A TOTAL MAXIMUM DAILY LOAD ANALYSIS FOR CEDAR POND IN NORTH BRANFORD, CONNECTICUT

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This document has been established pursuant to the requirements of Section 303(d) of the Federal Clean Water Act

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INTRODUCTION

The Federal Clean Water Act (CWA) provides regulations for the protection of streams, lakes, and estuaries within the United States. Section 303(d) of the CWA requires individual states to identify waters not meeting state water quality standards due to pollutant discharges and to develop Total Maximum Daily Loads (TMDLs) for these waters. A TMDL sets the maximum amount of a substance that a waterbody can receive without exceeding current state water quality standards. Waterbodies for which Connecticut is required to develop TMDLs are included on the *2004 List of Connecticut Waterbodies Not Meeting Water Quality Standards* [(1)] *(2004 List)*. Such waterbodies are identified on the *2004 List* as Tiers 2 and 3. Cedar Pond is included on the *2004 List* as a Tier 2 waterbody due to impairment of recreational use and aquatic life support caused by excessive nutrient (phosphorus) loading. As such, a TMDL for phosphorus has been prepared for Cedar Pond and is presented herein.

The purpose of the Cedar Pond TMDL is to establish phosphorus loading targets that, if achieved, will result in consistency with the *State of Connecticut Water Quality Standards* [(2)] (WQS). Water quality that is consistent with WQS is expected to protect designated uses, and implies that conditions will be similar to those expected under natural conditions without undue human influence. This TMDL analysis was prepared following the Environmental Protection Agency's (EPA) protocol for developing nutrient TMDLs [(3)]. The main objectives of this TMDL analysis report include the following:

- describe existing conditions and applicable standards and guidelines;
- estimate the loading capacity of Cedar Pond;
- assign loading capacities for existing and future sources;
- establish a margin of safety;
- account for seasonal variation;
- develop a monitoring plan;
- develop an implementation plan;
- provide reasonable assurances that the plans will be acted upon; and
- describe public participation in the TMDL process.

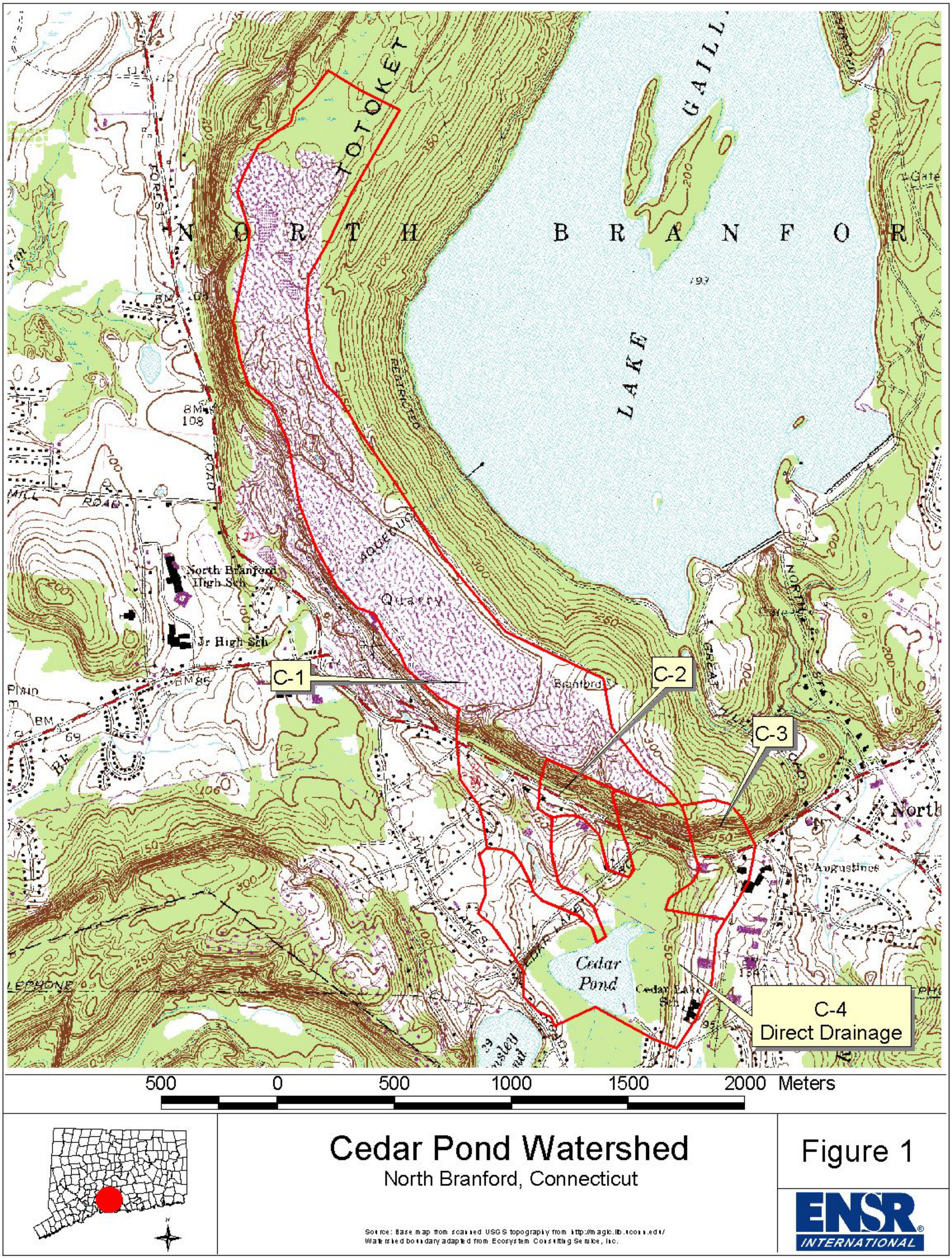
Determining the maximum daily nutrient load that a waterbody can assimilate without exceeding water quality standards is challenging and complex. First, many lakes receive a high portion of their nutrient loading from non-point sources and stormwater runoff, which are highly variable and are difficult to quantify. Secondly, lakes demonstrate nutrient loading on a seasonal scale, not a daily basis. Loading during the winter months may have little effect on summer algal densities. Additionally, the nutrient loading capacity of lakes is typically determined through water quality modeling, which is usually expressed on an annual basis. Therefore, it is most appropriate to quantify a lake TMDL as an annual load and evaluate the results of that annual load on mid-summer conditions that are most critical to supporting recreational uses. Finally, variability in loading may be very high in response to weather patterns, and the forms in which nutrients enter lakes may cause increased variability in response. Consequently, while a single value may be chosen as the TMDL for each nutrient, it represents a range of loads with a probability distribution for associated water quality problems (such as algal blooms). Uncertainty is likely to be very high, and the TMDL should be viewed as a nutrient-loading goal that helps set the direction and magnitude of management, not as a rigid standard that must be achieved to protect against eutrophication.

DESCRIPTION OF WATERBODY

Much of the waterbody information presented in this section was obtained from An Evaluation of Potential Stormwater Runoff Impacts to Cedar and Linsley Ponds, (EPSRI) [(4)] and a Characterization and Management of Stormwater in Tilcon Connecticut's North Branford Quarry (CMSW) [(5)].

