Water Quality Improvement Plan for

Casey Lake

Tama County, Iowa

Total Maximum Daily Load
for Algae and pH

clean water
starts with you.
IOWA DNR WATERSHED IMPROVEMENT

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Watershed Improvement Section
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General Report Summary

What is the purpose of this report?

This report serves two major purposes. First, this report satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for all impaired 303(d) waterbodies. Second, this report should serve as a resource for locally-driven water quality improvements to Casey Lake in an effort to improve the water quality and successfully restore the lake.

What's wrong with Casey Lake?

For the 2010 reporting cycle, the Class A1 (primary contact recreation) uses for Casey Lake are assessed as "not supported" based on results from the ISU statewide survey of lakes and the SHL ambient lake monitoring program. Using the median values from these surveys from 2004 through 2008 (21 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 67, 74, and 73 respectively for Casey Lake. The Secchi depth value places Casey Lake between the eutrophic and hypereutrophic categories, while the chlorophyll a and total phosphorus index values place Casey Lake in the hypereutrophic category. Additionally, the data for pH reveal 7 violations of the maximum criterion in 21 samples (33%). Based on IDNR's assessment methodology, these violations are significantly greater than 10 percent of the samples and therefore constitute an impairment (partial support/monitored).

What is causing the problem?

Casey Lake is subject to aesthetically objectionable conditions caused by poor water transparency caused by algae blooms. Violations of the criteria for pH also cause impairment at this lake. As previously noted, the Secchi depth value places Casey Lake in between the eutrophic and hypereutrophic categories, while the chlorophyll a and total phosphorus index values place Casey Lake in the hypereutrophic category. These values suggest very 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 levels of inorganic suspended solids at this lake were relatively low and do not suggest water quality problems are due to non-algal turbidity.

Data from the 2004-2008 ISU and SHL surveys suggest that a moderately large population of cyanobacteria exists at Casey Lake that contributes to aesthetically objectionable conditions. These data show that cyanobacteria comprised 78 percent of the phytoplankton wet mass at this lake.

What can be done to improve Casey Lake?

Although reducing phosphorus loads entering the lake is a step in the right direction, it does not directly address phosphorus previously accumulated within the lake, which can lead to algal blooms. To improve Casey Lake water quality, a physical mechanism (such as dredging) that removes phosphorus from the lake must be considered in addition to reductions from watershed sources.

Who is responsible for a cleaner Casey Lake?

Everyone who lives and works nearby, or wishes to utilize a healthy Casey Lake, has an important role to play in improving and maintaining the lake. The future of Casey Lake depends on citizens and landowners adopting land use changes on a voluntary basis. The best chance for success in improving Casey Lake lies with private citizens working with government agencies that can provide technical, and in some cases, financial support of efforts. Citizens interested in making a difference in Casey Lake should contact their local soil and water conservation district or the Iowa DNR Watershed Improvement Section for information on how to get involved.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Casey Lake Tama County, S13, T86N, R13W, 6 mi N of Dysart.
Surface water classification and designated uses:	Class A1 Class B(LW) Class HH
Impaired beneficial uses:	Class A1 Class B(LW)
TMDL priority level:	High
Identification of the pollutant and applicable water quality standards:	The Class A1 (primary contact recreation) uses are assessed (monitored) as "not supported" due to aesthetically objectionable conditions caused by poor water transparency caused by algae blooms. Violations of the Class A1 criteria for pH. The Class B(LW) (aquatic life) uses are assessed (monitored) as "partially supported" due to violations of the Class B(LW) criterion for 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 pH levels are attributed to total phosphorus (TP). The allowable average annual TP load = 156.8 lbs/year; the maximum daily TP load = 1.72 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 1517.6 lbs/year must be reduced by 1359.3 lbs/year to meet the allowable TP load. This is a reduction of 89.5 percent.

Identification of pollution source categories:	There are no permitted or regulated point source discharges of phosphorus in the watershed. Nonpoint sources of phosphorus include fertilizer and manure from row crops, sheet and rill erosion, waterfowl, other wildlife 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 141.1 lbs/year, and the allowable maximum daily LA is 1.45 lbs/day.
A margin of safety:	An explicit MOS of 10 percent is incorporated into this TMDL.
Consideration of seasonal variation:	The TMDL is based on annual TP loading. Although daily maximum loads are provided to address legal uncertainties, the average annual loads are critical to in-lake water quality and lake/watershed management decisions.
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 is no allowance 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 lists 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. In addition to developing the 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:

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

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

One purpose of this Water Quality Improvement Plan (WQIP) for Casey Lake, located in Tama County in central Iowa, is to provide a TMDL for algae and pH, which reduced lake water quality. 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. Algae, which impairs primary contact recreation, and pH, which impairs both primary contact recreation and aquatic life support, are addressed by development of a TMDL that limits total phosphorus (TP) loads to the lake.

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 algae and pH impairments. The solutions are a system of best management practices (BMPs) that will improve water quality in Casey Lake, with the 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 (IDNR) 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 IDNR has designed this plan for stakeholder use and is committed to providing ongoing technical support for the improvement of water quality in Casey Lake.

2. Description and History of Casey Lake

Casey Lake is a 41-acre lake in a 748-acre watershed, the majority of which is located in the 723-acre Hickory Hills Recreational Area (Figure 2.1). The lake was constructed in 1970 to provide a recreational park for the public with hunting, fishing, and scenic trails. Although the park is located in Tama County, it is owned and maintained by the Black Hawk County Conservation Board.

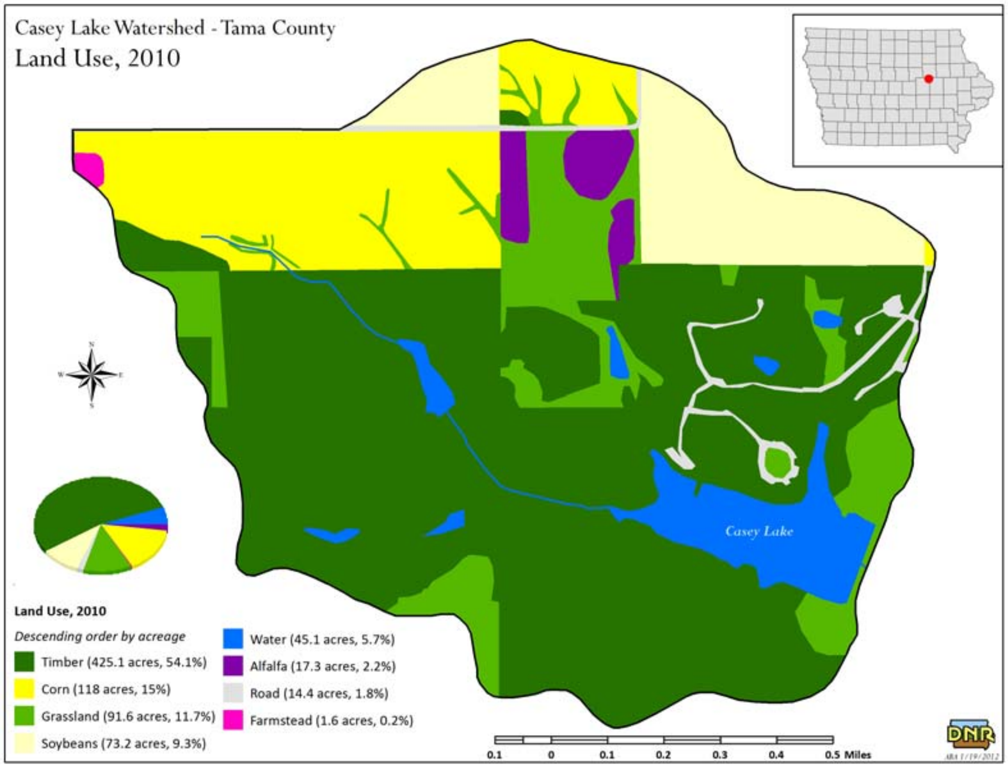

Figure 2.1. Casey Lake watershed and landuse.

2.1. Casey Lake

Weather Stations. There are 3 National Weather Service (NWS) stations within 25 miles of the Casey Lake watershed with daily precipitation data available through the Iowa Environmental Mesonet (IEM). The nearest station is located at Traer and is 14.75 miles west of the watershed boundary. The Thiessen polygon method was employed to develop an area-weighted precipitation data set for the watershed using the closest weather stations. However, application of the Thiessen polygon method resulted in a polygon that included only the Clutier station (Table 2.1). However, daily data is not available for this site. Therefore, rainfall data from the NCDC and NWS COOP station at Vinton was used for modeling purposes.

Table 2.1. Weather station information for Vinton, Iowa.

Station Identifier:	VINI4
Station Name:	VINTON
Network:	IA_COOP
County:	Benton
State:	IA
Latitude:	42.1706
Longitude:	-92.0233
Elevation [m]:	242
Time Zone:	America/Chicago

Morphometry & Substrate. Near Dysart, Iowa, the Hickory Hills Recreational Area is located in the Cedar River watershed on the Iowan Landform Region. The region was last covered by glaciers from 2.2 million to 500,000 years ago, and then heavily eroded during the last glacial period from 21,000-16,500 years ago. The Iowan Landform Region today is characterized by gently rolling topography and low relief land. Casey Lake is situated near a geological feature known as a Paha Ridge - a loess-capped glacial remnant. The Paha Ridge is located directly south of the lake within the Hickory Hills Recreational Area.

Paha Ridges tend to be in the southern part of the Iowan Surface and can be identified as prominent hills oriented from northwest to southeast, typically with large deposits of loess. They were developed during the period of erosion that developed on the Iowan surface, and are considered erosional remnants often at interstream divides. Paha Ridges generally rise above the surrounding landscape more than 20 feet (Figure 2.2). The ridges of these Paha are often wooded with mixed oak components, and soils often indicate development under forest or transitional cover type.

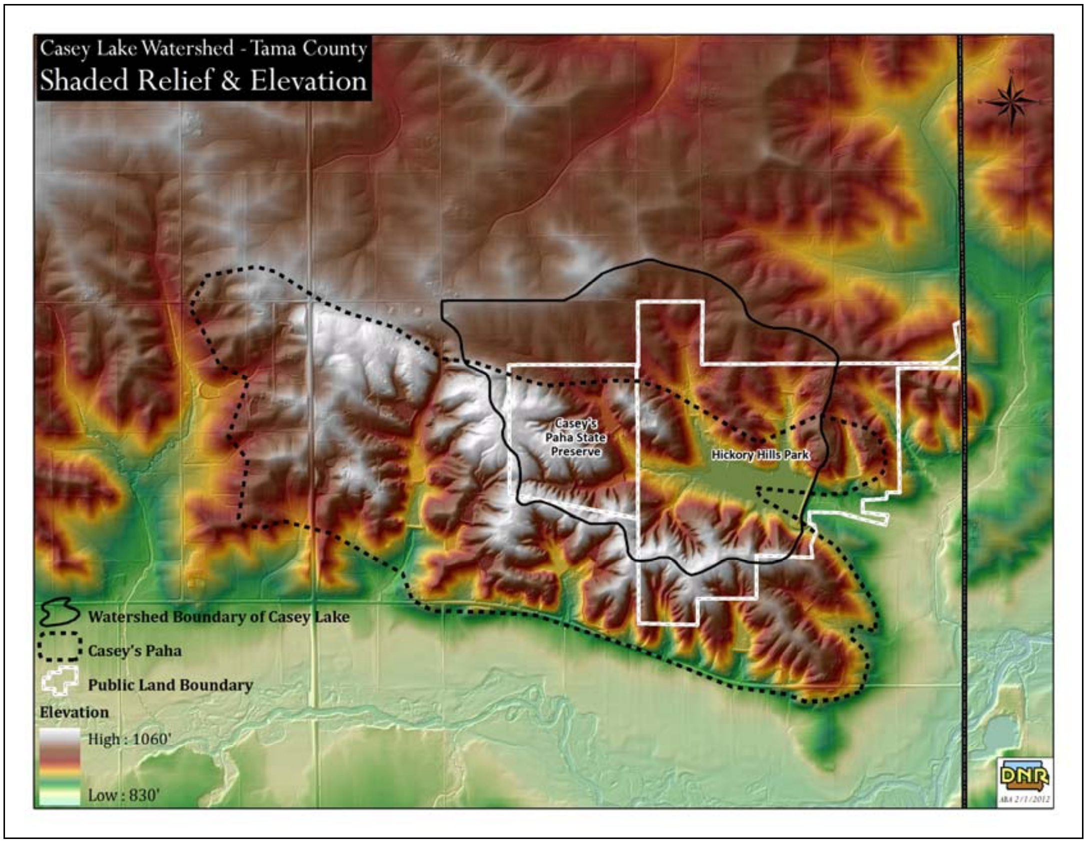

Figure 2.2. Shaded relief map of Casey Lake highlighting Pahas.

2.2. The Casey Lake Watershed

Land Use. Casey Lake is unique for an Iowa lake in that public land constitutes almost 75 percent of the watershed. Hickory Hills Park, located in Tama County, is managed by the Black Hawk County Conservation Board. The remaining land in the watershed is farmland used for corn and soybean production. All land surrounding the lake is parkland. Woodlands constitute over fifty percent of the watershed, making forestry management a necessary component of any watershed management plan (Table 2.2).

