygen, fish kills, and other impairments to aquatic life.

Excessive nutrient enrichment of surface waters is a widespread issue throughout the United States and the world. Connecticut has identified 21freshwater water bodies on the 2010 Impaired Waters List (CT DEP 2010) where nutrient enrichment is a contributing cause of the impairment. These waters were assessed as impaired based on citizen complaints or other anecdotal evidence that nutrient enrichment threatens or impairs aquatic life support or recreational designated uses. Other water bodies that are not currently listed may also be impacted by nutrient enrichment.

As a result of the high percentage of water bodies listed for nutrient-related impairments in the U.S. according to section 303(d) of the Clean Water Act, the U.S. EPA has targeted nutrient pollution reduction a priority and have encouraged states to adopt numeric nutrient criteria into their Water Quality Standards (Grubbs 2001, Grumbles 2007). The Connecticut *Water Quality Standards* (WQS) do not include numeric criteria for nutrients but rather incorporate narrative standards and criteria for nutrients. These narrative policy statements direct the Connecticut Department of Environmental Protection to impose discharge limitations or other reasonable controls on point and non point sources to support maintenance or attainment of designated uses. In the absence of numeric criteria for phosphorus, the Department has developed an interim nutrient management strategy for freshwater non-tidal streams based on the narrative policy statements in the WQS to meet the pressing need to issue NPDES permits and be protective of the environment. The strategy includes methods that focus on phosphorus because it is the primary limiting nutrient in freshwater systems. These methods were approved by the United States Environmental Protection (EPA) in their letter dated October 26, 2010 as an interim strategy to establish water quality based phosphorus limits in non-tidal freshwater for industrial and municipal water pollution control facilities (WPCFs) national pollutant discharge elimination system (NPDES) permits until the Department has established numeric nutrient criteria in the CT WQS.

The interim strategy is based on best available science using methods to identify phosphorus enrichment levels in waste receiving rivers and streams that adequately support aquatic life uses. A mosaic of enrichment conditions occur across the State, which requires an approach that accounts for site-specific differences and distinguishes between naturally occurring and human contributed sources of phosphorus. A spatial framework was used to extrapolate site specific characteristics to a broader spatial scale so that appropriate management could be applied at a state-wide level. This is necessary in natural resource management because it is often unrealistic and cost prohibitive to monitor every site or stream in the State particularly when working with short management timeframes. The approach provides distinct advantages to managers by maintaining a more natural enrichment distribution that traditional management schemes might not achieve at a statewide level.

Causal links between anthropogenic inputs of phosphorus and aquatic life response were identified to focus the analysis on direct responses of aquatic life to excess phosphorus (Figure

1). Benthic algae species composition was used to assess aquatic life responses to enrichment because it responds directly to nutrients and may provide a better indicator of enrichment condition in streams than assessment of water chemistry, macroinvertebrates, fish or benthic algal biomass (EPA, 2000). Species composition of benthic algae communities is also more likely to reflect actual stream conditions because they integrate the effects of stressors over time and space (Stevenson, 2006). Changes in the benthic algal community in response to excess phosphorus loading from anthropogenic inputs were analyzed within a spatial framework using geographic information systems (GIS) and statistical techniques.

