Water Quality Improvement Plan
for

Big Creek Lake

Polk County, Iowa

Total Maximum Daily Load
For Pathogen Indicators (*E. coli*)

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Watershed Improvement Section
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Report Summary

What is the purpose of this report?

This Water Quality Improvement Plan (WQIP) has two purposes. First, it is a resource to be used by watershed planners, water quality action groups, individual citizens, and local and state government staff. It serves as a guide to help these groups understand and identify the cause of Big Creek Lake water quality problems and to guide locally driven water quality improvements in the lake. The problem addressed in this plan is the high concentration of bacteria that have been measured at the beach. Secondly, this report satisfies the Federal Clean Water Act obligation to establish a Total Maximum Daily Load (TMDL) for waterbodies on the 303(d) impaired waters list.

What is wrong with Big Creek Lake?

Big Creek Lake is impaired for pathogen indicator bacteria counts that exceed the Water Quality Standards (WQS) criteria. This problem impairs recreational use of the lake.

What is causing the problem?

Big Creek Lake is impaired for bacteria at the lake's swimming beach. The bacteria problem, measured by *E. coli* concentration, is caused by wildlife, livestock manure, and poorly functioning septic systems.

What can be done to improve Big Creek Lake?

To improve Big Creek Lake water quality, bacteria loads to the lake must be reduced. A combination of the following management practices can be implemented to achieve these reductions:

- management of geese population and removal of feces from the beach and lawn areas adjacent to the lake,
- restricting cattle from streams,
- adoption of manure application strategies that reduce loss in runoff, and
- inspection, repair, and maintenance of septic systems.

Who is responsible for a cleaner Big Creek Lake?

Everyone who lives, works, or plays in the Big Creek Lake watershed has a role in water quality improvement. Because there are no regulated point sources in the watershed, voluntary management of land and animals will be required to see positive results. Improving water quality will require the collaboration of citizens and agencies with an interest in protecting the lake now and in the future.

Required Elements of the TMDL

This Water Quality Improvement Plan has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7 in compliance with the Clean Water Act. These regulations and consequent TMDL development are summarized below:

Table 1-1 Required TMDL Elements

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Big Creek Lake, Polk County Section 22,T81N,R25W Latitude 41.8122 Longitude 93.7413
Use designation classes:	Class A1 Primary Contact Recreation Class B (WW1) Aquatic Life Class HH (Human Health)
Impaired beneficial uses:	Class A1 Primary Contact Recreation
Identification of the pollutants and applicable water quality standards:	Primary contact recreational use (Class A1) is not supported due to violation of the *E. coli* Water Quality Standard criteria of 126 organisms/100 ml for the geometric mean (GM) and 235 organisms/100 ml for the single sample maximum (SSM).
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The *E. coli* load capacity has been calculated for five flow recurrence intervals. Tables 3-4 and 3-5 list the load capacities.
Quantification of the amount or degree by which the current pollutant loads in the water body deviate from the pollutant loads that attain water quality standards:	The *E. coli* load departure from capacity has been calculated for five flow recurrence intervals. Table 3-7 lists these departures.
Identification of pollution source categories:	Nonpoint watershed *E. coli* sources are identified as the cause of the Big Creek Lake pathogen indicator impairment.
Wasteload allocations for pollutants from point sources:	There are no permitted point sources that discharge in the watershed and the WLA summation is zero.
Load allocations for pollutants from nonpoint sources:	The *E. coli* load allocations have been calculated for five design flow recurrence intervals. Tables 3-8 and 3-9 list the load allocations.
Margin of safety (MOS):	The margin of safety for this TMDL is an explicit 10 percent of the load capacity. Tables 3-8 and 3-9 list the MOS.

Consideration of seasonal variation:	The recreation season as defined in the Iowa Water Quality Standards runs from March 15 through November 15. This is the season used in the development of this pathogen indicator TMDL.
Allowance for reasonably foreseeable increases in pollutant loads:	An allowance for increased pathogen indicator loading was not included in this TMDL. The Iowa Department of Natural Resources owns and maintains most of the shoreline around Big Creek Lake. The rest is in agricultural production with row-crop predominating. A change in watershed land use is unpredictable.
Implementation plan:	An implementation plan is provided in Section 4 of this document to guide local citizens, government, and water quality improvement planning groups.

1. Introduction

The Federal Clean Water Act requires states to assess their waterbodies every even numbered year and incorporate these assessments into the 305(b) Water Quality Assessment Report. Assessed lakes and streams that do not meet the Iowa Water Quality Standards criteria are placed on the 303(d) Impaired Waters List. Subsequently, a Total Maximum Daily Load (TMDL) for each pollutant must be calculated and a Water Quality Improvement Plan written for each impaired waterbody.

A TMDL is a calculation of the daily maximum amount of a pollutant a waterbody can receive without exceeding the water quality standards. The total maximum daily load is allocated to permitted point sources (wasteload allocations), nonpoint sources (load allocations), and a margin of safety that accounts for uncertainty in the calculations.

This TMDL report is for Big Creek Lake in Polk County, Iowa. Big Creek Lake is on the 2008 impaired waters list for *E. coli*, a pathogen indicator.

There are two primary purposes of this report: 1) Satisfy federal TMDL requirements for impaired waters, and 2) Serve as a resource for guiding water quality improvement projects in the Big Creek Lake watershed that address bacteria problems. Local citizens, water quality groups, and government agencies will find it a useful description of the causes and solutions to Big Creek Lake water quality concerns.

A TMDL report has some limitations:

- The 305(b) water quality assessment is made with available data that may not adequately describe lake water quality. Additional targeted monitoring is often expensive and requires time. Assumptions and simplifications on the nature, extent, and causes of impairment can create uncertainty in calculated values.
- A TMDL may not fully address unregulated nonpoint sources of pollutants. It can be challenging to reduce pollutant loads when nonpoint sources are significant contributors.

This document can guide local water quality improvement projects targeted at pollutant sources in the watershed. The lake water quality mirrors the land that drains to it and reflects how well that land is managed. Local landowners, tenants, and other stakeholders often have the greatest influence on water quality.

2. Description and History of Big Creek Lake

Big Creek Lake is a significant publicly owned lake located in central Iowa in Polk County, three miles north of Polk City. It is the central feature of Big Creek State Park, a popular outdoor recreation area. There are two primary tributaries that discharge into the lake, Big Creek to the east and Little Creek to the west. These streams were impounded to create Big Creek Lake in 1977 during the construction of Saylorville Reservoir. A state park was also established at that time.

2.1. Big Creek Lake

Big Creek Lake is the focus of a 3,550 acre DNR owned complex. The lake was created as part of the Saylorville Dam and Reservoir project by a dam across Big Creek and was primarily developed as a flood control measure to protect Polk City. Big Creek State Park and the adjoining public hunting areas provide recreation for visitors include boating, fishing, and swimming. The lake features a swimming beach and ten miles of multi-use trails. The lake lies mostly within an area owned and managed by the DNR. Big Creek Lake has designated uses of Class A1 (primary contact recreation), Class B(WW-1) (aquatic life), and Class HH (human health). Table 2-1 lists basic lake information.

Table 2-1 Big Creek Lake

Waterbody Name	Big Creek Lake
8 Digit Hydrologic Unit Code (HUC):	07100004
IDNR Waterbody ID	IA 04-UDM-0140-L_0
Location	S22,T81N,R25W
Latitude	41.8122
Longitude	93.7413
Water Quality Standard Designated Uses	Class A1 Primary Contact Recreation Class B (WW-1) Aquatic Life HH Human Health
Tributaries	Big Creek and Little Creek
Receiving Waterbody	Des Moines River
Lake Surface area	755 acres (does not include area behind sediment detention structure)
Maximum Depth	53.4 feet
Mean Depth	19.4 feet
Volume	14,573 acre-feet
Watershed Area (with lake)	47,666 acres
Watershed/Lake Area Ratio	62

Figure 2-1 shows a bathymetric map of the lake and the park boundaries and amenities. The beach is the tan area along the shoreline just south of the three adjacent parking lots located on the east side of the lake. *E. coli* bacteria samples used for the water quality assessment were collected at the beach during the swimming season, May through September.

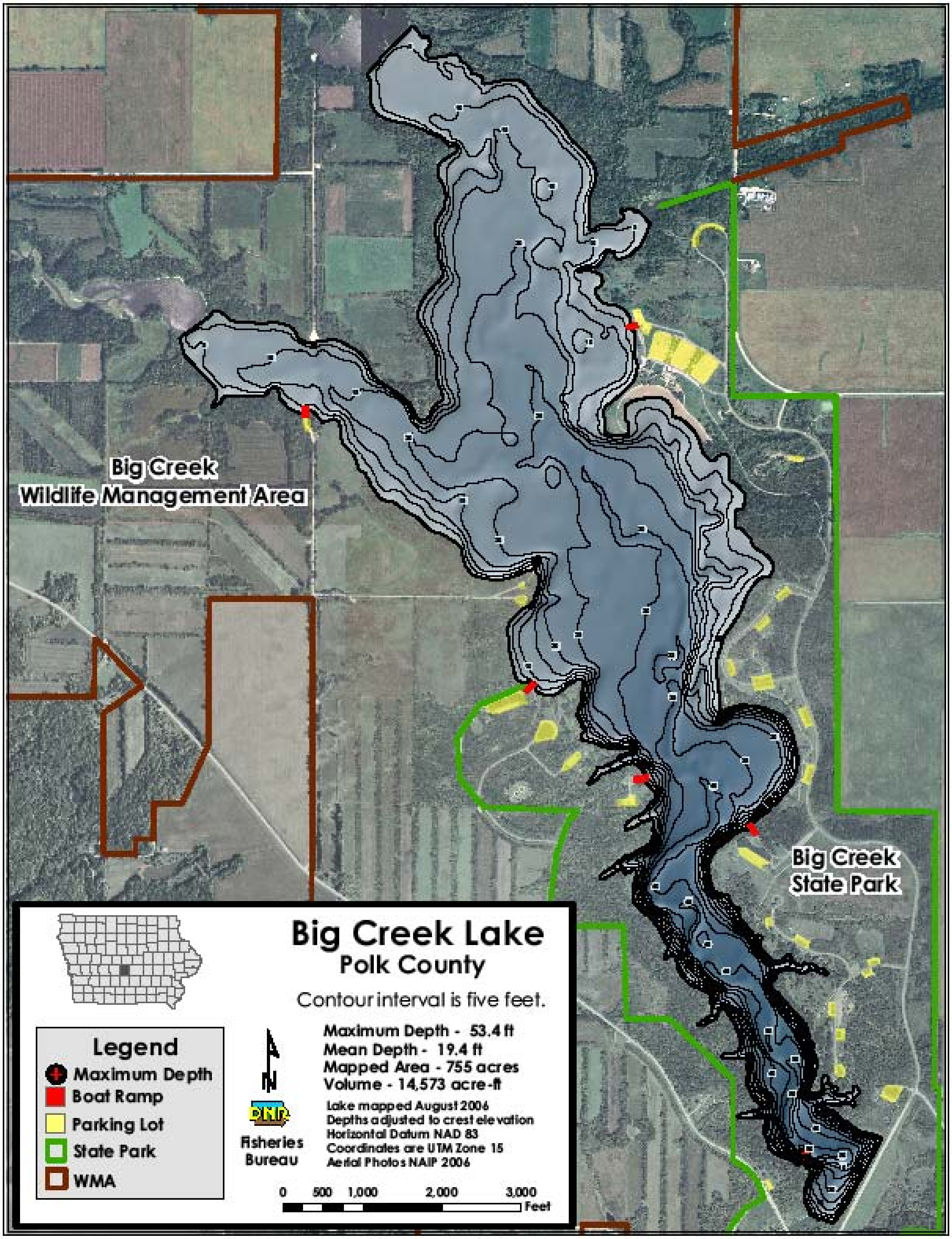

Figure 2-1 Big Creek Lake bathymetric map.

Hydrology and hydraulics.
Big Creek Lake has two major tributaries, Big Creek and Little Creek. Big Creek discharges into the north end of the lake and Little Creek discharges into the northwest side. There is another tributary, Turkey Creek, which discharges to the lake from the east, north of the beach. The lake outlet is in the south on the west side of the Diversion Dam. The average annual precipitation between 1893 and 2009 was 31.7 inches/year. The average annual precipitation in the fifteen years between 1995 and 2009 was 35.0 inches/year with a high of 50.1 inches in 2008. There were two years between 1893 and 2009 in which the average annual precipitation exceeded 50 inches, 1993 and 2008.

When the Saylorville project was designed, a dam was included to prevent the reservoir from backing up into Polk City and flooding it. Figure 2-2 shows this dam south of Polk City, labeled as Saylorville Lake Barrier Dam. Big Creek was also dammed creating an impoundment called Big Creek Lake. To accomplish this, the Diversion Dam was built across Big Creek north of Polk City with an outlet to Saylorville Reservoir. The outlet channel runs one mile to a spillway before discharging into Saylorville Reservoir.

The water surface elevation of Big Creek Lake is maintained at about 920 feet and it discharges to Saylorville Reservoir over a wide weir at the end of a long channel. The discharge over this weir varies with the flow into the lake. Generally, the lake water surface elevation does not vary much from the elevation of the weir crest. The exception to this is during long dry periods when evaporation exceeds flow into the lake and the water surface elevation drops below the weir crest. During wet periods the average daily outlet channel flow can be as high as 3,000 cfs. During dry periods the average daily discharge is usually zero and the water surface elevation can drop five to six feet below the weir crest elevation.

When this happens the only discharge from the lake is to the continuation of the original stream past the dam. This discharge is a constant four cfs with the purpose of maintaining creek integrity downstream. Big Creek continues downstream in its original channel meandering down through Polk City and ending in the Big Creek Ponding Area on the northeast side of the Saylorville Reservoir Barrier Dam. Figure 2-2 shows the dam structures and their spatial relationships to the channels, streams and lakes and Polk City.

The water surface elevation of Saylorville Reservoir fluctuates over a considerable range. The normal conservation pool elevation is 836 feet and the spillway crest is 884 feet. After the floods of 1993, an additional six feet of inflatable barrier was added to the spillway crest making the maximum lake surface elevation 890 feet before the spillway is overtopped. Therefore, it is not possible for Saylorville Reservoir to back up into Big Creek Lake.

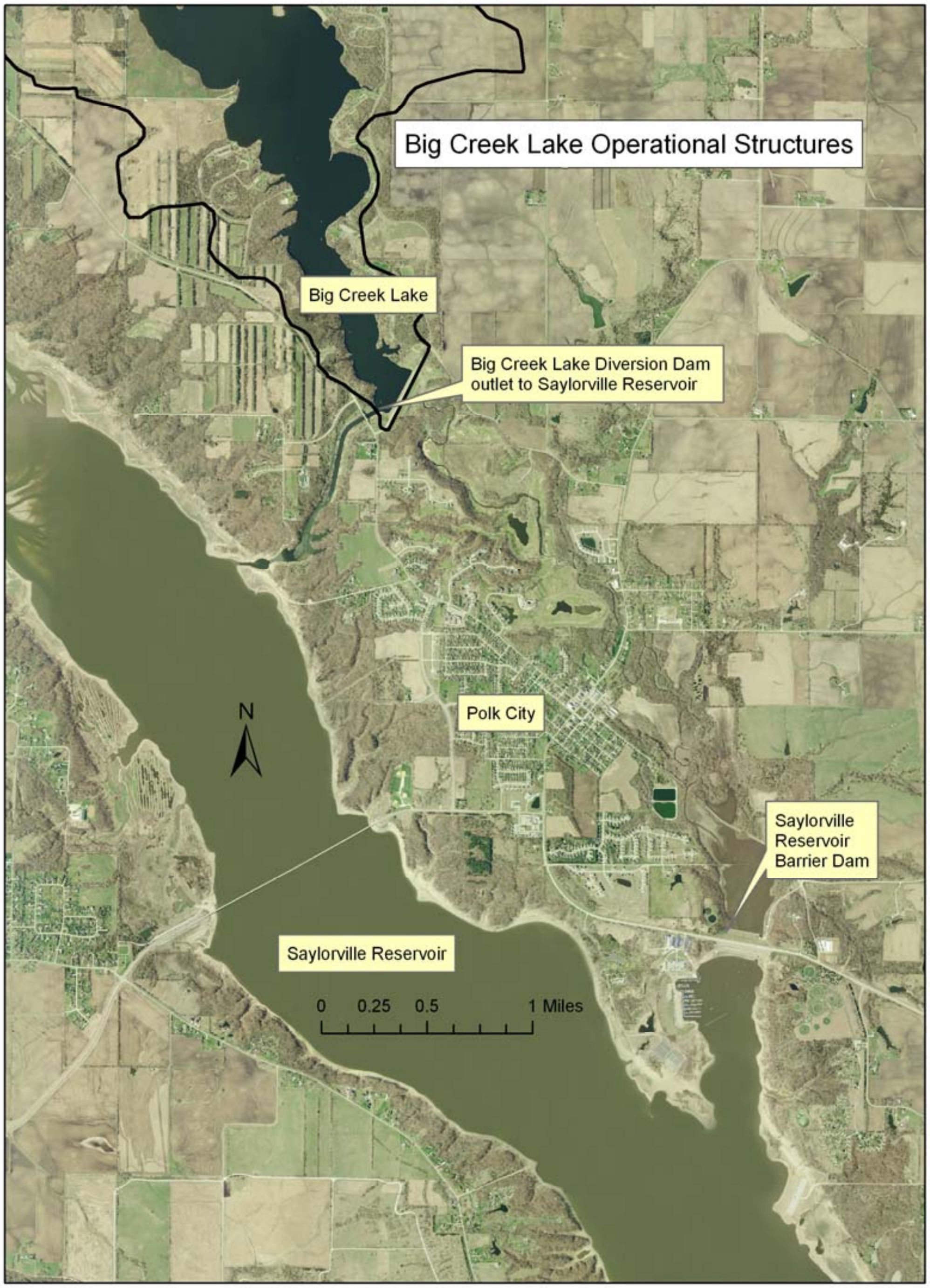

Figure 2-2 Big Creek and Saylorville Lakes Diversion and Barrier Dams

Morphometry.
Big Creek Lake, completed in 1977, follows the original Big and Little Creeks' stream channels. It is widest at the middle and narrows and deepens as it flows towards the dam as can be seen in the Figure 2-1 bathymetric map. Table 2-2 shows the morphometric

characteristics for Big Creek Lake. The lake is dendritic and has a scalloped irregular shoreline typical of impounded streams. These characteristics are reflected in the values for shoreline and volume development and Index of Basin Permanence.

Table 2-2 Big Creek Lake morphometric characteristics

Characteristic	Value	Unit	Year
Lake Surface Area	755	acres	2006
Lake Volume	14,573.6	acre-feet	2006
Maximum Depth	53.4	feet	2006
Mean Basin Slope	4.2	percent	2006
Mean Depth	19.4	feet	2006
Shoreline Length	16.8	miles	2006
Shoreline Development[1]	4.2	Ratio of shoreline length to circumference of a circle of the same area.	2006
Volume Development[2]	0.36	Ratio of mean depth to max depth shows how lake shape differs from a cone (0.33).	2006
Index of Basin Permanence[3]	0.67	Ratio of the lake volume (m^3 x10^6) divided by the shoreline length (km).	

1. The closer the ratio is to one, the more circular the lake. A large ratio indicates that the shoreline is more crenulated and reflects the potential for development of aquatic plants and higher biological productivity. SD=length ÷ $(2*(area*\pi)^{0.5})$
2. Volume development is greatest in shallow lakes with flat bottoms. VD= (mean depth) / (max depth). A cone has a d_{mean}/d_{max} ratio of 0.33. Lakes with flat bottoms and deep holes have values <0.33 and deep lakes with steep sides (U-shaped) have ratios >0.5 (approaching one). Most lakes have ratios between 0.33 and 0.5.
3. Shows the littoral effect on basin volume; the lower the IBP the greater the impact of rooted aquatic plants. Where IBP < 0.1 rooted plants will probably dominate due to shallowness of the lake.

2.2. The Big Creek Lake Watershed

The Big Creek Lake watershed has an area of 47,666 acres including the lake. Without the lake, the watershed has a drainage area of 46,911 acres and a watershed to lake ratio of 62. This watershed to lake area ratio is high. IDNR Fisheries and lake restoration staff consider a good ratio for a high quality lake to be less than or equal to 20:1. Figure 2-3 shows the lake and its watershed.

There are no cities or NPDES permitted point sources in the watershed, but there are 328 occupied residences. The residences use onsite septic tank systems for wastewater treatment and it is assumed that some are not functioning properly and may be discharging directly to surface drainage. Big Creek State Park has wastewater collection and treatment facilities that were originally designed as no discharge systems. However, there have been recent discharges that were made on an emergency basis but have been currently discontinued.

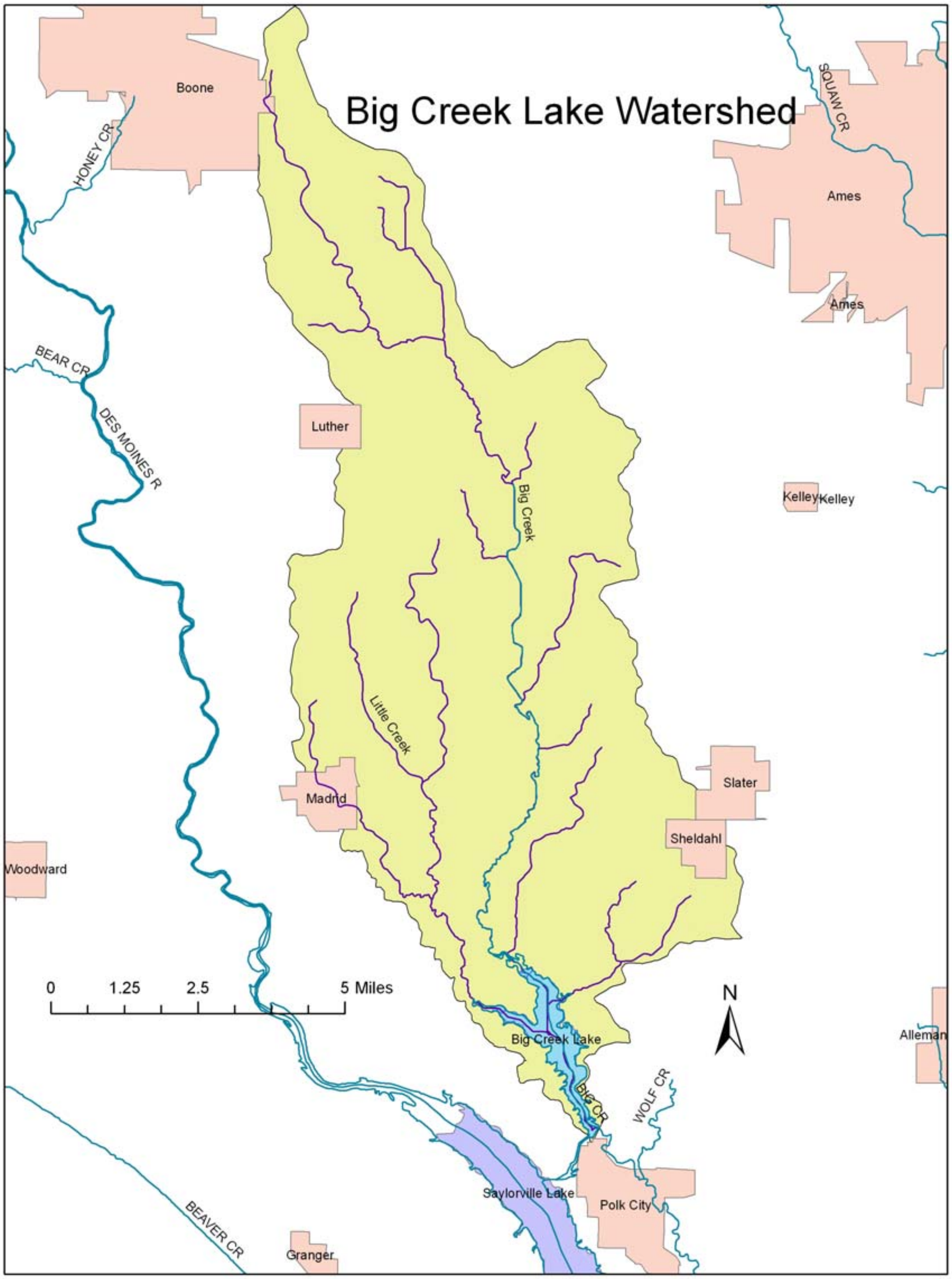

Figure 2-3 Big Creek Lake and its watershed

Land Use.