Cedar Pond is a 22-acre fresh water pond located in North Branford, Connecticut (New Haven County). The pond and its 593-acre watershed lie within the Branford River basin and form the headwaters of Pisgah Brook. The watershed is divided into four sub-basins and is outlined in Figure 1. The maximum and mean water depths of the pond are 17.1 and 10.8 feet, respectively. The pond volume is approximately 10.1 million cubic feet, with a retention time of approximately 58 days (flushing approximately six times per year). The watershed is mostly comprised of industrial (quarry; 58%) and developed (residential; 21%) areas. Base flow and groundwater flow from the watershed accounts for 12% of the total inflow to Cedar Pond. Stormwater flow provides approximately 82%. As a result of high stormwater inputs, the retention time of Cedar Pond varies mainly in response to precipitation.

Limited stormwater controls exist throughout the watershed. The quarry located within the watershed maintains detention systems that reduce nutrient and solids loading to the pond only slightly. Water is pumped from the quarry, however, so control over the discharge of collected stormwater is possible. The pond experiences eutrophic conditions such as non-algal turbidity in response to inclement weather (stormwater runoff with soil erosion), and algal blooms under low-flow conditions (high fertility with low flushing). Increased phosphorus loading from anthropogenic sources is a cause of eutrophication in Cedar Pond and is therefore the subject of this TMDL. Phosphorus is the primary nutrient of concern and limitation of phosphorus inputs will likely yield the desired conditions without any substantive change in the loading of other nutrients.



C-1
C-2
C-3
C-4
Direct Drainage
Cedar Pond
North Branford High Sch
Jr High Sch
Quarry
LAKE
N O R T H B R A N F O R
TOTOKET
500 0 500 1000 1500 2000 Meters
Cedar Pond Watershed
North Branford, Connecticut
Figure 1
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PRIORITY RANKING AND POLLUTANTS OF CONCERN

Cedar Pond is included on the *2004 List* due to impairment of recreational and aquatic life support uses caused by excessive anthropogenic phosphorus loading. Excess nutrient loading to Cedar Pond has resulted in increased algae growth, chlorophyll *a*, low dissolved oxygen, and reduced water clarity. Cedar Pond is ranked a "T" priority on the *2004 List*, which indicates that the waterbody is currently under study and may lead to TMDL development if results of the investigation warrant implementation of a TMDL as the solution to remedy the water quality impairment. TMDLs may be completed for waterbodies ranked "T" on the *2004 List* within the two years. The Connecticut Department of Environmental Protection (DEP) has determined that establishing a TMDL for phosphorus based on the results of the two existing reports: An Evaluation of Potential Stormwater Runoff Impacts to Cedar and Linsley Ponds (EPSRI) [(4)] and a Characterization and Management of Stormwater in Tilcon Connecticut's North Branford Quarry (CMSW) [(5)] is an appropriate pollution control strategy for Cedar Pond.

POLLUTANT SOURCES

Identification of Sources

Sources of phosphorus include stormwater runoff, construction activities, quarry activities, use of fertilizers, waterfowl, and to a lesser extent failed or improperly functioning septic systems. The routes of entry for phosphorus to Cedar Pond include the following:

- surface water base flow (dry weather tributary flows, including groundwater infiltration);
- stormwater flow (runoff added to tributaries or directly to the pond);
- atmospheric deposition (direct precipitation to the pond);
- waterfowl (direct inputs to the pond from birds); and
- internal recycling (release from the sediment, either by chemical interaction with overlying waters, resuspension by wind, or "pumping" by macrophytes).

Permitted point source discharges of nutrients in Cedar Pond's basin include only certain stormwater discharges that are regulated as point sources under the federal NPDES regulations (For more information, see pages 13 - 14).

Analysis of Current and Background Loading

Current nutrient loading to Cedar Pond were assessed using the following three methods:

1. A combination of estimated and actual data from the EPSRI [(4)] and CMSW [(5)]. Data collected during dry weather (EPSRI) was used to determine instantaneous mass loadings (measured flow multiplied by concentration in tributaries). Annual runoff

estimates provided in the EPSRI study and wet weather data were used to estimate stormwater runoff nutrient loading (dry weather concentration data were used when wet weather data were not available). Direct assessment is the most traditional method of evaluating loading, but requires substantial data to be reliable. As all individual sources are not directly assessed in field studies, extrapolation and estimation were necessary. However, direct measurement provides real data upon which to base loading estimates, and acts as a valuable reality check on modeling approaches.

2. The average of empirical models (Bachman [(6)], Kirchner-Dillion [(7)], Vollenwieder [(9)], Vollenweider [(8)], Reckhow [(10)], Larsen-Mercier [(11)], and Jones-Bachmann [(12)]). Empirical models generate estimates of the load necessary to achieve observed in-lake conditions, based on system features such as depth and retention time. They are based on relationships derived from many other lakes. As such, they may not apply accurately to any one waterbody, but provide an approximation of current total loading, including stormwater and base flows. In addition, empirical models provide a reasonable estimate of the direction and magnitude of changes that might be expected if loading is altered.
3. A calibrated land use export coefficient model developed by ENSR [(13)] under contract to the DEP. Export coefficient models depend on empirical or assumed yields of water and nutrients from the watershed as a function of land use. Yields are assigned to each defined parcel in each defined sub-watershed of the lake. These yields can be modified as they move toward the lake through attenuation factors, based on distance to the lake, soil types, and any Best Management Practices (BMPs) in place. The export coefficient model employed here was developed by Kenneth Wagner, Ph.D. of ENSR for use in southern New England, and allows the user to select yield coefficients and attenuation factors from a range appropriate to this area. Values encompass those applied in the Long Island Sound Study [(14)] and work by Frink and Norvell [(15)] at the Connecticut Agricultural Station over many years. The generated load to the lake is processed through the empirical models noted above to derive estimates of in-lake concentrations and effects on algal productivity and water clarity. This model is most effective when calibrated with water quality data for the target system. While it is a spreadsheet model with inherent limitations on applied algorithms and resultant reliability of predictions, it provides a rational means to link actual water quality data and empirical models in an approach that addresses the whole watershed and lake.

This combination of approaches yield a range of probable loads and provide a reasonable approximation of actual conditions over the longer term. From the three methods, total phosphorus loading ranged from 76 to 113 kg/yr. Loading estimates from the three approaches are generally similar. Certainly the inter-annual range of phosphorus loads could be expected to exhibit such a range. The results of each method are provided in Table 1.

Table 1. Annual Phosphorus Loading in Cedar Pond.

