Total Maximum Daily Load
For Pathogens
Beeds Lake
Franklin County, Iowa

2006

Iowa Department of Natural Resources
Watershed Improvement Section

Table of Contents

1. Executive Summary

Table 1. Beeds Lake summary.

Waterbody Name:	Beeds Lake
County:	Franklin
Use Designation Class:	A1 (primary contact recreation) B(WW) (aquatic life)
Major River Basin:	Cedar River Basin
Pollutant:	Pathogens (*E. coli*)
Pollutant Sources:	Nonpoint, wildlife (background)
Impaired Use(s):	A1 (primary contact recreation)
2002 303d Priority:	High
Watershed Area:	20,480 acres
Lake Area:	100 acres
Lake Volume:	860 acre-ft
Detention Time:	22 days
Target(s):	Daily maximum: 235 CFU/100ml Geometric mean: 126 CFU/100ml
Target Total *E. coli* Load:	235 CFU/100ml
Existing Total *E. coli* Load:	Up to 7700 CFU/100ml
Load Reduction to Achieve Target:	80%
Margin of Safety	24 CFU/100ml
Wasteload Allocation	0% reduction
Load Allocation	80% reduction

The Federal Clean Water Act requires the Iowa Department of Natural Resources (IDNR) to develop a total maximum daily load (TMDL) for waters that have been identified on the state's 303(d) list as impaired by a pollutant. Beeds Lake has been identified as impaired by pathogens. The purpose of the TMDL for Beeds Lake is to calculate the maximum allowable pathogen load for the lake associated with *Escherichia coli (E. coli)* levels that will meet water quality standards.

This document consists of a single TMDL for pathogens designed to provide Beeds Lake water quality that fully supports its designated uses. *E. coli* delivered from the watershed is targeted to address the pathogen impairment.

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature and sources of water quality impairments are not well understood. In Phase 1, the waterbody load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on the limited information available. A monitoring plan will be used to determine if prescribed load reductions result in attainment of water quality standards and whether or not the target values are sufficient to meet designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling.

Section 5.0 of this TMDL includes a description of planned monitoring. The TMDL will have two phases. Phase 1 will consist of setting specific and quantifiable targets for *E. coli*. Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.

Monitoring is essential to all TMDLs in order to:

- Assess the future beneficial use status;
- Determine if the water quality is improving, degrading or remaining status quo;
- Evaluate the effectiveness of implemented best management practices.

The additional data collected will be used to determine if the implemented TMDL and watershed management plan have been or are effective in addressing the identified water quality impairment. The data and information can also be used to determine if the TMDL has accurately identified the required components (i.e. loading/assimilative capacity, load allocations, in-lake response to pollutant loads, etc.) and if revisions are appropriate.

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

1. **Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:** Beeds Lake, S20, T92N, R20W, 2 miles northwest of Hampton, Franklin County.

2. **Identification of the pollutant and applicable water quality standards:** The pollutant causing the water quality impairments is pathogens associated with excessive loading of fecal material. Designated uses for Beeds Lake are Primary Contact Recreation (Class A1) and Aquatic Life (Class B(WW)). Excess pathogen loading has impaired the primary contact recreation use for *E. coli* as described in the Iowa Administrative Code (1) and hindered the designated uses.

3. **Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:** The target of this TMDL is an *E. coli* level which does not exceed a geometric mean of 126 organisms per 100 ml of water or a sample maximum of 235 organisms per 100 ml of water. This criteria applies during the recreational season from March 15 to November 15 of each year.

4. **Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:** The existing *E. coli* concentration reaching Beeds Lake is up to 7,700 colony forming units (CFU) per 100ml. The maximum daily *E. coli* concentration allowed by state standards is 235 CFU/ 100ml. To achieve and maintain lake water quality goals and protect for beneficial uses, the concentration must be reduced by 80%.

5. **Identification of pollution source categories:** Nonpoint sources of *E. coli* have been identified as the cause of impairments to Beeds Lake.

6. **Wasteload allocations for pollutants from point sources:** Two point sources have been identified for this TMDL: the City of Latimer-Coulter wastewater treatment facility and the CAL Community Schools. The CAL Community Schools discharge is an unpermitted discharge into Spring Creek. The school is in the process of connecting to the Latimer-Coulter sanitary sewer system. It will receive a wasteload allocation of 0.

   Although the Latimer-Coulter wastewater treatment plant is a permitted point source that discharges within the Beeds Lake watershed, bacterial modeling has determined that the contribution of the facility to violating loads is insignificant. Therefore, there is no numerical wasteload allocation in this TMDL.

7. **Load allocations for pollutants from nonpoint sources:** The total pathogen load allocation for the nonpoint sources is 211 CFU/100 ml.

8. **A margin of safety:** The explicit margin of safety for this TMDL is set at 10% (24 CFU/100ml).

9. **Consideration of seasonal variation:** This TMDL was developed based on the pathogen loading that will result in attainment of water quality targets for the recreational season (March 15 through November 15).

10. **Allowance for reasonably foreseeable increases in pollutant loads:** An allowance for increased pathogen loading was not included in this TMDL. Significant changes in the Beeds Lake watershed landuse are unlikely. However, future changes in wildlife populations, particularly deer and geese, could change natural background and wildlife levels of *E. coli*. Because such events cannot be predicted or quantified at this time, a future allowance for their potential occurrence was not included in the TMDL.

11. **Implementation plan:** Although not required by the current regulations, an implementation plan is outlined in the body of the report.

2. Beeds Lake, Description and History

2.1 The Lake

Beeds Lake was formed in 1857 when a dam was constructed on Spring Creek. The original dam was used to power a sawmill and flourmill. In 1864, the flourmill was bought by William Beed who continued the operation until 1903. Beeds Lake State Park opened in 1934 and the Civilian Conservation Corps built the current dam in 1937.

The lake is located within the 320-acre Beeds Lake State Park in north central Iowa, 2 miles northwest of the City of Hampton in Franklin County. Public use for the park and lake is estimated at approximately 230,000 visitor days per year (2). Users of the lake and of Beeds Lake State Park enjoy fishing, swimming, picnicking, hiking, bicycling, bird watching, canoeing, boating, and ice-skating. Fishing jetties and a boat ramp in the eastern portion of the lake make Beeds Lake a popular fishing area. The beach at Beeds Lake is located on the southern shore.

Table 2. Beeds Lake features.

Waterbody Name:	Beeds Lake
Hydrologic Unit Code:	HUC10 0708020404
IDNR Waterbody ID:	IA 02-WFC-0090-L
Location:	Section 20 T92N R20W
Latitude:	42° 46’ N
Longitude:	93° 15’ W
Water Quality Standards Designated Uses:	1. Primary Contact Recreation (A1) 2. Aquatic Life Support (B(WW))
Tributaries:	Spring Creek, unnamed tributary
Receiving Waterbody:	Spring Creek
Lake Surface Area:	100 acres
Maximum Depth:	24 feet
Mean Depth:	9 feet
Volume:	860 acre-feet
Length of Shoreline:	15,300 feet
Watershed Area:	20,480 acres
Watershed/Lake Area Ratio:	205:1
Estimated Detention Time:	22 days

Morphometry

Beeds Lake has a mean depth of 9 feet, a surface area of 100 acres, and a storage volume of approximately 860 acre-feet. A causeway divides the lake into a shallower western section with a maximum depth of about 8 feet and a deeper eastern section with a maximum depth of 24 feet (Figure D-2). Water flows from the western section to the eastern section through a small opening in the north end of the causeway and a larger opening in the south end of the causeway. The beach is located just west of the southern opening in the causeway.

Temperature and dissolved oxygen sampling in the eastern half of the lake indicates that Beeds Lake stratifies throughout the growing season with temperature and oxygen levels declining sharply below the thermocline. The lake has a shoreline development ratio of 2.1.

Hydrology

Beeds Lake is fed by Spring Creek as well as a few other small tributaries. Spring Creek empties into the western end of Beeds Lake and an unnamed tributary enters from the north just west of the causeway. A dam at the east end of Beeds Lake discharges into Spring Creek.

The topography of the watershed draining into Beeds Lake ranges from moderately steep to nearly level. The western part of the watershed is tile drained, and enters into Spring Creek through 36" and 42" tile outlets.

There are no stream gauges upstream of Beeds Lake on Spring Creek. The only USGS gauge on Spring Creek downstream of Beeds Lake has extremely limited data (7 measurements taken 30+ years ago) and was not useable for this report. Average rainfall in the area is 33.0 inches/year, with 75% of the rain falling between April and September.

The hydrologic properties of Beeds Lake were estimated based on drainage area, average annual precipitation, land slope, watershed land use, and data from small, gauged streams in Iowa. Average annual flow of Spring Creek as it enters Beeds Lake is estimated at 20 cubic feet per second or 14,500 acre-feet per year. Average residence time for water in Beeds Lake is approximately 22 days. The methodology and calculations used to determine the detention time are shown in Appendix A.

2.2 The Watershed

The Beeds Lake watershed has an area of approximately 20,480 acres. With a lake area of 100 acres, the watershed-to-lake ratio is 205:1. This is a very high ratio, allowing a small concentration of bacteria per acre in runoff to accumulate to a very large overall load. This ratio also makes the lake susceptible to overloading with sediment that can carry the pathogens and nutrients that can sustain them.

The watershed is predominately gently sloping (0-9%) prairie-derived soils. Three soil associations encompass the watershed. The Clarion-Nicollet-Webster soil association dominates the watershed with the Clarion-Storden-Lester and Nicollet-Canisteo-Webster associations covering the rest of the land.

Land Use

Landuse data was collected during a 2002 watershed survey by the IDNR in cooperation with the Franklin County Soil and Water Conservation District (Figure D-1). The watershed is dominated by row crop agriculture with 86% of the watershed in corn or soybeans. The incorporated area of the City of Latimer is 1,500 acres. The urbanized area of Latimer, including residences, businesses, and a golf course, covers approximately 170 acres of the watershed. Watershed landuse information is shown in Table 3.

Livestock in the watershed includes approximately 320,000 chickens and 19,000 hogs in CAFOs, and 900 cattle in pastures and feedlots. CAFOs are animal feeding operations in which animals are confined to areas that are totally roofed. CAFOs typically utilize earthen or concrete structures to contain and store manure prior to land application. Bacteria from CAFOs are delivered via runoff from land-applied manure or from leaking/failing storage structures. Open feedlots are unroofed or partially roofed animal feeding operations in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are held in the lot. Runoff from open feedlots can deliver substantial amounts of bacteria to a waterbody depending on factors such as proximity to a water body, number and type of livestock, and manure controls.

Table 3. 2002 Landuse in the Beeds Lake watershed.

Landuse	**Area in Acres**	**Percent of Total Area**
Row Crop	17,640	86.1
CRP / Grass / Hay	910	4.4
Farmsteads	450	2.2
Pasture	430	2.1
Roads	360	1.8
Urban	170	0.8
Timber	160	0.8
Public Areas	140	0.7
Other	220	1.1
Total	20,480	100

Soil conservation practices were in use in approximately 45% of the watershed in the early 1990s (2). A watershed project was funded through Clean Water Act Section 319 grant funds from 1994-98 and led to the addition of several grassed waterways, the installation of terraces that improved 350 acres, and the restoration of a wetland. In addition, Beeds Lake is scheduled for dredging and lake restoration in 2009 and 2010.

3. TMDL for Pathogens

3.1 Problem Identification

In 1998, Beeds Lake was included on the impaired water list as recommended by the DNR Fisheries and Water Quality Bureaus due to elevated levels of nutrients. The nutrient impairment was removed in 2002, but the lake remains on the impaired waters list due to levels of indicator bacteria (fecal coliform and *E. coli*) that exceed the water quality standard. Indicator bacteria are measured in organisms or colony-forming units (CFUs) per 100 ml of water.

Impaired Beneficial Uses and Applicable Water Quality Standards

The Surface Water Classification document (3) lists the designated use for Beeds Lake as Class A1 and Class B(WW). The *Iowa Water Quality Standards* (1) describe these use classifications as follows:

- Primary contact recreational use (Class "A1"). Waters in which recreational or other uses may result in prolonged and direct contact with the water, involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. Such activities would include, but not be limited to, swimming, diving, waterskiing, and water contact recreational canoeing.
- Significant resource warm water (Class "B(WW)"). Waters in which temperature, flow and other habitat characteristics are suitable for the maintenance of a wide variety of reproducing populations of warm water fish and associated aquatic communities, including sensitive species.

