Conneaut Lake TMDL for Nutrients

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TMDL for Conneaut Lake

Introduction

The Conneaut Lake TMDL addresses the impairments noted on Pennsylvania's 1996 and 1998 303(d) Impaired Waters lists. Existing water quality problems in Conneaut Lake include extensive weed growths and occasional algae blooms. Localized erosion problems also cause turbidity during storm events. Although achieving water quality standards is a common goal of TMDL analyses, Pennsylvania does not currently have water quality criteria for nutrients or suspended solids. Therefore Pennsylvania is using Carlson's Trophic Status Index (TSI) as an indicator of Conneaut Lake water quality. This TMDL uses TSI analysis to determine the necessary phosphorus reduction targets. Conneaut Lake is phosphorus limited; this means phosphorus is the nutrient controlling biological growth in the lake. Control of both in-lake and external sources of phosphorus should result in reduced algae blooms and an overall improvement in lake water quality. Suspended Solids reduction targets are set based on identifying and correcting localized erosion problems through implementation of Best Management Practices (BMPs).

All information used for the TMDL computations is taken from the December 1995 Phase I Diagnostic Study (also known as the Clean Lakes Study) conducted by Coastal Environmental Services (Attachment A).

Causes of impairment

The Environmental Protection Agency (EPA) Impairment Cause Codes on the 1996 and 1998 303(d) lists describe excessive Suspended Solids and Nutrient Loadings as the causes of impairment to Conneaut Lake. The source of this information is the Phase I Study. The Phase I study investigated Conneaut Lake hydrology, limnology, pollutant budgets, restoration alternatives, etc. to better define the causes, magnitude, and solutions of identified lake problems. The Phase I Report concludes that both external (runoff from the watershed) and in-lake phosphorus loadings (from nutrient recycling and nutrient rich sediments) contribute to algal blooms and excessive weed growth. The Phase I Report documents elevated suspended solids loadings in runoff from localized watershed sources during a monitored storm event. However, the Phase I Report does <u>not</u> document in-lake use impairments or other in-lake problems due to these elevated suspended solids loadings. The Phase I monitored areas, plus problem areas to be identified in the future, can cause lake infilling, increased transport of nutrients to the lake from adsorption to sediment particles, and reduced water clarity. Conneaut Lake is noted to be crystal clear during dry weather.

Sources of Impairment

EPA Source Codes on the 1996 and 1998 303(d) lists describe sources of impairment to Conneaut Lake as Urban Runoff / Storm Sewers and other Non-point sources. There are no permitted National Pollutant Discharge Elimination System (NPDES) point source discharges of phosphorus from pipes into the lake. Urban runoff pollution originates from residential and commercial land disturbance activities. Limited agricultural activities also generate excessive nutrient and suspended solids loadings. Several storm sewer culverts draining these residential and agricultural areas discharge these excessive nutrients and suspended solids loadings directly to the lake. Monitoring of these culverts during the Phase I Study indicated elevated levels of phosphorus and suspended solids are delivered to the lake during storm events. "Other" pollution sources in the past included sewage spills from pump station Sanitary Sewer Overflows (SSOs). However, as discussed later, these SSOs have not been active since early 1997. Another important source of phosphorus is an "internal" loading that results from nutrient release during breakdown of organic matter on the lake bottom. Phosphorus is also released from phosphorus rich bottom sediments in the absence of dissolved oxygen in the hypolimnion during summer stratification. SSOs and internal loading are discussed later.

Background

Conneaut Lake is the largest natural lake in Pennsylvania and is the recreational and aesthetic focal point adjacent to Conneaut Lake Park. It is a state owned lake located in Summit and Sadsbury Townships in Crawford County. Water quality problems like nuisance aquatic plant growth and occasional algal blooms interfere with aquatic and lakeside recreation. Residents complain the weed growth in recent years is the worst it has been in over twenty years. Agricultural practices, residential and commercial development and urbanization combined with a highly erodible soil type can contribute to elevated suspended solids loads to the lake during storm events.

Conneaut Lake is a unique and valuable asset to Crawford County. Residents of northwestern Pennsylvania and surrounding areas heavily use it. A multitude of land and water based recreational activities can be found there. The Phase I Clean Lakes Study discusses lake uses on page 6.

TMDL Endpoints

Page 69 of the Phase I Study includes a "Pollutant Loading Summary" with cumulative Total Phosphorus, Total Nitrogen, and Total Suspended Solids (TSS) loadings. The Phase I study uses accepted land use runoff coefficients to estimate these loadings for each land use category. The study also considers precipitation on the lake surface and groundwater nutrient inputs. Finally, the importance of an internal phosphorus loading is discussed and quantified. There are no permitted National Pollutant Discharge Elimination System (NPDES) point source discharges of phosphorus from pipes into the lake. Load reductions for phosphorus are based on the necessary reduction of the in-lake phosphorus concentration needed to achieve the target TSI. Suspended Solids loading reductions are based on the reality that this is a natural lake with no set "endpoint" or goal for a Suspended Solids fill rate. The Phase I Study documents watershed runoff problems from several monitored urban and agricultural areas. Best Management Practices (BMPs) may help mitigate some of these local problems.

The lake water quality objective for phosphorus is set at achieving a 10% change in the lake TSI. To achieve this goal requires an overall phosphorus loading reduction to the lake of 30%. However, a 40% reduction is recommended as a safety factor to help ensure the TSI goal will be met. The additional load reduction from 30% to 40% is recommended to account for: 1) variability in seasonal in-lake phosphorus concentrations and existing TSI calculations; 2) inherent phosphorus loading model errors, considering most models predict water quality changes within 1 or 2 times the average; and 3) the uncertainties in the phosphorus pollutant budget developed under the Phase I Study. The Phase I study states the Dillon-Rigler phosphorus loading model is valid to use as a tool to predict changes in Conneaut Lake water quality due to changes in phosphorus loadings. The model indicates a 40% load reduction should result in a 10% change in the lake TSI. Conneaut Lake is presently borderline mesotrophic-eutrophic; the objective with the 40% phosphorus reduction is to restore the lake to an improved mesotrophic status. It is believed this 40% reduction will allow Conneaut Lake to meet water quality standards and protect its designated uses.

The water quality objective for Suspended Solids is based on practical considerations. Conneaut Lake is the largest natural glaciated lake in Pennsylvania. The Phase I study indicates nearly all of the Suspended Solids loadings originate from watershed runoff. This natural kettle lake was not "designed" with a sediment fill rate similar to a man-made lake or impoundment.

