UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7
11201 Renner Boulevard
Lenexa, Kansas 66219

OCT 07 2019

Mr. Alex Moon
Water Quality Bureau Chief
Iowa Department of Natural Resources
Wallace Building,
Wallace State Office Building E. 9th St.
Des Moines, Iowa 50319

Dear Mr. Moon:

RE: Approval of TMDL document for Green Valley Lake

This letter responds to the submission from the Iowa Department of Natural Resources, originally received by the U.S. Environmental Protection Agency, Region 7 on December 4, 2017, for a Total Maximum Daily Load document which contained a TMDL for Algae, Turbidity and Dissolved Oxygen. Green Valley Lake was identified on the 2016 Iowa Section 303(d) List as being impaired by Algae, Turbidity, and Dissolved Oxygen. This submission fulfills the Clean Water Act statutory requirement to develop TMDLs for impairments listed on a state's §303(d) list. The specific impairments (water body segments and causes) are:

Water Body	WBIDs	Causes
Green Valley Lake	IA 05-PLA-1472	Algae, Turbidity, Dissolved Oxygen

The EPA has completed its review of the TMDL document with supporting documentation and information. By this letter, the EPA approves the TMDLs submitted under § 303(d). Enclosed with this letter is Region 7, TMDL Decision Document which summarizes the rationale for the EPA's approval of the TMDLs. The EPA believes the separate elements of the TMDLs described in the enclosed document adequately address the cause of concern, taking into consideration seasonal variation and a margin of safety.

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

The EPA appreciates the thoughtful effort that the IDNR has put into these TMDLs. We will continue to cooperate with and assist, as appropriate, in future efforts by the IDNR, to develop TMDLs. If you have any questions, contact Jennifer Kissel, of my staff, at (913) 551-7982.

Sincerely,

Jeffery Robichaud
Director
Water Division

Enclosure

cc: Mr. Allen Bonini, Supervisor, Watershed Improvement Program, IDNR

United States Environmental Protection Agency
Region 7
Total Maximum Daily Load Approval

Green Valley Lake, Iowa
Algae, Turbidity and Dissolved Oxygen

Jeffery Robichaud
Director
Water Division

10/4/19
Date

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EPA Region 7 TMDL Review

TMDL ID: IA-05-PLA-1472 **State:** IA
Document Name: Green Valley Lake
Basin(s): West Platte River-Platte River
HUC(s): 102400120102
Water body(ies): Green Valley Lake
Tributary(ies): Platte River, unnamed streams
Cause(s): Algae, Turbidity, and Dissolved Oxygen

Submittal Date: Initial - 12/04/17, Final Date - 08/23/19 **Approved**: Yes

Submittal Letter and Total Maximum Daily Load Revisions

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

The Iowa Department of Natural Resources (IDNR) officially submitted the TMDL document to Region 7 of the U.S. Environmental Protection Agency (EPA) on December 4, 2017. Following comments from the EPA, revised TMDL documents were submitted as email attachments on August 23, 2019.

Water Quality Standards Attainment

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

The target pollutant, total phosphorus (TP), is validated and identified through assessment and data.

IDNR's review and interpretation of the water quality provides justification for linking phosphorus loads to the impairments. The TMDL document shows that reductions in phosphorus will prevent high levels of algal production and turbidity caused by phosphorus loads to the lake, as well as reducing the plant and algal growth that causes the DO impairment. The Loading Capacity (LC) is calculated at monitoring stations, but the targeted total phosphorus concentrations apply at all points in the segments identified in the waterbody.

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

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

The maximum daily load was estimated from the growing season average load using a statistical approach outlined in Appendix G of the TMDL document, based on the EPA's guidance, Options for Expressing Daily Loads in TMDLs. This approach uses a lognormal distribution to calculate the daily maximum from the long-term (e.g., seasonal) average load. The LC is calculated at monitoring stations, but the targeted total phosphorus concentrations apply at all points in the segments identified in the waterbody.

The LC expressed as the maximum daily load is as follows:

TMDL = LC = WLA (XX lb-TP/day) + LA (XX lb-TP/day) + MOS (XXX lb-TP/day) = XXX lb-TP/day

TMDL = LC = WLA (0 lb-TP/day) + LA (16.6 lb-TP/day) + MOS (1.8 lb-TP/day) = 18.4 lb-TP/day

The current annual load of phosphorus to the water body is 7,012 lbs/year. This annual load must be reduced by 72% to meet the allowable annual average TP LA of 2,160 lbs/year.

The EPA agrees that the TMDL targets will attain and maintain water quality standards.

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

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

Green Valley Lake is classified for the following designated uses: Primary Contact, Aquatic Life, Drinking Water, and Human Health. Green Valley Lake is listed on the 2016 303(d) list of impaired waters because it is not meeting the following uses: Primary Contact and Aquatic Life.
The Green Valley Lake is protected for the following designated uses:

Primary Recreation – Class A1: Waters in which recreational or other uses may result in prolonged and direct contact with the water, involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. Such activities would include, but not be limited to, swimming, diving, water skiing and water contact recreational canoeing.

Aquatic Life – Class B (LW) - Man-made and natural impoundments with hydraulic retention times and other physical and chemical characteristics suitable to maintain a balanced community normally associated with lake-like conditions.

Drinking Water Supply – Class C: Waters which are used as a raw water source of potable water supply.

Human Health (fish consumption, drinking water) – Class HH: Waters in which fish are routinely harvested for human consumption or waters both designated as a drinking water supply and in which fish are routinely harvested for human consumption.

The EPA-approved water quality standards that apply to the lake's impairments are found in the Iowa Administrative Code, Environmental Protection Rule 567, Chapter 61.

> *61.3(2) General water quality criteria. The following criteria are applicable to all surface waters including general use and designated use waters, at all places and at all times for the uses described in 61.3(1)"a."*
> *a. Such waters shall be free from substances attributable to point source wastewater discharges that will settle to form sludge deposits.*
> *b. Such waters shall be free from floating debris, oil, grease, scum and other floating materials attributable to wastewater discharges or agricultural practices in amounts sufficient to create a nuisance.*
> *c. Such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable condition.*
> *d. Such water shall be free from substances attributable to wastewater discharges or agricultural practices in concentrations or combinations which are acutely toxic to human, animal or plant life.*
> *e. Such water shall be free from substances attributable to wastewater discharges or agricultural practices in quantities which would produce undesirable or nuisance aquatic life.*

Specific water quality standard for dissolved oxygen impairments is listed below:
61.3(3) Specific water quality criteria.

> *b. Class "B" waters. All waters which are designated as Class B(CW1), B(CW2), B(WW-1), B(WW-2), B(WW-3) or B(LW) are to be protected for wildlife, fish, aquatic, and semiaquatic life. The following criteria shall apply to all Class "B" waters designated in subrule 61.3(5).*
>
> 1) *Dissolved oxygen. Dissolved oxygen shall not be less than the values shown in Table 2 of this subrule.*
> 2) *pH. The pH shall not be less than 6.5 nor greater than 9.0. The maximum change permitted as a result of a waste discharge shall not exceed 0.5 pH units.*

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

The impairments are caused by algal and non-algal turbidity and low levels of dissolved oxygen. Iowa does not have numeric water quality criteria for turbidity. The designated uses are based on a narrative water quality standard, "free from aesthetically objectionable conditions." Iowa has specific water quality standards for low dissolved oxygen.

In order to remove the water body/ pollutant from the 303(d) list for the algae and turbidity impairment to uses the water body will meet WQS and the median growing season chlorophyll-a and Secchi depth TSI must not exceed 63 in two consecutive listing cycles, per DNR de-listing methodology.

In order to remove the water body/pollutant from the 303(d) list for the low dissolved oxygen impairment to its uses, the water body will meet WQS and DO levels must not drop below thresholds listed in Table 3-1, per DNR delisting methodology for two consecutive listing cycles.

The EPA agrees that the TMDL will attain and maintain water quality standards.

Pollutant(s) of Concern

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

The TMDL document establishes a link between the narrative water quality standards and the total phosphorus targets. Excessive nutrients can lead to eutrophic conditions associated with the algae and turbidity impairments. Also, the excessive plant and algae growth that result of eutrophication can lead to low DO levels. Chlorophyll-a concentrations and the corresponding trophic state index are used to measure algal growth and the extent of nutrient enrichment and excursions of the narrative water quality standards.

Green Valley Lake is impaired for excessive algae growth, turbidity, and dissolved oxygen. Data interpretation indicates that phosphorus load reduction will best address these impairments. The turbidity is caused by algal growth in the lake. Much of the phosphorus enters the lake attached to sediments. Therefore, practices to reduce phosphorus will also reduce any sediment levels impacting turbidity. The primary focus of the TMDL document is quantifying and reducing phosphorus loads to achieve water quality standards.

The linkage between total phosphorus and the listed impairments is appropriate and will attain and maintain water quality standards.

The EPA agrees that the TMDL document targets the appropriate pollutant.

Source Analysis

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

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

The TMDL document describes the history of the lake and its location in the Green Valley watershed. As there are no point sources located in in the lake's watershed, all load is nonpoint in origin. The document uses a Spreadsheet Tool for Estimating Pollutant Load (STEPL) watershed loading model to estimate an average phosphorus load to the lake. This spreadsheet model uses land use/land cover, precipitation and soil characteristics to estimate loads from the watershed. The modeling parameters and information is provided in an appendix to the document.

Green Valley Lake is a 386-acre lake constructed in 1952 and is surrounded by a 990-acre park. Recreational opportunities include boating, fishing, and swimming. The existing TP load to Green Valley Lake is mainly from nonpoint sources of pollution. Nonpoint sources in the watershed include: erosion from land in row crop production, erosion from grasslands, erosion from timber/wooded areas, transport from developed areas, wildlife defecation, and atmospheric deposition.

Table 1: Average annual TP loads from each source (Table 3-4 in the TMDL document)

Source	**Description**	**TP Load (lb/yr)**	**Percent (%)**
Row Crops	Sheet and rill erosion from corn and soybeans dominated agriculture	5,505.1	78.5
Internal Recycling	Phosphorus in lake sediment	135.3	1.9
Pastureland	Seasonally grazed grassland	281.6	4.0
Urban	Urban areas, roads, and farmsteads	296.3	4.2
Groundwater	Agricultural tile discharge, natural groundwater flow	281.3	4.0
User Defined	Forest, all non-grazed grassland, CRP	407.5	5.8
All others	Wildlife, atmospheric deposition, septic	105.3	1.6
	Total	**7,012.4**	**100**

Livestock:
IDNR reports that there are some Concentrated Animal Feeding Operations (CAFOs) outside the watershed. No CAFO's were reported within the Green Valley Lake watershed. Any CAFO that does not obtain an NPDES permit must operate as a no-discharge facility. A discharge from an unpermitted CAFO is a violation of Section 301 of the Clean Water Act. It is the EPA's position that all CAFOs should obtain an NPDES permit because it provides clarity of compliance requirements. This TMDL document does not reflect a determination by the EPA that such facilities do not meet the definition of a CAFO nor that the facility does not need to obtain a permit. To the contrary, a CAFO that discharges has a duty to obtain a permit. If it is determined that any such operation is a CAFO that discharges, any future WLA assigned to the facility must not result in an exceedance of the sum of the WLAs in this TMDL document as approved. Any future CAFO in the watershed would have zero discharge permits.

Wildlife:
An average deer population of 10 deer per square mile was estimated in the STEPL model. Because data was not available, 5 raccoons, 5 beavers and 5 other per square mile was used to account for wildlife. While phosphorus loads due to geese were not simulated by STEPL, but was added to BATHTUB as an internal load.

Table 2: Land use composition of Green Valley Lake watershed (Table 2-3 in the TMDL document)

Land Use	**Area (acres)**	**Percent (%)**
Corn / Soybean Rotation	3,538	68.4
Forest / Parkland	572	11.0

Grassland / CRP	433	8.4
Developed	164	3.2
Pasture	75	1.4
Water	393	7.6
Total area =	**5,175**	**100.0**

There are no municipal separate storm sewer permits in the applicable watershed.

The TMDL document has identified all known sources of phosphorus in the watershed.

Allocation - Loading Capacity

The submittal identifies appropriate loading capacities, wasteload allocations for point sources and load allocations for nonpoint sources. If no point sources are present, the WLA is stated as zero. If no nonpoint sources are present, the LA is stated as zero [40 CFR § 130.2(i)]. If this is a revised TMDL document the change in loading capacity will be documented in this section. All TMDLs must give a daily number. Establishing TMDL "daily" loads consistent with the U.S. Court of Appeals for the D.C. circuit decision in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006).

The TMDL document uses modeling to determine the maximum total phosphorus load the lake can receive and meet applicable WQS. The form of the load capacity equation is;

TMDL=LC=∑WLA+∑LA+MOS

For this TMDL;

LC = 2,160 lbs/year =0 lbs/year + 1,944 lbs/year + 216 lbs/year on an annual loading basis accounts for how lakes function across a hydrological cycle.

And;

LC = 18.4 lbs/day = 0 lbs/day + 16.6 lbs/day + 1.8 lbs/day on a maximum daily basis using a statistical method outlined in a document appendix.

The LCs are calculated at the monitoring station, but the targeted TP concentrations apply at all points in the segments covered by this TMDL document.

The LCs identified in this document are established to attain and maintain water quality standards.

Wasteload Allocation Comment

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

There are no permitted facilities in the watershed of Green Valley Lake. The WLA is zero.

Load Allocation Comment

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

The LA is the amount of the pollutant load that is assigned to nonpoint sources and includes all existing and future nonpoint sources, as well as natural background contributions. LAs are calculated as the remainder of the LC after the allocations to the WLA and the MOS.

The TMDL document expresses the LA as an annual load of 1,944 pounds and a daily maximum of 16.6 pounds. While estimates are made of load by land use/land cover and the TMDL document provides examples of load reductions and BMPs effective for different land uses/land covers, the LA is given as a sum of all LAs and not broken out by and subdivision of source.

The TMDL document has identified all known nonpoint sources of phosphorus in the watershed

Margin of Safety

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

The TMDL document identifies an explicit 10 percent margin of safety (MOS). An explicit total phosphorus MOS of 10 percent (216 lbs/year, 1.8 lbs/day) was used in the development of the TMDL. Uncertainties could include changes in seasonal nutrients concentrations of influent to the TMDL watershed or changes in internal recycling that could be seasonal.

The EPA agrees that the state has provided explicit MOS to support the TMDL.

Seasonal Variation and Critical Conditions

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

Models used in this TMDL document estimate and use annual loads to generate predictions of annual condition. This is appropriate as the lake is assessed against narrative targets for algae and turbidity, and numeric criteria for dissolved oxygen.

The EPA agrees that the state considered seasonal variation and critical conditions during the analysis of this TMDL and the setting of the TMDL targets.

Public Participation

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

The public was given opportunity to provide feedback during the TMDL process through website postings and public hearings. A public meeting was held on February 28, 2017 and a public presentation was held on November 8, 2017. A public comment period began on October 26, 2017. Comments were accepted until November 27, 2017. No comments were received from the public.

EPA agrees that the public has had a meaningful opportunity to comment on the TMDL document.

Monitoring Plan for TMDL(s) Under a Phased Approach

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

The TMDL document outlines plans for future monitoring. This includes continued ambient monitoring under the DNR Ambient Lake Monitoring Program which was initiated in the year 2000. Implementation monitoring is identified to determine the effect of best management practices undertaken in the watershed. Any such monitoring could include automated samplers as well as grab samples during runoff events. This implementation monitoring would include a greater sampling frequency than that currently undertaken with the ambient monitoring program. It will also require local stakeholders to implement BMPs and monitor success.

Reasonable Assurance

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

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

As there are no point sources located in this watershed, reasonable assurances are not a required component of this TMDL. However, the TMDL document does identify a general approach for planning and implementation which, if followed, will lead to the attainment of applicable water quality standards. Both management and structural BMPs are identified as well as potential total phosphorus reductions to be expected from their implementation.

DEPARTMENT OF NATURAL RESOURCES

GOVERNOR KIM REYNOLDS
LT. GOVERNOR ADAM GREGG

DIRECTOR CHUCK GIPP

December 4, 2017

Bruce Perkins
U.S. EPA, Region VII
11201 Renner Blvd.
Lenexa, KS 66219

Subject: Submittal of Final Green Valley and Thayer Lakes, Union County TMDL for EPA approval

Dear Mr. Perkins:

The Final Green Valley Lake and Thayer Lake, Union County Phase I Total Maximum Daily Load documents completed by the Iowa Department of Natural Resources are enclosed. These lakes were recently included on Iowa's 2016 303(d) list. Included are:

- Green Valley Lake, Phase I TMDL for Algae, Turbidity, and Dissolved Oxygen (IA 05-PLA-00295-L_0)
- Thayer Lake, Phase I TMDL for Algae and Turbidity (IA 05-GRA-01410-L_0)

The draft TMDLs were posted on the Iowa Department of Natural Resources website on October 26, 2017 and comments were accepted from October 26, 2017 to November 27, 2017. On November 8, 2017, a public meeting was held in at the Southwestern Community College in Creston, Iowa to obtain comments and input. The Iowa DNR received no public comments on the draft.

Please accept these documents for approval as the completed TMDLs for Green Valley Lake and Thayer Lake, Union County.

Sincerely,

Allen P. Bonini, Supervisor
Watershed Improvement Section

Enclosure

Water Quality Improvement Plan for

Green Valley Lake

Union County, Iowa

Total Maximum Daily Load
for Algae, Turbidity, and Dissolved Oxygen

Prepared by:
Andrew Frana

Iowa Department of Natural Resources
Watershed Improvement Section
2019

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General Report Summary

What is the purpose of this report?

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

What's wrong with Green Valley Lake?

Green Valley Lake is listed as impaired on the 2014 303(d) list for not supporting its primary contact recreation designated use. The impairment is due to elevated levels of algae and turbidity, which is caused by overly-abundant nutrients and sediment, including sediment-bound phosphorus in the lake. The 2016 303(d) list adds aquatic life support as not supported due to low dissolved oxygen (DO) levels in the lake.

What is causing the problem?

The amount of phosphorus transported to the lake from the surrounding watershed is sufficient to cause excessive growth of algae and excessive levels of turbidity, which reduces water clarity. Phosphorus is carried to the lake in two primary forms: (1) attached to eroded soil that is transported to the lake by rainfall runoff and stream flow, and (2) dissolved phosphorus in runoff and subsurface flow (e.g., shallow groundwater). Phosphorus within the water column and on the lake bed may become resuspended under certain conditions, which can add to algae and turbidity issues. There are no allowable discharging point sources in the Green Valley Lake watershed; therefore all phosphorus loads to the lake are attributed to nonpoint sources.

Low levels of DO can contribute to a diminished aquatic life support for the lake. The main causes of low DO are algal blooms and submerged aquatic vegetation, both of which uptake dissolved oxygen throughout their growth cycles. Continued and excessive low DO levels can cause fish kills.

Nonpoint sources are discharged in an indirect and diffuse manner, and often are difficult to locate and quantify. Nonpoint sources of phosphorus in the Green Valley Lake watershed include sheet and rill erosion from various land uses, runoff and subsurface flows from lands that receive fertilizer application, poorly functioning septic systems, manure deposited by wildlife, and particles carried by dust and wind (i.e., atmospheric deposition). A portion of the phosphorus carried to the lake eventually settles to the lake bottom and accumulates. Under certain conditions, this accumulated phosphorus can become available for algal uptake and growth through an internal recycling process; internal loading was found to be a significant source of phosphorus in Green Valley Lake.

What can be done to improve Green Valley Lake?

Reducing phosphorus loss from row crops and implementing or improving existing structural BMPs such as terraces, grass waterways, and constructed sediment basins in beneficial locations will significantly reduce phosphorus loads to the lake. Special attention should be given to row crops where manure from animal feeding operations is applied. Runoff from these areas can transport high levels of nutrients into Green Valley Lake. Increasing the trapping efficiency of the existing sediment basins may be the most cost effective structural alternative. Additionally, in-lake practices such phosphorus stabilization may be necessary in order to address algae and turbidity concerns post lake renovation.

Who is responsible for a cleaner Green Valley Lake?

Everyone who lives, works, or recreates in the Green Valley Lake watershed has a role in water quality improvement. Nonpoint source pollution is unregulated and responsible for the vast majority of sediment and phosphorus entering the lake. Therefore, voluntary management of land, animals, and the lake itself will be required to achieve measurable improvements to water quality. Many of the practices that protect and improve water quality also benefit soil fertility and structure, the overall health of the agroecosystem, and the value and productivity of the land. Practices that improve water quality and enhance the long-term viability and profitability of agricultural production should appeal to producers, land owners, and lake users alike. Improving water quality in Green Valley Lake, while also improving the quality of the surrounding land, will continue to require collaborative participation by various stakeholder groups, with land owners playing an especially important role.

Does a TMDL guarantee water quality improvement?

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

Reducing pollutants from unregulated nonpoint sources requires voluntary implementation of best management practices. Many solutions have benefits to soil health and sustained productivity as well as water quality. However, quantifying the value of those ecosystem services is difficult, and those benefits are not commonly recognized. Consequently, wide-spread adoption of voluntary conservation practices is often difficult to achieve. A coordinated watershed improvement effort for Green Valley Lake and surrounding lakes could address some of these barriers by providing financial assistance, technical resources, and information / outreach to landowners to encourage and facilitate adoption of conservation practices.

What are the primary challenges for water quality implementation?

In most Iowa landscapes, implementation requires changes in land management and/or agricultural operations. Management decisions may include changes in the number of acres that are actively tilled and the diversity and rotation of crops produced. These changes present challenges to producers by: requiring new equipment (e.g., no-till planters); narrowing planting; harvesting and fertilization windows; and necessitating more active and complex farm management.

Additionally, potential short-term losses in yields are more easily recognized and quantified than long-term benefits to soil health and sustained productivity. It is not easy to overcome existing incentives and the momentum of current practices. Promoting a longer-term view with an emphasis on long-term soil fertility, production, agroecosystem health, and reduced input costs will be essential for successful, voluntary implementation by willing conservation partners. However, water quality improvement and enhancement of Green Valley Lake as a recreational resource are appropriate and feasible near-term goals for a coordinated watershed improvement effort.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Green Valley Lake, Waterbody ID IA 05-PLA-1472, located in S26, T73N, R31W, 2.5 miles NW of Creston
Surface water classification and designated uses:	A1 – Primary Contact B(LW) – Aquatic Life C – Drinking Water Source HH – Human Health (fish consumption)
Impaired beneficial uses:	A1 – Primary Contact
TMDL priority level:	Priority Group 1
Identification of the pollutants and applicable water quality standards (WQS):	Aesthetically objectionable conditions due to algal and non-algal turbidity, low levels of dissolved oxygen due to excessive growth of submergent aquatic vegetation
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of WQS:	Excess algae and turbidity are associated with total phosphorus (TP). The allowable average annual TP load = 2,160 lbs/year; the maximum daily TP load = 18.4 lbs/day.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain WQS:	The existing annual load of 7,012 lbs/year must be reduced by 4,852 lbs/year to meet the allowable TP load. This is a reduction of 72 percent.
Identification of pollution source categories:	There are no regulated point source discharges of phosphorus in the watershed. Nonpoint sources of phosphorus include streambank and gully erosion, fertilizer and manure from row crops, sheet and rill erosion, wildlife, septic systems, groundwater, atmospheric deposition, and others.
Wasteload allocations (WLAs) for pollutants from point sources:	There are no allowable point source discharges.
Load allocations (LAs) for pollutants from nonpoint sources:	The allowable annual average TP LA is 1,944 lbs/year, and the allowable

	maximum daily LA is 16.6 lbs/day.
A margin of safety (MOS):	An explicit 10 percent MOS is incorporated into this TMDL, equating to 216 lbs/year and 1.84 lbs/day.
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.
Reasonable assurance that load and wasteload allocations will be met:	Reasonable assurances for reductions in nonpoint source pollution are provided by (1) a list of BMPs (see Section 4 of this WQIP) that would provide phosphorus reductions, (2) a group of nonstructural practices that prevent transport of phosphorus, (3) proposed methodology for prioritizing and targeting BMPs on the landscape, and (4) best available data for estimating the efficiency/reduction associated with BMPs.
Allowance for reasonably foreseeable increases in pollutant loads:	Although watershed development may continue in the future, an increase in the pollutant load from land use change is not expected.
Implementation plan:	An implementation plan is outlined in Section 4 of this Water Quality Improvement Plan. Phosphorus loading and associated impairments must be addressed through a variety of voluntary management strategies and structural practices.

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 Green Valley Lake, located in Union County in southwest Iowa, is to provide a TMDL for algae and turbidity, which has decreased water quality in the lake. Another purpose is to provide local stakeholders and watershed managers with a tool to promote awareness and understanding of water quality issues, develop a comprehensive watershed management plan, obtain funding assistance, and implement water quality improvement projects. Over-abundance of phosphorus is largely responsible for excessive algal growth, which impairs the primary contact designated use of Green Valley Lake. The impairments are addressed by development of a TMDL that limits total phosphorus (TP) loads to the lake. Phosphorus reductions should be accompanied by reduced algal growth and increased water clarity.

The plan also includes descriptions of potential solutions to the impairments. This group of solutions is presented as a toolbox of best management practices (BMPs) for improving water quality in Green Valley Lake, with the ultimate goal of meeting water quality standards and supporting designated uses. These BMPs are outlined in the implementation plan in Section 4.

The Iowa Department of Natural Resources (DNR) recommends a phased approach to watershed management. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict. Iterative implementation of improvement practices and additional water quality assessment (i.e., monitoring) will help ensure gradual progress towards water quality standards, maximize cost efficiency, and prevent unnecessary or ineffective implementation of costly BMPs. Implementation guidance is provided in Section 4 of this report, and water quality monitoring guidance is provided in Section 5.

This plan will be of limited value unless additional watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and land owners. Experience has shown that locally-led watershed plans have the highest potential for success. The Watershed Improvement Section of DNR has designed this plan for stakeholder use and may be able to provide technical support for the improvement of water quality in Green Valley Lake.

2. Description and History of Green Valley Lake

Green Valley Lake was built in 1952 to create a recreational area in Union County, 2.5 miles northwest of Creston in southwest Iowa. The lake is part of the Green Valley Lake Park, a 990 acre park that is managed by Iowa Department of Natural Resources (IDNR). The park contains close to 12 miles of hiking trails, 145 camping sites, four picnic areas, two open shelters, and a publicly accessible beach.

Table 2-1 lists some of the general characteristics of Green Valley Lake and its watershed, as it exists today. Figure 2-1 shows the vicinity map for the lake system and its watershed. Estimation of physical characteristics such as surface area, depth, and volume are based on a bathymetric survey conducted by DNR in September of 2014.

