Water Quality Improvement Plan
for

Raccoon River, Iowa

Total Maximum Daily Load
for Nitrate and *Escherichia coli*

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EXECUTIVE SUMMARY

The Federal Clean Water Act requires the Iowa Department of Natural Resources (IDNR) to develop a Watershed Improvement Plan, also known as a Total Maximum Daily Load (TMDL), for waters that have been identified on the state's 303(d) list as impaired by a pollutant. Three segments of the Raccoon River have been identified as impaired by nitrate-nitrogen (nitrate) and five segments have been identified as impaired by the pathogen indicator *Escherichia coli* (*E.coli*) bacteria. TMDLs have been determined for the eight segments. The purpose of these TMDLs is to calculate the maximum allowable nitrate and pathogen loads for the impaired segments of the Raccoon River that will allow the river to meet water quality standards. TMDLs for pathogen indicator *E.coli* have also been determined for all other Class A1 streams in the Raccoon River watershed not previously identified as impaired. Although these segments have not been listed on the state's 303(d) list, TMDLs have been determined for these segments in the event that monitoring data is collected in the future that could be used for listing purposes.

Site Description

The Raccoon River watershed in west-central Iowa drains a watershed of 3,625 mi^2 above its confluence with the Des Moines River in the City of Des Moines. The watershed receives water from portions of 17 Iowa counties and flows approximately 186 miles from its origin in Buena Vista County to its mouth. The North, Middle and South Raccoon rivers form major tributary branches to the Raccoon River. Overall land use in the Raccoon River watershed is predominantly agricultural consisting of 73.2 percent row crops of primarily corn and soybeans. Row crop land use comprises 85 percent of the land area in the North Raccoon River watershed above Sac City, and 61 percent of the area in the South Raccoon River watershed above Redfield.

Average annual precipitation for the watershed, from 1980 to 2005 was 33.08 inches. Over the same period, total streamflow and baseflow in the Raccoon River at Van Meter averaged 8.48 and 4.76 inches, respectively. The baseflow fraction of streamflow varied from 42% in 1982 to 87% in 1988 and averaged 60%. Seasonally, the months of March through July accounted for 70.2 percent of total annual flow and 68.1 percent of total annual baseflow.

Nitrate TMDLs

Surface water from the Raccoon River is used by two municipalities (City of Des Moines and the City of Panora) for drinking water. Because of the water use for drinking water supply, the Class C water quality standard applies to the Raccoon River at the two surface water intakes. The applicable water quality standard for nitrate for Class "C" designated use is the United States Environmental Protection Agency (USEPA) maximum contaminant level (MCL) of 10 mg/l. The 2004 305(b) assessment reports that the Class "C" designated use of the Raccoon River at the two drinking water intakes was impaired due to levels of nitrate that exceed the MCL.

A daily record of nitrate concentrations and discharge in the Raccoon River at Des Moines Water Works (DMWW) from the 1996 to 2005 period indicated that nitrate concentrations ranged from 0 to 18.3 mg/l and averaged 6.45 mg/l. Concentrations exceeded 10 mg/l approximately 24.0 % of the time from 1996 to 2005. At the City of Panora, daily nitrate concentrations were found to exceed the MCL 21.5 percent of the time from 2003 to 2005 (235 out of 1095 samples).

Nitrate concentrations exhibit clear seasonality, with higher concentrations occurring during April, May and June as well as November and December. Mean seasonal concentrations ranged from 5.11 mg/l in summer to 9.27 mg/l in spring. Nitrate concentrations also vary with stream discharge, decreasing from 10.0 mg/l when streamflow is in the upper 25 percent of flow to 2.4 mg/l in the lowest 25 percent. Nitrate concentrations and loads in the Raccoon River are better related to baseflow than total streamflow, with baseflow contributing nearly two-thirds of the annual nitrate export from the watershed.

There are major differences in nitrate concentration and loading patterns within large subbasins of the Raccoon River. In the North Raccoon River above Sac City, nitrate concentrations averaged 13.1 mg/l and exceeded the MCL in over 76 percent of the samples collected. In contrast, nitrate concentrations in the South Raccoon at Redfield rarely exceeded the MCL (0.1 percent) and averaged 5 mg/l. Similarly, annual nitrate loads averaged 22.5 to 25.7 kg/ha (20.1 to 23.0 lbs/ac) from the North Raccoon and 9.8 kg/ha (8.8 lbs/ac) from the South Raccoon.

The sources of nitrate can be divided into two major categories, point sources and nonpoint sources. The point sources include municipal, industrial, semi-public, sanitary district stormwater (MS4 permits), and permitted animal feeding operations. There are a total of seventy-seven (77) entities in the Raccoon River watershed with National Pollution Discharge Elimination System (NPDES) permits. The estimated total daily nitrogen point source load in the Raccoon River at Des Moines was 4.97 metric tons (Mg) per day. Nonpoint sources of nitrate to the Raccoon River include contributions from agricultural, developed land (urban and residential areas), and natural sources. Potential nonpoint sources from agricultural sources include fertilizer, soil mineralization, legume fixation, and manure. Potential nonpoint sources from developed land sources include septic systems and turf grass fertilizer, whereas potential naturally occurring nonpoint sources include atmospheric deposition and wildlife. Soil mineralization and nitrogen fertilizer are the largest nonpoint sources of nitrogen in the Raccoon River watershed, contributing approximately 48 to 60% of the total nitrogen input. Legume fixation accounted for 15.5 percent of the total nitrogen in the Raccoon River watershed above Van Meter, and nitrogen from animal manure accounted for 12.6 to 16.9 percent of the total nitrogen inputs in the watershed.

The load duration curve (LDC) modeling approach was used in this TMDL to compare measured pollutant concentrations and daily flow data to the water quality standard at a range of flow conditions. A nitrate TMDL target of 9.5 mg/l was adopted that allows for a margin of safety (MOS) of 0.5 mg/l. Daily nitrate loads exceed the TMDL target across much of the range of flow conditions, but greater exceedances typically occurred during higher flows. Greatest reduction of daily nitrate loads is needed when flow is in the highest 10 percent of flows (100-90 percentile), when a maximum reduction of 48.1 percent is needed. Over the 10-year monitoring period, 27 percent of the days exceeded the 9.5 mg/l TMDL target. When exceedances occurred, nonpoint sources contributed to 88.9 percent of the nitrate loads whereas point source contributions were 11.1 percent. Seasonally, the greatest maximum reduction of nitrate is needed in the months of May and June when reductions greater than 67 percent are needed. During these two months, more than 68 percent of the days exceeded the TMDL and nonpoint sources contributed more than 99 percent of the nitrate load.

Point sources do not contribute substantially to the nitrate impairment at the DMWW in the City of Des Moines, so the total wasteload allocated to point sources in the Raccoon River above the City of Des Moines was set to the existing point source load (4.97 Mg/day). The load allocation (LA) for nonpoint sources varies by flow and was set to be the difference between the TMDL target of 9.5 mg/l and the sum of the wasteload allocation (WLA) and the MOS.

At Panora, nitrate loads exceeded the TMDL target of 9.5 mg/l in the upper 60 percent of flows. Greatest reduction of daily nitrate loads was associated with the two highest flow percentiles when a maximum reduction of 37.9 percent was needed. When nitrate loads exceeded the TMDL in the upper 40 percent of flows, nonpoint sources comprised greater than 91 percent of the load. The total wasteload allocation for point sources in the Raccoon River above Panora was set to the existing point source load (0.506 Mg/day). The LA was set to be the difference between the TMDL with a MOS and the existing WLA.

E.coli TMDLs

In 2003, Iowa's water quality standards and methodology for assessing indicator bacteria were changed so that *E.coli* is now the indicator bacterium (not fecal coliform), and the high flow exemption was eliminated and replaced with language stating that the Class A criteria for *E.coli* apply when Class A1, A2, or A3 uses "can reasonably be expected to occur." The applicable *E Coli* water quality standards for Class A1 waters are listed below:

Water Quality Standards for *E.coli* for Class A1 Waters.

Date Range	Geometric Mean (CFU/100 ml)	Sample Maximum (CFU/100 ml)
3/15 to 11/15	126	235
11/16 to 3/14	Does not apply	Does not apply

*All indicator bacteria values reported in this TMDL are for *E Coli* only.

The 2004 305(b) report reported that two segments (IA 04-RAC-0010-1&2 from the mouth to the confluence with the North and South Raccoon rivers) are "partially supporting" their Class A uses. From 1997 to 2005, 2,155 samples were collected from the Raccoon River at DMWW, of which 1,522 samples were collected during the March 15 to November 15 recreation season. Approximately 39 percent of the recreation season samples exceeded the single sample maximum value for *E Coli*. The mean concentration of all samples collected by the DMWW was 1,156 colony forming units (CFU)/100 ml whereas the median value was substantially lower at 68 CFU/100 ml.

The 2004 305(b) assessment report identified two adjoining segments of the North Raccoon River as "partially supporting" their Class A designated use (North Raccoon River Near Sac City, IA 04-RAC-0040-5 & 6). The annual geometric mean averaged 340 CFU/100 ml and 75 of 160 samples (47%) collected from 1986 to 2005 exceeded Iowa's single sample maximum value of 235 CFU /100 ml. The 2004 305(b) assessment report also identified a segment of the North Raccoon River near Jefferson as "partially supporting" its Class A designated use (IA 04-RAC-0040-1). Overall, 18 of 52 samples (32%) collected from 2000 to 2005 exceeded Iowa's single sample maximum value of 235 CFU /100 ml.

New water quality standards designating all perennial streams as Class A1 waters will make other stream segments in the Raccoon River watershed eligible for assessment and potentially added to the state impaired waters list provided credible water monitoring data is available which demonstrate the segments do not support their intended uses. Currently, available sampling data suggests that all Class A1 waters in the Raccoon River watershed could be considered as "not supporting" their designated uses. It is the conclusion of this TMDL that all Class A1 streams in the Raccoon River watershed would benefit from a TMDL determination. Thus, a TMDL will be assigned to not only the five stream segments identified in the 2004 305(b) report, but also to other Class A1 stream segments in the Raccoon River watershed not previously classified. In this manner, a TMDL for indicator bacteria will be established for each of these Class A1 water segments in the likely event some segments are added to the state's impaired waters list in the near future.

Temporal patterns of *E Coli* concentrations in the Raccoon River are based on water quality data collected by the DMWW at the watershed outlet. Monthly E Coli concentrations exhibited clear seasonality with higher concentrations occurring in May, June and July although maximum *E Coli* concentrations in excess of 10,000 CFU/100 ml were observed in all months except February and December. *E Coli* concentrations are higher during periods of greater discharge in the Raccoon River and decreased sharply from a median concentration of 665 CFU/100 ml when flow is in the upper 25 percent range, to median concentrations of 84, 36 and 24 when flow is in the lower three quartiles, respectively.

As was noted for nitrate, there are a total of seventy-seven (77) entities in the Raccoon River watershed with NPDES permits. For *E coli* bacteria, very few wastewater treatment facilities monitor for bacteria in their effluent. Therefore, estimates of the quantities of bacteria are derived from generic conservative assumptions based on type of treatment, quantity and quality of influent wastewater, and per capita pollutant generation. The daily bacteria load exported from the Raccoon River watershed from point sources was estimated to be approximately 1.57 x 10^{12} colony forming units (CFUs). Potential nonpoint sources of E coli bacteria include contributions from animal manure, septic systems and wildlife. Manure from hogs and cattle comprise a significant portion of the total bacteria population in the Raccoon River watershed (98 percent), poultry manure provides an estimated 1.5 to 2 percent of the total bacteria input, whereas bacteria counts from septic systems and wildlife provide less than 0.1 percent of the total.

An *E.coli* TMDL target of 200 CFU/100 ml was adopted that allows for a margin of safety (MOS) of 35 CFU/100 ml. The existing load for E Coli measured in the Raccoon River at the City of Des Moines indicated that daily E Coli loads exceeded the TMDL target at all flow ranges evaluated, with a maximum reduction of 99.7 percent needed in the 90-80 percent flow range. Approximately 44.5 percent of days exceeded the TMDL target, and when exceedances occurred, nonpoint point sources contributed up to 99 percent of the E Coli loads. E Coli loads exceeded the TMDL target to a greater degree in the spring and early summer compared to the late summer and fall.

Because all permitted WWTPs and other point sources discharge to a perennial stream in the Raccoon River watershed, the daily wasteload allocation for all point sources in the watershed is established, by rule, to be based on a concentration standard of 235 CFU/100 ml. The total daily wasteload allocation for point sources in the Raccoon River watershed was set to be 9.33E+11CFUs. To achieve the new water quality standard for Class A1 waters, collectively, point sources will require a reduction of daily CFUs from 1.57E+12 to 9.33E+11, or a reduction of 59.4 percent. The load allocation for nonpoint sources for E Coli bacteria will be flow dependent since daily bacteria loads in the river vary greatly by flow. The LA is set to be the difference between the TMDL of 235 CFU/100 ml and the sum of the WLA and the MOS (35 CFU/100 ml).

For *E Coli* loads in two segments of the North Raccoon River near Sac City a maximum *E Coli* reduction of 99.8 percent is required for all measured samples to be less than the TMDL. The total daily wasteload allocation for point sources in the North Raccoon River watershed above Sac City was set to be 1.63E+11 CFUs. For the *E.coli* impairment in the North Raccoon at Jefferson, a maximum E Coli reduction of 99.7 percent is required for all measured samples to be less than the TMDL. The total daily wasteload allocation for point sources in the North Raccoon River watershed above Jefferson was set to be 3.93E+11 CFUs. For the three segments, the LA for nonpoint sources was set using the following equation: LA = TMDL (235 CFUs/100 ml x Flow) – WLA (1.299E +10 CFUs) – MOS (35 CFUs x Flow).

A TMDL determination was made for Class A1 waters in 112 subbasins in the Raccoon River basin. Because no monitoring data has been collected from most of the Class A1 stream segments, no analysis of existing load or departure from load capacity assessment was conducted for these sites. The acceptable load for an unmeasured subbasin was determined by applying the following TMDL equation based on the LDC: TMDL (235 CFUs/100 ml x Flow) = WLA + LA + MOS (35 CFUs x Flow). Point sources may contribute to future bacteria indicator impairments in 44 of the 112 subbasins that contain WWTPs. In these subbasins, the total number of allowable CFUs per day was determined as the product of the WWTP daily discharge multiplied by the TMDL target of 235 CFUs/100 ml. The load allocations for nonpoint sources for indicator bacteria in all 112 subbasins will be flow dependent since daily bacteria loads in the river vary greatly by flow. The load allocation for *E Coli* bacteria for the subbasins was set using the following equation: LA = TMDL (235 CFUs/100 ml x Flow) – WLA (daily CFUs from point sources) – MOS (35 CFUs x Flow). If no point sources (WWTPs) are present in a subbasin, the daily LA was equal to the TMDL minus the MOS.

Raccoon River Watershed Model

The Soil and Water Assessment Tool (SWAT) model was used evaluate streamflow and pollutant loading patterns in the Raccoon River watershed. The SWAT model was run on a daily time step for the 1986 to 2004 period. The model inputs included climate, topography, land use, soils, feedlots and confinements, manure application areas, WWTPs and census data. Tile drainage was incorporated into the model with estimates suggesting that 77.5 percent of the row crop ground in the North Raccoon watershed may be tile drained compared to 42.1 percent in the South Raccoon watershed. Fertilizer information provided by the Agriculture's Clean Water Alliance (ACWA) indicated that on average 142 lbs/ac of N was (NH_3, urea, UAN)applied to the corn ground and an average of 76 lbs/ac of P (DAC) was applied to 60 percent of the crop ground in the watershed.

The streamflow calibration process was completed by varying several SWAT hydrologic calibration parameters within their acceptable ranges. Results indicate that large portions of the watershed yield between seven to nine inches of water per year, with greater water yield associated with the northern portions of the North Raccoon and Middle Raccoon rivers and the suburban watersheds near the City of Des Moines. Tile flow was estimated to contribute an average annual flow of 2.1 in, which was 25.6 percent of the total streamflow and 44.1 percent of the overall baseflow.

Nitrate calibration was achieved by adjusting only a few factors. The modeled average annual average nitrate load at Van Meter (24.5 kg/ha or 21.9 lbs/ac) was close to the estimated value (27.8 kg/ha or 24.8 lbs/ac) for the 20-year period, but extremely close during the last seven years of the simulation (26.3 versus 25.9 kg/ha, respectively). Model results indicated nitrate loading rates were highest in the headwater region of the North Raccoon River watershed above Sac City. The subbasin with the highest annual nitrate loading rate was Outlet Creek with an estimated average annual nitrate load of 84.9 kg/ha (75.8 lbs/ac). On a normalized basis, annual nitrate losses from several subbasins exceeded 30 kg/ha (26.8 lbs/ac), and a large region shows nitrate losses in excess of 20 kg/ha (17.9 lbs/ac). Most of the subbasins with higher nitrate loading rates were located in the western half of the Raccoon River watershed in the headwater regions of the North and Middle Raccoon rivers. Model results suggest that nitrate loading rates in the South Raccoon are substantially lower than the North Raccoon, which is consistent with water quality monitoring data.

The SWAT model for *E Coli* was successfully calibrated for average annual and monthly bacteria loads. For the 1997 to 2004 period, the modeled average annual E Coli load at the DMWW was 1.79E+16 CFUs, slightly lower than the average measured load of 5.84E+16 CFUs. Model results suggest that *E Coli* loads originate in headwater regions or tributary subbasins and accumulate as the river flows downstream. Maintenance of high stream bacteria loads in the main channels indicates that the in-stream loads are being continually replenished with bacteria as water is flowing downstream. Annual *E Coli* loads in excess of 1E+11 CFUs/ha were evident in subbasins in the South Raccoon, and headwater subbasins in the North and Middle Raccoon rivers.

Implementation Plan

Best management practices (BMPs) implemented in the Raccoon River watershed can be used to reduce nitrate and *E.coli* bacteria loads. Watershed scale nitrate and bacteria load reductions were evaluated using the calibrated SWAT model. Five load reduction strategies were retained for analysis with the model and included the following scenarios: 1) Reduce the rate of ammonia fertilizer application in the watershed to 150 kg/ha, 100 kg/ha and 50 kg/ha (134, 89 and 45 lbs/ac); 2) Remove all cattle from the streams; 3)Remove all human waste from the watershed; 4) Convert all row crop lands located on slopes greater than C slopes to CRP grassland and 5) Convert all row crop lands located on floodplain alluvial soils to CRP. Nitrate load reductions ranged from 29.9 to 0.6 percent, with the greatest potential load reduction associated with reducing fertilizer inputs from 170 to 50 kg/ha (152 to 45 lbs/ac). For every 10 kg/ha (8.9 lbs/ac) of reduced fertilizer input, model results suggest annual nitrate loads could be reduced about 2.4 percent.

Eliminating all human waste in the watershed achieved a nitrate reduction of 9.8 percent, which suggests that human waste sources contribute about 10 percent of the nitrate export. Changing land cover from row crop to CRP reduced nitrate loads at about a 1:1 ratio for CRP conversion of sloping ground and alluvial soils. Converting floodplain soils from row crop to CRP may hold promise for gaining more water quality impact for the same amount of land converted compared to upland slopes, although more work is needed to confirm this effect.

Results from the load reduction scenarios for *E.coli* suggest that converting row crop land on slopes to CRP would reduce stream bacteria loads more than the other scenarios. Similarly, the conversion of row crop on alluvial soils to CRP was effective for reducing bacteria loads in some subbasins. Point source reductions did not appear to result in significant bacteria load reductions. Removing cattle from the stream and removing all human waste from the watershed resulted in an average reduction of less than one percent.

Local scale efforts to reduce loads from nitrate and *E.coli* bacteria involve improved nutrient use, better in-field management and off-site management techniques. In particular, strategically sited wetlands offer promise for reducing nitrate losses from tile drainage systems. A variety of actions to control nonpoint urban sources include both structural and non-structural practices.

Monitoring Plan

Existing monitoring programs provide large-scale estimates of water loss and pollutant export from various major subbasins. Combined with stream gaging, water quality monitoring conducted by the DMWW at Fleur accurately captures the total nitrate and bacteria export from the basin. At monitoring sites other than the DMWW, the frequency of *E Coli* monitoring is inadequate to characterize daily, seasonal and annual variations. Although the large-scale monitoring enables export loads from major subbasins to be estimated in a cost-effective manner, the size of the monitored basins will limit the detectability of improvements from TMDL implementation.

A new three step monitoring paradigm is suggested that would shift the focus of monitoring to smaller basins with the objective of detecting water quality changes. The first step would be to identify basins contributing the highest concentrations and loads. Several subbasins in the North and South Raccoon river watersheds showed consistently elevated concentrations of nitrate and bacteria in surface water. These subbasins could be appropriate targets for BMP implementation. The size of the targeted watershed will affect the ability of monitoring to detect whether water quality improvements occur since it is easier to detect changes in smaller watersheds than larger watersheds. Subbasins that range less than 10,000 ha may be appropriate for targeting BMP implementation and detecting water quality improvements in a reasonable timeframe.

Once a basin has been selected for monitoring, the second step is developing a monitoring program that includes the following elements: 1) monitoring objectives; 2) monitoring design; 3) sampling locations; 4) sample parameters; and 5) sample frequency and duration. Attention should be given to designing a monitoring program suitable for pollutant of interest. Sampling for nitrate may be on a fixed interval basis whereas *E.Coli* should be sampled with an event-based and fixed interval approach. Because nitrate is delivered primarily to streams with subsurface flow it may take many years for practices that reduce nitrate leaching to have an impact on stream water quality. In contrast, a shorter time lag may be expected with observing changes in E.Coli concentrations in streams from BMP implementation. Overall, it is important for the public to realize that it will take time to accomplish water quality improvements. Step three of the monitoring program would include a reevaluation to assess whether or not the program is meeting the monitoring objectives. Sampling parameters and frequency can be adjusted to better reflect monitoring objectives or any changes in the program focus.

1.0 INTRODUCTION

The Federal Clean Water Act requires the Iowa Department of Natural Resources (IDNR) to develop a Total Maximum Daily Load (TMDL) for waters that have been identified on the state's 303(d) list as impaired by a pollutant. Three segments of the Raccoon River have been identified as impaired by nitrate-nitrogen (nitrate) and five segments have been identified as impaired by the pathogen indicator *Escherichia coli* (*E.coli*) (Figure 1-1). TMDLs have been determined for the eight segments. The purpose of these TMDLs is to calculate the maximum allowable nitrate and pathogen loads for the impaired segments of the Raccoon River that will meet water quality standards.

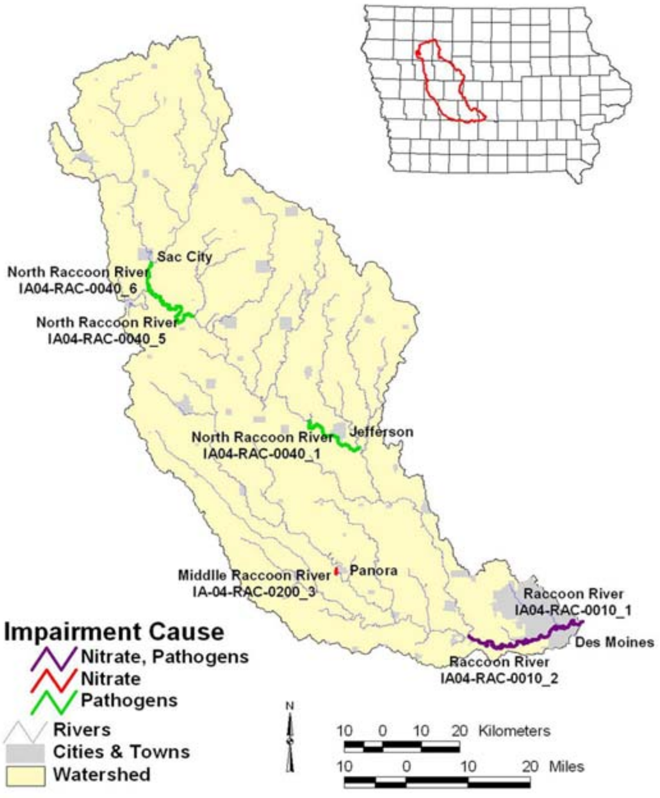


Figure 1-1. Location map of Raccoon River watershed including impaired segments.

In addition, TMDLs for pathogen indicator *E.coli* have been determined for all other Class A1 streams in the Raccoon River watershed not previously identified as impaired. Although these segments have not been listed on the state's 303(d) list, TMDLs have been determined for these segments prior to collection of monitoring data that could be used for listing purposes in the future. The purpose of these TMDLs is to calculate the maximum allowable pathogen loads for all Class A1 segments of the Raccoon River that will meet water quality standards.

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

Section 7.0 of this TMDL includes a description of planned monitoring. The TMDL will have two phases. Phase 1 will consist of setting specific and quantifiable targets for nitrate and *E.coli*, including waste load allocations for all permitted facilities. Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.

Monitoring is essential to all TMDLs in order to:

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

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

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

1. Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:

Eight segments of the Raccoon River are impaired, three segments for nitrate and five stream segments for pathogen indicator *E.coli*. The impaired segments for nitrate include 1) the Raccoon River from mouth to confluence with the North Raccoon and South Raccoon river (segments IA 04-RAC-0010-1&2 combined) and 2) the Middle Raccoon River from City of Panora drinking water intake to Lake Panorama (IA-04-RAC-0200_3). The impaired segments of pathogen indicator *E.coli* include: 3) the Raccoon River from mouth to confluence with the North Raccoon and South Raccoon river (segments IA 04-RAC-0010-1&2 combined); 4) two adjoining segments of the North Raccoon River near Sac City (IA 04-RAC-0040-5&6) and 5) North Raccoon River near Jefferson from Buttrick Creek to Short Creek (IA 04-RAC-0040-1).

2. Identification of the pollutant and applicable water quality standards:

The pollutants causing the water quality impairments are nitrate and pathogen indicators (*E.coli*). For impaired segments 1 and 2 (listed above), the Class C (drinking water) uses were assessed as “not supporting” due to level of nitrate that exceeds state water quality standards and USEPA maximum contaminant level (MCL). The applicable water quality standard for nitrate is 10 mg/l.

For impaired segments 3, 4 and 5 (listed above) the Class A1 designated uses for primary contact recreation are "partially supporting" due to high levels of indicator bacteria *E.coli*. The applicable water quality standards for bacteria (*E.coli*) are a seasonal geometric mean of 126 CFU/100 ml of water, and a single maximum value of 235 CFU/100 ml. These limits for *E.coli* are applied to surface water during a March 15 to November 15 recreation season.

3. Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:

For nitrate, the acceptable load that may be present in the river is the product of the allowable nitrate concentration (10 mg/l) multiplied by the flow rate. Maintaining this level as the maximum allowable nitrate load would ensure that designated uses of the Raccoon River for drinking water supply are maintained at all times.

For *E.coli*, the target of the TMDL is a reduction of *E.coli* loading to the Iowa water quality standard numeric limits for Class A1 waterbodies. The acceptable load of *E.coli* that may be present in the river is the product of the single sample maximum concentration (235 CFU/100 ml) multiplied by the flow rate.

4. Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:

A load duration curve approach was used in this TMDL to compare measured pollutant concentrations and daily flow data to the water quality standard at a range of flow conditions. Based on this method, the maximum reduction of daily nitrate loads was 93 percent and 61 percent for the Raccoon River and Middle Raccoon River, respectively (impaired segments 1 and 2 identified above). For *E.coli*, the maximum reduction of daily *E.coli* loads needed was 99.7 percent, 99.8 percent, and 99.7 percent for impaired segments 3, 4 and 5.

5. Identification of pollution source categories:

Nonpoint sources of nitrate have been identified as the main cause of the drinking water impairment at the cities of Des Moines and Panora. Nonpoint sources of pathogen indicators also have been identified as the main cause of the primary contact recreation use impairment for the Raccoon River. Point sources, such as wastewater treatment plants and septic systems, are also likely contributors to the nitrate and total pathogen loads, but these sources play a less significant role.

6. Wasteload allocations for pollutants from point sources:

The wasteload allocations (WLA) for nitrate from point source dischargers to the Raccoon River is set to the existing nitrate load of 4.97 Mg/day at the City of Des Moines and 0.051 Mg/day for the Middle Raccoon River at Panora. Point sources do not appear to be contributing significantly to the nitrate impairments at the two stream segments. The WLA for *E.coli* at all Class A1 streams is set based on a concentration standard of 235 CFU/100 ml.

7. Load allocations for pollutants from nonpoint sources:

The load allocations (LA) assigned to nonpoint sources of pollution for this TMDL is based upon the applicable water quality standards for the stream's designated use. For nitrate and *E.coli*, the LA is set to be the difference between the maximum allowable pollutant load and the WLA plus the margin of safety (see below).

8. A margin of safety:

This TMDL contains both an explicit and implicit margin of safety. The MOS for nitrate was explicitly set to be 0.5 mg/l. and for *E.coli* was set to be 35 CFU/100 ml. An implicit margin of safety was set by using very conservative assumptions in the derivation of numeric targets for the WLA and LA.

9. Consideration of seasonal variation:

Seasonal variation in nitrate and *E.coli* loads was evaluated using the load duration curve that accounted for seasonal and annual variations in streamflow. When data availability allowed, nitrate and *E.coli* loads were evaluated by month.

10. Allowance for reasonably foreseeable increases in pollutant loads:

There was no allowance for future growth included in this TMDL because current watershed land uses are predominantly agricultural and the addition/deletion of animal feeding operations (which could increase or decrease nitrate and pathogen indicator loading) cannot be predicted or quantified at this time.

11. Implementation plan:

An implementation plan is outlined in section 6 of this TMDL. The reduction of nitrate and bacterial pathogen loads will be carried out through a combination of non-regulatory activities and monitoring for results. Nonpoint source pollution will be addressed using available programs, technical advice, information and education, and financial incentives.

2.0 DESCRIPTION AND HISTORY OF THE RACCOON RIVER

The Raccoon River watershed in west-central Iowa drains a watershed of 3,625 mi^2 above its confluence with the Des Moines River in the City of Des Moines (Figure 2-1). The watershed receives water from portions of 17 Iowa counties and flows approximately 186 miles from its origin in Buena Vista County to its mouth. The North, Middle and South Raccoon rivers form major tributary branches to the Raccoon River (Figure 2-1). The major tributaries converge to a single river a few miles downstream of the City of Van Meter and the Raccoon River flows uninterrupted to its mouth approximately 29 miles downstream from this point. Flow from the 78.4 mi^2 Walnut Creek watershed provides the only substantial surface water input to the Raccoon River from Van Meter to Des Moines.

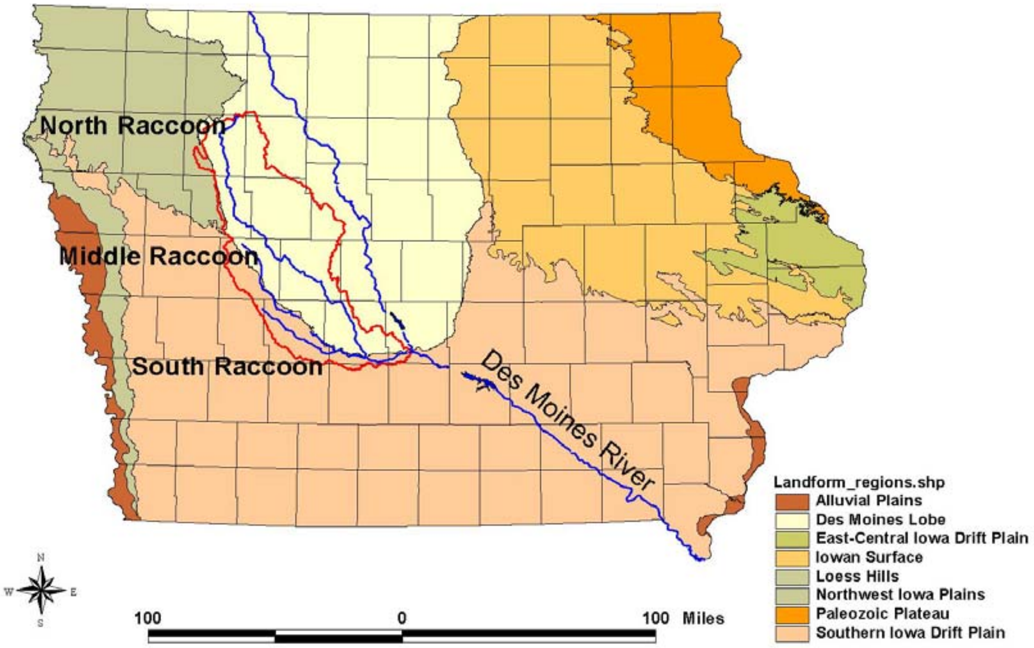


Figure 2-1. Location of Raccoon River watershed in Iowa landform regions.

2.1 Raccoon River Watershed

The watershed of the Raccoon River includes drainage from two Iowa landform regions (Figure 2-1). The North and Middle Raccoon Rivers flow through the recently glaciated (<12,000 years old) Des Moines Lobe landform region, a region dominated by low relief and poor surface drainage (Prior, 1991). The geology of the Des Moines Lobe region consists largely of pebbly glacial drift (unsorted mixture of sand, silt and clay) in flat till plains, clay and peat in depressions or prairie pothole areas, and sand and gravel deposits in floodplains of larger streams and rivers. In contrast, The South Raccoon River drains an older (>500,000 years old) Southern Iowa Drift Plain landscape region characterized by higher relief, steeply rolling hills and well-developed drainage. The geology of this region consists of 5 to 30 feet of loess (silt) mantling a clay-rich ancient soil (paleosol or “gumbotil”) developed in a dense, fine-grained glacial till.

Because of the geologic history of the two landform regions, differences in basin characteristics are evident in watersheds found each region. For example, a comparison of basin properties of a watershed in the Des Moines Lobe landform region (North Raccoon River at Sac City) with a watershed primarily in the Southern Iowa Drift Plain region (South Raccoon River at Redfield) reveals important differences (Table 2-1). Watersheds draining the older, well-dissected southern Iowa landscape have greater basin relief and slope compared to the more-recently glaciated Des Moines Lobe region. Average basin slope in the South Raccoon was nearly five times greater than the slope in the North Raccoon River at Sac City. Moreover, because the older glacial landscape had more time for stream networks to develop, the stream density in a typical southern Iowa watershed is considerably greater than a typical Des Moines Lobe watershed. In this example, the number of first-order streams (FOS) per square mile of watershed was three times greater in the South Raccoon basin. Similarly, stream sinuosity was higher in the older landscape than the younger landscape.

Table 2-1. Comparison of various watershed properties in North Raccoon and South Raccoon basins.

Watershed	Area (sq mi)	Basin Relief (ft)	Average Basin Slope (%)	Stream Density (mi/sq mi)	Drainage Frequency (#FOS/sq mi)	Main Channel Sinuosity Ratio
North Raccoon at Sac City	700	362.4	1.34	0.72	0.21	1.54
South Raccoon at Redfield	994	588.4	5.35	1.38	0.64	1.77

#FOS = number of first order streams

2.2 Stream Network and Watershed Delineations

Although the North, Middle and South Raccoon rivers form the major tributary rivers in the watershed, other major tributary streams can be delineated (Figure 2-2). In the North Raccoon River basin, seven major 3rd order tributaries streams (or larger) flow into North Raccoon River above its confluence with the Middle and South Raccoon rivers. The major tributary streams include (from north to south): Cedar Creek, Camp Creek, Lake Creek, Purgatory Creek, Cedar Creek, Hardin Creek and Buttrick Creek. Mosquito Creek and Willow Creek form major tributaries to the Middle Raccoon River. In the South Raccoon basin, Brushy Creek is a 4th order stream that discharges into the South Raccoon River near Monteith in Guthrie County. South of the confluence of the North and South Raccoon rivers, Walnut Creek is the only major tributary stream discharging into the Raccoon River.

Subwatersheds within the Raccoon River bain are delineated based on their size or Hydrologic Unit Code (HUC). The North and South Raccoon rivers are HUC8 (390-1953 mi^2) basins (HUC numbers 07100006 and 07100007, respectively). Within this size designations there are 26 HUC10 basins (62.5 to 390 mi^2) and 108 HUC12 basins (15.6 to 62.5 mi^2). For much of this TMDL, primary consideration will be given to assessing loads from HUC12 size watersheds wherever practicable.

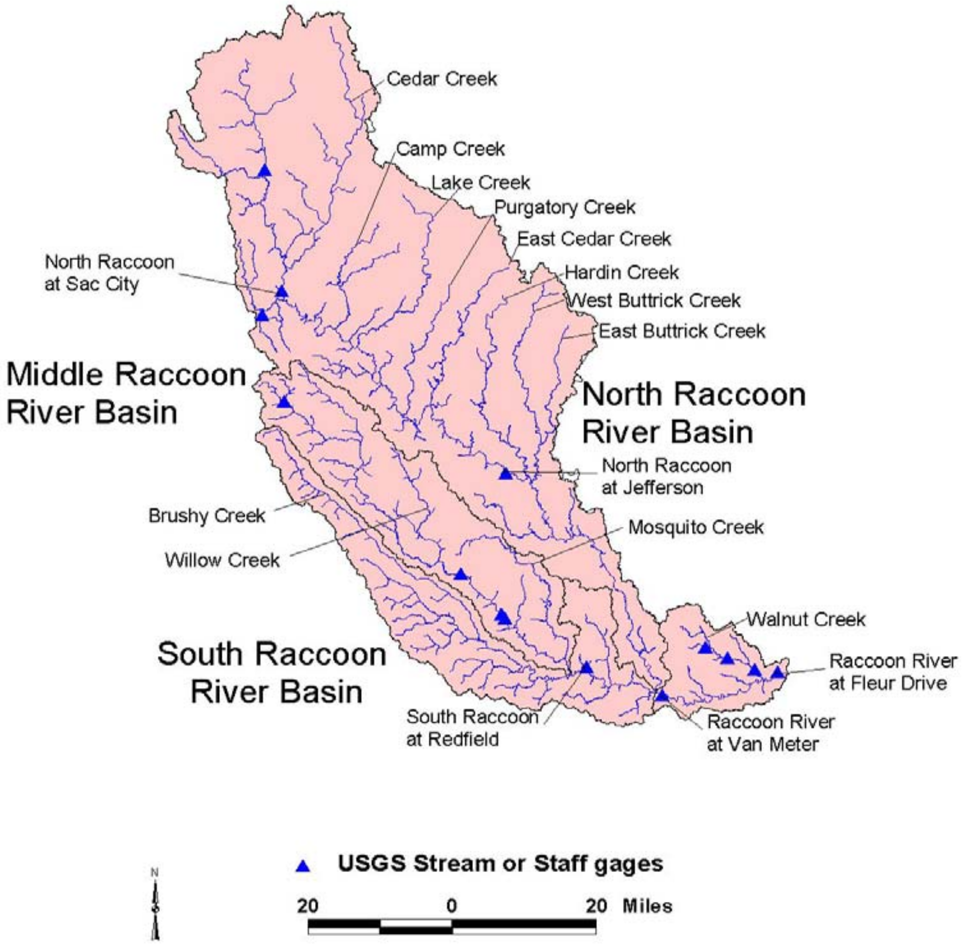


Figure 2-2. Location of major tributaries, basins and stream gages in Raccoon River watershed.

2.3 Soils

The major soil associations found in the Raccoon River watershed are different in the Des Moines Lobe region of the watershed compared to the Southern Iowa region. In the Des Moines Lobe region, the dominant soil association is the Clarion-Nicollet-Webster association which comprises 14.4, 11.8 and 13.2 percent of the watershed, respectively. Canesteo soils are also found with the dominant association and comprise another 12.1 percent of the watershed. The Clarion-Nicollet-Webster association soils formed in Wisconsin glacial till and sediments under native grass vegetation. Clarion soils are well drained and are in higher, steeper areas, Nicollet soils are somewhat poorly drained drained on lower parts of gentle slopes, and Webster soils are found in poorly drained low areas. Canisteo soils are similar to Webster soils and are found in swales occurring on a gently undulating till plain (Sherwood, 1982; 1985). Approximately 77.5 percent of soils in the North Raccoon River watershed may be tile drained (see Section 5.2).

Sharpsburg soils are the dominant soil type found in the Southern Iowa Drift Plain region of the Raccoon River watershed comprising 1.5 percent of the watershed. Sharpsburg soils formed in loess and are moderately well drained soils on upland divides and upper parts of side slopes. Other soils typically associated with Sharpsburg soils include Shelby soils developed in glacial till on sideslopes and Colo-Ely-Zook soils formed in silty alluvium on bottom lands (Dideriksen, 1983). In the South Raccoon watershed, approximately 42.1 percent of soils may be tile drained (see Section 5.2).

2.4 Land Use

Land use in the Raccoon River watershed is predominantly agricultural (Table 2-2). Land use/land cover (in percent) was summarized from the 2002 Statewide land cover map for watershed areas above the major stream gages considered in this TMDL (see Hydrology section).

Table 2-2. Land use percentages (2002 data) in watershed areas above major gaging stations.

Watershed Area	Area (mi^2)	Row Crops	Grasses	Woods	Roads/ Impervious	Water Wetlands
N. Raccoon at Sac City	700	85.4	10.8	1.3	1.4	1.1
N. Raccoon at Jefferson	1,619	83.4	12.3	1.9	1.4	1.0
S. Raccoon at Redfield	994	61.3	29.2	7.0	2.0	0.5
Raccoon River at Van Meter	3,441	75.3	18.1	4.0	1.8	0.8
Raccoon River at Fleur	3,625	73.2	18.6	4.3	3.0	0.9

Row crops of primarily corn and soybeans accounted for the largest percentage of land use in the Raccoon River watershed. More than 83 percent of the land in the North Raccoon basin above Sac City and Jefferson is in row crop production. Lower row crop percentages at Van Meter and Fleur reflected the lower percentage measured in the South Raccoon basin and increased urbanization (roads/impervious surfaces) near the City of Des Moines. The greatest proportion of grass (pasture, CRP, alfalfa) and woods in the Raccoon River watershed is in the South Raccoon basin where these land covers accounted for 36.2 percent of the land area. Figure 2-3 shows the percentage of land under row crop production in HUC12 basins within the Raccoon River watershed. Most HUC12 basins have row crop land use over more than 75 percent of their area. Four basins have less than 20 percent row crop, two basins in the South Raccoon watershed and two urban counties including Des Moines. Row crop percentages exceeded 90 percent in 16 HUC12 basins within the North Raccoon basin (Figure 2-3).

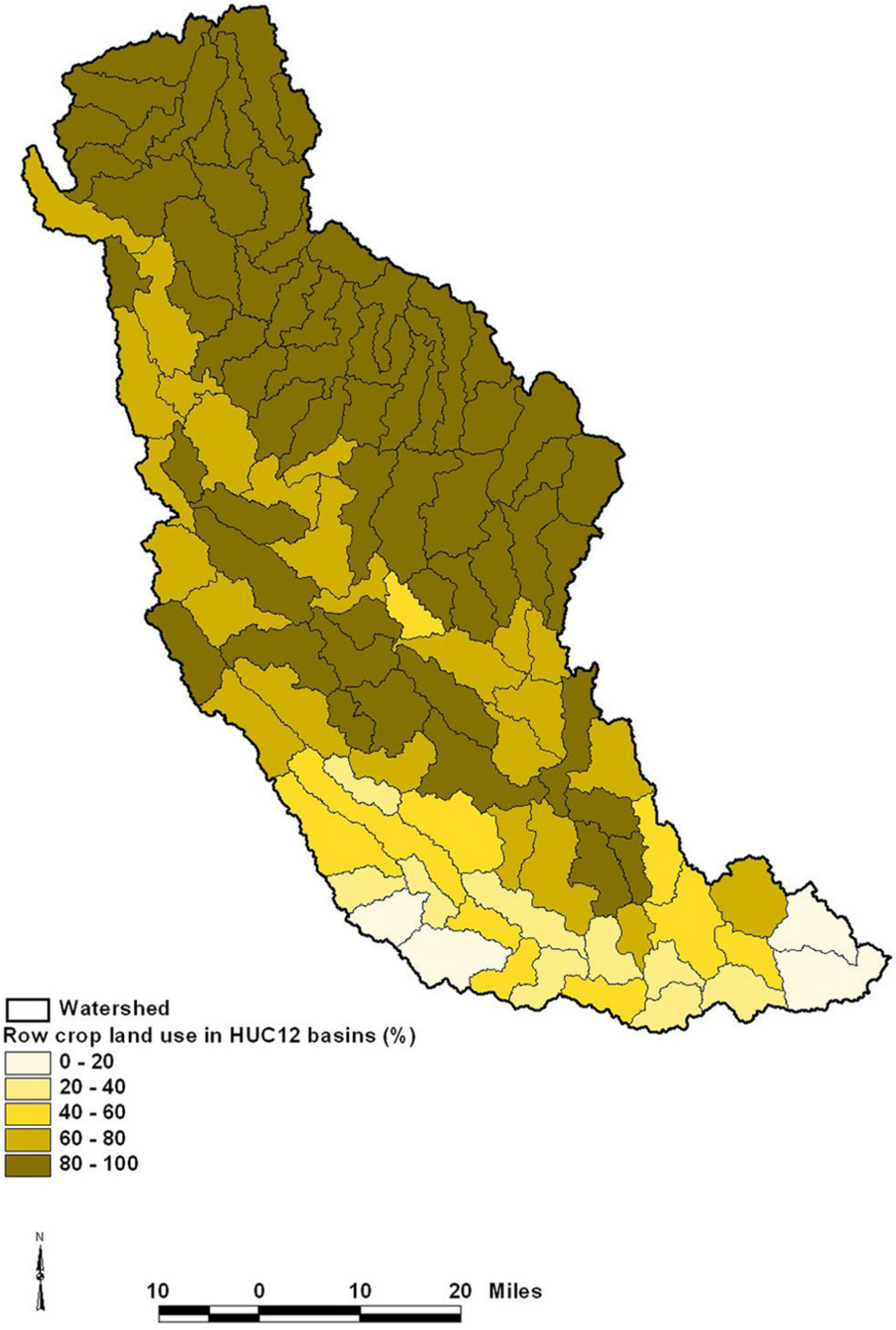


Figure 2-3. Percentage of land in row crop land use in HUC12 subbasins of the Raccoon River watershed.

Differences in land cover between the North and South Raccoon basins can be traced largely to their different landform regions and the suitability of land for intensive row crop agriculture. The level till plains of the Des Moines Lobe are heavily utilized for row crop production throughout the North Raccoon basin, whereas row crops in the steeply sloping landscape of the Southern Iowa Drift Plain are primarily found on relatively level uplands and bottomlands or on contoured and terraced sideslopes. Grasses and trees generally are scattered throughout the South Raccoon basin on terrain difficult to cultivate.

2.5 Climate

Climatic conditions in the Raccoon River watershed were assessed for a 25 year period from 1980 to 2005. Daily temperature data (high and low values) and daily precipitation were downloaded from the Iowa Environmental Mesonet (http://mesonet.agron.iastate.edu/ index.phtml) for five representative locations within the watershed. The weather station sites at Storm Lake, Sac City, Carroll, Perry and Des Moines, span the longitudinal axis of the Raccoon River watershed and provide information on annual and seasonal climate patterns in the watershed. Table 2-3 includes the summary of annual precipitation patterns and Figure 2-4 shows the annual departure from the average precipitation for each site. Figure 2-5 presents the monthly average high and low temperature and average total monthly precipitation at the five measurement sites.

Table 2-3. Summary of annual precipitation totals at sites within Raccoon River watershed.

	Total Annual Precipitation (in)				
Year	**Storm Lake**	**Sac City**	**Carroll**	**Perry**	**Des Moines**
1980	25.14	22.65	14.56	21.75	25.09
1981	26.48	27.56	30.34	25.57	31.30
1982	42.91	42.15	34.51	39.28	44.80
1983	43.37	43.67	38.22	41.11	41.17
1984	40.17	43.12	44.39	35.50	41.78
1985	31.96	28.32	28.30	20.20	28.50
1986	45.35	43.13	44.71	45.45	42.58
1987	34.80	38.78	36.67	33.84	36.97
1988	30.43	26.83	32.93	17.97	21.99
1989	21.12	17.99	28.50	23.09	29.12
1990	40.59	40.23	41.53	39.15	43.93
1991	42.78	40.88	33.72	35.74	39.77
1992	43.85	35.90	32.79	32.60	33.51
1993	40.01	37.91	39.01	40.80	55.88
1994	29.97	31.63	26.85	25.45	28.20
1995	32.59	32.09	26.31	33.39	31.74
1996	39.23	35.10	39.34	34.57	25.08
1997	32.64	24.93	25.17	25.13	28.53
1998	42.33	38.00	36.32	39.62	37.70
1999	28.82	30.30	37.67	36.11	27.15
2000	21.78	21.86	19.98	23.61	26.14
2001	28.05	31.14	33.77	31.11	29.76
2002	29.50	30.95	33.42	28.80	29.25
2003	28.97	27.42	30.28	33.75	31.57
2004	31.34	36.52	31.19	34.45	33.80
2005	30.81	33.98	27.37	32.92	28.05

The average annual precipitation total for the watershed, as measured at the five stations, over the 25-year period was 33.08 inches and it varied by location from 34.04 inches at Storm Lake to 31.97 inches at Perry. Variations by year were pronounced, with drier than normal years in 1980-1981, 1985 and 2000-2005 and wetter than normal years in 1982-1983, 1986, 1990-1993 and 1998 (Figure 2-4). Overall, the long-term average value indicates a central tendency, but year-to-year variations in precipitation appear to be the norm rather than the exception.

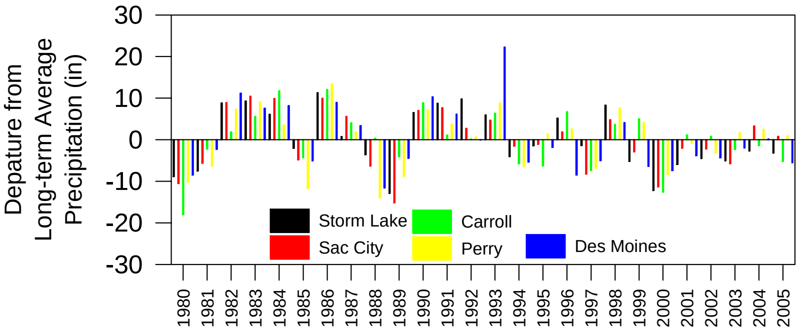


Figure 2-4. Departure from long-term average annual precipitation at various Iowa Environmental Mesonet sites in Raccoon River watershed.

Seasonally, temperature and precipitation patterns were consistent among the stations (Figure 2-5). Average monthly high and low temperatures increased slightly from northern to southern locations and were highest in Des Moines. Highest monthly precipitation totals typically occurred in May and June when average precipitation exceeded 4.3 inches at all sites and occasionally exceeded five inches. The months of April, July and August averaged between 3 and 4.5 inches, March, September and October precipitation generally ranged between 2 to 3 inches, and the remaining months were less than 2 inches.

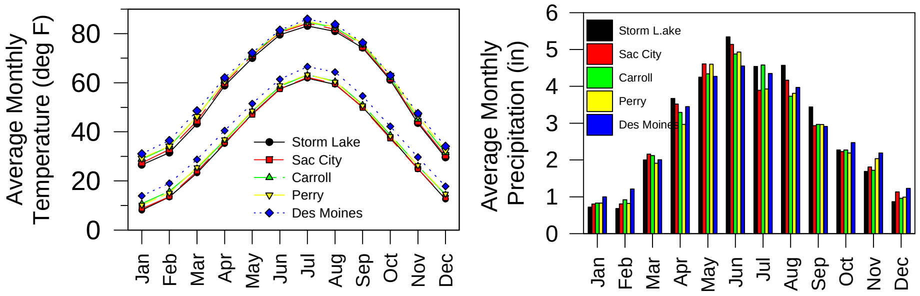


Figure 2-5. Summary of monthly climate data for various Iowa Environmental Mesonet sites in Raccoon River watershed.

2.6 Hydrology

Daily streamflow records from seven USGS gaging stations located in the Raccoon River watershed were evaluated in this TMDL (Table 2-4). Locations of the gaging stations are shown on Figure 2-1. The hydrograph of streamflow was separated into baseflow and stormflow components using the USGS program PART (Rutledge, 1998). Baseflow is the portion of streamflow derived from groundwater discharge to stream channels.

Table 2-4. Summary of annual streamflow, baseflow and baseflow percentage at major USGS gaging stations.

				Mean Values 1980-2005		
Station Location	**USGS ID**	**Drainage Area (mi^2)**	**Period of Record**	**Q (in)**	**Qb (in)**	**%Qb**
North Raccoon at Sac City	05482300	700	1958-2005	9.12	6.26	69.1%
North Raccoon at Jefferson	05482500	1619	1940-2005	8.55	5.59	68.2%
Middle Raccoon at Bayard	05483450	375	1979-2005	8.84	5.97	69.7%
South Raccoon at Redfield	05484000	994	1940-2005	7.97	4.79	62.9%
Raccoon River at Van Meter	05484500	3441	1915-2005	8.48	4.76	60.0%
Walnut Creek at Des Moines	05484800	78	1971-2005	9.86	5.88	57.3%
Raccoon River at						

The 1980 to 2005 period of streamflow record was evaluated at gaging sites above Van Meter and the results indicate wide variability in annual discharge (Figure 2-6). Long-term average flow in the Raccoon River is probably best represented by conditions at Van Meter because the daily record extends back to 1915 and streamflow at Van Meter includes flow from the three major tributaries. From 1980 to 2005, total streamflow and baseflow at Van Meter was 8.48 and 4.76 inches, respectively.

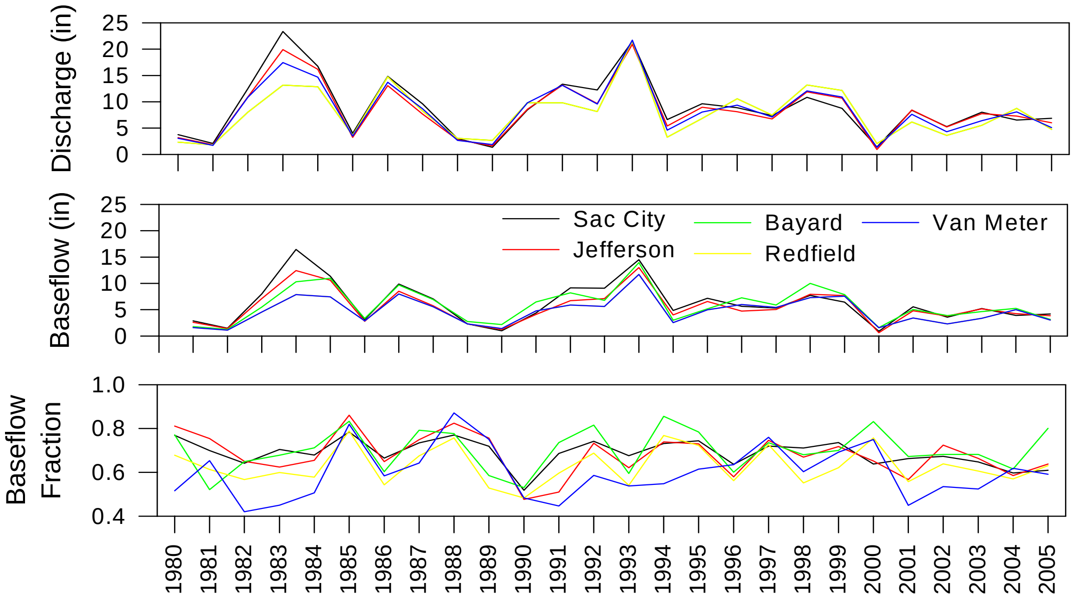


Figure 2-6. Summary of total discharge, baseflow and baseflow fraction at five gage sites in Raccoon River watershed.

Annual discharge (i.e., watershed yield) varied from 0.9 inches in the North Raccoon River at Jefferson in 2000 to 23.3 inches in the North Raccoon River at Sac City in 1983. Lower annual discharge occurred during several periods, in particular 1981, 1985 1989-90 and 2000, and was associated with below normal precipitation. Two major peak streamflow periods occurred in 1983-84 and 1993. Flow during both periods approached or exceeded 20 inches during these two periods.

Annual baseflow trends followed total discharge patterns. At Van Meter, the baseflow fraction of streamflow varied from 42% in 1982 to 87% in 1988 and averaged 60% over the 26-year record. In general, baseflow fraction tended to increase in drier years when less precipitation was routed to streams as runoff. Baseflow fraction appeared to be greater in the North Raccoon than South Raccoon and was lowest in the more heavily urbanized Walnut Creek watershed. Higher baseflow percentage at Fleur was due to the shorter streamflow record available at this location. Evidence from the Fleur gage and other streamflow data indicates that the most recent 2000 to 2005 period records lower than average flows compared to the previous 25 years.

Seasonally, greatest discharge tended to occur in May through June when average discharge exceeded 1.5 inches in the Raccoon River at Van Meter (Figure 2-7). Baseflow discharge was equally high during these months, peaking near 1 inch in May and June. Monthly baseflow fraction reflected increased runoff from snowmelt and spring rainfall periods, with increasing baseflow contribution to surface water through the fall and winter. On an annual basis, the months of March through July accounted for 70.2 percent of total annual flow and 68.1 percent of total annual baseflow.

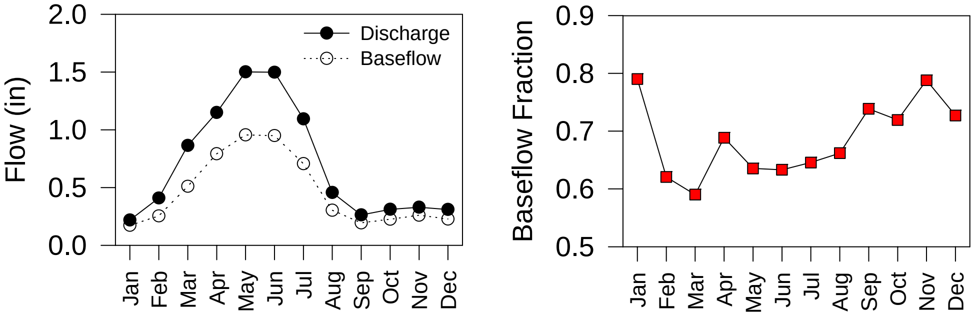


Figure 2-7. Summary of monthly streamflow and baseflow fraction at Van Meter gage, 1980-2005.

2.7 Historical Changes in Raccoon River Streamflow

Like many other Iowa watersheds, stream discharge, baseflow discharge, stormflow, and the percentage of streamflow as baseflow have increased substantially in the Raccoon River during the 20th century (Schilling, 2003; Figure 2-8). Although annual precipitation increased during this time period as well, regression residuals of stream discharge components versus precipitation indicate that there has been a significant change in the relationship of streamflow to precipitation over time. All four streamflow components showed that a significant increase has occurred in the overall rainfall-runoff relationship since 1916 ($p<0.05$). Thus more precipitation is being routed into streamflow during the latter portion of the 20th century. Seasonally, increases in discharge and baseflow over time were found to occur in all months except February and (snowmelt periods) (Schilling, 2003). Reasons for the observed streamflow trends include improved land management and conservation practices (soil conservation practices that reduce runoff and increase infiltration), greater artificial drainage, increasing row crop production (i.e., changing from perennial to annual cropping systems) and widespread channel incision (Schilling and Libra, 2003).

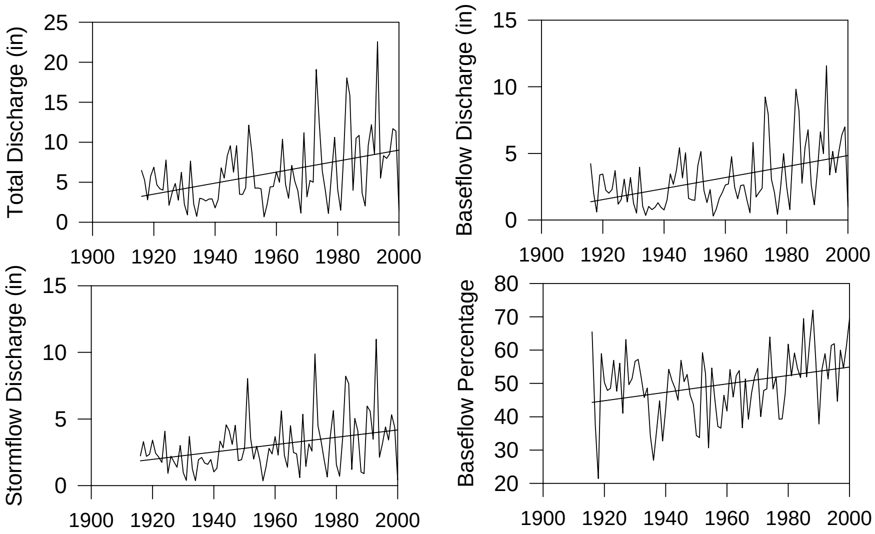


Figure 2-8. Trends in annual discharge, baseflow, stormflow and baseflow fraction at U.S.G.S. Van Meter gage, 1917-2000.

3.0 TOTAL MAXIMUM DAILY LOAD (TMDL) FOR NITRATE

A Total Maximum Daily Load (TMDL) is required for the Raccoon River by the Federal Clean Water Act. This chapter will quantify the maximum amount of nitrate that the Raccoon River can tolerate without violating the state's water quality standards.

3.1 Problem Identification

Surface water from the Raccoon River is used by two municipalities (City of Des Moines and the City of Panora) for drinking water. Because of the water use for drinking water supply, the Class C water quality standard applies to the Raccoon River at the two surface water intakes. The definition of Class "C" waters (IAC Chapter 61) states:

> "Class "C" waters. Water which are designated as Class "C" are to be protected as a raw water source of potable water supply."

The applicable water quality standard for nitrate for Class "C" designated use is the USEPA maximum contaminant level (MCL) of 10 mg/l.

The 2004 305(b) assessment reports that the Class "C" designated use of the Raccoon River at the two drinking intakes was impaired due to levels of nitrate that exceed the MCL. The specific impairments of Class "C" designated use at the City of Des Moines and City of Panora are described in sections 3.1.1 and 3.1.2, respectively.

3.1.1 Class "C" impairment at City of Des Moines

The 2004 305(b) assessment states:

> "The Class C (drinking water) uses remain assessed (monitored) as "not supported" due to levels of nitrate that exceed state water quality standards and U.S. EPA's maximum contaminant level (MCL). Accordingly, the Raccoon River from mouth to confluence with the North Raccoon and South Raccoon rivers (segment IA 04-RAC-0010-1 & 2), does not meet its designated use as a Class C drinking water source. Results of monitoring during a 2000-2002 assessment period by the Des Moines Water Works in this river segment showed that 48% of the samples collected (187 of 393) contained nitrate above the 10 mg/l MCL. IDNR's assessment methodology states that if more than 25% of samples exceed the nitrate MCL, nonsupport of drinking water uses is indicated. In addition, the continued periodic use of a nitrate removal system by the Des Moines Water Works also suggests an impairment to drinking water uses due to high levels of nitrate in the Raccoon River. According to U.S. EPA's Section 305(b) guidelines (page 3-44 of U.S. EPA 1997b), the use of the nitrate removal system by the DMWW constitutes "more than conventional treatment" and thus indicates that the designated drinking water uses are not fully supported (=impaired)."

Although the 2004 305(b) assessment considered a 2000-2002 assessment period, a longer 10-year assessment period is evaluated in this TMDL. Water quality data were obtained from the Des Moines Water Works (DMWW) for the 1996 to 2005 period to evaluate the degree of nitrate impairment at their raw water intake. Surface water samples were collected from the Raccoon River by the DMWW on a daily to weekly basis from 1996 to 2005 and analyzed for nitrate using EPA Method 300.0. A daily nitrate record for this assessment period was generated by the DMWW using linear interpolation between measured values to estimate nitrate concentrations for days when no water samples were collected. Using a daily nitrate concentration record calculated in this manner is appropriate for this TMDL for the following reasons: 1) nitrate concentrations do not vary significantly during baseflow periods between storm events, and during wet periods, more frequent samples were collected by the DMWW; 2) daily nitrate concentrations were measured by the DMWW when concentrations approached the MCL (thus measured data accurately reflects more vulnerable high-nitrate periods); and 3) a daily record does not have a sampling bias that only reflects intermittent samples collected only during high nitrate periods (thus weighted toward higher than average values and not indicative of the daily concentrations over the long term). Attention was given in the 2004 305(b) assessment to the problem of sampling bias in assessing the percentage of time stream nitrate concentrations exceeded 10 mg/l when only periodic data were available. This issue was addressed in this TMDL by using a daily record made up of measured values and estimated daily values.

A daily record of nitrate concentrations and discharge in the Raccoon River at Des Moines (DMWW) is shown in Figure 3-1. During the 1996 to 2005 period, nitrate concentrations ranged from 0 to 18.3 mg/l and averaged 6.45 mg/l. Nitrate concentrations peaked greater than 12 mg/l for eight of the 10 monitored years, and greater than 16 mg/l every year from 2001 to 2005. Concentrations exceeded 10 mg/l approximately 24.0 % of the time from 1996 to 2005.

Examining the specific 2000 to 2002 assessment period of the 2004 305(b) report using the daily DMWW data indicates that nitrate concentrations exceeded the 10 mg/l MCL approximately 17.1% of the time (125 out of 732 daily values). This percentage is less than the value cited in the 305(b) report, because this record includes estimated values for days when samples were not collected. If only measured values by DMWW were used for the 2000-2002 assessment period, the 305(b) report indicated that 48% of the samples exceeded the MCL (187 of 393). The 305(b) report acknowledged that this may be due to over-sampling by the DMWW during times of the year when nitrate levels tended to be high and was thus biased high. When summarized on a weekly basis for the 2000-2002 period, 41 of 142 weeks (29%) indicated average nitrate concentrations exceeding the MCL.

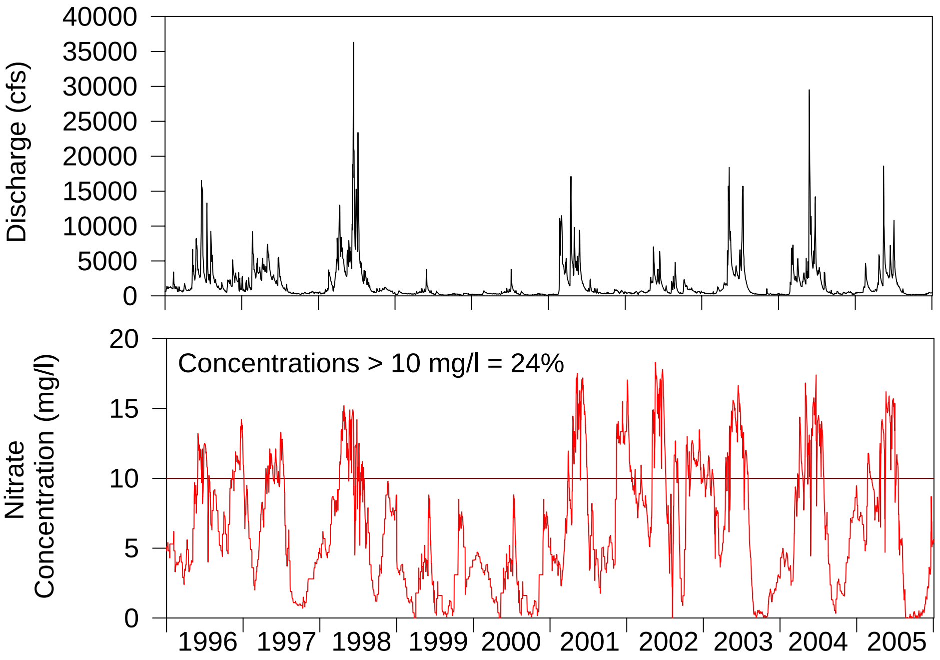


Figure 3-1. Daily streamflow at U.S.G.S. Fleur gage and nitrate concentrations measured by DMWW in the Raccoon River at Fleur, 1996-2005.

The 2004 305(b) assessment also cited results from ambient monitoring at Van Meter collected as part of the Iowa State University/Army Corps of Engineers (ISU/ACOE) network. Similar to the DMWW monitoring, sampling was skewed toward greater frequency in spring and summer months when nitrate concentrations tended to be higher compared to winter. Because of the sampling bias, the percentage of water samples exceeding the MCL may be higher than an unbiased sampling frequency would indicate. For three monitoring periods, the MCL of 10 mg/l was exceeded at slightly differing percentages at the Van Meter ISU/ACOE station (Table 3-1). The long term record of MCL exceedances is similar to that determined by Schilling and Lutz (2004) for the 1972 to 2000 period (252 of 981, or 26 percent).

Table 3-1. Comparison of nitrate exceedances for three sampling periods at Van Meter ISU/ACOE site.

Sampling Period	Purpose	#Exceedances/#samples	% Exceedance
2000-2002	2004 305(b) period	17 of 66	25.7%
1996-2005	DMWW period	71 of 220	32.3%
1980-2005	Long term analysis	202 of 717	28.2%

3.1.2 Class “C” impairment at City of Panora

The 2004 305(b) assessment states:

> The Class C (drinking water) uses remain assessed (monitored) as "partially supported" due to issuance by the Panora Water Works of four notices of MCL violations for nitrate during the 2000-2002 assessment period. According to the State of Iowa Public Drinking Water Program Annual Compliance Reports prepared by the IDNR Water Supply Section (http://www.iowadnr.com/water/drinking/reports.html), these violations occurred in June and July 2001 and in June and July of 2002. According to EPA and DNR methods for assessing support of Class C (drinking water) uses, one or more drinking water advisory lasting 30 days or less per year suggests that the Class C use is only "partially supported" (see pages 3-38 to 3-44 of U.S. EPA 1997b (http://www.epa.gov/owow/monitoring/guidelines.html) and the DNR assessment methodology for Section 305(b) reporting (see http://wqm.igsb.uiowa.edu/WQA/303d/2004/2004FinalMethodology.pdf).

The 2004 305(b) assessment considered finished water for the 2000 to 2002 assessment period. For this TMDL assessment, additional raw water data were evaluated. Daily nitrate concentrations were made available by the City of Panora for the 2003 to 2005 period. Nitrate concentrations were found to exceed the MCL at the City of Panora intake 21.5 percent of the time from 2003 to 2005 (235 of 1095) (Figure 3-2). Concentrations exceeded 10 mg/l for sustained periods of time each of the three years during late spring through summer. Concentrations exceeded 10 mg/l for the May 10 to August 24 period in 2003, April 11 to August 8 period in 2004 and May 3 to July 15 period in 2004. Maximum concentrations approached or exceeded 15 mg/l in June each year (Figure 3-2).

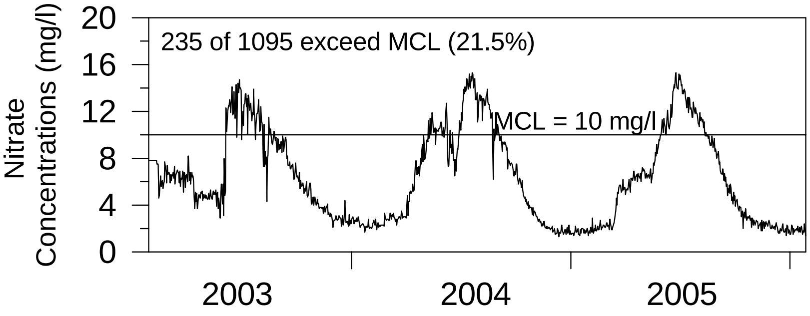


Figure 3-2. Daily nitrate concentrations in Middle Raccoon River measured by City of Panora at water intake, 2003-2005.

Finished water data from the City of Panora were provided for 2000, 2001 and 2003 as monthly concentrations (Table 3-2). Finished water is likely to be very similar to raw water since the City of Panora does not provide nitrate treatment. Like the City of Des Moines data, nitrate concentrations were low in 2000, but monthly finished water concentrations exceeded 10 mg/l for three months in 2001 and two months in 2003.

Table 3-2. Summary of nitrate concentrations in finished water at City of Panora.

	Nitrate Concentrations in City of Panora Water (mg/l)		
	2000	**2001**	**2003**
JAN	3.3	1.0	4.6
FEB	3.8	1.2	6.6
MAR	3.6	2.0	6.2
APR	3.5	5.0	5.8
MAY	2.8	8.0	6.6
JUN	2.6	12	14
JUL	1.0	15	12
AUG	2.4	12	7.6
SEP	1.3	5.0	4.2
OCT	1.0	3.2	2.6
NOV	0.7	3.2	6.5
DEC	0.8	3.0	6.5
Avg.	2.2	5.9	6.9

3.1.3 Temporal Patterns of Nitrate Concentrations

Schilling and Lutz (2004) examined patterns of nitrate concentrations in the Raccoon River at Van Meter for the period 1972 to 2000 and noted the following temporal patterns. Monthly mean nitrate concentrations exhibited clear seasonality, with higher concentrations occurring during April, May and June as well as November and December (Figure 3-3). Nitrate concentrations were typically lowest in August and September when streamflow was also at a minimum and biological uptake of nitrogen in the river was particularly evident. Cyclic nature of monthly nitrate concentrations was particularly apparent when grouped as seasons of winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep) and fall (Oct-Dec) (Figure 3-4). Mean concentrations by season varied from 5.11 mg/l in summer to 9.27 mg/l in spring.

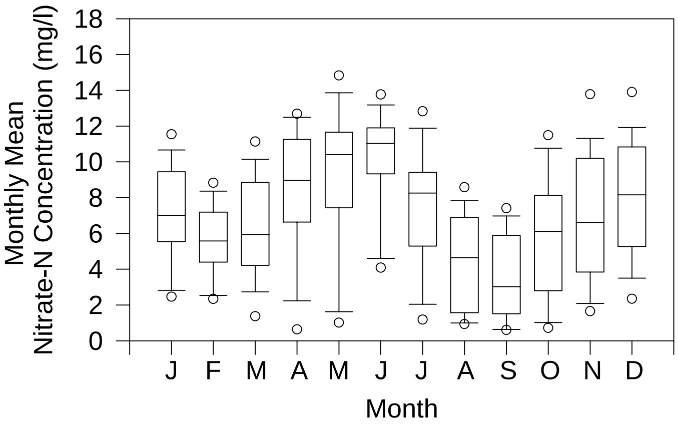


Figure 3-3. Variations in monthly nitrate concentrations in Raccoon River. Box plots illustrate the 25th, 50th and 75th percentiles; the whiskers indicate the 10th and 90th percentiles; and the circles represent data outliers.