Land uses and associated areas for the watershed are listed in Table 2-3. Figure E-1 in Appendix E is a land use map. Row crop agriculture is the predominant land use in the watershed. There are twenty two animal feeding operations in the watershed and these are described in Section 3. IDNR owns or maintains most of the shoreline around the lake.

Table 2-3 Land use in the Big Creek Lake Watershed

Land Uses from 2008 Assessment	Area, acres	Percent of total
Farmstead	1,038.6	2.18%
Parkland	751.7	1.58%
Pasture/ Hay	831.0	1.74%
Row Crop	38,725.0	81.24%
Timber	931.0	1.95%
Ungrazed Grass	2,277.4	4.78%
Urban/ Roads	2,271.5	4.77%
Vineyard	23.3	0.05%
Water	816.1	1.71%
Total	**47,665.6**	**100.00%**

Ecoregion, topography and soils.
Big Creek Lake is located in the Des Moines Lobe ecoregion. The topography of this region is a recently glaciated, poorly drained landscape. Numerous ponds and marshes are located in the areas between ridges with no drainage outlets. This glaciated area is part of the much larger Prairie Pothole Region that extends north and west into Canada. The southern boundary of the Des Moines Lobe is a glacial end moraine.

The last glacier to enter Iowa advanced in a series of surges beginning 15,000 years ago and reached its southern limit, the site of modern-day Des Moines, 14,000 years ago. The ice sheet was gone 2,000 years later, leaving behind a poorly drained landscape of unconsolidated deposits from the melting ice, sands and gravels, and clay and peat from glacial lakes. Today, broadly curved bands of ridges and knobby hills set among irregular ponds and wetlands punctuate the glaciated landscape.

One of the youngest and flattest surfaces in Iowa, the Des Moines Lobe ecoregion is currently under extensive agriculture. In general, the land is level to gently rolling with the moraines having the most relief. The morainal ridges and hummocky knob and kettle topography contrast with the flat plains of ground moraines, former glacial lakes, and outwash deposits. A distinguishing characteristic of the Des Moines Lobe from other Iowa ecoregions is the lack of loess over the glacial drift. The stream network is poorly developed and widely spaced. The major rivers have carved valleys that are relatively deep and steep-sided. Almost all of the natural lakes of Iowa are found in the northern part of this region. Most of the area has been converted from wet prairie to agricultural use with substantial surface water drainage. Only a small fraction of the wetlands remain, and many natural lakes have been drained as a result of agricultural drainage projects. Figure 2-4 shows the Big Creek Lake watershed in its ecoregion context.

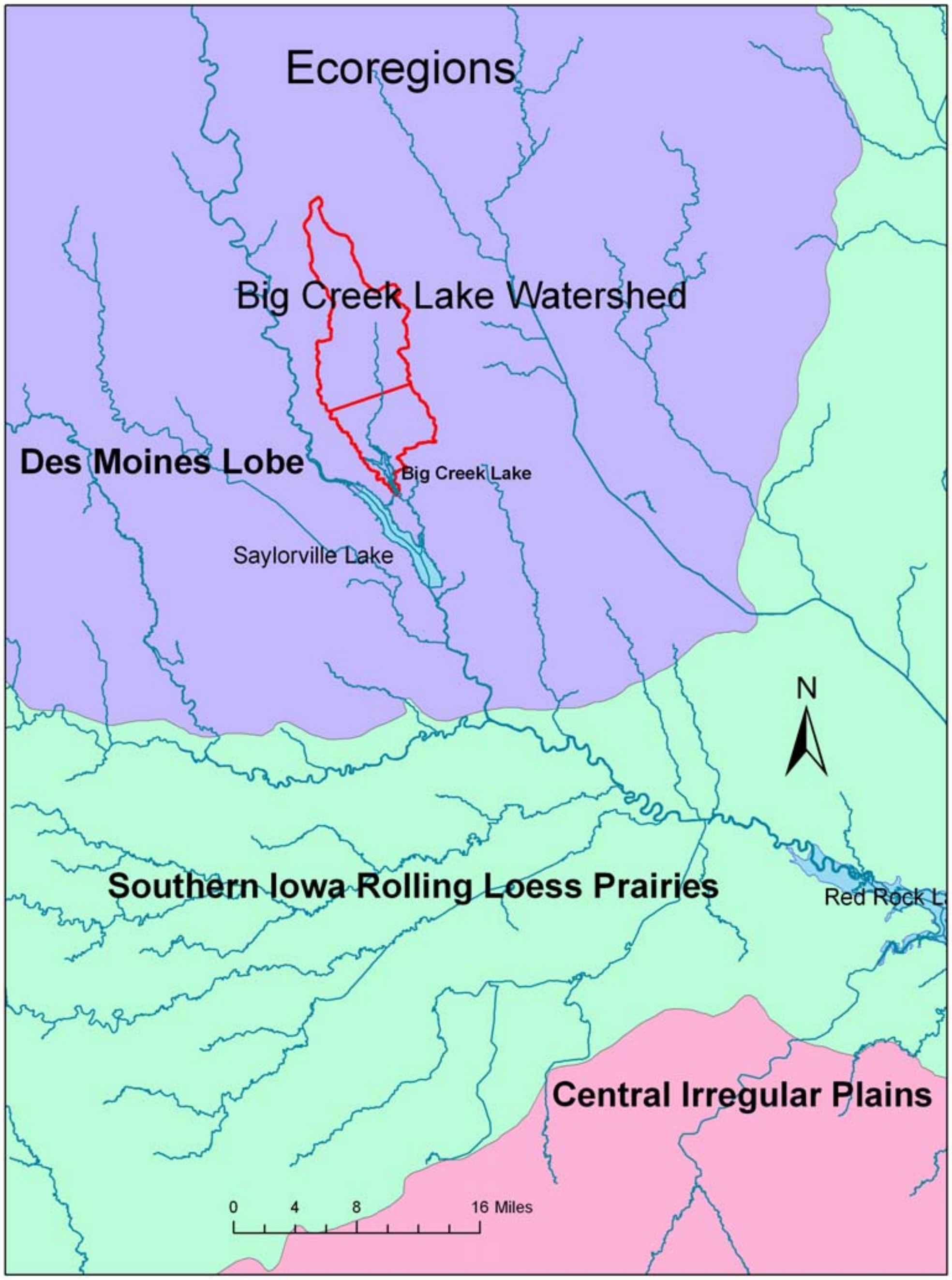

Figure 2-4 Ecoregions around the Big Creek Lake watershed

3. Total Maximum Daily Load for Pathogen Indicators (*E. coli*)

A Total Maximum Daily Load (TMDL) for the pathogen indicator *E. coli* is required for Big Creek Lake by the Federal Clean Water Act. This section quantifies the maximum daily *E. coli* load that can be delivered to Big Creek Lake without exceeding the Iowa water quality standards.

3.1. Problem Identification

Applicable water quality standards.
The applicable designated uses and water quality standards for pathogen indicators are found in *Iowa Administrative Code 567, Chapter 61, Water Quality Standards.* Table 3.1 summarizes the water quality standards for pathogen indicators for the Class A1 use.

Table 3-1 *E. coli* bacteria criteria (organisms/100 ml of water) for Class A1 Uses

Use Class A1 - Primary Contact Recreational Use.	***Geometric Mean Concentration***	***Sample Maximum Concentration***
Class A1		
3/15 – 11/15	*126*	*235*
11/16 – 3/14	*Does not apply*	*Does not apply*

Problem statement.
The 2008 305(b) water quality assessment for Big Creek Lake is included in Appendix F. For Big Creek Lake, Class A1 uses are assessed as "not supported" based on results of monitoring for indicator bacteria (*E. coli*). According to IDNR assessment and impaired listing methodology, if monitoring shows that greater than ten percent of samples exceed the single sample maximum, a lake is partially supported for Class A1 use and is impaired.

The basis for impairing Big Creek Lake is the 2008 305(b) water quality report that the Class A1 uses are assessed (monitored) as "not supporting" due to levels of indicator bacteria (*E. coli*) that exceed state water quality standards. The assessment is based on beach water quality monitoring conducted by IDNR. Figure 3-1 shows the beach monitoring data *E. coli* concentrations plotted with the SSM criteria of 235 orgs/100 ml and the daily rainfall.

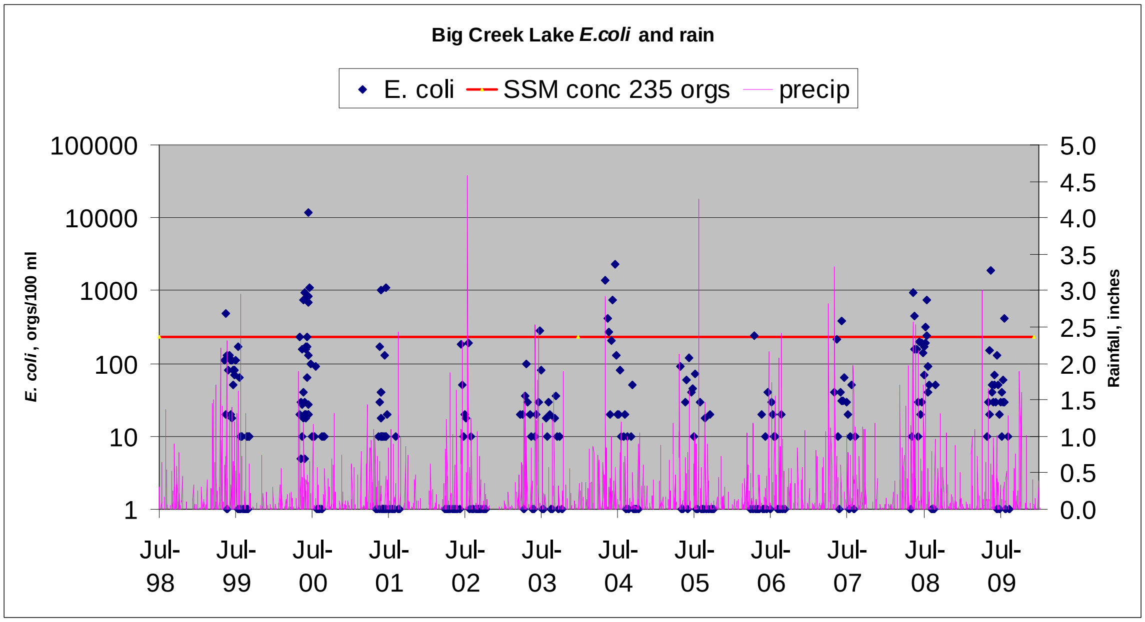

Figure 3-1 *E. coli* data plotted with SSM criteria and daily rainfall data

Data sources.
The assessment of the pathogen indicator impacts on the Class A1 use is based on the results of the IDNR-UHL summer beach monitoring program from 2000 through 2008. Samples were collected at the lake's beach once a week, usually from mid-April to mid-October. The watershed model Soil and Water Assessment Tool (SWAT) output was used to simulate flows to the lake based on precipitation and temperature data from the nearby Ames West weather station.

Interpreting Big Creek Lake E. coli *data.*
Flow and load duration curves were used to establish the occurrence of water quality standards violations and compliance targets and to set pollutant allocations and margins of safety. Flow duration curves are derived from flow plotted as a percentage of recurrence. *E. coli* loads are calculated from *E. coli* concentrations and flow volume. Load duration methods have been applied to the Big Creek Lake *E. coli* data and simulated flow to establish existing and target *E. coli* loads for five flow conditions (see Appendix D). The five flow intervals represent conditions that can be used to interpret sources of *E. coli*. These flow interval midpoints are the quartiles (25, 50, and 75 percent) and the 5 and 95 percent values of flow recurrences and are values frequently used with flow and load duration analysis. The five flow conditions are described in Table 3-2.

Table 3-2 Five flow conditions used to establish existing and target loads

Flow condition	Description
High flow - zero to ten percent recurrence interval	Runoff conditions predominate here and the flows and loads are the greatest primarily from nonpoint sources available for washoff.
Moist conditions - ten to forty percent recurrence interval	Runoff conditions are gradually decreasing in volume as is their contribution to bacteria loading.
Mid-range flow - forty to sixty percent recurrence interval	Impacts from runoff in this flow recurrence interval are still an important fraction but flow from groundwater and interflow are a growing part of the total. Loads originate from minor occurrences of local runoff and from the continuous septic tank, and cattle in the stream.
Dry conditions - sixty to ninety percent recurrence interval	Runoff loads at this flow recurrence interval are a shrinking fraction of the total. Flow from groundwater and interflow are a growing part of the total. Loads originate from minor occurrences of local runoff and increasingly from failed septic tanks, and cattle in the stream.
Low flow - ninety to one hundred percent recurrence interval	This is the low flow to no flow condition. Loads in this flow condition are nearly all from local continuous sources although the delivery of these continuous loads can be greatly reduced in the driest conditions.

The flow and load duration curves were developed using 11 years (October 1, 1995 to September 30, 2009) precipitation data from the Ames West weather station to simulate flows to the lake using SWAT watershed modeling. SWAT was actually run using precipitation data starting in 1995 but the first three years were discarded as model spin-up and because there is little monitoring data from those years.

To construct the flow duration curves, the bacteria monitoring data and the Water Quality Standard (WQS) geometric mean (GM, 126 *E. coli* orgs/100 ml) single sample maximum criteria (SSM, 235 *E. coli* organisms/100 ml) were plotted with the flow duration percentile. Figure 3-2 shows the flow duration curve for Big Creek Lake with SSM data exceeding the criteria at four of the five flow conditions. High flow violations indicate that the problem occurs during run-off conditions when most bacteria are washing off from nonpoint sources. Criteria exceeded during low or base flow, when runoff is generally not occurring, indicate that continuous sources such as faulty septic tank systems and cattle in the stream, especially near the lake, are the problem.

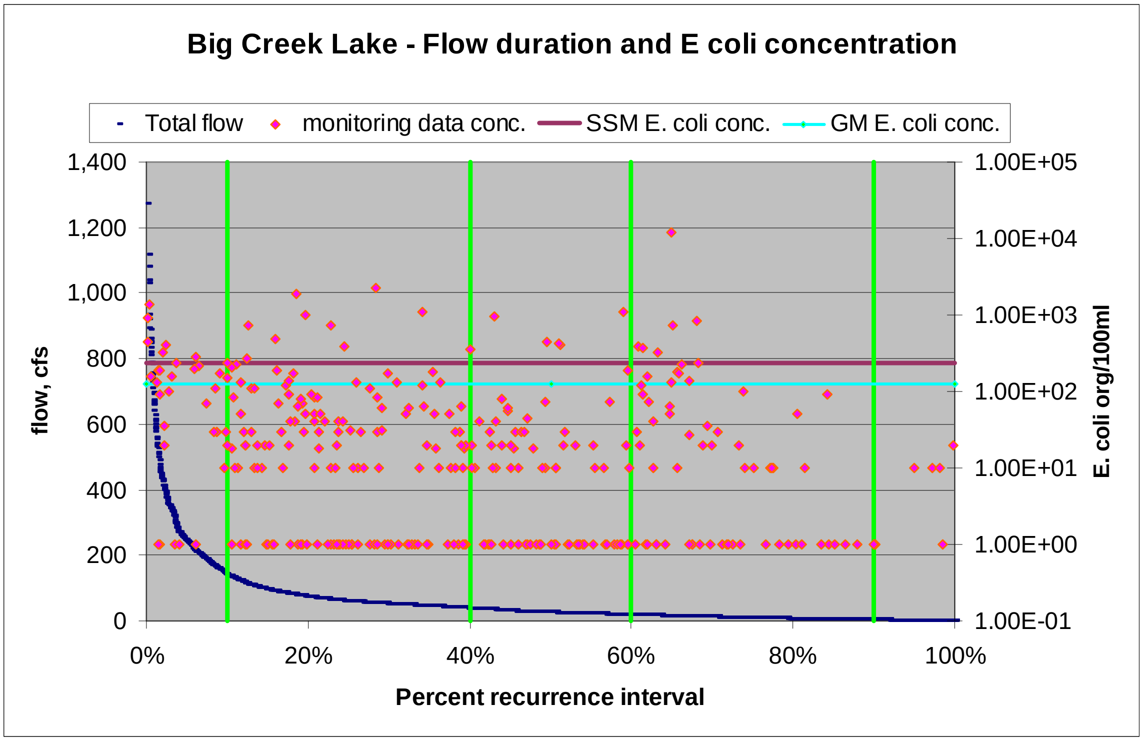

Figure 3-2 Flow Duration Curve

3.2. TMDL Target

The target for this TMDL is the water quality standard for Class A1, Primary Contact Recreational Use. The criteria are a geometric mean (GM) of 126 *E. coli* organisms/100ml and a single sample maximum (SSM) of 235 *E. coli* organisms/100ml. The loads associated with these concentrations are based on the daily flows through the lake. The criteria used to determine attainment of the water quality standards are explained in the 305(b) report assessment protocol in Appendix F.

General description of the pollutant.
The nonpoint source (NPS) pollutants in the watershed have two components. One is episodic and comprised of livestock and wildlife fecal material that is periodically transported during precipitation events. The other is continuous loading from leaking septic tank systems, cattle manure in and near watershed streams, and feces from geese in and near the lake. Goose feces near the lake are tracked in by beachgoers and are delivered by wave action and brief rains that do not always show up as runoff but that transport bacteria due to lake proximity.

Selection of environmental conditions.

The recreation season as defined in the Iowa WQS runs from March 15 through November 15. This is the season relevant to the development of this *E. coli* TMDL and only recreation season monitoring data has been used to develop the duration curves.

Waterbody pollutant loading capacity (TMDL).
The *E. coli* load capacity is the number of organisms for a flow volume that can be in the lake and still meet the water quality criteria. The loading capacity for each of the five flow conditions is calculated by multiplying the midpoint flow and *E. coli* criteria concentrations. Table 3.3 shows the median, maximum, and minimum flows for the five recurrence intervals.

Table 3-3 Maximum, minimum and median flows for recurrence intervals

Flow description	Recurrence interval range (mid %)	Midpoint of flow range, cfs	Maximum of flow range, cfs	Minimum of flow range, cfs
High flow	**0 to 10% (5)**	240.4	1272.6	139.3
Moist conditions	**10% to 40% (25)**	60.2	139.3	38.4
Mid-range	**40% to 60% (50)**	25.7	38.4	18.5
Dry conditions	**60% to 90% (75)**	9.1	18.5	2.9
Low flow	**90% to 100% (95)**	1.4	2.9	0.1

A load duration curve based on the simulated flow has been used to establish the target loads for Big Creek Lake and is shown in Figure 3-3. The lower curve shows the *E. coli* count for the geometric mean criteria and the upper curve shows the *E. coli* count for the single sample maximum (SSM) criteria. The points on the chart represent observed (monitored) *E. coli* concentrations converted to loads using simulated flow for the sampling date. Points above the load duration curves are violations of the WQS criteria.

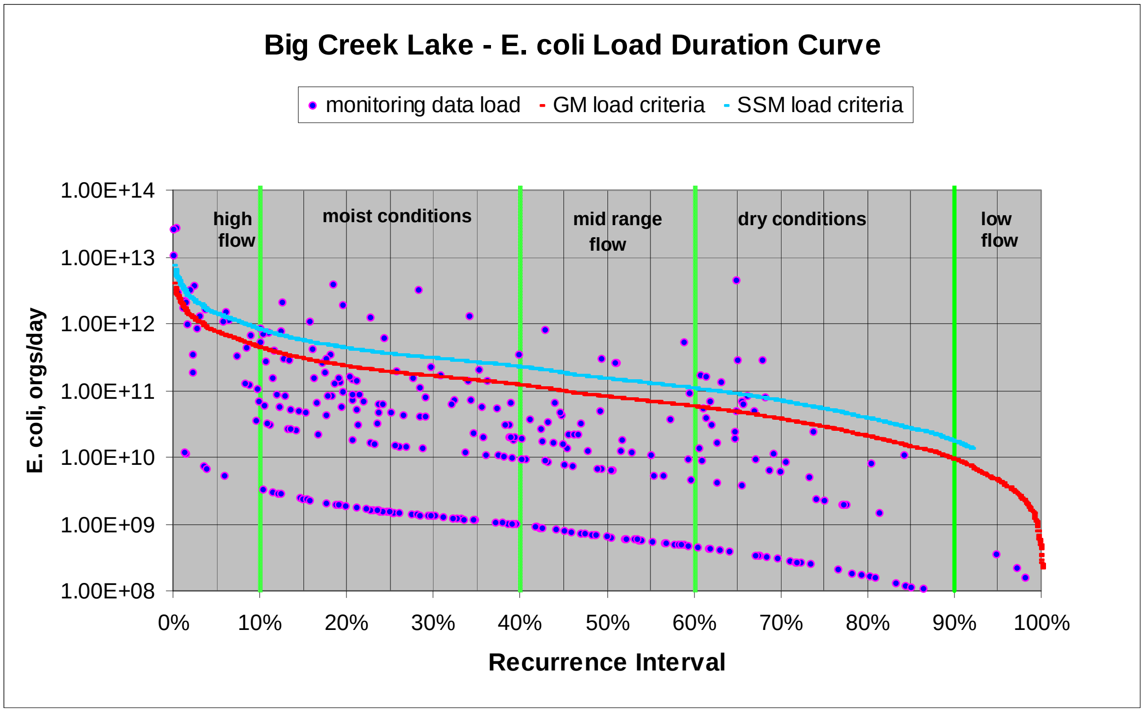

Figure 3-3 Load Duration Curve

Tables 3-4 and 3-5 show the load capacities (targets) for each of the midpoint flow conditions at the GM and SSM criteria, respectively.