Method	Method ID Number	Phosphorus (kg/yr)
Estimated and Actual (EPSRI & SWMGT)	1	76
Empirical Model Average	2	113
Land Use Export Coefficient Model	3	86
Mean of All Methods		**92**

Using the EPSRI & CMSW (method 1), and land use export nutrient budgets (method 3), direct precipitation provides approximately 4% of the annual phosphorus load. Total surface flow (storm and base flows) represented 69-73% of phosphorus (stormwater inputs accounted 39-42% of the annual total phosphorus load). Waterfowl provide 12-13% of the phosphorus load. Internal recycling is estimated to provide 11-13% of phosphorus loading on an annual basis, but most of this loading occurs during summer. Direct precipitation and waterfowl combined to provide only relatively small portions of the total phosphorus load. Internal loading is also small as a portion of annual loading, but the seasonal nature of internal loading may necessitate some action relating to this source. To achieve the greatest positive impact, management must focus on stormwater flow contributions to Cedar Pond.

Background conditions were estimated by modifying the land use export coefficient model. After the model was calibrated to reflect current conditions in the watershed of Cedar Pond, land use was changed to reflect pre-development background conditions (i.e. forested and wetland conditions) and the internal load was reduced by 50% (an estimate of more natural internal loading level). In addition, the overall watershed size was reduced because the quarry increased the current drainage area of Cedar Pond. Based on historic topographic maps, the drainage area of sub-basin C-1 (Figure 1) was reduced by 75% to represent pre-quarry conditions. Background phosphorus loading under these conditions was 32 kg/yr, (14 kg/yr from the watershed alone). Background in-lake phosphorus concentration predicted from empirical models was 26 ug/L. As such, a reduction of 58-72% reduction from the current total phosphorus load would be necessary to return the watershed to expected "background" loading conditions.

It should be noted that the estimated background phosphorus load is lower than the target load (page 17), as would be expected, however the predicted in-lake phosphorus concentration, based on the target load, is lower (23 ug/L). The in-lake phosphorus concentration represents the average results of several empirical models using the loads derived from the export co-efficient model. Further explanation is provided on page 12 of this document.

Assumptions and Calculations Regarding Phosphorus Sources

Estimation of nutrient loading involves assumptions and can be derived in multiple ways. To facilitate understanding of the approaches applied here, the following listing of assumptions and calculation methods is offered:

Hydrologic Inputs

Direct precipitation

- Average annual precipitation for southwestern New England [16] was multiplied by the lake area.

Surface Water Base & Storm Flow

- The mean measured discharge (dry weather flow), provided in the EPSRI [4], was used to calculate base flow. The estimated mean annual runoff provided in the EPSRI was used for the stormwater hydrologic contribution by basin.
- For the land use model, runoff and base flow coefficients were adjusted to provide a total inflow comparable to the estimated mean annual flows (base and runoff) determined using EPSRI [4] data.
- The land use model inflow, comparable to that estimated in the EPSRI [4], was used in the empirical models.
- Average annual precipitation was multiplied by stormwater and base flow coefficients [17] for land use categories obtained from UCONN [18] to estimate the predicted inflow from base and storm flows.

Groundwater

- Groundwater contribution was estimated by subtracting the precipitation, base and storm flow contribution from the total estimated outflow from Cedar Pond.

Nutrient Inputs

EPSRI [4] & CMSW [5]

- Measured concentrations during dry weather at each tributary were multiplied by measured flow rates to provide an instantaneous mass loading. The average of these values, by drainage basin, was extrapolated to yield an annual budget for base nutrient loading. The runoff flow value, provided in the EPSRI, was multiplied by the average measured concentration, provided in the CMSW, to estimate the annual nutrient load from stormwater. Dry weather concentrations provided in the EPSRI were used when stormwater concentration data were not available, and this will underestimate actual loading.
- Data provided in the EPSRI were used to calculate internal loading. The average of two methods was used: accumulation in the hypolimnion and the difference in concentration between the hypolimnion and epilimnion over the period of anoxia.

- A combination of literature values (for atmospheric deposition and waterfowl) and measured data were used to ascertain total nutrient loading to Cedar Pond.

Empirical Model

- Hydrologic lake features and known in-lake concentrations were used to back-calculate the nutrient load required to obtain observed in-lake concentrations.
- An average of five models was used (Kirchner-Dillion [7], Vollenweider [8], Reckhow [10], Larsen-Mercier [11], and Jones-Bachmann [12]).

Land Use Export Coefficient Model

- Nutrient export coefficients from the literature for different land use types were used to calculate potential nutrient loads. The quarry was classified as Open Exposed Surface and the export coefficients were adjusted using data presented in the CMSW.
- Loads were reduced based on estimated natural attenuation and any existing water quality control devices, and adjusted based on comparison of results with existing data.
- Once calibrated for the specific watershed, this model was also used to predict impacts of watershed management actions.

Relationships

- It was assumed that water transparency and chlorophyll *a* concentrations in Cedar Pond are mathematically related to total phosphorus concentrations as described by Carlson [19] and Frink and Norvell [15]. Interference by non-algal turbidity, toxicity, or other possible factors is assumed to be minimal.

Summary

Cedar Pond is a 22-acre fresh water pond with a 593-acre watershed of primarily industrial (quarry) and urbanized (developed residential) land. In-lake water quality is dependent on the quality of surface water entering the lake from the watershed, especially stormwater runoff quality. Inadequate stormwater controls have lead to a decline in runoff water quality and high variability of in-lake water quality. Excessive anthropogenic phosphorus loading over time has led to increased frequency and duration of algal blooms. Internal loading has also been identified as a contributor of phosphorus and should not be ignored. It is estimated that 11-13% of the annual phosphorus budget is provided through internal loading from the sediment, mostly entering the water column in summer and early autumn.

Multiple nutrient loading approaches provide estimates of the phosphorus loads to Cedar Pond that can be compared to desirable loading levels, in order to comply with water quality standards and use attainment goals. The current loading of phosphorus is estimated to be 76 to 113 kg/yr. Background phosphorus loading was estimated to be 32 kg/yr. As such, a 58-72% reduction in current total phosphorus load would be necessary to return the watershed to expected "background" loading conditions.

APPLICABLE WATER QUALITY STANDARDS

Cedar Pond has been assigned a surface water classification of A by the State of Connecticut. Surface water classifications are not a measure of existing water quality but rather they establish designated uses for a waterbody. Designated uses for Class A waters include habitat for fish and other aquatic life and wildlife; potential drinking water supply; recreation; navigation; and water supply for industry and agriculture. Existing uses for Cedar Pond include habitat for fish, other aquatic life and wildlife support, and recreation.

The applicable water quality standards for Cedar Pond include: Surface Water Criteria and Lake Trophic Categories. The surface water standards for phosphorus, for which Cedar Pond TMDLs have been derived, are narrative. Surface water quality standard numbers 8, 10, 11, 12, 13, 17, and 19 of the WQS [(2)] aid in the interpretation of such criteria. Specifically, standard 8 specifies that only those nutrients that remain following application of BMPs can be considered to be of natural origin. Achieving consistency with this standard requires that 1) BMPs be used to minimize nutrient releases resulting from human activity and, 2) the nutrient loading that remains following implementation of BMPs does not result in adverse impact to existing or designated uses. As noted in the previous section, current practices to manage stormwater runoff are inadequate and much of the present nutrient loading to the pond cannot be considered "natural" due to the absence of effective BMPs. In order for the nutrient loading to be considered "natural" and consistent with standard 8, additional BMPs must be implemented in the watershed. Further, the post-BMP implementation loading must not adversely impact an existing or designated use in order to be considered "natural". This determination is made based on an examination of the impact of the projected post-BMP loading on recreational uses. Recreational uses in lakes are primarily determined by the lake's natural trophic category. Nutrient loading from human activities that results in the degradation of a lake's natural trophic category represents an adverse impact to designated recreational uses.