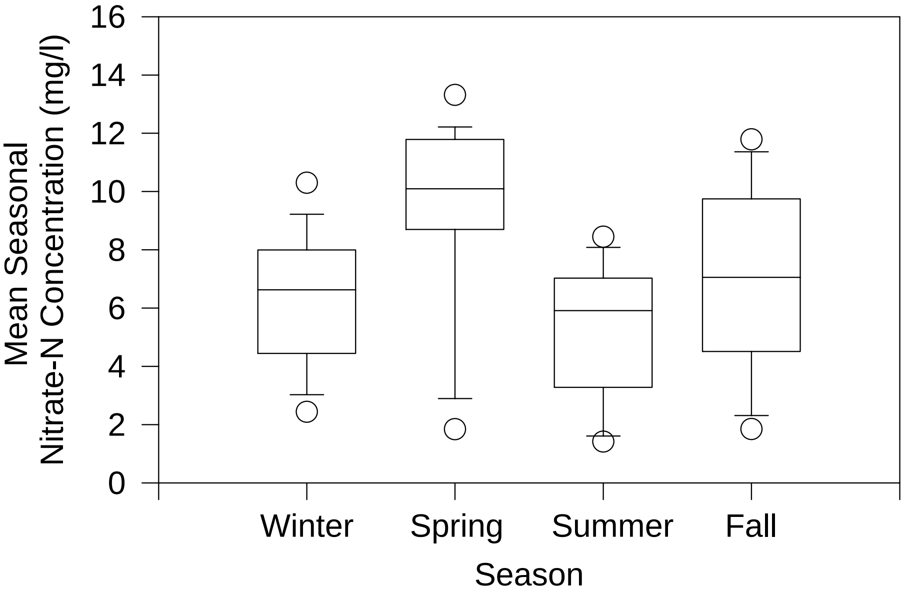


Figure 3-4. Variations in seasonal nitrate concentrations in Raccoon River. Box plots illustrate the 25th, 50th and 75th percentiles; the whiskers indicate the 10th and 90th percentiles; and the circles represent data outliers.

The relation of nitrate concentrations to discharge in the Raccoon River was evaluated based on the flow regime in the river during the sampling period (Schilling and Lutz, 2004). Discharge measured at the time of sampling was divided in in quartiles to determine whether nitrate concentrations related better to high or low flows in the river. Major differences were noted in nitrate concentrations in the upper half of the flow range compared to lower half (Figure 3-5). Mean nitrate concentrations decreased from 10.0 mg/l in the 75-100% quartile range to 2.4 mg/l in the lowest 25%. Moreover, nitrate concentrations and loads in the Raccoon River are better related to baseflow (portion of streamflow derived from groundwater inputs) than total streamflow. Nitrate concentrations are linearly related to streamflow at all time scales (daily, monthly, seasonal, annual), but the relation is improved when baseflow is used instead of total streamflow (Schilling and Lutz, 2004). In terms of nitrate loads, Schilling and Zhang (2004) evaluated baseflow in the Raccoon River and found that baseflow contributed nearly two-thirds of the annual nitrate export from the watershed. Seasonal patterns of nitrate loads were similar to concentration patterns, with baseflow contributions to nitrate loads greatest in spring and late fall when baseflow contributed more than 80 percent of the total nitrate export.

Zhang and Schilling (2005) completed a more detailed analysis of the temporal and spatial patterns of streamflow and baseflow in the Raccoon River. They found that nitrate concentrations and loads have a half-year cycle while daily precipitation, streamflow and baseflow have one-year cycles. A low frequency 6-8 year cycle appears to be present in the long-term nitrate concentration record at Van Meter. The cycle may be related to long-term temporal variations of the controlling factors of nitrate movement (e.g., wet and dry years, changes in agricultural management).

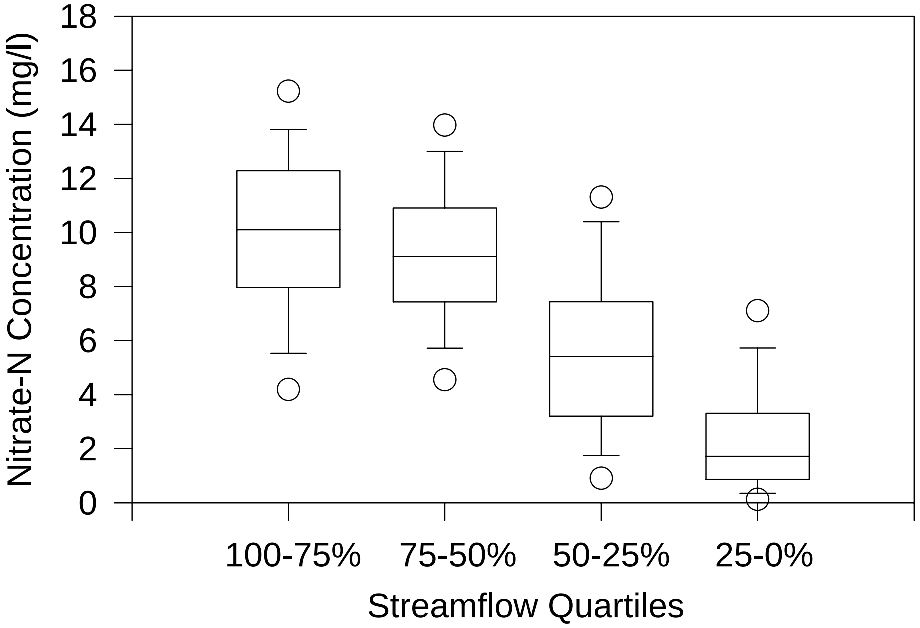


Figure 3-5. Variations in nitrate concentration with discharge in Raccoon River. Box plots illustrate the 25th, 50th and 75th percentiles; the whiskers indicate the 10th and 90th percentiles; and the circles represent data outliers

3.1.4 Spatial Patterns of Nitrate Concentrations and Loads

A variety of data sources and scales were used to evaluate spatial patterns of nitrate concentrations in the Raccoon River watershed. On a large scale, nitrate concentration data are available from the IDNR/UHL ambient water monitoring network at two sites located in the North Raccoon River basin and a single site located at the outlet of the South Raccoon River basin (Table 3-3). Combined with monitoring data from the ISU/ACOE site at Van Meter, nitrate concentration data from four upstream sites provide indications of nitrate concentration hot spots in the Raccoon River watershed. Comparison data are for the 1999 to 2005 period because ambient monitoring at Jefferson and Redfield only began in 1999.

Table 3-3. Comparison of nitrate concentrations measured at various monitoring sites.

Watershed	**Agency**	**Period of Record**	**Storet ID**	**Sample Freq.**	**Comparison of Nitrate Concentrations 1999 to 2005**			
					n	**Avg. (mg/l)**	**%>10 mg/l**	**Max (mg/l)**
Raccoon R. at Van Meter	ISU/ ACOE	1972-2005	10250002	Bimonth	154	7.6	32.5	18.2
N. Raccoon at Sac City	IDNR/ UHL	1986-2005	10810001	Month	105.	13.1	76.2	22
N. Raccoon at Jefferson,	IDNR/ UHL	1999-2005	10370001	Month	81	9.0	40.7	18
S. Raccoon at Redfield	IDNR/ UHL	1999-2005	10250001	Month	80	5.0	0.1	14

A comparison of nitrate concentrations at the scale of large basins (greater than 700 mi2) indicates substantial variation (Figure 3-6). In the North Raccoon River above Sac City, nitrate concentrations averaged 13.1 mg/l and exceeded the MCL in over 76 percent of the samples collected. In contrast, nitrate concentrations in the South Raccoon at Redfield rarely exceeded the MCL (0.1 percent) and averaged 5 mg/l. Concentrations downstream of Sac City at Jefferson, and downstream of the confluence of North and South Raccoon Rivers at Van Meter, showed lower concentrations than upstream levels. Thus, there are major differences in nitrate concentration patterns within large subbasins of the Raccoon River.

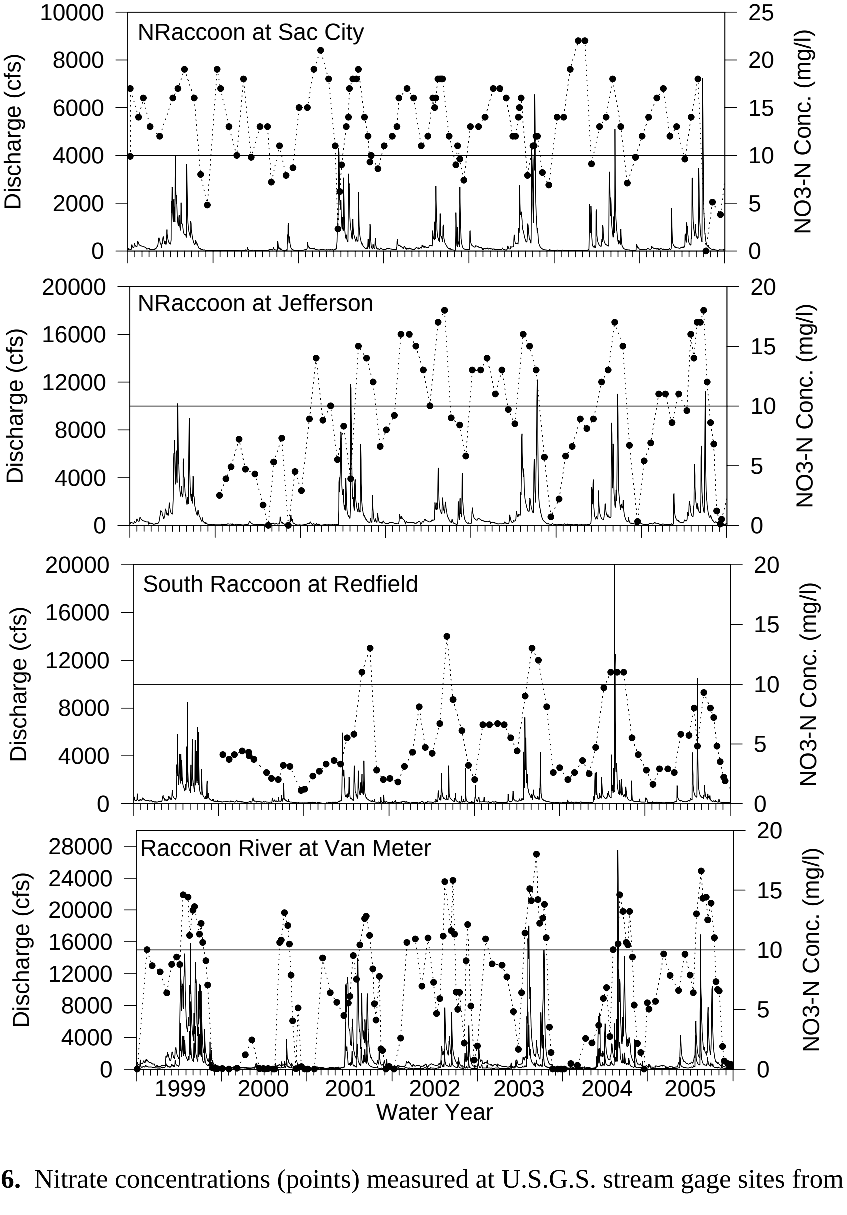


Figure 3-6. Nitrate concentrations (points) measured at U.S.G.S. stream gage sites from 1999-2005.

A longer period of nitrate monitoring record is available for the North Raccoon River at Sac City (Table 3-3). Examining the record from 1986 to 2005 reveals that nitrate concentrations in the North Raccoon River have significantly increased ($p<0.05$) during this 20-year period (Figure 3-7). Annually, mean nitrate concentrations increased approximately 0.27 mg/l/year from 1986 to 2005, with the increase primarily associated with the post-1998 period. The mean monthly nitrate concentration from 1986 to 1998 was 9.5 mg/l, whereas the mean concentration from 1998 to 2005 was 13.0 mg/l. During the same time period (1986 to 2005), no increase in daily nitrate concentration was observed in the Raccoon River at Van Meter (p>0.1).

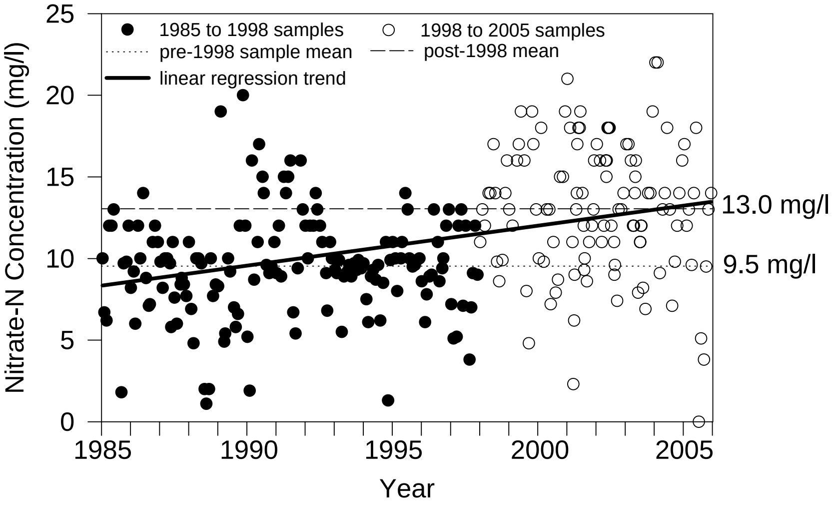


Figure 3-7. Monthly nitrate concentrations measured at Sac City from 1985 to 2005. Linear trend is associated with entire data set, whereas sample mean lines are associated with 1985-1998 and 1998-2005 time periods.

Nitrate loads were compared at the large basin outlets for the 1999 to 2005 period using the USGS program ESTIMATOR (Cohn et al, 1989; 1992; Gilroy et al., 1990). The ESTIMATOR program utilizes a Minimum Variance Unbiased Estimator to implement a seven-parameter regression model based on the relationship between log-flow and log-concentration. The program estimates a daily record of nitrate losses based on the relation between concentration and discharge. As such, results from the model are only an estimate of annual nitrate loads, not true measured values. The best estimates of nitrate loads from the Raccoon River are derived from daily discharge and near daily measured nitrate concentration at the DMWW.

Table 3-4. Estimated annual nitrate loads and flow-weighted concentrations at monitoring sites.

	N. Raccoon at Sac City		N. Raccoon at Jefferson		South Raccoon at Redfield		Raccoon River at Van Meter	
Year	N Load (lbs/ac)	FW NO3-N (mg/l)	N Load (lbs/ac)	FW NO3-N (mg/l)	N Load (lbs/ac)	FW NO3-N (mg/l)	N Load (lbs/ac)	FW NO3-N (mg/l)
1999	27.4	5.7	39.6	13.7	11.5	3.5	17.0	5.6
2000	4.6	10.5	1.9	7.7	2.1	3.7	1.8	4.9
2001	33.9	17.3	35.2	16.1	10.2	5.4	20.2	8.6
2002	18.6	16.5	20.7	19.1	5.7	6.0	10.6	10.1
2003	24.4	10.7	21.3	11.9	10.2	6.1	14.6	8.3
2004	18.0	7.2	24.5	13.6	14.5	6.1	18.9	8.8
2005	13.5	9.2	17.7	13.8	7.2	5.5	11.1	8.4
Avg.	20.1	11.0	22.9	13.7	8.8	5.2	13.5	7.8

FW = flow weighted concentration determined by dividing total estimated load by

Model results indicate greater nitrate losses from the North Raccoon River at Sac City and Jefferson than from the South Raccoon, averaging 22.5 to 25.7 kg/ha (20.1 to 23.0 lbs/ac) from the North Raccoon and 9.8 kg/ha (8.8 lbs/ac)from the South Raccoon (Table 3-4). Similarly, flow weighted nitrate concentrations (FW NO_3-N) for the seven-year period are greater than 11 mg/l in the North Raccoon and 5.2 mg/l in the South Raccoon. The average values include very low nitrate losses that occurred in 2000 when nitrate export was less than 5 kg/ha (4.5 lbs/ac). Overall, using the record from Van Meter as a gauge, estimated loads from the seven-year period are lower than nitrate export estimated for a longer period of record. Schilling and Zhang (2004) used the same ESTIMATOR model to estimate nitrate export from the Raccoon River watershed for the 1972 to 2000 period. They noted that nitrate export was extremely variable ranging from 1.4 kg/ha (1.3 lbs/ac) in 1977 and 2000 to more than 65.9 kg/ha (58.8 lbs/ac) in 1983 and 1993 and averaged 26.0 kg/ha (23.2 lbs/ac) (s.d. = 18.3) over the 28-year record. This long term average export is similar to that reported by Goolsby et al. (1998) (26.1 kg/ha or 23.3 lbs/ac). Greater nitrate losses were associated with periods of above normal precipitation and discharge. Maximum nitrate loads often occurred following the second year of below normal precipitation and discharge. Nitrate storage in the agricultural soils during dry periods is typically mobilized during periods of higher rainfall and runoff (Lucey and Goolsby, 1992).

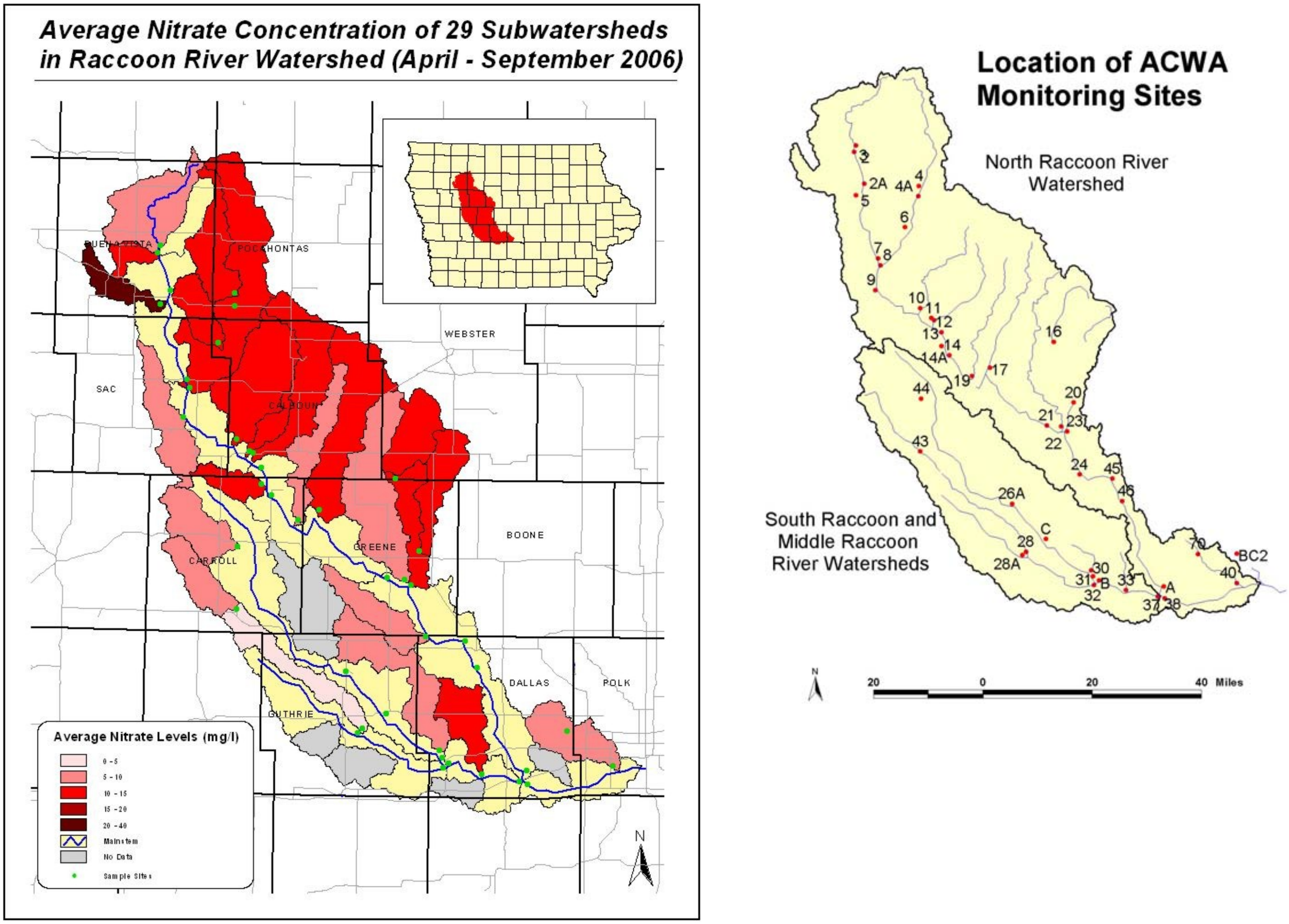
The contribution of nitrate loads from the large watershed areas to the total load measured at Van Meter for the 1999 to 2005 period is shown in Table 3-5. The South Raccoon watershed constitutes 28.9 percent of the area in the Raccoon River above Van Meter, but contributes approximately 20.6 percent of the annual load. In contrast, the Raccoon River above Jefferson comprises 47.1 percent of the land area but nearly 77 percent of the total nitrate export. Similarly, the area above Sac City contributes more nitrate export than the area of the watershed alone would predict. Thus, as suggested by the nitrate concentration data, the North Raccoon River appears to contribute a substantially greater proportion of nitrate loads to the impaired segment at Des Moines (Van Meter to Des Moines) than does the South Raccoon River. These results were confirmed by flow and nitrate concentration modeling using DAFLOW (Diffusion Analogy Surface Water Flow) and WASP (Water Quality Simulation Program) (Appendix A). Modeling suggested that discharge from the North Raccoon River provided 62 percent of the flow at Van Meter, but 79 percent of the nitrate load. Flow from the South Raccoon River provided 38 percent of the flow at Van Meter 21 percent of the nitrate load.

Table 3-5. Percentage of annual nitrate load at Van Meter derived from various watershed regions.

	Percentage of Nitrate Load Measured at Van Meter		
Year	**South Raccoon at Redfield**	**North Raccoon at Jefferson**	**North Raccoon at Sac City**
1999	19.7%	110.3%	32.9%
2000	33.4%	50.0%	54.5%
2001	14.6%	81.9%	34.1%
2002	15.5%	91.5%	35.4%
2003	20.1%	68.4%	34.0%
2004	22.1%	60.6%	19.3%
Average	20.6%	76.8%	33.6%
Watershed Area	28.9%	47.1%	20.3%

3.1.5 Qualified Volunteer Monitoring

Two volunteer monitoring efforts in the Raccoon River watershed contribute understanding the spatial patterns of nitrate concentrations in stream water. It should be noted that the qualified volunteer data was used in this TMDL for background information only, and was not used in making TMDL determinations. The Agriculture's Clean Water Alliance (ACWA) is a group comprised of 11 fertilizer dealers in the Raccoon River watershed who have partnered with the DMWW, Iowa State University, the National Soil Tilth Laboratory and IDALs to sponsor a water monitoring program in the watershed. During April to August from 2001 to present, volunteers have collected bi-weekly water samples from 42 remote sites located throughout the watershed (Figure 3-8). Samples are analyzed at the DMWW water quality laboratory.



Graphic provided by Anthony Seaman, ACWA

Figure 3-8. Location of ACWA monitoring sites and mean nitrate concentrations measured by ACWA in 2005.

A map of mean nitrate concentrations from 2005 indicates spatial variations in stream nitrate concentrations in the Raccoon River watershed (Figure 3-8). Results from 2005 are consistent with previous years and indicate that mean annual nitrate concentrations in many streams within the North Raccoon River subbasin exceeded the MCL during 2005. Highest concentrations were observed at Site 5 located downstream of the City of Storm Lake (Table 3-6). Nitrate concentrations averaged 30.5 mg/l during the monitoring period and peaked at 59 mg/l. At other North Raccoon sites, nitrate concentrations in April through July typically exceeded 10 mg/l and peaked greater than 15 mg/l, but concentrations were observed to substantially decrease in August and September. A similar pattern of mean annual concentrations and seasonal patterns was observed in the Middle Raccoon River, whereas South Raccoon River samples typically showed nitrate concentrations less than 10 mg/l. Concentrations in Walnut Creek ranged between 0 and 13.9 mg/l and averaged 8.1 mg/l in 2005. Overall, volunteer monitoring data from the ACWA are consistent with the regional data from the North and South Raccoon rivers and provide greater spatial resolution to the nitrate concentration patterns within the watershed.

Table 3-6. Nitrate concentrations measured by ACWA at select monitoring sites in 2005.

	North Raccoon Sites				**Middle Raccoon**	**South Raccoon**	**Walnut Creek**
Sample Date	**Site 5**	**Site 4A**	**Site 10**	**Site 23**	**Site 26A**	**Site 28A**	**Site 40**
4/28/2005	16.1	17.0	17.5	17.1	16.4	6.5	11.1
5/12/2005	22.0	16.6	17.5	14.0	11.8	3.8	12.7
5/26/2005	17.2	19.3	19.1	17.1	17.1	7.9	13.1
6/9/2005	19.4	19.7	18.0	14.9	15.6		9.1
6/23/2005	41.6	19.7	21.7	13.6	16.5	7.3	13.9
7/7/2005	10.0	17.0	12.0	14.7	13.5	5.6	11.1
7/21/2005	29.1	12.4		2.7	5.4	4.2	1.0
8/4/2005	36.5	6.0	12.2	0.3	4.5	4.0	0.5
8/18/2005	53.7	2.7	6.0	0.0	2.3	4.0	0.0
9/1/2005	59.0	0.3	0.1	0.1	1.2	3.4	
Average	*30.5*	*13.1*	*13.8*	*9.4*	*10.4*	*5.2*	*8.1*

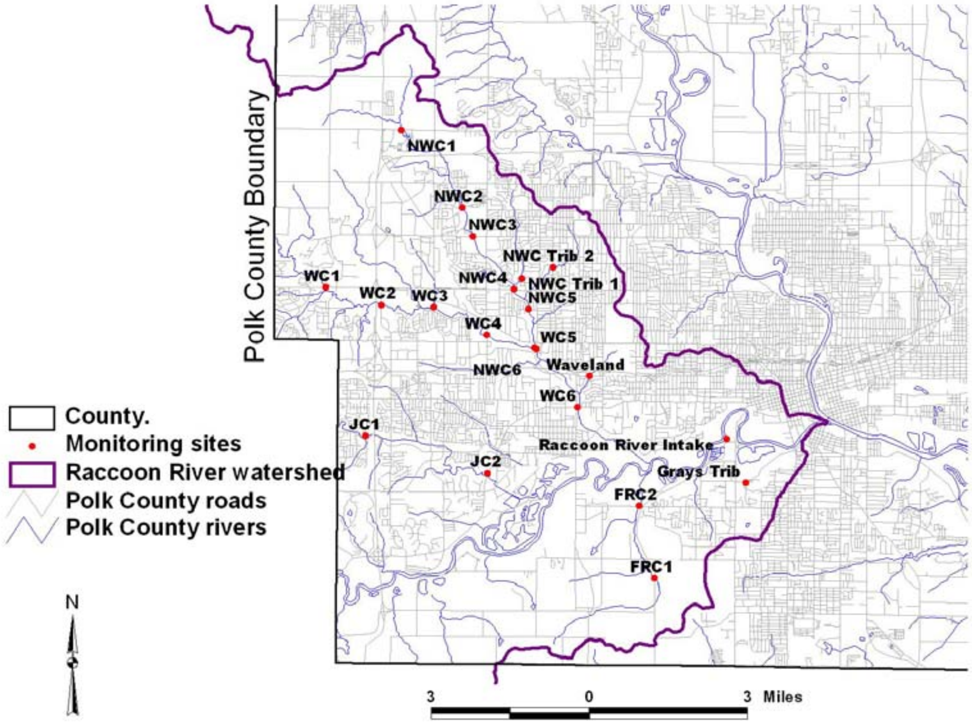


Figure 3-9. Location of Polk County snapshot monitoring sites.

A second source of qualified volunteer data available for the Raccoon River TMDL is four county-wide "snapshot" sampling events that were conducted in Polk County in spring and fall during 2004 and 2005 (Figure 3-9). Volunteers collected stream water samples throughout Polk County on a single day to assess the quality of county surface water at a single point in time (i.e., snapshot). Water samples were analyzed by the University of Iowa Hygienic Laboratory using standard methods. Results of the snapshot monitoring indicate variations in stream nitrate concentration measured in Polk County (Table 3-7). Highest stream nitrate concentrations were typically measured in the Raccoon River and Walnut Creek, both larger streams with watersheds that extend well beyond the limits of Polk County. Lowest concentrations were measured in several smaller urban creeks, including Frink Creek, Jordan Creek, and small creeks associated with Grays Lake and Waveland Golf Course. Headwaters of North Walnut Creek extend into northern Polk County, but the stream largely flows through northern suburbs and Des Moines. Concentrations in this stream were typically were higher in spring (up to 17 mg/l) in its headwater regions with concentrations decreasing as the stream flowed south through urban areas.

Table 3-7. Nitrate concentrations measured at Polk County snapshot sites in 2004 and 2005.

		Nitrate Concentration (mg/l)			
Site ID	**Site Description**	**6/2/04**	**10/13/04**	**5/18/05**	**12/12/05**
FRC1	Frink Creek at SW 42nd St.	5.6	1	0.79	1.3
FRC2	Frink Creek at Park	3.9	0.13	2.4	0.55
Grays Trib	Unnamed Creek - Trib to Gray's Lake	1.8	0.83	1.6	0.39
JC1	Jordan Creek (Prairie View Drive)	4.9	<0.05	4.2	1.1
JC2	Jordan Creek (Grand Ave)	3.7	0.37	1.9	<0.05
NWC Trib 1	North Walnut Creek Tributary	5.2	1.1	3.9	1
NWC Trib 2	North Walnut Creek Tributary	4	3.2	2	0.42
NWC1	North Walnut Creek (54th Ave)	17	0.52	9.1	0.76
NWC2	North Walnut Creek (Aurora Ave)	11	0.12	9.4	0.47
NWC3	North Walnut Creek	10	0.14	7.6	0.19
NWC4	North Walnut Creek	9.5	0.16	6.5	0.58
NWC5	North Walnut Creek at College Ave	8.8	<0.05	6.2	0.4
NWC6	North Walnut Creek (near 73rd St)	9	2.5	5	
RR - US	Raccoon River Van Meter	14	0.27	14	0.27
Waveland	Waveland Golf Course	1.4	<0.05	1.1	1.2
WC1	Walnut Creek	18	0.06	12	<0.05
WC2	Walnut Creek	17	<0.05	13	<0.05
WC3	Walnut Creek	16	0.17	14	<0.05
WC4	Walnut Creek (86th St)	16	<0.05	14	0.1
WC5	Walnut Creek	12	<0.05	12	<0.05
WC6	Walnut Creek	15	1.9	9.2	<0.05
DMWW Intake	Raccoon River	13	1	15	0.15

3.2 Pollution Source Assessment

The sources of nitrate can be divided into two major categories, point sources and nonpoint sources. Point sources are facilities whose discharge is covered by an NPDES permit that discharge pollutants directly into a stream, such as pipe effluent from a wastewater treatment plant. Nonpoint sources of pollutants are located diffusely across the landscape and discharge to streams with overland surface water runoff or groundwater discharge as baseflow or tile drainage. Waste loads from point sources are easier to assess because concentration and flow are assessed at the end of a pipe, whereas determining load allocations from nonpoint sources or point sources addressing stormwater and animal feeding operations requires understanding of the concentration and rate of discharge of pollutants over large geographical areas (Schilling and Wolter, 2001). In this section, potential pollution sources are assessed from point and nonpoint sources.

3.2.1 Point Sources

There are a total of seventy-seven (77) entities in the Raccoon River watershed with National Pollution Discharge Elimination System (NPDES) permits. Most of these facilities are municipal sewage treatment plants, but there are several industrial contributors, animal feeding operations (AFOs) and urban areas covered by Municipal Storm Sewer Systems (MS4s). For this TMDL, load estimates were calculated for WWTPs with Discharge Monitoring Records (DMRs) that discharge measurable quantities of effluent to surface waters.

Some animal feeding operations may be considered a point source because facilities larger than 1000 animal units are required to have an NPDES permit. However, by state law, discharge of pollutants from livestock operations is set at zero tons per year (IAC – Chapter 65). Any nitrate discharged from these facilities occurs from either manure application or episodic events such as spills. For open feedlots, facilities larger than 1000 animal units are considered NPDES facilities and their permits require retention and application of manure on cropped fields. Of the smaller open lots, it is required that facilities settle solids before runoff enters a stream. The list of point sources does not include permitted facilities that do not treat an organic waste stream, such as quarry operations.

For nitrate, very few wastewater treatment facilities monitor for this constituent in their effluent. Therefore, estimates of the quantities of nitrogen are derived from generic conservative assumptions based on type of treatment, quantity and quality of influent wastewater, and per capita pollutant generation. For nitrate, what little monitoring data is available from WWTPs exists for Total Kjeldahl Nitrogen (TKN) and not nitrate. Hence, all nitrogen point source loads in this TMDL are provided as TKN only. In terms of TKN, 100 percent of the TKN was assumed to convert to nitrate when in fact, some nitrogen is lost from the system as converted plant or soil matter (process known as immobilization) or as nitrogen gas (denitrification). Thus point source nitrate loads from WWTPs are overestimated.

Table 3-8. Summary of WWTP facilities, flow rates, and daily TKN loads in Raccoon River watershed. Basin names: NR-SC = North Raccoon at Sac City; NR-J = North Raccoon at Jefferson; MR-P = Middle Raccoon at Panora; SR-R = South Raccoon at Redfield; RR-VM = Raccoon River at Van Meter; RR-DSM = Raccoon River at Des Moines (Fleur).

EPA_ID	Facility Name	Flow Type	Permit Type	Basin	Population Equivalents	Max Flow Rate (MGD)	TKN Estimate Type	Daily TKN (lb/day)	Daily TKN (Mg)
IA0076554	Rembrandt Enterprises, Inc	Continuous	Domestic	NR-SC	23952	0.0032	1	232	0.1053
IA0033219	City of Rembrandt	Controlled	City	NR-SC	407	0.5890	2	117	0.0033
IA0046671	City of Fonda	Controlled	City	NR-SC	1146	1.0240	2	251	0.0129
IA0025950	City of Laurens	Controlled	City	NR-SC	2383	2.2400	2	359	0.0184
IA0065731	Spectra Health Care Facility STP	Controlled	Semi-Public	NR-SC	71	0.0500	2	15	0.0008
IA0064998	Tyson Fresh Meats Storm Lake	Daily	Industry	NR-SC	116766	2.9490	1	3260	1.4800
IA0032484	City of Storm Lake	Daily	City	NR-SC	33874	6.2240	1	1080	0.4903
IA0021989	City of Newell	Daily	City	NR-SC	1257	1.3670	1	34	0.0154
IA0034312	Albert City	Daily	City	NR-SC	892	1.5000	2	19	0.0086
IA0033090	Sac City	Daily	City	NR-SC	4042	1.9950	3	74	0.0336
IA0067652	City of Marathon	Daily	City	NR-SC	461	0.4054	2	8	0.0036
	North Raccoon at Sac City Subtotal								**2.1724**
IA0057029	City of Auburn	Controlled	City	NR-J	455	0.3000	2	128	0.0044
IA0056103	City of Breda	Controlled	City	NR-J	647	1.2000	2	77	0.0066
IA0062162	City of Lanesboro	Controlled	City	NR-J	249	0.2400	2	359	0.0126
IA0027189	City of Manson	Controlled	City	NR-J	1964	1.0240	2	869	0.0404
IA0020842	Lake City	Controlled	City	NR-J	2509	2.7700	2	868	0.0294
IA0070114	Twin Lakes Sanitary Sewer District STP	Controlled	Sanitary District	NR-J	897	0.5880	2	581	0.0197
IA0021300	City of Jefferson	Daily	City	NR-J	9281	4.5770	2	125	0.0567
IA0041998	City of Lake View	Daily	City	NR-J	3221	1.0450	1	35	0.0157
IA0026026	City of Lohrville	Daily	City	NR-J	659	1.0890	2	12	0.0053
IA0020940	City of Lytton	Daily	City	NR-J	5305	1.6690	3	582	0.2642
IA0033715	City of Rinard	Daily	City	NR-J	15	0.0550	2	2	0.0009
IA0032409	City of Scranton	Daily	City	NR-J	1144	1.2200	2	16	0.0074
IA0033138	Rockwell City	Daily	City	NR-J	4671	10.0000	1	61	0.0278
	North Raccoon at Jefferson Subtotal								**2.6634**
IA0028983	City of Coon Rapids	Controlled	City	MR-P	1542	1.6260	2	232	0.0159
IA0056855	City of Lidderdale	Controlled	City	MR-P	359	0.1350	2	70	0.0024
IA0075281	DNR Springbrook State Park-Campground Area	Daily	Semi-Public	MR-P	156	0.1110	2	4	0.0019
IA0075272	DNR Springbrook State Park-Education Center	Daily	Semi-Public	MR-P	48	0.0114	2	1	0.0006
IA0061468	City of Bayard	Daily	City	MR-P	713	0.6410	2	14	0.0066
IA0021377	City of Carroll	Daily	City	MR-P	20868	4.8220	1	1021	0.4635
IA0024571	City of Glidden	Daily	City	MR-P	3593	1.2000	2	34	0.0154
	Middle Raccoon at Panora Subtotal								**0.5063**
IA0035181	City of Dedham	Controlled	City	SR-R	350	0.5000	2	98	0.0033
IA0041866	City of Guthrie Center	Controlled	City	SR-R	2222	1.3240	2	1374	0.0946
IA0075817	City of Halbur	Controlled	City	SR-R	216	0.1070	2	65	0.0023
IA0036099	City of Redfield	Controlled	City	SR-R	1222	3.6600	2	742	0.0515
IA0068381	Diamond Head Lake	Controlled	Semi-Public	SR-R	313	0.2500	2	118	0.0082
IA0041874	City of Bagley	Daily	City	SR-R	365	0.3650	2	10	0.0043
IA0057045	City of Panora	Daily	City	SR-R	6174	1.2070	1	122	0.0554
IA0041858	City of Stuart	Daily	City	SR-R	1701	3.1320	2	46	0.0210
IA0075361	Rose Acre Farms, Inc. Guthrie Center Egg Farm	Daily	Industry	SR-R	0	0.5400	1	370	0.1680
	South Raccoon at Redfield Subtotal								**0.9148**

Table 3-8…continued

EPA_ID	Facility Name	Flow Type	Permit Type	Basin	Population Equivalents	Max Flow Rate (MGD)	TKN Estimate Type	Daily TKN (lb/day)	Daily TKN (Mg)
IA0077101	West Central Cooperative	Continuous	Operation Permit	RR-VM	377	0.8630	2	3	0.0014
IA0057096	City of Callender	Controlled	City	RR-VM	407	1.4100	2	297	0.0050
IA0031216	City of Churdan	Controlled	City	RR-VM	698	0.1400	2	68	0.0046
IA0076244	City of Harcourt	Controlled	City	RR-VM	365	3.4200	1	9	0.0003
IA0023418	City of Minburn	Controlled	City	RR-VM	407	0.8200	2	186	0.0064
IA0060321	City of Paton	Controlled	City	RR-VM	489	2.5000	2	50	0.0026
IA0032824	City of Pomeroy	Controlled	City	RR-VM	898	1.4100	2	518	0.0269
IA0041882	City of Rippey	Controlled	City	RR-VM	419	0.4000	2	53	0.0028
IA0076465	Country View Estates	Controlled	Semi-Public	RR-VM	42	0.7050	2	8	0.0003
IA0076562	Ortonville Business Park	Controlled	Semi-Public	RR-VM	144	0.0140	2	3	
IA0041921	City of Adel	Daily	City	RR-VM	4820	3.1750	3	133	0.0603
IA0056821	City of Desoto	Daily	City	RR-VM	1317	0.9900	2	27	0.0124
IA0027421	City of Earlham	Daily	City	RR-VM	952	1.4980	1	35	0.0159
IA0028967	City of Farnhamville	Daily	City	RR-VM	467	0.2550	2	12	0.0053
IA0020966	City of Gowrie	Daily	City	RR-VM	1629	1.6250	2	28	0.0127
IA0032379	City of Perry	Daily	City	RR-VM	20958	8.9060	1	992	0.4504
IA0002089	Tyson Fresh Meats Perry	Daily	Industry	RR-VM	60000	3.7400	3	1512	0.6864
	Raccoon River at Van Meter Subtotal								**4.8718**
IA0068888	Iowa Dot Rest Area #21 & #22 I80 Waukee	Controlled	Semi-Public	RR-DM	287	0.0600	2	62	0.0032
IA0036021	City of Van Meter	Controlled	City	RR-DM	1341	1.5750	2	257	0.0132
IA0032794	City of Waukee	Daily	City	RR-DM	7868	5.4760	1	138	0.0628
IA0035319	City of Dallas Center	Daily	City	RR-DM	1904	2.2300	1	43	0.0196
	Raccoon River at DMWW Subtotal								**4.9706**
IA0078638	Storm Lake MS4	Event based	Storm-water				4		
IA0078875	Waukee MS4	Event based	Storm-water				4		
IA0079201	E. R. Peterson & Sons	Event based	Agricul-tural				4		
IA0080250	Wiederin Feedlot	Event based	Agricul-tural				4		
IA0077755	S & S Farms	Event based	Agricul-tural				4		
IA0078590	Van Meter Feedyard	Event based	Agricul-tural				4		
IA0080284	Ray Lenz, Inc.	Event based	Agricul-tural				4		
IA0077810	Wendl Feedlot	Event based	Agricul-tural				4		
IA0076295	Hy.Vac	Event based	Agricul-tural				4		
IA0079731	Corey Agriculture, Inc.	Event based	Agricul-tural				4		
IA0080292	Pudenz, Lynn	Event based	Agricul-tural				4		
IA0078883	Grimes MS4	Event based	Storm-water				4		
IA0078867	Clive MS4	Event based	Storm-water				4		
IA0076767	Vigorena Feeds	Land Applied	Operation Permit				4		
IA0080390	Vonnhame Farms Trailer Wash Out	Land Applied	Operation Permit				4		
IA0079782	City of Truesdale	None	City				4		

Note: The daily TKN load for Rembrandt Industries Inc. was based on an industrial discharge, but it is now domestic only. The TKN load for Rembrandt Industries Inc. should be reevaluated during Phase 2 after site specific data is available.

The methods used to estimate point source nitrogen loads in the Raccoon River are provided in Herring (2006a; Appendix B). Table 3-8 lists the 77 facilities in the basin, their subbasin location (identification number), their EPA permit number, permit type, and discharge frequency. The daily point source loads for TKN for various subbasins were compiled as various subtotals. Thus the following subbasins were used to estimate the point source loads at various watershed outlets:

- NR-SC = North Raccoon River load at Sac City
- NR-SC + NR-J = North Raccoon River load at Jefferson
- MR-P = Middle Raccoon River load at Panora
- MR-P + SR-R = South Raccoon River load at Redfield
- SR-R + NR-J + RR-VM = Raccoon River load at Van Meter
- RR-VM + RR-DM = Raccoon River load at DMWW in Des Moines

The point sources include municipal, industrial, semi-public, sanitary district stormwater, agricultural, and operation permits. Pollutants were discharged to receiving waters either daily or as controlled discharge (i.e., supposed to discharge only when receiving stream flows are high). Event based discharges or land applications of pollutants were also considered in this point source inventory. When data were available, discharge rates (flow rates) and concentration data for TKN were evaluated as maximum measured or maximum estimated values.

Estimating daily loads from WWTPs with controlled discharge presents challenges in TMDL development. For the Raccoon River TMDL, monthly discharge records from WWTPs were examined to see if monthly patterns of discharges emerged. In the majority of cases, there was a typical spring and late fall discharge period, but the actual months of discharge varied year-by-year. While many previous TMDLs could evaluate discharge loads from facilities with controlled discharge on an annual basis and thus avoid problems related to the timing of releases, current EPA guidance indicates loads are to be calculated on a daily basis only. Thus, for the Raccoon River TMDL, the total annual controlled discharge load from a WWTP was determined and then divided by 365 days per year to obtain an estimate of daily discharge load. The approach would tend to overestimate the influence of the controlled discharge WWTP's at low flows since these facilities would not typically discharge during these periods and underestimate their effect at high flows when they would typically discharge. The daily load estimate determined for controlled discharge WWTPs can be converted to a typical two-month discharge period by multiplying the daily waste load allocation by 365 to obtain an annual load, and then dividing by the number of months when discharge occurred (typically two) and the number of days in the month. This conversion would allow for facility-specific waste loads to be assessed on a daily basis for time period when discharge may occur.

Highest maximum daily TKN loads were estimated for two IBP plants in Storm Lake and Perry where loads were 3260 and 1512 lb/day, respectively (Table 3-8). The City of Guthrie Center had the highest estimated daily controlled discharge effluent load (1374 lbs/day) when the lagoon was discharged. However, when annualized, the daily load from Guthrie Center was substantially less than many daily dischargers (0.095 Mg/day). Five facilities contributed TKN loads to the Raccoon River basin greater than 992 pounds per day (lbs/day) (all other loads were less than 330 lbs/day): Tyson Meats Storm Lake (3,260 lbs/day), Tyson Meats Perry (1,512 lbs/day), City of Storm Lake WWTP (1,080 lbs/day), City of Carroll WWTP (1,021 lbs/day) and City of Perry WWTP (992 lbs/day).

In this TMDL, the estimated nitrate loads from point sources contain a substantial margin of safety. First, TKN loads are allocated rather than nitrate directly. The estimate of TKN would include ammonia which would be oxidized to nitrate as well as organic nitrogen which would not add to the nitrate load. By assuming all TKN consisted of ammonia, subsequently converted to nitrate, this provides a margin of safety in the point source load estimates. Secondly, no in-stream nitrate assimilation (uptake) was considered in estimating the point source nitrate loads at the various watershed outlets. The degree of nitrate assimilation in the Raccoon River was estimated to provide an indication of the magnitude of this process compared to the estimated point source nitrate loads (details are provided in Appendix C). Using a typical value for nitrate uptake measured for an agricultural stream (1.65 mgN/m^2/day; Mulholland et al., 2004) and assumptions related to channel width and water velocity in the Raccoon River during 90% low flow conditions, it is estimated that the stream channel can assimilate considerably more nitrate than the amount discharged from point sources. For example, from the North Raccoon at Jefferson to the DMWW intake, the Raccoon River can assimilate approximately 1,912 Mg of nitrate during 4.3 days of water travel time. This value is nearly three orders of magnitude larger than the point source nitrate load at Jefferson (2.66 Mg), suggesting that nitrate uptake in the river could conceivably remove all the point source load in the river before the load would reach the DMWW intake at the watershed outlet. Similarly, in the Middle Raccoon River, it is estimated that 27.4 Mg of nitrate could be assimilated in the river before water flow reaches the drinking water intake at Panora. This value is also much larger than the point source nitrate load for the segment (0.51 Mg). Thus, the point source loads for nitrate in the Raccoon River watershed contain a substantial margin of safety.

3.2.2 Livestock Feeding Operations

There are currently nine livestock facilities in the watershed that have an NPDES permit (Table 3-8). However discharge of pollutants from livestock operations is set at zero tons per year (IAC – Chapter 65). Hence, the point source contribution from permitted livestock facilities in the Raccoon River watershed is assumed to be zero. Other livestock operations with less than 1000 animal units and other activities associated with all livestock operations (feedlot runoff, manure management, etc.) are considered nonpoint sources of nitrate in this TMDL report.

3.2.3 MS4 Permits

For municipalities in the watershed with an NPDES MS4 permit, development of a Storm Water Pollution Prevention and Management Program (SWMP) is required. The SWMP includes requirements for implementation of BMPs including controls to reduce pollutants in discharges from municipal application of fertilizers and operation of a public education and outreach program to inform the public of storm water impacts on water quality and measures that can be implemented to reduce water quality degradation from storm water. As recommended by the EPA, the waste load allocation for urban storm water point sources in the watershed will be implemented through the NPDES MS4 permits and will attempt to utilize best management practices in lieu of numeric limits.

3.2.4 Nonpoint Sources

Nonpoint sources of nitrate to the Raccoon River include contributions from agricultural, developed land (urban and residential areas), and natural sources. Potential nonpoint sources from agricultural sources include fertilizer, soil mineralization, legume fixation, and manure. Potential nonpoint sources from developed land sources include septic systems and turf grass fertilizer. Naturally occurring nonpoint sources include atmospheric deposition and wildlife contributions. These potential sources are briefly discussed in the following section. Potential sources of nitrate were estimated as total nitrogen inputs to the landscape with the understanding that all forms of nitrogen on the landscape have the potential to be mineralized and delivered to streams as nitrate.

The nonpoint sources of nitrogen (nitrate) in the Raccoon River watershed were evaluated using data and procedures developed for the statewide nutrient budget (Libra et al., 2004). Although the nutrient budget addressed only the 1997-2002 time period, assumptions developed for the report remain valid and budget results are useful to assess the relative contribution from the various nonpoint sources of nitrogen to the basin. Specific details and assumptions used to develop the nitrogen input estimates were presented in the nutrient budget report (Libra et al., 2004). Results are summarized for major Raccoon River basins where monitoring stations have been established, including the North Raccoon at Sac City and Jefferson, the South Raccoon at Redfield, and the Raccoon River at Van Meter. Tables 3-9 and 3-10 summarize the nonpoint source inputs of nitrogen and their relative proportions in the Raccoon River watershed above Van Meter and three major subbasins.

Table 3-9. Nitrogen inputs from nonpoint sources in various watershed areas. Inputs summarized from Libra et al. (2004).

Source Category	Nitrogen Inputs	Raccoon River at Van Meter	South Raccoon River at Redfield	North Raccoon River at Jefferson	North Raccoon River at Sac City
		----------------(nitrogen in tons per year)--------------			
Agricultural	Fertilizer	63,429	14,455	33,418	15,202
	Soil mineralization	93,747	17,686	51,278	23,605
	Legume fixation	42,685	12,753	18,800	8,013
	Manure				
	Hogs	20,353	5,039	13,079	6,835
	Cattle	9,814	4,473	4,041	1,624
	Chicken	2,574	821	801	801
	Turkey	1,857	0	1,857	1,857
Developed	Septic systems	49	14	20	12
	Turf grass	3,721	1,005	1,528	684
Natural	Atmospheric deposition	36,424	10,731	16,419	7,223
	Wildlife (deer)	97	48	17	7
	Wildlife (deer x 2)	194	96	34	14
	TOTAL	274,847	67,073	141,275	65,870

Table 3-10. Nitrogen inputs from nonpoint sources, as percentage of total, in various watershed areas.

Source Category	Nitrogen Inputs	Raccoon River at Van Meter	South Raccoon River at Redfield	North Raccoon River at Jefferson	North Raccoon River at Sac City
		----------------(percentage of total)--------------			
Agricultural	Fertilizer	23.1%	21.6%	23.7%	23.1%
	Soil mineralization	34.1%	26.4%	36.3%	35.8%
	Legume fixation	15.5%	19.0%	13.3%	12.2%
	Manure	12.6%	15.4%	14.0%	16.9%
	Hogs	(58.8%)	(48.8%)	(66.1%)	(61.5%)
	Cattle	(28.4%)	(43.3%)	(20.4%)	(14.6%)
	Chicken	(7.4%)	(7.9%)	(4.0%)	(7.2%)
	Turkey	(5.4%)	(0.0%)	(9.4%)	(16.7%)
Developed	Septic systems	0.0%	0.0%	0.0%	0.0%
	Turf grass	1.4%	1.5%	1.1%	1.0%
Natural	Atmospheric deposition	13.3%	16.0%	11.6%	11.0%
	Wildlife (deer)				
	Wildlife (deer x 2)	0.1%	0.1%	0.0%	0.0%
	TOTAL	100.0%	100.0%	100.0%	100.0%

*(58.8%) = percentage of nitrogen manure input associated with each animal group.

Results suggest that soil mineralization and nitrogen fertilizer are the largest nonpoint sources of nitrogen in the Raccoon River watershed, contributing approximately 48 to 60% of the total nitrogen input. Greater contribution from these two sources was found in the North Raccoon than South Raccoon watersheds consistent with a greater proportion of land use in row crops. Given the assumption that 20 pounds of nitrogen per row crop acre are mineralized for every one percent organic matter in the soil (Libra et al., 2004), it is clear that tilling Iowa’s organic rich soils (2-5 percent organic matter) has potential to release a substantial amount of nitrate to streams without additional fertilizer inputs. Indeed, studies of continuous corn plots with no N or very small amounts of N fertilizer applied indicate that elevated nitrate concentrations can still be lost to tile drainage water (Randall and Mulla, 2001; Gast et al., 1978). In one study, nitrate concentrations in drainage water from four plots allowed to go fallow for a six year period still exceeded 23 mg/l (Randall and Mulla, 2001). In a field study of groundwater along a non-cropped stream riparian zone, nitrate concentrations exceeded 20 to 30 mg/l for a two-year period after an overlying grass cover was removed (Schilling et al., 2006). In addition, studies of corn yields in Iowa suggest that even in plots without fertilizer N or no manure applied for many years, corn yields still averaged 50 to 60 bu/acre in continuous corn and 100 to 110 bu/acre in soybean-corn rotation (Sawyer et al., 2006). More commonly, fertilizer and manure added to cropped fields increases the soil organic matter N and this total N pool is available for mineralization. Thus a major source of nitrogen to the Raccoon River is leaching of soil nitrogen derived from organic matter, manure and fertilizer in row crop fields.

Fertilizer N applied to row crop fields was estimated to account for 22 to 24 percent of the total nitrogen inputs in the watershed. However, it should be noted that estimations fertilizer use in Iowa are poorly documented. In the state nutrient budget, estimated fertilizer N input were derived from county fertilizer sales statistics and then apportioned to corn acres in a watershed (Libra et al., 2004). The proportion of fertilizer sales in each county was applied to the statewide amount of N and P to generate the amount of N and P used in each county. Unit prices were also held constant across the state. Thus, while fertilizer use is a major source of N in the watershed, its actual amount remains an estimate only.

A second method of estimating N fertilizer use in the Raccoon River was conducted to verify the nutrient budget estimate. Information provided by cooperatives in the Raccoon River watershed through the ACWA indicated that on average 142 lbs/ac of N (NH_3, urea, UAN) was applied to 95 percent of corn ground in the counties that comprise the watershed. They also estimated that an average of 76 lbs/ac of P was applied to 60 percent of the crop ground. Using these values and the proportion of corn and soybean acres in the Raccoon River watershed, the total annual N fertilizer use in the watershed was estimated to be 63,057 tons. This value is remarkably close to the estimate based on the sales data in the nutrient budget (63,429 tons) and suggests that estimates of the fertilizer N use in the watershed are reasonable.

Legume fixation by crops such as soybeans, alfalfa and other hay and pasture may be a significant source of nitrogen in agricultural watersheds. Legume fixation is the process by which symbiotic bacteria around the roots of the plant convert elemental nitrogen gas (N_2) to inorganic nitrogen. The rate of nitrogen fixation varies by crop, with soybean N fixation estimated to be 2 lbs N/bu, alfalfa at 50 lbs N/ton and other hay and pasture at 90 lbs N/acre (Libra et al., 2004). Legume fixation accounted for 15.5 percent of the total nitrogen in the Raccoon River watershed above Van Meter, comprising a higher percentage in the South Raccoon (19 percent) than the North Raccoon (12-13 percent). A higher percentage in the South Raccoon is consistent with a greater proportion of land area in grassland, pasture or alfalfa.

Nitrogen from animal manure accounted for 12.6 to 16.9 percent of the total nitrogen inputs in the watershed (Table 3-10). Most of the manure N was associated with hogs (48.8 to 61.1 percent) and cattle (14.6 to 43.3 percent). A greater proportion of manure N was associated with cattle in the South Raccoon watershed than in the North Raccoon, whereas contributions from hog manure N comprise nearly two-thirds of the manure N in the North Raccoon above Jefferson. Poultry manure (chicken and turkey) was a substantial source of manure N in the North Raccoon watershed above Sac City (24 percent), but comprised only 13 percent of the manure N above Van Meter.

Nitrogen sources from developed lands (urban and residential areas) considered N contributions from septic systems and turf grass. Rural septic systems can be a significant source of total nitrogen to groundwater that may eventually discharge to surface water. The failure rate of septic systems varies considerably across counties in the Raccoon River watershed. County sanitarians who responded to requests for septic system information indicated that in some counties (Carroll, Guthrie, Adair, Audubon), from 70 to 90 percent of the systems would be considered failing due to lack of maintenance, failure to meet existing codes or are simply out of date (non-permitted). In regions where permitting regulations have been enforced, septic systems are monitored regularly and failure rates are much lower. Dallas County reported only a minor percentage of systems out of compliance, whereas at Lake Panorama where a management district checks nearly 800 septics regularly, all systems meet code and there is little potential for septic problems. For this TMDL, in order to build in a margin of safety, it was assumed that all septic systems have failed in the Raccoon River watershed.

While information regarding the specific number and status of septic systems in the watershed is not available, it can be reasonably assumed that rural populations rely nearly exclusively on septic systems for waste disposal. Using the 2000 U.S. Census estimate of rural population in the watershed and an estimated rate of 9.9 lbs N/person per year (Libra et al., 2004), the amount of N from septic systems in the Raccoon River watershed above Van Meter was estimated to be 49 tons N per year (Table 3-9). In terms of the other N inputs in the watershed, septic systems were found to contribute less than 0.05 percent of the total N.

Nitrogen inputs from turf grass considered commercial N applied to urban lawns, golf courses and other grasslands in incorporated areas. Turf grass fertilizer use was estimated from sales data by county and applied equally to all grasslands with incorporated areas. Estimated turf grass N in the watershed area above Van Meter was estimated to 3,721 tons/year, or approximately 1.4 percent of the total N inputs (Table 3-10).

Natural sources of N considered contributions from atmospheric deposition and wildlife, with atmospheric N inputs comprising an estimated 13.3 percent of the total N input to the watershed above Van Meter (Table 3-10). This percentage was equivalent to the contribution of manure N to the watershed. Atmospheric deposition was evaluated as the sum of wet and dry nitrogen dissolved in rain, attached to wind-blown particles, or existing as aerosols as estimated from rainfall monitoring records and other reports (Libra et al., 2004). While rainfall sources of N can be considered "natural", the concentrations of nitrogen in precipitation are likely influenced by agricultural activities, including N volatilization from fertilizer, manure storage, and crop senescence, as well as wind-blown erosion of soil N during crop planting and harvesting. Monitoring near Iowa State University in Ames has indicated approximately 2.5 mg/l of nitrogen in Iowa rainfall (Libra et al., 2004).

Contributions of N from wildlife in Iowa are difficult to assess due to lack of estimates of animal species densities. The closest approximation of wildlife density in Iowa is developed from deer populations tracked by the Iowa DNR. Deer populations are estimated annually for each county in Iowa for hunting and licensing purposes. From the nutrient budget it was estimated that deer populations numbered 13,291 in the Raccoon River watershed above Van Meter, and 6,635 above Redfield (South Raccoon), 2,395 above Jefferson and 901 above Sac City. With an estimated 0.05 lbs N generated per deer/day, it was estimated that deer contribute 97 tons of N per year in the Raccoon River watershed above Van Meter, which is approximately double the estimated contribution from septic systems. Because data is not available for wildlife densities for other animals, it was estimated that total wildlife N in the watershed could be approximated by multiplying the deer N contribution by a factor of two. Hence, total wildlife N was estimated to be 194 tons per year or 0.1 percent of the total N in the watershed (Table 3-10). It is evident that more work is needed to estimate contributions from all forms of wildlife to nonpoint source N loads in Iowa watersheds.

3.3 TMDL Approach and Target

As previously discussed in Section 3.1, a TMDL is required for the Raccoon River for nitrate. For nitrate, the TMDL was calculated using a duration curve analysis to assess the relation of measured daily loads to the water quality benchmark across a range of flow conditions. This approach was deemed appropriate because nitrate concentrations often varied by flow, tending to increase in concentration as streamflow discharge increased. In this Section, a general discussion of the TMDL calculation is initially presented followed by a discussion of the duration curve modeling approach. TMDLs developed for nitrate impairments in the Raccoon River and Middle Raccoon River are presented in Sections 3.4 and 3.5, respectively.

3.3.1 Waterbody Pollutant Loading Capacity

A TMDL is a calculation of the maximum amount of pollutant that a water body can receive and still meet water quality standards and/or designated uses. It is the sum of the loads of the selected pollutant from all contributing point and nonpoint sources. The TMDL is developed according to the following equation:

TMDL = WLA + LA + MOS

where:

TMDL = Total Maximum Daily Load
WLA = Waste load allocation (point sources)
LA = Load allocation (nonpoint sources)
MOS = Margin of safety (may be implicit or explicit)

The WLA includes contribution from point sources in the Raccoon River watershed, including discharge from municipal and industrial sewage treatment plants, MS4 permits and large animal feeding operations (see Table 3-8). The LA includes contributions from all nonpoint sources (agricultural, developed land and natural sources; see Table 3-9) as well as animal feeding operations and feedlots not covered in the point source inventory. The MOS is the part of the allocation that accounts for uncertainty that the allocations will result in attainment of water quality standards.

The three TMDL components (WLA, LA, MOS) were all calculated as daily loads. For nitrate, the daily load was measured in metric tons of nitrate per day (Mg). Metric tons are very similar to standard U.S. tons and can be converted by multiplying by a factor of 1.1.

3.3.2 Modeling Approach

The load duration curve (LDC) modeling approach was used in this TMDL to compare measured pollutant concentrations and daily flow data to the water quality standard at a range of flow conditions. The LDC method involves developing a flow duration curve or a representation of the percentage of days in a year when a given instream flow occurs. A lower percentile rank of flow indicates periods when flow rarely occur and typically represent high flow periods (storm events), whereas a low percentile rank of flow indicates periods when flow is exceeded most of the time (low flow periods). The allowable pollutant load curve is calculated using the flow duration curve by multiplying the flow values to the applicable TMDL target. The observed pollutant loads in the river are plotted on the developed curve and the points that fall above the allowable load curve indicate exceedances while the points that fall below the curve indicate acceptable loads.

Monitoring data that exceeds the water quality standard at high flows (low percentile) indicates pollutant sources that are problems during major precipitation and runoff events. Examples might include nitrogen or manure runoff from cropped fields after a heavy rainfall. Monitoring water quality violations at low flows (high percentiles) are often from continuous direct discharges, such as wastewater treatment plants, cattle in streams or failed septic systems. The load duration curve analysis can often separate the impact of point and nonpoint sources on stream water quality.

3.3.3 TMDL Target

The TMDL target for nitrate is as follows:

Pollutant	TMDL Target	Rationale for Target
Nitrate	10 mg/l	Class C water quality standard applies to drinking water intakes at DMWW and Panora

3.3.4 Margin of Safety

The TMDL target requires that stream nitrate concentrations do not exceed the target level for the entire range of streamflow. However, the TMDL target above does not include a margin of safety (MOS). The TMDL equation can be rearranged to reflect the MOS in the TMDL target as follows:

$$\text{TMDL} - \text{MOS} = \text{WLA} + \text{LA}$$

A MOS can be either explicit or implicit in the TMDL. For the Raccoon River, both MOS categories were used for nitrate. An explicit MOS of 5% (0.5 mg/l) was used for the 10 mg/l TMDL target. Thus a nitrate TMDL target that includes a MOS is 9.5 mg/l (10 mg/l TMDL – 0.5 mg/l MOS).

The explicit MOS is reinforced for nitrate through conservative assumptions implicit in the representation and modeling of point and nonpoint sources. In particular, the point source contributions were calculated using many conservative assumptions that overestimated the point source contributions. For example, point source loads were based on TKN concentrations, not nitrate, and thus overestimated pollutant discharge concentrations. When measured point source data were not available, estimates were based on population estimates. Comparing population-estimated data with measured data, it is apparent that the estimated data greatly overestimated nitrate discharge loads. Estimates based on population do not consider denitrification losses that occur during the treatment process and thus overestimate point source loads.

3.4 TMDL for Nitrate at City of Des Moines

3.4.1 Existing Load

The existing load for nitrate measured at the City of Des Moines is shown on the load duration curve (Figure 3-10). Based on 10 years of daily nitrate concentration and flow data (1996 to 2005), the daily nitrate load (in metric tons) was plotted against the percentile of streamflow. Results indicate that a wide range of nitrate loads was measured during the 10-year period and that nitrate loads varied with streamflow. Also shown in Figure 3-10 is the TMDL with and without a margin of safety. As noted above, these lines were derived from multiplying the TMDL target concentration by the daily flow, thus delineating the acceptable range of nitrate load for the range of flow conditions encountered during the 10-year period. Comparing the measured nitrate load (points) to the TMDL including a MOS (9.5 mg/l) indicates that many days had daily nitrate loads above the TMDL. These exceedances were more prevalent at high flows than low streamflows, but exceedances did occur at flow conditions above about the 85th percentile. The range of flow conditions account for seasonal and annual variations during the assessment period.

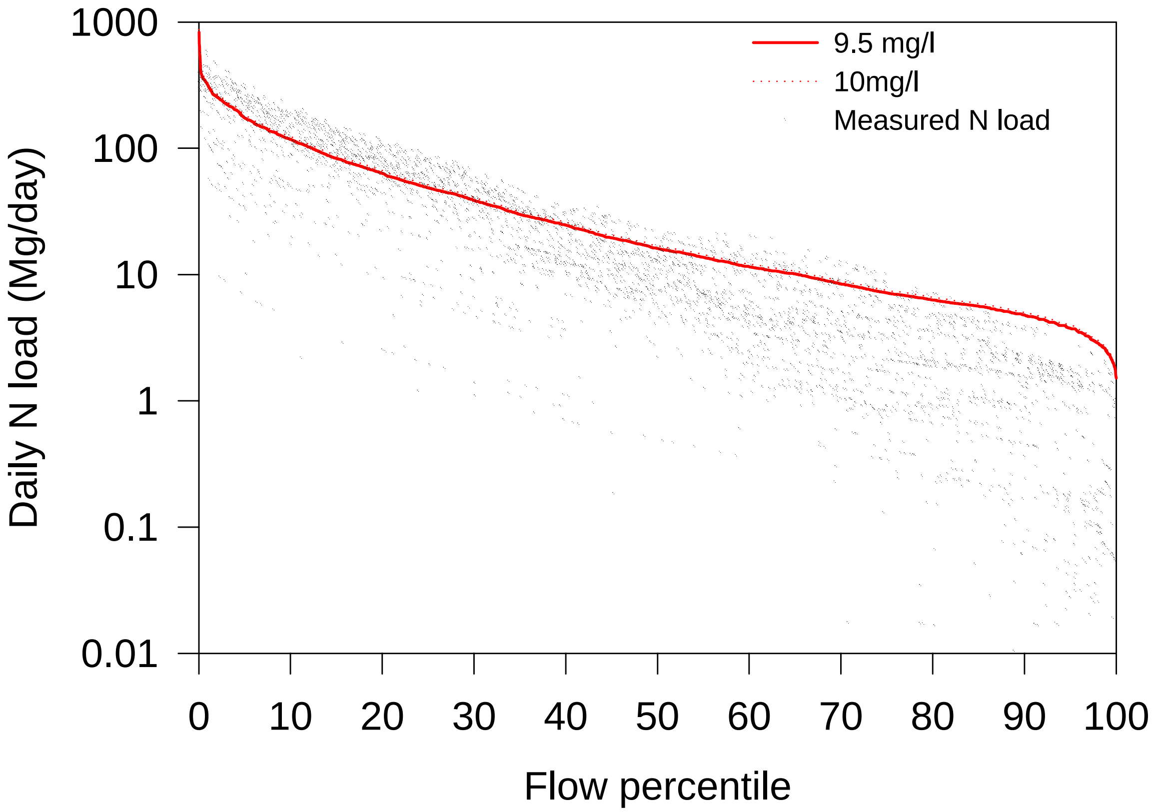


Figure 3-10. Load duration curve for daily Raccoon River nitrate loads at DMWW from 1996 to 2005. Point source load is taken from Table 3-8. Upper dashed line is TMDL target (10 mg/l) and solid red line is TMDL target – margin of safety (see text for further explanation).

As shown in Figure 3-10, at no times during the 10-year monitoring period does the point source nitrate loads exceed the TMDL target with a MOS. Thus, the difference between the point source load and measured load is attributable to nitrate loads derived from nonpoint sources. For the entire range of flow conditions, a nitrate load from nonpoint sources is required in order for measured nitrate loads to exceed the TMDL target (with and without the MOS).

3.4.2 Departure from Load Capacity

Figure 3-10 indicates that daily nitrate loads exceed the TMDL target across much of the range of flow conditions, but greater exceedances typically occurred during higher flows. Thus the difference between the current existing load and the desired TMDL target (9.5 mg/l) was evaluated by deciles of flow (10 percent flow ranges) (Table 3-11). The maximum daily nitrate reduction required to meet the required TMDL target in each flow range was identified. This number represents the maximum amount of nitrate reduction needed for all measured loads in a flow range to be reduced below the TMDL target. Also shown in Table 3-11, is the percentage of days in each flow range that exceeded the TMDL as well as the mean percentage reduction in each flow range. The mean value is presented to evaluate a middle of the road nitrate reduction scenario that accepts that nitrate exceedances will occasionally occur but assesses how much nitrate reduction is needed to reduce the exceedances by half. Also shown on Table 3-11 is the mean daily nitrate load in each flow decile. The values decreases greatly with flow, with the daily nitrate loads in the 100-90 percent decile more than 190 times greater than the 0 to 10 percent range. Finally, the percentage of the nitrate load from nonpoint and point sources are presented in Table 3-11 for the days when exceedances occurred. This percentage breakdown is useful when considering whether nonpoint or point sources are contributing more when nitrate loads exceed the TMDL.

Table 3-11. Summary of nitrate reductions needed, days requiring nitrate load reductions and percentage of load derived from nonpoint and point sources in Raccoon River at DMWW. Load reductions summarized for each flow range decile of streamflow

Flow Range	Max. Flow in Range (cfs)	Load Exceedance Factor [1]	Maximum Reduction Needed (%)[2]	% of Days Needing Reduction	Mean Reduction Needed (%)[2]	Max. Nitrate Load (Mg)	Mean NPS Contrib. (%)[3]	Mean Point Source Contrib. (%)[3]
100-90	35700	1.93	48.1	52.1	24.4	584.1	97.8	2.2
90-80	5070	1.89	47.0	64.7	25.4	202.0	95.5	4.5
80-70	2730	1.89	46.6	57.5	23.5	106.5	92.3	7.7
70-60	1660	1.67	40.3	34.0	16.8	60.7	86.7	13.3
60-50	1060	1.63	38.7	19.2	17.6	33.9	79.6	20.4
50-40	691	1.63	38.7	16.4	16.7	21.2	69.1	30.9
40-30	495	1.79	44.4	15.3	16.0	20.0	57.3	42.7
30-20	361	1.48	32.4	10.1	16.6	12.2	44.5	55.5
20-10	270	1.12	10.8	1.4	6.3	7.0	22.3	77.7
10-0	205			0.0				
100-0 (all data)		1.93	48.1	27.0	21.8	584.1	89.7	10.3

[1] Multiplication factor to assess degree of nitrate load exceedance (i.e., existing load in 100-90 range exceeds TMDL by factor of 1.93).
[2] Reductions determined for only those days with an exceedance.
[3] Nitrate source contributions determined for only those days with an exceedance.

Nitrate loads exceeded the TMDL target of 9.5 mg/l at all flow ranges above 10 percent, that is, all but the lowest 10 percent of flows had a daily nitrate load that exceeded the TMDL. In the 100-90 percentile, nitrate loads exceeded the TMDL by a factor of 1.93, nearly double the acceptable nitrate load allowed. The exceedance factor generally decreased with decreasing flow, and loads in the 10-20 percentile exceeded the TMDL by a factor of 1.12. Greatest reduction of daily nitrate loads is associated with the highest daily flows when a maximum reduction of 48.1 percent is needed in the 100-90 percentile. The maximum amount of nitrate reduction required decreases with decreasing decile range. Similarly, the percentage of days in each flow decile that exceed the TMDL decreases with decreasing flow percentile, although interestingly, the percentage of days exceeding the TMDL is greater in the 80-90 percentile than in the 90-100 percentile. For days with flows in the upper 30 percent, nitrate concentrations exceed the TMDL target of 9.5 mg/l more than 52 percent of the time. The mean percent reduction needed when nitrate loads exceed the TMDL varies less than the maximum amount, ranging from 21 to 38 percent in flow percentiles greater than 20 percent.

When nitrate loads exceeded the TMDL in the upper 30 percent of flows, nonpoint sources contributed more than 92 percent of the total loads (Table 3-11). With decreasing flow decile, the proportion of nonoint to point source loads changed as the relative proportion of point source inputs increased. This is a function of the constant point source inputs compared against the decreasing nitrate load. The ratio of nonpoint to point source decreased with decreasing decile range, but the percentage of days in each flow range also decreased. Thus, when flows were in the 10 to 20 percentile range, only about 1.4 percent of the days exceeded the TMDL target of 9.5 mg/l, but when the exceedances did occur, point sources could conceivably comprise approximately 78 percent of the nitrate load. When flows in the Raccoon River were at their lowest level (0 to 10 percent), no exceedances of the TMDL target occurred during the 10-year monitoring period despite the point source contribution line above the target TMDL. This indicates that the estimated point source load in the watershed is greater than the actual nitrate load delivered to the DMWW in Des Moines. Hence, there would appear to be a significant MOS implicit in the estimated point source load.

Overall for the entire flow range, the maximum percent reduction needed was 48.1 percent and mean reduction percent for all daily exceedances was 21.8 percent. Over the 10-year monitoring period, 27 percent of the days exceeded the TMDL with a MOS. When exceedances occurred, nonpoint sources contributed to 89.7 percent of the nitrate loads whereas point source contributions were 10.3 percent.