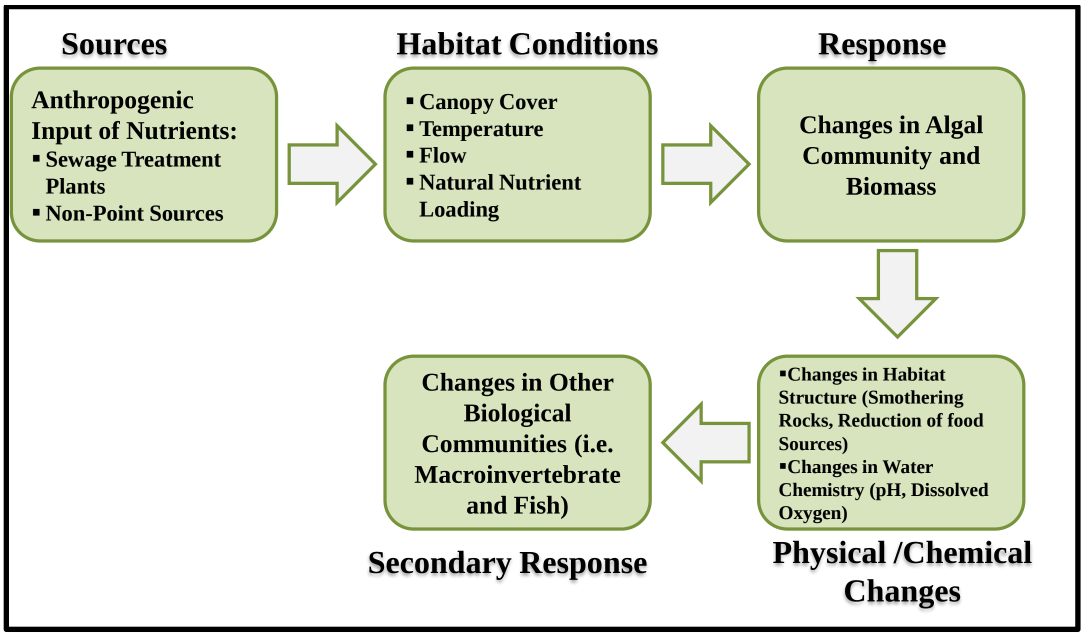


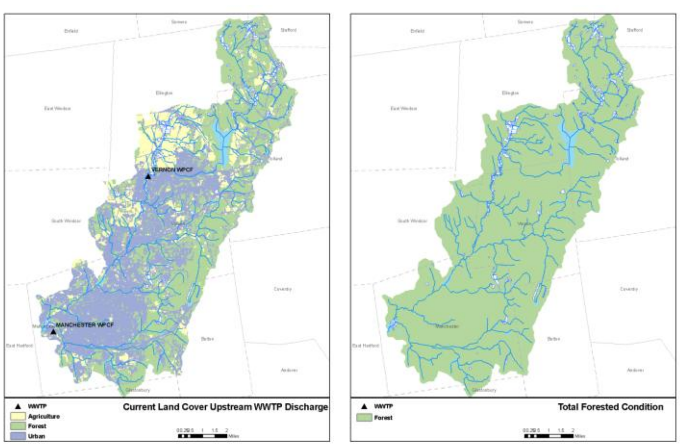
Figure 2. Simplistic conceptual model of aquatic life responses to excess nutrients.

Methods & Results

Periphyton surveys were conducted at 78 sites across the State in 2002, 2003 and 2004. In 2002 and 2003, CT DEP conducted the surveys as part of a State-wide probabilistic monitoring effort. Additional sites were sampled in 2004, with emphasis on historical reference streams and streams known to have high phosphorus loadings. The surveys were conducted in July and August. Periphyton is a complex mixture of microscopic algae, bacteria and fungi that grows on the bottom substrate (e.g. such as rock and logs) of a river or stream. Sampling consisted of collecting 15 cobble sized rocks throughout a stream reach and scraping periphyton from a oneinch-diameter circular area. In some cases where rocks were unavailable, woody snags were scraped instead. Periphyton samples were preserved and sent to a contracted taxonomist to be analyzed for diatom species identification. Diatoms were identified down to the lowest possible taxonomic level. Diatoms are a collection of microalgae in the Bacillariophyta group. Diatoms are widely recognized and used as indicators of river and stream water quality including enrichment conditions (Stevenson & Pan, 1999). Several state agencies are using diatom trophic indices to aid in the development of nutrient criteria (Ponader et al, 2007; Danielson, 2009).

An enrichment factor (EF) was calculated for each of the 78 periphyton sites using GIS (Becker & Dunbar 2009). An EF is representative of the amount of anthropogenic phosphorus loading to river and streams. It is calculated by dividing the current total seasonal phosphorus load by a modeled total phosphorus load under complete forested conditions at a particular point along the river (**Figure 2, Equation 1**). The current total phosphorus load is calculated by adding the total current NPDES load (2001 – 2007) to a modeled current land cover load using export coefficients (Becker & Dunbar 2009). The approach targets the critical 'growing' period (April through October) when phosphorus is more likely to be taken up by sediment and biomass because of low flow and warmer conditions.

Equation 1. Enrichment Factor Calculation



Example:

Current Load (lbs/day)	205.3
Forested Load (lbs/day)	4.80
Enrichment Factor	**42.79**

Figure 2. Example of how the enrichment factor (EF) is calculated.

The enrichment factor at the periphyton sites ranged from 1.2 to 76. A statistical technique called Threshold Indicator Taxa Analysis (TITAN) (Baker & King 2010) was used to look at changes in the diatom community in response to the varying enrichment factors seen at sites. TITAN detects changes in taxon specific responses and provides evidence for community thresholds by indicating synchronous taxa responses.

The TITAN analysis indicated that an enrichment factor of 1.9 and 8.4 represented a lower and upper threshold, respectively, at which a significant change was seen in the benthic algal community (**Figure 3**). Additional analysis showed that sites with EFs above 8.4 contained diatom species that only occurred in highly enriched conditions and typically increase in response to enrichment. Sites with EFs below 1.9 contained diatom species that are sensitive to phosphorus and decrease in abundance above a 1.9 EF.

