Water Quality Improvement Plan for

Duck Creek

Scott County, Iowa

Total Maximum Daily Load
for Indicator Bacteria (*E. coli*)

clean water
starts with you.
IOWA DNR WATERSHED IMPROVEMENT

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General Report Summary

What is the purpose of this report?

This report serves multiple purposes. First, it is a resource for guiding locally-driven water quality improvements in Duck Creek. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) for all federally impaired waterbodies. Duck Creek is an important water resource, and as an impaired waterbody is eligible for financial assistance to improve water quality. This document is meant to help guide watershed improvement efforts to remove Duck Creek from the federal 303(d) list of impaired waters.

What's wrong with Duck Creek?

Duck Creek is not supporting two of the intended uses of the stream: primary contact recreation (Class A1 use) and children's recreation, (Class A3). Primary contact recreation includes activities that involve direct contact with the water such as swimming and wading. Children's recreation is similar, but specific to activities or locations where children contact the water. Neither designated use is currently supported in Duck Creek due to high levels of indicator bacteria called *Escherichia coli* (*E. coli)* measured in the stream. High *E. coli* levels in a waterbody can indicate the presence of potentially harmful bacteria and viruses (also called pathogens). Humans can become ill if they come into contact with and/or ingest water that contains pathogens.

What is causing the problem?

E. coli and harmful pathogens found in a lake or stream can originate from point or nonpoint sources of pollution, or a combination of both. Point sources of pollution are easily identified sources that enter a stream or lake at a distinct location, such as a wastewater treatment plant discharge. Nonpoint sources of pollution are discharged in a more indirect and diffuse manner, and are often more difficult to locate and quantify. Nonpoint source pollution is usually carried with rainfall or snowmelt over the land surface and into a nearby lake or stream.

Both point and nonpoint sources of pollution are responsible for high *E. coli* levels in Duck Creek. Permitted point sources in the Duck Creek watershed include municipal stormwater systems (MS4s), municipal wastewater treatment facilities (WWTFs), and discharging onsite wastewater treatment and disposal systems. Onsite wastewater treatment systems are often called septic systems even though not all systems include a septic tank. The terms are used interchangeably in this document. Nonpoint sources result from livestock, pets, wildlife, and humans that live, work, and play in and around the stream. Specific examples of nonpoint sources of bacteria to Duck Creek include cattle with direct access to streams, manure applied to row crops, non-permitted onsite wastewater systems, and natural or background sources such as wildlife. Other sources may exist that are difficult to detect and document, such as resuspension of bacteria from the stream bed, or growth of bacteria within the storm sewer system.

What can be done to improve Duck Creek?

To improve the water in Duck Creek so that primary contact and children's recreation are fully supported, the amount of bacteria entering the stream must be reduced. Accomplishing this will require a combination of land, animal, stormwater, and wastewater management practices. In the rural areas of the watershed, efforts should focus on eliminating livestock access to streams, strategic manure application that considers both timing and application methods, and improving failing onsite wastewater treatment systems to meet state standards.

Urban activities should include the adoption of stormwater BMPs geared specifically to bacteria reduction and/or runoff reduction, elimination of sanitary sewer overflows (SSOs) and possible illicit sanitary sewer connections, strategic management of wastewater facility discharges (adjustment of discharge timing, disinfection, etc.), and public outreach and educational programs that encourage pet owners to pick up pet waste.

Who is responsible for a cleaner Duck Creek?

Everyone who lives, works, or plays in the Duck Creek watershed has a role in water quality improvement. Because there are several municipal point sources in the watershed, the cities of Davenport and Bettendorf must meet wasteload allocations (WLAs) that will be incorporated into to their National Pollutant Discharge Ellimination System (NPDES) permits. Voluntary management of land and animals by private citizens will also be required to see positive results. Roughly half of the land draining to the creek is in agricultural production, and financial assistance is often available from government agencies to individual landowners willing to adopt best management practices (BMPs). Rural homeowners can have their onsite wastewater treatment systems inspected to ensure they function properly. Failing or malfunctioning systems should be repaired or replaced. Improving water quality in Duck Creek will require a collaborative effort of citizens and agencies with a genuine interest in protecting the stream now and in the future.

Required Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	**Duck Creek in Scott County, Iowa** Segment IA 01-NEM-0060_1, from mouth (S27, T78N, R4E) to Hickory Grove Road (S16/21, T78N, R3E). Segment IA 01-NEM-0060_2 (presumptive use), from Hickory Grove Road (S16/21, T78N, R3E) to unnamed tributary (SE ¼ S14, T78N, R2E). **Tributaries to Duck Creek** Unnamed Creek (Pheasant Creek), from mouth (SW ¼, NW ¼, S20, T78N, R4E) to dam of small pond (NE ¼, NW ¼, S6, T78N, R4E). Goose Creek, from mouth (NE ¼, S24, T78, R3E) to confluence with Unnamed Creek (SW ¼, S2, T78N, R3E) Silver Creek, from mouth (E ½ S16, T78N, R3E) to the confluence with Unnamed Creek (S33, T79N, R3E).
Surface water classification and designated uses:	**Segment IA 01-NEM-0060_1:** A3: Children's contact recreation B(WW-2): Aquatic life (warm water) **Segment IA 01-NEM-0060_2:** A3: Children's contact recreation B(WW-2): Aquatic life (warm water) **Pheasant Creek:** A3: Children's contact recreation **Goose Creek:** Presumptive A1: Primary contact recreation **Silver Creek:** A3: Children's contact recreation

Impaired beneficial uses:	**Segment IA 01-NEM-0060_1:** A3: Children's contact recreation **Segment IA 01-NEM-0060_2:** A3: Children's contact recreation **Pheasant Creek:** A3: Children's contact recreation **Goose Creek:** Presumptive A1: Primary contact recreation **Silver Creek:** A3: Children's contact recreation
TMDL priority level:	Low
Identification of the pollutant and applicable water quality standards:	Indicator bacteria (*E. coli*) – *E. coli* concentrations exceed the Class A1/A3 criteria of single-sample maximum of 235 colony forming units per 100 milliliters (cfu/100 mL) and geometric mean (5 samples in 30 days) of 126 cfu/100 mL. These standards apply only during the recreation season (March 15 to November 15).
Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	See Tables 3-5 through 3-7 in Section 3.2. and Tables 4-3 through 4-5 in Section 4.2.
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:	See Tables 3-11 through 3-13 in Section 3.3. and Tables 4-9 through 4-11 in Section 4.3.

Identification of pollution source categories:	Point sources of bacteria include municipal separate storm sewer systems (MS4s) in the cities of Davenport and Bettendorf, three wastewater treatment facilities (WWTFs), onsite wastewater systems operating under NPDES permits, and sanitary sewer overflows (SSOs) from Davenport's sanitary sewer system. Nonpoint sources of pollution include cattle with direct access to streams, manure application to row crops, pet waste, non-permitted onsite wastewater treatment systems, and wildlife.
Wasteload allocations for pollutants from point sources:	See Tables 3-19 through 3-21 in Section 3.6 and Tables 4-13 through 4-15 in Section 4.6.
Load allocations for pollutants from nonpoint sources:	See Tables 3-19 through 3-21 in Section 3.6 and Tables 4-13 through 4-15 in Section 4.6.
A margin of safety:	See Tables 3-19 through 3-21 in Section 3.6 and Tables 4-13 through 4-15 in Section 4.6.
Consideration of seasonal variation:	The TMDLs are applicable during the recreation season, which runs from March 15 to November 15. Allocations are developed for a range of flow conditions, which help account for wet and dry periods within the recreation season.

Reasonable assurance that load and wasteload allocations will be met:	For point sources, reasonable assurance is provided through NPDES permits. For nonpoint sources, reasonable assurance is provided by: (1) planned implementation activities that address the pollutant of concern, (2) local stakeholders already planning for implementation, (3) development of detailed requirements for watershed planning to ensure that 319 applications meet EPA requirements, and (4) ongoing monetary support for nonpoint source pollution reduction. See Section 3.5 for more detailed discussion of reasonable assurance.
Allowance for reasonably foreseeable increases in pollutant loads:	There are no allowances for future increases to pollutant loads.
Implementation plan:	An implementation plan is outlined in Section 5 of this Water Quality Improvement Plan. The reduction of *E. coli* loads to Duck Creek will be accomplished through a combination of land use, livestock, manure, stormwater, and wastewater management strategies.

1. Introduction

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

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

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

One purpose of this Water Quality Improvement Plan (WQIP) for Duck Creek is to provide the TMDL for *E. coli* and satisfy the requirements of the Clean Water Act. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, assist the development of funding applications and a comprehensive watershed management plan, and guide water quality improvement efforts.

The WQIP outlines a phased approach to TMDL development and implementation. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict. The WQIP includes an assessment of the existing *E. coli* loads to Duck Creek and a determination of how much *E. coli* the stream can tolerate and still provide for primary contact and children's recreation. The allowable amount of pollutant that the waterbody can receive is the loading capacity, also called the TMDL target. The WQIP also includes a description of potential solutions to the water quality problems. This group of solutions forms an implementation strategy that includes best management practices (BMPs) to improve water quality in Duck Creek. The ultimate goal is to attain WQS and support designated uses. Potential BMPs are outlined in the implementation plan in Section 5.

The WQIP will be of little value to real water quality improvement unless watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and the collaboration of several state and local agencies. In addition to implementation of BMPs, completion of the TMDL must be followed by several other actions, including collection of water quality data as part of the ongoing monitoring plan, evaluation of collected data, and modification of the TMDL targets and/or implementation plan (if necessary). Monitoring is a crucial element to assess the attainment of water quality standards and designated uses, to determine if water quality is improving, degrading, or unchanged, and to assess the effectiveness of implementation activities and the possible need for additional BMPs. A water quality monitoring plan designed to help assess water quality improvement and BMP effectiveness is provided in Section 6.

2. Description and History of Duck Creek

The headwaters of Duck Creek form west of Davenport in rural Scott County west of Interstate 280. The creek runs from west to east, and flows through the cities of Davenport and Bettendorf, before discharging to the Mississippi River. In the 1830's, a saw mill was located near the mouth of Duck Creek, in what was then called the Pleasant Valley Township. The mill no longer exists, and the primary benefits Duck Creek provides today include recreation, aquatic and riparian wildlife habitat, aesthetic qualities, and storm drainage. Evidence of humans, especially children, recreating in and near the stream is commonly observed along Duck Creek. Duck Creek Parkway, a multiple-use paved trail system, runs along Duck Creek for over eight miles, connecting the cities of Davenport and Bettendorf. Davenport and Bettendorf comprise Iowa's portion of the Quad Cities, one of Iowa's larger urban metropolitan areas. Table 2-1 reports some characteristics of Duck Creek, names its major tributaries, and describes its designated uses.

Table 2-1. Duck Creek watershed and stream characteristics.

IDNR Waterbody ID	IA 01-NEM-0060_1 & IA 01-NEM-0060_2
8 Digit Hydrologic Unit Code (HUC)	07080101
8 Digit HUC Name	Copperas-Duck
Location	South of I-80 and west of I-280 in rural Scott County; south of I-80 and east of I-280 in Davenport and Bettendorf, Iowa.
Designated Uses	A1 – primary contact recreation (per 2006 and 2008 305(b) assessments) A2 and A3 – secondary contact and children's recreation, respectively (per 2008 UAAs) B(WW2) – aquatic life (warm water) HH – human health/fish consumption
Tributaries	Silver Creek, Pheasant Creek, Goose Creek, Candlelight Creek, Stafford Creek, Robin Creek, and several unnamed tributaries.
Receiving Waterbody	Mississippi River

2.1. Duck Creek

Hydrology
Duck Creek is a perennial stream that lies within the Copperas-Duck Hydrologic Unit Code eight-digit watershed (HUC-8). The Duck Creek watershed includes over eighty miles of streams, with Duck Creek having a total stream length of approximately 19 miles. Major tributaries to Duck Creek include Silver Creek, Goose Creek, and Pheasant Creek. A number of smaller streams also contribute flows, including Stafford Creek, Candlelight Creek, Robin Creek, and several unnamed tributaries. A map of the watershed is provided in Figure 2-1.

The hydrology of Duck Creek has been altered significantly since the 1930s, as the urban area of the watershed has grown and impervious land cover increased. During this same period, stream channelization occurred (in addition to earlier channelization), which also affects stream hydrology. Consequently, the stream exhibits "flashy" hydrologic behavior, and is prone to large and quick increases in flow during moderate rainfall events. The U.S. Geological Survey (USGS) maintains two stream gages on the main stem of Duck Creek. Stream gage information is reported in Table 2-2. Water quality monitoring site DC-16 is located at USGS Station 05422560, and site DC-10 is located at Station 05422600. USGS gage locations are shown in Figure 2-1.

Table 2-2. USGS stream gage information for Duck Creek.

Station Number	05422560	05422600
Station Name	Duck Creek at 110th Ave at Davenport, IA	Duck Creek at DC Golf Course at Davenport, IA
Latitude	41°33'24"	41°32'46"
Longitude	90°41'15"	90°31'26"
Datum Elev (ft - NGVD29)	659.00	597.00
Drainage Area (sq mi)	16.1	57.3
Discharge Begin Date	03/29/1994	11/24/1993
Discharge End Date	Ongoing	Ongoing
Precipitation Begin Date	06/30/2005	04/03/1999
Precipitation End Date	09/30/2005	08/15/2004
Gage Height Begin Date	10/01/2004	10/01/2004
Gage Height End Date	Ongoing	Ongoing

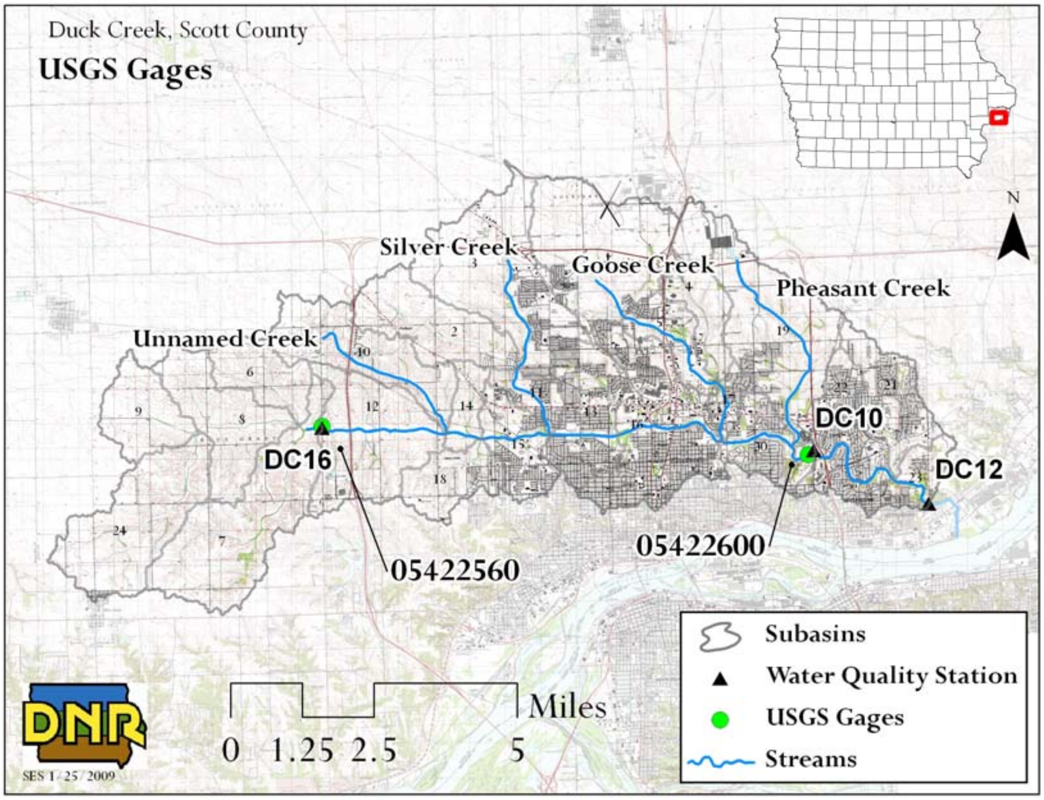

Figure 2-1. Aerial photography of the Duck Creek watershed.

There are two weather stations within 14 miles of the Duck Creek watershed for which a long record of daily precipitation data is available through the Iowa Environmental Mesonet (IEM). National Weather Service (NWS) COOP stations from which precipitation data were obtained are located at LeClaire (Station IA4705) and Muscatine (Station IA5837). The Thiessen polygon method was utilized to develop an area-weighted precipitation data set based on these two stations. This data set provided the strongest correlation to observed flows at the USGS gage stations (compared to either station individually or other sources of precipitation data). Weather station information is provided in Table 2-3, and annual precipitation from 1994-2008 is illustrated in Figure 2-2. The Thiessen polygon method precipitation used in the watershed model is plotted with observed flow in Figure 2-3.

Table 2-3. Weather station information for LeClaire and Muscatine, Iowa.

IEM Station ID	IA4705	IA5837
Station Name	LeClaire	Muscatine
Latitude	41.57	41.4
Longitude	-90.40	-91.07
Miles from watershed	4.6	13.5
Average Annual Precipitation (1994-2008)	34.4 inches	36.5 inches

Source (IEM, 2009)

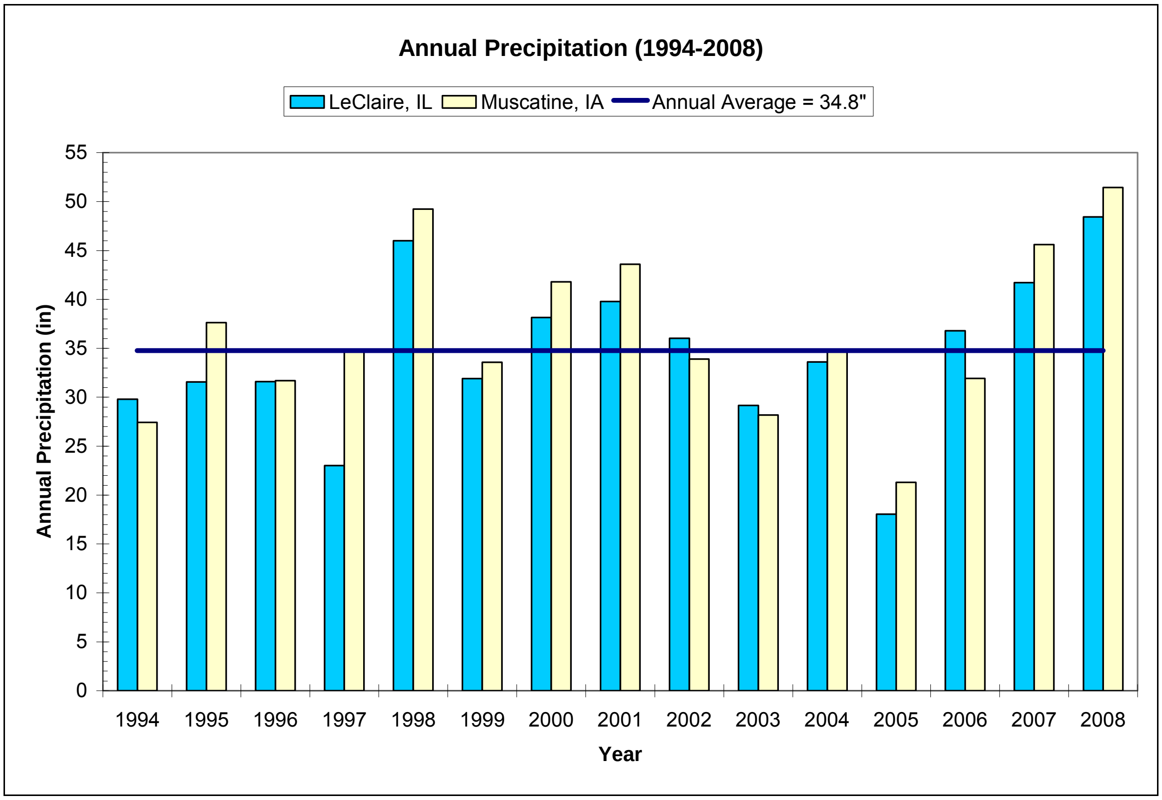

Figure 2-2. Annual precipitation LeClaire and Muscatine, Iowa.

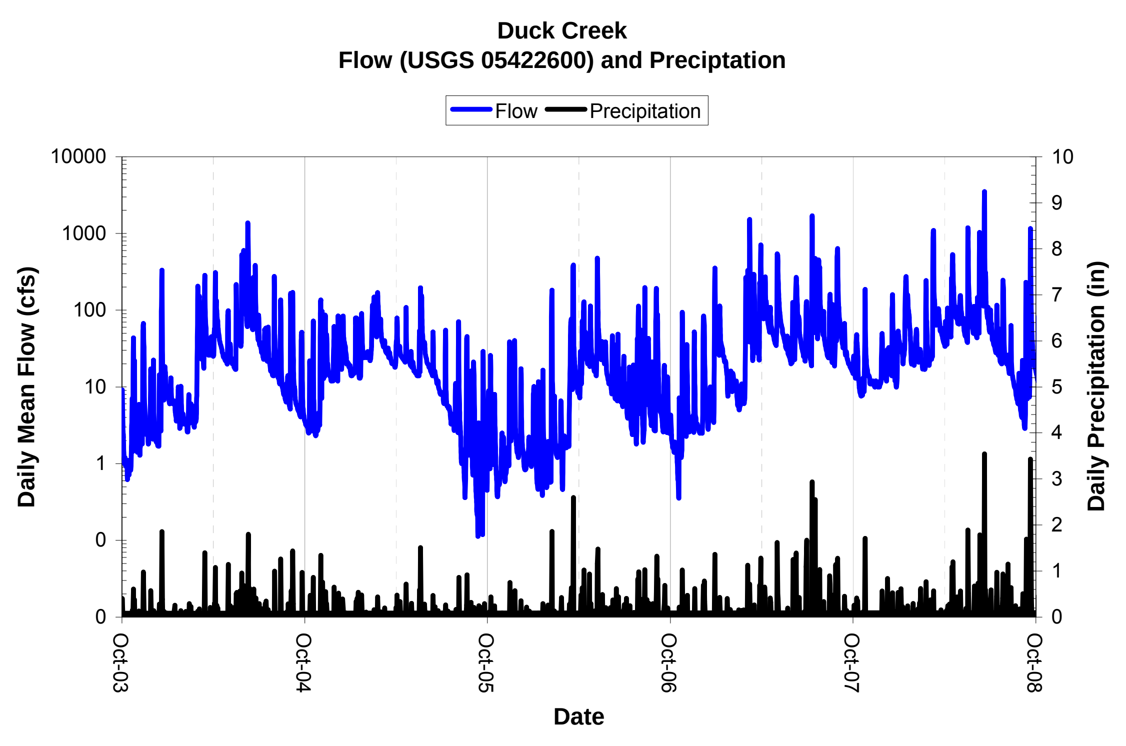

Figure 2-3. Precipitation and flow for water years 2004 through 2008.

Figures 2-4 and 2-5 show the daily mean stream flow and baseflow for both USGS gage stations, and Figures 2-6 and 2-7 illustrate flow duration curves. Baseflow separation was estimated using the recursive digital filter method (Eckhardt, 2005) available through a Web based Hydrograph Analysis Tool (WHAT) (Lim et al., 2005) and USGS gage data.

Station 05422560 is in the rural portion of the watershed, approximately 0.5 miles west of Interstate 280. Station 05422600 is over nine stream miles downstream of Station 05422560, has a significantly larger drainage area, and higher peak flows. A comparision of the data at both stations reveals that the downstream station exhibits more flashy behavior than the upstream station. Differences in localized rainfall patterns and the influence of urban land, which is highly impervious, may account for the more volatile fluctuations in flow at this station.

The flow duration plots (Figures 2-6 and 2-7) include curves for total stream flow, runoff, and baseflow. Baseflow comprises approximately 45 percent of the mean annual flow in Duck Creek, and exceeds runoff approximately 78 percent of the time (about 285 days in a typical year). It should be noted that baseflow could include flows from groundwater seepage, improperly functioning onsite wastewater treatment systems, discharging wastewater lagoons, leaking sewer systems, illicit connections, and irrigation/sprinkler runoff.

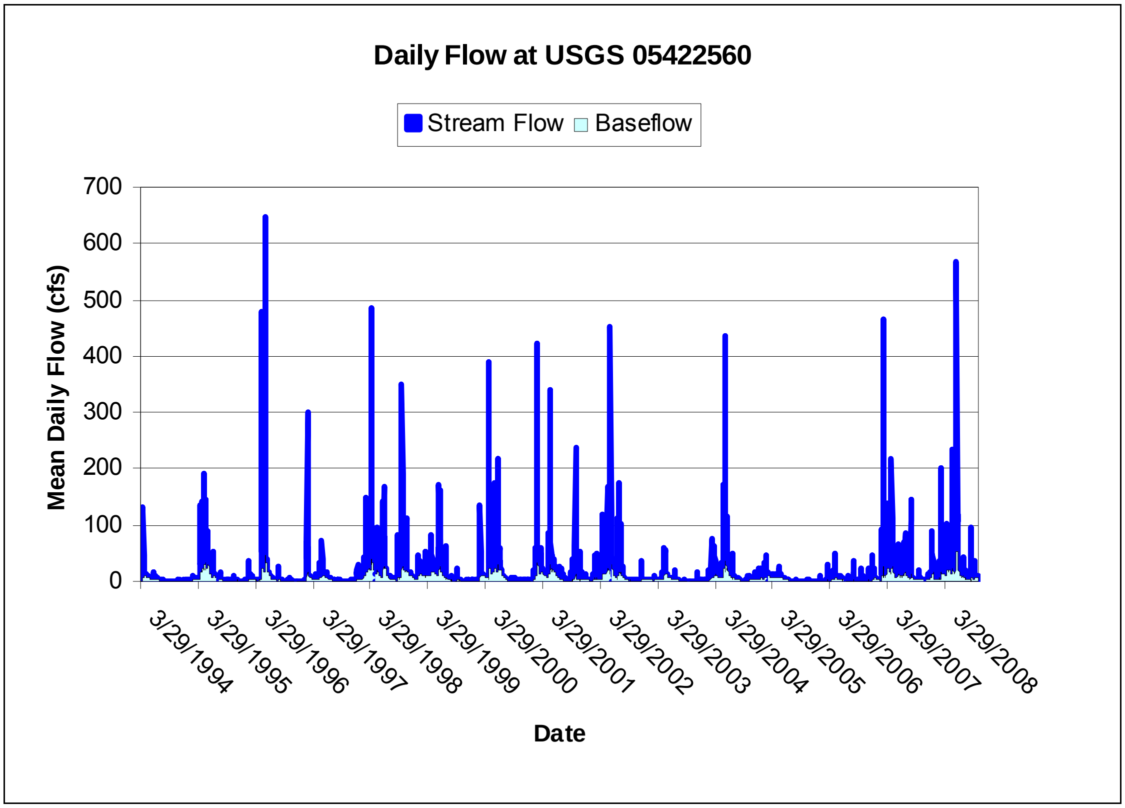

Figure 2-4. Daily flows at Station 05422560 (DC-16) from 1994 through 2008.

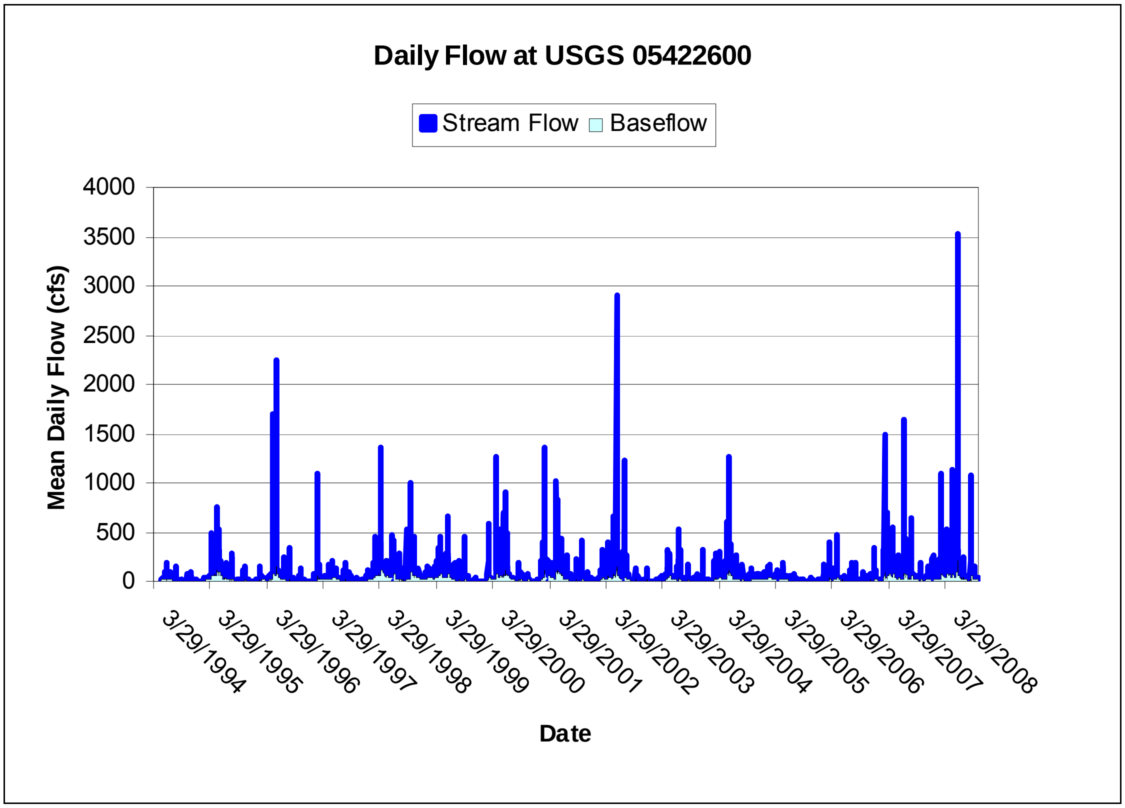

Figure 2-5. Daily flows at Station 05422600 (DC-10) from 1994 through 2008.

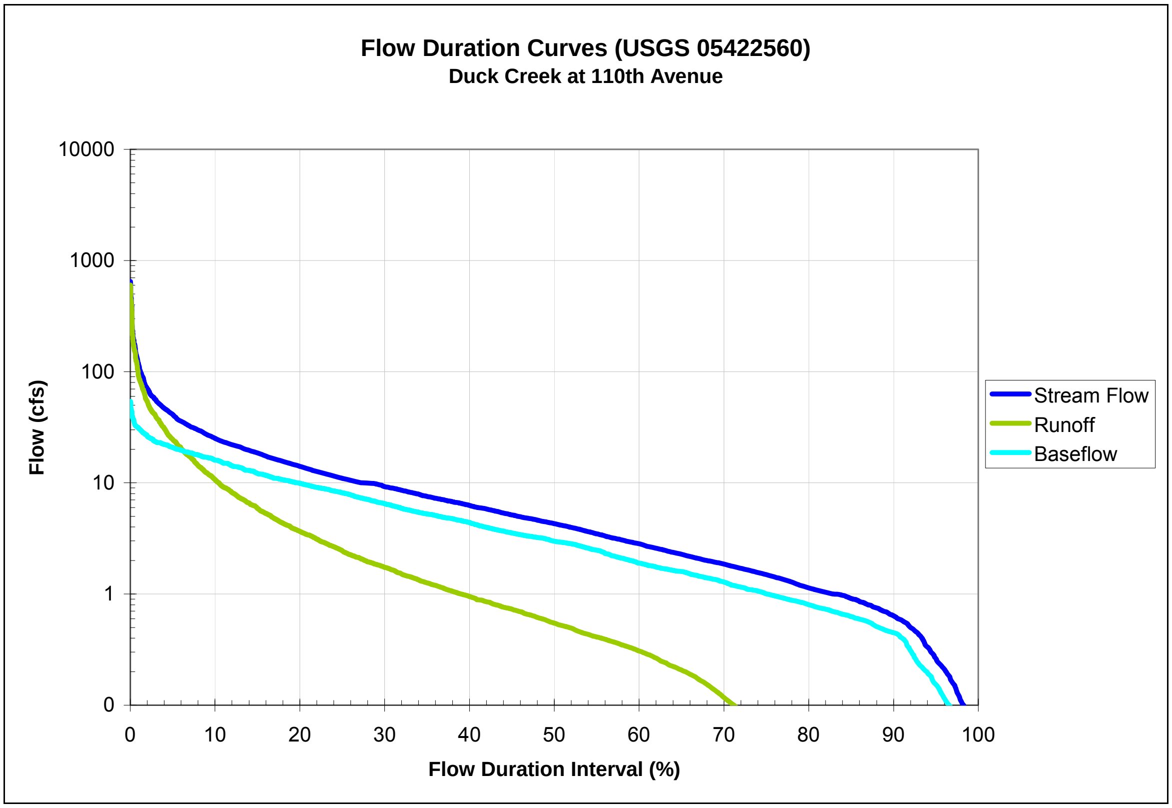

Figure 2-6. Flow duration curve for Station 05422560 (DC-16).

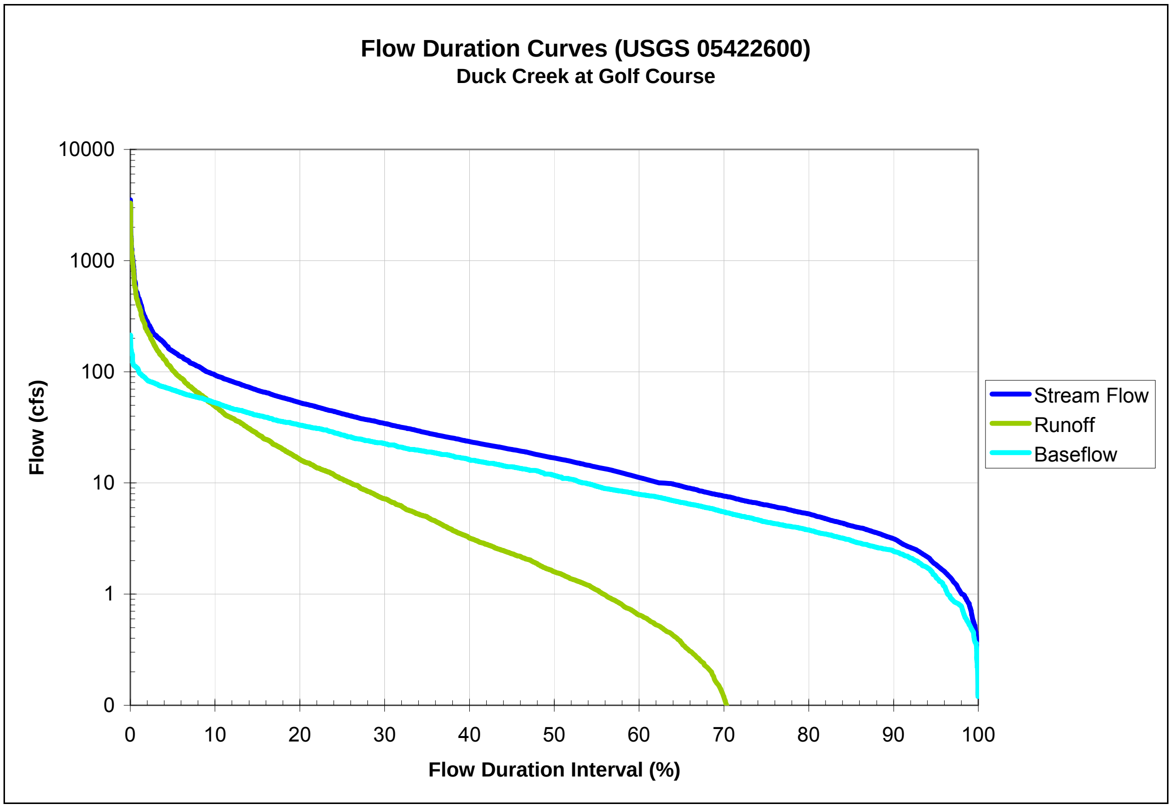

Figure 2-7. Flow duration curve for Station 05422600 (DC-10).

Morphometry and Substrate
The geomorphic characteristics of Duck Creek have been altered since pre-settlement conditions. In the agricultural portion of the watershed, the stream is highly channelized, with little to no undisturbed meandering reaches remaining. A majority of the stream within the urbanized area also exhibits a high degree of channelization. This is because much of the land adjacent to Duck Creek has transitioned from agricultural to urban land uses the past 50 years, and significant channelization occurred while the land was in agricultural production. Additionally, urban development frequently results in stream channelization for the purposes of flood reduction and construction of urban infrastructure (roads, bridges, properties, etc.).

Stream channelization and the construction of artificial drainage pathways (drain tiles, storm sewers, and concrete lined channels) have increased stream erosion in Duck Creek and its tributaries. As a result, there are a number of reaches in which the stream banks are incised and unstable, and where the channel is significantly degraded. In some cases, sediment deposition (channel aggradation) is occurring, which results in substrate dominated by silt deposits that can embed underlying rocks and gravel and reduce ecological diversity of the stream. The geology of the watershed is dominated by glacial outwash materials and dolomite, shale, and limestone bedrock. Outcroppings of the underlying bedrock are visible in a number of locations towards the downstream end of Duck Creek.

2.2. The Duck Creek Watershed

Land Use
The Duck Creek watershed is nearly evenly divided among rural and urban land uses, with the upstream (west) half of the watershed in agricultural uses and the downstream (east) half in urban areas. The total drainage area of the watershed to the confluence with the Mississippi River is approximately 64 square miles (40,786 acres). Land cover information from the 2002 statewide database was used as baseline data. Table 2-4 reports generalized land uses by acre and relative percentage of watershed area. Figure 2-8 illustrates the distribution of the various land uses throughout the Duck Creek watershed, and Figure 2-9 shows land cover breakdown in pie-chart form.

Table 2-4. Generalized land use composition of the Duck Creek watershed.

General Land Use	Description	Acres	%
Row Crops	Corn, soybeans, and other	16,499	40.4
Grassland	Ungrazed grassland and CRP	8,769	21.5
Residential	--	4,716	11.6
Roads	--	3,360	8.2
Commercial/Industrial	--	2,764	6.8
Timber	Coniferous and deciduous forest	2,197	5.4
Pasture	Grazed grassland	1,798	4.4
Water/Wetlands	Ponds, wetlands, etc.	224	0.6
Other	Alfalfa and barren land	459	1.1
Total		**40,786**	**100**

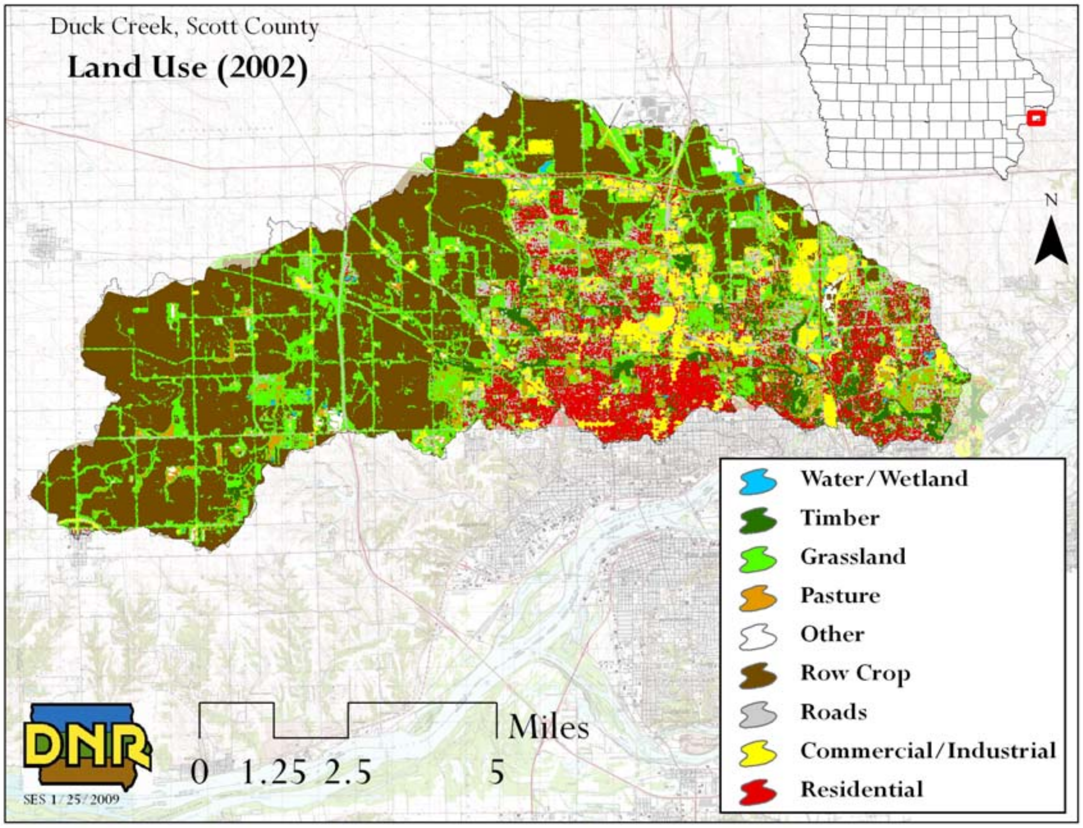

Figure 2-8. Land cover distribution in the Duck Creek watershed.

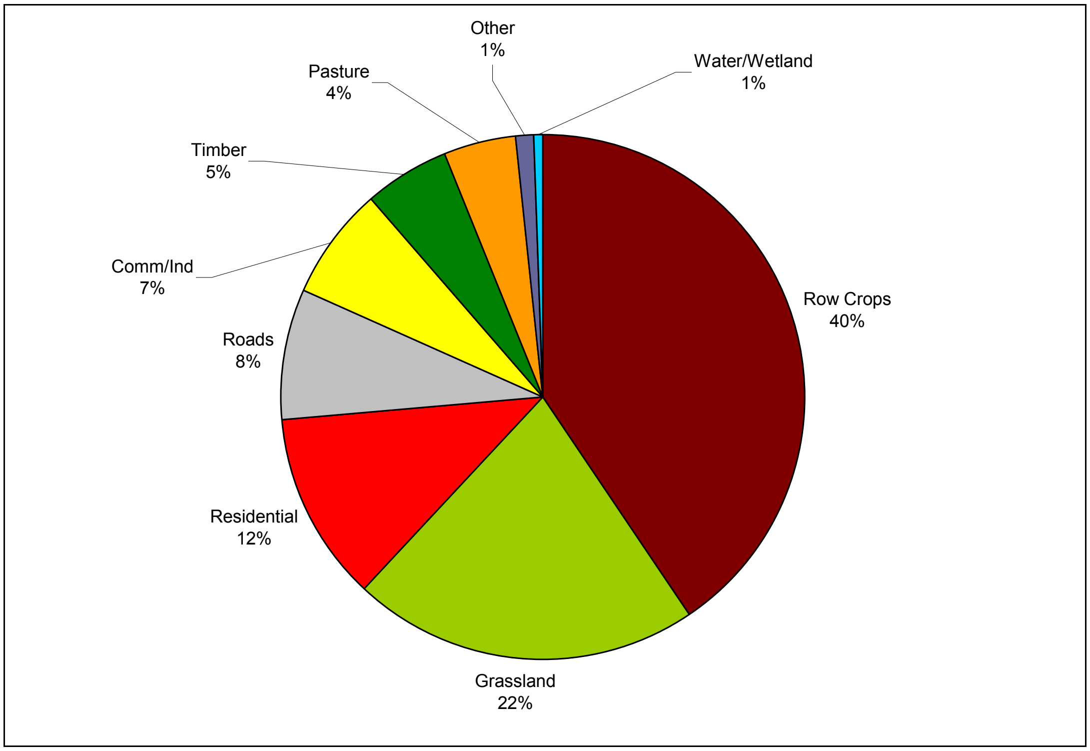

Figure 2-9. Relative breakdown (by percent) of land cover.

Soils, Climate, and Topography

The landscape of the Duck Creek watershed is characterized by outcroppings of bedrock, steep side slopes, and narrow stretches of bottom land. The upland portions of the watershed include glacial till plains covered with loess. Three soil associations are present in the watershed: the Tama, Muscatine-Tama-Garwin, and Downs-Fayette associations. Of these, Tama comprises the largest portion of the watershed.

The Tama association is characterized by gentle to moderately steep slopes, well drained soils in loess, and is found primarily in upland areas. The Muscatine-Tama-Garwin association is also found in upland areas on nearly level to moderately steep slopes, and includes areas of both well drained and poorly drained soils. The Downs-Fayette association includes gentle to very steep slopes, and is generally well-drained. Table 2-5 describes the six most common (comprising the largest area) minor soil types in the watershed.

Table 2-5. Predominant soils in the Duck Creek watershed.

Soil Name	Watershed Area (%)	Description	Typical Slopes (%)
Tama	37	Silty clay loam, dark brown, well drained	2-5
Downs	28	Silt loam, dark grayish brown, well drained	2-5
Muscatine	13	Silty clay loam, dark grayish brown, poorly drained	0-2
Killduff	7	Silty clay loam, dark brown, moderately well drained	5-14
Ackmore	3	Silt loam, dark grayish brown, somewhat poorly drained	0-5
Garwin	4	Silty clay loam, black to very dark gray, poorly drained	0-2

Source: USDA-NRCS, 1996

3. Total Maximum Daily Load (TMDL) for *E. coli* in Duck Creek

A Total Maximum Daily Load (TMDL) is required for Duck Creek by the Federal Clean Water Act. This chapter quantifies the maximum amount of *Escherichia coli (E. coli)* that Duck Creek can tolerate without violating the state's water quality standards.

3.1 Problem Identification

Stream Segment Designations
Prior to the 2008 Section 305(b) water quality assessment, the downstream segment of Duck Creek (IA 01-NEM-0060_1) was designated for Class A1 (primary contact recreation) and Class B(LR) aquatic life uses. Upon changes in Iowa's surface water classification that were approved by EPA in February of 2008, the aquatic life use was reclassified as Class B(WW2).

Prior to the 2008 305(b) assessment, the upstream segment of Duck Creek (IA 01-NEM-0060_2) was designated only for Class B(LR) aquatic life uses. Due to the changes in Iowa's surface water classification described above, this segment became presumptively designated for Class A1 (primary contact recreation) uses. The upstream segment remains designated for aquatic life, which is now termed Class B(WW2).

To further confound matters, a Use Attainability Analysis (UAA) was conducted on Duck Creek in 2008. Based on the findings of the UAA, the designated recreational use in the downstream segment (IA 01-NEM-0060_1) was changed from Class A1 (primary contact recreation) to Class A3 (children's recreation). The UAA split the upstream segment (IA 01-NEM-0060_2) into Class A3 and Class A2 (secondary contact recreation) uses. Additionally, there are differences in the stream segment boundaries used in the 305(b) assessments and the UAA. Figure 3-1 illustrates the stream segments and designated uses as defined in the 2008 305(b) assessment, whereas Figure 3-2 illustrates the segments and uses defined in the UAA. As of December, 2009, only the change in segmentation and proposed Class A3 designated uses of the UAA have been approved by EPA (EPA, 2009).

The TMDLs for Duck Creek included in this Water Quality Improvement Plan (WQIP) were developed using the stream segments and designated uses as defined in the 2008 305(b) assessment. However, loads allocated in this TMDL are applicable to segments and designated uses defined in the UAA as well. Table 3-1 summarizes the segments and designated uses as defined in the TMDL and 305(b) assessment, compared with segments and uses defined in the UAA.

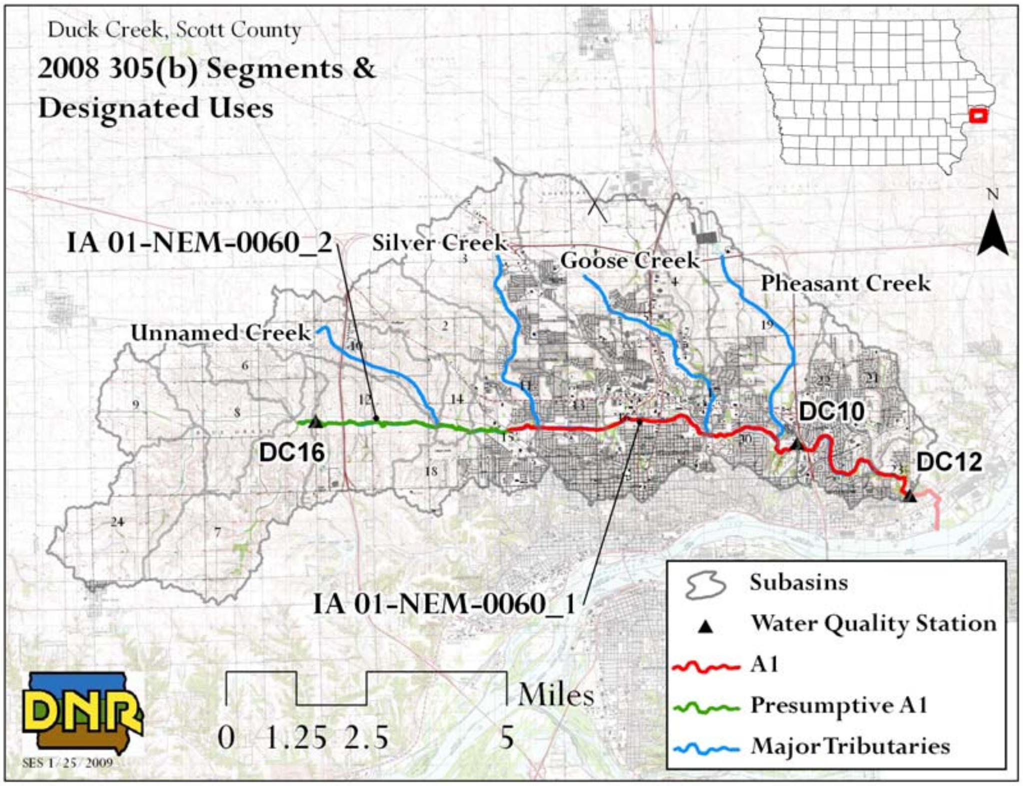

Figure 3-1. Duck Creek segmentation and designated uses per 2008 305(b).

