# PROJECT OVERVIEW

## I. Objectives of the study

The primary purpose of this project as stated in the contract is to locate as precisely as possible sources of Nitrate, Nitrite, and *Escherichia coli* contamination and associated parameters within the Contractor's delineated watershed protection area, within the 72 hour time of transport. This includes the Des Moines River and tributaries south of the Saylorville Reservoir, the North Raccoon south of Jefferson, the Middle Raccoon south of Lake Panorama, and the South Raccoon.

Subordinate tasks necessary to fulfill this goal are:

1. Tabulating relevant data from all reliable sources to determine possible ambient water quality conditions, water quality trending for each location, and probable causes and sources of impairment based on water quality analyses.
2. Identify new sites for additional testing based on historical data and subsequent analyses of additional sites.
3. Characterize stream loading for *E. coli* and nitrogen at strategic location(s) on the Raccoon River so that information as to the tributary source and contribution to contamination can be determined.
4. Determine and compare bacterial counts and nutrient concentration of tributary streams (creeks) for each branch of the river and relative contribution to load.
5. Conduct detailed sub-watershed investigations on tributaries with elevated pollutants to define as precisely as possible location specific sources of pollutants.

## II. Sources of Information

A compilation of water quality data from all available sources for the Raccoon River and Des Moines River was reported in the March 31, 2006 compilation report. These sources were used to prioritize which streams to investigate while the DNR interactive mapping website, which identifies registered feedlot sites and wastewater treatment facilities, was used to help identify specific potential sources of contamination within a watershed when investigating sources of contamination in impaired tributaries. The experience gained during the development of the monitoring activity in the Raccoon River was invaluable to this project and provided the framework for the current investigative approach to identifying specific contributors to water quality impairment (Section 3).

Unpublished snapshot data from the Beaver Creek Snapshot study headed by Steven Witmer (2006) has just been received but not yet reviewed. This data as well as Urban Watershed studies by DMWW and the Polk County Snapshot Study will be reviewed to help target sites within the Beaver Creek watershed for more in depth investigation.

Flow data from USGS stream gauging stations is used to document stream dynamics during sampling events. Load calculations will be done where possible when data collected is completed.

## DES MOINES AND RACCOON RIVER WATER QUALITY

Daily sampling of the Raccoon River and Des Moines River at the intake locations within the City of Des Moines provides detailed data on water quality dynamics in these rivers in response to weather conditions, watershed activities, and flow. Flow data from stream gauging stations in Des Moines provides a frame of reference for interpreting water quality data and for calculating contaminant loading to the Mississippi River and the Gulf of Mexico.

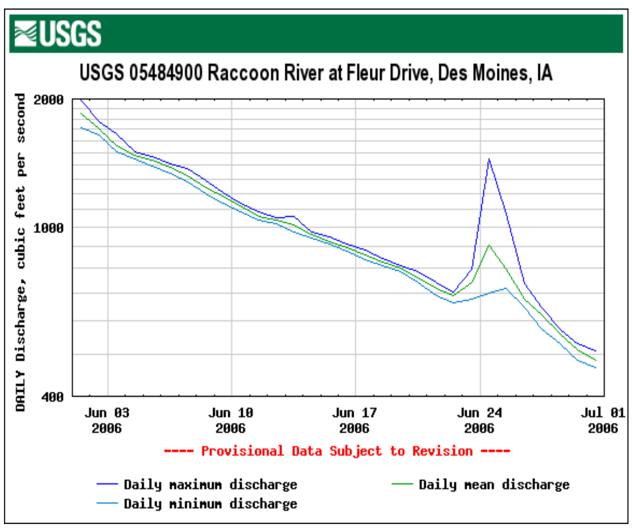


**fig 1. Raccoon River flow at DMWW 6/01/06 through 7/1/06**

### Raccoon River

Fig 1 displays Raccoon flow at Fleur Drive during the June through August sampling period.

Flow in the Raccoon River steadily decreased in June 2006. Only one small rain event occurred as seen in the small spike in flow on June 24. High algae counts were observed throughout this period and relatively low nitrate concentrations for this time of year. *E. coli* levels exceeded the water quality standard only during the runoff event and associated spike in turbidity (Table 1).

**(Table 1). Raccoon River Reference Data, June 2006**

| ST_CommonName | Raccoon River |
|---|---|

| Average of number | T_FullName | | | | | |
|---|---|---|---|---|---|---|
| IP_SampleDate | Chloride | Nitrate as N | Nitrite as N | Total Nitrogen as N | Turbidity | E. coli |
| 06/01/06 | 29.17 | 12.28 | | | 43.3 | 36 |
| 06/02/06 | 29.36 | 12.58 | | | 39.4 | 13 |
| 06/05/06 | 29.88 | 12.61 | | | 31.4 | 36 |
| 06/06/06 | 30.22 | 12.83 | | | 30.8 | 47 |
| 06/07/06 | 30.32 | 12.94 | | | 31.2 | |
| 06/08/06 | 30.84 | 12.97 | | | 30.3 | 33 |
| 06/09/06 | 31.21 | 12.80 | | | 31.3 | 21 |
| 06/12/06 | 31.27 | 12.39 | | 12.43 | 23.5 | 91 |
| 06/13/06 | 30.97 | 12.17 | | | 17.6 | 77 |
| 06/14/06 | 32.02 | 12.08 | | | 18.1 | 68 |
| 06/15/06 | 31.22 | 11.84 | | | 26.6 | 62 |
| 06/16/06 | 31.89 | 11.97 | | | 25.3 | 84 |
| 06/19/06 | 35.29 | 10.74 | 0.07 | 10.70 | 18.6 | 201 |
| 06/20/06 | 35.47 | 10.25 | 0.06 | | 29.7 | 58 |
| 06/21/06 | 35.22 | 10.03 | 0.06 | | 34.6 | 102 |
| 06/22/06 | 34.12 | 9.52 | | | 30.4 | 142 |
| 06/23/06 | 33.00 | 9.06 | 0.07 | | 31 | 91 |
| 06/26/06 | 33.42 | 8.05 | | 8.09 | 29.3 | 517 |
| 06/27/06 | 31.70 | 7.86 | | | 30.9 | 162 |
| 06/28/06 | 30.72 | 7.68 | | | 26.8 | 166 |
| 06/29/06 | 31.81 | 7.26 | 0.06 | | 17.1 | 133 |
| 06/30/06 | 32.17 | 6.73 | 0.07 | | 22.5 | 108 |

Total nitrogen concentrations were the same as nitrate concentrations. No detectable forms of nitrogen were present as ammonia, organic substances, or fixed algal biomass. Low *E. coli* counts suggest little fecal contamination present to contribute to TKN forms of nitrogen as well.

July had two measurable rain events (fig 2) which caused temporary spikes in turbidity and E. coli. Chloride levels dipped during runoff but very quickly returned to normal suggesting local urban runoff. Flow in the Raccoon River stayed below average. Nitrate concentrations decreased to non-detectable levels by the end of the month. Total nitrogen (TN) values were similar to nitrate. Two of the TN measurements that were higher than nitrate concentrations occurred during elevated E. coli counts (the mid July runoff event). Elevated TKN would be expected but the differences are small and may be a function of instrumentation variability rather than actual concentration.

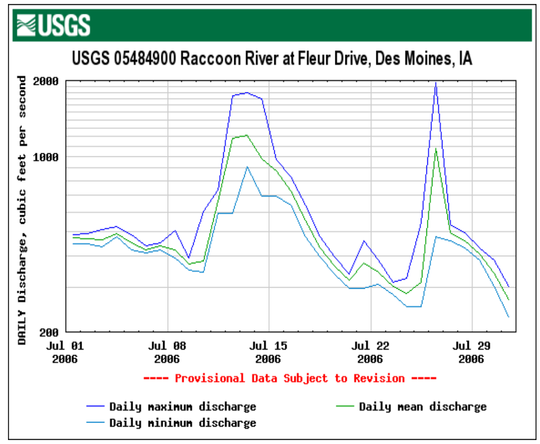


**fig 2. July flow in the Raccoon River at Des Moines**

**Table 1 continued (July 2006)**

| ST_CommonName | Raccoon River |
|---|---|

| Average of number | T_FullName | | | | | |
|---|---|---|---|---|---|---|
| IP_SampleDate | Chloride | Nitrate as N | Nitrite as N | Total Nitrogen as N | Turbidity | E. coli |
| 07/03/06 | 32.73 | 5.69 | | 5.20 | 19 | |
| 07/05/06 | 32.35 | 5.15 | 0.06 | | 26.2 | |
| 07/06/06 | 29.81 | 4.44 | | | 22.6 | 172 |
| 07/07/06 | 30.51 | 3.88 | | | 22.3 | 122 |
| 07/10/06 | 32.84 | 3.52 | | | 22 | 105 |
| 07/11/06 | 30.41 | 2.16 | | 2.54 | 43.3 | 3270 |
| 07/12/06 | 31.04 | 2.33 | | | 38 | 713 |
| 07/13/06 | 15.22 | 3.63 | 0.08 | | 341 | 1680 |
| 07/14/06 | 22.65 | 3.43 | | | 155 | 4020 |
| 07/17/06 | 26.87 | 3.98 | | 4.48 | 57.6 | 410 |
| 07/18/06 | 28.48 | 3.10 | | | 48.7 | 210 |
| 07/19/06 | 30.42 | 2.44 | | | 39.1 | 118 |
| 07/20/06 | 31.04 | 1.76 | | | 36.2 | 115 |
| 07/21/06 | 31.22 | 1.09 | | | 34.8 | 102 |
| 07/24/06 | 30.46 | 0.07 | | 1.46 | 35.5 | 16 |
| 07/25/06 | 32.22 | 0.09 | | | 34.2 | 58 |
| 07/26/06 | 14.40 | 0.36 | | | 275 | 8160 |
| 07/27/06 | 29.71 | 0.40 | | | 133 | 1040 |
| 07/28/06 | 29.45 | 0.44 | | | 43.4 | 579 |
| 07/31/06 | 29.16 | | | | 41.8 | 105 |

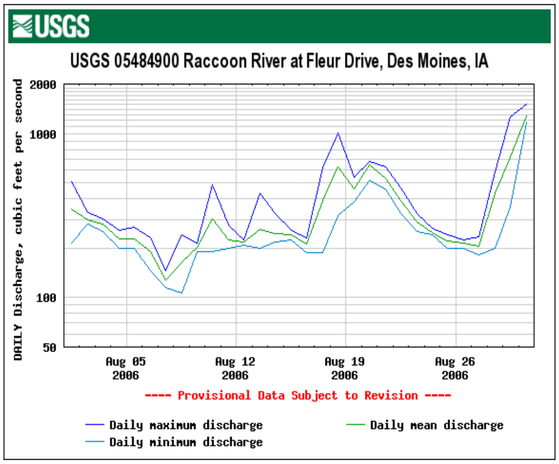


**fig 3. August flow in the Raccoon River**

August had several small runoff events in mid-month. Little change in turbidity was observed though a large change in *E. coli* counts occurred. Minor rain events toward the end of August are not clearly resolved but collectively contributed to an overall increase in flow that suggests some recharge in water tables and an increase in base flows (fig 3).

The jump in *E. coli* counts during a small increase in flow and turbidity suggests localized runoff of manure or concentrated wastes.