Table 3-4 GM load capacity at five recurrence intervals

Flow condition	Recurrence interval	Associated midpoint flow, cfs	Estimated flow interval load capacity, *E. coli* orgs/day
High flow	**0 to 10%**	240.4	7.4E+11
Moist conditions	**10% to 40%**	60.2	1.9E+11
Mid-range	**40% to 60%**	25.7	7.9E+10
Dry conditions	**60% to 90%**	9.1	2.8E+10
Low flow	**90% to 100%**	1.4	4.4E+09

Table 3-5 SSM load capacity at five recurrence intervals

Flow condition	Recurrence interval	Associated midpoint flow, cfs	Estimated flow interval load capacity, *E. coli* orgs/day
High flow	**0 to 10%**	240.4	1.4E+12
Moist conditions	**10% to 40%**	60.2	3.5E+11
Mid-range	**40% to 60%**	25.7	1.5E+11
Dry conditions	**60% to 90%**	9.1	5.2E+10
Low flow	**90% to 100%**	1.4	8.1E+09

Decision criteria for water quality standards attainment.
Water Quality Standards will be attained in Big Creek Lake when the monitored *E. coli* concentrations meet the criteria of a geometric mean of 126 org/100 ml and a single sample maximum concentration of 235 org/100 ml.

3.3. Pollution Source Assessment

As previously noted, there are two mechanisms of *E. coli* transport to Big Creek Lake. The first is the wash-off load from the bacteria accumulated on land surfaces when it rains. The other is wildlife and livestock in tributary streams and adjacent to the lakeshore and in the lake. Deer and goose feces near the lake are tracked in by beachgoers or are delivered by wave action or brief rainfall events that do not show up as runoff but that carry bacteria because of proximity to the lake. These latter sources are delivered in dry conditions and at low flow.

Existing load.
The existing loads are derived from the observed data for each flow interval. These are the monitored points shown in the flow and load duration curves. *E. coli* concentrations are multiplied by the daily flow to get the loads plotted with the load duration curves. The allowable load for a recurrence percentage is the flow multiplied by the GM or SSM. Observed data that exceed the WQS criteria are above the GM and SSM curves.

The maximum existing load occurs during storms when maximum runoff and bacteria concentrations are highest. These elevated loads and flows often cause bacteria concentration to exceed the criteria. The other condition leading to criteria violations occurs during dry and low flow periods when loads from cattle in streams and faulty septic tank systems are delivered to the lake. These two conditions are seen in Figure 3-3, where the peak sample loads occur during high, moist, and mid-range flow conditions and lower sample loads are seen in dry conditions. There are not any elevated sample loads at the low flow condition.

The assessment methodology used to evaluate pathogen indicator criteria assume that if 10 percent or more of samples exceed the *E. coli* criteria then the waterbody is not supporting recreational use. The 90^{th} percentile of observed concentrations within each flow condition is multiplied by the midpoint flow for each condition to estimate existing loads. Table 3-6 shows the existing loads for each flow condition.

Table 3-6 Existing loads at the five recurrence intervals

Flow condition	Recurrence interval	Associated midpoint flow, cfs	Existing 90th percentile conc., orgs/100ml	Existing *E. coli* load, orgs/day
High flow	**0 to 10%**	240.4	422	2.48E+12
Moist conditions	**10% to 40%**	60.2	202	2.98E+11
Mid-range	**40% to 60%**	25.7	76	4.77E+10
Dry conditions	**60% to 90%**	9.1	256	5.69E+10
Low flow	**90% to 100%**	1.4	15	5.19E+08

Departure from load capacity.
The departure from load capacity is the difference between the existing load and the load capacity. This varies for each of the five flow conditions. Table 3-7 shows this difference. At high flow runoff conditions loads are elevated, since this is when watershed bacteria are washed off by storm events. In high flow conditions, the concentration is usually higher than when runoff is not occurring. This high runoff bacteria concentration combined with high flow results in high 90th percentile bacteria loads. The difference between the load capacity (target) and existing loads for each of the flow intervals is displayed graphically in Figure 3-4.

Table 3-7 Departure from load capacity, SSM loads

Flow condition	Recurrence interval	Existing *E. coli* orgs/day	Load capacity[1], orgs/day	Departure from capacity, orgs/day[2]
High flow	**0 to 10%**	2.48E+12	1.4E+12	1.10E+12
Moist conditions	**10% to 40%**	2.98E+11	3.5E+11	Meets standards
Mid-range	**40% to 60%**	4.77E+10	1.5E+11	Meets standards
Dry conditions	**60% to 90%**	5.69E+10	5.2E+10	4.67E+09
Low flow	**90% to 100%**	5.19E+08	8.1E+09	Meets standards

1. This is calculated using the single sample maximum of 235 organisms/100 ml.
2. Meets standards, i.e., negative departure from load capacity indicates that the existing load for the flow interval is less than the load capacity.

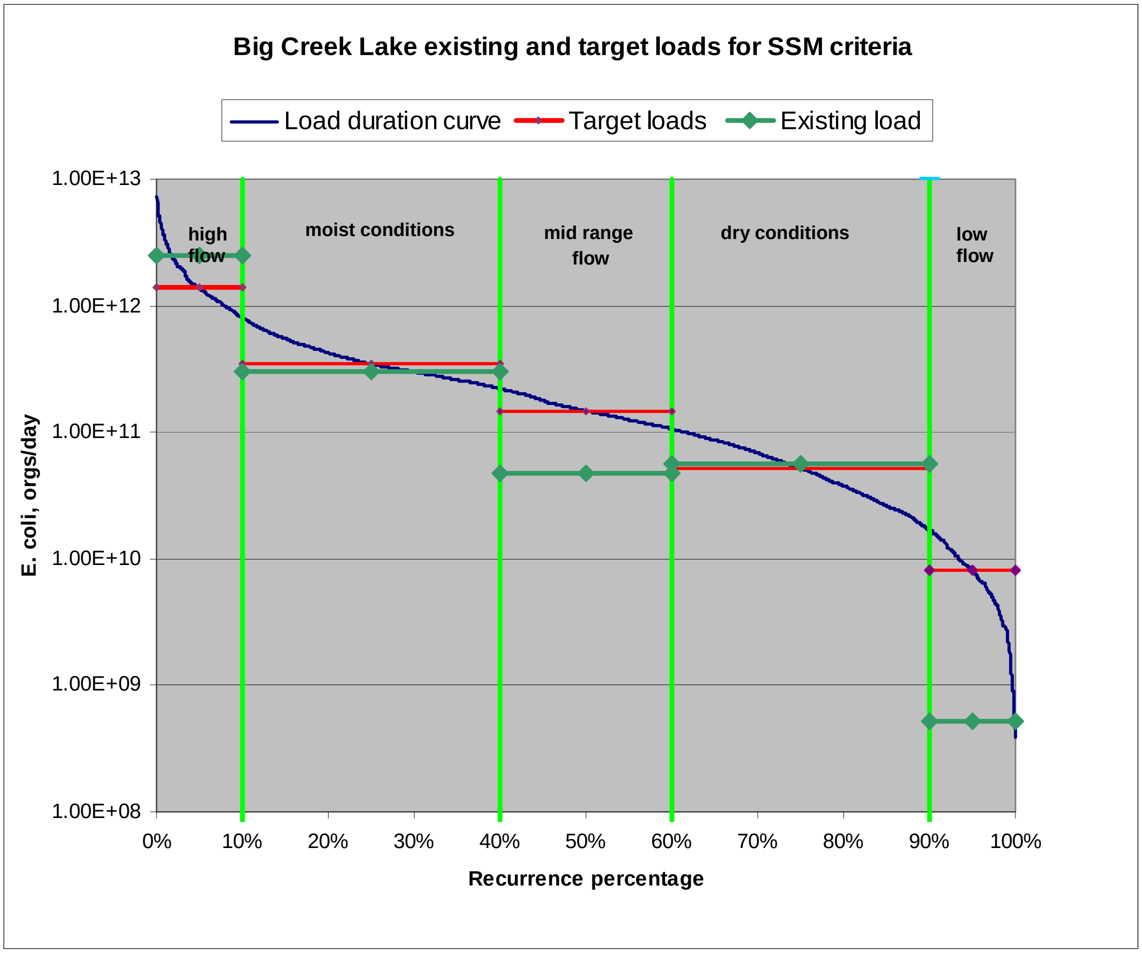

Figure 3-4 Existing and SSM criteria target loads

Identification of pollutant sources.
The two types of bacteria sources that are evaluated for TMDL development are point and nonpoint sources. Point sources are permitted discharges that are usually municipal wastewater treatment facilities. The second category is nonpoint sources that include all other discharges. Nonpoint sources are usually of a diffuse nature such as runoff from agricultural areas.

<u>Point Sources</u>: There are no permitted point sources that discharge in the Big Creek Lake watershed. The state park wastewater collection and treatment system was designed in 1977 as a zero discharge system. There have been some instances over the years in which emergency discharges to the lake were made. Currently the lagoon is receiving minimal wastewater and the collection and treatment system is being reconfigured to discharge outside of the Big Creek Lake watershed.

<u>Nonpoint Sources</u>: The nonpoint sources of *E. coli* in the lake and watershed originate from the feces of warm blooded animals. In Big Creek Lake the sources are:

- Wildlife (primarily geese and deer in the park).

- Grazing animals in pastures.
- Cattle manure directly deposited in tributary streams (cattle in stream).
- Land application of manure.
- Faulty septic tank systems in the watershed.

The contributions from each of these sources have been estimated using information from:

- IDNR State Park staff that are on site daily.
- IDNR Wildlife and Fisheries biologists who work in the area and are familiar with lake and watershed aquatic and wildlife populations.
- Conservation District staff that performed a watershed assessment in 2008 estimating the numbers of cattle and hogs in the basin.
- IDNR Field Office staff familiar with manure problems in the watershed.
- IDNR Beach Monitoring staff responsible for collecting bacteria data.

Watershed E. coli *source analysis.*
The nonpoint source categories listed below have been evaluated for lake bacteria contamination potential. These assessments have been integrated into two source models; the EPA Bacteria Indicator Tool (BIT) and SWAT. These models have quantified bacteria sources and estimated source potential to contribute to the impairment.

In general, the bacteria sources have been estimated for the peak five month recreation season, May through September. Though the statutory recreational season runs from March 15 to November 15, violations have been monitored only during this peak season, partly because that is when samples are collected. This has a modest effect because the analyses are based on worst case accumulation for washoff for days when there is rainfall. Bacteria loads are not cumulative in the lake. They rise and fall as bacteria are washed off and then decay over time. The *E. coli* sources are listed below.

1. Wildlife - Geese and deer.
    - The typical number of geese at Big Creek Lake from June through October is about 63 with no migrants in the summer and up to 80 migrants in the late fall. The geese are frequently in or near the lake so the potential for bacteria loads from their feces is very high, especially since they prefer to spend most of their time on the beach and lawns near sampling locations.
    - The number of deer in Polk County is about 2500, mostly located in forested land adjacent to streams. This works out to about 0.009 deer per acre and has been increased ten percent to account for wildlife other than deer and geese, such as raccoons, so that the total estimate is one deer per 100 acres. It is estimated that there are 548 deer in the watershed with 129 in the park or in close proximity to the lake. The deer are in the park year round and have high source potential because of their proximity to the lake.

2. Grazing livestock and feedlots.
    - The number of cattle in the watershed is about 530 and the number of horses is 39. It is assumed that both the cattle and horses are on pasture and that they are there throughout the recreation season. The grazing animals have a medium potential to deliver bacteria loads to the lake since many of the operations are relatively distant from the sampling locations.
    - Cattle and horses are distributed by subbasin and the 2008 assessment. Manure available for washoff is input to the SWAT model to estimate delivery to the lake.

3. Cattle in streams.
    - Of the 530 cattle in pastures, one to six percent of those on pasture are assumed to be in the stream on a given day during the recreation season. The number on pasture and the fraction in the stream varies by month. Cattle in the stream have a medium potential to deliver bacteria based on proximity, however the source potential is high since bacteria deposited directly in the stream are transported to the lake with or without rainfall.
    - Cattle in the stream bacteria loads have been input in the SWAT model by subbasin as a continuous point source varying by month.

4. Field applications of manure.
    - There are about 10,862 hogs in confinement in the watershed. The manure from these confinements is stored and land applied to cropland. The manure management plans for these confinements show the fields where the manure is assumed to have been applied. The manure has been distributed to the fields in the plan nearest the confinement in the fall and also the spring as shown in the plans. The proximity of manure application is low to medium. Some application fields are relatively distant from the lake. The potential for recreation season *E. coli* impacts is significantly reduced by the fall and spring timing of manure application.
    - Manure application field bacteria loads have been input in the SWAT model by subbasin according to where the application fields are located as a load available for washoff varying by month.

5. Non functional septic tank systems.
    - There are about 329 onsite septic tank systems in the watershed. IDNR staff responsible for coordinating onsite systems estimate that 25 percent are not functioning properly. It is assumed that these are continuous year round discharges. Estimates for these bacteria loads were calculated in the BIT worksheet.
    - Faulty septic tank loads have been input into the SWAT model by subbasin as a continuing point source that does not vary.

6. Built-up area washoff.
    - There are two built-up areas in the watershed. These are located in subbasins 12 and 16 and are associated with the cities of Madrid and Sheldahl.
    - Built-up area loads have been input into SWAT based on literature values for the number of *E. coli* orgs per ha/day for the medium density residential landuse HRUs.

The watershed has been divided into 19 subbasins in the SWAT model. Livestock operations and fields where manure is applied have been distributed to the 19 sub-basins. Figure 3-5 shows the locations of livestock operations and manure management plan (MMP) fields. The livestock operations include cattle, hogs or horses. The MMP fields are the assumed locations where manure from the hog confinement operations is applied in fall and sometimes in the spring. The numbered subbasins were developed in the SWAT modeling.

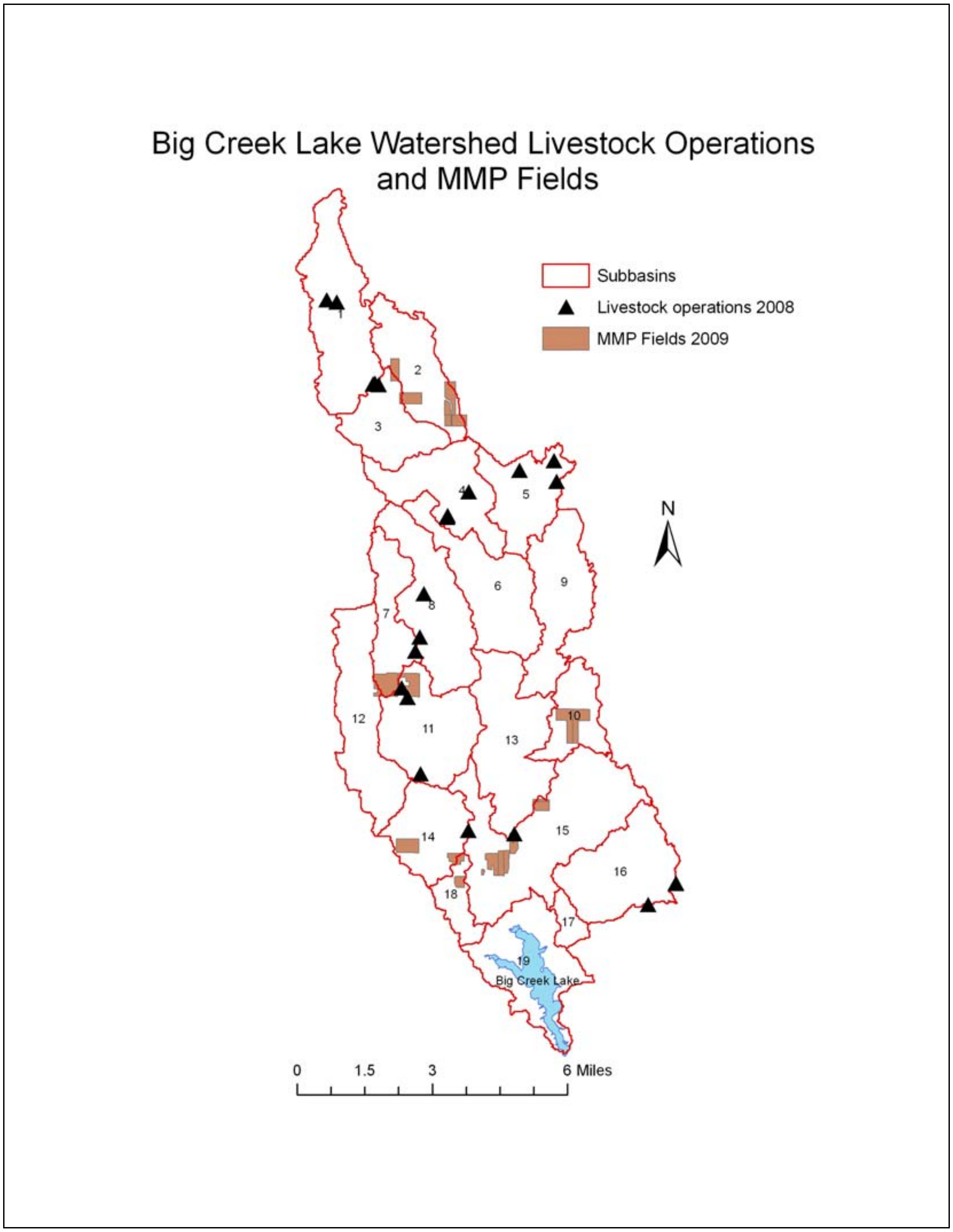

Figure 3-5 Potential livestock and applied manure bacteria sources

The septic tank systems in the watershed have been located and distributed by subbasin. Figure 3-6 shows the locations of the 329 septic tank systems in the watershed.

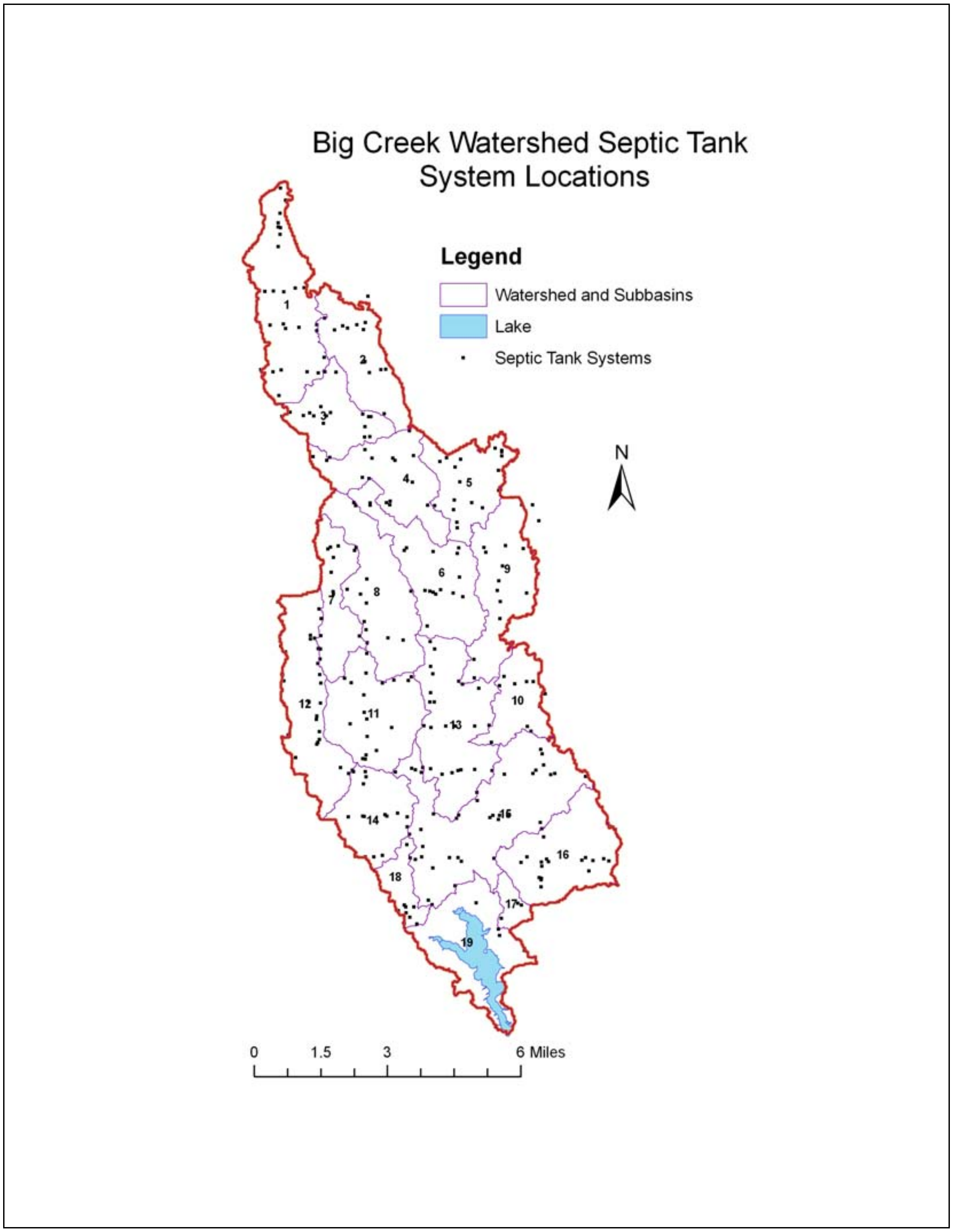

Figure 3-6 Watershed septic system locations

Linkage of E. coli *sources to the lake: flow and load analysis.*
The loads delivered to the lake vary with runoff conditions in the watershed. During peak runoff conditions the loads are dominated by washed off bacteria. The SWAT model estimates the bacteria delivered to the lake by wash off from all of the subbasins. Only a fraction of the bacteria available for wash off is actually delivered to the lake. The flow and load duration curves estimate existing loads at each of the five flow

conditions. The fraction delivered by precipitation is the existing observed load during runoff conditions divided by the maximum load available for washoff.

Figure 3-7 shows the runoff duration curve, the SSM flow duration curve and the observed concentrations from the monitoring data. It also illustrates that:

- Runoff is an asymptotically decreasing fraction of total flow as recurrence increases and getting quite low as the recurrence approaches dry flow conditions.
- Interflow and baseflow increase as a fraction of total flow until they make up the entire flow.
- There are not any criteria exceedances above 68 percent recurrence meaning that the continuous sources, cattle in the stream and faulty septic tank systems alone are not causing the impairment.
- The exceedances are almost all below 1,000 *E. coli* orgs/100 ml indicating that the sources are not extensive.