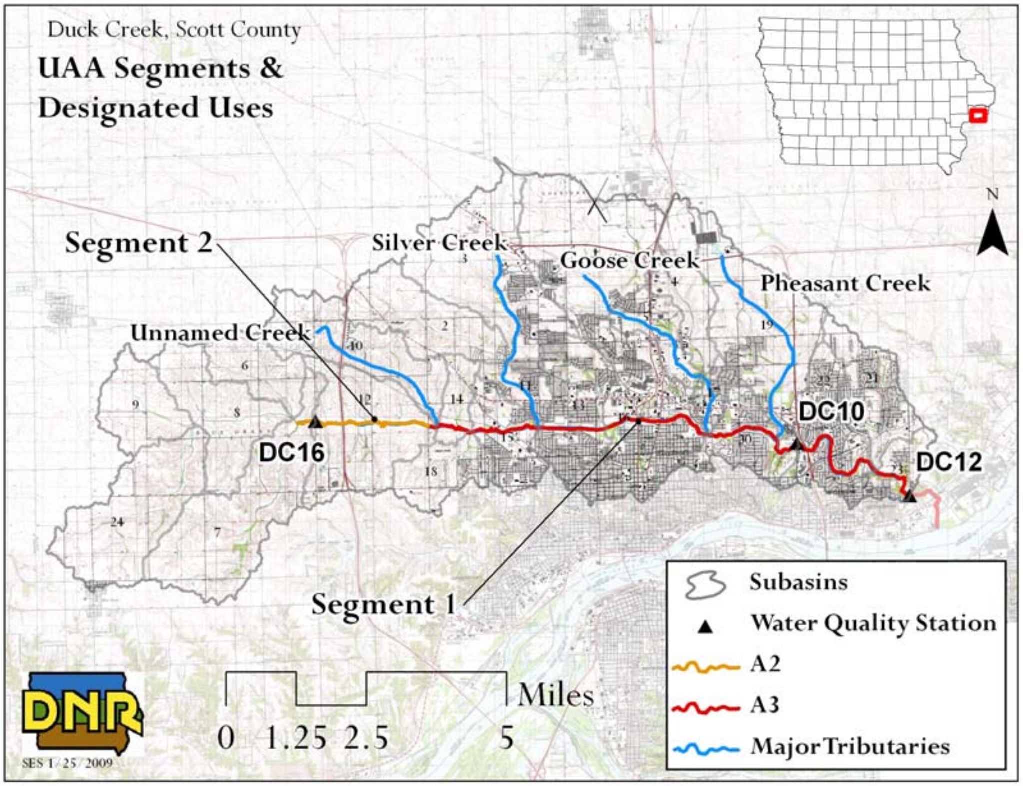

Figure 3-2. Duck Creek segmentation and designated uses per the UAA.

Table 3-1. Stream segmentation and designated use classifications.

Segment	Location Description	Designated Uses
2008 305(b)		
IA 01-NEM-0060_1 (Downstream)	From mouth at Mississippi River (S27, T78N, R4E) upstream to Hickory Grove Road (S16/21, T78N, R3E)	Class A1 Class B(WW2) Class HH
IA 01-NEM-0060_2 (Upstream)	From Hickory Grove upstream to unnamed tributary (SE ¼ S14, T78N, R2E)	Presumptive A1 Class B(WW2)
UAA		
Segment 1 (Downstream)	From mouth at Mississippi River upstream to Wisconsin Avenue (S17/S18, T78N, R3E)	Class A3 Class B(WW2) Class HH
Segment 2 (Upstream)	From Wisconsin Avenue to confluence with Unnamed Creek (SE ¼ S14, T78N, R2E)	Class A2 Class B(WW2)

Applicable Water Quality Standards

The applicable water quality standards from the Iowa Administrative Code (IAC) for the impairments to primary contact and children's recreation in Duck Creek are reported in Table 3-2. The criteria for the Class A3 use (as determined by the UAA) are the same as for Class A1. The upstream segment (Segment 2) in the UAA was designated for Class A2 use. However, the short stream distance and travel time to the downstream segment would require *E. coli* levels in the A2 segment to comply with Class A1 and A3 criteria.

Table 3-2. Bacteria criteria table reproduced from IAC Chapter 61.

Designated Use	Geometric Mean	Single-Sample Maximum
Class A1		
March 15 to Nov 15	126 cfu/100 mL	235 cfu/100 mL
Nov 15 to March 14	Does not apply	Does not apply
Class A2		
March 15 to Nov 15	630 cfu/100 mL	2,880 cfu/100 mL
Nov 15 to March 14	Does not apply	Does not apply
Class A3		
March 15 to Nov 15	126 cfu/100 mL	235 cfu/100 mL
Nov 15 to March 14	Does not apply	Does not apply

According to Iowa water quality standards, in addition to a maximum daily load based on the single-sample maximum (SSM) criterion of 235 cfs/100 mL, all facilities operating under an NPDES permit must meet the 30-day geometric mean (GM) *E. coli* concentration of 126 cfu/100ml. The GM is used instead of an arithmetic mean because it handles highly skewed data or data with large variation/outliers better. The observed GM is calculated based on the following permitting protocols for bacteria monitoring:

- All facilities must collect and analyze a minimum of five *E. coli* samples in one calendar month during each three-month period during the appropriate recreation season associated with the receiving stream designation,
- Samples must be spaced over one calendar month,
- No more that one sample can be collected on any one day,
- There must be a minimum of two days between each sample, and
- No more than two samples may be collected in a period of seven consecutive days.
- The geometric mean must be calculated using all valid sample results collected during a month. The geometric mean formula is as follows:

  Geometric Mean = (Sample 1*Sample 2*Sample3*…SampleN) (1/N), where N is the number of samples collected over given sampling period.

Problem Statement

The 2006 and 2008 Section 305(b) water quality assessments state that primary contact recreation in Segment IA 01-NEM-0060_1 of Duck Creek is “not supported” due to high levels of indicator bacteria (*E. coli)* that routinely violated state water quality standards. The 2008 305(b) assessment also states the same for the presumptive Class A1 use for Segment IA 01-NEM-0060_2 (the next segment upstream). Excerpts from the Section 305(b) water quality assessments relevant to the bacteria impairments on Duck Creek are provided in Appendix G. The assessments can be viewed in their entirety at the following web address: http://programs.iowadnr.gov/adbnet/index.aspx

The significance of the impairments noted in the assessments is that desireable recreational activities, such as swimming and wading, are not adequately provided by existing water quality in Duck Creek. As a result of these findings, the Federal Clean Water Act requires that TMDLs be developed in all impaired segments for *E. coli*, the pollutant causing the impairments.

The remainder of this section addresses the impairments caused by *E. coli* and discusses the development of subsequent TMDLs. The TMDLs are based on stream segments and designated uses described in the 2008 305(b) assessment. It is expected that these TMDLs will apply, as written, to the UAA segments when the UAA is fully approved by EPA and/or when future 305(b) assessments are completed by IDNR. Proposed Class A3 uses were approved in May of 2009 (EPA, 2009).

Data Sources

The primary sources of water quality data used in the development of this TMDL are the 2008 305(b) assessment and water quality data collected by IDNR, UHL, and the Davenport Water Pollution Control Plant. Scott County Snapshot data collected through the IOWATER monitoring program were also utilized. These data consist primarily of grab samples collected by the aforementioned organizations during the recreation season (March 15 to April 15) from 2003 to 2008.

Non-water quality related data was also utilized in the development of this TMDL for Duck Creek. The following list summarizes sources of these data:

- Land cover data from 2002 statewide database
- Land cover data collected by the Scott County SWCD in 2008
- Stream and watershed assessment data collected by the Scott County SWCD in 2008
- Climate data from the Iowa Environmental Mesonet (IEM)
- In-stream flow data from USGS Gage Stations 05422560 and 05422600
- Manure management plans (MMPs) obtained from IDNR field offices
- Soils data from the state's SSURGO database and USDA-NRCS Soil Survey of Scott County

Interpreting Duck Creek Data

Figure 3-3 shows observed *E. coli* concentrations in Duck Creek at three monitoring locations from 2003 through 2008. The data clearly reveal frequent violations of the SSM criterion of 235 cfu/100 mL at all three locations. Figure 3-4 illustrates the running 30-day GM for all three stations. This plot reveals continuous violation of the GM criterion throughout the 2008 sampling season at all three locations.

Figure 3-5 shows the probability exceedance curves for each station on Duck Creek. This curve illustrates the percent of time that given *E. coli* concentrations are exceeded, and provides graphic analysis of the frequency of water quality standard violations in Duck Creek. The SSM is exceeded in 91.8 percent of samples at 100th Avenue (DC-16), 96.9 percent of samples at the Duck Creek Golf Course (DC-10), and 83.5 percent of samples at Devils Glen Road (DC-12).

Analysis of the data plotted in Figures 3-3 through 3-5 shows consistently high *E. coli* levels that significantly exceed both criteria set forth in Iowa's water quality standards for primary contact recreation. Significant reductions in *E. coli* loading will be required to comply with the standards and fully support Duck Creek's designated recreation use.

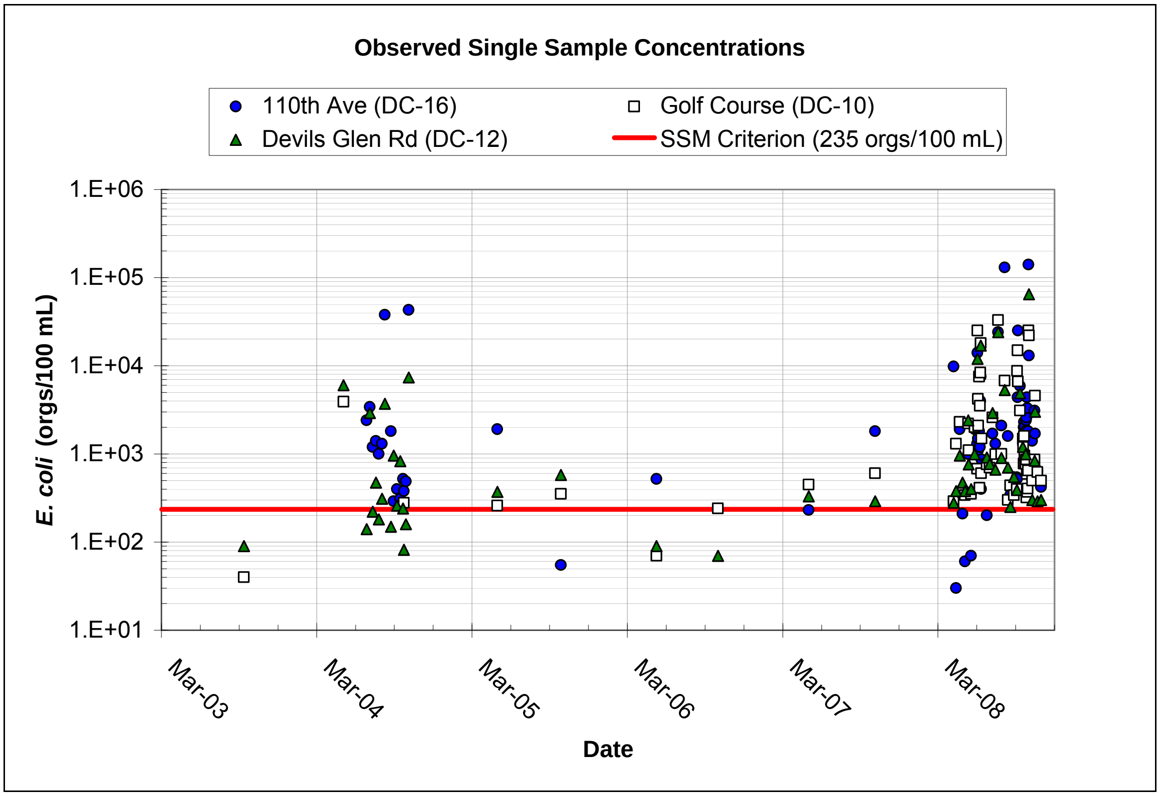

Figure 3-3. Observed single sample *E. coli* concentrations from 2003-2008.

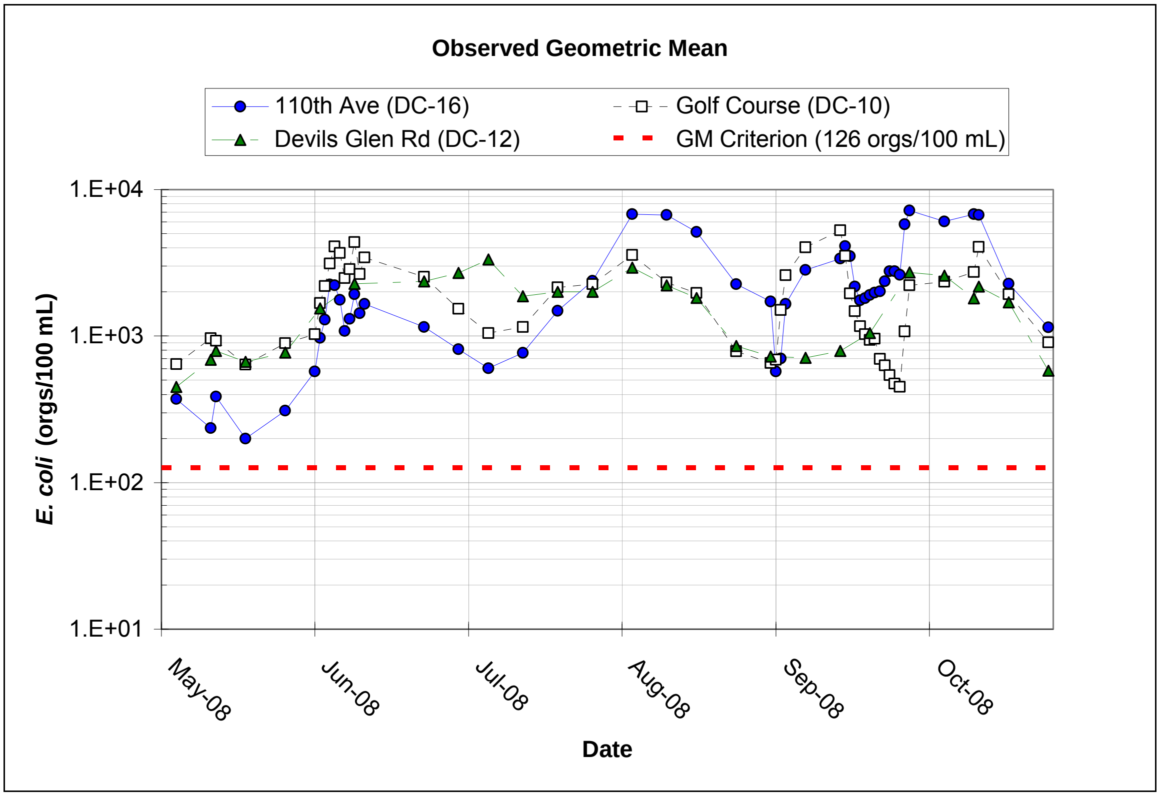

Figure 3-4. Measured 30-day geometric mean concentrations observed in 2008.

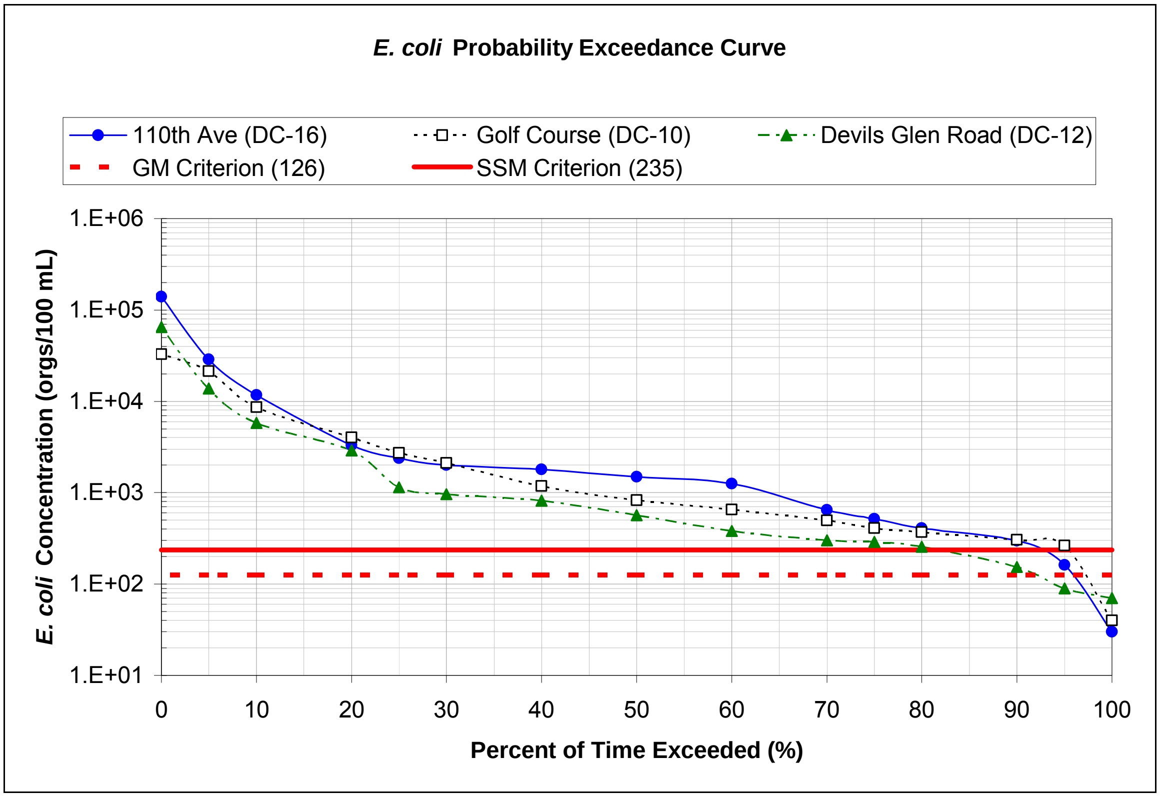

Figure 3-5. *E. coli* probability exceedance curve for data collected in 2003-2008.

Daily *E. coli* samples were collected and analyzed for one 10-day and one 14-day period in 2008 to evaluate *E. coli* levels during both wet and dry conditions. Figure 3-6 shows daily flow and *E. coli* concentration during wet weather conditions in June. Flow and concentration during dry weather in September is plotted in Figure 3-7. Several observations can be made from these plots.

First, *E. coli* concentrations were generally higher during wet weather. The median concentration ranged from 1,300 orgs/100 mL at DC-16 to 3,700 orgs/100 mL at DC-12 during the wet weather sampling, whereas median concentrations ranged between 630 orgs/100 mL at DC-12 and 2,000 orgs/100 mL at DC-16 during the September sampling. Second, there appears to be a first flush effect at the end of September when a runoff event followed 13 days of dry weather (see Figure 3-7). *E. coli* concentrations appear to be correlated to flow; however, it is not safe to assume that the observations made in these two periods adequately describe water quality trends over the broad range of conditions occurring in Duck Creek.

Data used in Figures 3-3 through 3-7 were collected by the Partners of Scott County Watersheds in 2003-2008, the Davenport Water Pollution Control Plant as part of the 2004 Midwest Bacteria Project, and UHL and Scott County SWCD in 2008.

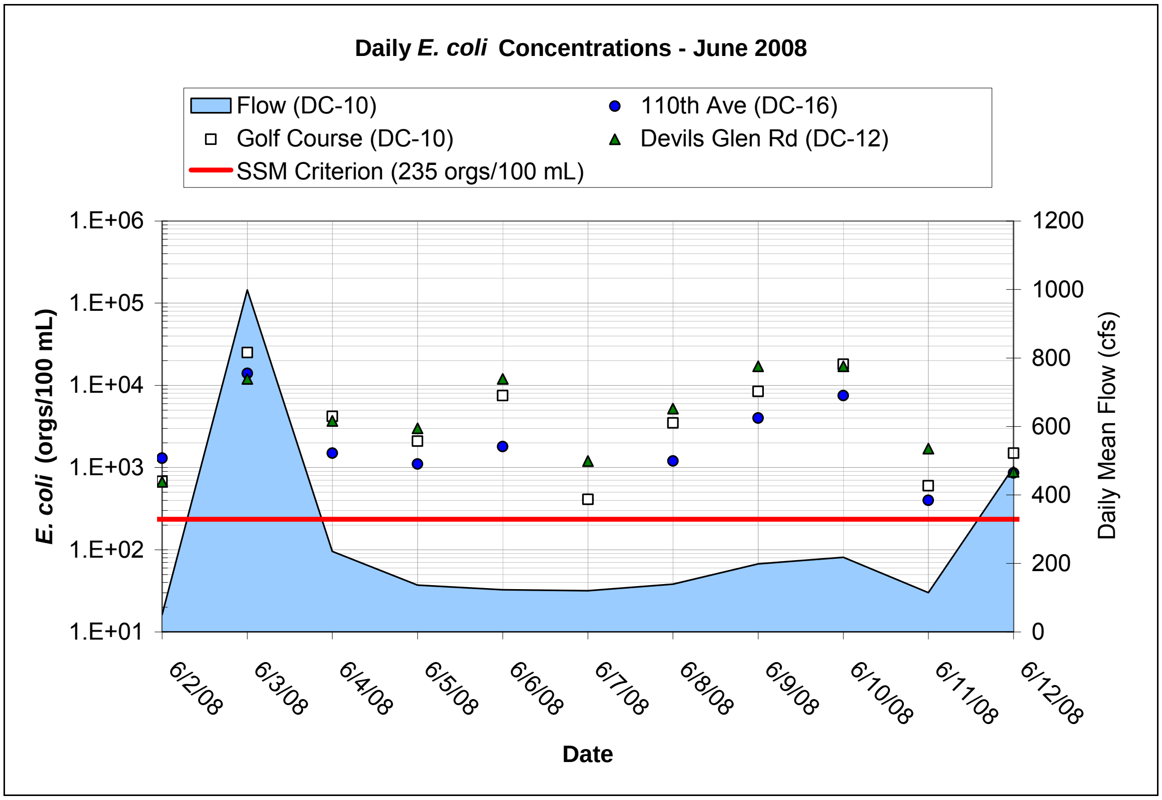

Figure 3-6. Daily *E. coli* concentrations during wet conditions in June 2008.

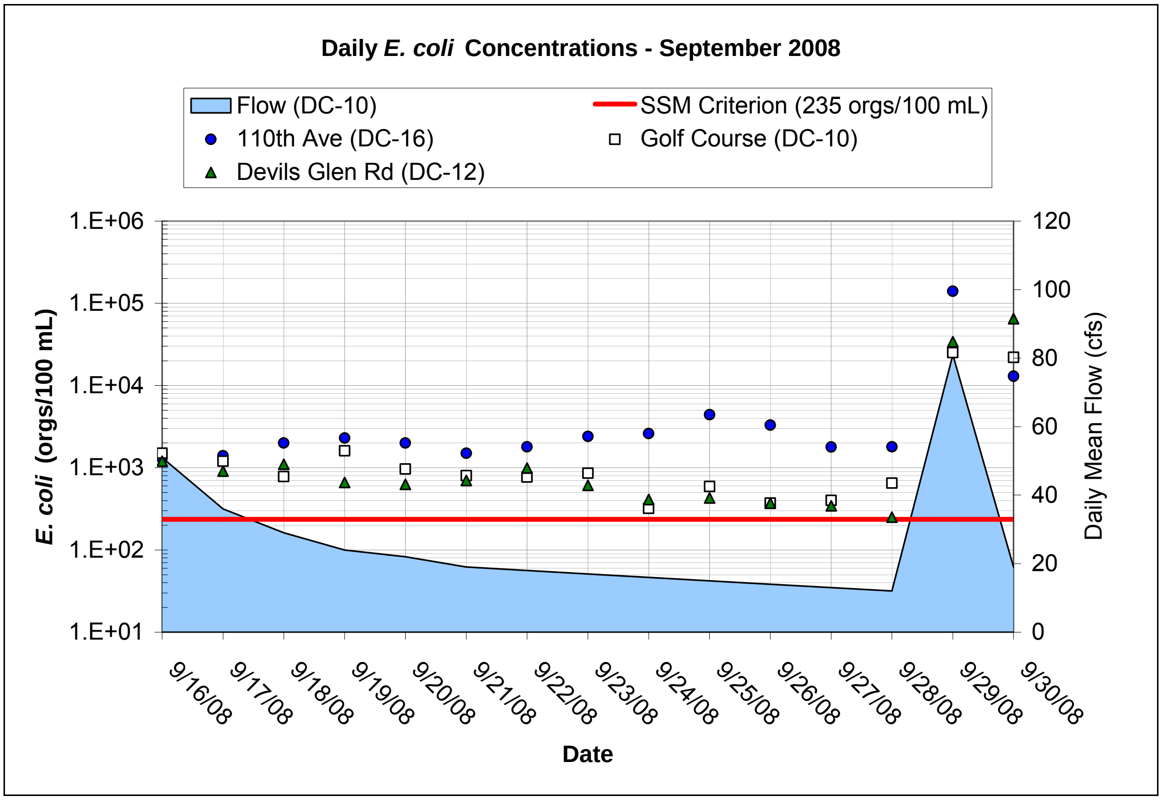

Figure 3-7. Daily *E. coli* concentrations during dry conditions in September 2008.

Observed *E. coli* concentrations were evaluated on a monthly basis to investigate whether temporal trends exist within the recreation season. The box plots in Figures 3-8 through 3-10 illustrate the minimum, first quartile (25th percentile), median, third quartile (75th percentile), and maximum *E. coli* concentration observed for each month in which data was collected.

Concentrations in Duck Creek at 110th Avenue (DC-16) tend to increase from April to September as flows decline. This may suggest in-stream sources such as direct deposition by cattle or wildlife in streams and discharging or failing onsite wastewater treatment systems could be of particular importance. There are no immediately obvious trends at the downstream sites; however, median and maximum concentrations are largest in June, July, and September at the Duck Creek Golf Course (DC-10) and Devils Glen Road (DC-12).

Overall, the box plots in Figures 3-8 through 3-10 provide another indication of the degree to which the water quality criteria are exceeded. The maximum *E. coli* concentration exceeds the SSM criterion in every month at all three locations. In fact, the third quartile (75th percentile) of concentrations exceeds 235 orgs/100 mL in every instance. Likewise, the median *E. coli* concentration exceeds the GM criterion of 126 orgs/100 mL every month at every location. The lower quartile (25th percentile) of concentrations observed each month also exceed the GM criterion, with April at 110th Avenue (DC-16) being the only exception. Both criteria are frequently exceeded, and normally by a large magnitude, regardless of month and location.

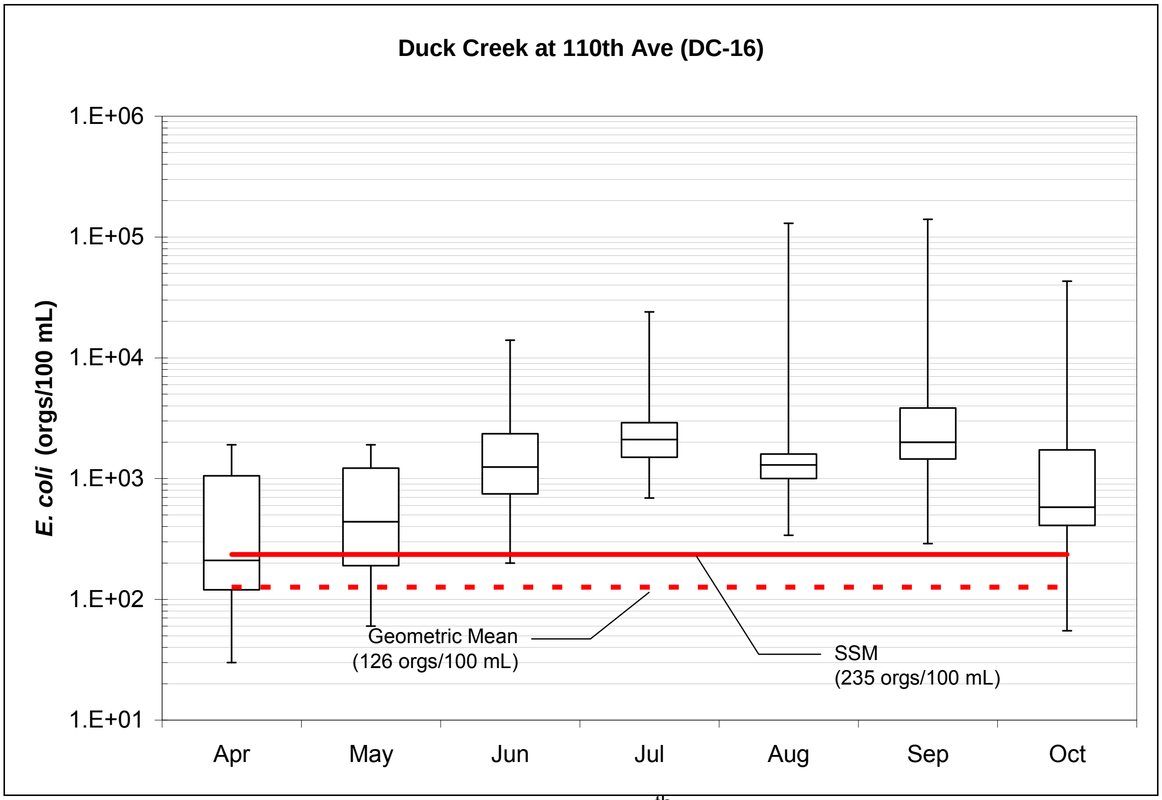

Figure 3-8. Monthly box plots of *E. coli* at 110th Avenue (DC-16).

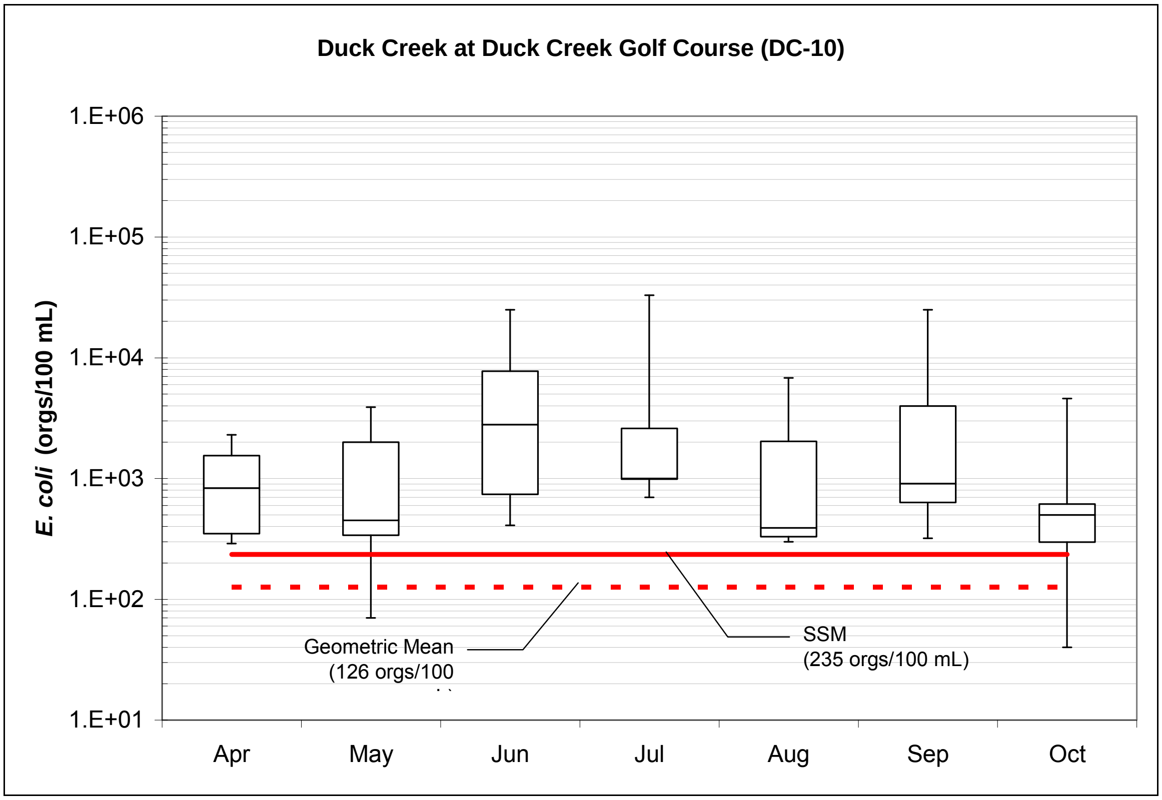

Figure 3-9. Monthly box plots of *E. coli* at the golf course (DC-10).

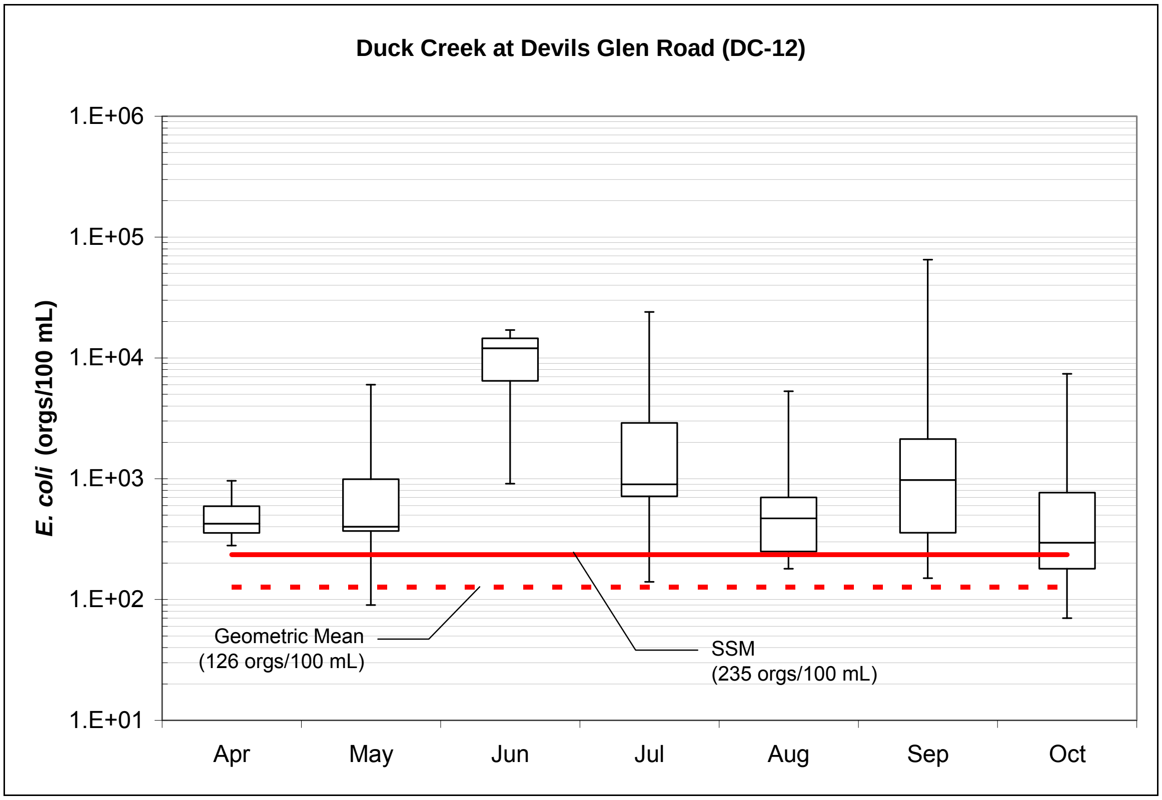

Figure 3-10. Monthly box plots of *E. coli* at Devils Glen Road (DC-12).

3.2. TMDL Target

General Description of the Pollutant
Digestive waste, sometimes called fecal material, from warm-blooded animals contains many microorganisms. Some of these microorganisms can cause illness or disease if ingested by humans. The term pathogen refers to a disease-causing microorganism, and can include bacteria, viruses, and other microscopic organisms. Humans can become ill if they come into contact with and/or ingest water that contains pathogens.

It is not practical to test water for every possible pathogen that may be present – there are simply too many different kinds of pathogens. Instead, water quality assessments typically test for an organism such as total coliform, fecal coliform, or *E. coli* to indicate the presence of pathogens from fecal material. *E. coli* is a type of fecal coliform, and its presence theoretically correlates with illnesses that result from human exposure to water that is contaminated with fecal material (Mishra et al, 2008). It should be noted that not all types of *E. coli* cause human illness; however, the presence of *E. coli* indicates the likelihood that pathogens are present. For the purposes of this TMDL, *E. coli* is used as the indicator bacteria. The two primary reasons for using *E. coli* are: (1) the EPA currently considers *E. coli* to be the preferred bacterial indicator, and (2) Iowa's water quality standards are written for *E. coli*.

Selection of Environmental Conditions
The critical period in which the impairment occurs is the recreation season, which runs from March 15 to November 15 each year.

Waterbody Pollutant Loading Capacity (TMDL)
Attainment of the WQS in Duck Creek requires that the geometric mean (GM) be no greater than 126 orgs/100 mL and the single sample maximum (SSM) be no greater than 235 orgs/100 mL. The *E. coli* loading capacity of Duck Creek is the maximum number of *E. coli* organisms that can be in the stream while the above criteria are met.

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

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

Load duration curves (LDCs) constructed using observed *E. coli* concentrations and mean daily flows were used to calculate the loading capacity of Duck Creek on a daily basis. The LDC approach involves developing flow duration curves, which represent the percent of mean daily flows that equal or exceed a given flow value. A low flow duration (low percent) indicates conditions in which flows are high and are rarely observed or exceeded. Conversely, high flow duration (high percent) flows commonly occur and are exceeded most of the time. The LDC, or allowable *E. coli* "load" curve, is obtained by multiplying the flow values of the flow duration curve by the applicable TMDL targets (i.e., the water quality criteria). Therefore, the LDC represents the loading capacity across a range of flow conditions. Points above the LDC indicate violations of the WQS, while points on or below the curve are acceptable loads and comply with WQS.

Attainment of water quality standards for the two segments of Duck Creek assessed as impaired on the 2008 303(d) list will be evaluated at three monitoring stations on Duck Creek. The two upstream compliance points (DC-16 and DC-10) are located at USGS stream gage stations. Flow at the downstream site (DC-12) was extrapolated from the USGS gages. Grab samples for *E. coli* analysis have been collected at all three locations, including intensive sampling during the 2008 recreation season. Table 3-3 shows the TMDL segments and lists the respective water quality sampling station IDs, USGS stream gage numbers, and location descriptions.

Table 3-3. TMDL segments with respective WQ stations and stream gages.

2008 303(d) Segment	WQ Stations	USGS Gage	Location
IA 01_NEM_0060_2	DC-16	05422560	110th Avenue
IA 01_NEM_0060_1	DC-10 DC-12	05422600 N/A	Duck Creek Golf Course Devils Glen Road

Notes: 1. WQS compliance in IA 01_NEM_0060_1 assessed at DC-10 and DC-12.
2. Flows at DC-12 were extrapolated from USGS flows at the two gage stations.
3. Bacteria levels must meet Class A1 (and A3) criteria in both segments.

The duration curves are categorized into five hydrologic (flow) conditions summarized in Table 3-4. Compliance with WQS is assessed at the midpoint of each flow condition, also reported in Table 3-4. The loading capacity for each location considers both SSM and GM values, enabling incorporation of both WQS criteria into the TMDL. The SSM provides a daily maximum load, while the GM provides a representation of the long-term daily loading goal. Loading capacities for each station and flow condition are reported in Tables 3-5 through 3-7. These target loads are obtained at the midpoint of each flow condition from the LDC for each location, shown in Figures 3-11 through 3-13.

Table 3-4. Flow condition descriptions and midpoint percentiles.

Flow Condition	Duration Interval (%)	Description	Midpoint (%)
High	0-10	Infrequent storm events; runoff dominates	5
Moist	10-40	Runoff component large but decreasing	25
Mid-Range	40-60	Both runoff and continuous flows	50
Dry	60-90	Continuous flows begin to dominate	75
Low	90-100	Infrequent low flow; point sources dominate	95

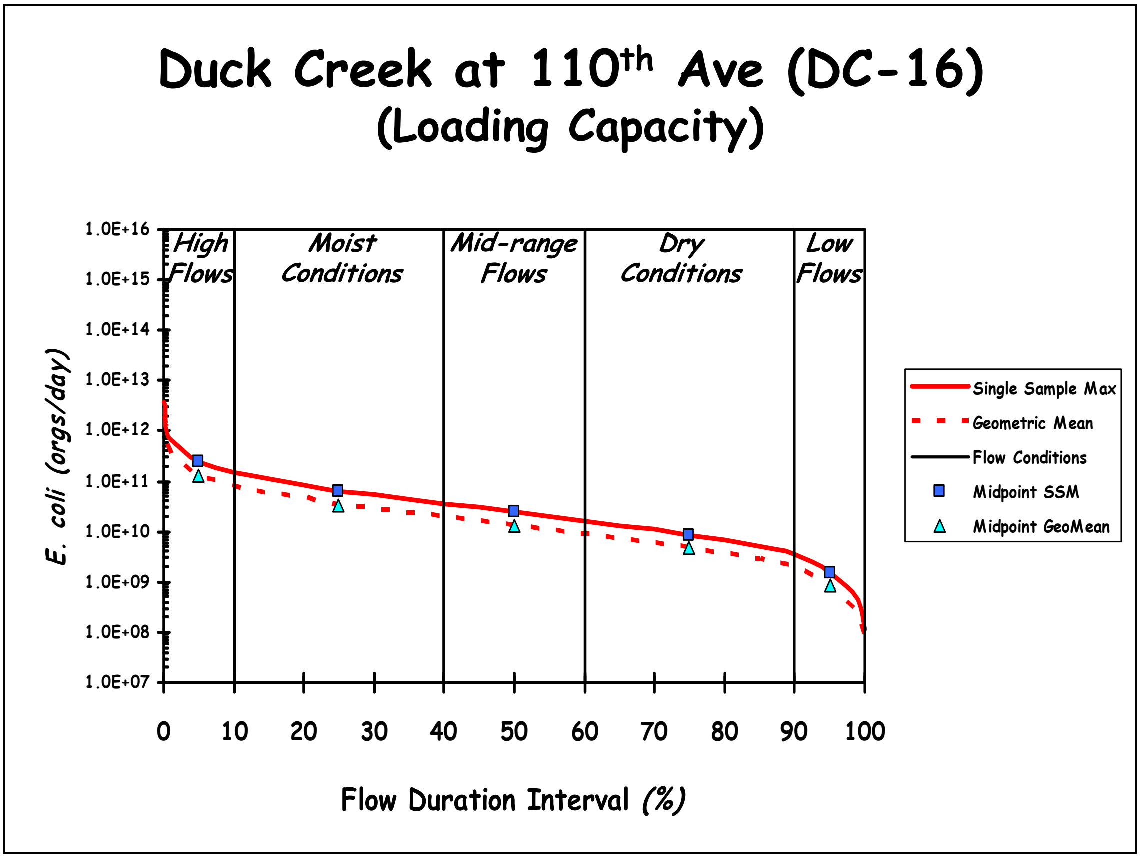

Figure 3-11. Flow variable *E. coli* loading capacity at 110th Avenue.

Table 3-5. Flow variable loading capacity at 110th Avenue (DC-16).

Loading Capacity Summary	Loading capacities (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
SSM Load	2.41E+11	6.32E+10	2.47E+10	8.62E+09	1.55E+09
GM Load	1.29E+11	3.39E+10	1.33E+10	4.62E+09	8.32E+08
Midpoint flow (cfs)	42	11	4.3	1.5	0.3

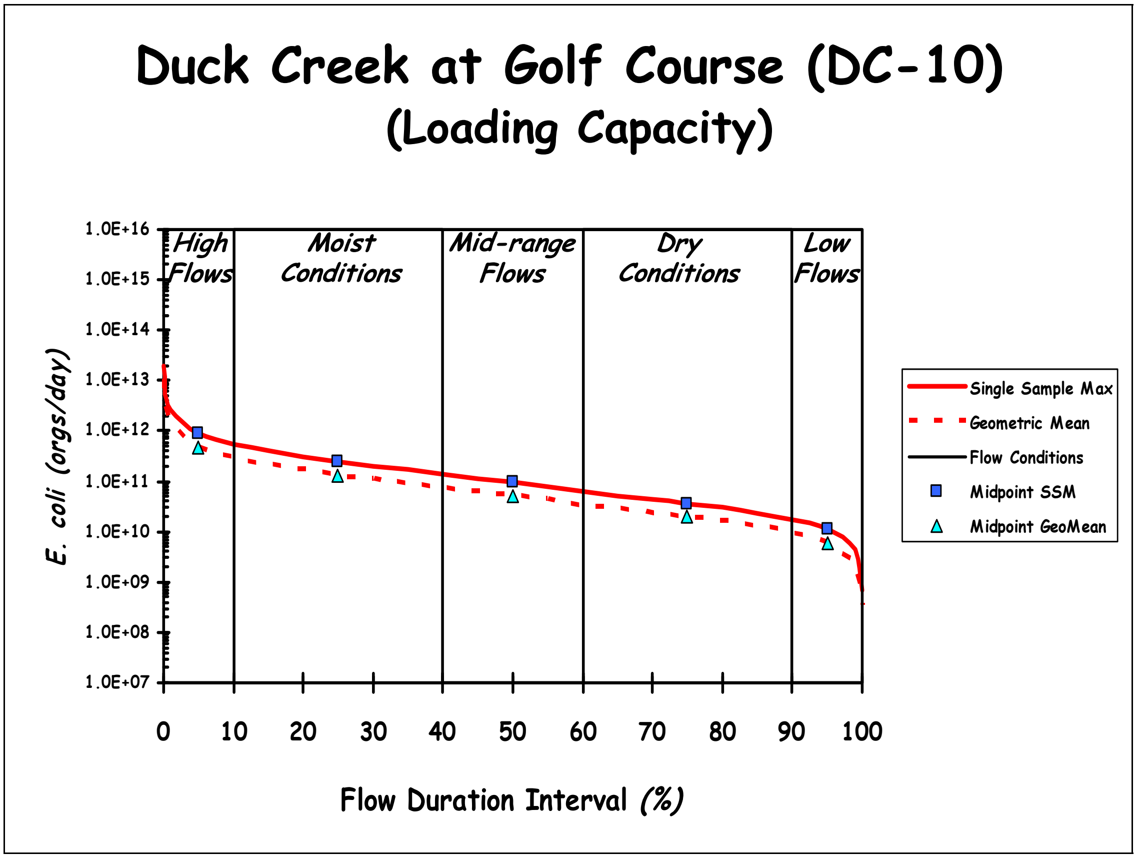

Figure 3-12. Flow variable *E. coli* loading capacity at Duck Creek Golf Course.

Table 3-6. Flow variable loading capacity at the golf course (DC-10).

Loading Capacity Summary	Loading capacities (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
SSM Load	8.85E+11	2.47E+11	9.77E+10	3.62E+10	1.09E+10
GM Load	4.75E+11	1.33E+11	5.24E+10	1.94E+10	5.86E+09
Midpoint flow (cfs)	150	43	17	6.3	1.9

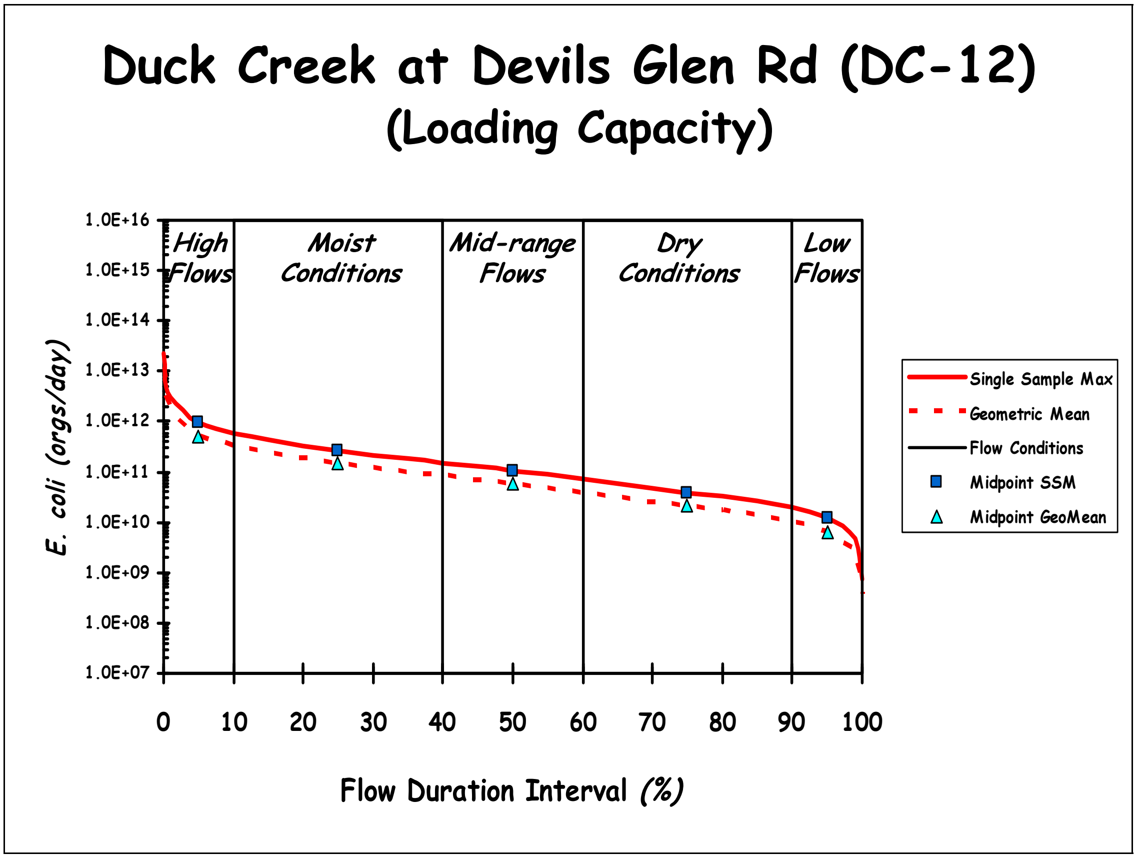

Figure 3-13. Flow variable *E. coli* loading capacity at Devils Glen Road.

Table 3-7. Flow variable loading capacity at Devils Glen Road (DC-12).