Lake trophic categories include expected numerical ranges for total phosphorus, chlorophyll *a*, and Secchi disk transparency. The values of these parameters vary depending on the trophic category. Designated recreational uses will be fully supported and maintained for lakes that do not exceed the numerical values for their expected trophic category. The natural trophic categories are determined through assessments of lakes, absent of significant cultural impacts. Based on the estimated concentrations under background conditions, the expected natural trophic state of Cedar Pond is mesotrophic to late mesotrophic. The in-lake phosphorus concentration based on background loading was estimated to be 26 ug/L. Connecticut WQS establish the following concentration ranges for phosphorus, chlorophyll *a* and transparency as a guideline for evaluating attainment of mesotrophic conditions:

Total Phosphorus	10 - 30 ug/L (spring and summer)
Chlorophyll *a*	2 - 15 ug/L (mid-summer)
Secchi Disk Transparency	2 - 6 meters (mid-summer)

However, Cedar Pond experiences elevated nutrient loading and subsequent excessive algal and macrophyte growth. Such conditions have resulted in limitations on some forms of recreation that are an apparent consequence of human-derived inputs that have not been effectively managed. As such, Cedar Pond is considered eutrophic according to Connecticut WQS [(2)], while the trophic condition that would exist in the absence of significant cultural impact is mesotrophic to late mesotrophic. To achieve consistency with Connecticut WQS and fully support designated recreational uses, nutrient loading to Cedar Pond must be reduced.

Mesotrophic lakes generally provide desirable conditions for water contact recreation. A significant percentage of the mesotrophic lakes in Connecticut have designated swimming areas and other primary contact activities such as water skiing and tubing. Boating and other secondary contact uses are considered recreational uses in mesotrophic lakes as well. There may be brief times during the year or limited areas of a mesotrophic lake where aesthetic considerations (i.e. macrophyte growth or short duration algal blooms) cause some reduction in the level of recreational activity. These limitations are not considered to be “impairments” since they reflect the normal and expected conditions in a mesotrophic lake, and do not occur as a response to excessive anthropogenic nutrient loading.

TOTAL MAXIMUM DAILY LOAD

Cedar Pond is listed on the *2004 List* for impairment to recreational uses and aquatic life support caused by excessive nutrient concentrations. Although phosphorus is a naturally occurring element, the amount of phosphorus entering Cedar Pond has increased due to anthropogenic activities (such as development, fertilizer use, illicit connections, quarry activities, direct stormwater piping to the pond, and inadequate stormwater controls). Increased phosphorus loading has led to increased phytoplankton densities, reduced water clarity, poor aesthetic quality, and low dissolved oxygen near the pond bottom.

In order to achieve conditions consistent with Connecticut WQS, the TMDL must be based on reducing current loads to a level that can be considered “natural” in accordance with standard 8. This equates to the loading that will be achieved following implementation of Best Management

Practices (BMPs) to control nutrients throughout the watershed, provided that loading does not adversely impact any existing or designated uses.

The phosphorus TMDL for Cedar Pond is effective at the entrance to the pond and is expressed as an annual load with the critical time being spring and early summer (see the "Seasonal Variation" section for a discussion of the critical time and seasonal loading component of the TMDL). As required, the TMDL accounts for waste load allocations (WLA) for all point sources, including stormwater discharges regulated under the NPDES program; and load allocations (LA) for all non-point sources, as well as background levels; and a margin of safety (MOS). The MOS accounts for any uncertainty regarding the relationship between waste load and load allocations and water quality.

The equation for the TMDL analysis is as follows:

$$\text{TMDL} = \text{LA} + \text{WLA} + \text{MOS}$$

The following section describes how the target loading was estimated. Based on the target loading, the expected resulting conditions for Cedar Pond were modeled and evaluated with respect to achieving compliance with the WQS (Appendix A).

Target Loading

The target load for phosphorus to Cedar Pond was determined using the land use export coefficient model (method 3). This approach was selected because it provides loading estimates based on land use categories and allows for reductions to be applied toward those land use categories associated with urban and industrial uses, where it is generally anticipated that BMPs will be applied. In addition, this method calculates stormwater flow, which is needed in order to separate allocations for regulated and non-regulated stormwater as requested in the EPA's 2002 Guidance Memorandum [(20)].

As previously mentioned, 58-72% reduction in current total phosphorus loading would be necessary to return the watershed to expected “background” loading conditions. Realistically, an aggressive reduction of phosphorus loading attained by using BMPs applied to manageable sources is expected to result in loading reductions on the order of 60% [(21)]. Greater reductions are possible without consideration of costs, space requirements, or legal ramifications (e.g., land acquisitions), but most techniques applied in a practical manner do not yield a reduction >60% in phosphorus loads. Algal blooms in Cedar Pond are dominated by nitrogen-fixing blue-greens (cyanobacteria) whose abundance is not likely impacted by nitrogen availability but whose excessive growth and dominance in the algal community is a function of high levels of available phosphorus. Control of phosphorus is expected to achieve the desired conditions of greater water clarity.

The form of phosphorus will have a substantial impact on achievable loading reduction and choice of BMPs, with particulate forms easier to reduce than dissolved forms. Aerated soil will remove particulate phosphorus by filtration and adsorption, but substantial detention time is needed to remove dissolved forms. The assumption of a 60% reduction in phosphorus from the total watershed load is ambitious but possible for the Cedar Pond watershed. In addition, a 50% reduction of phosphorus in internal loading is possible and expected as part of the management objectives.

A 60% reduction of the total phosphorus watershed load from urban and industrial land uses combined with a 50% reduction in internal loading of phosphorus within Cedar Pond would result in a total annual phosphorus load of 49 kg/yr (Table 2). Using the target TMDL load in several empirical calculations resulted in a range of in-lake concentrations (21 ug/L - 38 ug/L), with an average in-lake phosphorus concentration of 23 ug/L. In comparison, background phosphorus loading was estimated to be 32 kg/yr and the corresponding in-lake phosphorus concentration was estimated to be 26 ug/L, with a range of 21 to 38 ug/L. Upon implementation of BMPs within urban and industrial land use areas, nutrient loading could be considered "natural" provided it does not result in adverse impacts to designated uses.

The background and post-TMDL phosphorus loads were derived from an export coefficient model. In order to model background conditions, the watershed size was reduced in the model since Tilcon's activities have increased the area of Cedar Pond's existing watershed. The resultant loads were then entered into a number of empirical calculations to estimate the in-lake phosphorus concentrations under both conditions. The average of empirical model results for background conditions was 26 ug/L and 23 ug/L for post-TMDL conditions. The in-lake post-TMDL concentration is slightly (3 ug/L) less than background conditions due to an increased water yield from the larger watershed. This increased water yield results in a greater flushing rate, which is an important parameter in the empirical calculations. Regardless, a difference of 3 ug/L is not considered significant, but rather within the uncertainty of the TMDL analysis.