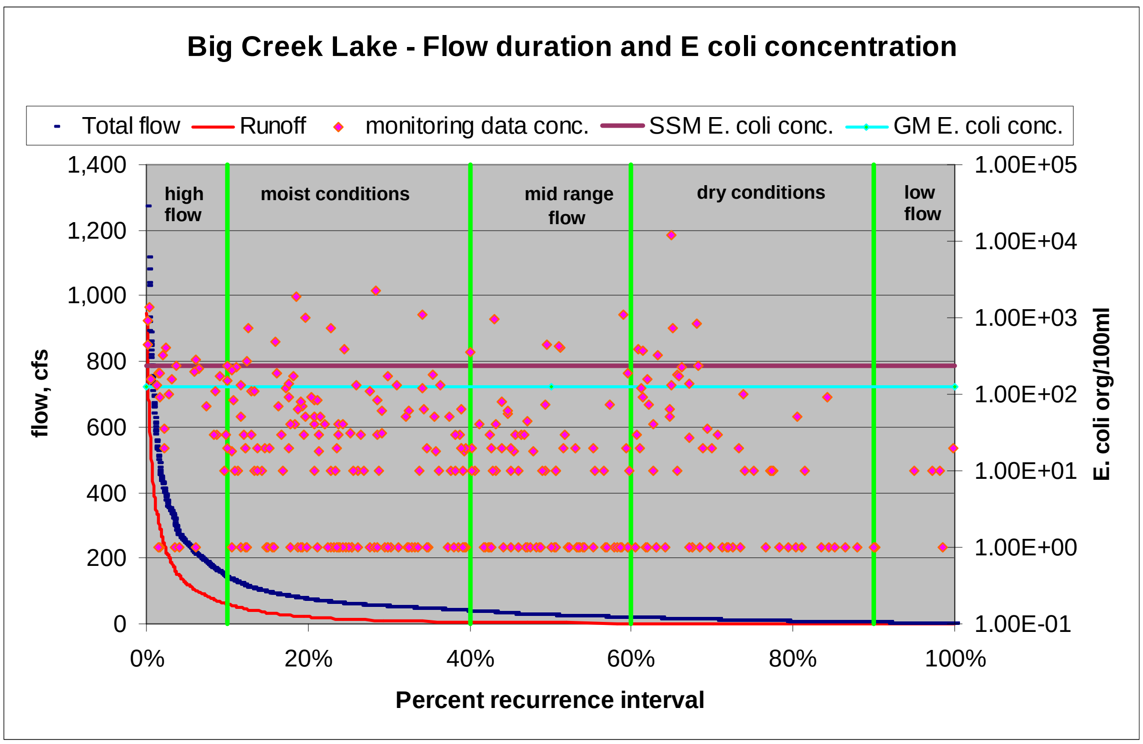

Figure 3-7 Total flow and runoff duration curves

Examination of the runoff duration curve shows that most simulated runoff occurs at recurrence intervals that are less than 30 percent. It also shows that 87 percent of samples exceeding the SSM criteria (26 out of 30) were collected when flows were less than 60 percent recurrence (the higher flows). This is about the same recurrence interval as for runoff flows. The other four samples exceeding the SSM criteria occur between 60 and 77 percent recurrence. This means that bacteria loads exceeding the criteria at dry and low flow conditions are not a cause of impairment. The implications of this are that sources that are usually considered to be continuous, in this case cattle in the stream and septic tank systems, are not causes of impairment and addressing these will have little effect on the lake water quality problem.

It is also useful to examine Figure 3-8, which shows the existing and SSM criteria target loads for each of the five flow conditions. As previously explained, the load duration analysis is used to obtain the median target load for each recurrence interval. The existing load is the 90th percentile of all the observed data for each recurrence interval. It can be seen that the lowest interval, from zero to ten percent recurrence, has existing loads that exceed the target loads. At moist to dry condition flows, ten to sixty percent recurrence, the target loads are higher than the existing loads, i.e., the existing loads meet the SSM criteria. At the dry conditions flows the existing load exceeds the target load by nine percent while at the lowest flow the existing load is well below the target load.

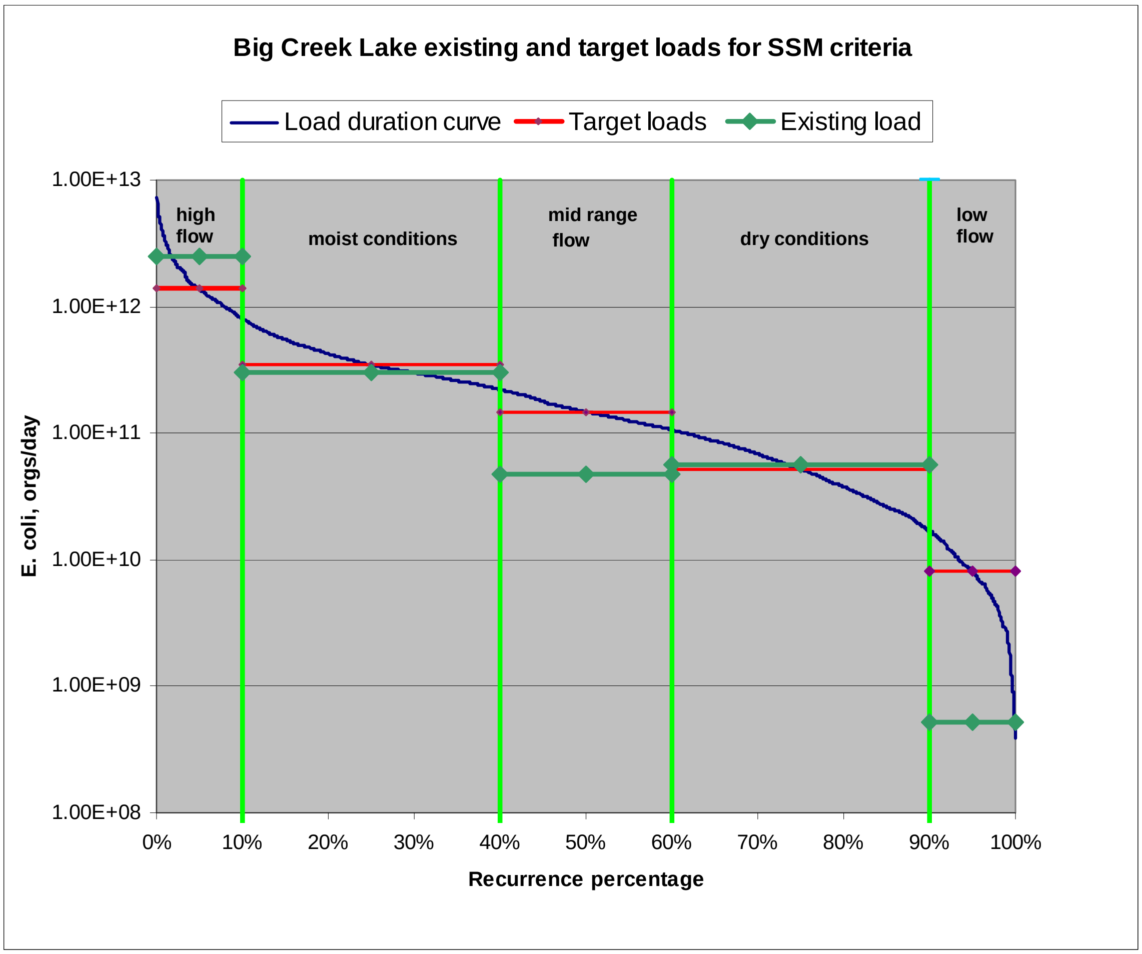

Figure 3-8 Existing and SSM criteria target loads

The SWAT model simulation of the bacteria delivery reinforces the importance of loads washing off the land and being delivered to the lake at higher flows as the primary cause of the impairment.

Figures 3-9 through 3-12 show how reducing various bacteria sources effect the *E. coli* concentration in the model output. Figure 3-9 shows the simulated existing concentrations plotted over time against the *E. coli* SSM water quality criteria. Progressing through the next three figures, the loads from some of the sources are removed or decreased.

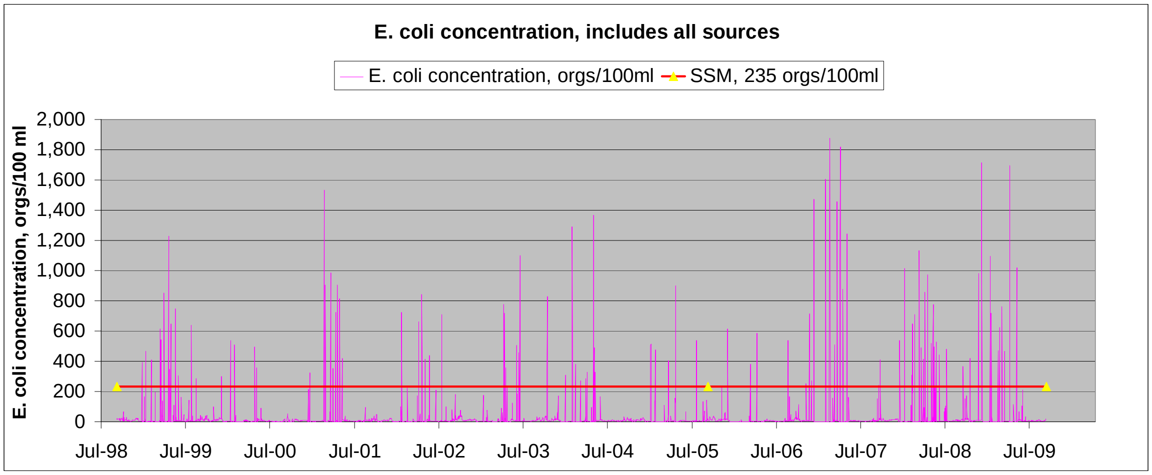

Figure 3-9 SWAT output showing bacteria concentrations with all load sources included

In Figure 3-10 the loads from geese are eliminated from the SWAT model. The result is a significant reduction in the magnitude and frequency of *E. coli* concentrations that exceed the criteria.

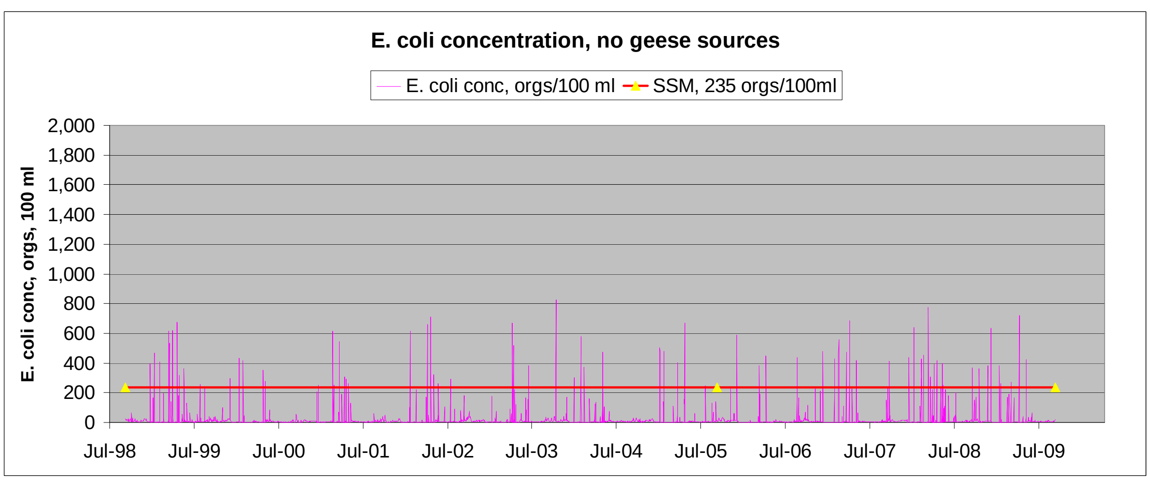

Figure 3-10 SWAT output showing bacteria concentrations without geese sources

In Figure 3-11, in addition to removing the geese load, the loads from continuous sources, the faulty septic tanks and cattle in the stream, have been eliminated. This has less of an effect on *E. coli* concentrations than removing the geese load because continuous sources have little impact on impairments occurring primarily during runoff conditions. Local washoff transports bacteria from geese feces to the lake near the beach area. Continuous bacteria loads have their greatest impact at low flow when there is less volume to dilute loads.

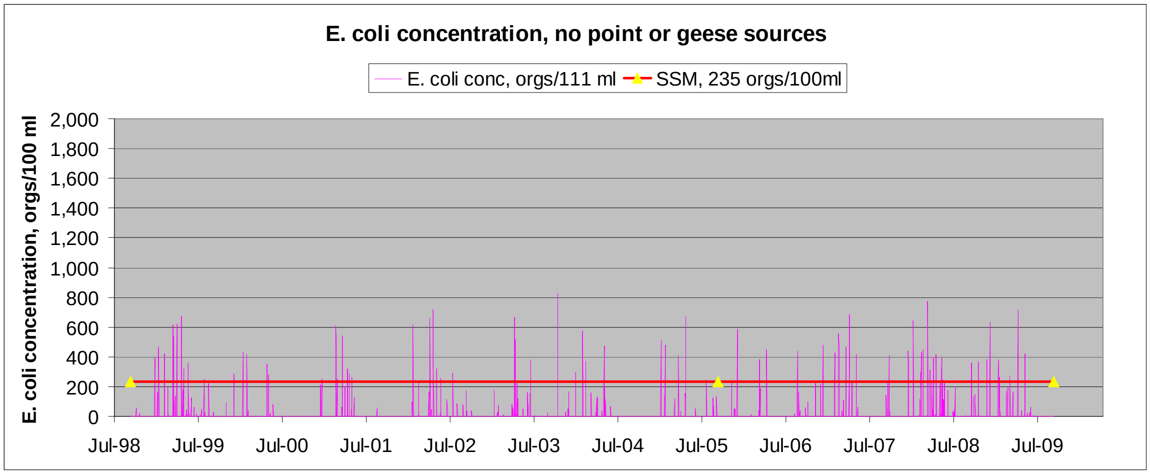

Figure 3-11 SWAT output showing bacteria concentrations without geese or continuous sources

In Figure 3-12 the continuous loads (cattle in the stream and septic systems) have been put back into the model and half of the deer and grazing cattle loads have been eliminated. This has a significant impact on delivery because these loads are transported by washoff and cause elevated bacteria concentrations at the high flow when the impairment is occurring. Almost all simulated *E. coli* concentrations are below the SSM criteria at all flow conditions with these loads removed.

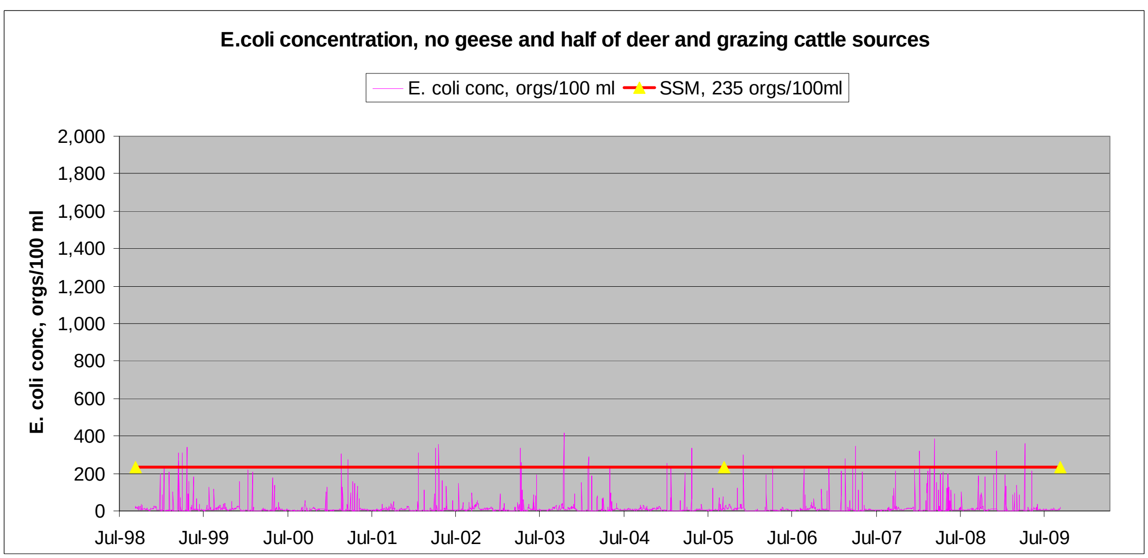

Figure 3-12 Simulated *E. coli* concentration with the geese and half the deer and grazing cattle sources removed

The next four figures, 3-13 through 3-16, correspond to Figures 3-9 to 3-12. They show the simulated flow plotted with the associated *E. coli* load as a bacteria count. They also show the 90th percentile existing loads at the high and low flow conditions as well as the SSM target load. The existing and target loads are straight horizontal lines because their values do not change over time. The existing high flow and low flow loads (2.48 E+12 and 5.19 E+08 *E. coli* orgs/day) are calculated using the 90th percentile concentrations and median flows for the flow conditions in the load duration curve as previously discussed.

The existing high flow and low flow load values usually define the range of expected loads for the lake. The simulated existing loads follow this expectation as seen in these figures, falling mostly between the high and low flow loads. The scale for *E. coli* is logarithmic and there is a difference of four orders of magnitude between the high flow and low flow loads. Comparison of the flow and the bacteria load shows a correspondence between high flow and high load. Figure 3-13 shows the simulated loads with all existing sources included and corresponds to Figure 3-9.

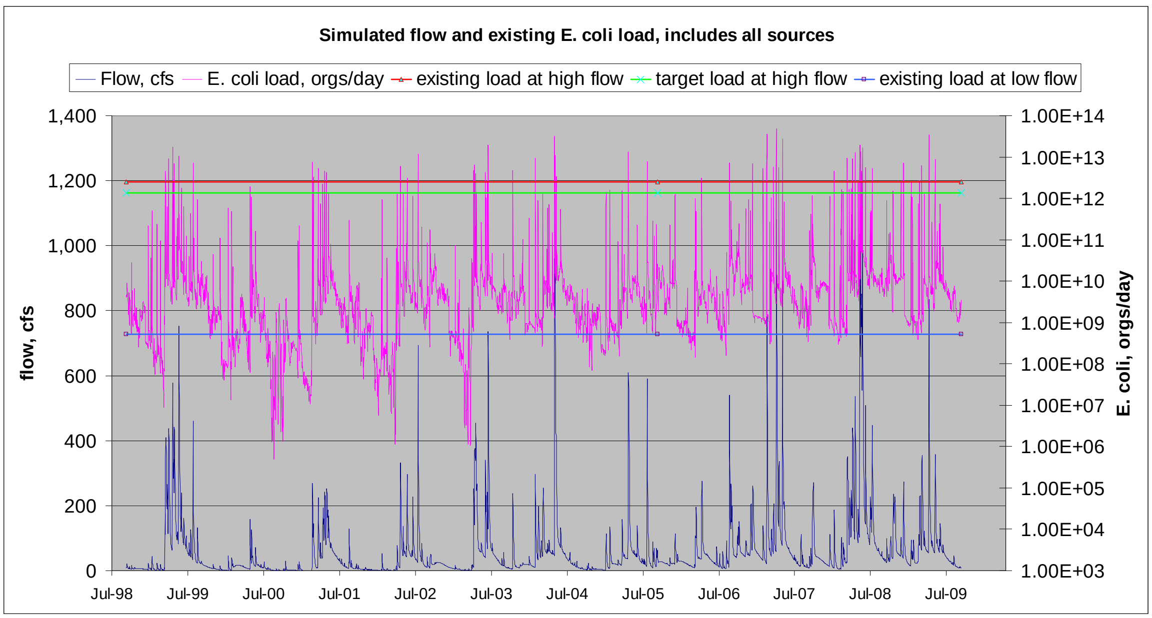

Figure 3-13 SWAT output with all source loads included

Figure 3-14 shows the simulated source loads with the geese loads eliminated and corresponds to Figure 3-10. The load reduction does not have as obvious an effect as in Figure 3-10 because of the logarithmic scale for *E. coli*.

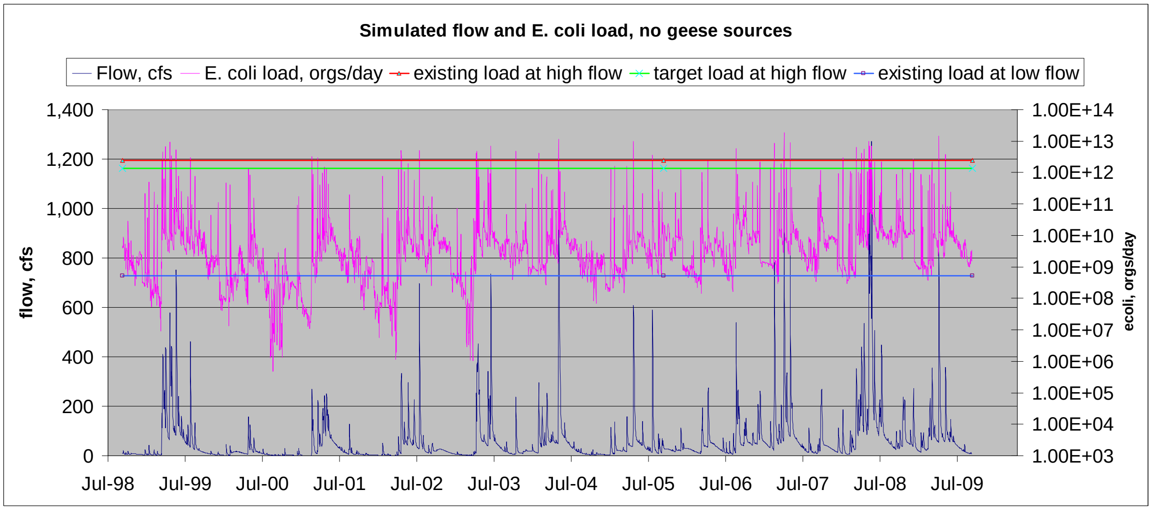

Figure 3-14 SWAT output without geese loads

Figure 3-15 shows the simulated source loads with the geese and continuous loads eliminated and corresponds to Figure 3-11. The load reduction does not have as obvious an effect on the higher loads as seen in Figure 3-11 because of the visual distortion caused by the logarithmic scale for *E. coli*. The simulated *E. coli* loads have been represented in Figure 3-15 as individual points rather than as connected points as in previous figures. This is because at low flows loads are much less without constant loads from cattle in the stream and septic systems. This makes the connecting lines long and distracting.

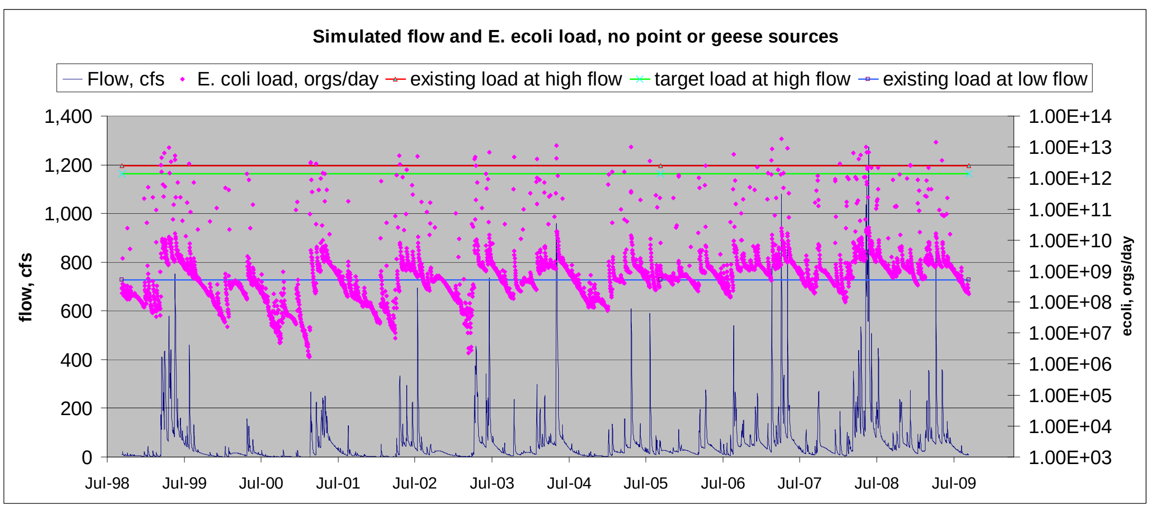

Figure 3-15 SWAT output without geese or continuous loads

Figure 3-16 shows simulated source loads with the continuous loads put back in, the geese loads eliminated, and the deer and grazing cattle loads reduced by half. It corresponds to Figure 3-12. This scenario shows load conditions where the modeled *E. coli* are mostly less than the water quality criteria SSM of 235 orgs/100 ml as shown in Figure 3-12.