Loading Capacity Summary	Loading capacities (orgs/day)				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
SSM Load	9.71E+11	2.71E+11	1.07E+11	3.94E+10	1.19E+10
GM Load	5.21E+11	1.45E+11	5.76E+10	2.11E+10	6.37E+09
Midpoint flow (cfs)	169	47.2	18.7	6.8	2.1

Decision Criteria for Water Quality Standards Attainment
The criteria set forth in the water quality standards for Class A1 use (equal to Class A3 criteria) must be met at all three locations for Duck Creek to attain water quality standards and fully support designated uses. Although secondary contact recreation (Class A2) is proposed for a portion of the upstream segment in the UAA, the more stringent criterion is applied to this upstream reach as well. This is due to short travel time to the Class A3 use reach, which does not allow significant die-off of *E. coli* bacteria. This assumption provides partial basis for an implicit margin of safety (MOS).

3.3. Pollution Source Assessment

Existing Load
Observed *E. coli* loads were estimated by multiplying observed concentrations (orgs/100 mL) by the mean daily flow (cfs) on the day the sample was collected (including a units conversion). Using the LDC approach, these measured loads are plotted against the flow duration interval, which allows loads to be grouped into the same flow conditions used in the plots of flow variable loading capacities. Individual loads at each monitoring location are represented by blue diamonds in Figures 3-14 through 3-16. Points above the red SSM and GM curves represent violations of the WQS, whereas points below the curves are acceptable and meet criteria.

The existing daily maximum load (for each flow condition) is estimated by multiplying the 90th percentile measured *E. coli* concentration by the flow at the midpoint of each flow condition. This is consistent with an LDC approach recommended by EPA (EPA, 2007). The 90th percentile loads are represented by solid green lines in Figures 3-14 through 3-16. The median loads (50th percentile) are illustrated by dashed green lines. Although the median load is not mathematically equivalent to the GM, they both reflect “typical” or long-term “average” loads. Both measures (90th percentile and median) of existing loads are utilized in the calculation of the TMDL for Duck Creek. The points (diamonds) in Figures 3-14 through 3-16 that include a blue “+” symbol within them represent samples collected in the months of July, August, and September. Gray shading within the diamonds indicates samples where storm flow (runoff) comprises over 50 percent of the total flow. These points are considered storm events.

Examination of the LDCs and observed data clearly reveals that bacteria concentrations exceed water quality criteria in a majority of instances (all points above the SSM and GM curves). Compliant loads (points below the curves) are rare under all hydrologic conditions except at the lowest flows (90-100 percent duration interval). However, apparent compliance during low flows should be viewed with some skepticism. At most, only a handful of observations were made during low flows, and at 110th Avenue (DC-16), only one low flow data point exists. It is likely that observed data are not capturing potential violations of the WQS under low flow conditions due to limited sampling frequency.

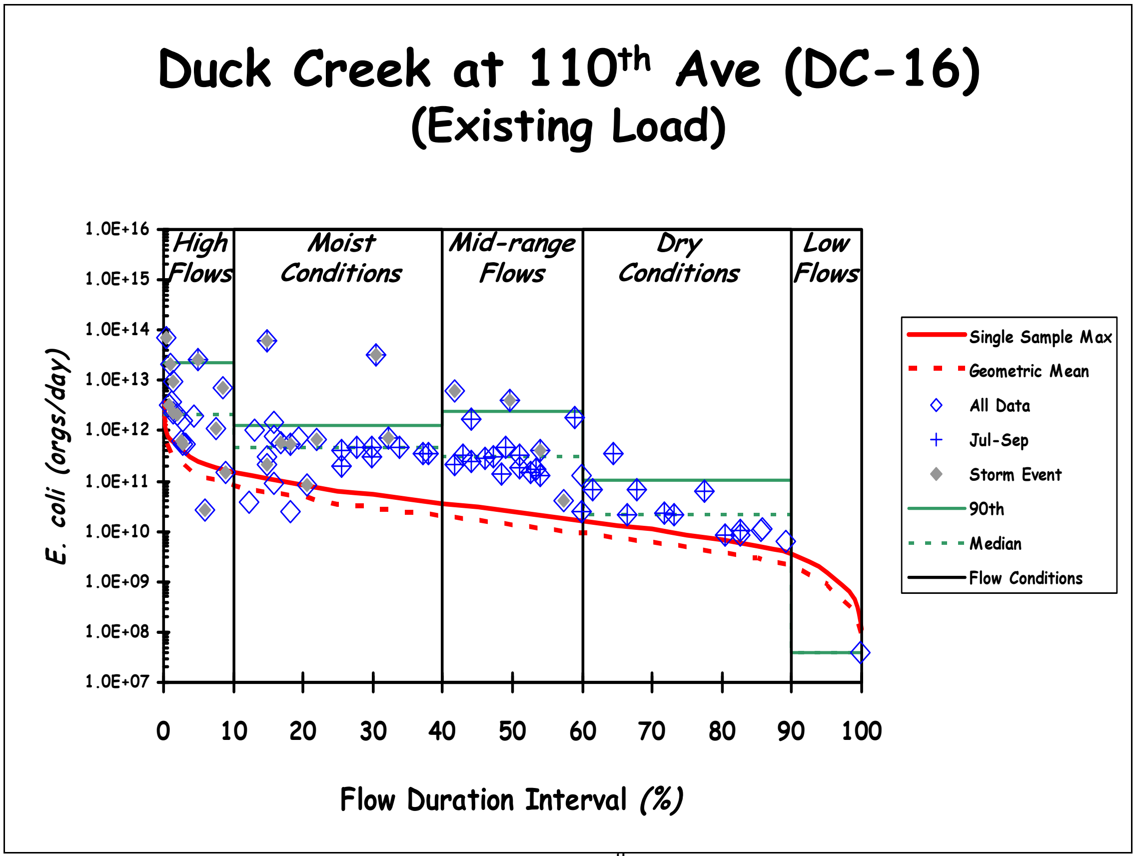

Figure 3-14. Measured *E. coli* loads at 110th Avenue.

Table 3-8. Existing load estimates at 110th Avenue (DC-16).

Existing Load Summary	Existing Loads (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
90th Percentile Load	2.28E+13	1.32E+12	2.51E+12	1.03E+11	4.04E+07
Median Load	2.17E+12	4.59E+11	2.99E+11	2.16E+10	4.04E+07
Midpoint flow (cfs)	42	11	4.3	1.5	0.3

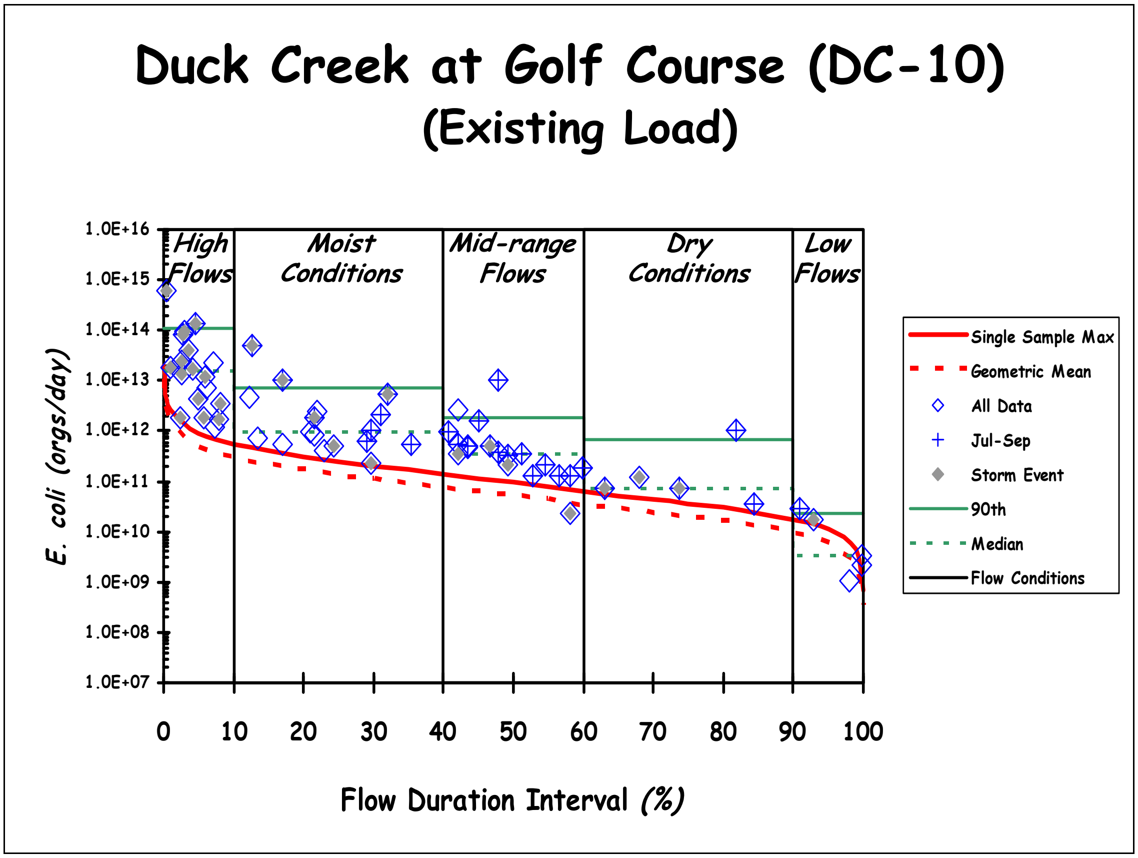

Figure 3-15. Measured *E. coli* loads at the Duck Creek Golf Course.

Table 3-9. Existing load estimates at Duck Creek Golf Course (DC-10).

Existing Load Summary	Existing Loads (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
90th Percentile Load	1.08E+14	7.39E+12	1.79E+12	6.61E+11	2.39E+10
Median Load	1.52E+13	9.67E+11	3.58E+11	7.34E+10	3.43E+09
Midpoint flow (cfs)	150	43	17	6.3	1.9

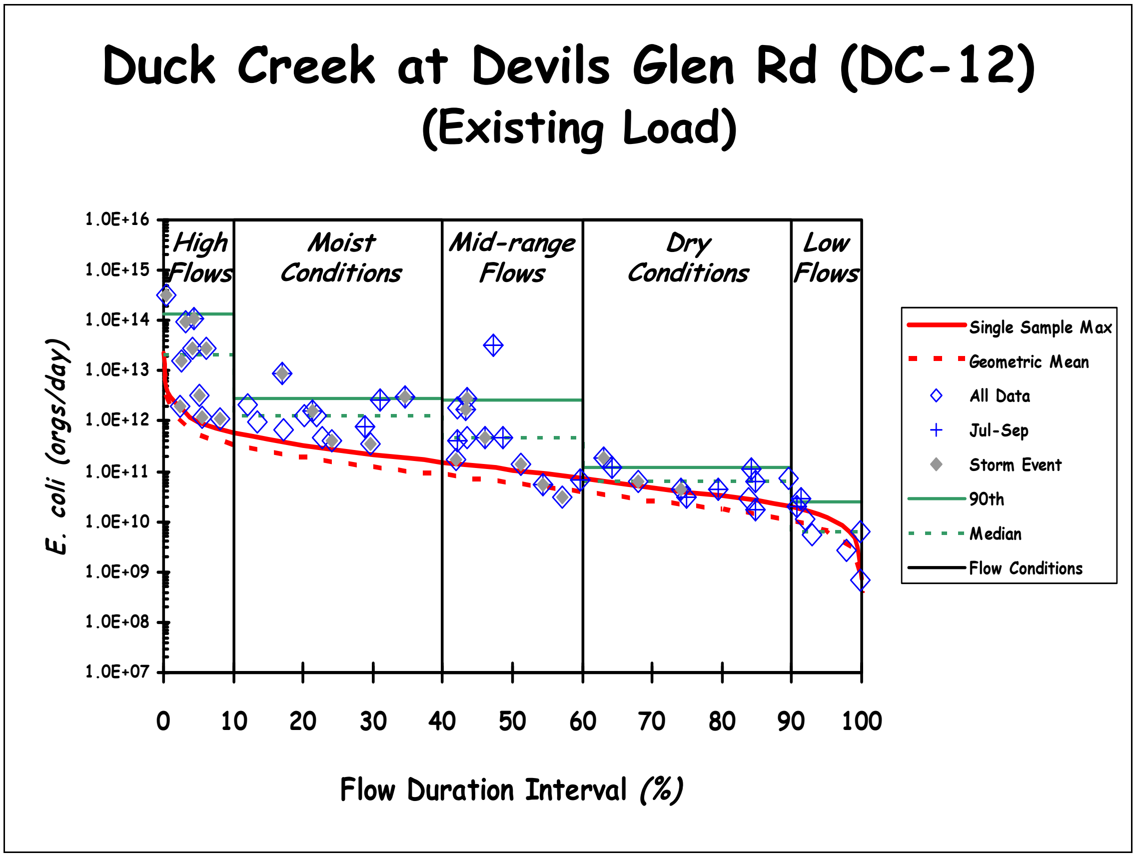

Figure 3-16. Measured *E. coli* loads at Devils Glen Road.

Table 3-10. Existing load estimates at Devils Glen Road (DC-12).

Existing Load Summary	Existing Loads (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
90th Percentile Load	1.31E+14	2.87E+12	2.62E+12	1.20E+11	2.41E+10
Median Load	2.14E+13	1.31E+12	4.77E+11	6.17E+10	6.38E+09
Midpoint flow (cfs)	169	47.2	18.7	6.8	2.1

Departure from Load Capacity

The LDCs and 90th percentile and median loads in each flow condition are plotted in Figures 3-17 through 3-19. The figures include arrows that illustrate the departure of existing loads from the loading capacity. The darker blue arrows graphically represent the departure from the 90th percentile loads to the loads equivalent to the SSM criterion. The lighter colored arrows represent the departure of median loads from the GM criterion. Two general trends can be observed from Figures 3-17 through 3-19. First, the departure (extent of WQS violation) is typically larger for SSM criterion than for the GM. Second, the largest departures are observed under high flow conditions, and departures decrease as flow decreases. There are some exceptions to this trend, such as higher departures in the mid-range flow condition compared to the moist condition at DC-16 and DC-12. Departures are quantified in terms of orgs/day and percent in Tables 3-11 through 3-13.

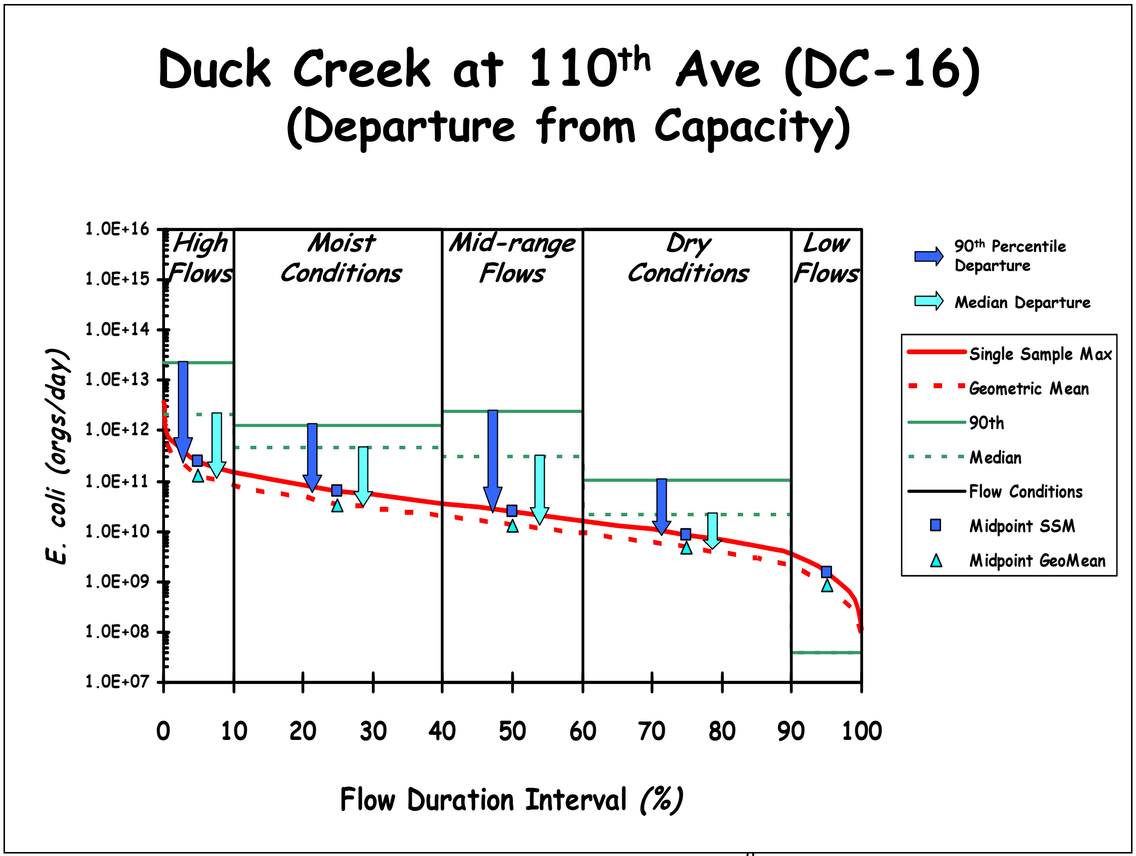

Figure 3-17. Departure from loading capacity at 110th Avenue.

Table 3-11. Departure from loading capacity at 110th Avenue (DC-16).

Departure from Capacity	Departure in orgs/day and (%)				
	High	Moist	Mid-Range	Dry	Low
SSM Departure	2.25E+13 (98.9)	1.25E+12 (95.2)	2.49E+12 (99.0)	9.47E+10 (91.7)	--
GM Departure	2.04E+12 (94.0)	4.26E+11 (92.6)	2.86E+11 (95.6)	1.70E+10 (78.6)	--
Midpoint flow (cfs)	42.0	11.0	4.3	1.5	0.3

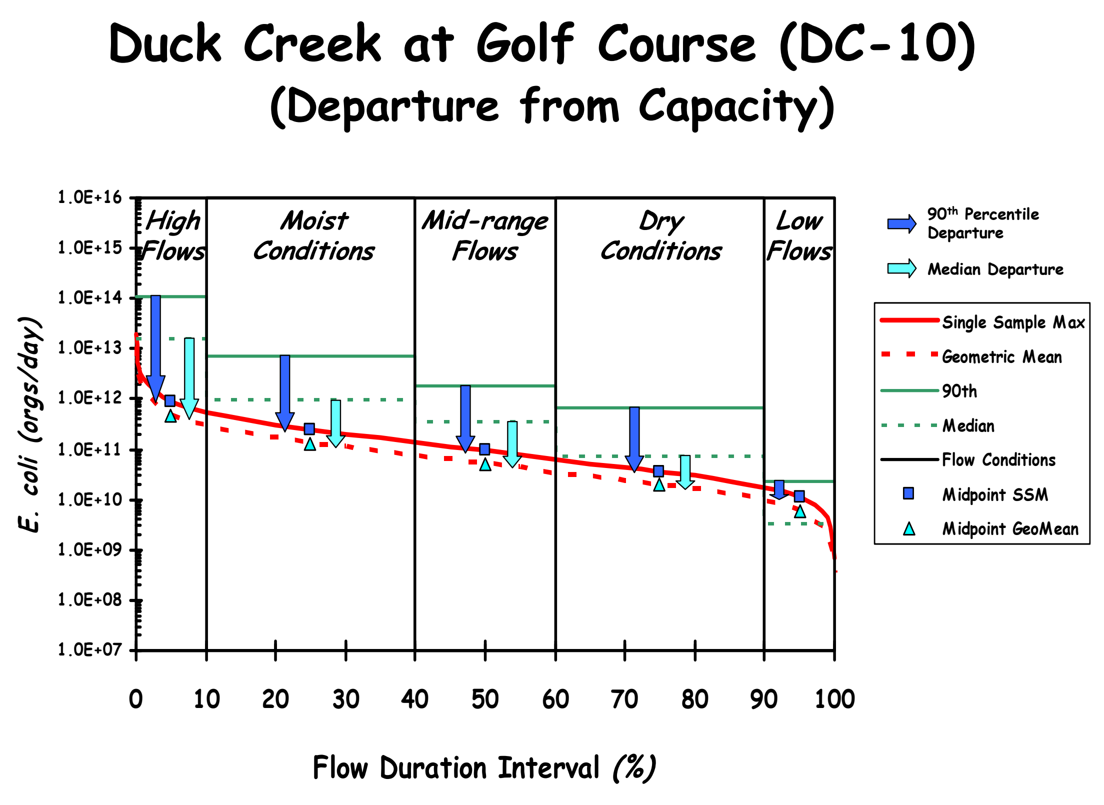

Figure 3-18. Departure from loading capacity at the Duck Creek Golf Course.

Table 3-12. Departure from loading capacity at the golf course (DC-10).

Departure from Capacity	Departure in orgs/day and (%)				
	High	Moist	Mid-Range	Dry	Low
SSM Departure	1.07E+14 (99.2)	7.14E+12 (96.7)	1.69E+12 (94.5)	6.24E+11 (94.5)	1.30E+10 (54.3)
GM Departure	1.47E+13 (96.9)	8.34E+11 (86.3)	3.05E+11 (85.3)	5.40E+10 (73.5)	--
Midpoint flow (cfs)	154	43.0	17.0	6.3	1.9

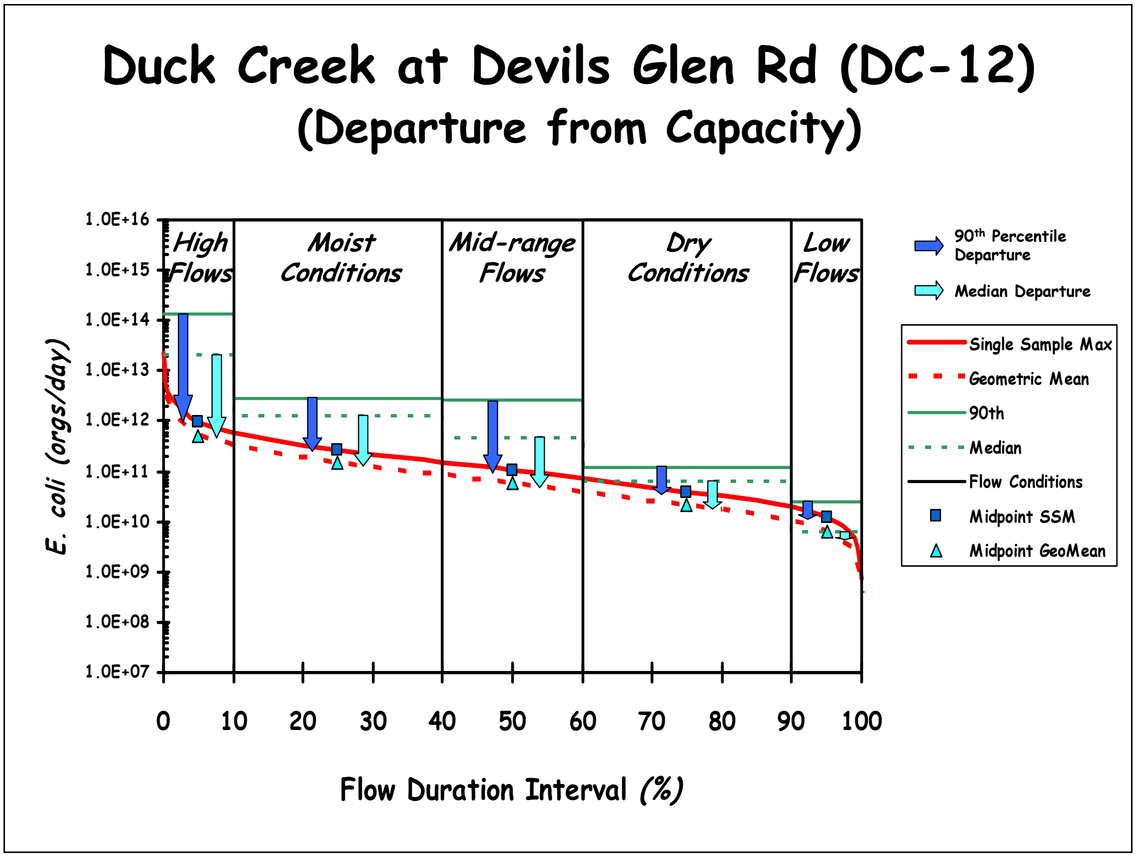

Figure 3-19. Departure from loading capacity at Devils Glen Road.

Table 3-13. Departure from loading capacity at Devils Glen Road (DC-12).

Departure from Capacity	Departure in orgs/day and (%)				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
SSM Departure	1.30E+14 (99.3)	2.60E+12 (90.5)	2.51E+12 (95.9)	8.02E+10 (67.1)	1.22E+10 (50.6)
GM Departure	2.09E+13 (97.6)	1.16E+12 (88.9)	4.19E+11 (87.9)	4.06E+10 (65.8)	1.47E+07 (0.2)
Midpoint flow (cfs)	169	47.2	18.7	6.8	2.1

E. coli Concentration and Flow Duration

Figures 3-20 through 3-22 illustrate the same concept as the LDCs, but represent the assimilative capacity, existing bacteria levels, and departure in terms of concentration (per the WQS), rather than loads. The LDCs are more useful for calculating required reductions, but both types of plots reveal the same general trends.

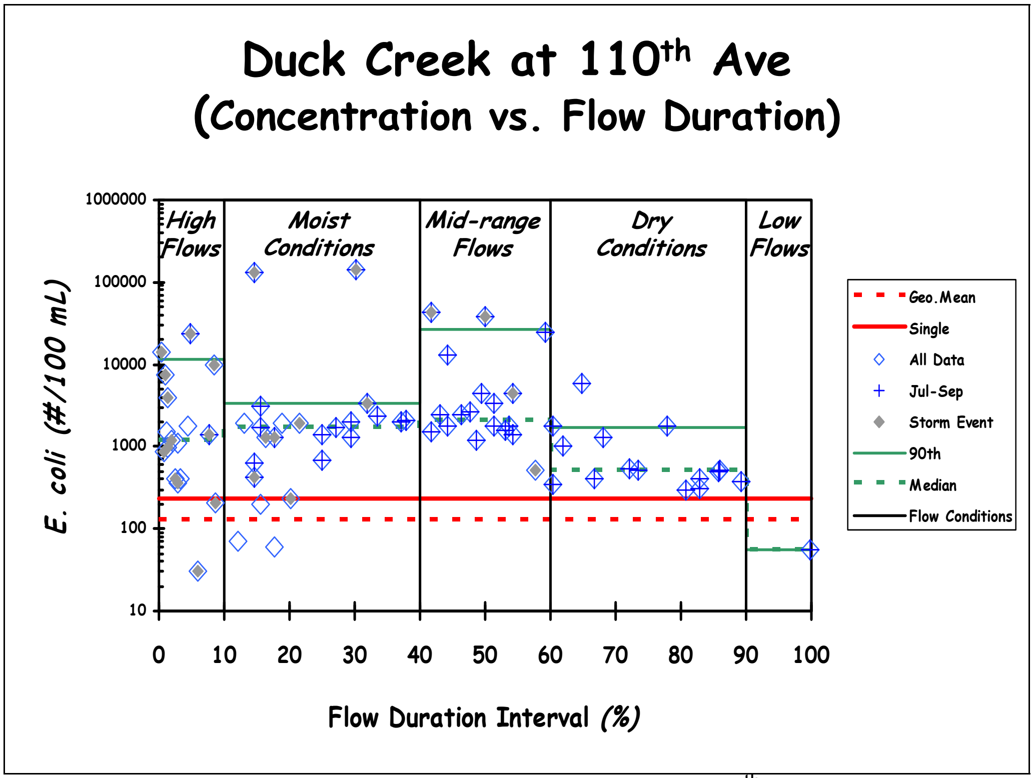

Figure 3-20. Observed *E. coli* concentrations at 110th Avenue (DC-16).

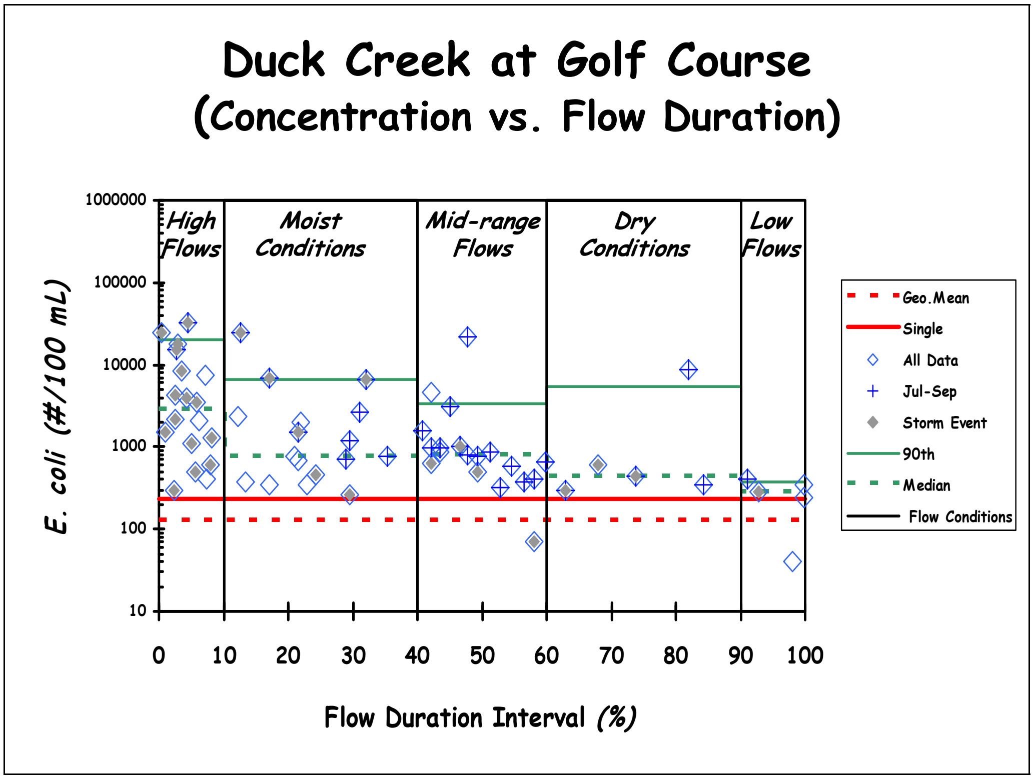

Figure 3-21. Observed *E. coli* concentrations at the golf course (DC-10).

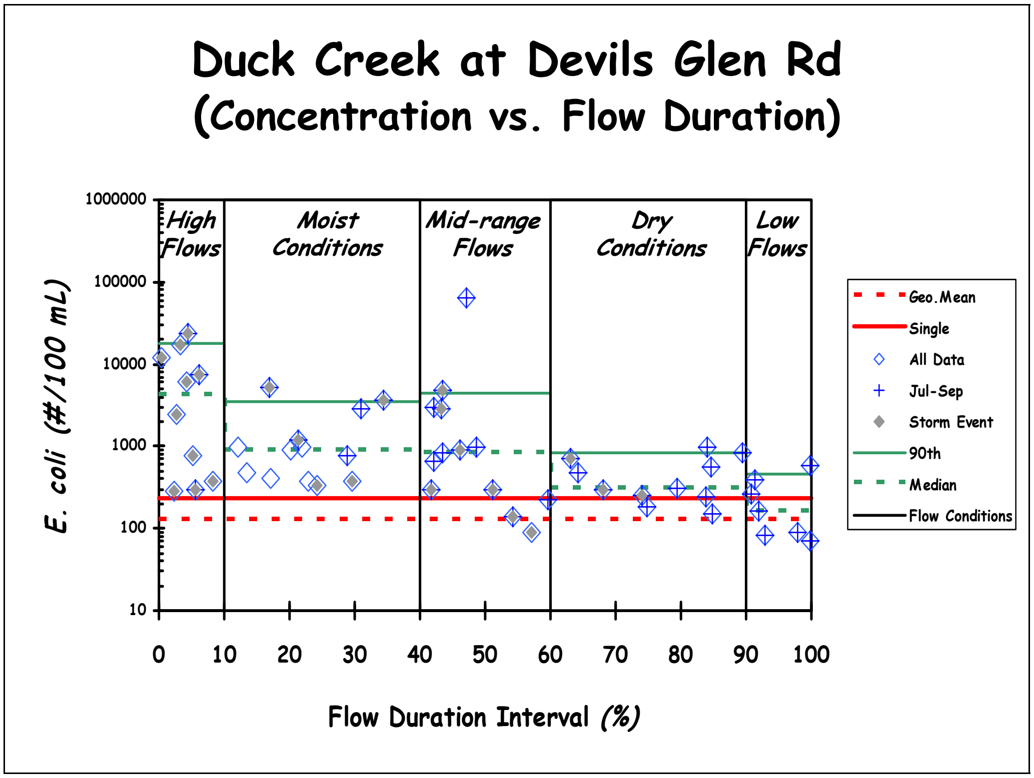

Figure 3-22. Observed *E. coli* concentrations at Devils Glen Road (DC-12).

Identification of Pollutant Sources

There are a variety of *E. coli* sources in the Duck Creek watershed. Point sources include municipal separate storm sewer systems (MS4s), three wastewater treatment facilities (WWTFs), sanitary sewer overflows (SSOs), onsite wastewater systems with permitted discharges, and animal feeding operations (AFOs) large enough to require permits. Nonpoint sources include wildlife, manure application to row crops, grazing livestock and small feeding operations, direct deposition by livestock in streams, and non-permitted (i.e., non-discharging) onsite wastewater systems. Onsite wastewater treatment systems included septic systems, but not all onsite systems have septic tanks. The terms are used interchangeably in this document; however septic system usually implies an unpermitted and non-discharging system in the context of this WQIP.

Some point sources behave like nonpoint sources in that they are spread out and not localized to a single, discrete discharge location. Examples include some stormwater sources, which result from buildup of bacteria on urban land uses, waste production by pets and wildlife within urban areas, and even deposition and growth of bacteria within the storm sewer system. However, because Davenport and Bettendorf are regulated under NPDES MS4 permits, they are considered point sources regardless of the loading processes.

From a practical standpoint, onsite wastewater treatment systems (often called septic systems) are usually considered to be nonpoint sources because of their widespread distribution throughout a watershed. However, some septic systems in Iowa, including a number of systems in the Duck Creek watershed, discharge to surface water under NPDES General Permit #4. EPA requires sources regulated by an NPDES permit to be considered point sources. For the purposes of this TMDL, discharging septic systems operating under an NPDES permit are considered point sources whereas non-discharging systems are considered nonpoint sources.

The use of LDCs is helpful for understanding the importance that hydrology plays on pollutant loading. However, the approach does not offer convenient or accurate quantification of contributions from specific sources. However, analysis of the LDCs with existing loads (Figures 3-14 through 3-16) in conjunction with Table 3-14 provides insight to the relative magnitude of various potential sources under different flow conditions.

Table 3-14. Potential relative importance of pollutant sources.

Departure from Capacity	Departure in orgs/day and (%)				
	High	Moist	Mid-Range	Dry	Low
Stormwater	H	M			
Manure application	H	H			
SSOs	M	H	H		
Cattle in streams			M	H	H
Septic systems			M	M	H
WWTFs				M	H

Modified from An Approach for Using Load Duration Curves in the Development of TMDLs (EPA, 2007). Potential relative importance indicated by: H = high; M = medium.

Detailed source analysis is discussed in Appendix D, Sections D.5 and D.6. Assumptions regarding the location and magnitude of each source is included. An estimate of the relative contributions of each source to the overall *E. coli* load is provided in the Implementation Plan (Section 5). Source allocations developed for the TMDL are discussed in the Sections 3.4 and 3.6.

Allowance for Increases in Pollutant Loads

The Duck Creek watershed includes existing urban areas as well as undeveloped agricultural land on the west side of Davenport, Iowa. It is likely that urban development will continue, and the jurisdictional area of Davenport's MS4 will increase. Rather than reserve a portion of the WLA for this urban development, any future increases in urban stormwater bacteria sources should be offset by additional stormwater controls. Stormwater controls may include ordinances and best management practices (BMPs) to mitigate the impact of urbanization so that the City's MS4 WLA does not increase as development continues. Potential BMPs are described in the implementation plan in Section 5 of this WQIP.

Some residences that currently have private onsite wastewater systems may eventually be served by Davenport's municipal sanitary sewer collection system. Because Davenport's primary WWTF does not discharge to Duck Creek, this would reduce the amount of E.

coli loading in the watershed. Therefore, no portion of the WLA is reserved for unsewered residences.

It is also possible that some aging and non-compliant private onsite wastewater systems not currently regulated will become permitted (under General Permit No. 4) in the future. Iowa Senate File (SF) 261 was passed in the 2008 legislative session and became effective July 1, 2009. SF 261 requires existing onsite systems be inspected before transfer of property from one owner to the next. If existing systems are failing, they must be repaired and/or replaced. While failing infiltration systems may not require replacement with permitted (i.e., discharging) systems, it is possible that in some cases this conversion may occur. Non-permitted infiltration-based systems are nonpoint sources and included in the LA of the TMDL. Conversion of failing non-discharging systems to permitted systems would represent an increase in the WLA. However, the corresponding reduction from the LA and overall reduction in load would be much greater since General Permit No. 4 requires end-of-pipe compliance with the water quality standards for bacteria. Therefore, there is no need to reserve WLA capacity for this potential transition of on-site wastewater systems.

For these reasons, there is no allowance for any future increase in bacteria loads incorporated into the Duck Creek E. coli TMDLs.

3.4. Pollutant Allocation

Wasteload Allocation (WLA)

There are several permitted point sources that receive a portion of the overall WLA in the Duck Creek *E. coli* TMDL. These include three wastewater lagoons, two MS4s, and over 90 permitted onsite wastewater treatment systems that discharge to surface water. Individual WLAs are assigned to each lagoon system and MS4, whereas permitted onsite wastewater treatment systems are given a collective WLA.

Point sources that are not assigned a portion of the WLA in the TMDL include AFOs and SSOs, which are not permitted to discharge, and several industrial/stormwater dischargers, which have no likely source of bacteria associated with their discharges. Table 3-15 lists and describes these facilities and indicates which sources receive a portion of the WLA.

Table 3-16 reports the WLAs for WWTF compliance with the SSM criterion of 235 orgs/100 mL. The WLA is calculated by multiplying the SSM concentration by the maximum allowable discharge (flow) from the facility. The allowable discharge is specified in the NPDES permit for each facility, and is reported in Table 3-15. The resulting WLAs assign a maximum allowable daily *E. coli* load to each permitted discharge. The MS4 allocations reported in Table 3-17 vary by flow condition. MS4 WLAs are the product of the SSM criterion (235 orgs/100 mL) and the midpoint flow in each flow condition. The midpoint flow for each MS4 is the summation of surface runoff from SWAT subbasins within each MS4s jurisdictional area.

Table 3-15. Permitted point sources in the Duck Creek watershed.

Facility	Permit Type	EPA Permit ID	Iowa Permit ID	Receiving WLA?
West Locust Lagoon	Municipal wastewater	IA0076261	8222004	Yes
West Kimberly Mobile Home Park	Semi-public wastewater	IA0064432	8222604	Yes
Lakewood Estates Mobile Home Park	Municipal wastewater	IA0067695	8200602	Yes
Discharging Onsite Wastewater Systems	Private sewage disposal systems	--	General Permit No. 4	Yes
City of Davenport STP (SSOs)	Municipal	IA0043052	8222003	No
City of Bettendorf MS4	Municipal stormwater	IA0078191	8209000	Yes
City of Davenport MS4	Municipal stormwater	IA0078808	8222005	Yes
Flying J Travel Plaza	Industrial/stormwater	IA0074110	8222201	No
Iowa DOT Maintenance Garage	Industrial/stormwater	IA0076139	8222902	No
John Deere Davenport Works	Industrial/stormwater	IA0059501	8222107	No
Multiple Animal Feeding Operations	Agricultural	--	--	No

Table 3-16. Wasteload allocations to meet the SSM criterion (wastewater).

Facility	SSM Criteria (orgs/100 mL)	Discharge (MGD)	WLA (orgs/day)
West Locust Lagoon	235	[1]0.2400	2.13E+09
West Kimberly Mobile Home Park	235	[2]0.0075	6.67E+07
Lakewood Estates Mobile Home	235	[2]0.1171	1.04E+09
Discharging Septic Systems	235	[3]0.0419	1.40E+08
Total from wastewater sources =			3.38E+09
Davenport and Bettendorf MS4s	235	Flow variable	(see table 3-17)

[1] Equal to 10 times the average wet weather (AWW) flow, per operations requirements.
[2] Equal to maximum wet weather (MWW) flow as specified in permit.
[3] Equal to design flow of 150 gal/bedroom/day (cumulative for the entire watershed).

According to Iowa water quality standards, in addition to a maximum daily load based on the SSM criterion, all facilities operating under an NPDES permit must meet a 30-day GM *E. coli* concentration of 126 cfu/100mL. The GM is used instead of an arithmetic mean because it handles highly skewed data or data with large variation/outliers better. Table 3-18 lists WLAs for WWTFs and Table 3-19 reports MS4 WLAs for compliance with the GM criterion.

Table 3-17. MS4 wasteload allocations to meet the SSM criterion.

MS4	Flow Condition	SSM Criteria (orgs/100 mL)	Midpoint Runoff (cfs)	WLA (orgs/day)
Davenport	High Flow	235	110	6.32E+11
	Moist	235	2.7	1.54E+10
	Mid-Range	235	0.02	1.34E+08
	Dry	235	*	*
	Low Flow	235	*	*
Bettendorf	High Flow	235	23.2	1.33E+11
	Moist	235	0.46	2.65E+09
	Mid-Range	235	*	*
	Dry	235	*	*
	Low Flow	235	*	*

* Indicates zero runoff condition, therefore no WLA assigned to MS4.

Table 3-18. Wasteload allocations to meet the GM criterion (wastewater).

Facility	GM Criteria (orgs/100 mL)	Discharge (MGD)	WLA (orgs/day)
West Locust Lagoon	126	[1]0.0240	1.14E+08
West Kimberly Mobile Home Park	126	[1]0.0075	3.58E+07
Lakewood Estates Mobile Home	126	[1]0.1100	5.25E+08
Discharging Septic Systems	126	[2]0.0419	7.51E+07
		Total from wastewater sources =	7.50E+08
Davenport and Bettendorf MS4s	235	Flow variable	(see table 3-19)

[1] Equal to average wet weather (AWW) flow as specified in permit.

[2] Equal to design flow of 150 gal/bedroom/day (cumulative for the entire watershed).

Table 3-19. MS4 wasteload allocations to meet the GM criterion.

MS4	Flow Condition	GMCriteria (orgs/100 mL)	Midpoint Runoff (cfs)	WLA (orgs/day)
Davenport	High Flow	126	110	3.39E+11
	Moist	126	2.7	8.26E+09
	Mid-Range	126	0.02	7.16E+07
	Dry	126	0.00	*
	Low Flow	126	0.00	*
Bettendorf	High Flow	126	23.2	7.14E+10
	Moist	126	0.46	1.42E+09
	Mid-Range	126	0.00	*
	Dry	126	0.00	*
	Low Flow	126	0.00	*

* Indicates zero runoff condition, therefore no WLA assigned to MS4.

Load Allocation (LA)

The LA includes *E. coli* contributions from nonpoint sources. Nonpoint sources in the Duck Creek watershed were described in *Identification of Pollutant Sources*, in Section

3.3 of this WQIP. An inventory of nonpoint sources is included in the implementation plan in Section 5. Quantification of nonpoint sources is documented in Sections D.5 and D.6 of Appendix D.

Margin of Safety
An explicit margin of safety (MOS) of 10 percent is applied to the calculation of loading capacities in this TMDL. The resulting target in-stream *E. coli* concentrations are therefore 212 orgs/100 mL for the SSM, and 113 orgs/100 mL for the GM. Several conservative assumptions applied to modeling used for implementation planning also provide an implicit MOS. These include:

- In-stream sources such as failed septic systems, permitted onsite wastewater treatment systems, cattle in streams, and wildlife in streams are assumed to discharge continuously throughout the time frame in which they contribute.
- All pet waste is assumed to be dog waste (rather than cat), which has higher *E. coli* levels. Also, dog populations were multiplied by 1.2 to account for cat waste in the calculation of total pet waste. Most cat defecation is likely in litter boxes and would not contribute to bacteria in streams.
- A literature value for raw wastewater was used as the *E. coli* concentration for SSOs.
- The number of cattle assumed to reside in the watershed is likely an over-estimate.
- Bacteria die-off on soil particles and in soil solution was considered negligible.
- The TMDL for the upstream segment of Duck Creek requires compliance with the Class A1/A3 criteria, rather than the less restrictive Class A2 criteria.

3.5. Reasonable Assurance

Under current EPA guidance, TMDLs that allocate loads to both point sources (WLAs) and nonpoint sources (LAs) must demonstrate reasonable assurance that required load reductions will be implemented. For point sources, reasonable assurance is provided through NPDES permits. Permits include operation requirements and compliance schedules that are developed based on water quality protection. For nonpoint sources, allocations and proposed implementation activities must satisfy four criteria:

- They must apply to the pollutant of concern
- They will be implemented expeditiously
- They will be accomplished through effective programs
- They will be supported by adequate water quality funding

Nonpoint source measures developed in the Duck Creek TMDL satisfy all four criteria. First, LAs and implementation activities described in Section 5 of the report apply directly to *E. coli*. Attainment of designated uses and existing water quality are measured using these indicator bacteria. Second, the implementation plan sets forth an approximate timeline for implementation activities. Additionally, there is an active local watershed group that is already pursuing detailed watershed planning and implementation activities in parallel with TMDL development. Third, IDNR has set forth detailed requirements for watershed planning and implementation to ensure that watershed management plans and Section 319 applications meet EPA requirements, include ongoing monitoring to track progress towards water quality improvement, include a phased and prioritized schedule of activities, and target the impairment appropriately. Finally, ongoing monetary support is available for implementation in a variety of forms, including Section 319 grants, as well as Watershed Improvement Review Board (WIRB) grants, the Water Protection Fund (WPF), and the Watershed Protection Fund (WSPF). WIRB funds were authorized in Chapter 466A of the Iowa Code and are administered by WIRB representatives from the Iowa Department of Agriculture and Land Stewardship (IDALS), IDNR, two state representatives, and two state senators. WPF and WSPF funds are appropriated from the Iowa State Legislature and are administered by the IDALS Division of Soil Conservation (DSC).

3.6. TMDL Summary

This TMDL is based on meeting the water quality criteria for primary contact and children's recreation in Duck Creek. Although the WQS are based on *E. coli* concentration, the TMDL is also expressed as a load, in light of the November 2006 EPA memorandum. The following equation represents the total maximum daily load (TMDL) and its components:

$$TMDL = LC = \Sigma\ WLA + \Sigma\ LA + MOS$$

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

Once the loading capacity, waste load allocations, load allocations, and margin of safety are determined for the Duck Creek watershed, the general equation above can be expressed for the Duck Creek *E. coli* TMDLs as shown on the following pages.

Upstream Segment
Table 3-20 reports maximum daily loads allowable at the midpoint of each flow condition for compliance with SSM and 30-day GM criteria in the upper segment of Duck Creek (IA-01-NEM-0060_2 per 305(b) or UAA Segment 2). Figure 3-23 illustrates the flow-dependant TMDL curve for compliance with the SSM criterion.

Downstream Segment
Tables 3-21 and 3-22 and Figures 3-24 and 3-25 summarize the TMDL for the downstream segment of Duck Creek (IA-01-NEM-0060_1 per 305(b) or UAA Segment 1). Compliance with WQS in the downstream reach will be achieved when the allowable

loads are no longer exceeded at the Duck Creek Golf Course (DC-10) or Devils Glen Road (DC-12) locations.

Table 3-20. TMDL summary for upstream segment (110th Avenue/DC-16).

IA 01-NEM-0060_2				
Flow Condition	**TMDL (orgs/day)**	**WLA (orgs/day)**	**LA (orgs/day)**	**MOS (orgs/day)**
SSM (90th Percentile Load)				
High Flow	2.41E+11	2.40E+07	2.17E+11	2.41E+10
Moist	6.32E+10	2.40E+07	5.69E+10	6.32E+09
Mid-Range	2.47E+10	2.40E+07	2.22E+10	2.47E+09
Dry	8.62E+09	2.40E+07	7.73E+09	8.62E+08
Low Flow	1.55E+09	2.40E+07	1.37E+09	1.55E+08
GM (Median Load)				
High Flow	1.29E+11	1.29E+07	1.16E+11	1.29E+10
Moist	3.39E+10	1.29E+07	3.05E+10	3.39E+09
Mid-Range	1.33E+10	1.29E+07	1.20E+10	1.33E+09
Dry	4.62E+09	1.29E+07	4.15E+09	4.62E+08
Low Flow	8.32E+08	1.29E+07	7.36E+08	8.32E+07

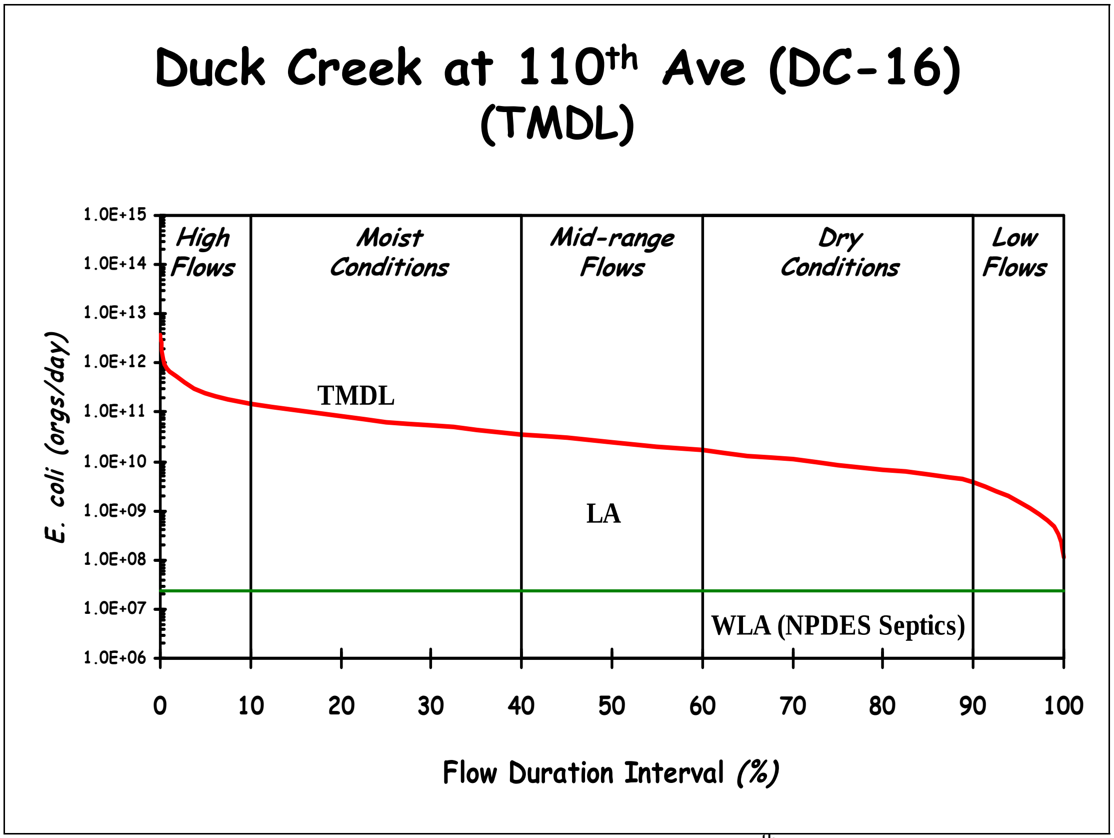

Figure 3-23. TMDL curve for upstream segment (110th Avenue/DC-16).