Table 2.2. Landuse by acres and percentages.

Landuse	Acres	Percent of Watershed
Timber	425.1	54.1
Corn	118	15
Grassland	91.6	11.7
Soybeans	73.2	9.3
Water	45.1	5.7
Alfalfa	17.3	2.2
Urban*	16	2

*In STEPL urban consists of farmstead and roads.

Climate. The mean annual precipitation for the watershed is 35.3 inches per year. The driest month is January with an average of 1.0 inches and the wettest month is June with an average of 4.4 inches. The lowest mean temperature occurs in January at 19 degrees Fahrenheit and the highest mean is in July with a mean of 74 degrees Fahrenheit.

2.3 Watershed Improvements and Projects

In 2005, the Tama County Soil and Water Conservation District (SWCD) submitted a Section 319 project proposal to decrease sediment and nutrient loading to Casey Lake. The Hickory Hills Lake Watershed Project was a four-year (2005-2008) project that coupled implementation of three best management practices (BMPs) with water-quality monitoring (Figure 2.3).

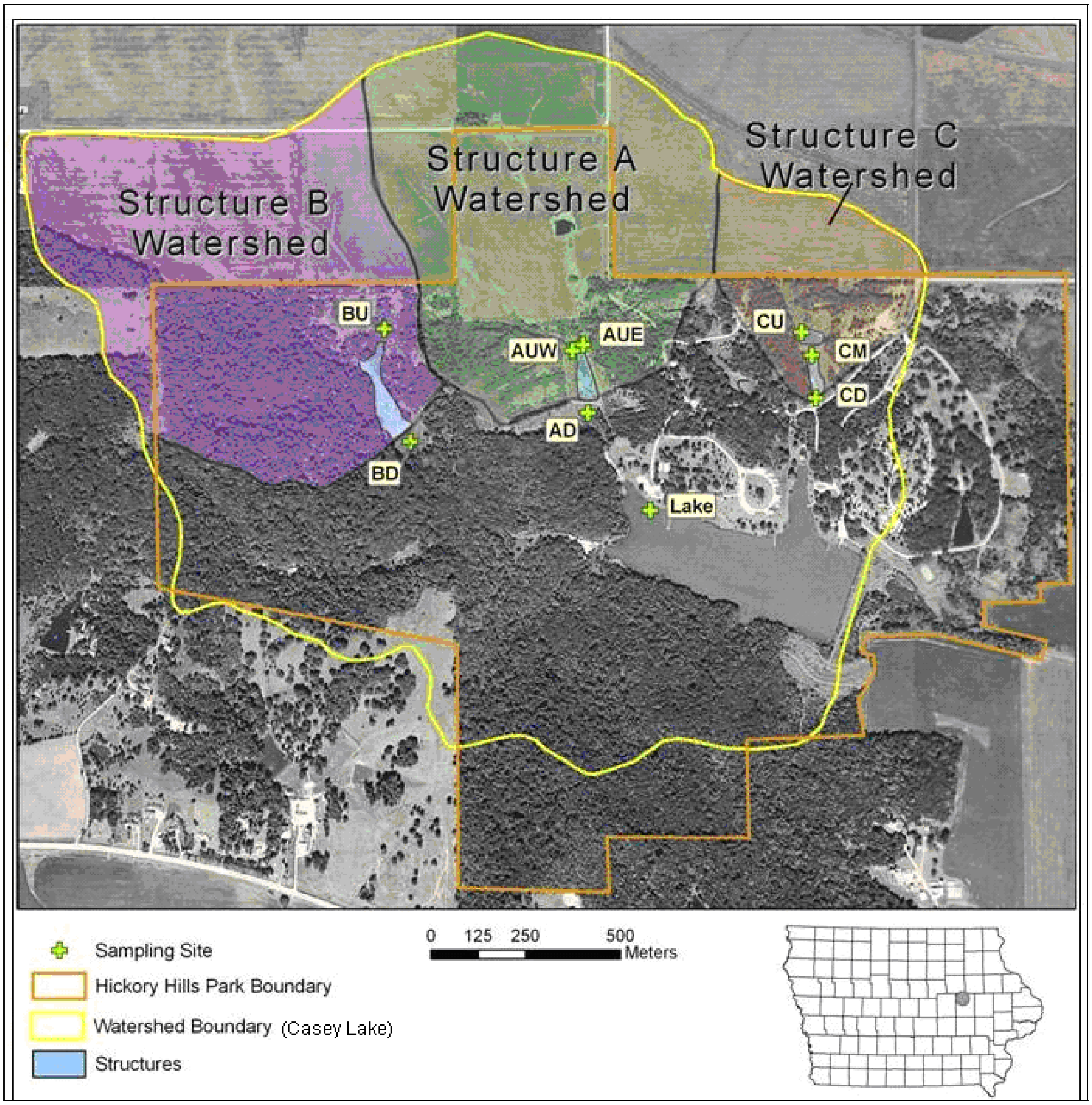

Figure 2.3. Sediment basin structures in Casey Lake watershed. Site labels indicate sampling locations.

The project was designed to observe and compare the influence of BMPs on pollutants from three major tributary watersheds of Casey Lake. These major tributaries drain the northern part of the Casey Lake watershed and are under the direct influence of row crop agriculture. Although much of Casey Lake watershed is owned by the park, the northern quarter of the watershed drains row cropped agricultural land. The Casey Lake Project had three goals and objectives:

1) Reduce the sediment and phosphorus loading to the lake by 60 percent.
2) Evaluate the effectiveness of structures at phosphorus removal.
3) Develop a watershed management team.

The first two goals of the project were based on the implementation of three BMPs in the northern, agriculturally influenced section of Casey Lake watershed. Each of these BMPs underwent water quality monitoring for comparison of changes in nutrients, sediment, and pathogens caused by the BMPs. Two structures (B & C) have a year (2005) of pre-BMP monitoring data to compare with post construction (2006-08). All structures had upstream/downstream sampling stations. These sampling stations were meant to both quantify the reductions of pollutants to Casey Lake and to compare the effectiveness of the different structures in reducing pollutants. Sampling took place at these stations on an event driven (i.e. rainfall) basis throughout the months of May-November during the 4-year study period.

After installation, water quality monitoring was conducted near the structures. The three structures were well suited for monitoring as they are all relatively small, have definitive upstream and downstream monitoring stations (typically a culvert), and have similar watershed shapes, sizes and land use patterns.

Nine sampling stations were chosen for the monitoring effort - eight stations to monitor upstream/downstream of the three structures and one station to monitor the water quality of the lake itself (Figure 2.3). The sites were chosen to measure the effects each of these BMPs would have on water quality. Six water quality parameters were measured at each site: Total Suspended Solids (Sediment), Total Phosphorus (TP), Nitrate + Nitrite (NO_x), Total Kjeldahl Nitrogen (TKN), ammonia nitrogen, and *Escherichia coli (E. coli)*.

Sampling was completed during the spring/summer/fall months from 2005-2008 following the same procedures and protocols used by the State Hygienic Laboratory (SHL) and DNR Water Monitoring personnel. The samples were collected on a monthly and event-driven basis after significant precipitation and runoff events. Monitoring was conducted by Hawkeye Community College students who were trained and coordinated by Iowa DNR staff.

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

A Total Maximum Daily Load (TMDL) is required for Casey Lake by the Federal Clean Water Act. This section of the Water Quality Improvement Plan (WQIP) quantifies the maximum amount of total phosphorus (TP) the lake can assimilate and still support primary contact recreation and aquatic life in Casey Lake. It is assumed that the TMDL for algae also addresses the pH impairment, which are both attributed to excess nutrients, particularly phosphorus.

3.1. Problem Identification

Applicable water quality standards. Casey Lake is a Significant Publicly Owned Lake, and is protected for the following designated uses:

- Primary contact recreation – Class A1
- Aquatic life – Class B(LW)
- Fish consumption – Class HH

The 2010 Section 305(b) Water Quality Assessment Report states the Class A1 (primary contact recreation) uses are assessed (monitored) as “not supported” due to aesthetically objectionable conditions caused by poor water transparency caused by algae blooms. Violations of the Class A1 criteria for pH also cause impairment at this lake. The Class B(LW) (aquatic life) uses are assessed (monitored) as “partially supported” due to violations of the Class B(LW) criterion for pH. See Appendix B of this document for further explanation.

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 (IDNR, 2008). In order to de-list a lake impaired by algae from the 303(d) list, the median growing season chlorophyll-a TSI must not exceed 63 in two consecutive listing cycles, per IDNR de-listing methodology. To avoid exceeding a TSI value of 63, the median summer chlorophyll-a concentration must not exceed 27 micrograms per liter (ug/L). 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.”

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.”*
c. Such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions.

The WQS can be accessed on the web at
http://www.legis.iowa.gov/DOCS/ACO/IAC/LINC/Chapter.567.61.pdf

With respect to pH, the same numeric criteria apply to primary contact recreation (Class A1) and aquatic life (Class B(LW)). Per Section 61.3(3) of the Water Quality Standards, pH shall not be less than 6.5 nor greater than 9.0 for full support of either designated use. Water quality data and subsequent analysis suggest that addressing the eutrophication in Casey Lake causing the algae impairment will also address the pH impairment. It is excess nutrients, particularly phosphorus, that leads to eutrophic conditions associated with both impairments.

Sediment attached phosphorus that enters the lake and becomes available for uptake allows for the establishment of algal blooms. Through photosynthesis the blooms remove CO2 from the water inhibiting the natural carbon cycle to produce carbonic acid. This results in a more alkaline system with a higher pH.
Data sources. Sources of data used in the development of this TMDL include those used in the 2010 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development. These sources are summarized in the following list.

- Results of the statewide survey of Iowa lakes sponsored by IDNR and conducted by Iowa State University (ISU) from 2001-2006
- Water quality data collected by the State Hygienic Laboratory (SHL) at the University of Iowa from 2005-2009 as part of the Ambient Lake Monitoring Program and/or TMDL monitoring
- Precipitation data from the National Climatic Data Center (NCDC)
- National Weather Service (NWS) precipitation data (IEM, 2011a) and evaporation data (IEM, 2011b) accessed through the Iowa Environmental Mesonet
- 3-m LiDAR elevation data maintained by IDNR
- SSURGO soils data maintained by United States Department of Agriculture – Natural Resource Conservation Service (USDA-NRCS)
- Statewide 2002 land cover data

Interpreting Casey Lake data. The 2010 305(b) assessment was based on both ISU and SHL ambient monitoring data from 2004-2008. For modeling purposes, assessment of in-lake water quality in this TMDL utilized SHL and ISU data from 2001-2006. In-lake water quality data is reported in Appendix C.

The time period of 2001-2006 was chosen for two reasons. First this was a dry time and reflective of worst case scenario conditions. Second, a BMP project began in 2005 (installation began in 2006) so the TMDL is calculated to conditions prior to BMPs being constructed. Additional models reflecting possible effects of the BMP installation can be found in Section 4 of this document.

Carlson’s Trophic State Index (TSI) was used to evaluate the relationships between TP, algae (chlorophyll-a), and transparency (Secchi depth) in Casey Lake. If the TSI values for the three parameters are the same, the relationships between the three are strong. If the TP TSI values are higher than chlorophyll TSI, it suggests there are limitations to algal growth besides phosphorus or that much of the TP is not biologically available. Figure 3.1 illustrates each of the individual TSI values throughout the analysis period. Table 3.1 describes the implications of TSI values on attributes of lakes.

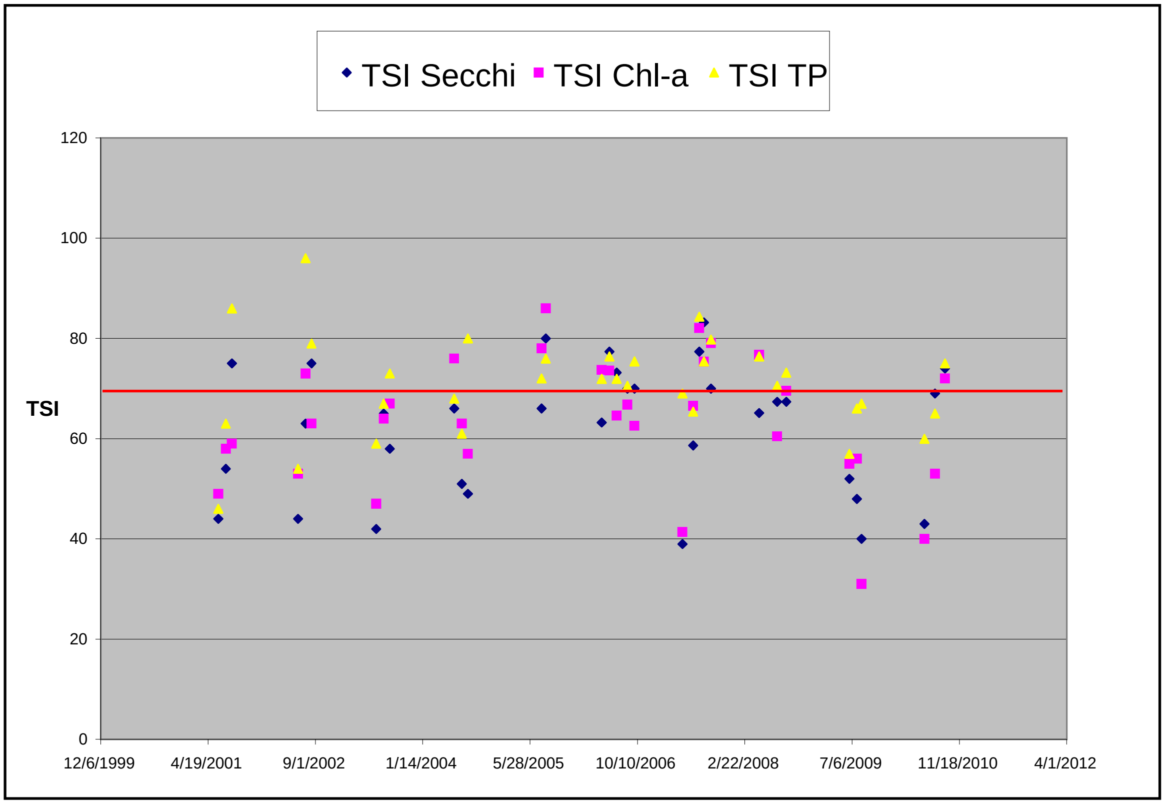

Figure 3.1. Casey LakeTSI values (2001-2010) Red line indicates the TSI of 70.