Pennsylvania also does not have water quality criteria for Suspended Solids. Therefore, reducing in-lake suspended solids to otherwise meet design fill rates or water quality criteria is infeasible. The purpose of a TMDL is to establish pollutant loadings that will allow water quality standards to be attained in a waterbody that is not currently attaining water quality standards. The Phase I Study does not document in-lake suspended solids problems or discuss use impairments due to in-lake inorganic suspended solids. Instead elevated suspended solids runoff problems are noted. This document will therefore discuss known localized suspended solids runoff "problem areas" in lieu of setting an in-lake TMDL goal for suspended solids. The realistic suspended solids objective will be to control runoff from these and future identified "problem areas".

<u>Data Compilation</u>

This section is separated into lake information and pollutant source information.

Lake samples were collected on 17 May, 17 August, 30 September, and 20 October 1994. This provided data from the spring, when the lake was well mixed, through the summer stratification period, and into the period prior to the fall overturn. Composite samples from the epilimnion (upper layers) and hypolimnion (bottom layers) were taken on each sample date at one station over the deepest part of the lake. The epilimnion phosphorus concentrations over these periods ranged from 16 ug/l to 18.9 ug/l. These values are normally used in calculating the Carlson TSI. Watershed samples, largely from storm sewer culverts, were taken during both wet and dry conditions. All Clean Lakes projects follow the Clean Lakes Program requirements for temporal and spatial sampling, and parameters to be sampled (40 CFR Part 35 Subpart H and 40 CFR Part 31, attachment B). The diagnostic/feasibility study done in this watershed is a Clean Lakes Phase I study funded under Section 314 of the Federal Clean Water Act.

Table 1. Lake Information

Data	**Value**	**Source**
Lake Type	Anoxic	Info from Phase I Clean Lake Study
Lake Status	High Quality – Warm Water Fishes	This is a Special Protection Lake – equivalent to EPA's Tier II Waters
Existing P Conc.	0.018 mg/l	This is computed by plugging load into the Dillon and Rigler model – see p. 73 of Clean Lakes Study
Hydraulic Residence Time	211 days	Info from Phase I Lake study(average value)
Surface Area	947 acres	Info from Phase I Lake study(average value)
Mean Depth	8.1 meters	Info from Phase I Lake study(average value)

The existing phosphorus concentration above represents the 1994 predicted average annual phosphorus concentration in the lake based on the 1994 annual phosphorus loading shown in Table 4. The Dillon-Rigler phosphorus loading model is used to calculate this value. This predicted value is consistent with measured total phosphorus in-lake concentrations ranging between 0.016 and 0.0189 mg/l of total phosphorus. The measured values account for background loads such as internal loading from organic matter decomposition, nutrient recycling, and past SSOs. These values also account for seasonal variation because the measured values reflect summer stratification of Conneaut Lake, and the spring/fall overturn. Correlation of predicted vs. measured values validates the use of the Dillon-Rigler model for predicting changes in lake water quality from reduced phosphorus loadings.

Biomonitoring was also conducted as part of the Clean Lakes Study. This included chlorophyll a, phytoplankton and zooplankton densities and an aquatic macrophyte assessment.

The Study concludes phosphorus is the limiting nutrient in the lake (Attachment A). Conneaut Lake is borderline mesotrophic-eutrophic at present; the public objects to nuisance aquatic plant growth and occasional algal blooms. The Phase I study indicates Conneaut Lake water quality has changed little in the past twenty years. The existing TSI is around 48; past TSI values over the last 17 years show values in this same range (page 71).

<u>Watershed Runoff Pollutant Source Information</u>

The Clean Lakes Study developed Non-Point Source (NPS) Nutrient and Suspended Solids watershed loadings to Conneaut Lake in two different ways: **1**. by land use type in the lake watershed, and **2**. by monitoring some of the lake inlets during dry and storm events (p.30 of Clean Lakes Report). Refer to 1 and 2 below for more detail. There are no permitted NPDES point source discharges of phosphorus into the lake; there is no need to account for such sources.

1. This TMDL uses the Unit Areal Loading method (UAL) to calculate watershed Nutrient and Suspended Solids contributions based on land use. This method, according to the Clean Lakes Study (p.64), is widely accepted for calculating pollutant inputs from NPS. About 50% of the phosphorus loading to the lake comes from runoff in the watershed. Nearly all of the Suspended Solids loading comes from watershed runoff. The UAL method is a logical approach for land use load quantification; it also has the advantage of directing watershed management techniques to those land uses identified as causing water quality degradation. Refer to Table 3.

2. The monitoring program involved collection of runoff samples from 13 inlet streams and the lake outlet on 28 September and 12 October 1994. This is a direct measure of watershed pollutant contributions; however, the Phase I study acknowledges it is only an estimate based on the average of these two sampling events. Most of the inlet sampling occurred at culvert locations receiving urban runoff, agricultural runoff, etc. The September sampling occurred during a storm event, with a rain sample also being collected. October sampling occurred during dry weather (normal conditions). Lake monitoring included 4 sample events at one station over the deepest part of the lake. Groundwater monitoring occurred at two wells (one on the east side of the lake, one on the west side) to determine the importance of groundwater nutrient inputs to the lake (estimated at 2.7% of the total phosphorus load). Precipitation nutrient input is also discussed and quantified (about 4.5% of the total phosphorus load).

Comparison of NPS loading methodology

The Clean Lakes Study on page 67 compares the total annual phosphorus watershed loadings computed using the two methods described above. Method #2 involves calculating a loading based on two samples only (a wet weather and a dry weather sample), which is recognized as only being a rough estimate of watershed contributions. The UAL method, #1 above, is recognized as being much more representative of actual watershed loadings. The UAL method provides a watershed loading of 4124 lbs./yr. Method #2 yielded 3837 lbs./yr. Although there is good agreement with these loadings, the Clean Lakes Study notes the agreement is much better than expected given the potential errors inherent to both methods.

Table 3 depicts the UAL values for the land use categories considered in this evaluation. The phosphorus loading from runoff in the watershed is tabulated to be approximately 53.6% of the total annual phosphorus load to Conneaut Lake. Watershed runoff also accounts for approximately 99% of the Suspended Solids load to the lake. This indicates certain watershed land use activities can create problematic suspended solids loadings. Table 4 is a summary of total pollutant loading to the lake.