Table 3-21. TMDL summary for downstream segment (Golf Course/DC-10).

IA 01-NEM-0060_1				
Flow Condition	**TMDL (orgs/day)**	**WLA (orgs/day)**	**LA (orgs/day)**	**MOS (orgs/day)**
SSM (90th Percentile Load)				
High Flow	8.85E+11	6.35E+11	1.61E+11	8.85E+10
Moist	2.47E+11	1.88E+10	2.04E+11	2.47E+10
Mid-Range	9.77E+10	3.51E+09	8.44E+10	9.77E+09
Dry	3.62E+10	3.38E+09	2.92E+10	3.62E+09
Low Flow	1.09E+10	3.38E+09	6.43E+09	1.09E+09
GM (Median Load)				
High Flow	4.75E+11	3.40E+11	8.80E+10	4.75E+10
Moist	1.33E+11	9.01E+09	1.11E+11	1.33E+10
Mid-Range	5.24E+10	8.22E+08	4.63E+10	5.24E+09
Dry	1.94E+10	7.50E+08	1.67E+10	1.94E+09
Low Flow	5.86E+09	7.50E+08	4.52E+09	5.86E+08

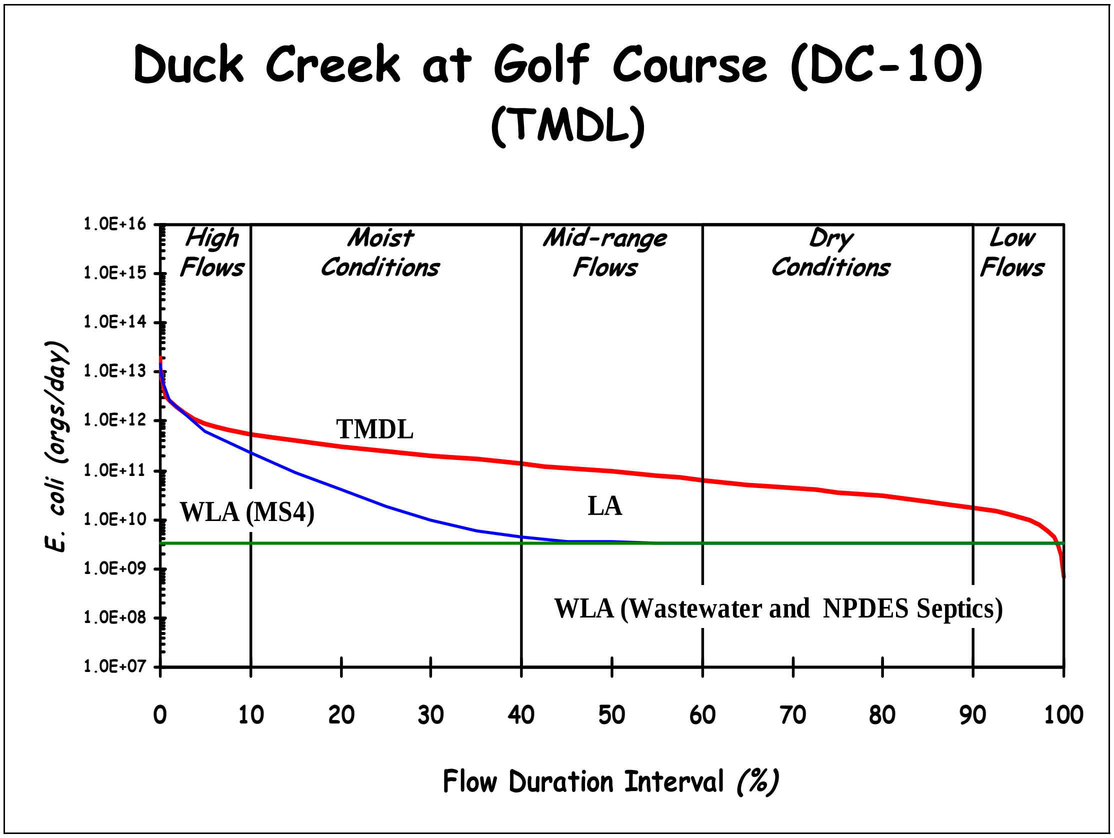

Figure 3-24. TMDL curve for downstream segment (Golf Course/DC-10).

Table 3-22. TMDL summary for downstream segment (Devils Glen/DC-12).

IA 01-NEM-0060_1				
Flow Condition	**TMDL (orgs/day)**	**WLA (orgs/day)**	**LA (orgs/day)**	**MOS (orgs/day)**
SSM (90th Percentile Load)				
High Flow	9.71E+11	7.68E+11	1.05E+11	9.71E+10
Moist	2.71E+11	2.14E+10	2.22E+11	2.71E+10
Mid-Range	1.07E+11	3.51E+09	9.28E+10	1.07E+10
Dry	3.94E+10	3.38E+09	3.21E+10	3.94E+09
Low Flow	1.19E+10	3.38E+09	7.33E+09	1.19E+09
GM (Median Load)				
High Flow	5.21E+11	4.11E+11	5.79E+10	5.21E+10
Moist	1.45E+11	1.04E+10	1.20E+11	1.45E+10
Mid-Range	5.76E+10	8.22E+08	5.10E+10	5.76E+09
Dry	2.11E+10	7.50E+08	1.82E+10	2.11E+09
Low Flow	6.37E+09	7.50E+08	4.98E+09	6.37E+08

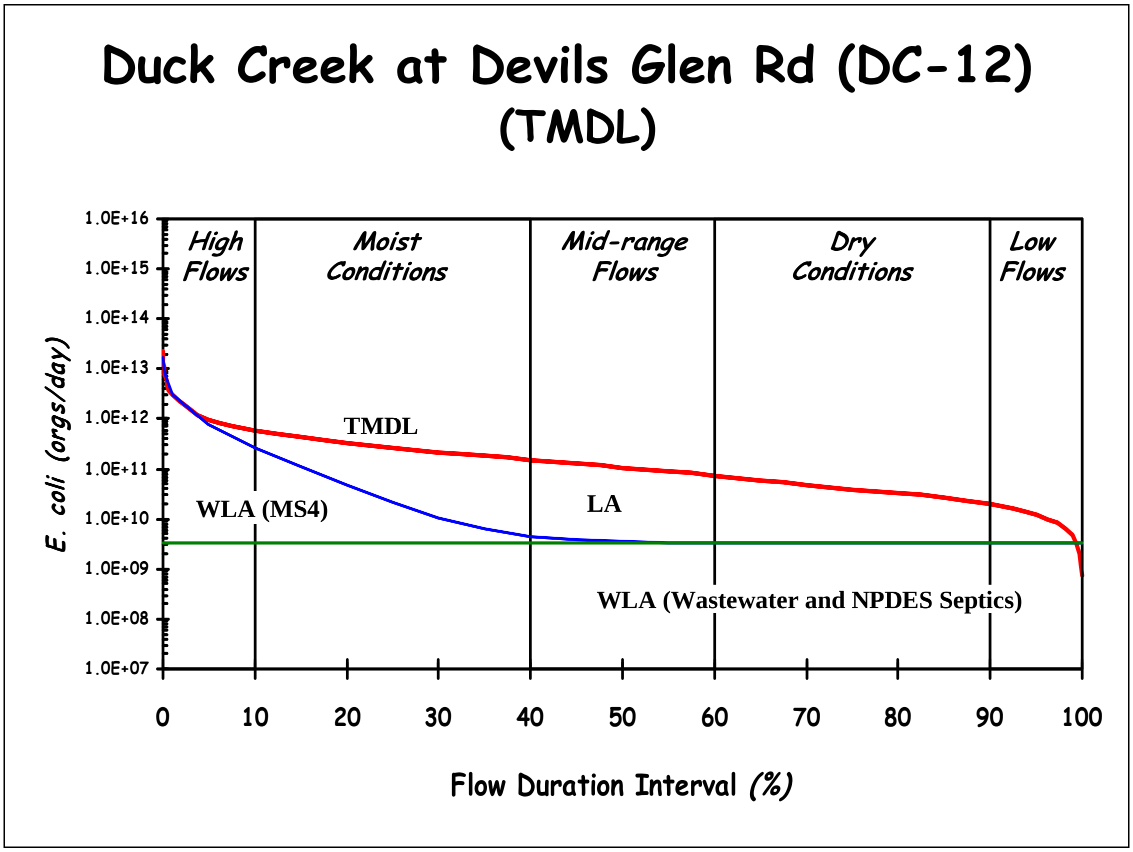

Figure 3-25. TMDL curve for downstream segment (Devils Glen Road/DC-12).

4. Total Maximum Daily Load (TMDL) for *E. coli* in tributaries to Duck Creek

Section 3 of this Water Quality Improvement Plan (WQIP) includes the Total Maximum Daily Load (TMDL) for two impaired segments of Duck Creek required by the Federal Clean Water Act. This section (Section 4) quantifies the maximum amount of *Escherichia coli (E. coli)* that several tributaries to Duck Creek can tolerate without violating the state's water quality standards (WQS). These tributaries have not been officially assessed and included on the state's 303(d) list. However, data collected in 2008 indicate that bacteria levels in these tributaries are exceeding WQS and preventing full support of recreational uses.

4.1. Problem Identification

Several tributaries to Duck Creek have recreational designated uses (Class A1, A2, and A3). The presumptive A1 (primary contact recreation) use was applied to these streams with adoption of changes to the WQS in 2008. All but one of these streams were assigned new uses as defined by use attainability assessments (UAAs) conducted in 2008. No UAA was completed on Goose Creek, which retains the presumptive A1 use. Water quality data reveals these tributaries are not supporting their recreation-related designated uses. Table 4-1 describes the tributary locations and reports the recreational use of each.

Table 4-1. Duck Creek tributaries and designated use classifications.

Waterbody	Location Description	Recreational Use
Unnamed Creek (Pheasant Creek)	From mouth at Duck Creek (SW ¼, NW ¼, S20, T78N, R4E) to the dam of a pond (NE ¼, NW ¼, S6, T78N, R4E)	Class A3
Goose Creek	From mouth at Duck Creek (NW ¼, NW ¼, S24, T78N, R3E) to upstream extents	Presumptive A1
Silver Creek	From mouth at Duck Creek (S16, T78N, R3E) to confluence with Unnamed Creek (S33, T79N, R3E)	Class A3
[1] Unnamed Creek (1)	From the mouth at Duck Creek (SW ¼, SW ¼, S17, T78N, R3E) 110th Avenue (West Line, S12, T78N, R2E)	Class A2

[1] The unnamed creek does not have a WQ monitoring station, therefore no data is available and a TMDL is not proposed at this time. Future monitoring efforts should include collecting data in this stream.

Applicable Water Quality Standards

The applicable water quality standards for the impairments to recreation-related designated uses are provided in Table 3-2 of Section 3.1. Although the Unnamed Creek (1) was designated for Class A2 use in the UAA, the short stream distance and travel time to the A3 segment of Duck Creek would require *E. coli* levels in this tributary to comply with Class A3 criteria to meet WQS in Duck Creek. However, no water quality data is available for this tributary, and a TMDL will not be developed at this time.

Problem Statement

Intensive grab sampling conducted by UHL and Scott County SWCD in 2008 revealed that high levels of indicator bacteria (*E. coli)* routinely violated state water quality standards in several tributaries to Duck Creek. This section describes the development of TMDLs for three tributary streams in the Duck Creek watershed. It is anticipated that these TMDLs will apply, as written, when UAAs are fully approved by EPA and/or when future 305(b) assessments are completed by IDNR. If no UAA is conducted or approved for Goose Creek, the Presumptive A1 use will remain in place. No TMDL is developed for Unnamed Creek (1) because no water quality data has been collected in this tributary. Future monitoring efforts should address this data gap. See Section 6 of this WQIP for future monitoring recommendations.

Data Sources

Non-water quality related data was utilized for TMDL development, and is described in Section 3.1 of the WQIP. The primary sources of water quality data used in the development of these TMDLs are the in-stream water quality data collected by UHL and Scott County SWCD. Table 4-2 lists the TMDL tributary streams with their respective UHL/SWCD water quality monitoring stations. Figure 4-1 illustrates tributaries with recreational uses and the location of water quality monitoring stations.

Table 4-2. Perennial streams with UHL/SWCD monitoring stations.

Stream Name	Monitoring Station ID	Monitoring Station Location
Unnamed Creek (Pheasant Creek)	PC-2	Just upstream of E. 32nd St. between Elmore Ave. and Fernwood Ct.
Goose Creek	GC-4	Near mouth just downstream of E. 33rd St. between Adams St. and E. 35th St.
Silver Creek	SC-1A	Near mouth (approximately 2,400 feet downstream of W. Kimberly Rd.) between Elmwood Ave. and N. Pine St.
Unnamed Creek (1)	None	No monitoring data collected. TMDL not developed at this time.

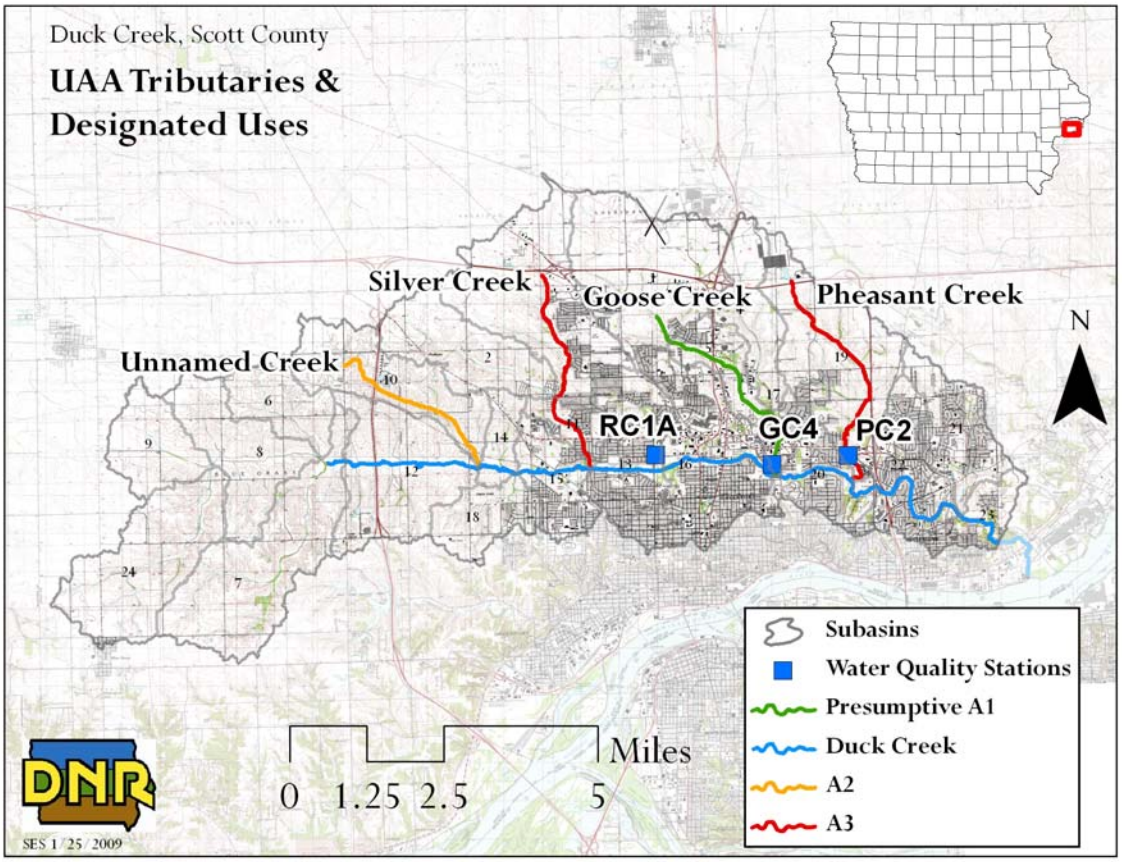

Figure 4-1. Duck Creek tributaries with recreation-related designated uses.

Interpreting in-stream data

Figure 4-2 shows *E. coli* concentrations measured during the 2008 monitoring season in Pheasant, Silver, and Goose Creeks. The unnamed creek was not monitored in 2008 and observed data is not available, therefore no TMDL will be developed at this time. Data for the other three streams reveal frequent violations of the single-sample maximum (SSM) criterion of 235 orgs/100 mL. Silver Creek exhibits the most variability in bacteria levels, with both the highest and lowest *E. coli* observations.

Figure 4-3 illustrates the running 30-day geometric mean (GM) for all three stations. This plot reveals continuous violation of the GM criterion throughout the 2008 sampling season at all three locations, with the exception of one compliant GM value in Silver Creek in May. Silver Creek had the lowest measured GM of all three streams in May and June, and Pheasant had the lowest GM values in September and October. The GM is generally highest in Goose Creek through most of the recreation season.

Analysis of the data plotted in Figures 4-2 and 4-3 reveals consistently high *E. coli* levels that significantly exceed both criteria set forth in Iowa's water quality standards for primary contact (Class A1) and children's (Class A3) recreation. Significant reductions in *E. coli* loading will be required to comply with the standards and fully support recreation-related designated uses.

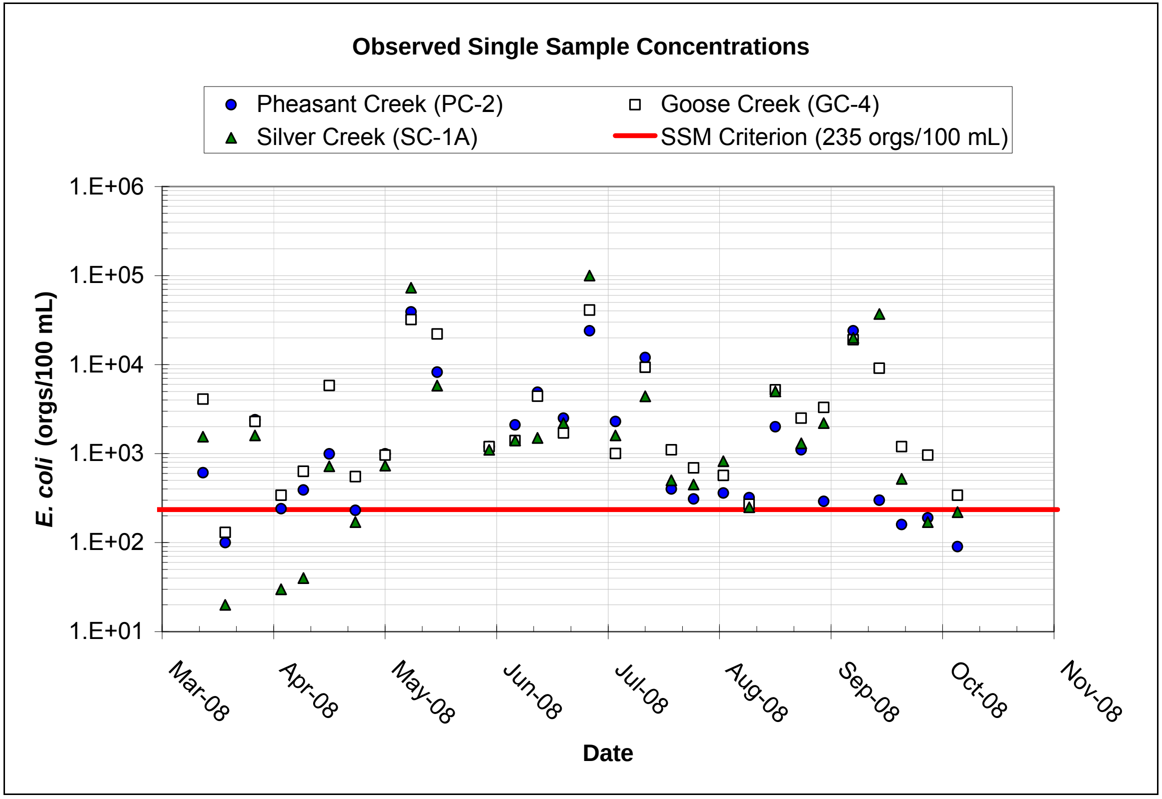

Figure 4-2. Observed single sample *E. coli* concentrations in 2008.

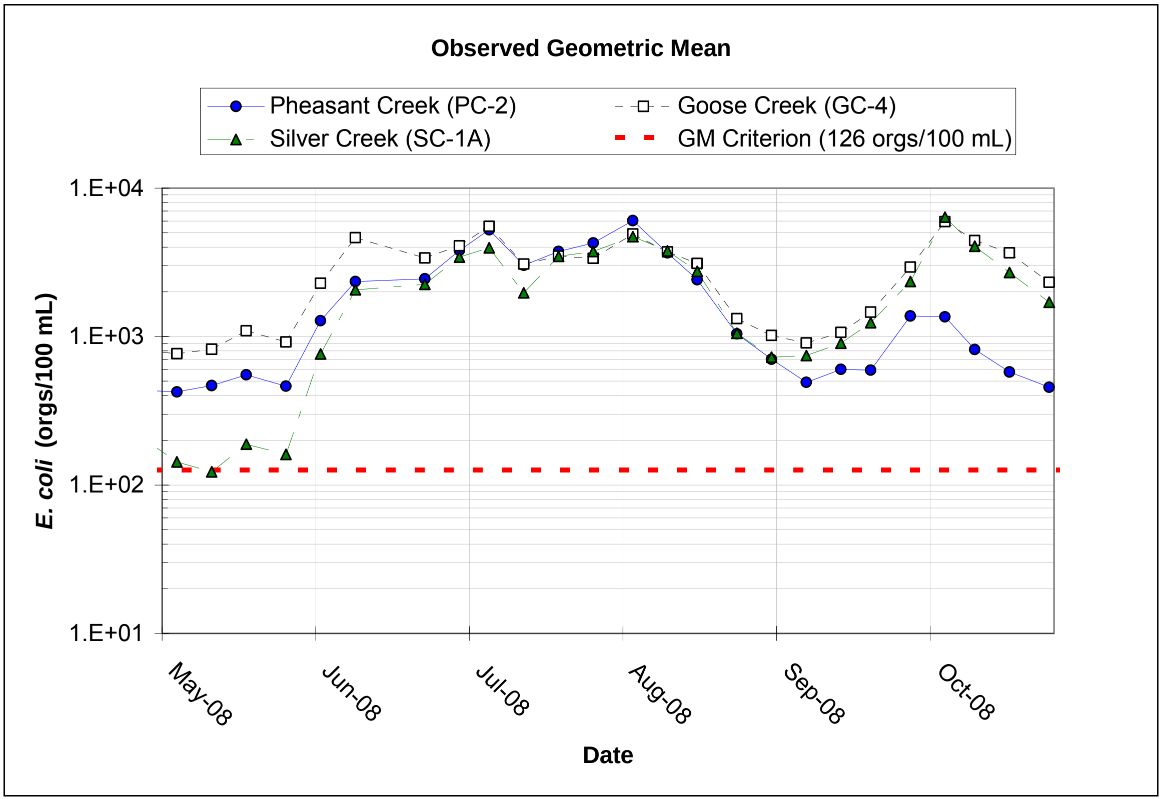

Figure 4-3. Measured 30-day geometric mean concentrations observed in 2008.

Observed *E. coli* concentrations were evaluated on a monthly basis to investigate whether or not temporal trends within the recreation season exist. The box plots in Figures 4-4 through 4-6 illustrate the minimum, first quartile (25th percentile), median, third quartile (75th percentile), and maximum *E. coli* concentration observed for each month in which data was collected.

Concentrations in Pheasant Creek at East 32nd Street (PC-2) tend to increase from April to the highest level in June, and then decrease from June through October. In fact, the 75th percentile concentration in October is below the SSM criterion. There is much less variation in Goose Creek, and the lowest quarter of all samples collected exceed the SSM criterion in every month from April to October. Silver Creek exhibits the same general pattern as monthly data in Pheasant and Goose, but with more variation (more extreme low and high concentrations). The highest maximum concentrations in all three streams are observed in June and July.

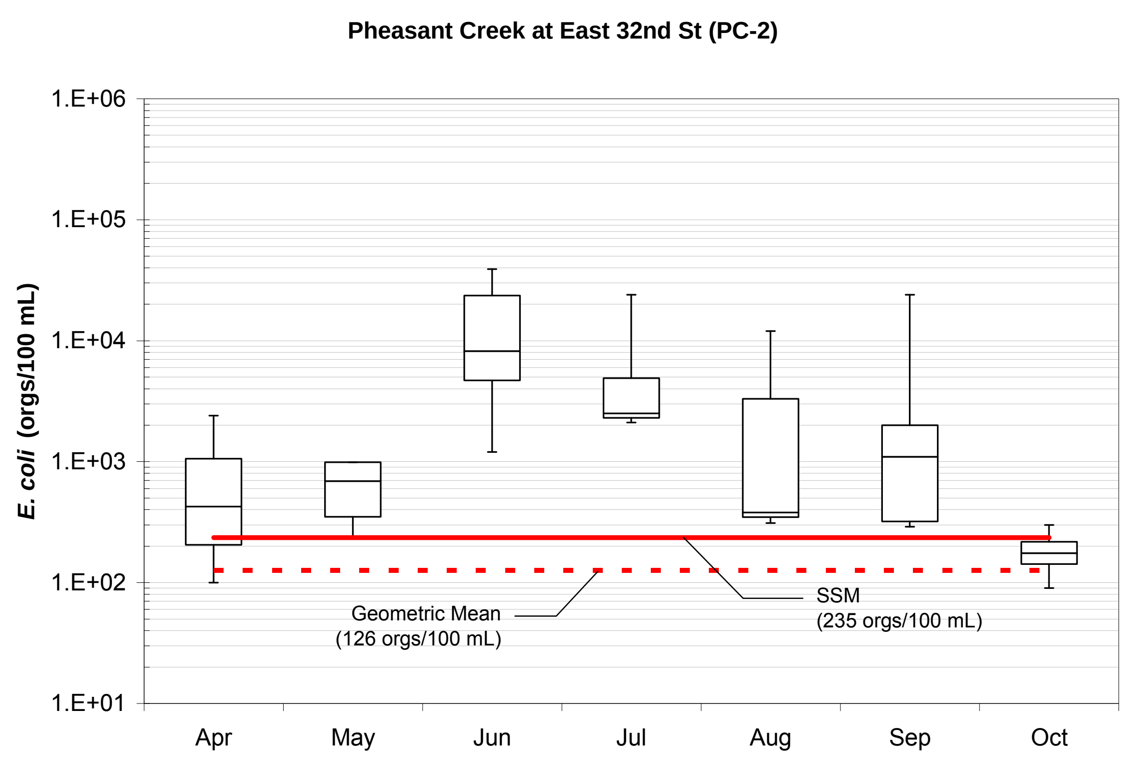

Figure 4-4. Monthly box plots of *E. coli* in Pheasant Creek (PC-2).

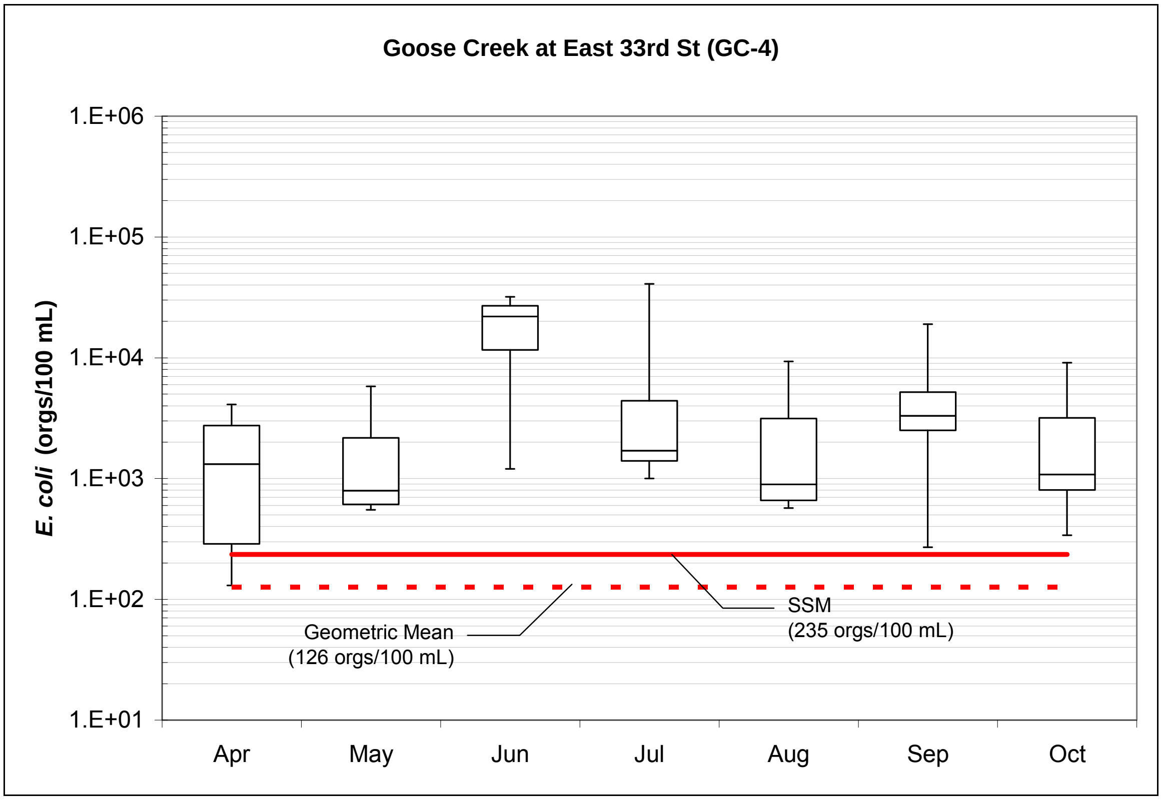

Figure 4-5. Monthly box plots of *E. coli* in Goose Creek (GC-4).

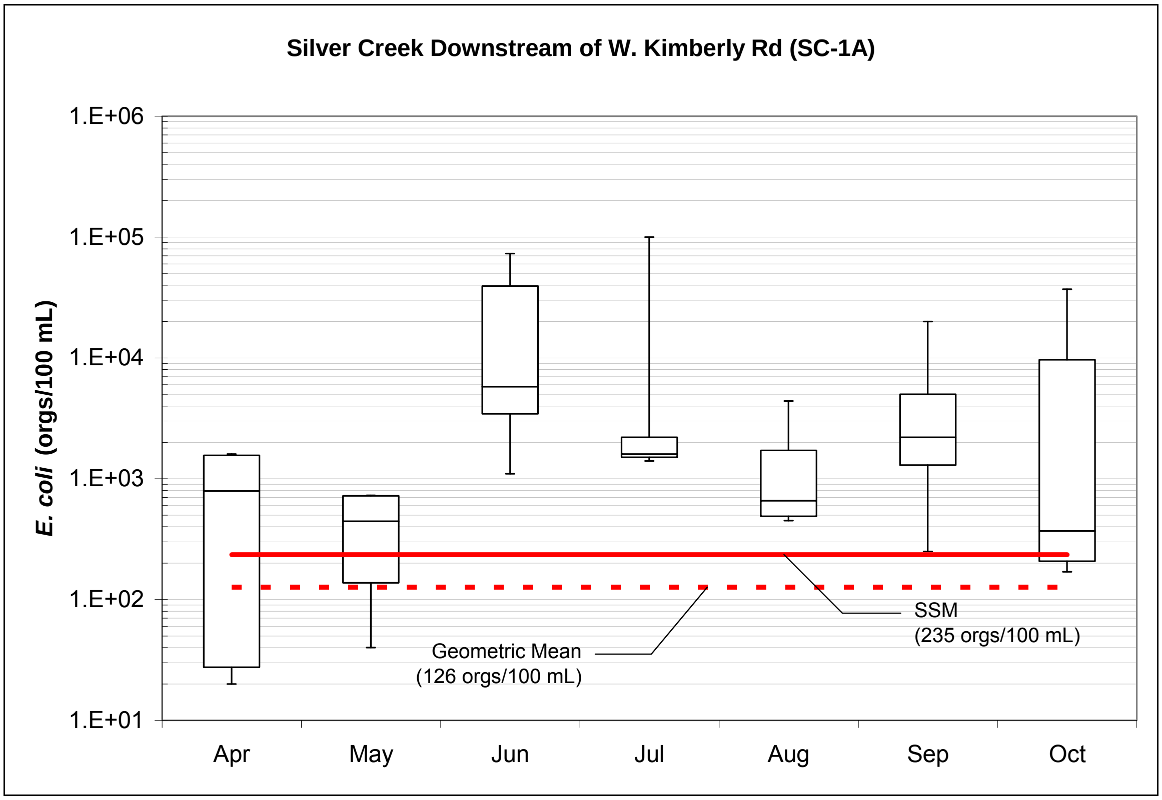

Figure 4-6. Monthly box plots of *E. coli* in Silver Creek (SC-1A).

4.2. TMDL Target

General Description of the Pollutant
The pollutant of concern is *E. coli*, as described in Section 3.2 of this report.

Selection of Environmental Conditions
The critical period in which the impairment occurs is the recreation season, which runs from March 15 to November 15 each year.

Waterbody Pollutant Loading Capacity (TMDL)
Attainment of the WQS in all tributaries with recreation-related designated uses requires that the GM be no greater than 126 orgs/100 mL and the SSM be no greater than 235 orgs/100 mL. The *E. coli* loading capacity of a stream is the maximum number of *E. coli* organisms that can be in the stream while the above criteria are met.

Load duration curves (LDCs) constructed using observed *E. coli* concentrations and mean daily flows were used to calculate the loading capacity of Duck Creek tributaries on a daily basis. Attainment of water quality standards in each tributary to Duck Creek is evaluated at one compliance point in each creek. These compliance points are located at UHL/SWCD water quality monitoring stations described previously in Table 4-2.

Flow at each site was measured at the time grab samples were collected. During several sampling events at each location, flow was either too high or too low for manual measurements to be obtained. Regression equations were developed for measured flows at each site, and missing flows were calculated based on the regression equation for each location. Measured and calculated flows, along with *E. coli* concentrations observed via grab sampling, were utilized to construct LDCs for each tributary. The duration curves are categorized into the same five hydrologic (flow) conditions summarized in Section 3.2, Table 3-4. Use of the LDCs for assessment of compliance with WQS is also discussed in Section 3.2.

The LDCs in Figures 4-7 through 4-9 illustrate the flow variable loading capacity for each creek. Loading capacities will be assessed quantitatively at the midpoint of each flow condition. These midpoint loading capacities are illustrated on the solid red curve (SSM) and dashed red curve (GM) in each LDC, and are reported in Tables 4-3 through 4-5.

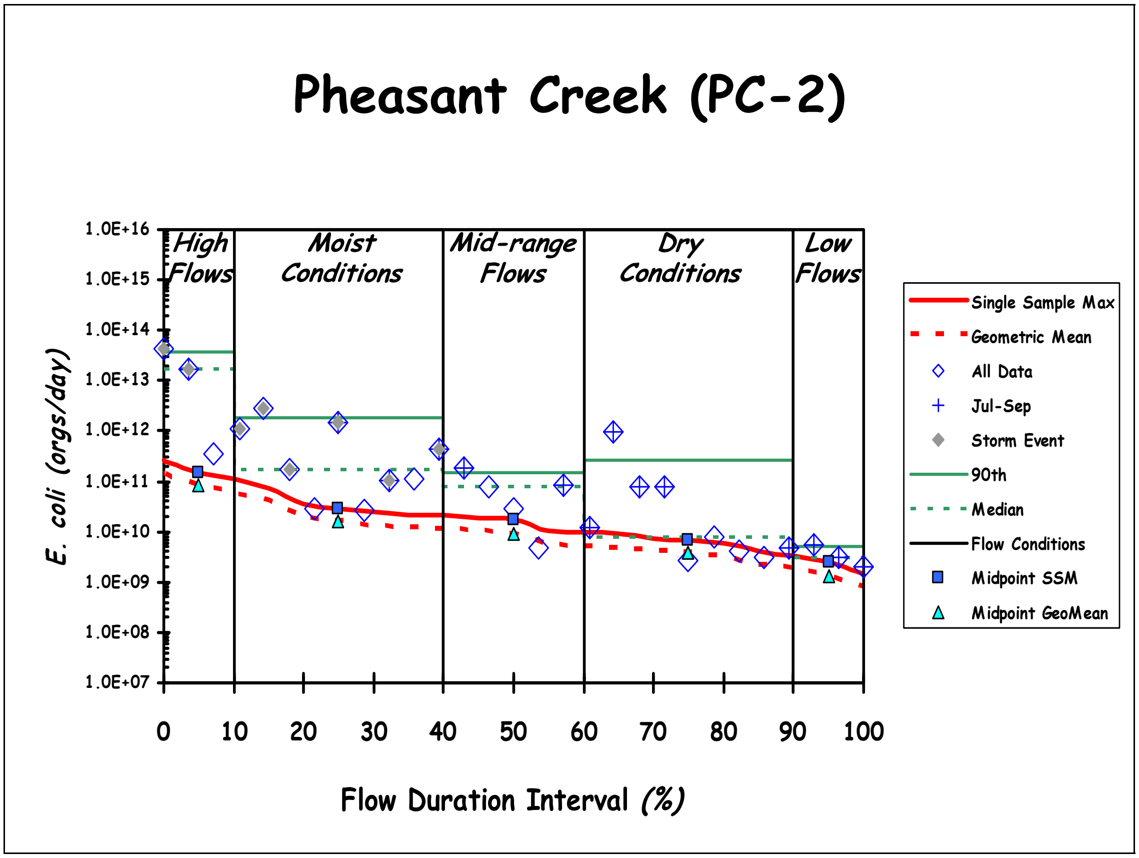

Figure 4-7. Load duration curve (LDC) for Pheasant Creek (PC-2).

Table 4-3. Flow variable loading capacity in Pheasant Creek (PC-2).

Loading Capacity Summary	Loading capacities (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
SSM Load	1.53E+11	2.93E+10	1.74E+10	6.96E+09	2.52E+09
GM Load	8.22E+10	1.57E+10	9.34E+09	3.73E+09	1.35E+09
Midpoint flow (cfs)	26.7	5.1	3.0	1.2	0.4

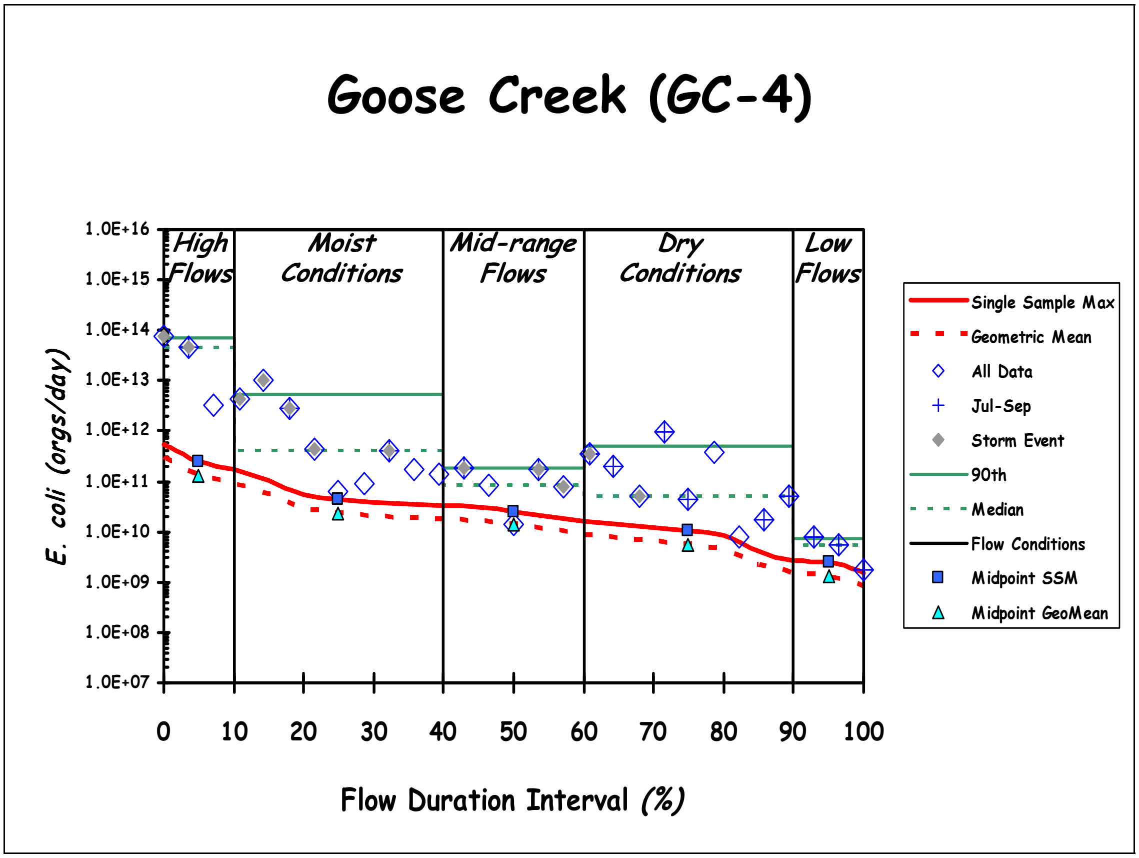

Figure 4-8. Load Duration Curve (LDC) for Goose Creek.

Table 4-4. Flow variable loading capacity in Goose Creek (GC-4).

Loading Capacity Summary	Loading capacities (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
SSM Load	2.41E+11	4.34E+10	2.53E+10	1.06E+10	2.42E+09
GM Load	1.29E+11	2.33E+10	1.36E+10	5.66E+09	1.30E+09
Midpoint flow (cfs)	41.9	7.6	4.4	1.8	0.4

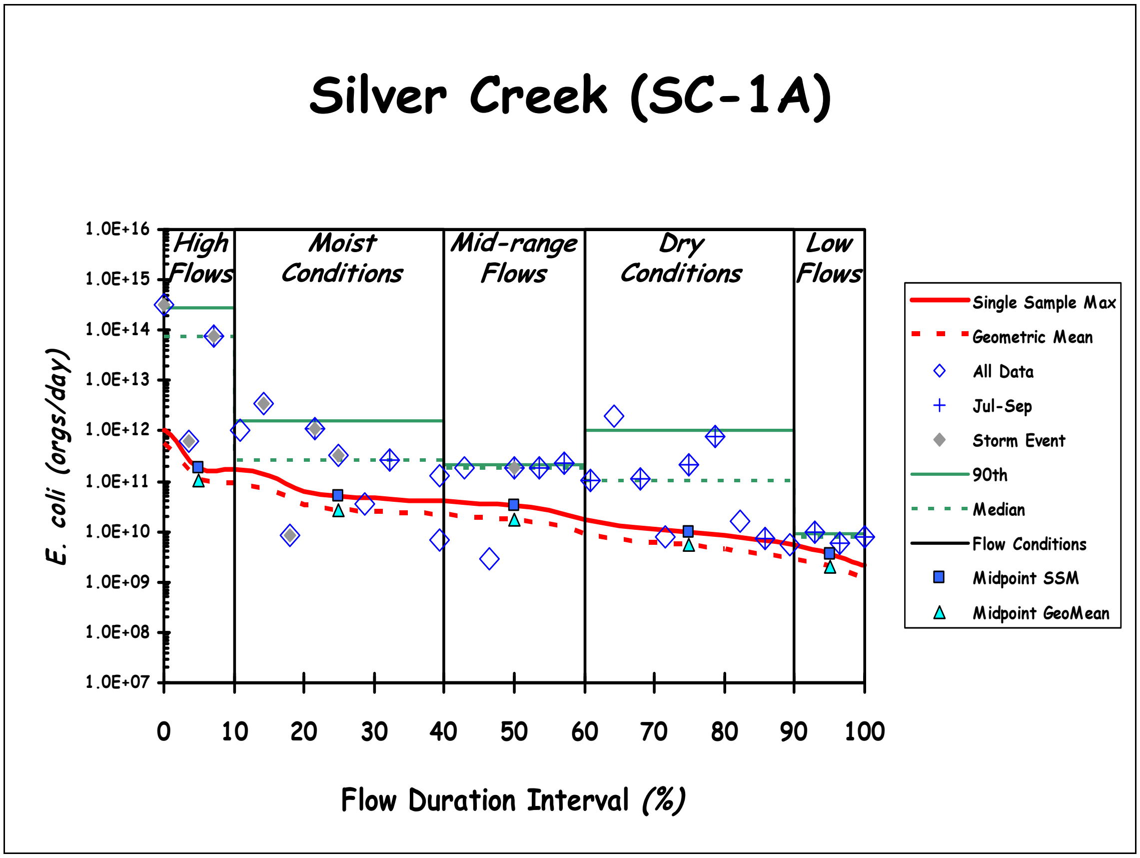

Figure 4-9. Load Duration Curve (LDC) for Silver Creek.

Table 4-5. Flow variable loading capacity in Silver Creek (SC-1A).

Loading Capacity Summary	Loading capacities (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
SSM Load	1.89E+11	4.97E+10	3.23E+10	1.01E+10	3.67E+09
GM Load	1.01E+11	2.66E+10	1.73E+10	5.43E+09	1.97E+09
Midpoint flow (cfs)	32.9	8.6	5.6	1.8	0.6

Decision Criteria for Water Quality Standards Attainment
The criteria set forth in the WQS for Class A1 and Class A3 uses must be met in all three tributaries to attain water quality standards and fully support designated uses.

4.3. Pollution Source Assessment

Existing Loads
Observed *E. coli* loads were estimated by multiplying observed concentrations (orgs/100 mL) by the mean daily flow (cfs) on the day the sample was collected (including a units conversion). Using the LDC approach, these measured loads are plotted against the flow duration interval, which allows loads to be grouped into the same flow conditions used in the plots of flow variable loading capacities. Individual loads at each monitoring location are represented by blue diamonds in Figures 4-7 through 4-9. Points above the red SSM

and GM curves represent violations of the WQS, whereas points below the curves are acceptable and meet the criteria.

The existing daily maximum load (for each flow condition) is estimated by multiplying the 90th percentile measured *E. coli* concentration by the flow at the midpoint of each flow condition. This is consistent with an LDC approach recommended by EPA (EPA, 2007). The 90th percentile loads are represented by solid green lines and median loads (50th percentile) are illustrated by dashed green lines in Figures 4-7 through 4-9. Although the median load is not mathematically equivalent to the GM, they both reflect "typical" or long-term "average" loads. Both measures (90th percentile and median) of existing loads are utilized in the calculation of TMDLs for Duck Creek tributary streams. The points (diamonds) in Figures 4-7 through 4-9 that include a blue "+" symbol within them represent samples collected in the months of July, August, and September. Gray shading within the diamonds indicate samples where storm flow (runoff) comprises over 50 percent of the flow. These points are considered storm events. Tables 4-6 through 4-8 report existing load estimates at the midpoint of each flow condition.

Table 4-6. Existing load estimates in Pheasant Creek (PC-2).

Existing Load Summary	Existing Loads (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
90th Percentile Load	3.75E+13	1.77E+12	1.44E+11	2.57E+11	5.01E+09
Median Load	1.69E+13	1.75E+11	7.61E+10	7.71E+09	3.15E+09
Midpoint flow (cfs)	26.7	5.1	3.0	1.2	0.4

Table 4-7. Existing load estimates in Goose Creek (GC-4).

Existing Load Summary	Existing Loads (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
90th Percentile Load	6.94E+13	5.45E+12	1.83E+11	5.11E+11	7.43E+09
Median Load	4.76E+13	4.08E+11	8.17E+10	5.17E+10	5.41E+09
Midpoint flow (cfs)	41.9	7.6	4.4	1.8	0.4

Table 4-8. Existing load estimates in Silver Creek (SC-1A).

Existing Load Summary	Existing Loads (orgs/day)				
	High	Moist	Mid-Range	Dry	Low
90th Percentile Load	2.80E+14	1.60E+12	2.10E+11	1.01E+12	9.10E+09
Median Load	7.51E+13	2.59E+11	1.80E+11	1.04E+11	7.62E+09
Midpoint flow (cfs)	32.9	8.6	5.6	1.8	0.6

Examination of the LDCs and observed data clearly reveals that bacteria concentrations exceed water quality criteria in a majority of instances (all points above the SSM and GM curves). Compliant loads (points below the curves) are rare under all hydrologic conditions. Most of the few observations in compliance with WQS occur during "mid-range" and "moist" flow conditions. Although observed *E. coli* loads in all three tributaries tend to be smaller magnitude and closer to compliant levels during low flow conditions, they are still in violation of the WQS. This differs from low flow loads in the main stem of Duck Creek, which generally comply with WQS. This suggests that in urban areas associated with these tributaries, continuous sources of *E. coli* may be of particular concern. These sources could include wildlife deposition in streams and in the stormwater system, and/or illicit discharges to stormwater (i.e., leaky sanitary sewers). The available data do not allow drawing these conclusions with a high degree of certainty, and the implementation and monitoring plans (Sections 5 and 6 of this report) suggest actions to further evaluate and quantify potential sources.