**Table 1 continued (August 2006)**

| ST_CommonName | Raccoon River |
|---|---|

| Average of number | T_FullName | | | | | |
|---|---|---|---|---|---|---|
| IP_SampleDate | Chloride | Nitrate as N | Total Nitrogen as N | Phosphorus-O as P | Turbidity | E. coli |
| 08/01/06 | 29.28 | | | | 38.5 | 387 |
| 08/02/06 | 30.67 | | | | 36.1 | |
| 08/03/06 | 31.18 | | | | 36.6 | 210 |
| 08/04/06 | 30.42 | | | | 30.5 | 248 |
| 08/07/06 | 29.96 | | 0.40 | | 31.9 | 56 |
| 08/08/06 | 30.07 | | | | 30.1 | 86 |
| 08/09/06 | 30.35 | | | | 7.66 | 69 |
| **08/10/06** | **37.32** | **0.09** | | | **9.58** | **5040** |
| 08/11/06 | 27.27 | 0.11 | | | 7.44 | 75 |
| 08/14/06 | 30.88 | | | | 7.6 | 613 |
| 08/15/06 | 30.72 | | 0.91 | | 5.68 | 615 |
| 08/16/06 | 29.90 | 0.07 | | | 4.57 | |
| 08/17/06 | 27.59 | 0.18 | | 0.56 | 57.2 | |
| 08/18/06 | 27.70 | 0.31 | | | 136 | |
| 08/21/06 | 18.70 | 0.95 | 1.38 | | 186 | |
| 08/22/06 | 23.13 | 1.56 | | | 114 | 615 |
| **08/23/06** | **27.94** | **1.33** | | | **79.3** | **6700** |
| 08/24/06 | 30.23 | 0.71 | | | 43.5 | 144 |
| **08/25/06** | **32.43** | | | | **55.7** | **6330** |
| **08/28/06** | **27.75** | **0.28** | | | **96.5** | **23820** |
| **08/29/06** | **31.97** | **0.69** | | | **60** | **5500** |
| **08/30/06** | **19.35** | **1.39** | | | **441** | **6867** |
| 08/31/06 | 24.35 | 3.30 | | | 142 | 86 |

## Des Moines River

The DMWW intake on the Des Moines River is approximately 4 miles below the confluence of Beaver Creek with the Des Moines River. Beaver Creek is the only perennial stream between the Saylorville Reservoir and the intake. During normal dry weather flow, discharge from the reservoir is at least an order of magnitude greater than flow in Beaver Creek (fig 4). Beaver Creek would have little impact on water quality in the Des Moines River during low flow and indeed little change occurs (Table 2).

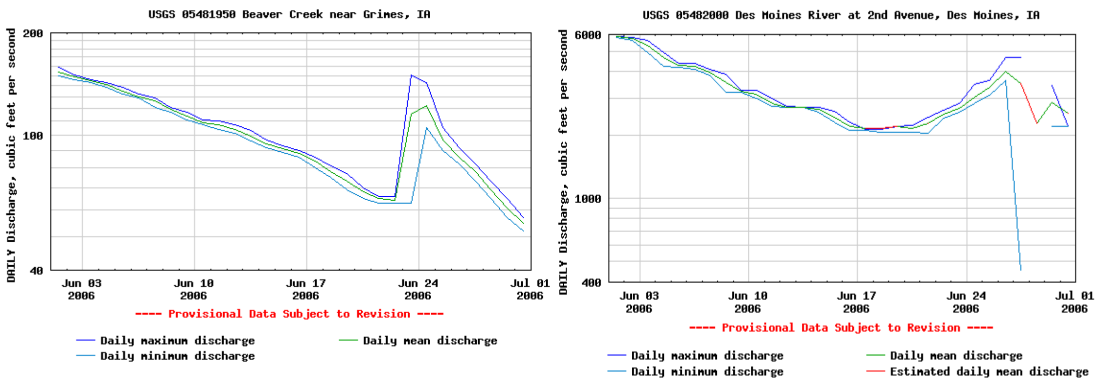


**Fig 4. Comparison in flow between Beaver Creek and the Des Moines River in July**

### Table 2 continued. June Water Quality at the Moines River Intake

| Average of number | T_FullName | | | | |
|---|---|---|---|---|---|
| IP_SampleDate | Chloride | Nitrate as N | Nitrite as N | Turbidity | E. coli |
| 06/01/06 | 24.40 | 10.29 | | 12.7 | 21 |
| 06/02/06 | 24.89 | 10.34 | | 11.5 | 21 |
| 06/05/06 | | 9.72 | | 15.3 | 24 |
| 06/06/06 | 24.59 | 9.45 | | 20.6 | 20 |
| 06/07/06 | 25.06 | 9.54 | | 16.4 | |
| 06/08/06 | 25.17 | 9.47 | 0.07 | 12.9 | 32 |
| 06/09/06 | 25.67 | 9.38 | | 15.1 | 40 |
| 06/12/06 | 25.37 | 9.11 | 0.10 | 14.9 | 40 |
| 06/13/06 | 25.54 | 8.97 | 0.12 | 12.4 | 40 |
| 06/14/06 | 26.01 | 9.09 | | 16.3 | 27 |
| 06/15/06 | 26.48 | 8.99 | 0.09 | 17.6 | 44 |
| 06/16/06 | 27.13 | 8.88 | 0.10 | 13.3 | 57 |
| 06/19/06 | 26.51 | 8.69 | 0.07 | 12.1 | 71 |
| 06/20/06 | 26.86 | 8.51 | 0.10 | 14.1 | 99 |
| 06/21/06 | 27.53 | 8.26 | 0.11 | 15.6 | 82 |
| 06/22/06 | 27.10 | 8.11 | 0.11 | 10.8 | 74 |
| 06/23/06 | 26.85 | 7.82 | 0.12 | 9.28 | 37 |
| 06/26/06 | 28.03 | 7.47 | 0.11 | 10.5 | 129 |
| 06/27/06 | 27.16 | 7.25 | 0.10 | 14.4 | 86 |
| 06/28/06 | 27.72 | 7.17 | 0.09 | 17.4 | 99 |
| 06/29/06 | 27.73 | 7.09 | 0.13 | 18.4 | 135 |
| 06/30/06 | 26.98 | 7.59 | 0.09 | 15.5 | 45 |

However in July, spikes in flow from two rain events in the Beaver Creek Watershed contributed to most of the increased flow in the Des Moines River (fig 5).

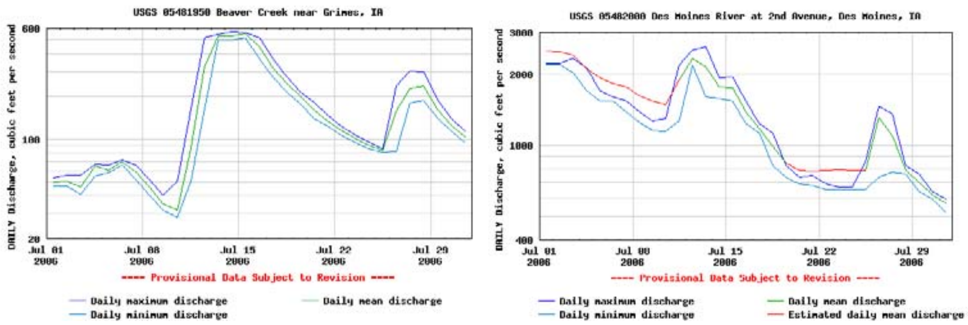


**Fig 5, Comparison in July flow rates in Beaver Creek and the Des Moines River.**

This produced bumps in turbidity, indicating erosion and transport from the landscape and stream. *E. coli* counts however increased nearly two orders of magnitude (Table 2). Little change is water chemistry occurred.

## Table 2 (continued), July Water Quality in the Des Moines River

| Average of number | T_FullName | | | | |
|---|---|---|---|---|---|
| IP_SampleDate | Chloride | Nitrate as N | Nitrite as N | Turbidity | E. coli |
| 07/03/06 | 27.62 | 7.38 | 0.12 | 10.8 | |
| 07/05/06 | 26.67 | 7.57 | 0.09 | 14.2 | |
| 07/06/06 | 26.45 | 7.27 | 0.07 | 15 | 82 |
| 07/07/06 | 26.76 | 7.24 | 0.10 | 12.2 | 46 |
| 07/10/06 | 26.94 | 6.67 | 0.09 | 12.9 | 24 |
| 07/11/06 | | | | 14.9 | 579 |
| 07/12/06 | 26.37 | 6.24 | 0.09 | 13.4 | 315 |
| **07/13/06** | | | | **29.5** | **1733** |
| 07/14/06 | 26.01 | 7.70 | 0.13 | 19.1 | 556 |
| 07/17/06 | 26.79 | 8.11 | 0.18 | 21.1 | 436 |
| 07/18/06 | 26.77 | 7.13 | 0.11 | 19.7 | 281 |
| 07/19/06 | 27.45 | 6.80 | 0.14 | 19.6 | 281 |
| 07/20/06 | 27.32 | 6.18 | 0.15 | 18.9 | 276 |
| 07/21/06 | 27.36 | 5.63 | 0.13 | 17.1 | 135 |
| 07/24/06 | 27.53 | 4.85 | 0.20 | 18.2 | 105 |
| 07/25/06 | 26.64 | 4.57 | 0.23 | 18.5 | 51 |
| **07/26/06** | **20.86** | **3.09** | **0.23** | **72.7** | **3730** |
| **07/27/06** | **26.88** | **3.64** | **0.43** | **30.8** | **1460** |
| **07/28/06** | **27.31** | **5.30** | **0.32** | **21.6** | **2419** |
| 07/31/06 | 28.44 | 3.82 | 0.38 | 21.8 | 152 |

August flow in Beaver Creek was slightly elevated in mid-month suggesting frequent light rain with little runoff. The spike in flow at the end of August indicates a runoff event. The Des Moines River flow was more variable and complex (fig 6).

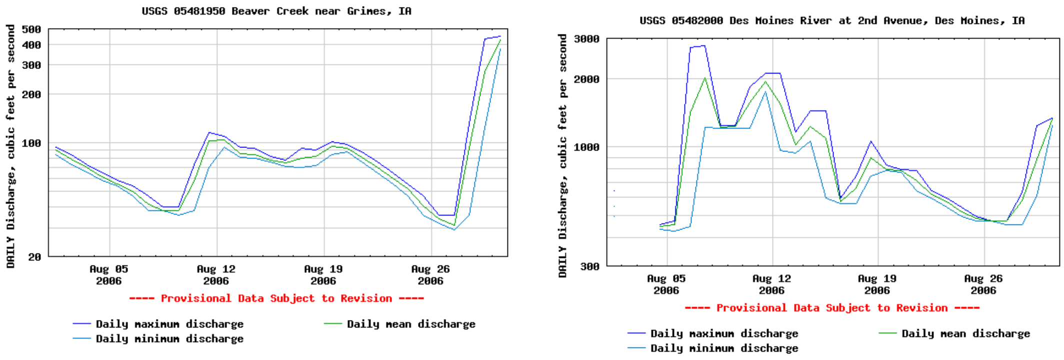


**fig 6. August 2006 flow in Beaver Creek and Des Moines River in Des Moines**

Chemistry data in August (Table 2) stayed remarkably consistent, suggesting change in discharge from Saylorville as the cause in variable flow.

**Table 2 (continued) August Water Quality in the Des Moines River**

| Average of number | T_FullName | | | | | |
|---|---|---|---|---|---|---|
| IP_SampleDate | Chloride | Nitrate as N | Nitrite as N | Phosphorus-O as P | Turbidity | E. coli |
| 08/01/06 | 28.48 | 3.62 | 0.32 | | 17.9 | 109 |
| 08/02/06 | 28.52 | 3.24 | 0.31 | | 15.7 | |
| 08/03/06 | 28.71 | 3.32 | 0.30 | | 12.6 | 91 |
| 08/04/06 | 28.52 | 2.87 | 0.22 | | 10.6 | 29 |
| 08/07/06 | 28.87 | 2.02 | 0.29 | | 16.2 | 42 |
| 08/08/06 | | | | | 10.7 | 27 |
| 08/09/06 | 28.76 | 2.19 | 0.15 | | 10.2 | 22 |
| 08/10/06 | 28.65 | 2.34 | 0.08 | | 15.6 | 114 |
| 08/11/06 | 29.17 | 2.36 | 0.08 | | 17.1 | 50 |
| **08/14/06** | **28.84** | **2.70** | **0.08** | | **13.1** | **3100** |
| 08/15/06 | 27.87 | 2.49 | 0.12 | | 10.2 | |
| 08/16/06 | 28.12 | 2.65 | 0.09 | | 12.3 | |
| 08/17/06 | 27.15 | 2.57 | | | 19.7 | |
| 08/18/06 | 24.87 | 2.44 | | 0.06 | 55 | |
| 08/21/06 | 27.31 | 3.04 | | | 15.2 | |
| 08/22/06 | | | | | 13.6 | |
| 08/23/06 | 27.76 | 1.30 | | | 12.9 | 36 |
| 08/24/06 | 27.98 | 2.82 | | | 6.08 | 43 |
| **08/25/06** | **28.40** | **2.76** | | | **14.1** | **2490** |
| 08/28/06 | 27.30 | 1.90 | 0.06 | | 14.6 | 579 |
| 08/29/06 | | | | | 17.6 | 727 |
| **08/30/06** | **27.50** | **3.43** | **0.11** | **0.08** | **14.1** | **1986** |
| **08/31/06** | **27.91** | **4.22** | **0.13** | **0.07** | **19.5** | **1203** |

Rainfall distribution and resulting hydrology during the quarter was unusual. The months of May through July were the driest months on record in northwest Iowa while state-wide, August was the wettest month since May 2004. The rainfall distribution, however, was highly variable. In northern Iowa, Algona had 6.9 inches of rain on August 1 alone while Dubuque had a monthly total of 1.97 inches (Harry Hillaker, State Climatologist). The heavy rains in the northern area of the watershed probably account for the variability in discharge from the Saylorville Reservoir. Rainfall amounts and distribution have not yet been collected but will be invaluable to better determine source and transport of *E. coli* into the Des Moines and Raccoon Rivers. Obviously, the variability in *E. coli* counts within a watershed can be a function of the transport of fecal material well as distribution of livestock numbers in the watershed. Runoff events in small local watersheds can produce a heavy fecal load to the major rivers and cause large changes in *E. coli* counts.