"Other" Pollution Sources

- Sanitary Sewer Overflows (SSOs)

The Phase I Study notes on page 8 the long history of sewage spills to Conneaut Lake. There are 10 SSOs total located at pump stations; they activate when the station is overwhelmed during wet weather as a relief point. The two most active SSOs are called S-3 and S-7. DEP records indicate a total of 48 overflow events at various stations (total duration of events is 871 total hours) between 1/30/90 and 6/25/97. The records indicate these SSOs are infrequent and related to high flows in sewers due to precipitation events. There have been no overflows since 6/25/97. Due to corrective actions over the years, both the number of spills and the potential for future spills has been drastically decreased. There is currently one SSO on the east side of the lake (named S-3) from a sewage pumping station with the potential to discharge raw sewage to Conneaut Lake. However, a temporary holding facility captures any overflow from the pump station. Only if this facility were overwhelmed would there be a release of untreated sewage to the lake. Plans are to upgrade S-3 by the end of 2000 to eliminate its potential for any SSOs. The other of the two "main" overflows that is located on the west side of the lake (named S-7) was plugged in 1997. Therefore this SSO cannot discharge unless physical modifications are made to it. DEP records indicate 5 total overflows in 1994, none in 1995, and a total of 22 times in the period 1996-1997. No SSOs (with discharge to the lake) are recorded from June 1997 to the present from any station. Continuing SSOs should not be considered a threat to lake water quality since 1997 and into the future.

It is known that sewage contributes phosphorus to water bodies in a highly bioavailable form. However, it is believed that the 48 SSOs that occurred from 1990-1997 have not contributed a significant phosphorus load to the lake. To illustrate this point, an attempt to quantify this phosphorus load to the lake from SSOs is attached on Chart 2. The comments at the bottom of the spreadsheet should be noted; the volumes of overflow and mass load are only estimates. Actual volumes of SSO and phosphorus concentration are not measured. An estimated 756 pounds of phosphorus were contributed by SSOs to Conneaut Lake over a 7.5 year timeframe (or about 100 pounds/year on average).

The Clean Lakes Study sampling occurred during 1994-1995. The SSO phosphorus load (on a yearly basis, 100 lbs./year) can be compared to the yearly contributions calculated by the UAL method for other land uses in Table 3. This comparison shows the SSO contribution is small. Again it should be noted the actual SSO load is probably overestimated; even on this basis it is still a small contributor. Also, the Phase I in lake sampling program conducted in 1994-1995 would account for this small amount of phosphorus contribution. The measured in lake phosphorus concentration agrees well with the expected in lake concentrations considering the cumulative phosphorus loading (see Table 4). Because there are no large discrepancies between the measured and predicted in lake phosphorus concentrations, it is not believed the past SSO contribution has significantly impacted lake water quality. DEP Meadville Regional Office information indicates future SSOs are highly unlikely. It is therefore believed any future contribution of phosphorus load is also unlikely. Future threats to lake water quality should be minimal. It should be noted SSOs by current policies are not NPDES permitted discharges; this means any SSO discharge is not covered or acknowledged by a legal NPDES Federal permit.

The Clean Lakes Study notes on page 69 nearly all of the suspended solids loading to the lake is from non-point source runoff from the watershed. Therefore, the minimal amount of suspended solids contributed from these overflows is not being recognized as a major pollutant source. Also, the internal loading value in Table 4 should capture the minimal amount of phosphorus released from organic sediments contributed by these overflows.

Internal Nutrient Loading

Page 68 of the Phase I Study indicates internal phosphorus regeneration in Conneaut Lake is a significant part of the overall lake phosphorus budget. The Phase I Study estimates 40% of the annual phosphorus load to Conneaut Lake comes from internal sources. Past studies in 1989 (Ostrofsky and Owen) also estimated internal loading comprises about 44% of the lake phosphorus budget. Internal phosphorus recycling results from organic matter (weeds, algae, etc.) decomposition on the lake bottom which releases nutrients contained in the organic matter back into the water column. Also, phosphorus release from lake bottom sediments can contribute to internal loading. This occurs during the lake stratification period in summer, when the Conneaut Lake hypolimnion (bottom waters) become devoid of dissolved oxygen. Conneaut Lake is strongly thermally stratified in the summer with subsequent severe hypolimnetic dissolved oxygen depletion. At times no dissolved oxygen is measurable in lake bottom waters. In the absence of dissolved oxygen, phosphorus is transformed into a dissolved form and released from bottom sediments into bottom waters. During spring/fall overturn, this phosphorus effectively mixes with upper lake waters and can be bioavailable for further algae or plant growth. “Unused” recycled phosphorus in the epilimnion can re-settle into lake sediments, completing this nutrient cycle from top waters back to the bottom.

Scientific literature documents lake restoration can be severely hampered by failing to account for internal loadings (EPA Lake and Reservoir Restoration Guidance Manual). Several lake restoration case studies such as Shagawa Lake, Minnesota and Lake Morey, Vermont illustrate both the negative effects of not recognizing internal load in the former or positive effects of addressing it in the latter (refer to EPA Lake and Reservoir Restoration Guidance Manual).

The Phase I Study page 88 discusses the importance of internal loading on Conneaut Lake that is estimated around 40% of the total phosphorus load. An internal loading this high demands that a reduction in internal load is appropriate. Otherwise, scientific documents indicate that ignoring Conneaut Lake internal loading may result in a severely slowed progress toward restoration. This is because any progress in external (watershed) load reductions would be offset by the continued contribution from internal loading. Ideally, all of the internal loading would be controlled or eliminated. However this TMDL recommends a minimum 85% internal load reduction as a practical goal. External phosphorus load reductions should result in decreased amounts of phosphorus rich suspended solids being discharged to the lake. An 85% internal load reduction should result in decreased algae blooms and improved water quality in the lake.

The 85% internal load reduction, plus indicated external phosphorus load reductions, is to achieve a net phosphorus load reduction to Conneaut Lake of 40%. Refer to Table 6.