Table 3.1. Implications of TSI Values on lake attributes.

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	Warm water fisheries only; [1]percid fishery; 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	[2]Centrarcid fishery
70-80	hyper-eutrophy (light limited). Dense algae and macrophytes	weeds, algal scums, and low transparency discourage swimming and boating	Cyprinid fishery (e.g., common carp and other rough fish)
>80	algal scums; few	algal scums, and low	rough fish dominate;

	macrophytes	transparency discourage swimming and boating	summer fish kills possible

[1] Fish commonly found in percid fisheries include walleye and some species of perch
[2] Fish commonly found in centrarcid fisheries include crappie, bluegill, and bass
Note: Modified from Carlson and Simpson (1996).

There are many occurrences of chlorophyll-a TSI values above 70, and several instances in which the TSI is higher for chlorophyll-a than TP. This indicates that severe algal blooms do occur and suggests that TP is often the limiting factor. TSI scores for both TP and chlorophyll-a are significantly higher than for Secchi depth, indicating that non-algal turbidity is not a concern and that light is seldom limiting.

The trend is that chlorophyll-a TSI values are higher than those for Secchi depth, and TSI values for TP are higher than those for chlorophyll-a. Additionally, TSIs were low in 2009-2010, compared to previous years.

Figure 3.2 shows the results if the data means with Secchi depths greater than 3m are not included. A strong argument can be made for this being the most “representative” of the algal condition during the bloom months.

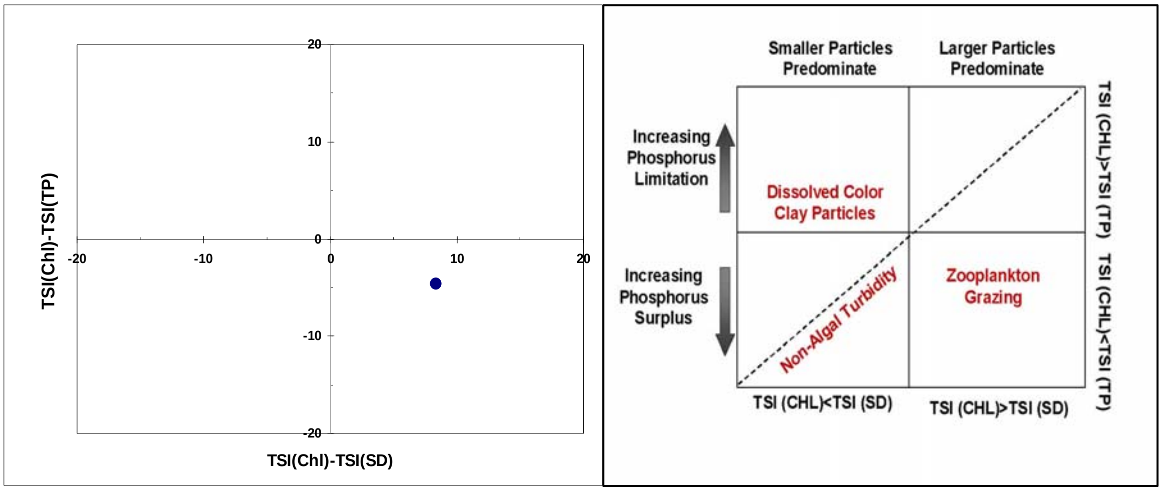

Figure 3.2. Results if the data means with Secchi depths greater than 3m are not included.

High pH levels also impair primary contact recreation in Casey Lake, as well as aquatic life. Figure 3-3 shows that pH exceeded the maximum criterion of 9.0 regularly between 2001 and 2010. Elevated pH is often related to and a direct result of algal blooms, which affect the lake’s carbonate chemistry and hence, pH. The algae remove CO_2 from the water for photosynthesis which buffers the water and raises the pH. This is further evidenced by the correlation between pH and dissolved oxygen (DO) within the lake. As respiration with algal blooms occur pH also increases (figure 3.4). Phosphorus reduction measures that prevent algal blooms would therefore also aid in lowering pH values.

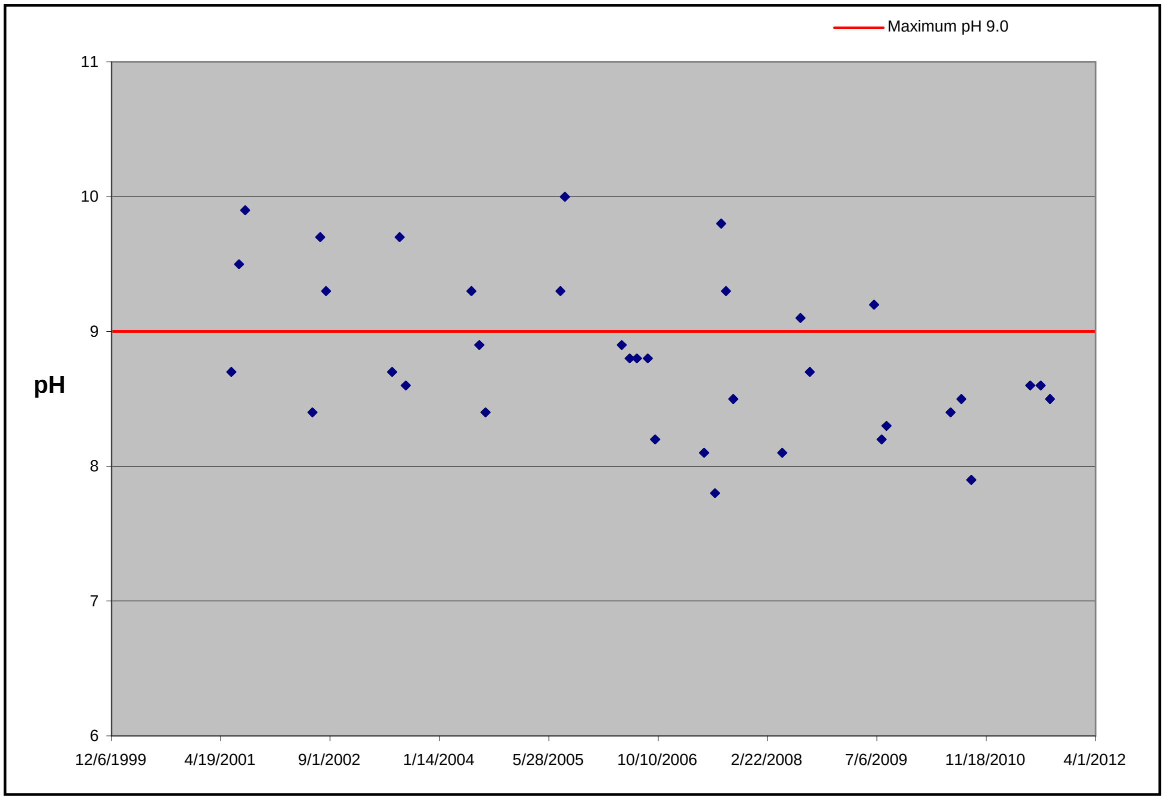

Figure 3.3. Measured pH levels in Casey Lake (2001-2010).

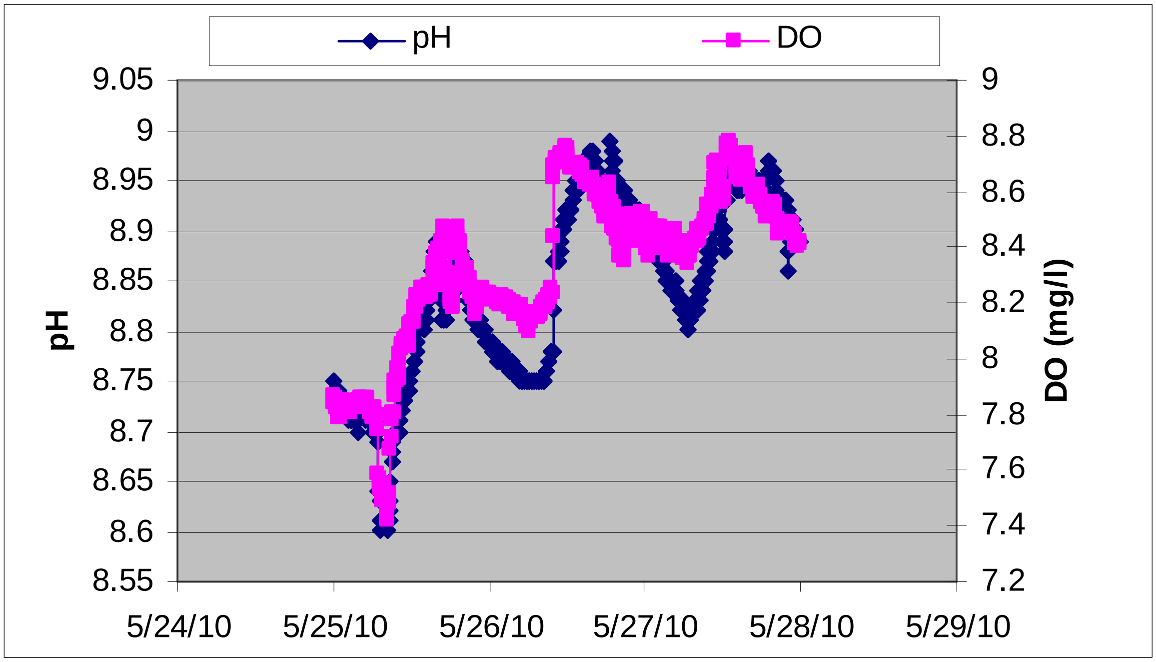

Figure 3.4. Relationship between pH and DO.

3.2. TMDL Target

General description of the pollutant. While some studies have suggested that control of both nitrogen and phosphorus may be needed to limit eutrophication in some lakes, phosphorus control is thought to be the critical factor in mitigating eutrophication in Casey Lake. If phosphorus reductions are attained and algal blooms continue to impair designated uses nitrogen reduction controls may also be needed. The TMDL for algae and pH is based on in-lake targets, which will be achieved by reducing phosphorus loads to the lake

Having established that nitrogen is not a limiting factor in this system means that phosphorus should be the target for addressing these impairments. Sediment attached phosphorus that enters the lake and becomes available for uptake allows for the establishment of algal blooms. Through photosynthesis the blooms remove CO2 from the water inhibiting the natural carbon cycle to produce carbonic acid. This results in a more alkaline system with a higher pH. Since, the phosphorus is the limiting nutrient, reductions in availability will result in reductions in algal blooms and that will in turn stabilize the carbon cycle and the pH of the system.

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 Casey Lake 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 Casey Lake 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. Additionally, chlorophyll-a TSI must not exceed 65.

The primary metric for water quality standards attainment set forth in this TMDL is obtaining/maintaining a of no greater than 63, which corresponds to a chlorophyll-a concentration of 27 ug/L. IDNR will de-list the impairment if the chlorophyll-a TSI is 63 or less in two consecutive 303(d) listing cycles, per the methodology IDNR uses to develop the Integrated Report. As discussed in Sections 3.1 and 3.2, attainment of the TSI criterion should result in compliance with the numeric pH standard.

3.3. Pollution Source Assessment

Existing load. Average annual simulations of hydrology and pollutant loading were developed using the STEPL model (Version 4.1). STEPL was developed by Tetra Tech, for the US EPA Office of Water, 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.

Using STEPL and BATHTUB, the average annual TP load to Casey Lake from 2001-2006, including watershed, internal, and atmospheric loading was estimated to be 1,517.6 lbs/yr. The 6-year period prior to BMP installation (2001-2006) was determined to be most appropriate for development of the numeric TMDL.

Departure from load capacity. The target TP load, also referred to as the load capacity, for Casey Lake is 158.3 lbs. To meet the target loads, an overall reduction of 89.5 percent of the TP load 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.