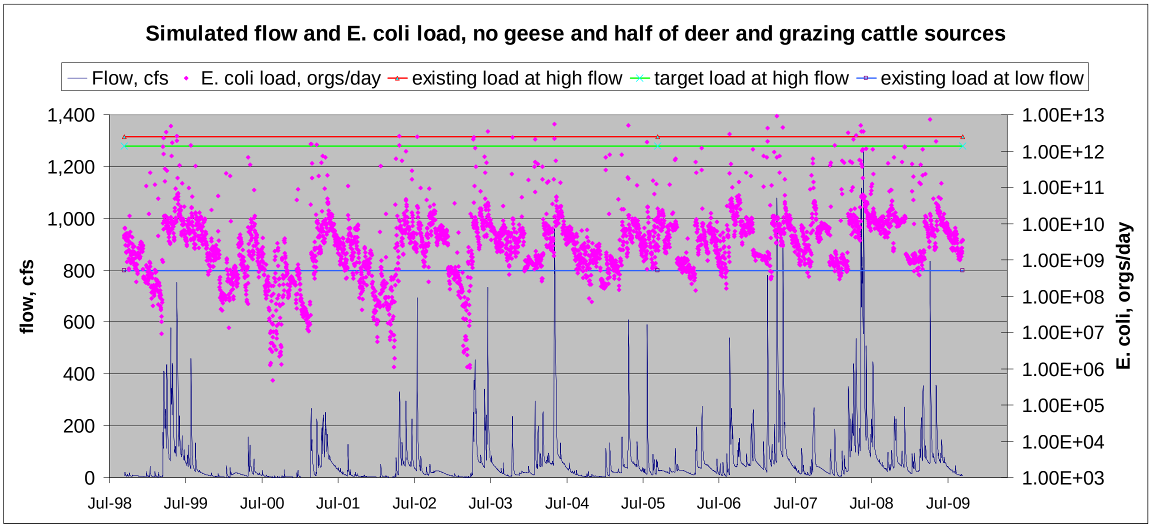

Figure 3-16 SWAT output with geese and half the deer and grazing cattle loads removed

Allowance for increases in pollutant loads.

An allowance for increased pathogen indicator loading was not included in this TMDL. The Iowa Department of Natural Resources owns and maintains most of the shoreline around Big Creek Lake. Some of the nearby watershed is in state owned forest, grass, and wetlands and most of the rest is in agricultural production with row-crop predominating. A significant change in watershed land use is unlikely.

3.4. Pollutant Allocation

Wasteload allocation.

There are no permitted point sources in the Big Creek Lake watershed and, therefore, there are no *E. coli* wasteload allocations and the sum of the wasteload allocations is zero.

Load allocation.

The load allocations for this *E. coli* TMDL are the load capacity less an explicit ten percent margin of safety (MOS). There are separate load allocations set for the geometric mean and single sample maximum criteria for each recurrence interval target. These load allocations and margins of safety are shown in Tables 3-8 and 3-9.

Table 3-8 Load allocations, geometric mean

Flow condition	Recurrence interval	Load capacity, orgs/day[1]	MOS, explicit 10%, orgs/day	Load Allocation, orgs/day
High flows	**0 to 10%**	7.4E+11	7.4E+10	6.7E+11
Moist conditions	**10% to 40%**	1.9E+11	1.9E+10	1.7E+11
Mid-range	**40% to 60%**	7.9E+10	7.9E+09	7.1E+10
Dry conditions	**60% to 90%**	2.8E+10	2.8E+09	2.5E+10
Low flow	**90% to 100%**	4.4E+09	4.4E+08	3.9E+09

1. Based on geometric mean criteria, 126 *E. coli* organisms/100 ml

Table 3-9 Load allocations, single sample maximum

Flow condition	Recurrence interval	Load capacity, orgs/day[1]	MOS, explicit 10%, orgs/day	Load Allocation, orgs/day
High flows	**0 to 10%**	1.4E+12	1.4E+11	1.2E+12
Moist conditions	**10% to 40%**	3.5E+11	3.5E+10	3.1E+11
Mid-range	**40% to 60%**	1.5E+11	1.5E+10	1.3E+11
Dry conditions	**60% to 90%**	5.2E+10	5.2E+09	4.7E+10
Low flow	**90% to 100%**	8.1E+09	8.1E+08	7.3E+09

1. Based on single sample maximum criteria, 235 *E. coli* organisms/100 ml

Margin of safety.
The margin of safety for *E. coli* is an explicit ten percent of the load capacity for the geometric mean and single sample maximum criteria for each recurrence interval target as shown in Tables 3-8 and 3-9.

3.5. TMDL Summary

The following equation represents the TMDL and its components for Big Creek Lake.

Total Maximum Daily Load = Σ Load Allocations + Σ Wasteload Allocations +MOS

A TMDL has been calculated for the GM and SSM criteria for each recurrence interval target. These TMDLs, LAs and MOS are shown in Tables 3-10 and 3-11. Figures 3-17 and 3-18 show the results of these calculations in the load duration curves.

Table 3-10 TMDL calculation, geometric mean criteria

Flow condition	Recurrence interval	Σ LA, orgs/day	Σ WLA, orgs/day	MOS, orgs/day	TMDL, orgs/day
High flows	**0 to 10%**	6.7E+11	zero	7.4E+10	7.4E+11
Moist conditions	**10 to 40%**	1.7E+11	zero	1.9E+10	1.9E+11
Mid-range	**40 to 60%**	7.1E+10	zero	7.9E+09	7.9E+10
Dry conditions	**60 to 90%**	2.5E+10	zero	2.8E+09	2.8E+10
Low flow	**90 to 100%**	3.9E+09	zero	4.4E+08	4.4E+09

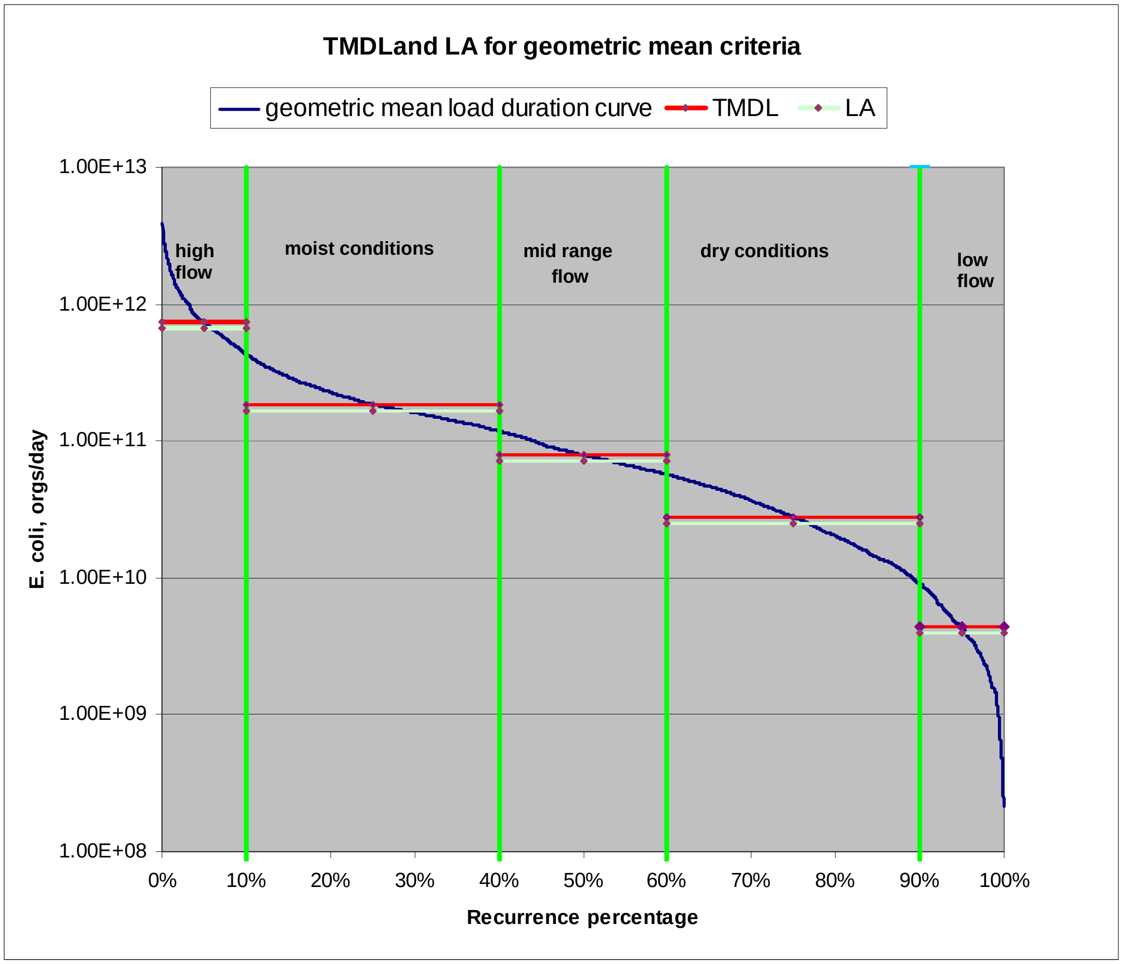

Figure 3-17 TMDL at the GM WQS of 126 orgs/100 ml for the five flow conditions

Table 3-11 TMDL calculation, single sample maximum criteria

Flow condition	Recurrence interval	Σ LA, orgs/day	Σ WLA, orgs/day	MOS, orgs/day	TMDL, orgs/day
High flows	0 to 10%	1.2E+12	zero	1.4E+11	1.4E+12
Moist conditions	10 to 40%	3.1E+11	zero	3.5E+10	3.5E+11
Mid-range	40 to 60%	1.3E+11	zero	1.5E+10	1.5E+11
Dry conditions	60 to 90%	4.7E+10	zero	5.2E+09	5.2E+10
Low flow	90 to 100%	7.3E+09	zero	8.1E+08	8.1E+09

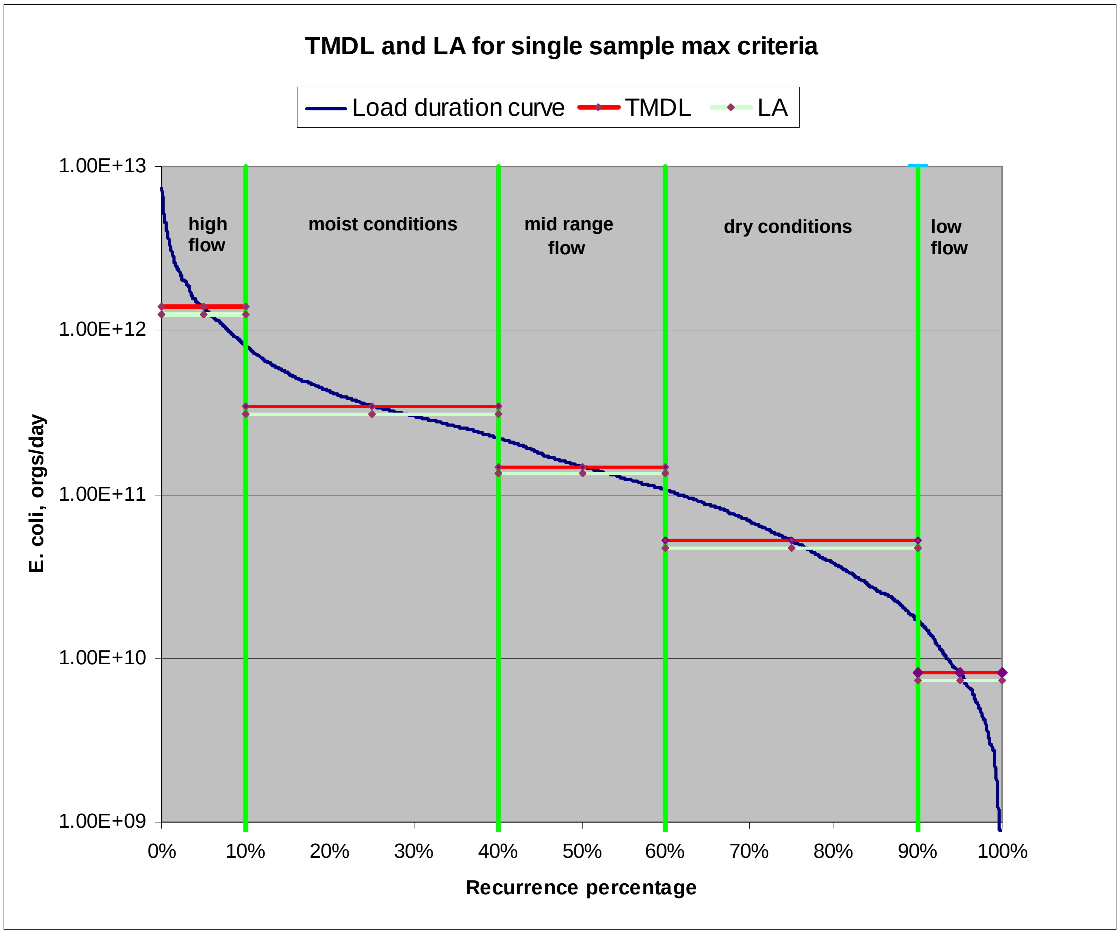

Figure 3-18 TMDL at the maximum single sample WQS of 235 orgs/100 ml for the five flow conditions

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that implementation guidance is important for the attainment of TMDL goals. Local watershed managers and citizens can use this report as a general guide for planning and decision making. The management practices discussed below may direct watershed activities toward achievement of water quality goals. Ultimately, it is up to land managers, citizens, and local conservation professionals to determine which management practices to use and how best to apply them.

4.1. Implementation Goals

Reducing bacteria delivery requires management practices that may differ from those already used, although basins and wetlands constructed to reduce sediment and nutrients also reduce bacteria transport.

The problem of *E. coli* bacteria in the lake near the beach has benefited from some existing management practices but monitoring shows that a problem persists. The bacteria sources that have the most impact on beach bacteria concentrations are those that have the most direct and shortest path to the lake when it rains. These are the geese and deer in the immediate vicinity.

Table 4.1 shows the estimated departures of existing loads from target loads for the five flow condition as a percent load reduction required. At the geometric mean there are potentially three flow conditions that call for a load reduction. At the single sample maximum there are two flow conditions requiring a load reduction. Negative values mean the existing load is less than the criteria load.

Table 4-1 Load reductions from existing conditions needed to meet *E. coli* targets

Flow percent recurrence	Geometric mean departure from capacity, orgs/day	Single sample max departure from capacity, orgs/day	Geometric mean percent reduction needed	Single sample max percent reduction needed
0 to 10 %	1.74E+12	1.10E+12	70.1%	44.3%
10 to 40 %	1.12E+11	-4.86E+10	37.6%	-16.3%
40 to 60 %	-3.16E+10	-1.00E+11	-66.2%	-210.0%
60 to 90 %	2.89E+10	4.67E+09	50.8%	8.2%
90 to 100 %	-3.84E+09	-7.62E+09	-740.0%	-1466.7%

Figure 4-1 shows two scenarios for simulated *E. coli* concentrations over time plotted on the same chart. One includes all existing source loads and the other eliminates geese and half of the deer and grazing cattle loads. This simple scenario eliminates the geese loads available for washoff in the immediate vicinity of the lake and half of the grazing cattle and deer loads available for washoff on land from the watershed without consideration for location. If the deer and cattle loads from the subbasins nearer to the lake were removed preferentially, the decrease in bacteria concentrations might be greater. The delivery of available washoff load for each subbasin varies as discussed in Appendix D. As a result, reductions in subbasins closer to the lake may have a greater impact on beach *E. coli* concentrations.

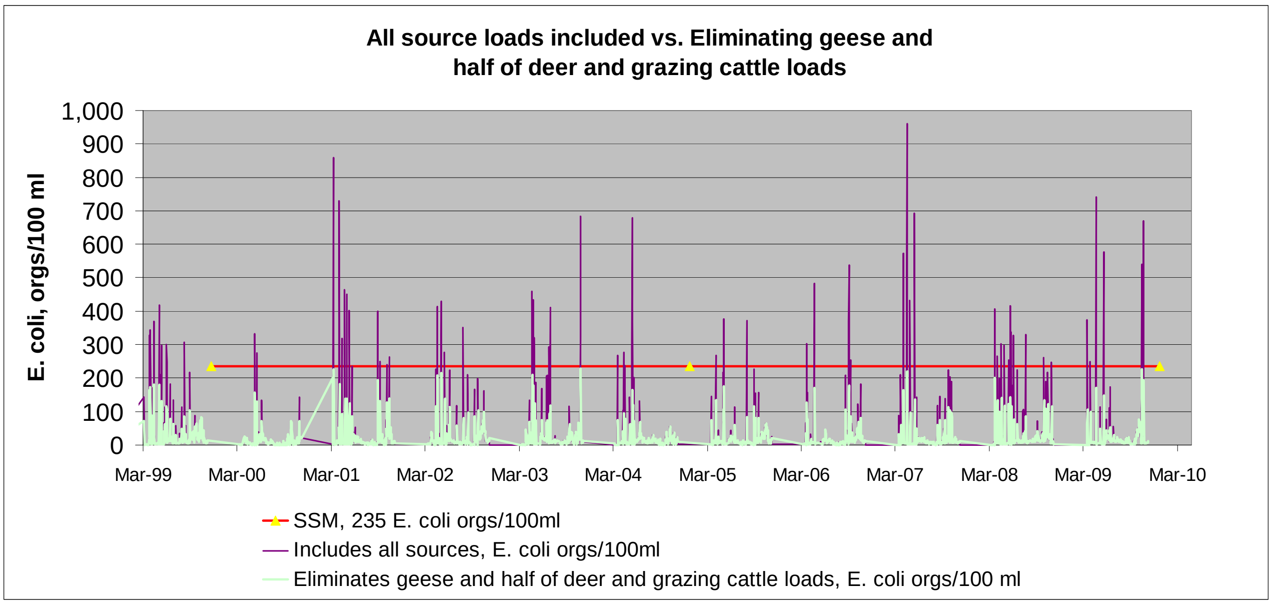

Figure 4-1 Existing *E. coli* concentrations with all sources included plotted with a scenario with the geese and half of the deer and grazing cattle loads eliminated to meet *E. coli* concentration criteria

4.2. Implementation Design and Timeline

This water quality improvement plan sets targets and load allocations for *E. coli* concentrations in Big Creek Lake. To be effective at improving water quality, watershed stakeholders will need to participate in the implementation of bacteria controls and continuing water quality evaluations.

Some watershed work has begun in the form of a water quality improvement project for Big Creek Lake. Since 2004, *E. coli* concentrations exceeding the state criteria have raised concerns. The bacteria sources are animal feces and Figure 4-2 shows just how close to beaches goose feces are often found.

Figure 4-2 Goose feces on the beach and in the water

The Polk County Soil and Water Conservation District (SWCD) is the lead agency for the Big Creek Watershed Project. The primary goal of the Big Creek Watershed Project is to implement best management practices addressing the bacterial impairment and removing Big Creek Lake from the impaired waters list. This is to be achieved through techniques such as pasture management, practices aimed at reducing runoff from manure applied to fields, providing information to owners of non-functioning septic systems, and goose management at Big Creek State Park.

The Polk County SWCD will also address sediment and phosphorous delivery to the lake. This will be accomplished through the implementation of best management practices that include: terraces, water and sediment control basins, grade stabilization structures, grassed waterways, stream bank stabilization, and CRP buffers. Watershed outreach activities will also be a component of this project. These activities will include landowner hosted field days geared towards water quality education, pasture management practices, septic system management, BMP education, newsletters and local media campaigns.

Polk SWCD is currently working on a comprehensive watershed management plan that will provide detailed information on placement of BMPs, pollutant load reductions, and a timeline and budget for these activities. The watershed management plan is expected to be completed December of 2010. Implementation of the plan will begin 2011.

Some management practices can be identified for implementation. Since the impairment occurs primarily during high and moist flow runoff conditions, practices must tackle washoff when it rains. The focus needs to be on nearby sources. These sources include geese on the beach and deer throughout the forested park. Reductions in these loads will require changes in the way wildlife feces are managed. Best management practices for reducing pathogen indicators near the lake include:

- Reducing the geese numbers and time spent on and near the lake, especially the beach area.
- Removing goose feces from the beach area daily outside of the watershed.
- Reducing the deer population in the park.
- Slowing down the runoff with detention basins in drainage ways.

There are other bacteria sources in the watershed but distance, time, sedimentation, and predation in ponds, and wetlands often dampens their impacts. These sources include the continuous cattle in the stream and septic tank sources and the pasture and field applied manure sources available for washoff when it rains. Best management practices for reducing pathogen indicators include:

- Limiting livestock access to waterways in pastures and providing alternate watering sources.
- Controlling manure in runoff using incorporation or subsurface application to physically separate fecal material from surface runoff.
- Placing buffer strips along tributaries to slow and divert runoff.
- Repairing or replacing improperly connected and malfunctioning septic tank systems.

Some of the management practices for the near lake state park subbasin involve housekeeping rather than construction. Daily removal of goose feces can be accomplished as soon as resources are available to do it. Managing geese and deer populations might take more time. Below are objectives and a suggested schedule to reduce *E. coli* in Big Creek Lake.

- Identify, assess, and rank the potential sources within a quarter mile of the lakeshore. Select best management practices for each source. Complete by May 2011.
- Begin implementation of the best management practices by priority ranking for the sources identified in step 1. Reduce the identified source pathogen loading 25 percent by May 2012.
- In 2012, begin the process of identifying, assessing and ranking watershed bacteria sources and selecting BMPs outward from the tributary streams in quarter-mile increments every year.

5. Future Monitoring

These monitoring recommendations for Big Creek Lake and its watershed are based on previous monitoring efforts and proposed monitoring to measure the progress of watershed improvement best management practices.

5.1. Existing Monitoring to Support Lake Water Quality Assessment

Existing Big Creek Lake monitoring consists of two separate programs supported by IDNR. In one, the State Hygienic Lab (SHL) collects three to six samples between April and October. These samples are analyzed for nutrients, suspended solids, temperature, pH, chlorophyll, and transparency. The other effort is the separate IDNR beach monitoring program in which samples are collected weekly at the park beach and analyzed for *E. coli*.