Table 2 Summary of SSO Information

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Conneaut Lake Joint Municipal Authority
Summary of Sanitary Sewer Overflows (SSOs) from 1990-1997

Date	Pump Station No.	Duration of SSO (MIN.)	Pump station capacity (gpm)	** (see note) Overflow volume (gal)	* (see note) Phosphorus conc. (mg/l)	Phosphorus mass load (lbs./day)
1/30/1990	S3	840	675	567,000	4	19
	S4	4440	150	666,000	4	22
	S7	4500	550	2,475,000	4	83
	S2	120	250	30,000	4	1
	N2	2880	200	576,000	4	19
	N3	3120	350	1,092,000	4	36
10/9/1990	S2	840	250	210,000	4	7
	S3	900	675	607,500	4	20
	S7	1020	550	561,000	4	19
10/12/1990	S7	2700	550	1485000	4	50
12/30/1991	S2	120	250	30000	4	1
	S3	840	675	567000	4	19
	S4	3840	150	576000	4	19
	S7	4500	550	2475000	4	83
	N2	3840	200	768000	4	26
2/10/1992	S7	240	550	132000	4	4
6/13/1992	S3	150	675	101250	4	3
7/13/1992	S3	90	675	60750	4	2
7/15/1992	S3	150	675	101250	4	3
7/20/1992	S3	240	675	162000	4	5
9/2/1993	S3	60	675	40500	4	1
9/2/1993	S7	210	550	115500	4	4
3/22/1994	S3	60	675	40500	4	1
	S7	450	550	247500	4	8
4/13/1994	S3	30	675	20250	4	1
	S7	18	550	9900	4	0
8/28/1994	S3	60	675	40500	4	1
1/19/1996	S3	210	675	141750	4	5
	S7	5910	550	3250500	4	108
4/23/1996	S7	720	550	396000	4	13
4/30/1996	S7	720	550	396000	4	13
5/10/1996	S7	2880	550	1584000	4	53

6/8/1996	S7	240	550	132000	4	4
6/18/1996	S1	120	280	33600	4	1
	S2	60	250	15000	4	1
	S3	150	675	101250	4	3
	S7	420	550	231000	4	8
Date	**Pump Station No.**	**Duration of SSO (MIN.)**	**Pump station capacity (gpm)**	**** (see note) Overflow Volume (gal)**	*** (see note) Phosphorus conc. (mg/l)**	**Phosphorus mass load (lbs./day)**
7/19/1996	S1	450	280	126000	4	4
	S2	450	250	112500	4	4
	S3	450	675	303750	4	10
	S7	2700	550	1485000	4	50
9/28/1996	S3	180	675	121500	4	4
	S7	300	550	165000	4	6
2/27/1997	S3	45	675	30375	4	1
6/2/1997	S3	70	675	47250	4	2
	S7	405	550	222750	4	7
					total	**756**

756 lbs. over a 7.5 year period equates to about 100 lbs./ yr. to the lake.

* the SSO phosphorus concentration is from Conneaut Lake MA NPDES renewal application dated December 15, 1995. This is the influent total phosphorus concentration to the sewage treatment plant per analytical samples. This should be representative of the raw untreated sewage being discharged to the lake through the SSOs.

** these estimates of overflow are likely overestimated. Most of the SSOs occur by gravity overflow; they are not pumped to the lake. However, only duration and frequency of SSO are measured. No actual measurements of overflow occur. Only frequency and duration of SSOs are recorded. Therefore, as a worst case, it was assumed the SSOs are pumped to the lake. An estimate of overflow can be made by multiplying the pump station capacity by the overflow duration in minutes. Multiplying the overflow volume by phosphorus concentration by 8.34 yields the load in lbs./day.

Table 3. Unit Areal Loadings for Conneaut Lake				
Land Use	Area (Acres)	% of Total Land	Parameter	lb/yr
Forest	8766	53.6	Total P	1563.3
			Total N	19556.1
			TSS	782217.1
Urban- residential	1737	10.6	Total P	412.3
			Total N	2575.4
			TSS	464944.1
Urban- commercial	289	1.8	Total P	412.3
			Total N	2575.4
			TSS	128820.5
Urban – other	24	0.1	Total P	6.6
			Total N	41.9
			TSS	6414.3
Recreational	351	2.1	Total P	94.8
			Total N	1565.6
			TSS	93979.3
Harvested Crop	1398	8.5	Total P	998.9
			Total N	24947.4
			TSS	748011
Hay/Pasture	1201	7.3	Total P	321.9
			Total N	7501.4
			TSS	321480.2
Inactive Farmland	1390	8.5	Total P	247
			Total N	6200.5
			TSS	248000.8
Orchards	36	0.2	Total P	26.5
			Total N	641.7
			TSS	9640.3
Transitional	113	0.7	Total P	30.9
			Total N	502.7
			TSS	40254.5
Brush/Scrub	106	0.6	Total P	28.7
			Total N	474.1
			TSS	18936.5
Extractive Mining	91	0.6	Total P	130.1
			Total N	3256.8
			TSS	81426.2
Wetland	718	4.4	Total P	-161
			Total N	0
			TSS	-128099.5
Forested Wetland	88	0.5	Total P	-19.8
			Total N	0
			TSS	-15697.4
Ponds	45	0.3	Total P	-11.0
			Total N	0
			TSS	-7973.3
Watershed Totals	**16352**	**99.8**	Total P	**4,081.5**
			Total N	**69,839**
			TSS	**2,792,354.6**

	Table 4.	Annual Pollutant Loadings to Conneaut Lake		- Existing
Source	**Parameter**		**Lb/yr**	**% of total**
Runoff from the watershed	Total P		4,087	51.7-53.6
	Total SS		368,235-2,791,530	96.1-99.5
Precipitation on Lake Surface	Total P		351	4.6-4.7
	Total SS		14,994	0.5-3.9
Internal Loading	Total P		3,021	39.1-40.7
Groundwater Inputs	Total P		214	2.8-2.9
Total Pollutant Loadings	Total P		7,673	100
	Total SS		381,685.5 - 2,806,965	100

Consideration of Critical Conditions

It is not practical with existing data and resources to explicitly consider critical conditions in terms of both pollutant loading and in-lake conditions. Such an explicit approach would require continuous model simulation of the watershed and lake. Further, by expressing the TMDLs for sediment and nutrients as annual loads, both the storm loads and the dry weather loads have been implicitly included. Given that there is generally a significant lag time between the introduction of sediment and nutrients to a waterbody and the resulting impact on beneficial uses, establishing this TMDL using average annual conditions is protective.

Explanation of TMDL Computations for Phosphorus

1. An existing TSI and Phosphorus loading are computed using both the Dillon-Rigler model and the Lake for Windows program "TSI Only" option. Refer to page 22 of the TSI analysis titled, "Existing conditions".