## SURVEY ANALYSIS TO IDENTIFY STUDY SITES

The extensive snapshot monitoring of tributaries in the Raccoon River has demonstrated considerable variability between tributaries. Most of the differences in nitrate contribution is related to landform and land use. More recent work with *E. coli* shows considerable variation between tributaries under similar rainfall and flow conditions and even within a tributary. Historic snapshot data has been a major source of information used for the selection of tributaries for the more in-depth investigation presented in this report. Therefore a thorough review of information collected over the years of the Raccoon River Volunteer Monitoring Study is presented for an understanding of the site selection process. Experience with the snapshot project also demonstrated the importance of logistics in the planning of sample collection and analyses. This is especially true for large watersheds where travel time is considerable and timing of sample collection is important if not critical.

**Raccoon River Volunteer Monitoring Project**

Specific information on sources of contamination within the Raccoon River watershed (fig 7) is limited primarily to a study initiated as a synoptic survey in 1999 through funding by an EPA grant and continued by the Agricultural Clean Water Alliance (ACWA). The initial study included weekly monitoring of all perennial streams in this project area for nitrate, ammonia, and turbidity from April through November. Biweekly analysis was performed in the more remote tributaries. Des Moines Water Works staff sampled the main stem tributaries three (3) times per week for these parameters as well as for Total Coliforms and *E. coli.* This study and the on-going monitoring by the ACWA has shown nitrate contribution to the Raccoon River to be a primarily a function of landform and related land-use. Tributaries within the Des Moines Lobe landform consistently had elevated nitrate concentrations while tributaries in the Southern Iowa Drift Plain (SIDP) seldom exceeded the water quality standard. During that study, wet weather conditions prevailed from April through mid July while drought conditions prevailed through November. During wet weather with high ground water conditions, differences in water quality correlated primarily to landform and land-use characteristics (fig 8). During dry weather, point source contributions became apparent. Outlet Creek (blue arrow) changed from below average nitrate concentrations in the spring to very high nitrate concentrations in the dry fall. The cause was eventually traced to a waste water treatment facility receiving high strength meat processing waste.

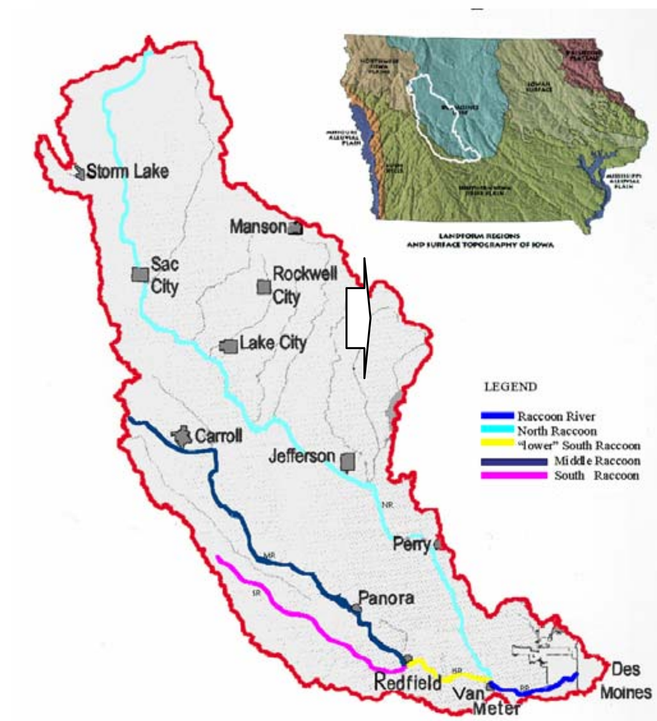


**fig 7. Raccoon River Watershed**

*E. coli* contamination was also shown to be related to landform topography and land-use. E. coli counts in the South Raccoon were much higher than in other tributaries during runoff events (fig 9). The hilly topography promotes erosion and overland runoff to well established drainage systems.

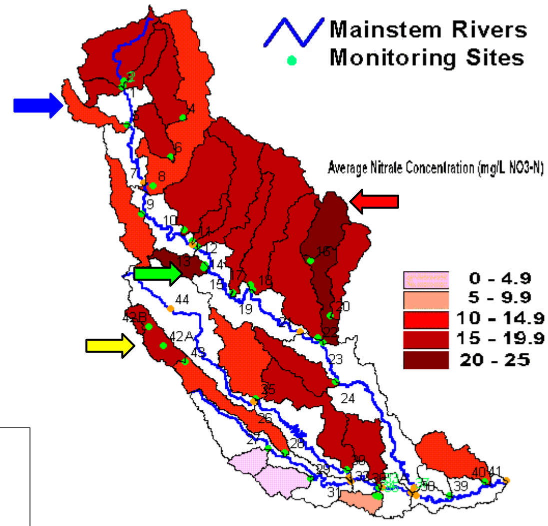


**fig 8 Nitrate distribution in the Raccoon**

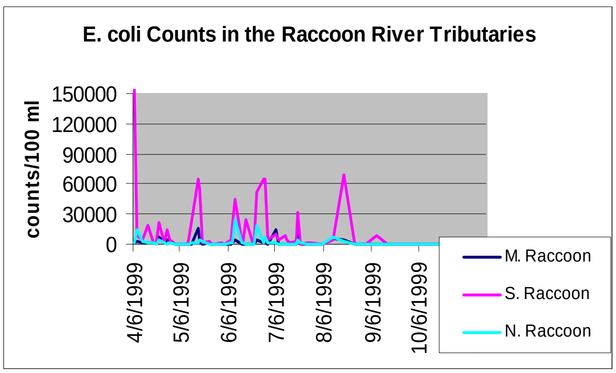


**fig 9 E. coli count comparison in main stem tributaries**

The relatively short travel distance and steeper stream gradient of the South Raccoon compressed peaks in flow and energy of transport per unit area (fig 10). These spikes in flow suggests that the higher turbidity and E. coli counts in the South Raccoon are perhaps more a function of run-off and transport energy than amount of fecal material in the watershed. Measures to reduce erosion and protect manure storage and holding areas are therefore more critical in the SIDP.

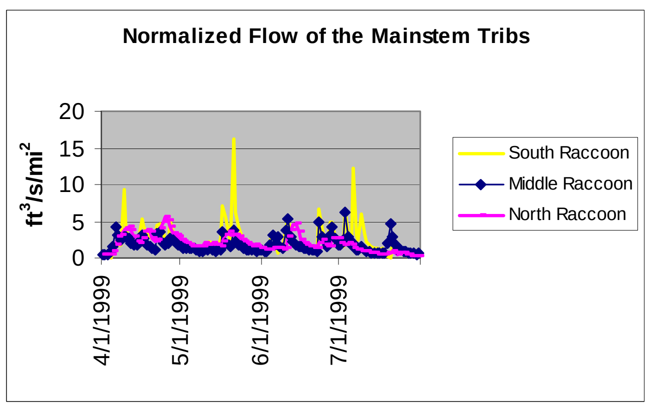


**fig 10. Normalized flow in the tree main stem tributaries**

Cattle grazing on the steep hillsides with direct access to streams for watering are especially common in the South Raccoon Watershed and may be a contributing factor to the higher E. coli counts.

Anomalies in stream water quality within a landform and especially within the same tributary raises the specter of point-source contributors to water quality impairments or questionable agricultural practices within a defined area. During a routine monitoring event, a sample collected from Elk Run Creek (fig 2, green arrow) was heavily contaminated with manure. This observation and the chronically-high nitrate levels in this watershed suggested the possibility that manure application may be a contributing factor to elevated nitrate levels in this and other tributaries. High nitrate concentrations in Buttrick Creek (fig 2, red arrow) however could not be traced to point source contamination or unusual agricultural activity.

In 2005, the ACWA supported a more comprehensive suite of analyses for all sites including chloride, nitrite, and phosphorus with E. coli added to designated sites. Chloride and o-phosphorus analysis especially showed significant point source contribution to flow during dry weather but these sources did not necessarily elevate nitrate concentrations or E. coli counts to the receiving stream. Brushy Creek, a major tributary of the South Raccoon (yellow arrow) showed anomalously high nitrate concentrations, especially in the upper reaches of the watershed. Chronically elevated E. coli counts during dry weather with normal chloride values and exceptionally high counts during rain events suggested regional manure management issues rather than domestic input.

Growing public and utility concerns about high levels of *E. coli* in the Raccoon River, estrogens, and antibiotics further encouraged a more comprehensive assessment of stream contamination. Therefore *E. coli* testing was performed on all tributary samples collected by ACWA volunteers as a synoptic survey of the entire watershed in May 2006. Counts for most sites were quite low because of the dry weather and low flow. Nonetheless, a number of sites had counts over 2000CFU/100ml. Water chemistry data showed the influence of wastewater discharge at several of these sites. Sites with counts >2000CFU/100 ml or other fecal indicators were monitored for *E. coli* through early September. Sites outside the designated area of study are presented in Table 3 as a frame of reference for water quality flowing into the study area.

**Table 3a. Water Quality in the North Raccoon at Sac City and Tributaries**

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 02 | North Raccoon 1 | 04/20/06 | 23.65 | 17.50 | <0.1 | 2.5 | |
| | | 05/04/06 | 24.00 | 20.00 | <0.1 | 21.0 | 161 |
| | | 05/18/06 | 22.48 | 18.21 | <0.1 | 86.8 | 228 |
| | | 06/01/06 | 21.22 | 17.17 | <0.1 | 35.4 | 727 |
| | | 06/15/06 | 21.63 | 16.35 | <0.1 | 38.1 | |
| | | 06/29/06 | 21.89 | 12.36 | <0.1 | 26.2 | |
| | | 07/13/06 | 20.30 | 5.10 | <0.1 | 22.5 | |
| | | 07/27/06 | 18.80 | 0.43 | <0.1 | 12.4 | |
| | | 08/10/06 | 16.33 | 0.56 | 0.08 | 25.4 | |
| | | 08/24/06 | 19.56 | 0.13 | <0.1 | 15.5 | |
| | | 09/07/06 | 61.08 | 0.09 | <0.1 | 17.9 | |
| 03 | Poor Farm Creek | 04/20/06 | 28.66 | 19.15 | <0.1 | 3.1 | 190 |
| | | 05/04/06 | 28.58 | 21.00 | <0.1 | 8.4 | 408 |
| | | 05/18/06 | 27.39 | 19.52 | <0.1 | 10.7 | 517 |
| | | 06/01/06 | 26.42 | 18.74 | <0.1 | 34.3 | 517 |
| | | 06/15/06 | 26.41 | 17.91 | <0.1 | 15.3 | 1203 |
| | | 06/29/06 | 27.53 | 14.33 | <0.1 | 20.0 | 2282 |
| | | 07/13/06 | 32.68 | 6.73 | <0.1 | 24.7 | 200 |
| | | 07/27/06 | 48.60 | 1.40 | <0.1 | 33.5 | 630 |
| | | 08/10/06 | 45.37 | 0.91 | 0.11 | 46.1 | 410 |
| | | 08/24/06 | 44.01 | 1.48 | <0.1 | 27.8 | 850 |
| | | 09/07/06 | 44.35 | 0.36 | <0.1 | 40.5 | 740 |
| 04 | Little Cedar Ck | 04/20/06 | 26.56 | 18.79 | <0.1 | 3.8 | |
| | | 05/04/06 | 26.36 | 20.29 | 0.07 | 12.2 | |
| | | 05/18/06 | 25.57 | 18.78 | <0.1 | 11.3 | 155 |
| | | 06/01/06 | 25.09 | 18.80 | <0.1 | 31.2 | 196 |
| | | 06/15/06 | 26.19 | 19.18 | <0.1 | 22.5 | |
| | | 06/29/06 | 25.80 | 16.73 | <0.1 | 18.2 | |
| | | 07/13/06 | 26.20 | 10.51 | <0.1 | 30.9 | |
| | | 07/27/06 | 28.80 | 1.04 | <0.1 | 34.6 | |
| | | 08/10/06 | 27.79 | 0.64 | 0.08 | 51.6 | |
| | | 08/24/06 | 30.24 | 0.15 | <0.1 | 19.5 | |
| | | 09/07/06 | 31.55 | 0.10 | <0.1 | 22.6 | |
| 04A | Big Cedar Creek | 04/20/06 | 26.27 | 19.42 | <0.1 | 9.4 | 285 |
| | | 05/04/06 | 26.29 | 21.67 | <0.1 | 15.7 | 226 |
| | | 05/18/06 | 26.50 | 19.73 | <0.1 | 10.7 | 118 |
| | | 06/01/06 | 26.12 | 18.68 | <0.1 | 28.8 | 1120 |
| | | 06/15/06 | 26.08 | 19.34 | <0.1 | 18.8 | 579 |
| | | 06/29/06 | 25.90 | 16.05 | <0.1 | 10.7 | 350 |
| | | 07/13/06 | 26.91 | 8.60 | <0.1 | 8.2 | 100 |
| | | 07/27/06 | 29.10 | 0.53 | <0.1 | 5.2 | |
| | | 08/10/06 | 26.58 | 0.30 | <0.1 | 15.0 | 310 |
| | | 08/24/06 | 30.39 | 0.12 | <0.1 | 20.0 | 100 |
| | | 09/07/06 | 31.41 | 0.11 | <0.1 | 23.1 | |