Identification of pollutant sources. The existing TP load to Casey Lake 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. Figure 3.5 breaks down the external sources phosphorus into the lake. Table 3-2 reports estimated annual average TP loads and resulting water quality based on the STEPL and BATHTUB simulation of 2001-2006 conditions.

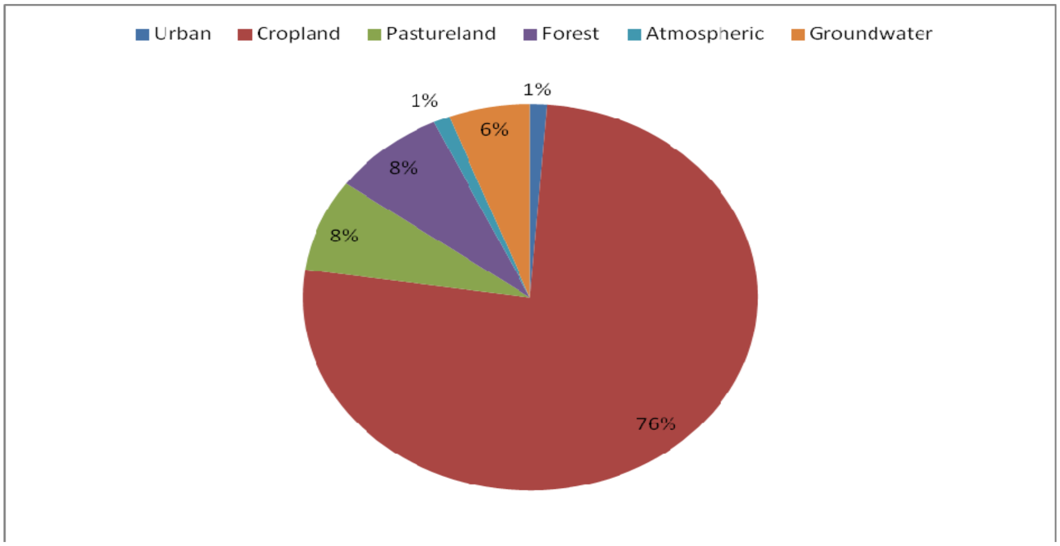

Figure 3.5. Percentage of external sources of phosphorus to Casey Lake.

Table 3.2. Average Annual TP existing conditions and target.

Model	Parameter	Existing	Target	Percent Reduction
BATHTUB	**TP (lbs/yr)**			
	External*	920.3	99.0	
	Internal	586.5	46.9	
	Atmospheric	10.8	10.8	
	Total	1517.6	156.8	89.6
STEPL	External **	924.7		

*includes precipitation
** includes groundwater

Allowance for increases in pollutant loads. There is no allowance for increased phosphorus loading included as part of this TMDL. A majority of the watershed is in parkland and is likely to remain in parkland in the future. There are no incorporated unsewered communities in the watershed. Therefore, it is unlikely that a future WLA would be needed for a new point source discharge.

3.4. Pollutant Allocation

Wasteload allocation. There are no permitted point source dischargers of phosphorus in the Casey Lake watershed. Therefore, the wasteload allocation (WLA) included in the TMDL is zero.

Load allocation. Nonpoint sources to Casey Lake include loads from agricultural land uses, internal recycling in the lake, and natural/background sources in the watershed, including wildlife and atmospheric deposition (from dust and rain). It is seldom feasible or economical to achieve large load reductions from natural/background sources. However, changes in agricultural land management, implementation of structural best management practices (BMPs), and in-lake restoration techniques can reduce phosphorus loads and improve water quality in Casey Lake.

The load allocation for this lake is:

Annual = LA 141.1 lbs-TP/year

TMDL (daily) = LA 1.45 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 15.7 lbs-TP/year

TMDL (daily) = MOS 0.17 lbs TP-day

3.6. TMDL Summary

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

TMDL = LC = Σ WLA + Σ LA + MOS

Where:
TMDL = total maximum daily load
LC = loading capacity
Σ WLA = sum of wasteload allocations (point sources)
Σ 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 Casey Lake watershed, the general equation above can be expressed for the Casey Lake algae TMDL.

Expressed as the allowable annual average, which is helpful for water quality assessment and watershed management:
Annual = LC = Σ WLA (0 lbs-TP/year) + Σ LA (141.1 lbs-TP/year)
+ MOS (15.7 lbs-TP/year) = **156.8 lbs-TP/years**:

TMDL= LC = Σ WLA (0 lbs-TP/day) + Σ LA (1.45 lbs-TP/day)
+ MOS (0.17 lbs TP-day) = **1.72 lbs-TP/days**:

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources (IDNR) 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 represent 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 Casey Lake 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 Casey Lake 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 Casey Lake 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.

4.1. General Approach & Reasonable Timeline

Watershed management and BMP implementation 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 required to meet water quality standards (WQS) in the main, open water area of the lake.

4.2. Best Management Practices

Casey Lake has already completed a Section 319 grant and is currently installing additional BMPs within the watershed to mitigate sediment input into the lake. Table 4.1 lists the planned BMPs applied through the Section 319 grant.

Overall, each structure significantly impacted pollutant concentrations. Structure A, with its limited retention time of less than 12-hours, did not impact sediment to the same degree as the other two longer retention period structures. In many ways, Structure A acted similar to a wetland, biologically uptaking nutrients because of its shallow nature and established vegetation and algae growth.

Structure B had the highest reductions of two of the four measured pollutants (on a concentration basis). Although it was not specifically designed to do so, Structure B noted significant reductions in *E. coli* and TN. Although TP did not see a significant reduction during the project period, it could be asserted from the data that the levels entering the retention pond were already so low that a statistically significant reduction would be difficult.

Structure C also decreased concentrations of three of the four measured pollutants. However, TN concentrations actually increased downstream of the primary structure, before the wetland. The wetland decreased the concentrations, but not to desired levels. There are several potential reasons for this, including:

- The wetland structure was completed in 2006, but the wetland vegetation was not planted until late 2007, after the monitoring effort was initiated.
- Temporary problems with the wetland outlet caused the depth of the wetland pool to be artificially elevated, restricting the rate of growth for the emerging wetland plants, reducing the ability for biological uptake of nutrients.
- It is unclear if the wetland slowed down the movement of water significantly enough to allow biological processes to uptake nitrogen and phosphorus.

As wetland flora continues to develop, larger reductions in the measured parameters are likely to take place. For continued (long-term) removal of phosphorus, regular maintenance activities will likely be required (e.g., dredging, vegetation removal, etc).

Table 4.1. Planned vs. Applied BMPs.

Best Management Practices (BMPs)	Planned	Applied
Grade Stabilization Structures	2	2
Water & Sediment Control Basins	2	0*
Grassed Waterways	3 acres	1 acre **
Wetland Establishment	1 acre	1 acre
Nutrient & Manure Management Planning	150 acres	0 acres ***

* Upon further in field-assessment of the identified gullies, it was determined that since the gullies were no longer actively eroding, the planned water & sediment control basins were no longer necessary.
** During the original assessment, it was noted there was a need for additional grassed waterways in the upland, cropland portion of the watershed. However, it appears the producer has adopted no-till farming and many of the planned grassed waterways are no longer needed.
*** The landowners and producers farming in the watershed already employ many of the modern agronomic practices, including no-till. Combing this with the current and rather lenient NRCS nutrient management practice standards, it was decided little could be gained in formally developing an NRCS Nutrient Management Plan.

The following pre-project sediment loading estimates are based upon RUSLE soil loss calculations with site-specific C & P values provided by the NRCS District Conservationist for Tama County. Once collected, the data was further processed by IDNR using their GIS-based watershed models. Tables 4.2 and 4.3 give the pre-project estimates and the estimated impacts of the structures.

Table 4.2. Pre-project sediment loading estimates.

Soil Loss Summary (using site-specific RUSLE values, with no credit for existing structures)

	Acres	Percent of Watershed	Total Erosion (tons/year)	SDR*	Sediment Loading (tons/year)	% of Total Sediment Loading
Cropland Areas	225.9	28.7%	940	43%	404	44.0%
Grassland Areas	113.3	14.4%	140	43%	60	6.6%
Timbered Areas	411.6	52.3%	1,053	43%	453	49.4%
Water	36.2	4.6%	0		0	0.0%
Totals	787	100.0%	2,133		**917**	100.0%

* Sediment Delivery Rate (SDR) was calculated using Southern Iowa Drift Plain values since the watershed is confined to a paha with a topography similar to that region of the state. Plus, the following modifiers were used: watershed shape (0), predominant topography (2), Channel Density (0), Channel (2), Drainage (2).

4.3. Modeling Results Using Post BMP Data

As indicated in Section 3 of this document, the TMDL was developed based on data collected prior to BMP installation, which represents a worst case scenario for Casey Lake. The same model was later applied to look at data collected during and post-BMP installation. This model indicates an overall improvement in the water quality of Casey Lake post-BMP installation.

The model ran for the period of 2001-2006 indicates a load of 1,517.6 lbs of P per year entering the lake and calls for an 89.5 percent reduction resulting in a total load of 158.3 lbs per year. The model ran for the period post BMP installation indicates a total existing load of 468.5 lbs of P per year. Unfortunately, the period following BMP installation was unusually wet and therefore the lake might have had a lower residence time. Flushing results in lower algal bloom activity, lower TP concentrations and improved Secchi depth. So there is a level of uncertainty with this result. However, it does indicate that the conditions of Casey Lake are improving with BMP installation.

Section five of this document provides a future monitoring scenario that would help determine the overall impact of the BMPs moving forward.

4.4. Future Remediation

As the watershed sources are remediated focus should shift to the in-lake approaches that could be used. Phosphorus recycled between the bottom sediment and water column of the lake is, at times, an important contributor of bioavailable phosphorus to Casey Lake. 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 readily available through internal loading, which is most likely to happen 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, reductions from watershed sources of TP should be given implementation priority. If and when monitoring shows that the external watershed load has been reduced/controlled, then additional in-lake measures may be warranted.

Increasing the mean depth of Casey Lake would lessen the reductions of internal and external TP loading required to meet water quality goals. This effect was not considered in the development of the TMDL in Section 3. If dredging is a desired alternative and adequate funding is available, technical analysis for watershed management and lake restoration planning should evaluate the impact of increased mean depth on in-lake water quality. Increasing mean depth would reduce required load reductions and/or improve water quality in Casey Lake. Table 4.4 outlines potential in lake BMPs.

Table 4.4. 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. Sediment and nutrient capture in the inlet could be enhanced by constructing submerged berms and/or jetties to create additional sediment forebays and increasing the low-flow residence time of the inlet.	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 Casey Lake.	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 significant. The entire shoreline of Casey Lake is publicly owned, making this alternative possible in all areas of the lake.	Low

[1] Reductions (High/Med/Low) are relative to each other and based on numerous research studies and previous IDNR 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 Casey Lake watershed can be agency-led, volunteer-based, or a combination of both. The Iowa Department of Natural Resources (IDNR) 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.

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 Casey Lake to assess water quality trends and compliance with water quality standards (WQS) is expected to include monitoring conducted as part of the IDNR Beach Monitoring Program and the IDNR Ambient Lake Monitoring Program. Unless there is local interest in collecting additional water quality data, future sampling efforts will be limited to these basic monitoring programs.

The Beach Monitoring Program consists of routine *E. coli* monitoring at state park beaches and locally managed beaches throughout Iowa. The beaches are sampled at least two times per week from Memorial Day to Labor Day. The reported *E. coli* concentration for a particular sampling event is typically a composite sample average of nine sampling points collected at three approximate depths (ankle, knee, and chest) at three locations (e.g., left, middle, right) along the beach.

The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 132 of Iowa's lakes are being sampled as part of this program, including Casey Lake. 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.

Table 5.1. Ambient Lake Monitoring Program water quality parameters.

Chemical	Physical	Biological
• 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	• 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	• Chlorophyll a • Phytoplankton (mass and composition) • Zooplankton (mass and composition)

5.2. Expanded Monitoring for Detailed Assessment and Planning

Data available from the IDNR Beach Monitoring Program and the IDNR 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 IDNR. Only through the interest and action of local stakeholders will funding and resources needed to acquire this important information become available. Figure 5-1 depicts where the ambient lake monitoring samples will be gathered along with tributary sites that would be helpful in monitoring the effectiveness of BMPs and the water quality entering the upper portion of the lake.