These two monitoring efforts provide the information used in the biannual 305(b) water quality assessment and currently form the foundation of Big Creek Lake monitoring activities. This data is sufficient to assess lake water quality because, over time, it can detect impairments. However, evaluation of pollutant sources, the impacts of specific implemented best management practices, and trends over time requires a more detailed and comprehensive monitoring approach.

5.2. Big Creek Lake Monitoring Recommendations

Watershed and in-lake water quality monitoring are important elements for support of water quality improvement efforts. They play key roles in the analysis and modeling of pollutant sources and water quality. Watershed stream monitoring provides information for several purposes related to Big Creek Lake water quality improvement. Table 5-1 outlines the purposes, periods, and general procedures for engaging in this type of monitoring.

Table 5-1 Watershed stream monitoring

Type ID	Purpose	Time frame	General procedure
W1[1].	Measure continuous flow. Required for calculating loads, baseflow separation, flow and load duration curves, model calibration, etc.	Stage measured hourly, April to October.	Requires continuous stage monitoring, monthly or biweekly field measurement of flow, and the development of a rating curve from these.
W2[1].	Event sampling for phosphorus, nitrogen, suspended solids, and *E. coli*. Provides information on loads during runoff conditions.	Once an hour for at least 24 hours.	Auto-sampler set to begin sampling as stage increases. Samples at preset interval to capture most of hydrograph rise and fall. Operates in conjunction with flow measurement.
W3[1].	Grab sampling for phosphorus, nitrogen, suspended solids, and *E. coli.* Also, field measurements of pH, DO and flow. Provides data for watershed and lake model parameterization.	Once or twice a month, April to October.	Grab samples, field pH, DO, flow. These need to be collected at a range of flow conditions to be most useful.
W4[1].	Long term sampling for phosphorus, nitrogen, suspended solids, and *E. coli* to evaluate long term trends and BMP effectiveness	Once or twice a month for 5 to 10 years, April to October.	Determine confidence required, usually 95%, and calculate number of samples needed to detect a long term trend. Design a statistical model that uses event and monthly sampling data to evaluate watershed loads and detect trends.

1. These are watershed monitoring type identifications used in Table 5-3.

In-lake monitoring is used to assess Big Creek Lake water quality and support lake modeling. Table 5-2 outlines the purposes, periods, and general procedures for in-lake monitoring.

Table 5-2 In-lake monitoring

Type ID	Purpose	Time frame	General procedure
L1[1].	Measure continuous discharge from the lake. Required for estimating total flow and a water balance, developing flow and load duration curves, and providing lake model input and calibration.	Stage measured hourly, ice out to ice in.	Requires continuous stage monitoring, at the discharge weir.
L2[1].	Daily precipitation near the lake. Needed for both watershed and lake models.	Long term and year round.	Well maintained automatic rain gage.
L3[1].	Beach *E. coli* samples collected at the lake swimming beach to determine if water is safe for swimming. It is also needed for load duration curve evaluation.	Sampling done once a week May through October.	Consists of grab samples collected at the swimming beach and analyzed for *E. coli*.

1. These are lake monitoring type identifications used in Table 5-3.

Many lake water quality improvement activities require or can benefit from monitoring. Table 5-3 provides a framework for the monitoring that is necessary or is recommended for each of these.

Table 5-3 Monitoring for future watershed and water quality evaluation and improvement activities

Activity	Time frame and site locations	Necessary monitoring types	Recommended monitoring types
Erosion and sediment control - BMP effectiveness	Two years before and five years after BMP installation, at tributary sites	W1, W2, W4	W3
Watershed BasinSims/GWLF modeling	Ten years of precipitation data and two years of lake discharge.	L1, L2	W1, W2, W3
Load duration curves for bacteria	Five years of precipitation and discharge data.	L1, L3	L2

An outline of a monitoring plan being developed by the IDNR monitoring and assessment section is shown below.

Monitoring Needs:

1. Monitor the lake and beach to determine if water quality standards for bacteria are being met.
2. Monitor the performance of BMPs including those for managing pastured cattle, geese, MMP plan field application, and faulty septic systems to determine if reduction strategies have been effective.
3. Monitor the performance of stream bank stabilization, terraces, CRP buffers, and water and sediment control structures. Track bacteria concentrations and delivery to the lake.
4. Repeat RASCAL stream bank and gully erosion assessment after BMP implementation to estimate sediment reduction from these sources.

Plan:

1. Develop a detailed plan with the project coordinator as implementation specifics are determined.
   a. Determine the number and locations of sites.
   b. Determine site sampling frequency and duration.
   c. Determine site monitoring parameters.
   d. Design flow monitoring to assess load reductions.
   e. Determine who from what organization with sample at each site.
2. Conduct annual lake monitoring.
   a. The IDNR ambient program will continue to monitor the lake three times spring to fall using the standard lake water quality protocols.
   b. The IDNR beach program will monitor twice weekly at the beach for *E. coli*.

    c. Work with the county to organize and support IOWATER volunteer monitoring to collect additional data.
3. Monitor stream sediment and phosphorus loads to the lake
    a. Utilize ISCO samplers with flow measurements within sub-watershed or micro-watersheds to determine effectiveness of implemented BMPs.
    b. Measure in-situ turbidity and total phosphorous.
4. Monitor geese control at the beach by tracking the amount of fecal matter removed from the beach.
5. Conduct pre and post-implementation RASCAL assessments to estimate reduction in sediment delivery from bank and gully erosion.

6. Public Participation

Public involvement is important in the TMDL process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that will determine Big Creek Lake water quality. During the development of this TMDL, efforts were made to ensure local stakeholder involvement.

6.1. Public and Stakeholder Meetings

A stakeholders meeting was held at the Ankeny NRCS office on March 22, 2010. Lake water quality issues and bacteria sources were identified and discussed. Information obtained at this meeting was used to support development of this WQIP.

The Big Creek Lake Water Quality Improvement Plan was placed on public notice starting August 5, 2010 and ending September 7, 2010. A public meeting was held on August 19, 2010 at the Polk City Community Center from 6 to 8 pm.

6.2. Written Comments

No comments were received during the comment period.

7. References

Big Creek Lake Specific References

Mathangwane, B. T. (2001). Seasonal variation of lake water quality: Influence of colloidal suspended solids and water chemistry in selected Iowa lakes.

United States Army Corps of Engineers, Rock Island District. (1970). Saylorville Reservoir, Des Moines River, Iowa: Big Creek Valley remedial works: Modifications to proposed terminal dam and spillway, and drainage of proposed diversion channel cut slopes - Design Memorandum.

United States. Army. Corps of Engineers. Rock Island District. (1970). Saylorville Reservoir, Des Moines River, Iowa : Big Creek Valley remedial works: modifications to slopes of diversion and barrier dams. Design Memorandum.

United States Army Corps of Engineers, Rock Island District. (1968). Saylorville Reservoir, Des Moines River, Iowa: Big Creek Valley remedial works: design memorandum.

General References

Canale, Raymond P., T. Lustig, P. Kehrberger, J. Salo. 1973. Experimental and Mathematical Modeling Studies of Protozoan Predation on Bacteria. Biotechnology and Bioengineering, Vol. XV, pages 707-728 (1973)

Canale, Raymond P., Auer, Martin T., Owens, Emmet M., Heidtke, Thomas M., and Effler, Steven W. (1993) Modeling Fecal Coliform Bacteria –II: Model Development and Application. *Water Research*. **27**:4, pp. 703-714.

Chapra, Steven C. Surface Water-Quality Modeling. New York: McGraw-Hill, 1997.

Helsel and Hirsch, Statistical Methods in Water Resources, USGS, Water Resources Division, 1992

Iowa Administrative Code (IAC) Chapter 567-61: Water Quality Standards. http://www.legis.state.ia.us/IAC.html

Moriasi, D.N., J.G. Arnold et al, Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations, *Transactions of the ASABE*, 2007 Vol. 50(3): 885-900

Nash, J.E.and Sutcliffe, J.V.; River flow forecasting through conceptual models, Part I - A discussion of principles, J. Hydrol., 10, 282-290, 1970

Novotny and Chesters. 1981. Handbook of Nonpoint Pollution Sources and Management.

Shelton, Daniel R. et al. Release Rates of Manure-Borne Coliform Bacteria from Data on Leaching through Stony Soil, *Vadose Zone Journal*, 2003. Vol. 2 p. 34-39.

SWAT Theoretical Documentation, Version 2005: Section 3, Chapter 4: *Equations: Bacteria*.

Tollner, Ernest W. 2002. Natural Resources Engineering.

US Environmental Protection Agency (EPA). June 1985. EPA/600/3-85/040. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition)

US Environmental Protection Agency (EPA). 2001. Bacterial Indicator Tool. U.S. Environmental Protection Agency, Office of Water, December 2001.

US Environmental Protection Agency (EPA). 2001. Protocol for Developing Pathogen TMDLs. U.S. Environmental Protection Agency, Office of Water, January 2001.

US Environmental Protection Agency (EPA). August 2007. EPA 841-B-07-006. An Approach for Using Load Duration Curves in the Development of TMDLs First Edition.

Zeckoski, R. W., B.L. Benham, S.B. Shah, M.L. Wolfe, K.M. Brannan, M. Al-Smadi, T.A. Dillaha, S. Mostaghimi, and C.D. Heatwole. 2005. "BSLC: A Tool for Bacteria Source Characterization for Watershed Management," Applied Engineering in Agriculture. 2005. Vol. 21(5) p. 879-889.

9. 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 0.2 AU.

Benthic: Associated with or located at the bottom (in this context, "bottom" refers to the bottom of streams, lakes, or wetlands). Usually refers to algae or other aquatic organisms that reside at the bottom of a wetland, lake, or stream (see periphyton).

Benthic macroinvertebrates: Animals larger than 0.5 mm that do not have backbones. These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. They include crayfish, mussels, snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

Base flow: Sustained flow of a stream in the absence of direct runoff. It can include natural and human-induced stream flows. Natural base flow is sustained largely by groundwater discharges.

Biological impairment: A stream segment is classified as biologically impaired if one or more of the following occurs, the FIBI and or BMIBI scores fall below biological reference conditions, a fish kill has occurred on the segment, or the segment has seen a > 50% reduction in mussel species.

Biological reference condition: Biological reference sites represent the least disturbed (ie. most natural) streams in the ecoregion. The biological data from these sites are used to derive least impacted BMIBI and FIBI scores for each ecoregion. These scores are used to develop Biological Impairment Criteria (BIC) scores for each ecoregion. The BIC is used to determine the impairment status for other stream segments within an ecoregion.

BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.

BMP: Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.

CAFO: Concentrated Animal Feeding Operation. A federal term defined as any animal feeding operation (AFO) with more than 1000 animal units confined on site, or an AFO of any size that discharges pollutants (e.g. manure, wastewater) into any ditch, stream, or other water conveyance system, whether man-made or natural.

CBOD5: 5-day Carbonaceous Biochemical Oxygen Demand. Measures the amount of oxygen used by microorganisms to oxidize hydrocarbons in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.

CFU: A Colony Forming Unit is a cell or cluster of cells capable of multiplying to form a colony of cells. Used as a unit of bacteria concentration when a traditional membrane filter method of analysis is used. Though not necessarily equivalent to most probably number (MPN), the two terms are often used interchangeably.

Confinement feeding operation: An animal feeding operation (AFO) in which animals are confined to areas which are totally roofed.

Credible data law: Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate. To be considered "credible," data must be collected and analyzed using methods and protocols outlined in an approved Quality Assurance Project Plan (QAPP).

Cyanobacteria (blue-green algae): Members of the phytoplankton community that are not true algae but are capable of photosynthesis. Some species produce toxic substances that can be harmful to humans and pets.

Designated use(s): Refer to the type of economic, social, or ecological activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.

DNR (or IDNR): Iowa Department of Natural Resources.

Ecoregion: Areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources based on geology, vegetation, climate, soils, land use, wildlife, and hydrology.

EPA (or USEPA): United States Environmental Protection Agency.

Ephemeral gully erosion: Ephemeral gullies occur where runoff from adjacent slopes forms concentrated flow in drainage ways. Ephemerals are void of vegetation and occur in the same location every year. They are crossable with farm equipment and are often partially filled in by tillage.

FIBI: Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.

FSA: Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.

General use(s): Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.

Geometric Mean (GM): A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendancy 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 criteria 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 which 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 which 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 which is the same as micrograms per liter (µg/L).

PPM: Parts per Million. A measure of concentration which 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.

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.

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 which 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 which 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.)

UHL: University 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.

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.

WWTP: Wastewater Treatment Plant. General term for a facility which treats municipal, industrial, or agricultural wastewater for discharge to public waters according to the conditions of the facility's NPDES permit.

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 used to assess water bodies for support of their aquatic life, recreational, and drinking water uses. There are different criteria for different waterbodies depending on their designated uses. All waterbodies must support the general use criteria.

General Use Segments

A general use water body does not have perennial flow or permanent pools of water in most years, i.e. ephemeral or intermittent waterways. General use water bodies are defined in IAC 567-61.3(1) and 61.3(2). General use waters are protected for livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses.

Designated Use Segments

Designated use water bodies maintain year-round flow or pools of water sufficient to support a viable aquatic community. In addition to being protected for general use, perennial waters are protected for three specific uses, primary contact recreation (Class A), aquatic life (Class B), and drinking water supply (Class C). Within these categories there are thirteen designated use classes as shown in Table B1. Water bodies can have more than one designated use. The designated uses are found in IAC 567-61.3(1).

Table B1 Designated use classes for Iowa water bodies.

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

Appendix C --- Big Creek Lake Water Quality Data

The following tables contain the beach monitoring data collected when beach monitoring at Big Creek Lake began and subsequent years through 2008.

Table C-1 IDNR 1999 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
6/1/1999	110	71.16	21.1%
6/6/1999	20	55.09	27.2%
6/7/1999	480	54.24	27.6%
6/14/1999	130	216.65	6.3%
6/15/1999	0	162.48	8.4%
6/21/1999	82	84.08	17.7%
6/22/1999	130	611.29	1.6%
6/28/1999	20	54.31	27.5%
6/29/1999	110	50.75	29.3%
7/6/1999	110	56.82	26.2%
7/7/1999	18	37.72	36.9%
7/12/1999	50	27.01	44.3%
7/13/1999	82	25.58	45.3%
7/19/1999	70	30.39	42.0%
7/20/1999	82	26.33	44.9%
7/26/1999	110	19.77	50.1%
8/2/1999	0	19.23	50.7%
8/3/1999	170	17.64	52.5%
8/9/1999	64	19.77	50.1%
8/10/1999	0	17.20	53.1%
8/16/1999	10	12.14	59.9%
8/18/1999	0	96.97	14.9%
8/23/1999	10	22.75	47.4%
8/24/1999	10	17.50	52.7%
8/30/1999	0	10.48	62.9%
8/31/1999	0	10.08	63.7%
9/7/1999	0	402.58	2.8%
9/8/1999	0	43.01	33.4%
9/13/1999	0	15.52	55.1%
9/14/1999	10	14.41	56.7%
9/20/1999	10	10.38	63.1%
9/21/1999	0	9.60	64.3%
9/27/1999	10	11.93	60.3%
9/28/1999	10	10.38	63.0%

Table C-2 IDNR 2000 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
5/26/2000	230	2.92	79.3%
5/27/2000	20	2.73	80.5%
5/27/2000	5	2.38	82.1%
5/28/2000	5	477.80	2.3%
5/28/2000	30	60.18	25.0%
6/2/2000	10	35.60	38.3%
6/3/2000	27	31.49	41.2%
6/3/2000	160	28.34	43.4%
6/10/2000	40	91.18	16.0%
6/10/2000	740	43.26	33.1%
6/11/2000	18	38.10	36.6%
6/16/2000	30	34.71	38.7%
6/17/2000	20	40.79	34.8%
6/17/2000	950	31.48	41.2%
6/18/2000	5	28.19	43.6%
6/21/2000	20	25.47	45.4%
6/23/2000	160	23.30	47.1%
6/24/2000	20	21.42	48.7%
6/24/2000	18	20.47	49.5%
6/25/2000	170	20.28	49.8%
6/30/2000	170	18.48	51.6%
7/1/2000	64	16.92	53.5%
7/1/2000	230	262.38	4.8%
7/2/2000	20	29.45	42.7%
7/2/2000	850	18.98	51.0%
7/3/2000	20	15.98	54.6%
7/3/2000	130	14.01	57.2%
7/4/2000	12000	12.60	59.2%
7/4/2000	680	17.63	52.5%
7/5/2000	20	12.36	59.4%
7/5/2000	27	10.88	62.0%
7/6/2000	20	12.80	58.8%
7/10/2000	1100	10.63	62.5%
7/17/2000	100	14.85	56.0%
7/24/2000	10	15.08	55.4%
7/31/2000	10	10.76	62.3%
8/7/2000	91	16.87	53.6%
8/14/2000	1	10.64	62.5%
8/21/2000	1	9.79	64.2%
8/28/2000	1	8.41	66.0%
9/4/2000	10	7.42	67.6%
9/4/2000	1	11.60	60.9%
9/11/2000	10	10.67	62.4%
9/18/2000	10	8.16	66.6%

Table C-3 IDNR 2001 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
5/21/2001	1	244.55	5.4%
5/29/2001	1	95.10	15.3%
6/4/2001	10	95.63	15.1%
6/11/2001	1	144.68	9.7%
6/12/2001	30	53.71	27.8%
6/13/2001	170	51.70	28.8%
6/14/2001	1000	44.99	32.1%
6/15/2001	10	43.65	32.9%
6/16/2001	18	39.34	35.9%
6/17/2001	40	36.97	37.3%
6/17/2001	10	34.79	38.7%
6/18/2001	10	33.70	39.5%
6/19/2001	40	32.11	40.7%
6/20/2001	1	30.68	41.8%
6/21/2001	1	29.23	42.9%
6/22/2001	1	27.74	43.8%
6/23/2001	10	26.69	44.6%
6/23/2001	1	25.78	45.2%
6/24/2001	1	24.80	46.0%
6/24/2001	10	24.06	46.5%
6/25/2001	1	23.15	47.2%
6/26/2001	1	19.73	50.2%
6/27/2001	10	18.95	51.1%
6/28/2001	1	18.24	52.0%
7/3/2001	1	22.02	48.2%
7/4/2001	10	16.69	53.8%
7/4/2001	1	15.43	55.2%
7/5/2001	1	13.96	57.2%
7/7/2001	130	12.96	58.5%
7/8/2001	1100	11.52	61.0%
7/9/2001	10	6.81	68.8%
7/10/2001	10	19.27	50.6%
7/11/2001	1	2.39	82.1%
7/12/2001	1	2.33	82.3%
7/16/2001	20	18.69	51.4%
7/23/2001	1	2.32	82.3%
7/30/2001	1	1.08	90.7%
8/6/2001	1	1.01	91.3%
8/14/2001	1	0.12	96.9%
8/16/2001	1	16.28	54.3%
8/20/2001	1	244.55	5.4%
8/27/2001	10	95.10	15.3%
9/4/2001	1	95.63	15.1%
9/10/2001	1	144.68	9.7%

Table C-4 IDNR 2002 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
4/16/2002	1	5.03	72.3%
4/23/2002	1	6.32	69.7%
4/30/2002	1	64.73	23.3%
5/7/2002	1	45.91	31.6%
5/14/2002	1	137.62	10.3%
5/21/2002	1	67.59	22.2%
5/28/2002	1	66.71	22.5%
6/4/2002	1	42.41	33.8%
6/11/2002	1	40.82	34.8%
6/18/2002	1	58.80	25.4%
6/25/2002	1	37.15	37.1%
7/2/2002	180	25.96	45.1%
7/9/2002	50	712.64	1.3%
7/15/2002	10	19.46	50.4%
7/23/2002	20	12.13	59.9%
7/30/2002	18	9.79	64.2%
8/6/2002	190	39.62	35.6%
8/13/2002	1	6.70	69.0%
8/20/2002	10	3.45	77.6%
8/27/2002	1	5.23	71.6%
9/3/2002	1	1.83	84.1%
9/10/2002	1	1.39	87.4%
9/17/2002	1	127.24	11.2%
9/24/2002	1	1.84	84.1%
10/1/2002	1	106.26	13.6%
10/8/2002	1	38.95	36.0%
10/15/2002	1	23.53	46.9%
10/22/2002	1	16.01	54.6%
10/29/2002	1	48.38	30.4%

Table C-5 IDNR 2003 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
4/14/2003	20	2.15	82.9%
4/21/2003	20	24.37	46.4%
4/28/2003	1	33.64	39.5%
5/5/2003	36	223.11	6.1%
5/12/2003	100	172.05	8.0%
5/19/2003	30	100.15	14.5%
5/27/2003	20	55.83	26.6%
6/2/2003	10	43.58	33.0%
6/9/2003	1	33.35	39.7%
6/16/2003	1	23.72	46.8%
6/23/2003	10	19.09	50.9%
6/30/2003	20	30.82	41.7%
7/7/2003	30	113.15	12.6%
7/14/2003	280	91.43	16.0%
7/21/2003	80	53.01	28.1%
7/28/2003	1	36.73	37.4%
8/4/2003	1	25.63	45.3%
8/11/2003	18	13.02	58.4%
8/18/2003	10	4.96	72.8%
8/25/2003	30	10.98	61.9%
9/1/2003	20	2.15	82.9%
9/8/2003	1	1.47	86.6%
9/15/2003	1	2.70	80.6%
9/22/2003	18	12.76	58.9%
9/29/2003	36	1.44	87.0%
10/6/2003	10	0.52	93.9%
10/13/2003	1	6.37	69.5%
10/20/2003	10	0.33	95.2%
10/27/2003	1	2.87	79.6%

Table C-6 IDNR 2004 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
5/24/2004	1400	450.61	2.4%
6/1/2004	410	207.65	6.7%
6/7/2004	270	88.21	16.5%
6/14/2004	20	67.20	22.4%
6/21/2004	210	337.81	3.7%
6/28/2004	740	31.43	41.3%
7/6/2004	2300	26.25	45.0%
7/12/2004	130	21.48	48.7%
7/19/2004	20	15.32	55.3%
7/26/2004	20	11.76	60.7%
8/2/2004	80	8.95	65.1%
8/9/2004	10	5.30	71.5%
8/16/2004	10	2.66	80.8%
8/23/2004	20	6.14	70.0%
8/30/2004	1	4.85	73.4%
9/7/2004	10	6.76	68.8%
9/13/2004	1	1.13	90.0%
9/20/2004	10	0.93	91.9%
9/27/2004	50	0.49	94.4%
10/4/2004	1	1.00	91.4%
10/11/2004	1	0.30	95.4%
10/18/2004	1	0.41	94.7%
10/25/2004	1	0.13	96.8%