In 2002, the aquatic life use was listed as "fully supporting/threatened" for Beeds Lake while the primary contact use was assessed as "not supporting". This assessment was based upon IDNR beach monitoring data, the 2000-01 Iowa State University (4, 5) lake survey, an ISU report on lake phytoplankton (6), and information from the DNR Fisheries Bureau.

Beeds Lake was added to the impaired waters list for violating the State of Iowa water quality standard for bacteria, which was based upon fecal coliform criteria. The standard stated that levels shall not exceed a geometric mean of 200 fecal organisms per 100ml of water or a single sample maximum of 400 fecal organisms per 100 ml of water. In 2002, the fecal coliform standard in the Iowa Water Quality Standards was replaced by a water quality standard for *E. coli*. The new *E. coli* standard states that levels shall not exceed a geometric mean of 126 organisms per 100 ml of water or a single sample maximum of 235 organisms per 100 ml of water. Beeds Lake violated both the previous fecal coliform standard and the new *E. coli* standard. Because the goal of this TMDL is to meet current water quality standards, loads and allocations will be presented based on the *E. coli* standard.

Data Sources

Water Quality data for this TMDL has been compiled from three sources. Each dataset represents samples collected at different times or covering different parameters:

- Data for fecal coliform was collected on 9 occasions from May 1994 to July 1997 for the Beeds Lake Water Quality Project (7).
- Ongoing monitoring by the IDNR's Water Monitoring Section at Beeds Lake Beach provides data on *E. coli* and fecal coliform beginning in May 2000. These samples include beach and watershed monitoring.
- General water quality surveys have been conducted on Beeds Lake in 1979, 1990, 1994-97 and 2000-04 (2, 4, 5, 7, 8, 9, 10, 11).

Bacterial information and general water quality data from these surveys may be found in Appendix B.

Interpreting Beeds Lake Water Quality Data

Fecal coliform data from the 1990s indicates high in-stream values for Spring Creek (Table B-1). On five of the nine occasions samples were collected, the highest concentrations were found in the headwaters of the stream at the tile outlet. On several other occasions, there were notable increases in fecal coliform at the West and South Spring Creek sampling sites (Figure D-3). However, low fecal coliform concentrations (5-20 fecal coliform CFU/100ml) were reported at two locations in Beeds Lake.

Levels of *E. coli* for the 2002-04 samples collected throughout the watershed show a wide variability in the inputs along different reaches of stream. During a major storm event in June of 2004, a concentration of 2,000 CFU/100ml was monitored in the headwaters upstream of the wastewater treatment plant. *E. coli* levels jumped to 4,900 CFU/100ml at the South sampling site. Water entering the lake from Spring Creek and the north tributary had 4,100 CFU/100ml and 1,900 CFU/100ml, respectively. On other occasions with less rainfall and lower *E. coli* levels, concentrations seem to increase most dramatically at the West and East Spring Creek sites.

Weekly beach monitoring samples show widely varying concentrations of *E. coli* (Figure 1). Over a third of the samples collected from 2000 to 2004 were at or below the detection limit of 10 CFUs/100ml while 16% of the samples exceeded the daily maximum of 235 CFU/100ml. The average concentration is 255 CFU/100ml and the median value is 30 CFU/100ml.

The Soil and Water Assessment Tool (SWAT) model was used to estimate daily flow into Beeds Lake from Spring Creek and the north tributary (12; Appendix C). The flow estimates were used to create a water quality duration curve. The beach monitoring data were plotted on the curve (Figure 2) with notations of samples collected while the Latimer-Coulter wastewater lagoons were discharging. Table 4 shows the occurrence of *E. coli* levels that exceed the daily maximum broken out by flow condition and month.

Figure 1. *E. coli* as monitored at Beeds Lake beach. The dashed line represents the daily maximum limit for *E. coli*.

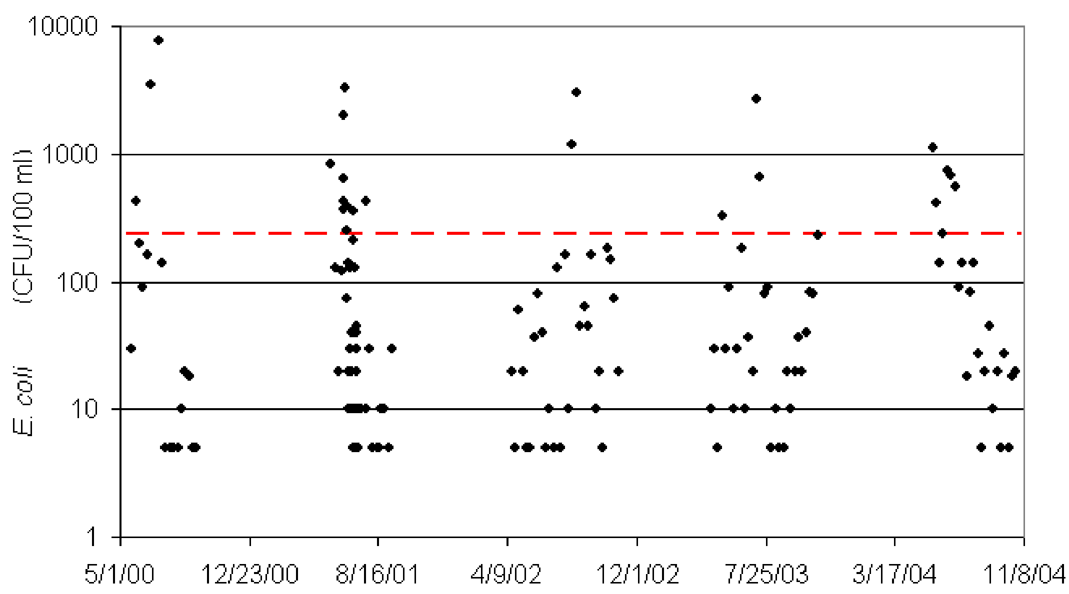


Figure 2. Water quality duration curve for Beeds Lake based on SWAT-generated flow data. The target in this figure is the single sample maximum water quality standard of 235 CFU *E. coli* /100ml. The recreational season samples were collected between April and October. Filled diamonds represent samples collected between June and August while crosses represent samples collected while the municipal wastewater lagoons were discharging to Spring Creek.

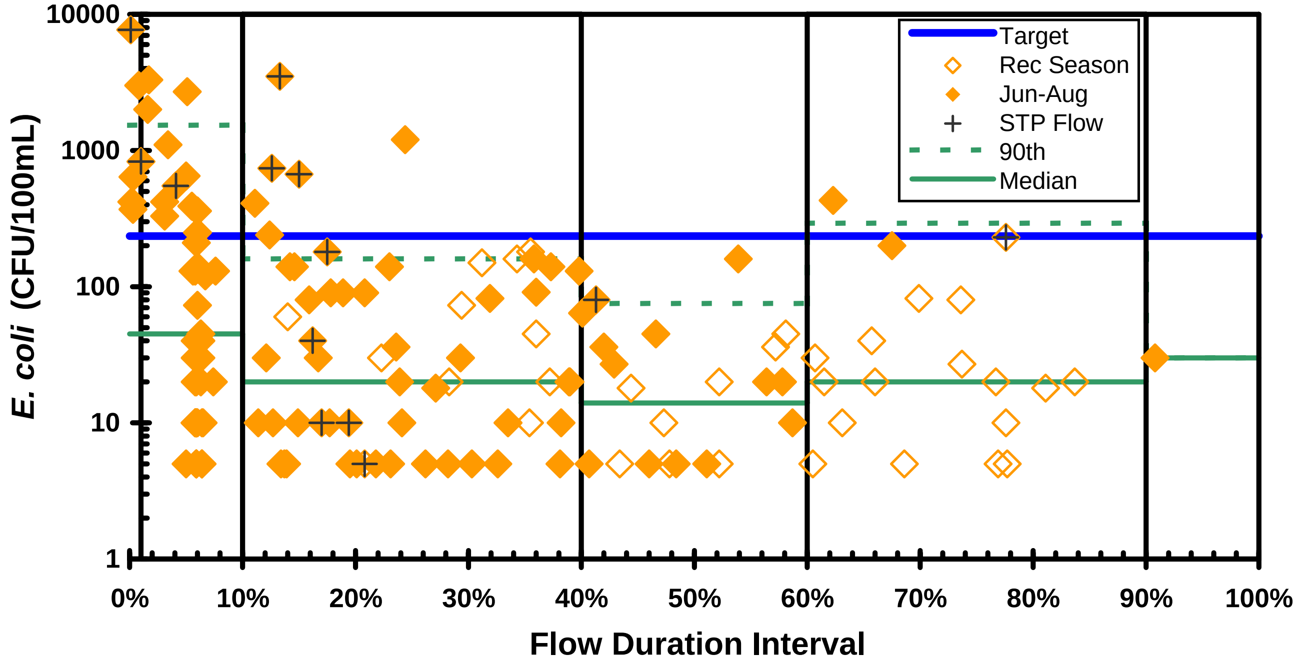


Table 4. Number of beach monitoring samples collected in 2000-04 that exceed the daily maximum *E. coli* standard of 235 CFU/100ml by month and flow condition.

Month	0-10% (high flow)	10-40% (moist)	40-60% (mid-range)	60-90% (dry)	90-100% (low flow)	Cumulative Frequency
April	0	0	0	0	0	0/6 = 0%
May	3	0	0	1	0	4/12 = 33%
June	7	5	0	0	0	12/40 = 30%
July	6	0	0	0	0	6/36 = 17%
August	1	1	0	0	0	2/22 = 9%
September	0	0	0	0	0	0/18 = 0%
October	0	0	0	0	0	0/13 = 0%

Of the 24 exceedances of the single-day maximum *E. coli* water quality standard at the Beeds Lake beach, seventeen occurred during high flow, six occurred under moist conditions and one during dry conditions. For the most part, elevated *E. coli* concentrations are associated with increased flow caused by rainfall (Table 4).

The in lake model simulated that an 80% reduction is needed to meet the single sample maximum of 235 organisms per 100 ml of water or the geometric mean of 126 organisms per 100 ml of water. Although levels of *E. coli* samples and model results show a wide variation (Figures 3, 4 and 5), the modeling results do not exceed the single sample max of 235 cfu/100 ml, and the geometric mean of 126 cfu/100 ml.

Use of the U.S. EPA's bacterial indicator tool (14) shows the Latimer-Coulter wastewater treatment facility is not a significant contributor of the bacteria found in Beeds Lake. The bacterial indicator tool shows that 93% of the bacteria source is from nonpoint sources within the watershed, including wildlife, chickens, hogs, cows and other nonpoint sources. The bacteria indicator tool estimates that cattle in the stream only contribute 3%, and CAL Community School contributes to 4% of E. coli in Beeds Lake.

Figure 3. Beach monitoring *E. coli* samples collected in 2002.

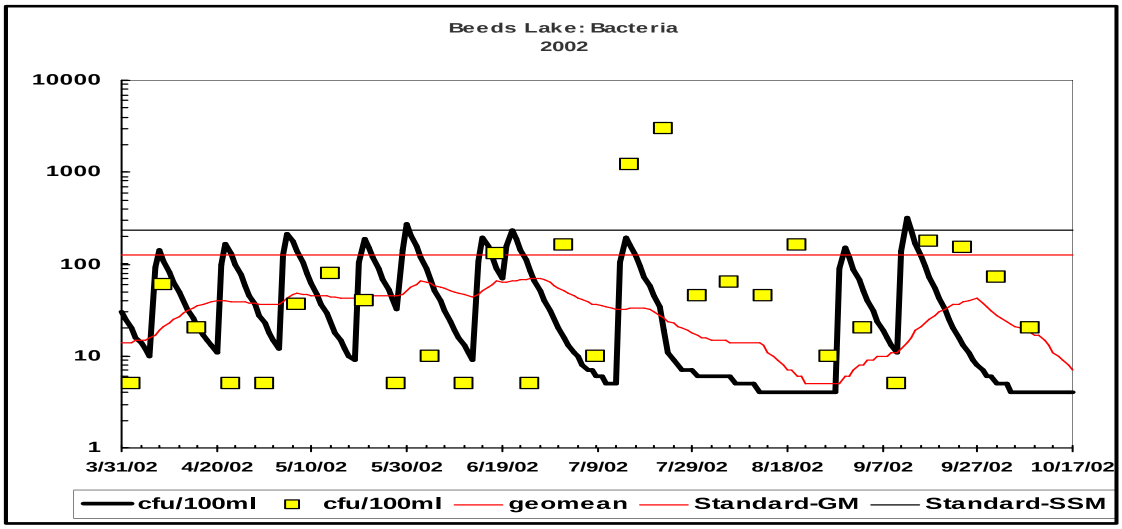


Figure 4. Beach monitoring *E. coli* samples collected in 2003.