Table 5. Summary of TSI Scenarios			
Scenario	In-Lake P concentration	TSI	Load(lb/yr)
Existing Conditions	0.018 mg/l	45.8	7,673
** Target TMDL	0.013	41.2	4,630

Load not being allocated= 2,786 lb/yr (from land uses where BMPs are not feasible) + 453 lb/yr (remaining internal load after 85% REDUCTION) + 149 lb./yr (Margin of Safety)= 3,388 lb./yr

Loading being re-allocated to 4 land uses requiring reductions= (4,630 – (2,786+149+453)) = 1,242 lb/yr

Margin of Safety = (4,630 – 3,139 (all-forest loading))* 0.1 = 149 lb/yr

2. The TMDL goal is set at achieving a 10% reduction in the existing TSI of the lake to a final value of 41. Using the Dillon-Rigler phosphorus loading model as a predictive tool, a 30% reduction of phosphorus loading is required to achieve a 10% reduction in TSI. However, to ensure the goal is met a 40% reduction in phosphorus loading is recommended. This extra reduction would help offset variability in the existing total phosphorus loading as calculated by the UAL or monitoring methods. The achievable TSI based on the 40% load reduction is computed as 41.2.

   Based on Table 3, it is apparent that certain land uses contribute minimal phosphorus loads to the lake. Assigning load reductions to these land uses is not practical; it is not believed a meaningful load reduction can be attained. Also there are no BMPs planned for certain land uses. The following NPS loadings are therefore deemed non-controllable and will not be involved in the allocation scenario: forest, urban-residential, urban-other, recreational, inactive farmland, orchards, transitional, brush/scrub, wetlands, forested wetlands, ponds, precipitation inputs, groundwater inputs, and the 15% internal loading (after a 85% reduction is made, discussed below). This load is tabulated to be 3,239 lb./yr. Refer to Table 6.

3. To determine the margin of safety, all of the land uses (except forest) are converted to an equivalent forest loading by multiplying the forest loading runoff coefficient by the acreage in the various land uses. This is quantity of phosphorus that might be exported to the lake from an all forested watershed, which is considered a “best case” scenario. The margin of safety is calculated as 10% of the difference between the TMDL goal and the all forest watershed (4630 lb./yr – 3139 lb./yr) *10% or 149 lb./yr. The MOS calculated in this manner will help ensure the TMDL goal is met when watershed loadings approach “best case” or forest type loadings.

4. The remaining load to reallocate to the 4 land uses requiring load reductions (urban-commercial, harvested crop, hay/pasture, extractive mining) is 1,242 lb./yr. The EMPR allocation method is used to determine the individual land use reductions necessary to meet the overall 40% reduction (refer to Attachment C). The overall reduction is calculated as:
   % reduction = 1- (TMDL load/existing load) * 100%
   = 1 – (4,630 lbs./year / 7,673 lbs./year) * 100 % = 40% reduction

   <u>Explanation of Suspended Solids Reduction Objectives</u>

Conneaut Lake is the largest **natural** freshwater lake in Pennsylvania. Therefore, the lake was not “designed” with any sediment fill rates similar to a man-made lake; reduction to some design criteria fill rate is impossible. Pennsylvania also does not have water quality criteria for Suspended Solids that could be used to develop a TMDL for water quality standards attainment. However, the Phase I Study does not document lake use impairments due to Suspended Solids loadings. Instead, the Phase I Study documents elevated Suspended Solids loadings during a monitored storm event from various urbanized and agricultural areas in the lake watershed. Anecdotal evidence also exists which indicates localized erosion problems can cause turbid water, sediment bar formations, etc. in the lake but not to the extent where lake uses are impaired. Therefore, Pennsylvania is not establishing a TMDL per se for Conneaut Lake

Suspended Solids. Instead, a realistic water quality objective for Suspended Solids is to identify and mitigate known erosion "problem areas" through implementation of BMPs where feasible.

The Phase I Study conducted a limited sampling program on September 28 and October 12, 1994 in order to develop a pollutant budget based on monitoring data. The September samples were collected during a storm event, the October samples under normal runoff conditions. Therefore only two data points for total phosphorus, nitrite-nitrate, ammonia nitrogen, total nitrogen, and total suspended solids are available. As discussed earlier and stated in the Phase I report, this limited data only yields an estimate of watershed pollutant loadings. However, the following monitored locations displayed elevated Suspended Solids loadings to Conneaut Lake:

Station Number	**Measured Suspended Solids (mg/l)**	**Description of monitoring location (p. 26 of Study)**	**lake location**
SS-7	40.4	agricultural and residential areas	east side
SS-12	29.5	culvert on Farm Road	west side
SS-5	11	culvert near Culvert Street	east side
SS-9	14.5	culvert on Gordon Road	north side

These areas are identified as "problem areas" on page 37 of the Phase I Study. Suspended Solids objectives should be to identify the sources of these elevated loadings and implement BMPs. Follow up monitoring would indicate the success of any corrective actions.

<u>Other anecdotal evidence of "problem areas":</u>

The Crawford County Conservation District notes the following (refer to map on p. 25 of Clean Lakes Study):

- Barberry Lane, Station #5 area. Resident sedimentation complaints routinely occur here due to excessive suspended solids in runoff during storm events. Sand bars form at the mouth of the tributary to the lake. Sources unknown at this point. No obvious problems of Pennsylvania Erosion Control regulations noted; needs further investigation.

- Site #3, just south of Midway Beach. Residents note sediment plumes during storm events, and sediment bars form at the mouth of the tributary. This tributary drains through a sand and gravel mining operation and residential areas. Residents pay an annual fee to have the sediment bars dredged to the Midway Beach Club. In addition, flooding problems are noted in this subwatershed.

- Site #13, on Aldenia Road between Pymatuning Road and Conneaut Lake Borough. Small tributary on the west side, sediment plumes out into the lake noted by residents, sediment accumulations also reported. This stream drains a fairly large watershed. No obvious violations of Pennsylvania Erosion Control regulations noted; this problem needs further investigation.

Actions taken to address sedimentation issues:

- The Conneaut Lake Aquatic Management Association (local watershed organization) has applied for Pennsylvania Growing Greener Grant monies that would provide funds for the County Conservation District to do a more thorough investigation of sediment sources to the lake. That grant application also includes a request for funds for the Natural Resources Conservation Service to work with landowners to install BMPs.

- The Crawford County Conservation District is also working with local Townships to stabilize several dirt and gravel roads surrounding the lake. Some of these roads are chronic sedimentation problems to the lake due to eroding road ditches, etc.