3.4.3 Seasonal Variation

Seasonal variation in nitrate loads in the Raccoon River at the City of Des Moines was evaluated by analyzing the daily nitrate load data by month (Table 3-12). Table 3-12 includes the same columns as Table 3-11. The greatest maximum reduction of nitrate is needed in the months of May and June when reductions greater than 46.6 percent are needed. During these two months, more than 68 percent of the days exceeded the TMDL and nonpoint sources contributed more than 95 percent of the nitrate load. Daily maximum nitrate load reductions greater than 30 percent are needed in seven months, although the percentage of days needing a load reduction was less than 39 percent (July). The month needing the least nitrate load reduction was September, when less than 1 percent of the days exceeded the nitrate load TMDL. Similarly, fewer than 10 percent of the days in February, March, August, September and October needed a nitrate load reduction. Like the flow deciles, nonpoint sources contributed more than 90 percent of the nitrate load when exceedances occurred.

Table 3-12. Summary of nitrate reductions needed by month in Raccoon River at DMWW.

Month	Load Exceedance Factor [1]	Maximum Reduction Needed (%)[2]	% of Days Needing Reduction	Mean Reduction Needed (%)[2]	Max. Nitrate Load (Mg)	Mean NPS Contrib. (%)[3]	Mean Point Source Contrib. (%)[3]
Jan	1.79	44.2	17.7%	14.2	62.4	55.4%	44.6%
Feb	1.24	19.5	9.2%	10.3	86.4	57.8%	42.2%
Mar	1.30	23.1	10.4%	7.6	275.1	81.3%	18.7%
Apr	1.77	43.6	36.3%	20.3	364.3	92.7%	7.3%
May	1.93	48.1	67.7%	27.9	584.1	95.3%	4.7%
Jun	1.87	46.6	72.3%	28.8	447.0	95.0%	5.0%
Jul	1.52	34.0	39.0%	16.6	370.5	92.3%	7.7%
Aug	1.34	25.1	6.5%	15.1	172.8	89.4%	10.6%
Sep	1.04	4.2	0.7%	4.2	32.3	81.5%	18.5%
Oct	1.37	26.9	6.8%	13.7	55.1	80.8%	19.2%
Nov	1.48	32.4	27.0%	16.1	150.0	76.5%	23.5%
Dec	1.63	38.7	30.0%	20.8	100.6	75.4%	24.6%

[1] Multiplication factor to assess degree of nitrate load exceedance (i.e., existing load in Jan exceeds TMDL by factor of 1.79).
[2] Reductions determined for only those days with an exceedance.
[3] Nitrate source contributions determined for only those days with an exceedance.

3.4.4 Pollutant Allocation

The pollutant allocation is the amount of daily nitrate load allocated to point sources (wasteload allocation), nonpoint sources (load allocation) and a margin of safety.

Wasteload allocation. Point sources do not contribute substantially to the nitrate impairment at the DMWW in the City of Des Moines. Therefore, the total wasteload allocated to point sources in the Raccoon River above the City of Des Moines is set to the existing point source load (4.97 Mg/day). This is appropriate for two main reasons: 1) the point source load estimate is very conservative and contains a substantial margin of safety (see

Section 3.2.1); 2) when nitrate exceeded the TMDL in the 10-years of monitoring, approximately 90 percent of the exceedance was due to nonpoint source contributions. Thus, nitrate loads from point sources appear to have little effect on daily nitrate exceedances in the Raccoon River above the City of Des Moines. The only measurable effect of point source contributions have on nitrate loads occurs when flows are in the lowest quartile and even then, point sources contributed only an average of 4 to 8 percent of the total nitrate load. The daily wasteload allocation for individual point sources is provided in Table 3-13.

The total wasteload allocated for NPDES permitted livestock animal feeding operations in the Raccoon River watershed is zero in accordance with IAC Chapter 65. In lieu of numeric standards for urban storm water sources in the watershed, the wasteload allocation will be implemented through the NPDES MS4 permits and utilize best management practices to reduce storm water runoff.

Load allocation. Nonpoint sources are contributing to the majority of the nitrate impairment in the Raccoon River measured at Des Moines. Because the daily nitrate load varies by flow, the load allocation will also vary by flow. The load allocation is set using the following equation:

LA = TMDL (10 mg/l x Flow)– WLA (4.97 Mg/day) – MOS (0.5 mg/l x Flow)

The load allocation is set to be the difference between the TMDL target of 10 mg/l and the sum of the WLA and the MOS. This is graphically illustrated in Figure 3-10 by the region between the point source line and the solid red line representing the daily nitrate load at 9.5 mg/l. Based on the maximum nitrate reduction needed for the 10-year record at the DMWW, nonpoint source nitrate loads require a reduction of 48.1 percent for all daily nitrate loads to be less than the TMDL target concentration of 9.5 mg/l. Reducing all daily nonpoint sources by this amount would ensure that all daily nitrate loads would be less than the LA. The specific nitrate load reduction needed in decile flow ranges is shown in Table 3-11. If daily flows are placed in a specific decile range, the amount of nitrate load reduction associated with each flow decile is known.

Margin of Safety. The MOS is set explicitly to be 0.5 mg/l multiplied by the daily flow. Because it is flow dependent, the actual daily nitrate MOS will vary. During all flows, establishing a MOS of 0.5 mg/l will ensure that nitrate concentrations in the Raccoon River remain less than 10 mg/l.

3.5 TMDL for Nitrate at City of Panora

3.5.1 Existing Load

The existing load for nitrate measured at the City of Panora is shown on the load duration curve (Figure 3-11). Based on three years of daily nitrate concentration and flow data (2003 to 2005) the daily nitrate load (in metric tons or Mg) was plotted against the percentile of streamflow. Results indicate that a wide range of nitrate loads was measured during the three-year period and that nitrate loads varied with streamflow. The TMDL with and without a MOS is shown on Figure 3-11. Comparing the measured nitrate load (points) to the TMDL indicates that many days had nitrate concentrations exceeding the TMDL. These exceedances primarily occurred when flow percentiles were greater than about 60 percent. The range of flow conditions account for seasonal and annual variations during the assessment period.

Table 3-13. Daily wasteload allocation for point sources in the Raccoon River watershed.

EPA_ID	Facility Name	WLA (lb/day)
IA0076554	Rembrandt Enterprises, Inc	232
IA0033219	City of Rembrandt	117
IA0046671	City of Fonda	251
IA0025950	City of Laurens	359
IA0065731	Spectra Health Care Facility STP	15
IA0064998	Tyson Fresh Meats Storm Lake	3260
IA0032484	City of Storm Lake	1080
IA0021989	City of Newell	34
IA0034312	Albert City	19
IA0033090	Sac City	74
IA0067652	City of Marathon	8
IA0057029	City of Auburn	128
IA0056103	City of Breda	77
IA0062162	City of Lanesboro	359
IA0027189	City of Manson	869
IA0020842	Lake City	868
IA0070114	Twin Lakes Sanitary Sewer District STP	581
IA0021300	City of Jefferson	125
IA0041998	City of Lake View	35
IA0026026	City of Lohrville	12
IA0020940	City of Lytton	582
IA0033715	City of Rinard	2
IA0032409	City of Scranton	16
IA0033138	Rockwell City	61
IA0028983	City of Coon Rapids	232
IA0056855	City of Lidderdale	70
IA0075281	DNR Springbrook State Park-Campground Area	4
IA0075272	DNR Springbrook State Park-Education Center	1
IA0061468	City of Bayard	14
IA0021377	City of Carroll	1021
IA0024571	City of Glidden	34
IA0035181	City of Dedham	98
IA0041866	City of Guthrie Center	1374
IA0075817	City of Halbur	65
IA0036099	City of Redfield	742
IA0068381	Diamond Head Lake	118
IA0041874	City of Bagley	10
IA0057045	City of Panora	122
IA0041858	City of Stuart	46
IA0075361	Rose Acre Farms, Inc. Guthrie Center Egg Farm	370
IA0077101	West Central Cooperative	3
IA0057096	City of Callender	297
IA0031216	City of Churdan	68
IA0076244	City of Harcourt	9
IA0023418	City of Minburn	186
IA0060321	City of Paton	50
IA0032824	City of Pomeroy	518
IA0041882	City of Rippey	53
IA0076465	Country View Estates	8
IA0076562	Ortonville Business Park	3
IA0041921	City of Adel	133
IA0056821	City of Desoto	27
IA0027421	City of Earlham	35
IA0028967	City of Farnhamville	12
IA0020966	City of Gowrie	28
IA0032379	City of Perry	992
IA0002089	Tyson Fresh Meats Perry	1512
IA0068888	Iowa Dot Rest Area #21 & #22 I80 Waukee	62
IA0036021	City of Van Meter	257
IA0032794	City of Waukee	138
IA0035319	City of Dallas Center	43
IA0078638	Storm Lake MS4	SWPP BMPs
IA0078875	Waukee MS4	SWPP BMPs
IA0079201	E. R. Peterson & Sons	0
IA0080250	Wiederin Feedlot	0
IA0077755	S & S Farms	0
IA0078590	Van Meter Feedyard	0
IA0080284	Ray Lenz, Inc.	0
IA0077810	Wendl Feedlot	0
IA0076295	Hy.Vac	0
IA0079731	Corey Agriculture, Inc.	0
IA0080292	Pudenz, Lynn	0
IA0078883	Grimes MS4	SWPP BMPs
IA0078867	Clive MS4	SWPP BMPs
IA0076767	Vigorena Feeds	0
IA0080390	Vonnhame Farms Trailer Wash Out	0
IA0079782	City of Truesdale	0

SWPP BMPs = Stormwater Pollution Prevention Best Management Practices

Note: The WLA for Rembrandt Enterprises Inc. was evaluated assuming industrial wastes were discharged but currently only domestic wastes are treated and released as a continuous discharge. Therefore, the WLA for Rembrandt Enterprises should be reassessed during Phase 2 after site specific information is available.

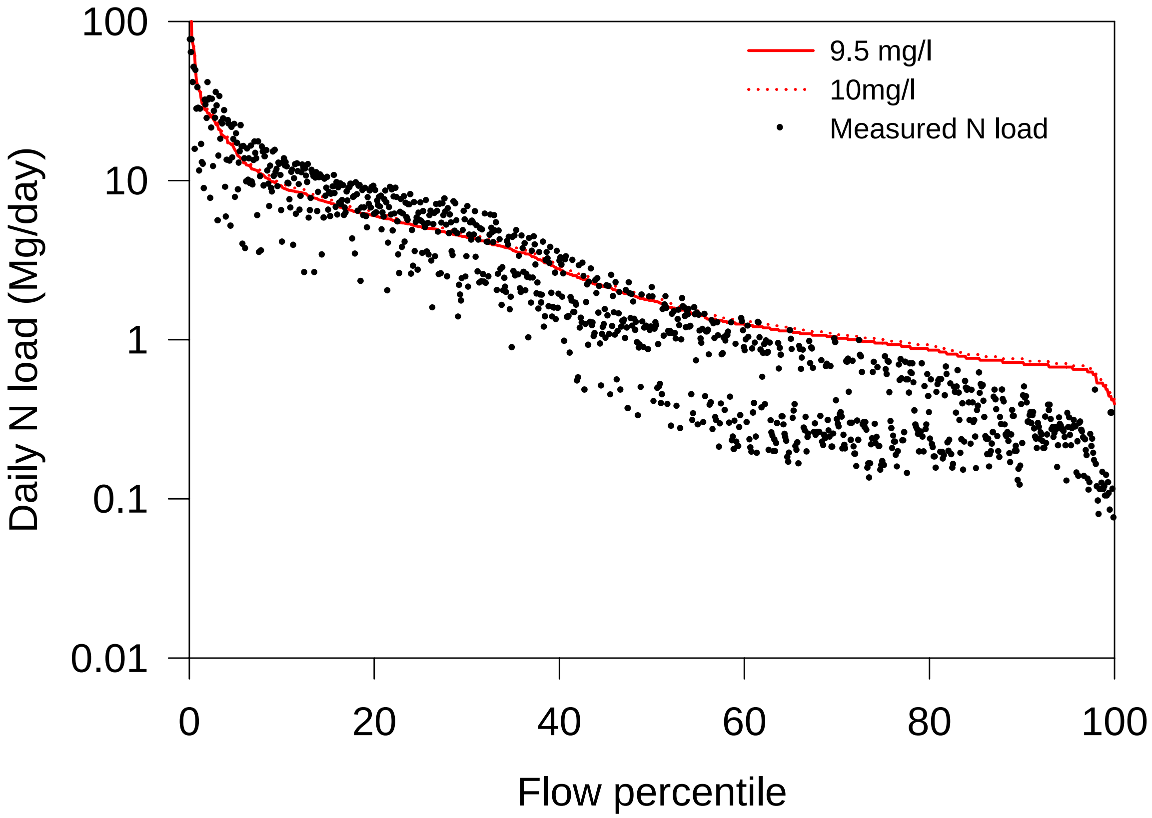


Figure 3-11. Load duration curve for daily Middle Raccoon River nitrate loads at Panora from 2003 to 2005. Point source load is taken from Table 3-8.

3.5.2 Departure from Load Capacity

The difference between the current existing load and the TMDL with a MOS (9.5 mg/l) was evaluated by quintiles of flow (20 percent flow ranges). This percentile range was selected because the length of the data record was not as great as measured at the DMWW. However, the daily record for the 3-year period of time was deemed sufficient to gauge the relation between daily flow and nitrate concentrations at 20 percent intevals.

Nitrate loads exceeded the TMDL at flow ranges greater than 20 percent, although it should be noted that only two days of 201 total days in the 20-40 percentile range exceeded the TMDL (one percent). Thus, nearly all of the nitrate load exceedances occurred in the upper 60 percent of flows. Greatest reduction of daily nitrate loads was associated with the two highest flow percentiles when a maximum reduction of 37.9 percent was needed. The number of days exceeding the TMDL target was greater than 55 percent during both upper two flow quintiles. The maximum amount of nitrate reduction required decreased to 20.2 percent in the 60 to 40 percentile range.

When nitrate loads exceeded the TMDL in the upper 40 percent of flows, nonpoint source comprised greater than 91 percent of the load (Table 3-13). During the 16.4 percent of the days that exceeded the TMDL in the 40-60 percentile range of flows, nonpoint sources comprised 75 percent of the total nitrate load. During the two days when loads exceeded the TMDL in the 20-40 percentile range, nonpoint sources comprised an average of 60 percent of the total load. Overall, for the entire flow record, nonpoint sources comprised approximately 94 percent of the total load when nitrate exceedances occurred. Thus nitrate loads at Panora are dominated by contributions from nonpoint sources.

Table 3-14. Summary of nitrate reductions needed, days requiring nitrate load reductions and percentage of load derived from nonpoint and point sources in Middle Raccoon River at Panora.

Flow Range	Max. Flow in Range (cfs)	Load Exceedance Factor [1]	Maximum Reduction Needed (%)[2]	% of Days Needing Reduction	Mean Reduction Needed (%)[2]	Max. Nitrate Load (Mg)	Mean NPS Contrib. (%)[3]	Mean Point Source Contrib. (%)[3]
100-80	5590	1.61	37.9	61.2	22.1	584.1	95.7	4.3
80-60	260	1.61	37.9	54.7	18.3	202.0	90.7	9.3
60-40	120	1.25	20.2	16.4	9.2	106.5	75.3	24.7
40-20	53	1.53	5.0	1.0	4.5	60.7	60.0	40.0
20-0	37	0.00		0.0		33.9	NA	NA
100-0 (all data)		1.61	37.9	26.7	18.9	584.1	93.8	6.2

[1] Multiplication factor to assess degree of nitrate load exceedance (i.e., existing load in 100-80 range exceeds TMDL by factor of 1.61).
[2] Reductions determined for only those days with an exceedance.
[3] Nitrate source contributions determined for only those days with an exceedance.

3.5.3 Seasonal Variation

Seasonal variation in nitrate loads in the Middle Raccoon River at Panora was evaluated using the load duration curve that accounted for seasonal and annual variations in streamflow.

3.5.4 Pollutant Allocation

Wasteload allocation. Point sources do not appear to be contributing significantly to the nitrate impairment at the City of Panora. When nitrate exceedances occurred at Panora, nonpoint sources comprised more than 90 percent of the total load (average across all flow ranges). When point sources could conceivably comprise the entire nitrate load in the river, no exceedances of nitrate were observed to occur. Therefore, the total wasteload allocation for point sources in the Raccoon River above Panora is set to the existing point source load (0.506 Mg/day). This wasteload allocation encompasses a large MOS implicit in the estimation of the point source load (see Section 3.2.1). The daily wasteload allocation for individual point sources is provided in Table 3-13.

Load allocation. Nonpoint sources appear to contributing to most of the nitrate impairment in the Raccoon River above Panora. Like the TMDL for the Raccoon River at Des Moines, the load allocation will vary by flow according to the equation:

LA = TMDL (10 mg/l x flow)– WLA (0.506 Mg/day) – MOS (0.5 mg/l x flow)

The LA is set to be the difference between the TMDL with a MOS and the existing WLA set at 0.506 Mg/day. Based on the maximum nitrate reduction needed for the 3-year daily monitoring period at the City of Panora, nonnpoint source nitrate loads will needed to be reduced approximately 61 percent in order for all daily nitrate loads to be less than the TMDL target. When flows are less than the 60 percentile, a maximum reduction of 25.3 percent is needed to meet the TMDL target. No reduction in nonpoint source loads is needed when flow are in the lowest 20 percent of flows.

Margin of Safety. The MOS is set explicitly to be 0.5 mg/l multiplied by the daily flow (units converted to Mg/day). The actual daily MOS will vary depending on the daily flow rate. During all flows, maintaining a MOS of 0.5 mg/l will ensure that nitrate concentrations in the Middle Raccoon River above Panora remain less than 10 mg/l.

3.6 Nitrate Loads in Raccoon River Subwatersheds

Although not required in this TMDL, a similar assessment of nitrate reductions and load allocations at monitored subwatersheds provides an indication of where nitrate loads could be reduced for greatest benefit to downstream nitrate impairments. LDCs were established for monitored subwatersheds at Sac City (North Raccoon), Jefferson (North Raccoon), Redfield (South Raccoon) and at Van Meter (combined North and South Raccoon rivers at confluence) (Figure 3-12). Point source nitrate contributions were evaluated in the same manner as done for the DMWW and Panora sites. Nitrate load reductions, percentage of days requiring a reduction and the proportion of nonpoint and point sources contributing during the exceedances are shown in Table 3-14.

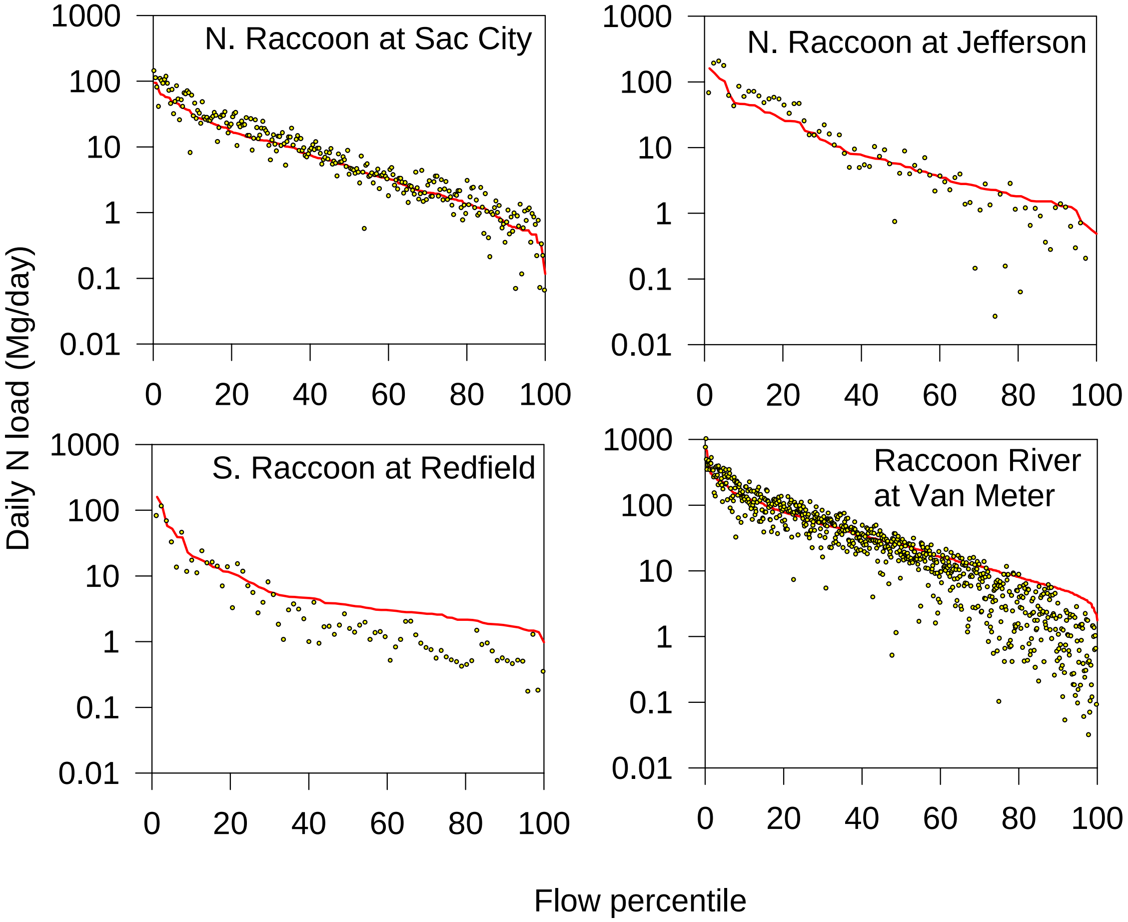


Figure 3-12. Load duration curves for daily nitrate loads at monitoring sites in the Raccoon River from 1999 to 2005. Point source loads are taken from Table 3-8.

Table 3-15. Summary of nitrate reductions needed, days requiring nitrate load reductions and percentage of load derived from nonpoint and point sources at various locations in Raccoon River watershed. Note that data from Raccoon River at Van Meter is broken into two time periods to assess effects of length of record on nitrate load reductions.

Sub-watershed	Point Source Load (Mg/ day)	Max. Nitrate Reduction Needed (%)	Days Needing Nitrate Reduction (%)	Mean Nitrate Reduction Needed (%)	% NPS During Exceed.	% Point Source During Exceed.
North Raccoon at Sac City	0.854	56.8	63.7 (165/259)	25.2	69.5	30.5
North Raccoon at Jefferson	2.664	47.2	44.9 (35/78)	28.6	70.5	29.5
South Raccoon at Redfield	0.912	32.1	11.7 (9/77)	18.2	94.2	5.8
Raccoon at Van Meter (1980-2005)	4.872	47.8	32.0 (228/712)	18.9	84.5	15.5
Raccoon at Van Meter (1996-2005)	4.872	47.8	35.5 (77/217)	23.1	89.7	10.3

Results indicate that substantial variations between the North and South Raccoon river watersheds in terms of the amount of nitrate reduction needed as well as the proportion of nonpoint and point source loads. Greatest maximum reduction in nitrate load is needed in the North Raccoon River at Sac City where a maximum reduction of 56.8 percent is needed and nearly two-thirds of the monitored days exceeded the TMDL. Point sources comprise a much large portion of the total load at Sac City when exceedances occurred (30.5 percent) compared to other gage sites and TMDLs at Des Moines and Panora. Point source contributions may account for all of the nitrate exceedance at low flows (flows exceeding 85 percent of the time). As noted in Section 3.2.1, large point source discharges occur to the North Raccoon above Sac City including the City of Storm Lake and an IBP facility at Storm Lake account for a large proportion of the point source contribution.

Substantial nitrate load reductions are also needed in the North Raccoon River at Jefferson where a maximum and average nitrate reductions of 47.2 and 28.6 percent were determined. It should be noted that the number of samples available to make the load reduction determination at Jefferson was far fewer than available at Sac City. The proportion of nonpoint to point source loads at Jefferson during the 35 days when nitrate loads exceeded the TMDL target was approximately 70 to 30 percent, respectively.

Fewer nitrate exceedances were measured in the South Raccoon River at Redfield when only 9 of 77 samples exceeded the TMDL (11.7 percent). When exceedances did occur, the maximum reduction needed was still high (32.1 percent) although much lower than the North Raccoon River sites. Exceedances were dominated by nonpoint source loads at Redfield (94.2 percent nonpoint). Interestingly, the number of nitrate exceedances at Redfield was far lower than measured upstream in the Middle Raccoon at Panora despite the Middle Raccoon River draining into the South Raccoon upstream of Redfield. This could indicate substantially less nitrate load from the South Raccoon is diluting nitrate loads in the Middle Raccoon River, or nitrate concentration losses are occurring the Middle Raccoon River at Lake Panorama, or a combination of both.

Substantial nitrate reductions are needed in the Raccoon River at Van Meter (maximum of 47.8 percent). Two periods are shown in Table 3-14 to account for a long-term 25-year sampling record as well as a sampling record similar to the record available at the DMWW in Des Moines. Both periods suggest similar levels of nitrate reduction are needed, although a higher percentage of nitrate exceedances appeared to have occurred during the last 10-years compared to the last 25-years (32.0 compared to 35.5 percent, respectively). Some of this difference may be due to irregular sampling intervals used during the two time periods. During both time periods the total loads during nitrate load exceedances were dominated by nonpoint source inputs.

4.0 TOTAL MAXIMUM DAILY LOAD (TMDL) FOR *E.COLI*

4.1 Problem Identification

The 2004 Section 305(b) Assessment Report identified five segments within the Raccoon River watershed as "partially supporting" their Class A designated uses based on results of monitoring from 2000 to 2002 for indicator bacteria (Figure 1-1). The report was based on the assessment of fecal coliform as the standard indicator bacteria and evaluated only those water quality samples collected when river flows were not materially affected by surface runoff. Hence, the water quality criterion for fecal coliform bacteria (200 orgs/100 ml) was applied to samples collected during non-runoff periods only. The IDNR used the long-term average monthly flow plus one standard deviation to determine when rivers flows were affected by runoff.

In 2003, Iowa's water quality standards and methodology for assessing indicator bacteria were changed. As of July 2003, *E.coli* is now the indicator bacterium (not fecal coliform), and the high flow exemption was eliminated and replaced with language stating that the Class A criteria for *E.coli* apply when Class A1, A2, or A3 uses "can reasonably be expected to occur." According to Chapter 61.3(1), all perennial rivers and streams as identified by the U.S. Geological Survey 1:100,000 DLG Hydrography Data Map or intermittent streams with perennial pools in Iowa are designated as Class A1 waters. The definition of Class A1 waters (IAC Chapter 61) states:

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

The applicable *E.coli* water quality standards for Class A1 waters are listed below:

Class A1	Geometric Mean	Sample Maximum
3/15 to 11/15	126	235
11/16 to 3/14	Does not apply	Does not apply

Because of the change in water quality standards, the rationale used in the 2004 305(b) report for listing the impaired segments in the Raccoon River watershed is no longer appropriate. In this TMDL, current water quality standards are applied to the impaired segments to assess their degree of attainment.

Because of the change of indicator bacteria from fecal coliform to *E.coli*, all indicator bacteria values reported in this TMDL are for *E.coli* only. When *E.coli* concentrations were measured at monitoring sites, they are reported in this TMDL. When fecal coliform concentrations were measured as the indicator bacteria, the fecal coliform concentrations were converted to estimated *E.coli* concentrations according to a regression relationship developed from monitoring data collected at ambient monitoring sites around the State of Iowa (Figure 4-1). Since *E.coli* is a subset of the fecal coliform, the ratio of the two indicator bacteria typically does not exceed one. Most frequently, *E.coli* concentrations are within 0.8 to 1 of fecal coliform concentrations (Figure 4-1). Using a statewide comparison of sampling events when both indicator bacteria were measured, multiplying the fecal coliform concentration by 0.92 is appropriate for estimating *E.coli* concentrations in the Raccoon River watershed. For the remainder of this TMDL all indicator bacteria concentrations are reported as *E.coli* concentrations, unless otherwise indicated.

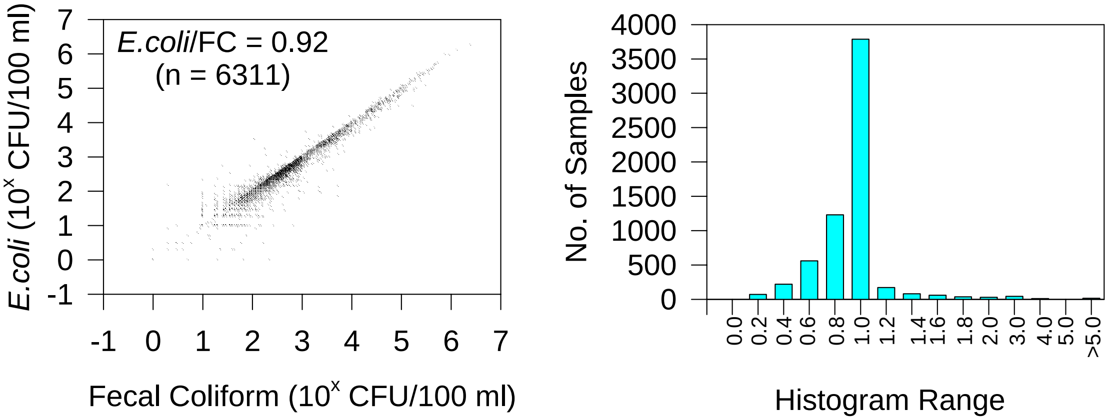


Figure 4-1. Relation of *E.coli* concentrations to fecal coliform concentrations developed from statewide monitoring (data from Eric O'Brien, Iowa DNR Watershed Monitoring and Assessment Section)

4.1.1 Indicator Bacteria Impairment in the Raccoon River, from mouth to confluence with the North and South Raccoon rivers (IA 04-RAC-0010-1&2)

The 2004 305(b) report reported indicator bacteria monitoring data from two stations in these segments to suggest that Class A uses are "partially supporting". Results from the ISU/ACOE monitoring station at Van Meter indicated that 35 percent of the 26 samples collected during the summers of 2000 to 2002 exceeded the single sample maximum value for fecal coliform. At the IDNR/UHL monitoring station, 23 percent of 13 non-runoff affected samples (condition that no longer applies) collected during the summers of 2000 to 2002 exceeded the single sample maximum value for fecal coliform. According to U.S. EPA guidelines for Section 305(b) reporting, if more than 10 percent of the samples exceed the single-sample maximum, the primary contact recreation uses are "partially supported". At both monitoring sites, geometric mean concentrations were evaluated for their periods of assessment and neither site were found to exceed the state water quality standard. However, this type of analysis is inherently flawed, when geometric means are calculated from monitoring data that span months and years. Hence, this TMDL is focused primarily on reducing exceedances from single sample maximum values.

Although the 2004 305(b) assessment considered a 2000 to 2002 assessment period, a longer assessment period was evaluated in this TMDL. Moreover, monitoring data in this TMDL considers *E.coli* only (not fecal coliform) and this TMDL does not distinguish between runoff and nonrunoff periods when comparing data to the sample maximum standard. *E.coli* concentration data were obtained from the DMWW for the 1997 to 2005 period to evaluate the degree of indicator bacteria impairment in the Raccoon River near its confluence with the Des Moines River.

Table 4-1. Summary of *E.coli* sampling information and concentrations measured by DMWW. Data are presented for recreation season period (March 15 to November 15) and for entire year. Concentrations are CFU/100 ml.

	Recreation Season			**All samples**		**Quartile – all samples**			
Year	**n > 235**	**total**	**% > 235**	**n**	**mean**	**25th**	**50th**	**75th**	**Max**
1997	58	161	36.0%	238	844	28	93	440	21430
1998	106	170	62.4%	245	1580	40	194	977	21420
1999	71	167	42.5%	240	1488	16	50	561	47860
2000	46	163	28.2%	238	468	11	33	145	20780
2001	64	166	38.6%	235	828	42	99	448	43520
2002	69	167	41.3%	240	1069	20	67	410	47860
2003	52	197	26.4%	239	1133	16	44	203	39780
2004	79	169	46.7%	243	1900	39	152	808	48840
2005	51	162	31.5%	237	1319	20	53	236	65100
Average	66.2	169.1	39.3%	239.4	1156[1]	21[1]	68[1]	405[1]	39621
Total	596	1522	39.7%	2155					

[1] value calculated from entire record, not averaged from annual records.

From 1997 to 2005, 2,155 samples were collected from the Raccoon River, of which 1,522 samples were collected during the March 15 to November 15 recreation season (Table 4-1). Results indicated that approximately 39 percent of the recreation season samples exceeded the single sample maximum value for *E.coli*. Annually, the percent exceedance ranged from 31 to 62 percent of approximately 169 samples collected during the March 15 to November 15 recreation season. The mean concentration of all samples collected by the DMWW from 1997 to 2005 was 1,156 CFU/100 ml whereas the median value was substantially lower at 68 CFU/100 ml (Table 4-1). This indicates that the bacteria concentration data are highly skewed (skewness = 7.4). Maximum annual single sample concentrations from 1997 to 2005 ranged from 20,780 to 65,100 CFU/100 ml and averaged 39,621 CFU/100 ml. Concentrations exceeded the single sample maximum value primarily during higher flow periods, although sample concentrations were greater than 235 at other times as well (Figure 4-2).

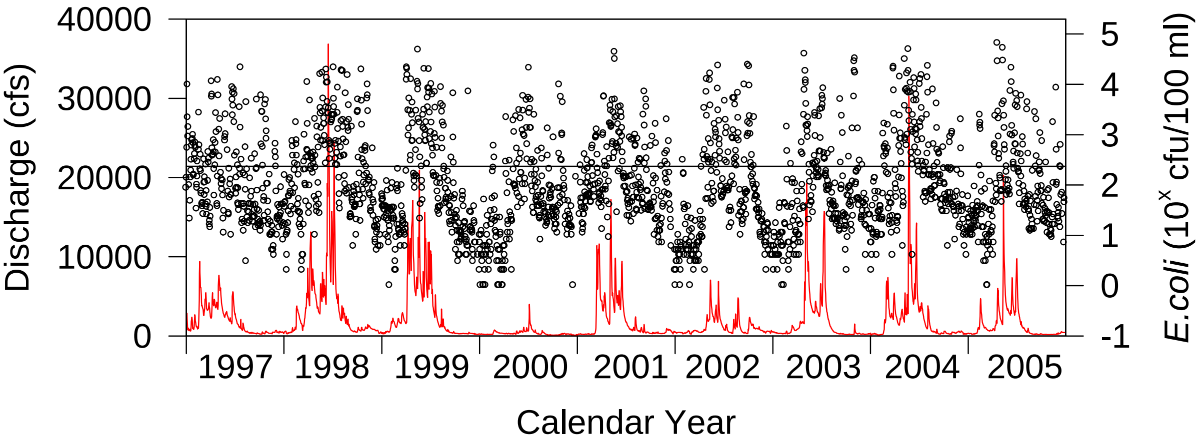


Figure 4-2. Daily streamflow at U.S.G.S. Fleur gage and *E.coli* concentrations measured by DMWW in the Raccoon River at Fleur, 1997-2005.

The 2004 305(b) assessment cited data from ambient monitoring at Van Meter collected as part of the ISU/ACOE network to indicate that Class A standards are not supported upstream of Des Moines. Water samples for bacteria analyses are collected biweekly during June through August (about nine samples per year) and thus relate to recreation season conditions. Three monitoring periods were assessed for this TMDL to provide comparisons across different time periods and with other data (Table 4-2). The long term record available at Van Meter is useful to evaluate how *E.coli* concentrations have fluctuated annually. Figure 4-3 indicates that the geometric mean of *E.coli* for the recreation season has far exceeded Iowa's Class A water quality criterion of 126 CFU/100 ml during 24 of the 25 years of monitoring at Van Meter. However, it should be noted that annual sampling patterns changed during the 25 year monitoring period. From 1980 to 1988, 15 to 25 samples were collected during the recreation season, whereas from 1989 to 2004, eight to 11 samples were collected. In 2005, 13 samples were collected from June to September. Interestingly, the plot of annual geometric mean concentrations over time suggests that concentrations have decreased over the last 25 years (Figure 4-3).

Table 4-2. Comparison of *E.coli* concentrations and exceedances for three sampling periods at Van Meter ISU/ACOE site. Concentrations are CFU/100 ml.

Sampling Period	**Mean**	**Median**	**Maximum**	**Sample Maximum Exceedances**	**Percentage of Exceedances**	**Geometric Mean**
2000-2002	529	145	4,234	10 of 19	53%	148
1996-2005	1,819	250	25,747	48 of 94	51%	333
1980-2005	3,022	497	80,352	235 of 348	68%	***

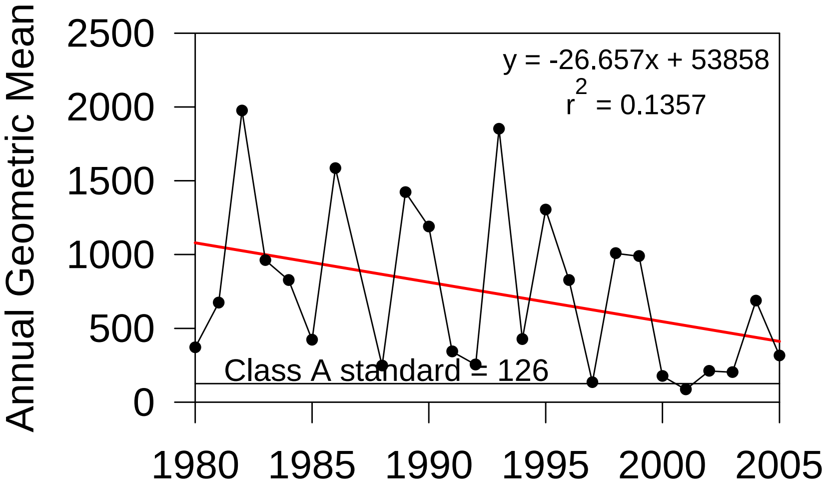


Figure 4-3. Annual geometric mean *E.coli* concentrations measured in Raccoon River at Van Meter, 1980-2005.

4.1.2 Indicator Bacteria Impairment in the North Raccoon River Near Sac City, (IA 04-RAC-0040-5 & 6)

The 2004 305(b) assessment report identified two adjoining segments of the North Raccoon River as “partially supporting” their Class A designated use. With the change to the Iowa Water Quality Standards, the two river segments are now assessed as “not supporting” due to indicator bacteria (*E.coli*) concentrations that violate Iowa water quality standards. Results from IDNR/UHL ambient monthly monitoring station located approximately 5 miles downstream from Sac City was used for the 305(b) assessment. With typically six to ten samples per year, the average annual geometric mean for the recreation season was determined for the 1986 to 2005 monitoring period (Figure 4-4). During a 20-year monitoring period, the annual geometric mean averaged

340 CFU/100 ml and exceeded the Iowa Class A water quality criterion (126 CFU/100 ml) for 15 of the 20 years.

In addition, 75 of the 160 samples (47%) collected from 1986 to 2005 exceeded Iowa's single sample maximum value of 235 CFU/100 ml. An examination of the *E.coli* concentrations and discharge at Sac City from 1999 to 2005 (period selected so comparisons can be made to other sites) revealed that 30 of the 74 samples (41%) exceeded the single sample maximum standard of 235. The geometric mean for this time period (1999 to 2005) was 280 CFU/100 ml (Figure 4-4). Lowest concentrations were measured in 2000 when stream discharge was substantially below normal (Figure 4-5).

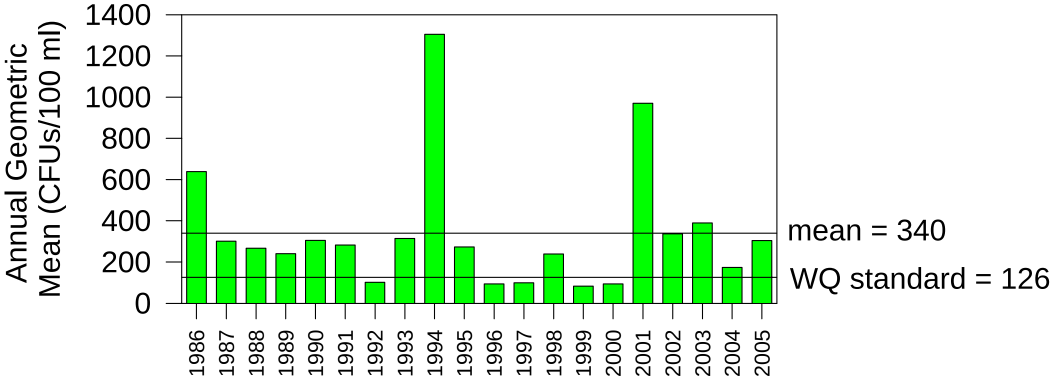


Figure 4-4. Annual geometric mean *E.coli* concentrations measured in North Raccoon River at Sac City, 1986-2005.

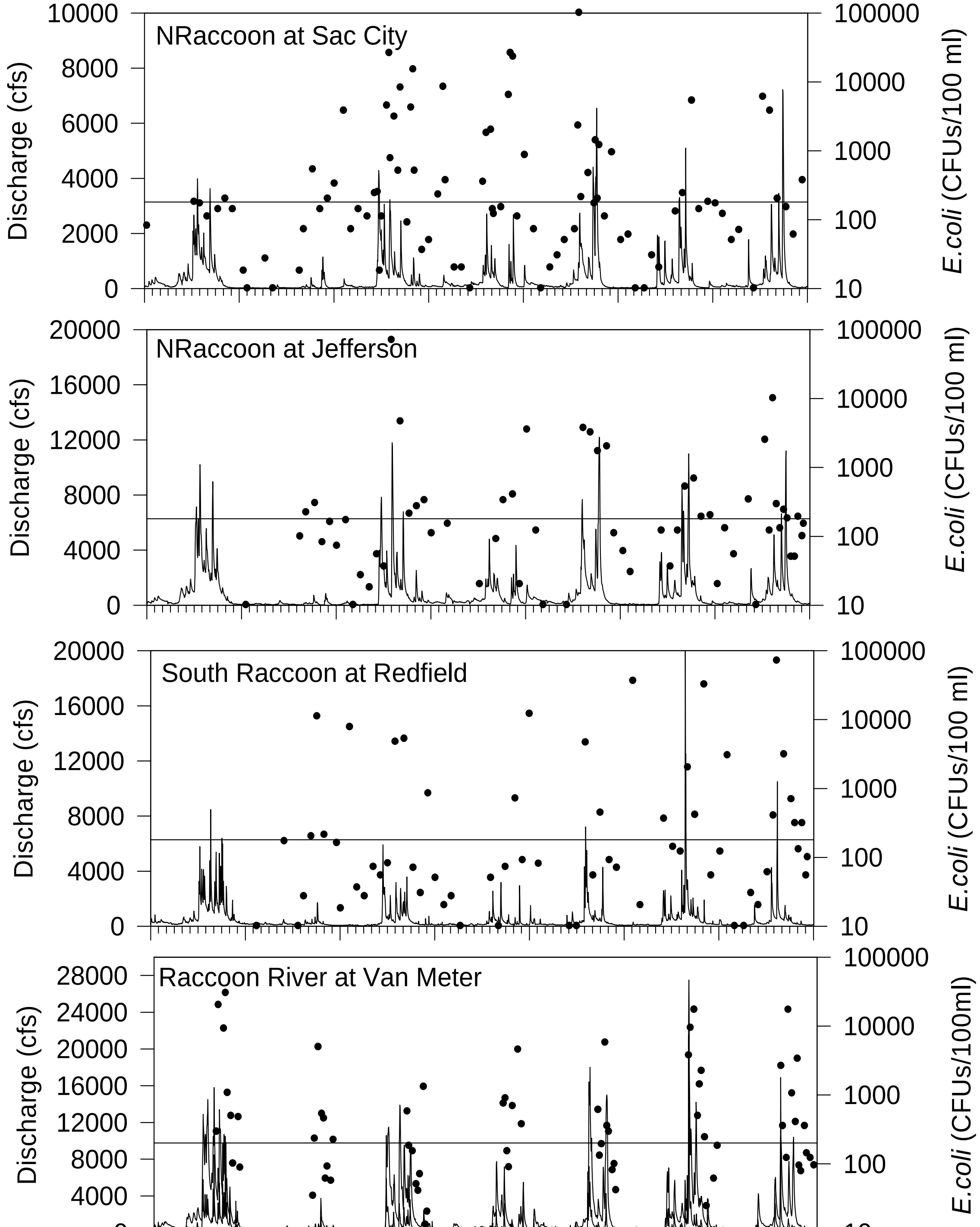


Figure 4-5. *E.coli* concentrations measured at U.S.G.S. stream gage sites from 1999-2005.

4.1.3 Indicator Bacteria Impairment in the North Raccoon River near Jefferson, from Buttrick Creek to Short Creek (IA 04-RAC-0040-1)

The 2004 305(b) assessment report identified a segment of the North Raccoon River near Jefferson as "partially supporting" its Class A designated use. With the change to the Iowa Water Quality Standards, the North Raccoon segment has since been assessed as "not supporting" due to indicator bacteria (*E.coli*) concentrations that violate Iowa water quality standards. Results from IDNR/UHL ambient monthly monitoring station located near Jefferson was used for the 305(b) assessment. From 2000 to 2005, 56 samples were collected from the North Raccoon River near Jefferson during the recreation season ranging from 8 to 14 samples per year (14 samples in 2005 only) (Figure 4-5). The annual geometric mean for the monitoring period ranged from 78 in 2000 to 353 CFU/100 ml in 2001 and averaged 161 CFU/100 ml during the five year period. Overall, 18 of 52 samples (32%) collected from 2000 to 2005 exceeded Iowa's single sample maximum value of 235 CFU/100 ml.

4.1.4 Temporal Patterns of E.coli Concentrations

Temporal patterns of *E.coli* concentrations in the Raccoon River are based primarily on water quality data collected by the DMWW at the watershed outlet. The near daily monitoring record developed by the DMWW is considerably better than any other monitoring site in the Raccoon basin. *E.coli* concentrations vary across seasons and flow conditions in the Raccoon River. Monthly *E.coli* concentrations exhibited clear seasonality with higher concentrations occurring in May, June and July when median monthly concentrations were greater than the single sample maximum of 235 CFU/100 ml (Figure 4-6). However, maximum *E.coli* concentrations in excess of 10,000 were observed in all months except February and December. Lowest monthly concentrations typically occurred during the fall and winter months. The seasonal nature of *E.coli* concentration patterns was evident when months were grouped as seasons of winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep) and fall (Oct-Dec) (Figure 4-7). Median *E.coli* concentrations were greater than 235 during the spring, with more than 75 percent of the concentrations greater than the standard in spring and summer.

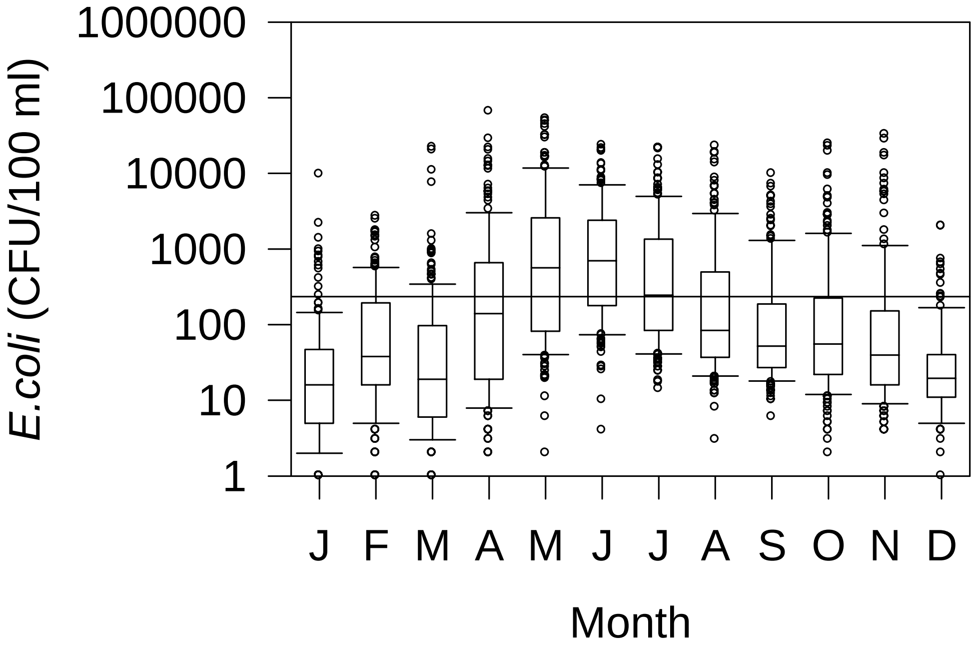


Figure 4-6. Variations in monthly *E.coli* concentrations in Raccoon River. Box plots illustrate the 25th, 50th and 75th percentiles; the whiskers indicate the 10th and 90th percentiles; and the circles represent data outliers.

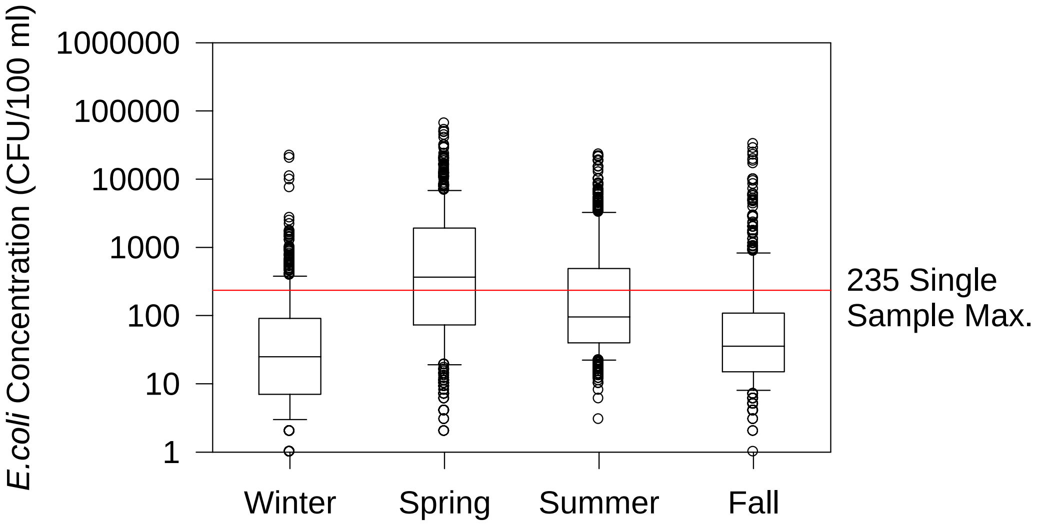


Figure 4-7. Variations in seasonal *E.coli* concentrations in Raccoon River. Box plots illustrate the 25th, 50th and 75th percentiles; the whiskers indicate the 10th and 90th percentiles; and the circles represent data outliers.

E.coli concentrations are higher during periods of greater discharge in the Raccoon River (Figure 4-8). Discharge at the time of sampling was divided into quartiles to determine whether *E.coli* concentrations related better to high or low flows in the river. Median *E.coli* concentrations decreased sharply from 665 CFU/100 ml when flow is in the upper 75-100% quartile range, to median concentrations of 84, 36 and 24 when flow is in the lower three quartiles (Figure 4-8).

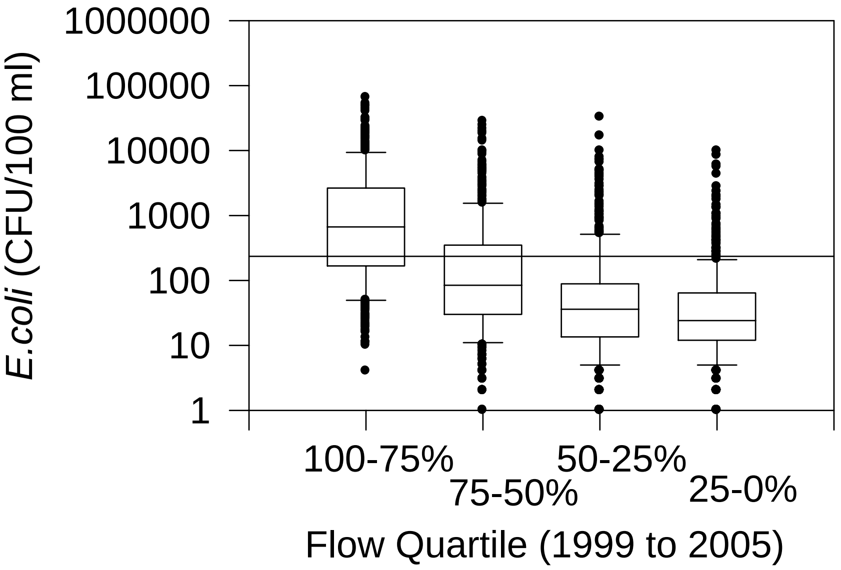


Figure 4-8. Variations in seasonal *E.coli* concentrations with discharge in Raccoon River. Box plots illustrate the 25th, 50th and 75th percentiles; the whiskers indicate the 10th and 90th percentiles; and the circles represent data outliers.

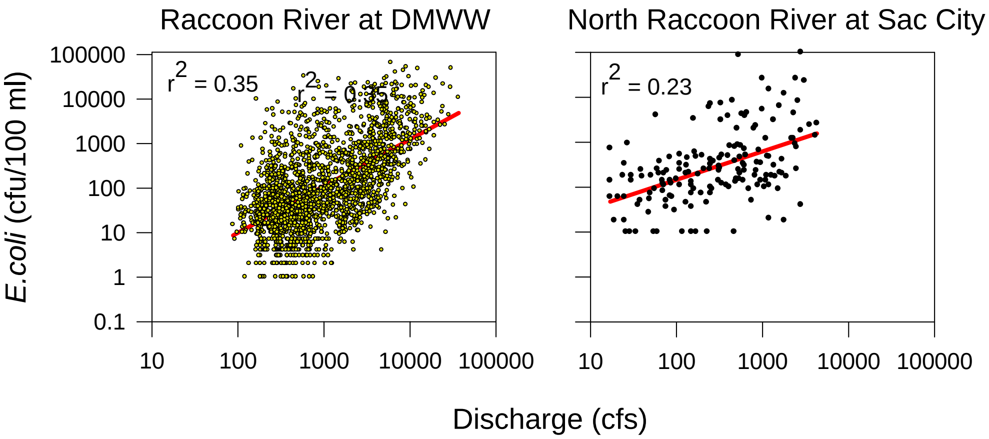


Figure 4-9. Variations in *E.coli* concentration with discharge in Raccoon River at DMWW and North Raccoon River at Sac City.

While *E.coli* concentrations are clearly higher during periods of greater discharge, the relation of daily *E.coli* to daily discharge is not particularly strong (Figure 4-9). Based on 2155 measurements at the DMWW, the coefficient of determination (r^2) is 0.35. The r^2 value is less based on fewer measurements at the North Raccoon River near Sac City over a longer period of time (0.23). However, both relations are statistically significant ($P<0.05$). Based on seven years of data from the DMWW, the relation of *E.coli* to discharge is greatest during the months of March, April and August when r^2 values ranged from 0.41 to 0.46 (Figure 4-10). Interestingly, the relation is not as strong during the months of May to July (r^2 varies from 0.28 to 0.34) when highest monthly *E.coli* concentrations are typically detected. The least significant relation occurs during September, November and December when r^2 values were less than 0.11.

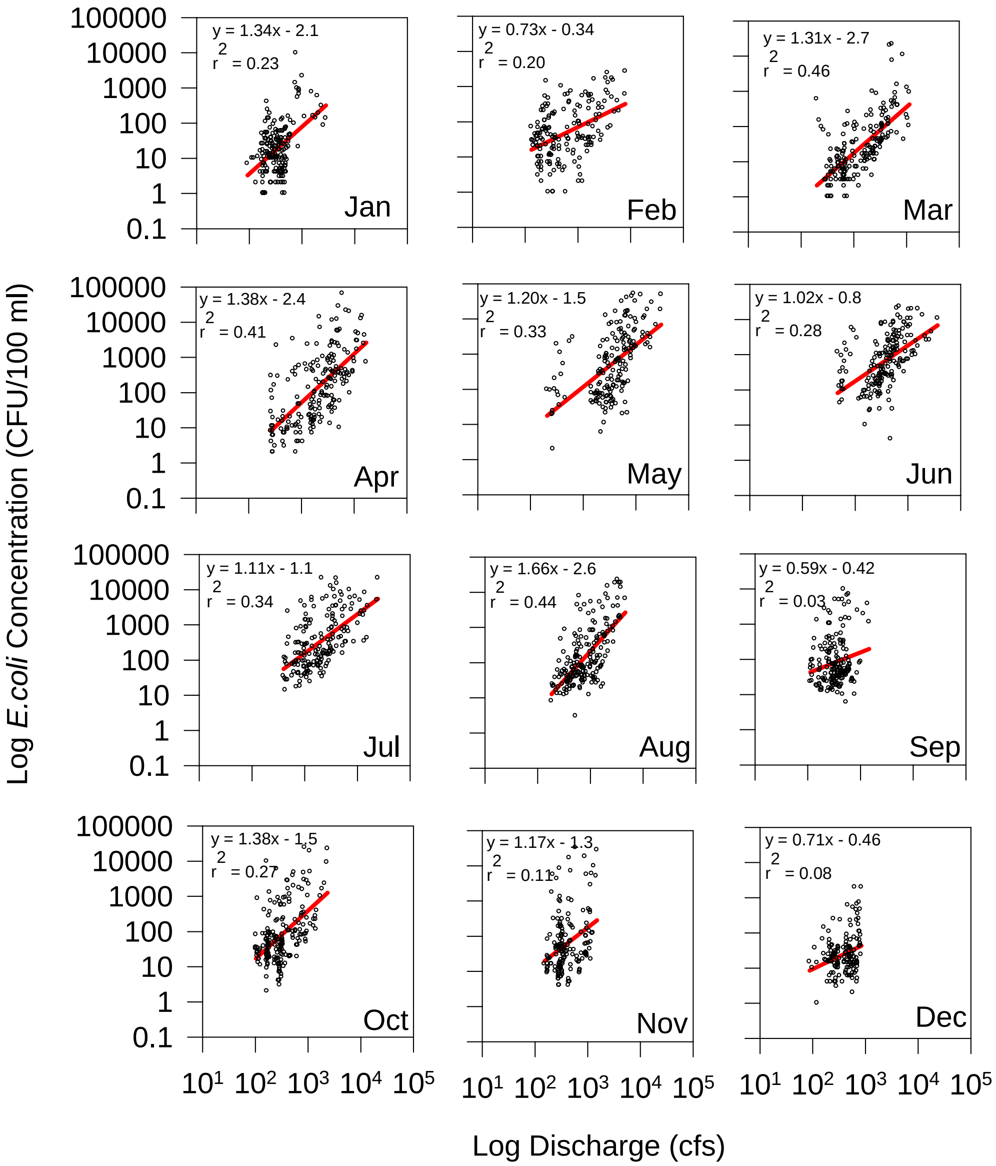


Figure 4-10. Variations in *E.coli* concentration with discharge by month in Raccoon River at DMWW.

4.1.5 Spatial Patterns of E.coli Concentrations

Like nitrate, a variety of data sources were used to evaluate spatial patterns of *E.coli* concentrations in the Raccoon River watershed. This includes monitoring data collected at the South and North Raccoon River stations as part of the IDNR/UHL ambient water monitoring network, the ACWA volunteer monitoring network, and several Polk County snapshot sampling events. These data source provide information on *E.coli* concentrations in stream segments in the Raccoon River watershed not specifically identified as impaired in the 2004 305(b) report.

Concentration data from IDNR/UHL ambient monthly monitoring station located near Redfield were available for the 2000 to 2005 monitoring period (Figure 4-5). From 2000 to 2005, 53 samples were collected from the South Raccoon River during the recreation season, averaging about one sample per month (8 per year). The annual geometric mean for the monitoring period ranged from 110 in 2002 to 551 CFU/100 ml in 2004 and averaged 217 CFU/100 ml during the six year period. Overall, 20 of 53 samples (38%) collected from 2000 to 2005 exceeded Iowa's single sample maximum value of 235 CFU/100 ml. The maximum *E.coli* concentration detected was 71,000 CFU/100 ml collected on May 12, 2005. *E.coli* monitoring results from the South Raccoon River at Redfield are similar to results from the North Raccoon at Jefferson.

Modeling using DAFLOW and WASP suggest that larger *E.coli* loads are associated with the North Raccoon River than South Raccoon River, although this is likely due to increased discharge from the North Raccoon (Appendix A). On a unit area basis, the South Raccoon River has higher bacteria concentrations per unit area and higher bacteria concentrations than the North Raccoon River.

Concentration data from IDNR/UHL ambient monthly monitoring station located upstream of Sac City (10810002) were available for the 2003 to 2005 monitoring period. From 2003 to 2005, 21 samples were collected from the North Raccoon River during the recreation season. The geometric mean for the monitoring period was 166 CFU/100 ml in 2004 and 6 of 21 samples (29%) exceeded Iowa's single sample maximum value of 235 CFU/100 ml. The maximum *E.coli* concentration detected as 38,000 CFU/100 ml collected on April 12, 2005. *E.coli* concentrations measured in the North Raccoon River upstream of Sac City were generally lower than concentrations downstream of Sac City.

Table 4-3. *E.coli* concentrations measured by ACWA at select North Raccoon monitoring sites in 2005. Concentrations are CFU/100 ml.

Sample Date	**4A**	**5**	**7**	**8**	**9**	**12**	**14**	**14A**	**17**	**19**	**21**	**22**
4/28/2005		1414	77	205		308	1553	172	114	138		120
5/12/2005	590	2460	6240	81640	178500	15530	214200	46110	8550	48840	1850	2238
5/26/2005	1414	2419	29090	5120	5810	2650	1986	1046	866	1300	291	687
6/9/2005	690	1080	6760	6200	5040	2280	8820	740	1340	2560	200	662
6/23/2005	411	2419	345	205	2419	2419	2880	770	980	2720	488	866
7/7/2005	214	2460	1046	411	2380	310	2419	3360	601	1317	310	657
7/21/2005	1414	4020	387	517	9590				263	1169	74	687
8/4/2005	210	3328	270	770	2419	2419	1970	550	816	1203	96	980
8/18/2005	461	1553	107	291	1986	517	980	199	18	19	135	1733
9/1/2005	131	2620	313	225	1733	1553	1986	43	14	2010	33	488
Average	615	2377	4464	9558	23320	3110	26310	5888	1356	6128	386	912
Median	461	2440	366	464	2419	2280	1986	740	709	1309	200	687
Geomean	459	2223	808	1016	5116	1515	3775	750	359	1157	200	724
%>235	0.667	1	0.8	0.7	1	1	1	0.67	0.7	0.8	0.56	0.9

Qualified volunteer monitoring data from the ACWA group was available for 17 remote sites in the Raccoon River watershed in 2005, including 12 sites in the North Raccoon basin, one site in the Middle Raccoon basin, three sites in the South Raccoon basin and one site in Walnut Creek (see Figure 3-8 for site locations). Fewer sites were sampled for *E.coli* bacteria compared to nitrate concentrations. Tables 4-3 and 4-4 show concentrations of *E.coli* bacteria measured at all available monitoring sites in 2005.

Table 4-4. *E.coli* concentrations measured by ACWA at select Middle and South Raccoon monitoring sites in 2005. Concentrations are CFU/100 ml.

Sample Date	Middle Raccoon C	South Raccoon 43	South Raccoon 32	South Raccoon 37	Walnut Creek 40
4/28/2005		1820	3873	1401	187
5/12/2005	194	1119900	81300	64880	6570
5/26/2005		2310	866	488	1553
6/9/2005		483840	11980	3130	4880
6/23/2005	49	1986	1986	461	1203
7/7/2005	17	1300	1710	950	770
7/21/2005	74	1333	740	452	14540
8/4/2005	96		104	365	613
8/18/2005	32	15650	727	214	649
9/1/2005	9	1733	76	70	
Average	67	181097	10336	7241	3441
Median	49	1986	1288	475	1203
Geomean	44	10196	1320	780	2010
%>235	0	1	0.8	0.8	0.89

Results from the ACWA monitoring in the Raccoon River watershed indicate widespread exceedance of Iowa's water quality standards. All monitored sites except Site C in the Middle Raccoon River exceeded the geometric mean standard of 126 CFU/100 ml in 2005. The 2005 geometric mean at nine sites was greater than 1000 CFU/100 ml. In addition, all monitored sites except Site C in the Middle Raccoon River had a majority of single sample maximum values exceed the water quality standard of 235 CFU/100 ml. The single sample maximum value was exceeded at five sites during every sampling event in 2005. The maximum value of 1,119,900 CFU/100 ml was measured by the ACWA at Site 43 in the South Raccoon River.

As described in Section 3.1.5, a second source of qualified volunteer data available for the Raccoon River TMDL is four county-wide "snapshot" sampling events that were conducted in Polk County in spring and fall during 2004 and 2005 (Figure 3-7). Volunteers collected stream water samples throughout Polk County on a single day to assess the quality of county surface water at a single point in time (i.e., snapshot). Water samples were analyzed by the DMWW using standard methods. Results of the snapshot monitoring indicated *E.coli* concentrations often exceed the single sample maximum value in Polk County (Table 4-5). Approximately 74 percent of the water samples collected at all sites exceeded the single sample maximum of 235 CFU/100 ml (61 of 82). Concentrations were typically higher during the two spring sampling events compared to the fall events, with highest concentrations at most sites observed on May 18, 2005. *E.coli* concentrations exceeded 10,000 CFU/100 ml at four sites in May 2005 and four sites in December 2005. Few spatial patterns of elevated concentrations were noted, as concentrations fluctuated considerably among the sites. The geometric mean across the four sampling events at all sites exceeded the water quality standard of 126 CFU/100 ml.

Table 4-5. *E.coli* concentrations measured at Polk County snapshot sites in 2004 and 2005. Concentrations are CFU/100 ml.

		***E.coli* Concentration (cfu/100 ml)**			
Site ID	**Site Description**	**6/2/04**	**10/13/04**	**5/18/05**	**12/12/05**
FRC1	Frink Creek at SW 42nd St.	172	980	1200	1986
FRC2	Frink Creek at Park	435	687	850	105
Grays Trib	Unnamed Creek - Trib to Gray's Lake	613	387	2780	29090
JC1	Jordan Creek (Prairie View Drive)	649	84	794	1300
JC2	Jordan Creek (Grand Ave)		>2419	15650	228
NWC Trib 1	North Walnut Creek Tributary	866	345	6867	77010
NWC Trib 2	North Walnut Creek Tributary	548	130	12360	4950
NWC1	North Walnut Creek (54th Ave)	156	47	860	210
NWC2	North Walnut Creek (Aurora Ave)	517	140	2613	488
NWC3	North Walnut Creek	866	111	11450	71
NWC4	North Walnut Creek	435	93	7170	980
NWC5	North Walnut Creek at College Ave		1986		5120
NWC6	North Walnut Creek (near 73rd St)	727	613	7510	
RR - US	Raccoon River Van Meter	3890	65	980	34
Waveland	Waveland Golf Course		345	9330	30760
WC1	Walnut Creek	488	261	1350	387
WC2	Walnut Creek	461	411	1210	219
WC3	Walnut Creek	489	173	1090	2130
WC4	Walnut Creek (86th St)	461	147	1750	488
WC5	Walnut Creek	649	219	2310	3790
WC6	Walnut Creek	770	201	61310	13130
DMWW Intake	Raccoon River		27	2030	62

4.1.6 Rationale for Basin-wide TMDL for Indicator Bacteria

Although the 2004 305(b) report identified five segments of the Raccoon River as impaired ("partially supporting") their Class A (primary contact recreation) use by indicator bacteria (fecal coliform) based on 2000 to 2002 monitoring results, changes in Iowa's water quality standards have made this assessment out of date. New water quality standards consider *E.coli* as the indicator bacterium and eliminate a high flow exemption; these standards are now applied to all Class A1 waters of the state (i.e., perennial streams). Because of the change in standards, the four "partially supporting" Raccoon River segments are now classified as impaired ("not supporting") their designated uses. The change in water quality standards does not affect the need to complete a TMDL for these five impaired segments.

However, with the new water quality standards designating all perennial streams as Class A1 waters, other stream segments in the Raccoon River watershed are now eligible for assessment and addition to the state impaired waters list provided credible water monitoring data is available. In fact, other monitoring data is available for stream segments in the Raccoon River not previously classified. This TMDL examined *E.coli* concentration data collected at the South Raccoon River at Redfield, North Raccoon upstream of Sac City, at 17 sites in the North, Middle, and South Raccoon rivers collected as part of the ACWA and at 22 sites around Polk County during snapshot sampling events. If current (*E.coli*) water quality standards for indicator bacterium were applied to all of these sites around the watershed, all sites could be classified as "not supporting" their designated uses given that *E.coli* concentrations often exceeded single sample maximum values (235 CFU/100 ml) or geometric mean concentrations were greater than 126 CFU/100 ml. Based on evidence from the sampling results assessed in this TMDL, it would appear that all Class A1 waters in the Raccoon River watershed may be considered as "not supporting" their designated uses. Future 305(b) assessments of streams in the Raccoon River will likely come to the same conclusion and continue to list streams in the watershed as "not supporting" whenever credible *E.coli* monitoring data becomes available.

Thus, it is the conclusion of this TMDL that all Class A streams in the Raccoon River will likely be considered "not supporting" their designated uses at some point in the future (if not already classified), and that most, if not all, Class A1 streams in the Raccoon River watershed would benefit from a TMDL determination. A TMDL is therefore assigned to not only the five stream segments identified in the 2004 305(b) report, but also to other Class A1 stream segments in the Raccoon River watershed not previously classified. In this manner, a TMDL for indicator bacteria will be established for each of these Class A1 water segments prior to collection of monitoring data. Water monitoring results from all available sites within the Raccoon River basin strongly suggest that most stream segments within the watershed will inevitably be assessed as "not supporting" and added to the impaired waters list whenever monitoring data becomes available.

The TMDL is targeted to specific stream segments in the Raccoon River watershed and a list of the stream segments is presented in Section 4-7. New water quality rules mandate that end-of-pipe discharge from permitted facilities to Class A1 waters comply with *E.coli* limits. Hence, wasteload allocations for permitted facilities in the specific stream segments are also established in this TMDL.

4.2 Pollution Source Assessment

As described in Section 3.2, pollution sources of *E.coli* can be divided into two major categories, point sources and nonpoint sources.

4.2.1 Point Sources

There are a total of seventy-seven (77) entities in the Raccoon River watershed with National Pollution Discharge Elimination System (NPDES) permits. Most of these facilities are municipal sewage treatment plants, but there are several industrial contributors, animal feeding operations (AFOs) and urban areas covered by Municipal Storm Sewer Systems (MS4s). For this TMDL, load estimates were calculated for WWTPs with Discharge Monitoring Records (DMRs) that discharge measurable quantities of effluent to surface waters.

Some animal feeding operations may be considered a point source because facilities larger than 1000 animal units are required to have an NPDES permit. However, by state law, discharge of pollutants from livestock operations is set at zero tons per year (IAC – Chapter 65). Any nitrate discharged from these facilities occurs from either manure application or episodic events such as spills. For open feedlots, facilities larger than 1000 animal units are considered NPDES facilities and their permits require retention and application of manure on cropped fields. Of the smaller open lots, it is required that facilities settle solids before runoff enters a stream. The list of point sources does not include permitted facilities that do not treat an organic waste stream, such as quarry operations.

Table 4-6. Summary of WWTP facilities, flow rates, and daily fecal coliform loads in Raccoon River watershed. Subtotals are presented for various subbasin areas. TMDL value is daily flow rate multiplied by single sample maximum value of 235 CFU/100 ml. Basin names: NR-SC = North Raccoon at Sac City; NR-J = North Raccoon at Jefferson; MR-P = Middle Raccoon at Panora; SR-R = South Raccoon at Redfield; RR-VM = Raccoon River at Van Meter; RR-DSM = Raccoon River at Des Moines (Fleur).