Departure from Load Capacity

The loading capacity and existing 90th percentile and median loads in each flow condition are plotted in Figures 4-7 through 4-9. The LDCs allow the departure from loading capacity to be evaluated graphically. The distance between the 90th percentile existing load in each flow condition (solid green lines) to the loading capacity associated with the SSM load (solid red curve) represents the departure from the SSM criterion. Similarly, the distance from the median existing load (dashed green lines) to the loading capacity associated with the GM load (dashed red curve) represents the departure from the GM criterion. Tables 4-9 through 4-11 list the departures (as loads and as percentages) at the midpoint of each flow condition for each tributary.

Table 4-9. Departure from loading capacity in Pheasant Creek (PC-2).

Departure from Capacity	Departure in orgs/day and (%)				
	High	Moist	Mid-Range	Dry	Low
SSM Departure	3.73E+13 (99.6)	1.74E+12 (98.3)	1.27E+11 (87.9)	2.50E+11 (97.3)	2.49E+09 (49.7)
GM Departure	1.68E+13 (99.5)	1.59E+11 (91.0)	6.68E+10 (87.7)	3.98E+09 (51.6)	1.80E+09 (57.1)
Midpoint flow (cfs)	26.7	5.1	3.0	1.2	0.4

Table 4-10. Departure from loading capacity in Goose Creek (GC-4).

Departure from Capacity	Departure in orgs/day and (%)				
	High	Moist	Mid-Range	Dry	Low
SSM Departure	6.91E+13 (99.7)	5.41E+12 (99.2)	1.58E+11 (86.2)	5.00E+11 (97.9)	5.01E+09 (67.4)
GM Departure	4.75E+13 (99.7)	3.85E+11 (94.3)	6.81E+10 (83.4)	4.60E+10 (89.1)	4.12E+09 (76.0)
Midpoint flow (cfs)	41.9	7.6	4.4	1.8	0.4

Table 4-11. Departure from loading capacity in Silver Creek (SC-1A).

Departure from Capacity	Departure in orgs/day and (%)				
	High	Moist	Mid-Range	Dry	Low
SSM Departure	2.80E+14 (99.9)	1.55E+12 (96.9)	1.78E+11 (84.6)	9.98E+11 (99.0)	5.43E+09 (59.7)
GM Departure	7.50E+13 (99.9)	2.32E+11 (89.7)	1.62E+11 (90.3)	9.86E+10 (94.8)	5.66E+09 (74.2)
Midpoint flow (cfs)	32.9	8.6	5.6	1.8	0.6

Two general trends can be observed from analysis of the departures. First, all three tributary streams require significant reductions in *E. coli* to comply with WQS. Second, the largest departures are observed under high flow conditions. Departures generally decrease as flow decreases, with the exception that departures from capacity are greater under dry flow conditions than they are during mid-range flow conditions for all three streams.

E. coli Concentration and Flow Duration

Figures 4-10 through 4-12 illustrate the same concept as the LDCs, but represent the assimilative capacity, existing bacteria levels, and departure in terms of concentration (per the WQS), rather than loads. The LDCs are more useful for calculating required reductions, but both types of plots are instructive for interpretation of water quality.

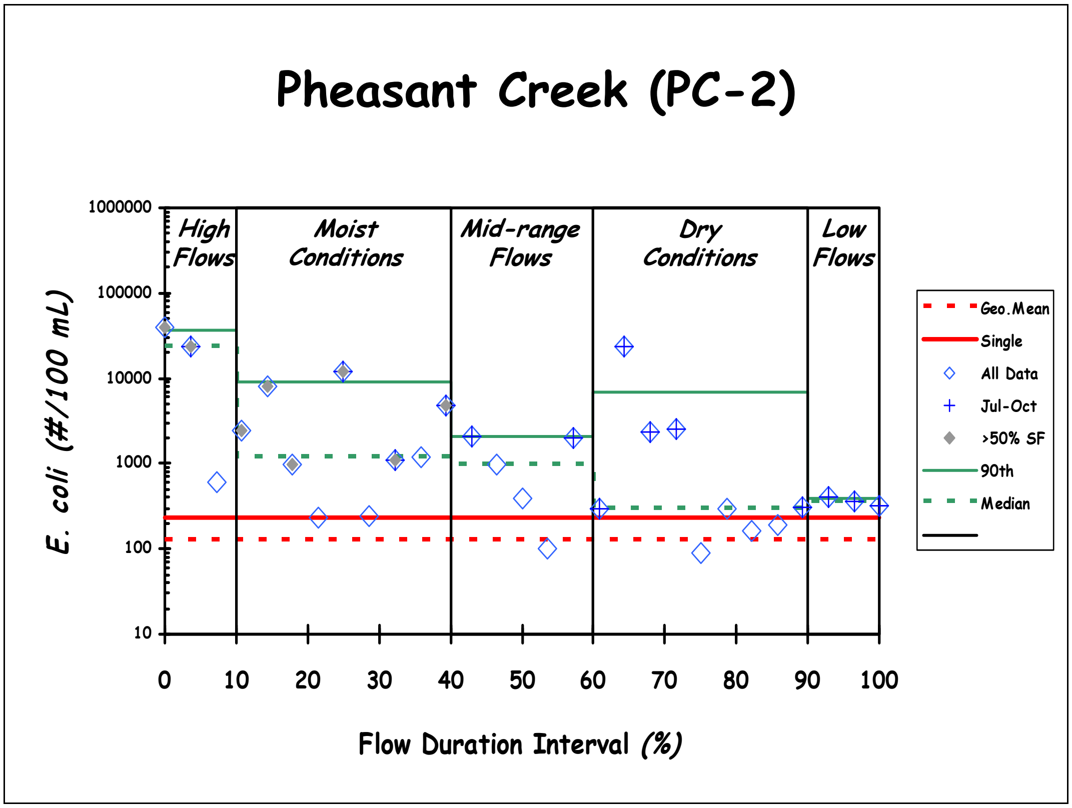

Figure 4-10. *E. coli* concentrations vs. flow duration in Pheasant Creek.

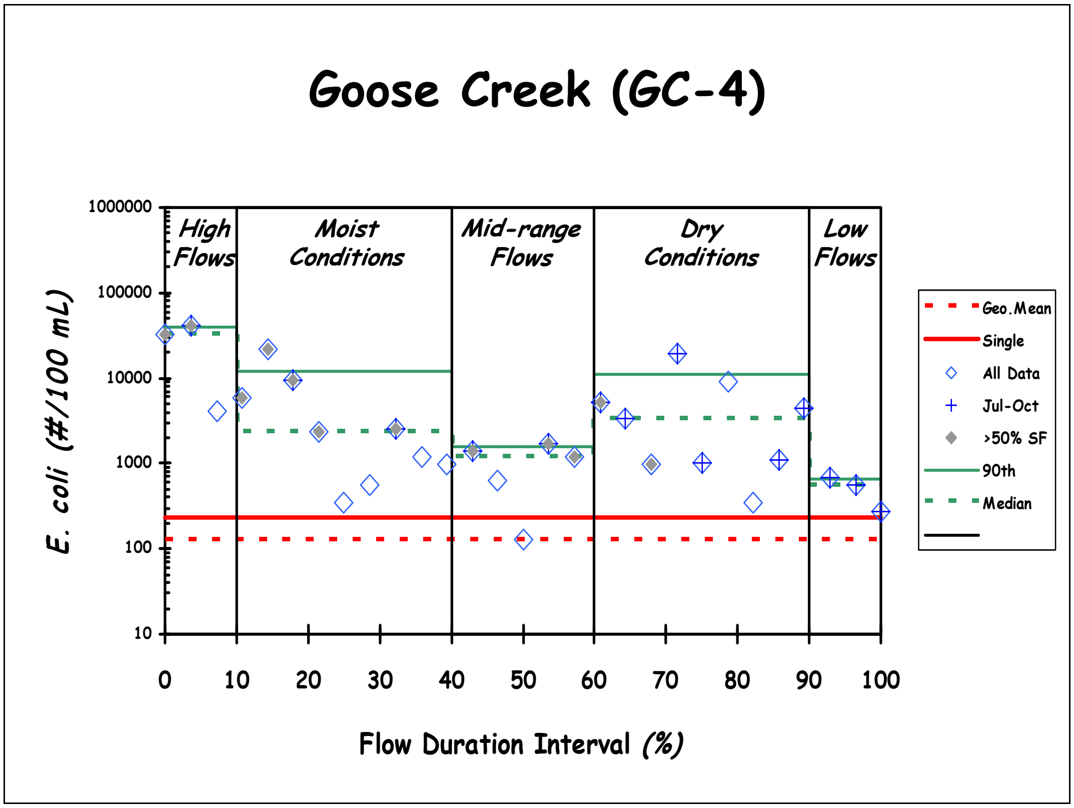

Figure 4-11. *E. coli* concentrations vs. flow duration in Goose Creek

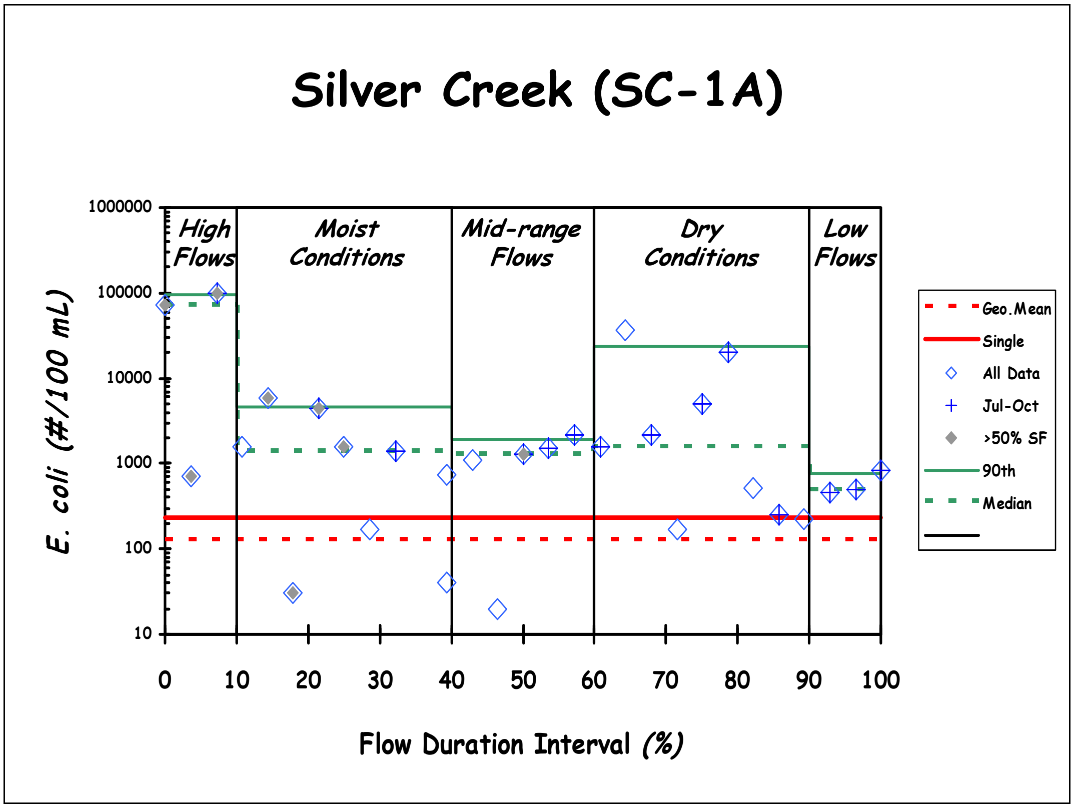

Figure 4-12. *E. coli* concentrations vs. flow duration in Silver Creek.

Identification of Pollutant Sources
Potential *E. coli* sources in the Duck Creek watershed are described in Section 3.3 of this report. Each tributary has a unique combination of *E. coli* sources. Potential sources to each of three tributary streams analyzed in this section are listed in Table 4-12.

Table 4-12. *E. coli* sources in each of the tributary subwatersheds.

Tributary Name	Point Sources	Nonpoint Sources
Pheasant Creek	City of Davenport MS4 City of Bettendorf MS4 SSOs	Wildlife Failing septic systems Regrowth/resuspension
Goose Creek	City of Davenport MS4 SSOs Permitted on-site systems	Wildlife Failing onsite systems Regrowth/resuspension
Silver Creek	City of Davenport MS4 SSOs Permitted on-site systems	Wildlife Livestock grazing Failing onsite systems Regrowth/resuspension

The separation of sources into point and nonpoint categories is not always straight forward. Some point sources behave like nonpoint sources in that they are diffuse and do not necessarily discharge to waterbodies at discrete, easily identifiable locations. Examples include stormwater sources, which result from waste production by pets and wildlife and buildup of bacteria on urban land uses. However, because Davenport and Bettendorf are regulated under NPDES MS4 permits, they are considered point sources regardless of the loading processes. From a practical standpoint, septic systems are often considered to be nonpoint sources. However, some permitted onsite wastewater treatment systems in Iowa, including a number of systems in the Duck Creek watershed, discharge to surface water under NPDES General Permit #4. EPA requires sources regulated by an NPDES permit to be considered point sources. For the purposes of this TMDL, discharging onsite wastewater systems operating under an NPDES permit are considered point sources (and receive a portion of the WLA) whereas failing non-discharging systems are considered nonpoint sources (and do not receive a portion of the WLA).

Table 3-14 (Section 3.3) can be analyzed along with Figures 4-7 through 4-9 to make general conclusions regarding the relative contributions from various sources under each flow condition. Detailed source assessment is discussed in Appendix D, Sections D.5 and D.6. Assumptions regarding the location and magnitude of each source is included. Source allocations (between point and nonpoint sources) developed for the tributary TMDLs are presented in the Section 4.6 (Tables 4-13 through 4-15).

Allowance for Increases in Pollutant Loads
Considerations regarding allowances for increased pollutant loads were discussed in Section 3.3 of this report.

4.4. Pollutant Allocation

Wasteload Allocation
The wasteload allocations (WLAs) for permitted point sources to Duck Creek and its tributaries are described in detail in Section 3.4 of this report. Applicable WLAs are reported as part of the TMDL summary for each tributary in Section 4.6.

4.5. Reasonable Assurance

Reasonable assurance is discussed in detail in Section 3.5 of this report.

4.6. TMDL Summary

This TMDL is based on meeting the water quality criteria for primary contact and children's recreation. Though the WQS is based on *E. coli* concentration, the TMDL is also expressed as a load, in light of the November 2006 EPA memorandum. The following equation represents the total maximum daily load (TMDL) and its components:

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

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

Once the loading capacity, waste load allocations, load allocations, and margin of safety are determined for the Duck Creek watershed, the general equation above can be expressed for the Pheasant, Goose, and Silver Creek *E. coli* TMDLs as shown on the following pages.

Pheasant Creek

Table 4-13 reports maximum daily loads allowable at the midpoint of each flow condition for compliance with SSM and 30-day GM criteria in Pheasant Creek. Figure 4-13 illustrates the flow-dependant TMDL curve for compliance with the SSM criterion.

Table 4-13. TMDL summary for upstream Pheasant Creek (PC-2)

Flow Condition	TMDL (orgs/day)	WLA (orgs/day)	LA (orgs/day)	MOS (orgs/day)
SSM (90th Percentile Load)				
High Flow	1.53E+11	1.01E+11	3.70E+10	1.53E+10
Moist	2.93E+10	1.43E+09	2.49E+10	2.93E+09
Mid-Range	1.74E+10	0.00E+00	1.57E+10	1.74E+09
Dry	6.96E+09	0.00E+00	6.26E+09	6.96E+08
Low Flow	2.52E+09	0.00E+00	2.27E+09	2.52E+08
GM (Median Load)				
High Flow	8.22E+10	5.40E+10	2.00E+10	8.22E+09
Moist	1.57E+10	7.67E+08	1.34E+10	1.57E+09
Mid-Range	9.34E+09	0.00E+00	8.41E+09	9.34E+08
Dry	3.73E+09	0.00E+00	3.36E+09	3.73E+08
Low Flow	1.35E+09	0.00E+00	1.22E+09	1.35E+08

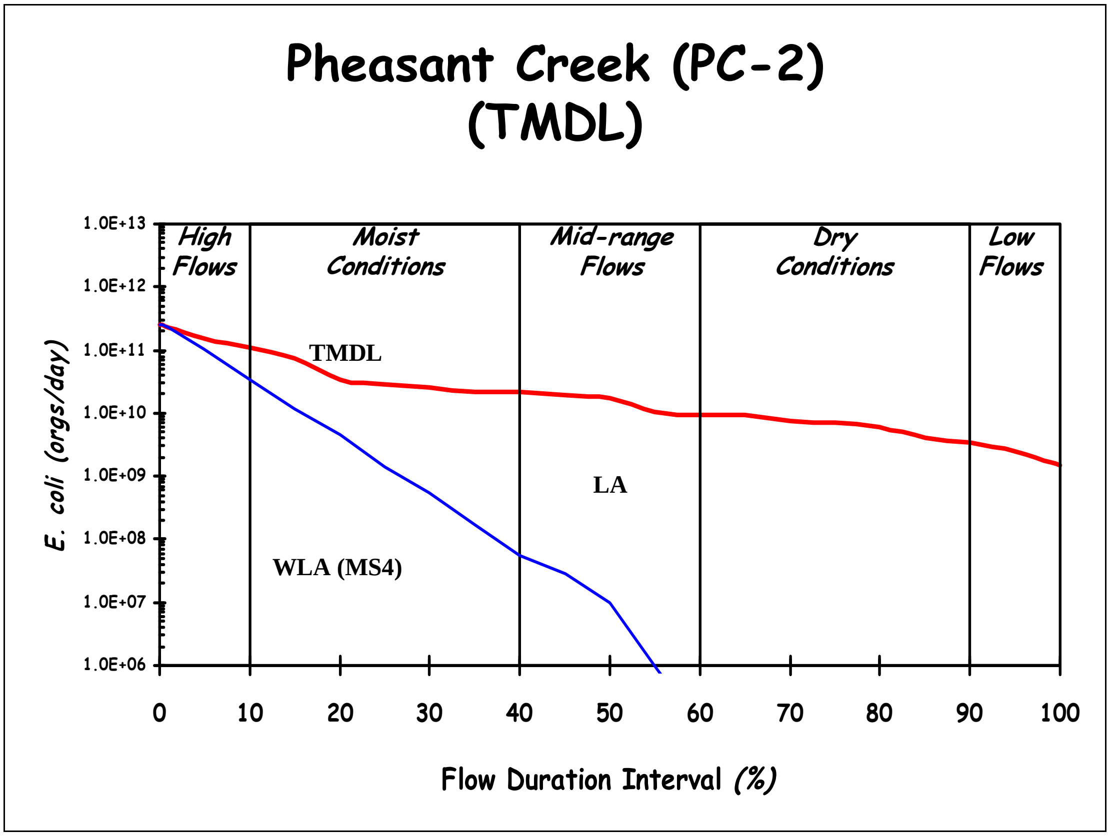

Figure 4-13. TMDL curve for Pheasant Creek (PC-2).

Goose Creek

Table 4-14 reports maximum daily loads allowable at the midpoint of each flow condition for compliance with SSM and 30-day GM criteria in Goose Creek. Figure 4-14 illustrates the flow-dependant TMDL curve for compliance with the SSM criterion.

Table 4-14. TMDL summary for Goose Creek (GC-4).

Flow Condition	TMDL (orgs/day)	WLA (orgs/day)	LA (orgs/day)	MOS (orgs/day)
SSM (90th Percentile Load)				
High Flow	2.41E+11	2.17E+11	0	2.41E+10
Moist	4.34E+10	8.82E+09	3.02E+10	4.34E+09
Mid-Range	2.53E+10	4.94E+07	2.27E+10	2.53E+09
Dry	1.06E+10	8.01E+06	9.53E+09	1.06E+09
Low Flow	2.42E+09	8.01E+06	2.17E+09	2.42E+08
GM (Median Load)				
High Flow	1.29E+11	1.16E+11	0	1.29E+10
Moist	2.33E+10	4.73E+09	1.62E+10	2.33E+09
Mid-Range	1.36E+10	2.65E+07	1.22E+10	1.36E+09
Dry	5.66E+09	4.29E+06	5.09E+09	5.66E+08
Low Flow	1.30E+09	4.29E+06	1.17E+09	1.30E+08

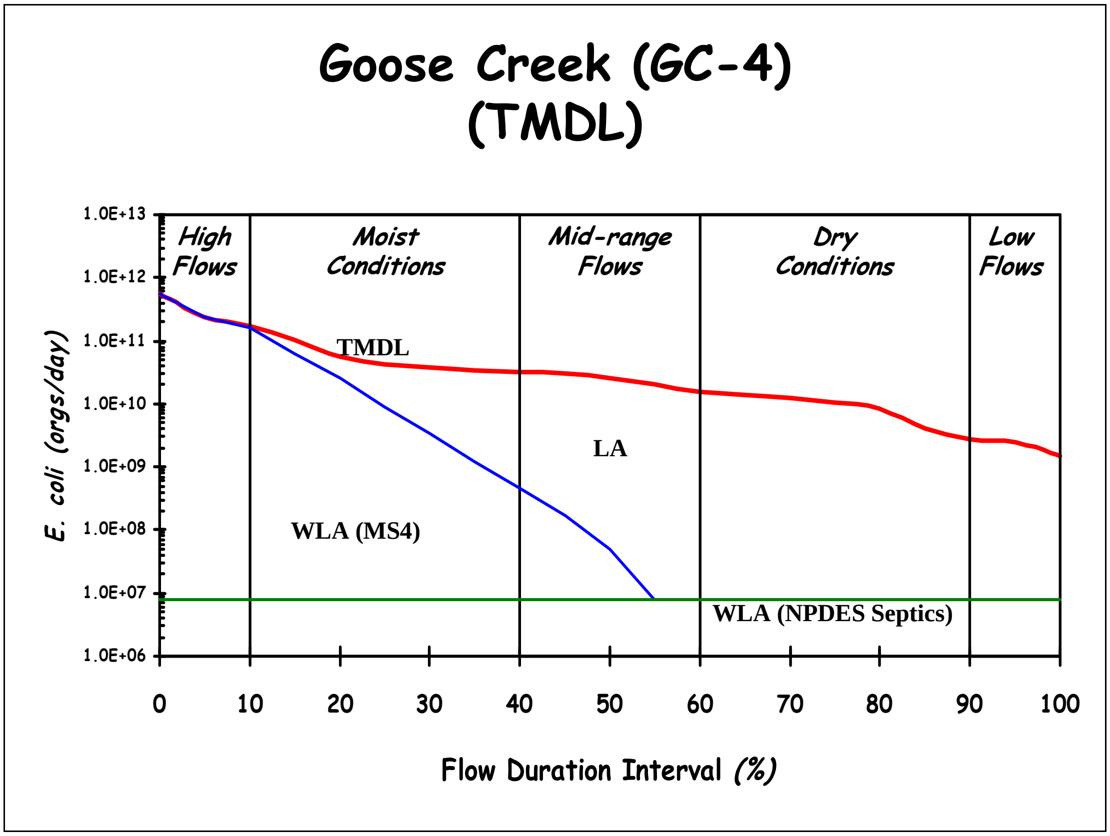

Figure 4-14. TMDL curve for Goose Creek (GC-4).

Silver Creek

Table 4-15 reports maximum daily loads allowable at the midpoint of each flow condition for compliance with SSM and 30-day GM criteria in Silver Creek. Figure 4-15 illustrates the flow-dependant TMDL curve for compliance with the SSM criterion.

Table 4-15. TMDL summary for Silver Creek (SC-1A).

Flow Condition	TMDL (orgs/day)	WLA (orgs/day)	LA (orgs/day)	MOS (orgs/day)
SSM (90th Percentile Load)				
High Flow	1.89E+11	1.70E+11	0	1.89E+10
Moist	4.97E+10	5.79E+09	3.89E+10	4.97E+09
Mid-Range	3.23E+10	6.30E+07	2.90E+10	3.23E+09
Dry	1.01E+10	3.20E+07	9.06E+09	1.01E+09
Low Flow	3.67E+09	3.20E+07	3.27E+09	3.67E+08
GM (Median Load)				
High Flow	1.01E+11	9.09E+10	0	1.01E+10
Moist	2.66E+10	3.10E+09	2.08E+10	2.66E+09
Mid-Range	1.73E+10	3.38E+07	1.55E+10	1.73E+09
Dry	5.43E+09	1.72E+07	4.87E+09	5.43E+08
Low Flow	1.97E+09	1.72E+07	1.76E+09	1.97E+08

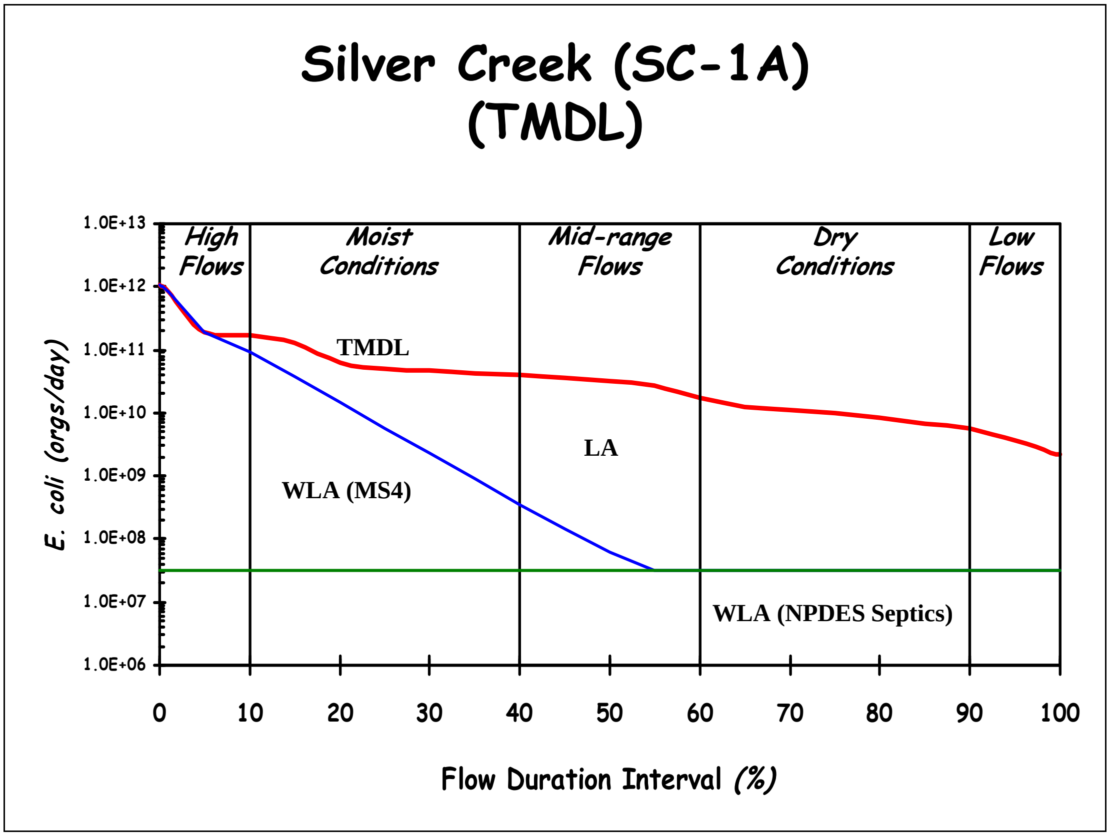

Figure 4-15. TMDL curve for Silver Creek (SC-1A).

5. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that technical guidance and support are critical to achieving the goals outlined in the Total Maximum Daily Load (TMDL). Therefore, this plan is included for use by local professionals, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) described in this plan represent a list of tools that may help achieve water quality goals if applied in an appropriate manner. However, it is up to land managers, citizens, and local conservation technicians to determine how best to implement them.

5.1. General Approach & Timeline

Collaboration and action by watershed residents, landowners, producers, business owners, and local agencies will be required to improve water quality in Duck Creek watershed to support designated uses. Locally-driven efforts have proven to be the most successful in obtaining real and significant water quality improvements. Each group has a stake in promoting awareness and educating others about Duck Creek, working together to adopt a comprehensive watershed improvement plan, and applying BMPs and land practice changes in the watershed. This large and diverse group of stakeholders provides the opportunity for an effective network of partnerships to be built. The existence of previously organized groups such as the Partners of Scott County Watersheds, which collaborates with the Scott County Soil and Water Conservation District (SWCD), increases the opportunity for development and implementation of a successful watershed management plan.

General approach
The existing loads, loading targets and allocations, a general menu of potential BMPs needed to improve water quality, and a monitoring plan to assess progress, are provided in this Water Quality Improvement Plan (WQIP). The TMDL must be followed by the development of a locally-led watershed management planning process. The watershed plan should include more comprehensive and detailed actions to better guide the implementation of specific BMPs. Other ongoing tasks required to obtain significant water quality improvements include continued monitoring to better understand and document bacteria sources, assessment of water quality trends, assessment of WQS attainment, and adjustment of proposed BMP types, locations, and implementation schedule.

A phased approach to improving water quality is recommended for the Duck Creek watershed. Sources of bacteria, both large and small, must be reduced. However, the largest and most identifiable sources of bacteria should be given highest priority and addressed first. Less significant and/or less understood sources can be addressed later as funding allows and new monitoring data increases stakeholder understanding of their impacts to water quality.

Timeline
Development of a comprehensive watershed management plan may take one to two years from the completion of the WQIP. Implementation of BMPs could take five to ten years, depending on funding, willingness of stakeholder participation, and time needed for design and construction of structural BMPs. Realization and documentation of water quality benefits may take an additional five to ten years, depending on weather patterns, amount of water quality data collected, and the successful location, design, construction, and maintenance of BMPs. Utilization of the monitoring plan outlined in Section 6 should begin immediately to help identify undocumented bacteria sources and establish a baseline. Monitoring should continue throughout implementation of BMPs and beyond to capture water quality improvement.

5.2. Source Inventory and and Implementation Strategy

Source Inventory
A detailed pollutant source analysis of the relative magnitude of each potential pollutant source is vital to the success of any implementation plan. The SWAT model described in Appendices D and E was utilized to develop detailed source inventories for the Duck Creek watershed. Inventories were developed for three monitoring locations (DC-16, DC-10, and DC-12) in the main stem of Duck Creek and across five flow conditions (high flow, moist conditions, mid-range conditions, dry conditions, and low flow). Analysis of the source contributions across these locations and conditions is instructive for understanding the pollutant loading processes that take place in the watershed. Understanding the source loading is needed to select and locate appropriate BMPs and for quantification of potential pollutant reductions.

Figure 5-1 illustrates the cumulative *E. coli* load at each monitoring station aggregated over the 2003-2008 recreation seasons. The upstream monitoring station (110th Avenue/DC-16) is located near the downstream end of the rural portion of the watershed. The drainage area to this location is primarily row crop agriculture, with some areas of grassland (grazed and ungrazed), timber, and transportation land uses. Not surprisingly, manure application is the largest single source of *E. coli* loads to Duck Creek at this location, accounting for 82.5 percent of the load on a cumulative basis. The second largest source is cattle in streams (15.1 percent), followed by non-permitted septic systems (NPS septics) and grazing, which are relatively insignificant.

The relative source contributions change dramatically at the two downstream locations, where the terrain becomes dominated by urban features, including commercial, industrial, and residential land use. In the urbanized area (DC-10 and DC-12), urban sources of *E. coli* account for nearly 90 percent of the total load. Urban sources (as illustrated in Figure 5-1) do not include permitted wastewater discharges, but do include stormwater runoff and other potential loads originating from the urban land surface or infrastructure, such as:

- illicit connections leading to dry weather flow from the storm sewer system,
- deposition of bacteria within the storm conveyance system,

- resuspension of bacteria in pipes, ditches and streams, and undocumented wildlife deposition within the urban area.

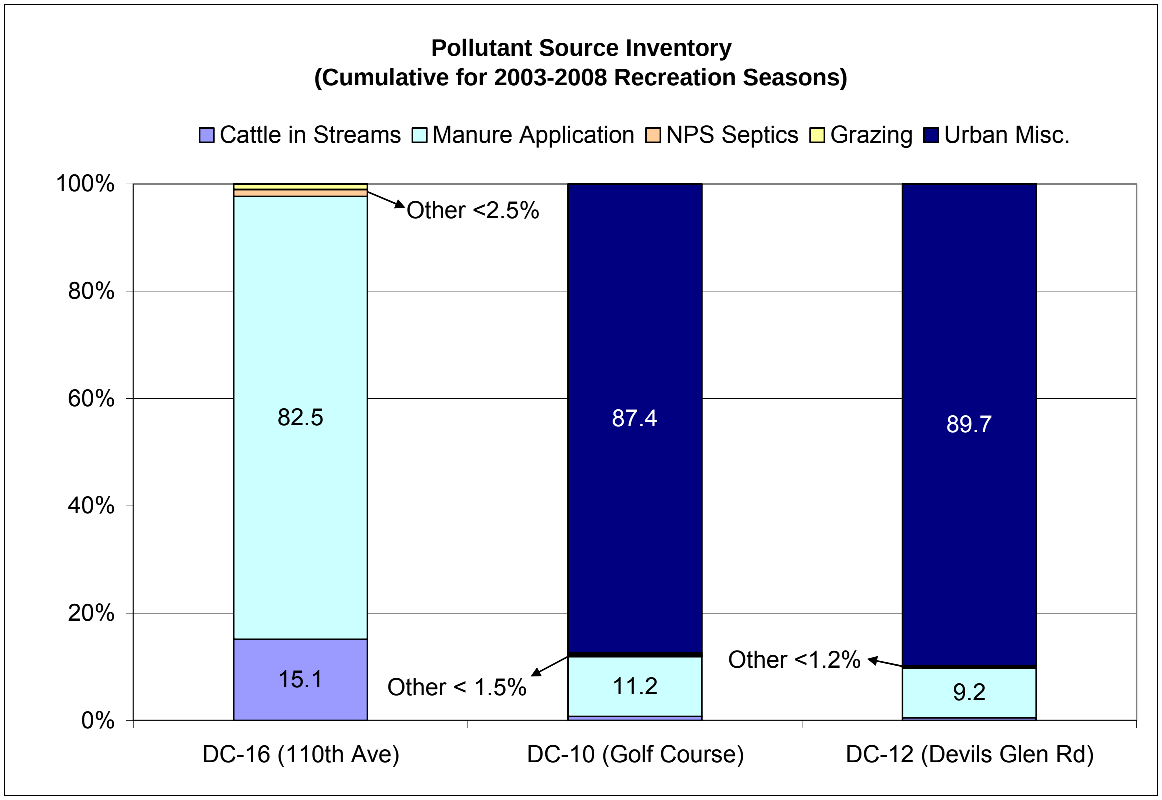

Figure 5-1. Source inventory summarized over 2003-2008 recreation seasons.

Before implementation of BMPs commences in the urban areas of the watershed, further monitoring should be conducted to better identify the individual components and magnitudes of the urban *E. coli* sources. Recommended monitoring activities are described in Section 6.

The dilution effect of the increased drainage area downstream of DC-16 causes the impacts from manure application and cattle in-stream to be less significant (approximately 9-11 percent, compared with over 80 percent in the upstream reach). However, it is not safe to assume that loads from manure application and/or cattle in streams could not cause a violation of WQS at the downstream segment of Duck Creek. Figure 5-1 is helpful for quick recognition of the largest sources of *E. coli* pollution over the long term; however, it does not reveal many clues to the specific loading processes involved, nor does it identify the various sources that contribute to water quality problems under specific conditions or within shorter time frames.

Figures 5-2 through 5-4 show the relative contributions of *E. coli* sources at DC-16, DC-10, and DC-12 within each flow condition. Analysis of these figures reveal that under varying conditions, several other sources (besides cattle in streams, manure application, and urban sources) are significant contributors to *E. coli* levels in Duck Creek.

During high flow conditions (0 to 10 percent flow duration interval), swine manure application to row crops accounts for nearly all (95 percent) of the load at DC-16, but only 5 percent at DC-10. Conversely, urban sources (primarily stormwater) contribute 94.6 and 99.2 percent of the load at DC-10 and DC-12, respectively. Implementation activities should focus on controlling *E. coli* loads from manure application in the rural areas of the watershed, and urban stormwater loads in the urbanized areas of Davenport and Bettendorf.

During moist conditions, runoff still comprises a significant portion of streamflow; however, flows are not as extreme as high flows conditions. Moist conditions are bounded by the 10th and 40th flow duration interval. Manure application is still the largest contributing source of *E. coli* in the upstream portion of the watershed during moist conditions; however, loads from direct deposition by cattle into the stream become less diluted and account for over 42.9 percent of the load at DC-16. At DC-10, manure application is the largest source (49.4 percent), but cattle in streams, non-permitted septic systems (NPS Septics), wastewater treatment facilities (WWTFs), and other urban sources are also significant.

Notice that as flow decreases, the relative importance of continuous sources increases. During low flow conditions, cattle in streams and non-permitted septic systems combine for over 99 percent of the *E. coli* load at DC-16. Cattle in streams and failing non-permitted septic systems are the largest source at the downstream locations as well, but other sources become significant at low flow. Loads from WWTFs is significant (over 14 percent of the total), and even wildlife deposition in streams is notable (over 5 percent). Development of an implementation strategy in the context of a detailed watershed management plan should consider the variety of sources across all flow conditions to maximize *E. coli* reductions and attain water quality objectives. Pollutant source and flow condition must influence the selection and design of appropriate BMPs.

Implementation Strategy

Tables 5-1 through 5-3 provide the TMDL summary for each monitoring location, as reported in Section 3.6. The wasteload allocations (WLAs), load allocations (LAs), and margins of safety (MOS) shown in Table 5-1 through 5-3 are based on the 30-day GM water quality criterion of 126 orgs/100 mL. Existing loads are based on the median load within each flow condition, as shown in the LDCs in Section 3.2. The reductions needed for compliance with the SSM and GM criteria are similar, so the implementation strategy focused on the GM criterion to focus on the general tendancies of water quality in the stream. The TMDL summaries from Section 3.6 are reorganized in Tables 5-1 through 5-3 and shown immediately below the respective source inventory figures. Looking at the figures and tables simultaneously is instructive for relating major sources and the required reductions. Together, these data form the foundation for an implementation strategy. Understanding the nature and magnitude of individual sources and the conditions under which they contribute *E. coli* to the stream is beneficial for targeting specific BMPs to meet required reductions.

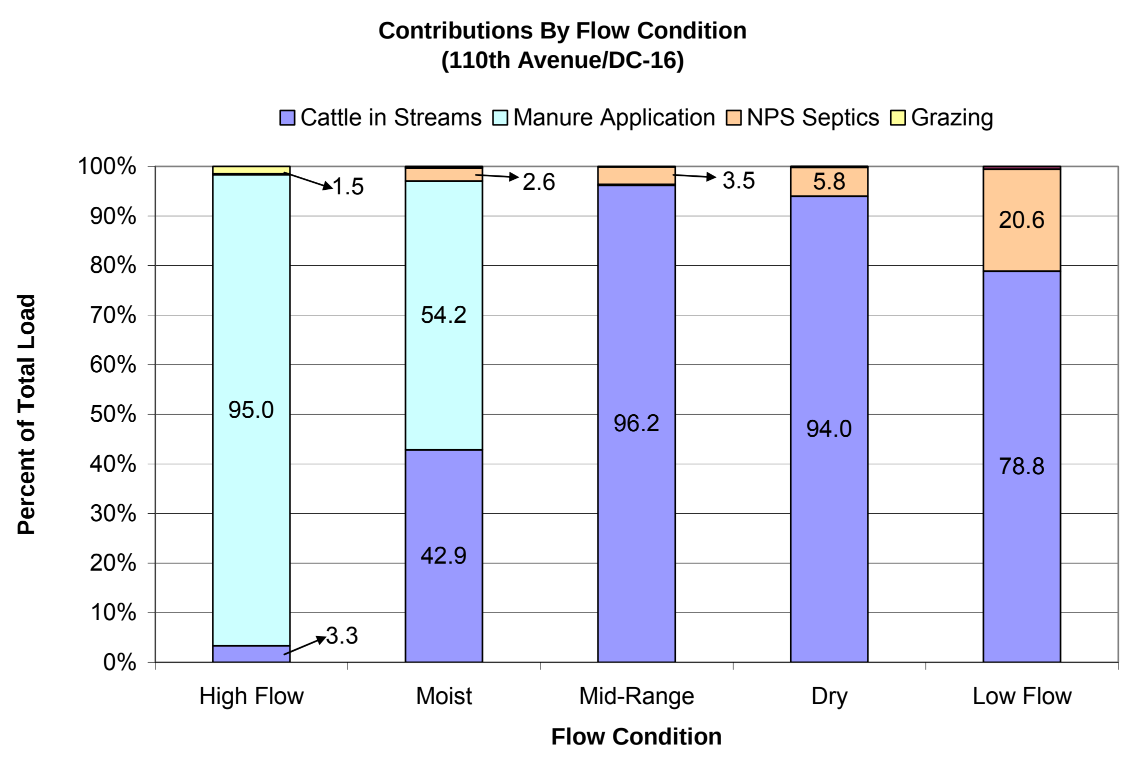

Figure 5-2. Source inventory for each flow condition at 110th Ave. (DC-16).

Table 5-1. Implementation strategy for areas upstream of DC-16.

TMDL Summary	***E. coli* loads (orgs/day)**				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
TMDL	1.29E+11	3.39E+10	1.33E+10	4.62E+09	8.32E+08
WLA	1.29E+07	1.29E+07	1.29E+07	1.29E+07	1.29E+07
LA	1.16E+11	3.05E+10	1.20E+10	4.15E+09	7.36E+08
MOS	1.29E+10	3.39E+09	1.33E+09	4.62E+08	8.32E+07
Existing Load	2.17E+12	4.59E+11	2.99E+11	2.16E+10	4.04E+07
Required Reduction	94.0%	92.6%	95.6%	78.6%	--
Implementation Strategy	Manure application management				
		Livestock exclusion from streams and riparian buffer creation/enhancement			
		Septic system inspection, repair, and maintenance activities			

Notes: TMDL loads are based on the 30-day GM identified in Iowa's WQS. Existing loads are based on the median load within each flow condition in LDCs developed using observed flow and water quality data.

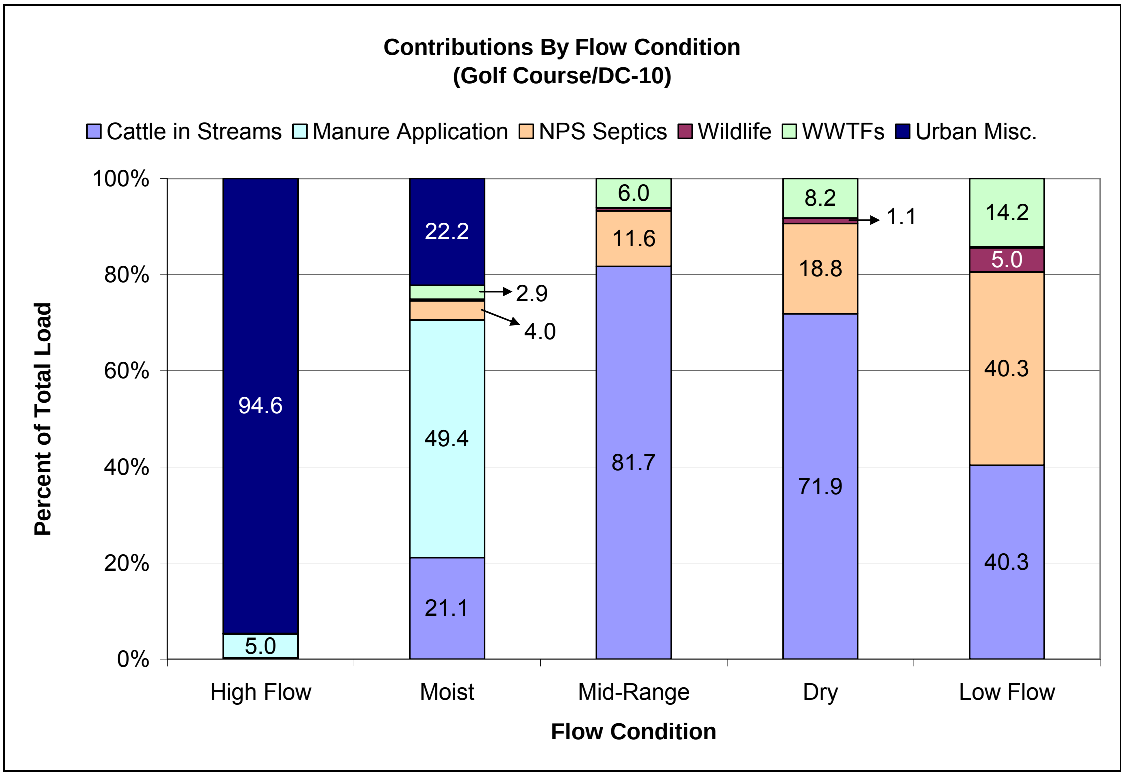

Figure 5-3. Source inventory for each flow condition at golf course (DC-10).

Table 5-2. Implementation strategy for areas upstream of DC-10.

<table>
<tr><th rowspan="2">TMDL Summary</th><th colspan="5"><i>E. coli</i> loads (orgs/day)</th></tr>
<tr><th>High</th><th>Moist</th><th>Mid-Range</th><th>Dry</th><th>Low</th></tr>
<tr><td>TMDL</td><td>4.75E+11</td><td>1.33E+11</td><td>5.24E+10</td><td>1.94E+10</td><td>5.86E+09</td></tr>
<tr><td>WLA</td><td>3.40E+11</td><td>9.01E+09</td><td>8.22E+08</td><td>7.50E+08</td><td>7.50E+08</td></tr>
<tr><td>LA</td><td>8.80E+10</td><td>1.11E+11</td><td>4.63E+10</td><td>1.67E+10</td><td>4.52E+09</td></tr>
<tr><td>MOS</td><td>4.75E+10</td><td>1.33E+10</td><td>5.24E+09</td><td>1.94E+09</td><td>5.86E+08</td></tr>
<tr><td>Existing Load</td><td>1.52E+13</td><td>9.67E+11</td><td>3.58E+11</td><td>7.34E+10</td><td>3.43E+09</td></tr>
<tr><td>Required Reduction</td><td>96.9%</td><td>86.3%</td><td>85.3%</td><td>73.5%</td><td>--</td></tr>
<tr><td rowspan="6">Implementation Strategy</td><td colspan="2">MS4 source reduction and BMPs</td><td colspan="3" rowspan="3"></td></tr>
<tr><td colspan="2">Elimination of illicit discharges and SSOs</td></tr>
<tr><td colspan="2">Manure application management</td></tr>
<tr><td rowspan="3"></td><td colspan="4">Livestock exclusion from streams and riparian buffer creation/enhancement</td></tr>
<tr><td colspan="4">Septic system inspection, repair, and maintenance activities</td></tr>
<tr><td colspan="4">WWTF monitoring and operations/management improvements, if necessary</td></tr>
<tr><td colspan="6">Notes: TMDL loads are based on the 30-day GM identified in Iowa’s WQS. Existing loads are based on the median load within each flow condition in LDCs developed using observed flow and water quality data.</td></tr>
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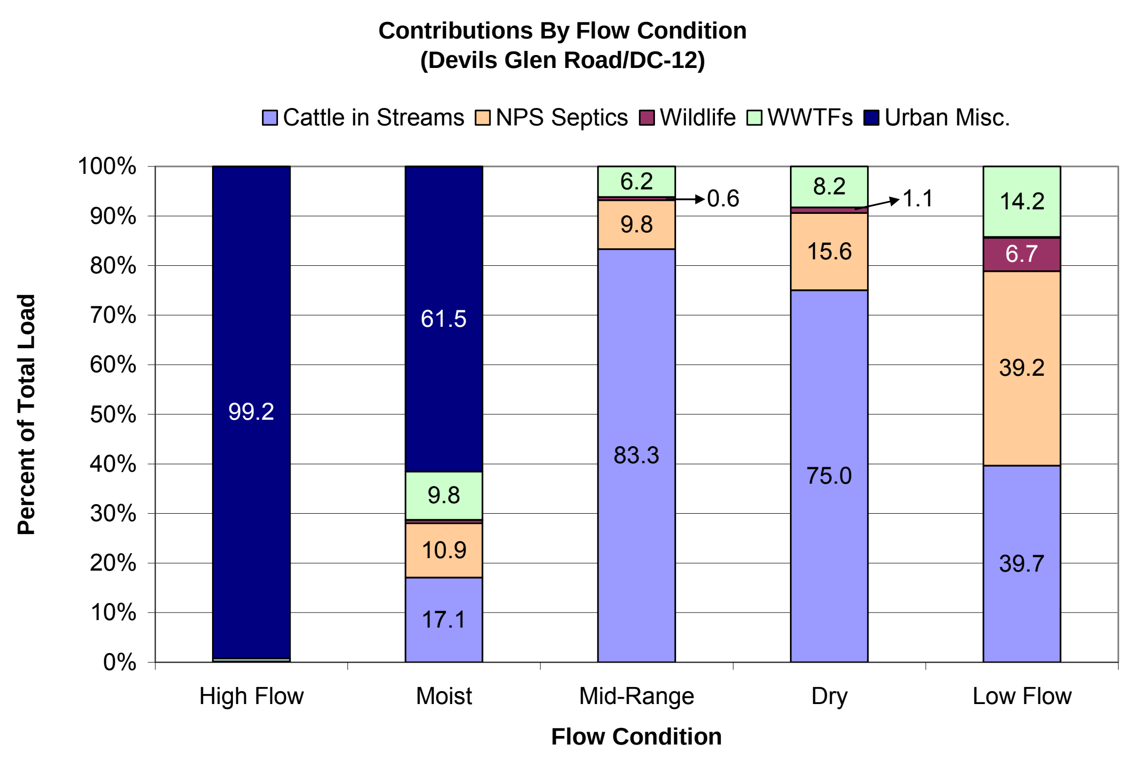

Figure 5-4. Source inventory for each flow condition at Devils Glen Rd. (DC-12).

Table 5-3. Implementation strategy for areas upstream of DC-12.