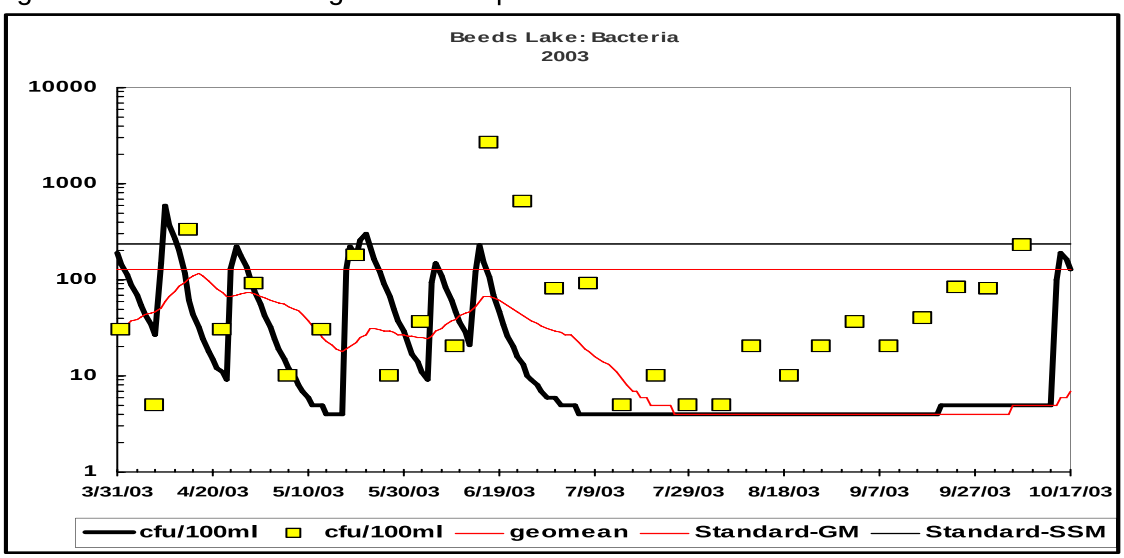
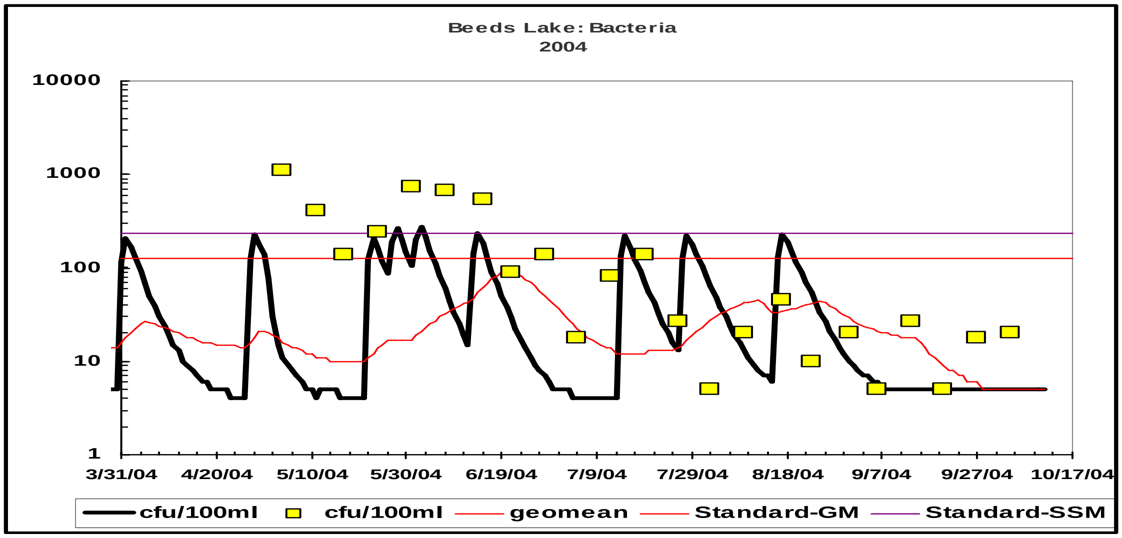


Figure 5. Beach monitoring *E. coli* samples collected in 2004.



Potential Pollution Sources

Point sources

There is one permitted point source in the Beeds Lake watershed; the Latimer-Coulter wastewater treatment facility located on Spring Creek 10 miles upstream of the lake. The facility is designed and operated as a facultative controlled discharge lagoon. Based on the Iowa Design Standards (13), the necessary hydraulic detention time for this controlled discharge lagoon is 180 days at the 180-day average wet weather (AWW) flow of 0.0789 MGD. The design population equivalent is 862; Latimer and Coulter currently have a combined population of approximately 800 residents.

An unpermitted point source was recently discovered in the Beeds Lake watershed. The CAL Community Schools wastewater is treated by a settling tank and three sand filters before being discharged into a county tile leading into Spring Creek. The school includes approximately 300 students and staff.

Nonpoint sources

There are several nonpoint sources of pathogens in the Beeds Lake watershed:

- The watershed of Beeds Lake is composed of 2.1% pasture. Most of these pastures are along Spring Creek with unrestricted access to the creek, which contributes to the pathogen load.
- Several farmsteads are relatively close to the stream, making septic system failures a potential pathogen source.
- Urban nonpoint sources, including pet wastes, contribute to the pathogen load.
- Land-applied manure from confined animal feeding operations (CAFOs) potentially adds to the bacteria load.
- Wildlife, particularly deer and waterfowl, add to the bacteria load, particularly in Beeds Lake State Park. The park is a 320-acre wildlife refuge known to have populations of geese and deer.

Natural Background Conditions

In the case of fecal bacteria, natural background levels are based on the wildlife population in the watershed. For this TMDL, background conditions will be based on estimates of the deer population in the watershed. Because of the load from the goose population in Beeds Lake State Park and the options available for controlling the population, geese are included as part of the nonpoint source allocation.

The Iowa DNR deer biologist estimates that deer density in Franklin County is approximately 5 deer per square mile. In Beeds Lake State Park, deer density may reach 30 deer per square mile. With a 32 square mile watershed and a 0.35 square mile park, approximately 170 deer reside within the Beeds Lake watershed. To account for additional wildlife sources of fecal bacteria, this estimate has been rounded to 200 deer. According to the US EPA (Table 5), *E. coli* concentrations from deer are approximately 3.1E+8 CFU/animal/day (the E+8 means add eight digits behind the decimal to see the full number – for example, 3.1E+8 is the same as 310,000,000 while 5.8E+6 is 5,800,000).

If we assume that only 15% of the deer are near the stream at any given time, the equivalent of 30 deer contribute to the background load. This would create a total bacterial load of 9.4E+9 *E. coli* CFU/day in the watershed.

Table 5. Fecal coliform and *E. coli* concentrations expected for wild animals and livestock (14). *E. coli* is calculated as fecal coliform * 0.625.

Animal	Fecal coliform (CFU/animal/d)	*E. coli* (CFU/animal/d)	Number of Animals	*E. coli* load (CFU/d)
Deer	5.0E+8	3.1E+8	30	9.4E+9
Goose	4.9E+10	3.1E+10	100	3.1E+12
Goose (migration)	4.9E+10	3.1E+10	3,000	3.3E+12
Chicken	1.4E+8	8.8E+7	316,000	2.8E+13
Hog	1.1E+10	6.9E+9	18,700	1.3E+14
Cow (pasture)	1.0E+11	6.3E+10	560	3.5E+13
Cow (confined)	1.0E+11	6.3E+10	310	1.9E+13

3.2 TMDL Target

Criteria for Assessing Water Quality Standards Attainment

Water quality standards in the State of Iowa (1) have dual criteria for bacteria.

<u>Geometric Mean</u>
E. coli levels shall not exceed a geometric mean of 126 CFU / 100 ml of water. The geometric mean is calculated as the average of five samples collected in a 30-day period.

<u>Daily Maximum</u>
E. coli levels shall not exceed a sample maximum of 235 CFU / 100 ml of water.

Selection of Environmental Conditions

The critical condition for this pathogen TMDL is limited seasonally. Recreational uses of Iowa lakes that involve bodily contact with the water occur primarily in the spring, summer and fall. For this reason, the *E. coli* standard for Class A primary contact recreational use only applies between March 15 and November 15.

Based on comparisons of the DNR Beach Monitoring data with rainfall information, *E. coli* levels in Beeds Lake that exceed water quality standards correlate with rainfall events. Therefore, this TMDL focuses on high-flow periods.

Waterbody Pollutant Loading Capacity

The load capacity for this TMDL is based on achieving an *E. coli* concentration in Beeds Lake that does not cause a water quality impairment. Because bacterial concentrations fluctuate dramatically from one week to the next and because high levels of *E. coli* are associated primarily with short-term high flow and storm events, the maximum daily concentration of 235 *E. coli* CFU/100ml is used to develop the percent load reduction needed to meet water quality standards.

3.3 Pollution Source Assessment

There are four *E. coli* sources for Beeds Lake in this TMDL. The first is the load from wildlife in the park and watershed. Deer and other wildlife are considered in the natural background conditions; geese are treated as a nonpoint source. The second source is septic discharges that are not required to have a permit. The third source is the *E. coli* load from livestock operations and manure applications within the watershed. The fourth source is the municipal wastewater treatment plant.

Existing Load

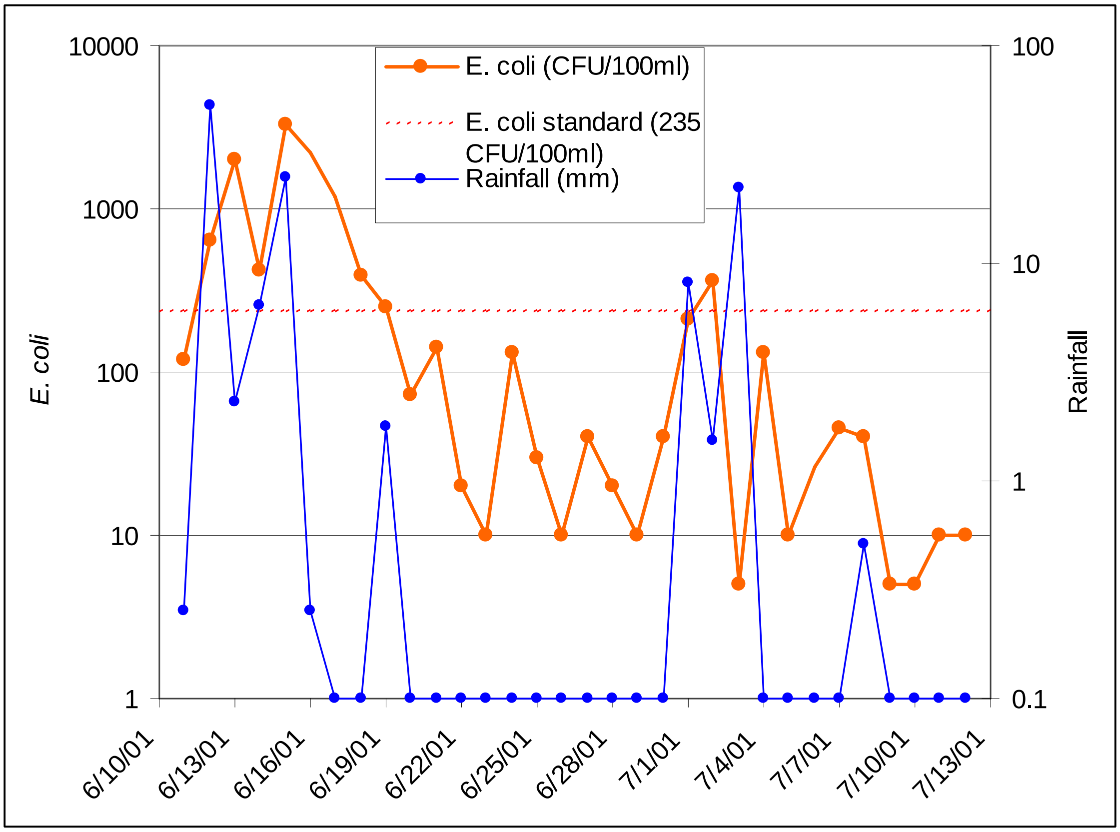
The current load to the stream is shown by the water quality duration curve (Figure 2). Table 6 shows the individual exceedances recorded in 2000-04 and the percent reduction required for these individual samples to meet water quality standards.