EPA_ID	Facility Name	Flow Type	Permit Type	Basin	Population Equivalents	Max Flow Rate (MGD)	FC Estimate Type	Effluent FC Monitoring?	Monitored FC Max. (DMR Data)	Daily EC Load (CFU)	WLA for EC load (CFU)
IA0076554	Rembrandt Enterprises, Inc	Continuous	Domestic	NR-SC	23952	0.0032	2	No		4.790E+10	2.8463E+07
IA0033219	City of Rembrandt	Controlled	City	NR-SC	407	0.5890	3	No		8.387E+05	5.2390E+09
IA0046671	City of Fonda	Controlled	City	NR-SC	1146	1.0240	3	No		1.133E+08	9.1082E+09
IA0025950	City of Laurens	Controlled	City	NR-SC	2383	2.2400	3	No		6.206E+08	1.9924E+10
IA0065731	Spectra Health Care Facility STP	Controlled	Semi-Public	NR-SC	71	0.0500	3	No		1.734E+08	4.4474E+08
IA0064998	Tyson Fresh Meats Storm Lake	Daily	Industry	NR-SC	116766	2.9490	1	Yes	352	3.928E+10	2.6231E+10
IA0032484	City of Storm Lake	Daily	City	NR-SC	33874	6.2240	2	No		5.249E+10	5.5361E+10
IA0021989	City of Newell	Daily	City	NR-SC	1257	1.3670	2	No		1.774E+09	1.2159E+10
IA0034312	Albert City	Daily	City	NR-SC	892	1.5000	2	No		1.418E+09	1.3342E+10
IA0033090	Sac City	Daily	City	NR-SC	4042	1.9950	1	Yes	4,700	3.548E+11	1.7745E+10
IA0067652	City of Marathon	Daily	City	NR-SC	461	0.4054	2	No		6.040E+08	3.6059E+09
	North Raccoon at Sac City Subtotal									**4.992E+11**	**1.632E+11**
IA0057029	City of Auburn	Controlled	City	NR-J	455	0.3000	3	No		4.551E+06	2.6684E+09
IA0056103	City of Breda	Controlled	City	NR-J	647	1.2000	3	No		1.259E+08	1.0674E+10
IA0062162	City of Lanesboro	Controlled	City	NR-J	249	0.2400	3	No		6.441E+06	2.1347E+09
IA0027189	City of Manson	Controlled	City	NR-J	1964	1.0240	3	No		3.084E+09	9.1082E+09
IA0020842	Lake City	Controlled	City	NR-J	2509	2.7700	3	No		3.333E+07	2.4638E+10
IA0070114	Twin Lakes Sanitary Sewer District STP	Controlled	Sanitary District	NR-J	897	0.5880	3	No		2.175E+08	5.2301E+09
IA0021300	City of Jefferson	Daily	City	NR-J	9281	4.5770	1	Yes	4,000	6.928E+11	4.0711E+10
IA0041998	City of Lake View	Daily	City	NR-J	3221	1.0450	2	No		2.556E+09	9.2950E+09
IA0026026	City of Lohrville	Daily	City	NR-J	659	1.0890	2	No		8.620E+08	9.6864E+09
IA0020940	City of Lytton	Daily	City	NR-J	5305	1.6690	3	No		1.202E+09	1.4845E+10
IA0033715	City of Rinard	Daily	City	NR-J	15	0.0550	2	No		1.440E+08	4.8921E+08
IA0032409	City of Scranton	Daily	City	NR-J	1144	1.2200	2	No		1.208E+09	1.0852E+10
IA0033138	Rockwell City	Daily	City	NR-J	4671	10.0000	2	No		4.528E+09	8.8948E+10
	North Raccoon at Jefferson Subtotal									**1.206E+12**	**3.925E+11**
IA0028983	City of Coon Rapids	Controlled	City	MR-P	1542	1.6260	3	No		1.340E+09	1.4463E+10
IA0056855	City of Lidderdale	Controlled	City	MR-P	359	0.1350	3	No		1.954E+06	1.2008E+09
IA0075281	DNR Springbrook State Park-Campground Area	Daily	Semi-Public	MR-P	156	0.1110	1	Yes	0		
IA0075272	DNR Springbrook State Park-Education Center	Daily	Semi-Public	MR-P	48	0.0114	1	Yes	0		
IA0061468	City of Bayard	Daily	City	MR-P	713	0.6410	1	Yes	1,300	3.15E+09	5.7015E+09
IA0021377	City of Carroll	Daily	City	MR-P	20868	4.8220	2	No		2.680E+10	4.2890E+10
IA0024571	City of Glidden	Daily	City	MR-P	3593	1.2000	2	No		2.506E+09	1.0674E+10
	Middle Raccoon at Panora Subtotal									**3.380E+10**	**7.493E+10**
IA0035181	City of Dedham	Controlled	City	SR-R	350	0.5000	3	No		1.694E+08	4.4474E+09
IA0041866	City of Guthrie Center	Controlled	City	SR-R	2222	1.3240	3	No		2.431E+08	1.1777E+10
IA0075817	City of Halbur	Controlled	City	SR-R	216	0.1070	3	No		1.516E+08	9.5174E+08
IA0036099	City of Redfield	Controlled	City	SR-R	1222	3.6600	3	No		1.942E+07	3.2555E+10
IA0068381	Diamond Head Lake	Controlled	Semi-Public	SR-R	313	0.2500	3	No		6.538E+07	2.2237E+09
IA0041874	City of Bagley	Daily	City	SR-R	365	0.3650	2	No		7.080E+08	3.2466E+09
IA0057045	City of Panora	Daily	City	SR-R	6174	1.2070	1	Yes	7,900	3.609E+10	1.0736E+10
IA0041858	City of Stuart	Daily	City	SR-R	1701	3.1320	2	No		3.424E+09	2.7858E+10
IA0075361	Rose Acre Farms, Inc. Guthrie Center Egg Farm	Daily	Industry	SR-R	0	0.5400	4	No			4.8032E+09
	South Raccoon at Redfield Subtotal									**7.467E+10**	**1.735E+11**

Table 4-6. ...continued

EPA_ID	Facility Name	Flow Type	Permit Type	Basin	Population Equivalents	Max Flow Rate (MGD)	FC Estimate Type	Effluent FC Monitoring?	Monitored FC Max. (DMR Data)	Daily EC Load (CFU)	WLA for EC load (CFU)
IA0077101	West Central Cooperative	Continuous	Operation Permit	RR-VM	377	0.8630	2	No		1.9600E+08	7.6762E+09
IA0057096	City of Callender	Controlled	City	RR-VM	407	1.4100	3	No		1.7882E+02	1.2542E+10
IA0031216	City of Churdan	Controlled	City	RR-VM	698	0.1400	3	No		1.1545E+09	1.2453E+09
IA0076244	City of Harcourt	Controlled	City	RR-VM	365	3.4200	2	No		8.4767E+07	3.0420E+10
IA0023418	City of Minburn	Controlled	City	RR-VM	407	0.8200	3	No		1.9193E+08	7.2937E+09
IA0060321	City of Paton	Controlled	City	RR-VM	489	2.5000	3	No		6.2046E+06	2.2237E+10
IA0032824	City of Pomeroy	Controlled	City	RR-VM	898	1.4100	3	No		9.4315E+07	1.2542E+10
IA0041882	City of Rippey	Controlled	City	RR-VM	419	0.4000	3	No		3.0678E+09	3.5579E+09
IA0076465	Country View Estates	Controlled	Semi-Public	RR-VM	42	0.7050	3	No		9.2875E+06	6.2708E+09
IA0076562	Ortonville Business Park	Controlled	Semi-Public	RR-VM	144	0.0140	3	No	14	7.6386E+05	1.2453E+08
IA0041921	City of Adel	Daily	City	RR-VM	4820	3.1750	1	Yes	170	2.0428E+09	2.8241E+10
IA0056821	City of Desoto	Daily	City	RR-VM	1317	0.9900	1	Yes	9,000	3.3722E+10	8.8058E+09
IA0027421	City of Earlham	Daily	City	RR-VM	952	1.4980	2	No		2.5960E+09	1.3324E+10
IA0028967	City of Farnhamville	Daily	City	RR-VM	467	0.2550	2	No		8.6000E+08	2.2682E+09
IA0020966	City of Gowrie	Daily	City	RR-VM	1629	1.6250	2	No		2.0760E+09	1.4454E+10
IA0032379	City of Perry	Daily	City	RR-VM	20958	8.9060	1	Yes	6,500	2.1909E+11	7.9217E+10
IA0002089	Tyson Fresh Meats Perry	Daily	Industry	RR-VM	60000	3.7400	1	Yes	650	9.2007E+09	3.3266E+10
	Raccoon River at Van Meter Subtotal									**1.5551E+12**	**8.4948E+11**
IA0068888	Iowa Dot Rest Area #21 & #22 I80 Waukee	Controlled	Semi-Public	RR-DM	287	0.0600	3	No		7.5602E+07	5.3369E+08
IA0036021	City of Van Meter	Controlled	City	RR-DM	1341	1.5750	3	No		5.5011E+08	1.4009E+10
IA0032794	City of Waukee	Daily	City	RR-DM	7868	5.4760	2	No		1.0252E+10	4.8708E+10
IA0035319	City of Dallas Center	Daily	City	RR-DM	1904	2.2300	2	No		3.1900E+09	1.9835E+10
	Raccoon River at DMWW Subtotal									**1.5691E+12**	**9.3257E+11**
IA0078638	Storm Lake MS4	Event based	Stormwater				4	No			
IA0078875	Waukee MS4	Event based	Stormwater				4	No			
IA0079201	E. R. Peterson & Sons	Event based	Agricultural				4	No			
IA0080250	Wiederin Feedlot	Event based	Agricultural				4	No			
IA0077755	S & S Farms	Event based	Agricultural				4	No			
IA0078590	Van Meter Feedyard	Event based	Agricultural				4	No			
IA0080284	Ray Lenz, Inc.	Event based	Agricultural				4	No			
IA0077810	Wendl Feedlot	Event based	Agricultural				4	No			
IA0076295	Hy.Vac	Event based	Agricultural				4	No			
IA0079731	Corey Agriculture, Inc.	Event based	Agricultural				4	No			
IA0080292	Pudenz, Lynn	Event based	Agricultural				4	No			
IA0078883	Grimes MS4	Event based	Stormwater				4	No			
IA0078867	Clive MS4	Event based	Stormwater				4	No			
IA0076767	Vigorena Feeds	Land Applied	Operation Permit				4	No			
IA0080390	Vonnhame Farms Trailer Wash Out	Land Applied	Operation Permit				4	No			
IA0079782	City of Truesdale	None	City				4	No			

Note: The WLA for Rembrandt Enterprises Inc. should be reassessed during Phase 2 (see page 60 for more details).

For *E.coli* bacteria, very few wastewater treatment facilities monitor for bacteria in their effluent. Therefore, estimates of the quantities of bacteria are derived from generic conservative assumptions based on type of treatment, quantity and quality of influent wastewater, and per capita pollutant generation. For *E.coli*, virtually all NPDES associated documentation and records use fecal coliforms as the standard for measuring pathogen indicators and not *E.coli*. Thus, all assessment and calculations of bacteria loadings from point sources apply to fecal coliform only. However, the use of fecal coliform as surrogates for *E.coli* is treated as a conservative estimates in this TMDL. Because *E.coli* is a subset of fecal coliform (recall that FC * 0.92 = EC in surface water), use of fecal coliform in estimating point source discharges will overestimate *E.coli* losses to streams. Thus estimates of *E.coli* point source loads from WWTPs provide a worst-case estimate of their inputs to Raccoon River receiving waters.

The methods used to estimate point source fecal coliform loads in the Raccoon River are provided in Herring, 2006b (Appendix B). Table 4-6 lists the 77 facilities in the basin, their subbasin location (identification number), their EPA permit number, permit type, and discharge frequency. The daily point source loads for fecal coliform for various subbasins were compiled as various subtotals. Thus the following subbasins were used to estimate the point source loads at various watershed outlets:

- NR-SC = North Raccoon River load at Sac City
- NR-SC + NR-J = North Raccoon River load at Jefferson
- MR-P = Middle Raccoon River load at Panora
- MR-P + SR-R = South Raccoon River load at Redfield
- SR-R + NR-J + RR-VM = Raccoon River load at Van Meter
- RR-VM + RR-DM = Raccoon River load at DMWW in Des Moines

The point sources include municipal, industrial, semi-public, sanitary district stormwater, agricultural, and operation permits. Pollutants were discharged to receiving waters either daily or as controlled discharge (i.e., supposed to discharge only when receiving stream flows are high). Event based discharges or land applications of pollutants were also considered in this point source inventory. When data were available, discharge rates (flow rates) and concentration data for *E.coli* were evaluated as maximum measured or maximum estimated values.

Estimating daily loads from WWTPs with controlled discharge presents challenges in TMDL development. For the Raccoon River TMDL, monthly discharge records from WWTPs were examined to see if monthly patterns of discharges emerged. In the majority of cases, there was a typical spring and late fall discharge period, but the actual months of discharge varied year-by-year. While many previous TMDLs could evaluate discharge loads from facilities with controlled discharge on an annual basis and thus avoid problems related to the timing of releases, current EPA guidance indicates loads are to be calculated on a daily basis only. Thus, for the Raccoon River TMDL, the total annual controlled discharge load from a WWTP was determined and then divided by 365 days per year to obtain an estimate of daily discharge load. The approach would tend to overestimate the influence of the controlled discharge WWTP's at low flows since these facilities would not typically discharge during these periods and underestimate their effect at high flows when they would typically discharge. The daily load estimate determined for controlled discharge WWTPs can be converted to a typical two-month discharge period by multiplying the daily waste load allocation by 365 to obtain an annual load, and then dividing by the number of months when discharge occurred (typically two) and the number of days in the month. This conversion would allow for facility-specific waste loads to be assessed on a daily basis for time period when discharge may occur.

The amount of bacteria discharged into a stream was estimated using a three-tiered approach. If a facility had bacteria monitoring data, then the monitoring data were used (Estimate Type 1). If the facility had no monitoring data available, an estimated discharge amount was assumed based on the population estimate (Estimate Type 2). The total bacteria amount produced by the population was then reduced by 99.9 percent from the wastewater treatment process. For controlled discharge facilities, the same rate of bacteria generation by population was used but the reduction rate varied depending on the length of time the wastewater was in storage (Estimate Type 3).

The largest estimated maximum daily fecal coliform loads were associated with municipal WWTPs at Jefferson, Sac City and Perry that each contributed more than 1E+11 CFUs per day (one hundred billion units per day). Combined the three plants could conceivably account for approximately 81 percent of the fecal coliform bacteria discharged from WWTPs in the Raccoon River watershed. However, it should be noted that the discharges from the three plants used a measured maximum concentration and the maximum flow rate to generate the estimated daily loads, whereas in actuality, the measured concentrations and flow rates are presumably quite lower. While the bacteria contributions from Jefferson, Sac City and Perry WWTPs may be overestimated, at least there was measured data available. For most of the plants, bacteria losses were estimated from population estimates and an assumed bacteria reduction during the WWTP process. Because of the different methods used to estimate bacteria discharge, variations in the amount of bacteria discharged from equivalent population densities were apparent. For example, comparing the cities of Carroll and Perry both with population equivalents of about 21,000, the estimated daily fecal bacteria load based on measured maximum concentration and discharge data at Perry was about an order of magnitude greater than the estimated bacteria load at Carroll. However, considering that the measured data at Perry were maximum values, the estimate developed for Carroll, despite being lower, may better represent typical discharge loads. Nonetheless, there would appear to be considerable conservatism assigned to the estimated daily bacteria losses from point sources in the Raccoon River watershed.

4.2.2 Livestock Feeding Operations

Some livestock operations in the Raccoon River watershed may be considered a point source because facilities larger than 1000 animal units are required to have an NPDES permit. There are currently nine livestock facilities in the watershed that have an NPDES permit (Table 4-6b). However discharge of pollutants from livestock operations is set at zero tons per year (IAC – Chapter 65). Hence, the point source contribution from permitted livestock facilities in the Raccoon River watershed is assumed to be zero. Other livestock operations with less than 1000 animal units and other activities associated with all livestock operations (feedlot runoff, manure management, etc.) are considered nonpoint sources of *E.coli* bacteria in this TMDL report.

4.2.3 MS4 Permits

For municipalities in the watershed with an NPDES MS4 permit, development of a Storm Water Pollution Prevention and Management Program (SWMP) is required. The SWMP includes requirements for implementation of BMPs including controls to reduce pollutants in discharges from municipal application of fertilizers and operation of a public education and outreach program to inform the public of storm water impacts on water quality and measures that can be implemented to reduce water quality degradation from storm water. As recommended by the EPA, the waste load allocation for urban storm water point sources in the watershed will be implemented through the NPDES MS4 permits and will attempt to utilize best management practices in lieu of numeric limits.

4.2.4 Nonpoint Sources

Potential nonpoint sources of *E.coli* bacteria include contributions from animal manure, septic systems and wildlife. The relative contribution from these sources to *E.coli* loads in the Raccoon River watershed was assessed using a budget approach based on the number of animals or people in a watershed area and the amount of bacteria generated on a daily basis in their associated waste. For this section of the TMDL, no differentiation was made regarding manure derived from land application versus grazing operations on pastures. Delivery of *E.coli* from their source (from people or animals) to the stream network is addressed by the watershed model of the Raccoon River described in Section 5 of this report.

Table 4-7. Numbers of animals and rural population in various watershed areas. Animal and rural population numbers summarized from Libra et al. (2004).

Source Category	Pathogen Inputs	Raccoon River at Van Meter	South Raccoon River at Redfield	North Raccoon River at Jefferson	North Raccoon River at Sac City
		--------(Number of animals or rural population)---------			
Agricultural	Manure				
	Hogs	1,394,008	345,159	895,818	468,171
	Cattle	160,211	73,493	65685	26303
	Chicken	4,701,500	1,500,000	1,463,500	1,463,500
	Turkey	807,700	0	807,700	807,700
Developed	Septic systems	9822	2860	3956	2350
Natural	Wildlife (deer)	13,291	6,635	2,395	901

The number of animals, rural population on septic systems and number of deer estimated for four major watershed areas of the Raccoon River were estimated in the same manner described in the nitrogen source assessment (Table 4-7). The bacterial content of manure associated with the various sources was obtained from literature estimates (USEPA, 2001). Concentrations are in fecal coliform densities, not *E.coli*, due to lack of literature values for *E.coli* bacteria counts. Bacteria counts for fecal coliform should approximate *E.coli* numbers and the data provide an indication of relative contributions from various bacteria sources in the watershed.

Table 4-8. Daily fecal coliform bacteria generated per source per day (USEPA, 2005) and total number of bacteria generated per year by sources in various watershed areas.

	Bacteria Count (fecal coliform) (orgs.day)	Raccoon River at Van Meter		South Raccoon River at Redfield		North Raccoon River at Jefferson		North Raccoon River at Sac City	
		# of bacteria	% of total	# of bacteria	% of total	# of bacteria	% of total	# of bacteria	% of total
Hogs	1.08E+10	1.51E+16	46.4%	3.73E+15	32.2%	9.67E+15	57.6%	5.06E+15	62.6%
Cattle	1.04E+11	1.67E+16	51.3%	7.64E+15	66.0%	6.83E+15	40.7%	2.74E+15	33.9%
Chicken	1.36E+08	6.39E+14	2.0%	2.04E+14	1.8%	1.99E+14	1.2%	1.99E+14	2.5%
Turkey	9.30E+07	7.51E+13	0.2%	0.00E+00	0.0%	7.51E+13	0.4%	7.51E+13	0.9%
Septic systems	2.00E+09	1.96E+13	0.1%	5.72E+12	0.0%	7.91E+12	0.0%	4.70E+12	0.1%
Wildlife (deer)	5.00E+08	6.65E+12	0.0%	3.32E+12	0.0%	1.20E+12	0.0%	4.51E+11	0.0%
TOTAL		3.25E+16		1.16E+16		1.68E+16		8.07E+15	

Manure from hogs and cattle comprise a significant portion of the total bacteria population in the Raccoon River watershed (Table 4-8). At Van Meter where the North and South Raccoon rivers meet, bacteria contributions from cattle slightly exceed those from hogs. However, differences are evident between the North and South Raccoon basins with cattle comprising a much larger proportion of total bacteria in the South Raccoon watershed and hogs dominating the bacteria sources in the two North Raccoon River watersheds. Cattle manure comprises 66 percent of the bacteria in the South Raccoon watershed, but hogs comprise 63 percent of the bacteria in the North Raccoon watershed above Sac City. Poultry manure provides an estimated 1.5 to 2 percent of the total bacteria input, whereas bacteria counts from septic systems and wildlife provide less than 0.1 percent of the total. Thus, manure from hogs and cattle dominate the potential bacteria sources in the Raccoon River watershed.

As noted earlier, the bacteria population totals in Table 4-8 are simply an accounting of bacteria counts from known animal and rural populations and do not take into account the delivery of bacteria from sources to the streams. Manure from hogs, chicken and turkey is typically land applied to cropland as fertilizer. Bacteria from land-applied manure are typically delivered to streams from rainfall or snowmelt runoff. Bacteria can enter the stream as overland runoff or may be in runoff that enters surface inlets of tile drainage networks and discharge to the stream via a tile outlet. Similarly, manure from cattle feedlots can be delivered to stream in the same manner as manure from hogs and poultry. However, cattle grazing in pastures often have direct access to streams. One report indicated that approximately 90 percent of cattle in pasturelands have access to a stream (IDNR, 2006). Manure from cattle grazing operations may be deposited directly in the stream or in close vicinity to a stream and provide direct input of bacteria without any bacteria losses that may occur during overland transport. Because of the difference in delivery, bacteria from grazing operations may be a larger source of bacteria than cattle manure from feedlots, particularly during hot, summer months when cattle spend more time in or near streams. The amount of time cattle spend in streams is unknown, but previous bacteria TMDLs completed for the Maquoketa River and Big Sioux River in Iowa suggested that for the May to October period, cattle may spend 6 percent of their time in streams.

Bacteria from septic systems, though comprising a minor component of the overall bacteria population in the watershed, may be a larger source of bacteria to streams than the total numbers would suggest. Septic systems may deliver bacteria to surface waters due to malfunction, failures or direct pipe discharges. Properly operating septic systems treat the wastewater and discharge the treated water into the ground through perforated pipes called a lateral field. Excess bacteria or nutrients not treated in the septic system and laterals are biologically processed in the subsurface soils. The systems can fail when the field lines are broken or the underground substrate is clogged or flooded. Septic water may reach the land surface and wash off into the nearest stream. Direct bypasses of waste from septic systems to streams may occur when pipes are laid from the septic tanks or field lines to the stream. Failed septic systems are similar to cattle in the stream in that they may directly discharge bacteria to the stream and thus contribute to bacteria loads to a greater degree than their total counts would suggest.

The failure rate of septic systems varies considerably across counties in the Raccoon River watershed. County sanitarians who responded to requests for septic system information indicated that in some counties (Carroll, Guthrie, Adair, Audubon), from 70 to 90 percent of the systems would be considered failing due to lack of maintenance, failure to meet existing codes or are simply out of date (non-permitted). In regions where permitting regulations have been enforced, septic systems are monitored regularly and failure rates are much lower. Dallas County reported only a minor percentage of systems out of compliance, whereas at Lake Panorama where a management district checks nearly 800 septics regularly, all systems meet code and there is little potential for septic problems. For this TMDL, as a margin of safety it was assumed that all septic systems have failed in the Raccoon River watershed.

Bacteria counts from wildlife were based on deer population statistics alone and probably underestimate the true bacteria loss from wildlife. Manure from all forms of wildlife may wash into the stream following a runoff event, or may be directly deposited in or near a stream at some point.

4.3 TMDL Approach and Target

As previously discussed in Section 4.1, a TMDL is required for reaches within the Raccoon River watershed for *E.coli* bacteria. The TMDL was calculated using a duration curve analysis to assess the relation of measured daily loads to the water quality benchmark across a range of flow conditions. This approach was deemed appropriate for both pollutants because bacteria concentrations varied widely by flow, tending to increase in concentration as streamflow discharge increased. In this Section, a general discussion of the TMDL calculation is initially presented followed by a discussion of the duration curve modeling approach. TMDLs developed specifically for *E.coli* impairments in the Raccoon River at Des Moines, North Raccoon River at Sac City, North Raccoon River at Jefferson and in basin-wide surface water are presented in Sections 4.4, 4.5, 4.6 and 4.7, respectively.

4.3.1 Waterbody Pollutant Loading Capacity

A TMDL is a calculation of the maximum amount of pollutant that a water body can receive and still meet water quality standards and/or designated uses. It is the sum of the loads of the selected pollutant from all contributing point and nonpoint sources. The TMDL is developed according to the following equation:

TMDL = WLA + LA + MOS

where:

TMDL = Total Maximum Daily Load

WLA = Waste load allocation (point sources)

LA = Load allocation (nonpoint sources)

MOS = Margin of safety (may be implicit or explicit)

The WLA includes contribution from all permitted facilities, animal feeding operations, MS4 and WWTP point sources in the Raccoon River watershed (see Table 4-6). The LA includes contributions from all nonpoint sources (agricultural, developed land and natural sources; see Table 4-8). The MOS is the part of the allocation that accounts for uncertainty that the allocations will result in attainment of water quality standards.

The three TMDL components (WLA, LA, MOS) were all calculated as daily loads. Daily *E.coli* loads were assessed as the number of organisms (colony forming units or CFUs) per day.

4.3.2 Modeling Approach

The load duration curve (LDC) modeling approach was used in this TMDL to compare measured pollutant concentrations and daily flow data to the water quality standard at a range of flow conditions. The LDC method involves developing a flow duration curve or a representation of the percentage of days in a year when a given instream flow occurs. A lower percentile rank of flow indicates periods when flow rarely occur and typically represent high flow periods (storm events), whereas a low percentile rank of flow indicates periods when flow is exceeded most of the time (low flow periods). The allowable pollutant load curve is calculated using the flow duration curve by multiplying the flow values by the applicable TMDL target. The observed pollutant loads in the river are plotted on the developed curve and the points that fall above the allowable load curve indicate exceedances while the points that fall below the curve indicate acceptable loads.

Monitoring data that exceeds the water quality standard at high flows (low percentile) indicates pollutant sources that are problems during major precipitation and runoff events. Examples might include nitrogen or manure runoff from cropped fields after a heavy rainfall. Monitoring quality violations at low flows (high percentiles) are often from continuous direct discharges, such as wastewater treatment plants, cattle in streams or failed septic systems. The load duration curve analysis can often separate the impact of point and nonpoint sources on stream water quality.

4.3.3 TMDL Target

In this TMDL, the *E.coli* target is set to be the maximum single sample concentration of 235 CFU/100 ml. This TMDL target applies to all perennial rivers and streams during the March 15 to November 15 recreation season for Class A1 primary contact recreation use.

According to Iowa water quality standards, in addition to a maximum daily concentration, all facilities operating under an NPDES permit must meet a geometric mean *E.Coli* concentration of 126 CFU/100 ml in addition to the maximum single sample criteria (Iowa Administrative Code 61.3(3)). This 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 water designation,
- Samples must be spaced over one calendar month,
- No more than 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:

Geometric mean = (Sample 1 * Sample 2 * …Sample n)$^{(1/n)}$

where n is the number of samples collected over a given period. The geometric mean is used as opposed to the arithmetic mean because it handles highly skewed data or data with large variations/outliers better.

The single sample maximum *E.Coli* concentration was used as the TMDL target rather than the geometric mean because the single sample maximum is more directly applicable to the concept of a maximum daily load. Within the context of a TMDL, compliance with the maximum single sample target of 235 CFU/100 ml is considered consistent with the compliance with the geometric mean standard of 126 CFU/100 ml.

4.3.4 Margin of Safety

The TMDL target requires that stream *E.coli* concentrations do not exceed the target level for the entire range of streamflow. However, the TMDL target above does not include a margin of safety (MOS). The TMDL equation can be rearranged to reflect the MOS in the TMDL target as follows:

TMDL – MOS = WLA + LA

A MOS can be either explicit or implicit in the TMDL. For the Raccoon River, both MOS categories were used for *E.coli*. An explicit MOS of 35 CFU/100 ml was used which reflects the difference between the fecal coliform water quality standard (200 CFU/100 ml) and the *E.coli* standard. While this MOS represents a greater MOS percentage than assigned to nitrate (approximately 15 percent) the MOS is consistent with many TMDLs for *E.coli* that assume *E.coli* concentrations are equal to fecal coliform. Thus an *E.coli* TMDL target that includes a MOS is 200 CFU/100 ml (235 CFU/100 ml TMDL – 35 CFU/100 ml MOS).

The explicit MOS is reinforced for *E.coli* through conservative assumptions implicit in the representation and modeling of point and nonpoint sources. In particular, the point source contributions were calculated using many conservative assumptions that overestimated the point source contributions. For example, point source loads were based on fecal coliform concentrations, not *E.coli*, and thus overestimated pollutant discharge concentrations. When measured point source data were not available, estimates were based on population estimates. Comparing population estimated data with measured data, it is apparent that the estimated data greatly overestimated *E.coli* discharge loads. Estimates based on population did not consider bacteria losses that occur during the treatment process and thus greatly overestimate point source loads. Because nonpoint source loads were estimated from the difference in measured load minus point source load, the MOS implicit in the nonpoint source load estimate is related to the MOS for the point source load.

4.4 TMDL for *E.coli* at City of Des Moines (IA 04-RAC-0010-1&2)

4.4.1 Existing Load

The existing load for *E.coli* measured in the Raccoon River at the DMWW in the City of Des Moines is shown on the load duration curve (Figure 4-11). Based on near daily *E.coli* concentration and flow data (1997 to 2005), the daily *E.coli* load (in number of organisms per day) was plotted against the percentile of flow. Results indicated that a wide range of *E.coli* loads were measured and that *E.coli* loads varied with streamflow. Comparing the measured *E.coli* loads with the TMDL target of 200 CFU/100 ml indicated that many days had *E.coli* loads above the TMDL target. Exceedances were more prevalent at higher flows than lower flows, but exceedances occurred throughout the entire range of flow conditions. Many of the exceedances were greater than two and three orders of magnitude.

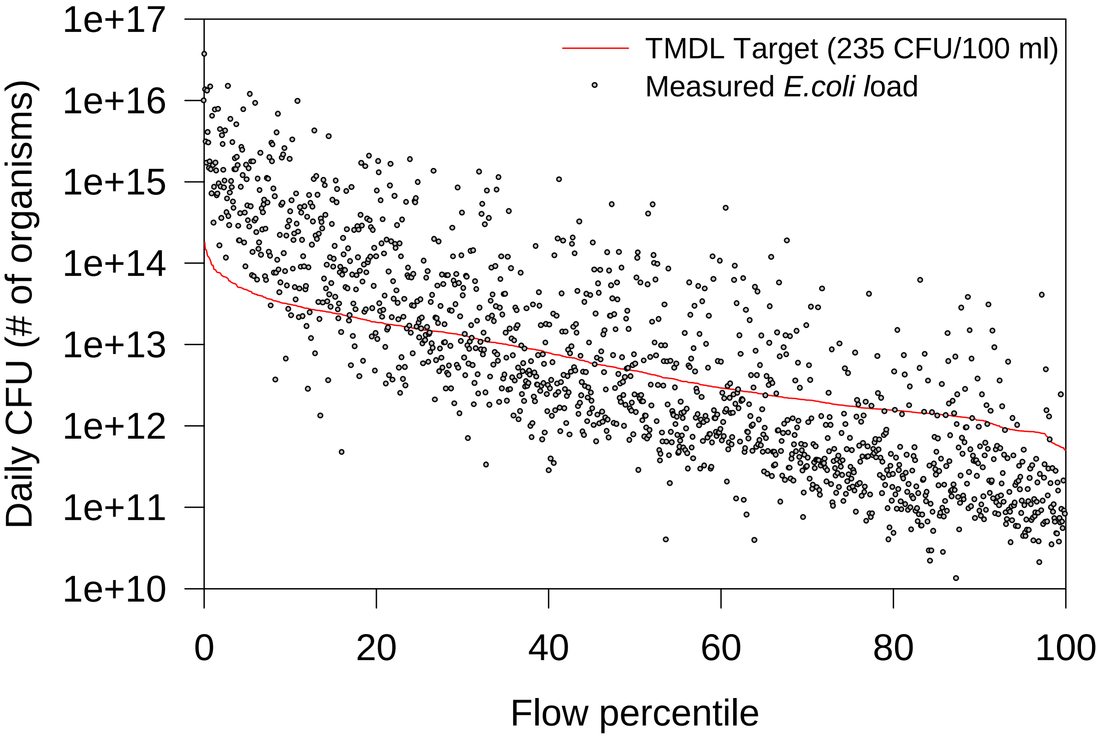


Figure 4-11. Load duration curve for daily Raccoon River *E.coli* loads at DMWW from 1997 to 2005. Point source load is taken from Table 4-6.

4.4.2 Departure from Load Capacity

Figure 4-11 indicated that daily *E.coli* loads exceeded the TMDL target across the range of flow conditions encountered in the Raccoon River. Because of the data availability at the DMWW, the difference between the current existing load and the desired TMDL target was evaluated by deciles of flow (10 percent flow ranges), just as done for the nitrate loads (see Table 3-10). The degree of *E.coli* load exceedance above the TMDL was considered as a load exceedance factor that is simply a multiplier to say how much the load exceeds the TMDL. The maximum daily *E.coli* reduction required to meet the TMDL target in each flow range was identified. The percentage of days in each flow range exceeding the TMDL target was identified. The median reduction is presented in Table 4-9 to provide an indication of the reduction needed for half of the exceedances to be reduced. (Note that this value is a median and not mean since the *E.coli* concentrations data were highly skewed.) The median CFUs in each flow range provides some context for evaluating how *E.coli* loads change with flow.

E.coli loads exceeded the TMDL target of 200 CFUs/100 ml at all flow ranges evaluated, with a maximum exceedance factor of 326 in the 90-80 percent flow range. This indicates that the *E.coli* load in the flow range is 326 times greater than the TMDL limit. In order for *E.coli* samples to be below the TMDL target, a 99.69 percent reduction in *E.coli* loads is needed in the 90-80 percent flow range. *E.coli* loads exceed the TMDL by a factor of more than 100 at flow ranges greater than 30 percent and loads reductions greater than 99 percent were needed. Median reductions decreased with decreasing flow range, from 93.1 percent in the 90-100 flow range to 51.2 percent in the 0-10 percent flow range. The number of days requiring a reduction in *E.coli* load decreased with decreasing flow range (Table 4-9). In the upper 10 percent of flow, virtually all of the days (97 percent) exceeded the TMDL target, whereas the next three flow ranges decreased to 83, 64, and 44 percent, respectively. In the lowest decile of flow (0-10 percent), nearly 13 percent of the days had *E.coli* loads that exceeded the TMDL target.

Table 4-9. Summary of *E.coli* reductions needed, days requiring *E.coli* load reductions and percentage of load derived from nonpoint and point sources in Raccoon River at DMWW. Load reductions summarized for each flow range decile of streamflow.

Flow Range	Max. Flow in Range (cfs)	Load Exceedance Factor [1]	Maximum Reduction Needed [2] (%)	% of Days Needing Reduction	Median Reduction Needed[2] (%)	Max. CFU in Flow Range
100-90	36835	260.2	99.61	97.0%	93.14	3.61E+16
90-80	6344	325.5	99.69	83.3%	84.79	9.58E+15
80-70	3842	113.7	99.12	64.4%	76.61	1.84E+15
70-60	2670	112.0	99.11	43.9%	71.98	1.29E+15
60-50	1608	140.4	99.29	43.2%	77.06	1.04E+15
50-40	972	121.0	99.17	36.4%	78.25	5.12E+14
40-30	595	161.6	99.38	30.3%	76.03	4.65E+14
30-20	425	24.8	95.97	15.2%	62.78	4.71E+13
20-10	318	41.8	97.61	18.9%	68.15	6.03E+13
10-0	239	49.0	97.96	12.9%	51.22	3.96E+13

[1] Multiplication factor to assess degree of bacteria load exceedance (i.e., existing load in 100-90 range exceeds TMDL by factor of 260.2 or, in other words, maximum load 260.2 times the standard)

[2] Reductions determined for only those days with an exceedance.

When *E.coli* loads exceeded the TMDL target in the upper half of flows, nonpoint sources contributed more than 92 percent of the total loads (Figure 4-12). With decreasing flow decile, the proportion of nonpoint to point source loads changed. This is a function of the constant point source inputs compared against a decreasing *E.coli* load. Only in the lowest 10 percent of flows measured in the Raccoon River, does the potential *E.coli* load contribution from point sources exceed nonpoint sources when exceedances occur.

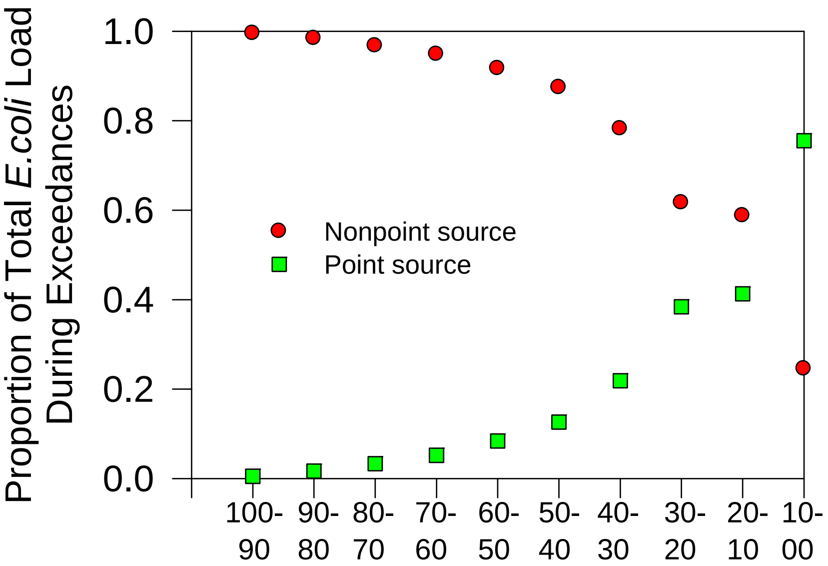


Figure 4-12. Proportion of total *E.coli* load from nonpoint and point sources when exceedances occur in various flow ranges.

Overall, for the entire flow range (all data), the maximum percent reduction needed was 99.69 percent (Table 4-9). For the intensive monitoring record at the DMWW, 44.5 percent of days exceeded the TMDL target. When exceedances occurred nonpoint point sources contributed to 90 percent of the *E.coli* loads whereas point source contributions were approximately 10 percent.

4.4.3 Seasonal Variation

Seasonal variation in *E.coli* loads in the Raccoon River at the City of Des Moines was evaluated in two ways. First, the load duration curve was used to account for seasonal and annual variations in streamflow. Secondly, because of the unique data availability, the seasonal variation was further analyzed by month (recreation season months only) (Table 4-10). While the greatest single day load exceedance was observed in April (326 times the TMDL limit), a greater proportion of days in May and June required *E.coli* reductions (60.3 and 74.3 percent of days, respectively). Maximum daily reduction in *E.coli* concentration was greater than 99 percent in all months except September when a reduction of nearly 92 percent was required. More than half of the measurement days required an *E.coli* load reduction in the months of April through July, although fewer measurement days required reductions in the months of August through November (23.5 to 34.5 percent). Thus, *E.coli* loads exceeded the TMDL target to a greater degree in the spring and early summer compared to the late summer and fall.

Table 4-10. Summary of *E.coli* load reductions needed by month in Raccoon River at DMWW.

Month	Load Exceedance Factor [1]	Maximum Reduction Needed [2] (%)	Median Reduction Needed [1] (%)	% of Days Needing Reduction	No. of Days with Exceed.	Maximum Daily CFU
Apr	325.5	99.69	65.64	57.0%	57 of 100	9.57E+15
May	260.2	99.62	89.71	60.3%	108 of 179	1.16E+16
Jun	116.2	99.14	83.61	74.3%	136 of 183	3.92E+15
Jul	107.2	99.07	82.97	53.6%	96 of 179	1.10E+15
Aug	113.7	99.12	75.49	34.5%	67 of 194	1.8E+15
Sep	12.2	91.81	78.81	23.5%	42 of 179	5.32E+13
Oct	121.0	99.17	77.78	27.3%	53 of 194	5.12E+14
Nov	160.6	99.38	80.66	25.0%	29 of 116	4.64E+14

[1] Multiplication factor to assess degree of bacteria load exceedance (i.e., existing load in 100-90 range exceeds TMDL by factor of 325.5, or, in other words, maximum load is 325.5 times the standard)
[2] Reductions determined for only those days with an exceedance.

4.4.4 Pollutant Allocation

The pollutant allocation is the amount of daily *E.coli* load allocated to point sources (wasteload allocation), nonpoint sources (load allocation) and a margin of safety.

Wasteload allocation. Point sources do not appear to contribute substantially to the *E.coli* impairment at the DMWW in the Raccoon River but may cause localized problems. When exceedances occurred during the monitoring period, WWTP point sources contributed approximately 10 percent of the *E.coli* load.

With the change in Iowa's water quality standards for indicator bacteria (now *E.coli*) such that all perennial rivers and streams are subject to Class A standards (see Section 4.1 for more details), assessing the point source contribution to the bacteria impairment is no longer appropriate. Current regulations state that during the recreation season (March 15 to November 15) all perennial rivers and stream will have the water quality standard of 126 CFUs/100 ml (geometric mean of multiple samples) or 235 CFUs/100 ml (single sample maximum). Thus, if a WWTP or other point source discharges to a perennial river or stream with effluent concentrations higher than 235 CFUs/100 ml, they would be in violation of the water quality standard. Considering that all the permitted WWTPs and other point source dischargers in the Raccoon River watershed discharge to a perennial stream, the daily wasteload allocation for all point sources in the watershed is established, by rule, to be based on a concentration standard of 235 CFU/100 ml.

Individual wasteload allocations for all point sources in the Raccoon River watershed above the DMWW are presented in Table 4-6. The total daily wasteload allocation for point sources in the Raccoon River watershed is set to be 9.326E+11 CFUs (Table 4-6). This value represents the sum of all daily point source inputs in the watershed above the DMWW. To achieve the new water quality standard for Class A1 waters, collectively, point sources will require a reduction of daily CFUs from 1.57E+12 to 9.33E+11, or a reduction of 59.4 percent.

The total wasteload allocated for NPDES permitted livestock animal feeding operations in the Raccoon River watershed is set at zero in accordance with IAC Chapter 65. The wasteload allocation for urban storm water sources will be implemented through the NPDES MS4 permits and utilize best management practices in lieu of numeric standards.

Load allocation. The load allocation for *E.coli* bacteria will be flow dependent since daily bacteria loads in the river vary greatly by flow. The load allocation for *E.coli* bacteria for the Raccoon River at the DMWW in Des Moines is set using the following equation:

LA = TMDL (235 CFUs/100 ml x Flow) – WLA (9.344E+11 CFUs) – MOS (35 CFUs x Flow)

The TMDL load allocation for bacteria in the Raccoon River is illustrated graphically in Figure 4-11 by the region between the point source line and the solid red line representing the daily bacteria load at 200 CFUs/100 ml.

Margin of Safety. The MOS is set explicitly to be 35 CFUs/100 ml multiplied by the daily flow. Because it is flow dependent the actual daily MOS will vary. During all flows, a MOS of 35 CFUs/100 ml will ensure that *E.coli* concentrations in the Raccoon River remain less than the single sample maximum value of 235 CFUs/100 ml.

4.5 TMDL for *E.coli* Impairment in the North Raccoon river Near Sac City (IA 04-RAC-0040-5 & 6)

4.5.1 Existing Load

The existing load for *E.coli* in the North Raccoon River near Sac City is shown on the load duration curve (Figure 4-13). During a 20-year monitoring period, results indicated a wide range of *E.coli* loads that varied with streamflow. Comparing the measured *E.coli* load with the TMDL target line (200 CFUs/100 ml) indicates that many days had daily *E.coli* loads above the target level. These exceedances were more prevalent at high flows than low flows, but exceedances occurred throughout most of the range of flow conditions. The range of flow conditions account for seasonal and annual variations during the assessment period.

4.5.2 Departure from Load Capacity

Based on the entire data record, a maximum *E.coli* reduction of 99.8 percent is required for all measured samples to be less than the TMDL target. Of the 141 samples collected during the recreation season, 77 samples (54.6 percent) exceeded the TMDL target.

4.5.3 Pollutant Allocation

The pollutant allocation is the amount of daily *E.coli* load allocated to point sources (wasteload allocation), nonpoint sources (load allocation) and a margin of safety. The TMDL for *E.coli* considers the relation of E.coli concentrations to flow in the North Raccoon River (Table 4-11).

Wasteload allocation. Point sources contribute to the *E.coli* impairment in the North Raccoon River near Sac City. When exceedances occurred, point sources comprised approximately 23 percent of the impairment. Individual wasteload allocations for point sources in the North Raccoon River watershed above the impaired segment are presented in Table 4-6a.

The total wasteload allocated for NPDES permitted livestock animal feeding operations in the North Raccoon River above Sac City is set at zero in accordance with IAC Chapter 65. The wasteload allocation for urban storm water sources will be implemented through the NPDES MS4 permits and utilize best management practices in lieu of numeric standards.

Load allocation. The load allocation for *E.coli* bacteria will be flow dependent since daily bacteria loads in the river vary greatly by flow. The load allocation for *E.coli* bacteria for the Raccoon River at Sac City is set using the following equation:

LA = TMDL (235 CFUs/100 ml x Flow) – WLA (1.709E+11 CFUs) – MOS (35 CFUs x Flow)

Margin of Safety. The MOS is set explicitly to be 35 CFUs/100 ml multiplied by the daily flow. During all flows, a MOS of 35 CFUs/100 ml will ensure that *E.coli* concentrations in the North Raccoon River above Sac City remain less than the single sample maximum value of 235 CFUs/100 ml.

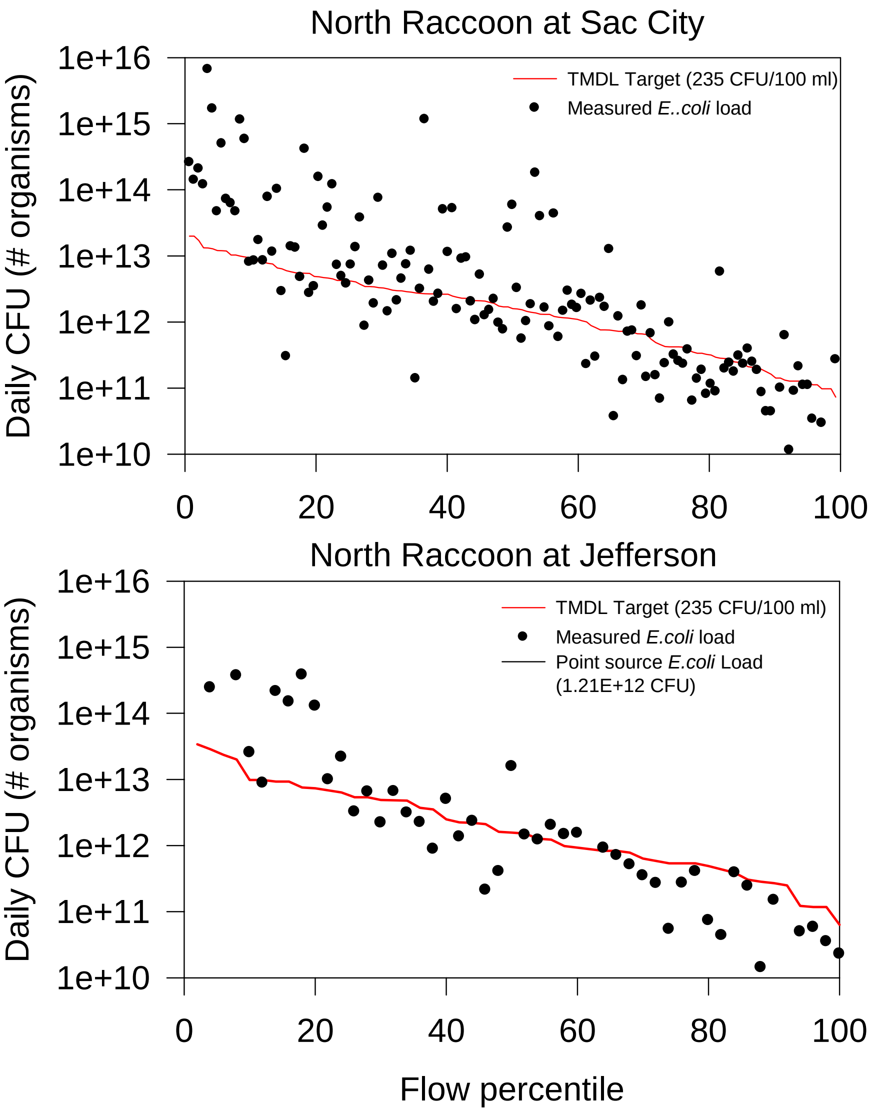


Figure 4-13. Load duration curve for daily North Raccoon River *E.coli* loads at Sac City and Jefferson. Point source load is taken from Table 4-6.

Table 4-11. TMDL determination for E.coli based on streamflow conditions in the North Raccoon River near Sac City.

North Raccoon near Sac City (IA-04-RAC-0040-5&6)

Percentile	Mean Daily Flow (cfs)	E.Coli TMDL 235 CFUs/100 ml	MOS 35 CFUs/100 ml	TMDL - MOS 200 CFUs/100 ml
10	1170	6.726E+12	1.002E+12	5.724E+12
20	644	3.702E+12	5.514E+11	3.151E+12
30	401	2.305E+12	3.433E+11	1.962E+12
40	259	1.489E+12	2.217E+11	1.267E+12
50	178	1.023E+12	1.524E+11	8.708E+11
60	121	6.956E+11	1.036E+11	5.920E+11
70	82	4.714E+11	7.020E+10	4.012E+11
80	53	3.047E+11	4.538E+10	2.593E+11
90	30	1.725E+11	2.568E+10	1.468E+11
100	2.6	1.495E+10	2.226E+09	1.272E+10

4.6 TMDL for *E.coli* Impairment in the North Raccoon river Near Jefferson (IA 04-RAC-0040-1)

4.6.1 Existing Load

The existing load for *E.coli* in the North Raccoon River near Jefferson is shown on the load duration curve (Figure 4-13). During a six-year monitoring period, results indicated a wide range of *E.coli* loads that varied with streamflow. Comparing the measured *E.coli* load with the TMDL target line (200 CFUs/100 ml) indicates that many days had daily *E.coli* loads above the target level. These exceedances were more prevalent at high flows than low flows, but exceedances occurred throughout most of the range of flow conditions. The range of flow conditions account for seasonal and annual variations during the assessment period.

4.6.2 Departure from Load Capacity

Based on the entire data record, a maximum *E.coli* reduction of 99.7 percent is required for all measured samples to be less than the TMDL target. Of the 50 samples collected during the recreation season, 19 samples (38.0 percent) exceeded the TMDL target.

4.6.3 Pollutant Allocation

The pollutant allocation is the amount of daily *E.coli* load allocated to point sources (wasteload allocation), nonpoint sources (load allocation) and a margin of safety. The TMDL for *E.coli* considers the relation of E.coli concentrations to flow in the North Raccoon River (Table 4-11).

Wasteload allocation. Point sources do not contribute substantially to the *E.coli* impairment in the Raccoon River near Jefferson. Of the days when exceedances occurred, point sources comprised approximately one percent of the total *E.coli* load. Individual wasteload allocations for point sources in the North Raccoon River watershed above the impaired segment are presented in Table 4-6. The total daily wasteload allocation for point sources in the North Raccoon River watershed above Jefferson is set to be 3.925E+11 CFUs (Table 4-6). This value represents the sum of all daily point source inputs in the watershed above the impaired segment. The value includes the contributions from the portion of the watershed included in the North Raccoon at Sac City TMDL. To achieve the new water quality standard for Class A1 waters, collectively, point sources will require a reduction of daily CFUs from 1.206E+12 to 3.925E+11, or a reduction of 32.5 percent.

The total wasteload allocated for NPDES permitted livestock animal feeding operations in the North Raccoon River above Jefferson is set at zero in accordance with IAC Chapter 65. The wasteload allocation for urban storm water sources will be implemented through the NPDES MS4 permits and utilize best management practices in lieu of numeric standards.

Load allocation. The load allocation for *E.coli* bacteria will be flow dependent since daily bacteria loads in the river vary greatly by flow. The load allocation for *E.coli* bacteria for the North Raccoon River at Jefferson is set using the following equation:

LA = TMDL (235 CFUs/100 ml x Flow) – WLA (1.299E +10 CFUs) – MOS (35 CFUs x Flow)

Margin of Safety. The MOS is set explicitly to be 35 CFUs/100 ml multiplied by the daily flow. During all flows, a MOS of 35 CFUs/100 ml will ensure that *E.coli* concentrations in the North Raccoon River above Jefferson remain less than the single sample maximum value of 235 CFUs/100 ml.

Table 4-12. TMDL determination for E.coli based on streamflow conditions in the North Raccoon River near Jefferson.

North Raccoon near Jefferson (IA-04-RAC-0040-1)

Percentile	Mean Daily Flow (cfs)	E.Coli TMDL 235 CFUs/100 ml	MOS 35 CFUs/100 ml	TMDL - MOS 200 CFUs/100 ml
10	1790	1.029E+13	1.533E+12	8.757E+12
20	947	5.444E+12	8.108E+11	4.633E+12
30	515	2.960E+12	4.409E+11	2.520E+12
40	317	1.822E+12	2.714E+11	1.551E+12
50	223	1.282E+12	1.909E+11	1.091E+12
60	152	8.738E+11	1.301E+11	7.436E+11
70	107	6.151E+11	9.161E+10	5.235E+11
80	75	4.311E+11	6.421E+10	3.669E+11
90	55	3.162E+11	4.709E+10	2.691E+11
100	19	1.092E+11	1.627E+10	9.295E+10

4.7 TMDL for Future Indicator Bacteria Impairments in the Raccoon River

As indicated in Section 4.1.6, new water quality standards designate all perennial streams as Class A1 waters and consider *E.coli* as the indicator bacterium with which to classify a stream as "supporting" or "not supporting" its designated use. Available water quality data suggests that all Class A1 waters in the Raccoon River would be considered as "not supporting" their designated uses. Monitoring results have documented *E.coli* concentrations exceeding the single sample maximum (235 CFUs/100 ml) or exceeding the geometric mean concentrations (126 CFUs/100 ml) at all sites where credible data have been collected. Thus, this report provides a TMDL determination for all Class A1 waters in the Raccoon River in advance of collection of credible water monitoring data that could be used to list the stream segment as impaired in the future.

For purposes of this TMDL, all Class A1 stream segments in the Raccoon River have been placed into their respective HUC12 basins (see Figure 5-1). These basins are the same basins used in watershed modeling (see Section 5). There are 108 HUC12 basins in the Raccoon River watershed and four main stem basins corresponding to the USGS stream gage locations on the main stems (North Raccoon River at Sac City and Jefferson, South Raccoon at Redfield, Raccoon River at Van Meter). These four "basins" are actually smaller subbasins contained within larger HUC12 subbasins that were subdivided to provide a watershed outlet corresponding to the location of the USGS stream gage. Overall, the Raccoon River watershed was subdivided into 112 subbasins for analysis and modeling.

Because no monitoring data has been collected from most of the Class A1 stream segments, no analysis of existing load or departure from load capacity assessment was conducted for these sites. The TMDLs for these stream segments is for future consideration of whether measured loads in the subbasins are within their respective TMDL capacity.

Table 4-13 lists the 112 subbasins in the Raccoon River and provides a basin number for map location on Figure 5-1. For the subbasins with the Class A1 stream segments designated, the stream segments are provided in Table 4-11. The number and name of WWTPs located in the appropriate subbasin are also indicated. These WWTPs are the same as those included in Table 4-6, only in this case they were further located into a specific HUC12 subbasin. All *E.coli* wasteloads for the various WWTPs were also the same as presented in Table 4-6. In Table 4-13, *E.coli* contributions from multiple WWTPs in a subbasin were added together to derive a total wasteload allocation for a subbasin.

Table 4-13. TMDL load allocations for streams located in Raccoon River subbasins. Wasteload allocations are summed for WWTPs located in each subbasin as determined from TMDL values on Table 4-6.

Subbasin Name	Map ID	Stream Segment	WWTPs in Subbasin	File Name	TMDL Target	MOS	WLA (Daily CFUs)	Load Allocation
Bay Branch	66	IA 04-RAC-0241_0	None	Baybr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Bear Cr - SRR	80	IA 04-RAC-0197_0	Earlham	Bearcr	235 CFUs x Flow	35 CFUs x Flow	1.3323E+10	TMDL-MOS-1.3323E+10
Beaver Cr - SRR	73	None	None	Beavercr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Buck Run	15	IA 04-RAC-0163_0	None	Buckrun	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Bulger Cr	83	None	Desoto	Bulgercr	235 CFUs x Flow	35 CFUs x Flow	8.8058E+09	TMDL-MOS-8.058E+09
Buttrick Cr	55	IA 04-RAC-0060_0	None	Buttrickcr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Cedar Cr - Branch 6	4	None	Laurens	Cedarcrbr6	235 CFUs x Flow	35 CFUs x Flow	1.9924E+10	TMDL-MOS-1.9924E+10
Cedar Cr - DD 121	41	IA 04-RAC-0100_1, IA 04-RAC-0100_2	Lohrville	Cedarcr121	235 CFUs x Flow	35 CFUs x Flow	9.6864E+09	TMDL-MOS-9.6864E+09
Cedar Cr - DD 20	23	IA 04-RAC-0150_1	None	Cedarcr20	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Cedar Cr - DD 37	17	IA 04-RAC-0150_2	None	Cedarcr37	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Cedar Cr - DD 74	13	IA 04-RAC-0150_2	None	Cedarcr74	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
DD 1 - Camp Cr	19	None	None	Dd1	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
DD 21 - Cedar Cr	5	None	None	Dd21	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
DD 29	14	None	Fonda	Dd29	235 CFUs x Flow	35 CFUs x Flow	9.1082E+09	TMDL-MOS-9.1082E+09
DD 57	29	None	None	Dd57	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
DD 67	8	None	None	Dd67	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
DD 81 - Cedar Cr	18	None	None	Dd81	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
DD 9 & 13	57	None	None	Dd913	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
E Br Panther Cr	69	None	None	Ebrpanther	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
E Cedar Cr	31	IA 04-RAC-0110_0	Manson, Rinard	Ecedarcr	235 CFUs x Flow	35 CFUs x Flow	9.5974E+09	TMDL-MOS-9.5974E+09
E Fk Hardin Cr	48	None	None	Efkhardin	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Elk Run - NRR	38	IA 04-RAC-0127_0	None	Elkrun	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Hardin Cr Headwaters	93	None	None	Hardincrhd	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Indian Cr - NRR	28	IA 04-RAC-0145_0	Lake View	Indiancr	235 CFUs x Flow	35 CFUs x Flow	9.2950E+09	TMDL-MOS-9.2950E+09
Jefferson Gage	112	IA 04-RAC-0040_1	Jefferson, Scranton	Jeffersong	235 CFUs x Flow	35 CFUs x Flow	5.1563E+10	TMDL-MOS-5.1563E+10
L Brushy Cr - SRR	70	IA 04-RAC-0250_0, IA 04-RAC-0251_0	None	Lbrushycr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L Camp Cr - NRR	33	IA 04-RAC-0140_0	None	Lcampcr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L DD 9 & 13	21	IA 04-RAC-0135_0	None	Ldd913	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L E Buttrick Cr	50	IA 04-RAC-0070_0	Paton	Lebuttrick	235 CFUs x Flow	35 CFUs x Flow	2.2237E+10	TMDL-MOS-2.2237E+10
L Greenbrier Cr	58	IA 04-RAC-0056_0, IA 04-RAC-0058_0	None	Lgreenbrie	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L Hardin Cr	54	IA 04-RAC-0090_0	None	Lhardincr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L Lake Cr	35	IA 04-RAC-0130_1, IA 04-RAC-0130_2	Lake City	Llakecr	235 CFUs x Flow	35 CFUs x Flow	2.4638E+10	TMDL-MOS-2.4638E+10
L Little Cedar Cr	10	IA 04-RAC-0161_0	None	Llitcedar	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L Mosquito Cr - MRR	72	IA 04-RAC-0240_0	None	Lmosquito	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L Purgatory Cr	43	IA 04-RAC-0120_0	None	Lpurgatory	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L Raccoon R	111	IA 04-RAC-0010_2, IA 04-RAC-0010_1	None	Lraccoonr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L W Buttrick Cr	49	IA 04-RAC-0080_0	None	Lwbuttrick	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
L W Fk Camp Cr	24	IA 04-RAC-0143_0	Lytton	Lwfkcamp	235 CFUs x Flow	35 CFUs x Flow	1.4844E+10	TMDL-MOS-1.4844E+10
Lateral 2	3	None	Albert City	Lateral2	235 CFUs x Flow	35 CFUs x Flow	1.3341E+10	TMDL-MOS-1.3341E+10
Lateral 4	1	None	None	Lateral4	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
M Brushy Cr - SRR	98	IA 04-RAC-0251_0	Dedham	Mbrushycr	235 CFUs x Flow	35 CFUs x Flow	4.4474E+09	TMDL-MOS-4.4474E+09
M Hardin Cr	47	IA 04-RAC-0090_0	Churdan	Mhardincr	235 CFUs x Flow	35 CFUs x Flow	1.2453E+09	TMDL-MOS-1.2453E+09
M Lake Cr	91	IA 04-RAC-0130_2	None	Mlakecr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Mason Cr	67	None	None	Masoncr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
MRR - Headwaters	95	IA 04-RAC-0230_2	None	Mrrheadwat	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
MRR - Kings Cr	101	IA 04-RAC-0210-L_0, IA 04-RAC-0220_0	Springbrook Camp and Education	Mrrkingscr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
MRR - Mosquito Cr	75	IA 04-RAC-0200_1, IA 04-RAC-0200_2, IA 04-RAC-0200_3	Panora, Redfield	Mrrmosquit	235 CFUs x Flow	35 CFUs x Flow	4.3291E+10	TMDL-MOS-4.3921E+10
MRR - Spring Br	96	IA 04-RAC-0230_2, IA 04-RAC-0248_0	None	Mrrspring	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
MRR - Storm Cr	45	IA 04-RAC-0230_2, IA 04-RAC-02485_0	Carroll	Mrrstorm	235 CFUs x Flow	35 CFUs x Flow	4.2890E+10	TMDL-MOS-4.2890E+10
MRR - Willey Br	99	IA 04-RAC-0230_1, IA 04-RAC-0230_2, IA 04-RAC-0245_0	Coon Rapids	Mrrwilley	235 CFUs x Flow	35 CFUs x Flow	1.4463E+10	TMDL-MOS-1.4463E+10
MRR - Willow Cr	61	IA 04-RAC-0230_1	None	Mrrwillow	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
NRR - Buck Run	22	IA 04-RAC-0050_2	Sac City	Nrrbuckrun	235 CFUs x Flow	35 CFUs x Flow	1.7744E+10	TMDL-MOS-1.7744E+10
NRR - Buttrick Cr	59	IA 04-RAC-0040_1, IA 04-RAC-0030_4	None	Nrrbuttric	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
NRR - Cedar Cr	52	IA 04-RAC-0040_2	None	Nrrcedarcr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
NRR - DD 101	11	IA 04-RAC-0050_3, IA 04-RAC-0050_2	None	Nrr101	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
NRR - DD 171	53	IA 04-RAC-0040_1	None	Nrr171	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
NRR - DD 25	32	IA 04-RAC-0040_5	Auburn	Nrr25	235 CFUs x Flow	35 CFUs x Flow	2.6684E+09	TMDL-MOS-2.6684E+09
NRR - DD 73	27	IA 04-RAC-0040_6	None	Nrr73	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
NRR - Doe Brook	40	IA 04-RAC-0040_3	None	Nrrdoebr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
NRR - Fannys Br	105	IA 04-RAC-0030_3	None	Nrrfannys	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS

Table 4-11. …continued

Subbasin Name	Map ID	Stream Segment	WWTPs in Subbasin	File Name	TMDL Target	MOS	WLA (Daily CFUs)	Load Allocation
NRR - Frog Cr	62	IA 04-RAC-0030_3, IA 04-RAC-0054_0	Perry, Rippey, IBP Perry	Nrrfrogcr	235 CFUs x Flow	35 CFUs x Flow	1.1604E+11	TMDL-MOS-1.1604E+11
NRR - Hickory Cr	81	IA 04-RAC-0030_2, IA 04-RAC-0030_1, IA 04-RAC-0051_0	Adel, Country View, Ortonville	Nrrhickory	235 CFUs x Flow	35 CFUs x Flow	3.4636E+10	TMDL-MOS-3.4636E+10
NRR - Lateral 3	7	IA 04-RAC-0050_3	None	Nrrlat3	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
NRR - Lateral 6	2	IA 04-RAC-0050_3	Rembrandt, Rembrandt Enterprises	Nrrlat6	235 CFUs x Flow	35 CFUs x Flow	5.2670E+09	TMDL-MOS-5.2670E+09
NRR - Lateral 9	86	None	Marathon	Nrrlat9	235 CFUs x Flow	35 CFUs x Flow	3.6057E+09	TMDL-MOS-3.6057E+09
NRR - Marrowbone Cr	42	IA 04-RAC-0040_4, IA 04-RAC-0040_3, IA 04-RAC-0123_0	Lanesboro	Nrrmarrow	235 CFUs x Flow	35 CFUs x Flow	2.1347E+09	TMDL-MOS-2.1347E+09
NRR - Prairie Cr	39	IA 04-RAC-0040_4	None	Nrrprairie	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
NRR - Swan Lake Br	109	IA 04-RAC-0030_2	Minburn	Nrrswanlk	235 CFUs x Flow	35 CFUs x Flow	7.2937E+09	TMDL-MOS-7.2937E+09
Outlet Cr	12	IA 04-RAC-0165_0	Storm Lake, IBP Storm Lake	Outletcr	235 CFUs x Flow	35 CFUs x Flow	8.1586E+10	TMDL-MOS-8.1586E+10
Panther Cr	78	IA 04-RAC-0190_0	None	Panthercr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Poor Farm Cr	6	None	Spectra Health	Poorfarmcr	235 CFUs x Flow	35 CFUs x Flow	4.4474E+08	TMDL-MOS-4.4474E+08
Prairie Cr - DD 1	16	None	Newell	Prairie1	235 CFUs x Flow	35 CFUs x Flow	1.2158E+10	TMDL-MOS-1.2158E+10
Prairie Cr - DD 198	34	IA 04-RAC-0137_0	None	Prairie198	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Redfield Gage	107	IA 04-RAC-0170_0	None	Redfieldg	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Sac City Gage	87	IA 04-RAC-0040_6	None	Saccityg	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Seely Cr	65	None	None	Seelycr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Short Cr - NRR	51	IA 04-RAC-0095_0	None	Shortcr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
SRR - Bear Cr	79	IA 04-RAC-0170_0	None	Srrbearcr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
SRR - Beaver Cr	74	IA 04-RAC-0180_1	None	Srrbeaver	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
SRR - Bulger Cr	82	IA 04-RAC-0170_0	None	Srrbulger	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
SRR - Deer Cr	106	IA 04-RAC-0180_1, IA 04-RAC-0249_0	None	Srrdeer	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
SRR - Frost Cr	64	IA 04-RAC-0180_2	None	Srrfrost	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
SRR - Long Br	76	IA 04-RAC-0180_1	Stuart, Diamond Head Lake	Srrlongbr	235 CFUs x Flow	35 CFUs x Flow	3.0082E+10	TMDL-MOS-3.0082E+10
SRR - Mason Cr	71	IA 04-RAC-0180_2	Guthrie Center, Rose Acre Farms	Srrmason	235 CFUs x Flow	35 CFUs x Flow	1.6580E+10	TMDL-MOS-1.6580E+10
Storm Cr	46	None	Lidderdale	Stormcr	235 CFUs x Flow	35 CFUs x Flow	1.2008E+09	TMDL-MOS-1.2008E+09
Sugar Cr - RR	84	IA 04-RAC-0025_0	Waukee, Rest Stops	Sugarcr	235 CFUs x Flow	35 CFUs x Flow	4.9421E+10	TMDL-MOS-4.9421E+10
Swan Lake Br	63	IA 04-RAC-0052_0	None	Swanlake	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Tank Pond	37	None	Gowrie	Tankpond	235 CFUs x Flow	35 CFUs x Flow	1.4454E+10	TMDL-MOS-1.4454E+10
U Brushy Cr - SRR	97	None	Halbur	Ubrushycr	235 CFUs x Flow	35 CFUs x Flow	9.5174E+08	TMDL-MOS-9.5174E+08
U Camp Cr - NRR	25	IA 04-RAC-0140_0	None	Ucampcr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
U DD 9 & 13	88	None	Pomeroy	U913	235 CFUs x Flow	35 CFUs x Flow	1.2542E+10	TMDL-MOS-1.2542E+10
U E Buttrick Cr	104	None	Harcourt	Uebuttrick	235 CFUs x Flow	35 CFUs x Flow	3.0420E+10	TMDL-MOS-3.0420E+10
U Greenbrier Cr	103	IA 04-RAC-0056_0	None	Ugreenbrie	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
U Hardin Cr	94	None	Farnhamville	Uhardincr	235 CFUs x Flow	35 CFUs x Flow	2.2680E+09	TMDL-MOS-2.2680E+09
U Lake Cr	89	IA 04-RAC-0130_2	Rockwell City, Twin Lakes SD	Ulakecr	235 CFUs x Flow	35 CFUs x Flow	9.4178E+10	TMDL-MOS-9.4178E+10
U Little Cedar Cr	9	None	None	Ulitcedar	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
U Mosquito Cr - MRR	102	IA 04-RAC-0240_0	Bagley	Umosquito	235 CFUs x Flow	35 CFUs x Flow	3.2466E+09	TMDL-MOS-3.2466E+09
U Purgatory Cr	90	None	None	Upurgatory	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
U Raccoon R	85	IA 04-RAC-0010_2	Van Meter	Uraccoonr	235 CFUs x Flow	35 CFUs x Flow	1.4009E+10	TMDL-MOS-1.4009E+10
U W Buttrick Cr	36	IA 04-RAC-0080_0	Callendar	Uwbuttrick	235 CFUs x Flow	35 CFUs x Flow	1.2542E+10	TMDL-MOS-1.2542E+10
U W Fk Camp Cr	20	None	None	Uwfkcampcr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Unnamed Cr - NRR	44	IA 04-RAC-0115_0	West Central Cooperative	Unnamedcr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Van Meter Gage	108	IA 04-RAC-0010_2	None	Vanmeterg	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
W Br Panther Cr	68	IA 04-RAC-0193_0	None	Wbrpanther	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
W Cedar Cr	30	None	None	Wcedarcr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Wall Lake Inlet	92	None	Breda	Walllake	235 CFUs x Flow	35 CFUs x Flow	1.0674E+10	TMDL-MOS-1.0674E+10
Walnut Cr - Little Walnut Cr	110	None	Dallas Center	Walnutlwal	235 CFUs x Flow	35 CFUs x Flow	1.9835E+10	TMDL-MOS-1.9835E+10
Walnut Cr - RR	77	IA 04-RAC-0020_2, IA 04-RAC-0020_1	None	Walnutrr	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Welshs Slough	26	None	None	Welshssl	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Willow Cr - DD 117	56	IA 04-RAC-0242_0	None	Willow117	235 CFUs x Flow	35 CFUs x Flow	0.0000E+00	TMDL-MOS
Willow Cr - DD 9 & 13	60	IA 04-RAC-0242_0	Bayard	Willow913	235 CFUs x Flow	35 CFUs x Flow	5.7015E+09	TMDL-MOS-5.7015E+09
Willow Cr Headwaters	100	None	Glidden	Willowhead	235 CFUs x Flow	35 CFUs x Flow	1.0674E+10	TMDL-MOS-1.0674E+10

The TMDL for indicator bacteria in the 112 subbasins uses the same load duration curve approach as discussed previously for impaired segments. However, unlike already impaired sites where monitoring data is available, daily flows or *E.coli* concentrations have not been measured in the subbasins. In this case, the acceptable load for a unmeasured subbasin can still be determined whenever a daily flow and *E.coli* concentration are measured by applying the following TMDL equation based on the LDC:

TMDL (235 CFUs/100 ml x Flow) = WLA + LA + MOS (35 CFUs x Flow)

The TMDL target for indicator bacteria in the 112 subbasins is the same for all areas and applies to the recreation season of March 15 to November 15. The TMDL target is based on the product of daily flow and the *E.coli* concentration target of 235 CFUs/100 ml. Similarly, the margin of safety is also based on the product of daily flow and the MOS *E.coli* concentration target of 35 CFUs/100 ml. Thus the TMDL and MOS for all subbasins is established on a daily basis accounting for any variations in flow that might occur during the recreation season between March 15 and November 15. Total allowable *E.coli* loads and the MOS are presented as total number of CFUs per day after units of discharge and concentrations are converted accordingly.

Wasteload allocation. Point sources may contribute to future bacteria indicator impairments in 44 of the subbasins that contain WWTPs (Table 4-11). In these subbasins, the total number of allowable CFUs per day was determined as the product of the WWTP daily discharge multiplied by the TMDL target of 235 CFUs/100 ml. For each point source with a daily or continuous discharge, the maximum daily discharge was multiplied by the single sample maximum value of 235 CFUs to derive the TMDL. For point sources with controlled discharges (intermittent releases), the total annual discharge from the facility was multiplied by the concentration standard of 235 CFUs/100 ml to derive the annual permitted bacteria load. This value was then divided by 365 days to estimate the maximum allowable daily load of bacteria. The total daily wasteload allocation for point sources in the 44 subbasins with WWTPs was determined by summing the daily TMDL for each point source in the subbasin. The daily TMDL for *E.coli* bacteria at each WWTP was previously determined and shown in Table 4-6. If no WWTP was present in a subbasin, the wasteload allocation was set to be zero.

Load allocation. The load allocation for indicator bacteria in all 112 subbasins will be flow dependent since daily bacteria loads in the river vary greatly by flow. The load allocation for *E.coli* bacteria for the subbasins is set using the following equation:

LA = TMDL (235 CFUs/100 ml x Flow) – WLA (daily CFUs from point sources) – MOS (35 CFUs x Flow)

If no point sources (WWTPs) are present in a subbasin, the daily LA is equal to the TMDL minus the MOS.

Margin of Safety. The MOS is set explicitly to be 35 CFUs/100 ml multiplied by the daily flow. During all flows, a MOS of 35 CFUs/100 ml will ensure that *E.coli* concentrations in all of the subbasins remain less than the single sample maximum value of 235 CFUs/100 ml.

5.0 RACCOON RIVER WATERSHED MODEL

5.1 SWAT Model Setup and Description

The Soil and Water Assessment Tool (SWAT) is a hydrologic and water quality model developed by the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) (Arnold et al., 1998 Arnold and Fohrer, 2005; Gassman et al., 2005). It is a long-term, continuous, watershed-scale, simulation model that operates on a daily time step and is designed to assess the impact of land use and different land management practices on water, nutrient and bacteria yields. The model is physically based and includes major components of weather, hydrology, soil temperature, crop growth, nutrients, bacteria and land management.