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 05 | Outlet Creek | 04/20/06 | 60.65 | 13.20 | 1.44 | 70.1 | 980 |
| | | 05/04/06 | 56.05 | 9.04 | 0.70 | 78.6 | 510 |
| | | 05/18/06 | 58.52 | 12.45 | 1.21 | 41.5 | 1986 |
| | | 06/01/06 | 109.59 | 23.27 | 3.09 | 32.0 | 2419 |
| | | 06/15/06 | 97.98 | 28.94 | 3.56 | 32.3 | |
| | | 06/29/06 | 137.35 | 27.45 | 4.89 | 55.0 | 3872 |
| | | 07/13/06 | 184.00 | 36.90 | 5.14 | 76.8 | 110 |
| | | 07/27/06 | 218.00 | 44.29 | 5.03 | 69.6 | 740 |
| | | 08/10/06 | 195.69 | 40.44 | 3.91 | 35.5 | 1350 |
| | | 08/24/06 | 222.31 | 40.07 | 4.40 | 45.3 | 850 |
| | | 09/07/06 | 221.27 | 43.34 | 5.28 | 31.7 | 1610 |
| 06 | Prairie Creek | 04/20/06 | 26.68 | 18.17 | <0.1 | 4.3 | |
| | | 05/04/06 | 27.19 | 21.17 | <0.1 | 12.2 | 1081 |
| | | 05/18/06 | 26.94 | 19.40 | <0.1 | 36.6 | 1733 |
| | | 06/01/06 | 26.24 | 19.62 | <0.1 | 33.1 | 194 |
| | | 06/15/06 | 29.48 | 17.37 | <0.1 | 36.5 | |
| | | 06/29/06 | 31.74 | 11.31 | <0.1 | 11.5 | |
| | | 07/13/06 | 42.14 | 3.75 | <0.1 | 5.9 | |
| | | 07/27/06 | 50.90 | 0.41 | <0.1 | 7.4 | 310 |
| | | 08/10/06 | 56.92 | 0.11 | <0.1 | 16.0 | 310 |
| | | 08/24/06 | 70.23 | | <0.1 | 25.5 | 410 |
| | | 09/07/06 | 84.98 | | <0.1 | 13.6 | 546 |
| 07 | North Raccoon 2 | 04/20/06 | 28.23 | 17.20 | 0.15 | 20.5 | 79 |
| | | 05/04/06 | 27.74 | 19.01 | 0.14 | 33.4 | 246 |
| | | 05/18/06 | 28.08 | 17.74 | 0.13 | | 112 |
| | | 06/01/06 | 29.15 | 17.72 | 0.17 | 26.4 | 308 |
| | | 06/15/06 | 30.15 | 17.25 | <0.1 | 27.4 | 411 |
| | | 06/29/06 | 38.49 | 14.12 | 0.42 | 22.0 | 471 |
| | | 07/13/06 | 47.71 | 9.89 | 0.41 | 19.6 | 100 |
| | | 07/27/06 | 56.30 | 5.50 | 0.33 | 31.8 | 520 |
| | | 08/10/06 | 72.97 | 6.42 | 0.46 | 37.4 | 980 |
| | | 08/24/06 | 70.88 | 8.45 | 0.69 | 29.2 | 1090 |
| | | 09/07/06 | 101.06 | 15.69 | 1.34 | 22.7 | 512 |

The influence of waste water discharge to Outlet Creek was profound during this dry summer (elevated chloride, o-phosphorus, and nitrate concentrations) and is observed in the North Raccoon at site 7. *E. coli* counts in Outlet Creek are somewhat higher than other tributaries. It was assumed to be from wastewater treatment but was not verified. There are stream-side cattle grazing that could also contribute to elevated *E. coli* counts. Elevated chloride in Prairie Creek (site 6) toward the end of the summer suggests wastewater discharge but no discernable contribution to nutrients or *E. coli* is apparent.

**Table 3b. Water Quality in the North Raccoon Between Sac City and Lanesboro**

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 08 | Cedar Creek | 04/20/06 | 27.25 | 18.23 | <0.1 | 11.5 | 770 |
| | | 05/04/06 | 26.10 | 21.28 | <0.1 | 16.5 | 598 |
| | | 05/18/06 | 25.98 | 19.05 | <0.1 | 18.5 | 248 |
| | | 06/01/06 | 25.24 | 18.53 | <0.1 | 27.6 | 1413 |
| | | 06/15/06 | 25.10 | 17.77 | <0.1 | 27.8 | 649 |
| | | 06/29/06 | 26.27 | 13.41 | <0.1 | 14.8 | |
| | | 07/13/06 | 26.31 | 5.80 | <0.1 | 7.3 | 310 |
| | | 07/27/06 | 29.50 | 0.19 | <0.1 | 7.1 | |
| | | 08/10/06 | 26.33 | 0.25 | <0.1 | 28.3 | |
| | | 08/24/06 | 29.64 | 0.18 | <0.1 | 6.6 | |
| | | 09/07/06 | 34.71 | 0.09 | <0.1 | 6.1 | |
| 09 | Indian Creek | **04/20/06** | **28.62** | **9.28** | **<0.1** | **18.6** | **1300** |
| | | **05/04/06** | **25.31** | **13.76** | **<0.1** | **51.7** | **2310** |
| | | **05/18/06** | **24.83** | **12.88** | **<0.1** | **31.8** | **1460** |
| | | **06/01/06** | **26.18** | **13.97** | **<0.1** | **52.1** | **2247** |
| | | 06/15/06 | 24.24 | 13.40 | <0.1 | 48.5 | |
| | | 06/29/06 | 28.97 | 7.34 | <0.1 | 19.0 | 1112 |
| | | 07/13/06 | 25.72 | 2.87 | 0.11 | 27.3 | |
| | | 07/27/06 | 31.00 | 1.03 | 0.18 | 38.3 | 740 |
| | | 08/10/06 | 39.55 | <0.05 | <0.1 | 60.5 | 850 |
| | | 08/24/06 | 39.58 | 0.76 | <0.1 | 11.1 | 200 |
| | | 09/07/06 | 51.65 | 1.44 | 0.13 | 12.8 | 3255 |
| 10 | Camp Creek | 04/20/06 | 30.69 | 18.39 | <0.1 | 15.6 | |
| | | 05/04/06 | 33.60 | 21.49 | <0.1 | 38.2 | 833 |
| | | 05/18/06 | 29.64 | 20.11 | <0.1 | 20.2 | 119 |
| | | 06/01/06 | 30.10 | 19.76 | <0.1 | 22.0 | 770 |
| | | 06/15/06 | 31.26 | 18.88 | <0.1 | 39.4 | |
| | | 06/29/06 | 31.57 | 14.18 | <0.1 | 15.7 | |
| | | 07/13/06 | 33.55 | 4.48 | <0.1 | 14.9 | |
| | | 07/27/06 | 32.70 | 0.07 | <0.1 | 30.4 | |
| | | 08/10/06 | 22.46 | 0.51 | 0.49 | 130.0 | |
| | | 08/24/06 | 51.35 | | <0.1 | 30.1 | |
| | | 09/07/06 | 33.87 | 0.11 | <0.1 | 30.2 | |
| 11 | Prairie Creek,South | 04/20/06 | 32.68 | 19.83 | <0.1 | 5.6 | 64 |
| | | 05/04/06 | 32.50 | 23.63 | <0.1 | 10.9 | 369 |
| | | 05/18/06 | 31.66 | 21.38 | <0.1 | 6.3 | 365 |
| | | 06/01/06 | 32.19 | 21.53 | <0.1 | 13.4 | 461 |
| | | 06/15/06 | 32.06 | 20.81 | <0.1 | 21.5 | 1300 |
| | | 06/29/06 | 31.92 | 16.84 | <0.1 | 20.5 | 1664 |
| | | 07/13/06 | 29.11 | 9.68 | <0.1 | 19.8 | 740 |
| | | 07/27/06 | 30.50 | 1.55 | <0.1 | 8.5 | 100 |
| | | 08/10/06 | 23.00 | 1.30 | <0.1 | 58.0 | 7220 |
| | | 08/24/06 | 24.59 | 0.54 | <0.1 | 28.8 | 100 |
| | | 09/07/06 | 23.74 | 0.61 | <0.1 | 30.9 | 100 |

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 13 | North Raccoon 3 | 04/20/06 | 29.39 | 17.67 | <0.1 | 22.8 | |
| | | 05/04/06 | 28.01 | 20.30 | 0.13 | 47.4 | 663 |
| | | 05/18/06 | 30.30 | 18.09 | <0.1 | 26.2 | 172 |
| | | 06/01/06 | 29.71 | 17.88 | <0.1 | 25.0 | 228 |
| | | 06/15/06 | 37.92 | 17.20 | <0.1 | 25.7 | |
| | | 06/29/06 | 31.73 | 13.38 | 0.11 | 16.2 | |
| | | 07/13/06 | 40.49 | 7.16 | 0.11 | 15.8 | |
| | | 07/27/06 | 42.30 | 0.34 | <0.1 | 23.7 | |
| | | 08/10/06 | 35.84 | <0.05 | <0.1 | 32.0 | |
| | | 08/24/06 | 50.42 | 2.38 | 0.11 | 17.9 | |
| | | 09/07/06 | 53.19 | 3.40 | 0.10 | 14.1 | |

In this downstream section of the North Raccoon, Indian Creek (site 9) had lower nitrate concentrations than other tributaries but somewhat elevated turbidity, o-phos concentrations, and *E. coli* counts. This tributary runs along the lateral moraine of the Des Moines Lobe where hummocky terrain enhances runoff. Grazing and livestock operations would likely be more common in this topography to contribute to elevated *E. coli* counts and phosphorus but on-site observation did not clearly support this hypothesis.

Tributaries in the section between Lanesboro and Jefferson had considerable variability in water quality (Table 3c). Lake Creek had elevated chloride during the dry summer months indicating wastewater discharge but otherwise water chemistry and E. coli counts were typical for Des Moines Lobe tributaries. Elk Run Creek had high nitrate levels in late spring. Most tributaries had very high E. coli counts during the mid-August rain.