Table 2. Summary of Total Phosphorus Current Load, Post-BMP Implementation Load and Predicted In-lake Concentrations.

	Current Conditions			Post – BMP Implementation			
	Watershed Load[1] (kg/yr)	Other Load[2] (kg/yr)	Total Load (kg/yr)	Watershed Load (kg/yr)	Other Load (kg/yr)	Total Load (kg/yr)	In-lake Concentration (ug/L)
TOTAL PHOSPHORUS							
Export Coefficient Model	63	23	86	28	20	49	23

1 Watershed Load = Surface water base flow, stormwater flow, and groundwater infiltration.
2 Other Load = Direct precipitation, waterfowl, and internal recycling.

Determination of the Regulated Stormwater Load

EPA policy guidance [20] requires that TMDL analyses provide separate allocations for "regulated" and "non-regulated" stormwater. Regulated stormwater is defined by EPA as stormwater that is discharged through a point source (discrete outfall) and requires a permit under federal NPDES regulations. This includes stormwater discharged from industrial facilities and construction sites covered under the "Phase I Rule" [22], as well as small municipal separate storm sewer system (MS4) discharges covered under the "Phase II Rule" [23] (MS4 permit). MS4 communities have been determined and mapped by the Census Bureau based on the 2000 population information. There is one regulated industrial outfall in the watershed for stormwater (Tilcon Connecticut, Inc.) that is covered under an individual permit. Regulated stormwater loading under the MS4 permit was approximated by overlaying the sub-basin map for Cedar Pond (Figure 1) with the Census Bureau's urban areas boundaries map. It is assumed that runoff from urbanized watershed areas is more likely to be captured by stormwater drainage systems that are regulated under the MS4 permit.

Approximately 11% of the area within sub-basins C-1, 66% of sub-basin C-2, 60% of sub-basin C-3, and 94% of sub-basin C-4 are located within the designated MS4 community (Figure 1). Although sub-basin C-1 only contained a small portion of MS4 area, all non-urban drainage passes through the MS4 area, and therefore stormwater loading from the entire sub-basin was considered regulated. Similarly, all non-urban areas in the remaining sub-basins (C-2 through C-4) pass through MS4 areas prior to entering Cedar Pond. Therefore, the stormwater load from the entire watershed of Cedar Pond was considered regulated (Table 3). Regulated stormwater constitutes the Waste Load Allocation.

Table 3. Distribution of Current Regulated and Non-Regulated Stormwater Loading.

Stormwater Distribution	Total Phosphorus (kg/yr)
Current Conditions	
Surface Water Base Load (includes groundwater load)	1
Stormwater Load	62
Total Watershed Load	63
Regulated Stormwater Load	**62**
Non-regulated Stormwater Load	**0**

Load Allocation

The non-point source load allocation for Cedar Pond includes allocations to surface water base flow (including groundwater infiltration), internal sediment loading, atmospheric deposition, and waterfowl loading (Table 4). Regulated stormwater and permitted discharges are covered under the waste load allocation.

The phosphorus load allocation for internal sediment recycling (i.e., release from sediment) is half the estimated current load, or about 5 kg/yr, and is most likely to be achieved by nutrient inactivation. Reduced loading from the watershed may eventually lead to reduced internal loading, but it is not expected that this will happen shortly after BMP implementation. While the phosphorus load from internal sources is small relative to watershed inputs, the timing of this load in the summer season and the potentially high availability of associated phosphorus make it a logical target for load reduction. A major but temporary reduction in phosphorus concentration in Cedar Pond may be realized as a consequence of inactivation of internal nutrient reserves, so the reduced load allocation for internal loading may have disproportionately larger benefits.

Load allocations for atmospheric deposition and waterfowl are set at the average current level for phosphorus (13 kg/yr). No reduction is assumed, although management of geese could provide a small decrease in total loading. Overall, however, these non-point sources do not account for enough of the total load for corresponding reductions to make much difference.

Table 4. Summary of Load Allocation to Cedar Pond.

Non-point Source	Total Phosphorus (kg/yr)
Surface Water Base Load	1
Internal Sediment Loading	5
Other (waterfowl, atmospheric deposition)	13
Total Load Allocation	**19**

Waste Load Allocation

As discussed in the "Determination of Regulated Stormwater Load" section, there is one individual stormwater discharger permitted under NPDES individual permit (Tilcon). In addition, stormwater from the entire Cedar Pond watershed is considered regulated under the Phase II Rule or MS4 permit. There are no Publicly Owned Treatment Works or additional NPDES permitted dischargers in the watershed.

With a phosphorus TMDL of 49 kg/yr (Table 2), and a load allocation of 19 kg/yr (Table 4), this leaves 30 kg/yr for distribution to waste load sources. A waste load allocation of 17 kg/yr was assigned to Tilcon and was derived from the export coefficient model. The remaining 13 kg/yr of phosphorus were allocated to NPDES Phase II Stormwater for the Cedar Pond watershed. The target loading for regulated stormwater is presented in Table 5.

No additional wasteload allocations have been made to accommodate future growth in this TMDL. Any discharge permits that may be granted in the future (such as stormwater permits) will require BMPs as necessary to insure that stormwater loadings of nutrients to Cedar Pond established in this TMDL are not exceeded.

Table 5. Summary of Waste Load Allocation to Cedar Pond.

Point Source	**Total Phosphorus (kg/yr)**
Regulated Stormwater NPDES - Tilcon	17
Regulated Stormwater NPDES Phase II - MS4	13
Other Point Source / Future growth	0
Total Waste Load Allocation	**30**

MARGIN OF SAFETY

Federal regulations require that all TMDL analyses include a margin of safety (MOS) to account for uncertainties regarding the relationship between load and waste load allocations, and water quality. The MOS may be either explicit or implicit in the analysis, or both.

The margin of safety applied in this TMDL is implicit in the analysis. The entire loading analysis employed in developing this TMDL is based on the total phosphorus load, while the impact of the load will be a function of nutrient availability. Dissolved nutrients are generally around 50% of the total nutrient level, with increased variability from stormwater. Although some portion of the particulate fraction of total phosphorus is likely to become available within a short time, much of the particulate fraction will be incorporated into the lake sediment and any later release is already accounted for as internal load. This suggests an implicit MOS of 50% as a function of nutrient availability. At the very least, the MOS is 25% and it could be as large as 75%, based on the typical particulate composition of stormwater, which is a dominant source in this system.

Most guidance for developing TMDLs discourages the use of arbitrary MOS values in favor of an MOS implicit in the TMDL by virtue of calculation method or an explicit MOS derived from statistical analysis of uncertainty (EPA [24], Walker [25]). Uncertainty in stormwater dominated systems is very high, as the available nutrient levels vary widely and temporal variability in loading is large. Even with substantial sampling, characterization of this uncertainty is difficult and likely to lead to a MOS of more than 25% or even 50%. As the proposed loading targets are to be achieved mainly by addressing stormwater inputs (the primary source of the variability), and represent the greatest practical reduction in current loads, there is little benefit to be gained by incorporating a large explicit margin of safety in addition to the implicit MOS which exists as described above. As such, adding a MOS at this time has little meaning within the greater context of meeting use attainment goals at Cedar Pond, and so no numerical MOS is proposed at this time.