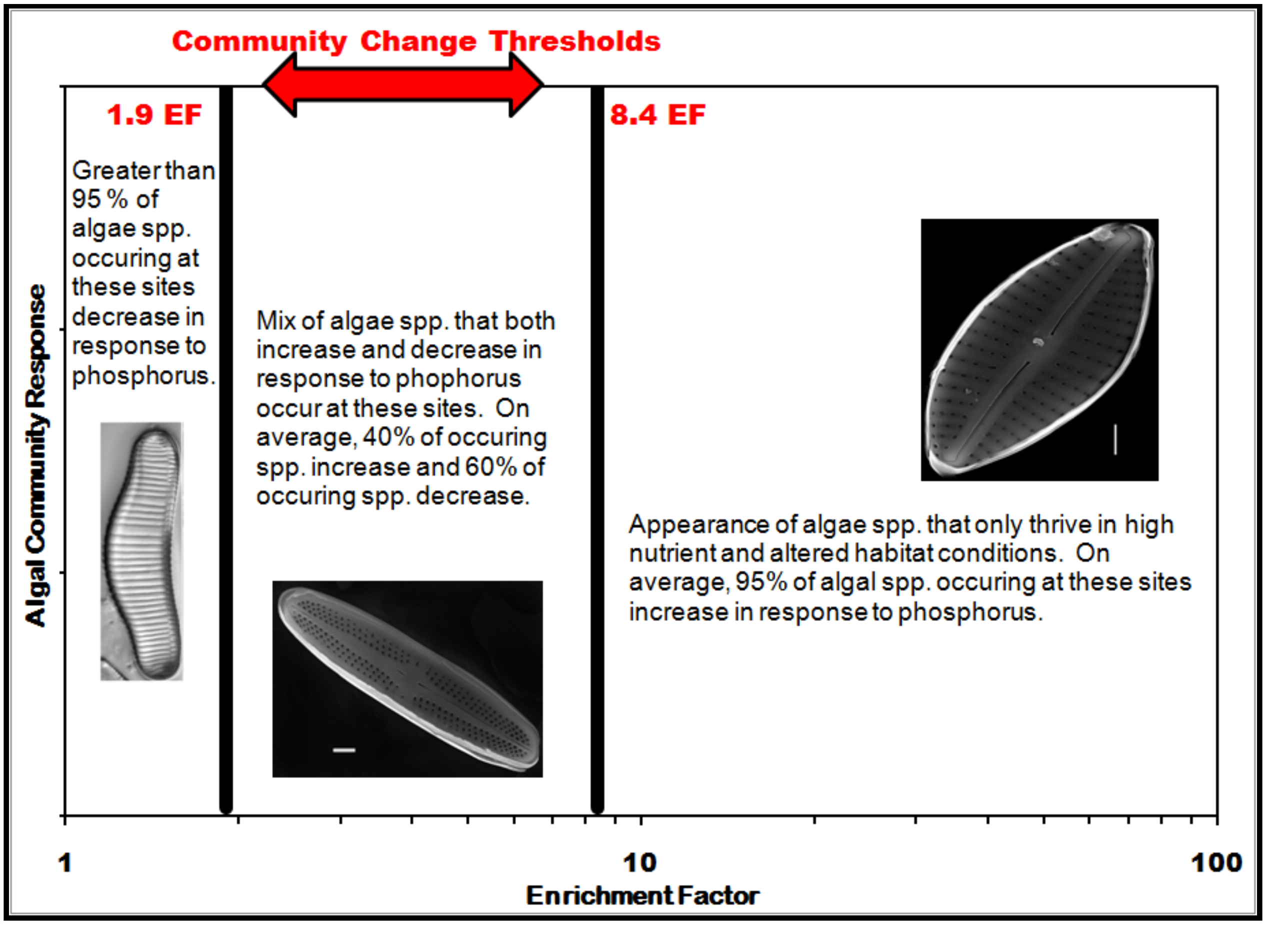


Figure 3. Upper and lower algal community thresholds in response to EF indicated in TITAN analysis

Interim Phosphorus Management Strategy

The upper threshold indicated in the TITAN analysis of an 8.4 EF was used as the aquatic life goal for waters below NPDES facilities for the interim strategy. The current EFs below NPDES facilities range from 2.8 to 138. The Department is requiring a reduction in current phosphorus loads from municipal WWTPs and industrial discharges to those streams or stream sections with an EF greater than 8.4. The reductions at these facilities will ensure that an 8.4 EF is maintained throughout the stream so that water quality management goals are achieved and aquatic life uses are met. The required load reductions will be incorporated into the facility permits when they are up for renewal. Those facilities discharging to streams with an EF below 8.4 will be required to maintain their current load. Any increases in flow at the facilities in the future will require that the facilities reduce their phosphorus concentration. Compliance schedules may be incorporated into the permit to allow for planning, design, financing and construction of any treatment facilities necessary to achieve performance levels.

