



**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7**

11201 Renner Boulevard
Lenexa, Kansas 66219

22 SEP 2016

Mr. Chuck Gipp
Director
Iowa Department of Natural Resources
Henry A. Wallace Building
502 East 9th Street
Des Moines, Iowa 50319

Dear Mr. Gipp:

RE: Approval of TMDL document for Lake Pahoja

This letter responds to the submission from the Iowa Department of Natural Resources, originally received by the U.S. Environmental Protection Agency, Region 7, on March 17, 2015, for a Total Maximum Daily Load document which contained TMDLs for algae and total phosphorus. Lake Pahoja was identified on the 2012 Iowa Section 303(d) List as impaired by algae/chlorophyll-a. This submission fulfills the Clean Water Act statutory requirement to develop TMDLs for impairments listed on a state's § 303(d) List. The specific impairment (water body segment and causes) are:

<u>Water Body Name</u>	<u>WBIDs</u>	<u>Causes</u>
Lake Pahoja	IA 06-BSR-00280-L_0	Total Phosphorus, Algae, pH

The EPA has completed its review of the TMDL document with supporting documentation and information. By this letter, the EPA approves the submitted TMDL document. Enclosed with this letter is the EPA Region 7 TMDL Decision Document which summarizes the rationale for the EPA's approval of the TMDL document. The EPA believes the separate elements of the TMDLs described in the enclosed document adequately address the pollutants of concern, taking into consideration seasonal variation and a margin of safety.

Although the EPA does not approve the monitoring or implementation plans submitted by the state, the EPA acknowledges the state's efforts. The EPA understands that the state may use the monitoring plan to gauge the effectiveness of the TMDLs and determine if future revisions are necessary or appropriate to meet applicable water quality standards. The EPA recognizes that technical guidance and support are critical to determining the feasibility of achieving the goals outlined in this TMDL document. Therefore, the implementation plan in this TMDL document provides information regarding implementation efforts to achieve the loading reductions identified.

The EPA is currently in consultation under Section 7 of the Endangered Species Act with the U.S. Fish and Wildlife Service regarding this TMDL document. While we are approving this TMDL document at



the present time, we may decide that changes to the TMDL document are warranted based upon the results of the consultation when it is completed.

The EPA appreciates the thoughtful effort that the IDNR has put into this TMDL document. We will continue to cooperate with and assist, as appropriate, in future efforts by the IDNR to develop TMDLs.

Sincerely,



Karen A. Flourney
Director
Water, Wetlands and Pesticides Division

Enclosure

cc: Mr. William Ehm, Administrator, Division of Environmental Services, IDNR
Mr. Allen Bonini, Supervisor, Watershed Improvement Program, IDNR
Mr. Kraig McPeck, U.S. Fish and Wildlife Service



EPA Region 7 TMDL Review

TMDL ID: IA 06-BSR-00280-L_0

State: IA

Document Name: LAKE PAHOJA

Basin(s): LOWER BIG SIOUX

HUC(s): 10170203

Water body(ies): LAKE PAHOJA

Tributary(ies): UNNAMED TRIBUTARIES

Cause(s): ALGAL GROWTH, CHLOROPHYLL-A - AQUATIC LIFE USE SUPPORT,
CHLOROPHYLL-A - PRIMARY CONTACT RECREATION

Submittal Date: 7/23/2015

Approved: Yes

Submittal Letter and Total Maximum Daily Load Revisions

The state submittal letter indicates final TMDL(s) for specific pollutant(s) and water(s) were adopted by the state, and submitted to the EPA for approval under Section 303(d) of the Clean Water Act [40 CFR § 130.7(c)(1)]. Include date submitted letter was received by the EPA, date of receipt of any revisions and the date of original approval if submittal is a revised TMDL document.

The Iowa Department of Natural Resources formally submitted the TMDL document for Lake Pahoja to the U.S. Environmental Protection Agency on July 20, 2015. Revisions were submitted by the IDNR in an email dated February 23, 2016, in response to the EPA comments on the TMDL document.

Water Quality Standards Attainment

The targeted pollutant is validated and identified through assessment and data. The water body's loading capacity for the applicable pollutant is identified and the rationale for the method used to establish the cause-and-effect relationship between the numeric target and the identified pollutant sources is described. The TMDL(s) and associated allocations are set at levels adequate to result in attainment of applicable water quality standards [40 CFR § 130.7(c)(1)]. A statement that the WQS will be attained is made.

Lake Pahoja is on Iowa's 2012 and 2014 Section 303(d) lists of impaired waters because its aquatic life and primary contact recreational uses are impaired. The impairment of primary contact recreation is due to high levels of algae that exceed Iowa's narrative criteria protecting against aesthetically objectionable conditions. Excursions to Iowa's water quality criterion for pH also contribute to the impairment of primary contact recreation and the impairment of aquatic life.

The assessment of Lake Pahoja is based on results of the statewide survey of Iowa lakes conducted by Iowa State University, results of the statewide ambient lake monitoring program conducted by the State Hygienic Laboratory, information from the IDNR Fisheries Bureau and results from the IDNR beach monitoring program. In the statewide ambient lake monitoring program, at least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day. All of the data for ambient lake monitoring and assessment were collected at a location near the deepest part of the lake. Sampling dates and lake water quality data from 2006 through 2014 are tabulated in Appendix C of the TMDL document. Additionally, the corresponding Carlson's Trophic State Indexes for chlorophyll-a, total phosphorus and Secchi depth are tabulated. Carlson's TSI provides an indication of algal biomass as a result of nutrient enrichment known as eutrophication. Using the median values from the lake surveys from 2008-2012 for the 2014 final 305(b) assessment of Lake Pahoja, Carlson's TSI scores for chlorophyll-a, total phosphorus and Secchi depth were 68, 75 and 66, respectively. According to Carlson these chlorophyll-a, total phosphorus and Secchi depth values place Lake Pahoja between the eutrophic and hypereutrophic categories. These values suggest high levels of chlorophyll-a and suspended algae in the water, poor water transparency and very high levels of phosphorus in the water column. The level of

inorganic suspended solids was moderately high in the lake, but does not suggest impairment due to high non-algal turbidity. The median inorganic suspended solids concentration at Lake Pahoja was 5.1 milligrams per liter.

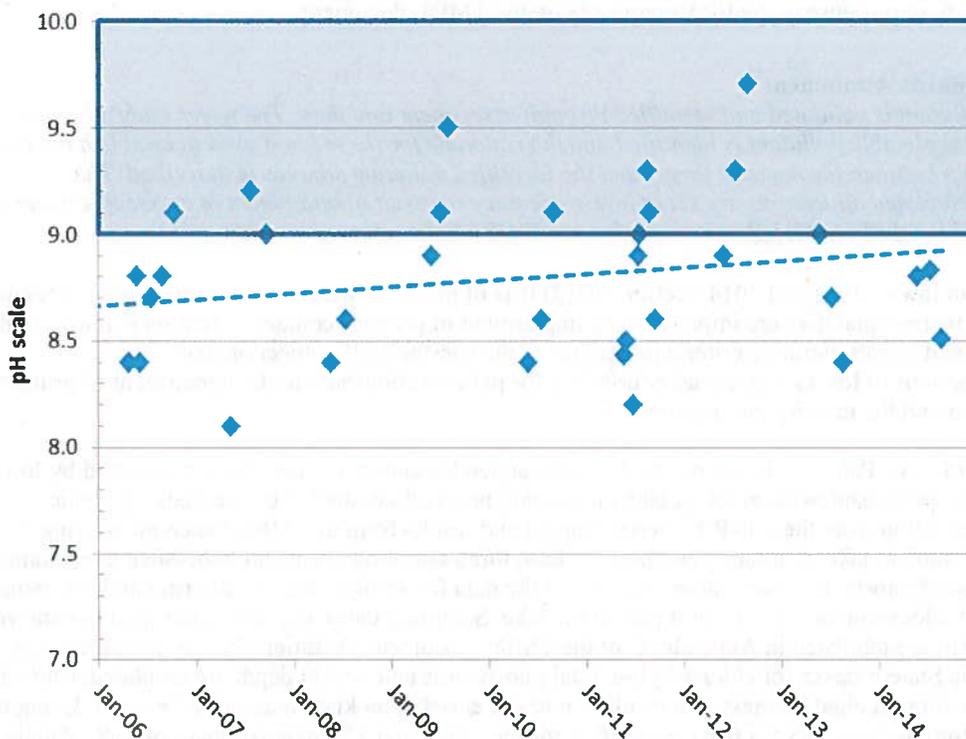
The IDNR's review and interpretation of the water quality data helped provide justification for linking phosphorus loads to chlorophyll-a, and a link between chlorophyll-a and the pH of Lake Pahoja. After phosphorus enters the lake, it can become available for algae within the lake to use in their lifecycle processes. In general, three things are needed for algal growth: light, nitrogen and phosphorus. Of these three, phosphorus is typically the limiting factor in Iowa lakes. By limiting phosphorus, algal growth is also limited. Table 3.3 of the TMDL document sums up the TN:TP ratios for this lake. In this analysis the lake was either P limited (TN:TP > 17) or N and P-co-limited (TN:TP between 10 and 17) for all samples exceeding a chlorophyll-a TSI of 65. Therefore, nutrient management for controlling algae should focus on reducing TP. The relationship between total phosphorus in the lake and observed chlorophyll-a levels is shown in Figure 3.1 of the TMDL document. Algae proliferate quickly and when large blooms die off the decaying mass can lead to oxygen depletion and/or release of harmful cyanotoxins. Algal blooms are aesthetically objectionable and can make swimming or wading hazardous.

TN:TP ratio analysis of samples exceeding chlorophyll-a TSI of 65

N-limited	Co-Limited	P-limited	Strongly P-limited
<10	11 to 16	17 to 32	33<
3	4	4	6

Levels of pH in Lake Pahoja have exceeded water quality standards on several occasions as shown in Figure 3.1, copied below, of the TMDL document. When algae remove carbon dioxide during photosynthesis the pH is elevated. Therefore, high pH (> 9.0) is an indication of photosynthesis by large quantities of algae, and an exceedance of the WQS for pH.

Observed pH values during assessment period



Iowa does not have numeric water quality criteria for algae, turbidity or water clarity/transparency. The Lake Pahoja designated uses are based on a narrative water quality standard, "free from aesthetically objectionable

conditions." For 303(d) listing purposes, aesthetically objectionable conditions are present in a water body when the average Carlson's TSI for chlorophyll-a or Secchi depth exceeds 65 during the growing season. From 2006-2010, measured TSI values in Lake Pahoja consistently exceeded 65 for TSI chlorophyll-a. In order to remove a lake from the 303(d) list, and restore the aquatic life and primary contact recreational use, the median growing season chlorophyll-a TSI must not exceed 63 in two consecutive listing cycles, per the IDNR listing methodology. To avoid exceeding a TSI value of 63, the median summer chlorophyll-a concentration must not exceed 27 micrograms per liter. Additionally, to meet a numeric criterion in Iowa WQS for pH, pH must not exceed 9.0 in Lake Pahoja.

The impairment caused by excessive algae is addressed by the development of the TMDL document which limits the TP load to Lake Pahoja. Based on relationships between TSI values for chlorophyll-a, total phosphorus, Secchi depth and modeled water quality results, the TP loading capacity of Lake Pahoja is established at 1,533 pounds per year. The current TP load and necessary load reduction were simulated using the Spreadsheet Tool for Estimating Pollutant Loads model. In-lake water quality responses were simulated using the BATHTUB model. To meet the target loads, an overall reduction of 88 percent of the existing TP load (12,828 lb/year) is required. The chlorophyll-a TSI response / target of 63 complies with the narrative criteria, and considers and protects the Class A1, Class B(LW) and Class HH designated uses of Lake Iowa.

The LC expressed as the allowable annual average which is helpful in the water quality assessment and for watershed planning and management, is as follows:

$TMDL = LC = \Sigma \text{wasteload allocations (0 lb-TP/year)} + \Sigma \text{load allocations (1,380 lb-TP/year)} + \text{margin of safety (153 lb-TP/year)} = 1,533 \text{ lb-TP/year}$

The maximum daily load was estimated from the growing season average load using a statistical approach outlined in Appendix F of the TMDL document, based on the EPA's guidance, *Options for Expressing Daily Loads in TMDLs*. This approach uses a lognormal distribution to calculate the daily maximum from the long-term (e.g., seasonal) average load. The LC expressed as the maximum daily load is as follows:

$TMDL = LC = \Sigma WLA (0 \text{ lb-TP/day}) + \Sigma LA (15.1 \text{ lb-TP/day}) + MOS (1.7 \text{ lb-TP/day}) = 16.8 \text{ lb-TP/day}$

The EPA concurs that meeting the TMDL targets will result in the attainment of all water quality standards in Lake Pahoja.

Designated Use(s), Applicable Water Quality Standard(s) and Numeric Target(s)

The submittal describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative criteria, and a numeric target. If the TMDL(s) is based on a target other than a numeric water quality criterion, then a numeric expression, site specific if possible, was developed from a narrative criterion and a description of the process used to derive the target is included in the submittal.

Lake Pahoja is a significant publicly owned lake, and it is protected for the following designated uses:

- Primary contact recreation – Class A1: Waters in which recreational or other uses may result in prolonged and direct contact with the water, involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. Such activities would include, but not be limited to, swimming, diving, water skiing and water contact recreational canoeing.
- Aquatic life – Class B(LW): Man-made and natural impoundments with hydraulic retention times and other physical and chemical characteristics suitable to maintain a balanced community normally associated with lake-like conditions.
- Fish consumption – Class HH: Waters in which fish are routinely harvested for human consumption or waters both designated as a drinking water supply and in which fish are routinely harvested for human consumption.

The state of Iowa Water Quality Standards are published in the Iowa Administrative Code, Environmental Protection Rule 567, Chapter 61. Although the state of Iowa does not have numeric criteria for sediment, nutrients or algae (chlorophyll-a), narrative water quality criteria are in the WQS. Chapter 61.3(2) of the WQS contains the general water quality criteria, which are applicable to all surface waters. These narrative criteria include that waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions.

The WQS - numeric criterion - for pH requires that pH shall not be less than 6.5 nor greater than 9.0 for the water body's designated Class A1 or Class B(LW) uses.

In order to remove from the 303(d) list the algae impairment to the Class A1 and Class B(LW) uses, the median growing season Trophic State Index score must not exceed 63 in two consecutive listing cycles, per the IDNR's listing methodology. To avoid exceeding a TSI value of 63, the median summer chlorophyll a concentration must not exceed 27 micrograms per liter. Chapters 61.3(2) and 61.3(3) of the WQS contain the general water quality criteria, which are applicable to all surface waters for this TMDL document.

In order to remove from the 303(d) list the pH impairment to the Class A1 and Class B(LW) uses, the observed pH values must remain within allowable levels (between 6.5 and 9.0) for two consecutive listing cycles, per the IDNR's listing methodology. Chapters 61.3(2) and 61.3(3) of the WQS contain the general water quality criteria, which are applicable to all surface waters for this TMDL document.

The impairments caused by excessive algae are addressed numerically by the loading capacity which limits the total phosphorus load to the lake. The target is based on relationships between TSI values for chlorophyll-a, total phosphorus, Secchi depth and modeled water quality results. The TP loading capacity for Lake Pahoja is established at 1,533 pounds per year (16.8 pounds per day). To meet the target loads, an overall reduction of 88 percent of the existing TP load (12,828 lb/year) is required. The current TP load and necessary load reduction were simulated using the Spreadsheet Tool for Estimating Pollutant Loads model and the in-lake water quality responses were simulated using the BATHTUB model. The chlorophyll-a TSI response target of 63 complies with the narrative criteria free from aesthetically objectionable conditions, and considers and protects the Class A1, Class B(LW) and Class HH designated uses of Lake Pahoja.

The TMDL target for the median growing season chlorophyll-a is a Carlson's TSI not to exceed 63 in two consecutive listing cycles which corresponds to a chlorophyll-a concentration of 27 micrograms per liter or less. The IDNR established target will ensure long-term protection to fully support primary contact recreation. All other uses will be protected at the stated TP and chlorophyll-a targets. For BATHTUB modeling purposes, the lake was divided into two segments (see Figure D-1 of Appendix D, and Figure E-1 of Appendix E of the TMDL document). The Lake Pahoja TMDL document's current model targeting approach uses surface area, mean depth and a single point of context. It is the EPA's opinion that an area-weighted approach is a more protective target that holistically protects the integrity of the biological, chemical and physical conditions for any lake system. The approach used for this specific TMDL document appears to be more specific in the lake target, but offers a lower level of protection than the area-weighted approach used in some other IDNR TMDL documents. While this approach is less protective, it still provides protection for all designated uses. The numerical translation is also protective of the narrative criteria which includes, "free from aesthetically objectionable conditions."

Pollutant(s) of Concern

A statement that the relationship is either directly related to a numeric water quality standard, or established using surrogates and translations to a narrative WQS is included. An explanation and analytical basis for expressing the TMDL(s) through surrogate measures, or by translating a narrative water quality standard to a numeric target is provided (e.g., parameters such as percent fines and turbidity for sediment impairments, or chlorophyll-a and phosphorus loadings for excess algae). For each identified pollutant, the submittal describes analytical basis for conclusions, allocations and a margin of safety that do not exceed the loading capacity. If the submittal is a revised TMDL document, there are refined relationships linking the load to water quality standard attainment. If there is an increase in the TMDL(s), there is a refined relationship specified to validate that increase (either load allocation or wasteload allocation). This section will compare and validate the change in targeted load between the versions.

There is an established link between the narrative water quality standard for Lake Pahoja and the total phosphorus target. In eutrophication impairments, chlorophyll-a concentrations and the corresponding trophic state index are used to measure algal growth and the extent of nutrient enrichment and excursions of the narrative WQS. Excess phosphorus enters surface waters and results in eutrophication stimulating blooms of algae and undesirable weeds, thus increasing pH and reducing water clarity.

Total phosphorus is the limiting nutrient for algae growth (as indicated by chlorophyll-a concentrations in the water column) and its quantification in the water column is used as a translator for determining algae impairment of the narrative WQS - free from aesthetically objectionable conditions. The TMDL document targets a growing season, whole lake area weighted average chlorophyll-a TSI of 63 (27 micrograms per liter) where the growing season is defined as April through September. The annual average chlorophyll-a levels were related to TP loads through the BATHTUB lake nutrient model. Figure E.2 of the TMDL document shows the load response

relationship between chlorophyll-a and TP as predicted by the BATHTUB model.

Source Analysis

Important assumptions made in developing the TMDL document, such as assumed distribution of land use in the watershed, population characteristics, wildlife resources and other relevant information affecting the characterization of the pollutant of concern and its allocation to sources, are described. Point, nonpoint and background sources of pollutants of concern are described, including magnitude and location of the sources. The submittal demonstrates all significant sources have been considered. If this is a revised TMDL document any new sources or removed sources will be specified and explained.

In the absence of a national pollutant discharge elimination system permit, the discharges associated with sources were applied to the load allocation, as opposed to the wasteload allocation for purposes of this TMDL document. The decision to allocate these sources to the LA does not reflect any determination by the EPA as to whether these discharges are, in fact, unpermitted point source discharges within this watershed. In addition, by establishing these TMDL(s) with some sources treated as LAs, the EPA is not determining that these discharges are exempt from NPDES permitting requirements. If sources of the allocated pollutant in this TMDL document are found to be, or become, NPDES-regulated discharges, their loads must be considered as part of the calculated sum of the WLAs in this TMDL document. Any WLA in addition to that allocated here is not available.

A table from the TMDL document copied below provides the acres of landuse per watershed used to develop the Spreadsheet Tool for Estimating Pollutant Loads. The outputs of the STEPL model provided both a load to enter into BATHTUB and also provided a breakdown of the total phosphorus input from land uses. This output suggests slightly more than eighty percent of the TP load comes from the row cropped regions. The row cropped lands in the highly erodible land depicted in Section 4 of the TMDL document should be addressed as the highest priority areas.

Watershed	Urban	Cropland	Pastureland	Grassland	Feedlots
W1	74.3	972.2	0	30.4	0
W2	18.8	522.6	2.4	10.7	2.0
W3	73.2	1069.8	12.8	174.9	2.5
W4	16.9	219.0	116.4	76.0	0
W5	24.6	243.6	0	143.5	0
Total	209.9	3027.1	131.6	435.6	4.5

There are several small animal operations within the watershed: two small feedlots used for finishing beef, one larger confinement with a lagoon for manure storage, and an area for grazing, and two hog confinements. These animals were accounted for within the STEPL model, and manure from the facilities applied to adjacent fields was modeled. However, it does not discharge into a man-made ditch or conveyance; thus it is not considered a CAFO and is therefore not assigned a WLA.

Animal Feeding Operations of the Lake Pahoja watershed

Watershed	Type	Facility ID	Animal Units
1	Confinement	311701952	108 (Swine)
1	Confinement	*310688961	900 (Beef)
2	Open	*†311705189	550 (Beef)
3	Open	†311532071	75 (Beef)
3	Confinement	311704331	115 (Swine)
5	Open	312466807	250 (Beef)
5	Confinement	*312466807	670 (Beef)

*Medium AFOs that do not have man made ditches and do not discharge directly into waters of the U.S. via any man-made conveyance or device

†Modeled as feedlot sources within the STEPL model framework

Any concentrated animal feeding operation that does not obtain a National Pollutant Discharge Elimination System permit must operate as a no discharge operation. Any discharge from an unpermitted CAFO is a violation of Section 301 of the Clean Water Act. It is the EPA's position that all CAFOs should obtain an NPDES permit because it provides clarity of compliance requirements, authorization to discharge when the discharges are the result of large precipitation events such as in excess of the 25-year and 24-hour frequency/duration event or are from a man-made conveyance. However, many large CAFOs contend that they do not discharge and therefore are not required to obtain an NPDES permit. It is the EPA's opinion that many of the "no discharge" CAFOs may not have adequate land application area to ensure the agronomic uptake of land applied waste or are not designed, constructed, operated or maintained so that they will not discharge. Furthermore, there are likely many animal feeding operations that meet the definition of a medium CAFO, i.e., discharge via a man-made conveyance, but are unpermitted and have not limited their impact on waters by applying best professional judgment to effluent reductions, pursuant to a permit.