TMDL Summary	***E. coli* loads (orgs/day)**				
	High	**Moist**	**Mid-Range**	**Dry**	**Low**
TMDL	5.21E+11	1.45E+11	5.76E+10	2.11E+10	6.37E+09
WLA	4.11E+11	1.04E+10	8.22E+08	7.50E+08	7.50E+08
LA	5.79E+10	1.20E+11	5.10E+10	1.82E+10	4.98E+09
MOS	5.21E+10	1.45E+10	5.76E+09	2.11E+09	6.37E+08
Existing Load	2.14E+13	1.31E+12	4.77E+11	6.17E+10	6.38E+09
Required Reduction	97.6%	88.9%	87.9%	65.8%	0.2%
Implementation Strategy	MS4 source reduction and BMPs				
	Elimination of illicit discharges and SSOs				
		Livestock exclusion from streams and riparian buffer creation/enhancement			
		Septic system inspection, repair, and maintenance activities			
		WWTF monitoring and operations/management improvements, if necessary			
Notes: TMDL loads are based on the 30-day GM identified in Iowa's WQS. Existing loads are based on the median load within each flow condition in LDCs developed using observed flow and water quality data.					

5.2. Best Management Practices

The implementation alternatives shown in Tables 5-1 through 5-3 comprise the foundation for an implementation strategy. However, more information about specific BMPs that apply to each pollutant source is needed to develop a successful watershed management plan. Information about bacteria removal capabilities of BMPs is sparse, and reported removal rates vary widely. Complex transport mechanisms and extreme variability in bacteria concentrations, even under "natural" conditions, makes quantifying BMP removal efficiencies very difficult. This section provides a general summary of BMPs applicable to bacteria reduction. It is not an all-inclusive list, and further investigation (during development of the watershed management plan) may suggest that some alternatives should be implemented in favor of others. An important task in development of the watershed management plan will be to identify additional water quality improvement BMPs (both structural and non-structural), as well as prioritize, locate, and schedule implementation of BMPs.

There are two general strategies for reducing pollutant loads: source control and in-drainage reduction. Source control strategies are usually non-structural practices related to the management of runoff or production and application of pollutants (e.g., manure, fertilizer, industrial products). As the name implies, source control strategies focus on stopping or reducing the pollution at its source. Examples of source control strategies for bacteria reduction are listed in Table 5-4.

Table 5-4. Example source control strategies (BMPs).

Strategy/BMP	Examples
Livestock manure management	Storage and/or treatment facilities, disposal
Manure application	Injection methods, timing of application, etc.
Pasture management	Elimination of stream access, grazing rotation
Septic system improvements	Inspection/repair/replacement
Wildlife management activities	Population control (particularly for geese)
Highway/roadway cleanup	Street sweeping, road kill pickup programs
Pet waste management	Educational programs, local ordinances
[1] Low impact development (LID)	LID ordinances/practices for new development
[1] Runoff reduction	Disconnection of impervious areas using rain barrels, porous pavement, rain gardens, etc.

[1] Some LID and runoff reduction strategies could be considered either source control or in-line drainage reduction.

In-drainage reduction strategies usually involve the use of structural BMPs to eliminate or reduce pollutants by intercepting and/or treating them within the drainage system using physical, chemical, or biological processes. Examples of in-drainage BMPs are provided in Table 5-5, along with their respective removal mechanisms.

Table 5-5. Example in-drainage strategies (BMPs).

Strategy/BMP	[1] Removal Mechanism(s)
Constructed wetlands	UV exposure, settling, predation
Wet detention ponds	UV exposure, settling, predation
Dry detention basin	UV exposure, settling, drying
Vegetated filter strips	Filtration, infiltration
Riparian buffers	Exclusion from stream, filtration, infiltration
Sand filters	Filtration
Infiltration trenches	Infiltration
Bioswales/bioretention	UV exposure, settling, infiltration, drying
[2] Proprietary stormwater treatment systems	Varies with device – usually settling and/or filtration

[1] Modifed from North Carolina Cooperative Extension Service, 2008.

[2] Examples include hydrodynamic devices, gravity separators, and catch basin inserts.

Estimated bacteria removal efficiencies associated with the various source control BMPs are provided in Table 5-6. Table 5-7 lists removal rates associated with in-drainage BMPs. Note that these rates are highly variable. Rates listed in Tables 5-6 and 5-7 assume that the BMP is properly designed, implemented, and maintained. Additionally, these rates apply only to the specific source of bacteria they treat, not the overall reduction. These removal rates must be applied with caution on a case-by-case basis to avoid overestimating potential water quality improvements.

Because of the large reductions required for attainment of WQS in Duck Creek and the highly variable nature of observed concentrations and removal, a combination of source control and in-drainage BMPs will be necessary. Additionally, many in-drainage BMPs function better when multiple systems are implemented in series. For example, grass bioswales may convey runoff to a vegetated filter strip before flows reach a constructed wetland. This type of treatment train approach offers the advantage of multiple removal mechanisms and built in redundancy to increase the reliability of bacteria reduction. The watershed management plan developed for Duck Creek should consider the use of treatment train approaches wherever possible.

Table 5-6. Source control BMPs and estimated bacteria removal rates.

BMP	Removal (%)	Additional Comments
Manure injection	[1] Up to 90	Removal will vary with injection method, application rates, land slope, weather, and other variables. Injection can offer up to 90% reduction in bacteria transport when compared to surface application.
Manure export/disposal	Up to 100	Removing manure from the watershed would provide a 100% reduction to from this source. However, if manure application is increased elsewhere, impacts to that watershed must be investigated.
Exclusion of livestock from streams	Up to 100	The removal associated with this practice is proportional to the percent of livestock that are excluded. If all livestock are excluded from streams at all times, then bacteria reduction from this source would be 100%.
Septic system improvements	Up to 100	Repair/replacement of all failing systems provides 100% reduction. Watershed wide removal rate would be proportional to the percent of failing systems fixed.
Wildlife management	Varies	If there are known areas of waterfowl populations (e.g., stormwater ponds), management of geese populations would provide some bacteria reductions. Removal rates would be proportional to population reduction.
Street sweeping	[1] Up to 22	Published literature contains conflicting information regarding potential bacteria reduction from street sweeping. This BMP should not be relied upon as a key part of the implementation strategy, but may help reduce bacteria loads in highly pervious urban areas.
Pet waste management	[1] Up to 75	Includes information and education programs regarding the importance of picking up after your pets. Could include the adoption of local ordinances.
LID and runoff reduction BMPs	Varies	Proportional to the amount of runoff reduction obtained. Some LID and runoff reduction measures are included as in-drainage BMPs in Table 5-7.

[1] Source: VDEQ et al., 2009

Table 5-7. In-drainage BMPs and estimated bacteria removal rates.

BMP	Removal (%)	Additional Comments
Constructed wetlands	[2,3] 78-99	Wetlands could act as a source if not properly designed or maintained, including management of potential waterfowl populations.
Wet detention ponds	[2,,3] 44-99	Ponds could act as a source if not properly designed or maintained, including management of potential waterfowl populations.
Dry detention basins	[2,3] Varies	Dry detention basins often act as a net source of bacteria and should not be considered reliable as stand-alone systems.
Vegetated filter strips	[2] 43-57	Vegetated filter strips are flat or very gently sloped segments of land intented to “treat” inflows to the stream. Filter strips should be distinguished from riparian buffers, which offer less removal potential.
Riparian buffers	[1] Up to 40	The primary benefits of buffers are to “buffer” the stream from nearby land uses and activities, as the name suggests. Actual removal rates depend on the width of the buffer and the type and density of vegetation, as well as the portion of runoff that the buffer intercepts.
Sand filters	[2] 36-83	Generally designed as part of the stormwater infrastructure to capture and treat the first flush of runoff from impervious surfaces.
Bioswales and bioretention	[1,2,3] 69-99	Includes rain gardens. Should be used with caution or avoided in areas where possible groundwater contamination is a concern.
Pervious concrete; porous asphalt	[4] 30-65	Requires careful design and construction and is only feasible in areas with adequate soil infiltration rates (at least 0.5 inches/hour).
Permeable pavers	[4] 65-100	Similar to pervious concrete and porous asphalt. Utilizes pre-cast permeable blocks to infiltrate water. Adequate soil infiltration rates required.
Hydrodynamic devices	[4] <30	Type of proprietary stormwater treatment system.
Gravity separators	[4] <30	Type of proprietary stormwater treatment system.
Coagulation and/or flocculation	[4] 65-100	Chemical treatment of stormwater. Usually implemented in conjunction with a stormwater pond. Offers high removal, but addition of coagulation/flocculation chemicals such as alum is required.

[1] Source: VDEQ et al., 2009
[2] Source: EPA, 2004
[3] Source: North Carolina Cooperative Extension Service, 2008
[4] Source: Iowa Stormwater Management Manual

Figures 5-5 through 5-9 illustrate the location of various sources of pollution throughout the Duck Creek watershed. These figures, along with the source inventories (Figures 5-1 through 5-4), implementation strategies (Tables 5-1 through 5-3), and potential BMP removal rates (Tables 5-6 and 5-7), should assist the development of a thorough watershed management plan prepared by local stakeholders

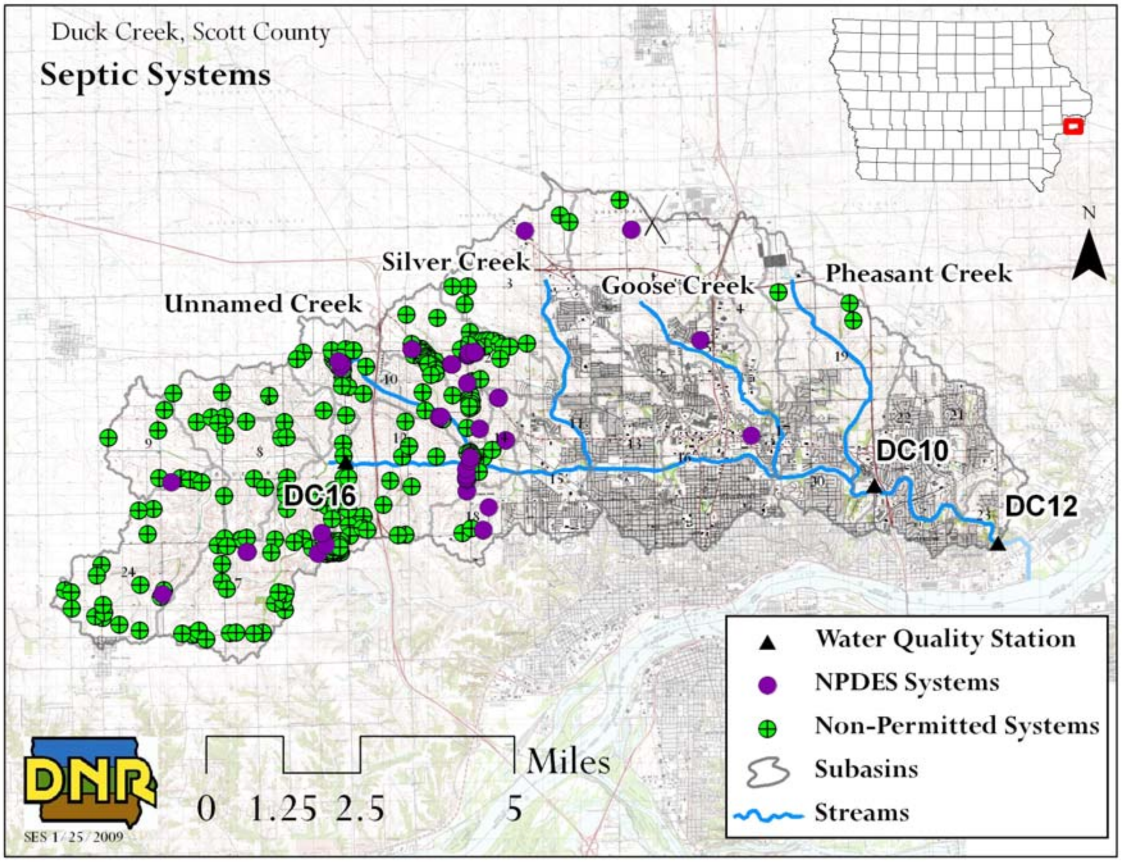

Figure 5-5. Map of Onsite wastewater treatment systems.

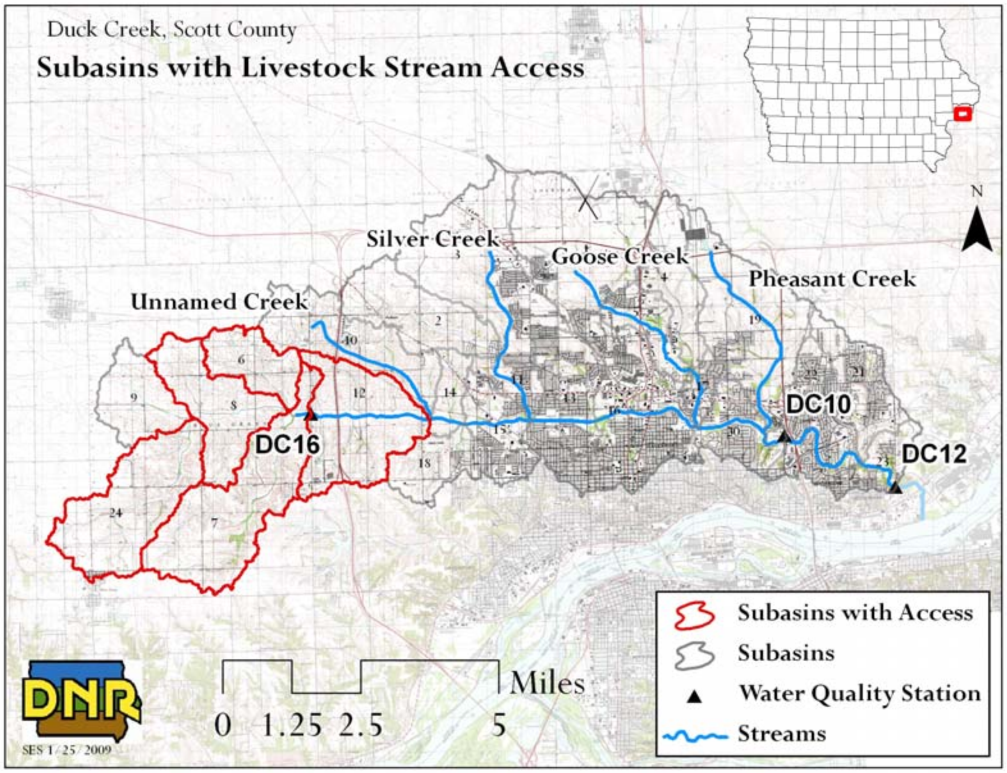

Figure 5-6. Subbasins with livestock stream access.

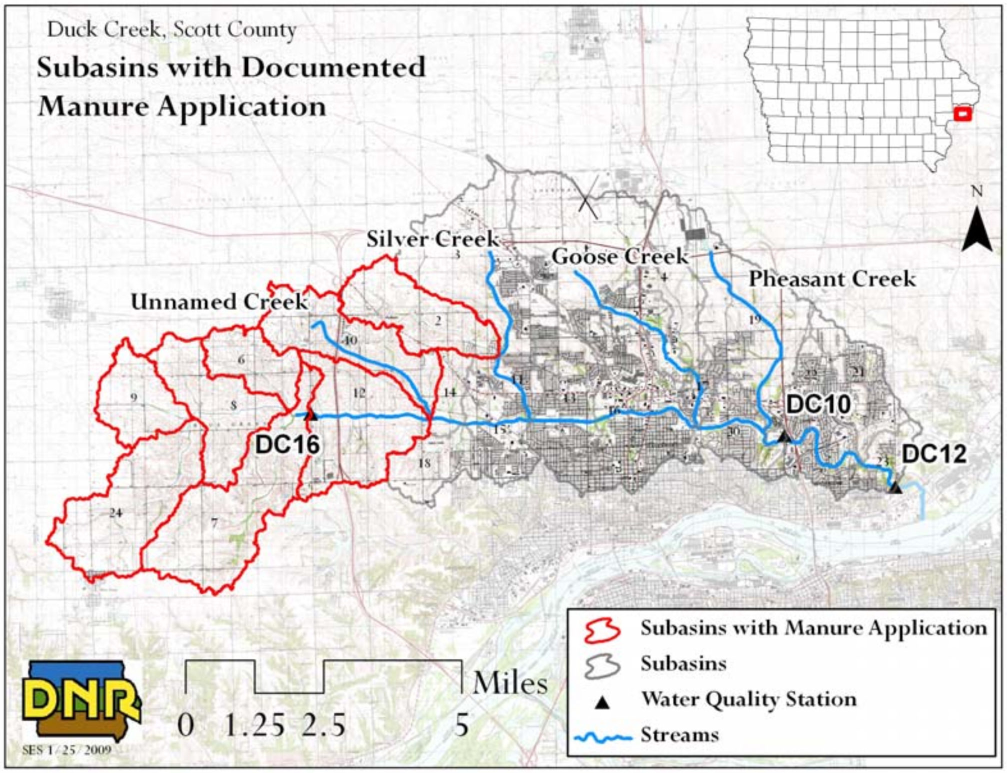

Figure 5-7. Subbasins with documented manure application.

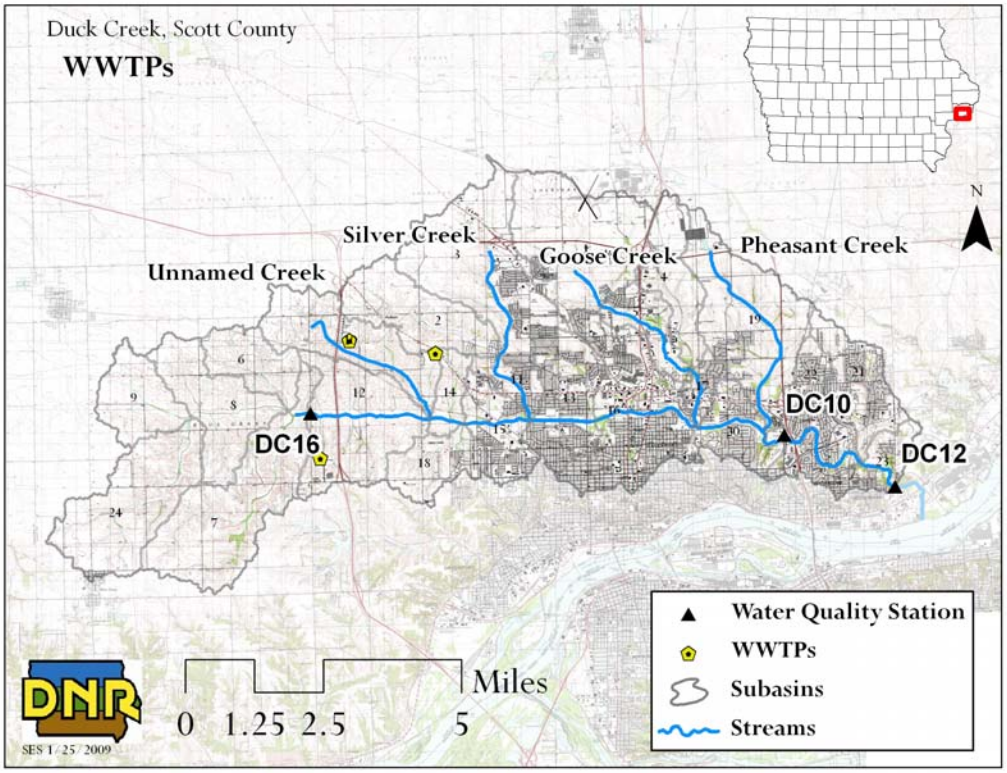

Figure 5-8. NPDES wastewater treatment facilities receiving WLAs.

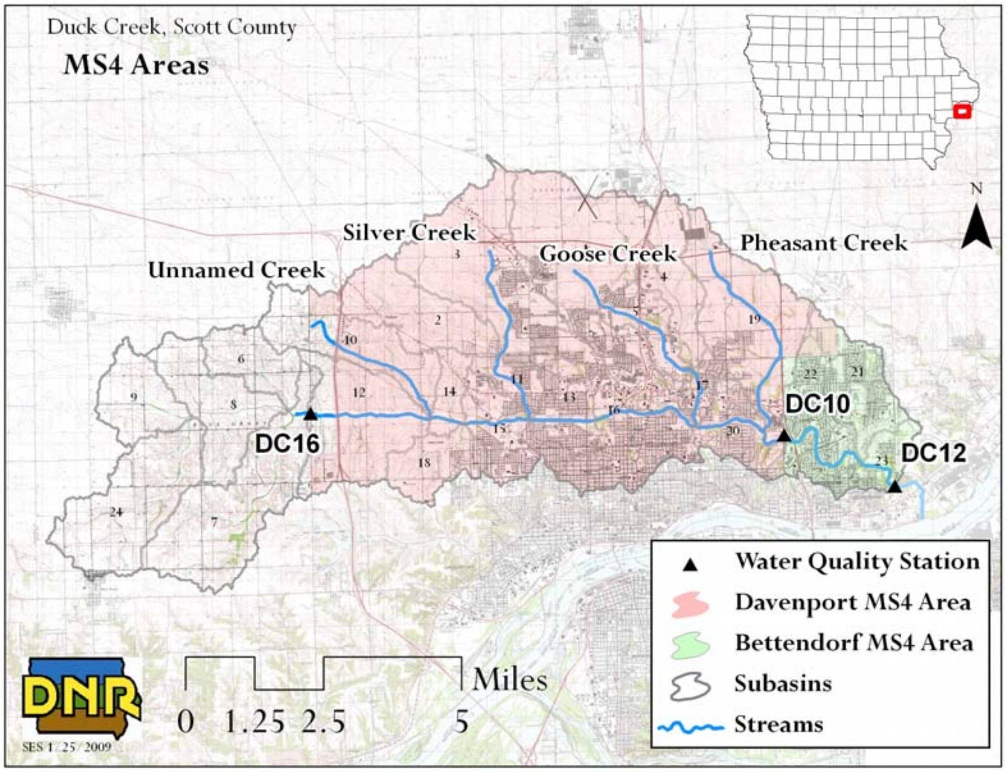

Figure 5-9. Municipal storm sewer areas covered by NPDES permits (MS4s).

6. Future Monitoring

Water quality monitoring is critical for assessing the status of water resources and historical and future trends. Furthermore, monitoring is necessary to track the effectiveness of BMPs implemented in the watershed and document the status of the waterbody in terms of achieving Total Maximum Daily Loads (TMDLs).

Future monitoring in the Duck Creek watershed can be agency-led, volunteer-based, or a combination of both. The Iowa Department of Natural Resources (IDNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program that provides training to interested volunteers. This program is called IOWATER, and more information can be found at the program website: http://www.iowater.net/Default.htm.

It is important that volunteer-based monitoring efforts include an approved water quality monitoring plan, called a Quality Assurance Project Plan (QAPP), in accordance with Iowa Administrative Code (IAC) 567-61.10(455B) through 567-61.13(455B). The IAC can be viewed here: http://www.iowadnr.com/water/standards/files/chapter61.pdf. Failure to prepare an approved QAPP will prevent data from being used to assess a waterbody's status on the state's 303(d) list – the list that assesses waterbodies and their designated uses as impaired.

The Scott County Snapshot Data, collected by the Partners of Scott County Watersheds through the IOWATER program, is an example of successful volunteer-led collection of data. Future monitoring efforts such as this are encouraged, as is the collection of more detailed data such as event sampling and continuous monitoring as described in the following sections. Care should be taken to ensure that any future data collected by volunteers satisfies Iowa's Credible Data Law.

6.1. Monitoring Plan to Track TMDL Effectiveness

Given current resources and funding, future water quality data collection in the Duck Creek watershed to assess water quality trends and compliance with water quality standards (WQS) will be limited. Unless there is local interest in collecting additional water quality data, it will be difficult to implement a watershed management plan and document TMDL effectiveness and water quality improvement. At a minimum, the Scott County Snapshot data should continue to be collected. However, Snapshot data alone is likely not enough to meet the needs of local stakeholders whose goal is to significantly improve water quality in Duck Creek.

6.2. Idealized Plan for Future Watershed Projects

An idealized plan will include, at a minimum, weekly flow and water quality monitoring similar to monitoring conducted by UHL and the Partners of Scott County Watershed in 2008. This monitoring data was sufficient for development of load duration curves (LDCs), and enabled the development of TMDLs and investigation of bacteria loads under varying flow conditions. However, these data were not sufficient to answer many questions about the exact nature of bacteria loads. Additional weekly flow and bacteria sampling will allow for development of more robust LDCs, and will help track changes in water quality as BMPs are implemented from year to year. More detailed monitoring data will be required to develop a successful watershed management plan and document water quality improvement. An "idealized" monitoring plan is outlined in Table 6-1. It is only through the interest and action of local stakeholders that funding and resources needed to acquire this data will become available.

The monitoring plan components in Table 6-1 are prioritized, with the highest priority data listed first. Data obtained through this idealized monitoring plan would better document the specific sources of existing bacteria loads and significantly reduce the level of uncertainty associated with load estimation and water quality trend analysis.

Table 6-1. Idealized monitoring plan for Duck Creek watershed.

Parameter(s)	Sampling Interval	Sampling Duration	Location(s)
E. coli and flow	Weekly snapshot	Throughout recreation season (ongoing)	DC-16, DC-10, DC-12, PC-2, GC-4, SC-1A, and [1] UC-1
[2] Microbial source tracking (MST)	Snapshot	At least two sampling events within recreation season. Consider one during high flow and one during low flow.	DC-16, DC-12, selected tributaries and/or stormwater outfalls
E. coli and flow (event sampling)	15-60 minutes	Throughout rising and falling limbs of hydrograph during at least two runoff events within recreation season.	DC-16, DC-12, selected tributaries, tile drains, and stormwater outfalls
E. coli and flow (dry weather sampling)	Snapshot	At least twice during low flow conditions within recreation season.	Selected stormwater outfalls in Davenport and Bettendorf
Biological monitoring (FIBI and BMIBI)	Snapshot	At least once during dry weather within recreation season.	DC-16 and DC-10 or DC-12

[1] UC-1 is a new location near the outlet of Unnamed Creek (1) as described in the 2008 UAA. This segment is designated as secondary contact recreation (Class A2). However, it drains to a Class A3 segment of Duck Creek and would likely need to meet A3 criteria. Existing water quality in this reach should be assessed, and ultimately, a TMDL may be required.

[2] There are several different types of MST. Selection should be researched and based on feasibility, cost, and advantage/disadvantages of each method. If budget does not allow for true MST methods, fluorometry or caffeine detection could be utilized in conjunction with *E. coli* sampling to document human sources of wastewater.

There are several different types of microbial source tracking (MST) methods, but all have a similar objective – to match microbes present in a waterbody to microbes from specific animal sources. Using information derived from MST, water quality decision makers would better understand the importance of different bacteria sources and select/design effective strategies to reduce bacteria in the stream. The source inventories developed using the SWAT model useful for these purposes, but are approximations and have high degrees of uncertainty. MST would help determine the impact that distinct sources, such as humans, hogs, cattle, pets, deer, waterfowl, and other wildlife might have on water quality. If MST is not affordable or feasible, the use of a fluorometer to detect the presence of detergents and/or sampling for caffeine may be substituted. Detection of detergents or caffeine would indicate the presence of human bacteria sources. Fluorometry and caffeine analysis may not be useful in subbasins where WWTFs or private onsite wastewater treatment systems are located, because residual amounts of caffeine and/or detergents would be expected.

Event sampling for *E. coli* and flow at 15 to 60 minute intervals using an ISCO or other automated sampling device will help evaluate the distribution of bacteria loads throughout a storm. This will assist stakeholders in the selection and design of BMPs by revealing the relative importance of loads contributed to the stream by the first flush, the peak of the storm, and the hours shortly after the storm peak. Additionally, event sampling will help quantify loads associated with a particular size/frequency of runoff event.

Dry weather sampling should be conducted to evaluate the possibility of illicit sanitary sewer connections to the storm sewer system. If sustained flows with high bacteria concentrations are observed during extremely dry periods, it is likely that illicit connections may be present. Use of MST, fluorometry, or caffeine analysis in conjunction with dry weather flow sampling may be desirable.

Some of the features of Duck Creek suggest that it may be impaired by other pollutants in addition to bacteria. The stream is extensively channelized, and in some reaches significant incision can be observed. Urban streams often lack the physical, chemical, and biological qualities needed to support a diverse array of aquatic organisms. Biological monitoring to assess the diversity and population of fish and invertebrate communities would indicate the presence or absence of a healthy ecosystem, and could lead to the detection of additional pollutants detrimental to water quality. If other pollutants are present, it would be most efficient and beneficial to address them in the development of the watershed management plan that follows this WQIP, rather than waiting for impacts to worsen. Biological monitoring would be a first step in helping to identify other potential pollutants in Duck Creek. However, it is unrelated to the existing impairment, and would not be eligible for 319 funding.

Figure 6-1 illustrates the primary water quality monitoring locations in the Duck Creek watershed listed in Table 6-1. A new monitoring location is recommended near the confluence of Unnamed Creek (1) and Duck Creek just downstream from site DC-16. This location is labeled UC-1. The Unnamed Creek (1) was designated for secondary contact (Class A2) recreation in the 2008 UAA. However, no water quality data was available for this reach for TMDL development. Flow and water quality data is needed at this location to establish a baseline and to allow for future development of a TMDL, if needed.

Monitoring plans should be continually evaluated. Adjustment of parameters, sampling intervals, and/or monitoring locations should be based on newly discovered or suspected pollutant sources, BMP placement/installation, and other dynamic factors. The IDNR Watershed Improvement Section can provide technical support to locally led efforts in collecting and analyzing further water quality and flow data in the Duck Creek watershed.

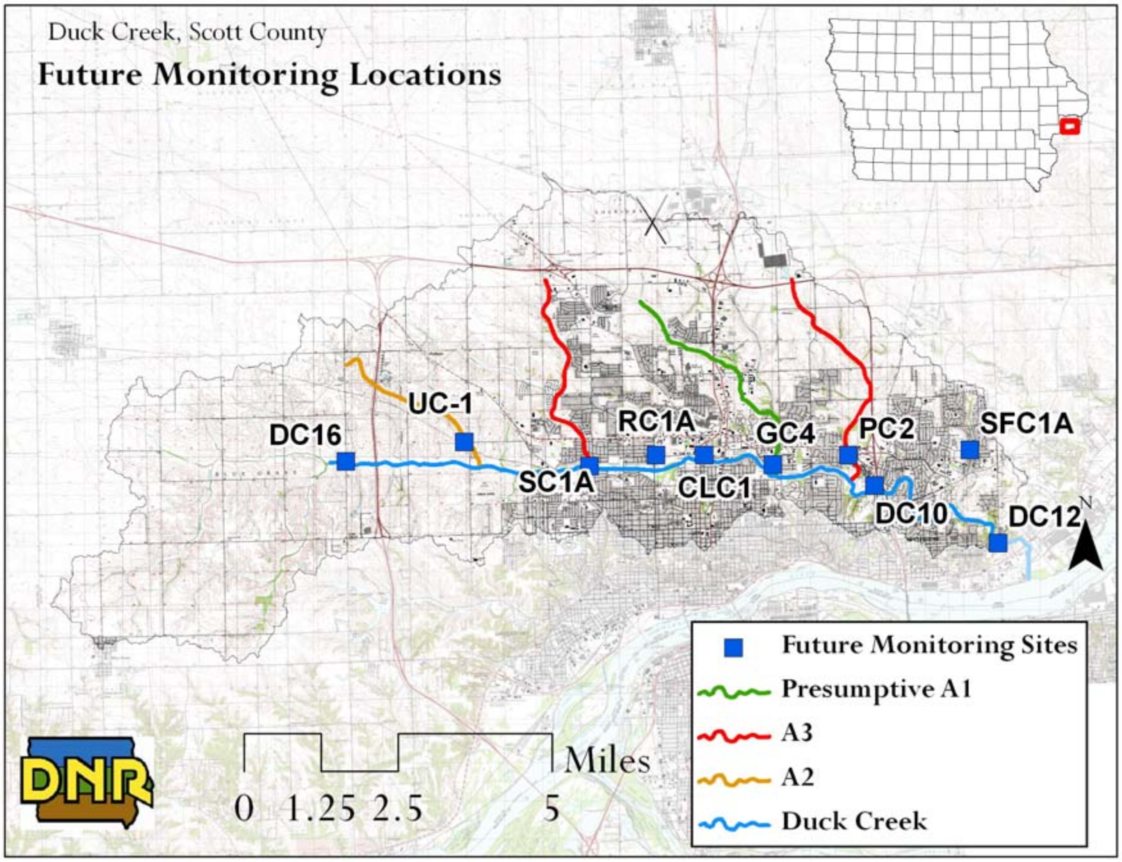

Figure 6-1. Recommended locations for future monitoring

7. 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 determine the water quality in Duck Creek. During the development of this TMDL, efforts were made to ensure that local stakeholders were involved in the decision-making process regarding goals and required actions for improving water quality in Duck Creek.

7.1. Public Meetings

November 25, 2008
An initial public meeting was held at the Bettendorf Fire Station at 5002 Crow Creek Road in Bettendorf, Iowa. This meeting was sponsored by the Partners of Scott County Watersheds and the Scott County Soil & Water Conservation District (SWCD). The goals of the meeting were to inform the public and seek feedback regarding water quality in Duck Creek.

Staff from the Iowa Department of Natural Resources (IDNR) presented a description of previous water quality monitoring efforts and an update of current water quality conditions in Duck Creek. IDNR also discussed the TMDL, including federal requirements, goals and objectives, and the projected timeline for TMDL development. IDNR staff emphasized that the TMDL would be available as a resource for local stakeholders, but that commitment and action by local groups (citizens, officials, and organizations) would be required to achieve significant water quality improvement in Duck Creek.

Approximately 45 individuals attended the meeting. Stakeholder groups present included public works staff from the cities of Davenport and Bettendorf, several local consulting firms, Iowa State Master Gardeners, board members from the Partners of Scott County Watersheds (PSCW), IOWATER snapshot volunteers, and watershed residents.

Key agency attendees included:
- IDNR – Watershed Improvement Section (TMDL and 319 programs)
- IDNR – Watershed Monitoring and Assessment (Section 305(b) Report)
- Scott County
- Scott County SWCD

7.2. Written Comments

[Enter text] Give dates and lengths of public comment periods, # letters received, etc.

8. References

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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.
Scientific notation:	See explanation on page 107.
Secchi disk:	A device used to measure transparency in waterbodies. The greater the Secchi depth (typically measured in meters), the more transparent the water.
Sediment delivery ratio:	A value, expressed as a percent, which is used to describe the fraction of gross soil erosion that is delivered to the waterbody of concern.
Seston:	All particulate matter (organic and inorganic) suspended in the water column.
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.
WWTF:	Wastewater Treatment Facility. 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. Used interchangeably with wastewater treatment plant (WWTP).
Zooplankton:	Collective term for all animal plankton suspended in the water column which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Scientific Notation

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

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

Here are some examples of scientific notation.

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

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

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

Introduction

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

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

General Use Segments

A general use segment water body is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B-1) which may apply, and a water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

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

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

Appendix C --- Water Quality Data

Table C-1. Observed flow and *E. coli* at site DC-16 in Duck Creek.

Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)	Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)
7/18/04	5.7	2,400	7/7/08	11	1,700
7/25/04	8.7	3,400	7/14/08	9.7	1,300
8/1/04	4.6	1,200	7/21/08	43	24,000
8/8/04	3.7	1,400	7/28/08	6.9	2,100
8/15/04	2.7	1,000	8/5/08	20	130,000
8/22/04	2.1	1,300	8/12/08	3.9	1,600
8/29/04	4.4	38,000	8/18/08	2.9	340
9/12/04	1.4	1,800	8/26/08	2.2	400
9/19/04	1.2	290	9/2/08	1.8	540
9/26/04	1.1	400	9/3/08	1.7	520
10/4/04	1.1	310	9/4/08	3.7	4,400
10/10/04	0.9	520	9/5/08	3.0	25,000
10/12/04	0.7	380	9/9/08	2.4	5,900
10/17/04	0.9	490	9/16/08	17	1,300
10/23/04	6.0	43,000	9/17/08	12	1,400
5/17/05	140	1,900	9/18/08	9.7	2,000
10/11/05	0.0	55	9/19/08	8.2	2,300
5/21/06	3.2	520	9/20/08	7.1	2,000
5/8/07	15	230	9/21/08	6.0	1,500
10/9/07	2.9	1,800	9/22/08	5.4	1,800
4/8/08	30	9,800	9/23/08	5.0	2,400
4/14/08	37	30	9/24/08	4.8	2,600
4/22/08	22	1,900	9/25/08	4.5	4,400
4/29/08	29	210	9/26/08	4.2	3,300
5/5/08	17	60	9/27/08	4.2	1,785
5/12/08	96	990	9/28/08	3.8	1,800
5/13/08	60	360	9/29/08	9.3	140,000
5/19/08	23	70	9/30/08	5.4	13,000
5/27/08	16	1,900	10/7/08	32	1,400
6/2/08	18	1,300	10/13/08	19	3,100
6/3/08	204	14,000	10/14/08	19	1,700
6/4/08	100	1,500	10/20/08	20	640
6/5/08	60	1,100	10/28/08	20	420
6/6/08	46	1,800	--	--	--
6/7/08	62	410	--	--	--
6/8/08	74	1,200	Min =	0.0	30
6/9/08	97	4,000	1st Quartile =	3.7	520
6/10/08	115	7,500	Median =	8.7	1,500
6/11/08	54	400	3rd Quartile =	21	2,400
6/12/08	152	860	Max =	204	140,000
6/24/08	19	200	Mean =	23	7,164
7/1/08	12	690	Std Dev =	37	22,627

[1] Flow is daily mean flow recorded at USGS Station 05422560.

Table C-2. Observed flow and *E. coli* at site DC-10 in Duck Creek.

Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)	Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)
10/7/03	1.1	40	9/5/08	33	6,600
5/25/04	179	3,900	9/9/08	21	3,100
10/12/04	2.5	280	9/16/08	51	1,500
5/17/05	36	260	9/17/08	36	1,200
10/11/05	0.4	350	9/18/08	29	780
5/21/06	13	70	9/19/08	24	1,600
10/10/06	0.4	240	9/20/08	22	960
5/8/07	45	450	9/21/08	19	800
10/9/07	8.1	600	9/22/08	18	770
4/8/08	255	290	9/23/08	17	860
4/14/08	112	1,300	9/24/08	16	320
4/22/08	83	2,300	9/25/08	15	590
4/29/08	77	370	9/26/08	14	370
5/5/08	48	340	9/27/08	13	402
5/12/08	246	2,200	9/28/08	12	650
5/13/08	156	1,100	9/29/08	81	25,000
5/19/08	63	350	9/30/08	19	22,000
5/27/08	50	2,000	10/7/08	145	500
6/2/08	51	680	10/13/08	22	860
6/3/08	999	25,000	10/14/08	23	4,600
6/4/08	235	4,200	10/20/08	23	620
6/5/08	137	2,100	10/28/08	18	500
6/6/08	123	7,500	--	--	--
6/7/08	120	410	--	--	--
6/8/08	140	3,500	--	--	--
6/9/08	199	8,400	--	--	--
6/10/08	218	18,000	--	--	--
6/11/08	115	600	--	--	--
6/12/08	481	1,500	--	--	--
6/24/08	52	760	--	--	--
7/1/08	37	700	--	--	--
7/7/08	34	2,600	--	--	--
7/14/08	23	990	--	--	--
7/21/08	169	33,000	--	--	--
7/28/08	20	1,000	--	--	--
8/5/08	63	6,800	Min =	0.4	40
8/12/08	10	300	1st Quartile =	17	408
8/18/08	6.6	440	Median =	35	830
8/26/08	4.3	340	3rd Quartile =	116	2,725
9/2/08	2.9	400	Max =	999	33,000
9/3/08	4.8	8,700	Mean =	86	3,655
9/4/08	222	15,000	Std Dev =	145	6,824

[1] Flow is daily mean flow recorded at USGS Station 05422600.

Table C-3. Observed flow and *E. coli* at site DC-12 in Duck Creek.

Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)	Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)
10/7/03	1.2	90	8/18/08	7.1	250
5/25/04	197	6,000	8/26/08	4.6	550
7/18/04	16	140	9/2/08	3.0	390
7/25/04	24	2,900	9/9/08	24	4,900
8/1/04	13	220	9/16/08	56	1,200
8/8/04	10	470	9/22/08	20	990
8/15/04	6.9	180	9/30/08	21	65,000
8/22/04	5.8	310	10/7/08	160	300
8/29/04	32	3,700	10/13/08	24	840
9/12/04	4.6	150	10/14/08	25	3,000
9/19/04	4.7	960	10/20/08	25	290
9/26/04	3.3	260	10/28/08	18	300
10/4/04	3.6	830	--	--	--
10/10/04	4.8	240	--	--	--
10/12/04	2.7	82	--	--	--
10/17/04	2.9	160	--	--	--
10/23/04	150	7,400	--	--	--
5/17/05	39	370	--	--	--
10/11/05	0.4	580	--	--	--
5/21/06	14	90	--	--	--
10/10/06	0.4	70	--	--	--
5/8/07	49	330	--	--	--
10/9/07	8.8	290	--	--	--
4/8/08	285	280	--	--	--
4/14/08	122	380	--	--	--
4/22/08	91	960	--	--	--
4/29/08	84	470	--	--	--
5/5/08	52	380	--	--	--
5/12/08	266	2,400	--	--	--
5/13/08	169	760	--	--	--
5/19/08	68	400	--	--	--
5/27/08	55	990	--	--	--
6/3/08	1,106	12,000	--	--	--
6/10/08	232	17,000	--	--	--
6/24/08	59	910	--	--	--
7/1/08	40	770	Min =	0.4	70
7/7/08	37	2,900	1st Quartile =	6.9	290
7/14/08	25	660	Median =	24	565
7/21/08	186	24,000	3rd Quartile =	66	1,148
7/28/08	22	900	Max =	1,106	65,000
8/5/08	69	5,300	Mean =	73	3,259
8/12/08	11	700	Std Dev =	160	9,578

[1] Flow is daily mean extrapolated from USGS Stations 05422560 and 05422600.

Table C-4. Observed flow and *E. coli* at site PC-2 in Pheasant Creek.

Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)	Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)
4/8/08	23.4	610	--	--	--
4/14/08	1.9	100	--	--	--
4/22/08	18.5	2,400	--	--	--
4/29/08	4.6	240	--	--	--
5/5/08	3.0	390	--	--	--
5/12/08	7.2	990	--	--	--
5/19/08	5.2	230	--	--	--
5/27/08	3.1	990	--	--	--
6/3/08	44.7	39,000	--	--	--
6/10/08	14.4	8,200	--	--	--
6/24/08	3.8	1,200	--	--	--
7/1/08	3.6	2,100	--	--	--
7/7/08	3.7	4,900	--	--	--
7/14/08	1.3	2,500	--	--	--
7/21/08	28.8	24,000	--	--	--
7/28/08	1.4	2,300	--	--	--
8/5/08	5.1	12,000	--	--	--
8/12/08	0.6	500	--	--	--
8/18/08	0.6	310	--	--	--
8/26/08	0.4	360	--	--	--
9/2/08	0.3	320	--	--	--
9/9/08	1.7	2,000	--	--	--
9/16/08	3.9	1,100	--	--	--
9/22/08	1.7	290	--	--	--
9/30/08	1.7	24,000	--	--	--
10/7/08	1.1	300	--	--	--
10/13/08	1.0	160	--	--	--
10/20/08	0.7	190	--	--	--
10/28/08	1.2	90	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	Min =	0.3	90
--	--	--	1st Quartile =	1.2	300
--	--	--	Median =	3.0	990
--	--	--	3rd Quartile =	5.1	2,400
--	--	--	Max =	45	39,000
--	--	--	Mean =	6	4,540
--	--	--	Std Dev =	10	9,146

[1] Flow is daily mean was measured manually during water quality sampling. Missing flow values were estimated by regression between USGS flow at DC-10 and measured flow at PC-2.

Table C-5. Observed flow and *E. coli* at site GC-4 in Goose Creek.

Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)	Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)
4/8/08	33.4	4,100	--	--	--
4/14/08	4.4	130	--	--	--
4/22/08	7.7	2,300	--	--	--
4/29/08	7.6	340	--	--	--
5/5/08	5.3	630	--	--	--
5/12/08	29.5	5,800	--	--	--
5/19/08	6.7	550	--	--	--
5/27/08	5.7	960	--	--	--
6/3/08	95.6	32,000	--	--	--
6/10/08	19.5	22,000	--	--	--
6/24/08	5.9	1,200	--	--	--
7/1/08	5.5	1,400	--	--	--
7/7/08	0.5	4,400	--	--	--
7/14/08	4.2	1,700	--	--	--
7/21/08	47.5	41,000	--	--	--
7/28/08	1.8	1,000	--	--	--
8/5/08	12.2	9,300	--	--	--
8/12/08	0.7	1,100	--	--	--
8/18/08	0.5	690	--	--	--
8/26/08	0.4	570	--	--	--
9/2/08	0.3	270	--	--	--
9/9/08	2.7	5,200	--	--	--
9/16/08	6.7	2,500	--	--	--
9/22/08	2.5	3,300	--	--	--
9/30/08	2.1	19,000	--	--	--
10/7/08	1.8	9,100	--	--	--
10/13/08	2.7	1,200	--	--	--
10/20/08	2.1	960	--	--	--
10/28/08	1.0	340	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	Min =	0.3	130
--	--	--	1st Quartile =	1.8	690
--	--	--	Median =	4.4	1,400
--	--	--	3rd Quartile =	7.6	5,200
--	--	--	Max =	96	41,000
--	--	--	Mean =	11	5,967
--	--	--	Std Dev =	20	10,035

[1] Flow is daily mean was measured manually during water quality sampling. Missing flow values were estimated by regression between USGS flow at DC-10 and measured flow at GC-4.

Table C-6. Observed flow and *E. coli* at site SC-1A in Silver Creek.

Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)	Date	[1]Flow (cfs)	*E. coli* (MPN/100 mL)
4/8/08	28.3	1,550	--	--	--
4/14/08	5.7	20	--	--	--
4/22/08	8.6	1,600	--	--	--
4/29/08	11.7	30	--	--	--
5/5/08	7.2	40	--	--	--
5/12/08	34.3	720	--	--	--
5/19/08	8.3	170	--	--	--
5/27/08	7.2	730	--	--	--
6/3/08	185.3	73,000	--	--	--
6/10/08	25.4	5,800	--	--	--
6/24/08	6.7	1,100	--	--	--
7/1/08	7.6	1,400	--	--	--
7/7/08	5.0	1,500	--	--	--
7/14/08	4.2	2,200	--	--	--
7/21/08	30.7	100,000	--	--	--
7/28/08	2.7	1,600	--	--	--
8/5/08	10.2	4,400	--	--	--
8/12/08	0.5	500	--	--	--
8/18/08	0.9	450	--	--	--
8/26/08	0.4	820	--	--	--
9/2/08	1.2	250	--	--	--
9/9/08	1.8	5,000	--	--	--
9/16/08	5.6	1,300	--	--	--
9/22/08	2.0	2,200	--	--	--
9/30/08	1.5	20,000	--	--	--
10/7/08	2.2	37,000	--	--	--
10/13/08	1.3	520	--	--	--
10/20/08	1.9	170	--	--	--
10/28/08	1.0	220	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	Min =	0.4	20
--	--	--	1st Quartile =	1.8	450
--	--	--	Median =	5.6	1,300
--	--	--	3rd Quartile =	8.6	2,200
--	--	--	Max =	185	100,000
--	--	--	Mean =	14	9,113
--	--	--	Std Dev =	34	22,986

[1] Flow is daily mean was measured manually during water quality sampling. Missing flow values were estimated by regression between USGS flow at DC-10 and measured flow at SC-1A.

Appendix D --- Watershed Modeling Methodology

Load duration curves based on observed flow and water quality data were used to develop the Total Maximum Daily Load (TMDL) for the two segments of Duck Creek reported as impaired on the Iowa Department of Natural Resources 2008 303(d) list. Use Attainability Analyses (UAAs) revealed that several tributaries to Duck Creek have recreational (Class A) designated uses, and water quality data collected in 2008 suggests future impairment of these tributary streams is likely. TMDLs for these tributaries were also developed using load duration curves constructed from observed flow and water quality data.

The Soil & Water Assessment Tool, version 2005 (SWAT2005), was applied to the watershed to assist with development of pollutant source inventories and an implementation strategy. The watershed modeling approach allows the holistic analysis of hydrology and water quality in the Duck Creek watershed, including the main stem and all significant tributaries.

D.1. SWAT Model Description

SWAT is a watershed-scale hydrology and water quality model developed by the U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS). SWAT is a long-term continuous-simulation model that operates on a daily time step, and was developed to assess the impacts of land use and management practices on hydrology and water quality (Gassman et al., 2007; Schilling et al., 2008). SWAT is capable of simulating a variety of pollutants, including sediment, nutrients, pesticides, and bacteria. Primary inputs include spatial coverage of soil types and land uses, climatic data including daily precipitation, temperature, solar radiation, relative humidity, and wind speed, and land management considerations that affect hydrology and water quality, such as crop rotation, tillage practices, best management practices, manure application, tile drainage characteristics, grazing, and loading from point sources of pollution.

Watersheds are delineated into subbasins based on a user-desired area threshold, which are further divided into hydrologic response units (HRUs) that consist of homogeneous soil, land use, and slope characteristics (Gassman et al., 2007; Schilling et al., 2008). Because each HRU represents the portion of a subbasin with the same soil, land use, and slope classification, HRUs are not spatially contiguous. An overall water balance is simulated for each HRU and flows are summarized at the subbasin level before being routed through the stream system. Pollutant loadings or concentrations can also be calculated for each HRU and summed at the subbasin level before being routed through the watershed. There is a long-history of the use of SWAT for hydrologic and water quality simulations (Gassman et al, 2007), and its utilization for the development of TMDLs is increasingly popular (Borah et al., 2006).