- The Crawford County Conservation District continues to enforce Pennsylvania's Chapter 102 - Erosion Control Regulations on any new land development activities. These efforts should continue to reduce elevated sediment loadings due to land disturbance activities in the lake watershed.

Table 6. Annual Loading Values (lb/yr)

		Phosphorus				
Land Use Category	**Area (ac)**	**current load (lb/yr)**	**Baseline Load (lbs./yr)**	**EMPR load (lb/yr)**	**TMDLs Load Allocat**	**% Reduction of Annual P Load**
Forest	8,766	1,564			1,564	0
Urban – Residential	1,737	413			413	0
Urban – Commercial	289	413	413	274	274	34
Urban – Other	24	7			7	0
Recreational	351	95			95	0
Harvested Crop	1,398	1,000	1000	666	666	33
Hay/Pasture	1,201	322	322	214	214	34
Inact. Farmland	1,390	247			247	0
Orchards	36	27			27	0
Transitional	113	31			31	0
Brush/Scrub	106	29			29	0
Extractive Mining	91	131	131	88	88	33
Wetland	718	-161			-161	0
Forested Wetland	88	-20			-20	0
Ponds	45	-11			-11	0
Precipitation		351			351	0
Groundwater Inputs		214			214	0
Internal Loading		3,021			453	85
Totals	**16,352**	**7,673**	**1,866**	**1,242**	**4,481**	**40**

Negative numbers shown in this table represent pollution sinks that account for removal of phosphorus from the overall phosphorus load to Conneaut Lake.