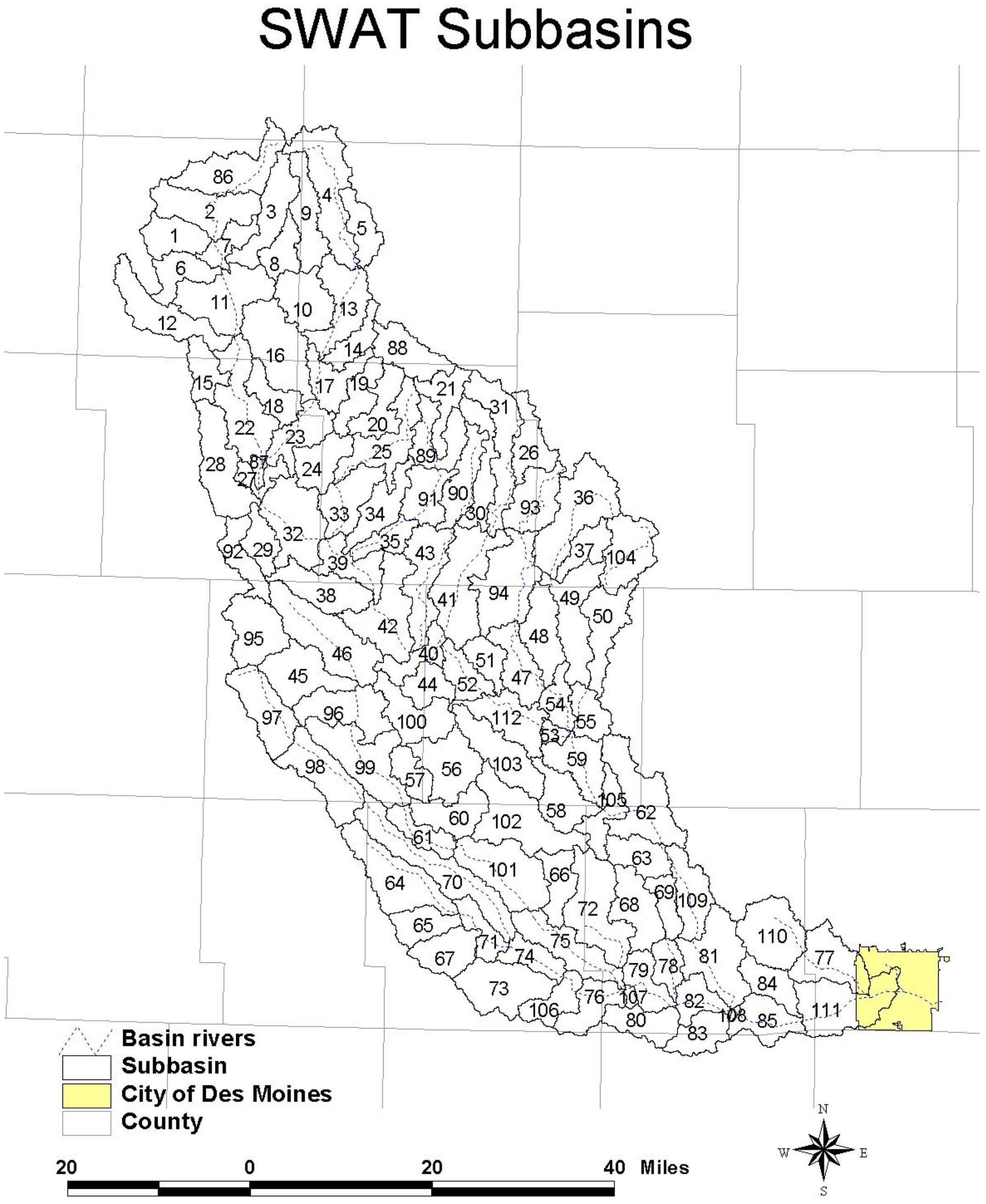


Figure 5-1. Location of 112 subbasins included in the Raccoon River SWAT model. Numbers correspond to basin names on Table 5-1.

In SWAT, a watershed is divided into multiple subwatersheds, which are further subdivided into unique soil/land use characteristics called hydrologic response units (HRUs). For the Raccoon River watershed, the subbasins were selected to match the 12-digit Hydrologic Unit Catalog (HUC) watershed boundaries plus additional sub-basins at gage station locations within the watershed. The process of creating the subbasin boundaries and HRUs was performed within the ArcView SWAT (AVSWAT) interface. Initially, the 30-meter Digital Elevation Model (DEM) was loaded into the model and the 1:100,000 scale National Hydrography Dataset (NHD) was used to burn the stream network into the DEM. This was done to ensure that watershed boundaries were properly delineated in the northern portion of the watershed typified by low relief of the Des Moines Lobe landscape region. The subbasin boundaries were then delineated to align with the 12-digit HUC boundaries (n = 108). In addition, four additional subbasins were added to the model at the locations of four major stream gages within the watershed. This was done so that model output could be matched with measured gage data for model calibration and validation. Thus, there were a total of 112 subbasins included in the model (Figure 5-1). Basin names and areas are provided on Table 5-1.

Table 5-1. Basin names and basin areas of subbasins used in SWAT model.

Basin No.	Basin Name	Basin Area (ha)	Basin No.	Basin Name	Basin Area (ha)
1	Lateral 4	6657.2	58	Lower Greenbrier Creek	7844.4
2	North Raccoon River-Lateral 6	11146.7	59	North Raccoon River-Buttrick Creek	8538.3
3	Lateral 2	9240.7	60	Willow Creek-Drainage Ditch 9-13	7662.2
4	Cedar Creek-Branch 6	14362.9	61	Middle Raccoon River-Willow Creek	6979.0
5	Drainage Ditch 21-Cedar Creek	5371.3	62	North Raccoon River-Frog Creek	14422.8
6	Poor Farm Creek	5986.7	63	Swan Lake Branch	6238.9
7	North Raccoon River-Lateral 3	4292.5	64	South Raccoon River-Frost Creek	13825.0
8	Drainage Ditch 67	4912.0	65	Seely Creek	5676.4
9	Upper Little Cedar Creek	8200.0	66	Bay Branch	5971.1
10	Lower Little Cedar Creek	8687.5	67	Mason Creek	7285.1
11	North Raccoon River-Drainage Ditch 101	13227.5	68	West Branch Panther Creek	8962.6
12	Outlet Creek	10798.4	69	East Branch Panther Creek	4154.9
13	Cedar Creek-Drainage Ditch 74	10438.0	70	Lower Brushy Creek-South Raccoon River	15473.3
14	Drainage Ditch 29	4517.2	71	South Raccoon River-Mason Creek	4729.8
15	Buck Run	5236.4	72	Lower Mosquito Creek-Middle Raccoon River	15700.9
16	Prairie Creek-Drainage Ditch 1	13854.8	73	Beaver Creek-South Raccoon River	11940.0
17	Cedar Creek-Drainage Ditch 37	6521.0	74	South Raccoon River-Beaver Creek	4944.5
18	Drainage Ditch 81-Cedar Creek	5448.2	75	Middle Raccoon River-Mosquito Creek	10249.3
19	Drainage Ditch 1-Camp Creek	5647.8	76	South Raccoon River-Long Branch	6615.2
20	Upper West Fork Camp Creek	6595.9	77	Walnut Creek-Raccoon River	9972.9
21	Lower Drainage Ditch 9 & 13	6193.0	78	Panther Creek	4221.1
22	North Raccoon River-Buck Run	13516.0	79	South Raccoon River-Bear Creek	5762.5
23	Cedar Creek-Drainage Ditch 20	7351.6	80	Bear Creek-South Raccoon River	6550.9
24	Lower West Fork Camp Creek	6990.0	81	North Raccoon River-Hickory Creek	12967.2
25	Upper Camp Creek-North Raccoon River	10604.0	82	South Raccoon River-Bulger Creek	4940.6
26	Welshs Slough	6763.0	83	Bulger Creek	5933.6
27	North Raccoon River-Drainage Ditch 73	3043.5	84	Sugar Creek-Raccoon River	5645.2
28	Indian Creek-North Raccoon River	12071.7	85	Upper Raccoon River	7214.0
29	Drainage Ditch 57	4857.3	86	North Raccoon River-Lateral 9	11877.8
30	West Cedar Creek	7632.2	87	Sac City Gage	1123.8
31	East Cedar Creek	11595.0	88	Upper Drainage Ditch 9 & 13	8104.3
32	North Raccoon River-Drainage Ditch 25	13141.6	89	Upper Lake Creek	4656.2
33	Lower Camp Creek-North Raccoon River	8397.6	90	Upper Purgatory Creek	7115.3
34	Prairie Creek-Drainage Ditch 198	7354.8	91	Middle Lake Creek	10064.6
35	Lower Lake Creek	4338.8	92	Wall Lake Inlet	5927.9
36	Upper West Buttrick Creek	15383.9	93	Hardin Creek Headwaters	8742.0
37	Tank Pond	4907.7	94	Upper Hardin Creek	10383.4
38	Elk Run-North Raccoon River	9269.0	95	Middle Raccoon River Headwaters	9868.5
39	North Raccoon River-Prairie Creek	6965.9	96	Middle Raccoon River-Spring Branch	10352.5
40	North Raccoon River-Doe Brook	5000.7	97	Upper Brushy Creek-South Raccoon River	10145.9
41	Cedar Creek-Drainage Ditch 121	15323.4	98	Middle Brushy Creek-South Raccoon River	11217.5
42	North Raccoon River-Marrowbone Creek	12855.4	99	Middle Raccoon River-Willey Branch	11648.8
43	Lower Purgatory Creek	11288.7	100	Willow Creek Headwaters	9055.3
44	Unnamed Creek-North Raccoon River	4990.4	101	Middle Raccoon River-Kings Creek	13820.2
45	Middle Raccoon River-Storm Creek	10313.7	102	Upper Mosquito Creek-Middle Raccoon River	13895.5
46	Storm Creek	15499.6	103	Upper Greenbrier Creek	10350.1
47	Middle Hardin Creek	11566.0	104	Upper East Buttrick Creek	7198.1
48	East Fork Hardin Creek	8657.4	105	North Raccoon River-Fannys Branch	5641.5
49	Lower West Buttrick Creek	11759.3	106	South Raccoon River-Deer Creek	5511.9
50	Lower East Buttrick Creek	11487.4	107	Redfield Gage	698.6
51	Short Creek-North Raccoon River	4388.3	108	Van Meter Gage	332.3
52	North Raccoon River-Cedar Creek	5401.9	109	North Raccoon River-Swan Lake Branch	8076.3
53	North Raccoon River-Drainage Ditch 171	1487.2	110	Walnut Creek-Little Walnut Creek	11350.8
54	Lower Hardin Creek	4438.6	111	Lower Raccoon River	4630.6
55	Buttrick Creek	5149.9	111	Lower Raccoon River	9099.5
56	Willow Creek-Drainage Ditch 117	10233.2	112	Jefferson Gage	9117.8
57	Drainage Ditch 9-13	4595.9			

The HRUs were created within AVSWAT by loading the Soil Survey Geographic (SSURGO) data and the 2002 landcover grid as a polygon coverage. The HRUs were determined using thresholds of 1% landcover and 5% soil. To differentiate among various grass landcover uses in SWAT, Indian grass was assumed for CRP ground, tall fescue was assumed for pasture and smooth brome was assumed for ungrazed grass. This was done to maximize the amount of pasture retained by the model so cattle on pasture could be distributed as realistically as possible. All together, a total of 3640 HRUs were created in the SWAT model. The hydrology and water quality components are computed at the HRU level and the loads are summed together at the subbasin level and routed downstream through main channels.

Daily weather data was obtained from the National Weather Service COOP monitoring sites available through Iowa Environmental Mesonet (http://mesonet.agron.iastate.edu). AVSWAT assigned the appropriate weather station information to each subbasin based on the proximity of the station to the centroid of the subwatershed. Eleven weather stations were used to provide the temperature and precipitation data for the 20-year time frame.

Overall, the following data sources were used to setup the basic SWAT model for the Raccoon River watershed:

- 30-meter DEM, USGS (http://seamless.usgs.gov)
- 1:100,000 scale NHD, USGS
- 2002 landcover grid, 15-meter, Iowa DNR
- 12-digit HUC boundaries, NRCS
- Climate data, Iowa Environmental Mesonet, National Weather Service COOP
- Soil Survey Geographic (SSURGO) soil data, NRCS
- Iowa Soil Properties and Interpretations Database (ISPAID), Iowa Cooperative Soil Survey
- Animal Feeding Operations database, Iowa DNR
- 2002 Iowa agriculture statistics, USDA-NASS
- 2000 US Census data, US Census Bureau
- WWTP data, Iowa DNR

The SWAT model was run on a daily time step for the 1985 to 2004 period, with the first ten years (1985 to 1994) consisting of a model calibration period and a second ten year period (1995 to 2004) comprising a model validation period. SWAT model setup and calibration was assisted by M. Jha (Center for Agriculture and Rural Development, Iowa State University) and based partly on work by Jha et al. (2007).

5.2 Data Inputs and Model Assumptions

The following section describes data inputs unique to the Raccoon River watershed SWAT model, data sources for these inputs, and assumptions incorporated into the model. In many cases, model input and parameterization was completed using a SWAT model input program called iSWAT developed by Iowa State University Center for Agriculture and Rural Development.

Tile Drainage: Tile drainage is known to be an important component to the hydrology and nutrient loss from poorly drained lands typical of the Des Moines Lobe landscape region. Two methods were used to estimate the amount of land with subsurface tile drainage in the watershed. Both methods were based on identifying soil types that would require tile drainage in order for farming to occur. The first method developed by the U.S.D.A. National Soil Tilth Lab (D. James, NSTL, personal communication) identifies soils that have a high slope range value (2% or less), a drainage class of poor to very poor and a hydrologic group code with the “D” determination. The second method developed at Iowa State University (J. Miller, ISU, personal communication) considers a high slope range value (5% or less), a drainage class code greater than 40 and a subsoil group of 1 or 2. The variables for both methods are found in the ISPAID (Iowa Soil Properties and Interpretations Database) table. Soils that met either of these criteria were combined with the 2002 landcover information to identify row crop ground with probable tile drainage (Figure 5-2). Differences in tile density on row crop lands were evident in the Raccoon River watershed. Approximately 77.5 percent of the row crop ground in the North Raccoon watershed may be tile drained compared to 42.1 percent in the South Raccoon watershed. On a HUC12 level, the amount of row crop land with drainage tiles ranged from 4 to nearly 100 percent and averaged 64 percent.

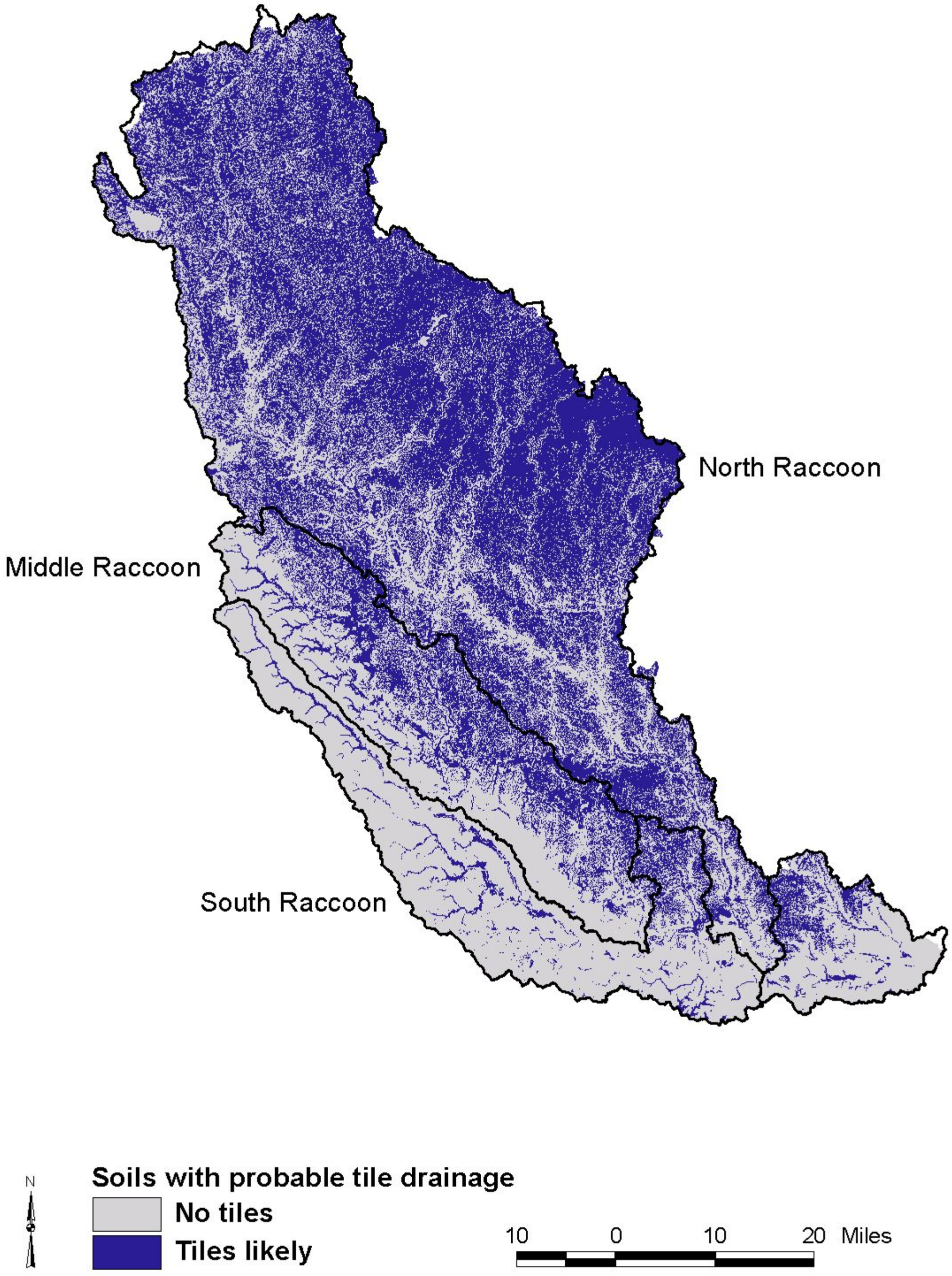


Figure 5-2. Soils with probable tile drainage in the Raccoon River watershed.

When tiles were placed in selected soil mapping units, they were assigned at depth of 1.2 m below ground surface. The combination of row crop ground with the specific soil mapping units was selected in the AVSWAT management files and the tile information was entered for those HRUs.

Fertilizer Application: Nitrogen and phosphorus fertilizer were applied to row-crop lands at rates and times consistent with available information. As noted in Section 3.2.3, fertilizer information provided by the ACWA indicated that on average 142 lbs/ac of N (NH_3, urea, UAN) was applied to 95 percent of the corn ground and an average of 76 lbs/ac of P (DAP) was applied to 60 percent of the crop ground in the watershed. In the model, N fertilizer was applied to 100 percent of the corn ground, di-ammonium phosphate fertilizer was applied to soybean ground before planting, and anhydrous ammonia was applied in the fall after soybeans are harvested. The rates and timing are consistent with data provided by the ACWA.

Manure Application: Nitrogen and bacteria losses from manure applications in the Raccoon River watershed are derived from three main sources: manure from feedlots (cattle manure), manure from grazing operations (cattle on pasture), and manure from confined animal feeding operations (CAFOs).

Cattle on Pastures: The number of cattle in pastures in the Raccoon River watershed was estimated using spatial landcover data and county-level cattle values. The number of cattle on pasture in each subbasin was calculated using only pasture polygons greater than 2 acres and those not within urban areas. The number of cattle on pasture for each county from the 2002 Ag Census data was divided by the amount of land in pasture from the 2002 landcover coverage for that county to obtain a cattle loading rate per hectare of pasture. This loading rate was then multiplied by the hectares for each pasture polygon in that county to obtain the number of cattle in each polygon of pasture. The preceding steps were done for each county in the watershed. The cattle on pasture in each subbasin were then summarized using the subbasin boundaries and the pasture polygon shapefile. The number of cattle on pasture in each subbasin was divided by the amount of acres of pasture in each subbasin to get a loading rate for cattle manure and amount of forage consumed per hectare to enter in the pasture management file for each subbasin. Cattle were assumed to graze from May through October.

Manure from Feedlots and CAFOs: The amount of manure in the watershed was distributed according to existing GIS coverages of cattle feedlots and CAFOs. The locations of cattle feedlots were used to estimate the amount of nitrogen from manure land applied by each feedlot. A manure distribution program from the U.S.D.A. National Soil Tilth Lab was run to determine how many hectares of row crop ground were needed to distribute the manure in each subbasin at a rate of 200 kg N/ha for two-year crop rotation (Figure 5-3). The number of hectares needed in each sub-basin was then matched up with hectares of row crop HRUs in that subbasin. A similar procedure was done for distributing manure from CAFOs in the watershed. Manure was distributed on ground to be planted with corn (half applied in the spring and half applied in the fall).

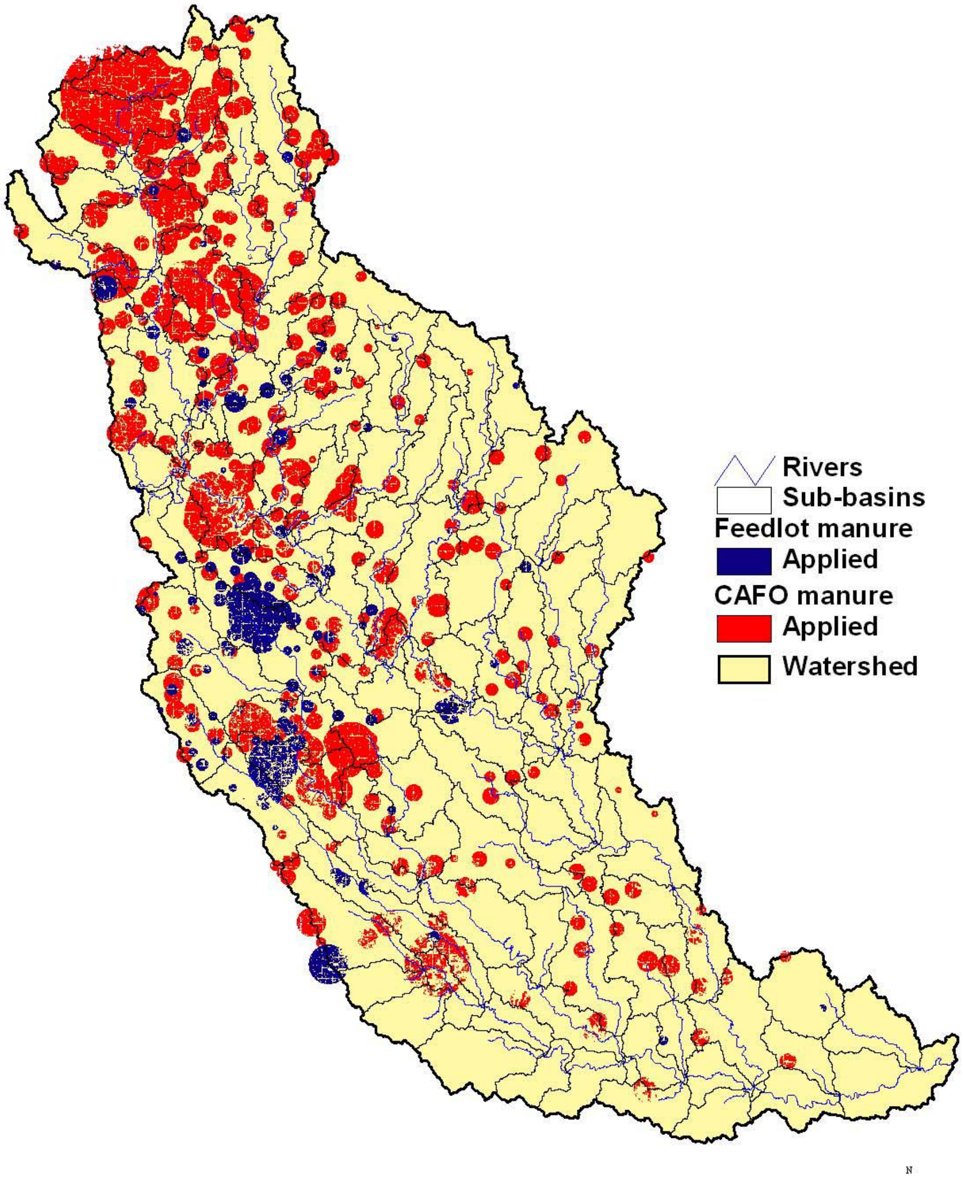


Figure 5-3. Distribution of manure from feedlots and CAFOs applied to row crop lands.

Wildlife Input: Deer grazing was added to the forest management file at the rate of 100 deer/square mile of forest.

Point Source Inputs: In the SWAT model, point source contributions to streams include inputs from cattle in streams, septic discharge and WWTP discharge. This approach differs from how point sources were evaluated in this TMDL as loads from WWTPs only. However, combining the three potential source terms in the model as a single point source input is primarily a function of how the model distinguishes between point and nonpoint sources. Point sources in the SWAT model are those sources that directly discharge into a stream. The total point source inputs from these three sources were individually assessed and then summed for each subbasin for input into the model as a single point source file. Since the sources were individually assessed, contributions from each can be individually evaluated by running various modeling scenarios. Specific details associated with the point source inputs follow below.

Cattle in Streams: Some cattle in pastures have direct access to the stream. The number of cattle with access to streams was estimated by intersecting the pasture polygons with the NHD stream network coverage and summing the number of cattle in those selected polygons for each subbasin. The amount of time cattle spend in streams was assumed to be 6% during the months of May through October. The 6% value is within the range used in the Maquoketa River pathogen TMDL and is lower than the value used in the Big Sioux River pathogen TMDL. A recent SWAT model of bacteria transport in Kansas used a value of 8.5%. This percentage was multiplied by the amount of nitrate and bacteria generated daily by the cattle to estimate the amount of N and bacteria directly input to the stream by cattle on pasture.

Human Inputs: The amount of human nitrogen and bacteria discharged into streams was estimated for each subbasin by summing the rural population from the 2000 census block coverage and multiplying the population by the average amount of nitrate and bacteria generated by an individual. For nitrate it was assumed that 9.9 pounds of nitrogen was generated per person per year. For bacteria, it was assumed that 2E+09 CFUs/day of fecal coliform bacteria was generated per person per day (USEPA, 2001). All nitrogen and total bacteria values were assumed to be as nitrate and *E.coli*, respectively. Nitrate and fecal coliform bacteria waste was assumed to be reduced by 99.5 percent before directly discharged into the streams.

> For waste water treatment plants three methods were used to determine the amount of nitrogen discharged to streams. If a facility had a design limit for nitrogen, this limit was used at all times. If a facility had no design limits, a constant nitrogen value was assumed that was derived from the population estimate (or population equivalent). If the WWTP was a controlled discharge, a worksheet was used to determine how much nitrogen was stored until discharge using the rate constant.
>
> For bacteria, a similar three-tiered method of assessing bacteria loads from WWTPs was used. If the constant discharge facility had bacteria monitoring data, then the monitoring data was used. If no WWTP monitoring data were available, then an estimated discharge amount was assumed based on the population estimate. The total bacteria amount produced by the population was then reduced by 99.9% from the wastewater treatment process to determine a daily discharge rate. For controlled discharge facilities the same rate of generation was used but the reduction rate varied depending on the length of time the wastewater was in storage.
>
> For the model, loads from WWTPs were input in monthly time steps. Because the model was set up to run and initiate calibration in 1983, average monthly WWTP loads were needed that extended back in time for 20 years. Hence, monthly discharge rates for nitrogen and bacteria were estimated by averaging the months of data that were available and applying these averages back in time. For the WWTPs with controlled discharge, the months that discharge occurred were examined to see which months discharge occurred most often. Average WWTP loads for those months were estimated from the available data and the same pattern of monthly and annual loads was then applied back in time to extend the data record to 1983.

5.3 Model Calibration and Validation

Measured data collected in the Raccoon River watershed were used for calibration of flow, nitrate and *E.coli* loads. The measured data used for model calibration were primarily collected from stream gaging sites and water monitoring stations located at: 1) DMWW at Fleur, 2) Raccoon River at Van Meter, 3) North Raccoon at Sac City and 4) South Raccoon at Redfield. Streamflow was primarily calibrated with daily records from the Van Meter, Sac City and Redfield gaging stations, since these sites had continuous streamflow measurements for the entire model period. The discharge record for the Raccoon River at Fleur did not begin until 1996, well into the model simulation period. Flow calibration of the model at the Van Meter site captured discharge from both the North and South Raccoon rivers and provided a suitable surrogate for calibrating the flow from the entire basin.

Nitrate loads were calibrated against measured monthly and annual loads for the 1997 to 2004 period at the Raccoon River at Fleur (DMWW), and estimated loads at Van Meter, Sac City and Redfield. The monitoring records at Van Meter and Sac City were considerably longer than for the South Raccoon at Redfield. Daily nitrate loads were estimated using the ESTIMATOR model (see Section 3.1.4) and aggregated into monthly and annual totals for SWAT model calibration. Calibration of the SWAT model for *E.coli* loads was completed using data collected by the DMWW at Fleur only. Given the variability and uncertainty of estimating bacteria loads from monthly grab samples, calibrating the SWAT model against monthly data was not deemed appropriate.

SWAT was executed for a total simulation period of 20 years, which included 1985-1994 as the calibration period and 1995-2004 period as the validation period. Parameter adjustment was performed only during the calibration period, whereas the validation process was performed by simply executing the model for the different time period using the previously calibrated input parameters. The calibration process was performed manually by adjusting hydrologic, nitrate and bacteria transport parameters (described below) and then comparing model output with measured data. The calibration process was initiated by calibrating the stream hydrology first, then nitrate loads, and finally *E.coli*. This approach followed a logical sequence from the most data rich to data poor. Further, calibrating water flux first recognizes the importance of “following the water” as the carrier of pollutant loads.

The model predictions were evaluated for both the calibration and validation periods using graphical comparisons and two statistical measures: the coefficient of determination (R^2) and the Nash Sutliffe simulation efficiency (E) developed by Nash and Sutliffe (1970). The R^2 value is an indicator of the strength of relationship between measured and simulated values, whereas the E value measures how well the simulated values agree with the measured value. Both values typically range from zero to one, with value of one considered a perfect match.

5.3.1 Streamflow Calibration

The streamflow calibration process was completed by varying several SWAT hydrologic calibration parameters within their acceptable ranges to match predicted annual and monthly streamflow time series with their corresponding measured values. Calibration was achieved by adjusting several hydrologic parameters, including the curve number, soil available water capacity, evaporation compensation coefficient, and groundwater delay within their acceptable ranges (Table 5-2).

Table 5-2. Summary of SWAT calibration parameters adjusted and their final calibrated value.

Component	SWAT Calibration Parameter	Final Calibrated Value
Streamflow	Curve number	
	Corn	67
	Soybeans	68
	Grass	59
	Alfalfa	59
	Urban	66
	Forest	66
	Surface Runoff Lag (SURLAG)	4 days
	Soil evaporation compensation coefficient (ESCO)	0.95
	Groundwater delay (GW_Delay)	30 days
	Alpha baseflow factor (Alpha_BF)	0.048 days
	Hargreaves ET method	
Nitrate	Ammonia fertilizer rate	170 kg/ha (152 lbs/ac)
	Di-ammonium phosphate fertilizer rate	175 kg/ha (156 lbs/ac)
	Nitrogen percolation coefficient (NPERCO)	0.8
E.coli	Die-off rate in solution	0.1 day^{-1}
	Die-off rate in soil	0.03 day^{-1}
	Bacteria partition coefficient	1
	Bacteria temperature factor	1.07
	Fraction of manure with CFUs	0.99

The Raccoon River SWAT model was initially calibrated and validated by comparing the simulated hydrology at the Van Meter gage with measured values at annual and monthly time steps (Figure 5-4). The graphical results indicate that SWAT accurately tracked the annual and monthly streamflow trends across the two time periods. Over the entire simulation period, the modeled average annual average streamflow at Van Meter (8.3 in) was very close to the measured value (8.2 in). Measured streamflow was higher than modeled values in some years (most prominently in 1986, 1991, 1993) whereas modeled values were higher than measured values in other years (Figure 5-4). The modeled average monthly streamflow (0.72 in) closely matched the measured monthly average (0.68 in) over the 240 month simulation period. Model calibration was confirmed by the statistical measures. The r^2 and E statistics for monthly comparisons were 0.84 and 0.83, respectively.

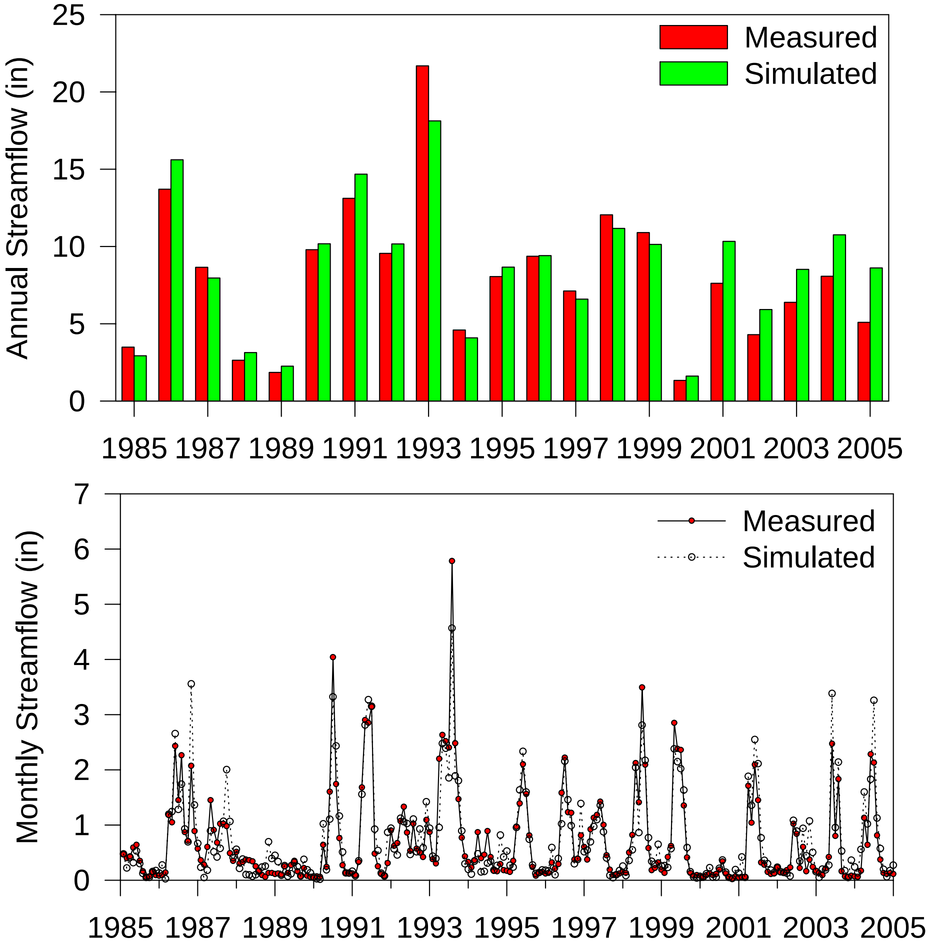


Figure 5-4. Annual and monthly flow calibration for the Raccoon River at Van Meter.

Streamflow calibration was further assessed in the North Raccoon River at Sac City and South Raccoon at Redfield (Figure 5-5). Graphical results suggest a good match between measured and modeled annual and monthly streamflow trends in the subbasins. For the 20-year simulation period of 1985 to 2004, the modeled average annual average streamflow at Sac City (8.64 in) was very close to the measured value (8.48 in) and the monthly average values were similarly close (0.73 in compared to 0.71 in, respectively). Similarly, for the South Raccoon at Redfield, the comparison of average annual streamflow to modeled values (8.06 in and 7.77 in, respectively) and average monthly measured and modeled values (0.69 and 0.68 in) were very close.

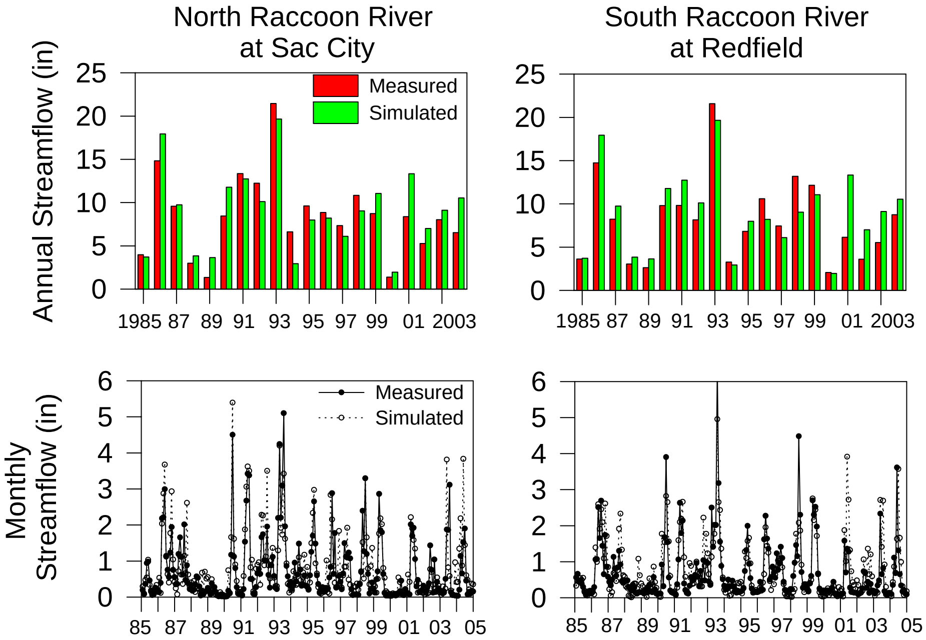


Figure 5-5. Annual and monthly flow calibration for the North Raccoon River at Sac City and South Raccoon at Redfield.

With the SWAT model successfully calibrated for water flux, the average annual water balance components for the Raccoon River can be evaluated (Table 5-3). Baseflow was assessed in the SWAT model by combining tile flow and groundwater flow and was estimated to be 4.8 in for the 20-year modeling period. This value matches the value of 4.8 in estimated with the hydrograph separation program (see Section 2.6). The baseflow fraction was modeled to be 58 percent using SWAT and 56 percent using the baseflow separation program. These values are similar to the value of 54 percent reported by Schilling and Zhang (2004) for the 1972 to 2000 period. Discharge and baseflow were estimated to represent approximately 25.4 and 14.7 percent of annual precipitation, respectively. These percentages are similar to the percentages determined by Schilling and Zhang (2004) for the 1972-2000 period (25.6 and 13.9 percent, respectively). The amount of evapotranspiration (ET) predicted by the model (24.3 in) was also similar to an estimate of 25.5 determined using a different water balance approach (Schilling and Zhang, 2004). By most measures, the watershed hydrology simulated with the SWAT model is consistent with available information and previous studies.

Table 5-3. Average annual water balance components for Raccoon River estimated by SWAT model.

Water Balance Components	Depth (in)
Precipitation	32.74
Surface Runoff	3.49
Baseflow	4.82
Tile Flow	2.13
Evapotranspiration	24.26
Total Streamflow	8.31

5.3.2 Streamflow Patterns

The calibrated SWAT model was used to assess the spatial patterns of average annual water yield in the Raccoon River watershed (Figure 5-6). Results indicate that large portions of the watershed yield between seven to nine inches of water per year, with greater water yield associated with the northern portions of the North Raccoon and Middle Raccoon rivers and the suburban watersheds near the City of Des Moines. In particular, the region around Des Moines appears to be influenced by a greater proportion of area with developed land. More area devoted to paved surfaces and less overall ET allows more water to leave the basins with surface runoff.

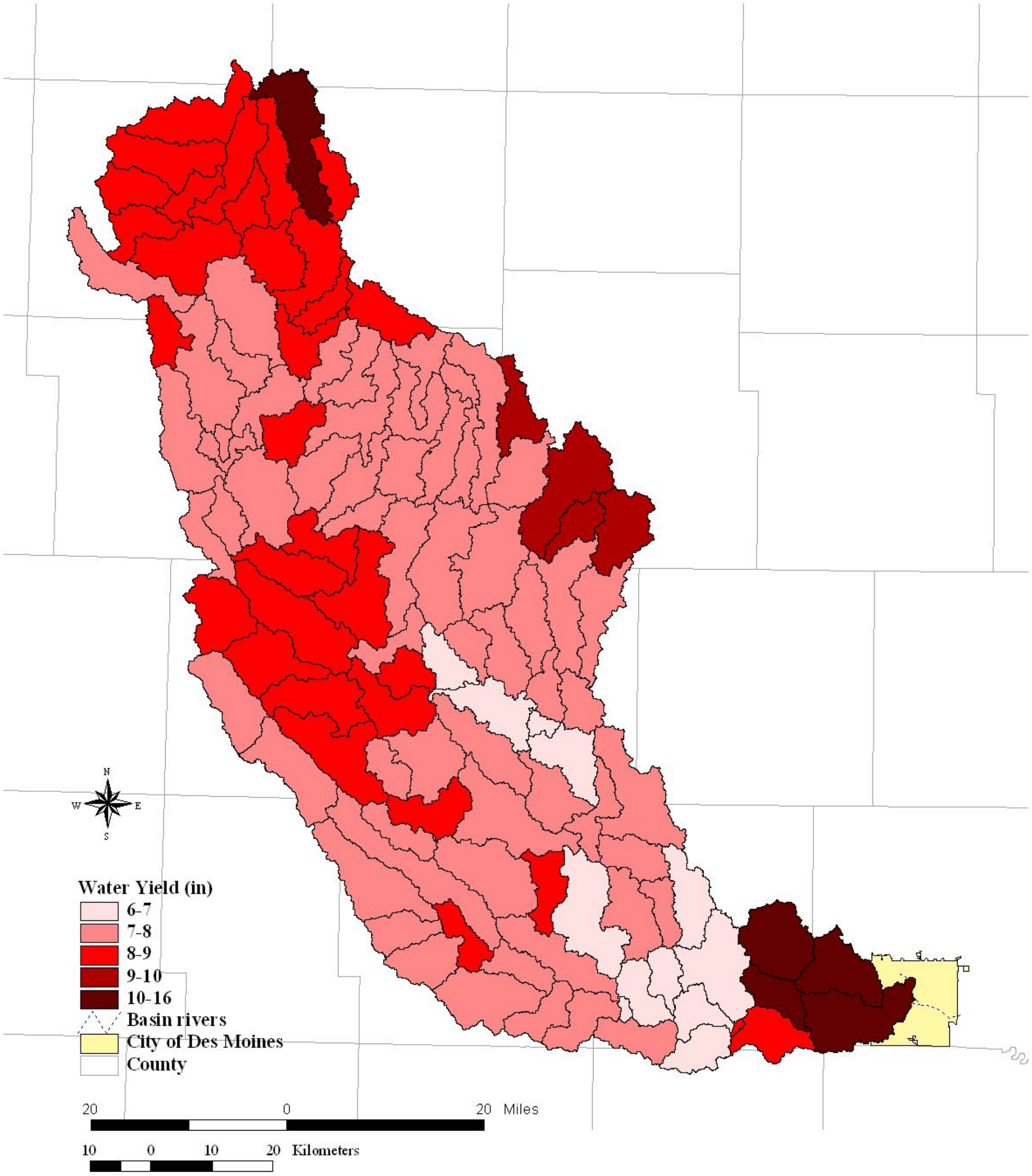


Figure 5-6. Average annual water yield in Raccoon River watershed subbasins.

The contribution of tile drainage to Raccoon River streamflow has not been previously evaluated. Tile flow was estimated to contribute an average annual flow of 2.1 in, which was 25.6 percent of the total streamflow and 44.1 percent of the overall baseflow. Results suggest that flow from drainage tiles contributes substantially to streamflow and baseflow in the Raccoon River. The spatial distribution of average annual tile flow in the Raccoon River watershed was estimated with SWAT (Figure 5-7). More than 2 inches of tile flow was associated with much of the North Raccoon River watershed, with flow exceeding 3-4 inches in HUC12 basins located in the northern half of the watershed. Northern Buttrick and Hardin creeks appeared to have the greatest amount of tile flow in the Raccoon River watershed (Figure 5-7).

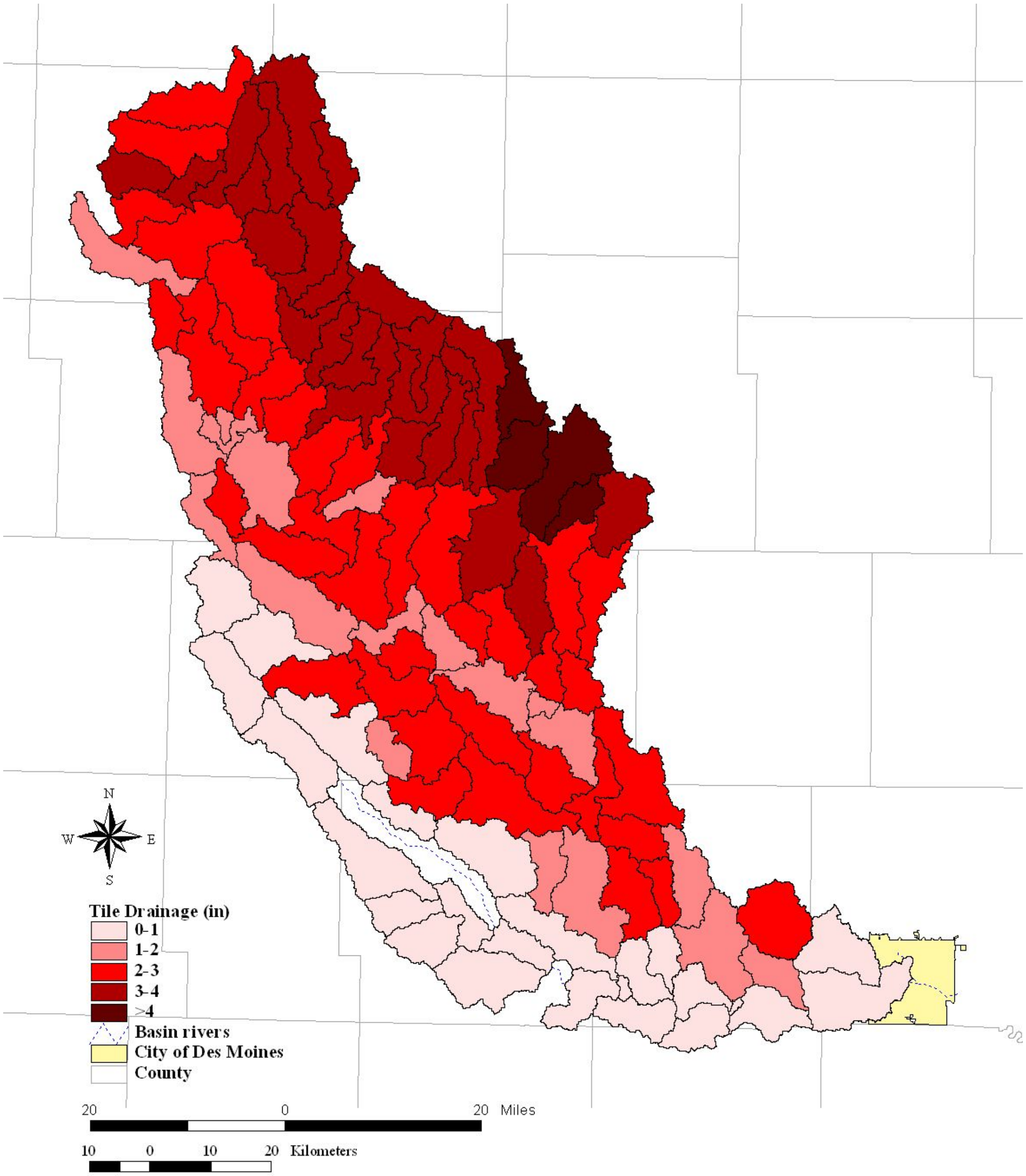


Figure 5-7. Average annual water yield from tile drainage in subbasins.

5.3.3 Nitrate Model Calibration

The nitrate calibration process was completed by varying several SWAT nitrogen calibration parameters within their acceptable ranges to match to model predicted annual and monthly nitrate loads with their corresponding measured values. With the hydrology calibration completed successfully, nitrate calibration was achieved by adjusting only a few factors (Table 5-2). The ammonia fertilizer rate was lowered from 190 kg/ha to 170 kg/ha during the calibration process and some in-stream factors were adjusted.

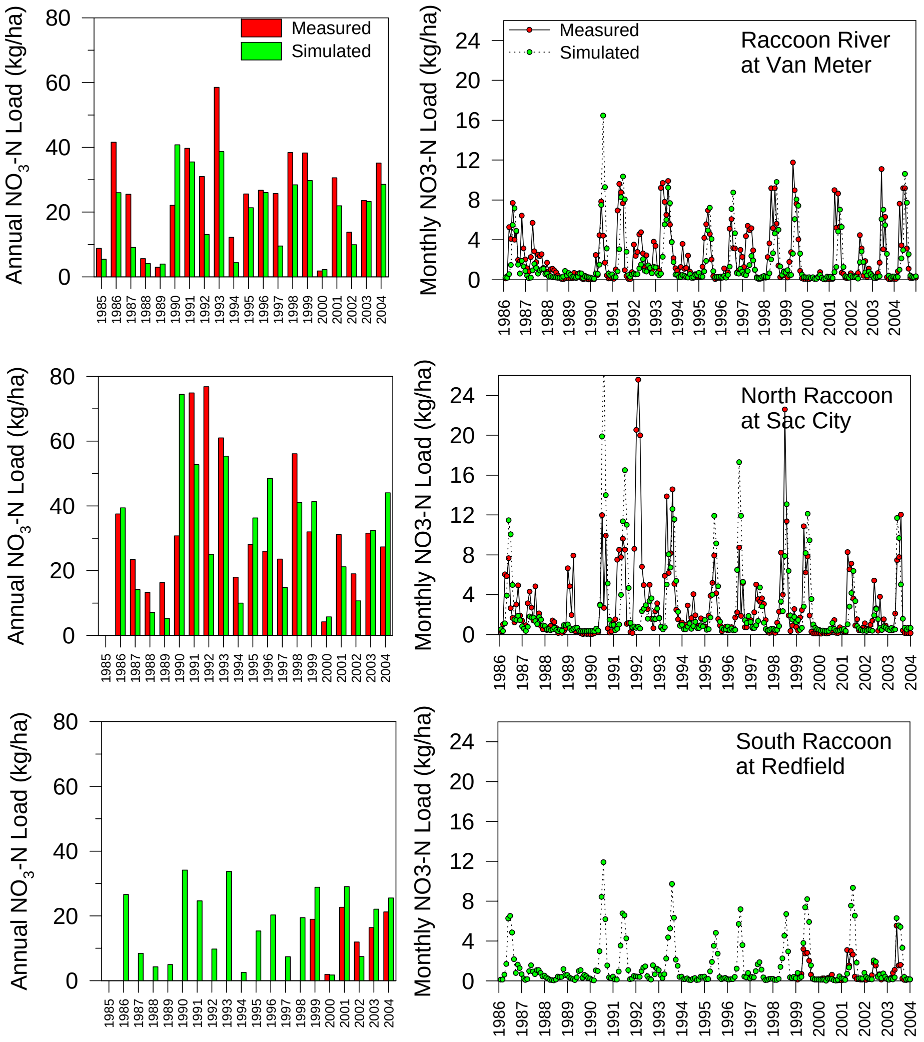


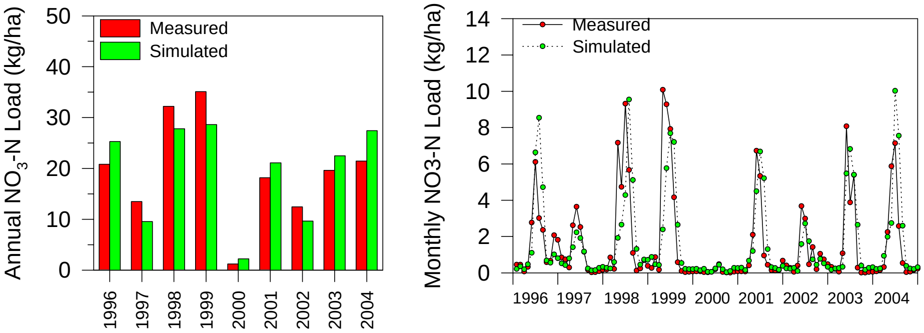
Figure 5-8. Annual and monthly nitrate load calibration for the Raccoon River at Van Meter, North Raccoon River at Sac City and South Raccoon River at Redfield.

The Raccoon River SWAT model was initially calibrated and validated by comparing measured and modeled nitrate loads at the Van Meter gage (Figure 5-8). It should be noted that “measured” in this case, does not refer to actual measured loads, but loads estimated using the ESTIMATOR model. Thus, in this calibration procedure, one modeled result (SWAT) was essentially being calibrated to another modeled result (ESTIMATOR regression model). The graphical results indicate that SWAT accurately tracked the annual and monthly nitrate load trends for the 20-year time period. The modeled average annual average nitrate load at Van Meter (24.5 kg/ha or 21.8 lbs/ac) was close to the estimated value (27.8 kg/ha or 24.8 lbs/ac) for the 20-year period, but extremely close during the last seven years of the simulation (26.3 versus 25.9 kg/ha, respectively or 23.5 versus 23.1 lbs/ac). The better agreement during the latter years in the model probably reflects using recent information (i.e., 2005 data) for input into the model. Conditions in 2005 input into the model may not accurately represent conditions in the early 1980's, particularly with respect to animal manure management.

Nitrate loads at subbasin sites at Sac City (North Raccoon) and Redfield (South Raccoon) were calibrated and validated (Figure 5-8). A longer period of record was available at Sac City, whereas only a five-year period was available for nitrate loads at the Redfield gage. Results indicate that SWAT tracked the annual and monthly patterns of nitrate loads at the two subbasin sites. The modeled average annual average nitrate load at Sac City (36.8 kg/ha or 32.8 lbs/ac) was close to the estimated value (33.2 kg/ha or 29.6 lbs/ac) for a 19-year simulation period. The shorter record of nitrate loads measured at the South Raccoon at Redfield does not allow for a rigorous assessment of model performance. The measured nitrate loads at Van Meter from 1999 to 2004 (10.1 kg/ha or 9.0 lbs/ac) were lower than estimated using SWAT (24.6 kg/ha or 22.0 lbs/ac).

The best measure of SWAT model performance was evaluated by comparing the model results to true measured data collected by the DMWW near the mouth of the Raccoon River at the Fleur gaging station (Figure 5-9). The modeled average annual average nitrate load at Fleur (25.1 kg/ha or 22.4 lbs/ac) were slightly higher than the measured nitrate load (19.4 kg/ha or 17.3 lbs/ac) for a nine-year assessment period. On a monthly basis, nitrate loads tracked closely, with the SWAT model tending to overestimate nitrate loads, particularly in 1999 (Figure 5-9). The average measured monthly nitrate load (1.3 kg/ha or 1.2 lbs/ac) was lower than the SWAT modeled monthly average nitrate load (2.1 kg/ha or 1.9 lbs/ac). The r^2 and E statistics for the monthly nitrate loads were 0.53 and 0.48, respectively.

Raccoon River at Fleur (DMWW)



Middle Raccoon at Panora

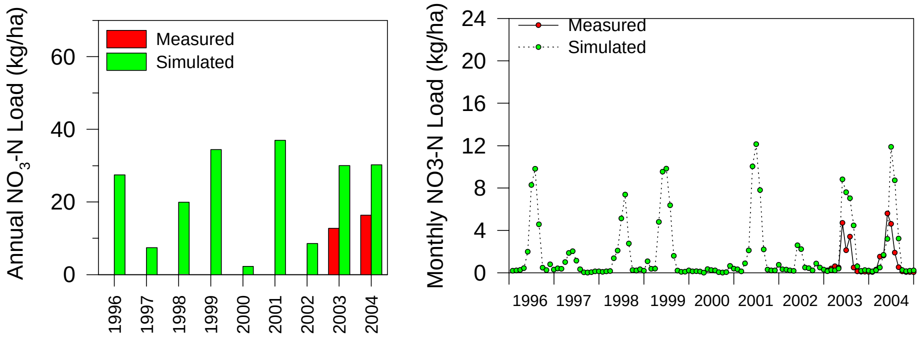


Figure 5-9. Annual and monthly nitrate load calibration for the Raccoon River at Fleur (DMWW) and Middle Raccoon River at Panora.

Less data was available to assess model performance at the site of the nitrate impairment at Panora (Figure 5-9). Although daily nitrate concentration data were available for a two-year period at Panora, the nearest stream gage was located at the Middle Raccoon River at Bayard. Thus, a true measured load at Panora cannot be obtained to calibrate against. The SWAT model was used to estimate nitrate loads at Panora for a 20-year period (only nine years are shown on Figure 5-9). A comparison of modeled and estimated average annual nitrate loads for 2003 and 2004 suggests that the SWAT model may have overestimated nitrate loads for the two years.

5.3.4 Nitrate Loading Patterns

The calibrated SWAT model for nitrate was used to assess the spatial patterns of nitrate loads in the Raccoon River watershed. The SWAT model provides output in several forms with which to evaluate spatial patterns of nitrate loads at the HUC12 subbasin level. In this report, nitrate loads were expressed as either a) the total nitrate export from a subbasin (termed a “reach” file), or b) nitrate loading rates generated from the land within a subbasin (termed an “HRU” file). Each of these approaches has benefits for assessing spatial patterns. In the total export approach (reach file), the total amount of nitrate exported from nonpoint sources in a subbasin is summed first and then contributions from point sources are added to this amount before water is routed into the next subbasin. Nitrate loads from one subbasin are carried into the next subbasin and routed downstream to see how loads propagate through the entire watershed. The total export approach has the advantage of assessing point versus nonpoint source loading rates, as well as viewing how nitrate loads are routed through the entire watershed. In the subbasin HRU approach, the amount of nitrate generated from the land is evaluated. This approach lends itself to evaluation of nonpoint sources only, but the advantage lies in being able to assess how much nitrate is generated per unit area in each subbasin, from both groundwater and surface water runoff. The subbasin HRU approach does not route loads through the watershed, but simply provides an “apples to apples” comparison across subbasins.

Nitrate Loads. Figure 5-10 shows the average annual total nitrate load exported from subbasins in the Raccoon River watershed (reach file approach). Nonpoint source loads were summed in a subbasin first, and point sources were added to this amount, before the loads were exported to the next subbasin downstream. Results show how nitrate loading rates are highest in the headwater region of the North Raccoon River watershed above Sac City (Figure 5-10). Modeled loads in this region were generally higher than 30 kg/ha (26.8 lbs/ac), similar in magnitude to measured loads at Sac City (33.2 kg/ha or 29.6 lbs/ac). The subbasin with the highest annual nitrate loading rate was Outlet Creek (subbasin 12; Figure 5-1), with an estimated average annual nitrate load of 84.9 kg/ha (75.8 lbs/ac). Point sources contribute significantly to total nitrate export from this subbasin (see below). Nine other subbasins in the northern portion of the North Raccoon River watershed exported nitrate between 30 and 41 kg/ha (26.8 and 36.6 lbs/ac).

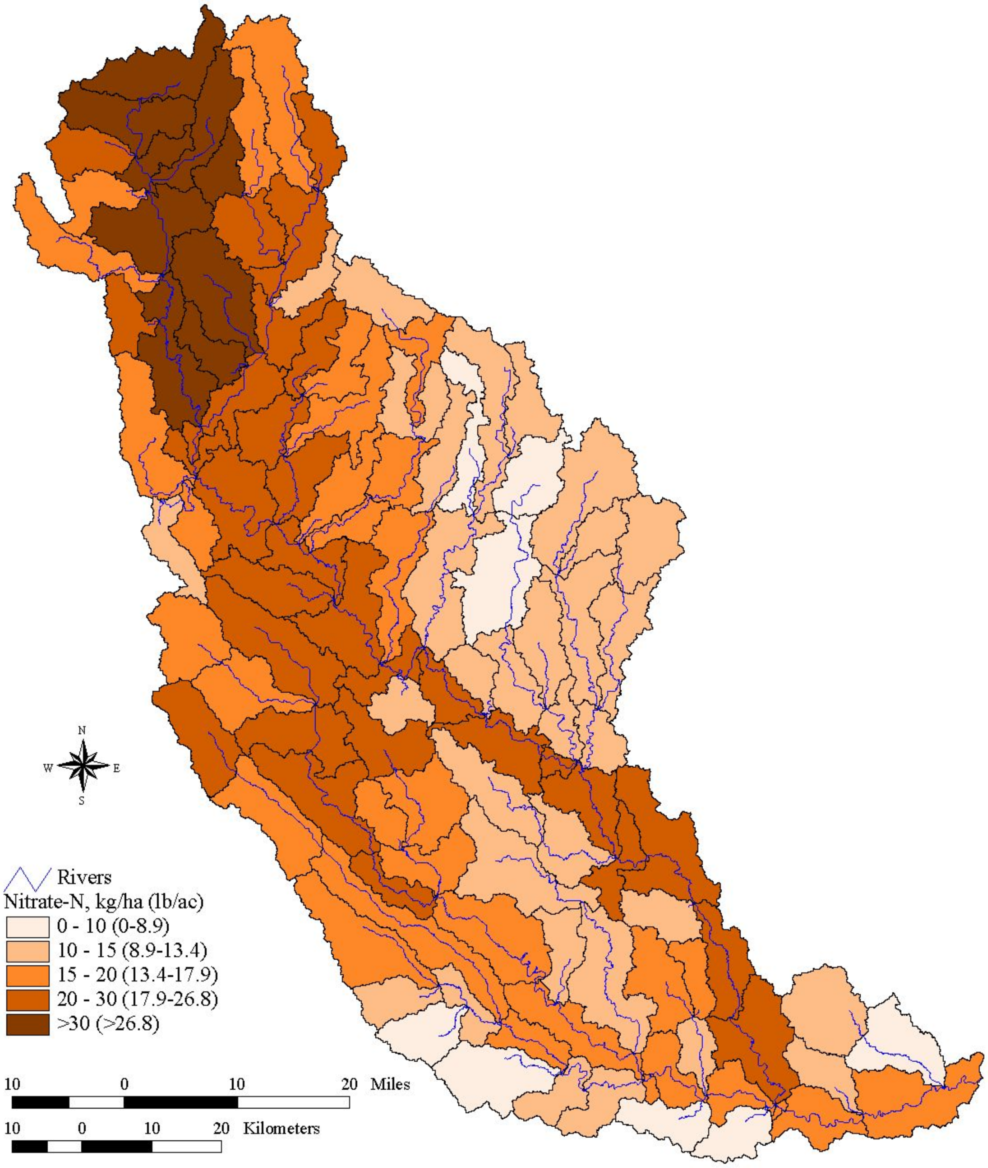


Figure 5-10. Total annual stream nitrate load exported from subbasins from RCH file. Point source nitrate loads were added back into the subbasins where they were generated.

Following the nitrate loads from the headwater region of the North Raccoon River downstream, nitrate loads remain greater than 20 kg/ha (17.9 lbs/ac) in subbasins containing the main channel of the river (Figure 5-10). This is a function of "following the water" downstream with loads from one subbasin carried into the next subbasin. Not until surface water loads are diluted from low nitrate loads delivered from the South Raccoon River and the Des Moines metropolitan area did Raccoon River loads fall below 20 kg/ha (17.9 lbs/ac) (18.6 kg/ha or 16.6 lbs/ac at subbasin 111; Figure 5-1). The pattern of greater nitrate loads in the North Raccoon River than South Raccoon River is consistent with DAFLOW and WASP modeling (Appendix A).

Several subbasins had nitrate loads less than 10 kg/ha (8.9 lbs/ac), with four of these subbasins located in the South Raccoon River watershed. This was expected given the low percentage of land in row crop and the lack of subsurface drainage in these subbasins. Unexpected were lower nitrate loads exported from Upper Hardin Creek (subbasins 93 and 94; Figure 1) and West Cedar Creek (subbasin 30) where average annual nitrate loads were less than 10 kg/ha (8.9 lbs/ac). Similarly, unexpectedly low nitrate loads were modeled in the eastern region of the North Raccoon watershed (i.e., East and West Buttrick Creek, Hardin Creek). This appeared to reflect the influence of in-stream biological processing occurring in these low-gradient Des Moines Lobe streams. The DEMs for these subbasins showed particularly wide and shallow stream channels conducive for in-stream processing. Further, the model suggested that stream nitrate loads entering many of these subbasins were higher than loads exiting the subbasins, consistent with in-stream nitrate losses. Monitoring data from the ACWA indicated that nitrate concentrations typically decreased to less than 1 mg/l in many Des Moines Lobe streams in the late summer and fall. It is recommended that the amount of in-stream nitrate processing that occurs in shallow Des Moines Lobe streams be further investigated.

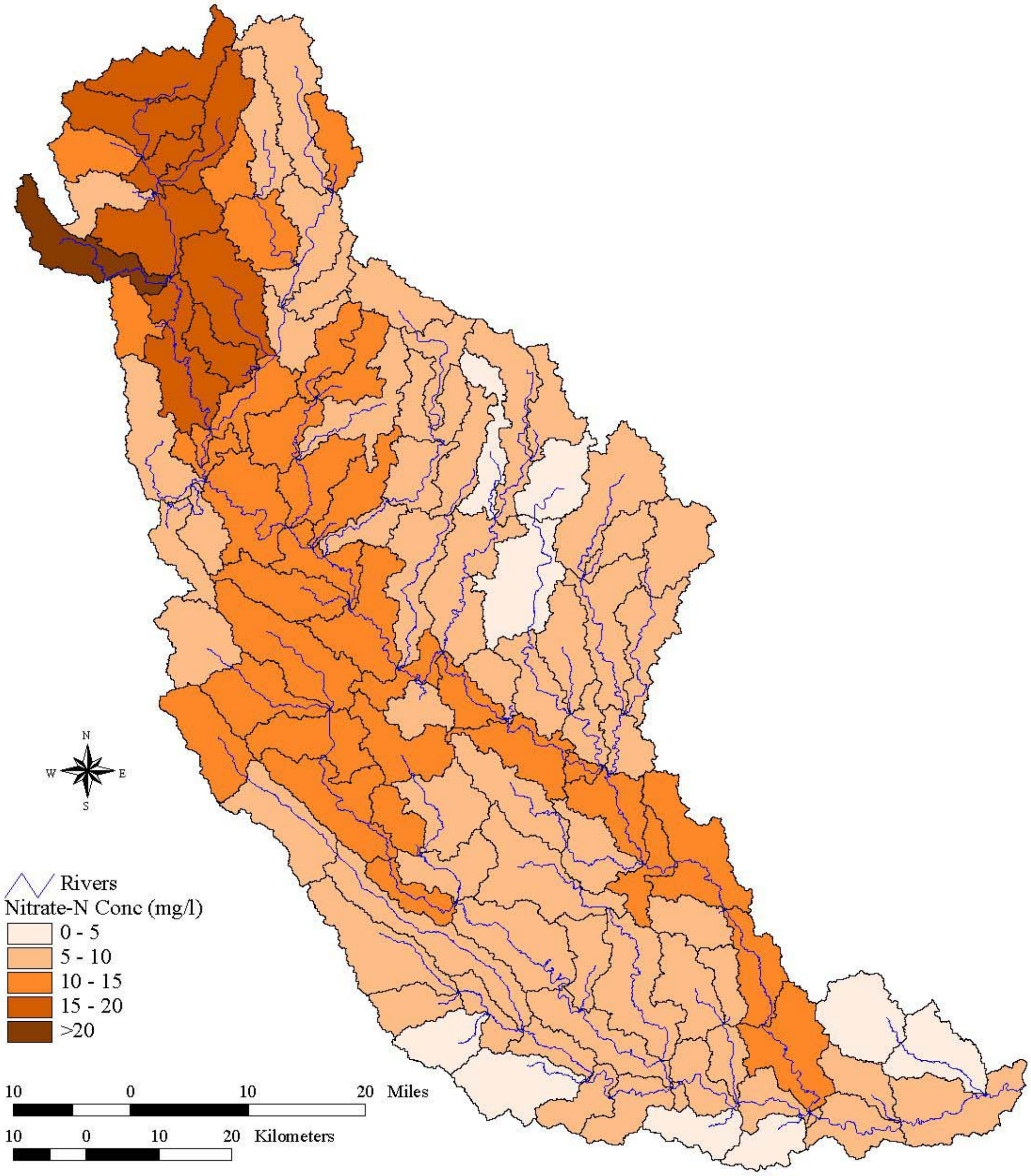


Figure 5-11. Average annual flow-weighted nitrate concentrations in subbasins. Nitrate load contributions from point sources were added back into the subbasins where they were generated.

Nitrate Concentrations. Flow-weighted annual average nitrate concentrations were evaluated for each subbasin (Figure 5-11). This figure includes contributions from point and nonpoint sources and was derived by dividing the total nitrate load by the total discharge from each subbasin. Results are consistent with spatial pattern exhibited by the total nitrate loads (Figure 5-10). The highest nitrate concentration was modeled in Outlet Creek where average annual nitrate concentration was approximately 45 mg/l. This concentration was consistent with concentrations measured by the ACWA in Outlet Creek (ranged from 10 to 59 mg/l, and averaged 30.5 mg/l in 2005). Elsewhere, average annual nitrate concentrations greater than 15 mg/l were modeled in the headwater region of the North Raccoon River watershed, and concentrations greater than 10 mg/l were found in the headwater region of the Middle Raccoon and along the main channel of the North Raccoon River. Like the nitrate loads, concentrations appeared to start high in the headwater region of the North Raccoon River watershed and continue to be elevated in the main channel as stream water flowed downstream through the basin. Average annual nitrate concentrations were between 5 and 10 mg/l throughout much of the Raccoon River watershed. Lower nitrate concentrations modeled in the subbasins of Hardin Creek, whereas lowest nitrate concentrations were modeled in subbasins in the South Raccoon River and the Des Moines area. These concentration patterns were consistent with water quality monitoring conducted by the ACWA.

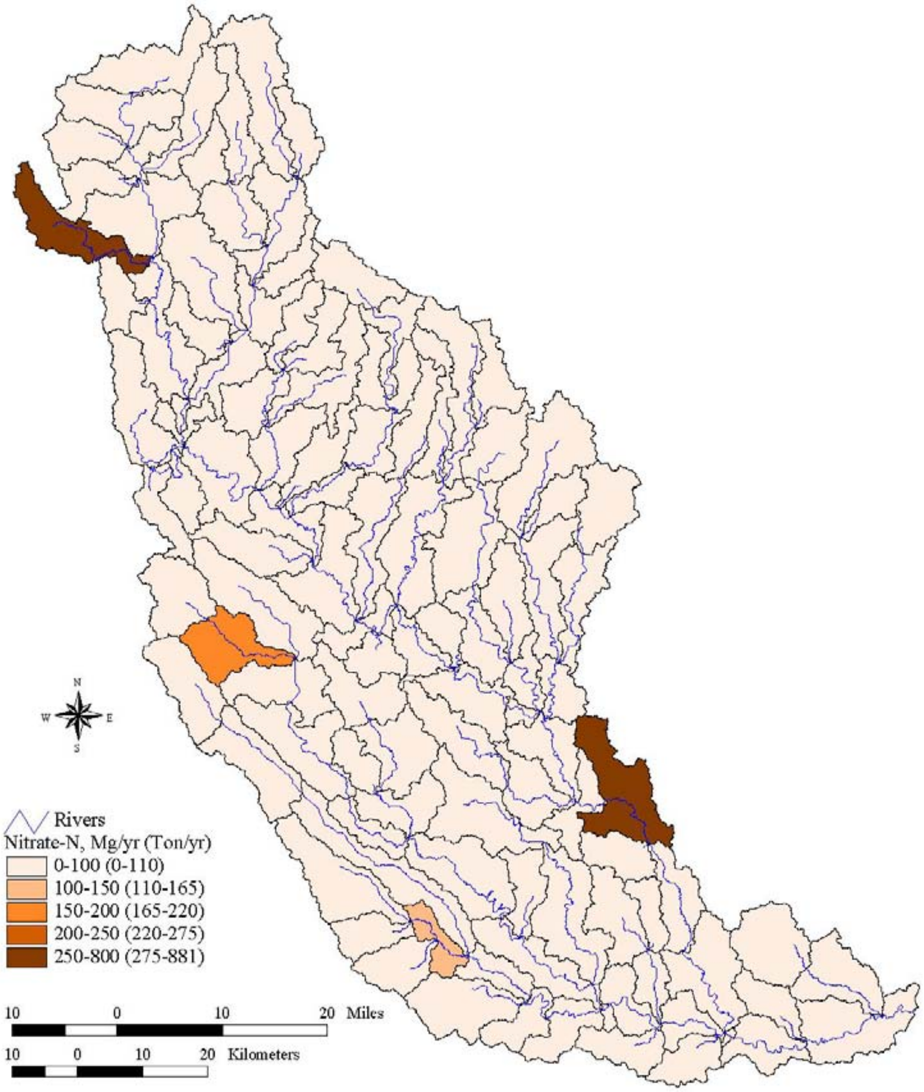


Figure 5-12. Total annual mass of nitrate exported from subbasins from point sources (metric tons or Mg per year). Metric tons are converted to tons by multiplying by 1.1.

Point vs. Nonpoint Loads. The contribution of point sources and nonpoint sources to total nitrate loads was evaluated by considering the total amount of nitrate mass produced (in kilograms) in each subbasin. Since the point source loads were added to the subbasin export as the water exited a subbasin, these loads were easily separated from the total so that point sources and nonpoint sources could be evaluated. The amount of nitrate generated from point sources in Raccoon River subbasins is shown on Figure 5-12. Greater point source nitrate loads were associated with subbasins containing wastewater treatment plants, with the greatest point source nitrate load found in the Outlet Creek subbasin (719,000 kg/year or 1,585,395 lbs/yr). Three other subbasins had point source contributing more than 100,000 kg (220,500 lbs) of nitrate per year (Figure 5-12). Subbasins 45, 62 and 71 contained wastewater discharges from cities of Carroll, Perry, and Guthrie Center, respectively. All other subbasins had point source loads less than 100,000 kg per year (220,500 lbs).

The total nonpoint source loads from each subbasin was derived from examining the HRU files within the subbasin, that is, summing the amount of nitrate lost per unit area in each subbasin. Results suggest that many subbasins within the Raccoon River watershed export more than 250,000 kg (551,250 lbs) of nitrate per year (Figure 5-13). Three subbasins with greatest nitrate load (range between 460-472,000 kg/year) were subbasins 2 (North Raccoon River lateral 2), subbasin 86 (North Raccoon River lateral 9) and subbasin 16 (Prairie Creek drainage ditch 1). These basins were located in the headwater region of the North Raccoon River. Elsewhere, elevated nitrate loads were found in the headwater region of the Middle Raccoon River and throughout the North Raccoon River, whereas lowest nitrate export was associated with subbasins in the South Raccoon River watershed (Figure 5-13). Total nitrate export from the watershed containing Hardin and Buttrick creeks (based on the HRU data) was higher than suggested by the stream loading rates, suggesting that while the landscape is yielding nitrate to streams, in-stream processing is reducing stream loads delivered downstream.