Table 2-1. Green Valley Lake watershed and lake characteristics

DNR Waterbody ID	ID Code: IA 05-PLA-1472
12-Digit Hydrologic Unit Code (HUC)	102400120102
12-Digit HUC Name	Platte River
Location	Union County, S26, T73N, R31W; 2.5 mi NW of Creston
Latitude	41.10° N (ambient lake monitoring location)
Longitude	94.39° W (ambient lake monitoring location)
Designated Uses	A1 – Primary Recreation B(WW-1) – Aquatic Life C – Drinking Water Supply HH – Human health (fish consumption, drinking water)
Tributaries	Platte River, unnamed streams
Receiving Waterbody	Mitchell Marsh, River, Summit Lake, to Platte River
Lake Surface Area	[1]386 acres
Length of Shoreline	[1]50,030 feet
Shoreline Development Index	3.44
Maximum Depth	[1]26.5 feet
Mean Depth	[1]10.5 feet
Lake Volume	[1]4,056 acre-feet
Watershed Area	5,175 acres (includes lake)
Watershed:Lake Ratio	12:1
Lake Residence Time	[2]246 days

[1] Per Sept 2014 bathymetric survey and subsequent calculations
[2] BATHTUB model prediction for average annual conditions (2002-2008 and 2012-2016)

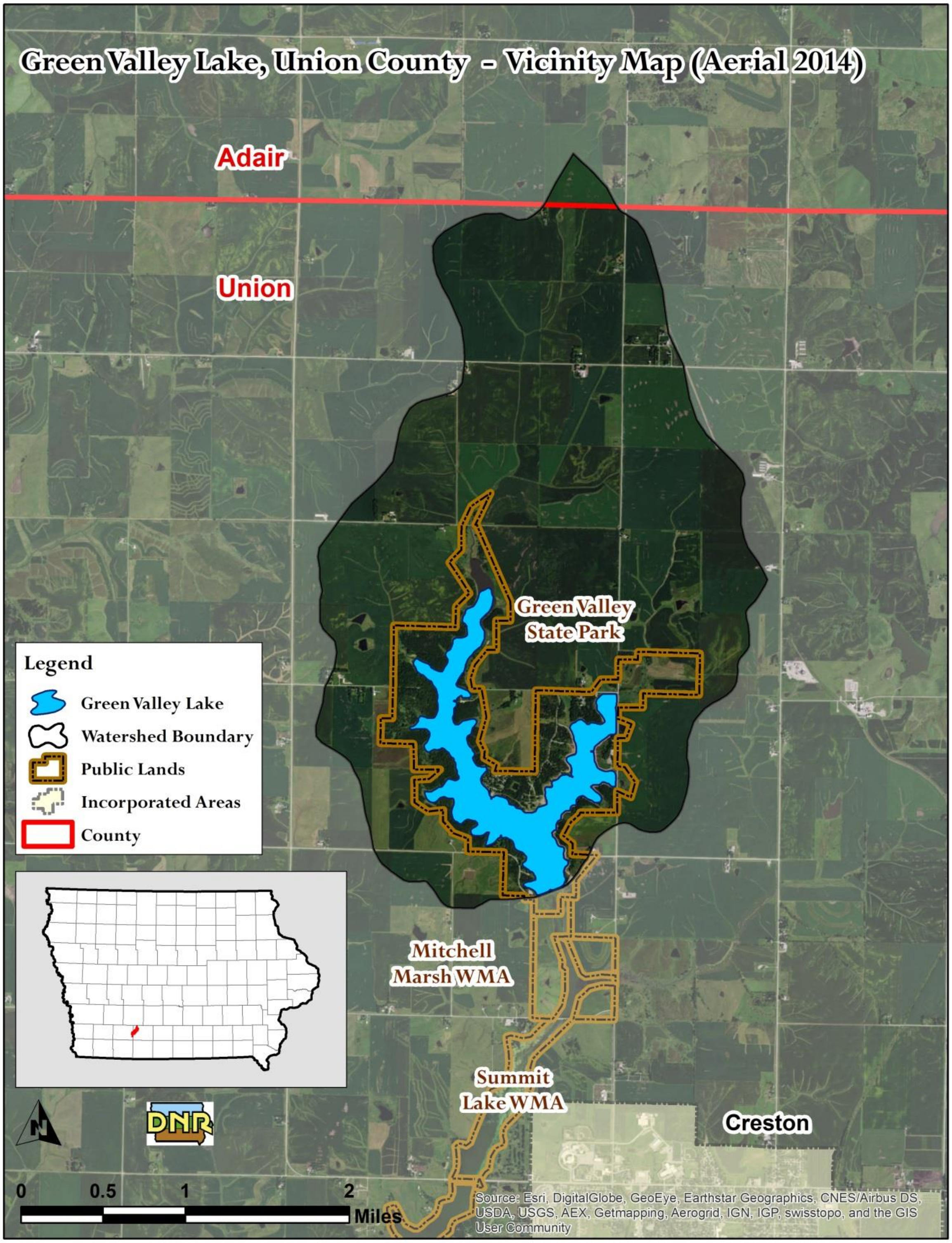

Figure 2-1. Vicinity Map

Water Quality History
Water quality data has been collected through the statewide survey of Iowa Lakes which was conducted from 2000 through 2016 by Iowa State University. A statewide ambient lake monitoring program conducted in 2008 by the State Hygienic Laboratory (SHL) also provided data on the water quality Green Valley Lake. A targeted water quality program conducted by Iowa Department of Natural Resources and analyzed by SHL took place in 2014 and 2015 to aide in the formation of future water quality improvement plans.

An Erosion and Sediment Worksheet provided by Natural Resource Conservation Service (NRCS) was done in 2007 to determine sheet and rill erosion, and sediment delivery to the lake. C- and P- factors for the analysis were provided by local watershed personnel.

Prior to the 2008 drawdown and renovation, tributary data was collected in concert with supplemental lake water quality sampling. This supplemental water quality collection also included bacteria analyses at the tributary sites and on the beach of Green Valley Lake. All water quality data used in the document are listed in Appendix C – Water Quality Data.

2.1. Green Valley Lake

Hydrology
Extensive lake management history is available for Green Valley Lake since its construction in 1952. The first lake drawdown and fishery renovation to improve water quality was in 1974, with subsequent drawdowns and fishery renovations taking place in 1986, 1999, and most recently 2008. Dredging to restore water quality and improve fish habitat took place in the 1999 and 2008 drawdowns. Most recently, shoreline stabilization measures around the lake and sediment bay renovations in the arms of the lake have provided protection from shoreline loss and sedimentation.

The National Weather Service (NWS) Cooperative Program (COOP) station in Creston, Iowa reports daily maximum and minimum temperature and precipitation. The Iowa State Climatologist provides quality control of these data, which are downloadable from the Iowa Environmental Mesonet (IEM, 2016a). Daily observations between January 1, 2002 and December 31, 2016 were used in climate assessment and model development. Daily potential evapotranspiration (PET) data were obtained for 2002-2016 from the Iowa Ag Climate Network, also downloadable from the IEM (IEM, 2016b). Table 2-2 reports weather station information.

Table 2-2. Weather station information for Green Valley Lake

Data	Temperature/Precipitation	Potential ET
Network	NWS COOP	ISU Ag Climate
Station Name (ID)	Creston, IA (IA1962)	Lewis (A134759)
Latitude	Latitude: 41.037°	41.313°
Longitude	Longitude: -94.394°	-95.173°

Due to lack of water quality data availability in years 2009-2011, climatological data from that same period will be removed from watershed and lake analyses. This gap is reflected in Figure 2-2 below. Average annual precipitation near Green Valley Lake was 35.4 inches from 2002-2008 and 2012-2016. Years 2007, 2008, and 2015 were, on average, much wetter than normal, with an annual average rainfall amount of 48.3 inches per year. Conversely, years 2002, 2003, 2005, and 2013 were much drier than normal, with an annual average rainfall of only 28.1 inches per year. Figure 2-2 illustrates the annual precipitation totals, along with lake evaporation (estimated as 70 percent of annual PET). This chart shows an inverse relationship between precipitation and lake evaporation, mainly due to climatological factors such as cloud cover and temperature. Wet years of 2007-2008, and 2015 show a surplus of precipitation, while 2012 shows a precipitation deficit in comparison to lake evaporation.

Figure 2-2. Annual precipitation and estimated lake evaporation

Precipitation varies greatly by season in southwestern Iowa, with 75 percent of annual rainfall occurring between April and September. Monthly average precipitation is illustrated in Figure 2-3, along with estimated evapotranspiration (ET) in the watershed based on k values of the watershed vegetation cover. Years included in the monthly precipitation analysis coincide with the annual precipitation analysis and water quality data availability. Although precipitation is highest during the growing season, so is ET, and a seasonal moisture deficit often occurs between June and September. Note that watershed ET is typically higher than lake evaporation in the summer months, a result of high temperatures and vegetation transpiring large volumes of moisture from the soil during the peak of the growing season. It is often during this period that harmful algal blooms develop in waterbodies, as water heats up and lake flushing is minimal. Additionally, although watershed ET is high, the watershed to lake ratio (12:1) is relatively low, meaning that rainfall events producing runoff will not affect lake water levels as dramatically as higher watershed to lake ratios. Together, the high watershed ET and low watershed to lake ratio keep the lake water level stable over time.

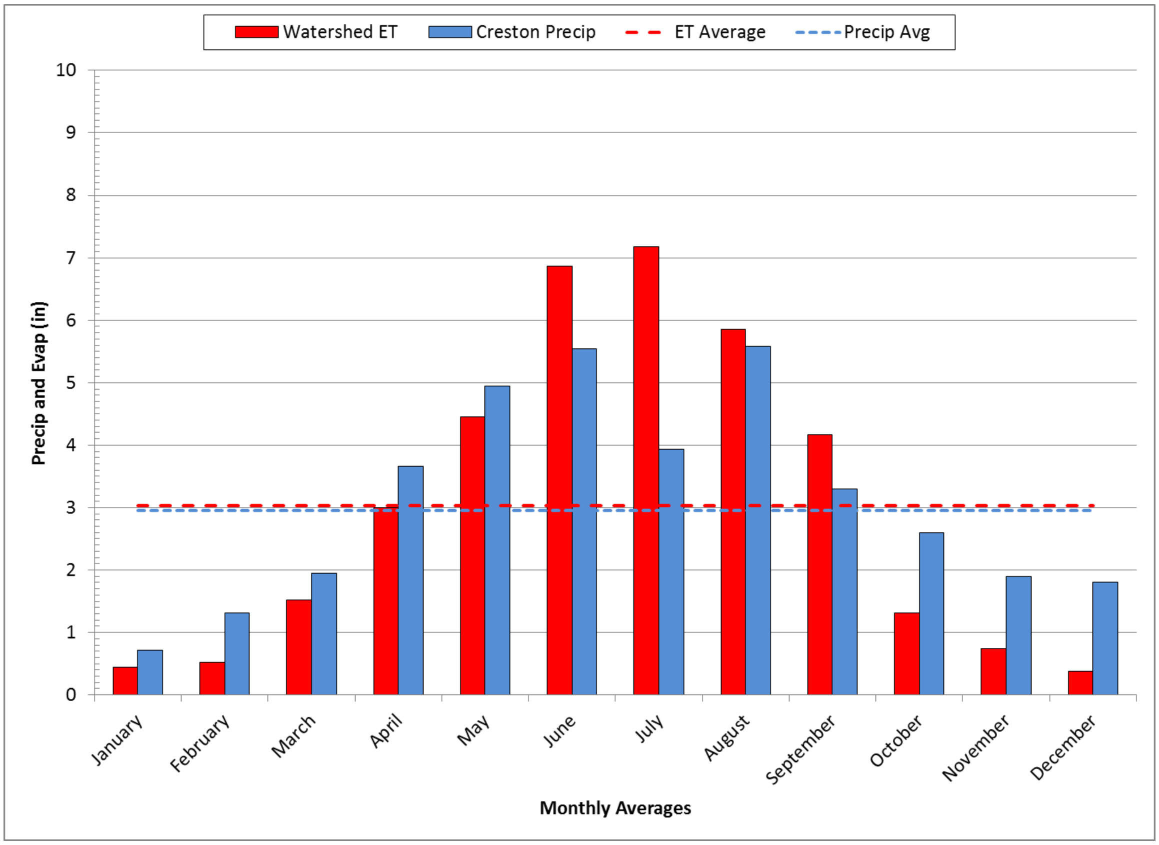

Figure 2-3. Monthly precipitation and estimated ET for the watershed

Rainfall runoff, direct precipitation, evapotranspiration, shallow groundwater flow, and deep aquifer recharge are all part of the lake's hydrologic system. Estimated residence time is based on annual precipitation and evaporation data, Spreadsheet Tool for Estimating Pollutant Load (STEPL) estimates of average annual inflow, and a water balance calculated within the BATHTUB model. The BATHTUB water balance calculation includes: inflows (from STEPL), direct precipitation, evaporation calculated from measured PET at Lewis, Iowa and obtained from the Iowa State University Ag Climate Network on the Iowa Environmental Mesonet (IEM, 2016b), and lake morphometry.

During years of below average precipitation, residence time increases. In wet years, the opposite is true as residence time decreases. In lakes with smaller watershed to lake ratios the residence time may be longer than lakes with higher residence times. The calculated residence time (246 days for average conditions) suggests that internal loading may play a role in algal blooms, since the flushing rate is low compared with most Iowa lakes.

Morphometry
According to the most current bathymetric data (Sept 2014), the surface area of Green Valley Lake is 386 acres. Estimated water volume of the main lake is 4,056 acre-feet (ac-ft), with a mean depth of 10.5 ft and a maximum depth of 26.5 ft in the southern section of the lake near the outfall. The reservoir has an irregular shape, with two distinct sections one to the northwest and one northeast of the public beach. Evidence of sedimentation in the lake and at upstream, impoundments suggests that the watershed of Green Valley Lake has a large impact on water quality. The significance of sediment (and associated phosphorus) loading from the watershed is further evidenced by the shoreline development index of 3.44, which is high. Values greater than 1.0 suggest the shoreline is highly dissected and indicative of a high degree of watershed influence (Dodds, 2000). High indexes are frequently observed in man-made reservoirs, and it is not surprising that watershed processes are critically important for the chemical, physical, and biological processes that take place in Green Valley Lake. Lake morphometry and bathymetry data are shown in Figure 2-4.

2.2. The Green Valley Lake Watershed

The watershed boundary of Green Valley Lake encompasses 5,175 acres (including the lake) and is illustrated in Figure 2-1. The watershed-to-lake ratio of 12:1 is below the threshold of 20:1, indicating a high potential for successful lake restoration. Mitigation of watershed influence will be required, and in-lake techniques may have short effective life spans in the absence of watershed improvements and renovations. A prudent watershed management strategy should focus on water quality improvement, problem areas that can be most easily addressed, and implementing alternatives that provide multiple benefits in addition to water quality, such as increased soil health, erosion reduction, and habitat enhancement. Watershed management and implementation strategies are discussed in more detail in Section 4 – Implementation Planning.

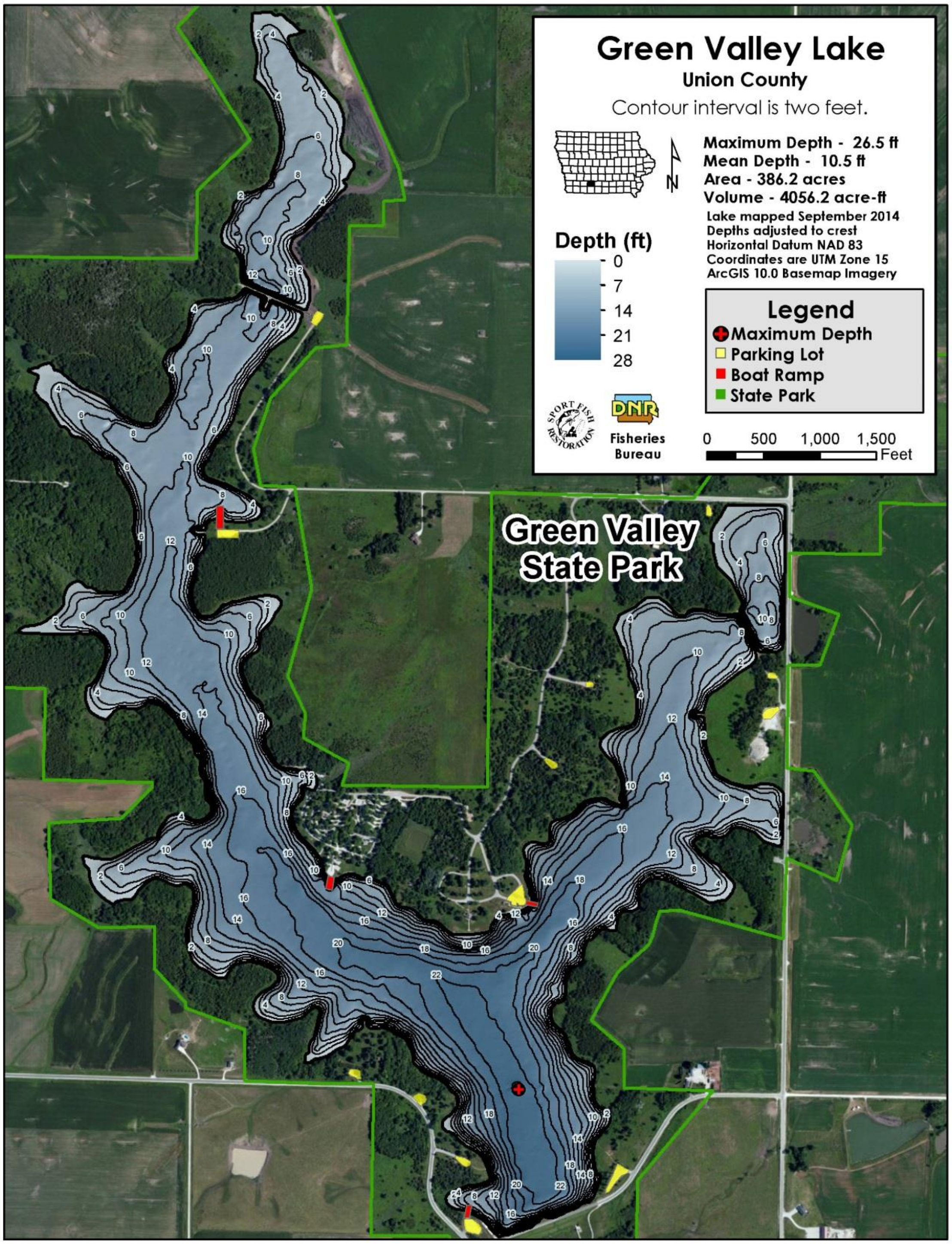

Figure 2-4. Bathymetric map of Green Valley Lake

Land Use

A Geographic Information System (GIS) coverage of land use information was developed using a tablet assessment based on field observations done in 2007 prior to the most recent drawdown and renovation of the lake. The tablet assessment notes landuse, conservation practices, and expected sediment loads based on a RUSLE assessment. The assessment was part of the diagnostic feasibility study done by Iowa DNR.

In addition to the tablet assessment, landuse, tillage, and management information was collected by state and local watershed personnel via 2017 windshield survey of the watershed. Due to annual changes in agricultural management in the watershed, areas with multiple land covers consisting of soybean and corn ground have been aggregated together under a “Row Crop” land cover (68.4 percent total area). Wooded grounds around the Green Valley Lake Park were modeled as forest area (11.0 percent). Two main types of grassland were modeled: grazed and ungrazed. Grazed grassland consists of pasture with livestock present (1.4 percent), while all other grassland and conservation reserve program (CRP) lands were modeled as ungrazed (8.4 percent). Farmstead and road areas were modeled as developed areas (3.2 percent). Assessment period land use is shown in Figure 2-5 and itemized in Table 2-3.

Analysis of historical aerial photography data reveals several trends. The size of common land units has increased with the consolidation of land and land owners. Crop diversification has decreased substantially in recent times to mainly consist of corn / soybean rotations. The implementation of contour strips, and grassed waterways in the watershed has increased over the years as have other conservation practices, while total cropland has slowly increased. Areas which were pasture or grassland in early years of the assessment period, but then changed to row crop will be modeled as row crop acres for the entire assessment period as a conservative measure.

Table 2-3. Land use composition of Green Valley Lake watershed

Land Use	Area (acres)	Percent (%)
Corn / Soybean Rotation	3,538	68.4
Forest / Parkland	572	11.0
Grassland / CRP	433	8.4
[1]Developed	164	3.2
Pasture	75	1.4
[2]Water	393	7.6
Total area =	**5,175**	**100.0**

[1] Includes roadways, paved lots, commercial, industrial, and residential areas

[2] Includes Green Valley Lake surface area

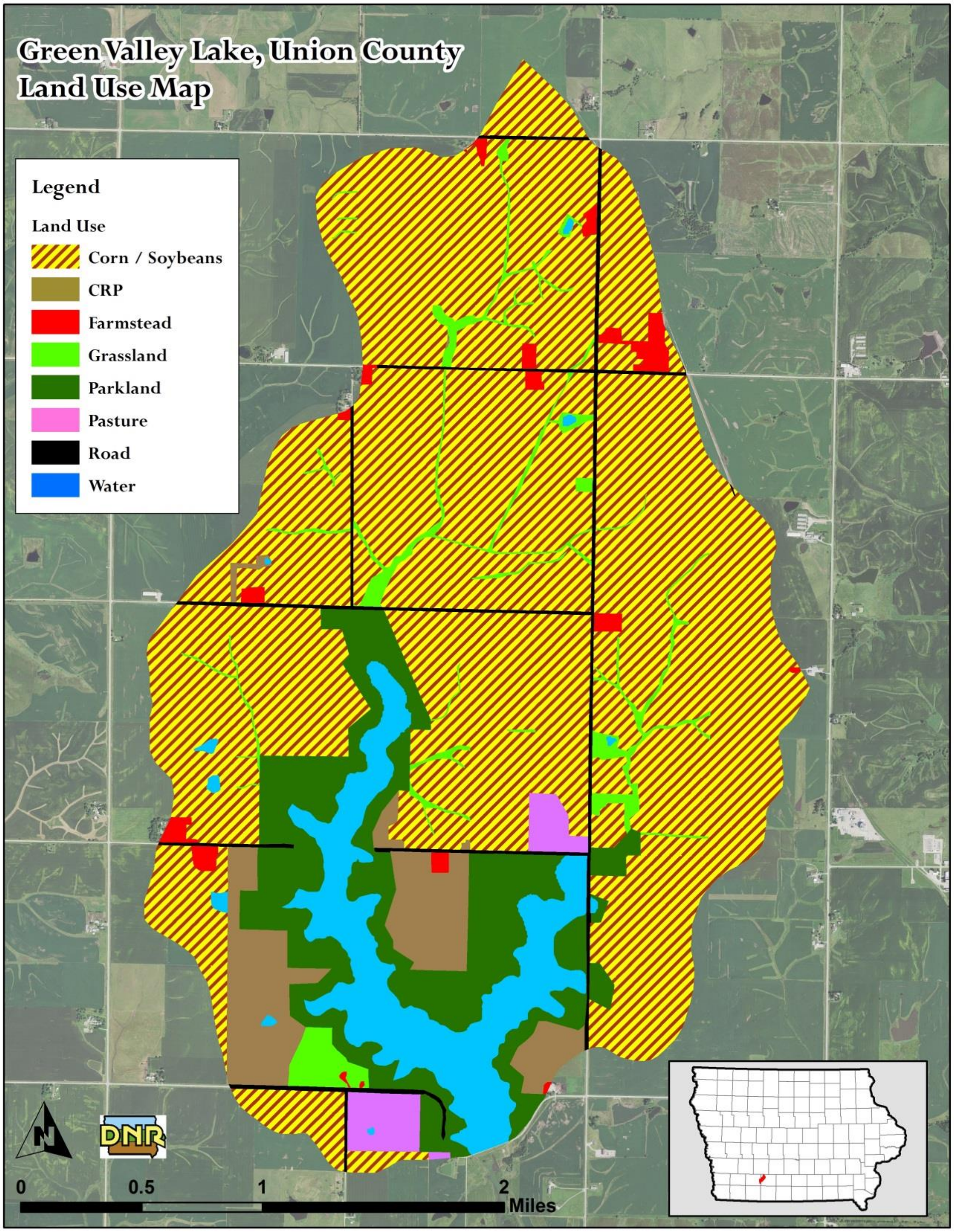

Figure 2-5. Green Valley Lake watershed land use map

Soils, Climate, and Topography

The Green Valley Lake watershed is in the central region of the Iowan Surface. Four soils series dominate the Green Valley Lake watershed, as shown in Figure 2-6 and Table 2-4. Of these, the Sharpsburg / Shelby / Adair soil association and its complexes comprise 54.6 percent of the watershed. These soils are characterized by gently rolling, long slopes of loess on broad ridges and outcrops of till plains (USDA-NRCS, 1979). This association is moderately well drained to somewhat poorly-drained. Table 2-4 and Figure 2-6 show descriptions and percentages of all major soils in the watershed. Many of the lower formations have been drained for use in agriculture. All other minor classes are listed as “Other.”

Table 2-4. Predominant soils of the Green Valley Lake watershed

Soil Name	Area (ac)	Area (%)	Description of Surface Soil Layer	Typical Slopes (%)
Sharpsburg	1335.2	25.8	Very deep, moderately well drained soils formed in loess	0-18
Nira-Sharpsburg	1109.9	21.5	Very deep, moderately well drained soils formed in loess	0-18
Coly-Ely	657.0	12.7	Very deep, poorly drained soils formed in alluvium and colluvium	0-9
Clarinda	537.8	10.4	Very deep, poorly drained soils formed in a till paleosol	5-18
Macksburg	452.3	8.7	Very deep, somewhat poorly drained soils formed in loess	0-9
Adair-Shelby	376.8	7.3	Very deep, somewhat poorly drained soils formed in loess over till	2-30
Clearfield	112.0	2.2	Very deep, poorly drained soils formed loess underlain by paleosol	5-14
Winterset	105.5	2.0	Very deep, poorly drained soils formed in loess	0-5
Others	92.9	1.7	Varies	Varies
Water	395.8	7.7	---	---
Total	5175.2	100.0	Varies	Varies

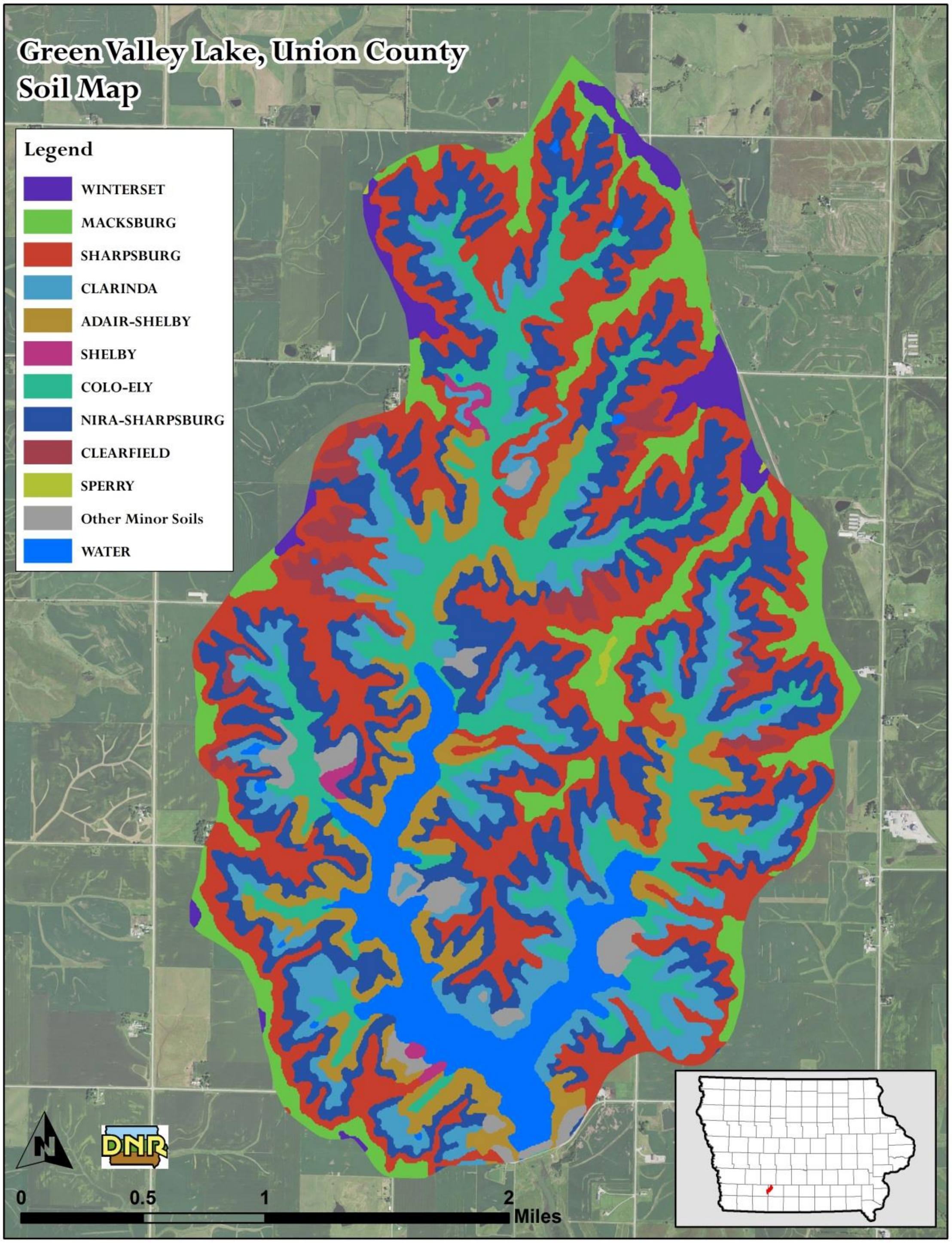

Figure 2-6. Green Valley Lake soil classification map

The topography consists of well-defined drainage systems formed by extensive erosion through glacial till, in some areas loess has been deposited over this till. In some areas, prolonged erosion has led to underlying sedimentary rock being exposed. Slopes are therefore mostly gently sloping, to sloping, but there are areas of strongly sloping to moderately steep slopes where the topography transitions to developed areas. Flat to gently sloping (0 – 5 percent slope) regions make up 90 percent of the watershed. The majority of slopes above 9 percent are part of roadway drainage ditch networks in the watershed. Table 2-5 shows the percentage breakdown of slope classifications throughout the watershed, and Figure 2-7 illustrates the distribution of the slopes within the Green Valley Lake watershed.