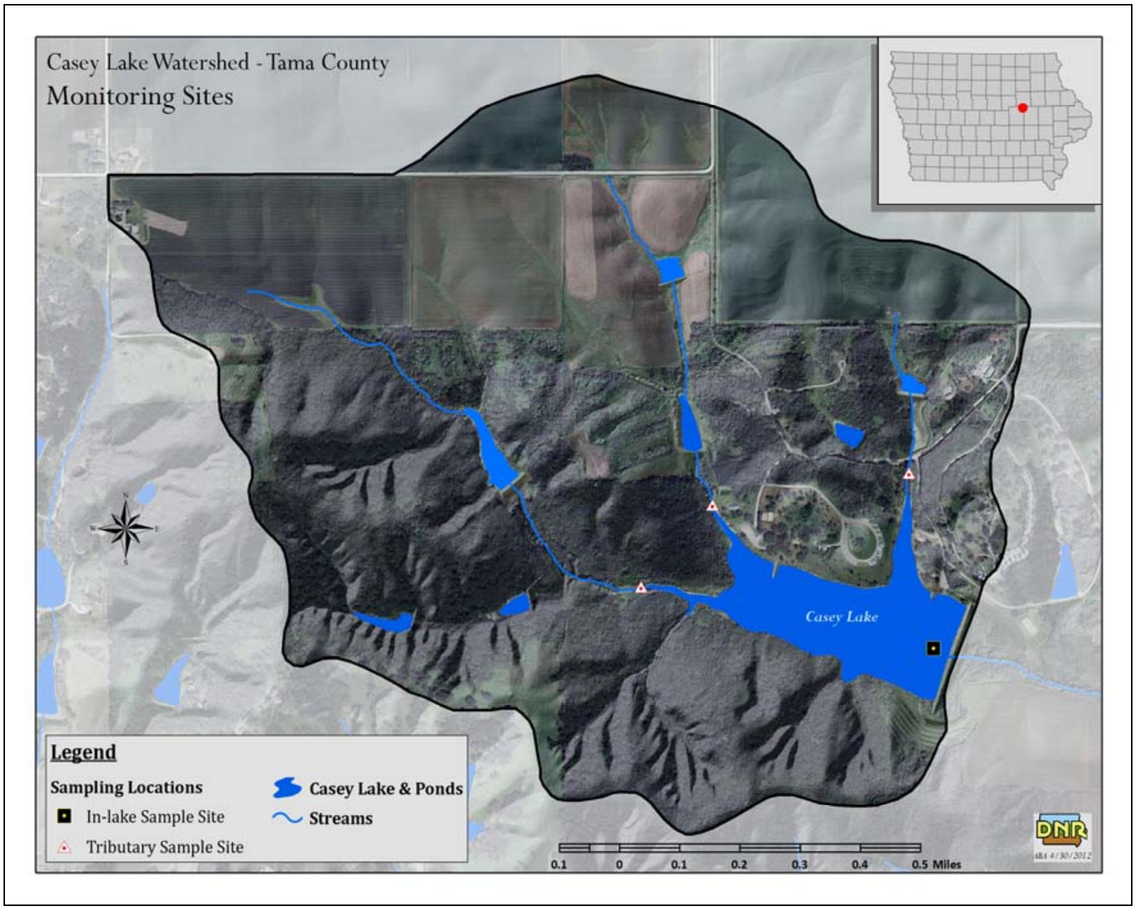

Figure 5.1. Sample locations for Casey Lake monitoring.

5.2. Idealized 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.

Table 5.2. Expanded monitoring plan.

Parameter(s)	Intervals	Duration	[1]Location(s)
Routine grab sampling for flow, sediment, P, and N	Every 1-2 weeks	April through October	Ambient and Tributaries
Continuous flow	15-60 minute	April through October	Outfall
Continuous pH, DO, and temperature	15-60 minute	April through October	Ambient and Tributaries
Runoff event flow, sediment, P, and N	Continuous flow, composite WQ	5 events between April and October	Tributaires
Event or continuous tile drain flow, N, and P sampling	15-60 minute	10 to 14-day wet weather periods if continuous sampling is not feasible	Tributaries

[1] Final location of tributary sites should be based 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 long-term trends 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.

Continuous flow data in the tributaries and at the outlet (i.e., spillway) of the lake would improve the predictive ability and accuracy of modeling tools, such as those used to develop the TMDL for Casey Lake. Reliable long-term flow data is also important because hydrology drives many important processes related to water quality, and 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 IDNR Watershed Improvement Section can provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Casey Lake 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 Casey Lake. During the development of this TMDL, every effort was 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 Casey Lake.

6.1. Public Meetings

On February 15th, 2012 a watershed tour was given to members of the WIS (Melinda Buyck and Jason Palmer) by Vern Fish, Executive Director of Black Hawk County Conservation board and staff. During this visit, a gully assessment, BMP assessment and a guided watershed tour were performed. This visit also served as a precursor to the public meeting to be held at completion of the TMDL.

A public meeting presenting the WQIP was held on November 8, 2012 at 6 pm in Waterloo, Iowa. The meeting was attended by park officials, members of the county conservation board, and private land owners.

6.2. Written Comments

No public comments were received during the 30 day comment period.

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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 any ditch, stream, or other water conveyance system, whether man-made or natural.
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 IDNR):	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 *E. coli* 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 (µg/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 *E. coli* 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. *Stormwater* 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 (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, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

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, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

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, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

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
Other	HQ	High quality water	Waters with exceptional water quality
	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

*Collected at ambient lake site

Parameter: Chlorophyll a, corrected for pheophytin		
Date	**Value**	**Unit**
7/6/2000	10.9	ug/l
8/1/2000 2:00:00 PM	13	ug/l
9/7/2000 1:00:00 PM	10.4	ug/l
6/6/2001 12:00:00 PM	6.3	ug/l
7/11/2001 10:30:00 AM	17.2	ug/l
8/8/2001 9:00:00 AM	18.8	ug/l
6/12/2002	9.5	ug/l
7/17/2002 10:00:00 AM	79	ug/l
8/13/2002	27.1	ug/l
6/11/2003 8:30:00 AM	5.4	ug/l
7/16/2003 4:40:00 PM	29.4	ug/l
8/13/2003	42	ug/l
6/8/2004 3:00:00 PM	107	ug/l
7/14/2004 10:15:00 AM	28.5	ug/l
8/11/2004 8:00:00 AM	15.1	ug/l
7/20/2005 11:30:00 AM	123.2	ug/l
8/9/2005 1:30:00 PM	298.1	ug/l
6/23/2009 1:23:00 PM	12	ug/l
7/28/2009 1:56:00 PM	14	ug/l
8/19/2009 9:29:00 AM	0	ug/l
6/8/2010 7:00:00 AM	0	ug/l
7/27/2010 7:25:00 AM	9	ug/l

Parameter: Chlorophyll a, free of pheophytin		
Date	**Value**	**Unit**
9/11/2010 11:30:00 AM	67	ug/l
5/19/2005 10:20:00 AM	4	ug/l
8/8/2005 8:20:00 AM	110	ug/l
9/22/2005 11:00:00 AM	150	ug/l
4/26/2006 12:00:00 PM	81	ug/l
6/1/2006 10:50:00 AM	80	ug/l
7/5/2006 11:00:00 AM	32	ug/l
8/24/2006 1:15:00 PM	40	ug/l
9/26/2006 11:00:00 AM	26	ug/l
5/8/2007 1:40:00 PM	3	ug/l
6/27/2007 12:55:00 PM	39	ug/l
7/25/2007 11:00:00 AM	190	ug/l
8/16/2007 12:45:00 PM	96	ug/l
9/18/2007 10:10:00 AM	140	ug/l
4/29/2008 11:50:00 AM	110	ug/l
7/22/2008 10:50:00 AM	21	ug/l
9/2/2008 11:20:00 AM	53	ug/l
5/20/2010 10:30:00 AM	6	ug/l
6/10/2010 2:30:00 PM	22	ug/l
7/8/2010 1:45:00 PM	17	ug/l
8/17/2010 1:50:00 PM	110	ug/l
9/16/2010 11:15:00 AM	88	ug/l

Parameter: Depth, Secchi Disk Depth		
Date	**Value**	**Unit**
7/6/2000	0.85	m
8/1/2000 2:00:00 PM	0.23	m
9/7/2000 1:00:00 PM	0.28	m
6/6/2001 12:00:00 PM	3	m
7/11/2001 10:30:00 AM	1.5	m
8/8/2001 9:00:00 AM	0.35	m
6/12/2002	3.05	m
7/17/2002 10:00:00 AM	0.8	m
8/13/2002	0.35	m
6/11/2003 8:30:00 AM	3.55	m
7/16/2003 4:40:00 PM	0.7	m
8/13/2003	1.17	m
6/8/2004 3:00:00 PM	0.65	m
7/14/2004 10:15:00 AM	1.9	m
8/11/2004 8:00:00 AM	2.1	m
5/19/2005 10:20:00 AM	3	m
7/20/2005 11:30:00 AM	0.65	m
8/8/2005 8:20:00 AM	0.3	m
8/9/2005 1:30:00 PM	0.25	m
9/22/2005 11:00:00 AM	0.2	m
4/26/2006 12:00:00 PM	0.8	m
6/1/2006 10:50:00 AM	0.3	m
7/5/2006 11:00:00 AM	0.4	m
8/24/2006 1:15:00 PM	0.5	m
9/26/2006 11:00:00 AM	0.5	m
5/8/2007 1:40:00 PM	4.3	m
6/27/2007 12:55:00 PM	1.1	m
7/25/2007 11:00:00 AM	0.3	m
8/16/2007 12:45:00 PM	0.2	m
9/18/2007 10:10:00 AM	0.5	m
4/29/2008 11:50:00 AM	0.7	m
7/22/2008 10:50:00 AM	0.6	m
9/2/2008 11:20:00 AM	0.6	m
6/23/2009 1:23:00 PM	1.7	m
7/28/2009 1:56:00 PM	2.3	m
8/19/2009 9:29:00 AM	4.1	m
5/20/2010 10:30:00 AM	3	m
6/8/2010 7:00:00 AM	3.2	m
6/10/2010 2:30:00 PM	2.1	m
7/8/2010 1:45:00 PM	2	m
7/27/2010 7:25:00 AM	0.6	m
8/17/2010 1:50:00 PM	0.5	m
9/11/2010 11:30:00 AM	0.4	m
9/16/2010 11:15:00 AM	0.5	m

Parameter: Depth, Thermocline		
Date	**Value**	**Unit**
5/19/2005 10:20:00 AM	4.8	m
8/8/2005 8:20:00 AM	4.2	m
9/22/2005 11:00:00 AM	2.8	m
4/26/2006 12:00:00 PM	4	m
6/1/2006 10:50:00 AM	1.6	m
7/5/2006 11:00:00 AM	1.7	m
8/24/2006 1:15:00 PM	2	m
9/26/2006 11:00:00 AM	0	m
5/8/2007 1:40:00 PM	2.5	m
7/25/2007 11:00:00 AM	1	m
9/18/2007 10:10:00 AM	2.8	m
4/29/2008 11:50:00 AM	0	m
7/22/2008 10:50:00 AM	1.6	m
9/2/2008 11:20:00 AM	2.3	m
6/23/2009 1:23:00 PM	1.5	m
7/28/2009 1:56:00 PM	2.3	m
8/19/2009 9:29:00 AM	2.4	m
5/20/2010 10:30:00 AM	0	m
6/8/2010 7:00:00 AM	2.4	m
6/10/2010 2:30:00 PM	2.3	m
7/8/2010 1:45:00 PM	1.8	m
7/27/2010 7:25:00 AM	2.1	m
8/17/2010 1:50:00 PM	2	m
9/11/2010 11:30:00 AM	5.5	m
9/16/2010 11:15:00 AM	0	m

Parameter: Nitrogen, ammonia (NH3) as NH3		
Date	**Value**	**Unit**
5/19/2005 10:20:00 AM	0	mg/l
8/8/2005 8:20:00 AM	0.03	mg/l
9/22/2005 11:00:00 AM	0	mg/l
4/26/2006 12:00:00 PM	0	mg/l
6/1/2006 10:50:00 AM	0	mg/l
7/5/2006 11:00:00 AM	0	mg/l
8/24/2006 1:15:00 PM	0	mg/l
9/26/2006 11:00:00 AM	0	mg/l
5/8/2007 1:40:00 PM	0.01	mg/l
6/27/2007 12:55:00 PM	0.01	mg/l
7/25/2007 11:00:00 AM	0	mg/l
8/16/2007 12:45:00 PM	0	mg/l
9/18/2007 10:10:00 AM	0.04	mg/l
4/29/2008 11:50:00 AM	0	mg/l
7/22/2008 10:50:00 AM	0	mg/l
9/2/2008 11:20:00 AM	0.02	mg/l
5/20/2010 10:30:00 AM	0	mg/l
6/10/2010 2:30:00 PM	0	mg/l
7/8/2010 1:45:00 PM	0	mg/l
8/17/2010 1:50:00 PM	0	mg/l
9/16/2010 11:15:00 AM	0	mg/l