Comparing the nonpoint source nitrate loads with the point source loads reveals that most of the nitrate load in the Raccoon River is derived from nonpoint sources. Point source loads from all but the top four subbasins (those greater than 100,000 kg) fall within the lowest range of nonpoint source loads. Summing the total point source loads (1,881,931 kg or 4,149,658 lbs) in the subbasins (n=112) and nonpoint sources loads in each (16,280,520 kg or 35,898,547 lbs) reveals that nonpoint sources comprise 89.6 percent of the total nitrate load in the watershed. This percentage is very close to the breakdown presented in Section 3 using analytical methods (89.7 percent nonpoint sources), indicating that there is internal consistency between the numerical and analytical methods used in this TMDL study.

Within the watershed, there is wide variation in the proportion of point versus nonpoint source loads. In the four subbasins with elevated point source loads, point sources dominate nitrate export, ranging from approximately 54 to 78 percent of the total nitrate export. Eighteen subbasins have point source nitrate loads comprising more than 10 percent of the total load. However, in most of the subbasins, nonpoint sources overwhelm point source contributions. Nonoint source loads in 78 out of 112 subbasins comprise more than 99 percent of the total nitrate load, and the median nonpoint source load for the entire population of subbasins is 99.89 percent. Thus, while point sources may contribute to nitrate loads in a few subbasins, nitrate export in the Raccoon River is predominantly a nonpoint source problem.

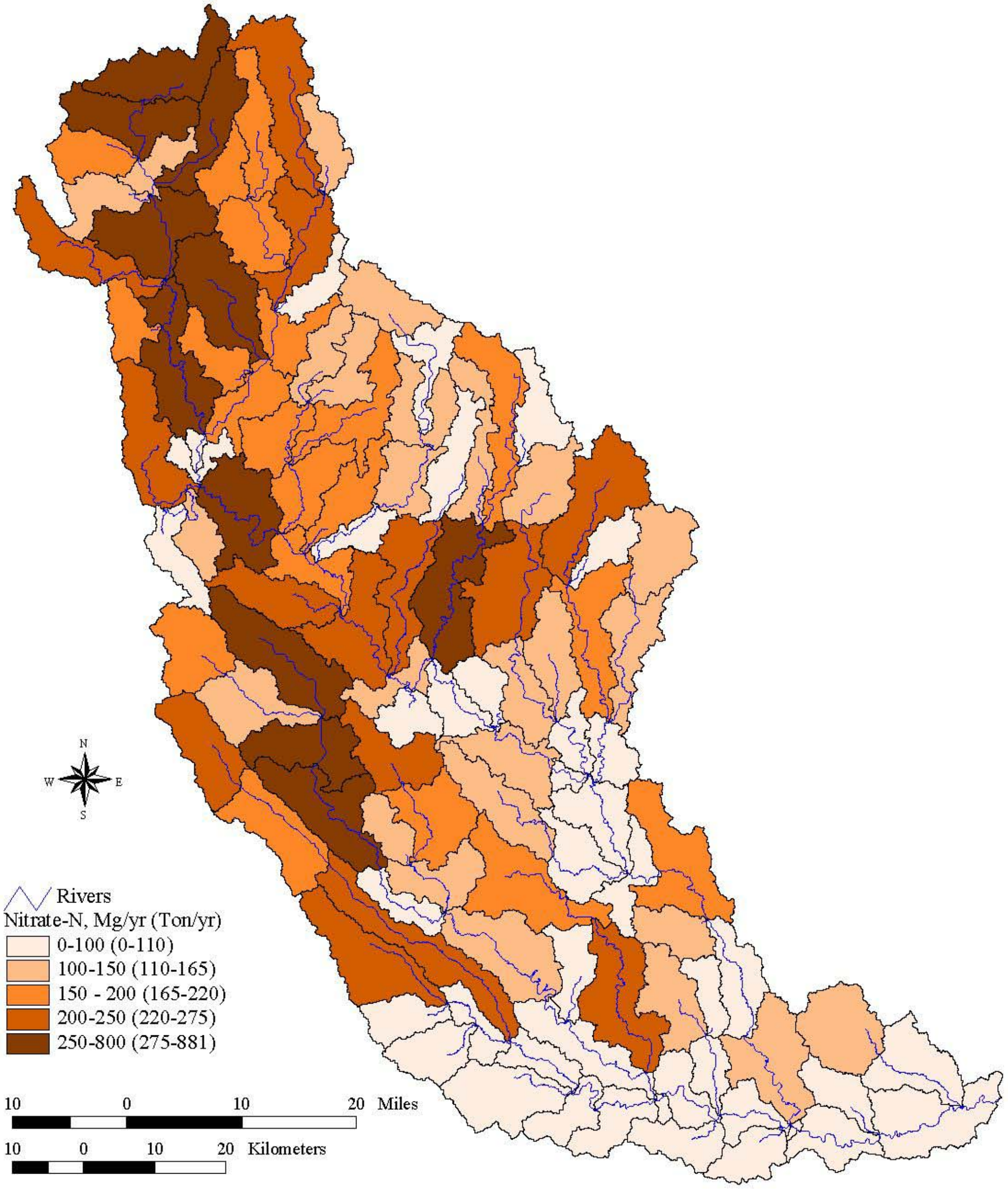


Figure 5-13. Total annual mass of nitrate exported from subbasins from nonpoint sources (metric tons or Mg per year). Metric tons are converted to tons by multiplying by 1.1.

Groundwater versus Runoff Nitrate Loads. The total nonpoint source nitrate load in subbasins was normalized to provide an assessment of the amount of nitrate lost per unit area in each subbasin (kg/ha; Figure 5-14). Annual nitrate losses from several subbasins may exceed 30 kg/ha (26.8 lbs/ac), and a large region shows nitrate losses in excess of 20 kg/ha (17.9 lbs/ac). Most of the subbasins with higher nitrate loading rates are located in the western half of the Raccoon River watershed in the headwater regions of the North and Middle Raccoon rivers. This region was also highlighted when examining the stream nitrate load map (Figure 5-10). Both maps also suggest that nitrate loading rates in the South Raccoon are substantially lower than the North Raccoon, which is consistent with water quality monitoring data.

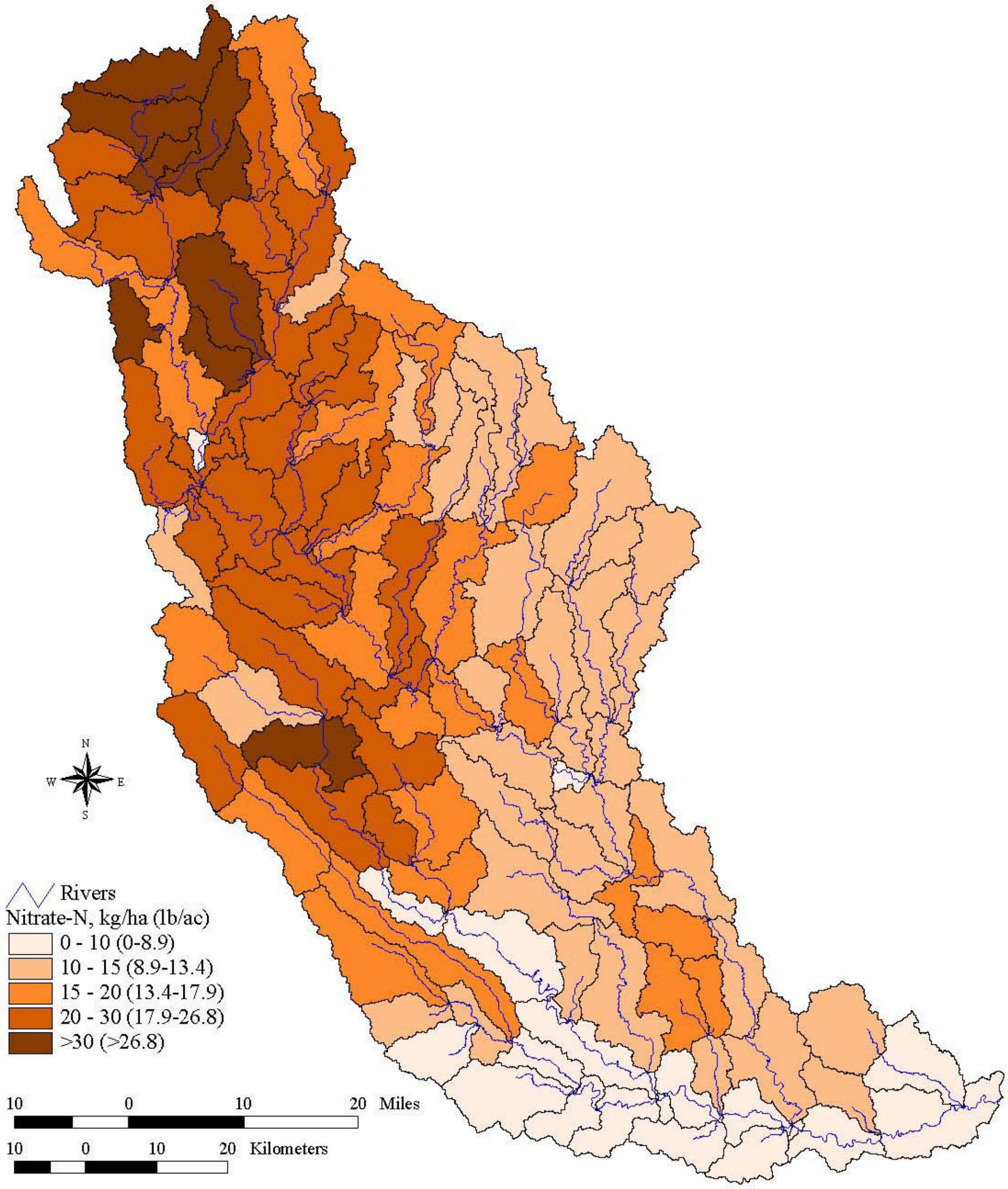


Figure 5-14. Total annual nitrate loss per unit area in subbasins generated from HRU file.

The total nonpoint source load was derived from inputs from surface runoff and groundwater sources and contributions from these sources were evaluated. Figure 5-15 shows the nitrate loads derived from surface flow and Figure 5-16 shows nitrate loads from groundwater sources (combined groundwater seepage and tile flow). Results indicate that the vast majority of nonpoint source nitrate loads are delivered to streams with groundwater and tile flow. The scale on the maps with surface runoff ranges up to the 3 kg/ha (2.7 lbs/ac), whereas the scale on the groundwater map exceeds 30 kg/ha(26.8 lbs/ac). Overall, in the 112 subbasins, groundwater sources comprised 90.5 percent of the total nonpoint source nitrate loads. This proportion was fairly consistent across all subbasins, ranging from 70.3 to 94.1 percent groundwater sources. Thus, contributions from groundwater seepage and tile drainage dominate the nonpoint source nitrate loading to streams in the Raccoon River watershed.

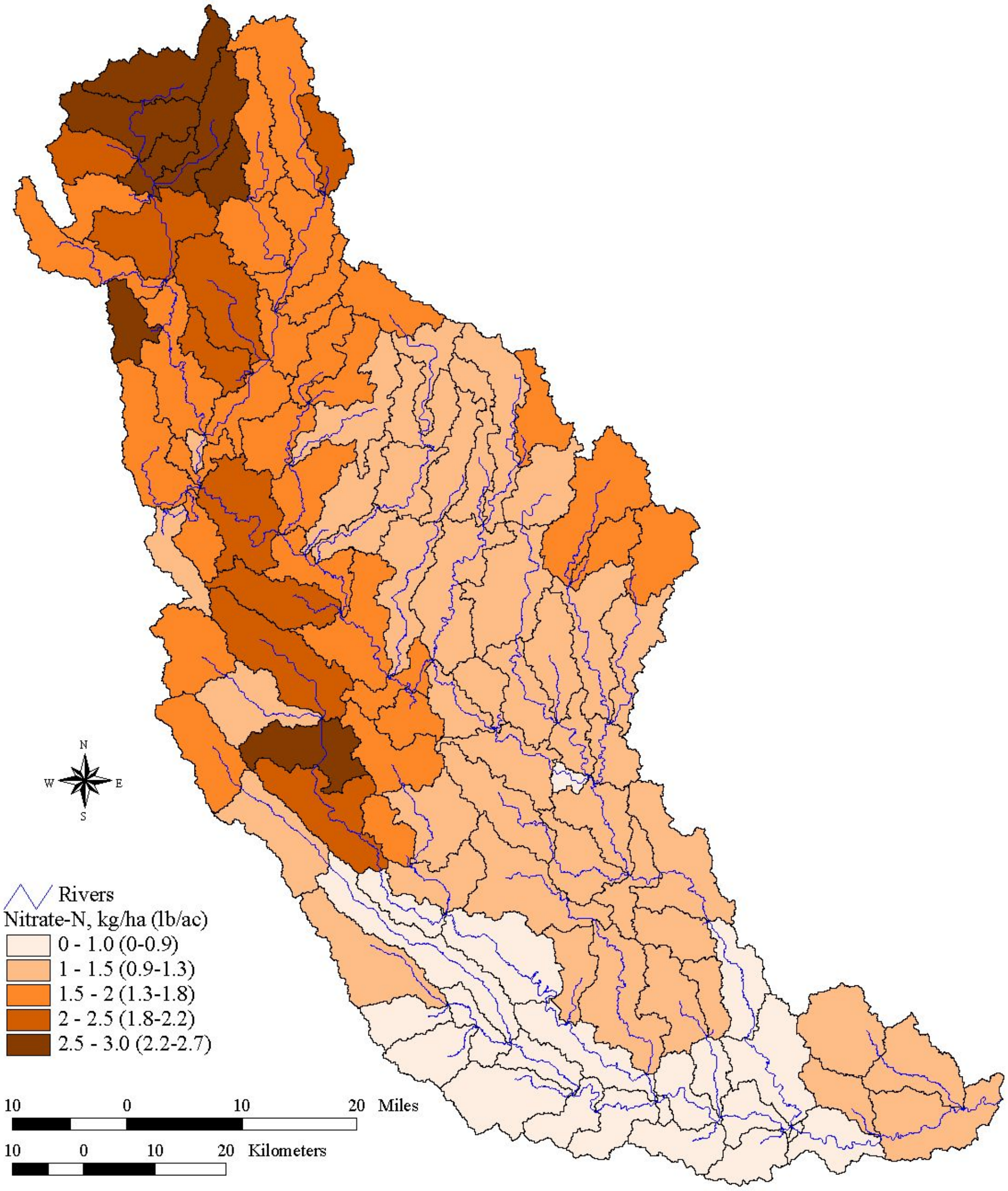


Figure 5-15. Total annual nitrate loss per unit area in subbasins from surface water runoff.

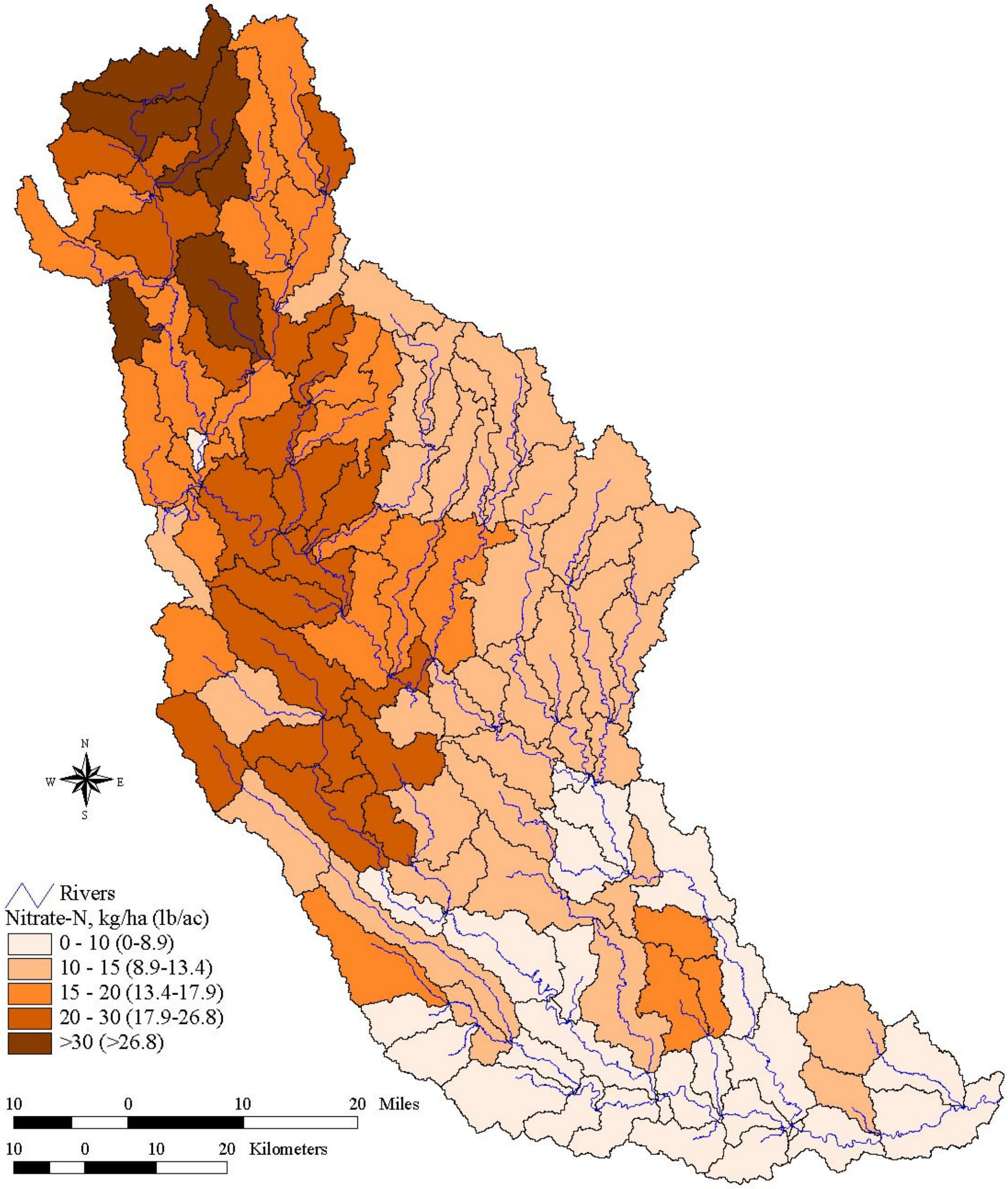


Figure 5-16. Total annual nitrate loss per unit area in subbasins from combined groundwater and tile drainage

5.3.5 E.coli Model Calibration

The SWAT model was calibrated for *E.coli* loads after the model was calibrated for streamflow and nitrate. Unlike streamflow and nitrate calibration, little data was available with which to calibrate the *E.coli* model. Periodic measurements at various water quality monitoring sites was inadequate to use for calibration given the magnitude of variation in *E.coli* concentrations over short time scales. The only suitable location to serve as a calibration site for the model was at the DMWW site on the Raccoon River at Fleur. Here the seven-year, near-daily sampling record available at the outlet of the Raccoon River combined with daily streamflow for the same period was available with sufficient resolution to calibrate *E.coli* loads in the SWAT model. While a single calibration site may not be ideal, the site is located at the watershed outlet at the source of surface water intake by the DMWW.

Calibration was achieved by varying several SWAT bacteria parameters within their acceptable ranges to match the model predicted annual and monthly bacteria loads with measured values at Fleur. With the streamflow at Fleur successfully calibrated, *E.coli* calibration was achieved by adjusting several factors (Table 5-2).

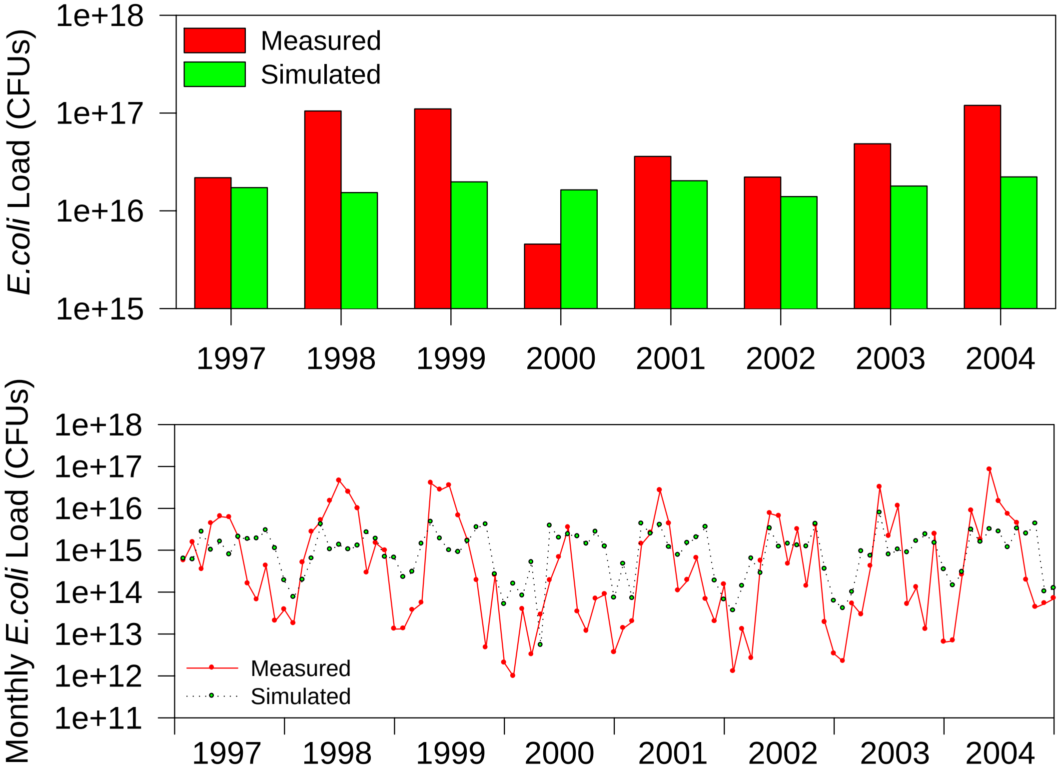


Figure 5-17. Annual and monthly *E.coli* load calibration for the Raccoon River at Fleur (DMWW).

The SWAT model for *E.coli* was successfully calibrated for average annual and monthly bacteria loads (Figure 5-17). For the 1997 to 2004 period, the modeled average annual *E.coli* load at Fleur was 1.79E+16 CFUs, slightly lower than the average measured load of 5.84E+16 CFUs. In general, the modeled annual *E.coli* loads did not show as much annual variation as measured values, ranging from 1.4 to 2.2E+16 CFUs in the model compared to 1.4E+15 to 1.2E+17 CFUs using measured data. Similarly, the monthly variation in modeled *E.coli* loads was not as great as observed with measured data (Figure 5-17). The average modeled monthly

E.coli load (1.49E+15) was slightly lower than the measured average monthly value (4.86E+15). Monthly modeled bacteria loads were approximately 3.2 times lower than measured values. Overall, the r^2 and E statistics for the monthly *E.coli* loads were 0.33 and 0.14, respectively.

While the SWAT model overestimated the lower *E.coli* loads typically observed during the fall and winter months, the upper range of the model was underestimated. The upper limit of measured monthly data was 8.2E+16 CFUs, which was about an order of magnitude higher than the maximum modeled limit (7.7E+15 CFUs). This may be a function of how bacteria sources are delivered to streams in the SWAT model. The SWAT model considers bacteria to be delivered to streams with surface runoff or point source discharges only. No subsurface bacteria delivery to streams is considered in the model, including potential bacteria losses that may occur though drainage tiles. Research has demonstrated that bacteria from surface applied manure can be lost to subsurface drainage tiles (Dean and Foran, 1992; Cook and Baker, 2001; Warnemuende and Kanwar, 2002; Ball Coelho et al., 2007). In field plots, *E.coli* applied to surface soils at a concentration of 7.4E+07 CFUs/100 ml was found at concentrations ranging from 1.3 to 2.7E+04 CFUs/100 ml in 4 cm of tile drainage water (Cook and Baker, 2001). Scaling this bacteria load up from the 1 m by 2.3 m plot to an approximate area of tiled agricultural land in the Raccoon River watershed (~2800 km2), suggests that drainage water could possibly contribute 2E+16 CFUs to surface water in the basin. This load is the same order of magnitude as the total annual *E.coli* load measured in the watershed and indicates that bacteria losses to drainage tiles may be a significant, unaccounted source of bacteria in the model. Further work is clearly needed to evaluate the potential for subsurface drainage losses of bacteria to contribute to water quality degradation. Subsurface drainage losses should be incorporated into future versions of SWAT to account for this important source.

Despite limitations in the level of calibration achieved with the *E.coli* bacteria SWAT model, the model was deemed sufficient for evaluating spatial patterns of *E.coli* loads in the Raccoon River watershed.

5.3.6 E.coli Loading Patterns

Like assessed for nitrate loads, *E.coli* loads are expressed as the total *E.coli* export from a subbasin downstream (essentially “following the water”) or as the loads of *E.coli* bacteria generated from the land area within a subbasin.

***E.coli* Loads.** Figure 5-18 shows the average annual *E.coli* load exported from subbasins in the Raccoon River watershed. Nonpoint source *E.coli* loads were summed in a subbasin first, then point sources added, before the loads were exported to the next subbasin downstream. Results show how *E.coli* loads follow the water downstream in the North, Middle and South Raccoon rivers (Figure 5-18). *E.coli* loads originate in headwater regions or tributary subbasins and accumulate as the river flows downstream. Figure 5-18 includes the effects of bacteria decay and die-off in the stream, so the maintenance of high stream bacteria loads in the subbasins containing the main channels indicates that the in-stream loads are being continually replenished with bacteria as water is flowing downstream.

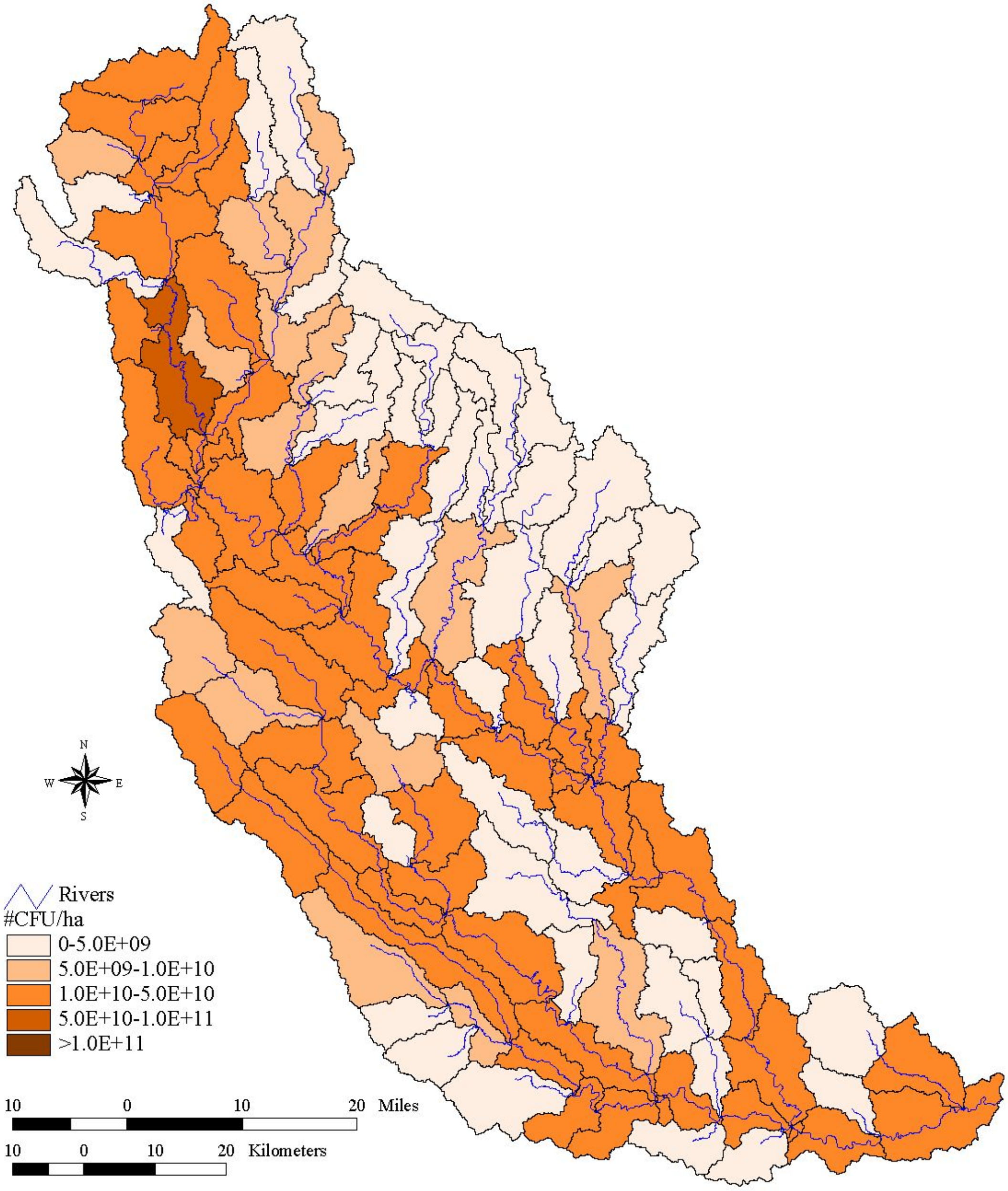


Figure 5-18. Total annual stream *E.coli* load exported from subbasins from RCH file. Point source *E.coli* loads were added back into the subbasins where they were generated.

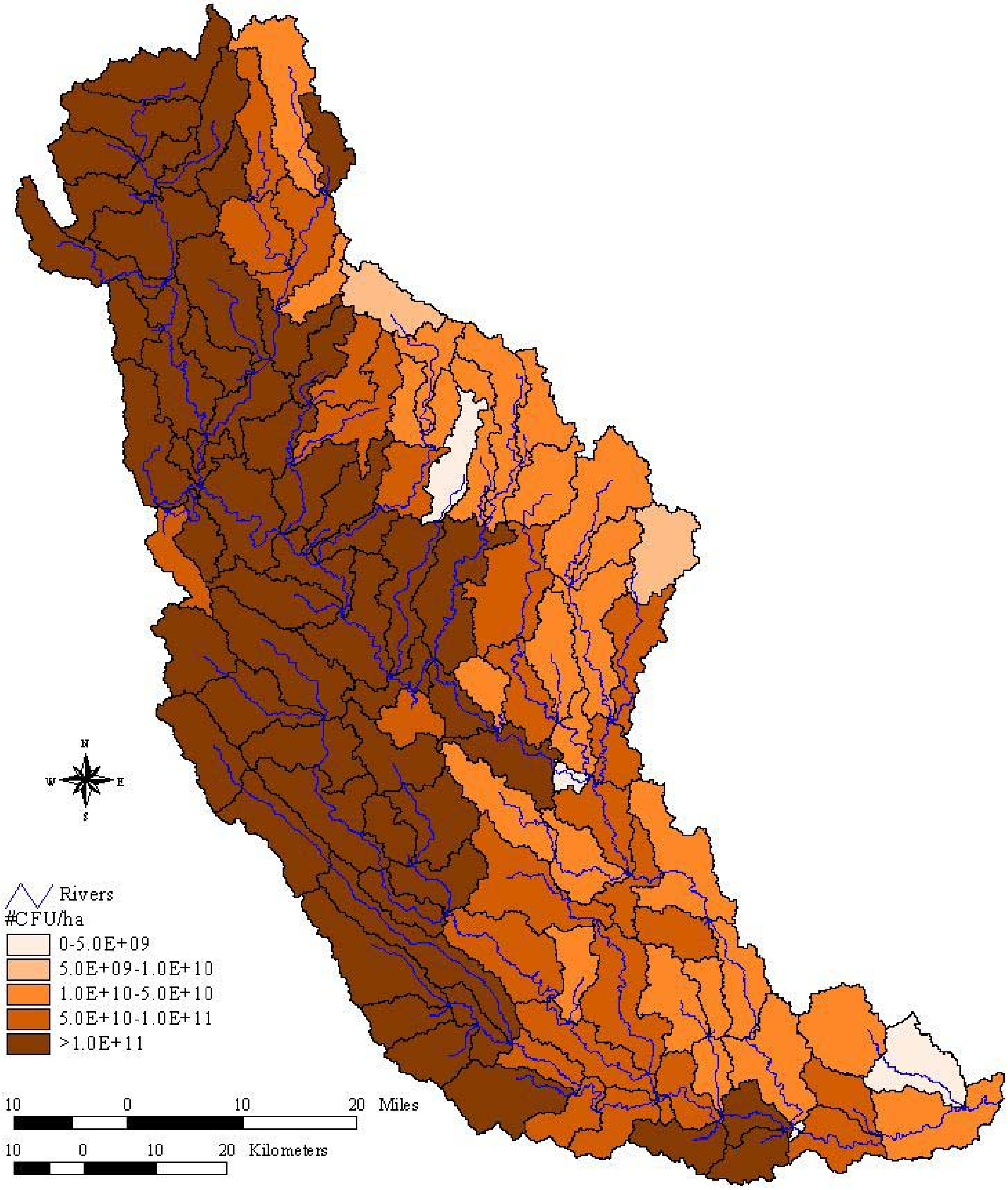


Figure 5-19. Total annual load of *E.coli* exported from subbasins from point and nonpoint sources.

The total amount of *E.coli* produced (in CFUs) per hectare in each subbasin was evaluated to delineate differences in *E.coli* loading rates within subbasins of the Raccoon River watershed (Figure 5-19). Annual *E.coli* loads in excess of 1E+11 CFUs/ha were evident in subbasins in the South Raccoon, and many headwater subbasins in the North and Middle Raccoon rivers. Since Figure 5-19 considers the amount of bacteria generated in each subbasin, and not routing of bacteria in stream water, *E.coli* loads were lower in the subbasins containing the main channels. Figure 5-19 strongly suggests that *E.coli* bacteria are produced throughout the watershed, from point and nonpoint sources, and bacteria loading rates are greatest in many headwater and tributary subbasins. Less difference in bacteria loading rate between the North and South Raccoon rivers was noted in the SWAT simulations than DAFLOW and WASP (Appendix A), although the greater spatial resolution of the SWAT model suggests that more subbasins with higher loading rates near the Raccoon River watershed outlet are located in the South Raccoon than the North Raccoon. A greater contribution of bacteria to the Raccoon River at Van Meter suggested by the WASP model may be a result of the closer proximity of subbasins with higher loading rates in the South Raccoon River .

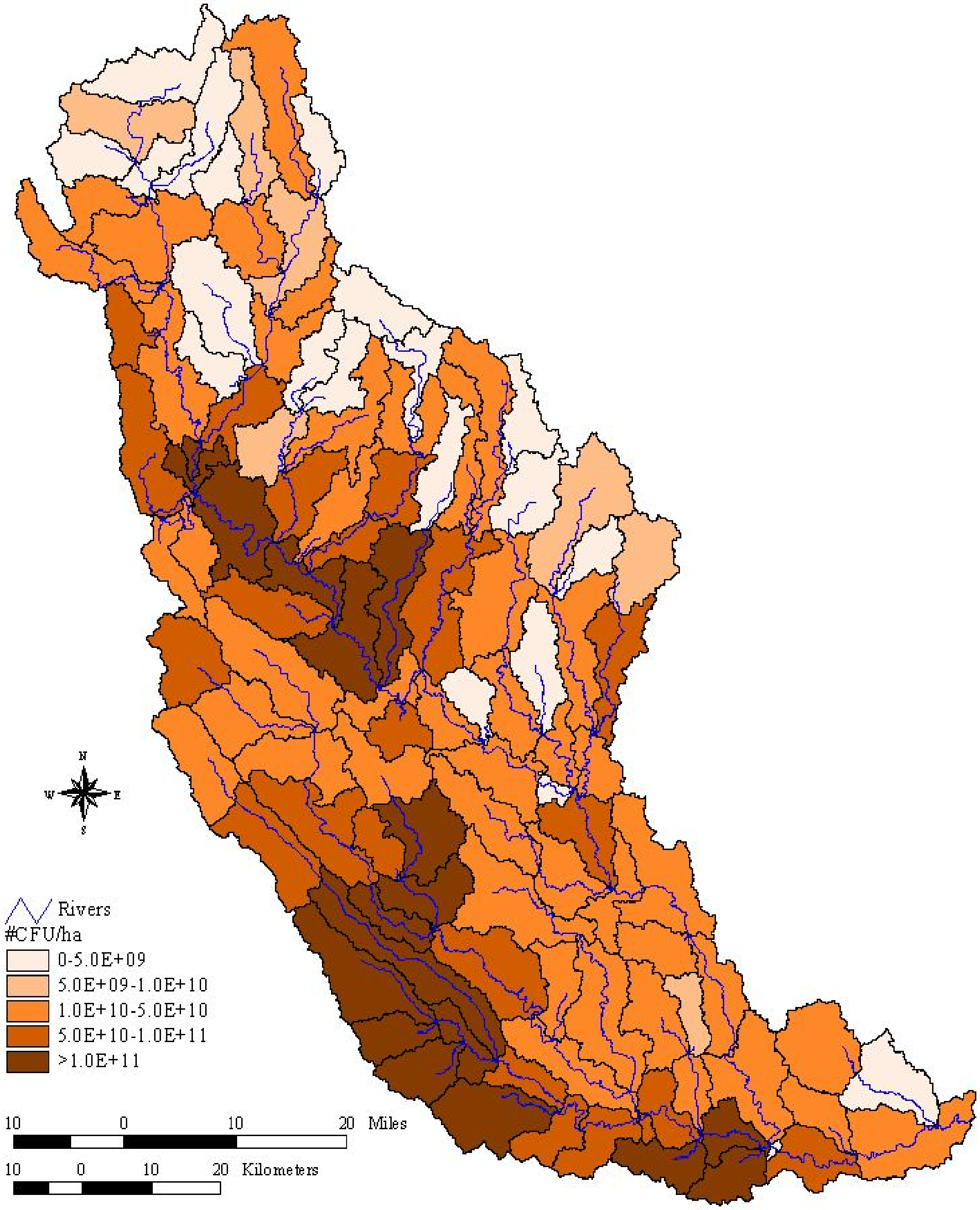


Figure 5-20. Total annual load of *E.coli* exported from subbasins from point sources. Point sources include WWTPs, septic systems and cattle in the stream.

Point vs. Nonpoint Loads. The contribution of point sources and nonpoint sources to total *E.coli* loads was evaluated by considering the total amount of *E.coli* produced (in CFUs/ha) in each subbasin from each source. Recall that in the SWAT model, point sources include the combined loads of cattle in the stream, WWTPs and septic systems. Loads from individual point sources are not evaluated in this section, but in Section 6 contributions from each point source are indirectly assessed. As part of evaluation of BMP implementation strategies, point sources are removed from the model and load reductions are assessed.

Point source loads of *E.coli* were highest in six headwater subbasins located in the South and Middle Raccoon River watersheds and seven subbasins in the North Raccoon watershed where *E.coli* loads exceeded 1.0E+11 CFUs/ha (Figure 5-20). Point sources in these subbasins were primarily associated with cattle in the streams in these areas. In general, bacteria loading rates were higher in subbasins in the South and Middle Raccoon river watersheds than in the northern portion of the North Raccoon watershed. Subbasins with bacteria losses from WWTP point sources were difficult to distinguish from subbasins dominated by the contributions from cattle in the stream.

Nonpoint source loads of *E.coli* were higher in the western half of the Raccoon River watershed (Figure 5-21). Note that the scale used in Figure 5-21 is the same and that used in Figure 5-20, so that visually, it is evident that many more subbasins were in the “high” category of loads (greater than 1.0E+11 CFUs/ha) in the map of nonpoint source loads compared to point source loads. Nonpoint source bacteria loads primarily consist of livestock manure from CAFOs and cattle feedlots. Overall, nonpoint source loads of *E.coli* represent 68.9 percent of the total *E.coli* load in the Raccoon River watershed, whereas point sources comprise 31.1 percent of the total. This proportion is substantially different than the proportion estimated in Section 4 where it was estimated that nonpoint sources comprised 99.5 percent of the total *E.coli* load. However, the estimate in Section 4 considered point source loads from WWTPs only, and the SWAT model considered additional point sources of septic systems and cattle in streams.

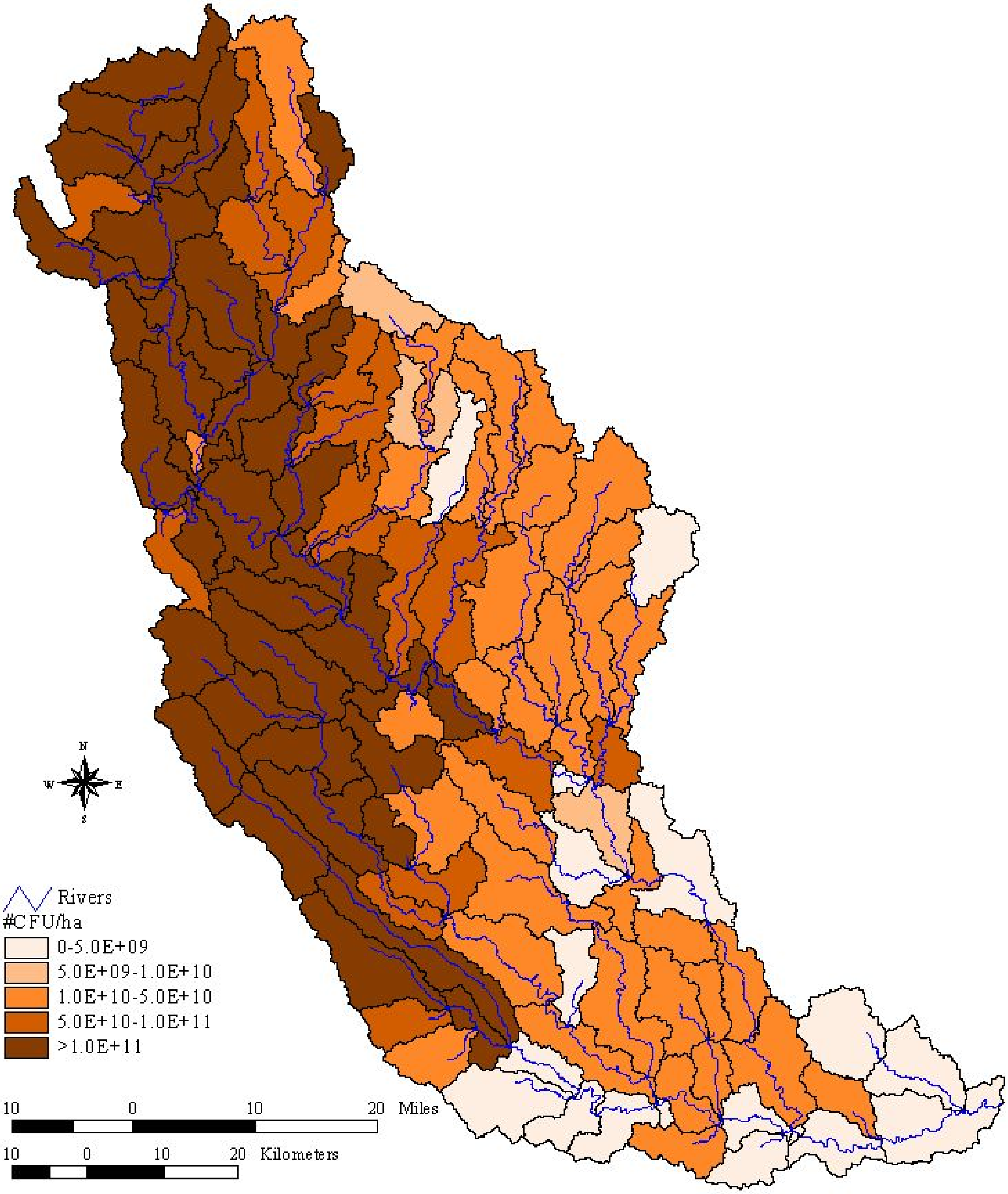


Figure 5-21. Total annual load of *E.coli* exported from subbasins from nonpoint sources.

6.0 IMPLEMENTATION PLAN

This section describes how best management practices (BMPs) implemented in the Raccoon River watershed can be used to reduce loads from nitrate and *E.coli* bacteria. An implementation plan is not a required component of a Total Maximum Daily Load but can provide department staff, partners and watershed stakeholders with a strategy for improving Raccoon River water quality.

This section is divided into two main parts based on two different scales of BMP implementation. In Section 6.1, the SWAT watershed model is used to evaluate the effectiveness of BMPs implemented on a global scale (i.e., uniformly across the entire watershed) to reduce nitrate and bacteria loads at watershed outlets. The benefit of this approach is that several load reduction alternatives can be evaluated to see what load reductions are possible if everyone in the watershed changed their management practice accordingly. The global assessment provides a best-case set of conditions to compare results from one practice against that of another. However, the problem with this scale of assessment is that the results are unrealistic. For example, it is fully understood that it is impossible for humans or animals to be removed from the watershed. Thus, the objective of Section 6.1 is to provide a large-scale view of load reduction strategies, in essence, a view from 30,000 feet above the watershed.

In Section 6.2, various field-scale or local BMPs are presented to reduce nitrate and bacteria losses from smaller parcels of land. This view is essentially "out the back door" and the discussion considers a wide range of BMP alternatives that may or may not be appropriate for any one landowner. A list of BMP options for nonpoint source loads is presented and the degree of BMP effectiveness to reduce pollutant loads is assessed. Options available to reduce the impacts from human nonpoint and point sources are presented in the context of local BMP implementation.

6.1 Watershed Scale Load Reduction Scenarios

Watershed scale nitrate and bacteria load reductions were evaluated using the calibrated SWAT model described in Section 5. Appropriate load reduction scenarios were identified and the model parameters and inputs were adjusted to incorporate the new management strategy into the model. Model results were then compared to the calibrated "baseline" condition to measure the degree of load reduction achieved. Reductions in nitrate and bacteria loads are expressed in terms of the percent reduction from the baseline condition. The assessment considered changes in the average annual export of nitrate and bacteria for a 20-year model simulation period.

6.1.1 Selection of Scenarios

Many options exist to reduce nitrate and bacteria loads from a watershed (see Section 6.2). In order to narrow the list of potential options to evaluate on a watershed scale, a survey was conducted of stakeholders to identify the most important scenarios to address with the SWAT model. A list of 12 options was considered by a total of 19 respondents. The top five load reduction strategies were retained for analysis with the model and included the following scenarios:

1. Reduce the rate of ammonia fertilizer application in the watershed to 150 kg/ha, 100 kg/ha and 50 kg/ha (134, 89 and 45 lbs/ac, respectively).
2. Remove all cattle from the streams.
3. Remove all human waste from the watershed.
4. Convert all row crop lands located on slopes greater than B slopes to CRP grassland.
5. Convert all row crop lands located on floodplain alluvial soils to CRP.

The first set of scenarios focused on reducing the application rate of nitrogen fertilizer in the watershed from the baseline condition of 170 kg/ha to 150, 100 and 50 kg/ha. This scenario did not affect manure applications as a source of nutrients, only fertilizer rates, and thus was not expected to have significant impact on bacteria export.

The objective of this scenario was to evaluate the degree by which water quality could be improved if nitrogen fertilizer rates were reduced in the Raccoon River watershed.

The second scenario was performed to assess the effect of removing all cattle from the stream on nitrate and bacteria export. This pollutant source is considered a point source by the SWAT model and was removed from the model by simply reducing the time spent by cattle in the stream to zero. Cattle (and manure) were allowed to be in pastures and contribute to nonpoint source loads, but were not allowed to be point sources in the stream. The objective of this scenario was to evaluate the degree of water quality improvement achievable if all cattle were removed from Raccoon River streams.

The third scenario addressed the impact of human waste in the watershed from septic systems and wastewater treatment plants. Contributions from both types of point sources were assumed to be zero. The purpose of this scenario was to distinguish between human and nonhuman impacts to the Raccoon River.

The fourth and fifth scenarios considered the effects of land use conversion on stream water quality. Increasing the amount of CRP in a watershed can be a very effective soil and water conservation practice because annual row cropping systems are converted to perennial grass, which results in less surface runoff and more evapotranspiration. Two CRP scenarios were executed with SWAT runs. In one case, row crop lands on sloping ground were converted to CRP. Sloping ground was considered to be “C” slopes or higher as identified by the soil series descriptions (soils on slopes greater than 5%). Using this criteria did not result in a large conversion of cropland to CRP (total of 9.5 percent of row crop land in the watershed), but was considered the most realistic method to apportion CRP ground across the basin. It was deemed highly impractical to convert large areas of relatively flat agricultural lands (slopes less than 5 percent) to CRP grasslands.

A fifth scenario involved converting all row crop lands located on floodplains to CRP. While this is not a traditional practice, floodplain lands are being increasingly scrutinized for their potential for flood control, improved habitat and biodiversity, and overall enhanced connectivity between terrestrial and aquatic ecosystems. Landowners with floodplains prone to flooding are being encouraged to retire the lands from row crop production to reduce crop insurance payments. For this scenario, selection of lands were made by identifying all SWAT HRUs that combined row crop production on various alluvial soils in the subbasins. This method identified 3.1 percent of the row crop land in the watershed available for conversion to CRP. Although this percentage was a measurable fraction, this total was lower than expected, possibly due to the lack of distinct floodplain soil development in the recently glaciated Des Moines Lobe landform region that comprises the North Raccoon River watershed. Hence, the conclusions derived from the floodplain CRP scenario may not reflect the possible magnitude of this strategy in other regions of Iowa dominated by hillslopes and discernible floodplains.

6.1.2 SWAT Model Scenario Results

Results of the SWAT model scenarios are divided into separate nitrate and *E.coli* load reduction sections. This was done because not all scenarios affected nitrate and bacteria equally. In addition, nitrate load reductions were evaluated at the watershed outlet, whereas bacteria results were assessed at both the watershed outlet and at the subbasin level.

Table 6-1. Nitrate load reductions from baseline condition assessed at the outlet of Raccoon River watershed.

Scenario	Annual Nitrate Load (Mg)	Annual Nitrate Load (tons)	Percent Change from Baseline
Baseline condition	17,430	19,173	0%
Reduce fertilizer from 170 to 150 kg/ha (152 to 134 lbs/ac)	16,436	18,080	-5.7%
Reduce fertilizer from 170 to 100 kg/ha (152 to 89 lbs/ac)	14,118	15,530	-19.0%
Reduce fertilizer from 170 to 50 kg/ha (152 to 45 lbs/ac)	12,218	13,440	-29.9%
No cattle in streams	17,325	19,058	-0.6%
No human waste	15,722	17,294	-9.8%
Convert crop ground on C slopes or greater to CRP	15,878	17,466	-8.9%
Convert crop ground on alluvial soils to CRP	16,837	18,521	-3.4%

Nitrate Load Reductions. Results from five load reduction scenarios for nitrate are shown in Table 6-1. Nitrate load reductions ranged from 29.9 to 0.6 percent, with the greatest potential load reduction associated with reducing fertilizer inputs from 170 to 50 kg/ha (152 to 45 lbs/ac). Overall, the response of nitrate loads to reduced fertilizer inputs in the watershed was approximately linear, from a 5.6 percent reduction at 150 kg/ha to 19 percent at 100 kg/ha and nearly 30 percent at 50 kg/ha (Figure 6-1). For every 10 kg/ha (8.9 lbs/ac) of reduced fertilizer input, model results suggest annual nitrate loads could be reduced about 2.4 percent. However, model results also suggest that even eliminating all fertilizer inputs in the watershed would still result in an annual export of nearly 10,000 Mg of nitrate, as a result of water flux through the nitrogen-rich soils. Overall, results suggest that reducing fertilizer inputs to row crop lands in the Raccoon River may substantially reduce nitrate loads at the watershed outlet in Des Moines. A 30 percent reduction achieved in nitrate load achieved with a reduced application rate of 50 kg/ha (45 lbs/ac) is less than the reduction in nitrate loads called for in the TMDL for the Raccoon River at the DMWW (48 percent reduction needed).

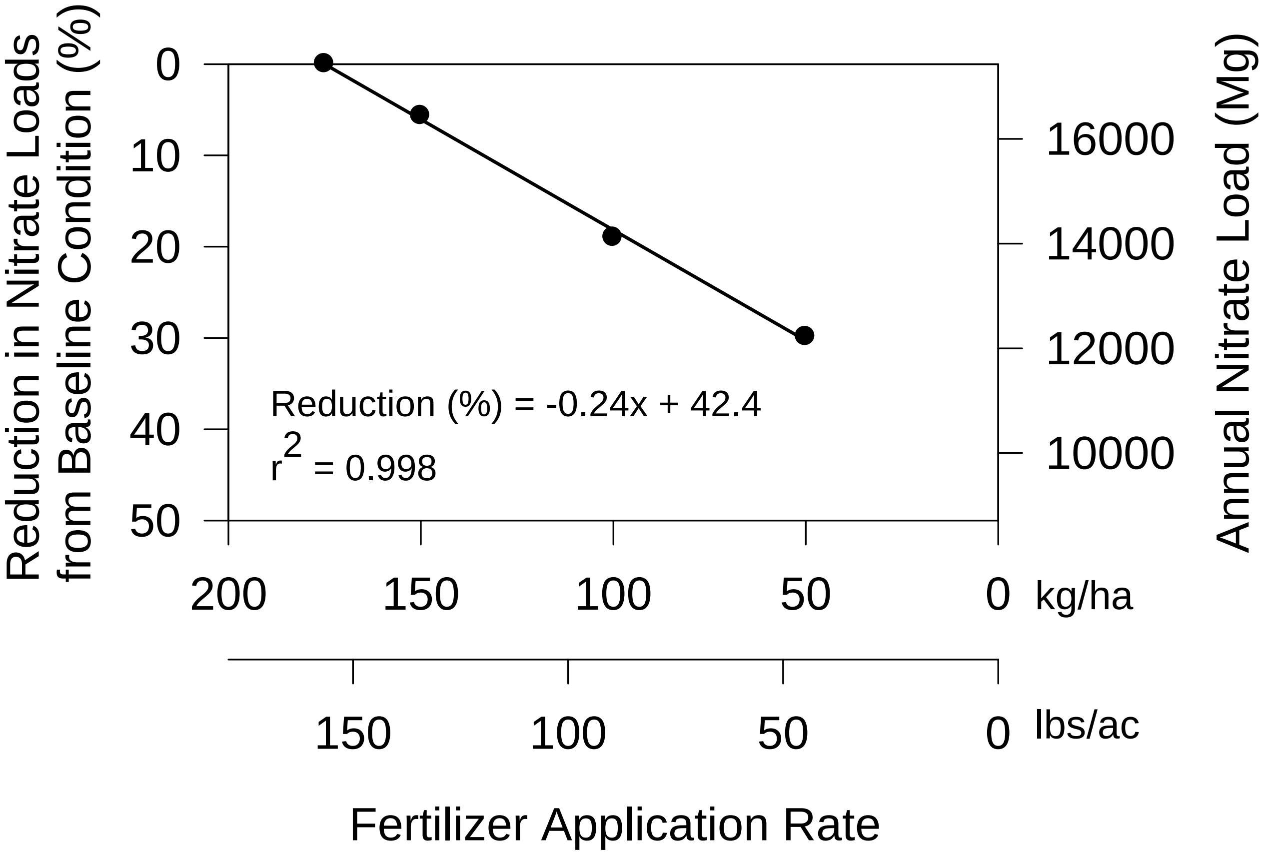


Figure 6-1. Relation of fertilizer application rate to reduced nitrate loads at watershed outlet.

In contrast, eliminating cattle from the streams would appear to have little effect on nitrate export. A reduction of less than one percent was achieved when cattle were prevented from entering the stream and discharging nitrogen waste directly to the stream.

Eliminating all human waste in the watershed achieved a nitrate reduction of 9.8 percent, which suggests that human waste sources contribute about 10 percent of the nitrate export. The percentage includes contributions from septic systems and WWTPs and is consistent with the nitrate load proportion developed in Section 3, which suggested that human waste from municipal and industrial WWTPs contributed 10.3 percent of the nitrate loads when impairments occurred. Thus, nitrate loads from human sources contribute relatively little to the total nitrate loads at the watershed outlet, and if they could be removed entirely from the hydrologic system, a reduction of 9.8 percent could be achieved.

Changing land cover from row crop to CRP reduced nitrate loads at about a 1:1 ratio for CRP conversion of sloping ground and alluvial soils. The ratio implies that for converting every one percent of land cover in the watershed, an approximate one percent decrease in nitrate loads could be achieved. This ratio is consistent with the ratio of row crop percentage to annual stream nitrate concentrations that was also determined to be about 0.1 (Schilling and Libra, 2000). It is interesting to note that the ratio is slightly less than one for the CRP conversion of sloping ground (8.9% load reduction for 9.5 percent land use change), and slightly greater than one for the conversion of alluvial soils (3.4% load reduction for 3.1 percent land use change). This suggests that converting floodplain soils from row crop to CRP may hold promise for gaining more water quality impact for the same amount of land converted compared to upland slopes. However, more work is needed to confirm this effect. Specifically, the proximity of the floodplain to the stream should be included in an evaluation of the effects of floodplain management on stream water quality. The close contact of the floodplain to the stream may result in an even larger difference than reported above since groundwater velocities are higher in permeable floodplain sediments and flow paths are shorter in the floodplain.

***E.coli* Load Reductions.** Evaluation of load reduction scenarios for *E.coli* is more complex compared to nitrate for several reasons. First, *E.coli* concentrations decay in streams, so a simple assessment of reductions of *E.coli* loads at the watershed outlet would greatly emphasize load contributions from local sources compared to distal sources that may actually contribute greater *E.coli* loads in the watershed. Given that bacteria impairments are located throughout the basin and a basin-wide TMDL for bacteria proposed, bacteria load reductions may be more appropriate to examine at the subbasin level compared to a single value at the watershed outlet.

Second, the way in which the SWAT model treats point sources makes it difficult to evaluate point source reductions uniformly. The SWAT model adds point source loads to streams after loads have been calculated from nonpoint sources in the watershed. The model then adds the point source loads to streams as the water is leaving a subbasin. Thus, for all headwater subbasins, point source impacts show up in the subbasin immediately downstream from where they originated. In the calibrated SWAT model for the Raccoon River, there are 49 headwater subbasins out of the 112 total subbasins with essentially no point source loads associated with them. A total of 63 subbasins have point sources load reductions to evaluate. It should be noted that in Section 5, care was taken to add the point source loads back into the basin where they originated, but evaluating many scenarios using this approach was not practicable given time constraints.

Table 6-2. *E.coli* load reductions from baseline condition assessed at 63 subbasins of the Raccoon River watershed.

Subbasin ID	Load Reduction from Baseline (%)			
	No Cattle in Stream	No Human Waste	Sloping Crop Ground to CRP	Alluvial Crop Ground to CRP
2	0.02	0.02	7.25	2.80
7	0.12	0.13	3.89	3.44
10	0.01	0.01	0.01	1.74
11	0.08	0.09	2.65	2.29
13	0.70	0.71	0.01	0.75
17	0.63	0.64	0.81	0.45
21	0.00	0.03	0.00	0.00
22	1.41	1.50	0.39	0.36
23	0.43	0.45	0.35	0.28
24	0.00	0.00	0.00	0.00
27	1.30	1.39	0.44	0.28
28	0.00	1.34	0.51	0.00
29	0.00	1.88	0.14	0.00
31	0.00	0.01	0.00	0.00
32	1.38	1.57	0.35	0.21
33	0.02	0.86	0.04	0.00
35	0.69	0.72	0.09	0.00
39	1.17	1.36	0.34	0.59
40	1.04	1.18	0.35	0.43
41	0.54	0.56	0.00	0.00
42	1.10	1.27	0.33	0.48
43	0.00	0.00	0.00	0.00
45	0.16	0.14	47.36	33.19
47	0.13	0.14	0.00	0.00
49	2.09	2.20	0.00	0.00
50	1.68	1.71	0.00	0.00
52	1.10	1.22	0.32	0.38
53	1.28	1.43	0.34	0.40
54	0.11	0.11	0.00	0.00
55	2.00	2.03	0.00	0.00
56	0.00	1.36	2.11	0.00
58	0.28	0.00	0.00	0.00
59	1.31	1.45	0.13	0.39
60	0.00	1.11	8.56	0.00
61	0.82	0.89	23.85	19.26
62	1.20	1.34	0.15	0.37
70	0.39	0.39	35.41	16.89
71	0.33	0.24	68.19	14.73
72	1.67	1.67	0.00	0.00
74	0.75	0.75	21.36	7.70
75	0.45	1.21	21.96	15.57
76	0.72	0.67	27.81	9.40
77	0.00	1.23	0.48	0.00
78	0.00	0.05	2.75	0.18
79	0.81	1.02	9.60	6.27
81	1.26	1.41	0.23	0.38
82	0.77	0.88	0.99	1.69
85	1.23	1.39	8.41	5.01
87	1.49	1.58	0.35	0.25
89	0.00	0.02	0.00	0.00
91	0.81	0.86	0.00	0.00
94	0.02	0.02	0.00	0.00
96	0.91	1.01	8.70	12.76
98	0.20	0.20	29.16	23.78
99	0.62	0.69	22.43	19.42
101	0.25	1.00	15.54	11.47
105	1.18	1.32	0.15	0.39
106	0.75	0.69	25.56	8.83
107	0.55	0.86	19.73	10.48
108	1.10	1.25	6.08	3.86
109	1.27	1.42	0.16	0.39
111	1.38	1.56	8.32	4.59
112	1.06	1.19	0.33	0.37

E.coli load reductions from four of the five scenarios were evaluated (effects of changing fertilizer inputs on stream bacteria levels were not assessed). In Table 6-2, the load reductions for the 63 subbasins are given for the four scenarios. The subbasin ID refers to the subbasin numbers presented in Figure 5-1 and basin names are provided in Table 5-1. In Table 6-3, statistical representations of the load reductions are presented (median, minimum and maximum), with the average considered a proxy for "load reductions for the entire watershed".

Table 6-3. Summary of *E.coli* load reductions associated with conservation scenarios.

	Reduction in *E.coli* Load from Baseline Condition (%) (63 Subbasins)			
Scenario	**Average**	**Median**	**Minimum**	**Maximum**
No cattle in streams	0.68	0.69	0.00	2.09
No human waste	0.88	0.89	0.00	2.20
Convert crop ground on C slopes or greater to CRP	6.90	0.35	0.00	68.19
Convert crop ground on alluvial soils to CRP	3.85	0.38	0.00	33.19

Results from the load reduction scenarios for *E.coli* suggest that converting row crop land on slopes to CRP would reduce stream bacteria loads more than the other scenarios. *E.coli* loads were reduced by as much as 68 percent in Subbasin 71 (Mason Creek watershed in South Raccoon basin), and more than a dozen subbasins had bacteria load reductions greater than 10 percent (Table 6-2). All of the subbasins with substantial reductions were located in either the South or Middle Raccoon river watersheds. The CRP scenario was aimed at reducing overland runoff with placement of CRP on sloping crop ground, and as such, was effective for reducing bacteria losses from subbasins with manure applications on sloping row crop land. Overall, an average reduction of nearly seven percent could be achieved in the 63 subbasins with the CRP conversion of sloping crop ground. Subbasin 111 represents output from the entire Raccoon River watershed at Fleur (DMWW) and suggests an 8.3 percent reduction in *E.coli* loads could be achieved with this scenario. This amount of reduction is far less than the 99 percent reduction called for in this TMDL.

Similarly, the conversion of row crop on alluvial soils to CRP was effective for reducing bacteria loads in some subbasins. *E.coli* load reductions were concentrated in the same subbasins in the Middle and South Raccoon rivers as noted in the CRP conversion of sloping crop ground. A maximum reduction of 33 percent could be achieved in subbasin 45 (Storm Creek watershed in Middle Raccoon basin) and an overall reduction of nearly four percent could be achieved for the 63 subbasins. Results from subbasin 111 (Raccoon River at DMWW) suggest a reduction of 4.6 percent could be achieved with this scenario.

Point source reductions did not appear to result in significant bacteria load reductions (Tables 6-2 and 6-3). Both removing cattle from the stream and removing all human waste from the watershed resulted in an average reduction of less than one percent, with a maximum reduction of about two percent achieved in subbasin 49 (Lower West Buttrick Creek). The lack of impact associated with removing point sources from the watershed is primarily a function of the overwhelming load contribution from nonpoint sources. Although removing point sources would be expected to have much larger effects during particular seasons (low flow periods), the load reduction scenarios considered annual loads only, and the annual loads were dominated by nonpoint source bacteria runoff during high flow periods. When nonpoint source runoff in May results in bacteria losses up to two orders of magnitude greater than the months of August to October combined (when point sources would dominate), eliminating bacteria loads from point sources would have little measurable effect on annual bacteria load reductions that are greatly weighted towards May.

6.2 Local BMP Implementation

6.2.1 NPS Load Reductions from Agricultural Sources

At the scale of an individual landowner, there are many options available for implementing BMPs that will help reduce loads of nitrate and bacteria in streams. Many BMPs will help reduce loads for both nitrate and bacteria, whereas other BMPs are targeted for one pollutant more than the other. Of the two target pollutants, nitrate reduction strategies are better documented than bacteria reduction strategies. For example, Dinnes et al. (2002) provides a useful summary of strategies to reduce nitrate leaching in tile-drained landscapes. However, because nitrate is ubiquitous in the environment and is delivered to streams from many sources, the ability of a single landowner to make a difference in reducing stream pollutant loads may be greater for bacteria than for nitrate.

Table 6-4 lists the conservation practice and identifies the effectiveness of the practice to reduce pollutant loads. Load reductions are evaluated in terms of reducing loads from surface water runoff or reducing groundwater loads as either baseflow or tile drainage. Practices that provide the greatest potential for load reductions are highlighted in the table and discussed below.

Improving nutrient use efficiencies by changing the timing and rate of nitrogen applications are considered among the best practices that an individual landowner could adopt that reduce losses of nitrate to streams with subsurface flow (Table 6-4). Changing the fertilizer application methods to injection methods that minimize surface application and volatilization may reduce runoff losses of nitrogen. Bacteria losses may be reduced if landowners improved manure management practices to take appropriate nutrient credit for manure applications and minimize the application of manure during periods that would facilitate runoff.

Table 6-4. List of conservation practices available to reduce nonpoint source loads of nitrate and *E.coli* bacteria and their potential effectiveness.

		Nitrate Load Reduction Effectiveness[1]		***E.coli* Load Reduction Effectiveness**[1]	
Conservation Practice	**Description**	**Surface runoff**	**Baseflow or Tile drainage**	**Surface runoff**	**Baseflow or Tile drainage**
Improve Nutrient Use					
Spring application of fertilizers	Change fertilizer application from the fall to spring to reduce N loss and increase fertilizer use efficiency. The closer the application is timed to crop needs, the less N is lost to streams.	+	++	±	±
Reduce fertilizer application rate	Reduce the rate of fertilizer applications below currently applied rate. A variable rate or site-specific fertilizer program could reduce applications on individual fields. Improved methodologies are needed to reliably assess site-specific N recommendations.	+	++	±	±
Change fertilizer application method	Change from conventional anhydrous NH3 application to innovative subsurface injection methods to minimize volatilization and reduce leaching.	++	- to +	±	±
Use nitrification inhibitors	Use of controlled or slow-release N fertilizers to slow conversion of fall-applied fertilizer to nitrate.	+	+	±	±
Manure management	Manage the application of manure to cropped fields according to the nutrient application rates of nitrogen or phosphorus. Manure should not be applied at rates that exceed the soil infiltration rate or during wet periods of runoff.	+	+	++	+
Adopt comprehensive farm nutrient management plan	Follow the guidance of NRCS Conservation Practice Standard 590 to manage the amount, source, placement, form and timing of the application of plant nutrients and soil amendments.	+	+	+	+
In-field Management					
Adopt conservation tillage	Utilize no-till or mulch-till practices on crop ground.	+	-	+	±
Contour planting and terracing	Plant crops in rows parallel to land surface topographic contours or install terraces to shorten the slope lengths of hillsides in order to reduce overland runoff.	+	-	+	±
Use cover crops	Plant cover crops of legumes, cereals, or grasses in fields during non-crop periods to reduce nitrate leaching during vulnerable fall and spring periods.	+	++	±	±

Table 6-4. …continued

Diversification of cropping systems and rotations	Include perennial legume or nonlegume crops in rotation with corn and soybeans to decrease water yield due to longer growing season. Perennial crops receive less fertilizer and tillage than annual cropping systems.	+	++	±	±
Retire lands through CRP	Convert vulnerable crop lands to perennial grass through Conservation Reserve Program.	++	++	±	±
Exclude livestock from streams	Manage pastures to exclude livestock access to streams. Install alternative watering systems if needed.	+	±	++	±
Establish rotational grazing systems	Establish fenced paddock system and rotate livestock grazing around pasture to reduce pasture degradation and manure buildup.	+	±	++	±
Incorporate manure into subsoil	Use techniques to incorporate manure into subsoil rather than spreading or applying manure to land surface.	+	± or -	++	± or -
Control feedlot runoff	Utilize run-on control (divert clean water away) and install berms, detention basins or other control structures to capture runoff and settle solids from feedlot runoff events.	+	± or -	++	± or -
Manage manure storage	Manage manure storage or modify manure storage structures to safely contain the manure until conditions are appropriate for field applications.	+	±	++	±
Use alternative tile drainage system design and management	Decrease drainage intensity using shallower tile depth or wider spacing to reduce subsurface flow and nitrate loss. Use controlled drainage when site conditions permit.	±	++	±	±
Install denitrification bioreactors	Use organic materials (corn stalks, wood chips, sawdust, etc.) as organic amendments to encourage denitrification during treatment of tile drain effluent or interception of subsurface drainage through a wall or trench.	±	++	±	±
Utilize in-field conservation buffers	Install conservation buffers, including field borders, filter strips, contour buffer strips, grass waterways, windbreaks hedgerows and other practices, to reduce surface water runoff and sediment erosion.	+	±	+	±
Off-site Management					
Plant riparian buffers	Riparian buffers of forest and herbaceous cover planted along stream corridors reduce pollutant transport to streams with surface runoff through combined processes of deposition, infiltration and dilution. Stream buffers may reduce groundwater nitrate concentrations but flows from tile drainage may bypass the buffer.	++	+ or ±	+	±
Install wetlands	Strategically site wetlands in the landscape to capture and remove nitrate from surface and subsurface water sources. For greatest reductions, wetlands should be placed in locations with highest nitrate concentrations. Utilize USDA programs (CREP) to install wetlands that intercept flows from large tile drainage systems.	+	++	±	±

[1] Ranking criteria: ++ = very effective, + = effective, ± = no effect, - = negative effect

In terms of improving in-field management of conservation practices, surface and subsurface nitrate losses could be reduced by incorporating perennial or cover vegetation into farming systems. Diversifying cropping systems, retiring lands to the CRP, or using cover crops during non-crop periods operate similarly by reducing annual water yield and nitrate losses during vulnerable spring and fall periods. Subsurface nitrate losses could also be reduced in heavily drained areas by using alternative tile drainage designs that decrease drainage density or enhance subsurface denitrification. Reducing bacteria losses from fields would involve better management of pastured systems either by excluding livestock from streams or incorporating rotational grazing systems. Improved handling of manure would reduce bacteria losses from surface runoff from fields, feedlots and manure storage structures.

Off-site measures could be adopted that reduce nitrate losses from surface runoff and subsurface delivery (Table 6-4). Riparian buffers planted along stream corridors would decrease nitrate and bacteria loads from surface runoff, whereas installing wetlands to intercept tile flows offers promise for reducing nitrate loads from larger geographic areas. Iowa State University studies of CREP (Conservation Reserve Enhancement Program) wetlands demonstrate that relatively small areas of wetlands intercepting tile drainage can remove up to 70% of the nitrate loads. Off-site actions may be facilitated or installed by individual landowners or by groups of individuals that seek to make landscape-wide changes that affect many landowners directly or indirectly.

6.2.2 NPS and Point Source Reductions from Human Sources

Pollutant losses from human sources includes urban stormwater runoff and discharge from WWTPs and septic systems. While these sources do not contribute significantly to nitrate and bacteria impairments in the Raccoon River, actions may be justified to improve local water quality.

Urban runoff comes from a variety of sources, including impervious surfaces like roads, rooftops and parking lots, as well as pervious surfaces like lawns. Urban runoff can be an important source of pollutants at a local scale. There are a variety of actions to control nonpoint urban sources, including both structural and non-structural practices. Many of these practices are described in detail in an USEPA guidance document (USEPA, 2005). Structural practices include those engineered to manage or alter the flow, velocity, duration and other characteristics of runoff by physical means (USEPA, 2005). These practices are designed to control storm water volume and peak discharge to improve water quality, reduce downstream erosion, provide flood control and promote groundwater recharge, in some cases. Nonstructural practices prevent or reduce urban runoff by reducing potential pollutants or manage runoff at the source. These practices may take the form of regulatory controls (e.g., codes, ordinances, regulations, standards, or rules) or voluntary pollution prevention practices. Nonstructural practices can be further divided into land use practices and source control practices. Land use practices are designed to prevent or reduce impacts from new development or in sensitive areas of the watershed. Source control practices are aimed at preventing or reducing potential pollutants at their source before they come in contact with runoff. This may involve educating citizens about proper disposal of used motor oil and application of lawn fertilizers and pesticides.

Permitted point source discharges include sewage treatment plants and industrial sources. Although they do not represent a dominant source of nitrogen or bacteria, they may account for a measurable portion of pollutant loads especially at lower streamflows. Existing technology may be used to reduce nitrogen or bacteria loads to stream from point sources. In some areas, nutrient and bacteria reductions from WWTPs have proven to be cost-effective and more certain than estimated reductions from agricultural BMPs. Use of Biologic Nutrient Removal and Enhanced Nutrient Removal technologies have been implemented to reduce N concentrations by 50 to 80 percent. Industrial WWTPs should be evaluated for opportunities to reduce nitrogen and bacteria discharges through pollution prevention, process modification or treatment.

Loads from failing septic systems do not significantly contribute to stream impairments, but they may be the easiest to address with readily available technology. Inspections of septic systems should be used to identify failing or outdated septic systems and these systems should be upgraded accordingly. While these upgrades may not substantially affect pollutant loadings the Raccoon River, they may improve local water quality noticeably.

7.0 MONITORING PLAN

This section describes the existing water quality monitoring being conducted in the Raccoon River watershed and presents suggestions for improving monitoring actions for detection of water quality improvements from TMDL implementation.