Table 6. Recorded exceedances of Iowa water quality standards for *E. coli* in 2000-04. The ‘actual load’ is calculated based on flow and concentration. The ‘load target’ is based on the daily maximum less the margin of safety (24 CFU/100ml) of 211 CFU/100ml at the flow for that day.

Date	Flow Percentile	Flow (cfs)	Rainfall (in / 3d)	E. coli (CFU / 100ml)	Actual load (CFU / d)	Load target (CFU / d)	% Reduction Needed
5/30/00	62.3%	12	0.3*	430	1.3E+11	6.2E+10	51%
6/26/00	13.3%	41	1.8	3500	3.5E+12	2.1E+11	94%
7/10/00	0.1%	732	3.7	7700	1.4E+14	3.8E+12	97%
5/21/01	1.0%	232	1.7	830	4.7E+12	1.2E+12	75%
6/12/01	0.3%	432	2.1	640	6.8E+12	2.2E+12	67%
6/12/01	0.3%	432	2.1	370	3.9E+12	2.2E+12	43%
6/13/01	1.6%	184	2.2	2000	9.0E+12	9.5E+11	89%
6/14/01	3.1%	103	2.4	420	1.1E+12	5.3E+11	50%
6/15/01	1.7%	168	1.3	3300	1.4E+13	8.7E+11	94%
6/18/01	5.5%	70	0.01**	390	6.7E+11	3.6E+11	46%
6/19/01	6.0%	67	0.1**	250	4.1E+11	3.5E+11	16%
7/2/01	6.0%	68	0.4	360	6.0E+11	3.5E+11	41%
7/25/01	0.2%	555	3.7	420	5.7E+12	2.9E+12	50%
8/6/02	24.4%	28	2.8	1200	8.2E+11	1.4E+11	82%
8/13/02	0.8%	262	3.0	3000	1.9E+13	1.4E+12	93%
5/6/03	3.1%	103	1.6	330	8.3E+11	5.3E+11	36%
7/8/03	5.1%	74	2.0	2700	4.9E+12	3.8E+11	92%
7/15/03	5.0%	75	1.0	650	1.2E+12	3.9E+11	68%
5/25/04	3.4%	97	1.9	1100	2.6E+12	5.0E+11	81%
6/1/04	11.1%	46	1.0	410	4.6E+11	2.4E+11	49%
6/14/04	12.4%	43	0.8	240	2.5E+11	2.2E+11	12%
6/21/04	12.6%	42	0.2***	740	7.6E+11	2.2E+11	71%
6/28/04	15.0%	38	0.0****	670	6.2E+11	2.0E+11	69%
7/6/04	4.1%	82	0.7	550	1.1E+12	4.2E+11	62%

* There was a 1.8-inch rainfall 3 days prior to this reading.
** There was a 1.0-inch rainfall 3 and 4 days prior to these readings (Figure 3).
*** There was a 0.6-inch rainfall 4 days prior to this reading.
**** There was a 0.3-inch rainfall 3 days prior to this reading.

Figure 6. *E. coli* at Beeds Lake beach and rainfall as measured in the City of Hampton. Note that *E. coli* concentrations still exceed the 235 CFU/100ml standard 4 days after the rain event on June 15.



Departure from Load Capacity

The target for *E. coli* in Beeds Lake is 211 CFU/100ml. From 2000-04, the maximum single sample concentration was 7,700 CFU/100ml. To achieve and maintain water quality standards and protect the designated uses, a total source load reduction of 80% is required.

Identification of Pollutant Sources

The vast majority of the *E. coli* delivered to the lake is from nonpoint sources. Delivery is controlled primarily by high flows associated with storm events (Figures 2 and 3).

<u>Geese</u>
Managers at Beeds Lake State Park estimate that 100 geese reside in the park throughout the recreational season. Geese are much more numerous in the spring and fall as they pass through on migratory routes with 2,000 to 4,000 geese passing through on each migration. According to Table 5, bacterial concentrations from geese are approximately 3.1E+10 *E. coli* CFU /animal/day.

Based on the assumption that the 100 resident geese spend the majority of their time in or near the lake, a large portion of the E. coli in their feces may end up in the lake. With some fecal material in the water and additional fecal material within only a few yards of the lake, even a small storm event could lead to a high *E. coli* concentration. This would give loads of 3.1E+12 CFU/day for the park throughout the recreational season.

Assuming that an average of 3,000 geese pass through the watershed during migration and spend one day at or near the lake at each migration, migratory geese may add up to 9.2E+13 *E. coli* CFU each spring and fall. If we spread this migration over the course of 28 days at each migration, these geese would contribute an additional 3.3E+12 CFU/day during the migration period.

<u>Septic systems</u>

The Franklin County Sanitarian estimates that 60% of the farmsteads in the county are unpermitted systems with improper septic hookups. These include leaky systems as well as those hooked directly to field tiles. Contributions from failing septic systems was estimated following procedures from the US EPA (15).

$$\text{Load} = 52 \ \frac{\text{unpermitted}}{\text{farmsteads}} * \frac{6.3\text{E+5 } \textit{E. coli} \text{ CFU}}{100 \text{ ml}} * \frac{70 \text{ gallons}}{\text{person day}} * \frac{2.4 \text{ people}}{\text{household}} * \frac{3785 \text{ ml}}{\text{gallon}}$$

$$= 2.1\text{E+11 } \textit{E. coli} \text{ CFU/d}$$

The load for farmsteads in the Beeds Lake watershed gives the total load from all septic systems. For the Beeds Lake watershed, septic system contributions are estimated at 3.3E+11 *E. coli* CFU/d.

<u>Livestock</u>

Estimates of total *E. coli* loads from livestock in the Beeds Lake watershed are found in Table 5. The contribution of each of these sources to the lake is calculated below.

Estimates of the contribution of cattle in pastures to the *E. coli* load in Beeds Lake is based on US EPA procedures (14) and the load estimate in Table 5. Assuming that all of the cattle in pastures have full stream access and that the cows spend approximately 15% of their time in or very near the stream, cattle directly deposit fecal material containing 5.3E+12 *E. coli* CFU/d into Spring Creek. The remaining 3.0E+13 *E. coli* CFU/d is deposited on the land surface.

The remaining livestock, including hogs, cows, and chickens, are in confinements that store the waste in pits or lagoons until it can be land-applied. The chicken waste amounts to 9.1 tons of manure per day while the hog and cattle waste is estimated as 27,000 gallons per day. It is difficult to estimate the proportion of waste applied by incorporation versus the amount sprayed onto fields. The amount of the waste that is spread inside the watershed and the amount of waste brought into the watershed is also unknown. For this TMDL, it is assumed that the waste created in the watershed is applied in the watershed and that no waste is brought in from outside the watershed.

The total *E. coli* produced by confined animals in the Beeds Lake watershed is 1.8E+14 CFU/d. Using the conservative assumption that all of the *E. coli* is condensed into the 27,000 gallons, the approximate concentration applied is 7.6E+4 *E. coli* CFU/100ml.

Approximately 80% of the manure is applied in the fall (October and November) following harvest. The remaining 20% is applied in the spring (April) before planting.

Because none of the recorded violations occurred in these periods, the contribution of this nonpoint source is expected to be very low.

Wastewater treatment

Because of the lack of maintenance of the CAL Community School wastewater treatment facility, there is high potential that the wastewater is receiving a very low level of treatment that might be compared to a failing septic system. Therefore, an estimate of E. coli contributed by the school was made following procedures adapted from the US EPA (15) guidance for failing septic systems.

$$\text{Load} = 300 \text{ people} * \frac{6.3\text{E}+5 \textit{ E. coli} \text{ CFU}}{100 \text{ ml}} * \frac{9 \text{ gallons}}{\text{person day}} * \frac{3785 \text{ ml}}{\text{gallon}}$$

$$= 6.4\text{E}+10 \textit{ E. coli} \text{ CFU/d}$$

Because there is some degree of treatment, this estimate is probably high. However, this calculation shows that the contribution of this unpermitted point source might be significant. This point source is scheduled to be eliminated by the end of 2005.

The only permitted point source in the Beeds Lake watershed is the Latimer-Coulter wastewater treatment plant (16).

Based on the AWW flow the required effective volume is (180)(0.0789)=14.2 million gallons and the provided effective volume is 15.5 million gallons. A controlled discharge lagoon is operated to discharge twice per year, in the spring and fall. These releases usually last for about three weeks during higher stream flows and it is assumed that the water quality impacts are minimal because of the short period of discharge and the dilution effects of higher stream flows.

The Latimer–Coulter lagoon system consists of three cells, a primary and two secondary cells. All raw wastewater enters the larger shallower primary cell. As this cell fills, its contents are released to one of the secondary cells. As this secondary cell fills, it is discharged to the other secondary cell. When effluent is discharged to the stream, it is first released from the secondary cell that has had the longest detention time. It is never released directly to the stream from the primary cell to prevent short-circuiting.

A review of the literature (17) shows that there is a 95 to 99% reduction of *E. coli* in three celled lagoons after 20 days detention time. Typical *E. coli* values for raw sewage are 1.0E+6 to 1.0E+8 CFU/100 ml. Using the higher value of 1.0E+8 and an *E. coli* removal of 95%, the estimated effluent concentration is 5.0E+6 CFU/100 ml. This is the value used in the bacteria model applied by the IDNR to calculate pathogen indicator die off in streams that feed recreational-use waterbodies. The model is part of the support document referenced in the Iowa Water Quality Standards and is therefore part of the Iowa Administrative Code.

Linkage of Sources to Target

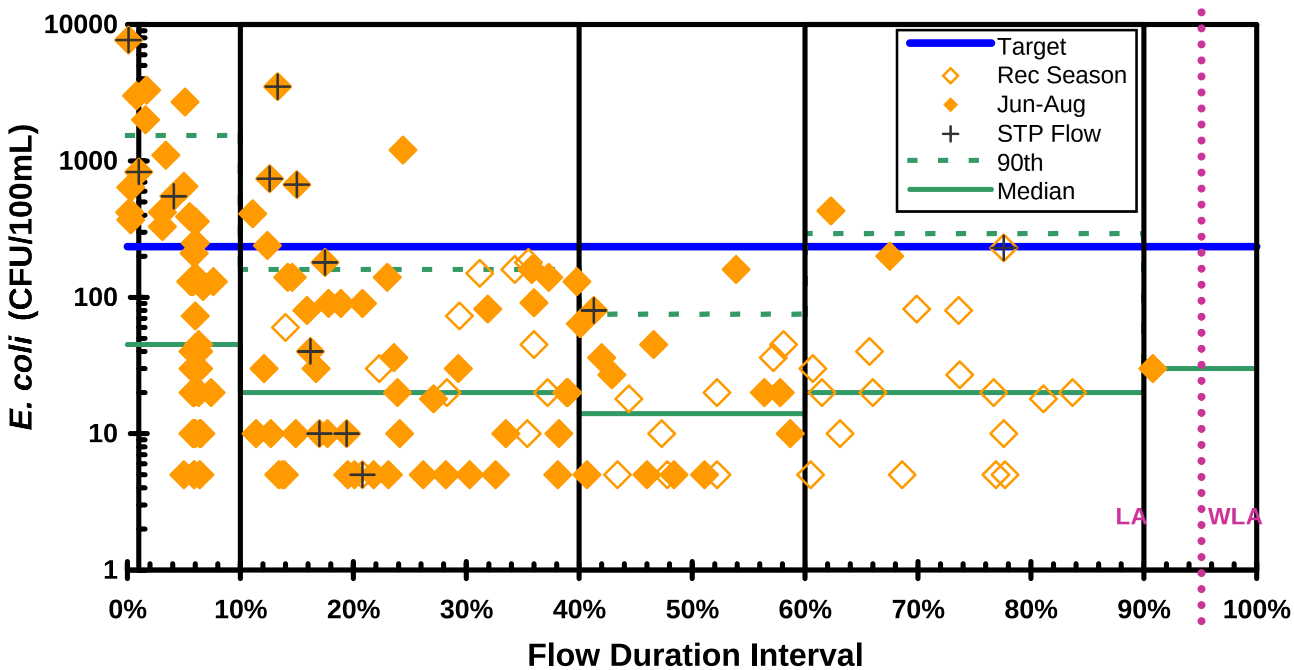
Due to the nature of point source versus nonpoint source contributions to *E. coli* loading, load duration curves are used to link *E. coli* loads to sources. Nonpoint contributions to the *E. coli* load are strongly correlated with high flow conditions and runoff from rainfall events. Point source contributions will dominate the loading when streamflow is low.