TMDL SUMMARY

The phosphorus TMDL for Cedar Pond is effective at the entrance to the pond. The TMDL represents the annual load predicted to remain after a 60% reduction in the current stormwater loading from urban and industrial land uses, achieved through BMP implementation, and a 50% reduction in the current internal total phosphorus load, achieved through nutrient inactivation. The target phosphorus load represents what can be achieved through aggressive watershed management, and equates to slightly more than half of the current total loading estimate (Table 6).

Any future land use change that potentially increases loading will be expected to incorporate BMPs that limit the load appropriately because the entire load allocation for the watershed is completely accounted for. As such, additional sources will have to be managed to achieve no net increase in loading. This is the approach currently applied in Maine with regard to watershed development, and while starting conditions may be closer to the natural trophic category in many Maine lakes, the process of “load re-allocation” to maintain a stable load has merit here. Post-BMP implementation loads, expressed as annual values constituting the TMDL are summarized in Table 6.

It should be noted that the target loads contain enough uncertainty that the TMDL should be viewed as reflecting the best judgment based on current information as to what will be needed to meet the WQS. The TMDL is not an absolute number that is guaranteed to be the endpoint of all management. Based on temporal loading variation, conditions could be much worse or much better at any instant in time than predicted by models into which average loads are inserted. Setting and achieving TMDLs for a stormwater dominated system such as Cedar Pond should be an iterative process, with realistic goals over a reasonable timeframe and adjustment as warranted by ongoing monitoring. The selected phosphorus target represents reductions that will require substantial time and financial commitment to be attained.

Table 6. Summary of Estimated Current Phosphorus Loading, and Total Maximum Daily Load Analysis for Cedar Pond.

	Current Total Phosphorus (kg/yr)	**Target Total Phosphorus (kg/yr)**
LOAD ALLOCATION		
Surface Water Base Flow	1	1
Non-regulated Stormwater Runoff	0	0
Internal Sediment Loading	10	5
Atm. Deposition & Waterfowl	13	13
TOTAL LOAD ALLOCATION	**24**	**19**
WASTELOAD ALLOCATION		
Regulated Stormwater NPDES (Tilcon)	42	17
Regulated Stormwater NPDES Phase II	20	13
Other Point Sources / Future Growth	0	0
TOTAL WASTELOAD ALLOCATION	**62**	**30**
MARGIN OF SAFETY		**Implicit**
TOTAL MAXIMUM DAILY LOAD	**86**	**49**

Once the TMDLs are achieved, the resultant trophic classification for Cedar Pond according to the system adopted by the State of Connecticut will be mesotrophic, which is the expected natural trophic category for Cedar Pond. Post-TMDL implementation in-lake conditions for phosphorus were predicted using a number of empirical calculations [6,7,8,9,10,11] and are summarized in Table 7. It has been assumed that phosphorus controls primary productivity in this system. Mean in-lake concentration phosphorus is estimated to be 23 ug/L. Predicted mean chlorophyll *a* and Secchi disk transparency (SDT) values under those conditions are 9.0 ug/L and 2.1 meters, which are typical mesotrophic values. Predicted maximum chlorophyll *a* is 30.4

ug/L, while predicted maximum SDT is 4.1 m. Extreme values may fall outside the mesotrophic category range for a brief period, but this is not expected to happen on a regular or sustained basis.

Table 7. Predicted Post-TMDL Implementation Conditions in Cedar Pond.

	Post-TMDL Conditions	Mesotrophic Category Conditions
Average In-Lake Total Phosphorus	23 ug/l	10-30 ug/l spring and summer
Average In-lake Chlorophyll *a*	9 ug/l	2-15 ug/l mid-summer
Average In-lake Secchi Disk Transparency	2.1 meters	2-6 meters mid-summer

Based on this analysis, there is a high probability that Cedar Pond will be restored to a mesotrophic condition and recreational uses associated with mesotrophic lakes in Connecticut will be fully supported. However, attainment of the target phosphorus load does not guarantee immediate full support for all uses designated for Cedar Pond. For example, additional in-lake techniques for control of rooted aquatic vegetation may be required to enhance recreational opportunities in the near term.

The TMDL is consistent with expectations based on documented BMP performance [26]. Compliance with current narrative water quality standards and criteria for use attainment appears achievable with a total annual phosphorus load of 49 kg/yr.

SEASONAL VARIATION

The TMDL, expressed as an annual target load, should be protective for all seasons since inputs are driven mainly by precipitation, which is distributed roughly evenly over the year on a long-term basis [27]. However, the precipitation pattern in any given year can vary dramatically from the long-term trend on a weekly to seasonal basis. Also, runoff is the actual vehicle for most nutrient transport, and runoff generation depends on factors additional to precipitation. Spring inputs are potentially the largest component of watershed loads and may be more influential than other seasonal loads as they coincide with the start of the growing season in Connecticut.

Cedar Pond flushes approximately six times per year, a moderate flushing rate, but as with precipitation patterns, variability can be substantial. The most critical time appears to be late spring and early summer, as loads up to this time may be larger than average and flushing rate tends to decline during summer. In addition to the spring load from the watershed, the onset of summer stratification and accelerated decomposition processes signal the initiation of higher internal loading of phosphorus via sediment release. Intense summer storms followed by extended periods of dryness may also represent critical sequences, as nutrients may enter the lake in large quantity in a short burst without sufficient water to flush the system.

In order to protect designated uses during the critical late spring and early summer period, seasonal and monthly loading rates were determined based on the annual target load.

- Seasonally: No more than 1/4 of the annual load should occur in each of the spring and summer seasons (TP ≤ 12 kg/season). Larger loads in spring or summer could cause failure to meet use attainment goals, even if the annual target is not exceeded. High loading during spring or summer can not be offset by lower fall or winter loading, given the timing of the growing season and the flushing characteristics of Cedar Pond.
- Monthly: No more than 1/3 of the seasonal load should occur in any given spring or summer month (TP ≤ 4 kg/month). Larger loads in any one-month may be offset by lower loads in a subsequent month, but as changes in loading generally equate with changes in flushing in the Cedar Pond system, the impact of elevated loads over a late spring or summer month may be disproportionately large. That is, if storm-induced loads of nutrient-rich runoff flush cleaner water out of the lake in late spring or summer and then remain without further significant dilution for an extended period, use attainment may be compromised.
- Weekly or Daily: Loading over periods shorter than monthly is not especially meaningful in this system. Cedar Pond flushes once every 58 days on average, and the nature of mixing and flushing in lake systems like this one is such that the impact of inputs is expressed over a period of time covering at least three flushings (174 days or 6 months).