Animal feeding operations and unpermitted CAFOs are considered under the load allocation because there is currently not enough detailed information to know whether these facilities are required to obtain NPDES permits. This TMDL document does not reflect a determination by the EPA that such a facility does not meet the definition of a CAFO nor that the facility does not need to obtain a permit. To the contrary, a CAFO that discharges has a duty to obtain a permit. If it is determined that any such operation is a CAFO that discharges, any future WLA assigned to the facility must not result in an exceedance of the sum of the WLAs in this TMDL document as approved.

The STEPL model assumes that wildlife add to the manure deposited on the land surface similar to livestock. For Lake Pahoja, an estimate of 5 geese and 2 deer per square mile was used. These are likely over estimates of wildlife populations. Even with overestimates of geese, furbearers and deer populations, wildlife contributions are relatively insignificant in terms of nutrient loading to the lake and do not increase STEPL nutrient runoff parameters.

Septic Systems:

According to the county sanitarian there are 14 septic systems within the watershed. For the purpose of modeling it was assumed 25 percent of these are failing based on age. Because the majority of the systems are newer, this is probably an over estimate of failure rate.

Gully Erosion and Streambank Erosion:

For the Pahoja Watershed, stream bank length and height were estimated using Light Detection and Ranging coverage and then observed via a site visit although no actual physical measurements were taken. Based

on windshield assessments, the lateral recession rates that were used represent the average of the STEPL range for each condition (i.e. slight, moderate or severe) assigned to the length. Clay loam was used for the soil textural class based on soil survey and parent material. Gully erosion was not included in the model.

Runoff and Groundwater:

The STEPL default concentrations were used to calculate nutrient input from runoff and groundwater. In respect to the user-defined grasslands (prairie or ungrazed), the best estimate was provided by using nutrient concentrations calculated from forest land.

The existing TP load to Lake Pahoja is entirely from nonpoint sources of pollution. There are no point sources operating under a National Pollution Discharge Elimination System permit or regulated by other Clean Water Act programs. Table 3.5 of the TMDL document reports estimated annual average TP loads and resulting water quality based on the STEPL and BATHTUB simulation of 2006-2014 conditions.

Table 3.5. Average Annual Total Phosphorus Load

Source	Description	Total Load pounds per year	Percent
Cropland	Corn and Soybean	9,926	77.5
Feedlots	Open and confined animal feeding	1,522	11.9
Pasture	Grazed and ungrazed private	159	1.2
Grassland	Public parkland, ungrazed private, savanna	321	2.5
Urban	City, town, farmstead, road	320	2.5
Atmosphere	Wind and rain	17	0.1
Streambank	Streambank erosion	168	1.3
Groundwater	Groundwater input	352	2.7
Septic	Failing or outdated septic	43	0.3
Total		12,828	100

The STEPL model incorporates both livestock and wildlife manure into the cropland TP source by relating livestock and wildlife densities to TP concentration in runoff from agricultural land. In the case of the Lake Pahoja model, wild animal populations are not large enough to increase runoff TP concentrations. This does not mean that TP loads from manure application and wildlife are zero, but instead, incorporates the relatively small impacts of these sources into the cropland source.

As submitted, the TMDL document has a complete listing and analysis of all known sources of the pollutant cause of impairment, TP.

Allocation - Loading Capacity

The submittal identifies appropriate loading capacities, wasteload allocations for point sources and load allocations for nonpoint sources. If no point sources are present, the WLA is stated as zero. If no nonpoint sources are present, the LA is stated as zero [40 CFR § 130.2(i)]. If this is a revised TMDL document the change in loading capacity will be documented in this section. All TMDLs must give a daily number. Establishing TMDL "daily" loads consistent with the U.S. Court of Appeals for the D.C. circuit decision in Friends of the

Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006).

$$LC = TMDL = \Sigma WLA + \Sigma LA + \text{Margin of Safety}$$

Watershed and in-lake modeling were used in conjunction with observed water quality data to develop the TMDL document to eliminate the impairments to primary contact recreation caused by excessive algae. The Spreadsheet Tool for Estimating Pollutant Loads was utilized to model watershed hydrology, sediment and total phosphorus loads. In-lake water quality modeling was performed using BATHTUB, an empirical lake and reservoir eutrophication model.

The loading capacity is 1,533 pounds total phosphorus per year, or 16.8 pounds per day.

$$\begin{aligned} \text{Annual} = LC &= \Sigma WLA (0 \text{ lb-TP/year}) + \Sigma LA (1,380 \text{ lb-TP/year}) \\ &+ \text{MOS} (153 \text{ lb-TP/year}) = 1,533 \text{ lb-TP/year} \end{aligned}$$

$$\begin{aligned} \text{TMDL} = LC &= \Sigma WLA (0 \text{ lb-TP/day}) + \Sigma LA (15.1 \text{ lb-TP/day}) \\ &+ \text{MOS} (1.7 \text{ lb TP-day}) = 16.8 \text{ lb-TP/day} \end{aligned}$$

Wasteload Allocation Comment

The submittal lists individual wasteload allocations for each identified point source [40 CFR § 130.2(h)]. If a WLA is not assigned it must be shown that the discharge does not cause or contribute to a water quality standard excursion, the source is contained in a general permit addressed by the TMDL, or extenuating circumstances exist which prevent assignment of individual WLA. Any such exceptions must be explained to a satisfactory degree. If a WLA of zero is assigned to any facility it must be stated as such [40 CFR § 130.2(i)]. If this is a revised TMDL document, any differences between the original TMDL(s) WLA and the revised WLA will be documented in this section.

There are no permitted or regulated point source discharges in the watershed. Therefore the wasteload allocation in this TMDL is zero.

Load Allocation Comment

All nonpoint source loads, natural background and potential for future growth are included. If no nonpoint sources are identified, the load allocation must be given as zero [40 CFR § 130.2(g)]. If this is a revised TMDL document, any differences between the original TMDL(s) LA and the revised LA will be documented in this section.

There are no permitted or regulated point source discharges of phosphorus in the watershed. Nonpoint sources include fertilizer and manure from row crops, stream bank erosion, septic systems and atmospheric deposition. The load allocation for total phosphorus is 1,380 pounds per year, or 15.1 pounds per day, which represents an 88 percent reduction from existing conditions.

There is no allowance for increased phosphorus loading included as part of this TMDL document. There are no incorporated unsewered communities in the watershed. Therefore, it is unlikely that a future wasteload allocation would be needed for a new point source discharge.

Margin of Safety

The submittal describes explicit and/or implicit margins of safety for each pollutant [40 CFR § 130.7(c)(1)]. If the MOS is implicit, the conservative assumptions in the analysis for the MOS are described. If the MOS is explicit, the loadings set aside for the MOS are identified and a rationale for selecting the value for the MOS is provided. If this is a revised TMDL document, any differences in the MOS will be documented in this section.

The margin of safety is the component of the TMDL that accounts for uncertainty in the response of the water quality of a water body to pollutant loads. An explicit MOS of 10 percent is incorporated into the TMDL document. The annual MOS is 153 pounds of total phosphorus per year, or 1.7 pounds per day as expressed as a daily MOS.

Seasonal Variation and Critical Conditions

The submittal describes the method for accounting for seasonal variation and critical conditions in the TMDL(s) [40 CFR § 130.7(c)(1)]. Critical conditions are factors such as flow or temperature which may lead to the excursion of the WQS. If this is a revised TMDL document, any differences in conditions will be documented in this

section.

The critical period for the occurrence of algal blooms resulting from high phosphorus levels in the lake is the growing season, April through September. However, long-term phosphorus loads lead to buildup of phosphorus in the reservoir that contributes to blooms regardless of when phosphorus first enters the lake. The IDNR's combined watershed and in-lake modeling approach using the EPA's Spreadsheet Tool for Estimating Pollutant Loads and BATHTUB lends itself to analysis of annual average conditions. Therefore, both existing and allowable TP loads to Lake Pahoja are expressed as annual averages.

Public Participation

The submittal describes required public notice and public comment opportunities, and explains how the public comments were considered in the final TMDL(s) [40 CFR § 130.7(c)(1)(ii)].

In November of 2014, prior to TMDL development, park officials were contacted to give input on lake history and a guided site visit was conducted.

A public meeting was held on June 25, 2015, at the Lake Pahoja West Shelter near Inwood, Iowa. The meeting was lightly attended by interested citizens in the area.

A public comment period was initiated via a press release on June 11, 2015. Comments were accepted from June 11 through July 13, 2015. No public comments were received during the public comment period.

Monitoring Plan for TMDL(s) Under a Phased Approach

The TMDL identifies a monitoring plan that describes the additional data to be collected to determine if the load reductions required by the TMDL lead to attainment of water quality standards, and a schedule for considering revisions to the TMDL(s) (where a phased approach is used) [40 CFR § 130.7]. If this is a revised TMDL document, monitoring to support the revision will be documented in this section. Although the EPA does not approve the monitoring plan submitted by the state, the EPA acknowledges the state's efforts. The EPA understands that the state may use the monitoring plan to gauge the effectiveness of the TMDLs and determine if future revisions are necessary or appropriate to meet applicable water quality standards.

Options for future monitoring in the Lake Pahoja watershed include agency-led, volunteer-based or a combination of both. The IDNR Watershed Monitoring and Assessment Section administers a water quality monitoring program called IOWATER, that provides training to interested volunteers.

It is important that volunteer-based monitoring efforts include an approved water quality monitoring plan, called a Quality Assurance Project Plan, in accordance with Iowa Administrative Code (IAC) 567-61.10(455B). Failure to prepare an approved QAPP will prevent data collected from being used to assess a water body's status on the state's 303(d) list.

The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa's Lakes. Currently, 137 of Iowa's lakes are being sampled as part of this program, including Lake Pahoja. Typically, one location near the deepest part of the lake is sampled, and many chemical, physical and biological parameters are measured. Sampling parameters are reported in Table 5.1 (copied below) from the TMDL document. At least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day. As data from the lake is gathered and analyzed, additional tributary sites may be added if these would be helpful in monitoring the effectiveness of best management practices and the water quality entering the upper portion of the lake. Table 5.2 of the TMDL document depicts an expanded monitoring plan that could be used to help identify and prioritize monitoring data needs.

Ambient Lake Monitoring Program water quality parameters

Chemical	Physical	Biological
Total Phosphorus	Secchi Depth	Chlorophyll a
Soluble Reactive Phosphorus	Temperature	Phytoplankton (mass and composition)
Total Nitrogen	Dissolved Oxygen	Zooplankton (mass and composition)
Total Kjeldahl Nitrogen	Turbidity	
Ammonia	Total Suspended Solids	
Un-ionized Ammonia	Total Fixed Suspended Solids	
Nitrate + Nitrite Nitrogen	Total Volatile Suspended Solids	
Alkalinity	Specific Conductivity	
pH	Lake Depth	
Silica	Thermocline Depth	
Total Organic Carbon		
Total Dissolved Solids		
Dissolved Organic Carbon		

Data available from the IDNR Ambient Lake Monitoring Program will be used to assess general water quality trends and water quality standards attainment. However, more detailed monitoring data is necessary to better understand trends in water quality and to better guide modeling efforts and watershed-based project implementation. As data from the lake is gathered and analyzed, additional tributary sites may be added if these would be helpful in monitoring the effectiveness of best management practices for water quality entering the upper portion of the lake. Section 5.3 of the TMDL document describes potential tributary monitoring.

Expanded monitoring plan

Parameter(s)	Intervals	Duration	Location(s)
Routine grab sampling for flow, sediment, phosphorus, algae and nitrogen	Every 1-2 weeks	April through October	Ambient and Tributaries
Continuous flow	15-60 minute	April through October	Lake Outfall
Continuous pH, dissolved oxygen, turbidity and temperature	15-60 minute	April through October	Ambient and Tributaries
Runoff event flow, total suspended solids, inorganic suspended solids and phosphorus	Continuous flow, composite water quality	3 events between April and October	Tributaries
Event or continuous flow, turbidity, nitrogen, and phosphorus sampling	15-60 minute	10 to 14-day wet weather periods if continuous sampling is not feasible	Tributaries

Emphasis should be placed on storm event sampling and the contributions of the tributaries at high flow. Routine

weekly or bi-weekly grab sampling (both upstream and downstream) with concurrent in-lake and tributary data would help identify potential sources and hot spots in water quality and nutrient loading. If funding is available, lake managers should consider data loggers for ambient monitoring location and possible tributaries to measure pH, temperature and dissolved oxygen on a continuous basis.

Reasonable Assurance

Reasonable assurance only applies when less stringent wasteload allocation are assigned based on the assumption that nonpoint source reductions in the load allocation will be met [40 CFR § 130.2(i)]. This section can also contain statements made by the state concerning the state's authority to control pollutant loads. States are not required under Section 303(d) of the Clean Water Act to develop TMDL implementation plans and the EPA does not approve or disapprove them. However, this TMDL document provides information regarding how point and nonpoint sources can or should be controlled to ensure implementation efforts achieve the loading reductions identified in this TMDL document. The EPA recognizes that technical guidance and support are critical to determining the feasibility of and achieving the goals outlined in this TMDL document. Therefore, the discussion of reduction efforts relating to point and nonpoint sources can be found in the implementation section of the TMDL document, and are briefly described below.

The states have the authority to issue and enforce state operating permits. Inclusion of effluent limits into a state operating permit and requiring that effluent and instream monitoring be reported to the state should provide reasonable assurance that instream water quality standards will be met. Section 301(b)(1)(C) requires that point source permits have effluent limits as stringent as necessary to meet WQS. However, for wasteload allocations to serve that purpose, they must themselves be stringent enough so that (in conjunction with the water body's other loadings) they meet WQS. This generally occurs when the TMDL(s)' combined nonpoint source load allocations and point source WLAs do not exceed the WQS-based loading capacity and there is reasonable assurance that the TMDL(s)' allocations can be achieved. Discussion of reduction efforts relating to nonpoint sources can be found in the implementation section of the TMDL document.

The IDNR has included an implementation plan in this TMDL document to provide technical guidance for reducing nonpoint source pollutants and restoring Lake Pahoja with potentially available and acceptable resources and best management practices. Collaboration and action by residents, landowners, lake patrons and local agencies will be essential to improve water quality in Lake Pahoja the degree that it supports all designated, beneficial uses. Locally-driven efforts have proven to be the most successful in obtaining significant and lasting water quality improvements. Improved water quality in Lake Pahoja results in economic and recreational benefits for people who live, work and play in the watershed. Therefore, individuals and organizations have a stake in promoting awareness and educating others about water quality, and should work together to adopt a comprehensive watershed improvement plan with applicable additional best management practices and land management within the watershed.

The primary focus of this implementation plan will be reducing phosphorus loads to remediate the algal turbidity issues in Lake Pahoja. Successful phosphorus controls will reduce algal blooms in the lake and improve water clarity. Reduction of algal blooms, which impact the lake's carbon cycle through high rates of photosynthesis, should also prevent exceedance of the pH criterion.

Table 4.1 of the TMDL document copied below lists commonly used BMPs in watershed management. These are generally used on agricultural land but should be explored as options for grasslands as well. Table 4.2 of the TMDL document specifically addresses agricultural BMPs that might be options for the cropland in the northern portion of the watershed.

(Table 4.1) Potential structural BMPs

BMP or Activity	Secondary Benefits	¹ Potential TP Reduction
Terraces	Soil conservation, prevent in-field gullies, prevent wash-outs	50 percent
² Sediment Control Structures	Some ecological services, gully prevention	Variable
³ Wetlands	Ecological services, potential flood mitigation, aesthetic value	20 percent

¹Adopted from the United States Department of Agriculture, Agricultural Research Service. Actual reduction percentages may vary widely across sites and runoff events.

²Reductions reported in Section 2 of the Nonpoint Source Nutrient Reduction Science Assessment, Iowa Nutrient Reduction Strategy.

³Note: Total phosphorus reductions in wetlands vary greatly depending on site-specific conditions. Increasing surface area, implementing multiple wetlands in series, and managing vegetation can increase potential TP reductions

(Table 4.2) Potential land management BMPs

BMP or Activity	¹ Potential TP Reduction (percent)
Conservation Tillage:	
Moderate vs. Intensive Tillage	50
No-Till vs. Intensive Tillage	70
No-Till vs. Moderate Tillage	45
Cover Crops	50
Diversified Cropping Systems	50
In-Field Vegetative Buffers	50
Phosphorus Nutrient Application Techniques:	
Knife/Injection Incorporation vs. Surface Broadcast	35
Phosphorus Nutrient Application Timing and Rates:	
Spring vs. Fall Application	30
Soil-Test P Rate vs. Over-Application Rates	40
Application: 1-month prior to runoff event vs. 1-day	30
Riparian Buffers	45

¹Adopted from USDA-ARS. Actual reduction percentages may vary widely across sites and runoff events.

Shorelines of reservoirs are subject to erosion from water level fluctuations and wave action. Assessing shorelines in spring and fall for eroding areas and stabilizing them with bio-engineering or hard armoring techniques may improve shoreline habitat and water clarity.

As watershed sources of phosphorus are addressed by BMP implementation, focus can shift to in-lake water quality measures. Phosphorus recycled between the bottom sediment and water column of the lake may be, at times, an important contributor of bioavailable phosphorus to Lake Pahoja. While smaller than watershed loads on an annualized basis, internal loads can be the primary driver of eutrophication in dry years with little surface runoff to the lake. Additionally, internal loads may exacerbate algal blooms in late summer periods, which are typically dry with low external loads. Phosphorus exported from the watershed to the lake bottom sediments may become available for algal uptake and growth under certain conditions. These conditions are most likely during prolonged hot, dry periods in late summer. Uncertainty regarding the magnitude of internal loads is one of the biggest challenges to lake restoration. Because of this uncertainty, and the importance of long-term external loads, reductions from watershed sources of TP are a priority for BMP implementation.

In lakes with internal phosphorus loading, in-lake dredging may be a viable alternative. Dredging can reduce phosphorus by removing phosphorus laden sediment from the system. Additionally, large-scale dredging may improve water quality by increasing the mean depth (and hence, volume) of the lake, which increases the lake's assimilative capacity. However, large-scale dredging is expensive, and site specific constraints may reduce the

feasibility of this alternative. In addition to costs and challenges associated with sediment removal, acquisition of land to store dredged sediment (i.e., a spoil site) may be necessary. Furthermore, dredged sediments often require dewatering and/or stabilization. If large-scale dredging is a desired alternative, a more detailed study, including a cost benefit analysis, should be undertaken before moving forward with this option. However, targeted dredging is much more financially feasible, and can increase sediment trapping efficiency of inlet areas and provide other benefits, such as improved fish habitat by creating deep water areas. The following table copied from the TMDL document outlines potential in-lake and shoreline BMPs.

Potential in-lake BMPs for water quality improvement

In-Lake BMPs	Comments	¹ Relative TP Reduction
Targeted dredging	Targeted dredging in shallow inlet areas, particularly the northern tributary, may increase the sediment capacity of the inlet areas, thereby reducing sediment loads to the larger, open water area of the lake.	Med
Large-scale Dredging	Dredging should be focused on areas of known sediment deposition or to create deep-water habitat as part of fisheries management. A cost benefit analysis may be necessary to examine the feasibility of large-scale dredging in Lake Pahoja.	Med-High
Shoreline stabilization (public areas)	Helps establish and sustain vegetation, which provides local erosion protection and competes with algae for nutrients. The entire shoreline of Lake Pahoja is publicly owned, making this alternative possible in all areas of the lake.	Low

¹Reductions (High/Med/Low) are relative to each other and based on numerous research studies and previous IDNR projects.

The existing loads, loading targets, a listing of BMPs needed to improve water quality and a monitoring plan to assess progress are established in this TMDL document. The TMDLs should be followed by the development of a watershed management plan. The watershed management plan should include more comprehensive and detailed strategies to better guide the implementation of specific BMPs. Other ongoing tasks required to obtain real and significant water quality improvements include continued monitoring, assessment of water quality trends, assessment of WQS (biological community) attainment and adjustment of proposed BMP types, locations and implementation schedule based on measured results.

Collaboration and action by residents, landowners, lake patrons and local agencies will be essential to improve water quality in Lake Pahoja and support its designated uses. Nonpoint source and water pollution control grants along with technical guidance from state and local government agencies may be available for local citizens and landowners to implement BMPs.

Watershed management and BMPs to reduce algae in the lake should utilize a phased approach to improving water quality. The preliminary phase(s) should consist of planning and implementation of watershed BMPs required to meet WQS. A reasonable timeline for long term watershed projects aimed at improving water quality is usually measured in years or decades.

Best management practices are dictated by landscape (including both natural conditions and land use). Both installation and effectiveness of any practice is entirely dependent on proper installation in the right location and landuse. The Lake Pahoja watershed sits on the Southern Iowa Drift Plain. This is the largest of Iowa's landforms. It is composed almost entirely of glacial drift. The resulting slopes of this landscape are fairly steep and have high erosion rates. The soil parent material is dominantly loess, which is a looser material and susceptible to erosion. Additionally there are alluvial soils along the stream beds. Therefore, it will be important in the planning process to first assess slope and soil since there is variability within this watershed.