Table 2-5. Slope classifications of the Green Valley Lake watershed

Slope Class (%)	Area (%)	Description of Slope Class
0 – 2 (Class A)	39.6	Flat to very gently sloping
2 – 5 (Class B)	50.4	Gently sloping
5 – 9 (Class C)	9.3	Sloping
9 – 14 (Class D)	0.6	Strongly sloping
14 and up (Class E, F)	0.1	Moderately steep, steep
Total	100.0	---

The combination of soil classification, slope, topography, and hydrologic soil group (discussed more in Appendix D) indicate that the majority of agricultural areas in the Green Valley Lake watershed would not be tile drained. The absence of drainage district data and anecdotal data on tile drainage location also indicate that minimal drainage is present in the watershed. Agricultural management practices related to tile drainage may change in the future, which would lead to changes in watershed loading and its effects on Green Valley Lake.

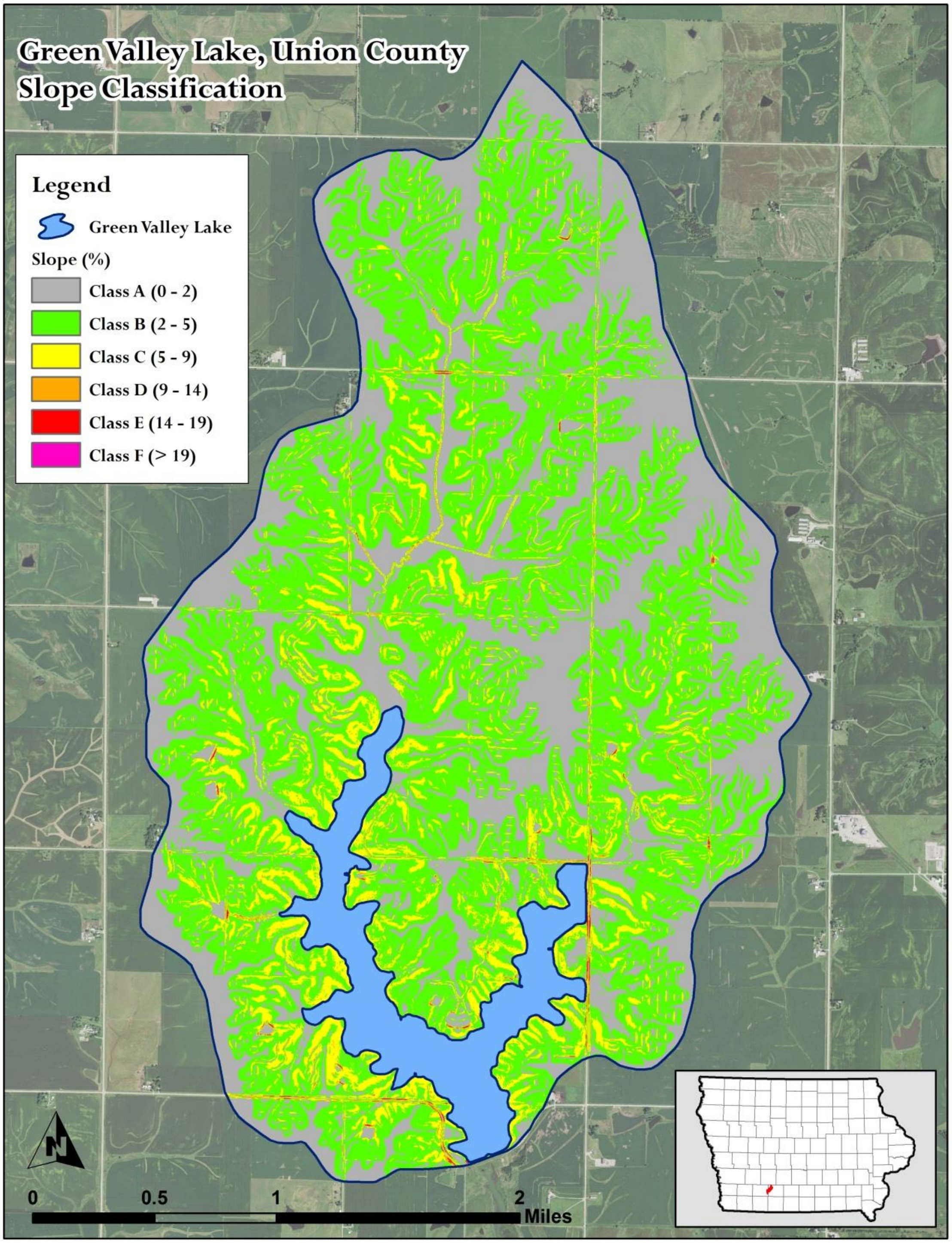

Figure 2-7. Slope classifications in the Green Valley Lake watershed

3. TMDL for Algae, Turbidity, and Low DO

A Total Maximum Daily Load (TMDL) is required for Green Valley 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 fully support primary contact in Green Valley Lake, which is impaired by algae and non-algal turbidity. This section includes an evaluation of Green Valley Lake water quality, documents the relationship between algae, turbidity, and TP in Green Valley Lake, and quantifies the in-lake target and corresponding TMDL.

This section also includes discussion on low dissolved oxygen in Green Valley Lake, which has caused the aquatic life support designated use to be classified as "not supporting" in the draft 2016 305(d) assessment list. The cause of low DO has been linked to organic enrichment, which is indirectly associated with phosphorus levels in the lake.

3.1. Problem Identification

Green Valley Lake is a Significant Publicly Owned Lake, and is protected for the following designated uses:

- Primary Contact – Class A1
- Aquatic life – Class B(LW)
- Drinking Water Supply – Class C
- Fish consumption – Class HH

The 2014 Section 305(b) Water Quality Assessment Report states that primary contact designated use in Green Valley Lake is assessed (monitored) as "not supported" due to poor water quality caused by algal and non-algal turbidity. The 2014 assessment is included in its entirety in Appendix H, and can be accessed at https://programs.iowadnr.gov/adbnet/Assessments/Legacy/16214

The preliminary 2016 Section 305(b) Water Quality Assessment report adds an aquatic life support impairment due to organic enrichment: low dissolved oxygen (DO). This is due to significantly greater than 10 percent of days failing to meet 16 hour criteria as defined in the applicable water quality standards.

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

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

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

The specific water quality standard for dissolved oxygen impairments is listed below in subrule (1):

61.3(3) Specific water quality criteria.

b. *Class "B" waters. All waters which are designated as Class B(CW1), B(CW2), B(WW-1), B(WW-2), B(WW-3) or B(LW) are to be protected for wildlife, fish, aquatic, and semiaquatic life. The following criteria shall apply to all Class "B" waters designated in subrule 61.3(5).*
    1) *Dissolved oxygen. Dissolved oxygen shall not be less than the values shown in Table 2 of this subrule.*
    2) *pH. The pH shall not be less than 6.5 nor greater than 9.0. The maximum change permitted as a result of a waste discharge shall not exceed 0.5 pH units.*

Table 3-1 below is the referenced low dissolved oxygen specific water quality criteria from section 61.3(3)b(1). The levels are specific to each class of waterbody. All values are expressed in milligrams per liter.

Table 3-1. Specific water quality standards for low dissolved oxygen

Criteria	Waterbody Class					
	B(CW1)	B(CW2)	B(WW-1)	B(WW-2)	B(WW-3)	[1]B(LW)
Min value for at least 16 hours of every 24 hour period	7.0	7.0	5.0	5.0	5.0	5.0*
Min value at any time during every 24 hour period	5.0	5.0	5.0	4.0	4.0	5.0*

*applies only to the upper layer of stratification in lakes

For 303(d) listing purposes, aesthetically objectionable conditions are present in a waterbody when Carlson's Trophic State Index (TSI) for the median growing season chlorophyll-a exceeds 65 (DNR, 2008). In order to de-list the algae and turbidity impairments for Green Valley Lake, the median growing season chlorophyll-a and Secchi depth TSI must not exceed 63 in two consecutive listing cycles, per DNR de-listing methodology. In order to delist the low dissolved oxygen impairment from the draft 2016 assessment for Green Valley Lake, DO levels must not drop below thresholds listed in Table 3-1, per DNR delisting methodology for two consecutive listing cycles.

Problem Statement

Green Valley Lake is impaired because aquatic life uses in the lake are not fully supported due to violations of WQS. High levels of algal production and turbidity fueled by phosphorus loads to the lake cause the impairment. TP loads must be reduced in order to reduce algae and fully support the lake's designated uses. The TP reductions will reduce chl-a (an algae indicator) that will stabilize pH in the water column.

Excess nutrients, particularly phosphorus, can cause eutrophic conditions associated with the algae and turbidity impairments to Green Valley Lake. Excess plant and algae growth, driven by excess nutrients, can often lead to low DO levels when the aquatic plants die and are broken down by oxygen consuming organisms. Therefore, addressing the algae impairment in Green Valley Lake by targeting phosphorus will also address the organic enrichment/low DO impairment.

Data Sources

Sources of data used in the development of this TMDL include those used in the 2014 305(b) report, several sources of additional water quality data, and non-water quality related data used for model development. Sources include:

- Ambient Lake Monitoring and / or TMDL monitoring including:
    - results of available statewide surveys of Iowa lakes sponsored by DNR and conducted by Iowa State University 2002-2016
    - available water quality data collected by the State Hygienic Laboratory (SHL) at the University of Iowa from 2008-2012
- Precipitation Creston, Iowa, from the NWS COOP program (IEM, 2016a)
- PET data at Lewis, Iowa, the ISU Ag Climate Network (IEM, 2016b)
- 3-m Digital Elevation Model (DEM) available from DNR GIS library
- SSURGO soils data maintained by United States Department of Agriculture – Natural Resource Conservation Service (USDA-NRCS)
- Aerial images (various years) collected and maintained by DNR
- Lake bathymetric data collected in September 2014

Interpreting Green Valley Lake Data

The 2014 305(b) assessment was based on results of the ambient monitoring program conducted from 2008 through 2012 by ISU and SHL, and information from the DNR Fisheries Bureau. Assessment of available in-lake water quality in this TMDL utilized available SHL and ISU data from 2002-2016. All data was collected at the ambient monitoring location, which is shown in Figure 3-1. Development of the in-lake target, the TMDL, and impairment status are based on data collected at this location, per DNR assessment methodology. In-lake water quality data is reported in Appendix C.

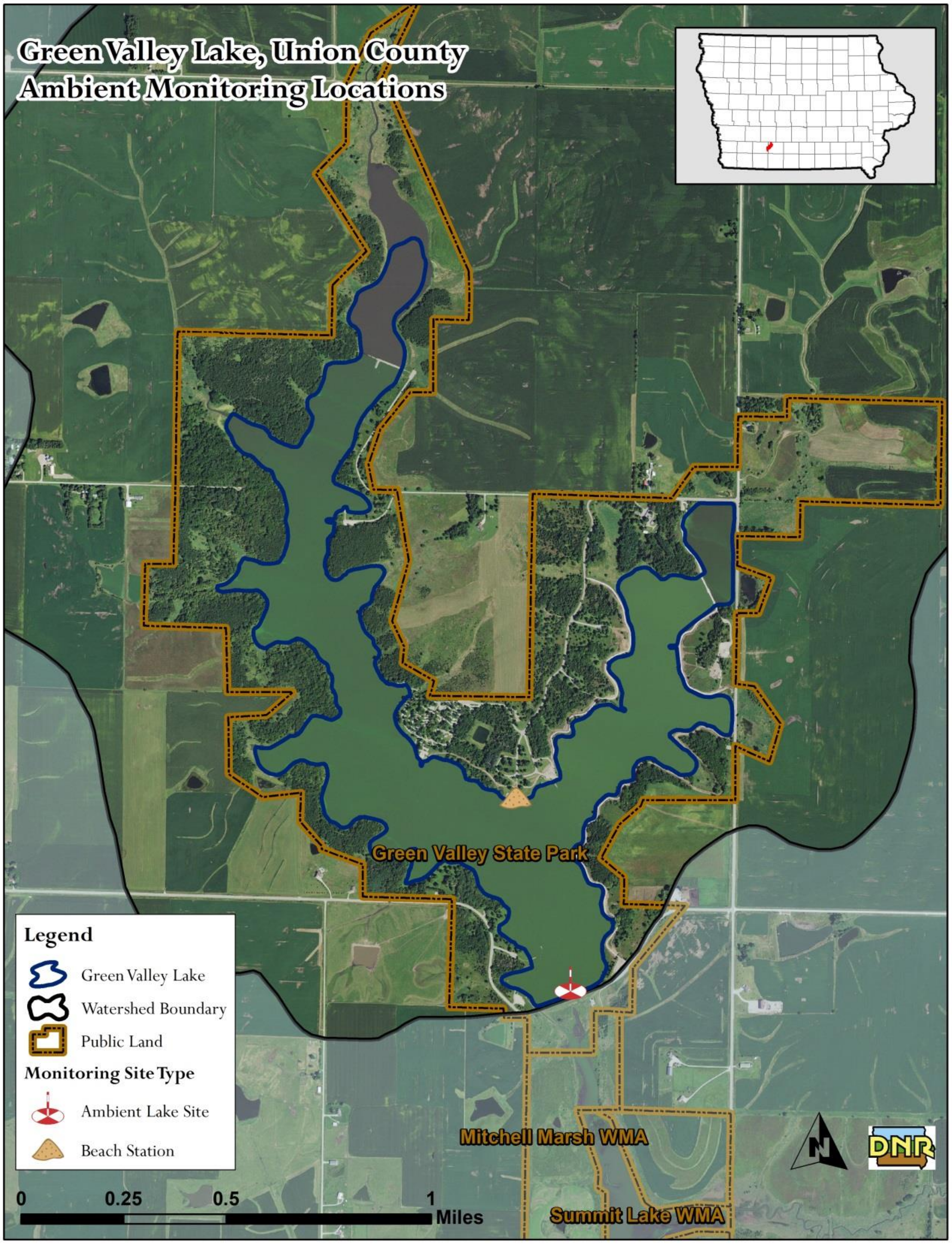

Figure 3-1. Ambient monitoring location for water quality assessment

Carlson's TSI was used to evaluate the relationships between TP, algae (chlorophyll-a), and transparency (Secchi depth) in Green Valley 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. Figure 3-2 illustrates each of the individual TSI values throughout the analysis period. TSI values that exceed the 303(d) listing threshold of 65 (for chlorophyll-a) are in the red-shaded box on the top half of Figure 3-2.

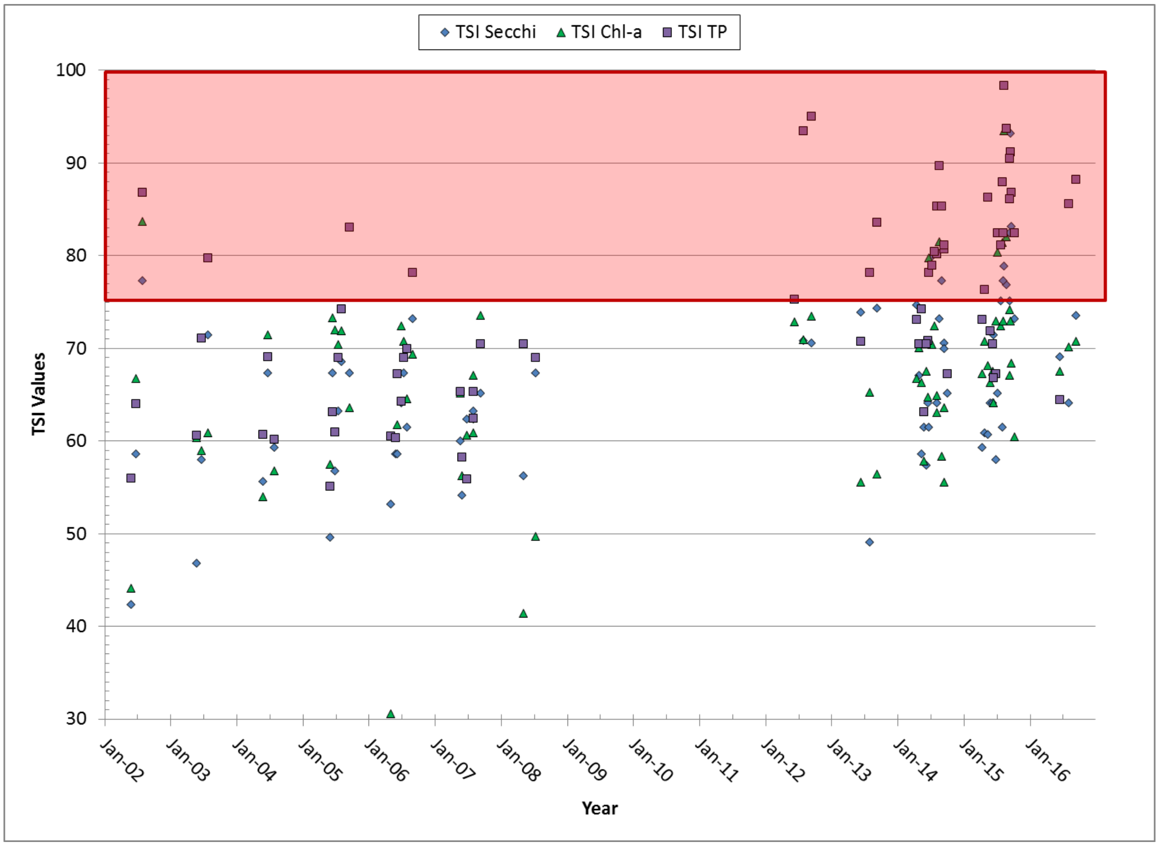

Figure 3-2. Growing season TSI values for individual samples in analysis period

Averaging the growing season TSI values for each year in the analysis period results in overall TSI values of 61 for Secchi depth, 69 for chlorophyll-a, and 77 for phosphorus. These values can be shown in Figure 3-3. The water clarity trend post renovation is positive, with decreasing TSI values for TP, and Secchi depth, and chl-a. However, there was a marked initial increase in TSI values post renovation, most likely due to construction in and around the lake disturbing sediment. Averaging growing season TSI values from data used in the 2014 Water Quality Assessment (2008-2012) results in TSI values of 68 for Secchi depth, 68 for chlorophyll-a, and 87 for TP.

Subsequent analyses show the link between the three indices of in-lake water quality. Figure 3-4 shows the relationship between total phosphorus and Secchi depth TSI values. Figure 3-5 shows the relationship between chlorophyll-a and total phosphorus. Figure 3-6 shows the relationship between Secchi depth and total phosphorus. The R^2 values between the various TSI indices are summarized in Table 3-1 below for pre renovation (2002-2008) and post renovation (2012-2016) time periods. There is a good correlation between phosphorus and Secchi depth, and moderate agreement between chlorophyll-a and Secchi depth. This suggests that transparency issues can be aggravated by algae in the water column. This also indicates that targeting phosphorus reductions in the watershed may improve chlorophyll-a and Secchi depth TSI values in Green Valley Lake.

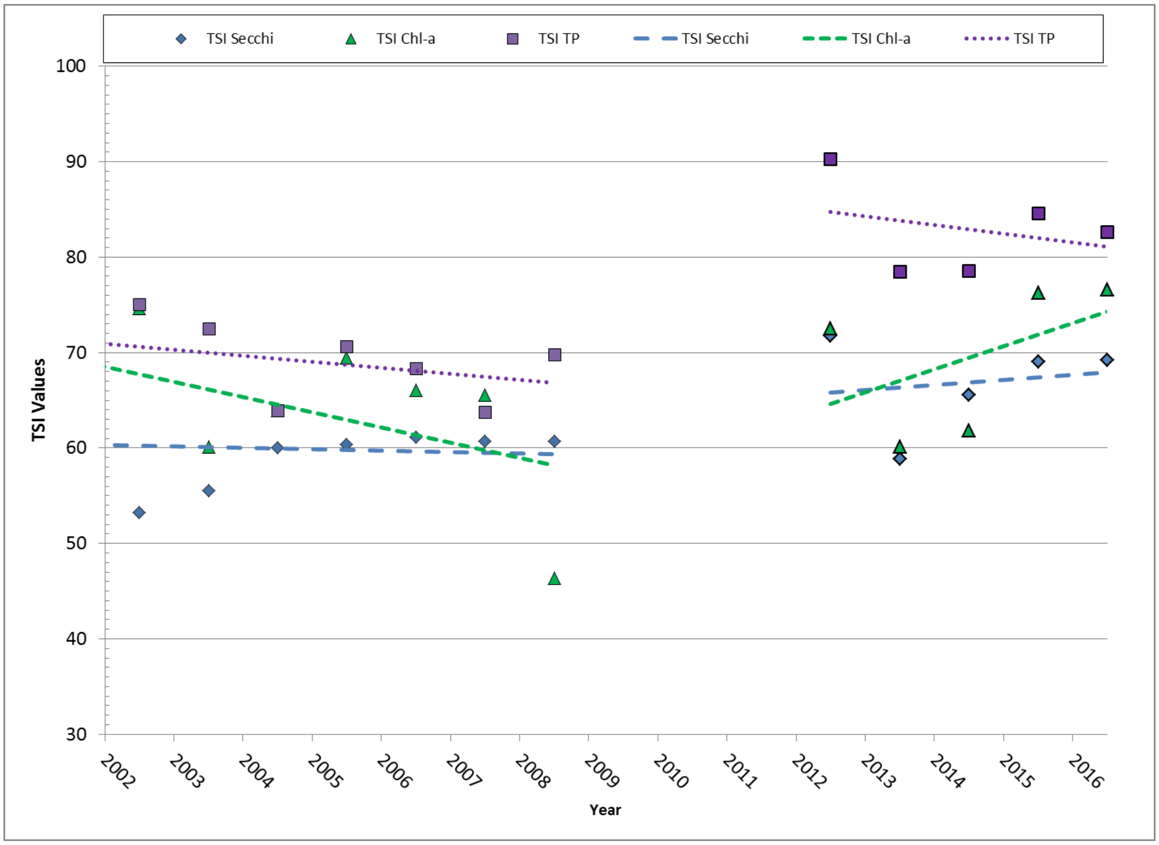

Figure 3-3. Growing season mean TSI values for analysis period

Table 3-1. TSI values and R^2 values when compared linearly pre and post renovation

TSI indicator	Total Phosphorus Pre (Post)	Chlorophyll-a Pre (Post)
Secchi depth Pre (Post)	0.040 (0.519)	0.347 (0.325)
Chlorophyll-a Pre (Post)	0.169 (0.229)	---

Table 3-2. TSI values with R^2 values compared to total nitrogen

TSI indicator	Total Nitrogen Pre (Post)
Secchi depth	0.043 (0.136)
Chlorophyll-a	0.008 (0.109)
Total Phosphorus	0.037 (0.197)