The Department conducted a watershed loading analysis to identify and assess the EFs in waste receiving streams. The EF was calculated at multiple locations on a waste receiving stream (**Figure 4a**). This was done by delineating the watershed at each of those points and calculating the land use load, NPDES load and a forested condition load for each of those watersheds. Reductions in NPDES facilities load were made to achieve the goal of an 8.4 EF throughout the stream (**Figure 4b**). In some cases the EF below a NPDES facility is lower to ensure that the 8.4 EF is met in downstream waters. The strategy results in overall watershed reductions of NPDES phosphorus loads ranging from 23% to 95% once the strategy is fully implemented.

Ongoing work is currently being conducted to refine the approach through additional data collection and by expanding the methodology to include non-waste receiving streams and to better incorporate spatial and temporal habitat conditions that can also effect changes in the diatom community. The current approach provides for a major statewide advancement in the level of phosphorus control that is expected to meet all freshwater designated uses in waste-receiving streams. The adaptive nature of Connecticut's strategy allows for revisions to permit limits in future permit cycles without delaying action that we know needs to be taken today. It also provides an opportunity to monitor and research the responsiveness of the aquatic systems to these initial steps to manage phosphorus from NPDES permitted sources.

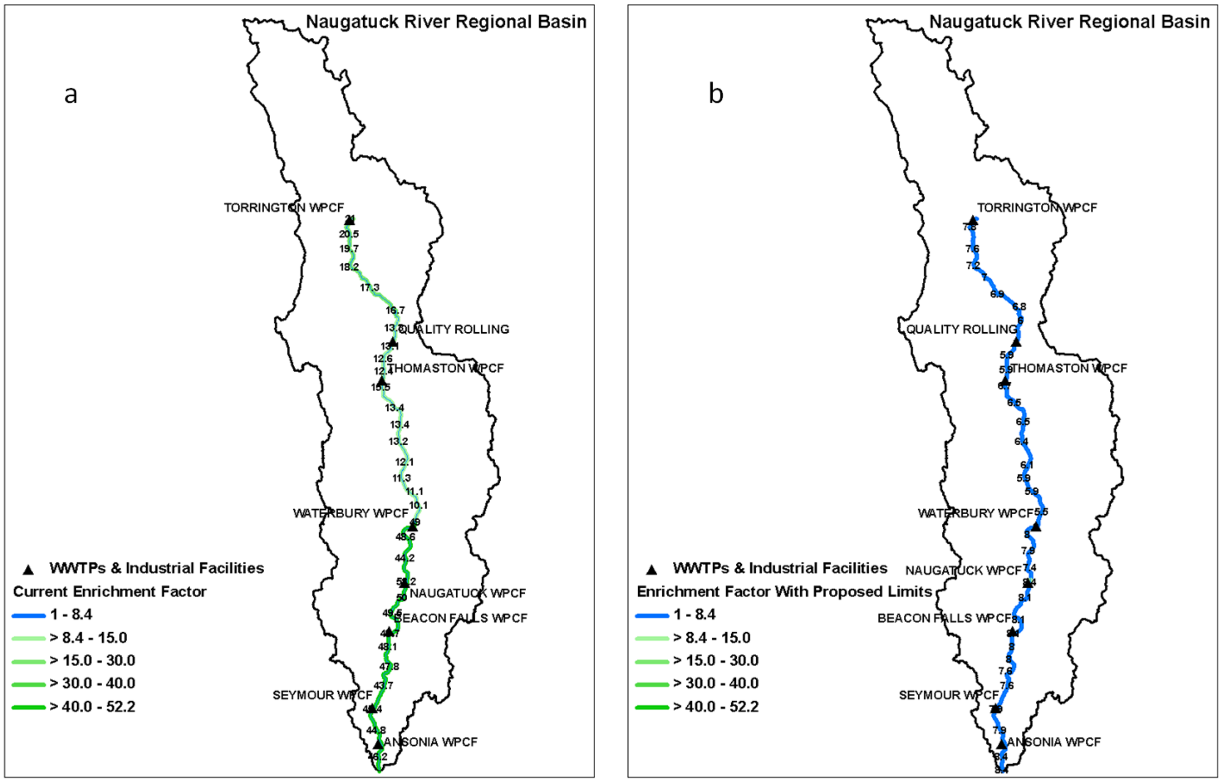


Figure 4. Example of GIS based watershed loading analysis to assess the current enrichment factor (a) and the enrichment factor with proposed limits to meet the goal of 8.4 or below (b).