Parameter: Nitrogen, ammonia as N		
Date	**Value**	**Unit**
6/8/2004 3:00:00 PM	0.036	mg/l
7/14/2004 10:15:00 AM	0.04	mg/l
8/11/2004 8:00:00 AM	0.296	mg/l
5/19/2005 10:20:00 AM	0	mg/l
7/20/2005 11:30:00 AM	0.034	mg/l
8/8/2005 8:20:00 AM	0.48	mg/l
8/9/2005 1:30:00 PM	0	mg/l
9/22/2005 11:00:00 AM	0	mg/l
4/26/2006 12:00:00 PM	0	mg/l
6/1/2006 10:50:00 AM	0	mg/l
7/5/2006 11:00:00 AM	0	mg/l
8/24/2006 1:15:00 PM	0	mg/l
9/26/2006 11:00:00 AM	0.05	mg/l
5/8/2007 1:40:00 PM	0.25	mg/l
6/27/2007 12:55:00 PM	0.11	mg/l
7/25/2007 11:00:00 AM	0	mg/l
8/16/2007 12:45:00 PM	0	mg/l
9/18/2007 10:10:00 AM	0.26	mg/l
4/29/2008 11:50:00 AM	0	mg/l
7/22/2008 10:50:00 AM	0	mg/l
9/2/2008 11:20:00 AM	0.08	mg/l
6/23/2009 1:23:00 PM	0	mg/l
7/28/2009 1:56:00 PM	0.258	mg/l
8/19/2009 9:29:00 AM	0.309	mg/l
5/20/2010 10:30:00 AM	0	mg/l
6/8/2010 7:00:00 AM	0	mg/l
6/10/2010 2:30:00 PM	0	mg/l
7/8/2010 1:45:00 PM	0	mg/l
7/27/2010 7:25:00 AM	0	mg/l
8/17/2010 1:50:00 PM	0	mg/l
9/11/2010 11:30:00 AM	0.323	mg/l
9/16/2010 11:15:00 AM	0.08	mg/l

Parameter: Nitrogen, Kjeldahl		
Date	**Value**	**Unit**
5/19/2005 10:20:00 AM	0.83	mg/l
8/8/2005 8:20:00 AM	4200	mg/kg
8/8/2005 8:20:00 AM	2.2	mg/l
9/22/2005 11:00:00 AM	2.6	mg/l
4/26/2006 12:00:00 PM	1.7	mg/l
6/1/2006 10:50:00 AM	2.1	mg/l
7/5/2006 11:00:00 AM	1.5	mg/l
8/24/2006 1:15:00 PM	1.6	mg/l
9/26/2006 11:00:00 AM	1.6	mg/l
5/8/2007 1:40:00 PM	1.3	mg/l
6/27/2007 12:55:00 PM	1	mg/l
7/25/2007 11:00:00 AM	2.5	mg/l
8/16/2007 12:45:00 PM	2.5	mg/l
9/18/2007 10:10:00 AM	2.4	mg/l
4/29/2008 11:50:00 AM	1.2	mg/l
7/22/2008 10:50:00 AM	1.6	mg/l
9/2/2008 11:20:00 AM	1.4	mg/l
5/20/2010 10:30:00 AM	0.5	mg/l
6/10/2010 2:30:00 PM	0.8	mg/l
7/8/2010 1:45:00 PM	0.7	mg/l
8/17/2010 1:50:00 PM	1.4	mg/l
9/16/2010 11:15:00 AM	1.9	mg/l

Parameter: Kjeldahl nitrogen as N		
Date	**Value**	**Unit**
6/8/2010 7:00:00 AM	0	mg/l
7/27/2010 7:25:00 AM	0.85	mg/l
9/11/2010 11:30:00 AM	2.51	mg/l

Parameter: Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N		
Date	**Value**	**Unit**
7/6/2000	0.44	mg/l
8/1/2000 2:00:00 PM	0.19	mg/l
9/7/2000 1:00:00 PM	0	mg/l
6/6/2001 12:00:00 PM	1.38	mg/l
7/11/2001 10:30:00 AM	0	mg/l
8/8/2001 9:00:00 AM	0.19	mg/l
6/12/2002	0.18	mg/l
7/17/2002 10:00:00 AM	1.38	mg/l
8/13/2002	0	mg/l
6/11/2003 8:30:00 AM	0.35	mg/l
7/16/2003 4:40:00 PM	0	mg/l
8/13/2003	0.16	mg/l
6/8/2004 3:00:00 PM	1.49	mg/l
7/14/2004 10:15:00 AM	0.88	mg/l
8/11/2004 8:00:00 AM	0.22	mg/l
5/19/2005 10:20:00 AM	0.55	mg/l
7/20/2005 11:30:00 AM	0	mg/l
8/8/2005 8:20:00 AM	0	mg/kg
8/8/2005 8:20:00 AM	0	mg/l
8/9/2005 1:30:00 PM	0.14	mg/l
9/22/2005 11:00:00 AM	0	mg/l
4/26/2006 12:00:00 PM	0	mg/l
6/1/2006 10:50:00 AM	0	mg/l
7/5/2006 11:00:00 AM	0	mg/l
8/24/2006 1:15:00 PM	0	mg/l
9/26/2006 11:00:00 AM	0	mg/l
5/8/2007 1:40:00 PM	1.1	mg/l
6/27/2007 12:55:00 PM	0	mg/l
7/25/2007 11:00:00 AM	0	mg/l
8/16/2007 12:45:00 PM	0	mg/l
9/18/2007 10:10:00 AM	0	mg/l
4/29/2008 11:50:00 AM	2.2	mg/l
7/22/2008 10:50:00 AM	0	mg/l
9/2/2008 11:20:00 AM	0	mg/l
6/23/2009 1:23:00 PM	0	mg/l
7/28/2009 1:56:00 PM	0	mg/l
8/19/2009 9:29:00 AM	0	mg/l
5/20/2010 10:30:00 AM	0.83	mg/l
6/8/2010 7:00:00 AM	0	mg/l
6/10/2010 2:30:00 PM	0.14	mg/l
7/8/2010 1:45:00 PM	0	mg/l
7/27/2010 7:25:00 AM	0	mg/l
8/17/2010 1:50:00 PM	0	mg/l
9/11/2010 11:30:00 AM	0	mg/l
9/16/2010 11:15:00 AM	0	mg/l

Parameter: Nutrient nitrogen		
Date	**Value**	**Unit**
7/6/2000	1.62	mg/l
8/1/2000 2:00:00 PM	2.03	mg/l
9/7/2000 1:00:00 PM	2.27	mg/l
6/6/2001 12:00:00 PM	1.7	mg/l
7/11/2001 10:30:00 AM	1.5	mg/l
8/8/2001 9:00:00 AM	2.54	mg/l
6/12/2002	0.71	mg/l
7/17/2002 10:00:00 AM	2.52	mg/l
8/13/2002	1.53	mg/l
6/11/2003 8:30:00 AM	1.02	mg/l
7/16/2003 4:40:00 PM	1.42	mg/l
8/13/2003	1.42	mg/l
6/8/2004 3:00:00 PM	2.35	mg/l
7/14/2004 10:15:00 AM	1.65	mg/l
8/11/2004 8:00:00 AM	1.29	mg/l
7/20/2005 11:30:00 AM	1.36	mg/l
8/9/2005 1:30:00 PM	2.13	mg/l
6/23/2009 1:23:00 PM	0.75	mg/l
7/28/2009 1:56:00 PM	1.68	mg/l
8/19/2009 9:29:00 AM	1.16	mg/l

Parameter: Pcb-aroclor 1016		
Date	**Value**	**Unit**
8/8/2005 8:20:00 AM	0	mg/kg
8/8/2005 8:20:00 AM	0	mg/kg
8/8/2005 8:20:00 AM	0	mg/kg
8/8/2005 8:20:00 AM	0	mg/kg
8/8/2005 8:20:00 AM	0	mg/kg
8/8/2005 8:20:00 AM	0	mg/kg
8/8/2005 8:20:00 AM	0	mg/kg

Parameter: pH		
Date	**Value**	**Unit**
7/6/2000	9	None
8/1/2000 2:00:00 PM	9.5	None
9/7/2000 1:00:00 PM	9	None
6/6/2001 12:00:00 PM	8.7	None
7/11/2001 10:30:00 AM	9.5	None
8/8/2001 9:00:00 AM	9.9	None
6/12/2002	8.4	None
7/17/2002 10:00:00 AM	9.7	None
8/13/2002	9.3	None
6/11/2003 8:30:00 AM	8.7	None
7/16/2003 4:40:00 PM	9.7	None
8/13/2003	8.6	None
6/8/2004 3:00:00 PM	9.3	None
7/14/2004 10:15:00 AM	8.9	None
8/11/2004 8:00:00 AM	8.4	None
5/19/2005 10:20:00 AM	8.2	None
7/20/2005 11:30:00 AM	9.3	None
8/8/2005 8:20:00 AM	7.9	None
8/9/2005 1:30:00 PM	10	None
9/22/2005 11:00:00 AM	9.1	None
4/26/2006 12:00:00 PM	8.9	None
6/1/2006 10:50:00 AM	8.8	None
7/5/2006 11:00:00 AM	8.8	None
8/24/2006 1:15:00 PM	8.8	None
9/26/2006 11:00:00 AM	8.2	None
5/8/2007 1:40:00 PM	8.1	None
6/27/2007 12:55:00 PM	7.8	None
7/25/2007 11:00:00 AM	9.8	None
8/16/2007 12:45:00 PM	9.3	None
9/18/2007 10:10:00 AM	8.5	None
4/29/2008 11:50:00 AM	8.1	None
7/22/2008 10:50:00 AM	9.1	None
9/2/2008 11:20:00 AM	8.7	None
6/23/2009 1:23:00 PM	9.2	None
7/28/2009 1:56:00 PM	8.2	None
8/19/2009 9:29:00 AM	8.3	None
5/20/2010 10:30:00 AM	8.8	None
6/8/2010 7:00:00 AM	8.4	None
6/10/2010 2:30:00 PM	8.4	None
7/8/2010 1:45:00 PM	9.4	None
7/27/2010 7:25:00 AM	8.5	None
8/17/2010 1:50:00 PM	6.7	None
9/11/2010 11:30:00 AM	7.9	None
9/16/2010 11:15:00 AM	8.4	None

Parameter: Phosphorus		
Date	**Value**	**Unit**
6/23/2009 1:23:00 PM	0.0391	mg/l
7/28/2009 1:56:00 PM	0.0729	mg/l
8/19/2009 9:29:00 AM	0.0773	mg/l

Parameter: Phosphorus as P		
Date	**Value**	**Unit**
6/6/2001 12:00:00 PM	0.018	mg/l
7/11/2001 10:30:00 AM	0.06	mg/l
8/8/2001 9:00:00 AM	0.297	mg/l
6/12/2002	0.031	mg/l
7/17/2002 10:00:00 AM	0.577	mg/l
8/13/2002	0.184	mg/l
6/11/2003 8:30:00 AM	0.044	mg/l
7/16/2003 4:40:00 PM	0.079	mg/l
8/13/2003	0.121	mg/l
6/8/2004 3:00:00 PM	0.081	mg/l
7/14/2004 10:15:00 AM	0.053	mg/l
8/11/2004 8:00:00 AM	0.188	mg/l
5/19/2005 10:20:00 AM	0.04	mg/l
7/20/2005 11:30:00 AM	0.111	mg/l
8/8/2005 8:20:00 AM	0.14	mg/l
8/9/2005 1:30:00 PM	0.148	mg/l
9/22/2005 11:00:00 AM	0.2	mg/l
4/26/2006 12:00:00 PM	0.11	mg/l
6/1/2006 10:50:00 AM	0.15	mg/l
7/5/2006 11:00:00 AM	0.11	mg/l
8/24/2006 1:15:00 PM	0.1	mg/l
9/26/2006 11:00:00 AM	0.14	mg/l
5/8/2007 1:40:00 PM	0.09	mg/l
6/27/2007 12:55:00 PM	0.07	mg/l
7/25/2007 11:00:00 AM	0.26	mg/l
8/16/2007 12:45:00 PM	0.14	mg/l
9/18/2007 10:10:00 AM	0.19	mg/l
4/29/2008 11:50:00 AM	0.15	mg/l
7/22/2008 10:50:00 AM	0.1	mg/l
9/2/2008 11:20:00 AM	0.12	mg/l
5/20/2010 10:30:00 AM	0.03	mg/l
6/8/2010 7:00:00 AM	0.0495	mg/l
6/10/2010 2:30:00 PM	0.08	mg/l
7/8/2010 1:45:00 PM	0.06	mg/l
7/27/2010 7:25:00 AM	0.0669	mg/l
8/17/2010 1:50:00 PM	0.11	mg/l
9/11/2010 11:30:00 AM	0.1349	mg/l
9/16/2010 11:15:00 AM	0.12	mg/l

Parameter: Phosphorus, orthophosphate as P		
Date	**Value**	**Unit**
6/12/2002	0	mg/l
7/17/2002 10:00:00 AM	0.002	mg/l
8/13/2002	0.003	mg/l
6/11/2003 8:30:00 AM	0	mg/l
7/16/2003 4:40:00 PM	0	mg/l
8/13/2003	0.026	mg/l
6/8/2004 3:00:00 PM	0.007	mg/l
7/14/2004 10:15:00 AM	0	mg/l
8/11/2004 8:00:00 AM	0.133	mg/l
5/19/2005 10:20:00 AM	0	mg/l
8/8/2005 8:20:00 AM	0.04	mg/l
8/9/2005 1:30:00 PM	0	mg/l
9/22/2005 11:00:00 AM	0	mg/l
4/26/2006 12:00:00 PM	0	mg/l
6/1/2006 10:50:00 AM	0	mg/l
7/5/2006 11:00:00 AM	0.03	mg/l
8/24/2006 1:15:00 PM	0.02	mg/l
9/26/2006 11:00:00 AM	0.04	mg/l
5/8/2007 1:40:00 PM	0	mg/l
6/27/2007 12:55:00 PM	0	mg/l
7/25/2007 11:00:00 AM	0.02	mg/l
8/16/2007 12:45:00 PM	0	mg/l
9/18/2007 10:10:00 AM	0	mg/l
4/29/2008 11:50:00 AM	0.02	mg/l
7/22/2008 10:50:00 AM	0	mg/l
9/2/2008 11:20:00 AM	0	mg/l
6/23/2009 1:23:00 PM	0	mg/l
7/28/2009 1:56:00 PM	0	mg/l
8/19/2009 9:29:00 AM	0.0306	mg/l
5/20/2010 10:30:00 AM	0	mg/l
6/8/2010 7:00:00 AM	0.0136	mg/l
6/10/2010 2:30:00 PM	0.03	mg/l
7/8/2010 1:45:00 PM	0	mg/l
7/27/2010 7:25:00 AM	0	mg/l
8/17/2010 1:50:00 PM	0	mg/l
9/11/2010 11:30:00 AM	0	mg/l
9/16/2010 11:15:00 AM	0	mg/l