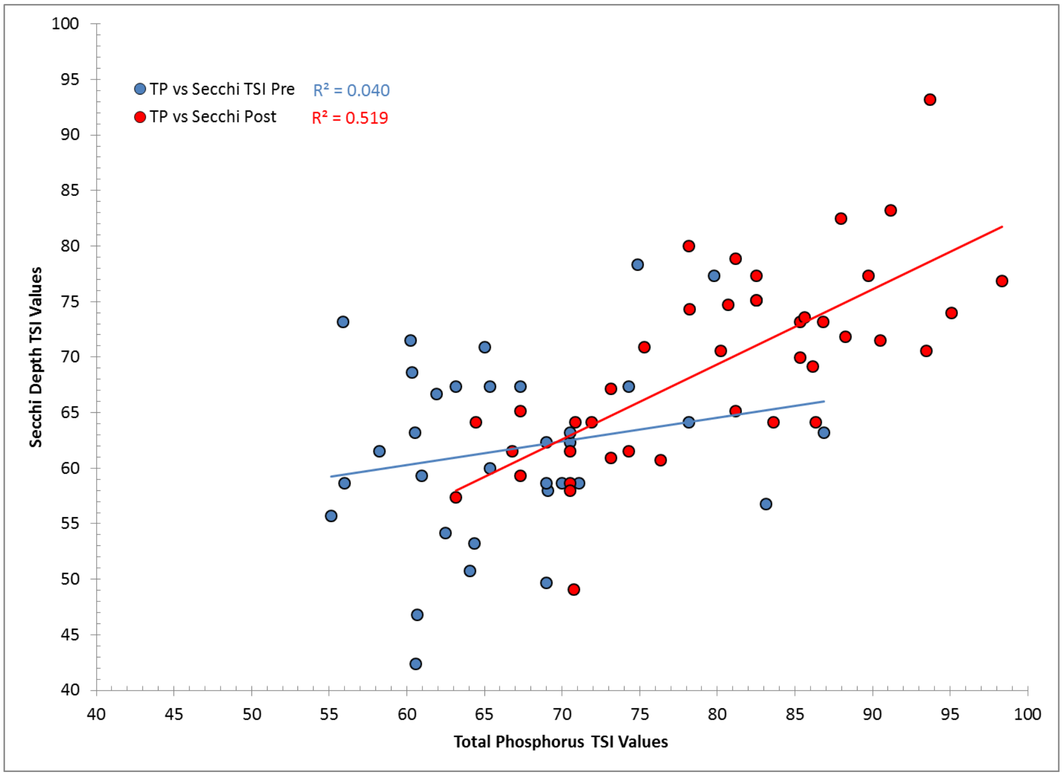

Figure 3-4. Analysis period TSI values for total phosphorus and Secchi depth

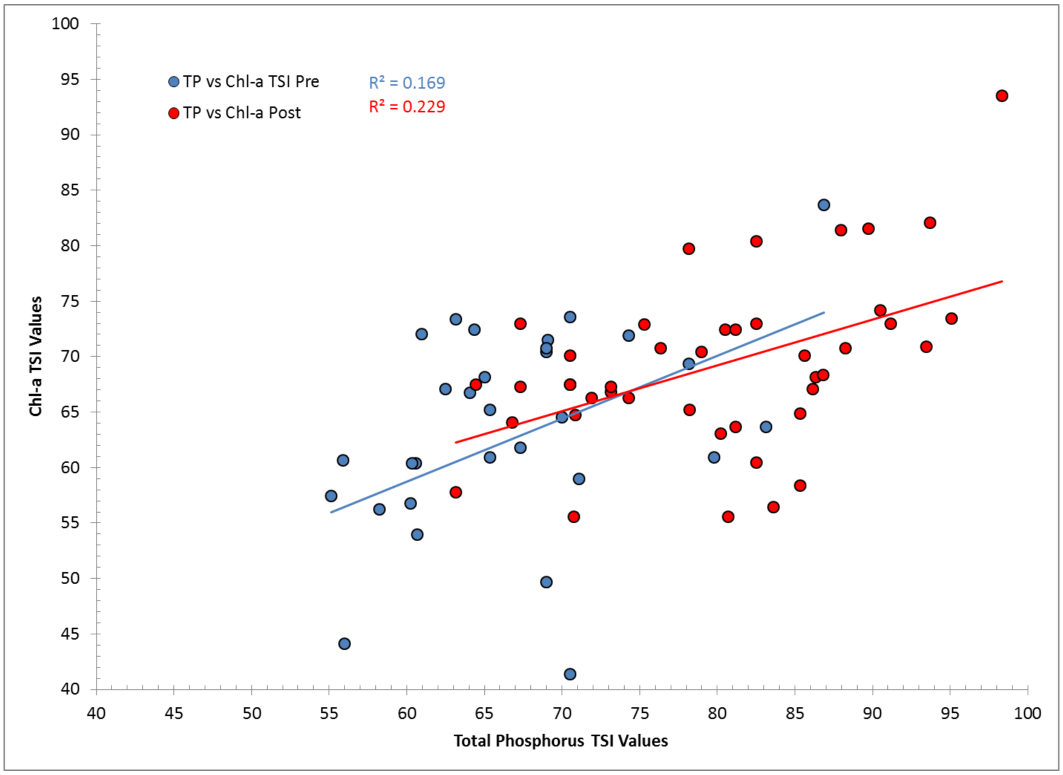

Figure 3-5. Analysis period TSI values for total phosphorus and chlorophyll-a

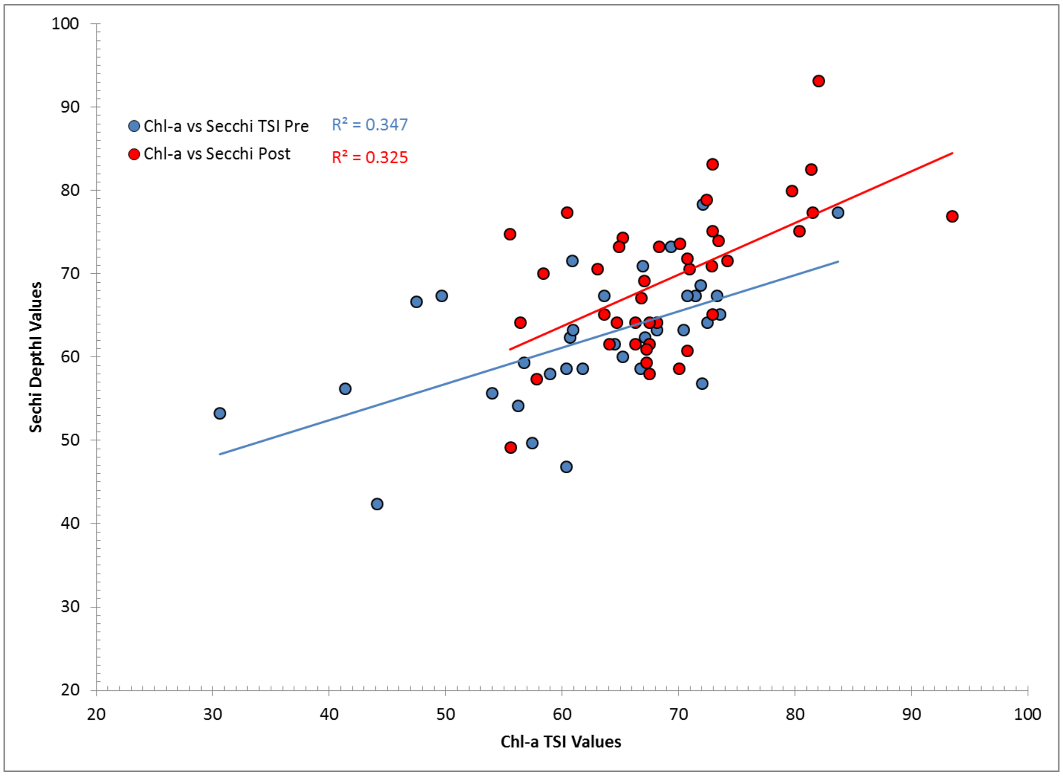

Figure 3-6. Analysis period TSI values for chlorophyll-a and Secchi depth

Figures 3-7 and 3-8 can be utilized to interpret differences (deviations) between Carlson's TSI values for TP, Secchi depth, and chlorophyll-a. Each quadrant of the chart indicates the potential factors that may limit algal growth in a lake. A detailed description of this approach is available in *A Coordinator's Guide to Volunteer Lake Monitoring Methods* (Carlson and Simpson, 1996). If the deviation between the chlorophyll-a TSI and TP TSI is less than zero (Chl TSI < TP TSI), the data point will fall below the X-axis. Pre-renovation water quality data points are shown in blue, and post-renovation water quality data points are shown in red.

Chlorophyll-a and TP TSI deviations are split between positive and negative deviations, with a majority (30 of 42 samples) lying below the x-axis in Figure 3-7. These metrics are indicative of high turbidity levels and high levels of phosphorus, depending on conditions at the time the water quality sample was collected. In addition, the low number of samples in the upper left quadrant (1 out of 42), indicates low levels of finely suspended particles and the low number of samples in the upper right quadrant (11 of 42) show that excess nutrients causing algal blooms may be causing turbidity issues as well.

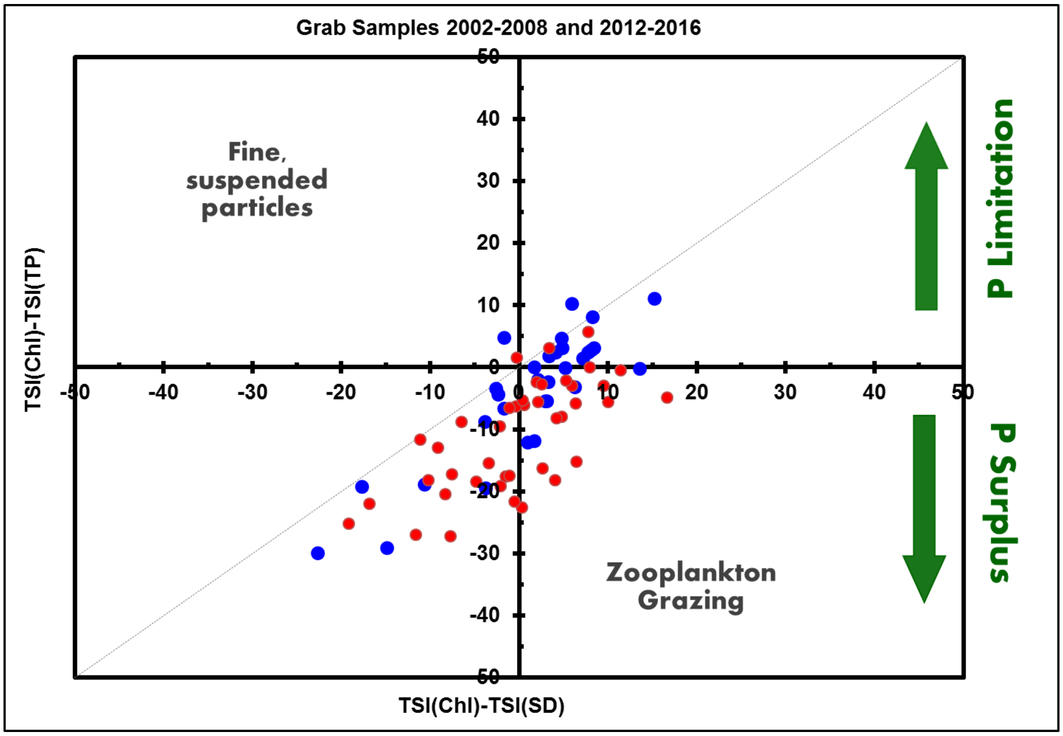

Figure 3-7. Phosphorus TSI deviations grab samples for analysis period

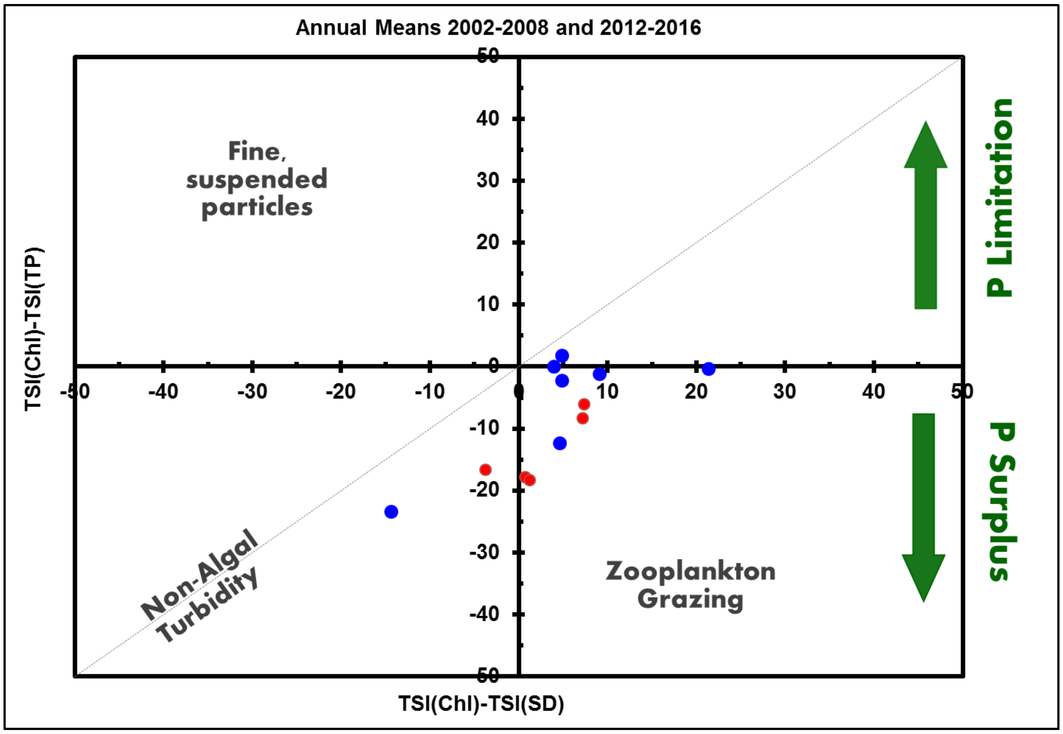

Figure 3-8. Phosphorus TSI deviations annual averages for analysis period

Neither chlorophyll-a, nor TP annual average TSI values show any correlation to annual or growing season precipitation (Figures 3-9, 3-10). Secchi depth shows a weak positive correlation to precipitation in Figure 3-11. This may be due to associated increases in wind speed, or increased sediment laden runoff, but without more data to corroborate the correlation it is difficult to modify existing models based on this relationship alone. This analysis reveals that high Secchi depth, chlorophyll-a, and TP levels are observed in both wet and dry years, and that both conditions must be considered when developing the TMDL.

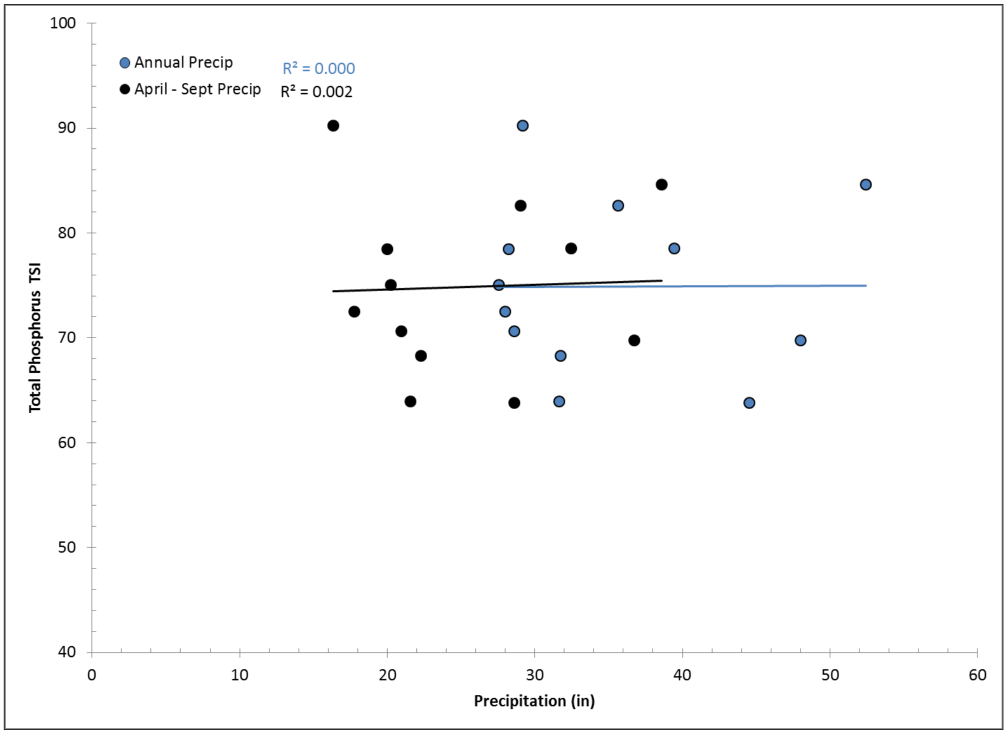

Figure 3-9. TP TSI values plotted against annual and growing season precip

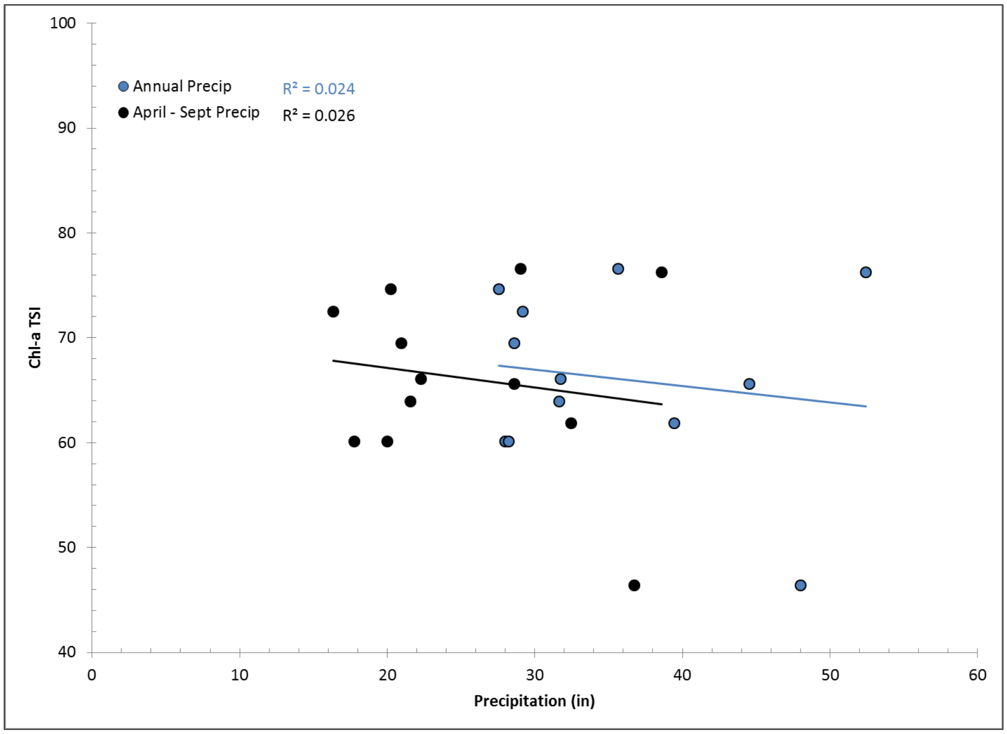

Figure 3-10. Chl-a TSI values plotted against annual and growing season precip

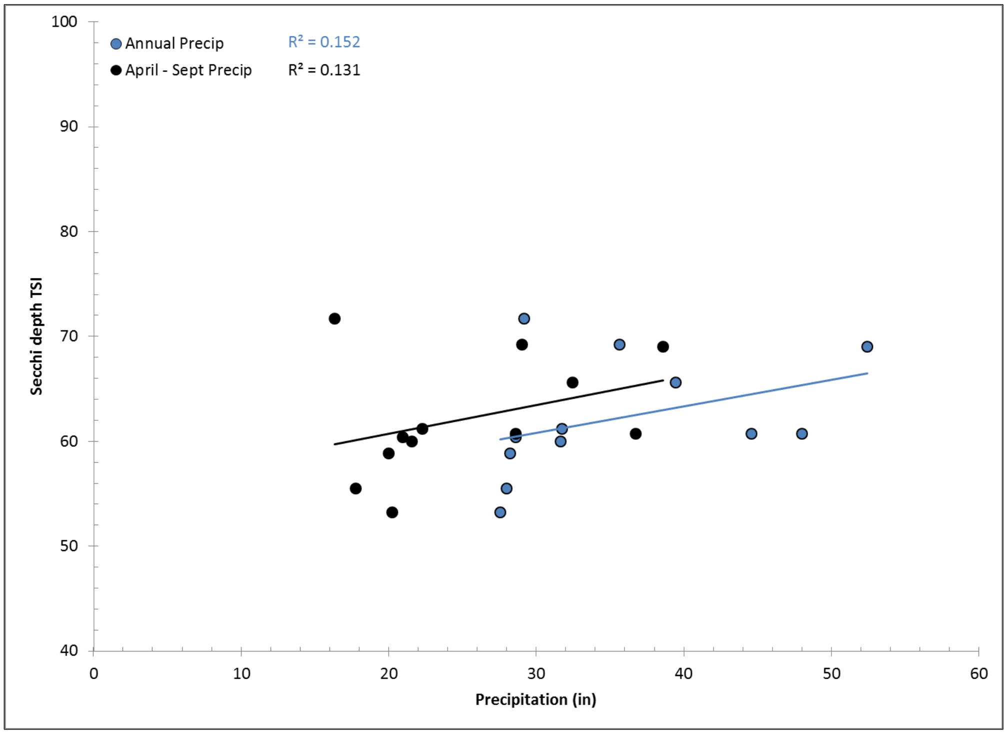

Figure 3-11. Secchi depth TSI values plotted against annual and growing season precip

Within lakes, the main two nutrients necessary for algal bloom development are nitrogen and phosphorus. When one nutrient is in short supply relative to the other, this nutrient supply will be exhausted first during growth. Once this nutrient is no longer available, growth is limited. Generally, in Iowa lakes, phosphorus is the limiting nutrient. Ratios of nitrogen to phosphorus can provide clues as to which nutrient is limiting growth in a given waterbody.

The overall TN:TP ratio in water quality samples from Green Valley Lake, using average grab sample concentrations from 2002-2008 and 2012-2016, is 14. According to a study on blue-green algae dominance in lakes, ratios greater than 17 suggest a lake is phosphorus, rather than nitrogen, limited (MPCA, 2005). Carlson states that phosphorus may be a limiting factor at TN:TP ratios greater than 10 (Carlson and Simpson, 1996). Ratios that fall between 10 to 17 are often considered “co-limiting,” meaning either nitrogen or phosphorus is the limiting nutrient or light is limited due to high non-algal turbidity.

Analysis of the TN:TP ratio in Green Valley samples reveals that the lake is P-limited 58 percent of the time and co-limited 22 percent of the time. Table 3-2 lists the mean TSI score for each nutrient limiting condition. The high total phosphorus TSI for N-limiting conditions seems to indicate an oversupply of phosphorus, rather than a limiting quantity of nitrogen. The applicability of the N-limiting concept is questionable at such high eutrophic states, where often light, temperature, or biological constraints on algal growth limit even higher states of productivity. Although a recent study recommends dual control of both N and P to limit eutrophication (Paerl et al., 2016), other studies indicate that phosphorus-only control is more effective and pushing lakes towards N-limiting conditions (by N reductions) can actually increase the prevalence of nitrogen fixing cyanobacteria (Schindler et al., 2016).

Table 3-2. TN:TP ratio summary in Green Valley Lake

Samples Collected	# of Samples	N-limited (< 10)	Co-Limited (10-17)	P-limited (>17)
All samples 2002-2014	45	9 (20%)	10 (22%)	23 (58%)
Samples with Chl-a TSI > 65	22	6 (27%)	6 (27%)	8 (45%)
Samples with Secchi TSI > 65	20	8 (40%)	6 (30%)	6 (30%)

When the chl-a TSI exceeds 65, the lake is either P-limited or co-limited 65 percent of the time. When the Secchi depth TSI exceeds 65, the lake is either P-limited or co-limited 52 percent of the time. This analysis reveals that water quailty improvement of algal blooms and turbidity via TP reduction is most feasible. If phosphorus reductions are not accompanied by reductions in agal blooms, then reductions in nitrogen may prove necessary to reduce algae to an acceptable level.

The 2016 draft 305(b) assessment of Green Valley Lake adds low DO as a cause of impairment to the aquatic life support designated use. Supplementary data collected in 2014 and 2015 show continuous DO and lake surface temperature. Figures 3-12 and 3-13 show this relationship throughout the recreation season of June through October. The water quality standard of 5 mg/L has been added to show when DO levels fall below the acceptable limits. These data show that DO levels in Green Valley Lake are quite variable throughout a single monitoring season and from year to year.

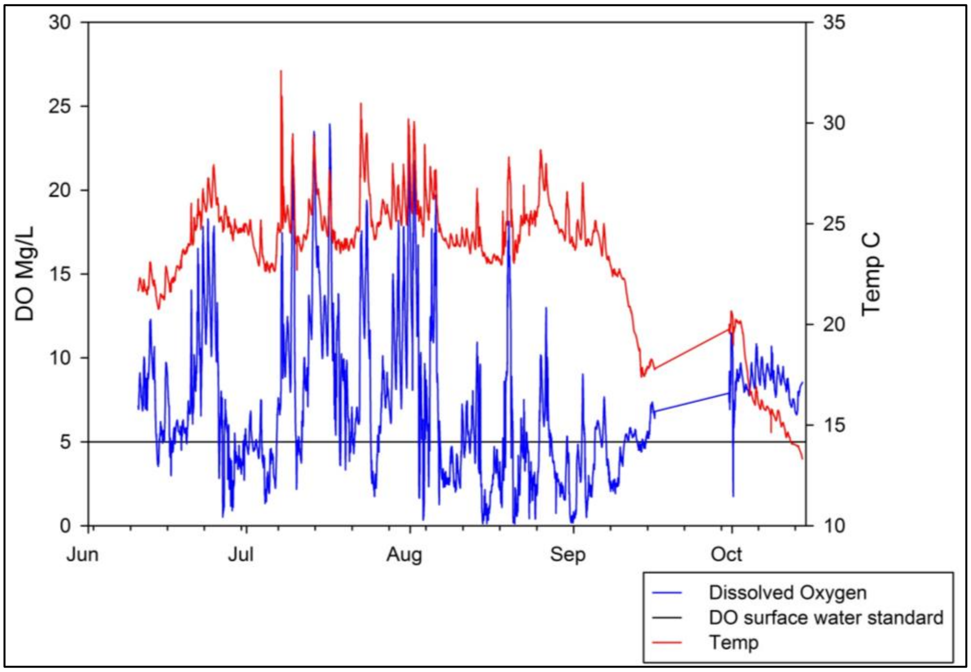

Figure 3-12 Dissolved oxygen and lake surface temperature for 2014

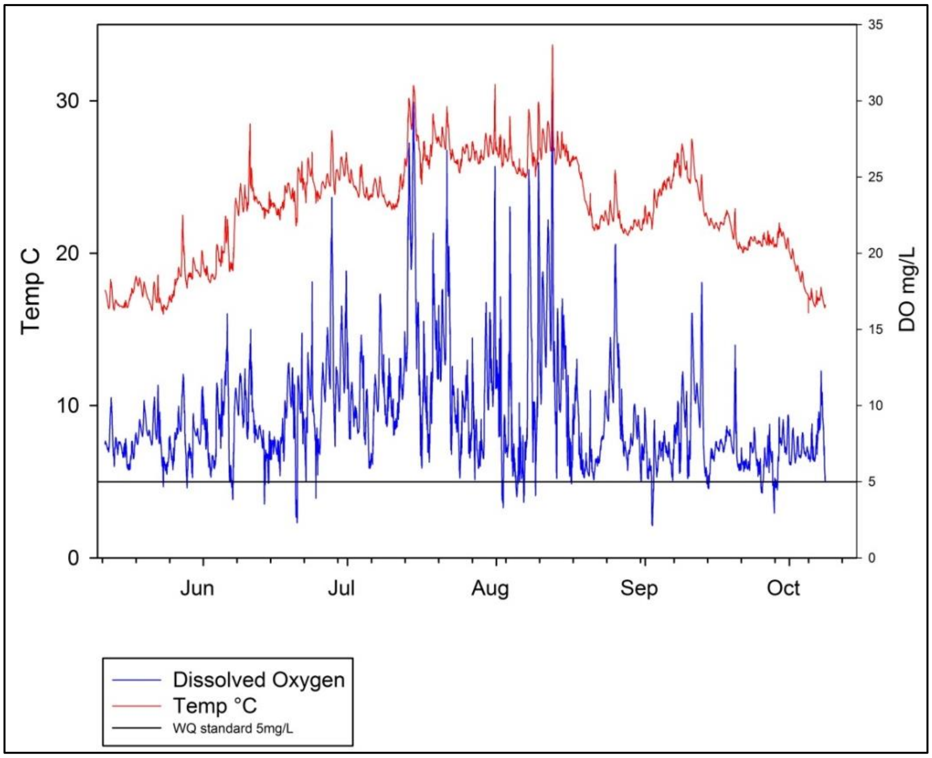

Figure 3-13 Dissolved oxygen and lake surface temperature for 2015

3.2. TMDL Target

General description of the pollutant
The 2014 305(b) assessment attributes poor water quality in Green Valley Lake to excess algae and turbidity, and the data interpretation described in Section 3.1 indicates phosphorus load reduction will best address the impairment. It will be important to continue to assess TSI values for chlorophyll-a and Secchi depth as phosphorus reduction practices are implemented. If phosphorus reductions are not accompanied by reductions in algal blooms and turbidity levels, then reductions of nitrogen may prove necessary to reduce algae to an acceptable level. However, phosphorus should be reduced first, as it is the primary limiting nutrient in algal growth. Additionally, reductions in nitrogen that result in nitrogen limitation favor growth of harmful cyanobacteria, which have the ability to fix nitrogen from the atmosphere. These bacteria, often referred to as blue-green algae, can emit cyanotoxins to the water, which can harm humans, pets, and wildlife if ingested.

Table 3-3 reports the simulated chlorophyll-a, TP, and Secchi depth at the ambient monitoring location for both existing and target conditions. In-lake water quality was simulated using the BATHTUB model, which is described in more detail in Appendix E. The chlorophyll-a TSI target of 63 complies with the narrative “free from aesthetically objectionable conditions” criterion. The Secchi depth target of 63 complies with turbidity impairment. Meeting both of these targets will result in delisting Green Valley Lake if attained in two consecutive 303(d) listing cycles. Note that TP values in Table 3-3 are not TMDL targets. Rather, they represent in-lake water quality resulting from TP load reductions required to obtain the chlorophyll-a and Secchi depth TSI targets in Green Valley Lake.