7.1 Existing Water Quality Monitoring

In a watershed the size of the Raccoon River, there are several entities conducting water flow and quality monitoring at various locations for multiple purposes. Major ongoing monitoring programs in the watershed are associated with (1) USGS stream gaging, (2) two water supplies that utilize the Raccoon River (Des Moines Water Works and the City of Panora), (3) ambient water quality monitoring conducted by the Iowa Department of Natural Resources and the Army Corps of Engineers through Iowa State University and (4) ambient water quality monitoring conducted by the ACWA. Each of these major water monitoring programs are discussed briefly below.

7.1.1 USGS Stream Gaging

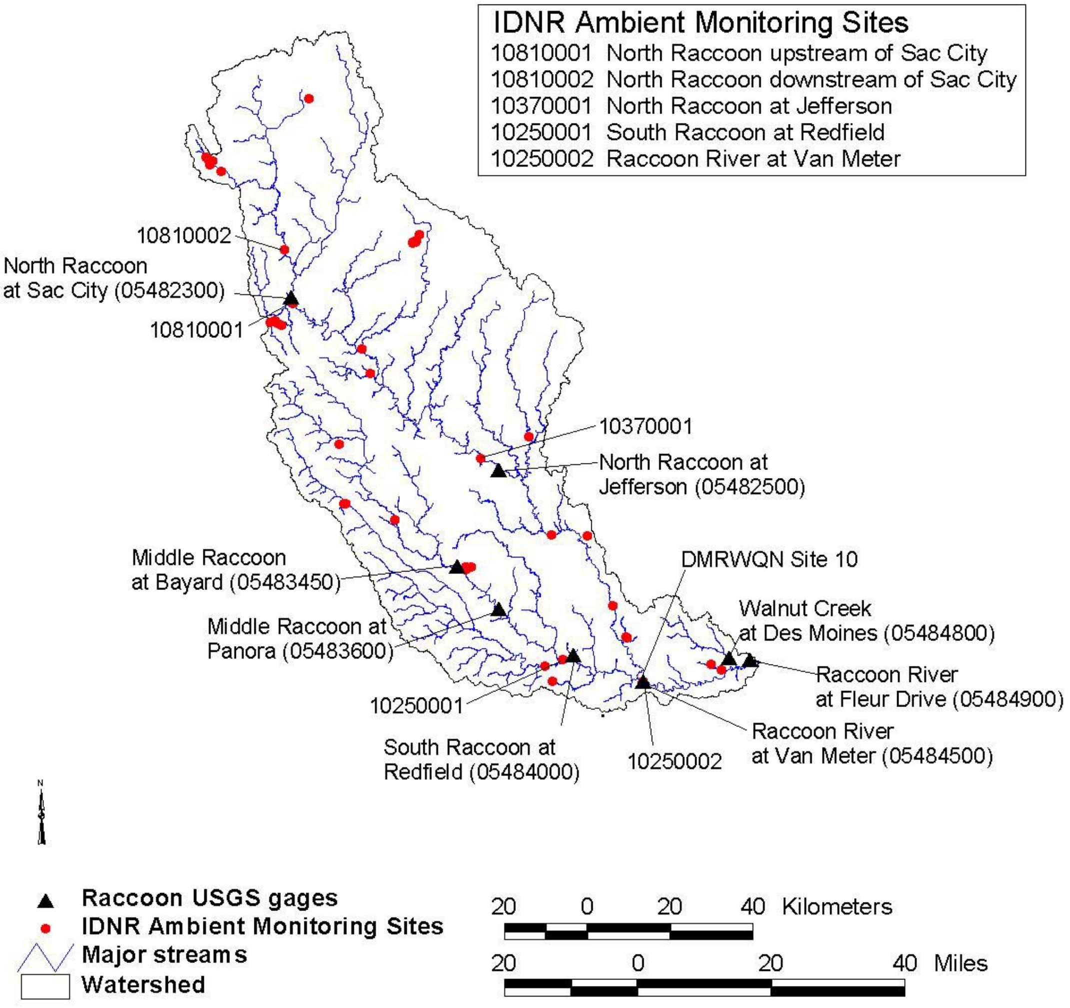


Figure 7-1. Locations of stream gages and monitoring sites in Raccoon River watershed. Unmarked IDNR ambient monitoring sites are associated with various short-term water quality monitoring projects in the basin.

The U.S. Geological Survey operates 12 gaging stations and three crest stage stations in the Raccoon River watershed. Ten of the 12 gaging stations measure water stage at stream locations whereas two stations measure lake stage (Black Hawk Lake and Lake Panorama). Locations of the 10 continuous stream gaging sites in the watershed are shown in Figure 7.1. The period of record varies among the stations. The longest record is associated with the Van Meter station (operated since 1915), two stations were started in 1940 (Jefferson and Redfield), two stations began in 1958 (Sac City and Panora), two started in the 1970's (Bayard and Walnut Creek) and three stations began operation since the 1990's (West Des Moines, 63rd Street and Fleur). Discharge measurements are collected every 15-minutes and reported as daily averages.

The stream gaging stations are critical for monitoring the routing and delivery of water in the basin. Since water is the pollutant carrier through the landscape, any assessment of loads should first "follow the water". Daily flow measurements collected at stream gage stations are useful for developing an understanding of the timing and magnitude of water export from basins and can be paired with water sample collection to measured pollutant loads. When water quality samples are spaced apart in time, continuously monitored discharge can be used to estimate daily loads using regression-based load estimating programs like ESTIMATOR, LOADEST or AUTOBEALE. Often, the first step in developing a hydrologic model for a watershed is calibrating the model for streamflow, and data from stream gages provide much needed information for model calibration.

At a minimum it is recommended that the existing stream gaging be continued in the Raccoon River watershed for the foreseeable future. Maintaining stream gaging records across decadal timeframes is critical to discern trends in streamflow and pollutant loading patterns. In addition, installing additional stream gages should be considered in targeted smaller basins. Currently, the smallest basin size with a stream gage is the Middle Raccoon River at Bayard (375 mi^2). Evaluating hydrologic conditions at the HUC12 level, as modeled in this TMDL, would necessitate installing stream gages in watersheds less than about 60 mi^2. While cost prohibitive at all HUC12 basins, targeting several HUC12 basins throughout the watershed for additional stream gaging would allow for improved hydrologic assessment and load estimation modeling. Stream gages could be installed in subbasins targeted for BMP implementation for better tracking of pollutant loads.

7.1.2 Water Supply Monitoring

The DMWW and City of Panora monitor surface water quality for nitrate in the Raccoon and Middle Raccoon rivers, respectively, on a daily or near daily basis. The DMWW also monitors Raccoon River water for *E.coli* on a similar basis. Both water supplies are strongly encouraged to continue this monitoring activity at a similar frequency to document whether stream nitrate concentrations (for which there is an MCL) respond to watershed BMP implementation. The water supplies represent the "point of compliance" for drinking water, inasmuch as the best measure of success for achieving nitrate load reductions is reduced exceedances at the drinking water intakes. The high-resolution data record of pollutant concentrations in the Raccoon River measured by the DMWW at Fleur is also needed to serve as the best estimate available of the export load of nitrate and bacteria from the watershed. This true "measured" load is rarely available in watersheds and serves as an important check on the ability of analytical and numerical models to reliably predict export loads.

Beginning in 2006, the USGS and DMWW installed a continuous "real-time" nitrate concentration monitor in the Raccoon River at Van Meter. This high-resolution nitrate monitoring offers exciting prospects for evaluating daily and seasonal nitrate concentration patterns and the relation of nitrate to streamflow. Early results suggest that the meter can detect concentration variations over short time scales during storm runoff events (Figure 7-2). Following an extended trial run, the reliability and accuracy of the unit should be evaluated to determine whether additional meters could be feasibly installed at other locations in the watershed.

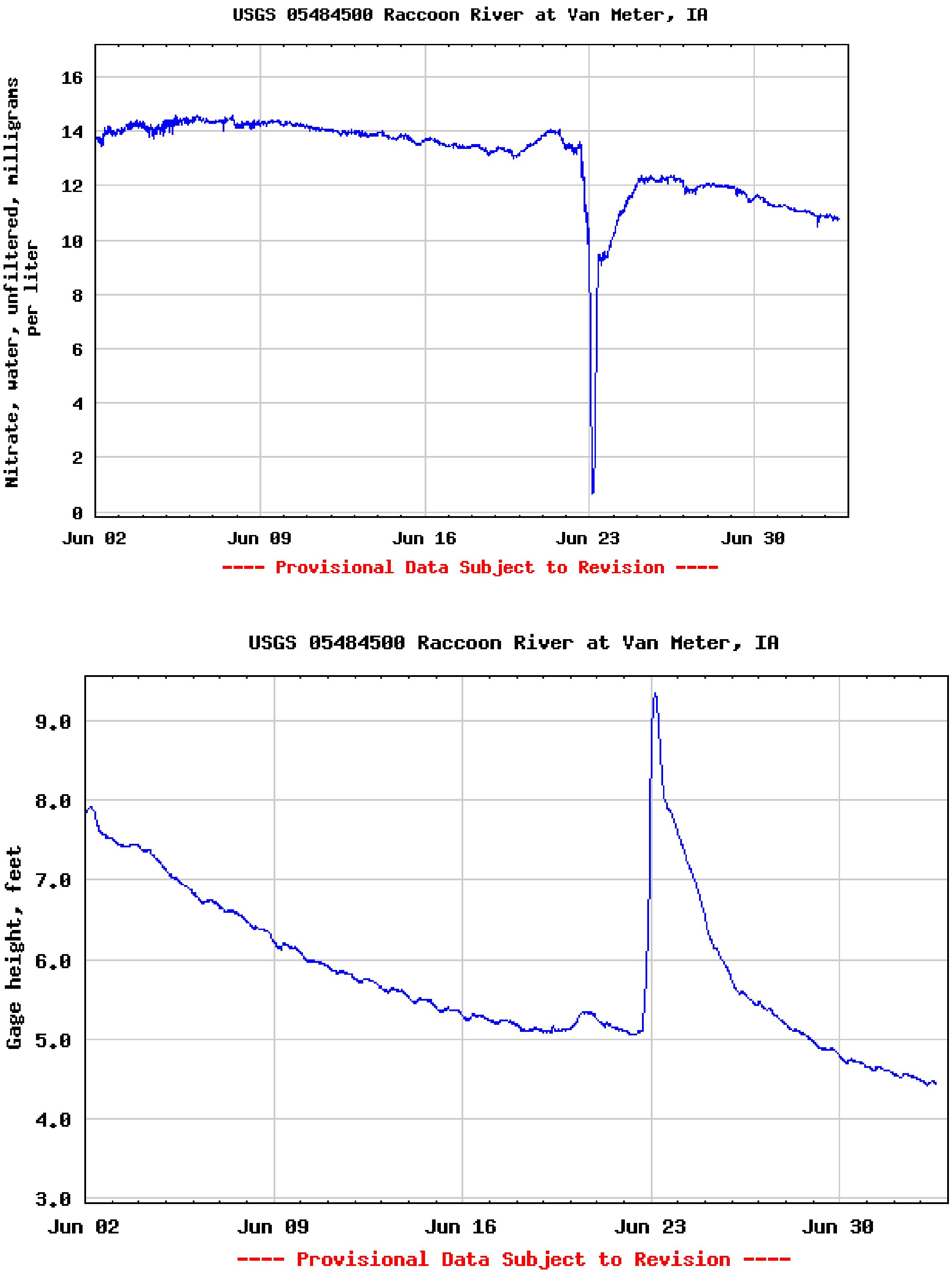


Figure 7-2. Screen capture of continuous nitrate monitor on Raccoon River at Van Meter.

7.1.3 IDNR Ambient Monitoring Program

The IDNR conducts ambient water quality monitoring at three sites in the Raccoon River watershed, one site on the North Raccoon at Sac City, a second site on the North Raccoon at Jefferson, and a third site on the South Raccoon at Redfield. These monitoring sites are sampled monthly for many constituents, including TMDL pollutants nitrate and *E.coli*. Because the sites are paired with USGS stream gages, the sampling data can be used with continuous discharge data to provide estimates of daily, seasonal and annual nitrate loads. However, the monthly sampling schedule for bacteria is not sufficient for reliable estimation of bacteria loads. Bacteria concentrations are extremely variable over short time periods and would not be reliably estimated with monthly data.

In addition, two additional sampling sites are located in the basin associated with city monitoring. One site is located upstream of Sac City on the North Raccoon, and a second is located upstream of Des Moines on the Raccoon River at Van Meter. The purpose of these sites is to document water quality conditions upstream of the city's wastewater treatment plant and other forms of urban discharge.

It is important for evaluating TMDL implementation that the ambient water quality network in the watershed to be maintained. Because the sites are located on major tributary branches of the river, results provide assessment of differences in pollutant loading patterns throughout the basin. Data from various locations in the basin also prove extremely valuable for calibrating watershed-scale models, particularly for nitrate. For the ambient sites to be valuable for bacteria assessment, a substantially greater number of samples would be needed throughout the year to capture the variability in concentrations. Continuation of ambient monitoring in the watershed would enable long-term trends to be better assessed in the future.

7.1.4 The Des Moines River Water Quality Network (DMRWQN)

The DMRWQN is a surface water quality project sponsored by the US Army Corps of Engineers that collects water samples at locations along the Des Moines and Raccoon Rivers and Saylorville and Red Rock reservoirs. The program maintains one site on the Raccoon River at Van Meter (site 10) where surface water samples are collected approximately 22 times per year for 50 parameters. However, bacteria is typically monitored only during the months of May to September each year. An important benefit of this monitoring program to the TMDL program is its longevity that extends back nearly 40 years. The long-term record provides an important link to historical water quality patterns in the basin and enables characterization of normal year-to-year variability and detection of water quality trends. The DMRWQN is thus an important component for evaluating the success of BMP implementation in the Raccoon River watershed.

7.1.5 ACWA Monitoring

The ACWA has collected surface water samples from locations throughout the Raccoon River watershed since 2001. In 2005, samples were collected from 42 sites on a bi-weekly basis by volunteers and analyzed for a variety of parameters by the DMWW water quality laboratory. The concentration data provide valuable information on spatial patterns of many pollutant concentrations, including TMDL parameters nitrate and *E.coli*. Several of the ACWA sites correspond to subbasins analyzed in this TMDL using the SWAT model and results show good correlation between elevated nitrate concentrations measured by the ACWA and elevated nitrate loads predicted with the model. However, collection of continuous stream discharge at ACWA monitoring sites would prove more useful when evaluating loading patterns in the watershed. Establishing continuous monitoring of discharge at one or more ACWA sites would improve the connection between measured stream concentrations at remote sites to loads and flow-weighted concentrations evaluated at the watershed outlet. Nonetheless, results from the ACWA monitoring are valuable for assessing temporal and spatial patterns and targeting problem areas in the basin. Monitoring activities should be continued and possibly expanded to the extent practicable.

7.1.6 Strengths and Weaknesses of Existing Monitoring Network

The five major components of the existing water monitoring network in the Raccoon River watershed address important needs for TMDL implementation monitoring but also have limitations. The strengths of the existing monitoring program lie in providing large-scale estimates of water loss and nitrate export from various major subbasins. Combined with stream gaging, water quality monitoring conducted by the DMWW at Fleur accurately captures the total nitrate export from the basin, whereas nitrate monitoring conducted for the IDNR ambient program and DMRWQN provide quality estimates of nitrate export from major subbasins. These total load estimates are needed to assess trends in nitrate concentrations and loads and enable watershed models to be better calibrated and validated.

A second strength for one monitoring site (DMWW at Fleur) is a weakness at other monitoring sites. *E.coli* monitoring conducted by the DMWW is unparalleled in a watershed the size of the Raccoon River and the data proved invaluable for evaluating *E.coli* loads and seasonal patterns and for SWAT model assessment. The near daily frequency of sampling ensured that the estimated total load of bacteria exported from the watershed was reasonably accurate. However, at all other monitoring sites, the frequency of *E.coli* monitoring is inadequate to characterize daily, seasonal and annual variations. *E.coli* concentrations simply vary too much over daily time frames to believe that monthly sampling will provide a reliable estimate of export loads. Maintaining the existing schedule for bacteria sampling at the other monitoring sites will not be sufficient to gauge the performance of TMDL implementation strategies.

A second weakness applies to all monitoring sites. Although the large-scale monitoring enables export loads from major subbasins to be estimated in a cost-effective manner, the size of the monitored basins will limit the detectability of improvements from TMDL implementation. Unless basin-wide, wholesale changes in practices or land use are implemented, the chances of seeing improvements in nitrate or bacteria loads at major watershed outlets are slim. Schilling and Thompson (2000) noted that "…monitoring NPS water quality improvements is not an easy task. Pollution results from runoff across a landscape which has varied land management practices, with the resulting impacts measured in perennial streams typically a mix of effects from many different parcels of land, many different components of management, integrated over many time scales." This concept is particularly true in a watershed the size of the Raccoon River. Monitoring for the detection of water quality improvement in nitrate or bacteria loads will require a shift in thinking from large-scale global assessments to smaller and more focused watershed assessments.

7.2 Proposed Monitoring Plan

This section provides guidance for establishing a new watershed monitoring program for detection of water quality improvements following BMP implementation. The existing monitoring network would continue to operate as described above, but a new monitoring paradigm would shift the focus of monitoring to smaller basins with the objective of detecting water quality changes. Steps needed to establish a new monitoring program are outlined below.

Step 1. Target a Basin. The first step towards implementing a new monitoring program is deciding where to monitor. Identifying an appropriate basin to invest time, money and effort to monitor will allow limited resources to be used most effectively. Implementation of BMPs to reduce nitrate and bacteria loads in the watershed should be targeted in those basins contributing the highest concentrations and loads. Reducing loads from these basins would have a proportionally larger effect on the overall export of nitrate and bacteria loads than load reductions occurring in less affected areas.

For the Raccoon River watershed selecting a suitable basin is perhaps easier than most because of existing monitoring data and SWAT modeling results. The ideal basin to target initially depends on what pollutant is being addressed. For nitrate load reductions, existing ambient monitoring data indicates that nitrate loads are significantly greater in the North Raccoon than South Raccoon. Hence, BMP implementation is better targeted in the North Raccoon watershed for reducing nitrate loads at the DMWW. For bacteria load reductions, BMP implementation may be more appropriate in the South Raccoon River watershed, although bacteria sources are found in both basins. The concentration data from the ACWA supports this division of resources. In addition, the ACWA data can also be used to provide further targeting criteria based on nitrate and bacteria concentration patterns in the watershed. Several subbasins in the North and South Raccoon river watersheds showed consistently elevated concentrations of nitrate and bacteria in surface water. These subbasins could be appropriate targets for BMP implementation.

The results from the SWAT model generated for this TMDL may provide the best tool for targeting subbasins for BMP implementation. Model results identified subbasins that contributed highest nitrate and bacteria loads to surface water. These identified subbasins should be targeted for BMP implementation because they contribute proportionally greater loads than other subbasins.

A second issue to address when targeting basins for load reductions is selecting an appropriate watershed size to monitor. The size of the targeted watershed will affect the ability of monitoring to detect whether water quality improvements occur since it is easier to detect changes in smaller watersheds than larger watersheds. Detecting improvements in Raccoon River water quality at the DMWW will be infinitely more difficult than detecting changes in a HUC12 watershed like West Buttrick Creek. The SWAT model for the Raccoon River evaluated loads emanating from HUC12 basins that ranged in size from 300 to more than 10,000 ha. This size of watershed may be appropriate for targeting BMP implementation and detecting water quality improvements in a reasonable timeframe. In a general sense, the smaller the watershed, the greater probability there is of detecting water quality improvements resulting from BMP implementation.

As an example, results from the Walnut Creek Monitoring Project provide some context for this discussion. In the HUC12 sized Walnut Creek watershed (20 mi^2) located in Jasper County, nitrate concentrations decreased approximately 1.2 mg/l over 10 years in response to 23.5 percent of watershed planted in reconstructed prairie (Schilling et al., 2006). In smaller subbasins less than 2000 acres in size, substantially greater nitrate concentration reductions were observed (up to 3.4 mg/l in 10 years). Considering that Walnut Creek watershed is a rather small HUC12 basin, project results suggest that even in small watersheds, the ability to detect water quality improvements was best associated with subbasins within the HUC12 watershed. Since subbasins comprise larger and larger watershed areas, it is recommended that monitoring stream water quality should focus on small subbasins where changes are detectable in reasonable time frames. Results from subbasin monitoring efforts that document water quality improvements can then be used as the basis to promote similar practices in other subbasins and eventually lead to watershed-wide adoption of BMPs.

Step 2. Developing a Monitoring Program. Once a basin has been selected for monitoring, the second step is developing a monitoring program that includes the following elements: 1) monitoring objectives; 2) monitoring design; 3) sampling locations; 4) sample parameters; and 5) sample frequency and duration. Each of these elements is discussed briefly below.

1. Monitoring Objectives. It is critical that before beginning a monitoring program, consideration is given to what the overall goals and objectives of the program will be. Is the monitoring objective aimed at measuring the true pollutant export load from a watershed, or is it simply to gather enough data to develop an analytical or numerical model? Is the objective to measure the water quality response from a given conservation practice or measure the cumulative response from a set of practices? Given an objective or series of objectives, a monitoring program can be designed to meet them. Monitoring objectives can be general or very specific, but it is important that objectives be given serious consideration before implementing a program. Tools are available to assist with this process (IDNR, 2007).

It is important that the public realize that although a project may be funded today, the time needed to effectively plan and implement a project may take some time. Time is needed to identify pollution sources and critical areas, design management measures, engage landowner participation and integrate new practices into cropping and management cycles (Meals and Dressing, 2006). It usually takes time for a water body to become impaired, and it will take time to accomplish the clean-up.

2. Monitoring Design. Monitoring design refers to how a monitoring program is set up to meet specific monitoring objectives. Depending on what your objectives are, a monitoring scheme can be designed to gather the information needed to answer the questions posed. Three monitoring designs common to water quality studies are before/after, upstream/downstream and paired watershed (Spooner et al., 1987). A before/after design incorporates water quality monitoring from a downstream station for a period of time before and after BMP implementation. An upstream/downstream design requires a calibration and treatment period (before/after design) with sampling locations positioned upstream and downstream of the treatment area. During a calibration period, the goal is to establish conditions before treatment and the treatment period refers to monitoring conditions after treatment occurs to see if conditions have changed. A paired watershed design comprises two watersheds of similar location and land use (control and treatment) and two time periods of study (calibration and treatment). Typically one sampling station is positioned at the outlet of each watershed. The goal is to first establish a relationship between the two watersheds during a calibration period, then implement BMPs, and finally monitor during a treatment period to see if the relationship between the two watersheds has changed.

With the three common designs, they each require that pre-BMP monitoring be conducted to establish background conditions before land treatment is conducted. Unfortunately, in practice, it is often difficult to convince stakeholders that monitoring is needed before BMPs are implemented. Probably the most common monitoring design is conducting a monitoring program while practices are being implemented and testing for a gradual change in pollutant concentrations at the watershed outlet. The problem with this common approach is that it is often difficult to distinguish the effects of treatment on downstream water quality from effects of climate variability or other factors unrelated to treatment. Year-to-year climate variability can often obscure and overshadow any reductions in pollutant loads due to treatment. Caution is thus needed with this gradual change design to attribute incremental improvements in water quality to treatment without first considering climate effects or other unrelated causes.

3. Sampling Locations. Sampling locations in a watershed are often related to the type of sampling design implemented. Most often, the primary sampling location in a watershed project is the watershed outlet. The outlet captures drainage and pollutant export from the watershed and is the thus a “bottom-line” measure for how well BMP implementation is improving watershed water quality. However, water quality effects initially occur at or near the location where practices are being implemented, so expectations that effects would appear promptly at the watershed outlet, perhaps miles downstream, are misguided. Monitoring can be best focused in smaller watersheds closer to pollution sources. Monitoring several subbasins within a watershed would allow comparisons of the differential effectiveness of BMPs over time and for analyzing their incremental contributions to the overall basin response. Upstream sampling locations allow an evaluation of upper basin effects on water quality, upstream of the treatment area. Upstream sampling is clearly needed when implementing an upstream/downstream sampling design.

Particularly in the North Raccoon watershed, tile drainage is an important source of water and nitrate loads to streams. Identifying sampling locations at major drainage tile outlets may be an important component to monitoring projects in heavily tiled areas. Drainage district maps may be used to assist identification of potential sampling points in a tile drainage network.

In larger watersheds, conducting periodic synoptic surveys over the course of a project may identify changes as they occur.

4. Sampling Parameters. Sampling parameters include discharge monitoring, chemical concentrations and other related parameters. It is recommended that discharge monitoring accompany chemical monitoring in a targeted watershed to accurately measure the streamflow portion of the total load. Measuring the water flux will provide valuable information on how precipitation is routed through the basin-wide hydrologic cycle, for example, whether discharge occurs mainly with storm runoff or baseflow, or how much runoff occurs with a given rainfall event. Continuous discharge measurements at the watershed outlet will also enable more accurate estimation of pollutant loads. In the North Raccoon, it may also be prudent to measure discharge from certain drainage tile outlets to account for these water sources in the watershed water balance. Discharge monitoring may involve establishing a new USGS stream gage on a stream, or simply monitoring stream stage with a water level recorder. The stream stage data may be converted to water discharge with development of a rating curve.

Depending on the objectives of the BMP implementation and monitoring design, TMDL pollutants of concern nitrate or *E.coli*, or both, should be part of a sampling program. However, these pollutants behave quite differently in the environment and would require different sampling strategies to measure concentrations accurately. A dissolved pollutant like nitrate is leached from soils and moves with shallow groundwater before being discharged to streams with groundwater seepage (baseflow) or, more rapidly, with tile drainage. Nitrate concentrations in streams do not typically exhibit wide fluctuations over short time intervals (i.e., days) and they generally follow a near-normal statistical distribution in a given year. Because of this, water quality sampling for nitrate may be conducted on a fixed interval basis where samples are collected at regularly scheduled times. Since nitrate is primarily delivered with baseflow and baseflow comprises a majority of total streamflow, a fixed sampling program will be biased toward collecting baseflow water samples when nitrate is delivered to streams. However, it may take many years for practices that reduce nitrate leaching to have an impact on surface water quality when groundwater travel times are considered.

Elevated *E.coli* concentrations are primarily associated with surface water runoff periods following rainfall events. Bacteria concentrations are orders of magnitude higher during stormflow runoff compared to baseflow periods, although elevated concentrations also occur during late summer low flow periods. An event-based sampling protocol in combination with a fixed sampling schedule would be recommended to detect changes in *E.coli* concentrations over time. Water quality samples could be collected with an automatic sampler during the rising and falling limbs of the hydrograph to assess the pattern of bacteria delivery to the stream and provide an estimate of the total bacteria load delivered during the runoff event. A shorter lag time may be expected with observing changes in *E.coli* concentrations in streams in response to BMP implementation. For example, practices affecting direct delivery of bacteria into surface runoff or streams may yield more rapid reductions in concentrations than practices designed to reduce nutrient leaching. Keeping livestock out of the stream may give immediate water quality improvement. Furthermore, since *E.coli* bacteria generally do not persist for long in the environment, the quantity of bacteria in the receiving stream could reflect reductions in bacteria inputs fairly quickly. Several studies that have documented the effectiveness of BMPs to reduce bacteria runoff from unrestricted livestock grazing (e.g., Meals, 2001; Line and Jennings, 2002; McNeil et al., 2003) have typically required a sampling program specifically designed to detect the change, including event-based sampling and before/after monitoring designs.

Sampling parameters may also include constituents that help explain the observed pollutant concentration and loading patterns in streams. These parameters may involve measurement of temperature, dissolved oxygen, specific conductance or other field parameters, or measurement of additional laboratory constituents that follow similar temporal or spatial patterns (e.g., major ions, ammonia or organic nitrogen, fecal coliform). Collection of additional analytical information may help resolve the sources and timing of pollutant delivery to streams. The continuous real-time nitrate monitoring installed at the Van Meter gage is a promising new technology for evaluating nitrate concentration patterns and loads in streams. Installing similar monitoring equipment at other locations within the watershed may expand the understanding of temporal variations in nitrate concentrations over short time scales.

Bacteria source tracking (BST) is a new technology that may prove useful to distinguish among potential sources of bacteria in the watershed and direct resources more effectively. The premise behind BST is that genetic and phenotypic tests can identify bacterial strains that are host specific so that the original host animal and sources of fecal contamination can be identified. *E.coli* are often used as the bacteria targets in source tracking, although there has been some controversy regarding host specificity and survival of *E.coli* in the environment (Gordon et al., 2002). However, *E.coli* has the advantage that it is known to correlate well with the presence of fecal contamination and is used for human health risk assessments. The USEPA has issued a microbial source tracking guidance document that provides technical details on many different BST methods, quality control measures, project design and case studies (USEPA, 2005).

5. Sampling Frequency and Duration. The question of how long should a monitoring program be implemented is really a function of the design of the sampling program. It is possible for water quality improvements to occur without anybody noticing unless the response is measurable and a suitable program is in place. The design of the program determines the ability to detect a water quality change against the background of natural variability. Sampling frequency is a key determinant of how long it will take to document change. Meals and Dressing (2006) stated "In a given system, taking n samples per year, a certain statistical power exists to detect a trend. If the number of samples per year is reduced, statistical power is reduced, and it may take longer to document a significant trend or to state with confidence that a concentration has dropped below a water quality standard." Simply stated, fewer samples collected will result in a longer period of monitoring needed to detect water quality improvements. At a minimum the sampling duration should be on the order of three to five years, not including a recommended pre-BMP monitoring program. For example, in the Walnut Creek watershed where large tracts of row crop lands are being replaced with native prairie at the Neal Smith National Wildlife Refuge, a minimum of three years of water quality monitoring was needed before the first statistically significant change was detected in stream nitrate concentrations (Schilling et al., 2006).

Monitoring is also conducted to reliably estimate pollutant loads. In this case, sufficient number of samples should be collected to pair with discharge data to provide data for standard regression models (e.g., ESTIMATOR, LOADEST). Although these models will run with monthly data, the model estimates would be greatly improved with higher resolution sampling data. Moreover, if sufficient numbers of samples are collected, as demonstrated by the DMWW dataset, pollutant loads may, in essence, become "known" and not estimated values. Monitoring should carefully consider whether to stratify the number of samples collected by month, that is, change the number of samples based on the season (e.g., greater number of samples in May and June). While this method may enable better estimation of total annual loads, the number of samples collected per month will need to be addressed when attempting to compare results by month.

For nitrate monitoring, bi-monthly sampling (one sample every two weeks) may be an appropriate balance between weekly sampling that may contain redundant information and monthly sampling that may miss important seasonal or flow correlations. For *E.coli* monitoring, bi-monthly monitoring combined with periodic event monitoring may be appropriate. Recent geostatistical analysis of *E.coli* concentrations measured at the DMWW suggests there is temporal correlation in concentrations over time (that is, *E.coli* concentrations in a sample collected on one day are related to concentrations measured the next day, two days later, and so on). However, results of this analysis revealed that temporal correlation of *E.coli* concentrations extends to a period of only 4 days (Schilling et al., 2007). Thus, samples collected for *E.coli* analysis at a time interval greater than 4 days are essentially independent of one another. This is in stark contrast to nitrate where temporal correlation exists up to two years (Zhang and Schilling, 2005). Bacteria sampling should account for short term fluctuations in concentrations to accurately capture the magnitude and patterns of bacteria losses. Ultimately, deciding on an appropriate sampling frequency is likely to be on a case-by-case basis based on cost-benefit considerations.

Step 3. Data Assessment and Reevaluation. By Step 3, the appropriate basin has been targeted for BMPs and a monitoring program has been designed and implemented. Sampling and analytical data should be archived regularly, and data should be evaluated annually to assess the water quality status and trends. Pollutant loads should be calculated if stream discharge data were collected at monitoring sites. Results from existing monitoring programs should be included in the data evaluation and incorporated into an overall watershed picture.

After an appropriate period of time, the monitoring program should be reevaluated to assess whether or not the program is meeting the monitoring objectives. Sampling parameters and frequency can be adjusted to better reflect monitoring objectives or any changes in the program focus. This is an important step to build into a monitoring program because it commits project leaders and stakeholders to assessing the ongoing benefits and costs of monitoring. If monitoring is not meeting its stated objectives, the program should be reevaluated and changed if necessary.

8.0 PUBLIC PARTICIPATION

Initial public meetings were held from December 7-13, 2006 in Jefferson, Sac City, Guthrie Center, and Des Moines to invite public comment and suggestions for the development of this TMDL and to seek local knowledge and experience from concerned citizens and officials.

All four meetings were well attended and included representatives from local city governments, Des Moines Water Works, North Raccoon Watershed Association, the Hawkeye Fly Fisherman Association, Iowa Farm Bureau Federation, Iowa Soybean Association, Iowa Chapter of the Sierra Club, and local citizens and landowners. Comments and discussion in these meetings included themes ranging from the increasing numbers of livestock in the watershed, the impact of wastewater treatment facilities, and the changing hydrology of the watershed due to tile drainage. These comments have been addressed through verbal communication and throughout this document where appropriate.

The Draft TMDL was available for public notice from October 18, 2007 through November 26, 2007. Four public meetings were held in the watershed to present the draft TMDL. Discussion at these meetings focused on the future direction, and what changes need to be made to improve the water quality. The meetings were attended by representatives from local city governments, Des Moines Water Works, North Raccoon Watershed Association, Iowa Soybean Association, Whiterock Conservency, Iowa Farm Bureau Federation, local citizens and landowners. Comments received at these meetings were considered and incorporated into the TMDL where appropriate. Written comments received during the public comment period and the Department responses are included in Appendix D.

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Appendix A

Diffusion Analogy Surface-Water Flow (DAFLOW) and Water Quality Simulation Program (WASP) modeling on Raccoon River

Diffusion Analogy Surface-Water Flow (DAFLOW) and Water Quality Simulation Program (WASP) modeling on Raccoon River

Daniel E. Christiansen and Douglas J. Schnoebelen

Introduction

Three segments of the Raccoon River have been identified as impaired for nitrate-nitrogen (nitrate) and five segments have been identified as impaired by the indicator bacteria *E.Coli*. The Iowa Department of Natural Resouces (IDNR) is developing Total Maximum Daily Loads (TMDLs) for these eight segments of the Raccoon River. The U.S. Geological Survey (USGS) assisted the IDNR in model simulations for stream flow routing and water-quality modeling, particularly for understanding the fate and transport of nitrate and bacteria as they enter the stream.

The Soil and Water Assessment Tool (SWAT) model was used by the IDNR for modeling watersheds in the Raccoon River Basin. The SWAT model is discussed in section five of this report. The SWAT watershed approach is especially useful for understanding different land management practices and effects on water-quality. In order to supplement and strengthen this approach, two additional models were used for simulating flow and concentrations of nitrate and bacteria in the Raccoon River. These models are the Diffusion Analogy Surface-Water Flow (DAFLOW) and the Water Quality Simulation Program (WASP) which are discussed in this appendix.

Model Overview

The DAFLOW model established a hydrodynamic framework in the Raccoon Basin for routing streamflow that could then be used for chemical modeling. The DAFLOW model is a hydrodynamic model for routing streamflow that uses the diffusion analogy form of flow equations. The DAFLOW model routes flow through a system of interconnected one-dimensional channels, and subdivides the system into a series of branches, with each branch divided into a grid of cells (Jobson and Harbaugh, 1999). The DAFLOW model allows for a stable solution using a minimal amount of field data and calibration. The program is simple and stable. The DAFLOW model has been used by the U.S. Geological Survey (USGS) since its development in the mid 1980s (Jobson, 1987; Jobson and Schoellhamer, 1987). A number of projects have documented the use of DAFLOW (Broshears and others, 2001; Bulak and others, 1993; California Water Resources Control Board, 1994; California Water Resources Control Board, 1995; Conrads, 1998; Jobson and Harbaugh, 1999). The DAFLOW model can be used for flow routing and to provide hydrodynamic data for a variety of chemical transport models which simulate the fate and movement of dissolved water-quality constituents in streams. An accurately calibrated flow model is critical for all chemical-transport models.

The Water Quality Simulation Program (WASP) model was used for all chemical and bacteria fate and transport in the Raccoon Basin. DAFLOW is the hydrodynamic model that was used in WASP. The WASP model is documented by Di Toro and others (1983), Ambrose and others (1988), and Wool and others (2005). The WASP model helps users to interpret and predict water-quality parameters in various aquatic systems. In particular, the WASP model is a dynamic transport model that the U.S. Environmental Protection Agency (EPA) has developed for assisting States, specifically for calculating TMDLs. WASP can model many different water-quality parameters; the model was constructed for nitrate and bacteria--the constituents on the impaired water list for the Raccoon River in central Iowa. WASP has a user-friendly graphic interface and a graphical post processor for viewing model results.

A modeling framework for the Raccoon River Basin has been established using DAFLOW and WASP. The two models provided one of the best combinations for meeting the objectives of the project within the given timeline and in building a framework for any future work in the Raccoon River Basin. In addition, the combination of SWAT, DAFLOW, and WASP models provided an extremely powerful set of "tools" in the Raccoon Basin for understanding watersheds, flow, and fate and transport of chemical constituents. Also, if additional data becomes available, various scenarios can be run using the modeling framework that has been built.

DAFLOW Model Setup

The basic principle of DAFLOW is the conservation of mass. In other words, the water volume and water-quality constituent masses being studied are tracked and accounted for over time and space using a series of mass balancing equations. Models are typically used to run simulations (scenarios) in order to make predictions. All models make assumptions and are typically limited by the amount and quality of data available. In general, the DAFLOW model uses the channel geometry, streamflow, and Manning's "**n**" (roughness of streambed) to compute flow routing simulations. The flow data are the most critical component. Actual stream gaging data over a period of at least 10 years are critical to all surface water models. In the case of the Raccoon River Basin, there are 15 gages, 9 of which have a record of over 10 years of recorded flow. Limitations of the DAFLOW model (and all surface-water models) are that it does not do well in areas of backwater (not the case in the Raccoon Basin) and in predicting large floods with extreme out-of-bank areas.

Model Calibration and Results

DAFLOW used streamflow data from USGS stream gages for the period of January 1, 1995 to December 31, 2005. Table 1 lists stream gages within the Raccoon River Basin that were used in the DAFLOW model of streamflow. Figure 1 shows locations of all streamflow gages, and Raccoon River Basin, and sub-basins. Boundary points are locations where the beginning flow was entered into the model. Calibration points are the locations along the stream where modeled flow were compared to observed flow at the gaging station. In addition, the DAFLOW model can be used in conjunction with dye-tracing data for predictions of streamflow and transport velocity. The dye-tracing provides accurate time of travel data that can be used in the DAFLOW model over a range of flow conditions. A dye tracing study was conducted by the U.S. Geological Survey on the Raccoon River from Sac City, Iowa to Van Meter, Iowa, from Van Meter, IA to Des Moines, IA, and from Humboldt, IA to Stratford, IA in the summer of 2006. This dye tracing study was then used in the calibration and verification of the DAFLOW model. Figure 2 shows the schematics of the DAFLOW model.

Table 1. Gaging station used by TMDL models.

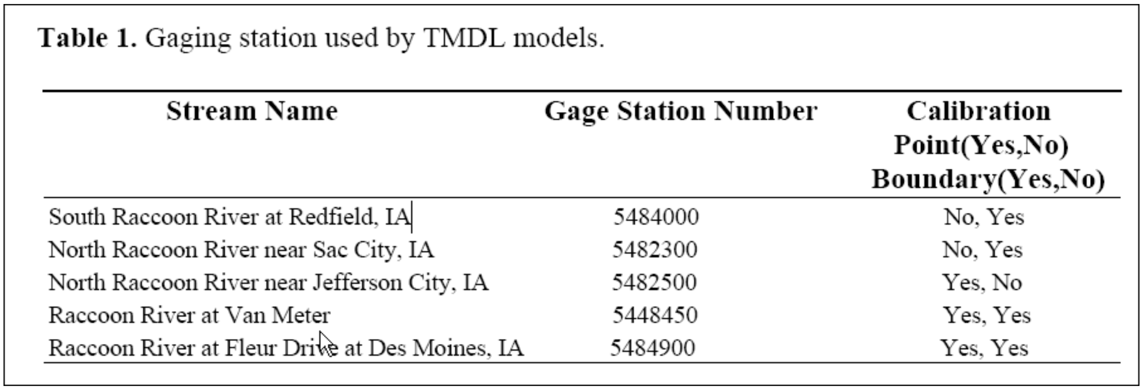


Table 1. Gaging station used by TMDL models.

Stream Name	Gage Station Number	Calibration Point(Yes,No) Boundary(Yes,No)
South Raccoon River at Redfield, IA	5484000	No, Yes
North Raccoon River near Sac City, IA	5482300	No, Yes
North Raccoon River near Jefferson City, IA	5482500	Yes, No
Raccoon River at Van Meter	5448450	Yes, Yes
Raccoon River at Fleur Drive at Des Moines, IA	5484900	Yes, Yes

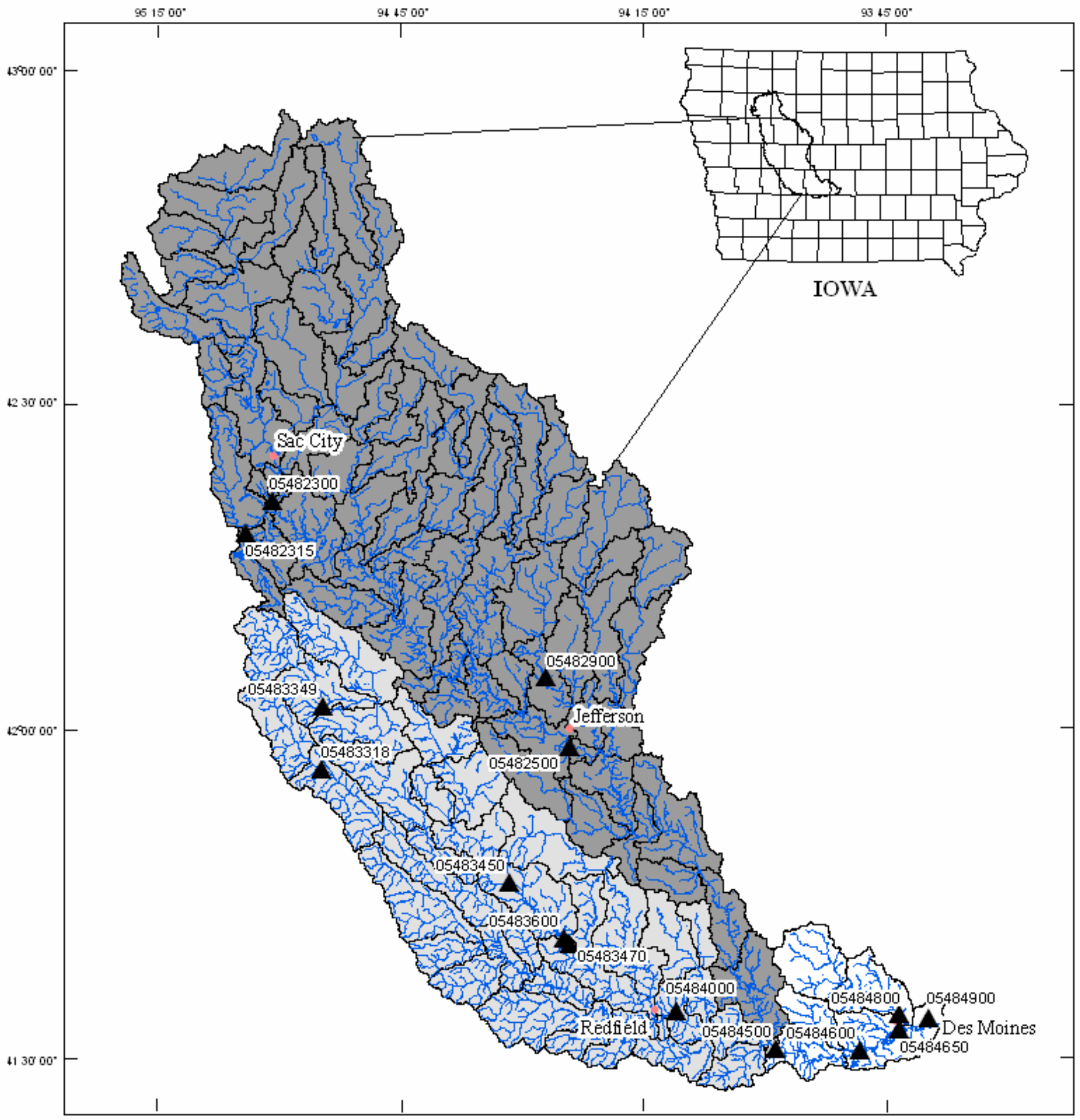


Figure 1. Study area, streamflow gages, and Raccoon River sub basins.

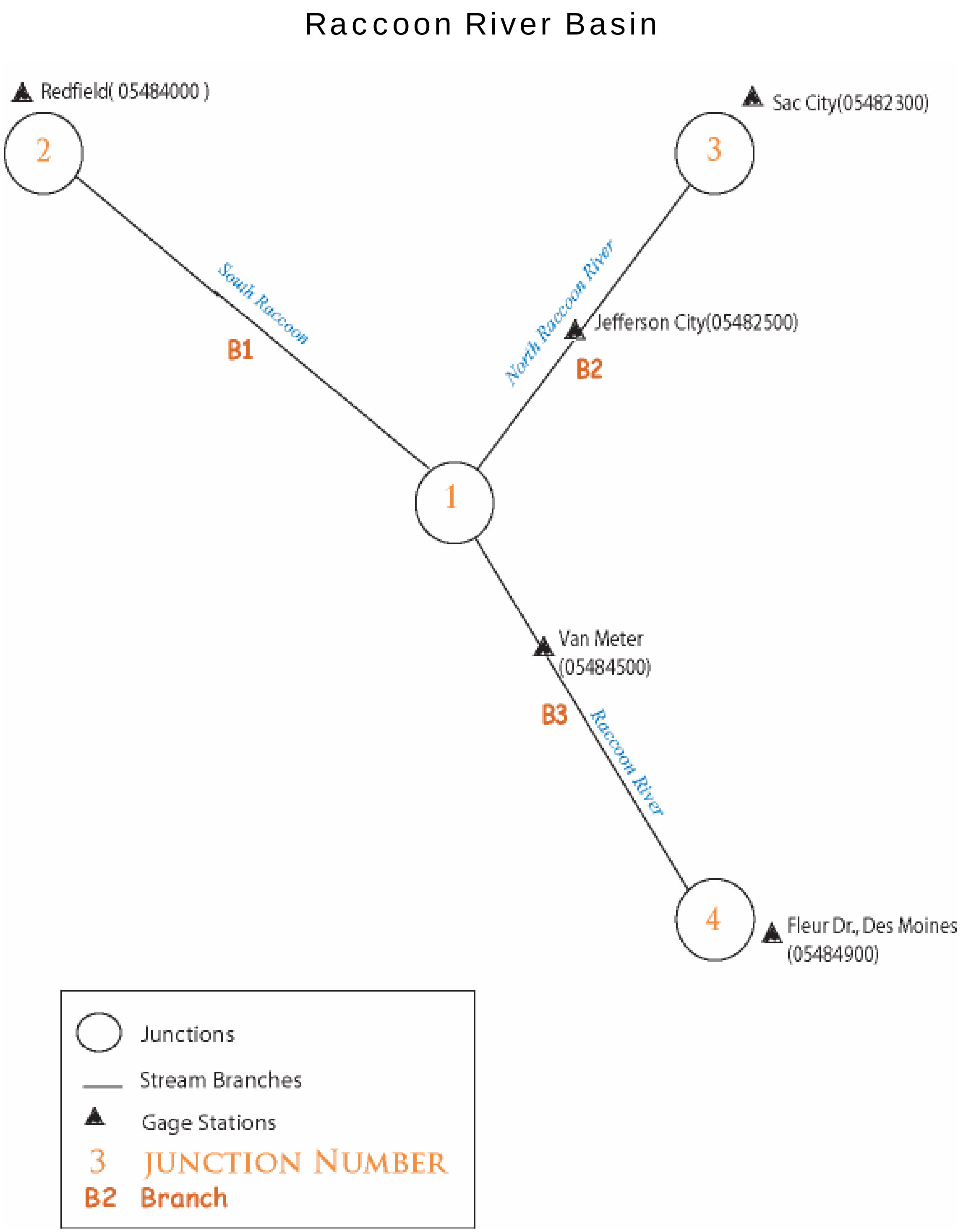


Figure 2. Schematic model of the Raccoon River Basin

Initially the DAFLOW model was run for a 16-month period from October 21, 1996 to February 16, 1998 to calibrate. This period was selected because when all the streamflow gage location data were compared, there were no variations in storm sequencing or any other anomalies. The DAFLOW model was run on streamflow data for a 10-year period (January 1, 1995 to December 31, 2005). The 10-year had a typical range of streamflow values. Figure 3 shows the predicted versus the observed data at Van Meter, Iowa for the entire 10-year period. The DAFLOW model calibrated flow data for the 10-year study period were used as input into the WASP model as the hydrodynamic linkage.

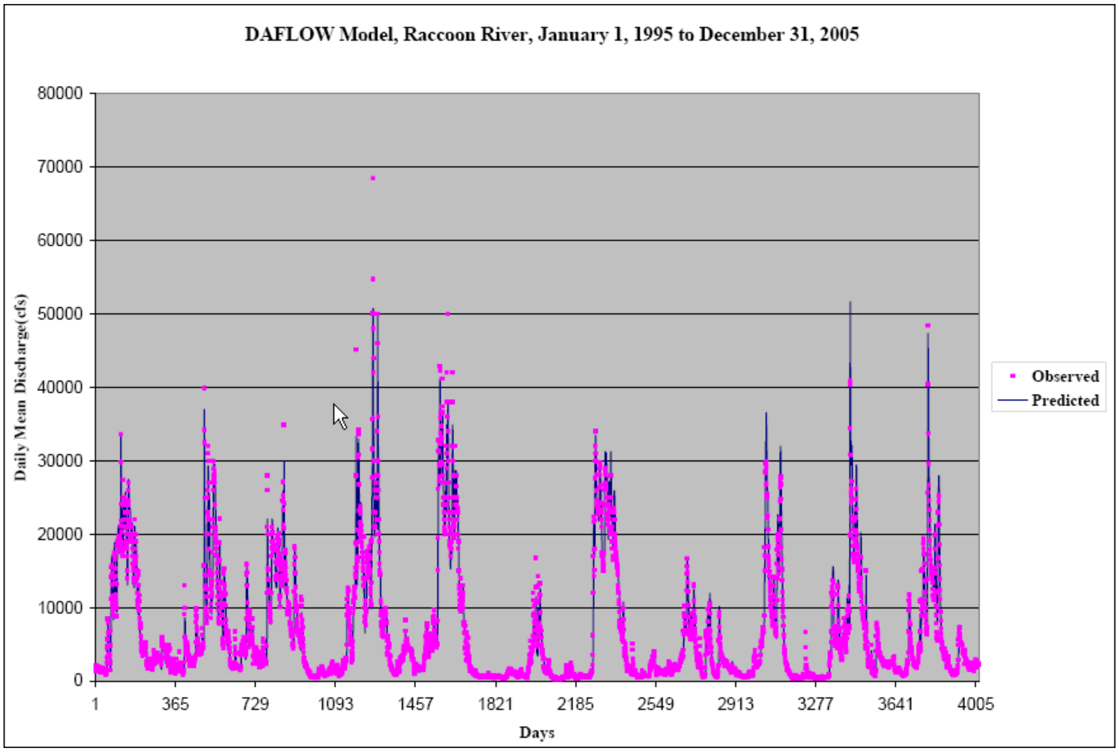


Figure 3. DAFLOW model run Raccoon River, 10-year period (January 1, 1995 – December 31, 2005).

WASP Model Setup

WASP is dynamic model (time varying or non-steady state) and water-quality processes are represented in special kinetic subroutines that can account for advection, dispersion, and point and diffuse loading. DAFLOW results were used in the hydrodynamic porition of WASP. Reactions can be specified both within the water-column and underlying benthos. In general, the WASP model can be constructed with many water quality reactions provided that the water-quality data are available. Detailed water quality data for the initial or boundary segments are an important condition for WASP. In dynamic models, the user must specify initial conditions for each variable in the segment. Typically, the more detailed the water quality data (quantity and quality) at the initial conditions, the better the modeling results. All available water quality data in the Raccoon River Basin were used; no new data were collected for the model. In the future, detailed water-quality data on a daily basis for segments in the Basin would improve modeling results.

The WASP model was schematically set up similar to DAFLOW, with added nodes along stream lengths. All available nitrate and bacteria data that were added for initial boundary conditions along all boundary locations are listed in Table 1. Nitrate and bacteria data included all USGS and Iowa Geological Survey (IGS) water samples from synoptic and longer-term monitoring studies. Typically, the amount of nitrite and ammonia is small (a few tenths of milligrams per liter) when compared to nitrate (milligrams per liter) in a stream. Nitrite is readily converted to nitrate in oxygenated water, and nitrate concentrations are typically two orders of magnitude greater than nitrite concentrations. Therefore, all nitrate plus nitrite concentrations are reported as simply “nitrate”. The nitrate concentration data used are dissolved (filtered) concentrations in milligrams per liter. In addition, nitrogen-containing compounds used were reported as equivalent amount of elemental nitrogen (milligrams per liter as N). Water temperature was modeled using temperature data collected with samples. WASP was run for just over a 6-year period using the available nitrate and bacteria data. Figure 4 and 6 show the observed versus predicted results for bacteria at locations Van Meter and Fleur Drive, and figure 5, and 7 show the observed versus predicted results for nitrate at Van Meter and Fleur Drive.

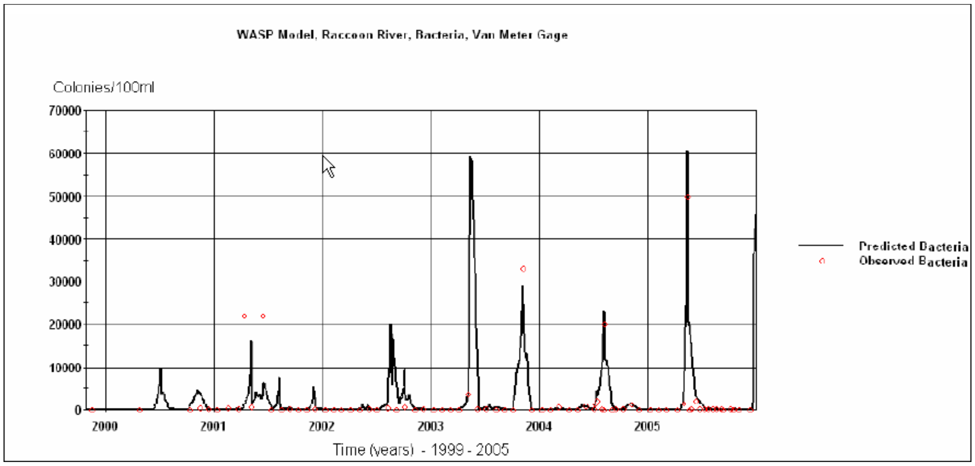


Figure 4. WASP model run Raccoon River, 6- year period, at Van Meter, Iowa, gage 5484500, Bacteria.

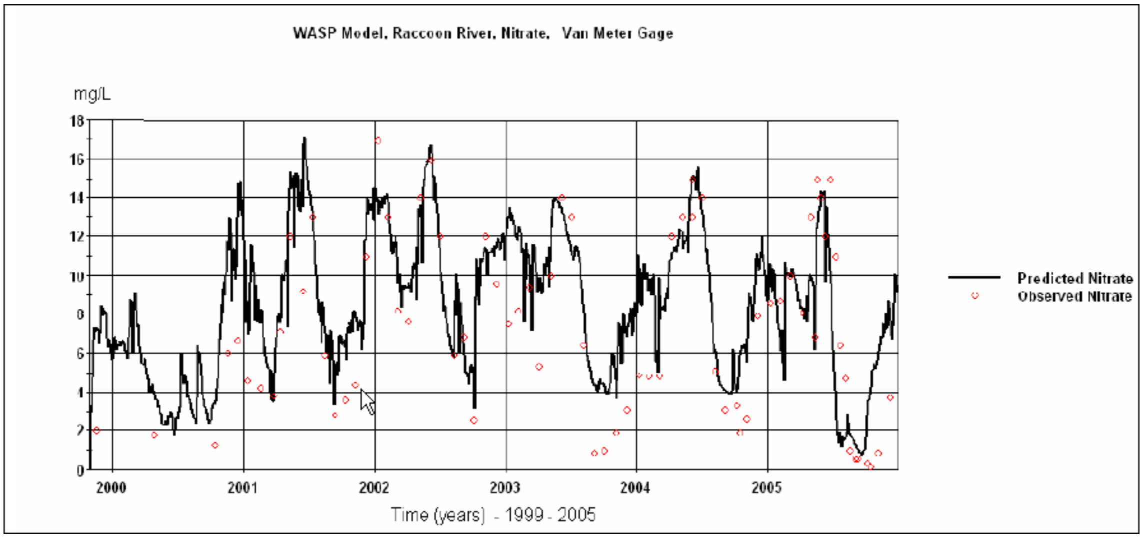


Figure 5. WASP model run Raccoon River, 6- year period, at Van Meter, Iowa, gage 5484500, Nitrate.

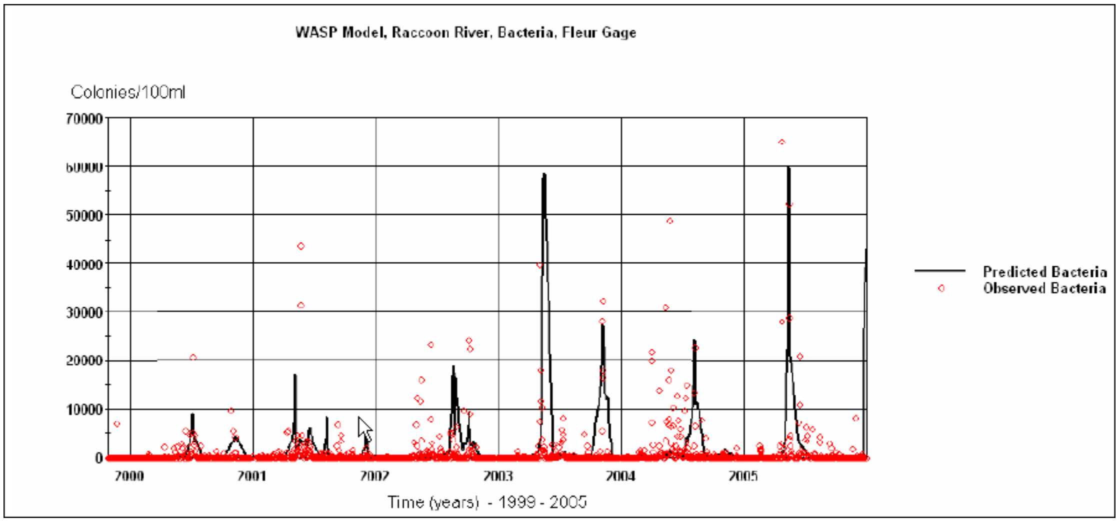


Figure 6. WASP model run Raccoon River, 6- year period, at Fleur Drive, Des Moines, Iowa, gage 5484900, Bacteria.

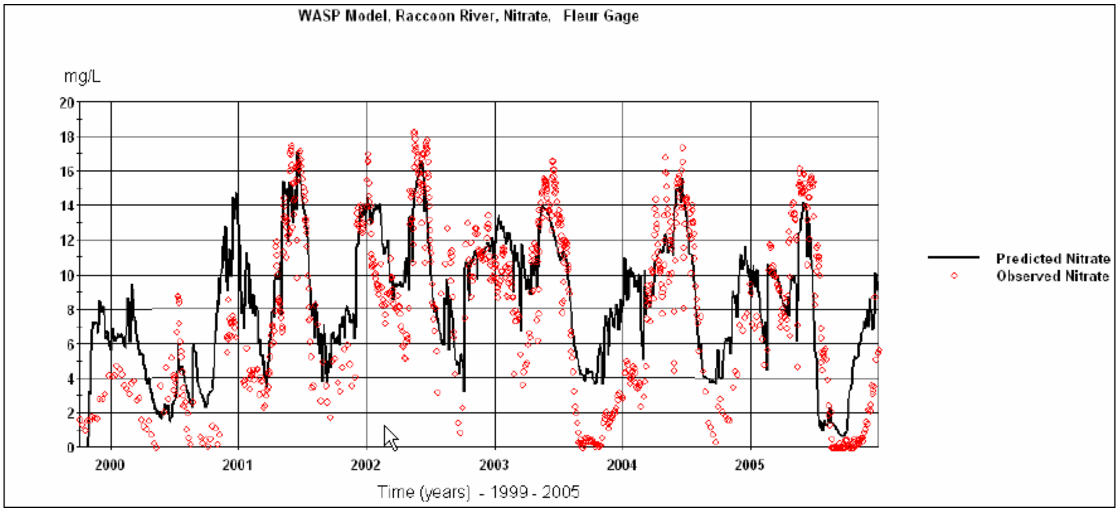


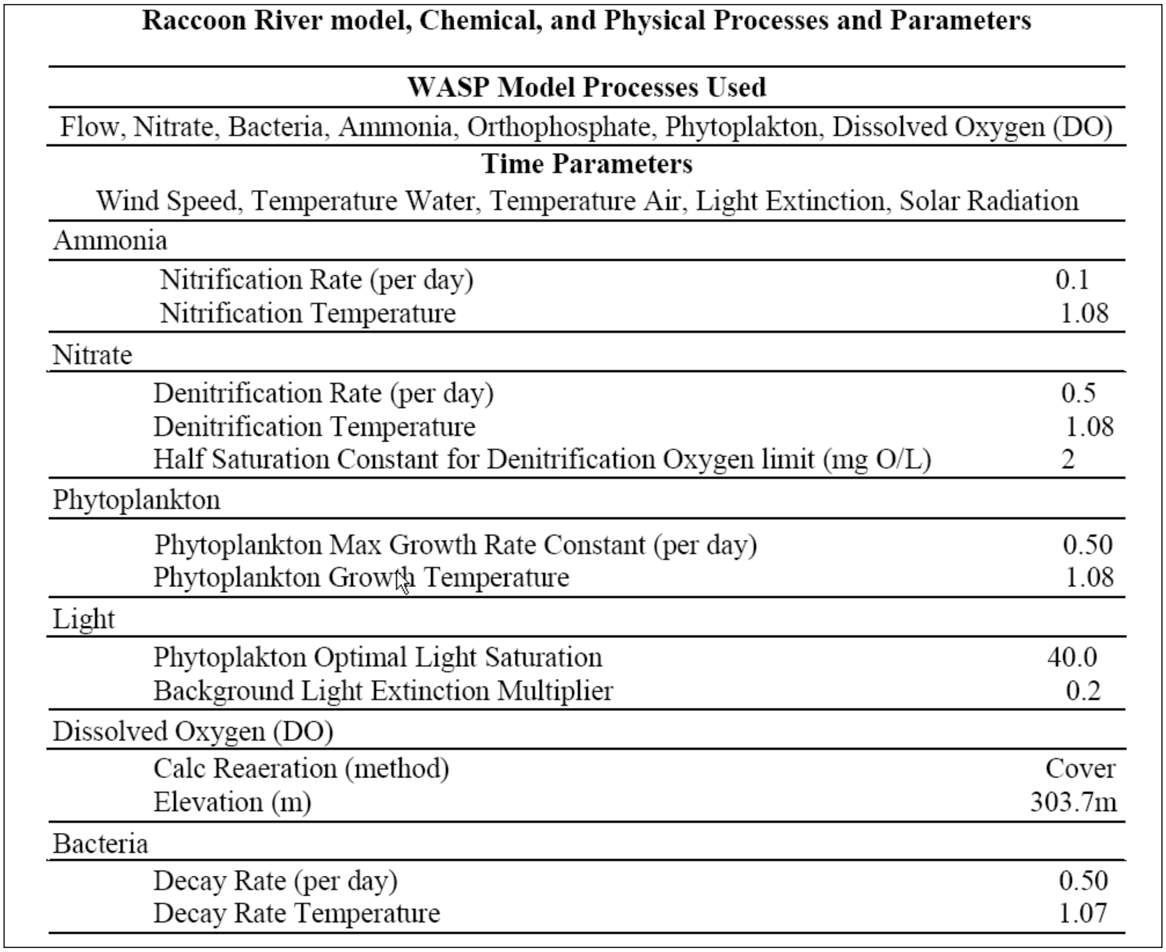
Figure 7. WASP model run Raccoon River, 6- year period, at Fleur Drive, Des Moines, Iowa, gage 5484900, Nitrate.

Model Calibration

The initial objective in the calibration was to get a good visual correlation and then the best statistical Coefficient of Efficiency (COE) between the observed and the predicted values as possible. A set of coefficients that were determined, were located in “Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling, 1985” (Bowie, George L. and others, 1985), and written communication with Robert Ambrose at U.S. Environmental protection Agency, (EPA), Athens Georgia. WASP has the ability to model many chemical parameters, constants, and processes. Weather data are from the Automated Surface Observing System (ASOS). Weather station A130209 located in Ames, Iowa was used for these parameters (Department of Agronomy, 1999). Table 2 shows all coefficients and time parameters used in this effort. In general all the chemical coefficients and time parameters were used where data was available. The use of the chemical coefficients and time parameters use factors that can affect the instream processing of nitrate, denitrification, uptake by algae, bacteria growth, bacteria die-off, and other factors that affect the fate of chemical or biological constituents in the stream.

COE can be represented in percentage or decimal form. A value of 0.7 to 0.8 usually indicates a fairly good fit for a streamflow simulation (Krysanova and others, 1998). A value of 0.5 and above indicates a good fit for a stream nutrients export simulation (Rosenthal and Hoffman, 1999). Using the observed and predicted values from DAFLOW, the COE was approximately 0.88 for the Raccoon River. This statistic was computed on the WASP model and the COE was approximately 0.6 for the Raccoon River. A slightly lower COE was observed from the WASP model due to the lack of daily water-quality boundary conditions. Statistically bacteria with an R2 of .40 or better would be considered a good fit (oral communication with Bob Ambrose, EPA). The WASP bacteria model at Van Meter, IA had an R2 of 0.65, statistically a good fit.

Table 2. WASP model processes, chemical constants, the parameters, and coefficients used.
[mg O/L, milligrams of oxygen per liter, m, meters,]



Raccoon River model, Chemical, and Physical Processes and Parameters

WASP Model Processes Used	
Flow, Nitrate, Bacteria, Ammonia, Orthophosphate, Phytoplakton, Dissolved Oxygen (DO)	
Time Parameters	
Wind Speed, Temperature Water, Temperature Air, Light Extinction, Solar Radiation	
Ammonia	
Nitrification Rate (per day)	0.1
Nitrification Temperature	1.08
Nitrate	
Denitrification Rate (per day)	0.5
Denitrification Temperature	1.08
Half Saturation Constant for Denitrification Oxygen limit (mg O/L)	2
Phytoplankton	
Phytoplankton Max Growth Rate Constant (per day)	0.50
Phytoplankton Growth Temperature	1.08
Light	
Phytoplakton Optimal Light Saturation	40.0
Background Light Extinction Multiplier	0.2
Dissolved Oxygen (DO)	
Calc Reaeration (method)	Cover
Elevation (m)	303.7m
Bacteria	
Decay Rate (per day)	0.50
Decay Rate Temperature	1.07

Model Results

The major two segments of the Raccoon River above the impaired segment are the North and South Raccoon River. Figures 8A-8D illustrate the results of modeling showing the average yearly discharge, nitrate loads, nitrate contribution per unit area, and nitrate concentration, respectively, for the total Raccoon and North and South Raccoon Rivers. Total discharge of the North Raccoon was 585,396 ac-ft/yr (62 percent of the total) compared to 343,804 ac-ft/yr (38 percent of the total) for the South Raccoon (fig. 8A). As expected the higher discharge of the North Raccoon as compared to the South Raccoon resulted in higher loads in the North Raccoon River segment. The yearly nitrate load for the North Raccoon was 8,910 tons per year (79 percent of the total) as compared to 2,369 tons per year for the South Raccoon (21 percent of the total), (fig. 8B). The nitrate contribution per unit area of the North Raccoon was higher than the South Raccoon (fig. 8C) as was the nitrate concentration of the North Raccoon (fig. 8D). In terms of concentration, the North Raccoon concentrations are approximately double those in the South Raccoon (fig. 8D). There may be several explanations for the dominance of nitrate concentrations and nitrate contributions per unit area in the North Raccoon versus the South Raccoon. The soils with probable tile drainage are much more prevalent in the North Raccoon than the South Raccoon. Tile drains provide an efficient means for routing water off fields and draining “wet areas” in fields for farming. However, tile drainage can also provide a mechanism for moving nitrate from fields to streams. Nitrate is readily dissolved in the water column and is mobile. Tiles can deliver much of this nitrate to streams bypassing natural denitrification that can occur in the subsoil and shallow ground water systems. In addition, the South Raccoon does not have the percentage of intensive row crop agriculture as in the North Raccoon. In general, a higher percentage of row crop agriculture has corresponded with a higher percentage of nitrate concentrations in other basins in eastern Iowa, such as the Cedar River Basin.

Model results for bacteria loads for simulations with bacteria “die off” are shown in figures 9A-9D. These simulations assume a die-off rate of 0.5 percent as bacteria are routed downstream. Simulations for bacteria with no die off are shown in figures 10A-10D. In these simulations bacteria are presumed to survive in transit through the modeled segment. The bacteria load results for simulations with die off (fig. 9B) and no die off (fig. 10B) show that the larger load is in the North Raccoon segment. This is to be expected given the larger discharge in the North Raccoon compared to the South Raccoon. However, when comparing the bacteria contribution per unit area and bacteria concentration for both simulations (figs. 9C, 9D, and 10C, 10D) the South Raccoon has larger bacteria concentrations per unit area and higher bacteria concentrations. These results indicate that even though the overall loads for the North Raccoon are larger (when compared to the South Raccoon) there are more bacteria being contributed in the South Raccoon segment. This may be due to concentrations of land application of animal wastes in the South Raccoon, more animals that are actively in the stream in the South Raccoon, or increased runoff of bacteria soon after application of animal waste to fields.

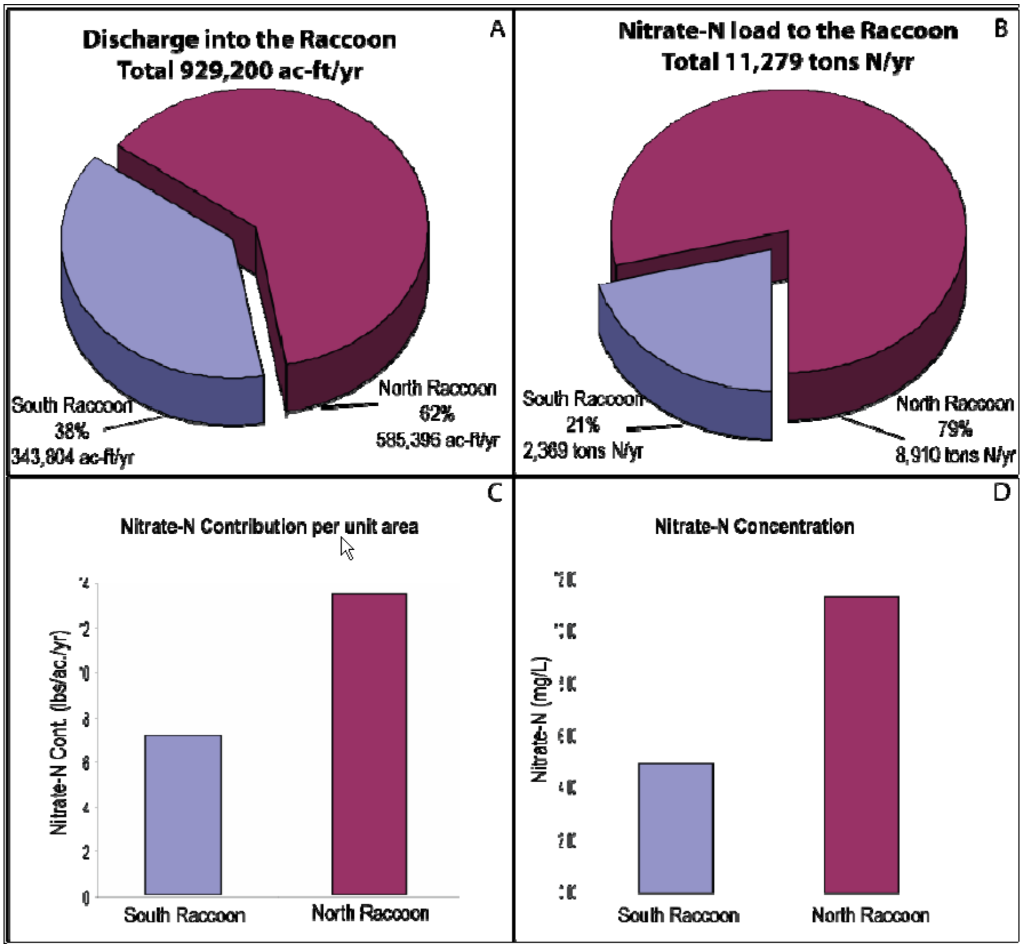


Figure 8. Estimated tributary contribution of flow and nitrate-N to the Raccoon River.