***Water Quality Improvement Plan
for***

**Lake Pahoja
Lyon County, Iowa**

Total Maximum Daily Load
For pH and Algae



Prepared by:
Jen Kurth



Iowa Department of Natural Resources
Watershed Improvement Section
2016

Table of Contents

List of Figures	4
List of Tables	5
General Report Summary	6
Technical Summary	9
1. Introduction	11
2. Description and History of Lake Pahoja	13
2.2. Hydrology and Morphometry	15
3. Total Maximum Daily Load (TMDL) for Algae and pH	18
3.1. Problem Identification	18
Interpreting Lake Pahoja Data	20
Existing load	25
Identification of pollutant sources	26
3.2. TMDL Target	27
General description of the pollutants	27
Selection of environmental conditions	28
Decision criteria for water quality standards attainment	28
Compliance point for WQS attainment	28
Departure from load capacity	28
Allowance for increases in pollutant loads	28
3.3. Pollutant Allocation	29
Wasteload allocation	29
Load allocation	29
Margin of safety	29
3.4. TMDL Summary	30
4. Implementation Plan	31
4.1. General Approach & Reasonable Timeline	31
4.2. Watershed Best Management Practices	31
4.3. In Lake Best Management Practices	35
5. Future Monitoring	37
5.1. Monitoring Plan to Track TMDL Effectiveness	37
5.2. Expanded Monitoring for Detailed Assessment and Planning	38
5.3. Idealized Plan for Future Watershed Projects	40
6. Public Participation	42
6.1. Public Meetings	42
6.2. Written Comments	42
7. References	43
Modeling References	44
Appendix A --- Glossary of Terms, Abbreviations, and Acronyms	45
Scientific Notation	53
Appendix B --- General and Designated Uses of Iowa's Waters	54
Appendix C --- Water Quality Data	56
Appendix D --- Watershed Modeling Methodology	57
D.1. STEPL Model Description	57
D.2. Meteorological Input	57
Precipitation Data.	57
D.3. Watershed Characteristics	58
Soils and Slopes and Curve Numbers.	58
Sediment Delivery Ratio.	59

Existing BMPs	59
D.4. Animals	59
Agricultural Animals and Manure Application.	59
Livestock	59
Wildlife.	60
Landuse	60
D.5. Other Potential Sources	61
Septic Systems	61
Gully Erosion and Streambank Erosion	61
Runoff and Groundwater	61
Appendix E --- In-Lake Water Quality Model	62
E.1. BATHTUB Model Description	62
E.2. Model Parameterization	62
Model Selections.	62
Global Variables.	63
Segment Data.	63
Tributary Data.	64
E.3. Model Performance and Calibration	65
E.4. BATHTUB Target Assessment.	66
Appendix F --- Establishing Daily Maximums	67
Appendix G --- Public Comments	69

List of Figures

Figure 2.1. Lake Pahoja watershed and landuse	14
Figure 2.2. Annual precipitation at Rock Rapids, Iowa	15
Figure 2.3. Bathymetric map of Lake Pahoja.	16
Figure 3.1. Total phosphorus and chl-a levels in Lake Iowa (annual mean 2000-2014)	21
Figure 3.2. Observed pH values during assessment period	22
Figure 3.3. Annual mean values of chlorophyll-a and observed pH	22
Figure 3.4. TSI values for sampling seasons 2006-2010. All TSI values 65 and above are violations of Iowa WQS	24
Figure 3.5. Phosphorus TSI deviations (2003-2014 grab samples).	25
Figure 3.6. Phosphorus TSI deviations (2003-2014 annual means).	25
Figure 3.7. Percentage of the phosphorus load per source	27
Figure 4.1. The highly erodible land within the Lake Pahoja Watershed.	33
Figure 5.1. Sample locations for Lake Pahoja monitoring.	39
Figure D.1. Subbasins used to develop STEPL model	58
Figure E.1. Segments used to develop BATHTUB model	65
Figure E.2. The load response relationship between TSI chlorophyll a and total P as predicted by BATHTUB	66

List of Tables

Table 3.1. Algae related parameters	19
Table 3.2. List of data/sources	20
Table 3.3. TN:TP ratio analysis of samples exceeding Chl-a TSI of 65	20
Table 3.3. Implications of TSI Values on lake attributes	23
Table 3.5. Average Annual Total Phosphorus Input	26
Table 4.1. Structural BMPs.	34
Table 4.2. Potential land management BMPs.	34
Table 4.3. Potential in-lake BMPs for water quality improvement.	36
Table 5.1. Ambient Lake Monitoring Program water quality parameters.	38
Table 5.2. Expanded monitoring plan.	40
Table B.1. Designated use classes for Iowa water bodies.	55
Table C.1. Water Quality Data for Lake Pahoja from sampling 2006-2010.	56
Table D.1. Animal Feeding Operations of the Lake Pahoja watershed	60
Table D.2. Subbasin landuse inputs for STEPL (acres).	60
Table E.1. Model selections for Lake Pahoja.	63
Table E.2. Global variables data for 2006-2010 simulation period.	63
Table E.3. Segment 1 and 2 inputs.	64
Table E.4. Tributary inputs for BATHTUB	64
Table E.5. Model Calibration Coefficients	65
Table F.1. Multipliers used to convert a LTA to an MDL.	68
Table F.2. Summary of LTA to MDL calculation for the TMDL.	68

General Report Summary

What is the purpose of this report?

This report serves multiple purposes. First, it is a resource for increased understanding of watershed and water quality conditions in and around Lake Pahoja. Second, this report satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for all impaired 303(d) waterbodies. Third, it provides a foundation for locally-driven water quality improvements to Lake Pahoja in an effort to improve water quality and successfully restore the lake. Finally, it may be useful for obtaining financial assistance to implement projects to remove Lake Pahoja from the federal 303(d) list of impaired waters.

What's wrong with Lake Pahoja?

Lake Pahoja is subject to extreme algae blooms that can lead to poor visibility, high pH levels, and aesthetically objectionable conditions. Water sampling has found very high levels of suspended algae and chlorophyll a, which lead to poor water transparency. High levels of phosphorus drive these algal blooms. Algae proliferate quickly and are often short lived. When the bloom dies off the decaying mass can lead to oxygen depletion and/or release of harmful cyanotoxins. Algal blooms are aesthetically objectionable and can make swimming or wading hazardous.

Results from the Iowa State University (ISU) and State Hygienic Laboratory (SHL) lake surveys suggest that primary contact recreation at the lake are not fully supported due to elevated pH and chlorophyll a (algae) levels, which indicate the presence of algal blooms. Additionally, aquatic life is only “partially supported” due to the elevated pH. Algal blooms can also disrupt the carbon cycle of the lake, which leads to spikes of pH.

What is causing the problem?

Large quantities of phosphorus entering the lake contribute to algal growth, which reduces water clarity and causes elevated pH levels. Most phosphorus enters Lake Pahoja attached to sediment that washes in from surface erosion and runoff. The erosion and runoff is precipitation driven but also varies with slope and landuse.

Within this watershed there are areas of steeper slope and large areas of Highly Erodible Land (HEL) that contribute higher amounts of sediment-attached phosphorus than what is seen in flatter areas. Other important factors such as land use, soil type, and implementation of best management practices may also influence the fate and transport of phosphorus from the watershed to Lake Pahoja. After phosphorus enters the lake it can become available for algae within the lake to use in their lifecycle processes. In general, three things are needed for algal growth: light, nitrogen and phosphorus. Of these three, phosphorus is typically the limiting factor in Iowa lakes. By limiting phosphorus, algal growth is also limited. Therefore, the nutrient management for controlling algae should focus on reducing total phosphorus (TP).

What can be done to improve Lake Pahoja?

Reducing phosphorus loads entering the lake from the watershed is the most important step for long-term water quality improvement. Until the external phosphorus loads are reduced, in-lake remediation steps will not be cost effective since high levels of phosphorus will remain in the lake. However, once watershed issues are addressed, directly addressing phosphorus accumulated within the lake may have substantial water quality benefits. The average annual TP load to Lake Pahoja from 2006-2010 was estimated to be 12,828 lbs. per year. In order to meet the requirements to remove Lake Pahoja from the impaired waters list, the load coming in to the lake must be reduced by 88.1 percent to not exceed the recommended annual load of 1,533 lbs. per year.

A combination of Best Management Practices (BMPs) including land management and control structures are often required to obtain reductions in sediment and phosphorus to meet water quality standards. Reducing phosphorus loss from row crops through strategic timing and methods of manure and fertilizer application, increasing use of conservation tillage methods, and implementing or improving existing structural BMPs such as terraces, grass waterways, and constructed wetlands in beneficial locations will be necessary to improve the water quality in Lake Pahoja. Special attention should be given to row crops on steep slopes, where the adoption of cover crops or perennial strips may be especially beneficial. See Section 4, page 28 for more information.

Who is responsible for a cleaner Lake Pahoja?

Everyone who lives and works nearby, or wishes to utilize a healthy Lake Pahoja, has an important role to play in improving and maintaining the lake. Since nonpoint source pollution is unregulated and responsible for the vast majority of sediment and phosphorus entering the lake; voluntary management of land, animals, and the lake itself will be required to achieve measurable improvements in water quality. Many of the practices that protect and improve water quality also benefit soil fertility and structure, the overall health of the agricultural ecosystem, and the value and productivity of the land. Practices that improve water quality and enhance the long-term viability and profitability of agricultural production should appeal to producers, land owners, and lake users alike. Improving water quality in Lake Pahoja, while also improving the quality of the surrounding land, will require collaborative participation by various stakeholders, with land owners playing an especially important role.

The future of Lake Pahoja depends on citizens and landowners adopting land use changes. The best chance for success in improving Lake Pahoja lies with private citizens working with government agencies that can provide technical, and in some cases, financial support for improvement efforts. Citizens interested in making a difference in Lake Pahoja should contact their local soil and water conservation district or the Iowa DNR Watershed Improvement Section for information on how to get involved.

Does a TMDL guarantee water quality improvement?

The Iowa Department of Natural Resources (DNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan (WQIP). The TMDL itself is only a document, and without implementation, will not improve water quality. Therefore, a basic implementation plan is included for use by local agencies, watershed managers, and citizens for decision-making support and planning purposes. This implementation plan should be used as a guide or foundation for detailed and comprehensive planning by local stakeholders.

What are the primary challenges for water quality improvement?

In most Iowa landscapes, implementation requires changes in land management and/or agricultural operations. Management decisions may include changes in the number of acres that are actively tilled and the diversity and rotation of crops produced. These changes present challenges to producers by requiring new equipment (e.g., no-till planters), narrowing planting, harvesting and fertilization windows, and necessitating more active and complex farm management. Additionally, potential short-term losses in yields are more easily recognized and quantified than long-term benefits to soil health and sustained productivity. It is not easy to overcome existing incentives and the momentum of current practices. Promoting a longer-term view with an emphasis on long-term soil fertility, production, agricultural ecosystem health, and reduced input costs will be essential for successful, voluntary implementation by willing conservation partners.

How should this document be used?

Because this document serves several purposes, not everyone will be interested in the entire document. While EPA will be interested in the technical segments that address the TMDL and loading calculations, for stakeholders in and around the Lake Pahoja watershed, the most pertinent information will be found in sections 4 and 5. These sections address what can be done to improve the water quality in Lake Pahoja.

Technical Summary

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Waterbody ID Code: IA 06-BSR-00280-L_0 Location: Lyon County, S23,T99N,R48W, 5 mi SSW of Larchwood.
Surface water classification and designated uses:	Class A1 Primary Contact Recreation Class B(LW) Aquatic Life Class HH Human Health
Impaired beneficial uses:	Class A1 Primary Contact Recreation Class B(LW) Aquatic Life
Identification of the pollutant and applicable water quality standards:	The Class A1 (primary contact recreation) uses are assessed (monitored) as “partially supported” due to aesthetically objectionable conditions due to poor water transparency caused by algae blooms. Class A1 and Class B(LW) Aquatic Life are assessed as “partially supported” due to elevated pH
Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	Excess algae blooms and subsequent chlorophyll a concentrations and high levels of turbidity are attributed to total phosphorus (TP). The allowable average annual TP load = 1,533 lbs/year; the maximum daily TP load = 16.8 lbs/day.
Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:	The existing annual load of 12,828 lbs/year must be reduced by 11,295 lbs/year to meet the allowable TP load. This is a reduction of 88 percent.
Identification of pollution source categories:	There are no permitted or regulated point source discharges of phosphorus in the watershed. Nonpoint sources include fertilizer and manure from row crops, stream bank erosion, septic systems, and atmospheric deposition.
Wasteload allocations for pollutants from point sources:	There are no permitted or regulated point source discharges in the watershed. Therefore the WLA in this TMDL is zero.

Load allocations for pollutants from nonpoint sources:	The allowable annual average TP LA is 1,380 lbs. per year, and the allowable maximum daily LA is 15.1 lbs. per day, resulting in an 88 percent reduction from existing conditions.
A margin of safety:	An explicit MOS of 10 percent is incorporated into this TMDL. The annual MOS is 153 lbs. of P and the daily MOS is 1.7 lbs. of P.
Consideration of seasonal variation:	The critical period for in-lake water quality is the growing season. These conditions are reflected in the TMDL because the monitoring data and in-lake model are based on the growing season. However, it is annual average loads to the lake that drive growing season water quality, therefore the TMDL is based on annual TP loading.
Allowance for reasonably foreseeable increases in pollutant loads:	Because there are no urbanizing areas in the watershed and significant land use change is unlikely, there are no allowances for reasonably foreseeable increases in pollutant loads.
Implementation plan:	An implementation plan is outlined in Section 4 of this Water Quality Improvement Plan. Phosphorus loading and associated impairments are addressed through a variety of voluntary nutrient and soil management strategies and structural BMPs.

1. Introduction

The Federal Clean Water Act requires all states to develop a list of impaired waterbodies that do not meet water quality standards (WQS) and support designated uses. This list of impaired waterbodies is referred to as the state's 303(d) list. A Total Maximum Daily Load (TMDL) must be developed for each impaired waterbody included on the list. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can tolerate without exceeding WQS and impairing the waterbody's designated uses. The TMDL calculation is represented by the following general equation:

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

Where: TMDL = total maximum daily load
 LC = loading capacity
 \sum WLA = sum of wasteload allocations (point sources)
 \sum LA = sum of load allocations (nonpoint sources)
 MOS = margin of safety (to account for uncertainty)

Lake Pahoja, located in Lyon County in northwestern Iowa, is on the impaired waters list because it is not meeting its designated uses for primary contact recreation (swimming, wading) or for aquatic life use (mainly fish) due to elevated pH and chlorophyll a (algae) levels, which indicate the presence of algal blooms. One purpose of this Water Quality Improvement Plan (WQIP) for Lake Pahoja is to provide a TMDL for pH and algae. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, develop a watershed management plan, and implement water quality improvement projects. The algae impairment is addressed by development of a TMDL that limits total phosphorus (TP) loads to the lake. Additionally, limiting the TP loads to the lake will also address the high pH, which results in a carbon cycle imbalance caused by the algal blooms.

This TMDL includes an assessment of the existing phosphorus load to the lake and a determination of how much phosphorus the lake can tolerate and still support its designated uses. The allowable amount of phosphorus that the lake can receive is the loading capacity, or the TMDL target load.

The plan includes a description of potential solutions to the impairments. This group of solutions is more precisely defined as a system of best management practices (BMPs) that will improve water quality in Lake Pahoja, with the ultimate goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the Section 4 Implementation Plan.

The Iowa Department of Natural Resources (Iowa DNR) recommends a phased approach to watershed management. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict. Iterative implementation of improvement practices and additional water quality assessment (i.e., monitoring) will help ensure progress towards water quality standards, maximize cost efficiency, and prevent unnecessary or ineffective implementation of costly BMPs. A water quality monitoring plan designed to help assess water quality improvement and BMP effectiveness is provided in Section 5.

This plan will be of little value unless additional watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and the collaboration of several state and local agencies. Experience has shown that locally-led watershed plans have the highest potential for success. The Watershed Improvement Section of Iowa DNR has designed this plan for stakeholder use and is committed to providing ongoing technical support for the improvement of water quality in Lake Pahoja.

2. Description and History of Lake Pahoja

2.1. History and Land Use

Lake Pahoja is a 65 acre man-made lake that was constructed in the 1970s and is surrounded by a 3,808 acre watershed in Lyon County (Figure 2.1). The Lyon County Conservation Board maintains and operates the Lake Pahoja Recreation Area that surrounds the lake. Recreational opportunities include fishing, boating, camping, and swimming. The Center for Agricultural and Rural Development (CARD) at Iowa State University estimates that between 2002 and 2005, Lake Pahoja averaged about 17,000 visitors per year.

Lake Pahoja is located within the Northwest Iowa Loess Prairies-Western Corn Belt Plains ecoregion (47a) (Prior 1991; Griffith et al., 1994). This area is a gently undulating plain with a moderate to thick layer of loess. It is the highest and driest region of the Western Corn Belt Plains. Although loess covers almost all of the broad upland flats, ridges, and slopes, minor glacial till outcrops occur near the base of some of the side slopes. Silty clay loam soils have developed on the loess. The area is mostly treeless, except for the more moist areas along some stream corridors and on farmstead windbreaks.

Land uses within the watershed are dominated by agriculture. According to 2011 land use data, approximately 79.5 percent of the acres in the watershed are devoted to row crops, 6.8 percent to grassland (CRP, grazed, ungrazed and hay), 2.8 to percent roads, 4.7 percent to parkland and 6.2 to percent pasture, feedlots and farmsteads. There are no permitted discharges within this watershed. The watershed-to-lake ratio is 59 to 1. This indicates landuse around the lake has a high impact on water quality.

The general soils within the watershed are of Moody Association. These are gentle to moderately sloping prairie-derived soils formed from loess. Slopes range from 2-9 percent within the watershed.

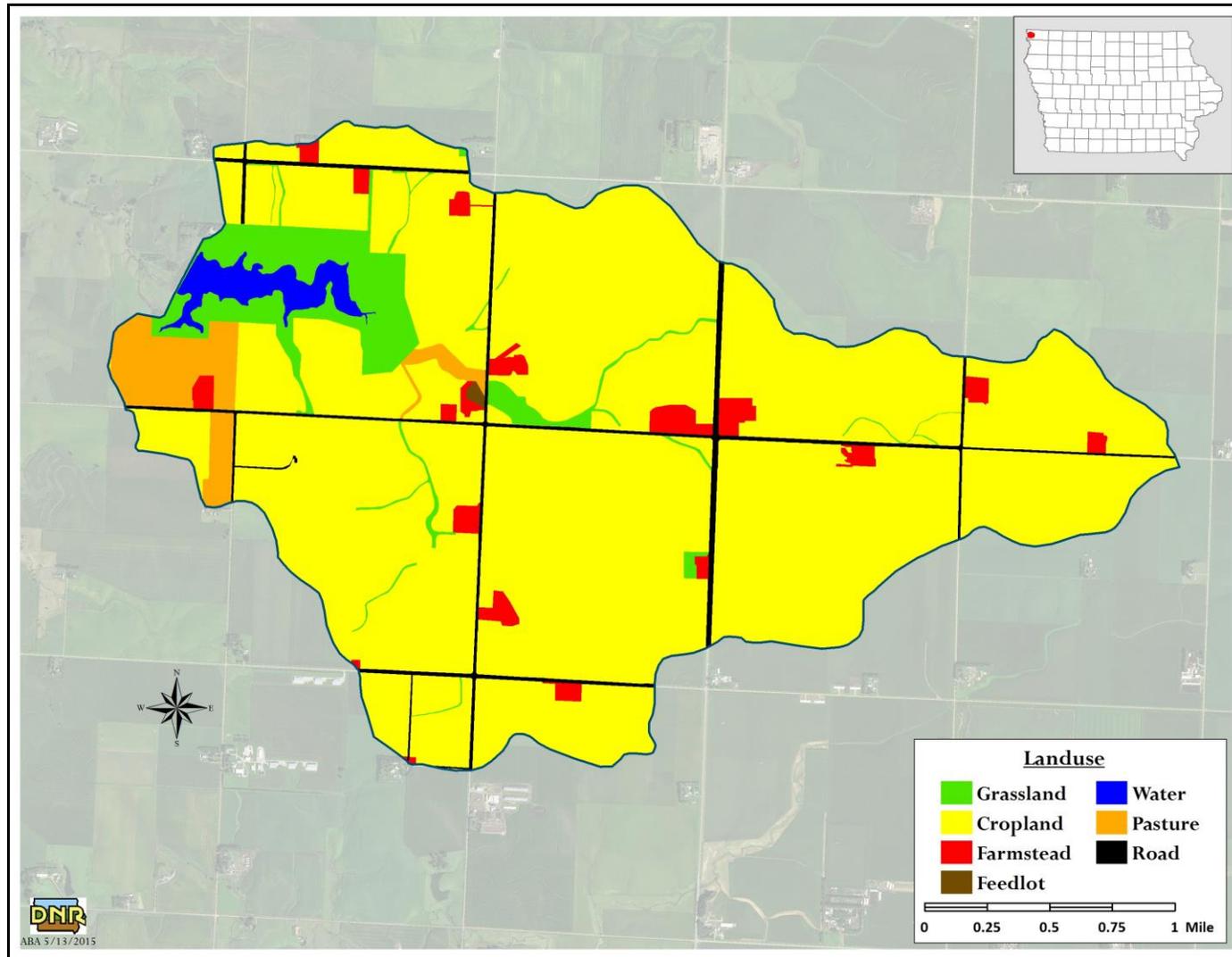


Figure 2.1. Lake Pahoja watershed and landuse

2.2. Hydrology and Morphometry

The nearest weather station to the Lake Pahoja watershed is in Rock Rapids, IA approximately 15 miles to the northeast. The average annual precipitation for the watershed from the 2006-2010 assessment timeframe was 29.9 inches. The long term average (LTA) (1893 to present) for the area is 26.5 inches (Figure 2.2). The driest month is January with an average of 0.57 inches of precipitation and the wettest month is June with an average of 4.2 inches of precipitation. The lowest average temperature occurs in January at 15 degrees Fahrenheit and the highest average temperature occurs in July at 74 degrees Fahrenheit.