Table 3-3. Existing and target water quality (ambient monitoring location)

Parameter	[1]2002-2008	[2]2012-2016	[3]Assessment	TMDL
Secchi Depth	1.1 m	0.7 m	0.9 m	1.5
TSI (Secchi Depth)	59	66	61	54
Chlorophyll-a	38.5 μg/L	65.8 μg/L	49.9 μg/L	27.3
TSI (Chlorophyll-a)	66	72	69	63
TP	94.3 μg/L	247.9 μg/L	158.3 μg/L	86.6
TSI (TP)	70	84	77	69

[1] Pre-renovation of lake and forebays
[2] Post-renovation of lake and forebays
[3] Assessment period for TMDL analysis 2002-2008 and 2012-2016

Selection of environmental conditions
The critical period for poor water clarity is the growing season (April through September). However, long-term phosphorus loads lead to buildup of phosphorus in the reservoir and can contribute to algal growth and turbidity regardless of when phosphorus first enters the lake. Therefore, both existing and allowable TP loads to Green Valley Lake are expressed as annual averages. Phosphorus loads are also expressed as daily maximums to comply with EPA guidance.

Waterbody pollutant loading capacity (TMDL)
This TMDL establishes a chlorophyll-a TSI target of 63 and a Secchi depth TSI target of 63 using analysis of existing water quality data and Carlson's trophic state index methodology. The allowable TP loading capacity was developed by performing water quality simulations using the BATHTUB model. BATHTUB is a steady-state water quality model that performs empirical eutrophication simulations in lakes and reservoirs (Walker, 1999). The BATHTUB model was calibrated to available water quality data collected by ISU and SHL from 2002 through 2016, and also includes prior and subsequent years for a modeling period of 2002-2008 and 2012-2016, consistent with the assessment period for the 2014 305(b) report and draft 2016 report. The BATHTUB models used do not include data from 2009-2011 due to lack of water quality data during this time.

The BATHTUB model is driven by weather, lake morphometry (i.e., size and shape), watershed hydrology, and sediment and nutrient loads predicted by the STEPL model. STEPL utilizes simple equations to predict sediment and nutrient loads from various land use and animal sources, and includes a tool that estimates potential sediment and nutrient reductions resulting from implementation of Best Management Practices (BMPs). STEPL input included local soil, land use, and climate data. A detailed discussion of the parameterization and calibration of the STEPL and BATHTUB models is provided in Appendices D through F.

The organic enrichment / low DO impairment included in the 2016 draft 303(d) list is addressed by reducing phosphorus and algal levels in Green Valley Lake. Reducing organic enrichment will reduce subsequent DO crashes in the lake. Continued monitoring will need to be implemented in order to track DO levels throughout the recreational season.

The annual TP loading capacity was obtained by adjusting the TP loads (internal load and tributary concentrations) in the calibrated BATHTUB model until chlorophyll-a and Secchi depth TSIs no greater than 63 were attained for the lake segment in which ambient monitoring data is collected. Due to the complexity of controlling internal lake loading and external watershed loading, many solutions exist to meet the water quality standard criteria. Figure 3-14 shows the relationship between reductions in internal / external loading, and total load. This model will be used to quantify maximum daily loads, while acknowledging that multiple solutions exist. Modeling equivalent reductions in external and internal loading shows the annual loading capacity of Green Valley Lake is 2,386 lbs/yr.

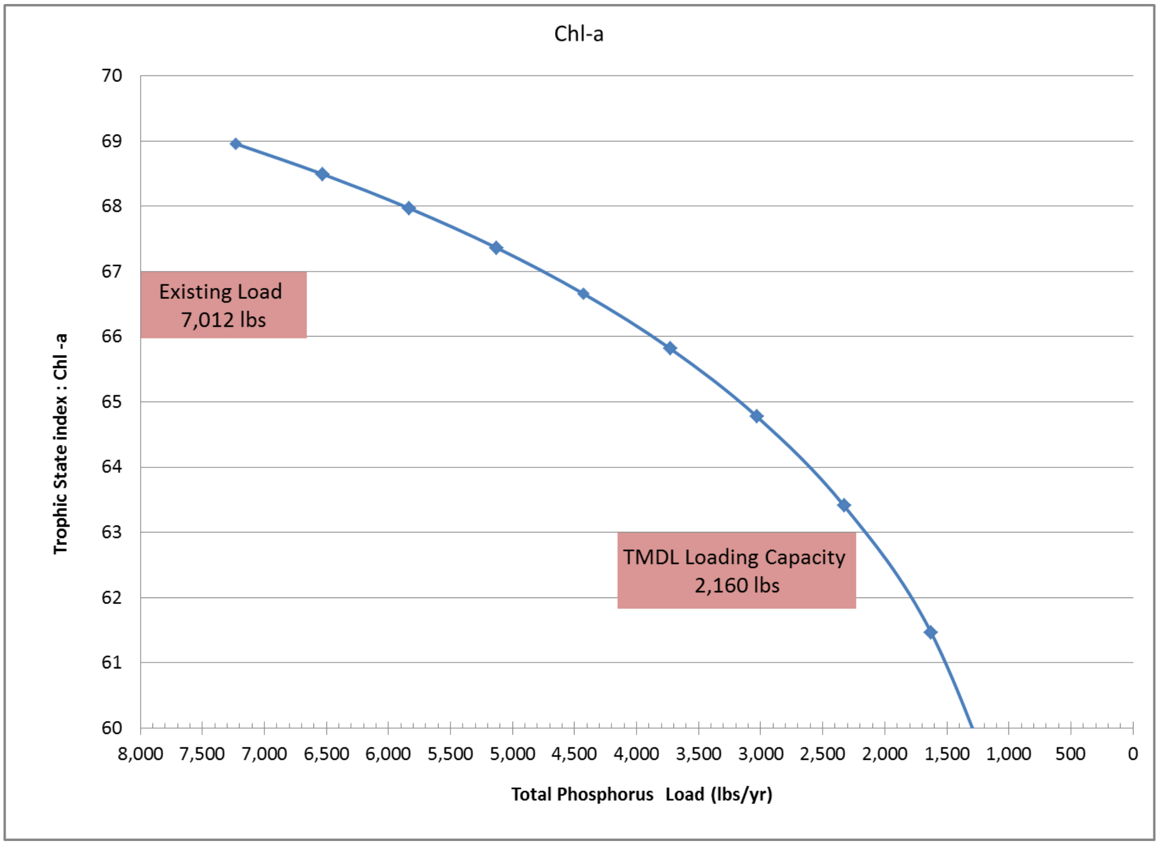

Figure 3-14 Internal and external load reduction combinations with associated total load

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 increment. In addition, TMDL submissions may include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards…"*

As recommended by EPA, the loading capacity of Green Valley Lake for TP is expressed as a daily maximum load, in addition to the annual loading capacity of 2,160 lbs/year. The annual average load is applicable to the assessment of in-lake water quality and water quality improvement actions, while the daily maximum load satisfies EPA's recommendation for expressing the loading capacity as a daily load.

The maximum daily load was estimated from the growing season average load using a statistical approach that is outlined in more detail in Appendix G. This approach uses a log-normal distribution to calculate the daily maximum from the long-term (e.g., annual) average load. The methodology for this approach is taken directly from a follow-up guidance document entitled *Options for Expressing Daily Loads in TMDLs* (EPA, 2007), and 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*. Using the approach, the annual loading capacity of 2,386 lbs/yr is equivalent to an average daily load of 6.5 pounds per day (lbs/day) and a maximum daily load of 18.4 lbs/day.

Decision criteria for WQS attainment
The narrative criteria in the water quality standards require that Green Valley Lake support primary contact for recreation. The metrics for WQS attainment for de-listing the impairments are a chlorophyll-a TSI and Secchi depth TSI of 63 or less in two consecutive 303(d) listing cycles.

The proactive WQS attainment criteria for stabilizing low DO levels in the lake are to keep minimum values for at least 16 hours of every 24 hour period above 5 mg/L or minimum values at any time during every 24 hour period above 5 mg/L as explained in section 61.3(3) of the Iowa Administrative Code

Compliance point for WQS attainment
The TSI target for listing and delisting of Green Valley Lake is measured at the ambient monitoring location shown in Figure 3-1. For modeling purposes, the lake was divided into multiple segments (see Figure E-2 of Appendix E). To maintain consistency with other Clean Water Act programs implemented by the Iowa DNR, such as the 305(b) assessment and 303(d) listing process, the TMDL target is based on water quality of Segment 1, which best represents the ambient monitoring location in Green Valley Lake.

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 Wetlands, Oceans, and Watersheds (OWOW), and has been utilized extensively in the United States for TMDL development and watershed planning. Model description and parameterization are described in detail in Appendix D.

Using STEPL and BATHTUB to simulate annual average conditions between 2002-2008 and 2012-2016, the annual TP load to Green Valley Lake was estimated to be 7,012 lbs/yr. The simulation period (for existing conditions) includes assessment period (for the 2016 Integrated Report) as well as pre and post lake renovation years where monitoring data was available.

Departure from load capacity
The TP loading capacity for Green Valley is 2,160 lbs/yr and 18.4 lbs/day (maximum daily load). To meet the target loads, an overall reduction of 71 percent of the TP load is

required. 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 Green Valley Lake is entirely from nonpoint sources of pollution. Table 3-4 reports estimated annual average TP loads to the lake from all known sources, based on the STEPL simulation of average annual conditions from 2002-2008 and 2012-2016. The predominant sources of phosphorus to Green Valley Lake include erosion from land in row crop production and internal recycling. Row crops in various rotations comprise over 68 percent of the land area of the watershed (Table 2-3), and 78.5 percent of the phosphorus load to the lake (Table 3-4). Other contributing sources of phosphorus include pastureland (4.0 percent), forested and grassland areas inside Green Valley park ground (5.8 percent), developed areas such as roads, residential, and other urban areas (4.2 percent); groundwater flow into the lake (4.0 percent); and all other loads (1.9 percent).

Internal recycling of phosphorus in the lake was included in the nutrient analysis of Green Valley Lake contributing less than 2 percent of the total phosphorus in the system based on seasonal cycling of lake bottom nutrients. The BATHTUB model allows users to quantify an internal loading input to the model. In lakes with substantial internal loading issues, inclusion of additional internal load inputs is sometimes necessary. Although there is evidence of an elevated flushing rate in the model, the characteristics of the outlet structure, downstream topography, and evaporation rate contribute to the significance of internal loading in Green Valley Lake. Internal recycling of phosphorus may be important in extremely dry conditions, typically late in the growing season, when the water level falls below the spillway crest, creating a stagnant pool in the reservoir. Reduction of internal lake loads is still thought to be a valid water quality improvement alternative, but watershed loads also need to be addressed to ensure long-term water quality in the lake.

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 agricultural row crop production, and is likely to remain in cropland in the future. Any future residential or urban development may contribute similar sediment loads and therefore will not increase phosphorus to the lake system. Green Valley Lake Park, which circumscribes the lake, is unlikely to undergo significant land use changes. There are currently no incorporated unsewered communities in the watershed; therefore it is unlikely that a future WLA would be needed for a new point source discharge. Any future development of animal feeding operations (AFO) qualifying as large concentrated animal feeding operations (CAFO) or meeting the requirements for NPDES permits as small or medium sized CAFOs will have zero discharge permits.

Table 3-4. Average annual TP loads from each source

Source	Descriptions and Assumptions	TP Load (lb/yr)	Percent (%)
Row Crops	Sheet and rill erosion from corn and soybeans dominated agriculture	5,505.1	78.5
Internal Recycling	Phosphorus in lake sediment	135.3	1.9
Pastureland	Seasonally grazed grassland	281.6	4.0
Urban	Urban areas, roads, and farmsteads	296.3	4.2
Groundwater	Agricultural tile discharge, natural groundwater flow	281.3	4.0
User Defined	Forest, all non-grazed grassland, CRP	407.5	5.8
All others	Wildlife, atmospheric deposition, septics	105.3	1.6
Total		**7,012.4**	**100**

3.4. Pollutant Allocation

Wasteload allocation
There are no permitted point source dischargers of phosphorus in the Green Valley Lake watershed. A small “zero-discharge” lagoon exists to support campground facilities located northwest of the beach. This lagoon was constructed with the proximity of the lake and no outflow as the main design considerations. Therefore, the wasteload allocation for this facility is zero.

Load allocation
Nonpoint sources of phosphorus to Green Valley Lake include erosion from land in row crop production, erosion from grasslands, erosion from timber / wooded areas, transport from developed areas (roads, residences, etc.), wildlife defecation, and atmospheric deposition (from dust and rain), and groundwater contributions. Septic systems in this watershed, which are not regulated or permitted under the Clean Water Act, but can fail or drain illegally to ditches, also contributed phosphorus to the lake during the assessment period.

In addition to watershed nonpoint sources, internal lake recycling has an impact on water quality when sediment becomes resuspended due to natural lake actions. Changes in agricultural land management, implementation of structural best management practices (BMPs), repair or replacement of failing septic systems, and in-lake restoration techniques can reduce phosphorus loads and improve water quality in Green Valley Lake. Based on the inventory of sources, management and structural practices targeting surface runoff and internal recycling contributions of phosphorus offer the largest potential reductions in TP loads.

Table 3-5 shows an example load allocation scenario for the Green Valley Lake watershed that meets the overall TMDL phosphorus target. The LA is 1,944 lbs/year, with a maximum daily LA of 16.6 lbs/day. The daily maximum LA was obtained by subtracting the daily WLA and daily MOS from the statistically-derived TMDL (as described in Section 3.2 and Appendix G). The specific reductions shown in Table 3-5 are not required, but provide one of many possible combinations of reductions that would achieve water quality goals.

Table 3-5. Example load allocation scheme to meet target TP load

TP Source	Existing Load (lb/year)	LA (lb/year)	NPS Reduction (%)
Row Crops	5,505.1	1,400	74
Internal Recycling	135.3	135	74
Pastureland	281.6	75	74
Urban	296.3	80	73
Groundwater	281.3	281	0
User Defined	407.5	109	73
All others	105.3	80	22
Total	**15633.4**	**2,160**	**72**

[1] Non grazed grassland and CRP
[2] Atmospheric contributions, direct lake contributions by waterfowl

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 10 percent (216 lbs/year, 1.8 lbs/day) was utilized in the development of this TMDL. These uncertainties may include seasonal changes in nutrient concentrations of influent to Green Valley Lake, changes in internal recycling that may be seasonal in nature, maintenance and efficiency of existing BMPs.

Reasonable Assurance
Under current EPA guidance, when a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, the TMDL should provide reasonable assurance that nonpoint source control measures will achieve expected load reductions. There are no permitted or regulated point source discharges contributing phosphorus to Green Valley Lake and the WLA is zero, therefore reasonable assurance of point source reductions is not applicable. Reasonable assurance for reduction of nonpoint sources is provided by the list of potential best management practices that would deliver phosphorus reductions, a group of nonstructural practices that prevent transport of phosphorus, a proposed methodology for prioritizing and targeting BMPs on the landscape, and monitoring for best available data for estimating the reductions associated with implemented BMPs.

3.5. TMDL Summary

The following general equation represents the total maximum daily load (TMDL) calculation and its components:

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 Green Valley Lake watershed, the general equation above can be expressed for the Green Valley Lake algae and turbidity TMDL.

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

TMDL = LC = Σ WLA (0 lbs-TP/year) + Σ LA (1,944 lbs-TP/year)
+ MOS (216 lbs-TP/year) = **2,160 lbs-TP/year**

Expressed as the maximum daily load:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (16.6 lbs-TP/day)
+ MOS (1.8 lbs-TP/day) = **18.4 lbs-TP/day**

4. Implementation Planning

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources (DNR) recognizes that technical guidance and support are critical to achieving the goals outlined in this Water Quality Improvement Plan (WQIP). Therefore, this 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 are potential tools that will help achieve water quality goals if appropriately utilized. It is possible that only a portion of BMPs included in this plan will be feasible for implementation in the Green Valley Lake watershed. Additionally, there may be potential BMPs not discussed in this implementation plan that should be considered. This implementation plan should be used as a guide or foundation for detailed and comprehensive planning by local stakeholders.

Collaboration and action by residents, landowners, lake users, and local agencies will be essential to improve water quality in Green Valley Lake and support its designated uses. Locally-led efforts have proven to be the most successful in obtaining real and significant water quality improvements. Improved water quality results in economic and recreational benefits for people that live, work, and recreate 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 BMPs and land management changes in the watershed.

4.1. Previous Watershed Planning and Implementation

Green Valley Lake has gone through several planning and implementation stages since its construction in 1952. As discussed previously, drawdowns and dredging have occurred multiple times throughout the life of Green Valley Lake. Extensive fisheries management activities have also been practiced to balance game and non-game fish species within the lake. The historical management practices of Green Valley Lake are listed in Appendix H.

In 2008, Iowa State University completed a diagnostics feasibility study for Green Valley Lake to show where restoration funding may be best utilized. The estimated total costs were \$4.7 million, with \$3.6 million being allocated to in lake activities and the remainder going to watershed activities and post restoration monitoring. A complete breakdown of the estimated costs from the diagnostics feasibility study can be found in Appendix H.

4.2. Future Planning and Implementation

General Approach
Future watershed management and BMP implementation efforts in the Green Valley Lake watershed should utilize a phased approach. Given the watershed-to-lake ratio and the morphology of this lake system, attainment of existing water quality standards may take considerable time to see improvement in the watershed. Efforts should be targeted to

maximize benefits and minimize costs. Emphasis should be placed on non-structural water quality practices that increase organic matter and infiltration (thereby reducing runoff and erosion), keep the soil covered with vegetation, maximize water uptake perennial non-agricultural plant species, along with possible in-lake practices.

Projects with multiple benefits (e.g., wildlife habitat, soil conservation, and water quality) may do more to protect and preserve the use of Green Valley Lake for future generations than those focused solely on water quality. Additional funding avenues include, but are not limited to state and federal funding opportunities, which may help facilitate multiple-objective projects, especially in the parkland around the lake.

Timeline

Planning and implementation of future improvement efforts may take several years, depending on stakeholder interest, availability of funds, landowner participation, and time needed for design and construction of any structural BMPs. Realization and documentation of significant water quality benefits may take 5-10 years or longer, depending on weather patterns, amount of water quality data collected, and the successful selection, location, design, construction, and maintenance of BMPs. Sustained improvement may be a more appropriate short term goal than impairment delisting.

Tracking milestones and progress

This WQIP, including the proposed monitoring plan outlined in Section 5, would address several of the elements required for a nine-element plan approved by EPA for the use of 319 funds, or other state and federal funding sources, as available. Establishment of specific short, intermediate, and long-term water quality goals and milestones would also be needed to additional funding from available sources. A path to full attainment of water quality standards and designated uses must be included for most funding sources, but efforts should first focus on documenting water quality improvement resulting from BMPs and elimination of any phosphorus “hot spots” that may exist.

4.3. Best Management Practices

No stand-alone BMP will be able to sufficiently reduce phosphorus loads to Green Valley Lake. Rather, a comprehensive package of BMPs will be required to reduce sediment and phosphorus transport to the lake, which can cause elevated algal growth and turbidity issues. By reducing the primary production of algal growth, low DO issues may also be addressed. The majority of phosphorus enters the lake via nutrient loss from agricultural fields through sheet / rill erosion and internal recycling in the lake. These sources have distinct phosphorus transport pathways and processes; therefore, each requires a different set of BMPs and strategies.

Other sources, although relatively small on an annualized basis, can have important localized and seasonal effects on water quality. It is important that all sources are considered to reduce phosphorus loads in the most comprehensive manner possible. Experience has shown that watershed projects that involve widespread “ownership” of potential solutions have the best chance of success. At the same time, resources to address the various sources of phosphorus should be allocated in a manner that is reflective of the importance to the impairment: algal blooms and turbidity issues caused primarily by excess phosphorus loads to the lake and in the lake. Potential BMPs are grouped into three types: land management (prevention), structural (mitigation), and in-lake alternatives (remediation).

Land Management (Prevention Strategies)

Many agricultural BMPs are designed to reduce erosion and nutrient loss from the landscape. These BMPs provide the highest level of soil conservation and soil health benefits, because they prevent erosion and nutrient loss from occurring. Land management alternatives implemented in row crop areas should include conservation practices such as no-till and strip-till farming, diversified crop rotation methods, utilization of in-field buffers, and cover crops. Incorporation of fertilizer into the soil by knife injection equipment reduces phosphorus levels, as well as nitrogen and bacteria levels, in runoff from application areas. Strategic timing of fertilizer application and avoiding over-application may have even greater benefits to water quality. Application of fertilizer on frozen ground should be avoided, as should application when heavy rainfall is forecasted. Land retirement programs such as the conservation reserve program (CRP), and conservation reserve enhancement program (CREP) constructed wetlands may be considered where appropriate.

Though not suspected to be a large source of phosphorus, even a few acres of pasture with direct access to a stream could impact water quality in the lake. Well-managed pastures can have very little negative impact on water quality, since the ground is covered with vegetation year-round. Stable and diverse pasture forages hold soil in place, filter runoff, and uptake nutrients for growth. Exclusion of livestock from streams and riparian areas can provide additional water quality benefits. Rotational grazing systems can improve water quality in adjacent waterbodies compared with continuously grazed systems. More research is needed, but there is evidence that forage diversity, degree of vegetation coverage or residue, and regrowth rates are higher in rotationally-grazed pastures (Dinnes, 2004). These characteristics increase erosion protection, filter runoff, and provide increased nutrient uptake compared with continually grazed grasses and forages. Table 4-1 summarizes land management BMPs and associated phosphorus reduction estimates.

Structural BMPs (Mitigation Strategies)

Although they do not address the underlying generation of sediment or nutrients, structural BMPs such as sediment control basins, terraces, grass waterways, saturated buffers, riparian buffers, and wetlands can play a valuable role in reduction of sediment and nutrient transport to Green Valley Lake. These BMPs attempt to mitigate the impacts of soil erosion and nutrient loss by intercepting them before they reach a stream or lake. Structural BMPs should be targeted to “priority areas” to increase their cost effectiveness and maximize pollutant reductions. Landowner willingness and the physical features of potential sites must also be considered when targeting structural practices. These practices may offer additional benefits not directly related to water quality improvement. These secondary benefits are important to emphasize to increase landowner and public interest and adoption. Potential structural BMPs are listed in Table 4-2, which includes secondary benefits and potential TP reductions.

Table 4-1. Potential land management BMPs (prevention strategies)

BMP or Activity	[1] Potential TP Reduction
Conservation Tillage:	
Moderate vs. Intensive Tillage	50%
No-Till vs. Intensive Tillage	70%
No-Till vs. Moderate Tillage	45%
Cover Crops	50%
Diversified Cropping Systems	50%
In-Field Vegetative Buffers	50%
Pasture/Grassland Management:	
Livestock Exclusion from Streams	75%
Rotational Grazing vs. Constant Intensive Grazing	25%
Seasonal Grazing vs. Constant Intensive Grazing	50%
Phosphorus Nutrient Application Techniques:	
[2]Deep Tillage Incorporation vs. Surface Broadcast	-15%
[2]Shallow Tillage Incorporation vs. Surface Broadcast	-10%
Knife/Injection Incorporation vs. Surface Broadcast	35%
Phosphorus Nutrient Application Timing and Rates:	
Spring vs. Fall Application	30%
Soil-Test P Rate vs. Over-Application Rates	40%
Application: 1-month prior to runoff event vs. 1-day	30%

[1] Adopted from Dinnes (2004) with professional judgment. Actual reduction percentages may vary widely across sites and runoff events.
[2] Note: Tillage incorporation can increase TP in runoff in some cases.

Landowner buy-in, ease of construction, and difficulty implementing preventative land management measures all contribute to the popularity of sediment control structures as a sediment and phosphorus mitigation strategy. This is a proven practice, if properly located, designed, constructed, and maintained. However, if not properly designed and constructed, sediment control basins may trap substantially less sediment and phosphorus than widely-used rules-of-thumb that are often assumed when quantifying reductions in the context of a watershed management plan. There are at least three general criteria that should be considered when designing sediment control basins. First, the area of the basin should be appropriate relative to the size of the drainage area. Effective sediment control basins require a minimum size of at least one percent of the total drainage area to the basin. Second, retention times (i.e., the time it takes for runoff from a storm event to drain from the basin) should be no less than 24 hours, and preferably 40 hours. Shorter retention periods do not adequately settle fine sediments, which carry a large portion of attached phosphorus, which can influence algal blooms and turbidity issues. Third, sediment basins should be shaped such that the length to width ratio is maximized to prevent short-circuiting across the shortest flow-path through the basin. A minimum length to width ratio of 3:1 is commonly cited in the literature.

To obtain reductions in TP load necessary to meet water quality targets, land management strategies and structural BMPs should be implemented to obtain the largest and most cost-effective water quality benefit. Targeting efforts should consider areas with the highest potential phosphorus loads to the lake. Factors affecting phosphorus contribution include: land cover, steep slopes; proximity to waterbodies; tillage practices, and method, timing, and amount of manure and commercial fertilizer application.

Table 4-2. Potential structural BMPs (mitigation strategies)

BMP or Activity	Secondary Benefits	[1] Potential TP Reduction
Terraces	Soil conservation, prevent in-field gullies, prevent wash-outs	50%
Grass Waterways	Prevent in-field gullies, prevent washouts, some ecological services	50%
[2]Sediment Control Structures	Some ecological services, gully prevention	Varies
[3]Wetlands	Ecological services, potential flood mitigation, aesthetic value	15%
Riparian Buffers	Ecological services, aesthetic value, alternative agriculture	45%
Saturated Buffers	Nitrate removal	[4]Varies

[1] Adopted from Dinnes (2004) with professional judgment. Actual reduction percentages may vary widely across sites and runoff events.
[2] Not discussed in Dinnes (2004). Phosphorus removal in sediment basins varies widely and is dependent upon the size of the structure relative to the drainage area, the length:width ratio, and drawdown time of a specified rainfall/runoff event.
[3] Note: TP reductions in wetlands vary greatly depending on site-specific conditions, such as those listed for sediment control structures. Generally, removal of phosphorus is lower in wetlands than in sediment control structures. Wetland can sometimes be sources, rather than sinks, of phosphorus
[4] Limited research in total phosphorus reduction values

The Spreadsheet Tool for Estimating Pollutant Load (STEPL) model was used in TMDL development to predict phosphorus loads to Green Valley Lake. Figure 4-1 shows the annual phosphorus export from each subbasin in the Green Valley Lake watershed STEPL model. Red-shaded basins indicate the heaviest phosphorus export and green shaded bars indicate the lowest export rates and loads relative to the sub basins in this study. The figures reveal that more phosphorus is annually exported from Subbasins 1, and 6 (1872 lbs, and 1627 lbs, respectively). Subbasin 5 (surrounding a portion of the lake) has the lowest TP export at 850 lbs. Figure 4-2 shows TP export rates in for each subbasin after adjusting for drainage area. On a per-area basis, sub basins with a large percentage of row crop have higher export rates than those with parkland. Subbasins 1 and 4 have the highest rates with 2.10 lbs/ac/year and 2.25 lbs/ac/year, respectively.

Subbasin-level information indicates that best management practices reducing phosphorus export should concentrate on upstream sub basins with higher levels of total phosphorus transport rates.