D.2. Meteorological Input

Precipitation and Temperature Data
There are two weather stations within 14 miles of Duck Creek watershed for which a long record of daily precipitation data is available through the Iowa Environmental Mesonet (IEM). National Weather Service (NWS) COOP stations from which precipitation data were obtained are located at LeClaire (Station IA4705) and Muscatine (Station IA5837). The Thiessen polygon method was utilized to develop an area-weighted precipitation data set based on these two stations. The LeClaire and Muscatine Theissen polygon precipitation data from 1993-2008 was converted to millimeters (mm) and imported to SWAT during model development. Similarly, the Theissen polygon method was applied to temperature data at the LeClaire and Muscatine NWS COOP stations to develop a daily record of maximum and minimum temperature (degrees Celsius) for SWAT input. A summary of weather station and precipitation data is provided in Section 2.1.

Solar Radiation, Wind Speed, and Relative Humidity
SWAT2005 allows the user to simulate solar radiation, wind speed, and relative humidity input, or import data from nearby weather stations. Oftentimes, daily solar radiation, wind speed, and humidity data near the watershed of interest are not available. Simulated input is generated through algorithms within the SWAT model that draw from historical weather data stored in the SWAT database and precipitation and temperature inputs. The SWAT model used in the development of the bacteria source inventories relied on simulated input data for solar radiation, wind speed, and relative humidity.

D.3. Hydrologic Response Unit (HRU) Input

Topography
The Duck Creek watershed boundary was delineated in the ArcSWAT 2.3.4 Interface for SWAT2005 using a 10-meter resolution digital elevation model (DEM) developed by the Iowa Department of Natural Resources (IDNR). Topographical input has two primary purposes. First, it provides a basis for watershed and subbasin delineation. Second, it allows calculation of average slope for each HRU, which is an important input for hydrologic and water quality simulation.

During the delineation process, a drainage area threshold of 404.6 hectares (1,000 acres) was entered to define the minimum subbasin size. This value was obtained through an iterative process and selected in order to provide a manageable number of subbasins. Subbasin outlets were also added manually as part of the delineation process to establish outlets at key locations. Specifically, outlets were added at two USGS stream gage stations (Station 05422560 at 110th Avenue and Station 05422600 at the DC Golf Course), and at Devils Glen Road. Flow and water quality data is available for all three manual outlet locations, which was utilized for SWAT calibration/validation. The monitoring station at Devils Glen Road (DC-12) is the downstream most monitoring station, and is considered to be the watershed outlet for modeling purposes, even though several hundred additional acres drain to the mouth of Duck Creek where it enters the

Mississippi River. Manual outlet definition was also helpful to ensure that the range of subbasin areas was within an order of magnitude, as recommended by SWAT model developers (R. Srinivasan, March 16, 2009, personal communication). The delineation resulted in a total watershed area of 16,307 hectares (40,295 acres), consisting of 24 subbasins ranging from 152 to 1,317 hectares (375 to 3,255 acres). The delineation is illustrated in Figure D-1.

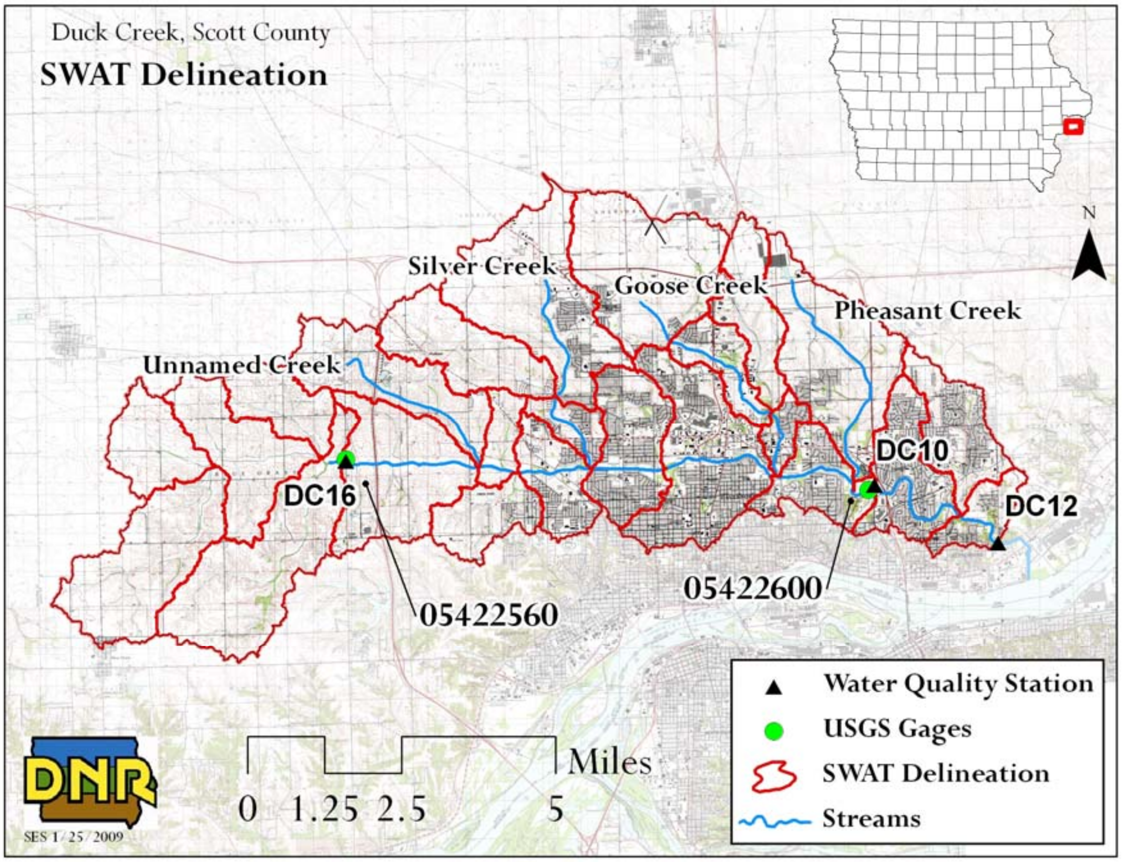

Figure D-1. SWAT subbasin delineation.

Land Use

Land use inputs for the SWAT model are based on the state's 2002 land cover grid. The 2002 data was updated with more detailed land cover data collected in 2008 as part of a watershed assessment conducted by the Scott County Soil and Water Conservation District (SWCD). The 2008 land cover assessment was used primarily to incorporate management practices such as crop rotation into watershed model development.

Sixteen land uses from the 2002 coverage are found within the watershed boundary. These land uses are generalized and illustrated in Figure 2-8 of Section 2.2. During SWAT model development, a filter was applied to land uses during HRU definition. The land use filter eliminates land uses that comprise less than 5 percent of each subbasin, and reapportions these small areas to the remaining (unfiltered) land uses in each subbasin. The filtration process reduces the number of resulting HRUs, which can significantly reduce model run time and increase model efficiency. Pasture land was exempted from the land use filter to ensure that no pasture adjacent to streams was eliminated from the analysis, which could artificially reduce bacteria loadings. Table D-1 reports the land use breakdown used for HRU definition (after filtering). This is the land use information that the SWAT model utilizes for hydrologic and water quality simulations.

Table D-1. Land use classifications in Duck Creek SWAT model.

2002 Land Use	SWAT Classification	Watershed Area (%)
Ungrazed grassland	Smooth Bromegrass (BROS)	22.4
Grazed grassland	Pasture (PAST)	4.4
Corn	Corn (CORN)	24.1
Soybeans	Soybean (SOYB)	19.1
Roads	Transportation (UTRN)	7.8
Commercial/Industrial	Commercial (UCOM)	6.4
Residential	Residential-Medium Density (URMD)	11.7
Deciduous forest	Forest-Deciduous (FRSD)	4.1

Soils

SWAT model development utilized the Soil Survey Geographic (SSURGO) soils coverage for Scott County, developed by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS). Soils data are discussed in more detail in Section 2.2 The SSURGO data was filtered during HRU definition so that soils comprising less than 10 percent of a land use in a given subbasin would be eliminated, and the corresponding area would be reapportioned to the remaining soils (soils comprising greater than 10 percent of the land use in a subbasin).

Slopes

During the watershed delineation process, ArcSWAT creates a slope grid using the input DEM. To complete the definition of HRUs, the SWAT user must define the desired slope classifications. For the Duck Creek SWAT model, five slope classifications were defined in accordance with classifications found in the NRCS soil surveys. A 10 percent filter was applied to the slopes during HRU definition, similar to the soils filter. The resulting slope classes in the Duck Creek SWAT model are reported in Table D-2.

Table D-2. Slope classifications in Duck Creek SWAT model.

Slope (%)	Description	Watershed Area (%)
0-2	Level and nearly level	21.9
2-5	Gently sloping	36.8
5-9	Moderately sloping	33.2
9-14	Strongly sloping	7.6
>14	Moderately to very steep	0.5

Source (IEM, 2009)

The HRU definition process resulted in 1,006 unique combinations of land use, soil, and slope in each subbasin. Hydrologic and water quality computations are performed in SWAT for each HRU, summed for each subbasin, and then routed through the watershed and ultimately to the watershed outlet.

D.4. Channel Routing

SWAT allows the user to choose two methods for routing flows through the stream channel. The default option is the Variable Storage Method, and the alternative method is the Muskingum Method. Both methods were evaluated in the development of the Duck Creek model. Because hydrologic output was not highly sensitive to the routing method, the default Variable Storage Method was used. SWAT assumes that each reach has a trapezoidal shape with side slopes of 2:1 (run:rise). Default channel widths and depths are calculated for each reach based on drainage area and channel geometry relationships. Channel geometry obtained from a Federal Emergency Management Agency (FEMA) hydraulic model of Duck Creek and several of its tributaries revealed that default channel geometry significantly underestimated actual channel depths. Default channel widths and depths were updated based on the FEMA data. Default depths in the main stem of Duck Creek were increased by a factor of 3.5, but channel width was not modified. Default depths in all tributary reaches were increased by a factor of 4.5 based on the FEMA data, and tributary widths were increased by a factor of 1.2. Even with large increases in depth, model output changed only slightly, and only above the 95th flow duration. This suggests efforts to obtain exact channel geometry may not be worth the time and effort expended. It should also be noted that the FEMA study is nearly 30 years old, and depths are likely even greater than estimated. However, this was the best available channel geometry data.

D.5. Operations Management Input

Tile Drainage

Tile drains with outfalls to Duck Creek and its tributaries were identified during the 2008 watershed assessment conducted by the SWCD. Tile outfalls were assigned spatial information and other data in a GIS coverage. The watershed is not tile-drained to the same extent as watersheds in Des Moines Lobe ecoregion. However, tile drainage is moderate to significant, and therefore included in the development of the watershed model. SWAT incorporates tile drainage using three parameters, described in Table D-3. Tile drainage was added to all HRUs that have slopes of less than or equal to 5 percent. In urban areas, it is assumed that storm sewer infrastructure functions similar to agricultural tile drains. Input values in Table D-3 are consistent with SWAT model development for other tile-drained watersheds in Iowa after small adjustments to reflect watershed size (Calvin Wolter, IDNR, personal communication, May 14, 2009).

Table D-3. SWAT tile drain parameters for the Duck Creek watershed.

Description	SWAT Variable	Value
Depth to subsurface drain	DDRAIN	1,200 mm
Time required to drain to field capacity	TDRAIN	48 hr
Drainage tile lag time (hr)	GDRAIN	24 hr

Crop Rotation

Land uses were assigned in the SWAT model using the statewide land cover database developed in 2002 and the local land cover assessment developed by the Scott County Soil and Water Conservation District (SWCD) in 2008. The 2008 assessment revealed that row crop lands are primarily in a corn and soybean rotation. Therefore, all HRUs described as corn in the 2002 database were modeled as corn in even years of the simulation period and soybeans in odd years. Similarly, areas described as soybeans in 2002 were designated as soybeans in even years and corn in odd years. A few HRUs were assigned other rotations (such as continuous corn) based on more detailed data reported in the 2008 land use assessment and available manure management plans (MMPs).

Tillage

The 2008 watershed assessment delineated tillage practices in row crop areas at the field scale. Tillage practices were not incorporated into the SWAT model because the vast majority (75 percent) of row crops are mulch till, which reflects the SWAT default Universal Soil Loss Equation (USLE) C-Factor. Tillage practices could be incorporated into the model at some point in the future if more detailed data regarding erosion and sediment delivery is required.

Fertilizer Application

Nitrogen and phosphorus fertilizers were applied to row crops at rates and times consistent with two previous SWAT applications for TMDL development in Iowa. Anhydrous ammonia was applied to all corn ground in the fall after the previous year’s soybean crop was harvested. Di-ammonium phosphate fertilizer (SWAT fertilizer ID 18-46-00) was applied to all soybean ground in the spring prior to planting. Table D-4 shows the rates and timing of fertilizer applications in the Duck Creek SWAT model. Even though the Duck Creek TMDL is for bacteria rather than nutrients, fertilizer application rates are needed to support crop growth in SWAT. Without adequate crop growth, the accuracy of hydrologic output from SWAT is compromised.

Table D-4. Fertilizer application in the Duck Creek watershed SWAT model.

Fertilizer Type	Application Rate	Timing
Di-ammonium phosphate	175 kg/ha (156 lbs/ac)	Spring – prior to planting soybeans
Anhydrous ammonia	170 kg/ha (152 lbs/ac)	Fall – after soybean harvest

Manure Application

Manure was applied to corn in the SWAT model as specified by available MMPs. IDNR requires MMPs for all confinements with greater than 500 animal units (AUs) and all open feedlots with over 1,000 AUs. Several animal feeding operations (AFOs) in or near the Duck Creek watershed have MMPs on file with IDNR. Manure application (location, volume, and timing) reported in the MMPs was input to the SWAT model. The areas of application fields reported in the MMPs were assigned to equivalent HRU areas in each SWAT subbasin. This provides spatial accuracy to the subbasin level, but not to field level. All manure is applied as hog manure according to the “Swine-Fresh Manure” classification in the SWAT2005 database.

Because the MMPs report application rates in gallons per acre (gal/acre) of liquid manure, application amounts were converted to a dry basis for model input in kilograms per hectare (kg/ha). Liquid application rates ranged from approximately 3,000 to 6,850 gal/acre, and a maximum of approximately 900 acres receive manure application in a given year. A swine manure *E. coli* concentration 1.32E+07 *E. coli* organisms per gram of dry manure (orgs/gram) was added to the SWAT database (ASAE, 1998). All conversions of fecal coliform to *E. coli* in the Duck Creek TMDL utilize a conversion ratio of 0.63, which represents the ratio of the geometric mean (GM) bacteria standards (126 *E. coli* orgs/day to 200 fecal coliform orgs/100 mL).

Livestock Grazing
The number of grazing livestock, including beef cattle, horses, and goats was estimated by the Scott County SWCD in 2008. Manure deposition rates, in kilograms per hectare per day (kg/ha/day), were entered for all pasture HRUs in each SWAT subbasin containing grazing livestock. Deposition rates consider the dominant livestock type, observed livestock population, the area of pasture in each subbasin, and published defecation rates (ASAE, 1998; USDA, 1992). Grazing was simulated from April 15 through November 15 of each year. Table D-5 shows grazing livestock manure characteristics.

Table D-5. Livestock grazing and manure characterization.

Livestock Type	[1]Dry Manure Production (kg/head/day)	[2]Manure *E. coli* (orgs/gram)
Beef cattle	2.44	2.68E+07
Horse	5.09	5.20E+04

[1] Dry manure production calculated from wet production rates reported by ASAE (1998) and manure moisture contents reported by USDA (1992).
[2] Manure *E. coli* concentration calculated using fecal coliform production rates reported by ASAE (1998) and a fecal coliform to *E. coli* conversion ratio of 0.63.

Wildlife
The estimated deer density in Scott County, based on road kill rates, is approximately 7 deer per square mile (Willie Suchy, IDNR, June 18, 2009, personal communication). The deer density was increased by 15 percent to account for manure deposition from other furbearing wildlife such as raccoons, beavers, opossums, etc. This ratio of deer to furbearers is consistent with TMDL input used in Virginia. No such data was readily available for the State of Iowa. Although wildlife densities will vary wildlife from one landscape and region to the next, assuming a similar ratio of deer to furbearers in similar land uses is the most reasonable assumption existing data allows.

Wildlife was assumed to reside in HRUs with forest and grass land cover (SWAT land use codes FRSD and BROS, respectively). The equivalent deer density in forest and grass areas is 27 deer per square mile. The overall density, after adding 15 percent for other wildlife, is 31 deer per square mile. Manure production from wildlife “grazing” was entered in SWAT using a manure production rate of 0.72 kg/ha/day on applied to all forest and grass HRUs in the model. Wildlife waste was assumed to have an *E. coli* concentration of 5.20E+04 orgs/gram (dry weight). The simulated wildlife waste deposition and bacteria concentration is equivalent to an *E. coli* production rate of 5.0E+08 fecal coliforms per head per day (orgs/head/day) as utilized in a prior application of SWAT for TMDL development in Iowa (IDNR, 2008). Wildlife grazing and subsequent manure deposition on forest and grass land is assumed to occur 365 days a year.

Pet Waste
The Humane Society of the United States (HSUS) estimates that 39 percent of U.S. households own at least one dog, and on average, dog owners have 1.7 dogs. Similarly, nearly 34 percent of households in the U.S. have at least one cat, with the average owner having 2.3 cats. HSUS obtained these statistics from a study conducted by the American Pet Products Manufacturers Association (APPMA) in 2007-2008 (HSUS, 2008).

The Duck Creek watershed has an approximate human population of 120,000 people (Amy Johannsen, Scott County SWCD, personal communication). This is equivalent to 50,000 homes in the watershed, assuming an average of 2.4 individuals per household. Based on the APPMA pet ownership statistics, there are an estimated 33,150 dogs and 39,100 cats in the watershed. Assuming dogs produce 0.32 pounds (lbs) of dry waste per day (Pitt, 1998; Godfrey, 1992; Geldrich et al., 1962) and that each gram of dog waste contains 2.3E+07 fecal coliform organisms per day (van der Wel, 1995), dogs produce 1.11E+14 fecal coliform organisms every day in the Duck Creek watershed. Similar calculations for cat waste reveal that dogs produce five times more bacteria than cats.

Therefore, all pet waste was assumed to be from dogs, and projected dog waste was increased by 20 percent to account for cat waste. This is a conservative assumption because most cat waste is likely deposited indoors in litter boxes. The resulting assumptions are that 3.0 kg/ha/day of pet waste is applied to all HRUs with residential land use and that pet waste contains 1.45E+07 *E. coli* orgs/gram. The total source load from pets is 4.38E+10 orgs/ha/day. Pet waste is assumed to account for all nonpoint sources of fecal bacteria from residential areas.

Other Urban Nonpoint Sources
There are no available data sufficient for quantifying source-specific bacteria loads in non-residential urban areas of Duck Creek watershed. However, published fecal coliform buildup rates were utilized to incorporate bacteria contributions from nonresidential land uses in urban areas of the watershed. All SWAT HRUs with transportation (UTRN) and industrial/commercial (UCOM) land use were assigned *E. coli* buildup rates of 1.11E+10 and 1.08E+09 orgs/ha/day, respectively. These values are calculated based on findings reported by Horsley and Witten (1996) and converted to units suitable for SWAT input.

Undocumented Urban Loads
Data describing bacteria sources in the urban areas is limited. Bacteria buildup values were taken from literature (described above), and many potential sources such as dry

weather flow from illicit connections, unreported SSOs, and bacteria buildup on the land and in the conveyance system, could not be quantified for model input. Instead, the urban buildup parameters were increased until the simulated and observed load duration curves showed reasonable agreement (see water quality calibration discussion in Appendix E). This additional urban buildup is termed "undocumented urban loads" and is equivalent to 3.00E+12 orgs/ha/day, which is relatively large when compared to literature values used for pet waste and buildup on commercial and transportation land uses.

D.6. Point Source Input

The only regulated point sources in the watershed are NPDES permitted discharges, discussed below. Due to limitations of SWAT, several other sources were modeled as point sources even though they are technically nonpoint sources of bacteria. These include failing non-permitted septic systems and direct deposition in streams by livestock and wildlife.

NPDES Facilities
There are several NPDES dischargers in the Duck Creek watershed. These include three wastewater treatment facilities (Davenport West Locust Lagoon, West Kimberly Mobile Home Park, and Lakewood Estates Mobile Home Park), sanitary sewer overflows (SSOs), MS4s in the Cities of Davenport and Bettendorf, a general statewide industrial permit for MidAmerican Energy, and individual industrial permits for John Deere, Flyin' J Travel Plaza, and the Iowa Department of Transportation (IDOT).

The wastewater treatment discharges located in the watershed were modeled as point sources in SWAT. The West Locust facility is a controlled discharge lagoon with available daily effluent records, which were entered into a point source input table. *E. coli* data is not available for the facility, so the best available data was used to estimate effluent concentration. This data consists of a statewide collection of *E. coli* concentrations in over 350 controlled discharge lagoons that have been submitted to IDNR along with permit applications per the permitting and compliance guidance for controlled discharge lagoons (effective December 15, 2006). The 90th percentile concentration of these lagoons is 1,990 *E. coli* orgs/100 mL, which is entered in the point source input table for the corresponding SWAT subbasin, along with daily flow records for the West Locust lagoon.

The West Kimberly and Lakewood Estates facilities discharge continuously. Daily flow records are available, but because there are thousands of daily flow values that would require tedious manual data entry, and because flows do not vary widely over short time frames, daily flows were averaged on a monthly basis. An effluent *E. coli* concentration was calculated for these facilities based on literature ranges of 1.0E+04 to 1.0E+06 total coliforms/100 mL for treated (but not disinfected) effluent (Novotny and Olem, 1994) and a typical *E. coli* component of 20 to 30 percent of total coliforms (Kadlec and Knight, 1996). Assuming a total coliform concentration of 1.0E+05 orgs/100 mL and that 25 percent of total coliforms are *E. coli*, a treated effluent *E. coli* concentration of 25,000 orgs/100 mL was used as model input for West Kimberly and Lakewood Estates.

There are several known locations of SSOs. SSO elimination must be addressed through the NPDES permit for the City of Davenport Sewage Treatment Plant (STP). Nine historical SSO events were simulated as point sources in SWAT to examine SSO impacts on water quality. Appoximate SSO volumes were recorded by DNR Field Office staff and a raw wastewater concentration of 6.3E+06 fecal coliforms per 100 mL was utilized (Overcash and Davidson, 1980). This is equivalent to 4.0E+06 *E. coli* orgs/100 mL and is a conservative assumption because nearly all SSO events are triggered by infiltration of rainfall into the sanitary system, which would dilute bacteria concentrations. However, it is likely that most SSO events were not captured in observed data or quantified in the SWAT model. Therefore, actual bacteria loads from SSOs are likely larger than estimated.

Septic Systems

A GIS coverage of the number of residential septic systems with NPDES discharge permits was obtained from the Scott County Health Department by the SWCD as part of the 2008 watershed assessment. Septic system contributions were aggregated at the subbasin level by multiplying the permitted design flow of 150 gallons per bedroom per day (gal/bedroom/day) by the number of homes with permitted systems (93 homes), assuming a typical home has three bedrooms. These flows, along with the permitted effluent limit of 235 *E. coli* orgs/100 mL, were incorporated into SWAT using the daily point source discharge tables for each subbasin.

Some non-discharging onsite wastewater systems that operate without NPDES permits likely contribute bacteria to Duck Creek due to aging and malfunctioning systems. The Scott County Health Department has one of the most advanced septic system programs in the state, and the rate of “failing” non-permitted systems is thought to be well under 10 percent (J. Hoskins, Scott County Health Department, October 5, 2009, personal communication). The number of these systems were estimated by counting the number of homes outside of sewered areas (262 homes) using aerial photos and sewer coverages in GIS. Bacteria contributions were calculated using EPA’s BIT spreadsheet model (EPA, 2000) assuming a 5 percent failure rate, per capita flow of 70 gallons per person per day (gal/person/day), an average of 2.4 people per household, and a septic system concentration of 1.0E+06 fecal coliform orgs/100 mL (6.3E+5 *E. coli* orgs/100 mL) (Horsley and Witten, 1996). Septic system bacteria contributions were input to SWAT using daily point source discharge tables for each subbasin.

In-Stream Deposition by Livestock

The SWCD watershed assessment included field reconnaissance efforts to estimate the number of livestock with direct access to streams. Livestock with direct access were assumed to defecate in streams a portion of the time during the grazing season, May 15 to October 15. The amount of time cattle spend in streams varies monthly, as shown in Table D-6. The percent of time cattle spend in streams is highest during hot weather periods. Iowa State University Extension has researched cattle behavior and found that even during the hottest weather, cattle spend a maximum of about 13 percent of the time (approximately 3 hours a day) within 100 feet of the stream and a maximum of 5 percent of the time in the stream itself (Dr. Jim Russell, Department of Animal Science, ISU-Extension, September 8, 2009, personal communication). During SWAT model development, it was assumed that approximately 75 percent of all manure deposited within this 100-foot corridor is effectively delivered directly into the stream. The number of cattle with stream access was added to the total number of grazing cattle, which results in a slight overestimate of the number of cattle in the watershed. These conservative assumptions further support an implicit MOS, because reductions simulated for implementation activities must attain WQS, even with a conservative estimate of direct loads to the stream.

Table D-6. Modeling assumptions regarding direct deposition by livestock.

Month	Time in Streams (%)	Time in Streams (hours/day)
January	0	0
February	0	0
March	0	0
April	0	0
May	3	0.7
June	6	1.4
July	10	2.4
August	10	2.4
September	6	1.4
October	3	0.7
November	0	0
December	0	0

Direct deposition was calculated in the EPA BIT spreadsheet by multiplying the fraction of time spent in streams by accepted defecation rates and manure bacteria concentrations (ASAE, 1998). Inputs were entered into SWAT via the daily point source discharge tables on a subwatershed basis. Note that only those livestock populations identified as having direct access to streams contribute to direct deposition in the SWAT model. This is a relatively small percentage of the overall livestock population in the watershed.

In-Stream Deposition by Wildlife

The SWAT model also simulates in-stream deposition from wildlife. TMDLs developed in Virginia have estimated that deer directly deposit waste into streams less than 1 percent of the time, whereas furbearers directly deposit between 2 and 25 percent of the time (VDEQ et al., 2006). Deer and furbearers in Duck Creek were assumed to directly deposit 0.5 and 10 percent of their waste (and subsequently bacteria) to streams, respectively. This results in an overall wildlife in-stream deposition rate of less than 2 percent when adjusted for relative waste production of deer versus furbearers. In-stream *E. coli* deposition was estimated in the BIT model by multiplying time spent in streams by the same wildlife bacteria production rate used in wildlife grazing, reported in Section D.5. Wildlife contributions were tabulated and entered into SWAT using the daily point source input table for each subbasin. Unlike livestock, wildlife was assumed to access the stream year round, and time spent in streams does not vary from month to month.

D.7. References

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Appendix E --- Model Calibration

E.1. Hydrologic Calibration

The Duck Creek watershed SWAT model was calibrated and validated by comparing simulated hydrology to mean daily flows reported at two USGS stream gage stations on Duck Creek. The USGS gage stations are discussed in detail in Section 2.1 of this TMDL, with stream gage information reported in Table 2-2 and stream gage locations illustrated in Figure 2-1. Calendar years 1994-1998 were utilized as a "spin-up" period to allow the SWAT model to reach equilibrium in terms of soil moisture content and nutrient concentrations. The calibration period was based on calendar years 2003-2008, and validation was performed using USGS data from calendar years 1998-2002. Because water quality data collection ended in October of 2008, and TMDL development commenced before the remainder of the year's flow data was available from USGS, flows are only analyzed through October of 2008.

Calibration of SWAT involved iterative adjustment of hydrologic parameters until graphical and/or statistical comparison of observed and simulated data revealed sufficient agreement. Primary hydrologic calibration parameters and their final calibrated values are reported in Table E-1.

Table E-1. Summary of hydrologic calibration parameters in SWAT model.

Parameter	Input Description	Calibrated Value
Curve Number	Corn – Soil Group B Soybeans – Soil Group B Pasture – Soil Group B/C Grassland – Soil Group B Forest – Soil Group B/C Commercial – Soil Group B/D Residential – Soil Group B/D Transportation – Soil Group B/D	69 70 64/74 61 65/76 68/78 68/78 68/78
IPET ESCO EPCO	Potential Evapotranspiration Method Soil Evaporation Compensation Plant Uptake Compensation Factor	Hargreaves 0.95 (default) 1.0 (default)
ICN CNCOEF SURLAG	Daily curve number calculation method Plant ET curve number coefficient Surface Runoff Lag	Plant ET 0.5 2 days
IRTE	Channel Routing Method	Variable Storage
NPERCO PPERCO	Nitrogen percolation coefficient Phosphorus percolation coefficient	0.2 (default) 10 (default)
GW_DELAY	Groundwater Delay	30 days
ALPH_BF	Alpha Base Flow Factor	0.3 days
GW_REVAP	Groundwater revap coefficient	0.02 (default)
REVAPMN	Threshold Revap Depth	10 mm

Annual Water Balance
The simulated average annual water balance at the watershed outlet for the entire simulation period was evaluated to ensure that the SWAT model was accounting for each of the hydrologic components. Simulated water balance components for calendar years 1998-2003 are reported in Table E-2. Baseflow includes lateral flow, groundwater flow, and tile flow.

Table E-2. Average annual water balance components.

Precipitation (in)	36.6
Surface runoff (in)	7.0
Baseflow (in)	5.7
Deep aquifer recharge (in)	0.3
Transmission losses (in)	0.1
Evapotranspiration (in)	23.4

Average Annual Flow
Due to the limited available data set, annual flows were not split into calibration and validation years. These relatively short periods (5-6 years) are not adequate for statistical analysis of annual data. However, the annual flows were used to graphically evaluate model performance for the entire simulation period (1998-2008). Figure E-1 illustrates the observed and simulated annual flows in Duck Creek at 110th Avenue, the location of USGS Gage 05422560 and water quality monitoring station DC-16. Figure E-2 compares annual flows at the Duck Creek Golf course (USGS Gage 05422600 and DC-10).

Analysis of annual flow data reveals that the hydrology model is providing reasonable predictions of annual flow in Duck Creek at both locations. The model overestimates annual flow at 110th Avenue in 1998, 2001, 2006, and 2007. Simulated annual flow is greater than observed flow at the golf course in all years except 1999, 2002, and 2005. Overall, results suggest a good match between observed and simulated annual flows. For the 10-year simulation period, the simulated average annual stream flow at 110th Avenue (9.1 inches) was reasonably close to the observed value (10.3 inches), a difference of 11.7 percent. Comparison of observed and simulated flow at the golf course is even more favorable, with a simulated value of 11.0 inches/year and an observed value of 10.8 inches/year (a difference of 2.7 percent).

Monthly Average Flow
Simulated monthly flows at 110th Avenue and the Duck Creek Golf Course were calibrated to USGS gage flows in the calibration period (January 2003-October 2008) and validated against measured flows observed in 1998-2002. Monthly average flows, in cubic feet per second (cfs), are plotted throughout the entire simulation period (1998-2008) for both stations in Figures E-3 and E-4. Close graphical analysis reveals that SWAT appears to more closely simulate flows at the golf course than at 110th Avenue. This is likely because of increased variability due to a relatively small drainage area at 110th Avenue (16.1 square miles) compared with the golf course (57.3 square miles).

Statistical analysis of monthly flows included use of linear regression, Pearson's coefficient of determination (R^2), and the slope of the regression to evaluate how well simulated data matched observed flow. The R^2 statistic describes the collinearity between simulated and observed data. R^2 values range from 0 to 1, with higher values indicating less error variance. R^2 values greater than 0.5 are typically considered acceptable for hydrologic simulation (Moriasi et al., 2007). The slope indicates the relative relationship between simulated and observed data. A slope of 1 indicates that the model perfectly predicts the magnitude of observed data. The linear regressions for both stations during the calibration period are plotted in Figures E-5 and E-6. The R^2 and slope for both calibration and validation regressions are reported in Table E-3.

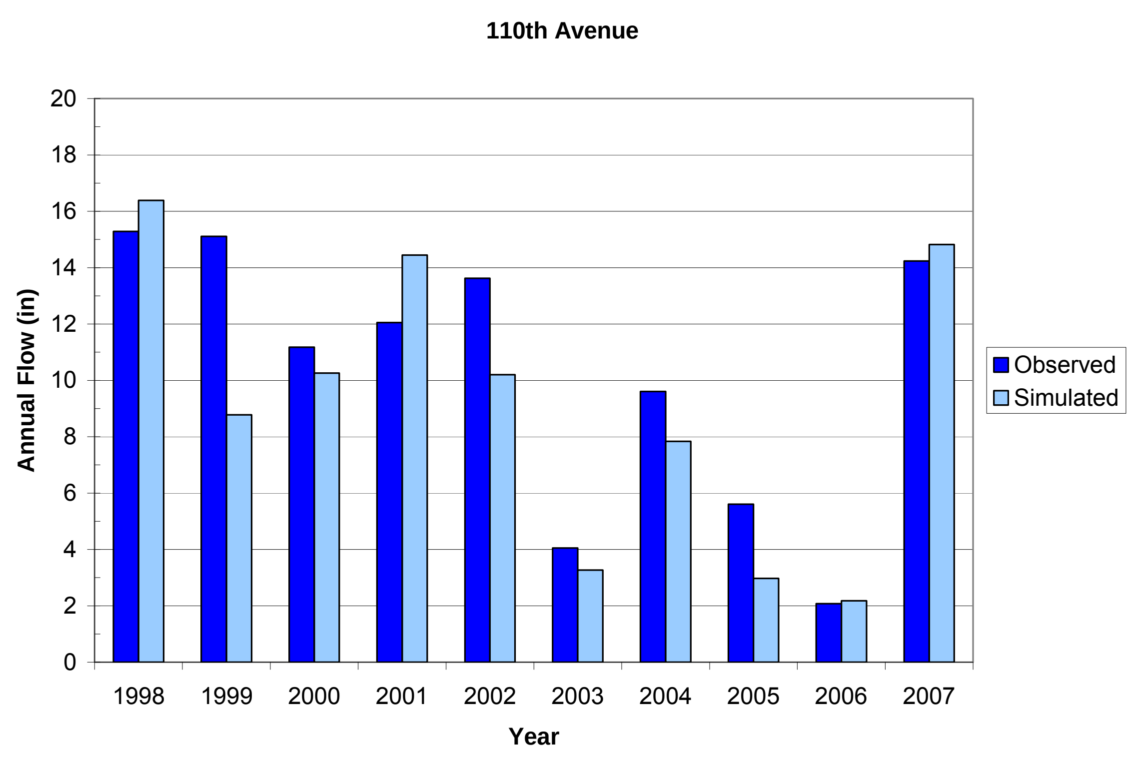

Figure E-1. Observed and simulated annual flow at 110th Avenue.

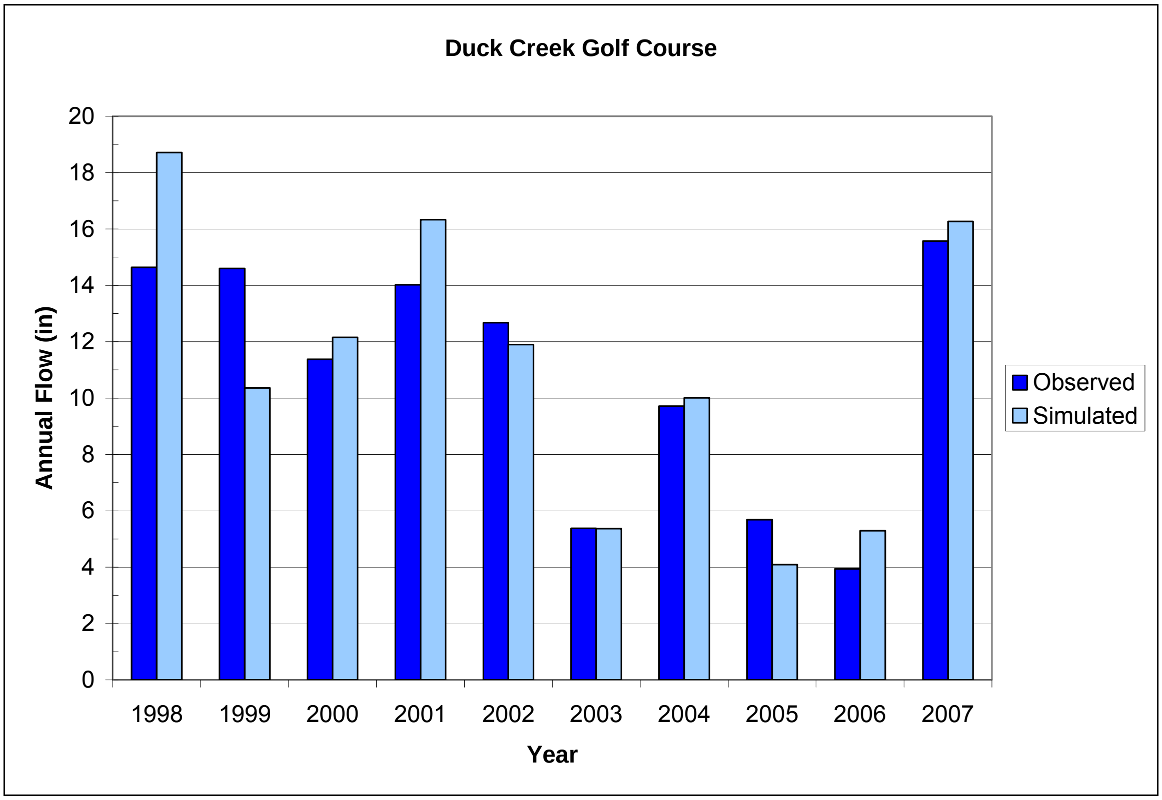

Figure E-2. Observed and simulated annual flow at Duck Creek Golf Course.

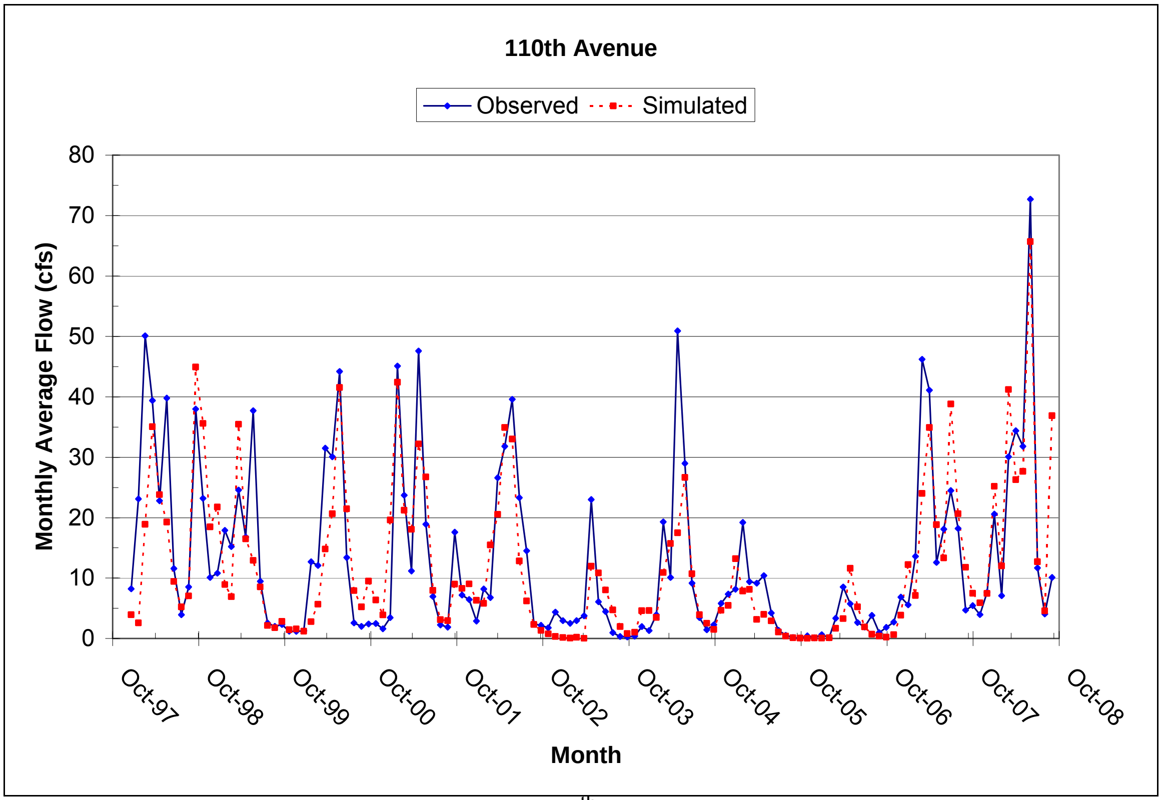

Figure E-3. Monthly average flow at 110th Avenue.

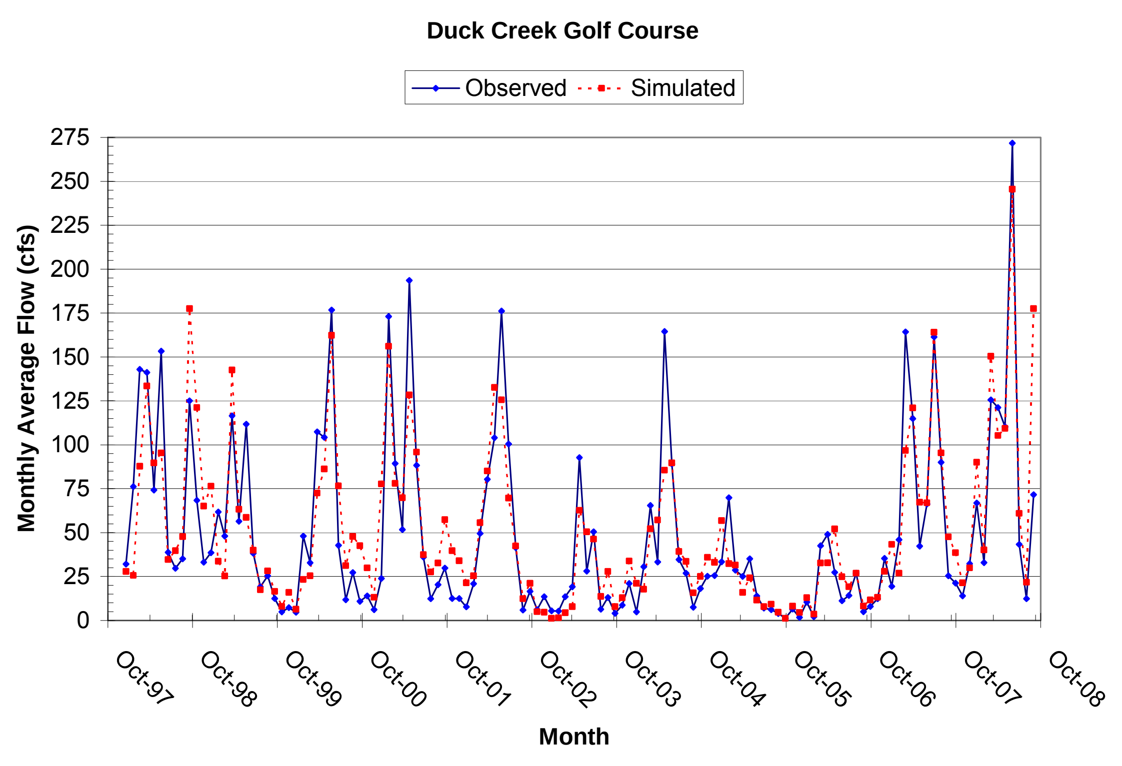

Figure E-4. Monthly average flow at the Duck Creek Golf Course.

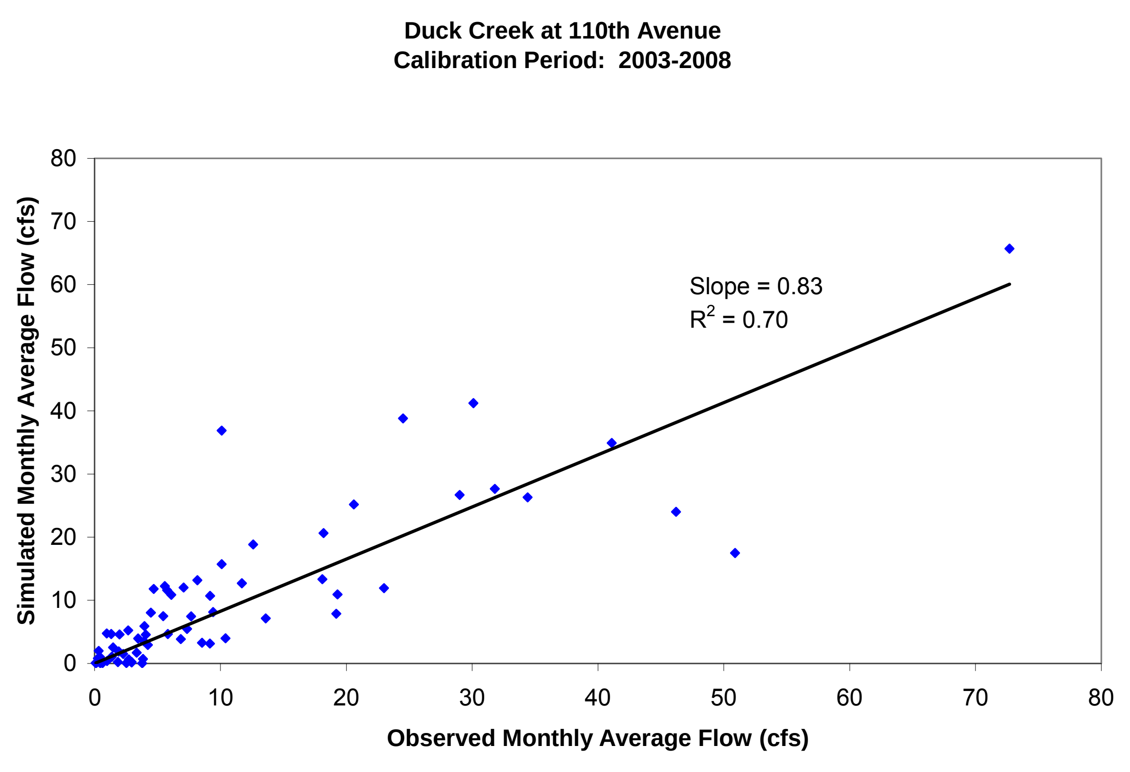

Figure E-5. Linear regression (calibration data) at 110th Avenue.

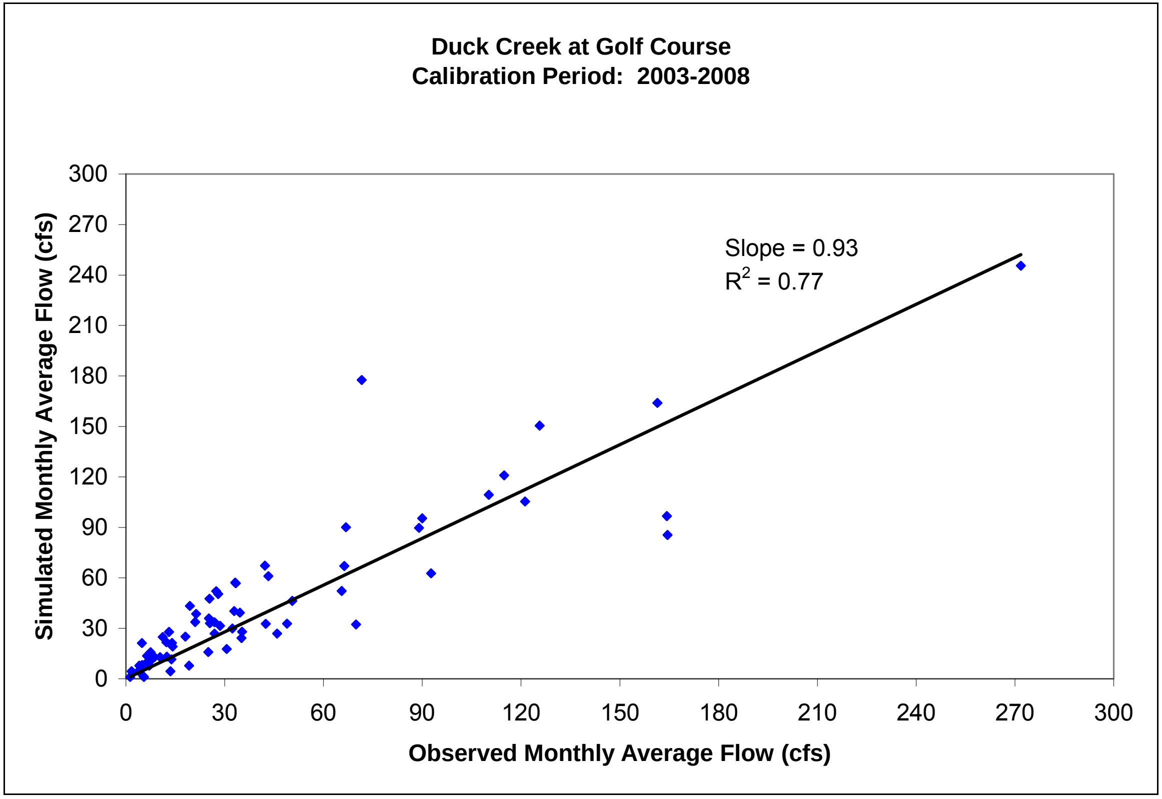

Figure E-6. Linear regression (calibration data) at the Duck Creek Golf Course.

The R^2 and slope values reported in Table E-3 suggest that the hydrologic model is adequately simulating stream flow at the two calibration/validation locations. SWAT provides better flow estimates at the downstream location (at the Duck Creek Golf Course), likely due to increased variability and flashiness in data reported at the 110th Avenue because of a much smaller drainage area. The slope of the linear regression line for both the calibration and validation scenario is near 1 (0.93) at the golf course location, with R^2 values well above the acceptable threshold of 0.5.

Table E-3. Monthly flow linear regression results.

	R^2		Slope	
Location	Calibration	Validation	Calibration	Validation
110th Avenue	0.70	0.58	0.83	0.79
Golf Course	0.77	0.65	0.93	0.89

Evaluation of model performance followed additional guidelines developed by researchers at the United States Department of Agriculture-Agricultural Research Service (USDA-ARS), which actively supports and updates the SWAT model. The evaluation included a thorough literature review of SWAT model application and performance, and recommended use of three quantitative statistics during calibration/validation, in addition to graphical techniques (Moriasi et al., 2007). The statistics include the Nash-Sutcliffe efficiency (NSE), percent bias (PBIAS), and ratio of the root mean square error to the standard deviation of measured data (RSR). Graphical techniques included hydrograph and percent exceedance probability curves (also called flow duration curves).