3.4 Pollutant Allocation

Wasteload Allocation

The Latimer-Coulter wastewater treatment plant is the only permitted point source in the Beeds Lake watershed. The CAL Community School unpermitted point source is in the process of being eliminated. This wasteload allocation assigns responsibility to the point source for maintaining water quality below the loading curve during flow conditions occurring in the 94-100% flow duration (Figure 7). This wasteload allocation is based on the fact that streams are particularly susceptible to the influence of point source discharges during low flow conditions. The low flow condition for this TMDL is defined as ten times the design flow of 0.0789 mgd or as the 7Q10 flow, whichever is greater. This equates to streamflows less than 1.2 cfs (ten times the facility design flow). Because these flows generally occur from December to March and because this is not the timeframe of concern for the recreational use, there have been no samples collected under the flow conditions of concern for the wasteload allocation.

Figure 7. Load duration curve for *E. coli* in Beeds Lake. The target is based on an *E. coli* concentration of 211 CFU/100ml. WLA = wasteload allocation; LA = load allocation



Load Allocation

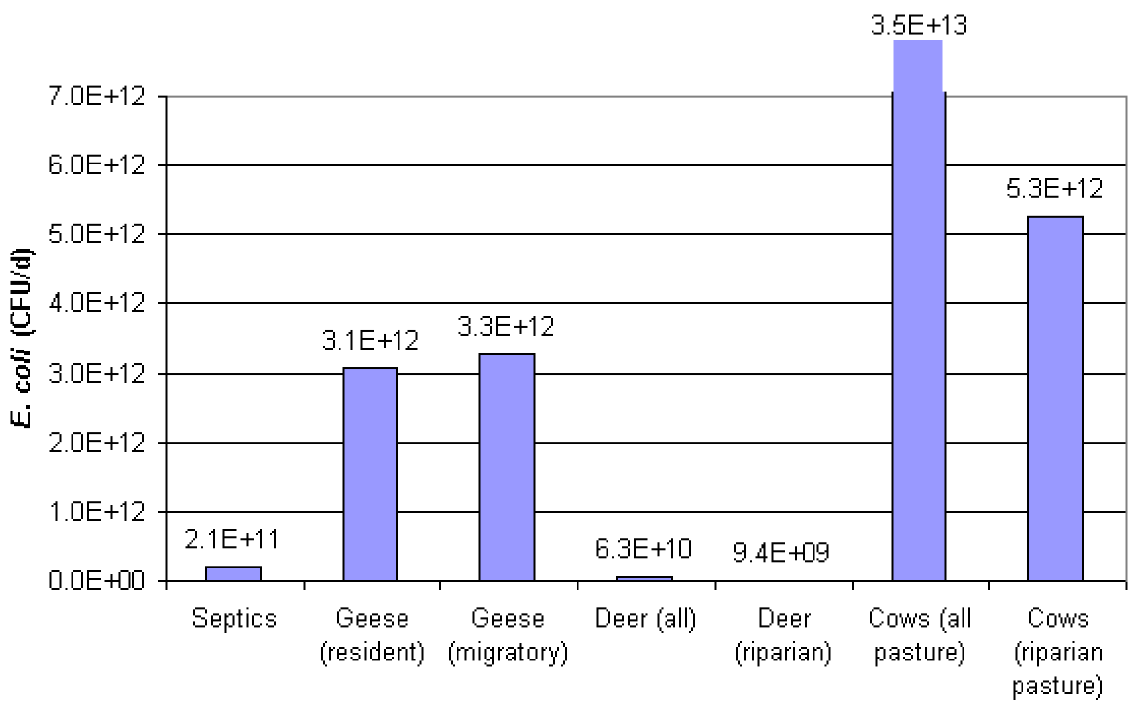
This load allocation assigns responsibility to nonpoint sources for maintaining water quality below the loading curve during flow conditions occurring in the 0-94% flow duration (Figure 7). This equates to streamflows greater than 1.2 cfs.

Based on source assessment, on the distribution of violations of the water quality standards, and on the relationship of this distribution to flow and runoff, nonpoint contributions of *E. coli* to Spring Creek and Beeds Lake are the primary source. Figure 8 shows the estimated contributions of various nonpoint sources.

The background contribution of deer and other wildlife is not considered a significant source of *E. coli*.

The load allocation in this pathogen TMDL for Beeds Lake is set as a percent load reduction, and is based on the maximum concentration of 7700 CFU/100ml measured at the Beeds Lake Beach and the maximum daily allowable concentration of 235 CFU/100ml set in Iowa water quality standards. To allow for a 10% Margin of Safety, this allowable concentration is lowered to 211 CFU/100ml. Based on modeling results, an 80% load reduction will be necessary to achieve the standard.

Figure 8. Estimated current nonpoint source loads as calculated in Sections 3.1 (Natural Background Conditions) and 3.3 (Identification of Pollutant Sources).



Margin of Safety

The Margin of Safety (MOS) for this TMDL is explicit. A numerical MOS of 24 CFU/100ml (10% of the allowable *E. coli* concentration) has been included to ensure that the required load reduction will result in attainment of water quality targets.

4. Implementation Plan

The Iowa Department of Natural Resources recognizes that an implementation plan is not a required component of a Total Maximum Daily Load. However, the IDNR offers the following implementation strategy to DNR staff, partners, and watershed stakeholders as a guide to improving water quality at Beeds Lake.

Pathogen loading to Beeds Lake originates primarily from nonpoint sources within the watershed. These sources include septic systems, livestock, and wildlife. Reductions in these loads will require waste and land management changes that take time to implement. For these reasons, the following timetable is suggested for watershed improvements:

- Reduce the current pathogen loading by 50% by 2010.
- Reduce the current pathogen loading by an additional 30% by 2015.
- Reduce the current pathogen loading the last 20% by 2020.

Best management practices (BMPs) to reduce pathogen delivery, particularly *E. coli*, should be emphasized in the Beeds Lake watershed. The large watershed to lake area ratio emphasizes the importance of watershed management to protect the water quality in Beeds Lake. Sediment sources from the watershed (such as eroding banks and shorelines and agricultural runoff) should be controlled to reduce sediment delivery to the lake. These practices should include the following:

- Management practices at Beeds Lake State Park should include some method for decreasing the population of geese near the beach, and/or the removal of fecal matter from the beach area.
- Cattle access to streams in pastures should be limited and alternative watering sources should be explored.
- Manure application should utilize incorporation or subsurface application of manure while controlling soil erosion. Incorporation will physically separate the fecal material from surface runoff.
- Improperly connected septic systems should be found and replaced with systems that meet current standards.

The location of the beach at Beeds Lake may lead to more frequent bacteria problems because nearly all incoming flow is directed at the beach. In addition, the causeway slows the flow into the eastern portion of the lake and may cause high bacteria levels to linger in the west end of the lake. Before any decision regarding potential beach relocation at Beeds Lake is made, further monitoring in the lake at potential beach sites should be completed to help determine the differences in water quality throughout the lake. Although moving the beach will not decrease the bacterial load to the lake, it may allow for increased facility use due to fewer swimming advisories.

One way to decrease bacterial numbers in water is to increase light penetration. Turbidity is not considered a problem in Beeds Lake based on ISU's data (Tables B-6 to B-9). However, Secchi disc readings have only been taken east of the causeway. It is possible that turbidity is higher and light penetration is lower to the west of the causeway. Decreasing sediment inputs to the lake from the two major tributaries would help to reduce non-algal turbidity while the associated decrease in phosphorus inputs would reduce algal turbidity. Therefore, the implementation of additional BMPs to address sediment delivery to the lake are encouraged.

In addition to the implementation of best management practices for the nonpoint sources, efforts should be made by the Latimer-Coulter Wastewater Treatment Plant to ensure that effluent is not discharged until it has been in the lagoon system for at least 20 days.

The DNR recognizes that an overall reduction of 80% may be difficult to achieve. For this reason, we suggest targeting specific nonpoint sources and working in Phase 1 to reduce the inputs from these sources. In Phase 2, the DNR will evaluate the success of these measures and determine if further changes need to be made.

4.1 Reasonable Assurance

To improve the water quality of Beeds Lake, both wasteload and load allocations were determined for bacteria. The wasteload allocations in this TMDL are set at existing levels, not requiring reductions at this time. However, nonpoint reductions are required.

A watershed project was funded through Clean Water Act Section 319 grant funds from 1994-98 led to the installation of best management practices to address sediment and nutrient delivery to Beeds Lake. This project resulted in the removal of the nutrient impairment at Beeds Lake, and indicates that members of the watershed are committed to improving the water quality in Beeds Lake.

5. Monitoring

Continued monitoring will be conducted by the DNR under the Beach Monitoring program. This monitoring will continue each year from approximately the last week of May until October 31.

Microbial source tracking (MST) is a technology used to determine the sources of fecal bacteria more specifically. Several MST methods are available and are being evaluated by DNR staff to determine the method(s) that are most feasible for Iowa lakes and streams. As a part of Phase 2, the DNR hopes to add MST to the monitoring plan as the technology becomes more accurate and affordable.

6. Public Participation

A public meeting was held at the Beeds Lake Lodge on June 30, 2004 regarding the TMDL process and the development of the pathogen TMDL for Beeds Lake. The meeting was attended by members of the Beeds Lake Homeowner’s Association, the Friends of Beeds Lake, and the Beeds Lake concessionaire. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

A second public meeting was held on October 14, 2004 to present a draft TMDL for Beeds Lake. The meeting was attended by the county sanitarian, an NRCS representative, a park ranger, one of the County Supervisors, a political candidate, and several homeowners from within the watershed and near the lake.

DNR staff met with local stakeholders at the First National bank of Hampton on January 19, 2006 to discuss the high levels of indicator bacteria in Beeds Lake. The public addressed their concerns to maintain the current uses of the lake, including fishing, boating, and primary contact recreation. Local stakeholders are interested in controlling the geese at the Beeds Lake beach, and also at the possibility of moving the beach to another area of the lake. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

7. References

1. IAC. 2002. Chapter 567-61: water quality standards. Iowa Administrative Code [effective date 8/14/02].

2. Bachmann, R.W., T.A. Hoyman, L.K. Hatch, and B.P. Hutchins. 1994. A classification of Iowa's lakes for restoration. Department of Animal Ecology, Iowa State University, Ames, Iowa. 517 p.

3. Water Resources Section, Water Quality Bureau, Environmental Services Division. May 2004. Surface water classification. Iowa Department of Natural Resources, Des Moines, Iowa. [online]. Available at: http://www.iowadnr.com/water/standards/files/swc.pdf (verified June 1, 2005).

4. Downing, John A. and Joy M. Ramstack. 2001. Iowa Lakes Survey – Summer 2000 Data. Iowa State University, Department of Animal Ecology. January, 2001.

5. Downing, John A. and Joy M. Ramstack. 2002. Iowa Lakes Survey – Summer 2001 Data. Iowa State University, Department of Animal Ecology. January, 2002.

6. Downing, J.A., C.T. Cherrier, and B. Dodd. 2002. Iowa lakes survey, summer 2000 biological report. Iowa State University, Department of Animal Ecology. 269 pp.

7. Peterson, Kenneth S. 1998. Beeds Lake Water Quality Project – Final Report.

8. Bachmann, R.W., M.R. Johnson, M.V. Moore, and T.A. Noonan. 1980. Clean lakes classification study of Iowa's lakes for restoration. Iowa Cooperative Fisheries Research Unit and Department of Animal Ecology, Iowa State University, Ames, Iowa. 715 p.

9. Downing, John A., Joy M. Ramstack, Kristian Haapa-aho, and Kendra Lee. 2003. Iowa Lakes Survey – Summer 2002 Data. Iowa State University, Department of Ecology, Evolution, and Organismal Biology. January, 2003.

10. Downing, John A., and George Antoniou. 2004. Iowa Lakes Survey – Summer 2003 Data. Iowa State University, Department of Ecology, Evolution, and Organismal Biology. January, 2004.

11. Downing, John A., and _. 2005. Iowa Lakes Survey – Summer 2004 Data. Iowa State University, Department of Ecology, Evolution, and Organismal Biology. _ 2005.

12. DiLuzio, M., R. Srinivasan, J.G. Arnold and S.L. Neitsch. 2002. ArcView Interface for SWAT 2000: User's Guide. Blackland Research and Extension Center. BRC Report 02-07.

13. Wastewater Section, Water Quality Bureau, Environmental Services Division. Iowa Wastewater Facilities Design Standards, Chapter 18C. Iowa Department of Natural Resources, Des Moines, Iowa. [online]. Available at: http://www.iowadnr.com/water/wastewater/dstandards/chapter18c.pdf (verified June 8, 2005).