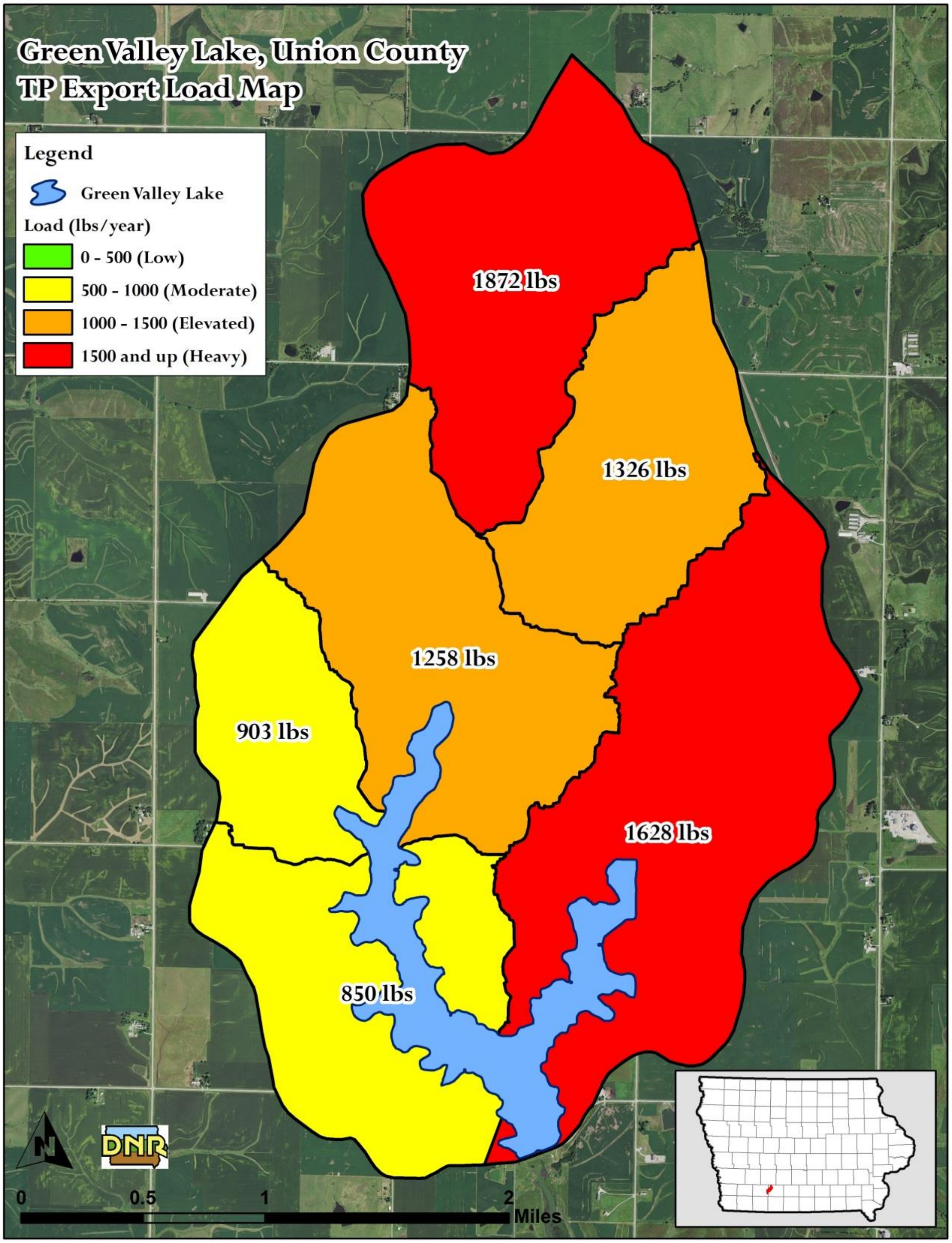

Figure 4-1. Predicted TP load from each STEPL subwatershed

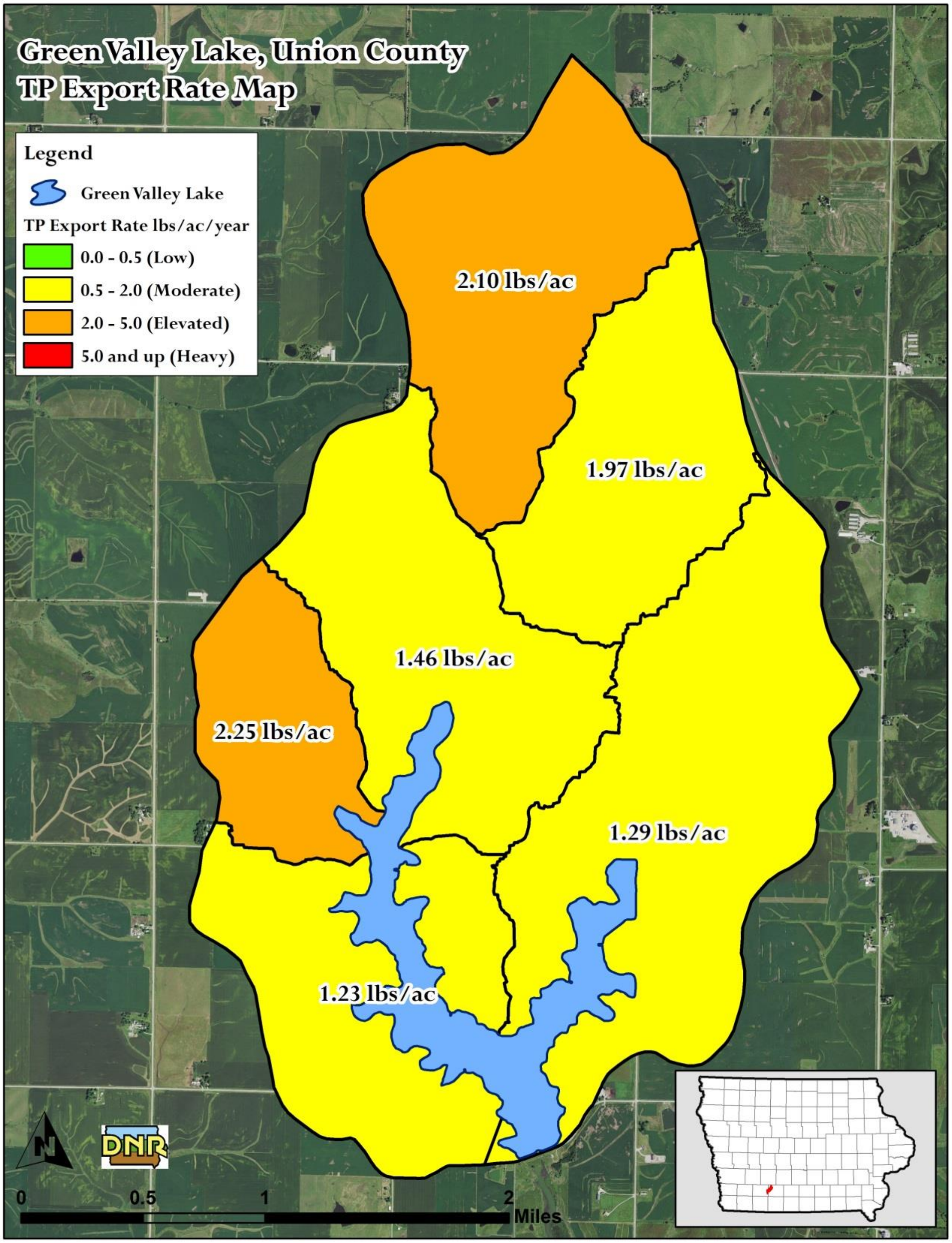

Figure 4-2. Predicted per-acre TP export for each STEPL subwatershed

More detailed information should be collected in order to target specific BMPs to specific areas (e.g., singular fields or waterways) within a subwatershed. This level of detailed targeting is best accomplished by local officials working collaboratively with local stakeholders and land owners.

In-Lake BMPs (Remediation Strategies)

The average annual contribution of TP to the system from internal loading is estimated as half the amount of total phosphorus entering the water column. Internal loads may lead to algal blooms, leading to booms and crashes in dissolved oxygen levels, and can worsen turbidity issues in late summer periods, especially if lake outflow ceases and water temperatures exceed normal levels. External phosphorus loads from the watershed supply the build-up of phosphorus in the bottom sediments. Although model results show internal load reductions are necessary, that internal load cannot be fixed in the long run without reductions to the external (i.e., watershed) loads. In lakes with high suspected internal loads, uncertainty regarding the magnitude of internal loads is one of the biggest challenges to TMDL development and lake restoration. Because of these factors, reductions from watershed sources of TP should be given implementation priority. If and when monitoring shows that the external watershed load has been adequately reduced, then additional in-lake measures may be warranted. Once existing watershed practices have been renovated and new practices have been implemented, a final phase of in-lake BMP implementation can begin.

Brief descriptions of potential in-lake restoration methods are included in Table 4-3. Phosphorus reduction impacts of each alternative will vary and depend on a number of site-specific factors. It is virtually impossible to determine how much of the internal load is due to each of the contributing factors, and equally difficult to predict phosphorus reductions associated with individual improvement strategies. In-lake measures should be a part of a comprehensive watershed management plan that includes watershed practices in order to enhance, prolong, and protect the effectiveness of in-lake investments.

Table 4-3. Potential in-lake BMPs for water quality improvement

In-Lake BMPs	Comments
Fisheries management	Low to moderate reductions in internal phosphorus load may be attained via continued fisheries management. The reduction of in-lake phosphorus as a result of this practice is uncertain, but the overall health of the aquatic ecosystem may be improved, which typically improves overall water quality as well. Resident rough fish may be problem and could be controlled through this method.
Targeted dredging and sediment basin improvement	Targeted dredging in shallow inlet areas of the receiving would recreate pockets of deep-water habitat for predatory fish that would help control rough fish populations. Strategic dredging would also increase the sediment capacity of both pools, thereby reducing sediment and phosphorus loads to the larger, main body where ambient conditions are monitored.
Shoreline stabilization	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 help improve water quality.
Phosphorus stabilization	Adding compounds, such as alum, to the water column can help stabilize phosphorus that may be resuspended from the lake bottom. This additive precipitates a layer of floc that removes phosphorus as it settles to the lake bottom, and can combine with phosphorus as it is released from sediment

Holistic Approach

An example of a holistic implementation plan would involve prevention, mitigation, and remediation practices across the Green Valley Lake watershed. These may include any of the practices from Table 4-3 at any scale. Extending grassed waterways in conjunction with renovation of existing terraces and contour buffers in corn and soybean ground will help mitigate soil loss from row crop ground. Further adoption of agricultural prevention measures like those listed in Table 4-1 will retain topsoil in the soil profile of the fields and prevent erosion. Potential in-lake strategies such phosphorus stabilization treatments in Green Valley Lake are included as well.

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 best management practice (BMP) implementation and to document attainment of total maximum daily loads (TMDLs) and progress towards water quality standards (WQS).

Volunteer-based monitoring efforts should 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: https://www.legis.iowa.gov/docs/iac/chapter/567.61.pdf

Failure to prepare an approved QAPP will prevent data collected from being used to evaluate waterbody in the 305(b) Integrated Report – the biannual assessment of water quality in the state, and the 303(d) list – the list that identifies impaired waterbodies.

5.1. Routine Monitoring for Water Quality Assessment

Data collection in Green Valley Lake to assess water quality trends and compliance with water quality standards (WQS) will include monitoring conducted as part of the DNR Ambient Lake Monitoring Program. This is the same source of data used to develop the TMDL. The Ambient Lake Monitoring Program was initiated in 2000 in order to better assess the water quality of Iowa lakes. Currently, 134 of Iowa’s lakes are sampled as part of this program, including Green Valley 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. While the ambient monitoring program can be used to identify trends in overall, in-lake water quality, it does not lend itself to calculation of watershed loads, identification of individual pollutant sources, or the evaluation of BMP implementation.

Table 5-1. Ambient Lake Monitoring Program water quality parameters

Chemical	Physical	Biological
• Total Phosphorus (TP) • Soluble Reactive Phosphorus (SRP) • Total Nitrogen (TN) • Total Kjeldahl Nitrogen (TKN) • Ammonia • Un-ionized Ammonia • Nitrate + Nitrite Nitrogen • Alkalinity • pH • 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 • Thermocline Depth • Lake Depth	• Chlorophyll a • Phytoplankton (mass and composition) • Zooplankton (mass and composition)

5.2. Expanded Monitoring for Detailed Analysis

Data available from the Iowa DNR and IGS Beach Monitoring Program and the Iowa DNR Ambient Lake Monitoring Program will be used to assess general water quality trends and WQS violations and 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.

If the goal of monitoring is to evaluate spatial and temporal trends and differences in water quality resulting from implementation of BMPs, a more intensive monitoring program will be needed. Table 5-2 outlines potential locations, type of monitoring, parameters collected, and the purpose of each type of data collected as part of an expanded monitoring effort. It is unlikely that available funding will allow collection of all data included in Table 5-2, but the information should be used to help stakeholders identify and prioritize data needs. Locations for expanded monitoring in the Green Valley Lake watershed have been chosen to take into account sub basin boundaries and can be used in assigning nutrient concentrations to each sub basin if deployed in such a manner.

Table 5-2. Recommended 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 location in Green Valley Lake, plus secondary locations
Continuous flow	15-60 minute	April through October	Green Valley Lake inlet & outlet
Continuous pH, DO, and temperature	15-60 minute	April through October	Ambient location in Green Valley Lake
Runoff event flow, sediment, P, and N	15-60 minute intervals during runoff	5 events between April and October	Select tile and/or culvert discharge locations in areas of focused BMP implementation to evaluate efficacy
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	Select tile and/or culvert discharge locations in areas of focused BMP implementation to evaluate efficacy
Shoreline mapping, bathymetry studies	Before and after dredging or construction, every 5 years	Design lifespan of waterbody	Near dredging operations, or near lake inlets, upstream sediment basins

[1] Tributary, tile drain, and gully site selection to be based on suspected pollutant source location, BMP placement, landowner permission, and access/installation feasibility.

It may be useful to divide the recommended monitoring plan into several tiers based on ease of deployment and cost effectiveness. This will help stakeholders and management personnel best direct their resources. This monitoring plan may be reevaluated at any time to change the management strategy. Data collection should commence before BMPs are renovated or implemented in the watershed to establish baseline conditions. Selection of tributary sites should consider location of BMPs, location of historical data (for comparative purposes), landowner permission (if applicable), and logistical concerns such as site access and feasibility of equipment installation (if necessary). This data could form the foundation for assessment of water quality trends; however, more detailed information will be necessary to make any statements about water quality trends with certainty. Therefore, routine grab sampling should be viewed only as a starting point for assessing trends in water quality.

Current Monitoring

With no locally-led effort, only three grab samples would be collected at the ambient location of Green Valley Lake between Memorial Day and Labor Day of each year.

Basic Monitoring

Targeted grab sampling of the Green Valley Lake ambient monitoring point should be continued on a bi-weekly basis. Grab samples on a seasonal basis at the inlet would be done to support data provided by the main lake.

Targeted Monitoring
If automated sampling devices cannot be procured, then grab samples should continue on a routine and runoff event based schedule. Flow data may be recorded by area-velocity measurements, or manual flow readings based on developed rating curves. Locations and sampling approaches would include the ambient monitoring station upstream inlets, and the main tile drainage ditch to the southeast.

Advanced Monitoring
Automated data recorded by ISCO devices would provide information on continuous flow, and continuous pH, DO, and temperature. Routine grab sampling for flow, sediment, P, and N will help provide a check on the automated sampling. In addition to routine sampling, runoff event sampling for event flow, sediment, N, and P will help show the effects of high recurrence interval events. Locations and sampling approaches would include the ambient monitoring station, a secondary ambient location in the northern segment of Green Valley, and outlets from upstream tributaries- such as roadway culverts. 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, saturated buffers, terraces and grassed waterways, riparian buffers, and wetlands.

The proposed 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 may provide technical support to locally led efforts in collecting further water quality and flow monitoring data in the Green Valley Lake watershed. A look at how these proposed monitoring plans may be deployed in the Green Valley Lake watershed is shown in Figure 5-1.

This expanded monitoring information would improve statistical analysis for evaluating changes and / or trends in water quality over time. Additionally, more detailed data could be used to develop / improve watershed and water quality models for simulation of implementation scenarios and prediction of water quality response. 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.

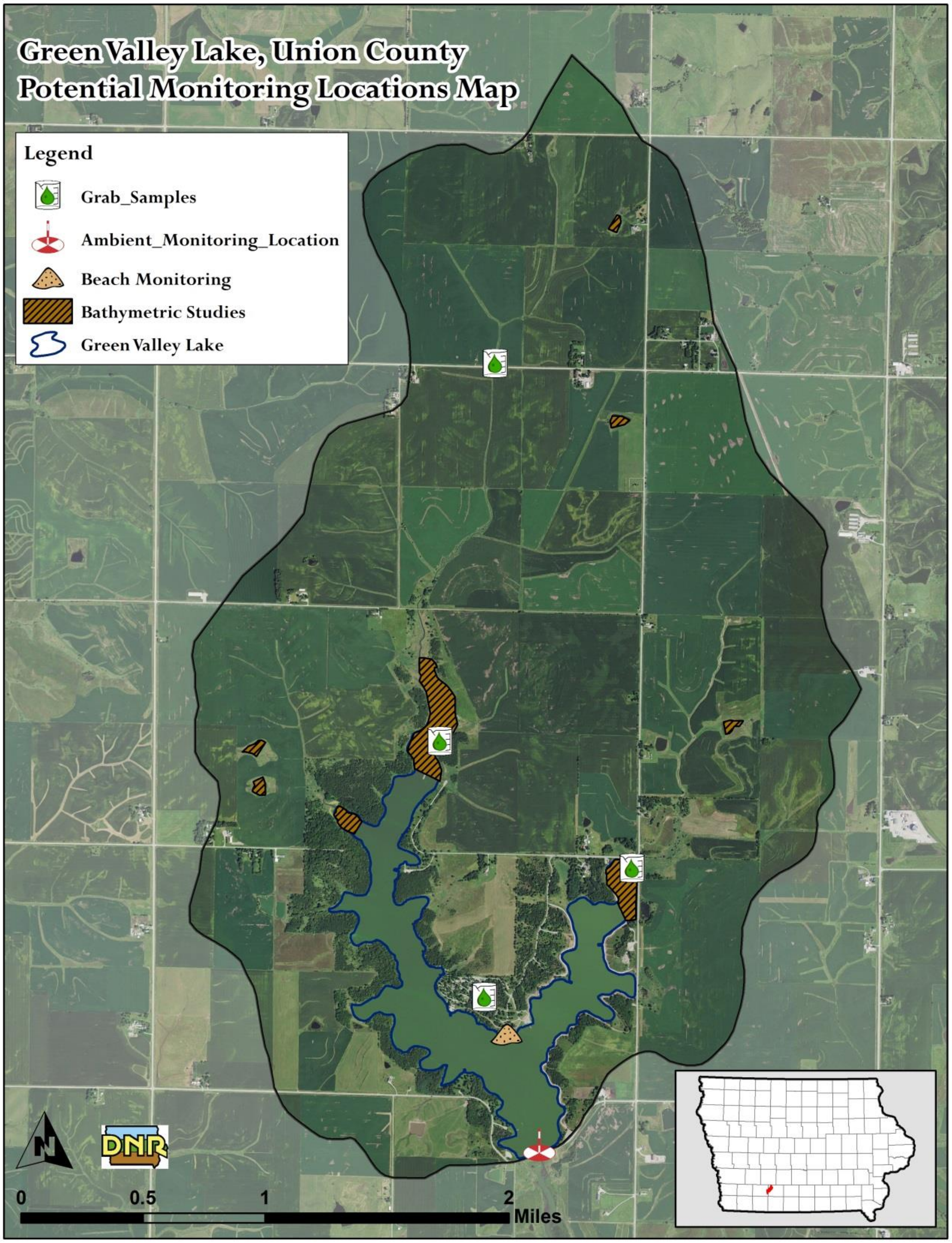

Figure 5-1. Potential monitoring locations

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 Green Valley Lake.

6.1. Public Meeting

Preliminary Meetings

February 28, 2017
Site investigation to ground truth the various land uses, topography, and flow paths of the Green Valley Lake and surrounding watershed.

Public Presentations

November 8, 2017
A public meeting to present the results of the TMDL study, obtain stakeholder input, and discuss next steps for community-based watershed planning was held in the Performing Arts Center, Room 124 of the Southwest Iowa Community College, located at 1201 W. Townline St. in Creston, Iowa. Members from Iowa DNR, Union County Board of Supervisors, local fish and wildlife authorities, and the general public were in attendance.

6.2. Written Comments

The public comment period began on October 26, and ended November 27, 2017. No public comments were received during the public comment period.

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8. Appendices

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 0.4 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 1,000 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:	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 waterbodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of waterbody (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the waterbody that is being dealt with. This appendix is intended to provide information about how Iowa's waterbodies 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 waterbody.

General Use Segments

A general use segment waterbody is one that 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 that 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 waterbody, 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 waterbodies that maintain flow throughout the year, or at least hold pools of water that 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 thirteen different designated use classes (Table B-1) that may apply, and a waterbody 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 waterbodies

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

Designated use classes are determined based on a Use Attainability Analysis, or UAA. This is a procedure in which the waterbody is thoroughly scrutinized, using existing knowledge, historical documents, and visual evidence of existing uses, in order to determine what its designated use(s) should be. This can be a challenging endeavor, and as such, conservative judgment is applied to ensure that any potential uses of a waterbody are allowed for. Changes to a waterbody's designated uses may only occur based on a new UAA, which depending on resources and personnel, can be quite time consuming.

It is relevant to note that on March 22, 2006, a revised edition of Iowa's water quality standards became effective which significantly changed the use designations of the state's surface waters. Essentially, the changes that were made consisted of implementing a "top down" approach to use designations, meaning that all waterbodies should receive the highest degree of protection applicable until a UAA could be performed to ensure that a particular waterbody did not warrant elevated protection. For more information about Iowa's water quality standards and UAAs, contact the Iowa DNR's Water Quality Bureau.

Appendix C --- Water Quality Data

The following is a summary of the sampling data from the Iowa State University (ISU) Iowa Lakes Information System and University of Iowa State Hygienic Laboratory (SHL) monitoring efforts.

C.1. Individual Sample Results

Table C-1. ISU and SHL water quality sampling data ([1]ambient location)

Source	DATE	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	TN (mg/L)	DO
ISU	28-May-02	3.40	3.96	36.47	1.98	9.64
ISU	24-Jun-02	1.10	39.74	63.84	1.41	6.87
ISU	29-Jul-02	0.30	223.68	311.23	1.89	16.92
ISU	27-May-03	2.50	20.80	50.27	2.68	11.75
ISU	23-Jun-03	1.15	18.07	104.20	1.74	5.65
ISU	29-Jul-03	0.45	21.94	190.46	1.46	*
ISU	25-May-04	1.35	10.85	50.57	2.50	8.17
ISU	21-Jun-04	0.60	64.62	90.63	3.98	8.49
ISU	27-Jul-04	1.05	14.38	48.99	2.08	6.21
ISU	31-May-05	2.05	15.43	34.34	3.11	10.16
SHL	15-Jun-05	0.60	78.00	60.00	3.50	7.20
ISU	27-Jun-05	1.25	68.11	51.54	2.20	8.82
SHL	14-Jul-05	0.80	58.00	90.00	1.20	8.50
ISU	02-Aug-05	0.55	67.49	129.84	1.24	5.83
SHL	14-Sep-05	0.60	29.00	240.00	1.97	6.40
SHL	03-May-06	1.60	1.00	50.00	1.18	8.10
ISU	30-May-06	1.10	20.84	49.39	2.23	10.53
SHL	06-Jun-06	1.10	24.00	80.00	2.80	7.30
ISU	27-Jun-06	0.75	71.25	65.17	2.27	9.02
SHL	11-Jul-06	0.60	60.00	90.00	1.92	7.80
ISU	01-Aug-06	0.90	31.76	96.59	1.27	5.21
SHL	29-Aug-06	0.40	52.00	170.00	2.05	5.20
SHL	23-May-07	1.00	34.00	70.00	5.40	14.20
ISU	29-May-07	1.50	13.68	42.72	5.13	9.50
ISU	26-Jun-07	0.85	21.43	36.30	3.51	4.89
SHL	30-Jul-07	0.80	22.00	70.00	1.60	5.30
ISU	31-Jul-07	0.85	41.30	57.23	0.69	7.17
SHL	12-Sep-07	0.70	80.00	100.00	1.80	6.60
SHL	06-May-08	1.30	3.00	100.00	3.10	8.30
SHL	08-Jul-08	0.60	7.00	90.00	3.60	5.70
ISU	11-Jun-12	0.47	74.37	139.50	2.10	9.24
ISU	30-Jul-12	0.48	60.96	491.60	1.37	6.44
ISU	12-Sep-12	0.38	79.00	550.00	2.09	6.29
ISU	10-Jun-13	2.13	12.74	101.65	3.08	10.22
ISU	29-Jul-13	0.37	34.10	170.90	1.80	4.15
ISU	09-Sep-13	0.75	13.88	248.35	1.28	4.91

Source	DATE	Secchi (m)	Chl-a (µg/L)	TP (µg/L)	TN (mg/L)	DO
ISU	16-Jun-14	0.75	32.42	102.30	1.80	4.70
ISU	04-Aug-14	0.48	27.32	196.35	2.65	2.85
ISU	14-Sep-14	0.36	12.72	203.10	2.46	4.42
SHL	17-Apr-14	0.61	40.00	120.00	*	*
SHL	29-Apr-14	1.10	56.00	100.00	*	*
SHL	14-May-14	0.90	38.00	130.00	*	*
SHL	27-May-14	1.20	16.00	60.00	*	*
SHL	10-Jun-14	0.90	43.00	100.00	*	*
SHL	23-Jun-14	0.25	150.00	170.00	*	*
SHL	07-Jul-14	*	58.00	180.00	*	*
SHL	23-Jul-14	*	71.00	200.00	*	*
SHL	07-Aug-14	0.40	33.00	280.00	*	*
SHL	19-Aug-14	0.30	180.00	380.00	*	*
SHL	03-Sep-14	0.50	17.00	280.00	*	*
SHL	16-Sep-14	0.70	29.00	210.00	*	*
SHL	30-Sep-14	1.05	42.00	80.00	*	*
SHL	13-Apr-15	0.94	42.00	120.00	*	*
SHL	27-Apr-15	0.95	60.00	150.00	*	*
SHL	11-May-15	0.75	46.00	300.00	*	*
SHL	27-May-15	0.75	38.00	110.00	*	*
SHL	10-Jun-15	1.15	43.00	100.00	*	*
SHL	25-Jun-15	0.70	75.00	80.00	*	*
SHL	07-Jul-15	0.35	160.00	230.00	*	*
SHL	23-Jul-15	0.27	71.00	210.00	*	*
SHL	12-Aug-15	0.31	610.00	690.00	*	*
SHL	24-Aug-15	0.10	190.00	500.00	*	*
SHL	16-Sep-15	0.20	75.00	420.00	*	*
SHL	21-Sep-15	0.40	47.00	310.00	*	*
SHL	08-Oct-15	0.30	21.00	230.00	*	*
SHL	06-Aug-15	0.35	75.00	230.00	*	*
SHL	10-Sep-15	0.45	85.00	400.00	*	*
ISU	15-Jun-15	0.90	30.4	77.4	3.48	6.9
ISU	3-Aug-15	0.21	177.8	336.2	2.78	15.15
ISU	13-Sep-15	0.53	41.1	295.7	1.37	7.17
ISU	13-Jun-16	0.75	43.0	65.6	1.09	13.8
ISU	1-Aug-16	0.39	56.2	285.5	1.26	4.1
ISU	13-Sep-16	0.44	60.0	343.0	1.21	6.0

[1] Ambient monitoring location = STORET ID 22880001

* Data not available

C.2. Annual Mean Data

Table C-2. Precipitation and annual mean TSI values ([1]ambient location)

Date	Annual Precipitation (in)	Apr-Sep Precipitation (in)	Secchi TSI	Chl-a TSI	TP TSI
2002	27.6	20.2	53	75	75
2003	28.0	17.8	56	60	73
2004	31.6	21.6	60	64	64
2005	28.6	21.0	60	69	71
2006	31.8	22.3	61	66	68
2007	44.6	28.6	61	66	64
2008	48.0	36.7	61	46	70
2012	29.2	16.3	72	72	90
2013	28.2	20.0	59	60	78
2014	39.4	32.5	66	62	79
2015	52.4	38.6	69	76	85
2016	35.7	29.1	69	77	83

[1] Ambient monitoring location = STORET 22880001

Appendix D --- Watershed Model Development

Watershed and in-lake modeling were used in conjunction with analysis of observed water quality data to develop the Total Maximum Daily Load (TMDL) for the algae impairment to Green Valley Lake in Union County, Iowa. This TMDL targets an allowable phosphorus load that will satisfy the primary contact recreation impairment (see Section 3 of this document for details). Reduction of phosphorus is expected to reduce algal blooms and non-algal turbidity, which decrease water clarity and impair the ability of the public to enjoy the recreational benefits of the lake. Reduction of bioavailable phosphorus will also limit algal growth which will in turn stabilize water column pH.