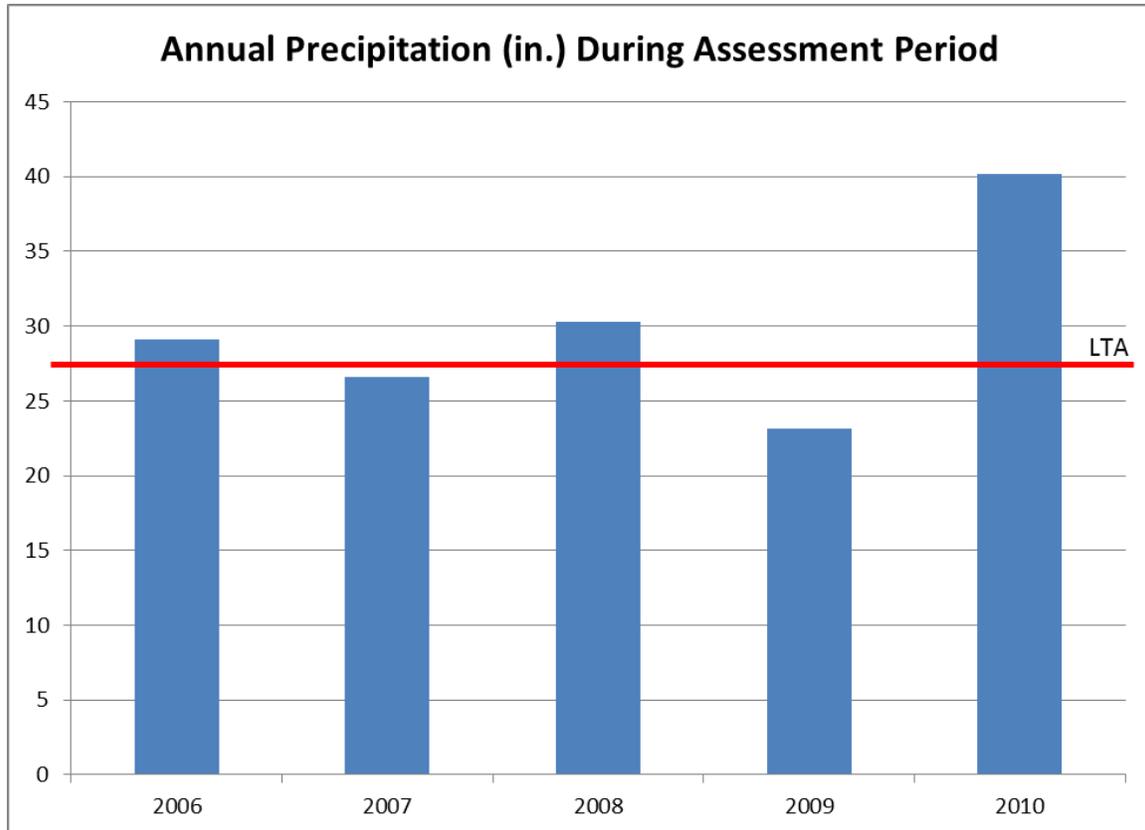


Figure 2.2. Annual precipitation at Rock Rapids, Iowa

*LTA is the long term average since records at site began

A 1,320-foot long, 50-foot high earthen dam controls outflow at the western end of the lake. The surface area of Lake Pahoja varies significantly with water level. At normal pool, the surface area is reported at 64.7 acres. While at flood pool, the lake expands to 110 acres. The lake was designed with a maximum depth of about 35 feet. However a 2007 bathymetric survey found that the maximum depth was 27 feet (Figure 2.3). The loss of depth and associated water storage is most likely a result of sediment deposition from one or more watershed sources: sheet and rill erosion, gully erosion, and streambed and bank erosion.

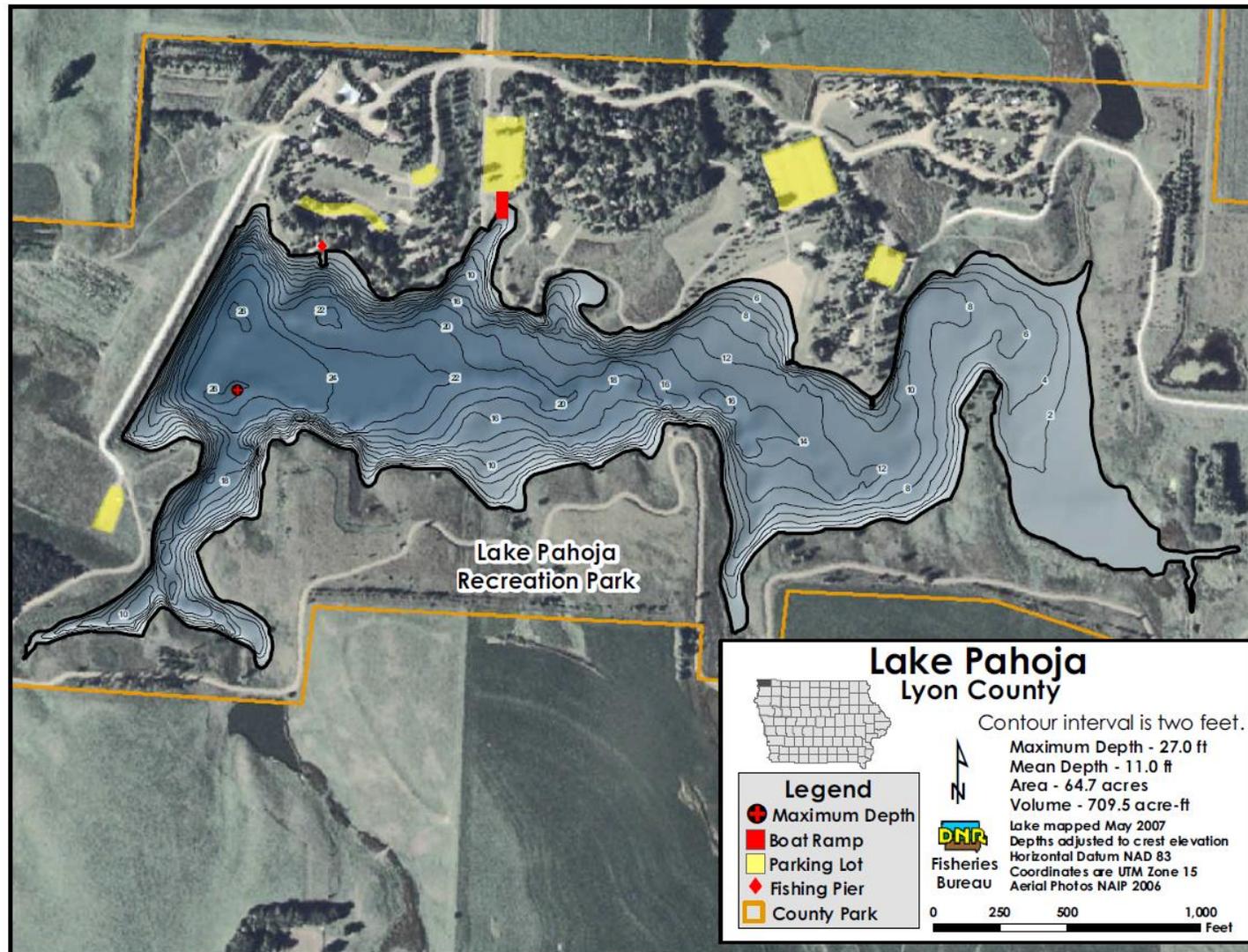


Figure 2.3. Bathymetric map of Lake Pahoja.

Rainfall runoff, direct precipitation, evapotranspiration, shallow groundwater flow, and deep aquifer recharge are all part of the lake's hydrologic system. The hydraulic residence time varies seasonally and is weather dependent. The average residence time for years included in the 2012 Water Quality Assessment (2006-2010) was 56 days. Estimated residence time is based on annual precipitation statistics, estimates of average annual inflow from the Spreadsheet Tool for Estimating Pollutant Load (STEPL), and a water balance calculated within the BATHTUB model.

3. Total Maximum Daily Load (TMDL) for Algae and pH

A Total Maximum Daily Load (TMDL) is required for Lake Pahoja by the Federal Clean Water Act. This section of the Water Quality Improvement Plan (WQIP) describes the pollutant, in this case phosphorus, leading to the algal and pH impairments and the maximum amount of total phosphorus (TP) the lake can assimilate and still support primary contact recreation and aquatic life in Lake Pahoja.

3.1. Problem Identification

The 2014 Section 305(b) Water Quality Assessment Report states that primary contact recreation in Lake Pahoja is assessed (monitored) as “partially supported” due to algae blooms that violate Iowa’s narrative criterion protecting against nuisance aquatic life. An additional impairment exists due to violations of the Class A1 and Class B(LW) criterion for pH. The 2014 assessment can be accessed at:

<https://programs.iowadnr.gov/adbnr/assessment.aspx?aid=16288>

Applicable Water Quality Standards.

The State of Iowa Water Quality Standards (WQS) are published in the Iowa Administrative Code (IAC), Environmental Protection Rule 567, Chapter 61 (<http://www.legis.iowa.gov/DOCS/ACO/IAC/LINC/Chapter.567.61.pdf>) [Note: This link must be copied and pasted into a web browser]. Although the State of Iowa does not have numeric criteria for sediment, nutrients, or algae (chlorophyll-a), general (narrative) water quality criteria below do apply:

61.3(2) General water quality criteria. *The following criteria are applicable to all surface waters including general use and designated use waters, at all places and at all times for the uses described in 61.3(1)“a.”*

- a. *Such waters shall be free from substances attributable to point source wastewater discharges that will settle to form sludge deposits.*
- b. *Such waters shall be free from floating debris, oil, grease, scum and other floating materials attributable to wastewater discharges or agricultural practices in amounts sufficient to create a nuisance.*
- c. *Such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions.*
- d. *Such waters shall be free from substances attributable to wastewater discharges or agricultural practices in concentrations or combinations which are acutely toxic to human, animal, or plant life.*
- e. *Such waters shall be free from substances, attributable to wastewater discharges or agricultural practices, in quantities which would produce undesirable or nuisance aquatic life.*

61.3(3) Specific water quality criteria.

- a. *Class “A” waters. Waters which are designated as Class “A1,” “A2,” or “A” in subrule 61.3(5) are to be protected for primary contact, secondary contact, and children’s recreational uses. The general criteria of subrule 61.3(2) and the following specific criteria apply to all Class “A” waters.*

- (2) The pH shall not be less than 6.5 nor greater than 9.0. The maximum change permitted as a result of waste discharge shall not exceed 0.5 pH units.
- b. Class “B” waters. All waters which are designated as Class B(BCW1), B(CW2), B(WW-1), B(WW-2), B(WW-3), or B(LW) are to be protected for wildlife, fish, aquatic, and semiaquatic life. The following criteria shall apply to all Class “B” waters designated in subrule 61.3(5)
- (2) The pH shall not be less than 6.5 nor greater than 9.0. The maximum change permitted as a result of waste discharge shall not exceed 0.5 pH units.

In order to de-list a lake impaired by algae from the 303(d) list, the median growing season TSIs must not exceed 63 in two consecutive listing cycles, per Iowa DNR delisting methodology. Chapters 61.3(2) and 61.3(3) of the WQS contain the general water quality criteria, which are applicable to all surface waters for this TMDL.

In order to de-list a lake impaired by pH from the 303(d) list, the observed pH values must remain within allowable levels (between 6.5 and 9.0) for two consecutive listing cycles, per Iowa DNR delisting methodology. Chapters 61.3(2) and 61.3(3) of the WQS contain the general water quality criteria, which are applicable to all surface waters for this TMDL.

As previously stated, the primary contact recreation (Class A1) uses at Lake Pahoja are only “partially supported” due to elevated chlorophyll a (algae) levels and high pH. Aquatic life use for warm water lakes (B(WL)) is also only “partially supported” due to high pH. Table 3.1 outlines the common terminology used when discussing algal lake impairments.

Table 3.1. Algae related parameters

Parameter	Physical Meaning
Secchi Depth, meters	Measures water column transparency and used as a translator for turbidity
Chlorophyll a, mg/L	Because Chlorophyll a is produced during photosynthesis, it can be used to measure algae concentration in the water column. Usually, chlorophyll a and volatile suspended solids will show a strong relationship.
Total Phosphorus, mg/L	Total phosphorus is often the limiting factor in algal blooms, or simply, this is usually what algae will run out of first. By controlling phosphorus levels, algal activity can be reduced.
pH	A measure of acidity and alkalinity of a solution that is a number on a scale on which a value of 7 represents neutrality and lower numbers indicate increasing acidity and higher numbers increasing alkalinity

Most phosphorus enters Lake Pahoja attached to sediment that washes in from surface erosion and runoff. The erosion and runoff is precipitation driven but also varies with slope and landuse. Within this watershed there are areas of steeper slope and large

areas of Highly Erodible Land (HEL) that contribute high amounts of sediment attached phosphorus than what is seen in flatter, highly tile-drained areas.

Interpreting Lake Pahoja Data

Sources of data used in the development of this TMDL include those used in the 2012 305(b) report, continued water quality monitoring data from 2011-2014, several sources of additional water quality data, and non-water quality related data used for model development. These sources are summarized in Table 3.2.

Table 3.2. List of data/sources

Data	Source
Precipitation	<ul style="list-style-type: none"> NWS COOP at Rock Rapids (2006-2010)
In-Lake Water Quality	<ul style="list-style-type: none"> Ambient lake data (2006-2014) - see Appendix C
Land Cover/Landuse	<ul style="list-style-type: none"> USDA NASS and CLU coverages
Topography	<ul style="list-style-type: none"> 10m DEM from Iowa DNR GIS library
Lake Bathymetry	<ul style="list-style-type: none"> Iowa DNR mapping

Reviewing and interpreting the water quality data will help provide justification for linking phosphorus loads to chl-a, which may in turn lead to a link between chl-a and pH of Lake Pahoja. After phosphorus enters the lake it can become available for algae within the lake to use in their lifecycle processes. In general, three things are needed for algal growth: light, nitrogen and phosphorus. Of these three, phosphorus is typically the limiting factor in Iowa lakes. By limiting phosphorus, algal growth is also limited. Table 3.3 sums up the TN:TP ratios for this lake. In this analysis the lake was either P limited (TN:TP > 17) or N and P-co-limited (TN:TP between 10 and 17) for all samples exceeding a chlorophyll a TSI of 65. (MPCA, 2005; Carlson and Simpson, 1996). Therefore, nutrient management for controlling algae should focus on reducing TP. The relationship between total phosphorus in the lake and observed chl-a levels is shown in Figure 3.1

Table 3.3. TN:TP ratio analysis of samples exceeding Chl-a TSI of 65

Range	N-limited	Co-Limited	P-limited	Strongly P-limited
	<10	11 to 16	17 to 32	33<
Number of samples	3	4	4	6
Percent	17.7%	23.5%	23.5%	35.3%

Algae proliferate quickly and when large blooms die off the decaying mass can lead to oxygen depletion and/or release of harmful cyanotoxins. Algal blooms are aesthetically objectionable and can make swimming or wading hazardous.

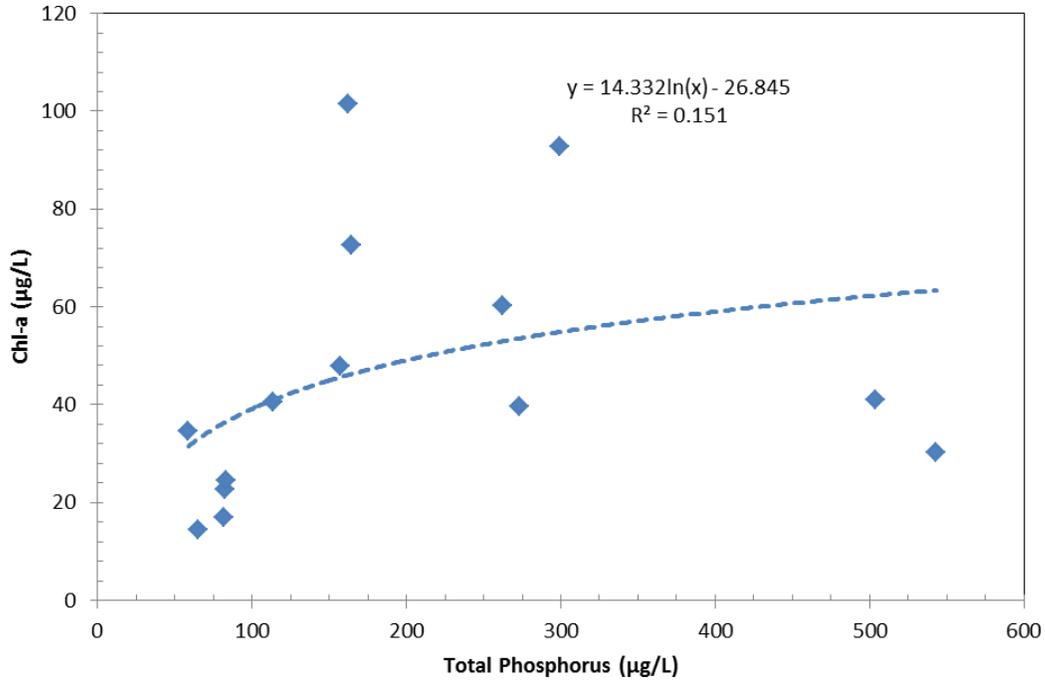


Figure 3.1. Total phosphorus and chl-a levels in Lake Iowa (annual mean 2000-2014)

Levels of pH in Lake Pahoja have exceeded these standards on several occasions (Figure 3.2). When algae remove carbon dioxide during photosynthesis the pH is elevated. Therefore, high pH (> 9.0) can be an indicator of photosynthesis by large quantities of algae. The blue box is the area above the maximum allowable pH of 9.0. All observed data points within that box violate the WQS for pH. The dashed line shows the trend among observed pH values.

Figure 3.3 shows the link between annual mean chlorophyll-a levels and pH over the assessment period. The dashed red line indicates the upper limit of the pH WQS and the blue line illustrates the link between chl-a and pH.

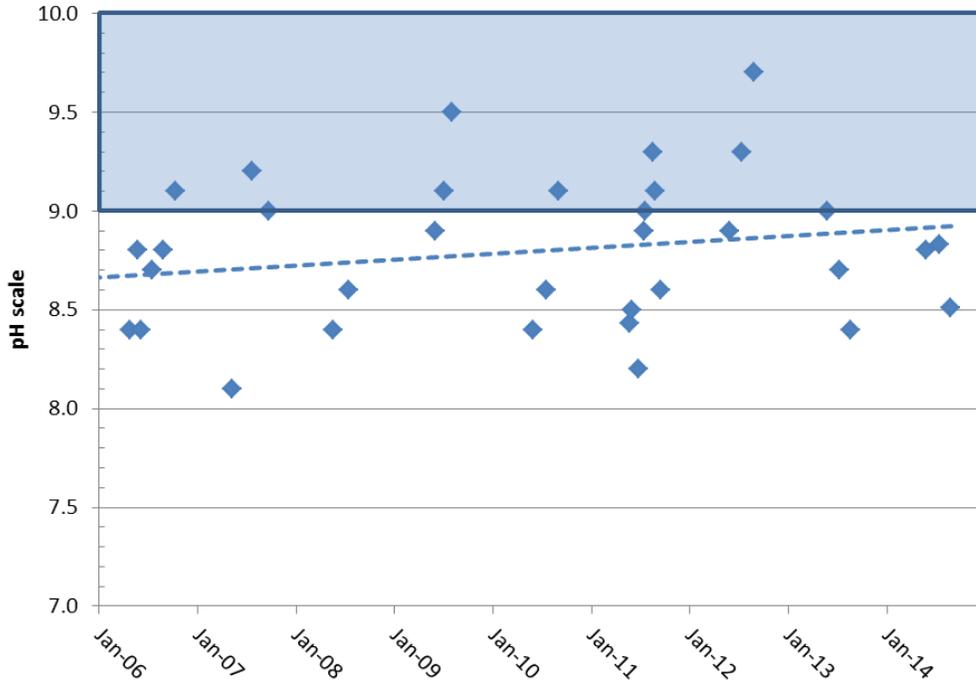


Figure 3.2. Observed pH values during assessment period

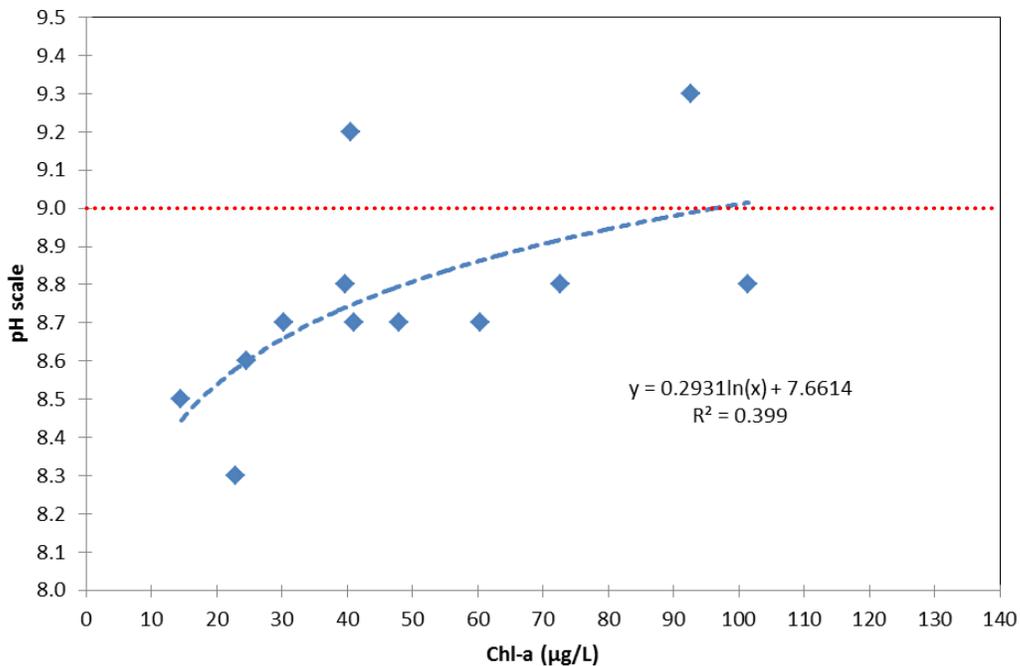


Figure 3.3. Annual mean values of chlorophyll-a and observed pH

The impairment caused by the algal blooms is for aesthetically objectionable conditions. For 303(d) listing purposes, aesthetically objectionable conditions are present in a waterbody when the median summer chlorophyll a or Secchi depth Trophic State Index

(TSI) exceeds 65 (Iowa DNR, 2008). Trophic state is the level of ecosystem productivity, typically measured in algal biomass. The Trophic State Index is a standardized scoring system that places trophic state on an exponential scale of Secchi depth, chlorophyll a, and total phosphorus. TSI levels for chlorophyll-a ranges between 0 and 100, with 10 scale units representing a doubling of algal biomass.

Understanding how TSI describes the overall lake system and not just the water clarity requires introducing the additional concept of eutrophication. Eutrophication is the process by which a body of water acquires a high concentration of nutrients, especially phosphates and nitrates, which typically promotes excessive growth of algae (Art, 1993). Table 3.3 ties TSI values to their corresponding eutrophication state and gives additional details of impacts on the lake system, impacts to recreation and to aquatic life.

Table 3.3. Implications of TSI Values on lake attributes

TSI Value	Attributes	Primary Contact Recreation Problems	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	Warm water fishes only; walleye and some perch; bass may be dominant
60-70	blue green algae dominate; algal scums and macrophyte problems occur	weeds, algal scums, and low transparency discourage swimming and boating	Crappie, bluegill, sunfish, and bass
70-80	hyper-eutrophy (light limited). Dense algae and macrophytes	weeds, algal scums, and low transparency discourage swimming and boating	common carp and other rough fish
>80	algal scums; few macrophytes	algal scums, and low transparency discourage swimming and boating	rough fish dominate; summer fish kills possible

Note: Modified from Carlson and Simpson (1996).