**Table 3c. Water Quality in the North Raccoon Between Lanesboro and Jefferson**

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 12 | Lake Creek | 04/20/06 | 38.33 | 16.75 | <0.1 | 22.2 | 91 |
| | | 05/04/06 | 34.29 | 20.01 | <0.1 | 58.6 | 860 |
| | | 05/18/06 | 55.36 | 17.64 | <0.1 | 27.7 | 365 |
| | | 06/01/06 | 42.16 | 18.41 | <0.1 | 43.4 | 1299 |
| | | **06/15/06** | **112.86** | **17.32** | **<0.1** | **36.1** | **687** |
| | | 06/29/06 | 47.17 | 14.49 | <0.1 | 12.0 | |
| | | **07/13/06** | **89.81** | **5.82** | **<0.1** | **10.7** | **310** |
| | | **07/27/06** | **98.60** | **<0.05** | **<0.1** | **25.5** | |
| | | **08/10/06** | **110.03** | **<0.05** | **<0.1** | **43.0** | |
| | | **08/24/06** | **170.85** | **<0.05** | **<0.1** | **22.0** | |
| | | **09/07/06** | **127.66** | **<0.05** | **<0.1** | **17.6** | |
| | | | | | | | |

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 14 | Elk Run A | **04/20/06** | **39.09** | **14.31** | **<0.1** | **14.9** | **2419** |
| | | **05/04/06** | **38.54** | **32.73** | **<0.1** | **13.0** | **3873** |
| | | **06/01/06** | **35.38** | **26.31** | **<0.1** | **20.0** | **4611** |
| | | **06/15/06** | **34.07** | **21.64** | **<0.1** | **9.4** | **3076** |
| | | 06/29/06 | 26.48 | 4.75 | <0.1 | 3.4 | 988 |
| | | 07/13/06 | 22.53 | 0.33 | 0.10 | 7.8 | 310 |
| | | 07/27/06 | 3.50 | 0.15 | <0.1 | 9.2 | 200 |
| | | **08/10/06** | **128.46** | **4.03** | **3.42** | **227.0** | **>2419200** |
| | | 08/24/06 | 10.59 | 0.10 | 0.25 | 44.5 | 2230 |
| | | 09/07/06 | 11.69 | 0.55 | 0.12 | 12.8 | 410 |
| 14A | North Raccoon | 04/20/06 | 29.31 | 17.59 | <0.1 | 25.9 | 67 |
| | | 05/04/06 | 27.80 | 20.45 | 0.11 | 51.9 | 798 |
| | | 05/18/06 | 30.22 | 18.17 | <0.1 | 24.6 | 2382 |
| | | 06/01/06 | 29.45 | 17.60 | <0.1 | 51.1 | 298 |
| | | 06/15/06 | 37.47 | 16.97 | <0.1 | 26.7 | 411 |
| | | 06/29/06 | 32.32 | 13.15 | <0.1 | 12.4 | 233 |
| | | 07/13/06 | 38.76 | 6.83 | 0.10 | 10.9 | |
| | | 07/27/06 | 38.30 | 0.06 | <0.1 | 26.8 | 100 |
| | | **08/10/06** | **34.73** | | **<0.1** | **38.0** | **8330** |
| | | 08/24/06 | 46.16 | 1.55 | <0.1 | 18.1 | 310 |
| | | 09/07/06 | 48.03 | 2.48 | <0.1 | 13.1 | 216 |
| 17 | Cedar Creek | 04/20/06 | 36.74 | 16.15 | <0.1 | 15.1 | 88 |
| | | 05/04/06 | 34.16 | 21.36 | <0.1 | 63.0 | 410 |
| | | 05/18/06 | 35.93 | 19.39 | 0.25 | 32.3 | 361 |
| | | 06/01/06 | 34.75 | 18.93 | <0.1 | 51.3 | 1299 |
| | | 06/15/06 | 43.73 | 18.49 | <0.1 | 35.9 | 1986 |
| | | 06/29/06 | 55.30 | 13.94 | <0.1 | 21.5 | 882 |
| | | 07/13/06 | 41.79 | 6.65 | <0.1 | 21.9 | |
| | | 07/27/06 | 39.60 | <0.05 | <0.1 | 30.4 | 300 |
| | | **08/10/06** | **119.35** | **0.21** | **<0.1** | **67.0** | **4870** |
| | | 08/24/06 | 110.84 | <0.05 | <0.1 | 29.0 | 200 |
| | | 09/07/06 | 158.00 | <0.05 | <0.1 | 22.8 | 173 |
| 19 | Purgatory Creek | 04/20/06 | 31.16 | 15.12 | <0.1 | 14.6 | 166 |
| | | 05/04/06 | 33.07 | 20.54 | <0.1 | 68.6 | |
| | | 05/18/06 | 31.98 | 18.59 | <0.1 | 32.8 | 411 |
| | | 06/01/06 | 32.03 | 18.08 | <0.1 | 68.2 | 701 |
| | | 06/15/06 | 31.60 | 17.19 | <0.1 | 38.0 | |
| | | 06/29/06 | 30.01 | 11.88 | <0.1 | 17.1 | 2755 |
| | | 07/13/06 | 27.91 | 3.74 | <0.1 | 14.5 | 520 |
| | | 07/27/06 | 21.10 | <0.05 | <0.1 | 40.6 | 30760 |
| | | **08/10/06** | **30.29** | **0.33** | **0.43** | **106.0** | **>241920** |
| | | 08/24/06 | 19.56 | <0.05 | <0.1 | 33.0 | 1730 |
| | | 09/07/06 | 16.87 | 0.08 | <0.1 | 22.7 | 3990 |
| 21 | N Raccoon - Henderson | 04/20/06 | 31.00 | 16.87 | <0.1 | 43.9 | 46 |
| | | 05/04/06 | 28.56 | 20.62 | 0.14 | 97.5 | 740 |

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| | | 05/18/06 | 30.85 | 17.81 | <0.1 | 29.4 | 194 |
| | | 06/01/06 | 31.63 | 16.57 | <0.1 | 44.6 | 102 |
| | | 06/15/06 | 41.04 | 15.90 | <0.1 | 55.2 | 119 |
| | | 06/29/06 | 35.02 | 11.58 | <0.1 | 21.1 | 122 |
| | | 07/13/06 | 37.59 | 4.57 | <0.1 | 20.8 | |
| | | 07/27/06 | 35.50 | <0.05 | <0.1 | 32.5 | |
| | | 08/10/06 | 42.18 | 0.26 | <0.1 | 67.0 | |
| | | 08/24/06 | 45.28 | <0.05 | <0.1 | 31.0 | |
| | | 09/07/06 | 46.96 | 0.56 | <0.1 | 27.5 | |

The elevated turbidity in Elk Run Creek and Purgatory Creek on August 10 relative to the North Raccoon and other tributaries suggests a local heavy rain that produced greater runoff of fecal material. *E. coli* analysis was not performed on the downstream North Raccoon location (site 21) so the impact of Purgatory Creek and Elk Run flow on E. coli counts in the North Raccoon is unknown. The above data on individual tributaries show point source contributors and considerable variability in E. coli contribution between tributaries and the impact of local rainfall. These are all blended together to contribute to the water quality in the North Raccoon at Jefferson (site 21). The blending together of all these sources gives the appearance of general non-point source contamination. The North Raccoon water quality within the study area shows a similar pattern (Table 3d). During low flow, point sources become evident in the smaller tributaries. Elevated chloride and o-phosphorus in West Buttrick Creek (site 16) indicates wastewater discharge contribution that is no longer evident downstream of the confluence with East Buttrick Creek at site 23. Two samples collected upstream of site 16 at a divergence (16BA and 16BB) on 8/10/06 showed the right fork (16BA) to be the primary source of chloride and o-phosphorus. The specific source is still under investigation. A large county tile (16A) just upstream of sample site 16 had nitrate-N concentrations much higher than the receiving stream and may account for some of the elevated levels at site 16. A sample upstream of the tile discharge was not collected at this time. The tile likely indicates local groundwater nitrate concentrations but no other tiles were observed in the area for comparison. The last three (3) downstream sites on the North Raccoon (45, 46, A) have no perennial tributary stream contributions between them. Water quality was similar as expected.

**Table 3d. Water Quality in the North Raccoon Below Jefferson**

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 16 | West Buttrick | 04/20/06 | 34.50 | 20.22 | <0.1 | 6.6 | |
| | | 05/04/06 | 33.37 | 24.40 | <0.1 | 19.4 | 120 |
| | | 05/18/06 | 32.96 | 21.80 | <0.1 | 12.9 | 108 |
| | | 06/01/06 | 33.53 | 21.73 | <0.1 | 45.2 | 261 |
| | | 06/15/06 | 37.53 | 20.18 | <0.1 | 22.4 | |
| | | 06/29/06 | 44.19 | 14.52 | <0.1 | 14.1 | |
| | | 07/13/06 | 46.11 | 8.95 | <0.1 | 22.8 | |
| | | 07/27/06 | **111.50** | 0.29 | **0.32** | 11.9 | |
| | | 08/10/06 | **59.94** | 0.76 | **0.69** | 41.0 | |
| | | 08/24/06 | **127.59** | 0.20 | **0.35** | 8.3 | |
| | | 09/07/06 | **100.44** | 0.35 | **0.36** | 21.6 | |
| | | | | | | | |
| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
| 16A | W Buttrck tile | 06/15/06 | 38.90 | 28.71 | 0.07 | 1.2 | |
| | | 07/27/06 | 40.80 | 23.01 | 0.39 | 6.5 | |
| 16BA | W.Buttrick rt | 08/10/06 | **80.80** | 0.23 | **1.62** | 8.2 | |
| 16BB | W Buttrick lt | 08/10/06 | 68.04 | <0.05 | <0.1 | 43.0 | |
| 20 | East Buttrick Creek | 04/20/06 | 37.12 | 15.69 | <0.1 | 6.9 | |
| | | 05/04/06 | 38.72 | 21.68 | <0.1 | 24.9 | 419 |
| | | 05/18/06 | 43.99 | 17.19 | <0.1 | 20.5 | 1203 |
| | | 06/01/06 | 34.96 | 18.62 | <0.1 | 20.7 | 816 |
| | | 06/15/06 | 36.25 | 15.99 | <0.1 | 22.0 | |
| | | 06/29/06 | 34.64 | 10.06 | <0.1 | 5.5 | |
| | | 07/13/06 | 32.44 | 12.24 | <0.1 | 17.4 | |
| | | 07/27/06 | 27.30 | 2.82 | <0.1 | 31.2 | |
| | | 08/10/06 | 20.57 | 0.56 | <0.1 | 60.0 | |
| | | 08/24/06 | 29.33 | 0.82 | <0.1 | 26.5 | |
| | | 09/07/06 | 32.37 | 1.52 | <0.1 | 20.1 | |
| 23 | Buttrick Creek | 04/20/06 | 37.09 | 17.11 | <0.1 | 8.7 | |
| | | 05/04/06 | 36.81 | 22.64 | <0.1 | | 228 |
| | | 05/18/06 | 37.41 | 18.78 | <0.1 | 20.7 | 291 |
| | | 06/01/06 | 36.48 | 18.91 | <0.1 | 22.1 | 461 |
| | | 06/15/06 | 36.15 | 17.04 | <0.1 | 20.1 | |
| | | 06/29/06 | 35.68 | 11.49 | <0.1 | 4.5 | |
| | | 07/13/06 | 33.54 | 11.48 | <0.1 | 10.1 | |
| | | 07/27/06 | 32.00 | 5.90 | <0.1 | 13.8 | |
| | | 08/10/06 | 17.16 | 1.03 | <0.1 | 192.0 | |
| | | 08/24/06 | 40.06 | 1.66 | <0.1 | 5.2 | |
| | | 09/07/06 | 25.61 | 4.33 | <0.1 | 6.0 | |
| 22 | Hardin Creek | 04/20/06 | 38.03 | 15.10 | <0.1 | 15.7 | 67 |
| | | 04/30/06 | 36.80 | 16.20 | <0.1 | 130.0 | 1310 |
| | | 05/01/06 | 37.91 | 20.50 | <0.1 | 178.7 | 1687 |