Table C-7 IDNR 2005 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
5/16/2005	90	152.63	9.2%
5/23/2005	1	70.95	21.3%
5/30/2005	1	44.88	32.2%
6/6/2005	30	30.84	41.6%
6/13/2005	60	37.72	36.9%
6/20/2005	1	66.36	22.7%
6/27/2005	120	32.25	40.6%
7/5/2005	40	13.19	58.1%
7/11/2005	45	10.98	61.9%
7/18/2005	10	9.94	63.8%
7/25/2005	72	33.16	39.8%
8/1/2005	1	8.17	66.6%
8/8/2005	1	1.20	89.2%
8/15/2005	30	13.99	57.2%
8/22/2005	1	3.55	77.1%
8/29/2005	1	1.45	86.9%
9/5/2005	1	1.05	90.9%
9/12/2005	18	232.54	5.7%
9/19/2005	1	12.98	58.4%
9/26/2005	1	75.54	19.8%
10/3/2005	20	55.65	26.9%
10/10/2005	1	33.91	39.3%
10/17/2005	1	22.40	47.9%
10/24/2005	1	16.94	53.5%

Table C-8 IDNR 2006 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
4/18/2006	1	40.15	35.3%
4/25/2006	1	26.61	44.7%
5/2/2006	240	179.71	7.7%
5/9/2006	1	67.13	22.4%
5/16/2006	1	42.41	33.8%
5/22/2006	1	30.79	41.7%
5/30/2006	1	25.16	45.7%
6/5/2006	20	18.34	51.9%
6/12/2006	1	15.05	55.5%
6/19/2006	1	14.03	57.1%
6/26/2006	10	10.86	62.1%
7/3/2006	1	6.70	69.1%
7/10/2006	40	94.89	15.3%
7/17/2006	1	2.48	81.7%
7/24/2006	30	1.08	90.7%
7/31/2006	20	6.49	69.4%
8/7/2006	10	1.13	90.0%
8/14/2006	10	4.73	74.0%
8/21/2006	1	1.49	86.3%
8/28/2006	1	32.20	40.7%
9/5/2006	1	9.56	64.3%
9/12/2006	20	141.68	9.8%
9/19/2006	1	193.24	7.2%
9/26/2006	1	105.24	13.7%

Table C-9 IDNR 2007 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
5/22/2007	41	49.65	29.8%
5/30/2007	218	233.99	5.7%
6/5/2007	10	95.91	15.0%
6/12/2007	1	46.44	31.3%
6/19/2007	41	33.08	39.9%
6/26/2007	390	24.92	45.9%
6/27/2007	31	24.11	46.5%
7/2/2007	31	18.83	51.3%
7/9/2007	63	8.96	65.1%
7/17/2007	30	3.98	75.9%
7/23/2007	20	5.95	70.4%
7/31/2007	1	2.37	82.2%
8/7/2007	10	3.14	78.5%
8/13/2007	51	1.58	85.7%
8/21/2007	1	54.17	27.7%
8/27/2007	10	7.20	68.0%

Table C-10 IDNR 2008 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
5/20/2008	1	61.23	24.5%
5/28/2008	10	71.55	20.9%
6/3/2008	930	2189.11	0.3%
6/4/2008	450	614.46	1.6%
6/9/2008	160	486.63	2.2%
6/18/2008	160	156.02	8.9%
6/23/2008	30	102.34	14.2%
6/25/2008	10	88.14	16.6%
6/30/2008	200	68.30	22.0%
7/7/2008	20	43.68	32.9%
7/9/2008	30	42.94	33.5%
7/14/2008	190	33.18	39.8%
7/16/2008	140	30.06	42.1%
7/22/2008	70	65.19	23.0%
7/23/2008	170	44.18	32.6%
7/28/2008	190	1319.68	0.6%
7/30/2008	320	178.69	7.8%
8/4/2008	240	87.37	16.8%
8/6/2008	730	74.51	20.0%
8/11/2008	90	52.26	28.5%
8/13/2008	40	47.96	30.6%
8/18/2008	50	35.30	38.5%
8/25/2008	1	25.20	45.6%
9/3/2008	1	16.56	54.0%
9/8/2008	1	15.43	55.2%
9/16/2008	50	15.57	55.0%

Table C-11 IDNR 2009 *E. coli* beach data

Collection date	Result, orgs/100ml	Simulated daily flow, cfs	Percent rank
5/19/2009	10	38.42	36.3%
5/26/2009	30	1205.27	0.7%
6/1/2009	150	82.32	18.1%
6/3/2009	20	68.97	21.8%
6/8/2009	1900	53.92	27.8%
6/10/2009	50	45.80	31.7%
6/15/2009	40	36.23	37.8%
6/17/2009	30	226.68	6.0%
6/22/2009	50	77.44	19.2%
6/24/2009	70	61.52	24.4%
6/29/2009	30	43.37	33.1%
7/6/2009	1	32.34	40.5%
7/8/2009	130	32.32	40.5%
7/13/2009	50	23.88	46.6%
7/15/2009	20	21.50	48.7%
7/20/2009	1	22.43	47.9%
7/22/2009	30	17.54	52.6%
7/28/2009	10	12.83	58.7%
7/29/2009	40	12.68	59.0%
8/3/2009	60	7.23	68.0%
8/5/2009	30	5.20	71.7%
8/10/2009	30	9.56	64.4%
8/12/2009	420	3.71	76.6%
8/17/2009	1	2.66	80.8%
8/25/2009	10	57.28	26.1%
8/31/2009	1	4.77	73.8%

Appendix D --- Watershed Hydrology, Water Quality Analysis, and Modeling

This water quality improvement plan was developed using a watershed model to simulate hydrology and washoff and transport of bacteria called *Soil and Water Assessment Tool (SWAT)*, a bacteria source evaluation spreadsheet called the *EPA Bacteria Indicator Tool (BIT)*, and flow and load duration curve analysis spreadsheets. These are briefly described in Table D-1.

Table D-1 Descriptions of the models used for Big Creek Lake

Model	Type and purpose	Time frame	Description
SWAT	Watershed model used to simulate hydrology and bacteria decay.	Annual, monthly, daily	Provides estimates of daily flow to generate recurrence intervals for duration curves and bacteria decay/loss between the source and the beach.
EPA Bacteria Indicator Tool (BIT)	Bacteria source loads available for washoff and those continuously discharged.	Multi-year	Estimates bacteria loads available from watershed sources for washoff and output of continuous discharges from cattle in the stream and faulty septic tank systems.
Flow and load duration curves	Multi-year flow and load analysis for *E. coli*	Multi-year	Transforms daily flow to recurrence intervals and inputs monitored *E. coli* data to calculate loads and evaluate source contributions and critical flow intervals.

Watershed Modeling – SWAT

The SWAT watershed model uses precipitation and temperature data from the Ames West National Weather Service COOP station (IA0200), land use information from a 2008 watershed assessment made into a GIS coverage, and SSURGO soil information made into a GIS coverage. The procedures used to simulate watershed hydrology for Big Creek Lake consist of:

- Obtaining the daily precipitation and temperature data from the Ames West weather station and inputting it into the SWAT model. The period used as weather input to the model was January 1, 1995 to December 31, 2009.
- Curve numbers based on SSURGO soils data and previously calibrated SWAT models in the Des Moines River watershed.
- Stream development and delineation based on a state digital elevation model and the establishment of nineteen subbasins.
- Defining hydrologic response units (HRU) with unique soil, landuse, and slope. There are 203 HRU's in the 19 subbasins.
- Entering the point source flows and bacteria loads from cattle in the stream and faulty septic tank systems derived from BIT estimates.
- Creating a reservoir in SWAT using Big Creek Lake characteristics as input.

- Creating a tile drainage input for row crop landuses.
- Running the SWAT model to obtain daily simulated flow into the lake from the watershed and adjusting it to the flow synthesized from four nearby streams that have USGS gages.
- Generating flow and load duration curves using the simulated flow.

These flow and load duration curves have been used to make the load allocations, margins of safety, existing loads, and total maximum daily loads in Section 3 of this report. Only the flows from the recreation season, March 15 to November 15, were used to generate the flow and load duration curves. The nineteen SWAT subbasins and subbasin outlets are shown in Figure D-1.

Big Creek SWAT Model Parameters
In 2009, a calibrated SWAT model was created for the Des Moines River Watershed upstream from Saylorville Reservoir for a TMDL that included the Big Creek Lake watershed. The primary hydrologic parameters used in this earlier model were used for the initial model runs and then were modified to the synthesized hydrology from the four nearby streams with gages. The final parameters are listed in Table D-2

Table D-2 SWAT hydrologic calibration parameters

Parameter	Input Description	Calibrated Value
Curve Number	Corn – Soil Group B	67
	Pasture – Soil Group B	59
	Meadow bromegrass – Soil Group B	59
	Forest – Soil Group B	66
	Residential – Soil Group B	59
IPET	Potential Evapotranspiration Method	Hargreaves
ESCO	Soil Evaporation Compensation	0.95
EPCO	Plant Uptake Compensation Factor	1.0
ICN	Daily curve number calculation method	Soil Moisture Method
CNCOEF	Plant ET curve number coefficient	1.0
SURLAG	Surface Runoff Lag	0.5 days
IRTE	Channel Routing Method	Variable Storage
GW_DELAY	Groundwater Delay	30 days
ALPH_BF	Alpha Base Flow Factor	0.8 days
GW_REVAP	Groundwater revap coefficient	0.12

The Des Moines Lobe ecoregion is poorly drained and most cropland is tile drained. SWAT incorporates tile drainage using three parameters, listed in Table D-3. Tile drainage was added to all corn HRU's. It is assumed that all corn HRU's are tile drained in the Big Creek watershed.

Table D-3 SWAT watershed tile drain parameters

Description	SWAT Variable	Value
Depth to subsurface drain	DDRAIN	900 mm
Time required to drain to field capacity	TDRAIN	48 hours
Drainage tile lag time	GDRAIN	48 hours

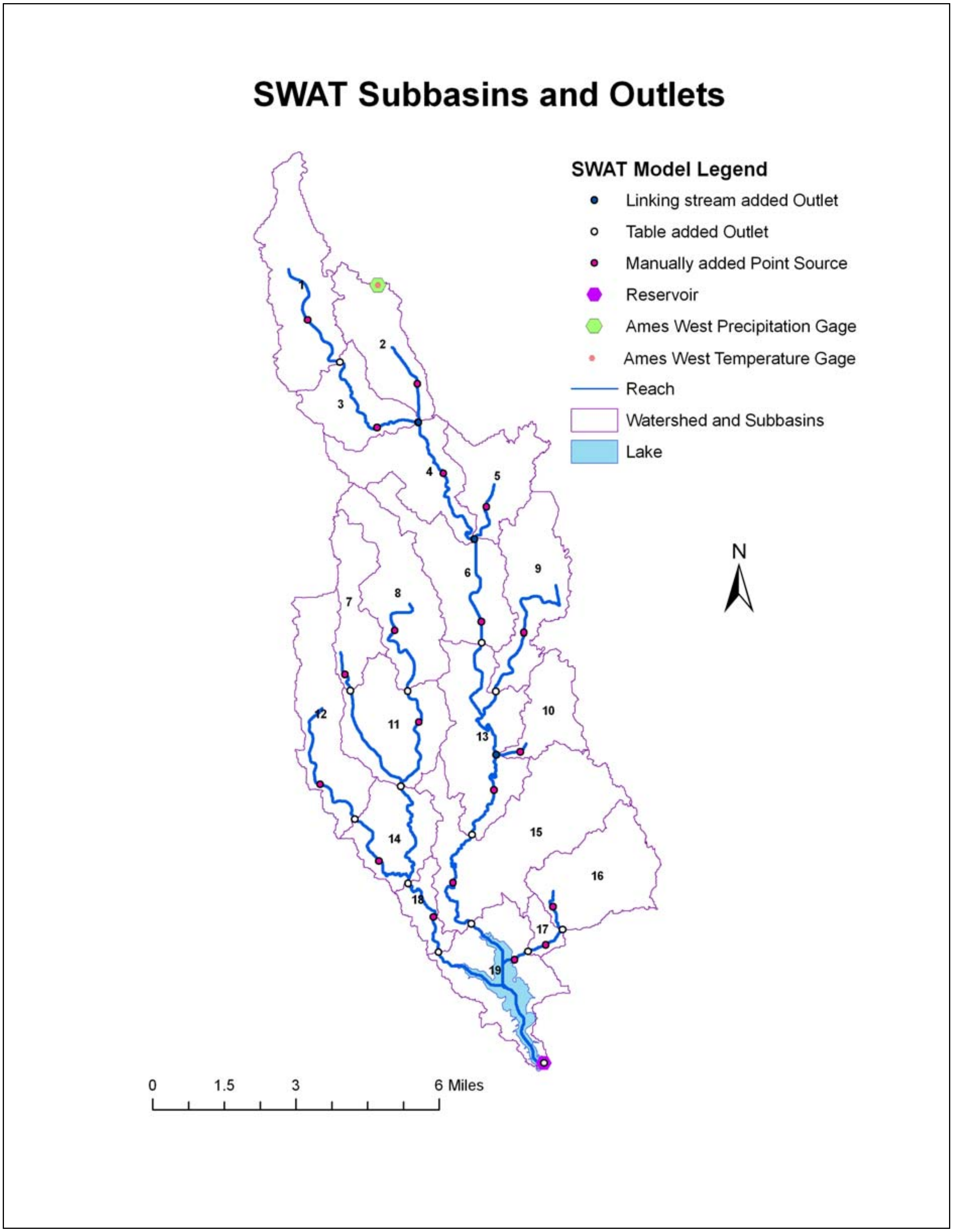

Figure D-1 Swat model Subbasins and Outlets

In Figure D-1 the SWAT subbasins, numbered 1 through 19, are shown with the stream network and the outlet for each subbasin. Also shown are subbasin point sources that represent the continuously discharging cattle in stream and faulty septic tank system flows and loads. The point sources are spatially located only at the subbasin scale. The Ames West weather station is located in the northern part of the watershed.

Big Creek Lake discharges to Saylorville Reservoir over a wide weir at the end of a long channel. The discharge over this weir varies with the flow into the lake. Generally, the lake water surface elevation does not vary much from the elevation of the weir crest. The exception to this is during long dry periods when evaporation exceeds flow into the lake and the water surface elevation drops below the weir crest. When this happens the only discharge from the lake is to Big Creek downstream of the dam. This discharge is a constant four cfs with the purpose of maintaining creek integrity downstream of the lake. In the SWAT model this discharge is represented as a fraction of the lake bottom seepage.

The weir that controls the water elevation serves as both the principal spillway and the emergency spillway for Big Creek Lake. Therefore the lake surface area and volume are the same for these two SWAT parameters. Big Creek Lake has been represented as a reservoir in the SWAT model with the characteristics shown in Table D-4.

Table D-4 SWAT reservoir parameters

SWAT code	SWAT Parameter	Units	Value
RES_ESA	Surface area of reservoir when filled to emergency spillway	hectares	307
RES_EVOL	Volume of reservoir when filled to emergency spillway	cubic meters	17,980,000
RES_PSA	Surface area of reservoir when filled to principal spillway	hectares	307
RES_PVOL	Volume of reservoir when filled to principal spillway	cubic meters	17,980,000
RES_VOL	Initial volume at beginning of model (January 1,1995)	cubic meters	17,980,000
RES_K	Hydraulic conductivity of reservoir bottom, seepage	mm/hr	1.2

Army Corps of Engineers Big Creek Lake stage and discharge data

The Army Corps of Engineers (ACOE) maintains a station that measures lake water surface elevation at the south end of the lake by the dam and have developed a rating curve for the discharge spillway. This provides some information about lake flow but there are some years, e.g. 2006 to 2009, for which the data cannot be used because there are obvious problems, i.e., annual discharge exceeds annual watershed precipitation.

The gage has shown errors in the measurement of stage. It is assumed that the rating table is reasonably accurate and that gage maintenance and data quality control are problems in some years. Therefore the ACOE record has not been used to calibrate the SWAT hydrology.

Synthetic flow and SWAT hydrology
Four streams near Big Creek Lake that have flow gages have been used to generate a synthetic flow for Big Creek Lake tributaries. A daily flow per square mile of watershed for each of the four streams has been calculated and used to determine the synthetic flow for Big Creek Lake. EPA Region 7 staff calculated the daily synthetic flow values. The four streams and their watershed areas are shown in Table D-5 as is the Big Creek watershed drainage area.

Table D-5 Drainage areas of Big Creek Lake and the four neighboring gauged streams used for hydrologic calibration

Stream Name	Drainage area, square miles	USGS gage ID
Fourmile Creek near Ankeny	68	05485605
Beaver Creek near Grimes	358	05481950
Walnut Creek near Cambridge	18	05471014
Squaw Creek at Ames	204	05470500
Big Creek	75	NA

The synthetic Big Creek Lake watershed drainage flow was used to calibrate the SWAT model flow that was then used to make the flow and load duration curves. Statistics evaluating the daily synthetic flow versus the daily SWAT simulated flow are shown in Table D-6.

Table D-6 Daily Synthetic versus SWAT simulated flow statistics

Statistic	Value	Interpretation[1]
R-squared	75 percent	Good
Nash-Sutcliff Efficiency	0.70	Good (0.65 to 0.75)
Root Mean Square Error	0.55	Good (0.50 to 0.60)
Percent Bias	15	Good (10 to 15)

1. The range for these model evaluation statistics consists of four categories, very good, good, satisfactory, and unsatisfactory. (Moriasi)

The monthly average synthetic flow versus the monthly SWAT simulated flow was also evaluated and the statistics are shown in Table D-7.

Table D-7 Monthly Synthetic versus SWAT simulated flow statistics

Statistic	Value	Interpretation[1]
R-squared	86 percent	Very Good
Nash-Sutcliff Efficiency	0.84	Very Good (0.75 to 1.0)
Root Mean Square Error	0.40	Very Good (0.0 to 0.5)
Percent Bias	12	Good (10 to 15)

1. The range for these model evaluation statistics consists of four categories, very good, good, satisfactory, and unsatisfactory. (Moriasi)

These statistics reflect a very reasonable correspondence of the SWAT simulated flows to the flows synthesized from the neighboring four streams at both the daily and monthly averages.

Flow and Load Duration Curves

The simulated flow from the SWAT modeling has been used to generate flow, load, and runoff duration curves. The observed concentration data is matched to the modeled flow for the day the sample was collected to calculate the estimated daily load. Similarly, multiplying daily flow values times the GM and SSM of 126 and 235 *E. coli* orgs/100 ml generates the criteria target loads for each day. In general, it is assumed that bacteria are distributed evenly through the stream and lake volumes.

Flows are converted to percent recurrence to generate the flow duration curve. The flows at the percent recurrence are multiplied by the relevant *E. coli* concentration to construct the load duration curve. The flow and load duration curves have been divided into five flow conditions that represent a flow recurrence range. These five flow conditions are described in Table 3-2 of the main report and are shown in Table D-8.

Table D-8 Flow conditions for recurrence intervals

Recurrence interval	Mid range flow, cfs	Flow condition
0-10%	240.4	High flows - runoff dominated
10-40%	60.2	Moist conditions
40-60%	25.7	Mid-range flow
60-90%	9.1	Dry conditions - mostly base flow
90-100%	1.4	Low (base) flow

Inspection of the sampled concentrations that exceed the criteria at these recurrence intervals provides insight into bacteria sources. In general, monitored bacteria concentrations exceeding the criteria at high flows are from the washoff of nonpoint sources and criteria exceeded at low flows are from continuous discharges sources such as septic tanks and wildlife and livestock in or near the tributary streams and the lake. Between these two extreme flow conditions, there is a continuum of sources from moist conditions when bacteria are delivered by runoff from rainfall, to dry and low flow conditions when more bacteria are delivered by continuous sources.

The midpoints of the five flow conditions occur at recurrences of 95%, 75%, 50%, 25%, and 5%. The median *E. coli* count for each flow condition is calculated at the two criteria concentrations (126 and 235 orgs/100 ml) for each interval median flow. This calculation becomes the target for the flow condition interval. Figure D-2 (aka Figure 3-3) shows the load duration curve plotted with the five recurrence intervals.

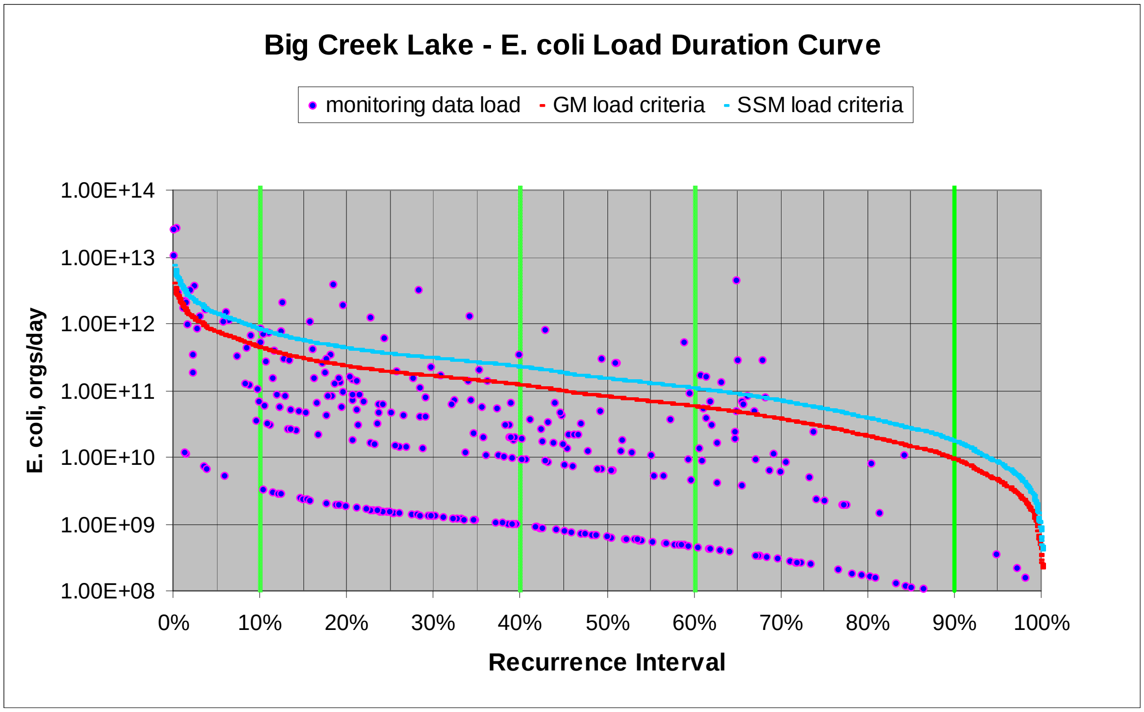

Figure D-2 Load duration curves

The recurrence interval TMDL targets for GM and SSM are listed in Tables 3-4 and 3-5, respectively. The SSM existing and target loads for the five intervals are shown graphically in Figure 3-4. The existing loads are estimated by multiplying the 90th concentration percentile of all of the monitored *E. coli* values in a flow condition by the midpoint flow.

Pathogen Indicator Analysis and Modeling

In 2004, the Iowa Department of Natural Resources converted from fecal coliform to *E. coli* bacteria as the indicator for primary contact recreation assessment. *E. coli* is now used as the pathogen indicator in the water quality standards but previously fecal coliform was used. There are a few instances in the development of this report where fecal coliform was used in the analysis because reference materials use it as the pathogen indicator.