From 2006-2010, measured TSI values consistently surpassed the water quality standard of 65 for TSI Chl-a. (Figure 3.4). The TSI level of 65 has been used to quantify the narrative violation of “aesthetically objectionable” conditions caused by elevated levels of algae (chlorophyll-a). Values above this level for observed Secchi depth, chl-a, and total phosphorus are highlighted by the red box in Figure 3.4.

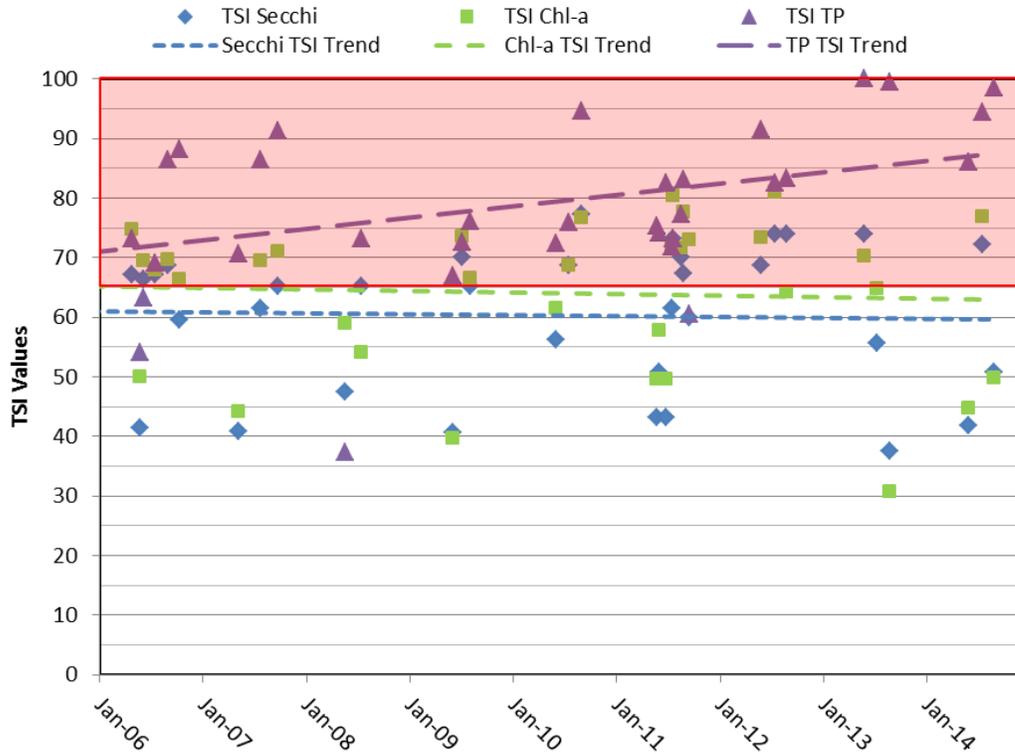


Figure 3.4. TSI values for sampling seasons 2006-2010. All TSI values 65 and above are violations of lowa WQS

Figures 3.5 and 3.6 can be utilized to interpret differences (deviations) between Carlson’s TSI values for TP, Secchi depth, and chlorophyll-a. Each quadrant of the chart indicates the potential factors that may limit algal growth in a lake. A detailed description of this approach is available in *A Coordinator’s Guide to Volunteer Lake Monitoring Methods* (Carlson and Simpson, 1996). If the deviation between the chlorophyll-a TSI and TP TSI is less than zero (Chl TSI < TP TSI), the data point will fall below the X-axis.

The central tendency of deviations forms an elliptical pattern just below and to the right of the dashed 1:1 line. These metrics are indicative of low non-algal turbidity levels and algal limitation that is caused by both TP limitation, and zooplankton grazing (or other non-nutrient related limitation), depending on conditions at the time the water quality sample was collected.

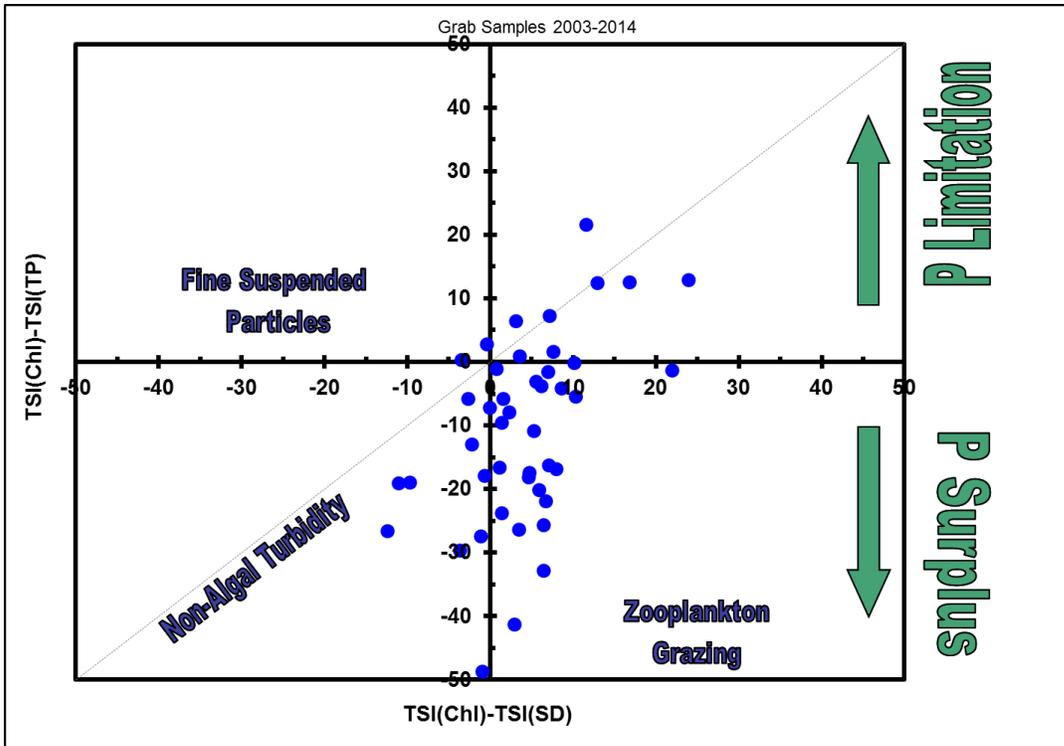


Figure 3.5. Phosphorus TSI deviations (2003-2014 grab samples).

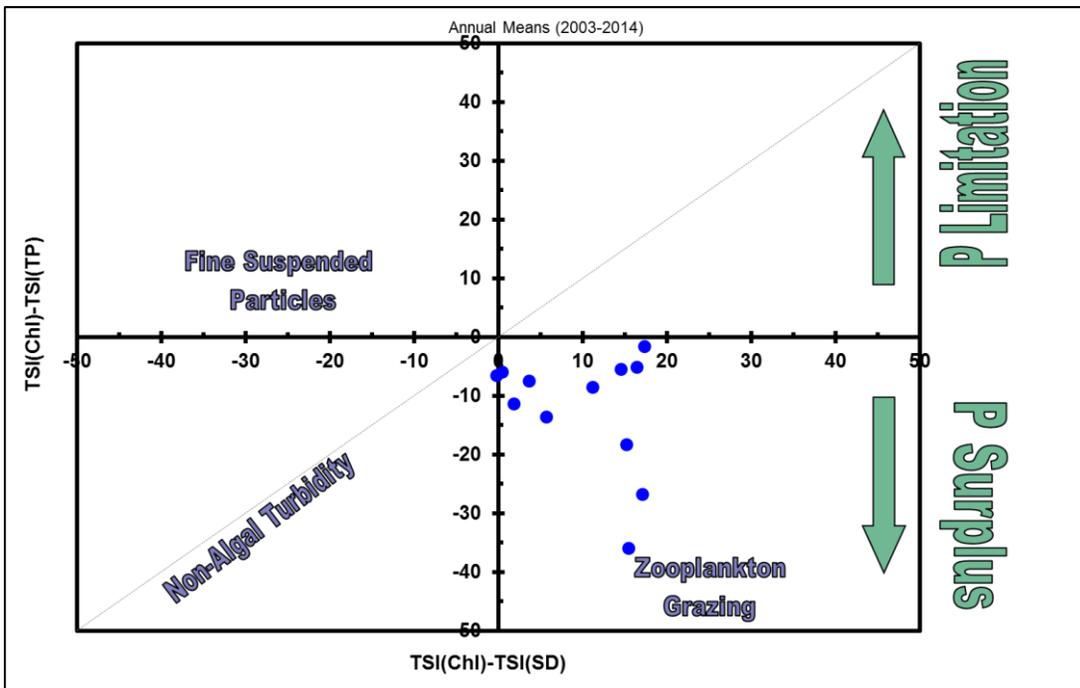


Figure 3.6. Phosphorus TSI deviations (2003-2014 annual means).

Existing load

Average annual simulations of hydrology and pollutant loading via watershed sources were developed using the STEPL model (Version 4.1). STEPL was developed by Tetra Tech for the US EPA Office of Wetlands, Oceans, and Watersheds (OWOW), and has been utilized extensively in the United States for TMDL development and watershed planning. Model description and parameterization are described in detail in Appendix D.

Annual pollutant loads and the subsequent effect on in-lake water quality were modeled using BATHTUB, a lake and reservoir water quality model developed by the U.S. Army Corps of Engineers (USACE). More information on BATHTUB and TMDL specific model inputs can be found in Appendix E.

Using STEPL and BATHTUB, the average annual TP load to Lake Pahojā from 2006-2010, including watershed, internal, and atmospheric loading was estimated to be 12,828 lbs. per year. In the case of Lake Pahojā, the external load was sufficient to produce the levels of chlorophyll-a and TP observed in the lake without the addition of an internal load. While an internal load may be an issue seasonally, overall the external loading is high enough to impair the lake without the internal load. Once external loading is reduced, addressing the internal load may be a valid option for speeding up water quality improvement in Lake Pahojā. However, for this TMDL, the net annual internal load is assumed to be zero.

Identification of pollutant sources

The existing TP load to Lake Pahojā is entirely from nonpoint sources of pollution. There are no point sources operating under a National Pollution Discharge Elimination System (NPDES) permit or regulated by other Clean Water Act programs. Table 3.5 reports estimated annual average TP loads and resulting water quality based on the STEPL and BATHTUB simulation of 2006-2014 conditions. Appendix D goes into further detail for each source.

Table 3.5. Average Annual Total Phosphorus Input

Source	Description	Total Load (lbs/yr)	Percent (%)
Cropland	Corn and Soybean	9,926	77.5
Feedlots	Open and confined animal feeding	1,522	11.9
Pasture	Grazed and ungrazed private	159	1.2
Grassland	Public parkland, ungrazed private, savanna	321	2.5
Urban	City, town, farmstead, road	320	2.5
Atmosphere	Wind and rain	17	0.1
Streambank	Streambank erosion	168	1.3
Groundwater	Groundwater input	352	2.7
Septic	Failing or outdated septic	43	0.3
Total		12,828	100.00

The STEPL model incorporates both livestock and wildlife manure into the cropland TP source by relating livestock and wildlife densities to TP concentration in runoff from agricultural land. In the case of the Lake Pahojā model, wild animal populations are not

large enough to increase runoff TP concentrations. This does not mean that TP loads from manure application and wildlife are zero, but instead, incorporates the relatively small impacts of these sources into the cropland source.

The STEPL model developed for the TMDL assesses landuse inputs of phosphorus and allows for quantification of inputs. Figure 3.5 quantifies percentage of the phosphorus load per land use. This will allow for better targeting when considering phosphorus reduction strategies. Section 4 of this document will further discuss strategies to reduce phosphorus.

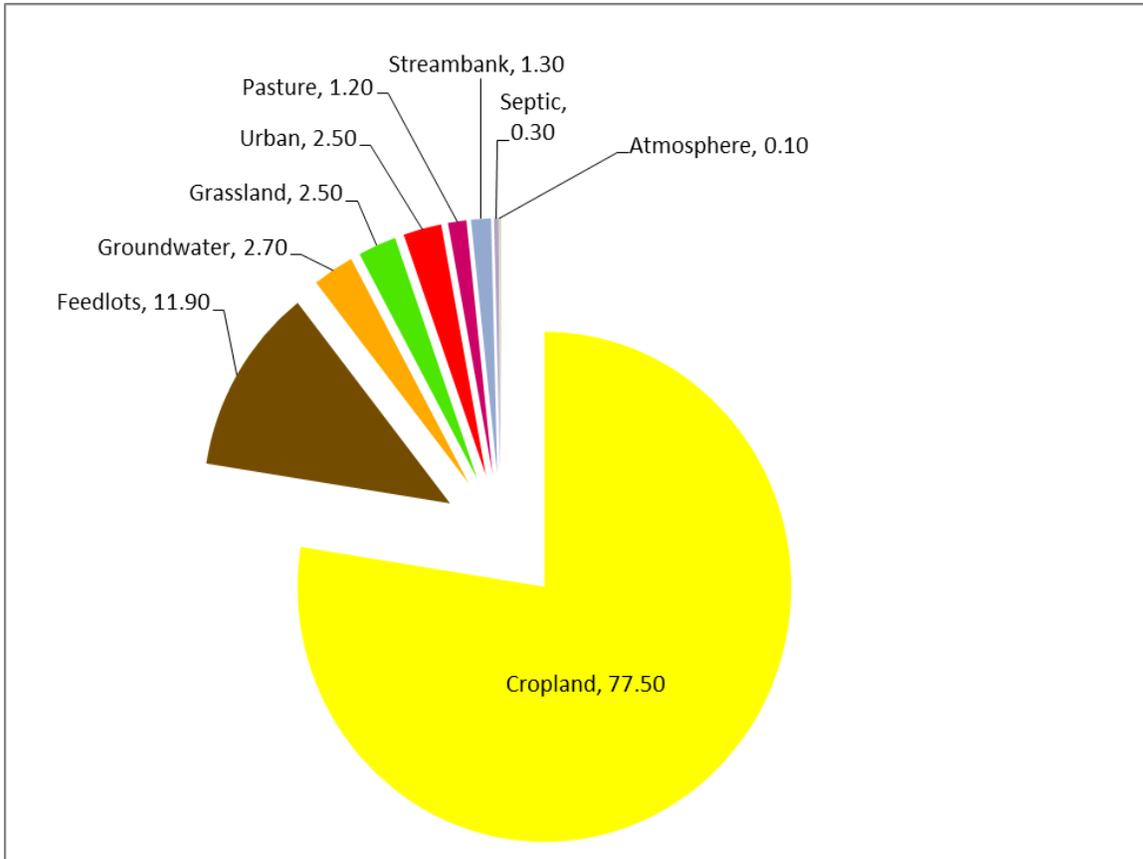


Figure 3.7. Percentage of the phosphorus load per source

3.2. TMDL Target

General description of the pollutants

As established in the previous sections, Lake Pahojā is impaired for excessive algal growth. This is caused by excess phosphorus entering the system. Beginning with this section, the primary focus of this document will be quantifying and reducing phosphorus loads to remediate the water clarity issues.

Selection of environmental conditions

The critical period for the occurrence of algal blooms resulting from high phosphorus levels in the lake is the growing season (April through September). However, long-term phosphorus loads lead to buildup of phosphorus in the reservoir and contribute to blooms regardless of when phosphorus first enters the lake. Additionally, the combined watershed and in-lake modeling approach using EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL) and BATHTUB lends itself to analysis of annual average conditions. Therefore, both existing and allowable TP loads to Lake Pahoja are expressed as annual averages. Phosphorus loads are also expressed as daily maximums to comply with EPA guidance.

Decision criteria for water quality standards attainment

The narrative criteria in the water quality standards require that Lake Pahoja be free from "aesthetically objectionable conditions." There are no numeric criteria associated with water clarity, therefore attainment of the standard is based on maintaining relatively good water clarity compared to other Iowa lakes. The primary metric for water quality standards attainment set forth in this TMDL is obtaining/maintaining a chlorophyll a TSI of no greater than 63. Iowa DNR will de-list the impairment if the chlorophyll a TSI is 63 or less in two consecutive 303(d) listing cycles, per the methodology Iowa DNR uses to develop the Integrated Report.

Chapter 61.3(2) of the WQS contains the general water quality criteria, which are applicable to all surface waters. These narrative criteria require that waters be free from "aesthetically objectionable conditions." See Appendix B for more information on "General and Designated Uses of Iowa's Waters."

Compliance point for WQS attainment

The TSI target for listing and delisting of Lake Pahoja is measured at the ambient monitoring location. For modeling purposes, the lake was divided into two segments (see Figure D-1 of Appendix D). To maintain consistency with other Clean Water Act programs implemented by the Iowa DNR, the TMDL target is based on water quality of Segment 2, which is represented by the ambient monitoring location in Lake Pahoja.

Departure from load capacity

The target TP load, also referred to as the load capacity, for Lake Pahoja is 1,533 lbs. per year. To meet the target loads, an overall reduction of 88.2 % of the existing TP load of 12,828 lbs. per year is required. This will require BMPs in addition to those already implemented during previous watershed improvement efforts. The implementation plan included in Section 4 describes potential BMPs, potential TP reductions, and considerations for targeted selection and location of BMPs.

Allowance for increases in pollutant loads

There is no allowance for increased phosphorus loading included as part of this TMDL. There are no incorporated unsewered communities in the watershed. Therefore, it is unlikely that a future wasteload allocation (WLA) would be needed for a new point source discharge.

3.3. Pollutant Allocation

Wasteload allocation

There are no permitted point source dischargers of phosphorus or CAFOs in the Lake Pahoja watershed. Therefore, the wasteload allocation (WLA) is zero. However, there are several AFOs that are possible sources that may contribute phosphorus to waterways feeding Lake Pahoja. These feedlots are modeled as nonpoint sources in STEPL and their potential contributions are attributed to the load allocation for Lake Pahoja. These operations and their contributions are described more in Appendix D.

Load allocation

Nonpoint sources to Lake Pahoja include loads from agricultural land uses, septic systems and natural / background sources in the watershed, including wildlife and atmospheric deposition (from dust and rain). Changes in agricultural land management and implementation of structural best management practices (BMPs) can reduce phosphorus loads and improve water quality in Lake Pahoja.

The load allocation for this lake is:

Annual = LA 1,380 lbs. TP/year

TMDL (daily) = LA 15.1 lbs. TP/day

Margin of safety

To account for uncertainties in data and modeling, a margin of safety (MOS) is a required component of all TMDLs. An explicit MOS of ten percent was utilized in the development of this TMDL. MOS for this lake is:

Annual = MOS 153 lbs. TP/year

TMDL (daily) = MOS 1.7 lbs. TP-day

3.4. TMDL Summary

The following equation represents the total maximum daily load (TMDL) and its components for Lake Pahoja:

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

Where: TMDL = total maximum daily load
 LC = loading capacity
 \sum WLA = sum of wasteload allocations (point sources)
 \sum LA = sum of load allocations (nonpoint sources)
 MOS = margin of safety (to account for uncertainty)

Once the loading capacity, wasteload allocations, load allocations, and margin of safety have all been determined for the Lake Pahoja watershed, the general equation above can be expressed for the Lake Pahoja algae and non-algal turbidity TMDL.

Expressed as the allowable annual average, which is helpful for water quality assessment and watershed management:

$$\text{Annual} = \text{LC} = \sum \text{WLA} (0 \text{ lbs.-TP/year}) + \sum \text{LA} (1,380 \text{ lbs.-TP/year}) \\ + \text{MOS} (153 \text{ lbs.-TP/year}) = \mathbf{1533 \text{ lbs.-TP/year}}$$

Expressed as the allowable maximum daily load as required by EPA (see Appendix F):

$$\text{TMDL} = \text{LC} = \sum \text{WLA} (0 \text{ lbs.-TP/day}) + \sum \text{LA} (15.1 \text{ lbs.-TP/day}) \\ + \text{MOS} (1.7 \text{ lbs. TP-day}) = \mathbf{16.8 \text{ lbs.-TP/day}}$$

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources (DNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan (WQIP). Therefore, this general implementation plan is included for use by local agencies, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) discussed represents a package of potential tools that will help achieve water quality goals if appropriately utilized. It is likely that only a portion of BMPs included in this plan will be feasible for implementation in the Lake Pahoja watershed. Additionally, there may be potential BMPs not discussed that should be considered. This implementation plan should be used as a guide or foundation for detailed and comprehensive management / restoration plan development by local stakeholders.

Collaboration and action by residents, landowners, lake patrons, and local agencies will be essential to improve water quality in Lake Pahoja and support its designated uses. Locally-driven efforts have proven to be the most successful in obtaining real and significant water quality improvements. Improved water quality in Lake Pahoja results in economic and recreational benefits for people that live, work, and play in the watershed. Therefore, each group has a stake in promoting awareness and educating others about water quality, working together to adopt a comprehensive watershed improvement plan, and applying additional BMPs and land management changes in the watershed.

The primary focus of this implementation plan will be reducing phosphorus loads to remediate the aesthetically objectionable conditions. Successful phosphorus controls will reduce algal blooms in the lake. Reduction of algal blooms, which impact the lake's carbon cycle through high rates of photosynthesis, should also prevent violations of the pH criterion.

4.1. General Approach & Reasonable Timeline

Watershed management and BMP implementation to reduce phosphorus inputs and subsequent algal blooms in the lake should utilize a phased approach to improving water quality. The preliminary phase(s) should consist of planning and implementation of watershed BMPs required to meet water quality standards (WQS). A reasonable timeline for long term watershed projects aimed at improving water quality is usually measured in years or decades and depends on stakeholder interest, availability of funds, landowner participation, and time needed for design and construction of any structural BMPs.

4.2. Watershed Best Management Practices

No stand-alone BMP will be able to sufficiently reduce nutrient loads to Lake Pahoja. Rather, a comprehensive package of BMPs will be required to reduce sediment and phosphorus transport to the lake. The majority of phosphorus and sediment that enters the lake is from lands in corn and soybean production, grazed lands, and streambank and gully erosion. Each source has distinct sediment and phosphorus transport pathways; therefore, each requires different BMPs and strategies. It is important that all sources are considered to reduce phosphorus loads in the most comprehensive manner

possible. Experience has shown that watershed projects that involve widespread “ownership” of potential solutions have the best chance of success.