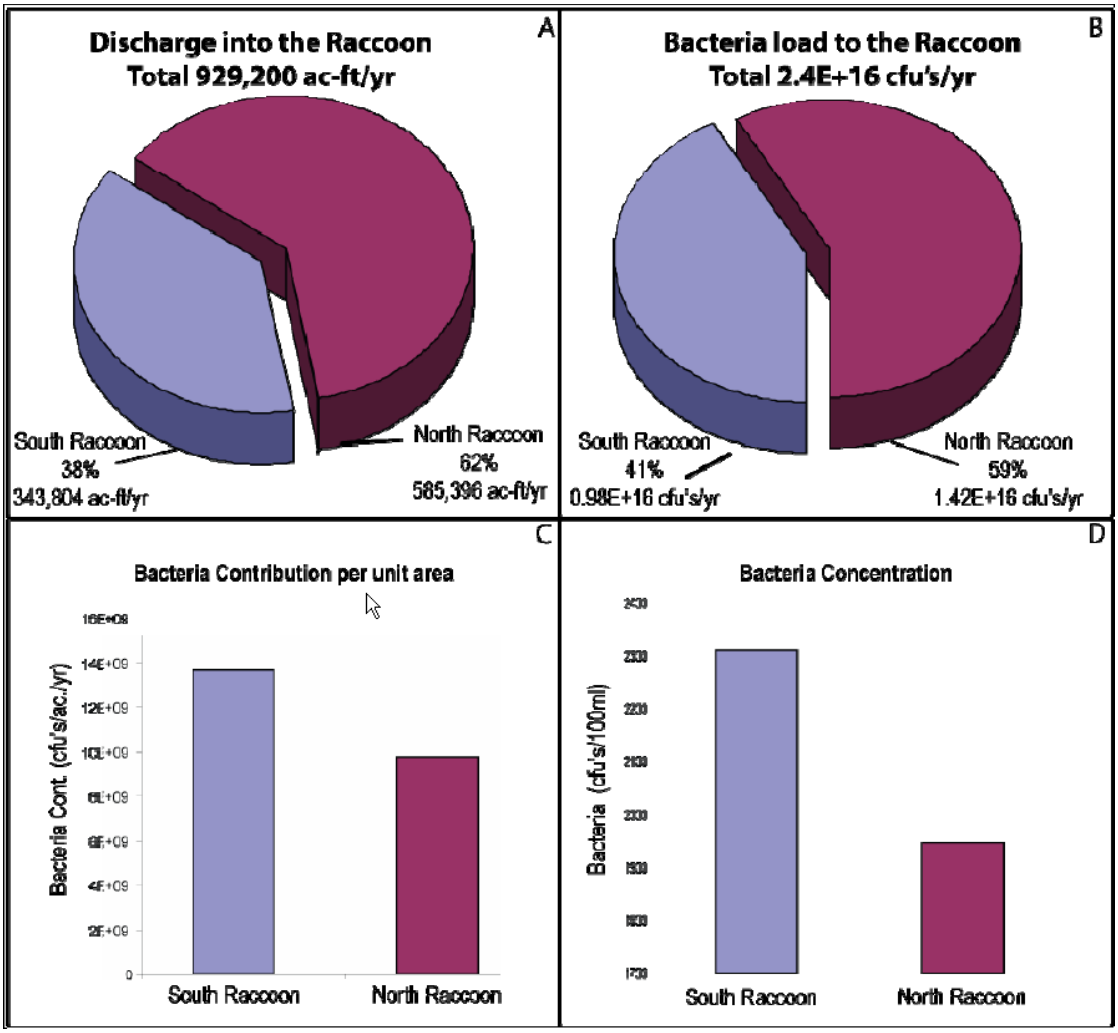


Figure 9. Estimated tributary contribution of flow and Bacteria to the Raccoon River with die off.

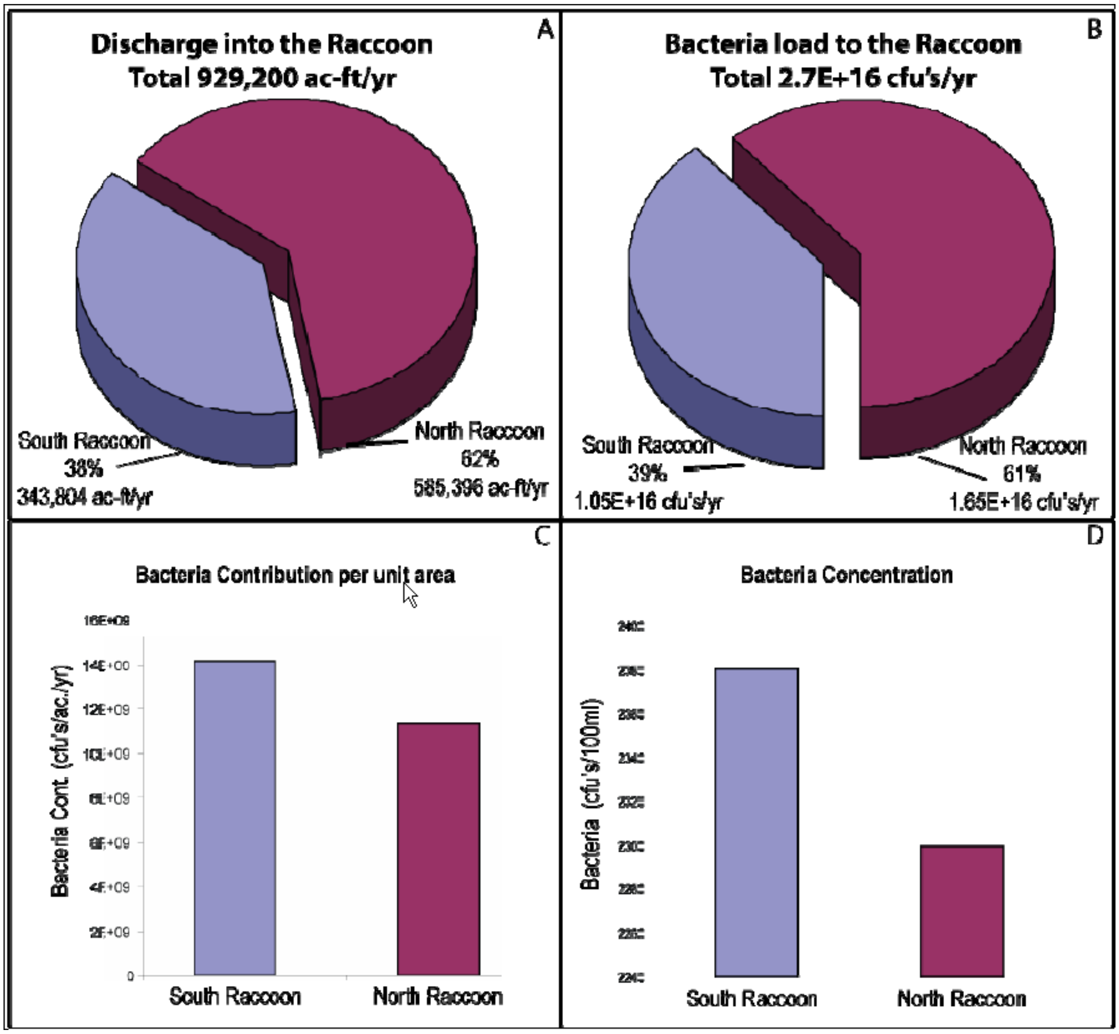


Figure 10. Estimated tributary contribution of flow and bacteria to the Raccoon River with no die off.

The entire Raccoon River, including both major tributaries was modeled from the initial boundary points, to the end of the impaired segment. Final results summarized below.

- Discharge = 929,100 ac-ft/yr
- Nitrate-N load = 20,654 tons/yr
- Watershed contribution, Nitrate = 17.8 lbs/ac/yr
- Daily mean concentration, Nitrate = 7.99 mg/L
- Bacteria load = 2.7E+16 CFU’s/yr
- Bacteria load with die off = 2.4E+16 CFU’s/yr
- Daily mean concentration Bacteria = 3489 CFU’s/100mL
- Daily mean concentration Bacteria with die off = 3100 CFU’s/100mL

The daily mean concentration of nitrate for the entire Raccoon River is lower overall than the North Raccoon, but higher than the South Raccoon, which can be related to the mixing of these two stream segments. Downstream of the confluence of the North and South Raccoon Rivers, there are some smaller tributaries that contribute flow, nitrate, and bacteria. The smaller tributaries downstream of confluences tend to be more urbanized streams, and tend to have lower concentrations of nitrate and bacteria.

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Appendix B

Documentation of methods for estimating nitrogen and *E.Coli* loads in the Raccoon River Basin

IOWA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL SERVICES DIVISION

PROTOCOL FOR ESTIMATING POINT SOURCE NITROGEN LOADS IN THE RACCOON RIVER BASIN

To: Chad Fields
From: Joe Herring
Date: October 31, 2006
Regarding: Point source nitrogen loads in the Raccoon River

SUMMARY

To estimate nitrogen loads from permitted point sources in the Raccoon River watershed, procedures were mainly based on those used by Larry Bryant in developing the Cedar River nitrate TMDL (see Larry Bryant's documentation). A comprehensive review was performed to identify all potential NPDES-permitted contributors in the watershed above the impaired segments. Since the downstream-most segment of the river is impaired for nitrates, this review encompassed the entire watershed.

There are currently 77 NPDES-permitted facilities in the watershed that deal with organic-based wastewater/stormwater (Table 1). Most of these facilities are municipal sewage treatment plants, but there are several industrial contributors, animal feeding operations, and urban areas covered by Municipal Separate Storm Sewer Systems (MS4s). At this time, load estimates were only calculated for WWTPs that discharge measurable quantities of effluent to surface waters and for which Discharge Monitoring Records (DMRs) could be obtained; thus, MS4s, animal feeding operations, and land-application permitted facilities were exempted from this assessment. This is mainly due to the nature of those operations in which pollutant discharge/washoff is event-based, of nonpoint origins, and difficult to track and monitor. Also, animal feeding operations are not allowed to discharge surface water under the regulations of their NPDES permit. This list does not include permitted facilities that do not treat an organic waste stream, such as quarry operations.

Very few wastewater treatment plants monitor for nitrates or total nitrogen in effluent. Therefore, estimates of the quantity of nitrates/total nitrogen are limited to generic, conservative assumptions based on type of treatment, quantity & quality of influent wastewater, and per capita pollutant generation. Since the cycling of nitrogen in the environment occurs rapidly and often unpredictably, and because what little monitoring in WWTPs does exists exists as Total Kjeldahl Nitrogen (TKN), load estimates in this assessment are provided as TKN and not nitrate.

Table 1. List of NPDES-permitted facilities in the Raccoon River watershed.

Facility Name	EPA Number	Permit Type	Discharge Frequency	TKN Monitoring?	Estimate Type
DNR Springbrook State Park-Campground Area	IA0075281	Semi-Public	Daily	No	2

DNR Springbrook State Park-Education Center	IA0075272	Semi-Public	Daily	No	2
Rose Acre Farms, Inc. Guthrie Center Egg Farm	IA0075361	Industry	Daily	Yes (n=3)	1
City of Bagley	IA0041874	City	Daily	No	2
City of Lytton	IA0020940	City	Controlled	No	3
IBP, Inc. Storm Lake (Tyson Fresh Meats)	IA0064998	Industry	Daily	No	1
IBP, Inc. Perry (Tyson Fresh Meats)	IA0002089	Industry	Daily	No	3
City of Carroll	IA0021377	City	Daily	No	1
City of Storm Lake	IA0032484	City	Daily	No	1
City of Rembrandt	IA0033219	City	Controlled	No	2
City of Newell	IA0021989	City	Daily	No	1
Albert City	IA0034312	City	Daily	No	2
Rockwell City	IA0033138	City	Daily	No	1
City of Lohrville	IA0026026	City	Daily	No	2
City of Glidden	IA0024571	City	Daily	No	2
City of Lidderdale	IA0056855	City	Controlled	No	2
City of Breda	IA0056103	City	Controlled	No	2
City of Van Meter	IA0036021	City	Controlled	No	2
City of Waukee	IA0032794	City	Daily	No	1
City of Minburn	IA0023418	City	Controlled	No	2
City of Adel	IA0041921	City	Daily	No	3
City of Gowrie	IA0020966	City	Daily	No	2
City of Paton	IA0060321	City	Controlled	No	2
City of Auburn	IA0057029	City	Controlled	No	2
City of Pomeroy	IA0032824	City	Controlled	No	2
City of Coon Rapids	IA0028983	City	Controlled	No	2
City of Rippey	IA0041882	City	Controlled	No	2

City of Dedham	IA0035181	City	Controlled	No	2
City of Churdan	IA0031216	City	Controlled	No	2
Diamond Head Lake	IA0068381	Semi-Public	Controlled	No	2
City of Callender	IA0057096	City	Controlled	No	2
City of Manson	IA0027189	City	Controlled	No	2
Iowa Dot Rest Area #21 & #22 I80 Waukee	IA0068888	Semi-Public	Controlled	No	2
City of Jefferson	IA0021300	City	Daily	No	2
City of Guthrie Center	IA0041866	City	Controlled	No	2
City of Scranton	IA0032409	City	Daily	No	2
Sac City	IA0033090	City	Daily	No	3
City of Fonda	IA0046671	City	Controlled	No	2
City of Panora	IA0057045	City	Daily	No	1
Twin Lakes Sanitary Sewer District STP	IA0070114	Sanitary District	Controlled	No	2
City of Stuart	IA0041858	City	Daily	No	2
City of Perry	IA0032379	City	Daily	No	1
Lake City	IA0020842	City	Controlled	No	2
City of Dallas Center	IA0035319	City	Daily	No	1
City of Bayard	IA0061468	City	Daily	No	2
City of Earlham	IA0027421	City	Daily	No	1
City of Lanesboro	IA0062162	City	Controlled	No	2
City of Laurens	IA0025950	City	Controlled	No	2
City of Farnhamville	IA0028967	City	Daily	No	2
City of Desoto	IA0056821	City	Daily	No	2
Spectra Health Care Facility STP	IA0065731	Semi-Public	Controlled	No	2
City of Redfield	IA0036099	City	Controlled	No	2
City of Lake View	IA0041998	City	Daily	No	1
City of Rinard	IA0033715	City	Daily	No	2

City of Harcourt	IA0076244	City	Daily	No	1
Storm Lake MS4	IA0078638	Stormwater	Event based	No	4
Waukee MS4	IA0078875	Stormwater	Event based	No	4
E. R. Peterson & Sons	IA0079201	Agricultural	Event based	No	4
Wiederin Feedlot	IA0080250	Agricultural	Event based	No	4
S & S Farms	IA0077755	Agricultural	Event based	No	4
Van Meter Feedyard	IA0078590	Agricultural	Event based	No	4
Ray Lenz, Inc.	IA0080284	Agricultural	Event based	No	4
Wendl Feedlot	IA0077810	Agricultural	Event based	No	4
Hy.Vac	IA0076295	Agricultural	Event based	No	4
Corey Agriculture, Inc.	IA0079731	Agricultural	Event based	No	4
Pudenz, Lynn	IA0080292	Agricultural	Event based	No	4
City of Marathon	IA0067652	City	Daily	No	2
City of Truesdale	IA0079782	City	None (Permit pending)	No	4
City of Halbur	IA0075817	City	Controlled	No	2
Grimes MS4	IA0078883	Stormwater	Event based	No	4
Clive MS4	IA0078867	Stormwater	Event based	No	4
Vigorena Feeds	IA0076767	Operation Permit	Land Applied	No	4
Rembrandt Enterprises, Inc	IA0076554	Industry	Continuous	No	1
Vonnhame Farms Trailer Wash Out	IA0080390	Operation Permit	Land Applied	No	4
West Central Cooperative	IA0077101	Operation Permit	Continuous	No	2
Country View Estates	IA0076465	Semi-Public	Controlled	No	2
Ortonville Business Park	IA0076562	Semi-Public	Controlled	No	2

TYPE 1 ESTIMATES: If facility has design influent TKN (from construction permit), assume that influent TKN = effluent TKN.

Facilities assessed this way:

1. Rose Acre Farms, Inc. Guthrie Center Egg Farm
2. IBP, Inc. Storm Lake (Tyson Fresh Meats)
3. City of Carroll
4. City of Storm Lake
5. City of Newell
6. Rockwell City
7. City of Waukee
8. City of Panora
9. City of Perry
10. City of Dallas Center
11. City of Earlham
12. City of Lake View
13. City of Harcourt
14. Rembrandt Enterprises, Inc

The premise of this assumption is to take a conservative approach, assuming that all nitrogen coming in to a plant is conserved through the treatment process and discharged in effluent. This approach was recommended by both Larry Bryant and Bill Graham.

The exception to this assessment method is facilities where a design TKN exists, but which are operated as controlled discharge lagoons. Since these facilities discharge in “batches”, a Type 2 estimate (see below) was used to allow intermittent discharge.

TYPE 2 ESTIMATES: Assume that influent TKN loads are equivalent to 0.027 lbs per person per day, and 100% of influent TKN is conserved through treatment process.

Facilities assessed this way:

1. DNR Springbrook State Park-Campground Area
2. DNR Springbrook State Park-Education Center
3. City of Bagley
4. Albert City
5. City of Rembrandt
6. City of Lohrville
7. City of Glidden
8. City of Lidderdale
9. City of Breda
10. City of Van Meter
11. City of Minburn
12. City of Gowrie
13. City of Paton
14. City of Auburn
15. City of Pomeroy
16. City of Coon Rapids
17. City of Rippey
18. City of Dedham
19. City of Churdan
20. Diamond Head Lake
21. City of Callender
22. City of Manson
23. Iowa Dot Rest Area #21 & #22 I80 Waukee

24. City of Guthrie Center
25. City of Scranton
26. City of Fonda
27. Twin Lakes Sanitary Sewer District STP
28. City of Stuart
29. Lake City
30. City of Bayard
31. City of Lanesboro
32. City of Farnhamville
33. City of Desoto
34. Spectra Health Care Facility STP
35. City of Redfield
36. City of Rinard
37. City of Marathon
38. City of Halbur
39. Country View Estates
40. Ortonville Business Park

For facilities with no design TKN in their permit, and in the absence of real data, the generic assumption of 0.027 lbs TKN/person/day was used to estimate influent loads to WWTPs. This value is based on the EPA's Nitrogen Control Manual.

The most recent U.S. Census (2000) was used to estimate population, and in the absence of population data (e.g. for semi-public facilities) the facility's population equivalent was used.

Example from City of Bayard:
2000 U.S. Census population = 536
Daily TKN in effluent = 536 * 0.027 = 14 lbs TKN/day

Many of these facitlites are controlled discharge lagoons, meaning that they discharge intermittently to surface waters. DMRs provide flow data for the day and quantity of discharge, allowing concentrations to be calculated. For these facilities, Larry Bryant's Controlled Discharge calculation worksheet in Excel was used to calculate intermittent loadings. The worksheet uses DMR data and the assumption of 0.027 lbs TKN/person/day and allows TKN to accumulate in the lagoon until discharge (for a maximum of 180 days).

TYPE 3 ESTIMATES: For industrial permits, or facilities accepting waste from significant industrial contributors, permits were evaluated individually to estimate combined loads from industrial contributors and municipal sewage.

Facilities assessed this way:
1. City of Lytton
2. IBP, Inc. Perry (Tyson Fresh Meats)
3. City of Adel
4. Sac City

Where nitrogen loads from industrial contributors were felt to be significant, influent TKN/max NH3 monitoring values were simply added to municipal sewage loads (estimated using same assumptions as Type 2 estimate) to get a combined total TKN load estimate.

For instance, in Lytton, the Proliant, Inc. plant may contribute a maximum of 50 lbs TKN per day to the city's sewage treatment plant, which is treating effluent for 305 people (2000 U.S. Census) and discharges intermittently (controlled). The total daily TKN load is calculated as follows:

Load from Proliant, Inc. coming into city WWTP = 50 lbs TKN/day
+
Effluent from city WWTP = 305 * 0.027 lbs/person/day = 8.2 lbs/day
=
50 lbs/day + 8.2 lbs/day = 58.2 lbs TKN/day allowed to accumulate in lagoon until discharge.

For both Sac City and the City of Adel, TKN monitoring from industrial contributors was dropped as a monitoring parameter from their NPDES permits, so a fall-back assumption had to be made. This was to use the maximum ammonia NH3 value as a surrogate for TKN.

One plant, Tyson Foods, Inc. of Perry, was estimated in a different manner than all others. This facility has no nitrogen effluent monitoring and the plant's design TKN limit could not be found in database records.

Values which predict TKN for high-processing packinghouses (based on live kill weight (kg/day)) were available from literature (*source*). Using the Perry Tyson Foods Inc. plant's daily live kill weight, Bill Graham predicted the daily TKN limit to equal 1,512 pounds.

A record was found which documented a plant inspection on June 5th, 2006, in which nitrate+nitrite was measured in final effluent. This was the only inspection report that could be found which monitored for any form of nitrogen other than ammonia. At this time, final effluent nitrate+nitrite nitrogen was measured at a concentration of 28 mg/L, which roughly approximates the TKN calculation done by Bill.

TYPE 4 ESTIMATES: Not Assessed (MS4s, Ag feedlots, and land-applied effluent).

Facilities assessed this way:

1. Storm Lake MS4
2. Waukee MS4
3. E. R. Peterson & Sons
4. Wiederin Feedlot
5. S & S Farms
6. Van Meter Feedyard
7. Ray Lenz, Inc.
8. Wendl Feedlot
9. Hy.Vac
10. Corey Agriculture, Inc.
11. Pudenz, Lynn
12. City of Truesdale
13. Grimes MS4
14. Clive MS4
15. Vigorena Feeds
16. Vonnhame Farms Trailer Wash Out

By the terms of their permits, agricultural feedlots are prohibited from discharging pollution to surface waters. MS4 cities may be assessed generically using watershed land use export coefficients, but were not evaluated at this time. Other facilities in this group are either not discharging effluent to surface waters (land applied) or are not yet permitted (i.e. City of Truesdale).

MIGRATION OF DATA TO GIS FORMAT:

All the load calculations described above were done using MS Excel spreadsheets for convenience. To transfer all relevant information from these load calculation worksheets to a spatially- and temporally-explicit GIS would be extremely complex, and therefore simplifications must be made in the time dimension to approximate a point source's typical daily contribution to watershed load.

To accomplish this, several attribute fields were included in the GIS dataset to describe typical daily loads, depending on estimate type. A list of the attribute fields and descriptions are provided below as metadata. (Also available in the dataset's ArcGIS metadata files)

The following fields already exist and were not altered from the original GIS shapefile for statewide NPDES WWTPs. Updates were made to the population equivalent where necessary (based on most recent permit). Records with no WWTP_ or WWTP_ID attribute are those which are missing from the statewide coverage of permitted WWTPs.

- FID
- Shape
- WWTP_
- WWTP_ID
- EPA_ID
- STATE_ID
- NAME
- DESIGN_FLO

The following fields were manually added to the dataset. It should be noted that in some cases, design AWW flows from the original statewide dataset had to be updated based on the most recent permit.

Note that there are several different attribute fields which refer to nitrate loads and concentrations. The appropriate load/concentration estimate to be used for a typical daily load depends on the type of facility, i.e. controlled vs. continuous discharge, or monitored vs.

estimated loads. Also, it depends on the use/application of the modeling situation, i.e. modeling for the “worst-case” scenario vs. modeling the “most realistic” current conditions.

FLOW_TYPE

Alias: FLOW_TYPE
Data type: String
Width: 14
Definition:

Frequency of discharge, whether continuous (daily), controlled, or irregular

AWW_FLOW

Alias: AWW_FLOW
Data type: Number
Width: 15
Number of decimals: 4
Definition:

Plant's design AWW flow (updated from most recent NPDES database if needed)

MAX_FLOW

Alias: MAX_FLOW
Data type: Number
Width: 13
Number of decimals: 4
Definition:

Plant's design max daily flow in MGD (updated from most recent NPDES database if needed)

ACTUAL_AWW

Alias: ACTUAL_AWW
Data type: Number
Width: 15
Number of decimals: 4
Definition:

Monitored AWW flow samples obtained from plant's Discharge Monitoring Records

ACTUAL_MAX

Alias: ACTUAL_MAX
Data type: Number
Width: 13
Number of decimals: 4
Definition:

Monitored max daily flow samples taken from plant's Discharge Monitoring Records

ACT_TKN_AV

Alias: ACT_TKN_AV
Data type: String
Width: 14
Definition:

Monitored average TKN samples (lbs) in effluent (or limits, if applicable)

ACT_TKN_MX

Alias: ACT_TKN_MX
Data type: String
Width: 13
Definition:

Monitored maximum daily TKN (lbs) taken from sampled effluent (or limits, if applicable)

DAILYTKNAV

Alias: DAILYTKNAV
Data type: Number
Width: 17
Number of decimals: 4
Definition:

Estimated daily average TKN (lbs) in effluent

DAILYTKNMX

Alias: DAILYTKNMX
Data type: Number
Width: 14
Number of decimals: 4
Definition:

Estimated maximum daily TKN (lbs) in effluent

IOWA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL SERVICES DIVISION

PROTOCOL FOR ESTIMATING POINT SOURCE FECAL COLIFORM LOADS IN THE RACCOON RIVER BASIN

TO: CHAD FIELDS
FROM: JOE HERRING
DATE: OCTOBER 30, 2006
RE: POINT SOURCE INVENTORY OF PATHOGEN SOURCES IN RACCOON RIVER

SUMMARY

There are a total of seventy-seven entities in the Raccoon River watershed with National Pollution Discharge Elimination System (NPDES) permits. Four of these seventy-seven facilities were exempted from this particular assessment as they were deemed to not be potential contributors of pathogen indicators to surface waters: Rose Acre Farms of Guthrie Center, City of Truesdale (permit pending), Rembrandt Enterprises, Inc., and Vonnhame Farms Trailer Wash-out. In addition, load contributions from MS4 cities and agricultural feedlots were not included at this time due to the difficult nature of estimating loads from them, as well as the fact that ag feedlots are prohibited from discharging to surface waters by the terms of their permit.

It is always more desirable to have discharge records with effluent monitoring data showing actual fecal coliform concentrations and flow measurements than to have to resort to using generic assumptions to estimate values from a WWTP. However, pathogen monitoring is rather rare among municipal STPs and other facilities, thus several different approaches were used to complete this inventory and assessment of pathogen loads for the Raccoon River.

In the absence of an EPA-approved method for measuring *E. coli* bacteria in wastewater effluent, virtually all NPDES-associated documentation and records use fecal coliforms as the standard for measuring pathogen indicators. Thus, the assessments and calculations in this report apply to fecal coliforms, and will have to be converted to *E. coli* values if that is the desired metric to be used.

Table 1 on the next page lists all seventy-seven facilities and summarizes key information about each one. The last column, “Estimate Type”, refers to the method used to estimate fecal loads being discharged in plant effluent, which are described in detail in following pages.

Table 1. List of NPDES-permitted facilities in the Raccoon River watershed.

Facility Name	EPA Number	Permit Type	Discharge Frequency	TKN Monitoring?	Estimate Type
DNR Springbrook State Park-Campground Area	IA0075281	Semi-Public	Daily	No	1
DNR Springbrook State Park-Education Center	IA0075272	Semi-Public	Daily	No	1
Rose Acre Farms, Inc. Guthrie Center Egg Farm	IA0075361	Industry	Daily	Yes (n=3)	4
City of Bagley	IA0041874	City	Daily	No	2
City of Lytton	IA0020940	City	Controlled	No	3
IBP, Inc. Storm Lake (Tyson Fresh Meats)	IA0064998	Industry	Daily	No	1
IBP, Inc. Perry (Tyson Fresh Meats)	IA0002089	Industry	Daily	No	1
City of Carroll	IA0021377	City	Daily	No	2
City of Storm Lake	IA0032484	City	Daily	No	2
City of Rembrandt	IA0033219	City	Controlled	No	3
City of Newell	IA0021989	City	Daily	No	2
Albert City	IA0034312	City	Daily	No	2
Rockwell City	IA0033138	City	Daily	No	2
City of Lohrville	IA0026026	City	Daily	No	2
City of Glidden	IA0024571	City	Daily	No	2
City of Lidderdale	IA0056855	City	Controlled	No	3
City of Breda	IA0056103	City	Controlled	No	3
City of Van Meter	IA0036021	City	Controlled	No	3
City of Waukee	IA0032794	City	Daily	No	2
City of Minburn	IA0023418	City	Controlled	No	3
City of Adel	IA0041921	City	Daily	No	1
City of Gowrie	IA0020966	City	Daily	No	2
City of Paton	IA0060321	City	Controlled	No	3
City of Auburn	IA0057029	City	Controlled	No	3

City of Pomeroy	IA0032824	City	Controlled	No	3
City of Coon Rapids	IA0028983	City	Controlled	No	3
City of Rippey	IA0041882	City	Controlled	No	3
City of Dedham	IA0035181	City	Controlled	No	3
City of Churdan	IA0031216	City	Controlled	No	3
Diamond Head Lake	IA0068381	Semi-Public	Controlled	No	3
City of Callender	IA0057096	City	Controlled	No	3
City of Manson	IA0027189	City	Controlled	No	3
Iowa Dot Rest Area #21 & #22 I80 Waukee	IA0068888	Semi-Public	Controlled	No	3
City of Jefferson	IA0021300	City	Daily	No	1
City of Guthrie Center	IA0041866	City	Controlled	No	3
City of Scranton	IA0032409	City	Daily	No	2
Sac City	IA0033090	City	Daily	No	1
City of Fonda	IA0046671	City	Controlled	No	3
City of Panora	IA0057045	City	Daily	No	1
Twin Lakes Sanitary Sewer District STP	IA0070114	Sanitary District	Controlled	No	3
City of Stuart	IA0041858	City	Daily	No	2
City of Perry	IA0032379	City	Daily	No	1
Lake City	IA0020842	City	Controlled	No	3
City of Dallas Center	IA0035319	City	Daily	No	2
City of Bayard	IA0061468	City	Daily	No	1
City of Earlham	IA0027421	City	Daily	No	2
City of Lanesboro	IA0062162	City	Controlled	No	3
City of Laurens	IA0025950	City	Controlled	No	3
City of Farnhamville	IA0028967	City	Daily	No	2
City of Desoto	IA0056821	City	Daily	No	1
Spectra Health Care Facility STP	IA0065731	Semi-Public	Controlled	No	3

City of Redfield	IA0036099	City	Controlled	No	3
City of Lake View	IA0041998	City	Daily	No	2
City of Rinard	IA0033715	City	Daily	No	2
City of Harcourt	IA0076244	City	Daily	No	2
Storm Lake MS4	IA0078638	Stormwater	Event based	No	4
Waukee MS4	IA0078875	Stormwater	Event based	No	4
E. R. Peterson & Sons	IA0079201	Agricultural	Event based	No	4
Wiederin Feedlot	IA0080250	Agricultural	Event based	No	4
S & S Farms	IA0077755	Agricultural	Event based	No	4
Van Meter Feedyard	IA0078590	Agricultural	Event based	No	4
Ray Lenz, Inc.	IA0080284	Agricultural	Event based	No	4
Wendl Feedlot	IA0077810	Agricultural	Event based	No	4
Hy.Vac	IA0076295	Agricultural	Event based	No	4
Corey Agriculture, Inc.	IA0079731	Agricultural	Event based	No	4
Pudenz, Lynn	IA0080292	Agricultural	Event based	No	4
City of Marathon	IA0067652	City	Daily	No	2
City of Truesdale	IA0079782	City	None (Permit pending)	No	4
City of Halbur	IA0075817	City	Controlled	No	3
Grimes MS4	IA0078883	Stormwater	Event based	No	4
Clive MS4	IA0078867	Stormwater	Event based	No	4
Vigorena Feeds	IA0076767	Operation Permit	Land Applied	No	4
Rembrandt Enterprises, Inc	IA0076554	Industry	Continuous	No	2
Vonnhame Farms Trailer Wash Out	IA0080390	Operation Permit	Land Applied	No	4
West Central Cooperative	IA0077101	Operation Permit	Continuous	No	2
Country View Estates	IA0076465	Semi-Public	Controlled	No	3
Ortonville Business Park	IA0076562	Semi-Public	Controlled	No	3

TYPE 1 ESTIMATE: Use monitored fecal coliform concentrations from plant effluent/limits to characterize daily load contributions.

Facilities assessed this way:

1. DNR Springbrook State Park-Campground Area
2. DNR Springbrook State Park-Education Center
3. IBP, Inc. Storm Lake (Tyson Fresh Meats)
4. IBP, Inc. Perry (Tyson Fresh Meats)
5. City of Adel
6. City of Jefferson
7. Sac City
8. City of Panora
9. City of Perry
10. City of Bayard
11. City of Desoto

These facilities are required by their permit to monitor and limit fecal coliform concentrations in treated effluent. Therefore, average daily concentrations and loads (with associated flow data) may be directly used, as opposed to being estimated.

TYPE 2 ESTIMATE: Use generic assumptions about per capita daily fecal coliform generation and amount of reduction achieved by treatment (for continuously discharging facilities without fecal coliform effluent monitoring/limits).

Facilities assessed this way:

1. City of Bagley
2. City of Carroll
3. City of Storm Lake
4. City of Newell
5. Albert City
6. Rockwell City
7. City of Lohrville
8. City of Glidden
9. City of Waukee
10. City of Gowrie
11. City of Scranton
12. City of Stuart
13. City of Dallas Center
14. City of Earlham
15. City of Farnhamville
16. City of Lake View
17. City of Rinard
18. City of Harcourt
19. City of Marathon
20. Rembrandt Enterprises, Inc
21. West Central Cooperative

With no effluent monitoring or permit limits for fecal coliforms, some generic assumptions had to be made to estimate pathogen loads coming out of WWTPs. Specifically, it was assumed that the amount of fecal coliforms generated per capita per day is $2x10^9$ organisms or counts (EPA, 2001; Metcalf and Eddy, 1991). Secondly, assumptions were made as to the amount of fecal coliforms removed by various treatment processes. Specifically, a uniform 90% reduction was assumed for all trickling filter, aerated lagoon, and activated sludge wastewater treatment based on Metcalf and Eddy, 1991. Although treatment processes are often likely to achieve higher reductions than 90-98%, these values were used since they represent the "worst case" values taken from literature. Thus, fecal coliform loads in effluent from these facilities were estimated by the following equation:

Fecal Coliform Load in Treated Effluent (counts/day) =
*Human Population (#) * $2x10^9$ organisms per day * 0.10*

Although there is no effluent monitoring at these facilities for fecal coliforms, there are data showing how much flow (in million gallons per day, MGD) was being discharged (monthly average and daily max). Thus, average daily fecal coliform concentrations can be calculated by dividing the results from the equation shown above by the average daily flow.

Where available, the most recent U.S. Census population (2000) was used to estimate the number of individuals generating fecal matter. Population equivalents were used otherwise.

TYPE 3 ESTIMATE: Use generic assumptions about per capita daily fecal coliform generation and variable treatment reductions based on detention time, temperature, and number of lagoon cells (for controlled (intermittent) discharge lagoons without fecal coliform monitoring/limits).

Facilities assessed this way:

1. City of Lytton
2. City of Rembrandt
3. City of Lidderdale
4. City of Breda
5. City of Van Meter
6. City of Minburn
7. City of Paton
8. City of Auburn
9. City of Pomeroy
10. City of Coon Rapids
11. City of Rippey
12. City of Dedham
13. City of Churdan
14. Diamond Head Lake
15. City of Callender
16. City of Manson
17. Iowa Dot Rest Area #21 & #22 I80 Waukee
18. City of Guthrie Center
19. City of Fonda
20. Twin Lakes Sanitary Sewer District STP
21. Lake City
22. City of Lanesboro
23. City of Laurens

24. Spectra Health Care Facility STP
25. City of Redfield
26. City of Halbur
27. Country View Estates
28. Ortonville Business Park

These facilities are controlled discharge lagoons, which discharge intermittently depending on lagoon capacity and inflow. Generally, they discharge during spring and fall, but time of year varies widely.

The same load generation assumption used in Type 2 estimates were applied, in that the daily fecal load generated is $2x10^9$ organisms per person per day. When applicable, the 2000 U.S. Census population was used as the number of individuals being served, but in the case of sanitary sewer districts or semi-public facilities the population equivalent was used. The daily influent loads were allowed to accumulate in the lagoon until the time of discharge, and to calculate the amount of this influent fecal matter removed by treatment, an equation that takes into account the detention time, temperature, and number of cells in the lagoon was used. After discharge, fecal loads coming into the lagoon were set back to zero and allowed to accumulate again until the next discharge.

The equation used to calculate % reduction of fecal matter was taken from an EPA publication titled *Wastewater Stabilization Ponds An Update on Pathogen Removal* (Reed, 1985).

$$Cf/Ci = 1/[1+tK_t]^n$$

Where Cf = effluent concentration, C, = influent concentration, t = actual detention time in the cell (days), n = number of cells in series, Kt = temperature dependant rate constant, estimated using average monthly air temperature as a surrogate for pond temperature.

TYPE 4 ESTIMATE: Not Assessed (MS4 cities, agricultural feedlots, land application effluent disposal, and non-pathogenic WWTPs).

Due to the difficult nature of estimating fecal coliform loads from these facilities, they were exempt from assessment at this time.

MIGRATION OF LOAD ESTIMATES TO GIS FORMAT:

All the load calculations described above were done using MS Excel spreadsheets for convenience. To transfer all relevant information from these load calculation worksheets to a spatially- and temporally-explicit GIS would be extremely complex, and therefore simplifications must be made in the time dimension to approximate a point source's typical daily contribution to watershed load.

To accomplish this, several attribute fields were included in the GIS dataset to describe typical daily loads, depending on estimate type. A list of the attribute fields and descriptions are provided below as metadata. (Also available in the dataset's ArcGIS metadata files)

The following fields already exist and were not altered from the original GIS shapefile for statewide NPDES WWTPs. Updates were made to the population equivalent where

necessary (based on most recent permit). Records with no WWTP_ or WWTP_ID attribute are those which are missing from the statewide coverage of permitted WWTPs.

- FID
- Shape
- WWTP_
- WWTP_ID
- EPA_ID
- STATE_ID
- NAME

The following fields were manually added to the dataset. It should be noted that in some cases, design AWW flows from the original statewide dataset had to be updated based on the most recent permit.

Note that there are several different attribute fields which refer to fecal coliform loads and concentrations. The appropriate load/concentration estimate to be used for a typical daily load depends on the type of facility, i.e. controlled vs. continuous discharge, or monitored vs. estimated loads. Also, it depends on the use/application of the modeling situation, i.e. modeling for the “worst-case” scenario vs. modeling the “most realistic” current conditions.

FLOW_TYPE
Alias: FLOW_TYPE
Data type: String
Width: 254
Definition:
Type of flow being discharged, whether continuous, controlled, or irregular

AWW_FLOW
Alias: AWW_FLOW
Data type: Number
Width: 20
Number of decimals: 5
Definition:
Design Average Wet Weather Flow (daily), in million gallons per day (MGD)

MAX_FLOW
Alias: MAX_FLOW
Data type: Number

Width: 20
Number of decimals: 5
Definition:
Design Max Flow (daily), in million gallons per day (MGD)

ACTUAL_AWW
Alias: ACTUAL_AWW
Data type: String
Width: 20
Definition:
Average of actual (monitored) daily flows in million gallons per day (MGD)

ACTUAL_MAX
Alias: ACTUAL_MAX
Data type: String
Width: 20
Definition:
Maximum actual (monitored) daily flow in million gallons per day (MGD)

FC_LIM_AVG
Alias: FC_LIM_AVG
Data type: String
Width: 20
Definition:
30-day geomean fecal coliform limits (if they exist) in counts/100 ml

FC_LIM_MAX
Alias: FC_LIM_MAX
Data type: String
Width: 20
Definition:
Max single sample fecal coliform limits (if applicable) in counts/100 ml

AVG_FC
Alias: AVG_FC
Data type: String
Width: 20
Definition:
Average fecal coliform concentration (per 100 ml) monitored in plant effluent

MAX_FC
Alias: MAX_FC
Data type: String
Width: 20

Definition:
Maximum fecal coliform concentration (per 100 ml) monitored in plant effluent

CALC_FCAVG
Alias: CALC_FCAVG
Data type: String
Width: 20
Definition:
Estimated (calculated) average daily fecal coliform load in effluent

CALC_FCMAX
Alias: CALC_FCMAX
Data type: String
Width: 20
Definition:
Estimated (calculated) maximum daily fecal coliform load in effluent

CALC100MLA
Alias: CALC100MLA
Data type: String
Width: 20
Definition:
Estimated (calculated) average fecal coliform concentration (per 100 ml) in effluent

CALC100M
Alias: CALC100M
Data type: String
Width: 20
Definition:
Estimated (calculated) maximum fecal coliform concentration (per 100 ml) in plant effluent

Appendix C

Documentation of Methods for Estimation of Nitrate Assimilation In the Raccoon River

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Subbasin	W (m) (at 90%)	W (ft) (at 90%)	Nitrate load assuming 9.5 mg/L and 10% exc Q (Mg/day)	90% Q (10% exc)	distance to dw seg (km)	ft^2	velocity fps	velocity (km/day)	gage ht (ft)	square meters bottom area from outlet to DW	days to drinking water segment	Mg Nitrate-N taken-up	PS N load by segment Mg	percent of daily flux as PS
N Raccoon at Sac City	17.7	58	628	27	125	33.9	0.8	21.1	6.95	2208682.4	5.94	1861.8	2.17	0.3%
N Racoon at Jefferson	28.9	95	1511	65	109	66.8	0.97	25.5	5.05	3154607.8	4.27	1912.4	2.66	0.2%
S Raccoon at Redfield	45.4	149	2139	92	30	141	0.65	17.1	3.33	1361766.9	1.75	339.1	0.91	0.0%
Raccoon River at Van Meter	64.0	210	5231	225	14	314	0.72	19.0	3.36	895659	0.74	94.0	4.87	0.1%

					(15)					(16)				
	W (m) (at 90%)	W (ft) (at 90%)	Nitrate load assuming 9.5 mg/L and 10% exc Q (Mg/day)	90% Q (10% exc)	dist from center point to outlet (most ps are > 36 km)	ft 2	velocity fps	velocity (km/day)	gage ht (ft)	sq m in seg (not counting res) 1/2 width at outlet	days to drinking water segment	Mg Nitrate-N taken-up	PS N load by segment Mg	percent of daily flux as PS
Middle Raccoon at Panora	19.5	64	1162	50	25	38.6	1.2	31.6	4.17	243717	0.79	27.4	0.51	0.04%

Notes:
1. Channel width at 90% low flow in meters
2. Channel width at 90% low flow in feet
3. Nitrate load at subbasin outlet assuming 9.5 mg/l concentration and low flow (10% flow exceedance)
4. Streamflow at 90% low flow (10% flow exceedance)
5. Distance (in kilometers) from subbasin outlet to drinking water segment (straight-line distance).
6. Cross section area of channel (square feet)
7. Stream velocity at gage at subbsin outlet (feet per second)
8. Stream velocity at gage at subbsin outlet (kilometers per day)
9. Gage height at subbasin outlet
10. Area of streambed (square meters) from subbasin outlet to drinking water segment
11. Travel time of stream (days) from subbasin outlet to drinking water segment
12. Mass of nitrate (in Mg) taken up in streambed assuming 1.65 mg/m2/day (Mulholland et al., 2004)
13. Estimated point source nitrate load at subbasin outlet
14. Percentage of daily nitrate flux as point source
15. Distance from center point in basin to basin outlet (most point sources are located more than 36 km away from outlet).
16. Area of streambed (square meters) from subbasin outlet to drinking water segment - does not include reservoir.

Appendix D

Public Comments

IOWA FARM BUREAU
PEOPLE. PROGRESS. PRIDE.™

October 19, 2007

Mr. Chris Van Gorp
Watershed Quality Improvement Section
Iowa Department of Natural Resources
502 E. 9th Street, Des Moines, IA 50319-0034

RE: Pre-Public Comment Period Issues on the Raccoon River Draft Total Maximum Daily Load

Dear Mr. Van Gorp:

The Iowa Farm Bureau Federation (IFBF), the state's largest general farm organization with more than 154,000 members, would like to provide these general comments regarding the draft Total Maximum Daily Load for the Raccoon River nitrate and bacteria impairments. The Iowa Farm Bureau appreciates the extensive efforts that went into this document and its attempts to deal with two of the most dynamic and difficult water quality issues. These comments are intended to draw your attention to specific issues that need to be addressed more clearly in the draft presented to the public.

Executive Summary

In the Executive Summary on Page 12, a new second paragraph is needed to summarize the focused sub-watershed concept that is mentioned in the Monitoring Plan section on page 17 of the Executive Summary. This language needs to clearly communicate (since the public may not read much more than the Executive Summary) the vision for how the TMDL serves the sub-watershed residents as a general guide to future voluntary activities that they may organize. You might also suggest the sources of information and resource agencies they should access to create a more detailed sub-watershed plan. This paragraph(s) should also give sub-watershed residents an idea of a realistic timeframe for organizing such an undertaking and for seeing water quality results for these impairments.

Also, the Executive Summary needs to give the public more information on the imperfectness of this process and the variability in its product. It is critical to emphasize the importance and challenges of sustained, long-term, citizen-led sub-watershed efforts.

In addition, the Implementation Plan summary on Page 21 contains language that should also be mentioned in the Executive Summary. In the new paragraph, we suggest also adding the following: "The reduction of nitrate and bacterial pathogen loads will be carried out through a combination of non-regulatory activities and monitoring for results. Nonpoint source pollution will be addressed using available programs, technical advice, information and education, and financial incentives."

These comments would also apply to any public fact sheets the department develops.

Human Contributions

Another issue that needs to be addressed more specifically in the draft document prior to public comment and meetings is that human contributions appear to have been significantly underestimated in this watershed for nitrogen and bacteria. No contributions were accounted for, it seems, including the applications of waste water treatment plant (WWTP) sludge for the active plants in the watershed. According to our information, sludge is applied three times a year, at a minimum, in the spring, summer and fall at agronomic N rates usually within a five mile radius of the WWTP. It is applied to either land the facility owns or on cropland with landowner agreements.

In addition, raw human sewage bacteria levels have not been accounted for in the loading rates. This is important because raw sewage contributes high bacteria loads and would drive up the bacteria numbers in the spring storm events when contributions in from manure or other agricultural sources would be low (as most manure is fall applied).

WWTPs in the area discharge bacteria daily to these streams that are not A1 and A2, and contributions were underestimated. Additionally, based on recent review of NPDES permit compliance, loading rate calculations may have overestimated the N and bacteria reductions that are occurring at each of the facilities in this watershed.

Additionally, Raccoon River watershed canoers have reported seeing raw sewage and human waste coming out of drainage tiles in these streams at normal float levels. These contributions need to be factored into the TMDL. Blanket statements in the TMDL minimizing the human factor are counterintuitive.

Storm water contributions of bacteria from overland flow in an any urban situation are not minimal. Recent snapshot sampling that we are aware of indicates that the bacterial loading from urban sources is fairly substantial for those small creeks

Also, loading rates from the failing septic tanks is underestimated. The loading rates from the failing septic tanks would occur daily and therefore would be an issue during low flows and high flows.

As one possible reference source, we suggest the Minnesota Pollution Control Agency's Bacteria TMDL Protocols and Submittal Requirements (http://www.pca.state.mn.us/publications/wq-iw1-08.pdf).

Another source of information for this and future bacteria TMDLs might be *Fecal Coliform TMDL Assessment for 21 Impaired Streams in the Blue Earth River Basin*, June 2007 (page 22-23) http://www.pca.state.mn.us/publications/wq-iw7-05b.pdf. This information points to potential source of fecal coliform bacteria in streams/rivers that is often overlooked is resuspension of streambed sediments. It cites several studies have reported significantly increased concentrations of water column fecal coliform density after disturbance of the surface sediments.

Weiskel et al. (1996) reported greatly increased values of fecal coliform density after artificial disturbance of the surface 2 cm of sediments in Buttermilk Bay, Massachusetts. Ewert (2005) in a study conducted in southern Minnesota, found that physical raking of streambed sediments resulted in bacteria concentrations several factors higher than the water column values before resuspension. Jolley et al. (2004) reported bottom sediment reservoirs of indicator bacteria in surface water increase surface water bacteria levels at base flow and should be considered sources of surface water contamination. Davis et al. (2005) reported that observations in Arkansas indicated it is possible for E. coli to survive in certain streambed sediments for at least four months with no fresh external inputs. Yagow and Shanholtz (1998) reported that as runoff during a storm event begins, the discharge and velocity increase, in turn scouring bacteria from the benthic areas of the stream. This scouring causes increased levels of bacteria in the water column and decreased levels in stream sediments."

Unsewered Communities

It appears that unsewered communities were not addressed in the TMDL. What was the rationale for this, or how might their contribution be addressed? The DNR has a list of prioritized unsewered communities that should be referenced, one way or the other, as to how this issue is being addressed either within the TMDL or outside of the TMDL. This is a glaring omission.

Nonpoint Sources

On page 49, section 3.2.4 Nonpoint Sources, it should be more clearly stated that there are several contributors to NPS, rather than the NPS “lumped” into one group. The problem with this is that the larger community receiving this document sees the NPS number as the responsibility of the ag community to reduce the bacteria and nitrogen numbers. NPS is actually a combination of communities; it is actually everything that isn’t a point source. For this size of a watershed, the list of NPS contributors is likely fairly extensive. There are urban and rural storm water contributions, wildlife, drainage tiles (where illegal and illicit point source discharges are occurring), unidentified septic dischargers, etc., and the potential solutions are equally as varied and site specific as the source. It can't be the work of the NPS community and watershed groups to differentiate the actual sources to the assumed loading rates. Therefore, this would be another good place to reemphasize the importance and challenges of sustained, long-term, citizen-led sub-watershed efforts.

On Page 136 in Section 6.2 Local BMP Implementation, we suggest the following modifications:

> "Improving nutrient use efficiencies by changing the timing and rate of nitrogen applications are considered among the best practices that an individual landowner could adopt that reduce losses of nitrate to streams with subsurface flow (Table 6-4). Changing the fertilizer application methods to injection methods that minimize surface application and volatilization may reduce runoff losses of nitrogen. Bacteria losses may be reduced if landowners improved manure management practices to take appropriate nutrient credit for manure applications and minimize the application of manure during periods that would facilitate runoff. However, the effectiveness of these options may be limited due to already broad adoption of them. As a result, edge of field options, such as constructed wetlands via the Iowa Conservation Reserve Enhancement Program may be more effective (for N reductions) in this region, but face regulatory hurdles that limit adoption.

The IFBF again thanks you for the opportunity to comment on this draft TMDL prior to the public comment period, and we recognize the extensive efforts to deal with two of the most dynamic and difficult water quality issues in one document.

Sincerely,

Rick Robinson

Rick Robinson
Environmental Policy Advisor

Cc: Allen Bonini

Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER, GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

December 14, 2007

Rick Robinson
Iowa Farm Bureau Federation
5400 University Ave
West Des Moines, IA 50266

Dear Mr. Robinson:

We are in receipt of your comments submitted on October 19, 2007 regarding the pre-public notice draft TMDL for the Raccoon River. Below are IDNR responses to your comments.

Your comments indicate that human contributions appear to have been significantly underestimated for nitrogen and bacteria by:

1) not accounting for the application of WWTP sludge,
2) not accounting for raw human sewage bacteria levels,
3) underestimating current WWTP bacteria discharges to streams that are not currently A1 or A2,
4) overestimating the reduction of nitrogen and bacteria occurring within facilities,
5) not accounting for raw sewage seen coming out of drain tiles,
6) not properly accounting for storm water contributions of bacteria, and
7) underestimating the loading rates from septic systems.

Items 1) and 6): Section 4.2.1 of the TMDL describes the pollution source assessment for point sources. As stated in this section (page 82), event based discharges or land applications of pollutants were considered in this point source inventory.

Item 2): For *E.coli* bacteria, very few wastewater treatment facilities monitor for bacteria in their effluent. Therefore, bacteria estimates were derived from conservative assumptions based on type of treatment, quantity and quality of influent wastewater, and per capita pollutant generation. For *E.coli*, virtually all NPDES associated documentation and records use fecal coliforms as the standard for measuring pathogen indicators and not *E.coli*. Thus, all assessment and calculations of bacteria loadings from point sources apply to fecal coliform only. However, the use of fecal coliform as surrogates for *E.coli* is treated as a conservative estimate in this TMDL. Because *E.coli* is a subset of fecal coliform (recall that FC * 0.92 = EC in surface water), use of fecal coliform in estimating point source discharges will overestimate *E.coli* losses to streams. Thus estimates of *E.coli* point source loads from WWTPs provide a worst-case estimate of their inputs to Raccoon River receiving waters.

The amount of bacteria discharged into a stream was estimated using a three-tiered approach. If a facility had bacteria monitoring data, then the monitoring data were used (Estimate Type 1). If the facility had no monitoring data available, an estimated discharge amount was assumed based on the population estimate (Estimate Type 2). The total bacteria amount produced by the population was then reduced by 99.9 percent from the wastewater treatment process. For controlled discharge facilities, the same rate of bacteria generation by population was used but the reduction rate varied depending on the length of time the wastewater was in storage (Estimate Type 3).

Item 3): In the development of the bacteria TMDL for the Raccoon River basin, the rebuttable presumption was assumed where all perennially flowing waters are protected for primary contact recreation and aquatic life. This results in all permitted facilities discharging to a Class A stream being required to meet water quality standards at the end of pipe. These permits will be updated as use attainability analysis are completed and approved.

Item 4): In calculating nitrogen reductions from WWTPs, in terms of TKN, 100 percent of the TKN was assumed to convert to nitrate when in fact, some nitrogen is lost from the system as converted plant or soil matter (process know as immobilization) or as nitrogen gas (denitrification). Thus point source nitrate loads from WWTPs are overestimated. See Section 3.2.1 of the TMDL.

Items 5) and 7): Raw sewage coming out of tiles is an enforcement issue with the local IDNR Field Office or local County Sanitarian. This source of human waste has been taken into account through the inclusion of septic systems and the assumption that 100% of the septic systems are failing. See Section 4.2.4 of the Final TMDL.

The citations that you provided on bacteria in streambeds correlates with what we are learning from the beach monitoring program. If sediments are disturbed, bacteria tend to be released into the water column. It appears that bacteria can survive in sediments for some period of time. However, there is no evidence that bacteria can reproduce in stream sediments, therefore the bacteria populations in the streambed would need to be constantly replenished (which they are) to continue to be a source. If the sources identified in the TMDL were reduced or removed, any contribution from the streambed would decrease as a result.

Unsewered communities were included in the TMDL calculations through the calculations for septic systems and the assumption that all septic systems in the watershed have failed.

Your letter suggests that nonpoint sources should be more clearly stated, rather than “lumped” into one group. On page 49 Section 3.2.4, the document notes that nonpoint source contributions are from agricultural, developed land (urban and residential areas), and natural sources. Potential nonpoint sources from agricultural sources include fertilizer, soil mineralization, legume fixation, and manure. Potential nonpoint sources from developed land sources include septic systems and turf grass fertilizer. Naturally occurring nonpoint sources include atmospheric deposition and wildlife contributions.

Your comment letter stated circumstances where visual observations were made or water quality data exist. In the future, it would be useful if your comment letters cited specific references or provided the actual data.

Thank you again for taking the time to comment on the draft TMDL for the Raccoon River. Your comments and this response will be included with the finalized TMDL submitted to the EPA Region VII office in Kansas City for approval. If you have any questions please contact Chris Van Gorp at 515-281-4791.

Sincerely,

Allen P. Bonini, Supervisor
Watershed Improvement Section

Nov. 19, 2007

Coon Rapids, IA

Chris:

I thank you and your colleagues for writing the "Water Quality Improvement Plan for Raccoon River, Iowa," and for the presentations you gave in the Raccoon River Watershed during the last month. As a resident and land manager within the Middle Raccoon watershed, I found both the report and dialogue at the public meeting at Springbrook State Park (on 11/08/07) a great wealth of information.

While tremendous amounts of funding and work went into the data collection and analysis for your report, it is troubling to me that the current deliverables of this TMDL process are but the report and meetings themselves. Unregulated non-point source pollution of nitrate and *E.coli* will continue to degrade our watershed each day.

The Iowa Department of Natural Resources (IDNR) and state legislature continue to claim that Iowa's water quality standards are in compliance with the federal Clean Water Act. Your report states that the EPA is likely to classify the entire Raccoon River watershed as impaired if and when additional testing is completed, while only 8 stream segments within the watershed are on the state's 303(d) list and addressed within the TMDL definition section of the report. This seems a contradiction.

The dependence of over 10% of the state's population on drinking water from the Raccoon River, and the obvious magnitude its impairment ought to prompt an aggressive response from the IDNR. Instead, watershed inhabitants are told to form sub-basin volunteer watershed groups in order to scramble for the limited state and federal funding for watershed improvement projects. While watershed groups are very important and have accomplished great things throughout the state, they should not bear the responsibility of maintaining acceptable levels of nutrients and pathogens in our waterways. Confined animal feeding operations may contribute the majority of *E.coli* into the Raccoon River watershed, but it has been largely ineffective for groups of citizens to band together to slow the expansion of CAFOs in highly localized areas. There are simply not enough informed and active volunteers in each HUC-12 sub-basin to change the way that industrial agriculture impacts the Iowan landscape.

As an inhabitant of the Raccoon River watershed and a member of a watershed association, I do not think that the large-scale pollution of our watershed is due to bad actors or uneducated farmers. I do not think that adherence to BMP's and "farmer-leaders" will clean up the rivers. I want the IDNR to aggressively regulate inputs (both point source *and* non-point source) entering public waterways. If the IDNR doesn't have enough money or enough power, I want the IDNR to lobby for legislation that will place enforceable limits and give the regulations muscle enough to punish those who don't comply. As an involved citizen, I will support your proposals to the legislature and ask for my neighbors and the watershed group I'm involved in to support you as well. This is not something that we can do on our own, though, and you must be the group of people in the state who understand this the very most.

The "Water Quality Improvement Plan for Raccoon River Iowa" has provided a protocol for the improvement of one watershed, but it seems tantamount to negligence for the IDNR to create this report and then prompt volunteers to carry out the recommendations (recommendations that were largely unable to drastically reduce pollutant loads within the SWAT model).

The only way to plausibly reduce nitrates and *E.coli* loading in our watershed is via state-wide regulation. I beg the IDNR to prompt the process of adopting regulations and punishments for non-point source pollutants and polluters.

Thank you,

Elizabeth Hill (Middle Raccoon River)
1585 140th Street
Coon Rapids, IA 50058

Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER, GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

December 14, 2007

Elizabeth Hill
1585 140th Street
Coon Rapids, IA 50058

Dear Ms. Hill:

Thank you for your interest and comments on the Draft TMDL for the Raccoon River. Below are IDNR responses to your comment letter dated November 19, 2007.

In your letter, you raise the question of the entire Raccoon River basin being listed as impaired for bacteria in the future, but the TMDL only addressing 8 segments. The TMDL for bacteria for the Raccoon River addresses bacteria loads for every perennially flowing stream in the basin, not just those segments identified as impaired on the impaired waters list (303(d) list). This was acknowledged in the executive summary of the TMDL on page 14, with the bacteria loads identified in Section 4.7 (Table 4.11).

Much of your comment letter was focused on the implementation of the TMDL, and actually achieving water quality improvements. The federal Clean Water Act establishes several tools that work together to address water pollution. States are required to determine how people and aquatic life use the waters and lakes and how those waters could be used. Water quality standards must then be established to set the maximum level of pollution that can exist in the waters without eliminating the actual and potential uses of that water.

In the event that uses are being impaired by excess pollution, then the State will develop a Total Daily Maximum Load or TMDL to identify the sources of pollution in a stream, if possible, and attempt to establish a plan for reducing that pollution to a level that will allow for the appropriate uses of the stream.

In order to limit the amount of pollution that is discharged to waters, states are authorized to implement a permit program to regulate “point source” discharges. (33 U.S.C. 1342) Point sources are individual conveyances, typically thought of as a pipe but also may include trucks or even earth moving equipment. Specifically excluded from federal regulation are nonpoint agricultural discharges except discharges from confined animal feeding operations (33 U.S.C 1362(14) and 40 CFR 122.3(e)). A federal court has ruled that confined animal feeding operations that are not designed or operated to directly discharge pollutants can not be required to obtain a permit until or unless they actually do discharge.

Also excluded due to a lack of authorization are other sources of nonpoint pollution.

Many nonpoint pollutants are conveyed to waters by stormwater. Federal stormwater regulations have been limited by rule to cover only municipal storm water discharges, specific types of industrial activity, and construction activities.

No federal authority exists to regulate nonpoint pollution from most agricultural activities or from non-industrial sites not currently under construction. Federal law allows individual states to enact nonpoint pollution regulations. As you mentioned in your letter, this would require legislation to be passed by the Iowa General Assembly granting authority to a state agency to enforce nonpoint source regulations.

Thank you again for taking the time to comment on the draft TMDL for the Raccoon River. Your comments and this response will be included with the finalized TMDL submitted to the EPA Region VII office in Kansas City for approval. If you have any questions please contact Chris Van Gorp at 515-281-4791.

Sincerely,

Allen P. Bonini, Supervisor
Watershed Improvement Section

VanGorp, Chris [DNR]

From: moonbean [moonbean@wccta.net]
Sent: Monday, November 26, 2007 3:58 PM
To: VanGorp, Chris [DNR]
Cc: Jerry Peckumn; elizabeth hill; Michael Delaney
Subject: comments on Raccoon River TMDL
Attachments: George Naylor.vcf

Comments regarding plans for improving water quality in the Raccoon River Watershed by George Naylor, Greene County farmer, and president of the National Family Farm Coalition (www.nffc.net).

These brief comments are based on observations from 31 years of farming in Greene County and analysis of family farm economics for almost as long. I hope they can be of use determining water quality improvement plans or the TDML

Many people have been alarmed by the loss of diversified family farms along with their extensive production of livestock production, crop rotations that include hay, pasture, and small grains, to be replaced by larger and larger corn and soybean operations and Confined Animal Feeding Operations (CAFO's). Now, an article by Jerry Hatfield, Laboratory director of the national soil Tilth Laboratory in Ames (Iowa Farm Bureau Spokesman, January 10, 2007, page 3) points to the fact that this loss has been more than an economic and social catastrophe; it is the source of our Iowa waterway pollution with nitrates. I would speculate that the change in livestock production from extensive to intensive systems with the latter aiming to dispose of the most animal waste on the smallest amount of land could be also a reason for increased nitrate pollution and bacterial contamination.

Without addressing the economic reasons for these changes in Iowa land use by farmers, conservation measures in either Farm Bill provisions or the TDML will be bound to fail.

The changes in livestock production and cropping patterns are the result of a change in federal farm policy over the years. New Deal farm programs aimed to place a price floor under basic storable commodities such as corn, soybeans, oats, and wheat, where the purchasers of the commodities had to pay a minimum price (roughly the non-recourse loan rate) with this minimum price adjusted for inflation. These programs have been replace in response to the lobbying of giant agribusiness towards "market oriented" policies that moved away from the price floor concept creating lower and lower price floors (in real dollars) eventually creating the Freedom to Farm model of relying totally on government payments to keep the farm economy solvent in the face of very low commodity prices. It was these low commodity prices that were the goal of agribusiness, and the policy was surprisingly supported by groups such as the American Farm Bureau Federation, the American Soybean Association, the National Corn Growers Association, the National Pork Producers Council, and the National Cattleman's Beef Association.

Low commodity prices—most apparently corn and soybean prices—result in low livestock feed prices and consequently low livestock prices. Because corn and soybean meal also form the majority of ingredients in manufactured feed used in industrial livestock feeding operations, these intensive operations are favored over the extensive operations that may not buy or sell corn and soybeans at all. When diversified family farms throw in the towel after years of unprofitable production, selling off their livestock, the only logical use for the land used to produce hay, pasture, and small grains is more corn and soybeans. That is because relatively little land actually produces fruits and vegetables in the US; in

2005 12 million acres produced fruits and vegetables versus 266 million acres of program crops. More corn and soybean production mean cheaper and cheaper corn and soybean prices and thus more intensive livestock production, with the cycle repeated *ad nauseum* (pun intended).
Recent improvements in corn and soybean prices have resulted in increased livestock prices. Nevertheless, increased production around the world in a globalized agricultural economy could result in very cheap commodities once again. Besides, for corn to be the equivalent price as in 1978, it would have to be over $7.00 per bushel. The next farm bill as currently spelled out in both House and Senate versions clearly intend to go down the agribusiness route of cheap commodities and more government payments. Claims that increased funding of conservation programs such as Conservation Security Program and EQIP can deal with our environmental problems are disingenuous.

In lieu of changes in federal farm policy to get our farm economy back in balance and favor extensive livestock production instead of intensive production, we must find ways to make extensive production more economically viable. This will require research and building of markets where consumers pay a better price for grass fed beef or pasture raised pork. Enforcing pollution controls on CAFO's so that they face the true cost of production is critical. Likewise new experimental programs in extensive production such as that at the Whiterock Conservancy can help farmers see a path of land stewardship in cooperation with consumers and those of us concerned with the environment.

George Naylor, president
National Family Farm Coalition
288 M Avenue
Churdan, IA 50050
515-544-3464 (cell 515-370-3710)

Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER, GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

December 10, 2007

George Naylor
National Family Farm Coalition
288 M Avenue
Churdan, IA 50050

Dear Mr. Naylor:

Thank you for your interest and comments on the Draft TMDL for the Raccoon River. IDNR received your comment letter on November 26, 2007 via email.

Your comments will be included with the finalized TMDL submitted to the EPA Region VII office in Kansas City for approval. If you have any questions please contact Chris Van Gorp at 515-281-4791.

Sincerely,

Allen P. Bonini, Supervisor
Watershed Improvement Section

VanGorp, Chris [DNR]

From: jim nedtwig [jnedtwig@earthlink.net]
Sent: Monday, November 26, 2007 2:38 PM
To: VanGorp, Chris [DNR]
Subject: raccoon river tmdl comment

Chris:

Thanks to you and your colleagues for producing the report "Water Quality Improvement Plan for Raccoon River, Iowa". The document presents Iowans with an excellent summary of data critically important for understanding the condition of the Raccoon River watershed, and the primary contributors to its impairment - namely, agricultural drainage tiles, and domestic livestock.

As was mentioned during the public meeting at Springbrook Park (11/8/07), the Raccoon watershed is the source of drinking water for approximately 400,000 Iowans (13% of the Iowa population). Your report states that the Environmental Protection Agency is likely to classify the entire Raccoon River watershed as impaired, if and when additional water testing is completed.

The degree and the systematic nature of impairment in the Raccoon River watershed demands an aggressive response from Iowa Department of Natural Resources (IDNR). At the very least, a 20 year subbasin water sampling program is merited, to be operated, staffed, and funded by IDNR. This sampling program must be comprehensive, and include both event-based and fixed interval approaches. Perhaps a partnering agreement with the Des Moines Water Works is possible, since they currently coordinate an effective water sampling system. Without credible and comprehensive data gathering over many years, there is no analytical and reasoned path toward the mitigation of current pollution loads.

Given the level of impairment described in "Water Quality Improvement Plan for Raccoon River, Iowa", the proposed development of local, volunteer subbasin watershed groups is an insufficient and flawed response. The idea that peer pressure from local watershed groups is an effective method of changing agricultural production methods has been raised (Springbrook meeting, 11/8/07). Recent history in Iowa, however, has shown peer pressure to be ineffective. Well organized local groups have done little to slow the expansion of confined animal feeding units (CAFOs), a source of E. coli in the Raccoon River watershed. Volunteers can not and should not be responsible for attempting to change the structure and production methods of industrial agriculture. Also, as volunteers come and go, required water samples will inevitably go uncollected, leaving gaps in the water monitoring data that is the basis for changes in public policy.

The only plausible method of dramatically reducing pollution in the Raccoon River watershed is via state wide regulation. The citizens of Iowa want and need IDNR to be aggressively regulating substances entering our public waters. The citizens of Iowa want and need IDNR to actively lobby for state legislation that would place legal and enforceable limits on nonpoint sources of pollution. Propose legislation that will empower IDNR, and ask the public for support.

The Federal Clean Water Act requires IDNR to develop a Watershed Improvement Plan for waters identified on the state's 303(d) list. Any proposed plan shifting this responsibility to volunteer citizen groups would be an act of negligence by IDNR, and must be rejected.

Thank you,

Jim Nedtwig   Land Owner, Middle Raccoon River Watershed
443 Tonawanda Drive
Des Moines, Iowa 50312

Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER, GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

December 14, 2007

Jim Nedtwig
443 Tonawanda Drive
Des Moines, IA 50312

Dear Mr. Nedtwig:

Thank you for your interest and comments on the Draft TMDL for the Raccoon River. Below are IDNR responses to your comment letter received November 26, 2007 via email.

In your letter, you raise the need for a sub-basin water sampling program operated, staffed, and funded by the IDNR. The IDNR currently receives annual funding from the Iowa Legislature to implement a long-term ambient water monitoring network across the state. In addition, other programs, such as the TMDL program, conduct more intensive, albeit shorter-term, monitoring on specific watersheds and waterbodies. IDNR agrees with your suggestion that such a sampling program should include both event-based and routine monitoring approaches. Such a program would be very worthwhile, not only for the Raccoon River Basin, but statewide. This type of monitoring program is very expensive, and would significantly limit any other surface water monitoring that is being conducted.

You suggest a cooperative approach with Des Moines Water Works, enhancing the current monitoring conducted by them and Agriculture's Clean Water Alliance. This may be a feasible alternative on a small number of priority sub-basins. IDNR does agree with you that it will be very difficult to document any changes in water quality without an ongoing monitoring program.

Much of your comment letter was focused on the implementation of the TMDL, and actually achieving water quality improvements. Your letter indicates that the development of local watershed groups is an insufficient and flawed response to improving the Raccoon River. In addition, your letter supports state wide regulation of substances entering our public waters.

The federal Clean Water Act establishes several tools that work together to address water pollution. States are required to determine how people and aquatic life use the waters and lakes and how those waters could be used. Water quality standards must then be established to set the maximum level of pollution that can exist in the waters without eliminating the actual and potential uses of that water.

In the event that uses are being impaired by excess pollution, then the State will develop a Total Daily Maximum Load or TMDL to identify the sources of pollution in a stream, if possible, and attempt to establish a plan for reducing that pollution to a level that will allow for the appropriate uses of the stream.

In order to limit the amount of pollution that is discharged to waters, states are authorized to implement a permit program to regulate “point source” discharges. (33 U.S.C. 1342) Point sources are individual conveyances, typically thought of as a pipe but also may include trucks or even earth moving equipment. Specifically excluded from federal regulation are nonpoint agricultural discharges except discharges from confined animal feeding operations (33 U.S.C 1362(14) and 40 CFR 122.3(e)). A federal court has ruled that confined animal feeding operations that are not designed or operated to directly discharge pollutants can not be required to obtain a permit until or unless they actually do discharge.

Also excluded due to a lack of authorization are other sources of nonpoint pollution.
Many nonpoint pollutants are conveyed to waters by stormwater. Federal stormwater regulations have been limited by rule to cover only municipal storm water discharges, specific types of industrial activity, and construction activities.

No federal authority exists to regulate nonpoint pollution from most agricultural activities or from non-industrial sites not currently under construction. Federal law allows states to enact nonpoint pollution regulations. At this point, the Iowa General Assembly has not elected to enact this type of regulation.

In the closing of your letter, you state:

> “The Federal Clean Water Act requires IDNR to develop a Watershed Improvement Plan for waters identified on the state’s 303(d) list. Any proposed plan shifting this responsibility to volunteer citizen groups would be an act of negligence by IDNR, and must be rejected.”

The Federal Clean Water Act (CWA) requires that TMDLs (Watershed Improvement Plans) are calculated for all waters identified on a state’s 303(d) list. The calculation of the TMDL includes wasteload allocations for permitted point sources, a load allocation for all combined nonpoint sources, and a margin of safety. The CWA does not require an implementation plan as part of the TMDL submitted for approval to EPA. However, IDNR has been proactive in the development of TMDLs throughout Iowa by including some level of implementation plan in all TMDLs that are developed. Wasteload allocations for point sources are implemented through the National Pollution Discharge Elimination System (NPDES) permit program. The implementation plans have provided guidance to local stakeholders and watershed groups to achieve the Load Allocations for nonpoint sources.

Thank you again for taking the time to comment on the draft TMDL for the Raccoon River. Your comments and this response will be included with the finalized TMDL submitted to the EPA Region VII office in Kansas City for approval. If you have any questions please contact Chris Van Gorp at 515-281-4791.

Sincerely,

Allen P. Bonini, Supervisor
Watershed Improvement Section

VanGorp, Chris [DNR]

From: Jerry Peckumn [jpeckumn@netins.net]
Sent: Monday, November 26, 2007 1:35 PM
To: VanGorp, Chris [DNR]
Subject: TDML
Attachments: Jerry Peckumn.vcf

Thank you for working so hard on the plan to clean up the river. A healthy ecosystem for the Raccoon River is so important to the future. As a society we need to be honest about what we have done and are still doing to the river. It is easy for us to just keep on doing the same thing while rationalizing our greed by believing there is not much wrong and the economy is more important. Both economics and the conservation ethic drive the need to clean up the river. Let's implement the solutions proposed in the TDML, continue to find more solutions, and recognize that we can have a viable ecosystem that is healthy for humans and all life. We can greatly reduce nutrients, many times at a cost savings to agriculture, we can get the bacteria out by keeping the manure on the land and fixing unsanitary septic systems, and we can implement sound water management keeping the sediment on the land.

Jerry Peckumn
1200 Westwood Dr
Jefferson, Iowa 50129
515-386-4000 home
515-370-0077 cell

Iowa
Fields of Opportunities

STATE OF IOWA

CHESTER J. CULVER, GOVERNOR
PATTY JUDGE, LT. GOVERNOR

DEPARTMENT OF NATURAL RESOURCES
RICHARD A. LEOPOLD, DIRECTOR

December 10, 2007

Jerry Peckumn
1200 Westwood Drive
Jefferson, IA 50129

Dear Mr. Peckumn:

Thank you for your interest and comments on the Draft TMDL for the Raccoon River. IDNR received your comment letter on November 26, 2007 via email.

Your support of implementing the TMDL with known best management practices, and continuing to identify additional solutions is encouraging. Proper management of fertilizer and manure can minimize delivery to our waterways, and identifying and correcting illegal and failing septic systems will eliminate a nutrient and bacteria sources to our waters.

Thank you again for taking the time to comment on the draft TMDL for the Raccoon River. Your comments and this response will be included with the finalized TMDL submitted to the EPA Region VII office in Kansas City for approval. If you have any questions please contact Chris Van Gorp at 515-281-4791.

Sincerely,

Allen P. Bonini, Supervisor
Watershed Improvement Section

WALLACE STATE OFFICE BUILDING / 502 EAST 9th STREET / DES MOINES, IOWA 50319-0034
515-281-5918   TDD 515-242-5967   FAX 515-281-6794   www.iowadnr.gov