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 Green Valley Lake and its watershed. This section of the Water Quality Improvement Plan (WQIP) discusses the modeling approach and development of the STEPL watershed and BATHTUB lake models.

D.1. Modeling Approach

Data from a 13-year period of record, 2002-2014, were analyzed and used to develop watershed and lake models for the simulation and prediction of phosphorus loads and in-lake response. Models representing a variety of conditions (e.g., wet, dry) and various years were developed. This process was instructive in understanding watershed and in-lake processes, and in the validation of model inputs and calibration. This simulation period is supplemental to the water quality assessment period (2008-2012) upon which the 2014 Integrated Report and 303(d) list were generated. As such, it best reflects the long term conditions of the impairment.

D.2. 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 used 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 local soil and precipitation data. Precipitation inputs include average annual rainfall and rainfall correction factors that describe the intensity (i.e., runoff producing) characteristics of long-term precipitation. Characteristics that affect STEPL estimates of hydrology and pollutant loading include land cover types, population of agricultural livestock, wildlife populations, population served by septic systems, and 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 watershed was divided into 6 subbasins to help quantify the relative pollutant loads stemming from different areas of the watershed and to assist with targeting potential BMP locations. These basins were created to coincide with the topography and interfluvial drainage ways throughout the Green Valley Lake watershed. Hydrology and pollutant loadings are summarized for each subbasin and also aggregated as watershed totals.

D.3. Meteorological Input

Precipitation Data

The STEPL model includes a pre-defined set of weather stations from which the user may obtain precipitation-related model inputs. Unfortunately, none of the NWS COOP stations within a reasonable distance of Green Valley Lake are included in the STEPL model. Therefore, rainfall data from the NWS COOP station at Creston, Iowa, was used for modeling purposes. Weather station information and rainfall data were reported in Section 2.1 (see Table 2.2 and Figures 2.2 and 2.3.)

Average annual precipitation from 2008-2012 was 42.1 inches/year, higher than the 13-year (2002-2014) annual average of 36.2 inches. Annual rainfall used in the STEPL model coincided with the long term 13-year period in order to simulate dry and wet precipitation patterns.

The STEPL precipitation correlation and rain day correction factors were calculated outside of STEPL and entered directly in the STEPL "Input" worksheet to override the default rainfall data. Precipitation data from the modeling period of 2002-2014 were utilized in parameterization. The rain day correction factor of 0.404 was calculated by dividing the number of days that it rained at least 5 mm by the number of days with at least 1 mm of rainfall. This ratio is intended to estimate the number of days that could potentially generate surface runoff. Precipitation inputs are reported in Table D-1, as entered in the "Input" worksheet of the 2002-2012 Green Valley Lake STEPL model.

Table D-1. STEPL rainfall inputs (2002-2014 average annual data)

Rain correction factors			
[1]0.888	[2]0.404		
[3]Annual Rainfall	**[4]Rain Days**	**[5]Avg. Rain/Event**	**Input Notes/Descriptions**
36.2	112	0.710	[1]The percent of rainfall that exceeds 5 mm per event
			[2]The percent of rain events that generate runoff
			[3]Annual average precipitation for modeling period (in)
			[4]Average days of precipitation per year (days)
			[5]Average precipitation per event (in)

D.4. Watershed Characteristics

Topography

The Green Valley Lake watershed was delineated into 6 subbasins using ArcGIS (version 10.2) and a 3-meter resolution digital elevation model (DEM) developed by the Iowa Department of Natural Resources (DNR). Figure D-1 illustrates the watershed and subbasin boundaries. The subbasins boundaries were chosen to coincide with internal fluvial boundaries both natural and artificial. These will aide in identifying areas to implement best management practice strategies in water quality improvement programs in the future.

Land Use

A Geographic Information System (GIS) coverage of land use information was developed using the Cropland Data Layer (CDL) for year 2014, which was obtained from the United States Department of Agriculture – National Agricultural Statistics Service (USDA-NASS, 2016). The CDL land cover data is summarized by Common Land Units (CLUs). According to the USDA – Farm Service Agency, CLUs are the smallest units of land that have a permanent, contiguous boundary, common land cover, common owner, and common producer (USDA-FSA, 2016). Cropping decisions can change from year to year and several instances were observed where a single CLU contained multiple land cover types in the same year. In such cases, CLU boundaries were split to incorporate all major land covers into the STEPL model. Because land cover pixels are much smaller than CLU field boundaries, many CLUs have one primary land cover, but small isolated pixels with several minor land cover types. In those cases, the dominant land cover within each CLU boundary was determined using a zonal statistic command within Spatial Analyst. This step served as a land cover “filter” to simplify the data and eliminate small isolated pixels of various land uses within a single field boundary. STEPL land cover classifications are reported in Table D-2, with land use distribution previously illustrated in the map (Figure 2-5) and table (Table 2-3) in Section 2.

Table D-2. STEPL land use inputs

Watershed	[1]Urban	Cropland	Pastureland	Forest	[2]User Defined	[3]Total
W1	26.54	830.09	0.00	0.00	30.58	887.209
W2	47.96	603.48	0.00	0.00	22.71	674.145
W3	17.96	702.55	0.00	106.15	37.27	863.936
W4	10.36	321.81	0.00	60.42	10.68	403.275
W5	33.68	166.46	46.38	206.86	244.29	697.678
W6	27.94	913.54	28.36	198.28	87.75	1255.873
[3]Total	164.44	3537.93	74.74	571.71	433.29	4782.12

1Urban includes all developed areas, including roads and farmsteads
2Includes non-pasture grassland and conservation reserve programs
3Totals exclude open water in STEPL land use inputs

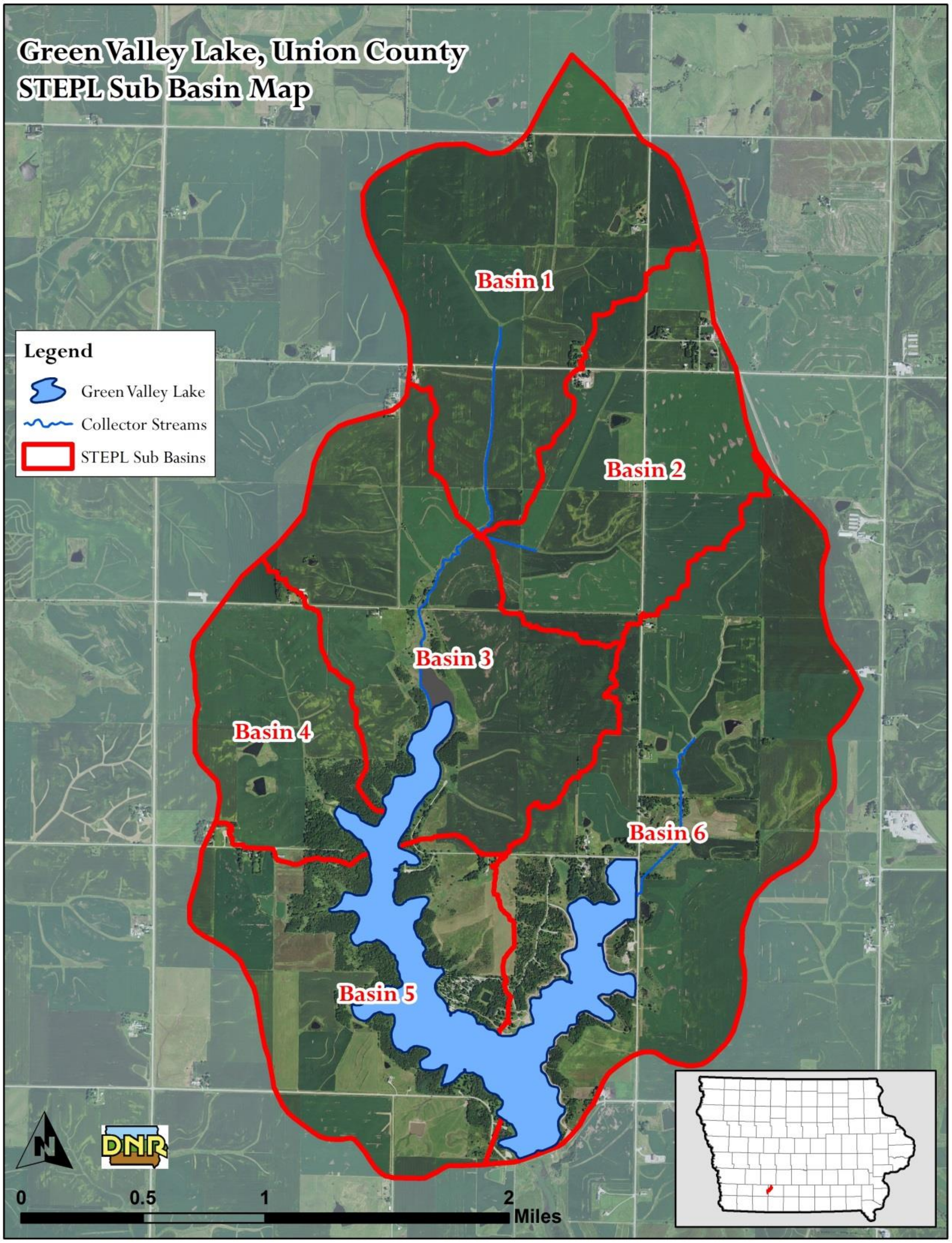

Figure D-1. STEPL subbasin map

Each land cover type was assigned a specific USLE C-factor and P-factor (Table D-3), based on regional estimates developed by DNR and Soil and Water Conservation district personnel for watershed assessments performed in the same ecoregion. C- and P-factors were assigned to each CLU using best available data. P-factors for row crop fields ranged from 0.56 to 0.79, with values of 1 representing no existing erosion practices. C-factors vary widely, from 0.0 for paved roads to 0.17 for row crops with extensive tillage and little plant residue. All USLE parameters were area-weighted and summarized for each subwatershed before input to the STEPL model.

Table D-3. C- and P-factors for each land cover and practice (BMP)

Land Cover Description	C-Factor	Practice	P-Factor
Corn-Soybeans; Conventional-Till	0.260	Terraces	0.6
Corn-Soybeans; Mulch-Till	0.125	Contour Farming	0.7
Corn-Soybeans; No-Till Beans, Mulch-Till Corn	0.080	Contour Buffers	0.7
Corn-Soybeans; No-Till Beans and Corn	0.050	Field Buffers	0.8
Grassland and Pasture	0.008	Ponds/Basins	0.4
Farmstead	0.020		
Timber	0.013		
Road	0.000		

Soils

Soils are discussed in detail in Section 2.2. 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 C soils, with some B and D soils interspersed. HSG values were area-weighted for each subbasin and used to modify curve numbers (CNs) in STEPL. Area-weighted calculations concluded HSG C is appropriate for all six sub basins. USLE K-factors are also specific to each soil type, and were area-weighted in the same fashion as C- and P-factors and entered into the “Input” worksheet in the STEPL model.

Slopes

Slopes are described in more detail in Section 2.2. USLE land slope (LS) factors were obtained from the SSURGO data and were assigned at the field-scale, then area-weighted to develop land-use specific LS factors for each STEPL subwatershed. Resulting LS-factors in entered into the “Input” worksheet in the STEPL model vary between 0.48 and 1.59.

Curve Numbers

The STEPL model includes default curve numbers (CNs) selected automatically based on HSG and land use. CNs in the Green Valley Lake STEPL model were manually adjusted by area-weighting HSG values and land use percentages so that differences in soil types are better reflected in CN values. In Iowa watershed modeling professionals across multiple agencies have found that standard NRCS curve numbers result in overestimation of surface runoff and flow (IDNR and ISU, unpublished data). Therefore, the HSG Type C CNs were modified to better reflect conditions in the watershed. Urban land use curve numbers were developed within STEPL based on percent landuse of the urban subcategories. Adjusted CNs were entered in the "Input" worksheet of STEPL, and are reported in Table D-4.

Table D-4. STEPL curve numbers

Subwatershed	[1]Urban	Cropland	[2]Pastureland	[3]User Defined
W1	90	85	79	75
W2	90	85	79	75
W3	95	86	79	75
W4	89	86	79	75
W5	87	86	79	75
W6	87	86	79	75

1Urban includes all developed areas, including transportation and farmstead areas
2Pastureland includes pasture and alfalfa ground in crop rotations
3User defined areas include non-pasture grassland

Sediment Delivery Ratio

The sediment load to each lake in the Green Valley Lake watershed will be dependent upon watershed morphology, water velocity, residence time, and other factors. The 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 the SDR for each subbasin using a simple empirical formula based on drainage area (i.e., subbasin area). The resulting SDR values range from 0.26 (Basin 6) to 0.32 (Basin 4).

Best Management Practices

STEPL is able to simulate load reduction efficiencies for a variety of urban and agricultural BMPs in each sub basin. Reductions are dependent on the overall efficiency of each practice and the area of the BMP to which it is applied. The main practices modeled in the Green Valley Lake watershed were the settling basins that occur throughout the watershed, but are most prevalent as forebays in the upper arms of the lake. These settling basins can allow suspended solids and the attached phosphorus to fall out of solution prior to reaching the main body of the lake. Percentages for area applied were based on manual delineation within each sub basin. The practices and BMP reduction efficiencies for each sub basin are listed in Table D-5.

Table D-5. BMP reduction efficiencies

Subwatershed	N	P	BOD	Sediment	BMP	Area Applied (%)
W1	ND	0.129	0.140	0.204	Settling Basin	25
W2	ND	0.129	0.140	0.204	Settling Basin	25
W3	ND	0.258	0.280	0.408	Settling Basin	50
W4	ND	0.077	0.084	0.122	Settling Basin	15
W5	---	0.000	0.00	0.000	No BMPs modeled	0
W6	ND	0.180	0.196	0.285	Settling Basin	35

D.5. Animals

Agricultural Animals and Manure Application

The STEPL model utilizes livestock population data and the duration (in months) that manure is applied to account for nutrient loading from livestock manure application. There are small feedlots within the Green Valley Lake watershed, as well as large confined animal feeding operations (CAFOs) directly outside of the watershed that contribute through manure application on cropland within the watershed. Inspection of manure management plans (MMP) showed that several facilities directly contribute to manure application within the Green Valley Lake watershed. Values were calculated by finding a ratio of land applied manure inside and outside the Green Valley watershed, and then relating this ratio to the total number of animal units for each facility. Manure applications are expected to occur over the course of 4 weeks (1 month total) in the spring and fall. However, as an annual average loading model, STEPL does not separate application times. Table D-5 lists the number and type of animals, the animal equivalent units (AEU) normalized per acre, and number of months manure is applied.

Table D-6. Agricultural animals and manure application

Watershed	Beef Cattle	Swine (Hog)	AEU (1000lb/ac)	# of months manure applied
W1	0	164	0.040	2
W2	15	53	0.042	2
W3	10	207	0.078	2
W4	0	26	0.016	2
W5	0	0	0.000	0
W6	0	0	0.000	0
Total	25	450	0.024	0 - 2

Livestock Grazing

There are two minor cattle grazing operations in the Green Valley Lake watershed. Erosion and nutrient loss from all grasslands are associated with the pasture landuse in the STEPL model, which likely results in an over-estimate of TP loads from this source. Erosion from pasture (and other grassland that may be in poor condition) carries sediment-bound phosphorus, which is accounted for by using a sediment nutrient enrichment ratio. The STEPL default enrichment ratio is 2.0. STEPL simulates nutrient loss in pasture and grassland runoff by assuming a phosphorus concentration of 0.3 mg/L in the runoff. Similarly, a phosphorus concentration of 0.063 was used to simulate phosphorus loads from shallow groundwater in grazed areas.

Open Feedlots

There are no open feedlots in the Green Valley Lake watershed in the IDNR Animal Feeding Operations Database. Feedlot operators are not required to report open feedlot information to IDNR for feedlots with less than 1000 animal units (AUs). No active open feedlot operations were observed during the February 2017 windshield survey.

Wildlife

The estimated county-wide average deer density is approximately 5 deer per square mile, but an average of 10 deer per square mile was entered in the "Animals" worksheet of the STEPL model for Green Valley Lake watershed to account for increased density of deer around the lake. Population densities of 5 raccoons, 5 beavers, and 5 other per square mile were used to account for other wildlife (e.g., furbearers, upland birds, etc.) for which data is lacking.

Phosphorus contributions from waterfowl in and near the lake by Canada geese were not simulated by STEPL, but calculated outside the model and added separately to BATHTUB as an internal load. An estimate of goose population and subsequent phosphorus contributions at Green Valley Lake were provided by DNR staff. On an annual average basis, there are less than 50 geese residing at the lake; however, populations vary throughout the year due to migratory patterns and nesting seasons. Recent census data from area management biologists estimate that migratory populations swell to 12,000 in mid-December and then decline to residential numbers by mid-March. Estimates of time spent on the lake are 40 percent of daylight hours due to foraging activity in upland grounds.

Septic Systems

A GIS coverage of rural residences with private onsite wastewater treatment systems (e.g., septic systems) was developed using aerial images and anecdotal data from various state, county, and local agencies. This procedure resulted in the identification of 24 septic systems in this sparsely populated watershed. It is estimated that 5 percent of these systems are not functioning adequately (i.e., are ponding or leaching). This is a fairly common occurrence in some rural parts of the state. This information is included in the "Inputs" worksheet of the STEPL model for Green Valley Lake.

D.7. References

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Appendix E --- Water Quality Model Development

Two models were used to develop the Total Maximum Daily Load (TMDL) for Green Valley 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.

In-lake water quality simulations were performed using BATHTUB 6.14, an empirical lake and reservoir eutrophication model. The BATHTUB model developed for Green Valley Lake does not simulate dynamic conditions associated with storm events or individual growing seasons. Rather, the model predicts average water quality in the modeling period of 2002-2014, which includes the 2014 Integrated Report (2008-2012). This appendix discusses development of the BATHTUB model. The integrated watershed and in-lake modeling approach allows the holistic analysis of hydrology and water quality in Green Valley 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. Water quality predictions are based on empirical models that have been calibrated and tested for lake and reservoir applications (Walker, 1985). Control pathways for nutrient levels and water quality response are illustrated in Figure E-1.

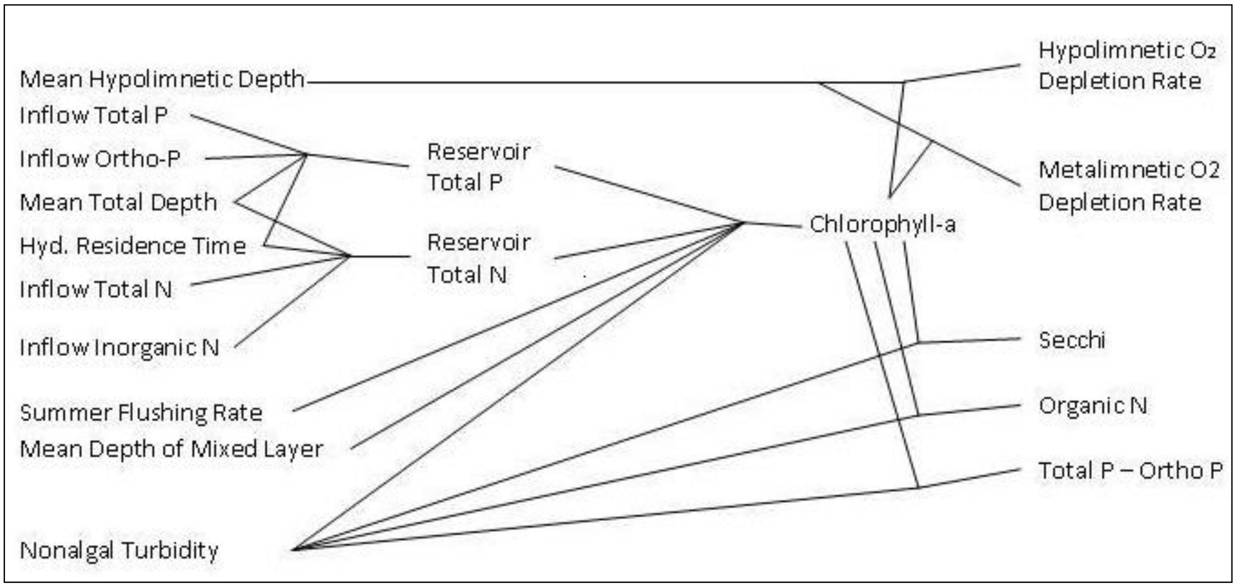


Figure E-1. Eutrophication control pathways in BATHTUB (Walker, 1999)

E.2. Model Parameterization

BATHTUB includes several data input menus and modules to describe lake characteristics, simulation equations, and external (i.e., watershed) inputs. Data menus utilized to develop the BATHTUB model for Green Valley 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 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 or 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 Green Valley Lake BATHTUB model and report input parameters for each menu.

Model Selections
BATHTUB includes several models and empirical relationships 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 (Walker, 1999). Alternative models are provided in BATHTUB to allow use of other eutrophication models, evaluate sensitivity of each model, and facilitate water quality simulation in light of data constraints.

Table E-1 reports the models selected for each parameter used to simulate eutrophication response in Green Valley Lake. Preference was given to Models 1 and 2 during evaluation of model performance and calibration of the Green Valley Lake model, but final selection of model type was based on applicability to lake characteristics, availability of data, and agreement between predicted and observed data. The default models were left to predict in-lake phosphorus and transparency levels because it provided the best agreement with observed data, and because Green Valley Lake is a manmade impoundment and representative of aquatic systems for which these specific models were developed. Chlorophyll model selection was based on observed data agreement and applicability of based on BATHTUB user manual IR-W-96 table 4.2. Model performance is discussed in more detail in Appendix F.

Table E-1. Model selections for Green Valley Lake

Parameter	Model No.	Model Description
Total Phosphorus	*01	2nd order, Avail. P
Total Nitrogen	02	2nd order decay
Chlorophyll-a	04	P, Linear
Transparency	*01	vs. chlorophyll-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 Green Valley 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 Green Valley Lake.

Table E-2. Global variables data for simulation period[1]

Parameter	Observed Data	BATHTUB Input
Averaging Period	Annual	1.0 years
[1]Precipitation	35.4 in	0.90 m
[1]Evaporation	38.3 in	0.97 m
[2]Increase in Storage	0	0
[3]Atmospheric Loads:		
TP	0.3 kg/ha-yr	30 mg/m^2-yr
TN	7.7 kg/ha-yr	770.3 mg/m^2-yr

[1]Precip and evaporation data are from 2002-2008 and 2012-2016 in order to provide accurate long term data
[2]Change in lake volume from beginning to end of simulation period.
[3]From Anderson and Downing, 2006.

Precipitation was summarized for the 13-year assessment period of 2002-2014 from the National Weather Service Cooperative weather station at Creston, Iowa (IEM, 2016a). Potential evapotranspiration data for the same period was obtained from the Lewis, Iowa weather station via the ISU Ag Climate database (IEM, 2016b). Net change in reservoir storage was assumed to be zero. This 13 year period was chosen in order to reflect the climate during the assessment period when water quality data was collected and analyzed to show the algal and non-algal impairments at Green Valley Lake. It was shown in Section 3.1 (Figures 3-9 to 3-11) that precipitation is not highly correlated with total phosphorus and the impairment seen at Green Valley Lake. For these reasons, it was assumed the extended assessment period climate conditions may be a more suitable basis for global variable data. These data were summarized and converted to BATHTUB units and entered in the global data menu. Atmospheric deposition rates were obtained from a regional study (Anderson and Downing, 2006). Nutrient deposition rates are assumed constant from year to year.

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. If evaluation of individual segments of the lake (or inflowing tributaries) is desirable, the lake can be split into multiple segments. Each segment may have a distinct tributary.

The Green Valley Lake BATHTUB model includes four lake segments to facilitate simulation of diffusion, dispersion, and sedimentation that occur as water traverses between the two main arms and the main body of the lake. This relationship is shown in Table E-5. Segment 4 contains the deep water area in which water quality data is regularly collected through DNR’s Ambient Monitoring Program. Because the ambient monitoring location is used for listing and delisting purposes, the TMDL target applies only to this segment of the lake system.

Two forebays that accept upstream overland flow and act as sediment basins prior to the two main arms of Green Valley Lake were excluded from the BATHTUB model. For most of the modeled period prior to lake renovation the forebays were separated by low water crossings, meaning that without high flow the forebays were not hydrologically connected to Green Valley Lake. However, their sediment trapping capabilities were modeled in STEPL where appropriate. Figure E-2 shows the location and naming convention of each lake in the BATHTUB model. Table E-4 shows the model variables for the monitored and assessed segment.

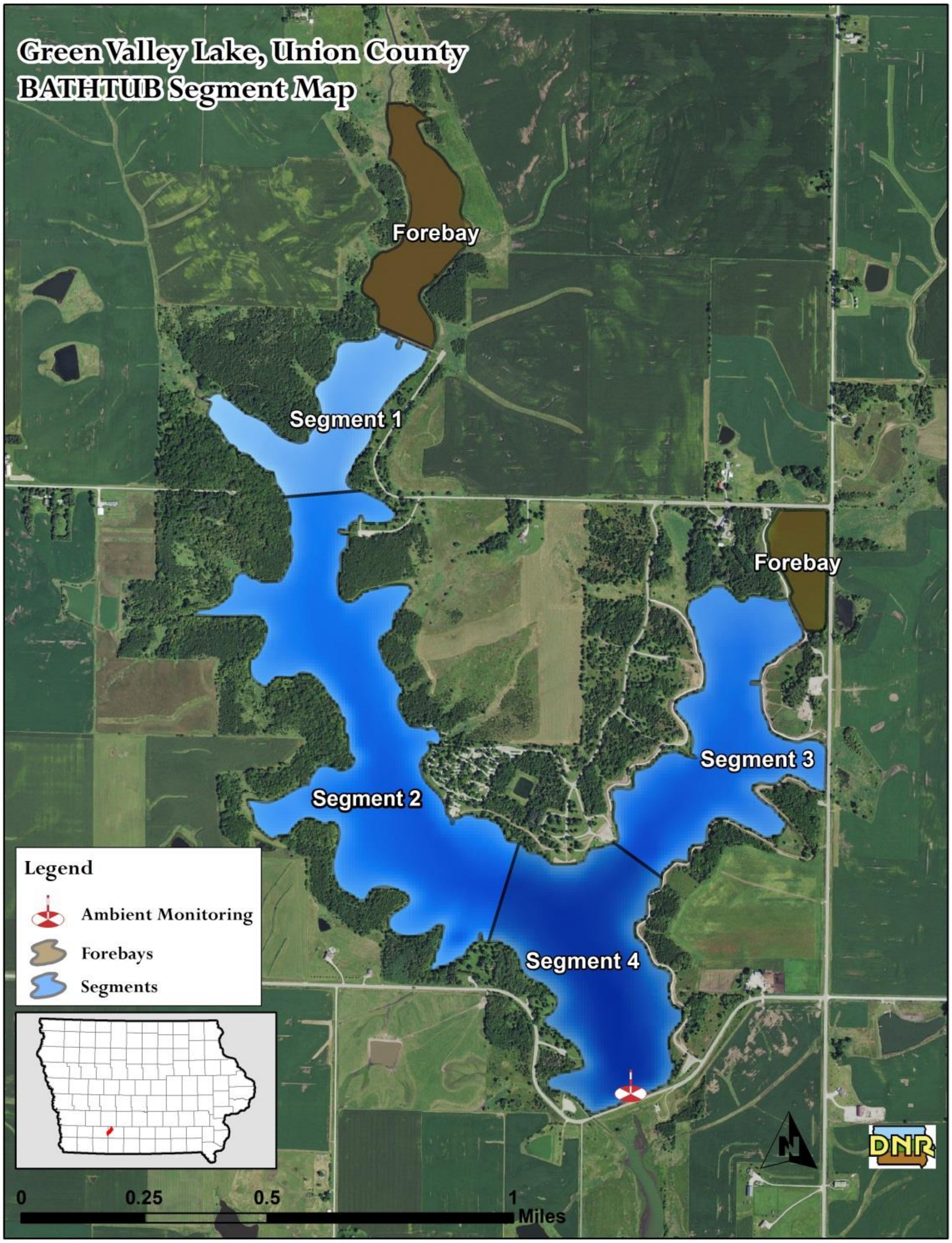


Figure E-2. Lake segmentation in BATHTUB model

Segment morphometry was calculated for each segment in the model. Bathymetric survey data and ESRI GIS software was used to estimate segment surface area, mean depth, and segment length. Temperature and dissolved oxygen (DO) profiles were used to estimate the mixed layer and hypolimnetic depth at the ambient monitoring location in Green Valley Lake. Segment physical parameters input into BATHTUB for the lake system area shown in Table E-3.