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| | | 05/02/06 | 39.65 | 22.45 | <0.1 | | |
| | | 05/04/06 | 39.78 | 21.95 | <0.1 | 74.4 | 200 |
| | | 05/18/06 | 37.92 | 18.55 | <0.1 | 23.3 | 326 |
| | | 06/01/06 | 36.51 | 20.02 | <0.1 | 33.4 | 613 |
| | | 06/15/06 | 38.44 | 16.75 | <0.1 | 41.7 | 980 |
| | | 06/29/06 | 37.56 | 10.33 | <0.1 | 8.8 | 495 |
| | | 07/13/06 | 34.39 | 2.94 | <0.1 | 6.3 | |
| | | 07/27/06 | 25.90 | 0.70 | <0.1 | 25.1 | 100 |
| | | 08/10/06 | | | <0.1 | 235.0 | 3640 |
| | | 08/24/06 | 31.84 | 0.16 | <0.1 | 31.2 | 410 |
| | | 08/28/06 | 11.85 | 1.93 | 0.10 | | 10300 |
| | | 09/07/06 | 37.19 | 3.55 | <0.1 | 10.3 | 256 |
| 24 | Greenbrier Creek | 04/20/06 | 31.52 | 11.31 | <0.1 | 6.9 | 210 |
| | | 05/04/06 | 33.12 | 18.18 | <0.1 | 47.1 | 1017 |
| | | 05/18/06 | 30.75 | 15.44 | <0.1 | 14.5 | 649 |
| | | 06/01/06 | 31.62 | 15.04 | <0.1 | 30.5 | 1300 |
| | | 06/29/06 | 29.64 | 9.83 | <0.1 | 5.0 | 933 |
| | | 07/13/06 | 24.45 | 2.41 | <0.1 | 8.3 | 410 |
| | | 07/27/06 | 14.90 | 3.51 | <0.1 | 42.0 | |
| | | 08/10/06 | 19.47 | 0.07 | <0.1 | 22.0 | |
| | | 08/24/06 | 21.61 | <0.05 | <0.1 | 13.4 | |
| | | 09/07/06 | 29.73 | 7.67 | <0.1 | 8.6 | |
| 45 | North Raccoon | 04/20/06 | 31.93 | 16.41 | <0.1 | 42.2 | |
| | | 05/04/06 | 28.82 | 20.98 | 0.13 | 113.0 | 785 |
| | | 05/18/06 | 31.14 | 17.24 | <0.1 | 29.9 | 26 |
| | | 06/01/06 | 32.03 | 16.07 | <0.1 | 38.9 | 50 |
| | | 06/15/06 | 38.28 | 15.19 | <0.1 | 27.0 | |
| | | 06/29/06 | 33.32 | 10.58 | <0.1 | 21.4 | |
| | | 07/13/06 | 35.23 | 5.37 | <0.1 | 21.7 | |
| | | 07/27/06 | 30.40 | 0.43 | <0.1 | 45.2 | |
| | | 08/10/06 | 36.81 | <0.05 | <0.1 | 47.5 | |
| | | 08/24/06 | 43.75 | <0.05 | <0.1 | 26.9 | |
| | | 09/07/06 | 40.63 | 2.22 | <0.1 | 17.1 | |
| 46 | North Raccoon | 04/20/06 | 31.63 | 16.33 | 0.08 | 42.5 | |
| | | 05/04/06 | 29.15 | 21.13 | 0.12 | 125.0 | 1259 |
| | | 05/18/06 | 31.70 | 17.26 | <0.1 | 31.1 | 83 |
| | | 06/01/06 | | | <0.1 | 46.0 | 154 |
| | | 06/15/06 | 36.40 | 15.38 | <0.1 | 28.8 | |
| | | 06/29/06 | 34.71 | 10.40 | <0.1 | 22.8 | |
| | | 07/13/06 | 34.51 | 6.30 | <0.1 | 22.4 | |
| | | 07/27/06 | 33.70 | 1.26 | <0.1 | 51.7 | |
| | | 08/10/06 | 39.56 | 0.45 | <0.1 | 39.3 | |
| | | 08/24/06 | 43.50 | 0.92 | <0.1 | 34.0 | |
| | | 09/07/06 | 41.50 | 3.55 | <0.1 | 12.3 | |
| A | North Raccoon | 04/20/06 | 31.77 | 15.81 | <0.1 | 45.7 | 36 |
| | | 05/04/06 | 28.72 | 20.95 | 0.12 | | 1340 |

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| | | 05/18/06 | 31.00 | 16.93 | <0.1 | 34.1 | 59 |
| | | 06/01/06 | 32.07 | 15.06 | <0.1 | 36.9 | 33 |
| | | 06/15/06 | 33.75 | 14.42 | <0.1 | 22.0 | 78 |
| | | 06/22/06 | 35.34 | 11.66 | <0.1 | 17.6 | 45 |
| | | 06/29/06 | 34.34 | 9.17 | <0.1 | 19.0 | 41 |
| | | 07/06/06 | 35.50 | 5.92 | <0.1 | | 63 |
| | | 07/13/06 | 30.94 | 5.20 | <0.1 | 20.3 | 200 |
| | | 07/20/06 | 39.94 | 1.73 | <0.1 | 24.8 | 30 |
| | | 07/27/06 | 34.30 | 0.57 | <0.1 | 49.7 | 300 |
| | | 08/03/06 | 36.79 | 0.38 | <0.1 | 21.9 | 100 |
| | | 08/10/06 | 43.10 | 0.15 | <0.1 | 22.0 | 200 |
| | | 08/17/06 | 41.17 | <0.05 | <0.1 | 29.0 | 310 |
| | | 08/24/06 | 40.88 | 0.47 | <0.1 | 32.6 | 100 |
| | | 09/07/06 | 37.63 | 2.73 | <0.1 | 19.5 | |

Water quality in the North Raccoon appears to be primarily a function of tributary inputs into the river. There is some suggestion of o-phosphorus uptake as water travels down the river. This would be expected from the high algae counts observed and low flow conditions giving additional time for phosphate assimilation. *E. coli* counts in the North Raccoon below Jefferson are somewhat lower than expected based on upstream tributary inputs. The low flow rates increase travel time for stabilization and *E. coli* die off. However, this may be biased as tributaries with low counts in May were not sampled in subsequent months for *E. coli* when the runoff events occurred. Contribution to flow from these tributaries may have had a dilution affect on *E. coli* counts in the North Raccoon River.

Water quality in the upper Middle Raccoon just downstream of the Carroll wastewater treatment facility is heavily influenced by treatment discharge during low flow (Table 4, sites 44). Its influence further downstream near Bayard (site 26A) is uncertain. Elevated phosphorus and *E.coli* counts suggest a continuation of the Carroll plume but chloride levels are normal for the watershed indicating considerable flow contribution from other sources that could influence water quality. Below Lake Panorama (site C), water quality in the Middle Raccoon greatly improves for NP nutrients and *E.coli*, meeting all water quality standards for most of the sampling period. The Mosquito Creek (site 30) is typical of Des Moines Lobe tributaries but made a negligible impact on water quality in the Middle Raccoon as seen at the confluence with the South Raccoon (site 31). Therefore no additional testing in the Middle Raccoon Watershed is planned.

**Table 4. Water Quality in the Middle Raccoon**

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 44 | M Raccoon | 04/20/06 | 69.97 | 6.73 | **0.09** | 13.9 | |
| | | 05/04/06 | 36.81 | **14.30** | **0.19** | 26.3 | 1725 |
| | | 05/18/06 | 43.88 | **11.20** | **0.22** | 38.6 | **3840** |
| | | 06/01/06 | 41.88 | **10.71** | **0.24** | 75.0 | **2419** |
| | | 06/15/06 | 54.01 | 9.70 | **0.15** | 56.7 | |
| | | 06/29/06 | **69.55** | 7.66 | **0.14** | 51.0 | |
| | | 07/13/06 | **72.51** | 6.73 | **0.19** | 19.5 | |
| | | 07/27/06 | 57.80 | 3.49 | **0.46** | 40.9 | **27550** |
| | | 08/10/06 | 13.88 | 0.86 | **0.14** | 330.0 | **10860** |
| | | 08/24/06 | **127.14** | 5.29 | **0.36** | 14.8 | 1730 |
| | | 09/07/06 | **125.84** | 6.18 | **0.29** | 9.0 | **2909** |
| 26A | M. Raccoon | 04/20/06 | 38.18 | 7.46 | <0.1 | 15.3 | |
| | | 05/04/06 | 32.18 | **18.67** | **0.13** | 88.0 | **2400** |
| | | 05/18/06 | 30.91 | **14.00** | **0.11** | 62.9 | 173 |
| | | 06/01/06 | 31.02 | **13.94** | **0.15** | 108.0 | **3466** |
| | | 06/15/06 | 39.97 | **11.17** | | 100.0 | |
| | | 06/29/06 | 35.05 | 5.28 | **0.08** | 25.0 | |
| | | 07/13/06 | 38.46 | 2.90 | **0.09** | 20.7 | |
| | | 07/27/06 | 26.20 | 3.22 | **0.14** | 100.0 | **11780** |
| | | 08/10/06 | 32.19 | 1.10 | **0.13** | 7.2 | 520 |
| | | 08/24/06 | 39.44 | 2.44 | **0.21** | 19.6 | 100 |
| | | 09/07/06 | 35.51 | 6.03 | **0.10** | 17.8 | **4611** |
| C | M. Raccoon Panora | 04/20/06 | 33.26 | 1.33 | <0.1 | 12.1 | 5 |
| | | 05/04/06 | 34.51 | 2.82 | <0.1 | | 31 |
| | | 05/18/06 | 30.47 | 6.36 | <0.1 | 18.4 | 10 |
| | | 06/01/06 | 31.50 | 8.35 | <0.1 | 11.4 | 64 |
| | | 06/15/06 | 30.51 | 7.51 | <0.1 | 23.2 | 228 |
| | | 06/29/06 | 31.00 | 6.67 | <0.1 | 10.5 | 393 |
| | | 07/13/06 | 29.95 | 5.35 | <0.1 | 10.3 | |
| | | 07/27/06 | 30.40 | 3.52 | <0.1 | 8.2 | 100 |
| | | 08/10/06 | 31.50 | 2.43 | <0.1 | 5.5 | |
| | | 08/24/06 | 30.80 | 1.52 | <0.1 | 12.5 | 100 |
| | | 09/07/06 | 30.00 | 0.78 | <0.1 | 16.3 | |
| 30 | Mosquito Ck | 04/20/06 | 25.63 | 10.04 | <0.1 | 7.3 | |
| | | 05/04/06 | 27.45 | 17.77 | <0.1 | 62.0 | 882 |
| | | 05/18/06 | 25.02 | 14.63 | <0.1 | 18.6 | 517 |
| | | 06/01/06 | 24.60 | 16.16 | <0.1 | 51.7 | 1986 |
| | | 06/15/06 | 24.31 | 14.10 | <0.1 | 18.5 | |
| | | 06/29/06 | 23.45 | 7.90 | <0.1 | 11.8 | |
| | | 07/13/06 | 20.14 | 10.53 | <0.1 | 22.7 | |
| | | 07/27/06 | 20.10 | 4.21 | 0.10 | 18.1 | 200 |
| | | 08/10/06 | 19.69 | 0.22 | <0.1 | 4.2 | 100 |
| | | 08/24/06 | 23.70 | 4.90 | <0.1 | 5.8 | 3410 |
| | | 09/07/06 | 24.54 | 6.89 | <0.1 | 8.3 | 2247 |

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 31 | M. Raccoon | 06/22/06 | 28.87 | 6.37 | <0.1 | 15.3 | 155 |
| | | 06/29/06 | 29.84 | 5.34 | <0.1 | 23.6 | |
| | | 07/06/06 | 30.64 | 4.40 | <0.1 | | 52 |
| | | 07/13/06 | 26.08 | 6.21 | <0.1 | 25.7 | |
| | | 07/20/06 | 29.92 | 2.98 | <0.1 | 30.2 | 93 |
| | | 07/27/06 | 24.10 | 2.37 | <0.1 | 38.5 | |
| | | 08/03/06 | 28.02 | 1.72 | <0.1 | 28.5 | |
| | | 08/10/06 | 30.05 | 1.32 | <0.1 | 22.3 | |
| | | 08/17/06 | 29.51 | 0.76 | <0.1 | 36.0 | 310 |
| | | 08/24/06 | 30.25 | 1.25 | <0.1 | 52.4 | |
| | | 09/07/06 | 28.39 | 1.91 | | 40.7 | |

During this study the South Raccoon did not consistently show elevated E. coli counts relative to the North Raccoon. This may in part be due to the dry summer where few runoff events occurred. The most notable exception was Brushy creek, especially site 43 which is toward the upper end of this long narrow tributary (Table 5). Data collected from during ACWA snapshot sampling is presented for comparison purposes. More in-depth investigation in Brushy Creek followed in response to this and historical data.