Chart 1

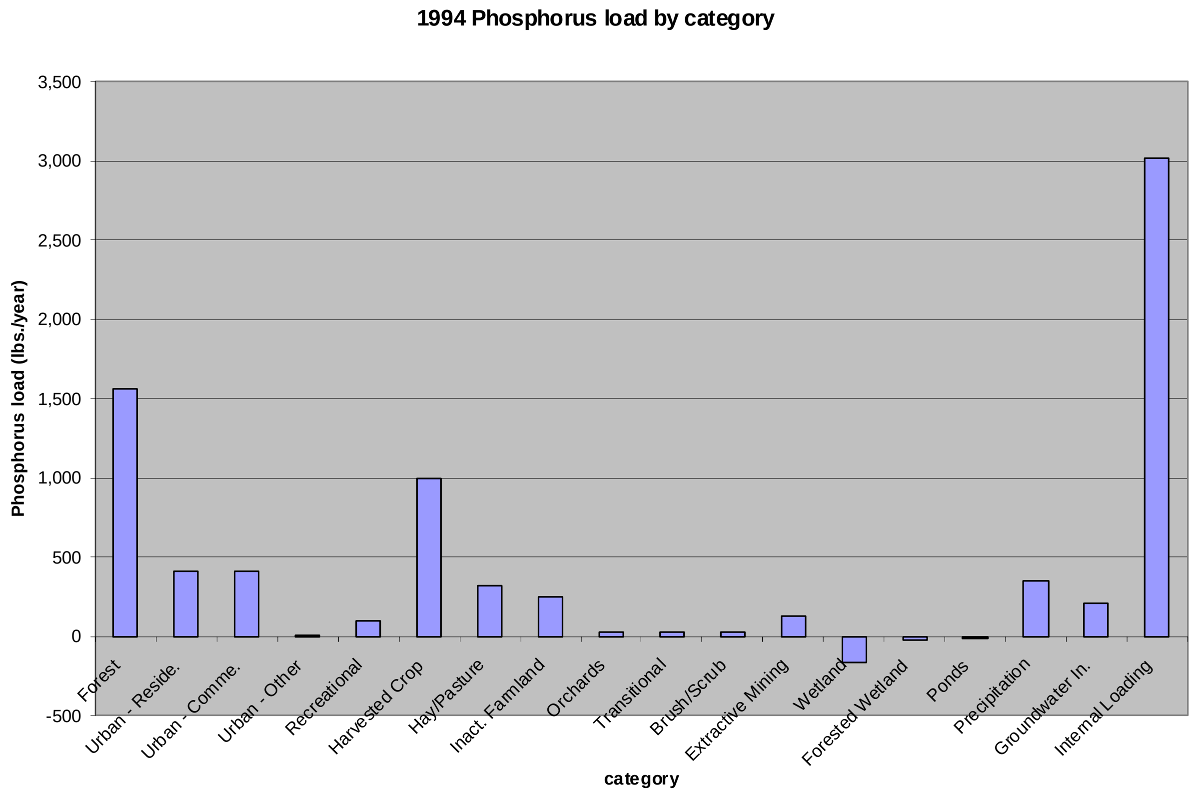

Chart 2 – New loadings after recommended reductions

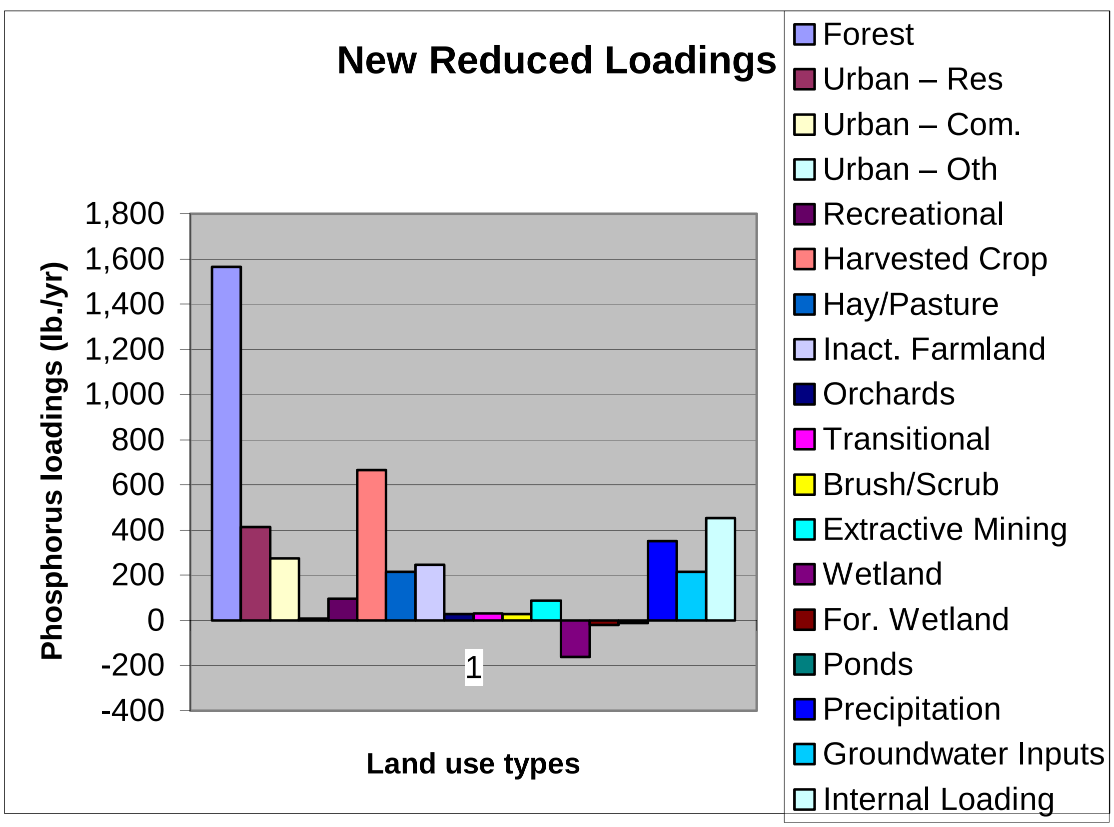

Table 7. Summary of Load Reductions			
Parameter	Existing Load (lb/yr)	TMDL Load (lb/yr)	% reduction to meet TMDL
Total Phosphorus	7,673	4,630	40

Table 8. TMDL Summary				
Parameter	WLA (lb/yr)	LA (lb/yr)	MOS (lb/yr)	TMDL (lb/yr)
Total Phosphorus	0[1]	4,481[2]	149[3]	4,630

This phosphorus TMDL implicitly considers seasonal variation by expressing the loads as annual averages. The annual loads encompass both storm flow and dry weather loads associated with the different seasons.

[1] There are no permitted NPDES point source discharges to Conneaut Lake. The SSOs discussed earlier in the document are not recognized in Conneaut Lake Municipal Authority's current draft NPDES Permit. Because they are unpermitted, no wasteload allocation is made to them. They are not assigned any part of the overall TMDL loading goal of 4,630 lb./yr as they are not "continuous" permitted discharges. No other known point source discharges exist.

[2] The load allocation for phosphorus can be broken down into the NPS loading from land uses not involved in the allocation scenario (land uses where BMPs are not feasible), plus the remaining 15% internal load after an 85% reduction is made, plus the remaining load of 1,242 lb./yr reallocated to the land uses.

[3] The explicit margin of safety is calculated as 10% of the difference between the computed TMDL goal and the loading from an "all forested" watershed scenario.

Recommendations

The Phase I Clean Lakes Study Restoration Plan (p. 97 of Study) will be the basis for restoration of Conneaut Lake. Some of the recommendations contained in the Phase I Study are already being implemented. Public education, hopefully resulting in watershed loading reductions, is a large component of lake restoration. Remediation activities to reduce nutrient and suspended solids contributions to the lake have already begun. The following is the list of measures that have or will be implemented through FY 2000.

Table 9. Completed /Projected Tasks

Tasks	Date Completed	Approximate Cost
Formation of CLAMA – Conneaut Lake Aquatic Management Association - guides restoration efforts	December 1995	$12,300
Lake and Watershed Monitoring	Almost every year this decade	$6,000
Aquatic Macrophyte Control		
a. Chemical Weed Treatments	Every year since 1996	$12,063
b. Mechanical weed harvester purchase	May 1995	$144,797 PADEP state grant
c. O/M costs of harvester + barge	1999 by CLAMA	$26,969
Implement Agricultural BMPs	1994-1996	$5,700
Educational efforts – CLAMA newsletters, displays, fact sheets	To be spent by June 2000	$9,250
Dirt/gravel road dust control in Summit Twp., Crawford County	1999	$4,960
Total		Approx. $222,070

All of the recommended initial restoration efforts, with the exception of alum treatment (phosphorus inactivation) are being implemented. Currently the three main activities resulting in phosphorus load reductions to the lake are the weed harvester operations, select agricultural BMP implementation/education, and public education/outreach efforts. For example, Dr. Milton Ostrofsky of Allegheny College, Meadville, Pennsylvania has conducted research regarding phosphorus removal due to weed harvesting operations in 1999. He estimates that approximately 94 lbs. of phosphorus was removed (as a result of removing Eurasian Milfoil) from Conneaut Lake in years 1999 and 2000. If considered as an annual removal, this reduces the required percent reduction to meet the TMDL from 40% to 39%. More intensive weed harvesting could net further internal load reductions. The alum treatment has been investigated but is “tabled” at this time. Instead, the improvements of the weed harvesting/chemical treatments/education efforts are being monitored before further action is taken towards alum treatment. Other in lake restoration methods are being investigated at this time.

Control of the external load by implementation of BMPs will result in reduced sediment accumulation. Over time the control of the external load will result in an inherent reduction of internal loading. Removal of in-lake sediment and control of additional external sediment loading would provide substantial reduction of the in-lake phosphorous concentration.

Ms. Lynn Sandieson, of the Crawford County Conservation District, reports public education efforts are on-going. This includes future concentrated education efforts from a WRAP (Watershed Restoration Assistance Program) grant to be spent by June 2000. Several newsletters and fact sheets on protecting lake ecology, pollution prevention, etc. will be prepared. Although farming is no longer a large phosphorus contributor in the watershed, NRCS outreach efforts resulting in some agricultural BMP changes has occurred.

The Clean Lakes Study, and Table 6 of this report, identify other sources of nutrient and suspended solids runoff that need to be addressed. Runoff from residential and commercial land use areas need to be addressed along with the other land use categories targeted for load reductions. Erosion and Sedimentation Control (Chapter 102) enforcement will lead to further sediment (and phosphorus bound to sediment) reductions.

Potential BMPs

The pollutant reductions in this TMDL are allocated to urban/commercial, hay/pasture, cropland, and extractive mining land use activities in the watershed. It is believed implementation of Best Management Practices (BMPs) in the affected areas should achieve the “modest” 33% external load reduction goals established in the TMDL.