Parameter: Solids, Total Suspended (TSS)		
Date	**Value**	**Unit**
7/6/2000	12	mg/l
8/1/2000 2:00:00 PM	2	mg/l
9/7/2000 1:00:00 PM	5	mg/l
6/6/2001 12:00:00 PM	3	mg/l
7/11/2001 10:30:00 AM	7	mg/l
8/8/2001 9:00:00 AM	9	mg/l
6/12/2002	3	mg/l
7/17/2002 10:00:00 AM	11	mg/l
8/13/2002	19	mg/l
6/11/2003 8:30:00 AM	3	mg/l
7/16/2003 4:40:00 PM	13	mg/l
8/13/2003	8	mg/l
6/8/2004 3:00:00 PM	18	mg/l
7/14/2004 10:15:00 AM	5	mg/l
8/11/2004 8:00:00 AM	5	mg/l
5/19/2005 10:20:00 AM	3	mg/l
7/20/2005 11:30:00 AM	11	mg/l
8/8/2005 8:20:00 AM	15	mg/l
8/9/2005 1:30:00 PM	4	mg/l
9/22/2005 11:00:00 AM	21	mg/l
4/26/2006 12:00:00 PM	13	mg/l
6/1/2006 10:50:00 AM	17	mg/l
7/5/2006 11:00:00 AM	16	mg/l
8/24/2006 1:15:00 PM	15	mg/l
9/26/2006 11:00:00 AM	10	mg/l
5/8/2007 1:40:00 PM	4	mg/l
6/27/2007 12:55:00 PM	10	mg/l
7/25/2007 11:00:00 AM	30	mg/l
8/16/2007 12:45:00 PM	20	mg/l
9/18/2007 10:10:00 AM	11	mg/l
4/29/2008 11:50:00 AM	11	mg/l
7/22/2008 10:50:00 AM	20	mg/l
9/2/2008 11:20:00 AM	13	mg/l
6/23/2009 1:23:00 PM	0	mg/l
7/28/2009 1:56:00 PM	5.8	mg/l
8/19/2009 9:29:00 AM	0	mg/l
5/20/2010 10:30:00 AM	2	mg/l
6/8/2010 7:00:00 AM	0	mg/l
6/10/2010 2:30:00 PM	3	mg/l
7/8/2010 1:45:00 PM	6	mg/l
7/27/2010 7:25:00 AM	5.2	mg/l
8/17/2010 1:50:00 PM	13	mg/l
9/11/2010 11:30:00 AM	6.7	mg/l
9/16/2010 11:15:00 AM	10	mg/l

Parameter: Turbidity		
Date	**Value**	**Unit**
7/6/2000	11	NTU
8/1/2000 2:00:00 PM	711	NTU
9/7/2000 1:00:00 PM	58	NTU
6/6/2001 12:00:00 PM	2	NTU
7/11/2001 10:30:00 AM	23	NTU
8/8/2001 9:00:00 AM	91	NTU
7/17/2002 10:00:00 AM	27	NTU
8/13/2002	34	NTU
6/11/2003 8:30:00 AM	4	NTU
7/16/2003 4:40:00 PM	54	NTU
8/13/2003	15	NTU
6/8/2004 3:00:00 PM	12	NTU
7/14/2004 10:15:00 AM	5	NTU
8/11/2004 8:00:00 AM	5	NTU
5/19/2005 10:20:00 AM	6	NTU
7/20/2005 11:30:00 AM	17	NTU
8/8/2005 8:20:00 AM	23	NTU
8/9/2005 1:30:00 PM	37	NTU
9/22/2005 11:00:00 AM	51	NTU
4/26/2006 12:00:00 PM	24	NTU
6/1/2006 10:50:00 AM	28	NTU
7/5/2006 11:00:00 AM	23	NTU
8/24/2006 1:15:00 PM	28	NTU
9/26/2006 11:00:00 AM	23	NTU
5/8/2007 1:40:00 PM	17	NTU
6/27/2007 12:55:00 PM	8	NTU
7/25/2007 11:00:00 AM	106	NTU
8/16/2007 12:45:00 PM	69	NTU
9/18/2007 10:10:00 AM	21	NTU
4/29/2008 11:50:00 AM	42	NTU
7/22/2008 10:50:00 AM	40	NTU
9/2/2008 11:20:00 AM	36	NTU
6/23/2009 1:23:00 PM	6.6	NTU
7/28/2009 1:56:00 PM	0.9	NTU
8/19/2009 9:29:00 AM	0.3	NTU
5/20/2010 10:30:00 AM	1.6	NTU
5/20/2010 10:30:00 AM	12	NTU
6/8/2010 7:00:00 AM	1.5	NTU
6/10/2010 2:30:00 PM	2.6	NTU
6/10/2010 2:30:00 PM	11	NTU
7/8/2010 1:45:00 PM	3.4	NTU
7/8/2010 1:45:00 PM	5	NTU
7/27/2010 7:25:00 AM	4	NTU

Parameter: Turbidity (cont.)		
Date	**Value**	**Unit**
8/17/2010 1:50:00 PM	11	NTU
8/17/2010 1:50:00 PM	30	NTU
9/11/2010 11:30:00 AM	14.3	NTU
9/16/2010 11:15:00 AM	15	NTU
9/16/2010 11:15:00 AM	30	NTU

Appendix D --- Modeling Equations and Methodology

Watershed and in-lake modeling were used in conjunction with observed water quality data to develop the Total Maximum Daily Load (TMDL) for the algae and pH impairments to Casey Lake in Tama County, Iowa. IDNR determined that a single TMDL targeting phosphorus reductions will satisfy both the algae and pH impairments (see Section 3 of this document for details). 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 6.1, 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 Casey Lake 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 and BATHTUB lake 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 the use of 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.

The Casey Lake watershed was delineated into subbasins based on BMP structures that were already built or in the process of being constructed. This would allow watershed groups to easily change inputs within the STEPL model and access BMP calculators in the future. The watershed was divided into six subbasins to help quantify the relative pollutant loads stemming from different areas of the watershed and to assist with assessing current BMPs and targeting potential future BMP locations. Hydrology and pollutant loadings are summarized for each subbasin and also aggregated as watershed totals.

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 Casey Lake, the Waterloo station was chosen as it was within a reasonable distance from the watershed (approx. 21 miles). This resulted in an annual average rainfall of 35 inches to be used in the STEPL model and also within BATHTUB.

D.3. Watershed Characteristics

Delineation.
The Casey Lake watershed boundary was delineated based on installed and planned BMPs, specifically retention ponds. Figure D-2 illustrates the watershed and subbasin boundaries.

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 Casey Lake 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 (CNs) 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. STEPL calculates SDR using a simple empirical formula based on drainage area (i.e., watershed size). The SDR in STEPL was calculated at 0.282.

D.4. Animals

Agricultural Animals and Manure Application.
The STEPL model utilizes livestock population data and the amount of time (in months) that manure is applied to account for nutrient loading from livestock manure sources. There are no swine, beef, dairy, or poultry operations within the shed. However, a small number of horses were noticed during a watershed tour. These are represented with-in the model and are most likely over estimated at 15 horses.

Livestock Grazing.
There are no significant livestock grazing operations in the Casey Lake watershed.

Open Feedlots.
There are no open feedlots in the Casey Lake watershed.

Wildlife.
STEPL assumes that wildlife add to the manure deposited on the land surface. If animal densities are significant, nutrient concentration in runoff is increased. For Casey Lake, an estimate of 100 geese (personal communication Vern Fish Feb 2012) and 8 deer per square mile were used. Both of these numbers represent over estimates. Even with overestimates of geese and deer populations, wild life contributions are relatively insignificant (in terms of nutrient loading to the lake) and do not increase STEPL nutrient runoff parameters.

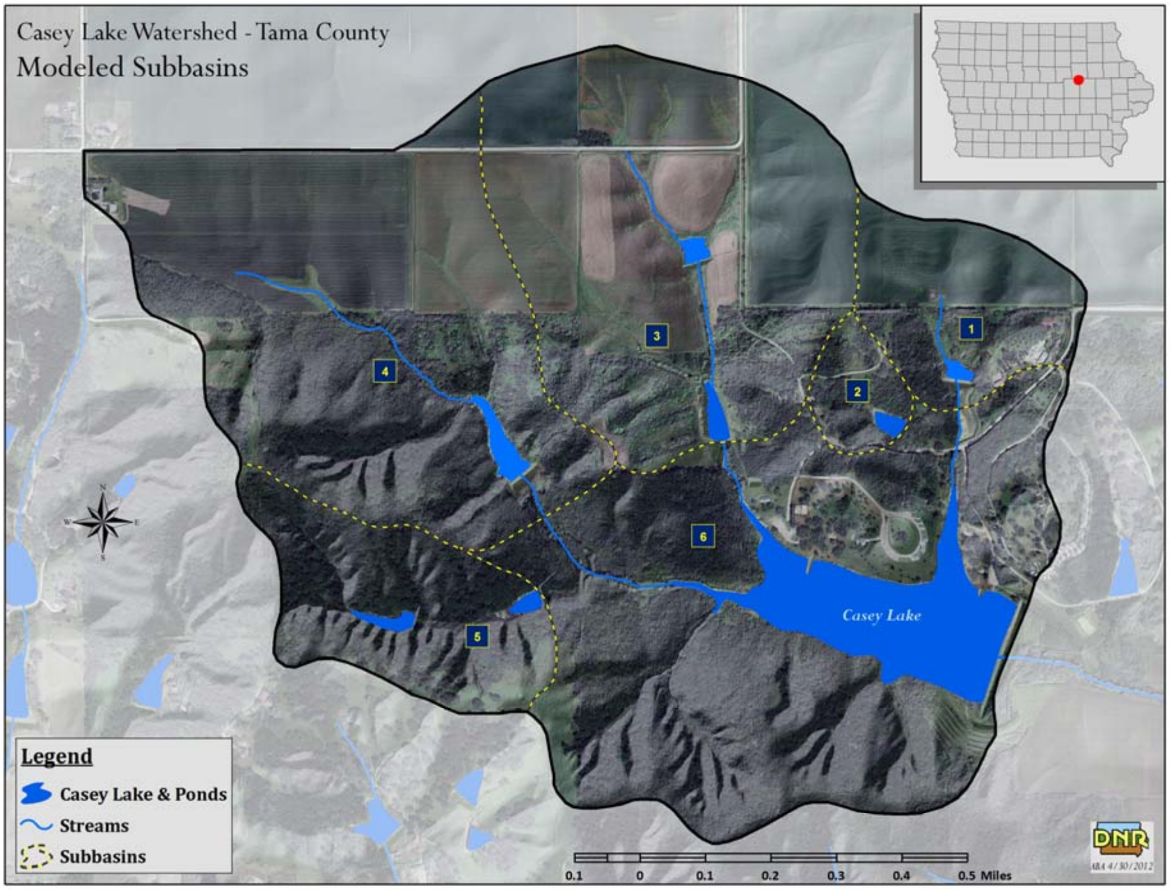

Figure D.1. Subbasins used in model development.

Table D.1. Subbasin landuse inputs for STEPL (acres).