Table E-3. Segment morphometry for the Green Valley Lake

Segment	Outflow Segment	Segment Group	Surface Area (km^2)	Mean Depth (m)	Length (km)
Segment 1	Segment 2	1	0.158	2.16	0.58
Segment 2	Segment 4	1	0.567	3.25	1.57
Segment 3	Segment 4	1	0.310	2.91	1.02
Segment 4	Out of Reservoir	1	0.336	4.86	0.85

Mean water quality parameters observed for the modeling period (2002-2014) are reported in Table E-4. These data were compared to output in Segment 4 of the BATHTUB lake model to evaluate model performance and calibrate the BATHUB and STEPL models for each scenario. Data for model calibration was available only for Segment 4 in Green Valley Lake. The TMDL and future water quality assessment and listing will be based solely on water quality data from Segment 4.

Table E-4. Ambient (Segment 4) water quality (2002-2014 annual means)

Parameter	Measured Data	[1]BATHTUB Input
Total Phosphorus	158.3 µg/L	158.3 ppb
Total Nitrogen	2.25 mg/L	2250 ppb
Chlorophyll-a	49.9 µg/L	49.9 ppb
Secchi Depth	0.9 m	0.9 m

[1] Measured or monitored data converted to units required by BATHTUB
ppb = parts per billion = micrograms per liter (ug/L)

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 Green Valley Lake BATHTUB model 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. Table E-5 summarizes the physical parameters and monitored inputs for Green Valley Lake.

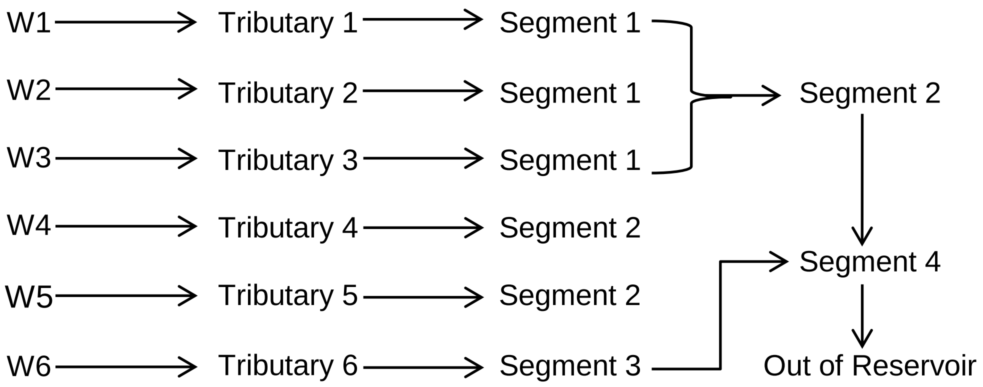
Table E-5. Tributary data for the Green Valley Lake

Tributary name	BATHTUB Receiving Segment	Total Watershed Area (km^2)	Avg Period Flow Rate (hm^3/yr)	STEPL Total P concentration (ppb)
Tributary 1	Segment 1	3.60	1.37	545.3
Tributary 2	Segment 1	2.73	1.04	511.1
Tributary 3	Segment 1	3.72	1.33	390.1
Tributary 4	Segment 2	1.71	0.61	546.6
Tributary 5	Segment 2	3.46	0.88	350.3
Tributary 6	Segment 3	5.73	1.87	341.7

Tributary data were obtained from the STEPL model, converted to units consistent with BATHTUB, and entered in the tributary data menu. Table E-6 lists the STEPL subbasins that drain to the tributary and also illustrates the connectivity of BATHTUB segments.

Table E-6. Flow and transport linkages in STEPL and BATHTUB

STEPL Subbasin	BATHTUB Tributary	BATHTUB Segment	Outflow Segment



E.3. References

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Appendix F --- Model Performance and Calibration

The Green Valley Lake watershed and water quality models were 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 2002 and 2014. Literature values and results from regional studies regarding sediment and phosphorus exports in similar watersheds were also utilized to evaluate model performance. 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 according to similar studies, and (2) provide good agreement with observed water quality in Green Valley Lake.

F.1. STEPL Performance and Calibration

The STEPL model is a long-term average annual simulation model, and is incapable of simulating storm events or short-term fluctuations in hydrology and nutrient loads. There is no long-term monitoring data for tributaries in the Green Valley Lake watershed, therefore model calibration relied heavily upon sediment and phosphorus exports reported in similar watersheds in the region. Table F-1 reports estimated sheet and rill erosion rates found in several Iowa watersheds that are similar composition or proximate in location. Values for Green Valley Lake watershed are before BMP reductions and only consider erosion losses from cropland, normalized with cropland acreage.

Table F-1. Sheet and rill erosion in Southern Iowa Drift Plain watersheds

Watershed	County	Area (acres)	Proximity (miles)	Erosion (tons/ac/yr)
Lake Hawthorne	Mahaska	3,289	126	5.3
Badger Creek Lake	Madison	11,397	35	3.9 – 4.5
Lake Miami	Monroe	3,595	80	2.2
Miller Creek	Monroe	19,930	90	2.3
[1]Green Valley Lake	**Union**	**5,175**	**--**	**2.7**

[1] Annual sheet/rill erosion estimated for this TMDL using STEPL (2002-2014).

The Green Valley Lake STEPL model predicts sheet and rill erosion rates that are consistent with those predicted by DNR for other watersheds in the area. The 2002-2014 simulated annual average sheet and rill erosion rate was 3.3 tons/acre, compared with average estimated rates between 2.2 to 5.3 tons/acre/year estimated in other watersheds in the Southern Iowa Drift Plain. Note that erosion rates in Table F-1 reflect sheet and rill erosion, not sediment delivered to the lake. Figure F-1 shows the sheet and rill erosion in the Green Valley Lake watershed.

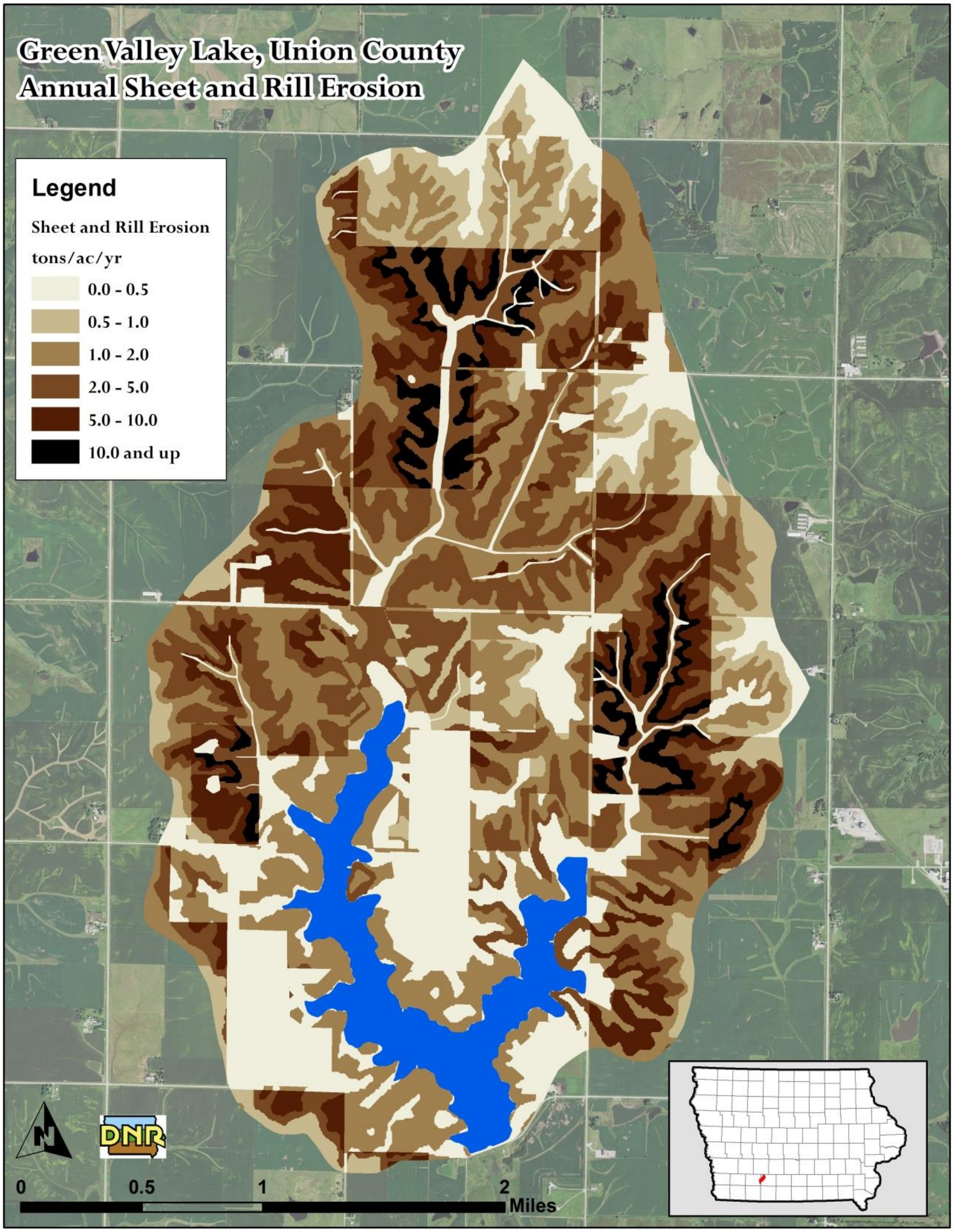

Figure F-1. Sheet and rill erosion in the Green Valley Lake watershed

Table F-2 compares the annual average TP export simulated by the Green Valley Lake Lake STEPL model with past study results in other watersheds in Iowa with an emphasis on the Southern Iowa Drift Plain. TP exports in the Green Valley Lake watershed are 1.6 pounds per acre per year. However, this reduced rate takes sediment basins throughout the watershed into account when calculating load reductions- reductions which may not occur in other watershed studies. Because the STEPL model predicted sediment and phosphorus loads similar in magnitude to estimates developed for other local and regional watersheds, IDNR has determined the STEPL model to be adequate for estimation of phosphorus loads to Green Valley Lake for development of TMDLs and implementation planning.

Table F-2. Comparison of TP exports in Southern Iowa Drift Plain watersheds

Watershed Location	Source	TP Export (lb/ac)
Lake Iowa, Iowa County	IDNR (Previous TMDL)	2.3
Windmill Lake, Taylor County	IDNR (Previous TMDL)	2.5
[1]Black Hawk Lake, Sac County	IDNR (Previous TMDL)	2.1
Badger Creek Lake, Madison County	IDNR (Previous TMDL)	2.2
Green Valley Lake, Union County	**STEPL Model (Current TMDL)**	**1.6**
[2]Green Valley Lake, Union County	**STEPL Model (Current TMDL)**	**2.5**

[1]Black Hawk Lake is at the intersection of the Southern Iowa Drift Plain, Des Moines Lobe, and Northwest Iowa Plain landforms
[2]TP Export considering only cropland acres and without reductions gained by BMP practices

F.2. BATHTUB Model Performance

Performance of the BATHTUB model was assessed by comparing predicted water quality with observed data collected in Green Valley Lake. Simulation of TP concentration and chlorophyll-a (algae) was critical for TMDL development, and were the focus of calibration efforts.

Calibration

Table F-3 reports observed and predicted annual average TP, chlorophyll-a, and Secchi depths in the open water area (Segment 4) of Green Valley Lake, along with the dispersion model and calibration coefficients for each parameter of interest. More comprehensive observed data is reported in Appendix C. Predicted water quality is based on BATHTUB simulations, and the calibration coefficients were iteratively adjusted in order to obtain the best possible agreement between observed and predicted water quality, while minimizing changes in the default coefficients. The calibration period was 2002-2008 and 2012-2016, the period for which water quality data was available.

Calibration coefficients listed alongside the simulated values in Table F-3 were entered in the “Segments” menu of the BATHTUB model, and apply to only the ambient monitoring segment (Segment 4) of Green Valley Lake. Other lake segments were uncalibrated due to lack of historical water quality data. Calibration coefficients for Green Valley Lake are within the recommended range according to the BATHTUB user guidance (Walker, 1999).

Initial testing showed phosphorus levels from watershed loading were inadequate for meeting observed water quality data in Green Valley Lake. Internal loading concentrations were increased for each lake segment until simulated phosphorus levels at the ambient monitored segment reached observed phosphorus levels. This resulted in 2 percent allocation of internal loading to Green Valley Lake with segment areal loading rates shown in table F-4. Loading was higher in the deeper, ambient monitoring segment due to the influence of hypoxia driven internal loading in the deep segment, as opposed to resuspension driven internal loading in the shallower segments (Filstrup 2016). Once simulated phosphorus levels were calibrated to observed phosphorus levels, other water quality measurements were calibrated by increasing or decreasing model coefficients within the BATHTUB model.

Table F-3. Observed and simulated water quality with calibration factors

Parameter	[1]Observed	[2]Predicted	Calibration Coefficient
Modeling period and TMDL conditions (2002-2008 and 2012-2016)			
Dispersion coefficient	--	--	--
Total Phosphorus (ug/L)	158.3	158.3	1.017
Chlorophyll-a (ug/L)	49.9	49.9	1.00
Secchi depth (m)	0.9	0.9	1.00
Chl-a/Secchi slope	--	0.025	0.020

[1]Average concentration observed at ambient monitoring location
[2]Average annual concentration predicted in Segment 4 of BATHTUB lake model

Table F-4. Segment internal loading for Green Valley Lake

Segment	Conservative substance (mg/m^2-day)	Total Nitrogen (mg/m^2-day)	Total Phosphorus (mg/m^2-day)
Segment 1	0	0	0
Segment 2	0	0	0
Segment 3	0	0	0
Segment 4	0	0	0.5

F.3. References

U.S. Geological Survey (USGS), 2001. Water Quality Assessment of the Eastern Iowa Basins – Nitrogen, Phosphorus, Suspended Sediment, and Organic Carbon in Surface

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

Appendix G --- Expressing Average Loads as 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 requirements, the loading capacity of Green Valley 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 4,882 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 the best option for identifying a maximum daily load (MDL) that corresponds to the allowable 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 2,160 lbs/year is equivalent to a long-term average (LTA) daily of 5.9 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 2.326, 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 18.4 lbs/day. The TMDL calculation is summarized in Table G-2. An explicit MOS of 10 percent (1.8 lbs) was applied, resulting in a daily LA of 37.5 lbs/day to the daily equation daily TMDL equations. The resulting TMDL, expressed as a daily maximum, is:

TMDL = LC = Σ WLA (0 lbs-TP/day) + Σ LA (16.6 lbs-TP/day)
+ MOS (1.8 lbs-TP/day) = **18.4 lbs-TP/day**

Table G-1. Multipliers used to convert a LTA to an MDL

Parameter	TMDL	Σ WLA	Σ LA	MOS
LTA (lbs/day)	5.9	0.0	5.3	0.53
Z Statistic	2.326	2.326	2.326	2.326
CV	0.6	0.6	0.6	0.6
σ^2	0.31	0.31	0.31	0.31
MDL (lbs/day)	**18.4**	**0.0**	**16.6**	**1.8**

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

Parameter	Value	Description
LTA	5.9 lbs/day	Annual TMDL (977 lbs) divided by 365 days
Z Statistic	2.326	Based on 180-day averaging period
CV	0.6	Used CV from annual GWLF TP loads
σ^2	0.31	ln $(CV^2 + 1)$
MDL	**18.4 lbs/day**	**TMDL expressed as daily load**

Appendix H --- 2014 305(b) Water Quality Assessment

Segment Summary

Waterbody ID Code: IA 05-PLA-1472
Location: Union County, S26, T73N, R31W, 2.5 mi NW of Creston.
Waterbody Type: Lake
Segment Size: 393 Acres

This is a Significant Publically Owned Lake

Segment Classes:

Class A1
Class B(LW)
Class C
Class HH

Assessment Comments

Assessment is based on: (1) the results of the IDNR-UHL beach monitoring program in the summer of 2008 and 2012, (2) results of the statewide survey of Iowa lakes conducted from 2009-2012 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted in 2008 by University Hygienic Laboratory (UHL), and (4) information from the IDNR Fisheries Bureau.

Assessment Summary and Beneficial Use Support

Overall Use Support - Not supporting
Aquatic Life Support - Fully
Fish Consumption - Not assessed
Primary Contact Recreation - Not supporting
Drinking Water - Not assessed

Assessment Type: Evaluated
Integrated Report Category: 5a
Trend: Stable
Trophic Level: Eutrophic

Basis for Assessment and Comments

SUMMARY: The Class A1 (primary contact recreation) uses are assessed (evaluated) as “not supported” due to algal and non-algal turbidity. The Class B(LW) (aquatic life) uses are assessed (evaluated) as “fully supported.” The Class C (drinking water) uses remain “not assessed” due to a lack of information upon which to base an assessment. Fish consumption uses are “not assessed” due to a lack of recent fish contaminant monitoring at this lake. Sources of data for this assessment include (1) the results of the IDNR-UHL beach monitoring program in summers of 2008 and 2012, (2) results of the statewide survey of Iowa lakes conducted from 2009-2012 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted in 2008 by University Hygienic Laboratory (UHL), and (4) information from the IDNR Fisheries Bureau.

Note: This assessment is considered an "evaluated" assessment because there were too few samples collected to support a "monitored" assessment. Restoration work completed throughout the assessment period limited the number of samples collected between 2008-2012. For the 2012 assessment/listing cycle, Green Valley Lake was assessed (monitored) as "partially supporting" its designated uses due to aesthetically objectionable conditions from algal and non-algal turbidity.

EXPLANATION: Results of IDNR beach monitoring from 2008 and 2012 suggest that the Class A1 uses are assessed (evaluated) as “fully supported." Levels of indicator bacteria at Green Valley Lake beach were monitored once per week during the primary contact recreation season (May through September) of 2008 (7 samples) and 2012 (4 samples) as part of the IDNR beach monitoring program. This assessment is considered an "evaluated" assessment because there were too few samples collected to support a "monitored" assessment. According to IDNR’s assessment methodology two conditions need to be met for results of beach monitoring to indicate “full support” of the Class A1 (primary contact recreation) uses: (1) the geometric mean of the samples from each recreation season of the three-year assessment period are less than the state’s geometric mean criterion of 126 E. coli orgs/100 ml and (2) not more than 10% of the samples during any one recreation season exceeds the state’s single-sample maximum value of 235 E. coli orgs/100 ml. If a sampling season geometric mean exceeds the state criterion of 126 orgs/100 ml during the three-year assessment period, the Class A1 uses should be assessed as “not supported.” Also, if significantly more than 10% of the samples in any one of the three recreation seasons exceed Iowa’s single-sample maximum value of 235 E. coli orgs/100 ml, the Class A1 uses should be assessed as “partially supported.” This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35 of U.S. EPA 1997b).

NOTE: Based on consultation with EPA Region 7 staff in 2011, IDNR’s methodology for assessing impairments based on the geometric mean water quality criterion was changed. Prior to the 2012 listing cycle, IDNR calculated geometric means for lakes based on a 30-day periods within the recreational season. Any violation of one of these 30-day periods within 3 years resulted in an impairment of the Class A1 uses of that lake. Because water quality standards do not identify a 30 day period but instead a recreational season, Region 7 concurred that the approach used for rivers and streams with less frequent bacteria data (seasonal geometric means) would be appropriate for identifying §303(d) impairments at lake beaches. Thus, for the 2014 listing cycle, IDNR identified primary contact recreation impairments for lakes when the geometric mean of all samples from the recreation season of a given year exceeded the geometric mean criterion. This does not impact the way IDNR assesses beaches for closure to protect the recreating public in the short term.

At Green Valley Lake beach, the geometric mean from 2008 and 2012 was below the Iowa water quality standard of 126 E. coli orgs/100 ml. The geometric mean was 16 E. coli orgs/100 ml in 2008. The geometric mean was 11 E. coli orgs/100 ml in 2012. The percentage of samples exceeding Iowa’s single-sample maximum criterion (235 E. coli orgs/100 ml) was 14% in 2008 and was 0% in 2012. These results are not significantly greater than 10% of the samples and therefore do not suggest impairment of the Class A1 uses. According to IDNR's assessment methodology and U.S. EPA guidelines, these results suggest "full support" of the Class A1 uses.

Results of the ISU and UHL lake surveys suggest that the Class A uses are "not supported" at Creen Castle Lake due to aestheticially objectionable conditions caused by high algal and non-algal turbidity. Using the median values from these surveys from 2008-2012 (approximately 8 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 70, 71, and 85 respectively for Green Valley Lake. According to Carlson (1977) the Secchi depth, chlorophyll a, and total phosphorus values all place Green Valley Lake in the hypereutrophic category. These values suggest very high levels of chlorophyll a and suspended algae in the water, very poor water transparency, and extremely high levels of phosphorus in the water column. This assessment is considered an "evaluated" assessment because there were too few samples collected to support a "monitored" assessment. Restoration work completed throughout the assessment period limited the number of samples collected between 2008-2012. For the 2012 assessment/listing cycle, Green Valley Lake was assessed (monitored) as "partially supporting" its Class A1 and Class B(LW) uses based on monitoring data collected by the ISU and UHL surveys in 2006-2010.

Data from 2008-2012 suggest moderately high populations of cyanobacteria exist at Green Valley Lake, which may contribute to aesthetically objectionable conditions at this lake. Thus, this lake is added to Iowa's list of waters in need of further investigation (IR 3b). These data show that cyanobacteria comprised 77% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (18.4 mg/L) and ranked 67th of the 134 lakes sampled.

The levels of inorganic suspended solids at this lake were high and may contribute to the non-algal turbidity impairment. The median level of inorganic suspended solids in Green Valley Lake (9.3 mg/L) and ranked 105th of the 134 lakes sampled by the ISU and UHL programs.

The Class B(LW) (aquatic life) uses are assessed (evaluated) as "fully supported." The ISU and UHL lake surveys data from 2008-2012 show no violations of the Class B(LW) criteria for ammonia in 8 samples, two violations of the Class B(LW) dissolved oxygen criterion in 8 samples (25%), and no violations of the Class A1,B(LW) pH criterion in 8 samples. Based on IDNR's assessment methodology these violations are not significantly greater than 10% of the samples and therefore do not suggest an impairment of the Class B(LW) uses of Green Valley Lake.

Note: A fishery renovation was completed in 2008. Watershed improvements are being installed and other a sediment removal project is scheduled for the winter of 2009/2010. Water quality improvements are expected as this project progresses and the lake is filled. Because of the water quality improvement project activities throughout the assessment period, a limited number of samples were collected in 2008-2012.

The Class C (drinking water) uses remain "not assessed" due to a lack of water quality information upon which to base an assessment. The only parameter collected as part of the ISU and UHL lake surveys relevant to support of Class C (drinking water) uses is nitrate. While the results of the ISU and UHL survey from 2008-2012 show that nitrate levels are low at this lake (maximum value = 4.1 mg/l; median = 0.2 mg/l) relative to the MCL (10 mg/L), these data are not sufficient for developing a valid assessment of support of the Class C uses.

Fish consumption uses are assessed (evaluated) as “fully supported” based on results of U.S.EPA/IDNR fish contaminant (RAFT) monitoring at Green Valley in 2011. The composite samples of fillets from largemouth bass and channel catfish had low levels of contaminants. Levels of primary contaminants in the composite sample of channel catfish fillets were as follows: mercury: 0.0541 ppm; total PCBs: 0.09 ppm; and technical chlordane: <0.03 ppm. Levels of primary contaminants in the composite sample of largemouth bass fillets were as follows: mercury: 0.200 ppm. The existence of, or potential for, a fish consumption advisory is the basis for Section 305(b) assessments of the degree to which Iowa’s lakes and rivers support their fish consumption uses. The fish contaminant data generated from the 2011 RAFT sampling conducted at this lake show that the levels of contaminants do not exceed any of the advisory trigger levels, thus indicating no justification for issuance of a consumption advisory for this waterbody.

Monitoring and Methods

Assessment Key Dates

5/6/2008	Fixed Monitoring Start Date
9/12/2012	Fixed Monitoring End Date

Methods

- Surveys of fish and game biologists/other professionals
- Non-fixed-station monitoring (conventional during key seasons and flows)
- Primary producer surveys (phytoplankton/periphyton/macrophyton)
- Water column surveys (e.g. fecal coliform)

Appendix I --- DNR Project Files and Locations

This appendix is primarily for future reference by DNR staff that may wish to access the original spreadsheets, models, maps, figures, and other files utilized in the development of the TMDL.

Directory\folder path	File name	Description
\\iowa.gov.state.ia.us\...\Data\Raw\	Various files	All raw data received from others
\\iowa.gov.state.ia.us\...\Data\Reduced\	Water_Quality_Data_GVL.xls	Summary of in-lake WQ data
\\iowa.gov.state.ia.us\...\Data\Reduced\Climate	Climate_Precip_ET_ GVL.xls	Summary of precipitation and PET data
\\iowa.gov.state.ia.us\...\Documents\Draft_TMDL	Draft TMDL reports	Includes review comments
\\iowa.gov.state.ia.us\...\Documents\Final_TMDL	Final report	Report fir submittal to EPA
\\iowa.gov.state.ia.us\...\Documents\References	Various .pdf and .doc files	References cited in the WQIP and/or utilized to develop model input parameters
\\iowa.gov.state.ia.us\...\GIS\GIS_Data	Various shapefiles (.shp) and raster files (.grd)	Used to develop models and maps
\\iowa.gov.state.ia.us\...\GIS\Projects	ArcGIS project files	Used to develop models and maps
\\iowa.gov.state.ia.us\...\Maps, Figures, Images\Maps	Various .pdf and .jpg files	Maps/figures used in the WQIP document
\\iowa.gov.state.ia.us\...\Modeling	Allocations_Final.xls	Used to develop phosphorus source inventory and potential load allocation scenario
	TMDL_Equation_Calcs_ GVL.xls	Used to develop the TMDL equation (LA, WLA, and MOS)
		Load response curve calcs
\\iowa.gov.state.ia.us\...\Modeling\STEPL	Stepl_ GVL _2002-2016_.xls	Used to simulated/predict existing watershed loads
	Various .xls files	Used to develop/calculate STEPL model inputs
\\iowa.gov.state.ia.us\...\Modeling\BATHTUB\InputFiles	STEPL_Conversion_ GVL.xls	Calculated/converted STEPL outputs to BATHTUB inputs for existing conditions
	BATHTUB _2002-2014.xls	
	Various .btb files	BATHTUB input files for various scenarios

Appendix J --- Public Comments

Public Comment:

The Iowa Department of Natural Resources received no public comments on the Green Valley Lake TMDL.