**Table 5. Water Quality in the South Raccoon and Tributaries**

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| 43 | Brushy Creek | 04/20/06 | 19.44 | 7.96 | | 4.9 | 261 |
| | | 05/04/06 | 20.54 | **15.49** | **0.16** | 22.3 | **3255** |
| | | 05/18/06 | 15.89 | 12.03 | | 15.0 | **2481** |
| | | 06/01/06 | 16.21 | 11.91 | 0.11 | 23.8 | **8212** |
| | | 06/15/06 | 15.41 | 10.05 | | 6.2 | 365 |
| | | 06/22/06 | 15.92 | 8.48 | | 12.5 | 225 |
| | | 06/29/06 | 15.06 | 7.83 | | 4.0 | 179 |
| | | 07/06/06 | 18.86 | 3.36 | **0.65** | | 1539 |
| | | 07/13/06 | 15.86 | 7.03 | **0.19** | 16.3 | 100 |
| | | 07/20/06 | 17.11 | 4.10 | **0.20** | 12.7 | 171 |
| | | 07/26/06 | 12.19 | 3.88 | **0.27** | 112.0 | **>241920** |
| | | 07/27/06 | 26.70 | 0.23 | **1.29** | 39.2 | **>241920** |
| | | 08/03/06 | 19.78 | 2.74 | **0.32** | 3.5 | 1100 |
| | | 08/10/06 | 23.57 | 2.45 | **1.00** | 223.0 | **>2419200** |
| | | 08/17/06 | 18.39 | 2.83 | | 32.0 | **2130** |
| | | 08/24/06 | 19.60 | 4.76 | **0.29** | 77.4 | **5830** |
| | | 09/07/06 | 19.92 | 6.87 | **0.11** | 21.5 | **2430** |
| 28 | Brushy | 05/04/06 | 17.63 | 9.86 | **0.11** | 44.0 | **2247** |
| | | 05/18/06 | 12.68 | 7.17 | **0.11** | 25.0 | 295 |
| | | 06/01/06 | 13.03 | 5.65 | **0.16** | 63.8 | 1120 |
| | | 06/15/06 | 12.27 | 4.43 | **0.12** | 29.6 | |
| | | 06/29/06 | 11.45 | 2.72 | | 14.0 | |
| | | 07/13/06 | 11.25 | 3.24 | **0.13** | 23.4 | |
| | | 07/20/06 | 12.22 | 1.83 | **0.12** | 18.1 | 1145 |

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| | | 07/26/06 | 9.57 | 1.53 | | 10.7 | **>24192** |
| | | 07/27/06 | 11.00 | 1.80 | **0.10** | 11.4 | 100 |
| | | 08/10/06 | 10.37 | 1.64 | **0.12** | 12.3 | 100 |
| | | 08/24/06 | 13.07 | 3.21 | **0.25** | 29.5 | 1340 |
| | | 09/07/06 | 13.70 | 4.35 | **0.20** | 29.3 | 2400 |
| 28A | South Raccoon 1 | 04/20/06 | 9.61 | 3.41 | 0.11 | 14.9 | |
| | | 05/04/06 | 14.79 | 6.30 | 0.22 | 53.4 | **2098** |
| | | 05/18/06 | 10.57 | 3.84 | | 20.4 | 265 |
| | | 06/01/06 | 7.48 | 4.98 | 0.11 | 79.3 | 517 |
| | | 06/15/06 | 7.18 | 2.89 | | 26.5 | |
| | | 06/29/06 | 13.57 | 2.32 | | 25.0 | |
| | | 07/13/06 | 6.12 | 2.83 | | 70.3 | |
| | | 07/27/06 | 7.80 | 3.02 | 0.09 | 43.7 | 510 |
| | | 08/10/06 | 7.37 | 2.60 | 0.10 | 14.7 | 100 |
| | | 08/24/06 | 7.23 | 2.94 | 0.08 | 52.6 | 1750 |
| | | 09/07/06 | 7.67 | 3.24 | 0.07 | 28.1 | 300 |
| 32 | South Raccoon 2 | 04/20/06 | 10.68 | 1.87 | | 23.8 | 32 |
| | | 05/04/06 | 13.83 | 6.85 | 0.11 | | 980 |
| | | 05/18/06 | 11.27 | 4.78 | | 30.0 | 172 |
| | | 06/01/06 | 9.33 | 4.27 | 0.10 | 195.0 | 184 |
| | | 06/15/06 | 9.48 | 2.80 | 0.10 | 49.8 | 411 |
| | | 06/29/06 | 9.33 | 1.48 | | 30.4 | 146 |
| | | 07/13/06 | 5.85 | 2.07 | 0.10 | 194.0 | 1220 |
| | | 07/27/06 | 6.80 | 1.49 | 0.07 | 44.6 | |
| | | 08/10/06 | 8.07 | 0.65 | | 9.6 | 1340 |
| | | 08/24/06 | 10.09 | 2.39 | 0.12 | 55.7 | |
| | | 09/07/06 | 9.86 | 2.98 | 0.13 | 34.8 | |
| 33 | Panther Creek | 04/20/06 | 27.70 | 11.21 | | 2.4 | |
| | | 05/04/06 | 32.18 | 18.77 | | 39.2 | 389 |
| | | 05/18/06 | 25.81 | 16.26 | | 13.0 | 365 |
| | | 06/01/06 | 32.75 | 15.84 | | 24.5 | 548 |
| | | 06/15/06 | 28.66 | 14.44 | | 16.1 | |
| | | 06/29/06 | 40.89 | 9.42 | | 5.5 | |
| | | 07/13/06 | 30.45 | 15.44 | | 22.4 | |
| | | 07/27/06 | 51.00 | 3.18 | | 6.2 | |
| | | 08/10/06 | 110.70 | 0.12 | | 5.6 | |
| | | 08/24/06 | 53.70 | 2.01 | 0.08 | 12.4 | |
| | | 09/07/06 | 35.60 | 7.61 | | 5.9 | |
| B | Lower South | 04/20/06 | 22.86 | 2.85 | | 20.7 | |
| | | 05/04/06 | 26.16 | 7.05 | | | |
| | | 05/18/06 | 23.22 | 6.61 | | 34.2 | 126 |
| | | 06/01/06 | 21.50 | 8.81 | | 77.2 | 884 |
| | | 06/15/06 | 21.82 | 5.90 | | 25.4 | |
| | | 06/29/06 | 20.29 | 3.36 | | 14.7 | |
| | | 07/13/06 | 16.00 | 4.28 | | 132.0 | |
| | | 07/27/06 | 13.50 | 1.65 | | 40.4 | |
| | | 08/10/06 | 17.80 | 0.79 | | 12.7 | |

| Site Id | Tributary | Date | Chloride | NO3-N | o-Phos | Turb | E.coli |
|---|---|---|---|---|---|---|---|
| | | 08/24/06 | 20.77 | 1.64 | | 49.9 | |
| | | 09/07/06 | 20.33 | 2.16 | | 33.3 | |
| 37 | Lower South | 06/22/06 | 24.25 | 4.51 | | 14.0 | 326 |
| | | 07/06/06 | 19.88 | 1.88 | | | 323 |
| | | 07/20/06 | 21.20 | 1.16 | | 31.3 | 63 |
| | | 08/03/06 | 18.89 | 0.40 | | 22.5 | 100 |
| | | 08/17/06 | 21.83 | 0.30 | | 29.6 | 1430 |
| | | 04/20/06 | 23.94 | 3.24 | | 22.0 | 56 |
| | | 05/04/06 | 26.44 | 7.79 | | 80.4 | 498 |
| | | 05/18/06 | 22.50 | 6.88 | | 36.4 | 101 |
| | | 06/01/06 | 21.54 | 8.07 | | 67.1 | 121 |
| | | 06/15/06 | 22.14 | 6.26 | | 26.0 | 238 |
| | | 06/29/06 | 21.56 | 3.28 | | 10.2 | 246 |
| | | 07/13/06 | 15.35 | 4.85 | | 189.0 | 410 |
| | | 07/27/06 | 19.90 | 1.51 | | 37.7 | 100 |
| | | 08/10/06 | 19.80 | 0.51 | | 22.0 | |
| | | 08/24/06 | 21.82 | 1.26 | | 52.2 | 520 |
| | | 09/07/06 | 20.66 | 2.09 | | 40.2 | 100 |

Water quality in the two tributaries close to Des Moines, Walnut Creek and Beaver Creek, is especially important to the Des Moines Water Works utility and is therefore presented separately in Table 6. Both of these tributaries have a rural component and an urban component. Both have demonstrated periodic episodes of high E. coli counts, even during relatively low flow. Spikes in E. coli counts in the Raccoon River have been traced to broken sewer lines and direct pumping of sewage into Walnut Creek (internal reports). Continued residential and commercial development in these areas increases impervious surfaces, and artificial curb and gutter drainage systems further contribute to runoff and transport of pollutants to urban streams. The proximity of their watersheds and discharge to the intake locations is of particular concern following a storm event during an otherwise dry period as observed in July. During these conditions flow from these two tributaries arrive first to discharge a disproportionately large volume of runoff water to flow in the rivers. This can produce a rapid change in river E. coli counts when the river stage is just beginning to rise (note the sudden change in E. coli counts in the Des Moines River, Table 2, on 7/13/06 and 7/26/06). This rapid change in water quality is of particular concern to the utility as there is little opportunity to adjust treatment or change sources in response to this change in water quality.

**Table 6. Water Quality in Walnut Creek and Beaver Creek**

| Site Id | Creek Name | Sample Date | Cl | Nitrate as N | TN | o-Phos as P | Turbidity | E. coli |
|---|---|---|---|---|---|---|---|---|
| 70A | Upper Wlnt | 07/12/06 | 45.7 | 8.3 | | 0.42 | 13.30 | 970 |
| 70B | Upper Wlnt | 07/12/06 | 34.6 | 5.9 | | | 34.10 | **9330** |
| 70 | W Ck Rural | 04/20/06 | 31.6 | 13.3 | | | 6.23 | 261 |
| | | 05/04/06 | 28.9 | 19.6 | | 0.14 | 22.60 | 223 |
| | | 05/18/06 | 25.9 | 17.4 | | | 23.10 | |
| | | 06/01/06 | 26.6 | 16.6 | | 0.09 | 31.40 | **1733** |
| | | 06/15/06 | 25.5 | 16.0 | 15.7 | 0.06 | 53.10 | **4352** |
| | | 06/29/06 | 26.4 | 10.9 | 10.8 | 0.07 | 37.50 | **2143** |
| | | 07/13/06 | 29.7 | 3.9 | | 0.20 | 38.30 | 200 |
| | | 07/27/06 | 19.7 | 2.9 | | 0.22 | 69.20 | **1220** |
| | | 08/10/06 | 41.3 | 0.2 | | 0.19 | 43.00 | 970 |
| | | 08/24/06 | 32.5 | 0.4 | | 0.15 | 19.50 | 300 |
| 40A | Walnut Ck | 08/17/06 | 9.4 | 0.4 | 0.8 | | 178.00 | 9880 |
| 40B | Walnut Ck | 08/17/06 | 17.3 | 0.3 | 0.7 | | 136.00 | 10140 |
| 40 | Wlnt Urban | 04/20/06 | **58.5** | 6.6 | | | 5.08 | 161 |
| | | 05/04/06 | 45.8 | 14.1 | | | 37.60 | 404 |
| | | 05/18/06 | 46.9 | 11.0 | | | 7.42 | 261 |
| | | 06/01/06 | 48.6 | 9.6 | | | 16.60 | 866 |
| | | 06/15/06 | 49.9 | 9.1 | 9.0 | | 8.16 | 866 |
| | | 06/29/06 | **57.0** | 3.9 | 4.1 | | 3.80 | 631 |
| | | 07/13/06 | 48.5 | 0.8 | | | 18.20 | 520 |
| | | 07/27/06 | 44.3 | 0.5 | | | 40.20 | 200 |
| | | 08/10/06 | 21.2 | 0.6 | | | 185.00 | **5040** |
| | | 08/17/06 | 10.0 | 0.4 | 0.8 | | 142.00 | **7330** |
| | | 08/24/06 | 79.2 | | | 0.31 | 126.00 | 200 |
| BC11C | Beaver Ck | 07/12/06 | 28.3 | 14.1 | | **0.21** | 54.90 | **27550** |
| BC11B | Beaver Ck | 07/06/06 | **56.0** | 12.7 | | **0.27** | 26.00 | 985 |
| | | 07/12/06 | 30.7 | 15.6 | | 0.10 | 28.60 | **3180** |
| BC11A | Beaver Ck | 07/06/06 | 30.5 | 14.2 | | | 39.90 | **2851** |
| | | 07/12/06 | 21.9 | 14.0 | | 0.18 | 34.00 | **92080** |
| BC11 | Beaver Ck | 06/22/06 | 26.6 | 14.6 | | 0.15 | 92.00 | **2419** |
| | | 07/06/06 | 33.9 | 12.4 | | | 49.60 | **1529** |
| | | 07/12/06 | 23.2 | 13.8 | | **0.22** | 52.40 | **36540** |
| BC10 | Beaver Ck | 06/22/06 | 29.5 | 13.2 | | 0.06 | 22.20 | 488 |
| | | 07/12/06 | 22.9 | 12.5 | | 0.12 | 210.00 | **61310** |
| BC8 | Beaver Ck | 07/26/06 | 19.0 | 6.4 | 6.2 | | 180.00 | |
| BC2 | Beaver Ck | 06/29/06 | 32.2 | 11.3 | 11.0 | 0.07 | | |
| | | 06/22/06 | 32.0 | 12.0 | | | 29.40 | 770 |
| | | 07/06/06 | 30.8 | 7.6 | | 0.07 | 143.00 | 833 |
| | | 07/12/06 | 20.6 | 5.2 | | 0.09 | 141.00 | **1850** |
| | | 07/26/06 | 24.3 | 5.3 | 4.7 | 0.09 | 187.00 | **8300** |
| | | 08/03/06 | 32.8 | 8.6 | | 0.09 | 21.00 | 520 |
| | | 08/10/06 | 32.0 | 4.4 | | 0.08 | 74.00 | |
| | | 08/17/06 | 20.9 | 3.9 | 3.8 | | 104.00 | **6380** |
| | | 08/24/06 | 37.9 | 7.4 | | | | 410 |

# LOCATION OF SAMPLE SITES

Sampling locations for the survey sites discussed in the Raccoon River watershed are presented in Table 7 in latitude/longitude format along with landform of their watershed.