The fecal coliform/*E. coli* relationship used in this TMDL is based on the WQS geometric mean for fecal coliform that was used before the *E. coli* standard was adopted. The values, respectively, for these geometric means are 200 fecal coliform organisms/100 ml and 126 *E. coli* organisms/100 ml for a ratio of 1.59. Until November 2006, IDNR used this ratio to convert NPDES permits for wastewater treatment plants from *E. coli* to fecal coliform. BIT model fecal coliform output has been converted to *E. coli* using this ratio.

EPA Bacteria Indicator Tool
EPA's Bacteria Indicator Tool (USEPA, 2001) estimates watershed bacteria accumulation available for washoff as well as continuous loads such as those from cattle in the stream and faulty septic tank systems. It is a spreadsheet that organizes and estimates the bacteria contribution from sources based on land use, livestock and wildlife populations, septic tanks, and built up area contributions.

The BIT was used to estimate monthly flows and loads of cattle in the stream and faulty septic tank systems for input into the SWAT model for each of the 19 subbasins. These inputs were configured as point source files. There are two subbasins with built-up area landuses and loads from these were estimated in the BIT and applied as loads available for washoff in the SWAT model.

The BIT used the following assumptions for estimates of livestock bacteria contributions:

- Access to pastureland for grazing cattle varies during the year. According to researchers at Iowa State University (Jim Russell, Dept. of Animal Science, Iowa State University. December 2005. Personal communication) cattle are:
- 80 percent confined from January through March.
- During the spring and summer months (April through October) they spend 100% of their time grazing.

SWAT model bacteria inputs
A field survey and watershed assessment in 2008 resulted in the livestock numbers and land uses that have been used in the development of this report. All cattle and horses have been assumed to be grazing and loads available for washoff have been distributed to the subbasin where they were located in the assessment. Deer have been distributed to the subbasins based on area and consolidated to the nearest subbasin with cattle for simplicity. The animal distribution is shown in Table D-9.

Table D-9 Animals in the watershed distributed by subbasin

Subbasin	Animal type	Number of animals
1	Beef cattle	40
1	Horses	3
1	Deer	66
3	Beef cattle	10
3	Deer	17
4	Beef cattle	70
4	Deer	24
5	Beef cattle	250
5	Horses	4
5	Deer	47
7	Beef cattle	50
7	Deer	16
8	Horses	24
8	Deer	56
11	Horses	8
11	Deer	71
15	Beef cattle	15
15	Deer	104
16	Beef cattle	95
16	Deer	28
19	Deer	129

There are also a large number of hogs in confinement in the watershed. The manure from these confinements is applied to cropland. It is assumed that the manure is applied to the fields shown in the manure management plans in the fall and some in the spring. The manure is input into the SWAT model as fertilizer on October 1 or April 15 in the nearest MMP field. Table D-10 shows the subbasins where the hog operations are located and the number of hogs in that subbasin.

Table D-10 Hogs in the watershed distributed by subbasin

Subbasin	Number of hogs
1	1,500
11	2,690
14	3,600
16	3,072

Livestock and Wildlife

Livestock includes beef cattle and horses. Manure deposition rates, in kilograms per hectare per day (kg/ha/day), were entered for subbasins where livestock were located using a single HRU that most closely matched the number of acres (two acres per cow) that is assumed. The manure applied per acre varied with the cattle and horse numbers in the subbasin using the HRU management practice for grazing. Deposition was simulated from April 15 through November 15 of each year.

Wildlife includes deer and geese. The number of deer per acre was increased ten percent to account for other wildlife such as raccoons. Like cattle and horses, deer manure is applied in a single HRU in the subbasin where the deer are located or in an adjacent subbasin. It is assumed that the deer density is higher in Subbasin 19, which is forested and adjacent to the lake. All geese loads are input into Subbasin 19 since the geese spend most of their time on the near shore lawns and beaches or in the water. Because beach sample collection is in the immediate area of the goose feces, the general watershed bacteria loss factor (0.025 available for washoff) on land has been increased so that 0.90 of the goose bacteria load is available for washoff. The general loss factor accounts for the bacteria reduction from the maximum potential count obtained by multiplying the number of bacteria per animal per day times the number of animals to the bacteria count that actually washes off.

The deer and goose manure is applied using the HRU management practice for grazing with deposition simulated from March 15 to November 15 for deer and May 1 to November 15 for geese. Table D-11 lists livestock and wildlife manure characteristics.

Table D-11 Livestock and wildlife manure characterization[1]

Animal Type	Dry Manure Production (kg/animal/day)	Manure *E. coli* (orgs/gram)
Beef cattle	2.44	2.68E+07
Horse	5.09	5.20E+04
Swine	0.52	1.32E+07
Deer	0.91	3.47E+05
Geese	0.033	4.09E+07

1. References for values in this table can be found in the documentation spreadsheets *BCgrazing_by sub.xls* and *Big Creek BIT2.xls*.

Estimating bacteria decay and loss
There are many factors that increase bacteria decay and removal and extend time of travel in the watershed. Bacteria delivery is affected by the fraction of organisms that are actually washed off. Bacteria decay and loss is affected by natural die off, settling, and predation in streams, detention basins and wetlands. Circuitous routing of flow through meandering streams, basins, ponds, and wetlands extends time of travel. Actual decay and loss and travel time are difficult to estimate because of the washoff and transport unknowns.

For this report, bacteria decay and loss are represented by the two SWAT parameters described below. One adjusts what load is washed off the land and the other reduces stream concentration over time and distance.

- General loss of available bacteria on land prior to wash off during precipitation events is controlled in the SWAT model by adjusting the parameter fraction of manure applied to land areas that has active *E. coli* colony forming units (BACT_SWF). This is in the General Watershed Parameters window and is set at

0.025 for the watershed except for the geese loads on the beach as previously discussed.
- Die off and decay in the stream during transport is controlled in the SWAT model by adjusting the die-off factor for moving water in streams (WDPRCH). This factor represents all bacteria loss between the subbasin sources and the sampling location in the lake including losses to sedimentation, sunlight, predation, natural die-off, temperature, time of travel, etc. The value used is entered in the General Watershed Parameter window and is 4.0.

Bacteria decay and loss from the source to the monitored location is estimated by adjusting the delivered load to approximate the midpoint existing loads derived from load duration curve calculations. For each flow interval, there is a ratio of the estimated potential loads at the sources and the existing loads in the lake. Decay and time of travel are used within the SWAT model calculations to adjust the potential loads from the watershed to the existing measured loads for the flow intervals in which the impairments occur.

Flow recurrence interval analysis
Two of the five flow intervals have been evaluated; high flow (zero to 10 percent) and dry conditions flow (60 to 90 percent). The median SSM loads at the moist flow (10 to 40 percent), mid-range (40 to 60 percent), and low (90 to 100 percent) flow recurrence intervals do not exceed the SSM criteria. Continuous flows and loads are separated from runoff flows and loads during low flow and so this condition has also been evaluated.

Figure D-3 shows the flow and loading output from the SWAT model and the existing load estimates from load duration curve analysis. The existing loads (90th percentile, 2.48 E+12 *E. coli* orgs/day) and the target load (1.40E+12 orgs/day) for the high flow condition are the red and green horizontal lines, respectively. The low flow existing load is the blue line (5.19 E+8 *E. coli* orgs/day). The required reduction at the impaired high flow condition is the difference between the red and green loads, 2.48 E+12 – 1.40 E+12 = 1.10 E+12 orgs/day. This is a 44 percent decrease. The required reduction at the impaired dry flow condition (60 to 90 percent) is the difference between the red and green loads, 5.69 E+10 – 5.20 E+10 = 4.67 E+09 orgs/day. This is an 8 percent decrease.

The existing loads at the other three flow recurrence intervals are less than the target loads for the intervals and so do not represent impaired conditions. The low flow load line approximates cattle in the stream and faulty septic tank system loads, i.e., the continuous flow loads. The simulated flow into the lake is also shown in this chart and shows how the loads causing exceedances correspond to high flows. This suggests that the continuous bacteria sources, cattle in the stream and septic tank systems, are not major sources of the bacteria impairment.

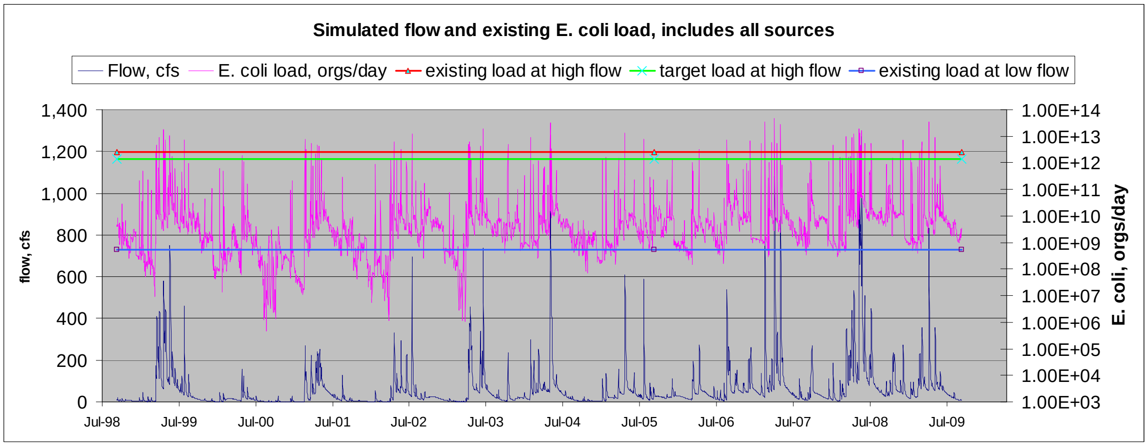

Figure D-3 SWAT output flow and *E. coli* load plotted with existing and target loads

Analysis and Model Documentation

The data analysis and modeling for the Big Creek Lake TMDL are contained in the spreadsheet and model input files listed below in Tables D-12 to D-15. These folders, spreadsheets, and model input files are located in the folder S*upport Documentation*. The spreadsheets contain the data and information used to develop this water quality improvement plan, the SWAT model development, input and output files, and the BIT bacteria sourcing. The model files, not listed here, can be used to run the Big Creek Lake SWAT model provided that ArcMap 9.3 with ArcSWAT Version 2.3.4 is available.

Table D-12 Data and analysis spreadsheets

Folder and file name	Description of contents
Data and analysis (folder)	**Spreadsheet files with data, data analysis and modeling for bacteria**
Big_Creek_Data.xls	Original *E. coli* data
BCLecoli and precip2.xls	*E. coli* concentrations and Ames West weather data
BCL geese numbers.xls	Watershed and lake geese information
BC_livestock.xls	Watershed livestock numbers
bclames.txt	Temperature and precipitation data from the Ames West weather station.
BC Spillway rating table4.xls	Estimates of discharge from Big Creek spillway
ReferenceStreams_BigCreekLake_SyntheticFlow.xls	EPA estimated synthetic flow for the Big Creek Lake watershed generated from analysis of four neighboring streams with USGS gages

Table D-13 SWAT watershed model folders and files

Folder and file name	Description of contents
SWAT model (folder)	SWAT model files used for duration curve development.
Input development (subfolder)	Spreadsheet files used in the development and parameterization of the SWAT model.
deer_nosr.xls	Deer numbers by subbasin
tile_drains.xls	Tile drain information
septicsbybasin.xls	Septic tank system locations listed by subbasin
precal30monflowin.xls	SWAT simulated average monthly flow.
calb_bactin.xls	SWAT simulated average daily bacteria concentration.
BC5_SWAT_EPA_flow.xls	SWAT calibration runs and regression statistics.
precal30.xls	Calibrates SWAT simulated daily and monthly average flow with synthetic daily and monthly average flow.
Input (subfolder)	The SWAT model soils and weather files are here
ssurgo_gridlu_01.txt	The SWAT SSURGO soils lookup file.
BCgrazing_by sub.xls	Cattle and deer grazing loads by subbasin
swat precip and temp.xls	Temperature and precipitation data in SWAT format from the Ames West weather station.
BCpoint sources (subfolder)	Subfolder containing monthly point source continuous loads – cattle in the stream and septic tanks by subbasin
B1ptsource.dbf *through* B19ptsource.dbf	19 files with monthly point source loads, one for each subbasin
septicsbybasin.xls	Septic tank system locations listed by subbasin
Output (subfolder)	The SWAT model output files are here
all_4_scenarios.xls	SWAT flow and *E. coli* values from 10/1/1998 to 9/30/2009 and associated charts.
33out.xls	SWAT flow and bacteria concentration output for the all loads scenario.
34out.xls	SWAT flow and bacteria concentration output for the no goose load scenario.
35out.xls	SWAT flow and bacteria concentration output for the no goose load and no cattle in stream or septics loads scenario.
37out.xls	SWAT flow and bacteria concentration output for the no goose load and a cattle and deer load reduction by half scenario.

Table D-14 Duration curve and BIT folders and files

Folder and file name	Description of contents
BIT and duration curves(folder)	**Spreadsheet files with BIT model and flow and load duration curves**
Big Creek BIT2.xls	Bacteria Indicator Tool used to evaluate watershed sources of bacteria.
LDC2.xls	Flow and load duration curves using SWAT hydrology and observed *E. coli* data
Runoff3.xls	Duration curve runoff estimate.

Table D-15 TMDL, LA, and MOS calculation folders and files

Folder and file name	Description of contents
TMDL calcs (folder)	**Spreadsheet files with BIT model and flow and load duration curves**
Big Creek TMDL and charts_2.xls	Spreadsheet calculations and charts showing TMDL, LA, and existing loads in charts.
Big creek load calcs_2.xls	Calculation of 90th percentile existing loads and target loads for each recurrence interval

Appendix E --- Land Cover Map

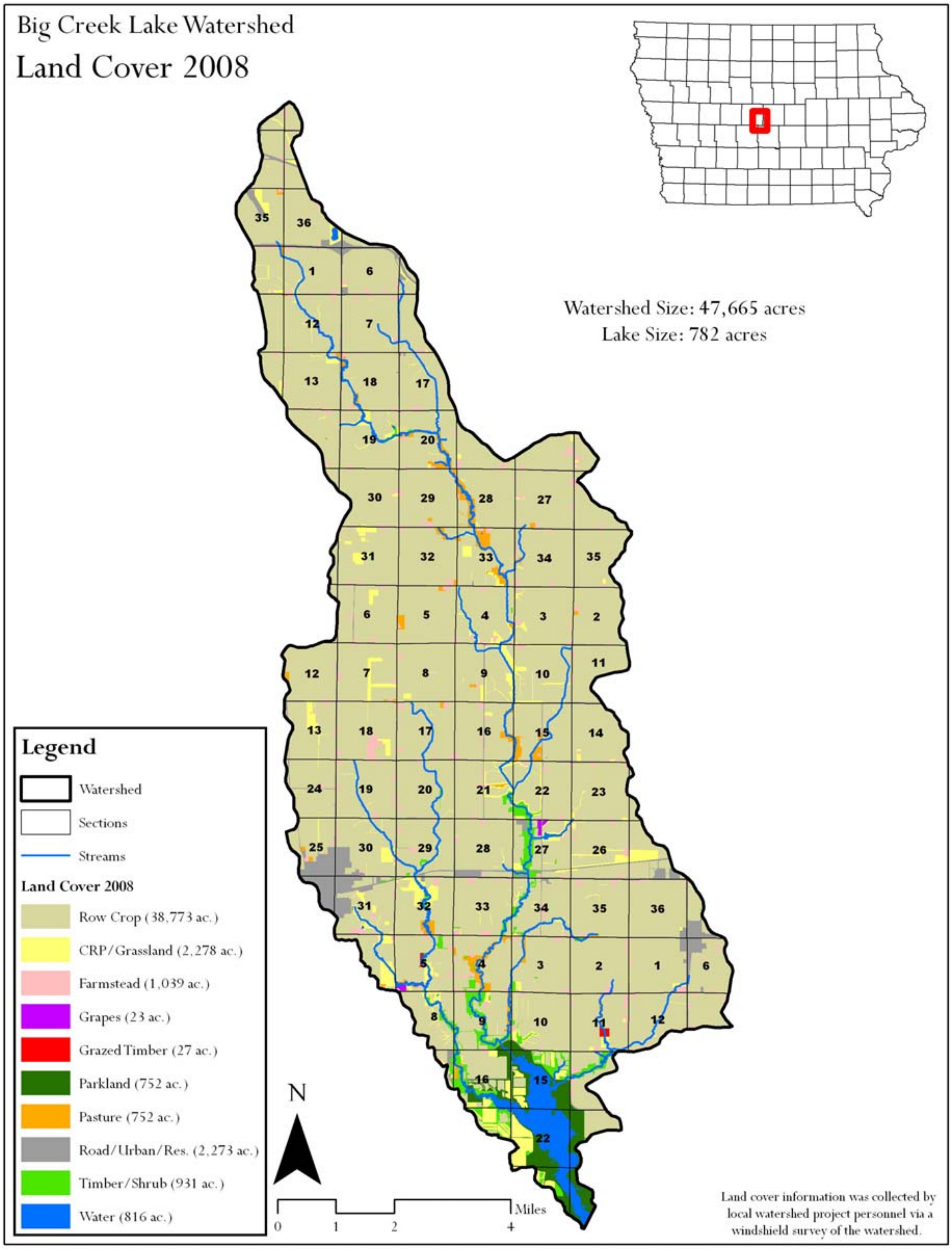

Figure E-1 Big Creek Lake land use map based on 2008 assessment

Appendix F --- Water Quality Assessments – 2008 305(b) Report

The 2008 305(b) water quality assessments for Big Creek Lake are found below. They describe the rationales behind the finding that the primary contact recreation use is not fully supported.

Big Creek Lake
2008 Water Quality Assessment: Assessment results from 2004 through 2006

Segment Summary
Waterbody ID Code: IA 04-UDM-0140-L_0
Location: Polk County, S22,T81N,R25W, near Polk City
Waterbody Type: Lake
Segment Size: 883 Acres
This is a Significant Publically Owned Lake

Segment Classes:
Class A1
Class B(WW-1)
Class HH

Assessment Comments
Assessment is based on: (1) results of the IDNR-UHL beach monitoring program in the summers of 2004, 2005, and 2006, (2) results of the statewide survey of Iowa lakes conducted from 2002 through 2006 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted from 2005 through 2006 by University Hygienic Laboratory (UHL), (4) information from the IDNR Fisheries Bureau, and (5) results of EPA/DNR fish contaminant (RAFT) monitoring in 2004.

Assessment Summary and Beneficial Use Support
Overall Use Support - Not supporting
Aquatic Life Support – Fully
Fish Consumption – Fully
Primary Contact Recreation - Not supporting

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

Basis for Assessment and Comments
SUMMARY: The Class A1 (primary contact recreation) uses are assessed (monitored) as “not supported” due to violations of the state water quality criteria for indicator bacteria. The Class B (WW-1) (aquatic life) uses are assessed (monitored) as “fully supported.” Fish consumption uses remain assessed (monitored) as “fully supported.” Sources of data for this assessment include (1) results of the IDNR-UHL beach

monitoring program in the summers of 2004, 2005, and 2006, (2) results of the statewide survey of Iowa lakes conducted from 2002 through 2006 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted from 2005 through 2006 by University Hygienic Laboratory (UHL), (4) information from the IDNR Fisheries Bureau, and (5) results of EPA/DNR fish contaminant (RAFT) monitoring in 2004.

EXPLANATION: Results of IDNR beach monitoring from 2004 through 2006 suggest that the Class A1 uses are "not supported." Levels of indicator bacteria at Big Creek Lake beach were monitored once per week during the primary contact recreation seasons (May through September) of 2004 (22 samples), 2005 (23 samples), and 2006 (28 samples) as part of the IDNR beach monitoring program. 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) all thirty-day geometric means for 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 5-sample, 30-day 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).

At Big Creek Lake beach, the geometric means of 6 thirty-day periods during the summer recreation season of 2004 exceeded the Iowa water quality standard of 126 *E. coli* orgs/100 ml. No geometric means violated this standard in 2005 or 2006. Also, the percentage of samples exceeding Iowa's single-sample maximum criterion (235 *E. coli* orgs/100 ml) was significantly greater than 10% in 2004 (23%). Less than 10% of the samples exceeded the single-sample maximum standard during the recreational seasons of 2005 (0%) and 2006 (4%). According to IDNR's assessment methodology and U.S. EPA guidelines, these results suggest impairment (nonsupport) of the Class A1 (primary contact recreation) uses of Big Creek Lake.

Results from the ISU and UHL lake surveys suggest full support of the Class A1 uses of Big Creek Lake. Using the median values from these surveys from 2002 through 2006 (approximately 23 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 48, 51, and 57 respectively for Big Creek Lake. According to Carlson (1977) the Secchi depth value places Big Creek Lake at the upper end of the mesotrophic category, while the value for chlorophyll a is at the low end of the eutrophic category. The index value for total phosphorus places Big Creek Lake at the upper end of the eutrophic category. These values suggest low levels of chlorophyll a and suspended algae in the water, exceptional water transparency, and relatively low levels of phosphorus in the water column.

The level of inorganic suspended solids was low at this lake and does not suggest water quality problems due to non-algal turbidity. The median level of inorganic suspended solids in Big Creek Lake (2.0 mg/L) was the 17th lowest median concentration among the 132 lakes sampled by the ISU and UHL lake surveys.

Data from the 2002-2006 ISU and UHL surveys suggest a small population of cyanobacteria exists at Big Creek Lake, which does not suggest impairment at this lake. These data show that cyanobacteria comprised 74% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (9.8 mg/L) was also the 31st lowest of the 132 lakes sampled.

The Class B(WW-1) (aquatic life) uses are assessed (monitored) as "fully supported" based on information from the IDNR Fisheries Bureau, results from the ISU and UHL lake surveys, and physical and chemical results associated with IDNR's beach monitoring program. The ISU and UHL lake survey results show good chemical water quality at Big Creek Lake. During 2002-2006 there were no violations of the Class B (WW-1) criterion for ammonia (16 samples), or dissolved oxygen (23 samples), and only one violation in 20 samples of the pH criterion. Based on IDNR's assessment methodology, the one violation of the pH criterion does not constitute an impairment at Big Creek Lake. The physical/chemical data associated with the beach monitoring data from 2004 through 2006 show no violations of the Class B(WW-1) criteria for dissolved oxygen (70 samples) or pH (71 samples).

Fish consumption uses were assessed (monitored) as "fully supported" based on results of U.S. EPA/IDNR fish contaminant (RAFT) monitoring at Big Creek Lake in 2004. The composite samples of fillets from channel catfish and largemouth bass had low levels of contaminants. Levels of primary contaminants in the composite sample of channel catfish fillets were as follows: mercury: <0.0181 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: 0.043 ppm; total PCBs: 0.09 ppm; and technical chlordane: <0.03 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 2004 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

6/3/2002	Fixed Monitoring Start Date
8/17/2004	Fish Tissue Monitoring
9/20/2006	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)
- Fish tissue analysis
- Water column surveys (e.g. fecal coliform)

Causes and Sources of Impairment

Causes	Use Support	Cause Magnitude	Sources	Source Magnitude
Pathogens	Primary Contact Recreation	Moderate	Source Unknown	Moderate

Appendix G --- Public Comments

There were no public comments received during the comment period.