Best management practices are dictated by landscape. The effectiveness of any practice is dependent on being installed within the right area and landuse. The soils and slopes of each ecoregion largely determine the erosion rates of soils in natural landscapes. Highly erodible land (HEL) is classified by the Natural Resource Conservation Service (NRCS) as land, which if used to produce an agricultural commodity, would have an excessive annual rate of erosion as determined by the Universal Soil Loss Equation (USLE). Figure 4.1 depicts the HEL lands within the Lake Pahoja watershed and where these lands intersect with the cropland. Of the 735 HEL acres in the watershed, 426 acres were in row crop production in 2011. These areas should be considered high priority for the proper BMPs to reduce erosion.

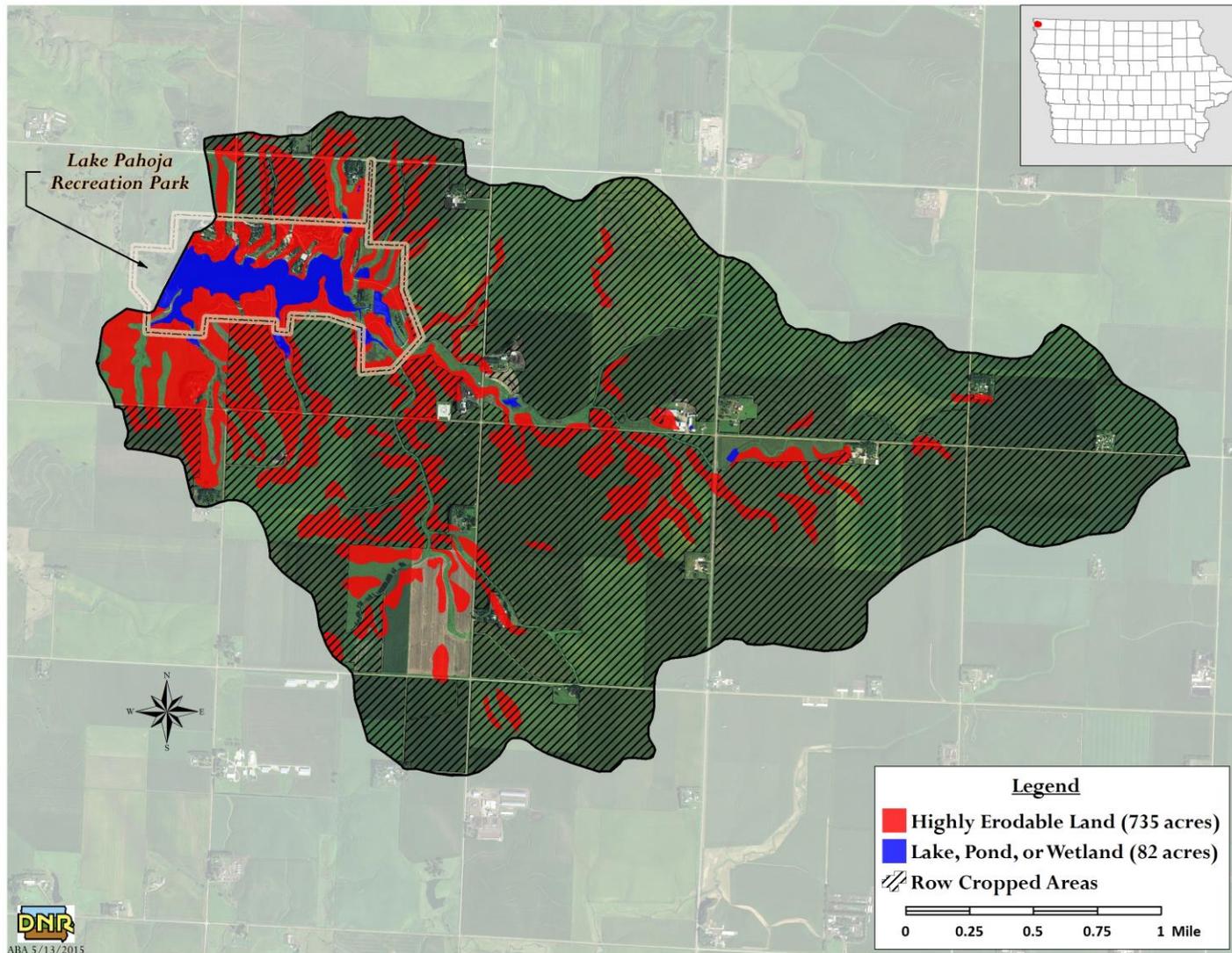


Figure 4.1. The highly erodible land within the Lake Pahoja Watershed.

Any BMPs placed with the Lake Pahoja watershed will need to be regularly inspected for efficiency. Terraces need to be maintained and catchments need to be evaluated for reduced capacity and if they are effectively retaining phosphorus. For modeling purposes, any existing structures were considered to have negligible impact on phosphorus loads to the lake.

Potentially beneficial BMPs include terraces on high slopes, grass waterways and sediment control structures or wetlands. Other management practices could also be operational such as conservation tillage, perennial strips, cover crops, and nutrient applications strategies. Ultimately, a combination of structural and operational BMPs will yield the best results in reducing phosphorus. Tables 4.1 and 4.2 give more detailed information on structural and operational BMPs.

Table 4.1. Structural BMPs.

BMP or Activity	Secondary Benefits	¹ Potential TP Reduction
Terraces	Soil conservation, prevent in-field gullies, prevent wash-outs	50%
² Sediment Control Structures	Some ecological services, gully prevention	85%
³ Wetlands	Ecological services, potential flood mitigation, aesthetic value	20%

¹Adopted from USDA-ARS (2004). Actual reduction percentages may vary widely across sites and runoff events.

²Reductions reported by Section 2:Nonpoint Source Nutrient Reduction Science Assessment (2012), Iowa Nutrient Reduction Strategy. Value assumes structures are sized/designed properly and routinely maintained.

³Note: TP reductions in wetlands vary greatly depending on site-specific conditions.

Increasing surface area, implementing multiple wetlands in series, and managing vegetation can increase potential TP reductions

Table 4.2. Potential land management BMPs.

BMP or Activity	¹ Potential TP Reduction
Conservation Tillage:	
Moderate vs. Intensive Tillage	50%
No-Till vs. Intensive Tillage	70%
No-Till vs. Moderate Tillage	45%
Cover Crops	50%
Diversified Cropping Systems	50%
In-Field Vegetative Buffers	50%
Phosphorus Nutrient Application Techniques	
Knife/Injection Incorporation vs. Surface Broadcast	35%
Phosphorus Nutrient Application Timing and Rates:	
Spring vs. Fall Application	30%
Soil-Test P Rate vs. Over-Application Rates	40%
Application: 1-month prior to runoff event vs. 1-day	30%
Riparian Buffers	45%

¹Adopted from USDA-ARS (2004). Actual reduction percentages may vary widely across sites and runoff events.

²Note: Tillage incorporation can increase TP in runoff.

4.3. In Lake Best Management Practices

Phosphorus recycled between the bottom sediment and water column of the lake is, at times, and important contributor of bioavailable phosphorus to lakes. The average annual contribution of TP to the system from internal loading appears to be very small in Lake Pahoja. However, internal loading may influence in-lake water under certain conditions despite its relatively insignificant average annual phosphorus contribution. Internal loads may exacerbate algal blooms in late summer periods, which are typically dry with low external loading. Phosphorus in the lake's bottom sediments may become available through internal loading, which is most likely to happen during prolonged hot, dry periods in late summer.

However, it is important to understand that external phosphorus loads from wet weather supply the build-up of phosphorus in the bottom sediments. Estimates of external loads from Lake Pahoja are of large enough magnitude to fully explain observed in-lake water quality. Even in lakes with high suspected internal loads, uncertainty regarding the magnitude of internal loads is one of the biggest challenges to TMDL development and lake restoration. Because of these factors, reductions from watershed sources of TP should be given implementation priority. If and when monitoring shows that the external watershed load has been adequately reduced, then additional in-lake measures may be warranted.

While not considered a significant source in this TMDL, shorelines in man-made reservoirs are subject to erosion from water level fluctuations and wave action. Assessing shorelines in spring and fall for eroding areas and stabilization with bio-engineering or hard armoring techniques may improve habitat and water clarity near the shoreline.

Descriptions of potential in-lake restoration methods are included in Table 4.3. Phosphorus reduction percentages of each alternative will vary and depend on a number of site-specific factors. It is virtually impossible to determine how much of the internal load is due to each of the contributing factors, and equally difficult to predict phosphorus reductions associated with individual improvement strategies. In-lake measures should be part of a comprehensive watershed management plan that includes practices that enhance, prolong, and protect the effectiveness of in-lake investments

Table 4.3. Potential in-lake BMPs for water quality improvement.

In-Lake BMPs	Comments	¹ Relative TP Reduction
Targeted dredging	Targeted dredging in shallow inlet areas would create pockets of deep-water habitat for predatory fish that would help control rough fish populations. Strategic dredging would also increase the sediment capacity of the inlet areas, thereby reducing sediment loads to the larger, open water area of the lake	Med
In-Lake Dredging	Dredging is seldom cost-effective on a large scale and as a stand-alone measure; disposal of dredged material is often a challenge; dredging should be focused on areas of known sediment deposition or to create deep-water habitat as part of fisheries management. A cost benefit analysis may be necessary to examine the feasibility of large-scale dredging in Lake Pahoja.	Med-High
Shoreline stabilization (public areas)	Helps establish and sustain vegetation, which provides local erosion protection and competes with algae for nutrients. Impacts of individual projects may be small, but cumulative effects of widespread stabilization projects can be beneficial. The entire shoreline of Lake Pahoja is publicly owned, making this alternative possible in all areas of the lake.	Low

¹Reductions (High/Med/Low) are relative to each other and based on numerous research studies and previous Iowa DNR projects.

5. Future Monitoring

Water quality monitoring is critical for assessing the current status of water resources as well as historical and future trends. Furthermore, monitoring is necessary to track the effectiveness of water quality improvements made in the watershed and document the status of the waterbody in terms of achieving Total Maximum Daily Loads (TMDLs) and Water Quality Standards (WQS).

Future monitoring in the Lake Pahoja watershed can be agency-led, volunteer-based, or a combination of both. The Iowa Department of Natural Resources (Iowa DNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program, called IOWATER, that provides training to interested volunteers. More information can be found at the program web site: <http://www.iowater.net/Default.htm>

It is important that volunteer-based monitoring efforts include an approved water quality monitoring plan, called a Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). The IAC can be viewed here: [http://search.legis.state.ia.us/NXT/gateway.dll/ar/iac/5670_environmental%20protection%20commission%20_5b567_5d/0610_chapter%2061%20water%20quality%20standards/_c_5670_0610.xml?f=templates\\$fn=default.htm](http://search.legis.state.ia.us/NXT/gateway.dll/ar/iac/5670_environmental%20protection%20commission%20_5b567_5d/0610_chapter%2061%20water%20quality%20standards/_c_5670_0610.xml?f=templates$fn=default.htm)

Failure to prepare an approved QAPP will prevent data collected from being used to assess a waterbody's status on the state's 303(d) list – the list that identifies impaired waterbodies.

5.1. Monitoring Plan to Track TMDL Effectiveness

Future data collection in Lake Pahoja to assess water quality trends and compliance with water quality standards (WQS) is expected to include monitoring conducted as part of the Iowa DNR Ambient Lake Monitoring Program. Unless there is local interest in collecting additional water quality data, future sampling efforts will be limited to this basic monitoring program.

The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 137 of Iowa's lakes are being sampled as part of this program, including Lake Pahoja. Typically, one location near the deepest part of the lake is sampled, and many chemical, physical, and biological parameters are measured. Sampling parameters are reported in Table 5.1. At least three sampling events are scheduled every summer, typically between Memorial Day and Labor Day. While the ambient monitoring program can be used to identify trends in lake water quality, it does not lend itself to calculation of watershed loads, identification of individual pollutant sources, or the evaluation of BMP implementation.

Table 5.1. Ambient Lake Monitoring Program water quality parameters.

Chemical	Physical	Biological
<ul style="list-style-type: none"> • Total Phosphorus (TP) • Soluble Reactive Phosphorus (SRP) • Total Nitrogen (TN) • Total Kjeldahl Nitrogen (TKN) • Ammonia • Un-ionized Ammonia • Nitrate + Nitrite Nitrogen • Alkalinity • pH • Silica • Total Organic Carbon • Total Dissolved Solids • Dissolved Organic Carbon 	<ul style="list-style-type: none"> • Secchi Depth • Temperature • Dissolved Oxygen (DO) • Turbidity • Total Suspended Solids (TSS) • Total Fixed Suspended Solids • Total Volatile Suspended Solids • Specific Conductivity • Lake Depth • Thermocline Depth 	<ul style="list-style-type: none"> • Chlorophyll a • Phytoplankton (mass and composition) • Zooplankton (mass and composition)

5.2. Expanded Monitoring for Detailed Assessment and Planning

Data available from the Iowa DNR Ambient Lake Monitoring Program will be used to assess general water quality trends and WQS attainment. More detailed monitoring data is required to reduce the level of uncertainty associated with water quality trend analysis, better understand the impacts of implemented watershed projects (i.e., BMPs), and guide future water quality modeling and BMP implementation efforts. Existing resources will not allow more detailed monitoring data to be collected by DNR. Only through the interest and action of local stakeholders will funding and resources needed to acquire this important information become available.

Within the Lake Pahoja watershed there are some retention ponds and structures already constructed. However, these have not been monitored and the effectiveness and conditions of these structures should be inspected (Figure 5.1). Data from monitoring these areas could be used to refine future models to both look at these BMP's effects on surface water quality and to identify which BMPs are most effective in this landscape for further planning. Figure 5.1 shows where the ambient lake monitoring samples will be

gathered along with additional sites that would be helpful in monitoring the effectiveness of BMPs and the water quality entering the upper portion of the lake. Section 5.3 will further describe tributary monitoring.

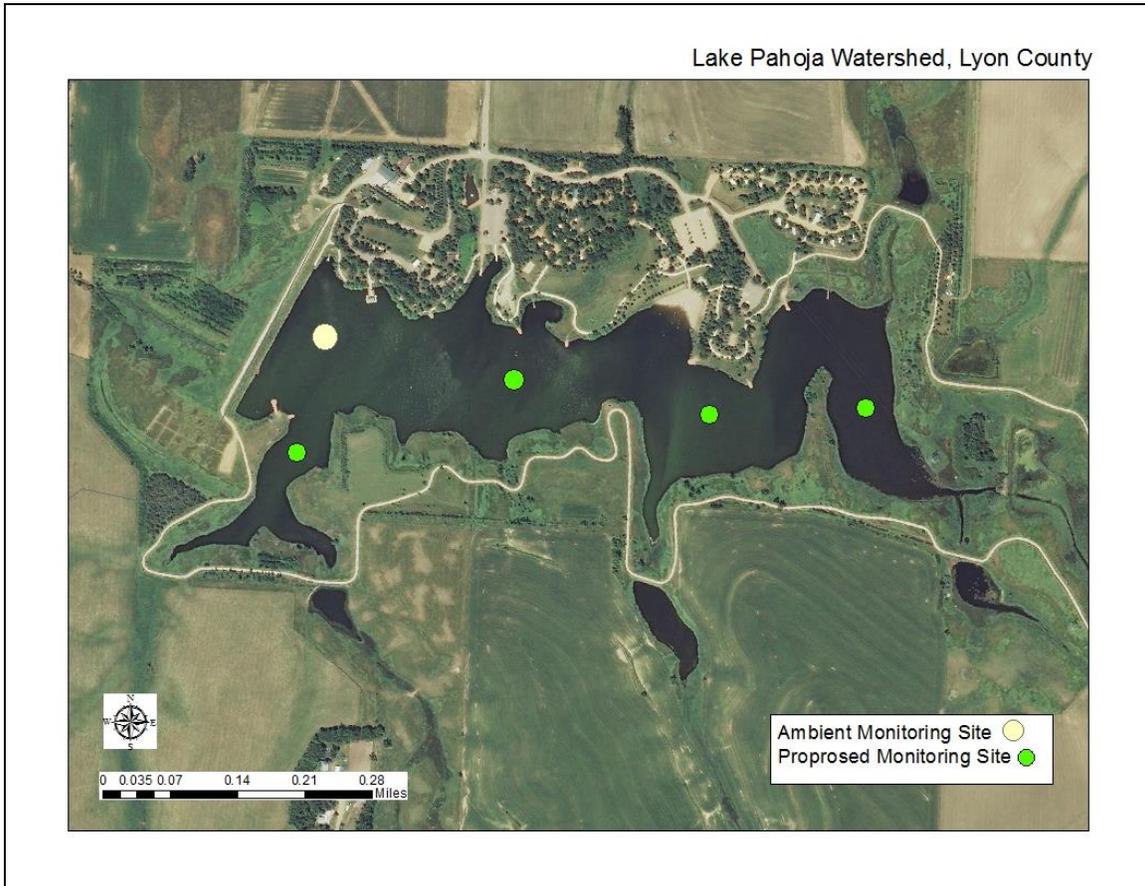


Figure 5.1. Sample locations for Lake Pahoja monitoring.

Monitoring of these sites might result in the decision to add additional sites further upstream in the watershed if better quantification of tributary load becomes necessary. Additional sites within the lake might also be desirable in the future.

5.3. Potential Plan for Future Watershed Projects

Table 5.2 outlines the detailed monitoring plan by listing the components in order, starting with the highest priority recommendations. While it is unlikely that available funding will allow collection of all recommended data, this expanded plan can be used to help identify and prioritize monitoring data needs. Additionally, a large emphasis should be placed on storm event sampling and the contributions of the tributaries at high flow. Within this watershed all the tributaries do not flow year round during normal to dry years. Therefore, storm event contribution may be high.

Table 5.2. Expanded monitoring plan.

Parameter(s)	Intervals	Duration	¹ Location(s)
Routine grab sampling for flow, sediment, P, algae and N	Every 1-2 weeks	April through October	Ambient and Tributaries
Continuous flow	15-60 minute	April through October	Lake Outfall
Continuous pH, DO, turbidity and temperature	15-60 minute	April through October	Ambient and Tributaries
Runoff event flow, TSS/ISS, P	Continuous flow, composite WQ	3 events between April and October	Tributaries
Event or continuous flow, turbidity N, and P sampling	15-60 minute	10 to 14-day wet weather periods if continuous sampling is not feasible	Tributaries

¹Final location of tributary sites should be based on BMP placement, landowner permission, and access/installation feasibility.

Routine weekly or bi-weekly grab sampling with concurrent in-lake and tributary data (ambient location and tributaries in Figure 5.1) would help identify potential sources and hot spots in water quality and nutrient loading. Particularly, grab samples both upstream and downstream of BMPs to assess efficiency of each structure would be helpful in assessing the overall watershed. Data collection should commence before additional BMPs are implemented in the watershed to establish baseline conditions. This data could form the foundation for assessment of general water quality trends; however, more detailed information will be necessary to evaluate loading processes, storm events, and reduce uncertainty. Therefore, routine grab sampling should be viewed only as a starting point for assessing trends in water quality.

Reliable long-term flow data is also important because hydrology drives many important processes related to water quality, including erosion and phosphorus transport. A good hydrologic data set will be necessary to evaluate the success of BMPs such as reduced-tillage, sediment control structures, terraces and grass waterways, riparian buffers, and wetlands.

If funding is available, lake managers should consider deploying a data logger at the ambient monitoring location and possibly in tributaries to measure pH, temperature, and dissolved oxygen (DO) on a continuous basis. This information will help answer questions about the causes and effects of algal blooms and will provide spatial resolution for evaluation of water quality in different areas of the lake. Routine grab sampling, described previously, should be coordinated with deployment of data loggers.

The proposed expanded-monitoring information would assist utilization of watershed and water quality models to simulate various scenarios and water quality response to BMP implementation. Monitoring parameters and locations should be continually evaluated. Adjustment of parameters and/or locations should be based on BMP placement, newly discovered or suspected pollution sources, and other dynamic factors. The Iowa DNR Watershed Improvement Section can provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Lake Pahoja watershed.

6. Public Participation

Public involvement is important in the Total Maximum Daily Load (TMDL) process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Lake Pahoja. During the development of this TMDL, efforts were made to ensure that local stakeholders were involved in the decision-making process to agree on feasible and achievable goals for the water quality in Lake Pahoja.

6.1. Public Meetings

In November of 2014, prior to TMDL development, park officials were contacted to give input on lake history and a guided site visit was conducted.

A public meeting was held on June 25, 2015 at the Lake Pahoja West Shelter near Inwood, Iowa. The meeting was lightly attended by interested citizens in the area.

6.2. Written Comments

A public comment period was initiated via a press release on June 11, 2015. Comments were accepted from June 11, 2015 through July 13, 2015. No public comments were received during the public comment period.

7. References

Art, H.W., 1993, Eutrophication, *in* Art, H.W., ed., A dictionary of ecology and environmental science (1st ed.): New York, New York, Henry Holt and Company, p. 196.

Carlson, R, and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Griffith, G.E., J.M. Omernik, T.F. Wilton, and S. M. Pierson. 1994. Ecoregions and sub-ecoregions of Iowa: a framework for water quality assessment and management. *Journal of the Iowa Academy of Science* 10: 5-13.

Iowa Environmental Mesonet. Weather data 2006-2010 Rock Rapids, Iowa.

Minnesota Pollution Control Agency (MPCA). 2005. Lake Water Quality Assessment Report: Developing Nutrient Criteria. Third Edition.

Prior, J.C. 1991. Landforms of Iowa. University of Iowa Press. Iowa City, Iowa. 153p.

U.S. Department of Agriculture, Agricultural Research Service (USDA-ARS). 2004. Assessments of Practices to Reduce Nitrogen and Phosphorus Nonpoint Source Pollution of Iowa's Surface Waters. Prepared for the Iowa Department of Natural Resources in Cooperation with the USDA-ARS National Soil Tilth Laboratory. Ames, Iowa.

U.S. Environmental Protection Agency (EPA). 1991. Technical Support Document for Water Quality-based Toxics Control. EPA/505/2-90-001. EPA Office of Water, Washington, DC.

U.S. Environmental Protection Agency (EPA). 2006. Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. circuit in *Friends of the Earth, Inc. v. EPA, et al.*, No. 05-5015, (April 25, 2006) and Implications for NPDES Permits. Memorandum from Benjamin Grumbles, Assistant Administrator, EPA Office of Water, Washington, DC.