The suggested croplands BMPs for the watershed are grassed waterways, diversion terraces, vegetated filter areas (buffers), and cropping systems. The vegetation controls runoff, filters nutrients, and uses up some of the excess phosphorus and nitrogen. Riparian buffers, especially forested buffers, remove nutrients from the shallow ground water before it reaches the stream. Cropping systems that take advantage of excess nutrients remaining from the previous crop also reduce the amount of nutrients that can leach or run off. Winter cover crops are an important part of the cropping system as they tie up nutrients over the winter.

The suggested BMPs for barnyards and feedlots are vegetated filter areas and storm water controls. In the hay/pasture areas suggested BMPs are rotational grazing and pasture management to reduce the concentration of livestock and the buildup of nutrients by spreading the animals over a wider area; a healthy stand of pasture grasses and legumes can use the nutrients for continued growth; fencing livestock out of the stream and creating cattle crossings. These BMPs for cropland and hay/pasture areas stabilize field and barnyard soil, establish a riparian (buffer) zone, and keep livestock out of the stream.

Reasonable Assurance of Implementation

There are funding sources available to support the development of site-specific implementation plans and remediation projects that address sources of water quality impairment. One of the primary sources is the Section 319 grant program that is specifically designated for addressing non-point source pollution. Pennsylvania has placed more emphasis on funding projects slated for implementation on waterbodies where TMDLs have been completed.

Conneaut Lake Aquatic Management Association (CLAMA) has applied in August 2000 for grant monies for NPS control activities under Governor Ridge’s Growing Greener grants program.

Existing Conditions

Lake Name:	Conneaut Lake
Type:	Anoxic
Status:	High Quality – Warm Water Fishes
Existing Phosphorous Concentration (mg/l):	0.018
Residence Time (days):	211
Surface Area (acres):	947
Mean Depth (meters):	8.1
Comment:	Lake is currently mesotrophic
Expected TSI:	45.8
Expected Load (lb/ac/yr):	8.12 (from Dillon and Rigler model, p. 72 of Clean Lakes Study)

We compute the existing TSI by inserting the measured total in lake phosphorus concentration from the Clean Lakes Study into Pennsylvania's Lake for Windows application.

The model computes an existing TSI of 45.8; this is in excellent agreement with the Carlson Trophic State indices listed on page 71 of the Clean Lakes Study. Therefore, the Lake for Windows application can be used to determine TSI values for other in lake phosphorus concentrations. However, the Lake for Windows application should <u>not</u> be used for Conneaut Lake to calculate in-lake phosphorus concentrations due to a reduction in phosphorus mass load. See explanation below.

Pennsylvania's Lake for Windows phosphorus loading model uses the Reckhow equations to determine expected in lake phosphorus concentrations for a given phosphorus loading. Page 73 of the Clean Lakes Study states the Reckhow models are <u>not</u> appropriate for use with Conneaut Lake. The Reckhow model gives a much higher existing in lake phosphorus concentration, based on the calculated total loading, than is actually measured. For example, we inserted the existing total phosphorus load listed on Table 4 of 8.12 lbs/acre/year into Lake for Windows. The Windows application calculated the in lake phosphorus concentration to be 0.051 mg/l, which is much higher than the measured value of 0.0189 mg/l. Page 73 of the Clean Lakes Study acknowledges that Reckhow based in lake phosphorus concentration results are high. The report further recommends that the Reckhow model is NOT recommended to predict the response of Conneaut Lake to changes in phosphorus loading. Rather, the report recommends the use of the Dillon and Rigler (1974) model.

The Dillon and Rigler (1974) model is a commonly used model for predicting phosphorus concentrations in lakes and has the form: [TP] = L(1-R)/flushing rate * mean depth. By using this loading/concentration model instead of Reckhow, a more realistic in lake phosphorus concentration is obtained. Refer to Page 73 of the Clean Lakes Study. By using the Table 4 Total phosphorus loading of 8.12 lbs/acre/yr, the existing inlake phosphorus concentration is calculated to be 0.018 mg/l. This agrees much more closely with Conneaut Lake's measured in lake P concentration of 0.0189 mg/l. Therefore, this TMDL recognizes the Dillon and Rigler model as being more realistic to predict Conneaut Lake's response to reductions in phosphorus loadings.

However, the Carlson TSI equation using in lake phosphorus concentration to calculate TSI can continue to be used. This relationship is built into the Lake for Windows application; it is listed below. Therefore, the following methodology is used in this TMDL:

1. Calculate total annual phosphorus loading in lbs./acre/ year.

2. Insert the loading into the **Dillon and Rigler model** (with other appropriate values given for Conneaut Lake from the Clean Lakes Study) to back calculate the in lake concentration.

3. Use the in lake concentration in the **Lake for Windows application** to calculate the corresponding TSI. However, ignore the loading value provided by Lake for Windows because it is Reckhow based. Use the Dillon-Rigler model loading from #2 above.

Carlson Trophic State Index Equation built into Lake for Windows:

TSI = [14.42*ln(1000*P)]+4.15

Where P = in-lake phosphorus concentration in mg/L.

TMDL Target

Lake Name:	Conneaut Lake
Type:	Anoxic
Status:	High Quality – Warm Water Fishes
Target Phosphorus Concentration (mg/l):	0.013
Residence Time (days):	211
Surface Area (acres):	947
Mean Depth (meters):	8.14
Comment:	Lake would be mesotrophic
Expected TSI:	41.2
Target Loading (lb/ac/yr):	4.9 lbs./acre/year

The TMDL Target was computed by setting a goal of a 10% reduction of the existing lake TSI. This 10% TSI reduction equates to a needed 30% phosphorus load reduction. However 40% load reduction is called for as a factor of safety. The scientific justification for relating a 40% reduction in load to a 10% change in TSI is explained in the body of the TMDL.

The TSI goal (41.2) is inserted into the Lake for Windows application to back calculate the corresponding target in-lake concentration (0.013 mg/l). This in-lake concentration is inserted into the Dillon- Rigler model to back calculate the corresponding phosphorus load (5.7 lbs./acre/year, 30% load reduction). However, loading goal should be 4.9-lbs./acre/year equating to a 40% reduction to help ensure goals are met.

The expected load for the existing condition will be divided by the expected load of the TMDL target scenario to determine the percent reduction of Phosphorus needed to attain the TMDL target TSI.

The allowable load for Phosphorus to meet the TMDL TSI for Phosphorus is as follows:

4,630 lbs./yr. / 947 ac = 4.9 lbs./ac/yr

The body of this paper explains how the margin of safety and the loads that will remain constant (precipitation, groundwater inputs, internal loading) are accounted for.