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

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

16. Iowa Department of Natural Resources. WW-Sewage File No. 6-35-54-0-01. City of Latimer-Coulter STP.

17. Metcalf and Eddy. 2003. Wastewater Engineering, Treatment and Reuse. Fourth Edition. McGraw-Hill, New York 109-111 pp.

8. Appendix A - Lake Hydrology

General Methodology

Purpose

There are approximately 127 public lakes in Iowa. The contributing watersheds for these lakes range in area from 0.028 mi^2 to 195 mi^2 with mean and median values of 10 mi^2 and 3.5 mi^2, respectively. Few, if any, of these lakes have gauging data available to determine flow statistics for the tributaries that feed into them. A select few have some type of stage information that may be useful in determining historical discharge from the lake itself.

With the large number of lakes on the State's 303(d) list and the requirement for rapid development of TMDLs for these lakes, it was realized that a method to quickly estimate flow statistics for required lake response model inputs would be desirable. In an attempt to achieve this goal, flow data and watershed characteristics for a number of USGS gauging stations with small contributing watershed areas were compiled and evaluated via both simple and multiple linear regressions. The primary focus of this evaluation was estimation of the average annual flow statistic for input to empirical lake response models. However, regression equations for monthly average and calendar year flow statistics were also developed that may be of additional use.

It should be noted that attempts were made to develop regression equations for low-flow streamflow statistics (1Q10, 7Q10, 30Q10, 30Q5 and harmonic mean) but the relationships derived were for the most part considered too weak (R^2 adj.< 70%) to be of practical use. One exception to this is the 30Q5 statistic, which gave an R^2 adj. of 85%. In addition, regression equations were developed for monthly flow prediction models for two months (January and May). Once again, the relationships did not exhibit a high level of correlation and due to the large amount of data required to develop these models, development of equations for additional months was not attempted.

Data

Flow data and watershed characteristics from 26 USGS gauging stations were used to derive the regression equations. The ranges of basin characteristics used to develop the regression equations are shown in Table A-1.

Drainage areas were taken directly from USGS gauge information available at http://water.usgs.gov/waterwatch/ . Precipitation values were obtained through the Iowa Environmental Mesonet IEM Climodat Interface at http://mesonet.agron.iastate.edu/climodat/index.phtml . Where weather and gauging stations were not located in the same town, precipitation information was obtained from the weather station located in the town with the shortest straight-line distance from the gauging station.

Average basin slope and land cover percentages were determined using Arc View and statewide coverages clipped within HUC-12 sub-watersheds. It should be noted that the smallest basin coverages used in determining land cover percentages and average basin slopes were single HUC-12 units (i.e. no attempt was made to subdivide HUC-12 basins into smaller units where the drainage area was less than the area of the HUC-12 basin). Therefore, the regression models assume that for very small watersheds the land cover percentages of the HUC-12 basin are representative of the watershed located within the basin.

The Hydrologic Region for each station was determined from Figure 1 of USGS Water-Resources Investigation Report 87-4132, Method for Estimating the Magnitude and Frequency of Floods at Ungaged Sites on Unregulated Rural Streams in Iowa. None of the stations included in the analyses were located in Regions 1 or 5. This is reflected in the regression equations developed that utilize the hydrologic region as a variable.

Table A-1. Ranges of basin characteristics used to develop the regression equations.

Basin Characteristic	Name in equations	Minimum	Mean	Maximum
Drainage Area (mi^2)	DA	2.94	80.7	204
Mean Annual Precip (inches)	$\bar{P}_A$	26.0	34.0	36.2
Average Basin Slope (%)	S	1.53	4.89	10.9
Landcover - % Water	W	0.020	0.336	2.80
Landcover - % Forest	F	2.45	10.3	29.9
Landcover - % Grass/Hay	G	9.91	31.3	58.7
Landcover - % Corn	C	6.71	31.9	52.3
Landcover - % Beans	B	6.01	23.1	37.0
Landcover - % Urban/Artificial	U	0	2.29	7.26
Landcover - % Barren/Sparse	B'	0	0.322	2.67
Hydrologic Region	H	Regions 1 - 5 used for delineation but data for USGS stations in Regions 2, 3 & 4 only.		

Methods

Simple regression models were developed for annual average and monthly average statistics with drainage area as the sole explanatory variable. Multiple linear regression models considering all explanatory variables were developed utilizing stepwise regression in Minitab. All data with the exception of the Hydrologic Region were log transformed. Explanatory variables with regression coefficients that were not statistically different from zero (p-value greater than 0.05) were not utilized.

Equation Variables

Table A-2. Regression equation variables.

Annual Average Flow (cfs)	$\overline{Q}_A$
Monthly Average Flow (cfs)	$\overline{Q}_{MONTH}$
Annual Flow – calendar year (cfs)	Q_{YEAR}
Drainage Area (mi^2)	DA
Mean Annual Precip (inches)	$\overline{P}_A$
Mean Monthly Precip (inches)	$\overline{P}_{MONTH}$
Antecedent Mean Monthly Precip (inches)	$\overline{A}_{MONTH}$
Annual Precip – calendar year (inches)	P_{YEAR}
Antecedent Precip – calendar year (inches)	A_{YEAR}
Average Basin Slope (%)	S
Landcover - % Water	W
Landcover - % Forest	F
Landcover - % Grass/Hay	G
Landcover - % Corn	C
Landcover - % Beans	B
Landcover - % Urban/Artificial	U
Landcover - % Barren/Sparse	B′
Hydrologic Region	H

Equations

Table A-3. Drainage area only equations.

Equation	**R^2 adjusted (%)**	**PRESS (log transform)**
$\overline{Q}_A = 0.832DA^{0.955}$	96.1	0.207290
$\overline{Q}_{JAN} = 0.312DA^{0.950}$	85.0	0.968253
$\overline{Q}_{FEB} = 1.32DA^{0.838}$	90.7	0.419138
$\overline{Q}_{MAR} = 0.907DA^{1.03}$	96.6	0.220384
$\overline{Q}_{APR} = 0.983DA^{1.02}$	93.1	0.463554
$\overline{Q}_{MAY} = 1.97DA^{0.906}$	89.0	0.603766
$\overline{Q}_{JUN} = 2.01DA^{0.878}$	88.9	0.572863
$\overline{Q}_{JUL} = 0.822DA^{0.977}$	87.2	0.803808
$\overline{Q}_{AUG} = 0.537DA^{0.914}$	74.0	1.69929
$\overline{Q}_{SEP} = 0.123DA^{1.21}$	78.7	2.64993
$\overline{Q}_{OCT} = 0.284DA^{1.04}$	90.2	0.713257
$\overline{Q}_{NOV} = 0.340DA^{0.999}$	89.8	0.697353
$\overline{Q}_{DEC} = 0.271DA^{1.00}$	86.3	1.02455

Table A-4. Multiple regression equations.

Equation	**R^2 adjusted (%)**	**PRESS (log transform)**
$\overline{Q}_A = 1.17 \times 10^{-3} DA^{0.998} \overline{P}_A^{\,1.54} S^{-0.261} (1+F)^{0.249} C^{0.230}$	98.7	0.177268 (n=26)
$\overline{Q}_{JAN} = 0.213 DA^{0.997} \overline{A}_{JAN}^{\,0.949}$	89.0	0.729610 (n=26;same for all $\overline{Q}_{MONTH}$)
$\overline{Q}_{FEB} = 2.98 DA^{0.955} \overline{A}_{FEB}^{\,0.648} G^{-0.594} (1+F)^{0.324}$	97.0	0.07089
$\overline{Q}_{MAR} = 6.19 DA^{1.10} B^{-0.386} G^{-0.296}$	97.8	0.07276
$\overline{Q}_{APR} = 1.24 DA^{1.09} \overline{A}_{APR}^{\,1.64} S^{-0.311} B^{-0.443}$	97.1	0.257064
$\overline{Q}_{MAY} = 10^{(-3.03+0.114H)} DA^{0.846} \overline{P}_A^{\,2.05}$ Hydrologic Regions 2, 3 & 4 Only	92.1	0.958859
$\overline{Q}_{MAY} = 1.86 \times 10^{-3} DA^{0.903} \overline{P}_A^{\,1.98}$	90.5	1.07231
$\overline{Q}_{JUN} = 10^{(-1.47+0.0729H)} DA^{0.891} C^{0.404} \overline{P}_{JUN}^{\,1.84} (1+F)^{0.326} G^{-0.387}$ Hydrologic Regions 2, 3 & 4 Only	97.0	0.193715
$\overline{Q}_{JUN} = 8.13 \times 10^{-3} DA^{0.828} C^{0.478} \overline{P}_{JUN}^{\,2.70}$	95.9	0.256941
$\overline{Q}_{JUL} = 1.78 \times 10^{-3} DA^{0.923} \overline{A}_{JUL}^{\,4.19}$	91.7	0.542940
$\overline{Q}_{AUG} = 4.17 \times 10^{7} DA^{0.981} (1+B')^{-1.64} (1+U)^{0.692} \overline{P}_A^{\,-7.2} \overline{A}_{AUG}^{\,4.59}$	90.4	1.11413
$\overline{Q}_{SEP} = 1.63 DA^{1.39} B^{-1.08}$	86.9	1.53072
$\overline{Q}_{OCT} = 5.98 DA^{1.14} B^{-0.755} S^{-0.688} (1+B')^{-0.481}$	95.7	0.375296
$\overline{Q}_{NOV} = 5.79 DA^{1.17} B^{-0.701} G^{-0.463} (1+U)^{0.267} (1+B')^{-0.397}$	95.1	0.492686
$\overline{Q}_{DEC} = 0.785 DA^{1.18} B^{-0.654} (1+U)^{0.331} (1+B')^{-0.490}$	92.4	0.590576
$Q_{YEAR} = 3.164 \times 10^{-4} DA^{0.942} P_{YEAR}^{\,2.39} A_{YEAR}^{\,1.02} S^{-0.206} \overline{P}_A^{\,1.27} C^{0.121} (1+U)^{0.0966}$	83.9	32.6357 (n=716)

General Application

In general, the regression equations developed using multiple watershed characteristics will be better predictors than those using drainage area as the sole explanatory variable. The single exception to this appears to be for the May Average Flow worksheet where the PRESS statistic values indicate that use of drainage area alone results in the least error in the prediction of future observations.

Although 2002 land cover grids for the state are now available with 19 different classifications, the older 2000 land cover grids with 9 different classifications were used in developing the regression equations. The 2000 land cover grids should be used in development of flow estimates using the equations.

The equations were developed from stream gauge data for watersheds with relatively minor open water surface percentages relative to other types of land cover (see Table A-

1). For application to lake watersheds, particularly those with small watershed/lake area ratios, the basin slope and land cover percentages taken from HUC-12 basins may need to be adjusted so that the hydraulic budget components of surface inflow and direct precipitation on the lake itself can be treated separately. One method of accomplishing this is by subtraction of lake water surface acreage from the total land cover and slope (lakes will have 0% slope) acreages and recalculation of the % coverages. The watershed (drainage) area used in the equations should not include the area of the lake surface.

Application to Beeds Lake - Calculations

Table A-5. Beeds Lake hydrology calculations.

Lake	Beeds Lake	
Type	Artificial	
Inlet(s)	Spring Creek	
Outlet(s)	Spring Creek	
Volume	864	(acre-ft)
Lake Area	97	(acres)
Mean Depth	8.95	(ft)
Drainage Area	20,197	(acres)
Mean Annual Precip	33	(inches)
Average Basin Slope	1.77	(%)
%Water	0.18	
%Forest	0.85	
%Grass/Hay	16.42	
%Corn	48.30	
%Beans	33.11	
%Urban/Artificial	1.01	
%Barren/Sparse	0.00	
Hydrologic Region	4	
Mean Annual Class A Pan Evap	48	(inches)
Mean Annual Lake Evap	35.52	(inches)
Est. Annual Average Inflow	14,448.14	(acre-ft)
Direct Lake Precip	265.94	(acre-ft/yr)
Est. Annual Average Det. Time (inflow + precip)	0.0587	(yr)
Est. Annual Average Det. Time (outflow)	0.0599	(yr)

9. Appendix B - Sampling Data

Table B-1. Fecal coliform data (#/100ml) collected in 1994-97 (7). SC indicates Spring Creek; SWL indicates Sewage Waste Lagoon.

Site	5/2/94	4/11/95	7/12/95	12/19/95	4/10/96	7/30/96	11/13/96	4/23/97	7/29/97
Lake 1	20	5	10	5	5	5	5	5	5
Lake 2	20	18	10	18	5	5	5	5	10
SC Southeast	10	360	1100	170	40	480	70	5	340
SC South	90	370	2200	270	40	410	890	140	1300
SC West	5	370	1100	540	70	410	300	950	950
SC Below SWL		500			20	55	430	40	120
SC Above SWL		150	6400	950	200	1200	1000	99	820

Table B-2. *E. coli* data (#/100ml) collected by IDNR in 2002-04.