The NSE, like the slope and R^2 statistic, indicates how well the plot of simulated versus observed data fits the 1:1 line (Nash and Sutcliffe, 1970). The PBIAS statistic quantifies the tendency of the model to over or underestimate observed data. The optimal PBIAS value is 0, with low absolute values representing accurate model simulation. Positive values indicate underestimation bias, and negative values indicate overestimation bias. RSR is an error index statistic that includes a scaling/normalization factor. The optimal value of RSR is 0, with lower RSR values indicating better model performance (Moriasi et al, 2007). Table E-4 reports general performance ratings for the recommended statistics for use with monthly stream flow data.

Table E-4. Performance ratings for recommended statistics.

Performance Rating	NSE	PBIAS (%)	RSR
Very good	0.75 < NSE ≤ 1.00	PBIAS ≤ ±10	0.00 ≤ RSR ≤ 0.50
Good	0.65 < NSE ≤ 0.75	±10 < PBIAS ≤ ±15	0.50 < RSR ≤ 0.60
Satisfactory	0.50 < NSE ≤ 0.65	±15 < PBIAS ≤ ±25	0.60 < RSR ≤ 0.70
Unsatisfactory	NSE ≤ 0.50	PBIAS ≥ ±25	RSR > 0.70

Adopted from Moriasi et al., 2007

Table E-5 reports the results of these statistics for the calibration and validation data of the Duck Creek SWAT model. Model performance is good at 110th Avenue and good to very good at the golf course during the calibration period. Model performance ranges from satisfactory to very good for model validation.

Table E-5. Monthly flow statistics using USDA-ARS guidelines.

	NSE		PBIAS		RSR	
Location	Calibration	Validation	Calibration	Validation	Calibration	Validation
110th Avenue	0.71 (Good)	0.59 (Satisfactory)	5.9 (Very Good)	11.5 (Good)	0.54 (Good)	0.64 (Satisfactory)
Golf Course	0.79 (Very Good)	0.72 (Good)	-5.0 (Very Good)	-2.4 (Very Good)	0.45 (Very Good)	0.53 (Good)

Monthly Average Runoff and Baseflow

The same calibration statistics used to evaluate simulation of total stream flow were also used to compare simulated and observed monthly average runoff and baseflow. Baseflow and runoff separation were estimated using the recursive digital filter method (Eckhardt, 2005) available through a Web based Hydrograph Analysis Tool (WHAT) (Lim et al., 2005) and USGS gage data. The analysis assumes a mostly porous aquifer, consistent with local geologic and groundwater conditions. The filter method utilizes a filter parameter of 0.98 and a BFImax (maximum value of long-term ratio of base flow to total stream flow) of 0.64.

SWAT does not provide separate baseflow and surface runoff output in each reach, but does tabulate baseflow and runoff at the overall watershed outlet. There is no USGS stream gage at the watershed outlet, but a water quality monitoring station (DC-12) is located near the outlet at Devils Glen Road. Total stream flow at Devils Glen Road was extrapolated based on drainage area using USGS gage data at 110th Avenue and Duck Creek Golf Course. This extrapolated flow was separated into runoff and baseflow for calibration/validation purposes. Table E-6 reports the linear regression statistics for runoff and baseflow simulation, and Table E-7 shows NSE, PBIAS, and RSR statistics. The calibration statistics suggest that SWAT is adequately simulating both runoff and baseflow on a monthly basis. All R^2 values are well above the minimum recommended value of 0.5, with the exception of validated baseflow ($R^2 = 0.48$). Slopes are reasonably near 1.0, which indicates that the model is not significantly over or underestimating observed data.

Table E-6. Monthly runoff and baseflow regression at Devils Glen Road.

	R^2		Slope	
Location	**Calibration**	**Validation**	**Calibration**	**Validation**
Runoff	0.72	0.64	0.93	0.93
Baseflow	0.68	0.48	1.01	0.88

Table E-7. Monthly runoff and baseflow statistics at Devils Glen Road.

	NSE		PBIAS		RSR	
Flow	Calibration	Validation	Calibration	Validation	Calibration	Validation
Runoff	0.69 (Good)	0.65 (Good)	-0.8 (Very Good)	-7.5 (Very Good)	0.56 (Good)	0.59 (Good)
Baseflow	0.67 (Good)	0.53 (Satisfactory)	-17.3 (Satisfactory)	-1.6 (Very Good)	0.58 (Good)	0.69 (Satisfactory)

Daily Flow Duration Curves

Flow duration curves provide an illustration of how well the model simulates the frequency of observed daily flows throughout the calibration and validation periods (Van Liew et al., 2003). The curves for both observed and simulated flows at 110th Avenue and at the Duck Creek Golf Course are shown in Figures E-7 and E-8, respectively. The flow duration curves for 110th Avenue reveal that the model accurately simulates flow between the 20th and 80th flow duration intervals, but tends to underestimate flows between the 5th and 10th flow duration interval and above the 85th flow duration. The simulated flow duration curve at the Duck Creek Golf Course closely approximates the observed curve for all flow conditions. However, simulated flows slightly exceed observed flows between the 40th and 85th duration intervals, and are slightly lower than the observed flows above the 90th flow duration interval. In general, the graphical analysis reveals that the SWAT model adequately reproduces the frequency of observed daily flows.

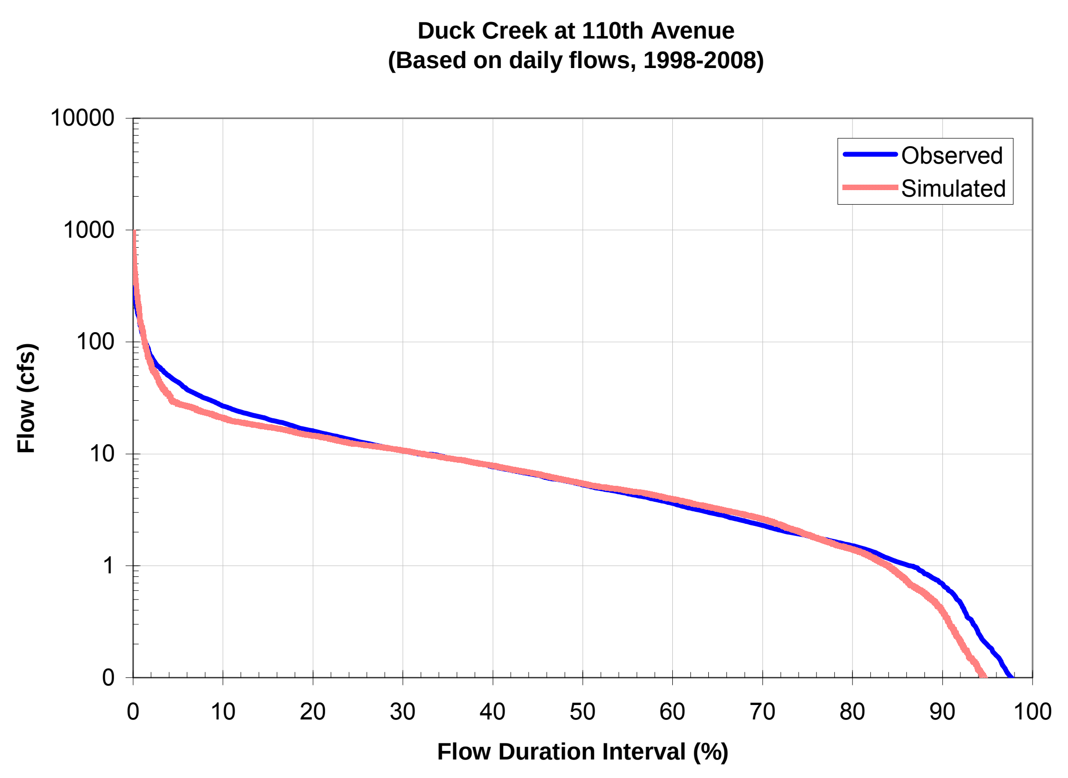

Figure E-7. Daily flow duration curve (simulated and observed) at 110th Avenue.

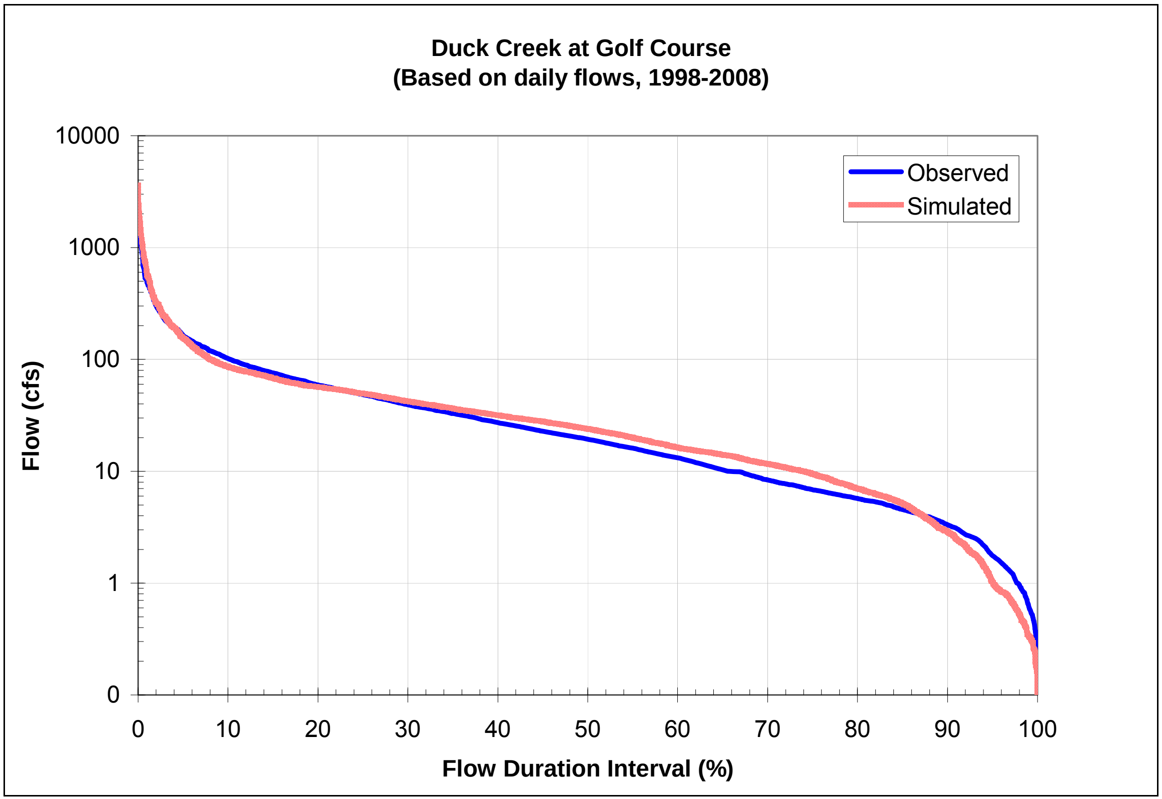

Figure E-8. Daily flow duration curve (simulated and observed) at Golf Course.

E.2. Water Quality Calibration

Comparison of simulated and observed bacteria concentrations and loads was based largely on graphical analysis, since the frequency and amount of observed bacteria data was often inadequate for detailed statistical measures. This is consistent with the approach taken in the calibration of an HSPF model for the Cedar River bacteria TMDL, which was developed by an EPA contractor (EPA, 2009, unpublished). Graphics used to assess model performance included bacteria concentration exceedance plots (also called probability plots) and load duration curves (LDCs). In addition to graphical methods, several basic statistics were utilized to evaluate model performance, including comparison of observed and simulated mean and median concentrations, as well as comparison of the frequency of water quality standard violations.

Enhancement of model performance for bacteria simulations involved iterative adjustment of bacteria-related parameters until graphical and/or statistical comparison of observed and simulated data revealed reasonable agreement. Primary bacteria calibration parameters and their final calibrated values are reported in Table E-8. Bacteria partition coefficients for manure were taken from a study of the fate and transport of pathogen indicators from manure deposited on pasturelands (Soupir, 2007). The partition coefficient (BACTKDDB) for swine manure was adjusted to 0.30 during calibration to reflect the incorporation of swine manure into the ground during application to row crops. This would increase the opportunity for bacteria to adsorb to soil particles. The partition coefficient for urban waste was adjusted to 0.80 to reflect more limited opportunity for soil adsorption in urban landscapes. Die-off coefficients for bacteria in soil solution and on soil particles were obtained from previous IDNR bacteria TMDLs (IDNR, 2008), and compared to die-off coefficients used in a SWAT model application in Kansas (Parajuli, 2007). However, die-off in soil solution and on particles was changed to zero during calibration, which is a conservative assumption and provided a better match with observed data. The bacteria soil partitioning coefficient (BACTKDQ) was left as the model default after sensitivity analysis revealed that bacteria output does not vary significantly with changes to this parameter.

Table E-8. Summary of bacteria calibration parameters in SWAT model.

Parameter	Input Description	Calibrated Value
BACTKDDB	Bacteria partition coefficient Swine manure Urban waste All other manure/waste	 0.30 0.80 [1]0.58
BACTMX	Bacteria percolation coefficient	20
WDPQ	Bacteria die-off in soil solution	0.00
WDPS	Bacteria die-off on soil particles	0.00
WDPF	Bacteria die-off on foliage	0.00
WDPRCH	Bacteria die-off in streams	0.96
THBACT	Temperature adjustment factor	1.07 (default)
BACTKDQ	Bacteria soil partitioning coefficient	175 (default)

[1] Soupir, 2007

Source Load Adjustments
Comparison of simulated to observed *E. coli* levels revealed that the model performs well in the rural/agricultural portions of the watershed. Agreement is generally better at the upstream monitoring station (110th Avenue/site DC-16) than at downstream locations in urbanized areas. The most likely explanation is better documentation and understanding of bacteria sources in the agricultural areas. To account for undocumented urban loads, urban bacteria buildup was increased until the simulated *E. coli* exceedence plots and load duration curves showed reasonable agreement with observed data. See Appendix Section D.5 of Appendix D for more detailed discussion of this calibration step.

E. coli Exceedance Plots
Comparison of observed and simulated bacteria exceedance plots shows reasonable agreement at 110th Avenue (DC-16), the Duck Creek Golf Course (DC-10), and Devils Glen Road (DC-12). Given the inherent variability of bacteria concentrations, simplifying assumptions required for modeling bacteria, and the limited amount of in-stream data collected, some differences must be expected.

The exceedance plots for all three monitoring locations are shown in Figures E-9 through E-11, and illustrate the percent of time specific concentrations are exceeded. The SSM criterion of 235 orgs/100 mL is also illustrated on the figures, which allows visual analysis of the instantaneous violation rates (IVRs) reported in Tables E-9 and E-10 for the two upstream locations. The solid blue line represents the observed *E. coli* probability curve and the thick dashed red line represents the simulated curve. Both curves are comprised of data obtained or simulated on water quality sampling dates. The thin dashed green curve reflects data simulated for the entire recreation seasons (March 15 through November 15) of 2003-2008. Overall, the model represents the exceedance probability of observed concentrations reasonably well, and was deemed adequate for quantification of source inventories and development of an implementation strategy.

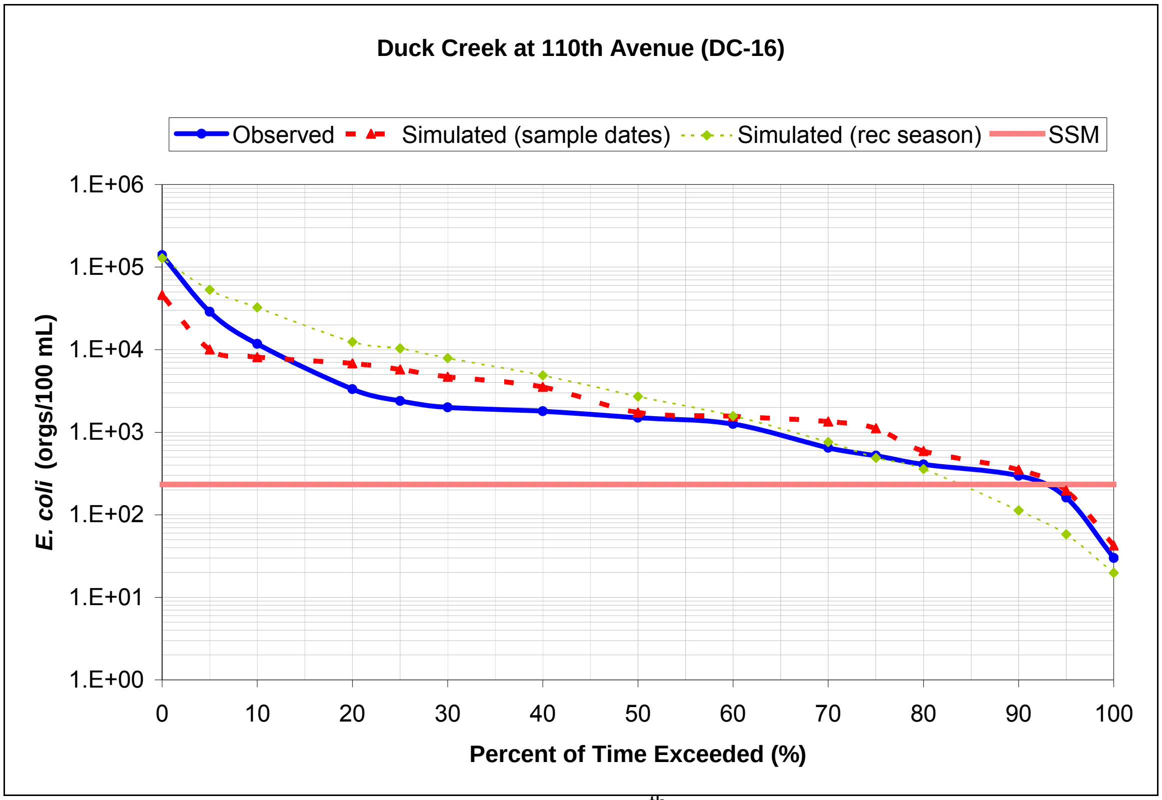

Figure E-9. *E. coli* exceedance curves at 110th Avenue.

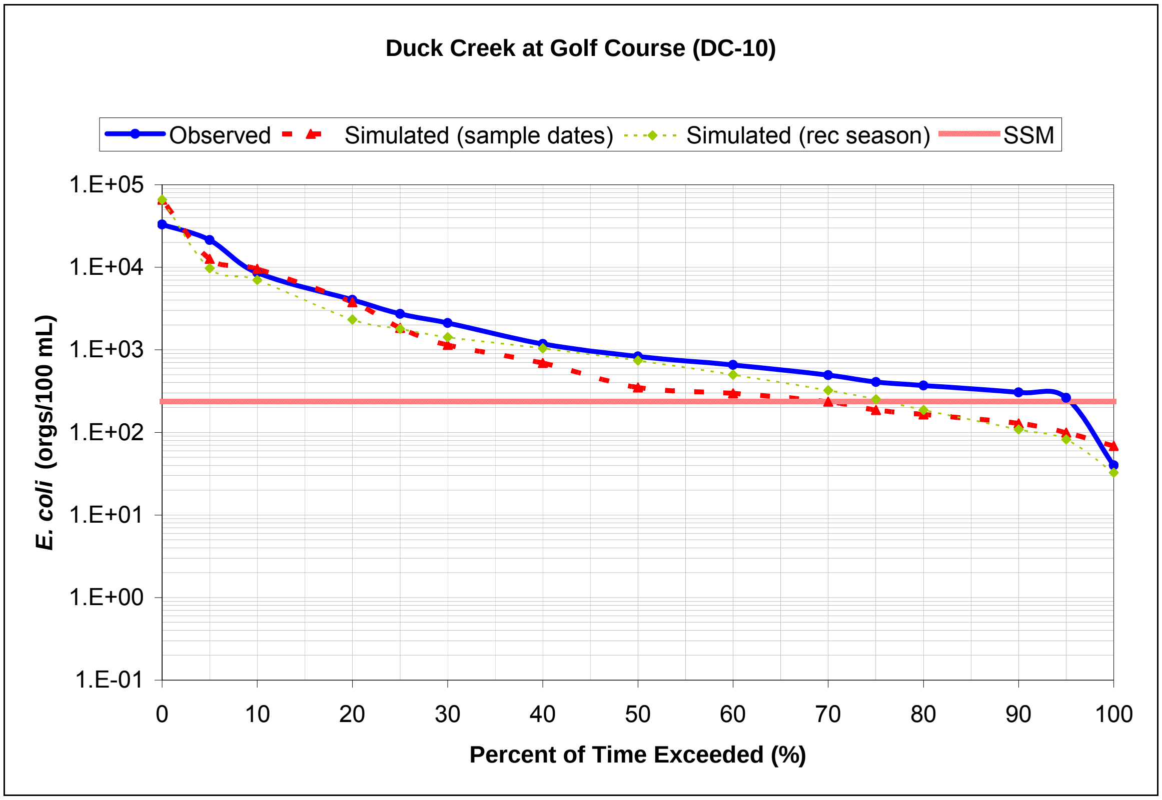

Figure E-10. *E. coli* exceedance curves at Duck Creek Golf Course.

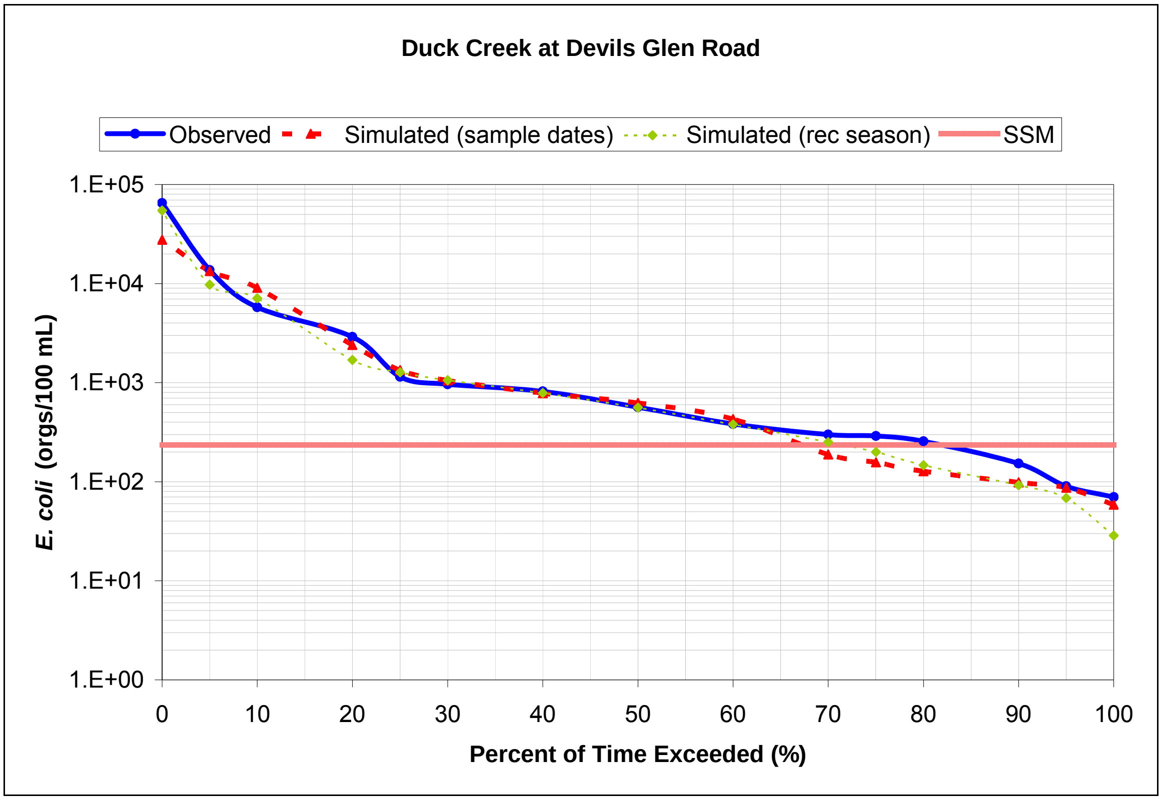

Figure E-11. *E. coli* exceedance curves at Devils Glen Road.

E. coli Load Duration Curves

The numeric *E. coli* allocations for the Duck Creek TMDLs are based on LDCs constructed from observed data. However, it is difficult to estimate relative contributions of *E. coli* from specific point and nonpoint sources using only observed data. Additionally, observed data alone does not enable development of a thorough watershed management plan. Therefore, SWAT model was used to construct “synthetic” or simulated LDCs for calibration purposes and for watershed planning. Visual analysis of the observed and simulated load duration curves reveals the model’s ability to represent loading processes under various flow conditions, and helps evaluate model performance.

The observed and simulated LDCs are illustrated in Figures E-12 through E-17. Inspection of the curves reveals that simulated loads reasonably approximate (usually within one log) observed loads in each of five flow conditions. The highest loads occur under extreme high flow events, which cause erosion and washoff of fecal material that contains *E. coli* into the stream. SWAT tends to over estimate loads as flows decrease, especially in the dry and low flow conditions. While the median and 90th percentile loads tend to decrease in the observed curves, the loads are relatively consistent between moist and dry conditions in the simulated curves. There are several possible explanations for this, including:

- The observed data sets contain a limited number of measured *E. coli* observations taken as a snapshot in time. It is likely that the observed data set does not capture the full range of non-continuous variables such as extreme precipitation and flow events, direct deposition from wildlife and/or livestock, and point source discharges.

- Simplifying assumptions regarding manure and bacteria inputs are necessary for SWAT model development. For example, the amount of time that cattle congregate in streams is constant in a given month (per the EPA BIT model). Therefore, in-stream loads from cattle are simulated whether or not the cattle reside in the stream on a particular day. This could inflate simulated loads and concentrations, particularly at lower flows. It also reduces the amount of variability in simulated loads, and causes the 90th percentile and median loads to be closer in magnitude than what is observed in-stream.

- The Duck Creek SWAT model does not account for some potential sources of bacteria, including unreported sanitary sewer overflows (SSOs), potential illicit connections to the storm sewer system, bacteria sources that originate within the storm sewer conveyance system (growth in pipes or deposition in pipes by wildlife), or bacteria resuspension in streams and conveyance systems. If these sources were incorporated into the simulated curves, they may show more close agreement with the observed LDCs.

Despite limitations regarding detailed *E. coli* calibration statistics, the model was determined adequate for source analysis and development of the implementation plan in Section 5. Existing loads and the TMDL targets were developed using observed data, as described in detail in Sections 3 and 4 of this document.

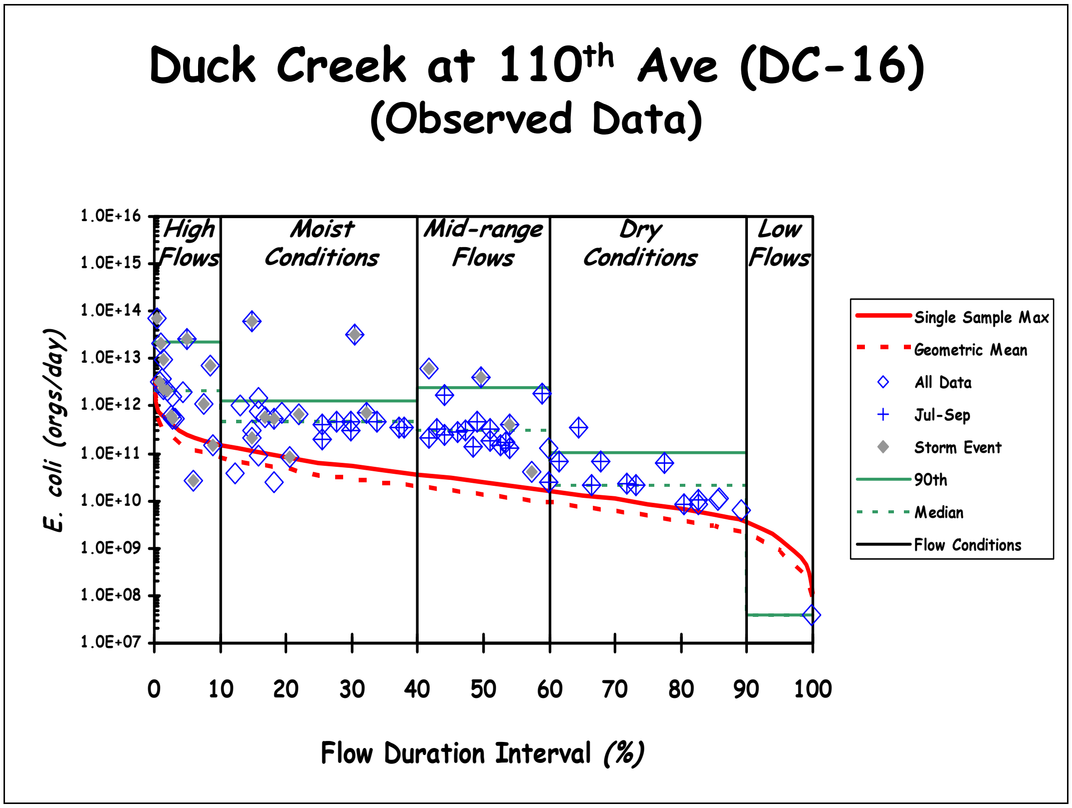

Figure E-12. Observed *E. coli* load duration curve at 110th Avenue.

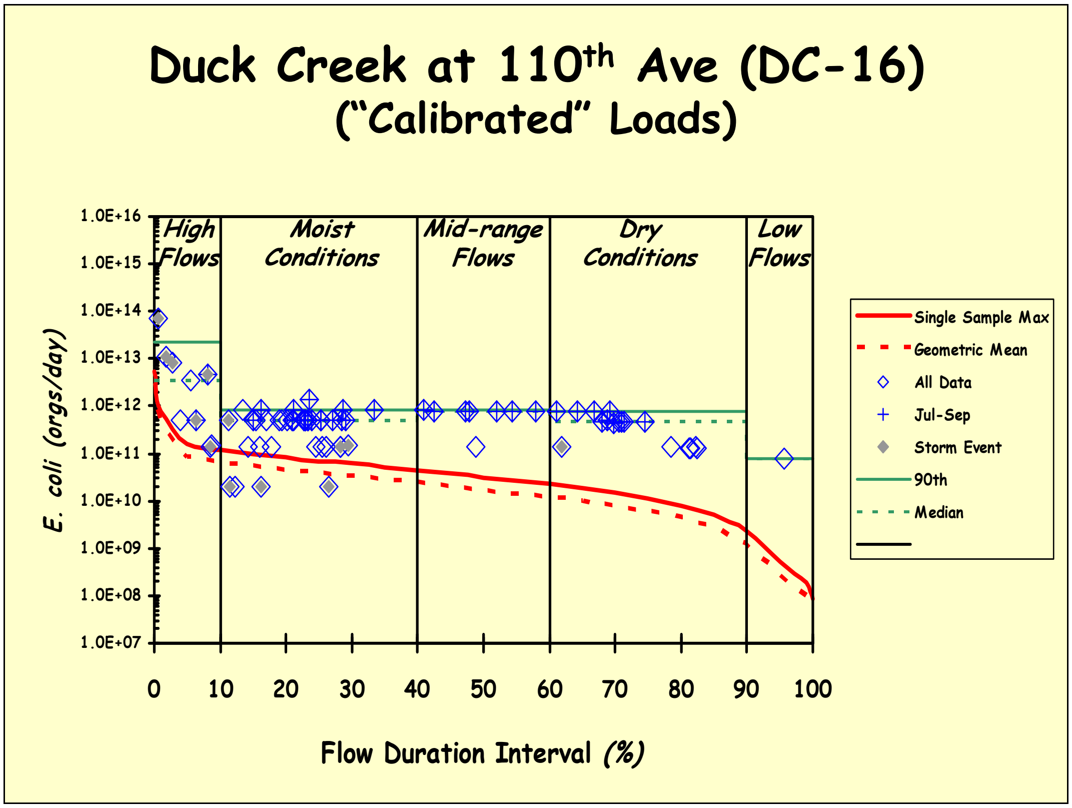

Figure E-13. Simulated *E. coli* load duration curve at 110th Avenue.

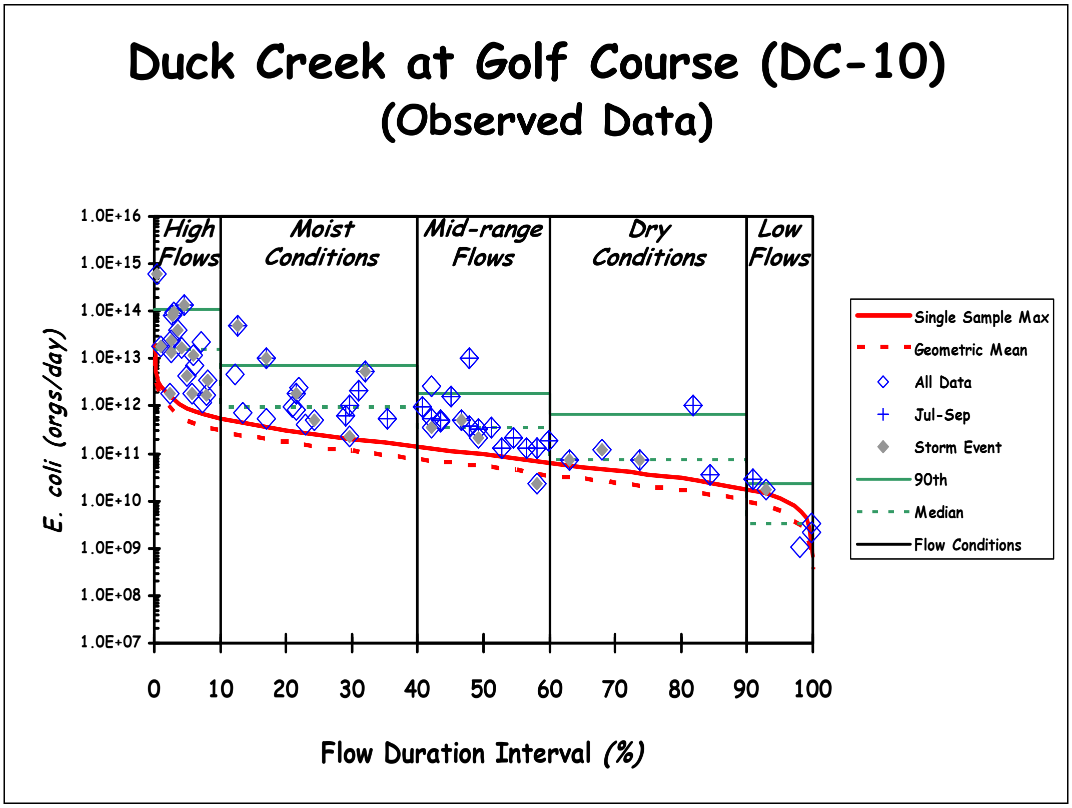

Figure E-14. Observed *E. coli* load duration curve at the golf course.

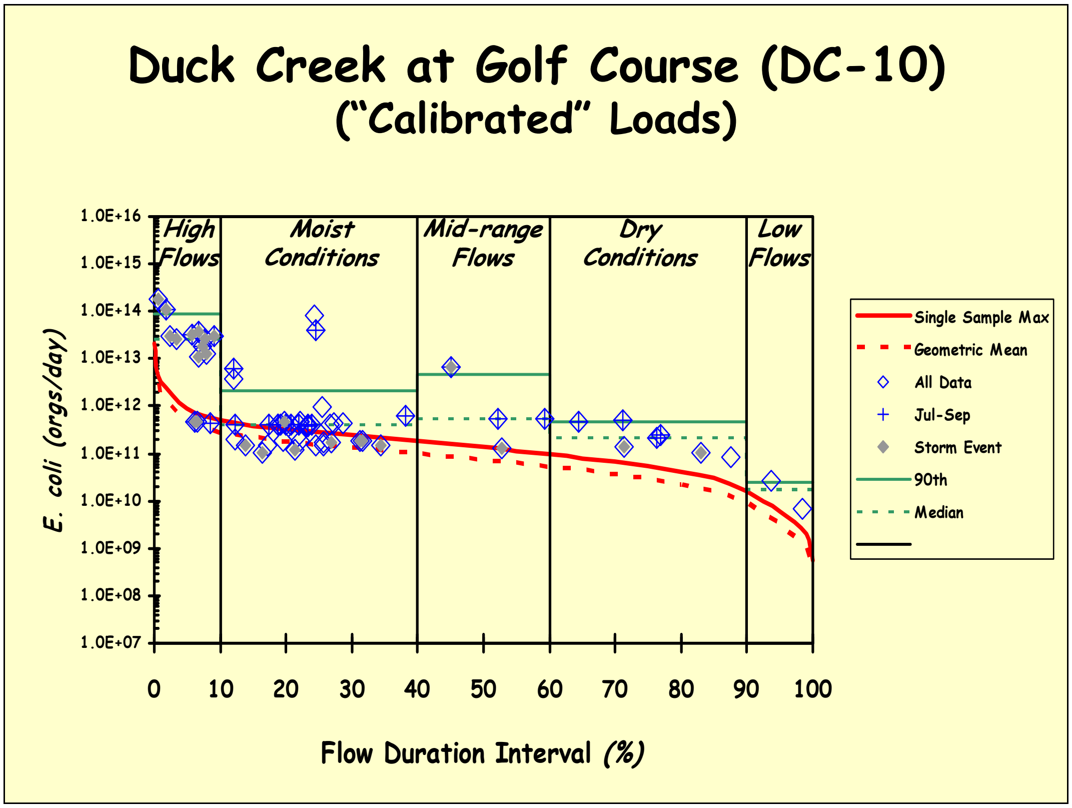

Figure E-15. Simulated *E. coli* load duration curve at the golf course.

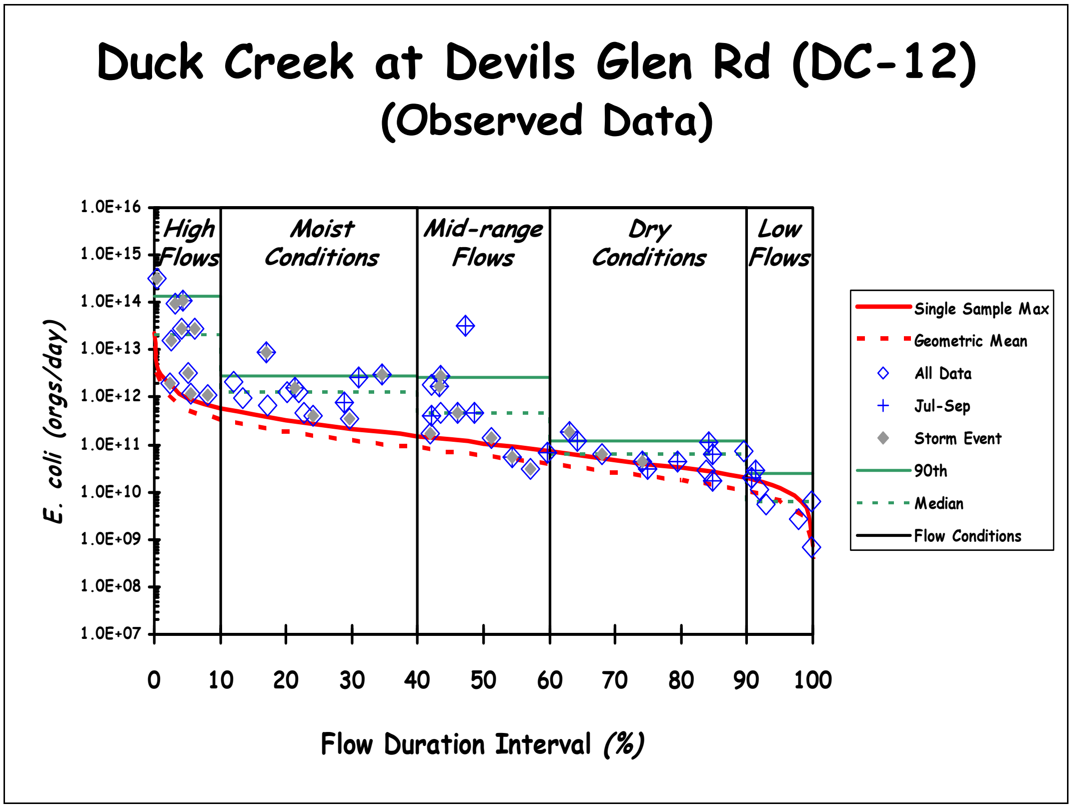

Figure E-16. Observed *E. coli* load duration curve at Devils Glen Road.

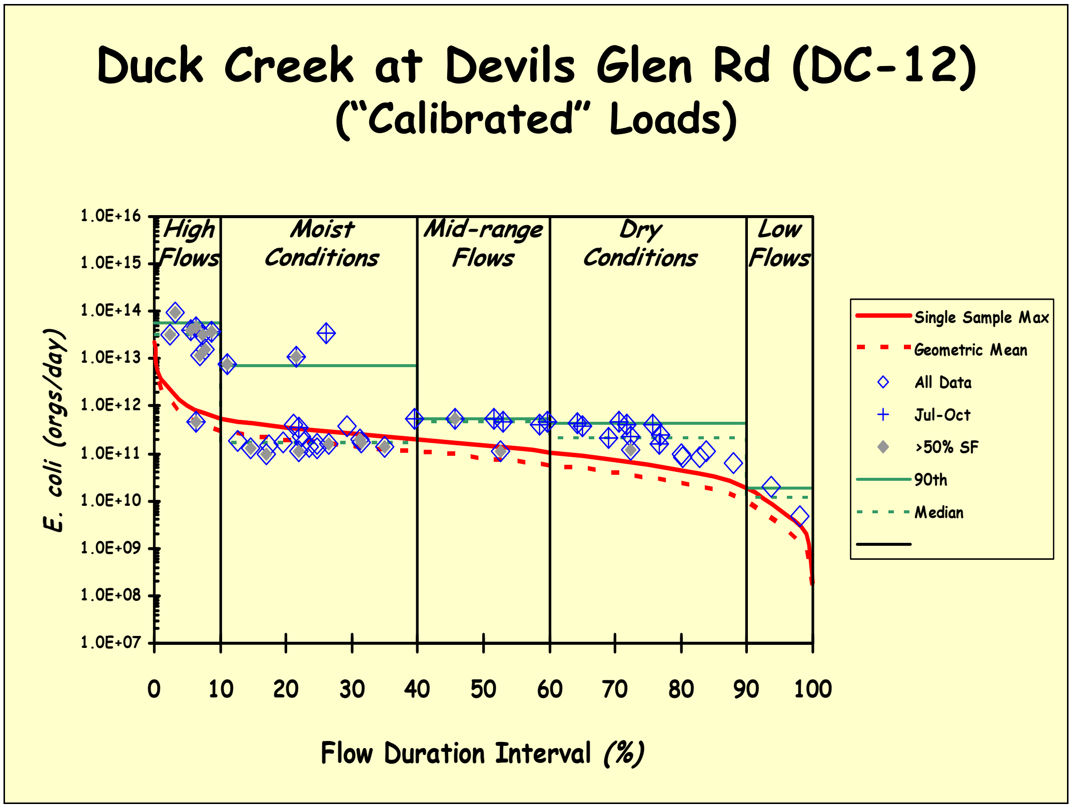

Figure E-17. Simulated *E. coli* load duration curve at Devils Glen Road.

Statistical Analysis

Water quality samples have been collected at several locations in the Duck Creek watershed. Bacteria simulation performance was evaluated statistically at the three locations utilized for graphical analysis. The error between the observed and simulated mean and median concentrations is well with the recommended criteria (±100 percent) for bacteria TMDL development in Virginia (Kim et al., 2007). Guidelines for TMDL development in Virginia also suggest analysis of the instantaneous violation rate (IVR), which is a measure of the percent of samples that exceed the single-sample maximum (SSM) water quality criterion. The IVR of simulated concentrations should be within ±10 percent of the observed IVR (Kim et al., 2007). The difference between observed and simulated IVR is well within the recommended criterion at 110th Avenue, but exceeds the criterion at the golf course and at Devils Glen Road. Calibration statistics are summarized in Tables E-9 through E-11.

Table E-9. Bacteria calibration statistics at 110th Avenue (DC-16).

Statistic	Observed	Simulated	% Difference
Mean (orgs/100 mL)	7,164	3,975	-44.5 %
Median (orgs/100 mL)	1,500	1,736	+15.7 %
IVR	91.8 %	94.3 %	+3.3 %

Table E-10. Bacteria calibration statistics at golf course (DC-10).

Statistic	Observed	Simulated	% Difference
Mean (orgs/100 mL)	3,655	1,587	-4.8 %
Median (orgs/100 mL)	830	420	-57.7 %
IVR	96.9 %	70.1 %	-27.7 %

Table E-11. Bacteria calibration statistics at Devils Glen Road (DC-12).

Statistic	Observed	Simulated	% Difference
Mean (orgs/100 mL)	3,259	2,504	-23.2 %
Median (orgs/100 mL)	565	626	+8.0 %
IVR	83.5 %	68.3 %	-18.2 %

Even though the IVR is underestimated at the two downstream stations, the exceedance plots, load duration curves, and statistical analysis support the use of the SWAT model for source assessment and implementation planning.

E.3. References

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Appendix F --- Public Comments

[Enter text] Include written comments (letters and emails) that were received

Appendix G --- 305(b) Water Quality Assessments (Excerpts)

This appendix includes excerpts from the Section 305(b) water quality assessments relevant to the bacteria impairments on Duck Creek. The assessments can be viewed in their entirety at the following web address:
http://programs.iowadnr.gov/adbnet/index.aspx

The 2008 305(b) assessment described the problem in Segment IA 01-NEM-0060_1 of Duck Creek as follows:

> *"…SUMMARY: The Class A1 (primary contact recreation) uses remain assessed (monitored) as "not supported" due to high levels of indicator bacteria that routinely violated state water quality standards. The Class B(WW2) aquatic life uses and the fish consumption uses remain "not assessed" due to the lack of information upon which to base an assessment. The source of data for this assessment is a joint monitoring project conducted in summer 2004 by University of Iowa Hygienic Laboratory (UHL) and the Davenport Water Pollution Control Plant at the following three sample sites: Site DC-12 (upstream of Highway 67, closest to the mouth of Duck Creek); Site DC-11 (near Middle Road in Bettendorf), and Site DC-8 (near Jersey Ridge Road in Davenport)."*

The assessment continues with the following explanation of the *E. coli* problem:

> *"…Results of monitoring for indicator bacteria conducted in mid to late summer 2004 suggest that the Class A1 uses of Duck Creek are "not supported." Levels of indicator bacteria were monitored once per week at three stations in this assessment segment from mid-July through mid-October, 2004 as part of a joint monitoring project between the University of Iowa Hygienic Laboratory and the Davenport Water Pollution Control Plant. A total of 14 samples per station were collected during this period; this allows calculation of ten, 30-day/five-sample geometric means for each monitoring station..."*
>
> *"…Results of monitoring in this segment of Duck Creek, whether based on data from UHL or from the Davenport Water Pollution Control Plant, suggest impairment of the Class A1 primary contact recreation uses. For both the UHL and DWPC data, all of the 30-day geometric means at all three monitoring stations exceeded Iowa's Class A criterion of 126 organisms / 100 ml. The following summary is based on results of UHL data. At Station 12, the minimum and maximum geometric means were 375 and 661, with 9 of 14 samples exceeding Iowa's single-sample maximum value of 235 orgs/100 ml. At station 11, minimum and maximum geometric means were 589 and 1,351, with all 14 samples exceeding Iowa's single-sample maximum value. And, at Station 8, minimum and maximum geometric means were 479 and 928, with all 14 samples exceeding Iowa's single-sample maximum value. According to U.S. EPA guidelines and IDNR's assessment/listing methodology, these results suggest non-support of the Class A1 (primary contact recreation) uses due to thirty-day*

> *geometric means that exceed Iowa's water quality criterion of 126 E. coli organisms/100…"*

Similarly, the 305(b) assessment described the problem in Segment IA 01-NEM-0060_2 of Duck Creek in the following manner:

> *"…SUMMARY: The presumptive Class A1 (primary contact recreation) uses are assessed (monitored) as "not supported" due to high levels of indicator bacteria that routinely violated state water quality standards. The Class B(WW2) aquatic life uses remain "not assessed" due to the lack of information upon which to base an assessment. The source of data for this assessment is a joint monitoring project conducted in summer 2004 by University of Iowa Hygienic Laboratory (UHL) and the Davenport Water Pollution Control Plant at the following sample sites in this assessment segment: Site DC-3 (near Hickory Grove Road in Davenport) and DC-Site 16 (at the west edge of Davenport; the most upstream sampling station).*

The assessment continues with the following explanation of the *E. coli* problem in the upstream segment:

> *"…Results of monitoring for indicator bacteria conducted in mid to late summer 2004 suggest that the pre[s]umptive Class A1 uses of Duck Creek are "not supported." Levels of indicator bacteria were monitored once per week at three stations in this assessment segment from mid-July through mid-October, 2004 as part of a joint monitoring project between the University of Iowa Hygienic Laboratory and the Davenport Water Pollution Control Plant. A total of 14 samples per station were collected during this period; this allows calculation of ten, 30-day/five-sample geometric means for each monitoring station…"*

"…Results of monitoring in this segment of Duck Creek, whether based on data from UHL or from the Davenport Water Pollution Control Plant, suggest impairment of the Class A1 primary contact recreation uses. For the UHL data, 18 of the 20 geometric means from the two monitoring stations exceeded Iowa's Class A1 criterion of 126 organisms / 100 ml. For the DWPC data, all 20 geometric means exceeded the Class A criterion. The following summary is based on results of UHL data. At Station 3, the minimum and maximum geometric means were 69 and 1,042, with 7 of 14 samples exceeding Iowa's single-sample maximum value of 235 orgs/100 ml. At station 16, minimum and maximum geometric means were 391 and 2,490, with all 14 samples exceeding Iowa's single-sample maximum value. According to U.S. EPA guidelines and IDNR's assessment/listing methodology, these results would suggest non-support of the Class A1 (primary contact recreation) uses due to thirty-day geometric means that exceed Iowa's water quality criterion of 126 E. coli organisms/100..."