Subbasin	Urban	Cropland	Pastureland	Forest	Total
W1	0.39	24.64	10.46	14.77	50.26
W2	0.7	0	5.18	9.18	15.06
W3	2.74	81.37	72.37	22.18	178.66
W4	1.35	88.11	11.42	105.26	206.14
W5	0	0	6.56	58.56	65.12
W6	7.1	0	59.44	166.3	232.84
Totals	**12.28**	**194.12**	**165.43**	**376.25**	**748.08**

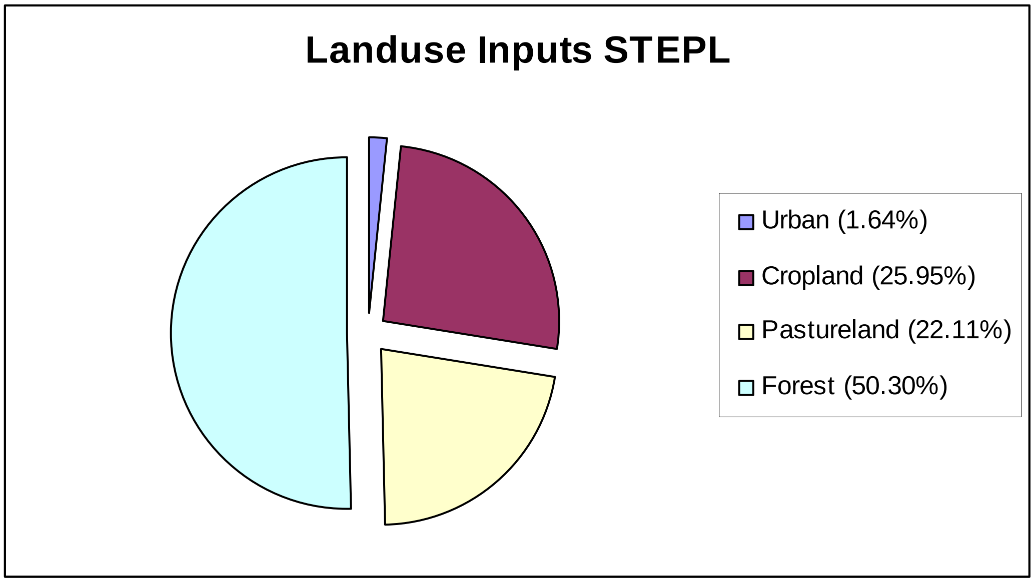

Figure D.2. Percent total landuse for Watershed.

Appendix E --- Water Quality Model Development

A combination of modeling software packages were used to develop the Total Maximum Daily Load (TMDL) for Casey Lake. 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 6.1, 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 Casey Lake 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 Casey Lake 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 Casey Lake 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 Casey Lake. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Casey Lake model. Final selection of model type was based on applicability to lake characteristics, availability of data, and agreement between predicted and observed data.

Table E-1. Model selections for Casey Lake.

Parameter	Model No.	Model Description
Total Phosphorus	01	2nd order*
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 Casey Lake 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 Casey Lake.

Table E-2. Global variables data for 2001-2006 simulation period.

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 year
Precipitation	35.01 in	0.889 m
Evaporation	35.50 in	0.901 m
[1]Increase in Storage	0	0
[2]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr

[1] Change in lake volume from beginning to end of simulation period.
[2] From 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. In lakes with simple morphometry and one primary tributary, simulation of the entire lake as one segment is often acceptable. Assessment and calibration of model performance for Casey Lake utilizes a two-segment model.

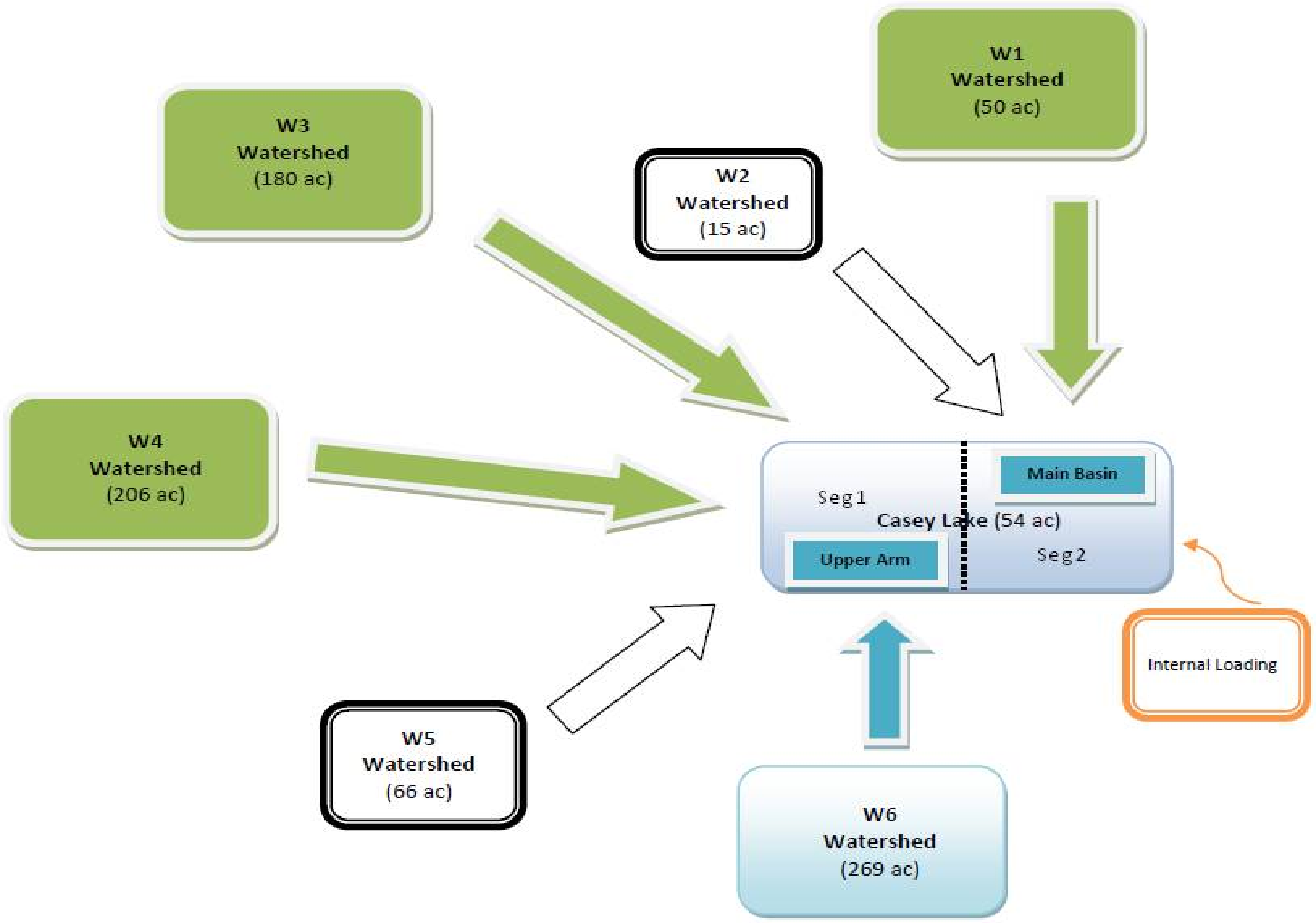

Figure E-1. Conceptual BATHTUB model for Casey Lake.

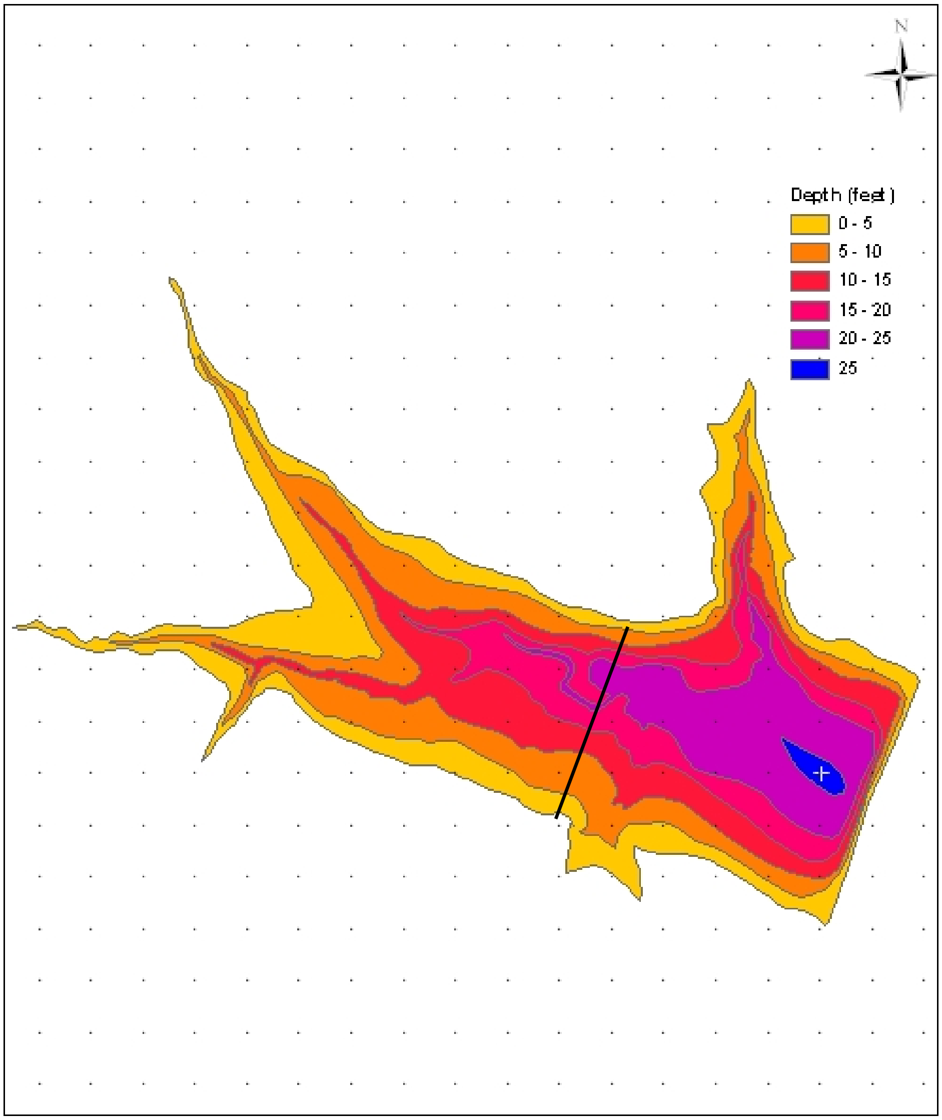

Figure E-2. Segmentation based on Bathemetry.

The BATHTUB model developed for Casey Lake does not simulate dynamic conditions associated with storm events or even between individual growing seasons. Rather, the model predicts the water quality period of 2001-2006 prior to BMP implementation. Observed water quality data for the lake is included in Appendix C – Water Quality Data.

Table E-3. Segments 1 and 2 inputs.

Segment 1 Parameter	BATHTUB Input	Calibration Factor	CV
Surface Area (km2)	0.092	N/A	N/A
Mean Depth (m)	1	N/A	N/A
Length (km)	0.38	N/A	N/A
Mixed layer Depth (m)	1.0	N/A	0*
Non-Algal Turbity (1/m)	0.08	1*	0*
Total Phosphorus (ug/l)	0	1*	0
Chlorophyll-a (ug/l)	0	1*	0
Secchi Depth (m)	0	1.5	0
Internal Load P (mg/mg2-day)	0	N/A	0*

* Indicates Default

Segment 2 Parameter	BATHTUB Input	Calibration Factor	CV
Surface Area (km2)	0.073	N/A	N/A
Mean Depth (m)	4.5	N/A	N/A
Length (km)	0.22	N/A	N/A
Mixed layer Depth (m)	3.0	N/A	0*
Non-Algal Turbity (1/m)	0.01	1*	0*
Total Phosphorus (ug/l)	158	0.82	0.45
Chlorophyll-a (ug/l)	72	1.4	0.26
Secchi Depth (m)	0.75	1.5	0
Internal Load P (mg/mg2-day)	10	N/A	0*

* Indicates Default

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 Casey Lake 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 units conversion and converting STEPL nutrient loads and flows.

Because of the segmented nature of Casey Lake and the implementation of BMPs, six subbasins were included in the STEPL model to provide tributary inputs for BATHTUB. Tributary data are reported in table E-4.

Table E-4. Tributary inputs for BATHTUB.

Watershed	Area (ac)	Flow (hm3)	TP (ppb)
W1	50.26	0.08	596.24
W2	15.06	0.02	120.65
W3	178.66	0.28	574.17
W4	206.14	0.31	532.20
W5	65.12	0.09	85.64
W6	232.84	0.32	108.42

E.3 Model Performance and Calibration

The Casey Lake 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 2001 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 Casey Lake.

BATHTUB Calibration.
Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Casey Lake from 2001 to 2006 in segment 2 of the BATHTUB model. Simulation of TP concentration was critical for TMDL development, as was chlorophyll-a and transparency predictions. Nitrogen constituents are less important because Casey Lake is not nitrogen limited. Therefore, nitrogen simulations were not calibrated. The observed data was obtained as part of the ambient lake monitoring program, and is based on data reported in Appendix C

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 both tributaries and internal loading until the desired Chl-a concentration of 27 mg/l was acheived for a whole lake average. This was expressed as an annual load and then expressed as an average daily maximum via a statistical approach described in Appendix F.

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 Casey Lake 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 158.3 lbs/year.

The maximum daily load was estimated from the allowable growing season 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 annul 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 156.8 lbs/year is equivalent to a long-term average (LTA) daily of 0.43 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 G-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 2.10 lbs/day. This is without the applied MOS of 10 percent. The TMDL calculation is summarized in Table G-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 by targeting a chlorophyll-a TSI value of 63, the IDNR delisting criterion, for the ambient monitoring location in Segment 2. The resulting TMDL, expressed as a daily maximum, is:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (1.45 lbs-TP/day)
+ MOS (0.17, explicit 10 percent) = **1.72 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	0.43lbs/day	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 (CV^2 + 1)
MDL	**1.74 lbs/day**	**TMDL expressed as daily load**

Appendix G --- Public Comments

No public comments were received during the public comment period.