Site	9/5/02	9/12/02	9/18/02	6/30/03	7/16/03	4/7/04	6/11/04
BL Near Dam	5	5				5	500
BL East	5			5	5	5	100
BL Across Beach	10	5		27	60	5	590
BL West Causeway	30	10		20	73	5	560
BL South Causeway	10	5		20	20	5	55
BL North Causeway	5						
BL North Tributary	170	140	880	200	1100	5	1900
BL West Tributary	30	30		55	50	5	4400
SC East	100	210	970	650	180	5	4100
SC South	160	82	1200	280	90	5	4900
SC West	110	140	1200	290	130	5	2400
SC Below SWL	170	260	240	73	63	5	2000
SC Above SWL	130	70	170	27	82		2000

(SC = Spring Creek; BL = Beeds Lake; SWL = Sewage Waste Lagoon)

Table B-3. *E. coli* data (#/100ml) from IDNR beach monitoring samples.

2000		2001		2002		2003		2004	
Date	***E.coli***	**Date**	***E.coli***	**Date**	***E.coli***	**Date**	***E.coli***	**Date**	***E.coli***
5/22/00	30	6/21/01	140	8/27/01	10	10/15/02	150	10/14/03	82
5/30/00	430	6/22/01	20	9/4/01	5	10/22/02	73	10/21/03	80
6/5/00	200	6/23/01	10; 10	9/10/01	30	10/29/02	20	10/28/03	230
6/12/00	91	6/24/01	10; 130	4/16/02	20	4/15/03	10	5/25/04	1100
6/19/00	160	6/25/01	30	4/23/02	5	4/22/03	30	6/1/04	410
6/26/00	3500	6/26/01	10	4/30/02	60	4/29/03	5	6/7/04	140
7/10/00	7700	6/27/01	40	5/7/02	20	5/6/03	330	6/14/04	240
7/17/00	140	6/28/01	20	5/14/02	5	5/13/03	30	6/21/04	740
7/24/00	5	6/29/01	10	5/21/02	5	5/20/03	90	6/28/04	670
7/31/00	5	6/30/01	5; 40	5/28/02	36	5/27/03	10	7/6/04	550
8/7/00	5	7/1/01	5; 210	6/4/02	80	6/3/03	30	7/12/04	90
8/14/00	5	7/2/01	360	6/11/02	40	6/10/03	180	7/19/04	140
8/21/00	10	7/3/01	5	6/18/02	5	6/17/03	10	7/26/04	18
8/28/00	20	7/4/01	130	6/25/02	10	6/24/03	36	8/2/04	82
9/4/00	18	7/5/01	10	7/2/02	5	7/1/03	20	8/9/04	140
9/11/00	5	7/7/01	20; 45	7/9/02	130	7/8/03	2700	8/16/04	27
9/18/00	5	7/8/01	30; 40	7/16/02	5	7/15/03	650	8/23/04	5
5/21/01	830	7/9/01	5	7/23/02	160	7/22/03	80	8/30/04	20
5/29/01	130	7/10/01	5	7/30/02	10	7/29/03	90	9/7/04	45
6/4/01	20	7/11/01	10	8/6/02	1200	8/5/03	5	9/13/04	10
6/11/01	120	7/12/01	10	8/13/02	3000	8/12/03	10	9/21/04	20
6/12/01	640; 370	7/16/01	10	8/20/02	45	8/19/03	5	9/27/04	5
		7/23/01	10	8/27/02	64	8/26/03	5	10/4/04	27
6/13/01	2000	7/25/01	420	9/3/02	45	9/1/03	20	10/11/04	5
6/14/01	420	7/30/01	30	9/10/02	160	9/9/03	10	10/18/04	18
6/15/01	3300	8/6/01	5	9/17/02	10	9/16/03	20	10/25/04	20
6/18/01	390	8/13/01	5	9/24/02	20	9/23/03	36		
6/19/01	250	8/16/01	5	10/1/02	5	9/30/03	20		
6/20/01	73	8/20/01	10	10/8/02	180	10/7/03	40		

Table B-4. Data collected in 1979 by Iowa State University (8).

Parameter	**7/26/1979**	**8/23/1979**	**9/25/1979**
Secchi Depth (m)	1.2	0.6	1.2
Chlorophyll (ug/L)	71	150	43
NO_3+NO_2-N (mg/L)			5.9
Total Phosphorus (ug/l as P)	68.7	126.7	42.2
Alkalinity (mg/L)	169	217	249

Data above is averaged over the upper 6 feet.

Table B-5. Data collected in 1990 by Iowa State University (2).

Parameter	**5/27/1990**	**6/28/1990**	**7/26/1990**
Secchi Depth (m)	0.9	0.7	0.1
Chlorophyll (ug/L)	88.7	24.3	94.1
Total Nitrogen (mg/L as N)	10.9	15.1	10.7
Total Phosphorus (ug/l as P)	126.5	283.6	293.3
Total Suspended Solids (mg/L)	8.2	52.8	95.9
Inorganic Suspended Solids (mg/L)	0.4	31.8	78.2

Data above is for surface depth.

Table B-6. Data collected in 2000 by Iowa State University (4).

Parameter	7/10/2000	7/31/2000	8/29/2000
Secchi Depth (m)	0.5	1.3	1.1
Chlorophyll (ug/L)	12	9	3
NH_3+NH_4^+ -N (ug/L)	949	307	757
NH_3 –N (un-ionized) (ug/L)	1	5	15
NO_3+NO_2-N (mg/L)	9.43	8.98	2.5
Total Nitrogen (mg/L as N)	11.21	10.92	3.45
Total Phosphorus (ug/l as P)	275	88	130
Silica (mg/L as SiO_2)	29	28	63
pH	6.3	7.5	7.6
Alkalinity (mg/L)	219	186	199
Total Suspended Solids (mg/L)	17.4	7.2	2.4
Inorganic Suspended Solids (mg/L)	13.3	4.4	1.1
Volatile Suspended Solids (mg/L)	4.1	2.7	1.3

Table B-7. Data collected in 2001 by Iowa State University (5).

Parameter	6/04/2001	7/09/2001	8/06/2001
Secchi Depth (m)	1.6	1.3	1.2
Chlorophyll (ug/L)	3	68	27
NH_3+NH_4^+ -N (ug/L)	282	242	341
NH_3 –N (un-ionized) (ug/L)	3	12	5
NO_3+NO_2-N (mg/L)	17.75	13.55	10.58
Total Nitrogen (mg/L as N)	16.12	14.64	10.67
Total Phosphorus (ug/l as P)	122	255	116
Silica (mg/L as SiO_2)	16	14	16
pH	7.7	8.1	7.5
Alkalinity (mg/L)	205	201	180
Total Suspended Solids (mg/L)	6.3	11.9	3.5
Inorganic Suspended Solids (mg/L)	4.3	4.8	1.6
Volatile Suspended Solids (mg/L)	2.0	7.1	1.9

Table B-8. Data collected in 2002 by Iowa State University (9).

Parameter	6/10/2002	7/15/2002	8/12/2002
Secchi Depth (m)	2.4	0.8	0.8
Chlorophyll (ug/L)	9	67	14
NH_3+NH_4^+ -N (ug/L)	75	74	253
NH_3 –N (un-ionized) (ug/L)	10	27	18
NO_3+NO_2-N (mg/L)	11.82	3.91	7.23
Total Nitrogen (mg/L as N)	12.56	4.90	8.73
Total Phosphorus (ug/l as P)	30	86	57
Silica (mg/L as SiO_2)	1	5	12
pH	8.5	9.0	8.2
Alkalinity (mg/L)	189	143	190
Total Suspended Solids (mg/L)	3.3	17.4	20.0
Inorganic Suspended Solids (mg/L)	0.3	6.4	12.8
Volatile Suspended Solids (mg/L)	3.0	11.0	7.2

Table B-9. Data collected in 2003 by Iowa State University (10).

Parameter	**6/9/2003**	**7/15/2003**	**8/11/2003**
Secchi Depth (m)	1.4	1.2	1.0
Chlorophyll (ug/L)	31.1	29.9	37.6
NH_3+NH_4^+ -N (ug/L)	253	134	218
NH_3 –N (un-ionized) (ug/L)	16	17	20
NO_3+NO_2-N (mg/L)	11.37	15.08	7.15
Total Nitrogen (mg/L as N)	12.45	14.74	8.24
Total Phosphorus (ug/l as P)	60	118	69
Silica (mg/L as SiO_2)	3	11	10
pH	8.2	8.5	8.2
Alkalinity (mg/L)	171	181	135
Total Suspended Solids (mg/L)	13	11	11
Inorganic Suspended Solids (mg/L)	8	6	4
Volatile Suspended Solids (mg/L)	5	4	7

Table B-10. Data collected in 2004 by Iowa State University (11).

Parameter	**6/7/2004**	**7/12/2004**	**8/9/2004**
Secchi Depth (m)	1.0	1.3	0.7
Chlorophyll (ug/L)	56.3	29.8	107.6
NH_3+NH_4^+ -N (ug/L)	19.6	2.4	16.4
NH_3 –N (un-ionized) (ug/L)	2.8	0.3	2.7
NO_3+NO_2-N (mg/L)	15.46	11.81	3.77
Total Nitrogen (mg/L as N)	14.11	11.49	5.06
Total Phosphorus (ug/l as P)	128	46	103
Silica (mg/L as SiO_2)	10.52	3.58	7.83
pH	8.6	8.5	8.6
Alkalinity (mg/L)	199	212	181
Total Suspended Solids (mg/L)	12	11	15
Inorganic Suspended Solids (mg/L)	8	1	4
Volatile Suspended Solids (mg/L)	5	10	11

Additional lake sampling results and information can be viewed at:
http://limnology.eeob.iastate.edu/

10. Appendix C - Streamflow Generation with SWAT

Beed's Lake Streamflow Generation Procedure

The streamflow for Beed's Lake was generated using the Soil and Water Assessment Tool 2000 (SWAT2000) hydrologic model (12). SWAT is a physically-based, semi-distributed, continuous, daily time step model designed to simulate water yield, sediment delivery, and nutrient and pesticide loading from large, ungauged watersheds. The model uses datasets typically available from government agencies. It is capable of predicting the relative impact of agricultural management and land use over long time periods.

SWAT was used to generate daily-simulated streamflow for the Beeds Lake watershed since this data was not available. This data was used to develop a flow duration curve to help identify under what conditions pollutant loads were being exceeded. Beeds Lake detention time data is generated only on an annual basis. For a load duration curve or water quality duration curve to be useful, daily and seasonal streamflow needed to be estimated.

The GIS interface of SWAT was used for this project. The ArcView SWAT version of the model allows geo-referenced data to be preprocessed for entry into the model. After model simulation, the GIS component post-processes the model output and displays the data as graphics, charts or tables.

For Beeds Lake, geo-referenced data and datasets specific to the watershed and area were used as input into the model to generate precipitation, runoff, and streamflow. A brief description of each data follows.

Spatial Data

Digitized Elevation Model (DEM). The DEM is a graphical representation of the land slope steepness and aspect (direction). The DEM is prepared as a 30-meter grid polygon format. Each "cell" of this 30-meter by 30-meter grid is given a single elevation value. This GIS coverage determines watershed and subbasin (subwatershed) boundaries, and thus, water flow direction and accumulation. The DEM is available through the Iowa Department of Natural Resources.

Streams. The digitized streams are line representations of accumulated perennial water flow over the soil surface. This coverage is important for the routing (i.e. movement and transformation) of runoff and pollutants originating in the watershed. The stream coverage was created by the hydrologic modeling component of SWAT utilizing the DEM.

Subbasins delineation. Subbasin outlets are geo-referenced points on a stream or river identifying the outlet of the subbasin. Outlets may occur in series on larger streams such that the outlet of one subbasin contributes channelized flow to a downstream subbasin. A subbasin is the land area contributing surface runoff to its outlet. In this project, three subbasin outlets in the lower watershed area were added to match three data sampling points. The remainder of the subbasin outlets and subbasin file were created automatically by ArcView SWAT.

Land use/land cover. This coverage is a graphical representation of land cover type. The land use/land cover is prepared as a 30-meter grid polygon format. Each “cell” of this 30-meter by 30-meter grid is designated a single land cover type. This coverage is used to define the plant growth characteristics SWAT will use to simulate the area. This coverage was obtained through Iowa DNR.