U.S. Environmental Protection Agency (EPA). 2007. Options for Expressing Daily Loads in TMDLs (Draft). EPA Office of Wetlands, Oceans & Watersheds, Washington, DC.

Modeling References:

Anderson, K., and J. Downing. 2006. Dry and wet atmospheric deposition of nitrogen, phosphorus, and silicon in an agricultural region. *Water, Air, and Soil Pollution*, 176:351-374.

Walker, W. 1985. Empirical methods for predicting eutrophication in impoundments; Report 4, Phase III: Applications manual, "Technical Report E-81-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Walker, W., 1996 (Updated 1999). Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. US Army Corps of Engineers Waterways Experiment Station. Instruction Report W-96-2.

Appendix A --- Glossary of Terms, Abbreviations, and Acronyms

- 303(d) list:** Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface waterbodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state’s “Impaired Waters List.”
- 305(b) assessment:** Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state’s public waterbodies’ ability to support their general and designated uses. Those bodies of water which are found to be not supporting or only partially supporting their uses are placed on the 303(d) list.
- 319:** Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.
- AFO:** Animal Feeding Operation. A lot, yard, corral, building, or other area in which animals are confined and fed and maintained for 45 days or more in any 12-month period, and all structures used for the storage of manure from animals in the operation. Open feedlots and confinement feeding operations are considered to be separate animal feeding operations.
- AU:** Animal Unit. A unit of measure used to compare manure production between animal types or varying sizes of the same animal. For example, one 1,000 pound steer constitutes one AU, while one mature hog weighing 200 pounds constitutes 0.2 AU.
- Benthic:** Associated with or located at the bottom (in this context, “bottom” refers to the bottom of streams, lakes, or wetlands). Usually refers to algae or other aquatic organisms that reside at the bottom of a wetland, lake, or stream (see periphyton).
- Benthic macroinvertebrates:** Animals larger than 0.5 mm that do not have backbones. These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. They include crayfish, mussels, snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.
- Base flow:** Sustained flow of a stream in the absence of direct runoff. It can include natural and human-induced stream flows. Natural base flow is sustained largely by groundwater discharges.
- Biological impairment:** A stream segment is classified as biologically impaired if one or more of the following occurs, the FIBI and or BMIBI scores fall

	below biological reference conditions, a fish kill has occurred on the segment, or the segment has seen a > 50% reduction in mussel species.
Biological reference condition:	Biological reference sites represent the least disturbed (i.e. most natural) streams in the ecoregion. The biological data from these sites are used to derive least impacted BMIBI and FIBI scores for each ecoregion. These scores are used to develop Biological Impairment Criteria (BIC) scores for each ecoregion. The BIC is used to determine the impairment status for other stream segments within an ecoregion.
BMIBI:	Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.
BMP:	Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.
CAFO:	Concentrated Animal Feeding Operation. A federal term defined as any animal feeding operation (AFO) with more than 1000 animal units confined on site, or an AFO of any size that discharges pollutants (e.g. manure, wastewater) into waters of the United States through a manmade ditch, flushing system, or other similar man-made device; or an AFO of any size that discharges pollutants directly into waters of the United States.
CBOD5:	5-day Carbonaceous Biochemical Oxygen Demand. Measures the amount of oxygen used by microorganisms to oxidize hydrocarbons in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.
CFU:	A Colony Forming Unit is a cell or cluster of cells capable of multiplying to form a colony of cells. Used as a unit of bacteria concentration when a traditional membrane filter method of analysis is used. Though not necessarily equivalent to most probably number (MPN), the two terms are often used interchangeably.
Confinement feeding operation:	An animal feeding operation (AFO) in which animals are confined to areas which are totally roofed.
Credible data law:	Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate. To be considered "credible," data must be collected and analyzed using methods and protocols outlined in an approved Quality Assurance Project Plan (QAPP).

Cyanobacteria (blue-green algae):	Members of the phytoplankton community that are not true algae but are capable of photosynthesis. Some species produce toxic substances that can be harmful to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecological activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.
DNR (or Iowa DNR):	Iowa Department of Natural Resources.
Ecoregion:	Areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources based on geology, vegetation, climate, soils, land use, wildlife, and hydrology.
EPA (or USEPA):	United States Environmental Protection Agency.
Ephemeral gully erosion:	Ephemeral gullies occur where runoff from adjacent slopes forms concentrated flow in drainage ways. Ephemerals are void of vegetation and occur in the same location every year. They are crossable with farm equipment and are often partially filled in by tillage.
FIBI:	Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.
FSA:	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
General use(s):	Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.
Geometric Mean (GM):	A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendency of data. It is often used to summarize highly skewed data or data with extreme values such as wastewater discharges and bacteria concentrations in surface waters. In Iowa's water quality standards and assessment procedures, the geometric mean criterion for <i>E. coli</i> is measured using at least five samples collected over a 30-day period.
GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.

Groundwater:	Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.
Gully erosion:	Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.
HEL:	Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land, which has the potential for long-term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.
IDALS:	Iowa Department of Agriculture and Land Stewardship
Integrated report:	Refers to a comprehensive document that combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public waterbodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.
LA:	Load Allocation. The portion of the loading capacity attributed to (1) the existing or future nonpoint sources of pollution and (2) natural background sources. Wherever possible, nonpoint source loads and natural loads should be distinguished. (The total pollutant load is the sum of the wasteload and load allocations.)
LiDAR:	Light Detection and Ranging. Remote sensing technology that uses laser scanning to collect height or elevation data for the earth's surface.
Load:	The total amount of pollutants entering a waterbody from one or multiple sources, measured as a rate, as in weight per unit time or per unit area.
Macrophyte:	An aquatic plant that is large enough to be seen with the naked eye and grows either in or near water. It can be floating, completely submerged (underwater), or partially submerged.
MOS:	Margin of Safety. A required component of the TMDL that accounts for the uncertainty in the response of the water quality of a waterbody to pollutant loads.
MPN:	Most Probable Number. Used as a unit of bacteria concentration when a more rapid method of analysis (such as Colisure or Colilert) is utilized. Though not necessarily equivalent to colony forming units (CFU), the two terms are often used interchangeably.

MS4:	Municipal Separate Storm Sewer System. A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned and operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act (CWA) that discharges to waters of the United States.
Nonpoint source pollution:	Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related either to land or water use including failing septic tanks, improper animal-keeping practices, forestry practices, and urban and rural runoff.
NPDES:	National Pollution Discharge Elimination System. The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Section 307, 402, 318, and 405 of the Clean Water Act. Facilities subjected to NPDES permitting regulations include operations such as municipal wastewater treatment plants and industrial waste treatment facilities, as well as some MS4s.
NRCS:	Natural Resources Conservation Service (United States Department of Agriculture). Federal agency that provides technical assistance for the conservation and enhancement of natural resources.
Open feedlot:	An unroofed or partially roofed animal feeding operation (AFO) in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation.
Periphyton:	Algae that are attached to substrates (rocks, sediment, wood, and other living organisms). Are often located at the bottom of a wetland, lake, or stream.
Phytoplankton:	Collective term for all photosynthetic organisms suspended in the water column. Includes many types of algae and cyanobacteria.

Point source pollution:	Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources are generally regulated by a federal NPDES permit.
Pollutant:	As defined in Clean Water Act section 502(6), a pollutant means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.
Pollution:	The man-made or man-induced alteration of the chemical, physical, biological, and/or radiological integrity of water.
PPB:	Parts per Billion. A measure of concentration that is the same as micrograms per liter ($\mu\text{g/L}$).
PPM:	Parts per Million. A measure of concentration that is the same as milligrams per liter (mg/L).
RASCAL:	Rapid Assessment of Stream Conditions Along Length. RASCAL is a global positioning system (GPS) based assessment procedure designed to provide continuous stream and riparian condition data at a watershed scale.
Riparian:	Refers to areas near the banks of natural courses of water. Features of riparian areas include specific physical, chemical, and biological characteristics that differ from upland (dry) sites. Usually refers to the area near a bank of a stream or river.
RUSLE:	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
Scientific notation:	See explanation on page 107.
Secchi disk:	A device used to measure transparency in waterbodies. The greater the Secchi depth (typically measured in meters), the more transparent the water.
Sediment delivery ratio:	A value, expressed as a percent, which is used to describe the fraction of gross soil erosion that is delivered to the waterbody of concern.
Seston:	All particulate matter (organic and inorganic) suspended in the water column.

SHL:	State Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring, ambient monitoring, biological reference monitoring, and impaired water assessments.
Sheet & rill erosion:	Sheet and rill erosion is the detachment and removal of soil from the land surface by raindrop impact, and/or overland runoff. It occurs on slopes with overland flow and where runoff is not concentrated.
Single-Sample Maximum (SSM):	A water quality standard criterion used to quantify <i>E. coli</i> levels. The single-sample maximum is the maximum allowable concentration measured at a specific point in time in a waterbody.
SI:	Stressor Identification. A process by which the specific cause(s) of a biological impairment to a waterbody can be determined from cause-and-effect relationships.
Storm flow (or stormwater):	The discharge (flow) from surface runoff generated by a precipitation event. <i>Stormwater</i> generally refers to runoff that is routed through some artificial channel or structure, often in urban areas.
STP:	Sewage Treatment Plant. General term for a facility that treats municipal sewage prior to discharge to a waterbody according to the conditions of an NPDES permit.
SWCD:	Soil and Water Conservation District. Agency that provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.
TDS:	Total Dissolved Solids: The quantitative measure of matter (organic and inorganic material) dissolved, rather than suspended, in the water column. TDS is analyzed in a laboratory and quantifies the material passing through a filter and dried at 180 degrees Celsius.
TMDL:	Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a waterbody can tolerate while still meeting its general and designated uses. A TMDL is mathematically defined as the sum of all individual wasteload allocations (WLAs), load allocations (LAs), and a margin of safety (MOS).
Trophic state:	The level of ecosystem productivity, typically measured in terms of algal biomass.

TSI (or Carlson's TSI):	Trophic State Index. A standardized scoring system developed by Carlson (1977) that places trophic state on an exponential scale of Secchi depth, chlorophyll, and total phosphorus. TSI ranges between 0 and 100, with 10 scale units representing a doubling of algal biomass.
TSS:	Total Suspended Solids. The quantitative measure of matter (organic and inorganic material) suspended, rather than dissolved, in the water column. TSS is analyzed in a laboratory and quantifies the material retained by a filter and dried at 103 to 105 degrees Celsius.
Turbidity:	A term used to indicate water transparency (or lack thereof). Turbidity is the degree to which light is scattered or absorbed by a fluid. In practical terms, highly turbid waters have a high degree of cloudiness or murkiness caused by suspended particles.
UAA:	Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular waterbody. (See Appendix B for a description of all general and designated uses.)
USDA:	United States Department of Agriculture
USGS:	United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's waterbodies.
Watershed:	The land area that drains water (usually surface water) to a particular waterbody or outlet.
WLA:	Wasteload Allocation. The portion of a receiving waterbody's loading capacity that is allocated to one of its existing or future point sources of pollution (e.g., permitted waste treatment facilities).
WQS:	Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.
WWTF:	Wastewater Treatment Facility. General term for a facility that treats municipal, industrial, or agricultural wastewater for discharge to public waters according to the conditions of the facility's NPDES permit. Used interchangeably with wastewater treatment plant (WWTP).
Zooplankton:	Collective term for all animal plankton suspended in the water column which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Scientific Notation

Scientific notation is the way that scientists easily handle very large numbers or very small numbers. For example, instead of writing 45,000,000,000 we write 4.5E+10. So, how does this work?

We can think of 4.5E+10 as the product of two numbers: 4.5 (the digit term) and E+10 (the exponential term).

Here are some examples of scientific notation.

10,000 = 1E+4	24,327 = 2.4327E+4
1,000 = 1E+3	7,354 = 7.354E+3
100 = 1E+2	482 = 4.82E+2
1/100 = 0.01 = 1E-2	0.053 = 5.3E-2
1/1,000 = 0.001 = 1E-3	0.0078 = 7.8E-3
1/10,000 = 0.0001 = 1E-4	0.00044 = 4.4E-4

As you can see, the exponent is the number of places the decimal point must be shifted to give the number in long form. A **positive** exponent shows that the decimal point is shifted that number of places to the right. A **negative** exponent shows that the decimal point is shifted that number of places to the left.

Appendix B --- General and Designated Uses of Iowa's Waters

Introduction

Iowa's water quality standards (WQS) (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's water quality standards apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the water body.

General Use Segments

A general use segment water body is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published water quality standards.

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards.

Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B.1) which may apply, and a water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards

Table B.1. Designated use classes for Iowa water bodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
	HQ	High quality water	Waters with exceptional water quality
Other	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Appendix C --- Water Quality Data

Table C.1. Water Quality Data for Lake Pahoja from sampling 2006-2010.

Date	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	TN (mg/L)	TSI Secchi	TSI Chl-a	TSI TP
4/24/2006	0.61	90.00	120	8.1	67.1	74.7	73.2
5/23/2006	3.65	7.20	32	8.55	41.3	49.9	54.1
6/5/2006	0.64	53.00	60	8	66.4	69.5	63.2
7/17/2006	0.61	45.00	90	3.9	67.1	67.9	69.0
8/28/2006	0.55	54.00	300	2.1	68.6	69.7	86.4
10/9/2006	1.04	38.00	340	2.26	59.6	66.3	88.2
5/8/2007	3.8	4.00	100	4.1	40.8	44.2	70.6
7/24/2007	0.9	53.00	300	1.7	61.5	69.5	86.4
9/24/2007	0.7	62.00	420	1.5	65.1	71.1	91.3
5/19/2008	2.4	18.00	20	4.4	47.4	59.0	37.4
7/14/2008	0.7	11.00	120	5.2	65.1	54.1	73.2
6/2/2009	3.9	0.50	78.2	1.51	40.7	39.6	67.0
7/7/2009	0.5	80.00	115.6	2.79	70.0	73.6	72.6
8/4/2009	0.7	39.00	147.4	1.89	65.1	66.5	76.2
6/2/2010	1.3	23.00	113.2	1.54	56.2	61.5	72.3
7/20/2010	0.6	48.00	143.9	3.68	68.6	68.6	75.8
9/2/2010	0.3	109.00	530.7	3.44	77.4	76.7	94.6
5/26/2011	3.20	7.00	140	6.2	43.2	49.7	75.4
6/2/2011	1.90	16.00	127.5	5.52	50.7	57.8	74.1
6/29/2011	3.20	7.00	230	1.9	43.2	49.7	82.6
7/19/2011	0.90	66.00	109.5	4.2	61.5	71.7	71.9
7/22/2011	0.40	160.00	120	2.4	73.2	80.4	73.2
8/19/2011	0.50	65.00	160	1.6	70.0	71.6	77.3
8/30/2011	0.60	122.00	239.7	2.93	67.4	77.7	83.2
9/19/2011	1.00	75.00	50.0	3.0	60.0	73.0	60.6
5/30/2012	0.55	77.8	427.2	2.21	68.6	73.3	91.5
7/17/2012	0.38	169.1	228.9	3.65	74.0	80.9	82.5
8/28/2012	0.38	31.0	242.2	3.85	74.0	64.3	83.3
5/29/2013	0.38	57.4	838.4	3.63	74.0	70.3	100.0
7/15/2013	1.35	32.6	50.0	2.58	55.7	64.8	60.6
8/26/2013	4.75	1.0	741.1	2.2	37.5	30.6	99.4
6/2/2014	3.55	4.2	291.8	1.22	41.7	44.6	86.0
7/21/2014	0.43	112.1	520.1	4.96	72.2	76.9	94.3
9/1/2014	1.90	7.1	699.1	1.26	50.7	49.8	98.6
Average	1.42	51.41	242.25	56.3	60.2	77.8	63.8

Appendix D --- Watershed Modeling Methodology

Watershed and in-lake modeling were used in conjunction with observed water quality data to develop the Total Maximum Daily Load (TMDL) for phosphorus as the primary cause for the algae and pH impairments to Lake Pahoja in Lyon County, Iowa. The Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1, was utilized to simulate watershed hydrology and pollutant loading. In-lake water quality simulations were performed using BATHTUB 6.14, an empirical lake and reservoir eutrophication model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Lake Pahoja and its watershed. This section of the Water Quality Improvement Plan (WQIP) discusses the overall modeling approach, as well as the development of the STEPL watershed model.

D.1. STEPL Model Description

STEPL is a watershed-scale hydrology and water quality model developed for the U.S. Environmental Protection Agency (EPA) by Tetra Tech, Incorporated. STEPL is a long-term average annual model developed to assess the impacts of land use and best management practices on hydrology and pollutant loads. STEPL is capable of simulating a variety of pollutants, including sediment, nutrients (nitrogen and phosphorus), and 5-day biochemical oxygen demand (BOD5).

Required input data is minimal if county-wide soils and coarse precipitation information is acceptable to the user. If available, the user can modify soil and precipitation inputs with higher resolution and/or local soil and precipitation data. Precipitation inputs include average annual rainfall amount and rainfall correction factors that describe the intensity (i.e., runoff producing) characteristics of long-term precipitation.

Land use characteristics that affect STEPL estimates of hydrology and pollutant loading include land cover types, presence/population of agricultural animals, wildlife populations, population served by septic systems, and characteristics of urban land uses. STEPL also quantifies the impacts of manure application and best management practices (BMPs). Almost all STEPL inputs can be customized if site-specific data is available and more detail is desired.

D.2. Meteorological Input

Precipitation Data.

The STEPL model includes a pre-defined set of weather stations from which the user must choose to obtain precipitation-related model inputs. For the purpose of Lake Pahoja, data from the Rock Rapids station for the 2006-2010 sampling period was selected. The Rock Rapids weather station is 18.2 miles from Lake Pahoja. While local variation in weather patterns might make this an unreliable source for short-term simulations, it is adequate for long-term average precipitation data. Annual average rainfall is 29.85 inches, which is a key input parameter for STEPL and BATHTUB.

D.3. Watershed Characteristics

The Lake Pahoja watershed was divided into five subbasins with in the STEPL model (Figure D-1). These five subbasins also correspond to five tributaries used to develop the in lake water quality model discussed in Appendix E.

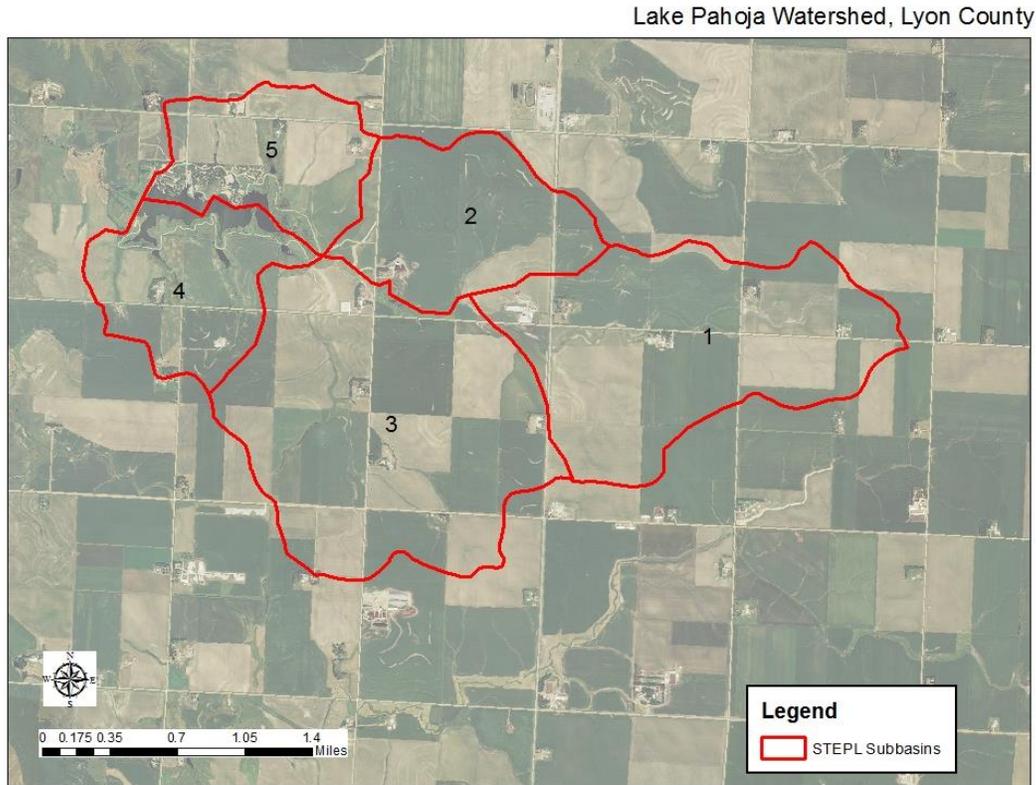


Figure D.1. Subbasins used to develop STEPL model

Soils and Slopes and Curve Numbers.

The hydrologic soil group (HSG) and the USLE K-factor are the critical soil parameters in the STEPL model. Watershed soils are predominantly HSG type B soils. USLE inputs were obtained from a previous RUSLE assessment completed for the Lake Pahoja watershed.

USLE K-factors vary spatially and by land use. K-factors for each landuse and subwatershed are entered into the “Input” worksheet in the STEPL model. USLE land slope (LS) factors were obtained from a previous RUSLE assessment, and were area-weighted by land use within each STEPL subwatershed.

The STEPL model includes default curve numbers (CN) selected automatically based on HSG and land use inputs. The STEPL default CN was left in place for other land uses.

Sediment Delivery Ratio.

The total sediment load to the lake is smaller than total sheet and rill erosion because some of the eroded material is deposited in depressions, ditches, or streams before it reaches the watershed outlet (i.e., the lake). The sediment delivery ratio (SDR) is the portion of sheet and rill erosion that is transported to the watershed outlet. By selecting to not treat all subbasins as one watershed, STEPL will calculate a SDR for each subbasin. The SDRs for Lake Pahoja ranged from 0.25-0.32.

Existing BMPs

Park management has installed small wetlands at points where tributaries empty into the lake. Because water quality within the watershed continues to show decline the assumption was made that these are currently considered to have minimal impact on water quality. In the future these structures should be inspected and or monitored for effectiveness and needed repairs made. Otherwise, there are no substantial BMPs within this watershed.

D.4. Animals

Agricultural Animals and Manure Application.