MONITORING PLAN

The monitoring plan outlined below is appropriate for assessing the effectiveness of BMPs and applicability of target loads generated in this TMDL. It should be noted that this plan is provided as guidance. The responsible parties are allotted flexibility to monitor for improvements in water quality following BMP implementation in order to evaluate in-lake response and achievement of the TMDL.

It is recommended that paired dry weather – wet weather samples be collected three times each summer, between May 15 and October 1, at the three major inlets (sub-basins C-1, C-2, and C-3) and at any stormwater discharge pipe directly entering Cedar Pond. Parameters should include total phosphorus, dissolved phosphorus, TKN, ammonium and nitrate nitrogen, conductivity and turbidity. During these surveys, the feasibility of potential management techniques should be investigated (i.e., land availability, funding, etc).

In-lake conditions should be assessed through monthly measures of total phosphorus, dissolved phosphorus, TKN, ammonium and nitrate nitrogen, temperature, dissolved oxygen, and water clarity from June through September at the top and bottom of the water column. If funds allow, phytoplankton and zooplankton counts should be considered a priority to confirm that expected changes in the algal community resulting from a change in the P:N ratio (reduced dominance of Blue-green algae) actually occurs.

The terminal pool in the Tilcon Quarry should be monitored for total phosphorus, dissolved phosphorus, nitrate, nitrate, ammonium and total Kjeldahl nitrogen at least weekly, with surface samples sufficient except in summer, when a near-bottom sample should also be collected. The total discharge from the quarry to the Cedar Pond basin should be recorded on a daily to weekly basis, as well as during sample collection.

The rooted plant assemblage should be mapped using standardized transects or point intercepts and consistent methods periodically. If any method of in-lake rooted plant control is planned, pre- and post-treatment plant surveys should be conducted slightly before (pre) treatment and in the year after (post) treatment.

IMPLEMENTATION PLAN

Suggestions regarding BMP implementation are provided in this section, however the goal is to allow the responsible parties flexibility to implement the most effective solutions to reduce phosphorus loading. The DEP supports an adaptive management approach where reasonable controls are implemented and water quality is monitored in order to evaluate for achievement of the TMDL goal and modification of controls as necessary.

It is the responsibility of the Town of North Branford to decide on appropriate management techniques to address nutrient loading through stormwater runoff to Cedar Pond. The Connecticut Department of Environmental Protection will be available to provide technical assistance to the town.

With specific regard to internal loading, the application of properly buffered aluminum compounds should be sufficient to curtail this load. Alternatively, installation of a mixing or aeration system could also reduce internal loading sufficiently and may disrupt blue-green blooms.

With specific regard to the quarry operation, an acceptable phosphorus load may be achievable without resorting to physical and chemical treatment through pumping schedule management. It may be possible to operate pumps on a schedule that meets the TMDL for the summer period. If warranted through monitoring, it may be appropriate to revise the TMDL following implementation and adherence to a pumping schedule. Treatment of the terminal pool with aluminum compounds to reduce the phosphorus level should be evaluated. If monitoring indicates that internal loading is a significant component of the phosphorus load in the terminal pool, inactivation of bottom sediments with aluminum compounds or vertical mixing of the pool water may reduce phosphorus to an acceptable level.

Several management alternatives that can be used to reduce phosphorus loading in this system are provided below. For additional information regarding specific management techniques, the reader is referred to the EPA document *Managing Lakes and Reservoirs* [28]. It should be noted that since a Diagnostic/Feasibility report was not prepared for Cedar Pond, not all management alternatives presented are appropriate for use for Cedar Pond and a feasibility assessment will be required before complete and appropriate implementation can occur.

Table 8. Potential Management Options

Watershed Management

- Source Reduction
  - Agricultural Best Management Practices
  - Behavioral Modifications
  - Waste Water Management
  - Zoning and Land Use Planning
  - Land Use Conversion
  - Bank and Slope Stabilization
  - Stormwater Diversion
- Transport Mitigation
  - Street Sweeping
  - Catch Basin Cleaning
  - Catch Basins with Sumps and Hoods
  - Swirl Concentrators
  - Oil/Grit Chambers
  - Infiltration Systems
  - Detention Systems
  - Chemical Treatment
  - Buffer Strips
  - Coffer Dams
  - Created/Enhanced Wetlands

In-Lake Management

- Phosphorus Inactivation
- Aeration/Oxygenation
- Circulation or Destratification
- Dilution/Flushing
- Drawdown
- Enhanced Grazing
- Dredging
- Chemical Treatment
- Dyes or Surface Cover

Monitoring

In-lake and watershed monitoring as described in the "Monitoring Plan" section.

REASONABLE ASSURANCES

Tilcon Connecticut, Inc. has adjusted operations several times over its history in this watershed to achieve compliance with the applicable NPDES permit, but additional steps may be required in order to meet the waste load allocation. It is expected that the new allocation will be incorporated into Tilcon's NPDES permit during the next renewal. It is expected that the Town of North Branford will take steps toward improving Cedar Pond through the MS4 permit. This TMDL has provided the framework for the monitoring program portion but a feasibility phase will need to be undertaken in order to determine which management techniques are appropriate for which locations in this watershed. The primary impediment to successful achievement of the TMDL for nutrient loading is funding. It may not be reasonable to assume that funding will be sustained at necessary levels without assistance at the State and Federal level. This may slow progress in what is already perceived as a ten-year program.

PROVISIONS FOR REVISING THE TMDL

The DEP reserves the authority to modify the TMDL as needed to account for new information made available during the implementation of the TMDL. Modification of the TMDL will only be made following an opportunity for public participation and be subject to the review and approval of the EPA. New information, which may be generated during TMDL implementation includes monitoring data, new or revised State or Federal regulations adopted pursuant to Section 303(d) of the Clean Water Act, and the publication by EPA of national or regional guidance relevant to the implementation of the TMDL program. The DEP will propose modifications to the TMDL analysis only in the event that a review of the new information indicates that such a modification is warranted and is consistent with the anti-degradation provisions in Connecticut Water Quality Standards. The subject waterbody of this TMDL analysis will continue to be included on the *List of Connecticut Water bodies Not Meeting Water Quality Standards* until monitoring data confirms that recreational uses are fully supported.

PUBLIC PARTICIPATION

This TMDL document was public noticed for public comment in the New Haven Register on March 1, 2005. In addition, the Towns of Branford and North Branford, Tilcon Connecticut, Inc., as well as several interested parties were notified by mail of the comment period. As of the end of the public review period, one comment letter regarding the TMDL document was received by the DEP. The DEP reviewed the comment letter and made revisions to the document where appropriate. A response to the comments document was also prepared by the DEP.

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Appendix A

Impact of Post-BMP Implementation Nutrient Loadings on Designated Uses

A series of models were used to evaluate anticipated in-lake conditions following implementation of BMPs to achieve the necessary reductions discussed above. This section provides an evaluation of the models with regard to the WQS for mesotrophic conditions. As explained in the "Applicable Water Quality Standards" section, the natural trophic state for Cedar Pond (absent of cultural impacts) is expected to be mesotrophic to late mesotrophic. It can be assumed that if water quality in Cedar Pond falls within the ranges of nutrients, chlorophyll a, and transparency specified for mesotrophic conditions in Connecticut's WQS then all designated uses will be supported. Table A-1 provides the required annual loading in order to bring Cedar Pond into the range of trophic classification values for mesotrophic systems.