Soils. This coverage is a graphical representation of soil distribution. The soils coverage is prepared as a 30-meter grid polygon format. Each “cell” of this 30-meter by 30-meter grid is designated a single soil type. This coverage is used to define the soil chemical and physical properties SWAT will use to simulate the area. The soils data and originated from the State Soil Geographic (STATSGO) Data Base.

Weather. SWAT used precipitation data from the weather station located at Hampton, Iowa. This weather station is located about 6 miles east of the center of Beeds Lake watershed. Additional weather data included in the model (e. g. daily temperature, wind speed, relative humidity, solar radiation) was artificially generated using the model weather generator based upon long-term monthly averages calculated at the Iowa Falls, Iowa weather station located about 16 miles southeast of the center of Beeds Lake watershed.

Non-spatial Data

Management Practice Schedules. Management practice schedules are the detailed cultural and management practices applied to a specific land use in the watershed. In this study, one management practice schedule is applied to all of a given land use within the watershed. Corn and Soybeans have locally developed management practice schedules applied to them. These schedules were developed using typical farming practices in region. Other land uses (e.g. Grasslands) have model-generated default management practice schedules applied.

11. Appendix D - Maps

Figure D-1. Beeds Lake watershed land uses based on a 2002 field assessment.

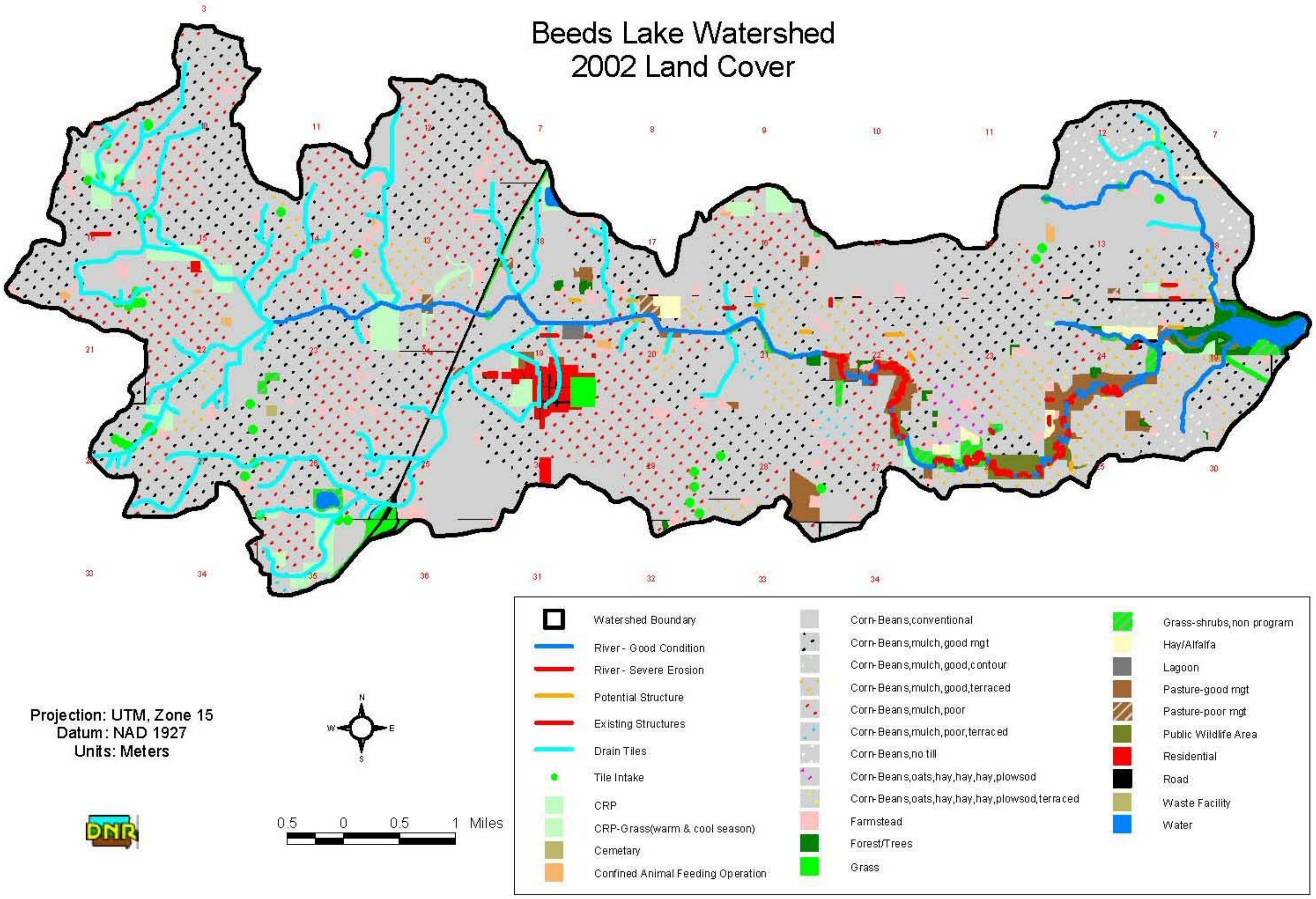


Figure D-2. Bathymetry for Beeds Lake.

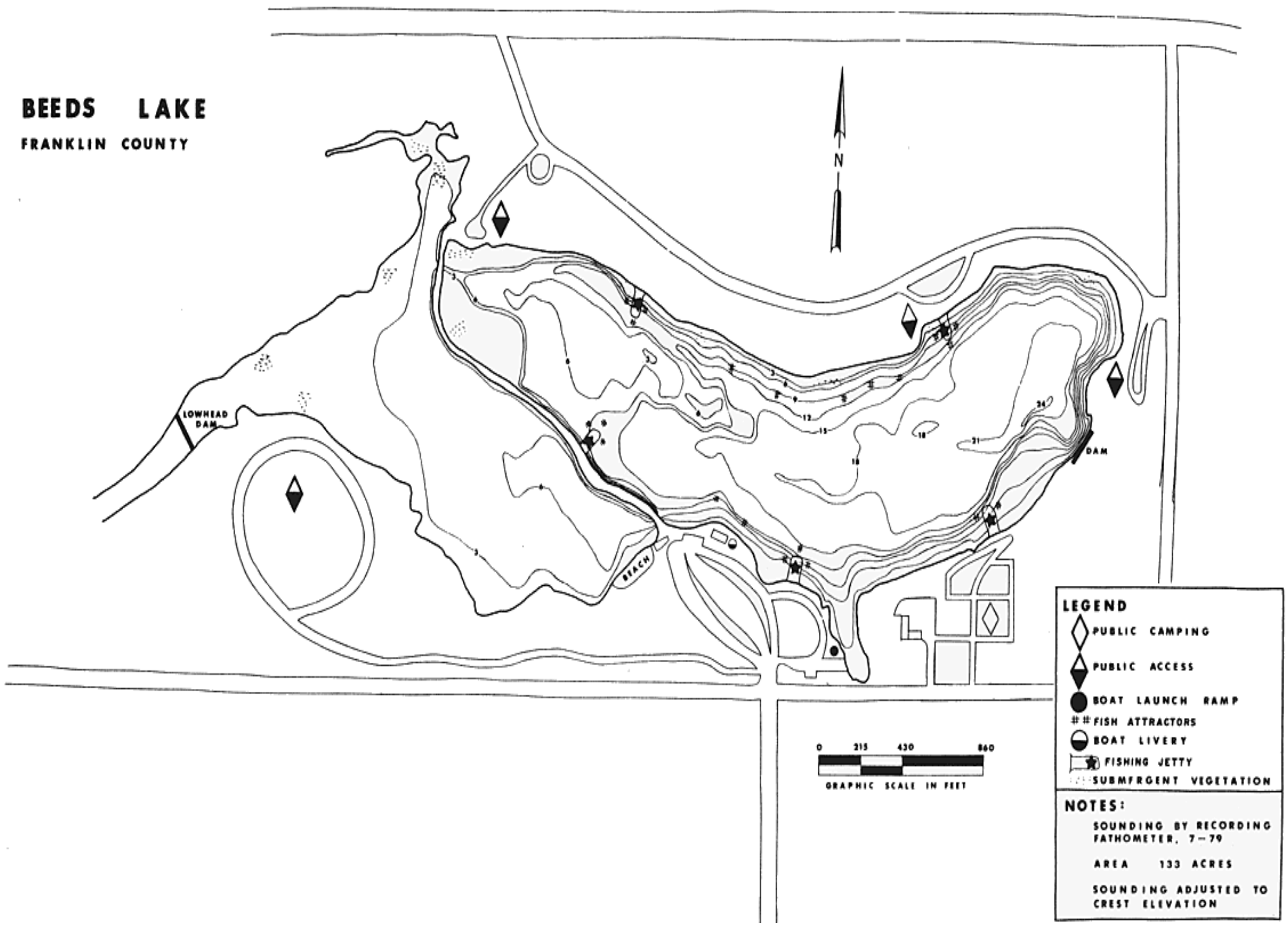


Figure D-3. Sampling locations in the Beeds Lake watershed. The black line is the watershed boundary.

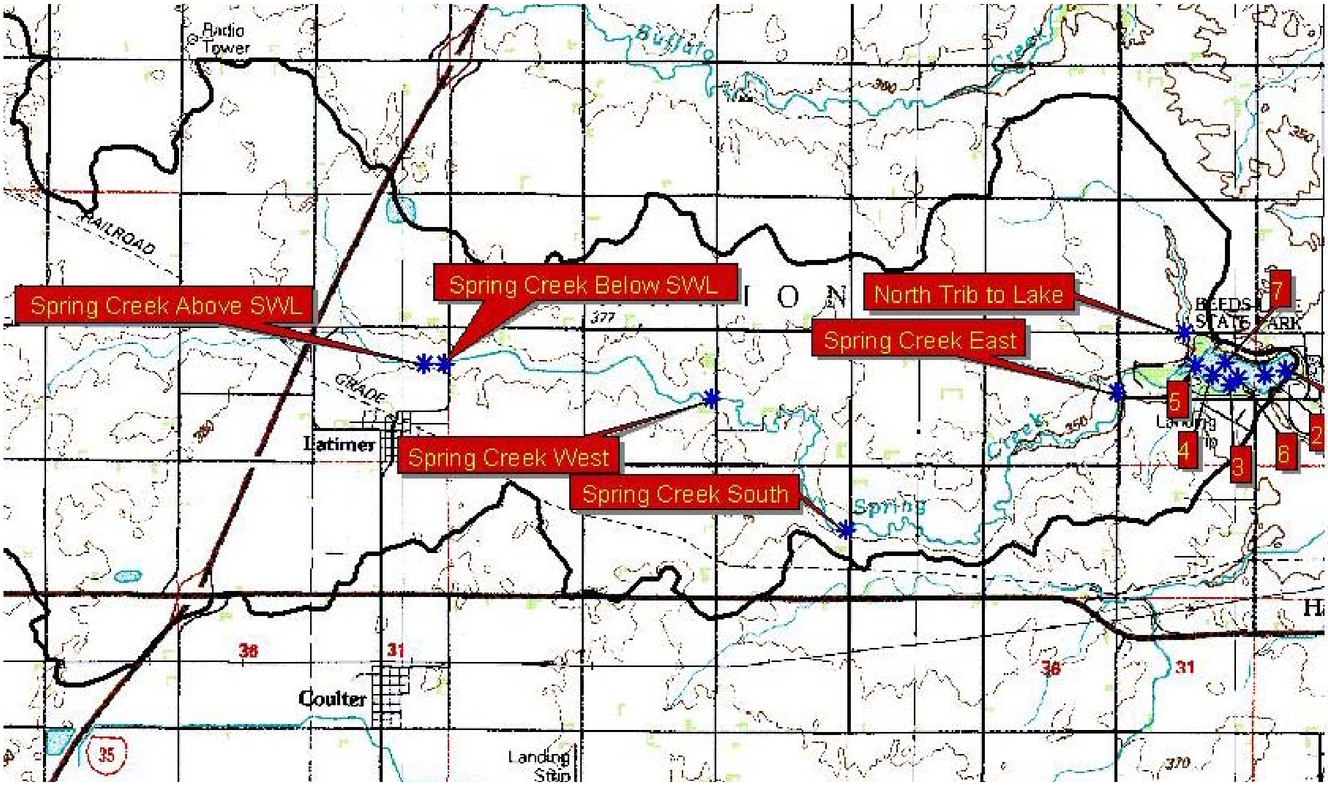


Figure D-4. Sampling locations in Beeds Lake. The green line represents the watershed boundary.