The STEPL model utilizes livestock type, livestock population data, manure production rates, and the amount of time (in months) that manure is applied to determine the nutrient runoff concentration in runoff from manure application areas. Nutrient loading from manure application is the resulting concentration multiplied by annual runoff volume.

Livestock

There are several small animal operations within the watershed: two small feedlots used for finishing beef, one larger confinement with a lagoon for manure storage, and an area for grazing, and two hog confinements. These animals were accounted for within the STEPL model, and manure from the facilities applied to adjacent fields was modeled. However, none of these facilities meet the EPA definition of a regulated CAFO, and therefore will not require a WLA. Two of the facilities were included as feedlots within the STEPL model due to proximity to the stream. However, they do not discharge into a man-made ditch, flushing system, or other similar man-made device; thus are not considered CAFOs and are therefore not assigned a wasteload allocation. The choice to model these facilities as feedlots was made to be conservative in developing the existing load. The field office was called to confirm that this facility does not meet the definition of CAFO. They reported the following: "estimate that he has less than 100 cattle total at his facility based on the ones that I could count from the road. In order for this to be considered a Medium CAFO, there would have to be a proven discharge from the facility as well as have more than 300 head of cattle on site" (Ben Shuberg, Field Office 3, personal conversation).

Table D.1. Animal Feeding Operations of the Lake Pahoja watershed

Watershed	Type	Facility ID	Animal Units
1	Confinement	311701952	108 (Swine)
1	Confinement	*310688961	900 (Beef)
2	Open	*†311705189	550 (Beef)
3	Open	†311532071	75 (Beef)
3	Confinement	311704331	115 (Swine)
5	Open	312466807	250 (Beef)
5	Confinement	*312466807	670 (Beef)

*Medium AFOs that do not have man made ditches and do not discharge directly into waters of the U.S. via any man-made conveyance or device

†Modeled as feedlot sources within the STEPL model framework

Wildlife.

STEPL assumes that wildlife add to the manure deposited on the land surface in similar fashion to livestock. If animal densities are significant, nutrient concentration in runoff is increased. For Lake Pahoja, an estimate of 5 geese and 2 deer per square mile, were used, based on conversation with Craig Van Otterloo, Lyon County Conservation Director. These are likely over estimates of wildlife populations. Even with overestimates of geese, furbearers and deer populations, wildlife contributions are relatively insignificant (in terms of nutrient loading to the lake) and do not increase STEPL nutrient runoff parameters.

Landuse

Table D.1 provides the acres of landuse per watershed used to develop the STEPL model. The outputs of the model provided both a load to enter into BATHTUB and also provided a breakdown of the TP input from land uses. This output suggests slightly more than eighty percent of the TP load comes from the row cropped regions. The row cropped lands in the HEL depicted in Section 4 should be of highest priority.

Table D.2. Subbasin landuse inputs for STEPL (acres).

Watershed	Urban	Cropland	Pastureland	Grassland	Feedlots
W1	74.33	972.19	0	30.36	0
W2	18.79	522.55	2.43	10.71	2.0
W3	73.16	1069.76	12.77	174.94	2.5
W4	16.93	218.96	116.44	76.04	0
W5	24.65	243.65	0	143.54	0
Total	209.86	3027.11	131.64	435.59	4.5

The model was developed based on the average conditions observed from 2006 to 2010. No special consideration was given to wet or dry periods since relationships between precipitation and TSI values or chlorophyll a concentrations could not be established, and because long-term average annual loading is what drives eutrophication in this system.

D.5. Other Potential Sources

Septic Systems

According to the county sanitarian there are 14 septic systems within the watershed. For the purpose of modeling it was assumed 25 percent of these are failing based on age. Because the majority of the systems are newer, this is probably an over estimate of failure rate.

Gully Erosion and Streambank Erosion

For the Pahojá Watershed stream bank length and height was estimated using LiDAR coverage and then observed via a site visit although no actual physical measurements were conducted. Based on windshield assessments, the lateral recession rates that were used represent the average of the STEPL range for each condition (i.e. slight, moderate, or severe) assigned to the length. Clay loam was used for the soil textural class based on soil survey and parent material. Gully erosion was not included in the model.

Runoff and Groundwater

STEPL default concentrations were used to calculate nutrient input from runoff and groundwater. In respect to the user-defined grasslands (prairie or ungrazed), the best estimate was provided by using nutrient concentrations calculated from forest land.

Appendix E --- In-Lake Water Quality Model

A combination of modeling software packages were used to develop the Total Maximum Daily Load (TMDL) for Lake Pahoja. Watershed hydrology and pollutant loading was simulated using the Spreadsheet Tool for Estimating Pollutant Load (STEPL), version 4.1. STEPL model development was described in detail in Appendix D of this Water Quality Improvement Plan (WQIP).

In-lake water quality simulations were performed using BATHTUB 6.14, an empirical lake and reservoir eutrophication model. This appendix of the WQIP discusses development of the BATHTUB model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Lake Pahoja and its watershed.

E.1. BATHTUB Model Description

BATHTUB is a steady-state water quality model developed by the U.S. Army Corps of Engineers that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). Eutrophication-related parameters are expressed in terms of total phosphorus (TP), total nitrogen (TN), chlorophyll a (chl-a), and transparency. The model can distinguish between organic and inorganic forms of phosphorus and nitrogen, and simulates hypolimnetic oxygen depletion rates, if applicable/desired. Water quality predictions are based on empirical models that have been calibrated and tested for lake and reservoir applications (Walker, 1985).

E.2. Model Parameterization

BATHTUB includes several data input menus/modules to describe lake characteristics, simulation equations, and external (i.e., watershed) inputs. Data menus utilized to develop the BATHTUB model for Lake Pahoja include: model selections, global variables, segment data, and tributary data. The model selections menu allows the user to specify which modeling equations (i.e., empirical relationships) are to be used in the simulation of in-lake nitrogen, phosphorus, chlorophyll a, transparency, and other parameters. The global variables menu describes parameters consistent throughout the lake such as precipitation, evaporation, and atmospheric deposition. The segment data menu is used to describe lake morphometry, observed water quality, calibration factors, and internal loads in each segment of the lake/reservoir. The tributary data menu specifies nutrient loads to each segment using mean flow and concentration in the averaging period. The following sub-sections describe the development of the Lake Pahoja BATHTUB model and report input parameters for each menu.

Model Selections.

BATHTUB includes several models for simulating in-lake nutrients and eutrophication response. For TP, TN, chlorophyll a, and transparency, Models 1 and 2 are the most general formulations, based upon model testing results.

Table E.1 reports the models selected for each parameter used to simulate eutrophication response in Lake Pahoja. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Lake Pahoja model. Final selection of model type was based on applicability to lake characteristics, availability of data, and agreement between predicted and observed data. For Lake Pahoja, models 1 and 2 produced the best calibrations based on data provided via in-lake sampling.

Table E.1. Model selections for Lake Pahoja.

Parameter	Model No.	Model Description
Total Phosphorus	01	2ND Order Avail P*
Total Nitrogen	00	Not computed
Chlorophyll a	02	P, Light, T*
Transparency	01	vs. Chl-a & Turbidity *
Longitudinal Dispersion	01	Fischer-Numeric *
Phosphorus Calibration	01	Decay rates *
Nitrogen Calibration	01	Decay rates *
Availability Factors	00	Ignore *

* Asterisks indicate BATHTUB defaults

Global Variables.

Global input data for Lake Pahoja are reported in Table E.2. Global variables are independent of watershed hydrology or lake morphometry, but affect the water balance and nutrient cycling of the lake. The first global input is the averaging period. Both seasonal and annual averaging periods are appropriate, depending on site-specific conditions. An annual averaging period was utilized to quantify existing loads and in-lake water quality, and to develop TMDL targets for Lake Pahoja.

Table E.2. Global variables data for 2006-2010 simulation period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 year
Precipitation	29.85 in	0.758m
Evaporation	23.88 in	0.607 m
¹ Increase in Storage	0	0
² Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m ² -yr
TN	7.7 kg/ha-yr	770.3 mg/m ² -yr

¹Change in lake volume from beginning to end of simulation period.

²From Anderson and Downing, 2006.

Segment Data.

Lake morphometry, observed water quality, calibration factors, and internal loads are all included in the segment data menu of the BATHTUB model. Separate inputs can be made for each segment of the lake or reservoir system that the user wishes to simulate. These segments are shown in Figure E.1. Due to the large watershed surrounding Lake Pahoja, five tributaries were used to provide better detail. Each tributary corresponds with a STEPL subbasin (see figure D.1)

The BATHTUB model developed for Lake Pahoja does not simulate dynamic conditions associated with storm events or even between individual growing seasons. Rather, the model predicts the water quality period of 2006-2010. Observed water quality data for the lake is included in Appendix C – Water Quality Data. Table E.3 lists BATHTUB segment inputs for Segment 1 and 2 and Table E.4 lists tributary inputs.

Tributary Data.

The empirical eutrophication relationships in the BATHTUB model are influenced by the global and segment parameters previously described, but are heavily driven by flow and nutrient loads from the contributing drainage area (watershed). Flow and nutrient loads can be input to the BATHTUB model in a number of ways. Flow and nutrient loads used in the development of the Lake Pahoja BATHTUB models utilize watershed hydrology and nutrient loads predicted using the STEPL model described in Appendix D. Output from STEPL includes annual average flow and nutrient loads. STEPL output requires conversion into forms compatible with BATHTUB. This includes unit conversion and converting STEPL nutrient loads and flows.

Table E.3. Segment 1 and 2 inputs.

Parameter	Segment 1	Segment 2
Surface Area (km ²)	0.12	0.14
Mean Depth (m)	1.99	4.47
Length (km)	0.727	0.567
Mixed layer Depth (m)	1.5	4.2
Non-Algal Turbidity (1/m)	0.08	0.08
Total Phosphorus (ug/l)	NA	178.3
Chlorophyll a (ug/l)	NA	43.2
Non-Algal Turbidity (1/m)	NA	1.3
Internal Load P (mg/mg ² -day)	0	0

Table E.4. Tributary inputs for BATHTUB

Tributary	Area (km ²)	Flow (hm ³ /yr)	TP (ug/l)
Trib 1	4.3	1.61	949.72
Trib 2	2.2	0.83	1045.22
Trib 3	5.3	1.96	967.7
Trib 4	1.7	0.60	721.70
Trib 5	1.6	0.59	821.92

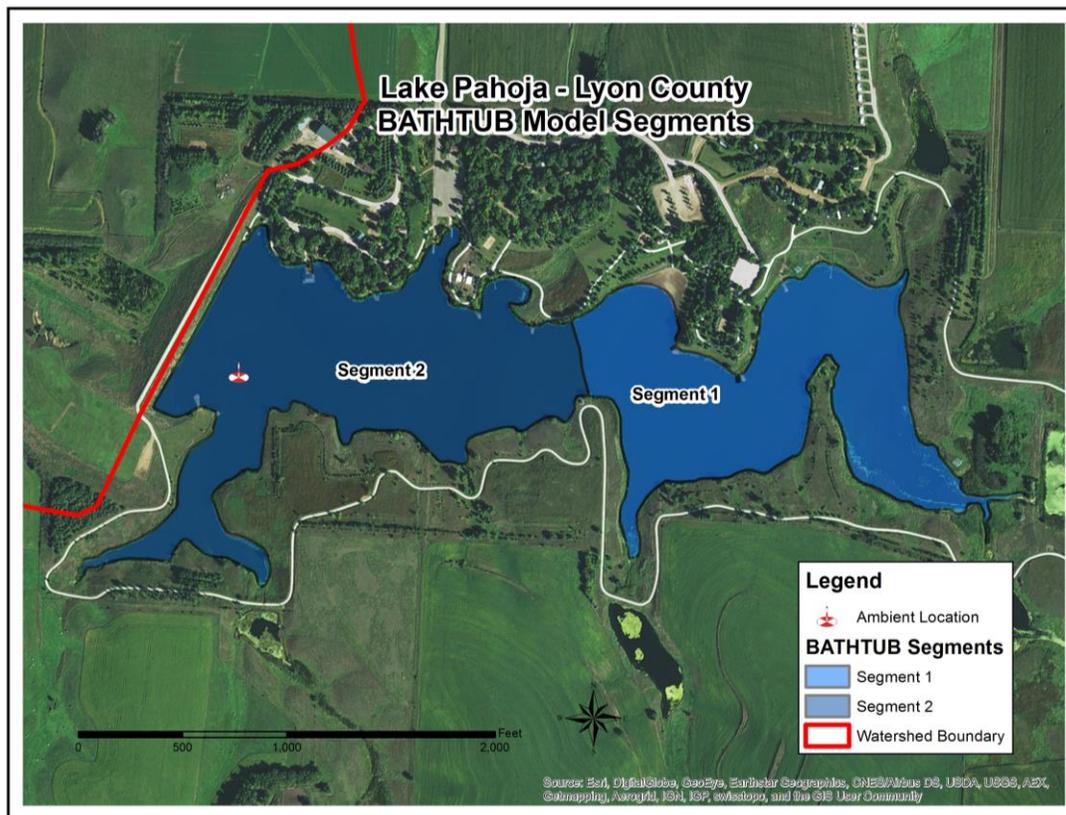


Figure E.1. Segments used to develop BATHTUB model

E.3. Model Performance and Calibration

The Lake Pahoja water quality model was calibrated by comparing simulated and observed local and regional data. The primary source of calibration data is the ambient lake monitoring data collected by Iowa State University (ISU) and the University of Iowa State Hygienic Laboratory (SHL) between 2006 and 2010. Calibration was an iterative process that involved running both the watershed model (STEPL) and in-lake model (BATHTUB), and refining model parameters to (1) produce simulated values that were within reasonable ranges, and (2) provide good agreement with observed water quality in Lake Pahoja. Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Lake Pahoja from 2006 to 2010 in segment 2 of the BATHTUB model. Simulation of TP concentration was critical for TMDL development, as were chlorophyll a and transparency predictions. The observed data is reported in Appendix C. Table E.5 reports model coefficients used in calibration.

Table E.5. Model Calibration Coefficients

Model Coefficients	Mean	CV
Dispersion Rate	1.00	0.70
Total Phosphorus	0.98	0.45
Chl-a Model	1.24	0.26
Secchi Model	1.50	0.10

E.4. BATHTUB Target Assessment.

After calibration the BATHTUB model was used to determine the water quality target. This was done by incrementally reducing loads of TP in all tributaries until the desired Chl-a TSI of 63 was achieved. This is expressed as an annual load and a daily maximum via a statistical approach described in Appendix F.

Because the ambient monitoring location is used for listing and delisting purposes, the TMDL target applies only to this segment of Lake Pahojá. Data for model calibration was available only in Segment 2. The TMDL and future water quality assessment and listing will be based solely on data from Segment 2.

The model assumes a uniform reduction in loads of all sources. In reality there would be many combinations of practices and pathways to achieve this goal and would most likely not be accomplished by trying to cut 87 percent of the load across all sources equally. In fact, that is most likely not possible. The best approach would be to target the highest contributing sources as discussed in Section 3 of this report and systematically treat watershed based sources. Figure E.2 below provides the load response curve for TSI Chl-a with total Phosphorus loads. This curve predicts reductions in TP will lead to a reduction in Chlorophyll a leading to an overall better water clarity for Lake Pahojá.

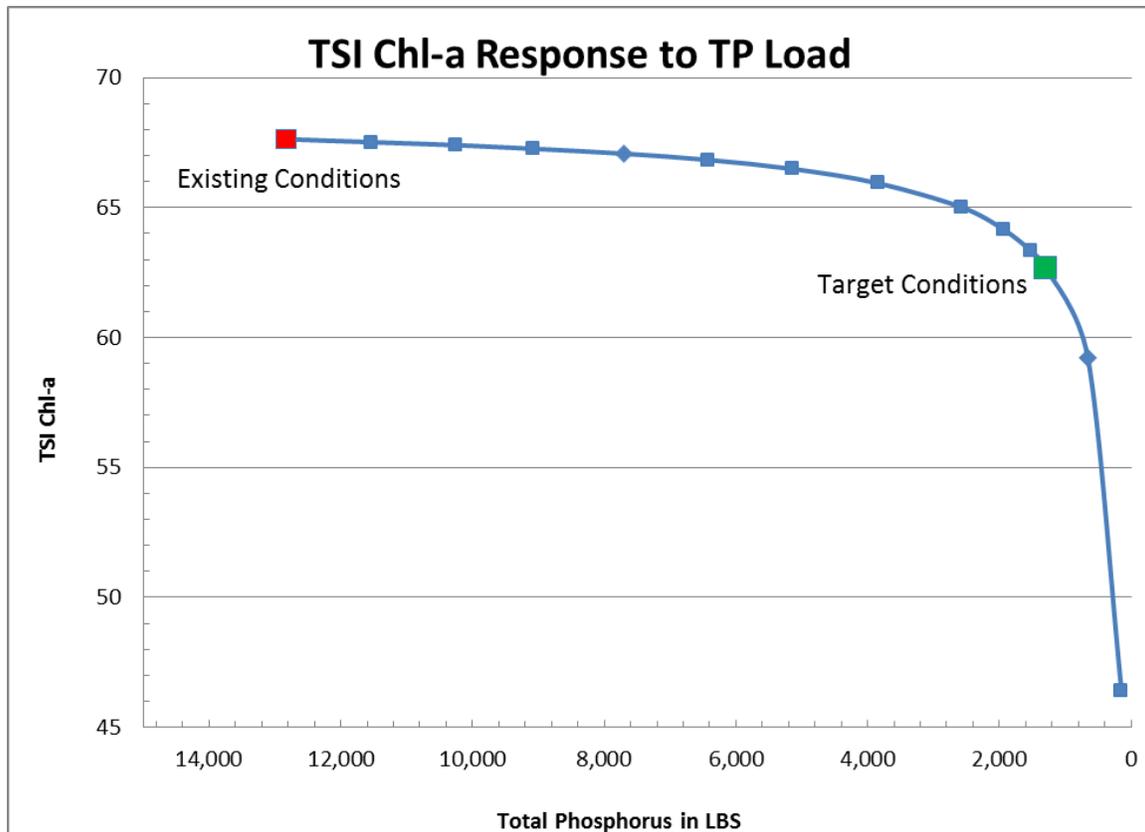


Figure E.2. The load response relationship between TSI chlorophyll a and total P as predicted by BATHTUB

Appendix F --- Establishing Daily Maximums

In November of 2006, The U.S. Environmental Protection Agency (EPA) issued a memorandum entitled *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006) and Implications for NPDES Permits*. In the context of the memorandum, EPA

"...recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increments. In addition, TMDL submissions may include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards..."

Per the EPA recommendations, the loading capacity of Lake Pahojä for TP is expressed as both a maximum annual average and a daily maximum load. The annual average load is more applicable to the assessment of in-lake water quality and water quality improvement actions, whereas the daily maximum load expression satisfies the legal uncertainty addressed in the EPA memorandum. The allowable annual average was derived using the BATHTUB model described in Appendix E, and is 1,533 lbs. per year.

The maximum daily load was estimated from the allowable annual average using a statistical approach. The methodology for this approach is taken directly from the follow-up guidance document titled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), which was issued shortly after the November 2006 memorandum cited previously. This methodology can also be found in EPA's 1991 *Technical Support Document for Water Quality Based Toxics Control*.

The *Options for Expressing Daily Loads in TMDLs* document presents a similar case study in which a statistical approach is considered an option for identifying a maximum daily load (MDL) that corresponds to the allowable annual average load. The method calculates the daily maximum based on a long-term average and considers variation. This method is represented by the equation:

$$MDL = LTA \times e^{[z\sigma - 0.5\sigma^2]}$$

Where: MDL = maximum daily limit
LTA = long term average
z = z statistic of the probability of occurrence
 $\sigma^2 = \ln(CV^2 + 1)$
CV = coefficient of variation

The allowable annual average of 1,533 lbs. /year is equivalent to a long-term average (LTA) daily of 4.2 lbs./day. The LTA is the allowable annual load divided by the 365-day averaging period. The average annual allowable load must be converted to a MDL. The 365-day averaging period equates to a recurrence interval of 99.7 percent and corresponding z statistic of 2.778, as reported in Table F.1. The coefficient of variation (CV) is the ratio of the standard deviation to the mean. However, there is insufficient data to calculate a CV as it relates to TP loads to the lake, because the models are based on annual averages over several years. In cases where data necessary for calculating a CV is lacking, EPA recommends using a CV of 0.6 (EPA, 1991). The

resulting σ^2 value is 0.31. This yields a TMDL of 16.8 lbs./day. This is without the applied MOS of 10 percent. The TMDL calculation is summarized in Table F.2.

Because there are no permitted/regulated point source discharges in the watershed, the WLA is zero. An explicit MOS of 10 percent is applied. The resulting TMDL, expressed as a daily maximum, is:

$$\text{TMDL} = \text{LC} = \sum \text{WLA (0 lbs.-TP/day)} + \sum \text{LA (15.1 lbs.-TP/day)} \\ + \text{MOS (1.7, explicit 10 percent)} = \mathbf{16.8 \text{ lbs.-TP/day}}$$

Table F.1. Multipliers used to convert a LTA to an MDL.

Averaging Period (days)	Recurrence Interval	Z-score	Coefficient of Variation								
			0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
30	96.8%	1.849	1.41	1.89	2.39	2.87	3.30	3.67	3.99	4.26	4.48
60	98.4%	2.135	1.50	2.11	2.80	3.50	4.18	4.81	5.37	5.87	6.32
90	98.9%	2.291	1.54	2.24	3.05	3.91	4.76	5.57	6.32	7.00	7.62
120	99.2%	2.397	1.58	2.34	3.24	4.21	5.20	6.16	7.05	7.89	8.66
180	99.4%	2.541	1.62	2.47	3.51	4.66	5.87	7.06	8.20	9.29	10.3
210	99.5%	2.594	1.64	2.52	3.61	4.84	6.13	7.42	8.67	9.86	11.0
365	99.7%	2.778	1.70	2.71	4.00	5.51	7.15	8.83	10.5	12.1	13.7

Table F.2. Summary of LTA to MDL calculation for the TMDL.

Parameter	Value	Description
LTA	4.2	Annual Average
Z Statistic	2.778	Based on 365-day averaging period
CV	0.6	Used CV from annual TP loads
σ^2	0.31	$\ln(\text{CV}^2 + 1)$
MDL	16.8 lbs./day	TMDL expressed as daily load

Appendix G --- Public Comments

No public comments were received during the public comment period.