Table A-1. State of Connecticut Trophic Classification Range for Mesotrophic Waterbodies and Corresponding Annual Load to Cedar Pond.

Parameter	Concentration	Annual Load (kg/yr)
Total Phosphorus	10 – 30 ug/L	21 – 62
Chlorophyll *a*	2 – 15 ug/L	TP Load = 15 – 71
SDT*	2 – 6 meters	TP Load = 15 – 51

* SDT = Secchi disk transparency

Empirical Equations

Mean and maximum chlorophyll *a* and Secchi Disk Transparency (SDT) levels were predicted using several empirical equations derived for northern temperate lakes from substantial databases [12,29,30,31,32]. Relationships observed for groups of lakes are not precisely applicable to any one lake in the data set, or to any other lake from the region. However, they do provide a conceptual basis for predicting the direction and magnitude of change expected in targeted lake features when nutrient loads are altered. Table A-2 lists the predicted chlorophyll *a* and SDT values using additional literature relationships. The predicted in-lake values match well with the Connecticut trophic classification range for mesotrophic waterbodies. In addition, the mesotrophic range matches well with predicted natural values (absence of human influence and/or practical reduction in anthropogenic loading achievable through BMPs).

Table A-2. Predicted Mean and Maximum Chlorophyll *a* and SDT Values with 60% Reduction of Surface Water Total Phosphorus Load and a 50% Reduction of Internal Total Phosphorus - Three Methods.

Source	Predicted In-Lake TP (ug/L)	Predicted Mean Chl (ug/L)[A]	Predicted Max Chl (ug/L)[B]	Predicted Mean SDT (m)[C]	Predicted Max SDT (m)[C]
Estimated and Actual (EPSRI & Tilcon)	19	7.2	24.7	2.4	4.3
Empirical Model Average	26	10.7	36.1	1.9	3.9
Export Coefficient Model	23	9.0	30.4	2.1	4.1

[A] From average of Dillon and Rigler 1974 (29), Jones and Bachmann 1976 (12), Oglesby and Schaffner 1978 (30), and Modified Vollenweider 1982 (31).
[B] From average of Modified Vollenweider (TP) 1982 (31), Vollenweider (CHL) 1982 (31), and Modified Jones, Rast and Lee 1979 (32).
[C] From Oglesby and Schaffner 1978 (30) (Avg) and Modified Vollenweider 1982 (31) (Max).

Trophic State Index

Lake use impairment was correlated to the Trophic State Index (TSI) developed by Carlson (19) and presented in the National Nutrient Guidance Manual for Lakes and Reservoirs (32). When developed by Carlson, the TSI was used to simplify water quality assessment of lakes. It is currently used by many states for trophic classification. The National Nutrient Guidance Manual for Lakes and Reservoirs describes changes in trophic states of lakes with use-related problems. TSI values for use criteria are presented in Table A-3. As such, if these values are attained, then designated uses can be considered supported. It is important to note that industrial and agricultural supplies were not addressed in the National Nutrient Guidance Manual, and complications introduced by macrophyte problems were not covered by Carlson's TSI. In addition, when applying this approach, it is important to remember that this TMDL has been prepared to guide management for recreational uses, not water supply management. Water quality criteria for drinking water supply use can be met through treatment, although attainment of a recreation-focused TMDL will also improve the quality of raw water that may be used for supply purposes.

Table A-3. Designated Uses and Associated TSI (Adapted from EPA [33]).

Lake Use	TSI*
Potable Water	≤ 40
Recreation	
Swimming/Primary contact recreation	≤ 60
Boating and Secondary contact recreation	≤ 70
Fish	
Salmonid fishery	<40-50
Percid fishery	50-60
Centrarchid fishery	60-80
Cyprinid fishery	>70-80
Wildlife (Aquatic Life)	No TSI Criteria.

* = TSI values based on calculations using the average summer values of Secchi Disk Transparency (SDT), chlorophyll *a*, phosphorus, and nitrogen.

Carlson [19] and Frink and Norvell [15] also established mathematical relationships between in-lake phosphorus concentrations and SDT and chlorophyll *a* concentrations. Carlson's relationships were based on lakes throughout North America, whereas Frink and Norvell's relationships were based on lakes in the State of Connecticut.

Equations used by Carlson, and Frink and Norvell are:

Carlson [21]

SDT = 48/TP	Chl *a* = 1.449*ln TP-2.442	SDT = 2.04-0.68*ln Chl *a*

Frink and Norvell [15]

No equation	Chl *a* = 0.374+0.431*TP	SDT = 1/(0.0277*Chl a + 0.1235)

Applying these equations to the predicted total phosphorus in-lake concentration after a 60% reduction in watershed total phosphorus load and a 50% reduction in internal load yields a range of SDT values of 0.8 to 2.8 meters (Table A-4). These equations assume that water transparency is linked to total phosphorus. Non-algal turbidity will weaken the strength of this relationship, and is an issue associated with storm events in Cedar Pond. Mean chlorophyll *a* concentrations are predicted to range from 5.2 to 11.6 ug/L using both Chl *a* equations. Mean and maximum chlorophyll *a* and SDT values using empirical models were presented in Table A-4.

Table A-4. Predicted Chlorophyll *a* and SDT with a 60% Reduction of Surface Water Load and a 50% Reduction of Internal Total Phosphorus.

Source	TP Load Post Reduction (kg/yr)	Predicted In-Lake TP (ug/L)	Predicted Mean Chl (ug/L)[A]	Predicted Mean SDT (m)[A]
Estimated and Actual (EPSRI & CMSW)	39	19	5.2 – 8.6	1.4 – 2.8
Empirical Model Average	54	26	8.2 – 11.6	0.8 –2.2
Export Coefficient Model	47	23	6.9 – 10.3	1.0 – 2.4

[A] = Range from Carlson 1977 [(19)] and Frink and Norvell [(15)]

Using the predicted SDT, chlorophyll *a*, and total phosphorus derived from empirical models assuming a 60% reduction in surface water inputs and 50% reduction in internal phosphorus load, Cedar Pond would have estimated TSI values as follows:

TSI of transparency = 45 - 63
TSI of chlorophyll = 47 - 55
TSI of phosphorus = 47 - 51

A 60% reduction in surface water total phosphorus loading and a 50% reduction in internal total phosphorus loading would result in achieving consistency with use-based (TSI-scored) criteria for recreation (compare above results to Table A-3) for SDT, chlorophyll and phosphorus.

The implementation of BMPs in the watershed (TMDL based on best practical reduction) will put Cedar Pond in the mesotrophic range, based on the Connecticut trophic classification system. It should be noted, however, that attainment of the target nutrient loads does not guarantee immediate full support for all uses designated for Cedar Pond. For example, additional in-lake techniques for control of rooted aquatic vegetation may be required to enhance recreational opportunities in the near term.