**Table 7. Raccoon River and Tributary Sampling Locations.**

| Site Id | Tributary Name | Lat/Long | Landform |
|---|---|---|---|
| 02 | North Raccoon 1 | 42.71983400,-95.07587017 | Des Moines Lobe |
| 03 | Poor Farm Creek | 42.70309350,-95.08279975 | Des Moines Lobe |
| 04 | Little Cedar Creek | | Des Moines Lobe |
| 04A | Big Cedar Creek | 42.58883961,-94.84785073 | Des Moines Lobe |
| 05 | Outlet Creek | 42.58743103,-95.07238900 | Des Moines Lobe |
| 06 | Prairie Creek | | Des Moines Lobe |
| 07 | North Raccoon 2 | 42.42195809,-94.98658111 | Des Moines Lobe |
| 08 | Cedar Creek | 42.40372695,-94.97779177 | Des Moines Lobe |
| 09 | Indian Creek | 42.33732778,-94.99381838 | Des Moines Lobe |
| 10 | Camp Creek | 42.29191605,-94.83237103 | Des Moines Lobe |
| 11 | Prairie Creek South | | Des Moines Lobe |
| 12 | Lake Creek | 42.26069581,-94.78252159 | Des Moines Lobe |
| 13 | North Raccoon 3 | 42.22906133,-94.75579103 | Des Moines Lobe |
| 14 | Elk Run A | 42.19236377,-94.75470071 | Des Moines Lobe |
| 14A | North Raccoon | 42.16859965,-94.72607777 | Des Moines Lobe |
| 16 | West Buttrick Creek | 42.20918415,-94.35522515 | Des Moines Lobe |
| 16BA | West Buttrick Creek | | Des Moines Lobe |
| 16BB | West Buttrick Creek | | Des Moines Lobe |
| 17 | Cedar Creek A | 42.13731830,-94.58008605 | Des Moines Lobe |
| 19 | Purgatory Creek | 42.11402860,-94.64411180 | Des Moines Lobe |
| 20 | East Buttrick Creek | 42.05006889,-94.28084406 | Des Moines Lobe |
| 21 | North Raccoon - Henderson | 41.98884504,-94.37412232 | Des Moines Lobe |
| 22 | Hardin Creek | 41.98640004,-94.32297444 | Des Moines Lobe |
| 23 | Buttrick Creek | 41.97369844,-94.30282954 | Des Moines Lobe |
| 24 | Greenbrier Creek | | Des Moines Lobe |
| 26 | Middle Raccoon 1 | | DM Lobe & SIDP |
| 26A | Middle Raccoon | 41.77877761,-94.49310738 | DM Lobe & SIDP |
| 28 | Brushy Fork Creek | 41.65241975,-94.44148701 | Southern Iowa Drift Plain |
| 28A | South Raccoon 1 | 41.64279263,-94.45444132 | Southern Iowa Drift Plain |
| 29A | South Raccoon | | Southern Iowa Drift Plain |
| 2A | North Raccoon | 42.61892729,-95.04329994 | Des Moines Lobe |
| 30 | Mosquito Creek | 41.60602022,-94.21010658 | Des Moines Lobe |
| 31 | Middle Raccoon 3 | | DM Lobe & SIDP |
| 32 | South Raccoon 2 | 41.56666048,-94.19989147 | Southern Iowa Drift Plain |
| 33 | Panther Creek | 41.55375126,-94.08610194 | Des Moines Lobe |
| 36 | South Raccoon 3 | | DM Lobe & SIDP |
| 37 | South Raccoon 4 | 41.53809847,-93.97365033 | DM Lobe & SIDP |
| 38 | Raccoon River VM | | DM Lobe & SIDP |
| 40 | Walnut Creek Urban | 41.57560271,-9369581924 | Des Moines Lobe |
| 42A | Brushy Fork Creek A | | Southern Iowa Drift Plain |
| 42B | Brushy Fork Creek B | | Southern Iowa Drift Plain |
| 43 | Brushy Fork Creek | 41.91289343,-94.82203002 | Southern Iowa Drift Plain |
| 44 | Middle Raccoon | 42.05332073,-94.82276310 | DM Lobe & SIDP |
| 45 | North Raccoon | 41.84932600,-94.13989725 | Des Moines Lobe |
| 46 | North Raccoon | 41.79096800,-94.10303389 | Des Moines Lobe |
| 70 | Walnut Creek Rural | 41.65181944,-93.83357372 | Des Moines Lobe |
| A | North Raccoon Puckerbrush | 41.61432560,-94.01145095 | Des Moines Lobe |
| B | South Raccoon | | DM Lobe & SIDP |
| C | Middle Raccoon Panora | 41.68658732,-94.37153005 | DM Lobe & SIDP |

Sample sites within the designated study area are presented in Table 8. This includes sites within Brushy Creek that were selected during the investigative process.

**Table 8. Sample Sites in the Raccoon and Des Moines Watershed Study Area**

| Site Id | Trib name | Lat/Long | Notes | Landform |
|---|---|---|---|---|
| 22 | Hardin Creek | | | Des Moines Lobe |
| 28 | Brushy Creek | 41.65231481,-94.44139942 | | Southern Iowa Drift Plain |
| 28A1 | Brushy Creek | 41.81270756,-94.78277162 | | Southern Iowa Drift Plain |
| 28B | Brushy Creek | 41.73044161,-94.51246689 | | Southern Iowa Drift Plain |
| 28C | Brushy Creek | 41.79105844,-94.65610019 | | Southern Iowa Drift Plain |
| 31 | Middle Raccoon | 41.59025445,-94.20319285 | | DM Lobe & SIDP |
| 32 | South Raccoon | 41.56666048,-94.19989147 | | DM Lobe & SIDP |
| 37 | Lower South VM | 41.53837482,-93.97409658 | | DM Lobe & SIDP |
| 40 | Walnut Creek | 41.57560271,-93.69581924 | at RR | Des Moines Lobe |
| 40A | Walnut Creek | | east branch | Des Moines Lobe |
| 40B | Walnut Creek | | main branch | Des Moines Lobe |
| 42A | Brushy Creek | 41.95393693,-94.89878336 | | Southern Iowa Drift Plain |
| 42B | Brushy Creek | 42.00074659,-94.94199308 | | Southern Iowa Drift Plain |
| 42B2 | Brushy Creek | 42.00824311,-94.95199772 | | Southern Iowa Drift Plain |
| 42B3 | Brushy Creek | 42.03542839,-94.97221864 | | Southern Iowa Drift Plain |
| 42BA | Brushy Creek | 42.00792954,-94.95900365 | | Southern Iowa Drift Plain |
| 42BA1 | Brushy Creek | 42.00273394,-94.97625637 | | Southern Iowa Drift Plain |
| 42BT | Brushy Creek | 41.96537261,-94.91874344 | tile b/n A&B | Southern Iowa Drift Plain |
| 42C | Brushy Creek | 42.06443891,-94.98727882 | | Southern Iowa Drift Plain |
| 42CA | Brushy Creek | 42.05008968,-95.03012108 | | Southern Iowa Drift Plain |
| 42CA1 | Brushy Creek | 42.05008968,-95.03012108 | tile | Southern Iowa Drift Plain |
| 42CA2 | Brushy Creek | 42.05008968,-95.03012108 | tile | Southern Iowa Drift Plain |
| 42D | Brushy Creek | 42.05537380,-95.03387215 | | Southern Iowa Drift Plain |
| 43 | Brushy Creek | 41.91289343,-94.82203002 | | Southern Iowa Drift Plain |
| 50 | Brushy Creek | 41.87232921,-94.76414435 | isco site | Southern Iowa Drift Plain |
| 50A | Brushy Creek | 41.89548220,-94.79002381 | | Southern Iowa Drift Plain |
| 50T | Brushy Creek | 41.87914256,-94.76394772 | Tile | Southern Iowa Drift Plain |
| 50T1 | Brushy Creek | | East tile | Southern Iowa Drift Plain |
| 50T2 | Brushy Creek | | West tile | Southern Iowa Drift Plain |
| 70A | Walnut Creek | 41.67286213,-93.89516269 | | Des Moines Lobe |
| 70B | Walnut Creek | 41.67271385,-93.84853718 | | Des Moines Lobe |
| A | North Raccoon | 41.56458143,-93.95281225 | | Des Moines Lobe |
| BC10 | Beaver Creek | 41.79728209,-93.91202766 | | Des Moines Lobe |
| BC11 | Beaver Creek | 41.93591081,-94.10814098 | | Des Moines Lobe |
| BC11A | Beaver Creek | 41.99367595,-94.11139383 | | Des Moines Lobe |
| BC11B | Beaver Creek | 41.99362281,-94.10543078 | | Des Moines Lobe |
| BC11C | Beaver Creek | 41.99367662,-94.12347936 | | Des Moines Lobe |
| BC2 | Beaver Creek | 41.65344696,-93.69707443 | | Des Moines Lobe |
| BC8 | Beaver Creek | | | Des Moines Lobe |
| DES MOINES INTAKE | Des Moines River | | | Des Moines Lobe |
| RACCOON INTAKE | Raccoon River | | | DM Lobe & SIDP |

## PROCESS USED TO SELECT TRIBUTARIES, SITES, AND METHODS

Identification of specific location and source(s) of contamination followed a three- tiered approach. Some adjustments were made in the initial plan to accommodate stream flow characteristics and logistical needs:

1) Des Moines Water Works' laboratory personnel and sub-contracted sampler trained in professional sampling collected scheduled samples on a weekly bases from perennial streams within the study area. On alternating weeks, a more investigative sampling was conducted within a defined area to locate as precisely as possible sources of contamination observed in previous sampling events. Sampling during or shortly after a rain event to characterize runoff water quality in each sub-watershed was conducted whenever logistically possible.

2) Based on historical information and data from scheduled and event based sampling, Brushy Creek was selected for more detailed investigation. An event triggered composite sampler (fig 11) was placed at a mid-way point (site 50) between the headwaters and confluence with the South Raccoon. Several iterations of programming were needed to trigger the sampler during a runoff event and collect samples at frequency that includes most of the flow hydrograph. Stage height was not effective as beaver activity and other factors lead to a poor correlation between stage height and flow. Rate increase in stage height worked best for this location. The sampling was programmed to collect one (1) sample every 30 minutes for four hours and then the sampling interval increased to one each hour for the next 16 hours. This included most of the hydrograph but with greater resolution of water quality during the ascending phase of the hydrograph when initial runoff occurs. A sub-set of these samples were analyzed to characterize changes in water quality against the hydrograph. Additional samples were analyzed as needed based analytical results and the ability to characterize pollutant runoff and potential source(s) and location within the watershed. The investigator conducted a visual

**fig 11. Event trigged composite sampler at site 50**

inspection of the watershed landscape for potential sources of contamination and collected grab samples accordingly from feeder streams and tile discharges.

3) Based off information in Tier 2 sampling and visual inspections, the sampler identified potential sources upstream of the site to sample during the next round of sampling – if possible during a runoff event. Several iterations of this process occurred to better locate specific sources and causes for water quality impairment.

After sources of pollutants are identified as precisely as possible within Brushy Creek, the sampling process will be repeated in another watershed as identified in the tier 1 sampling.

# BRUSHY CREEK INVESTIGATION AND RESULTS

**Watershed and stream morphology, visual observations**

Brushy Creek has a long narrow watershed that begins near the Mississippi-Missiouri River Divide nine (9) miles southwest of Carroll and discharges into the South Raccoon three (3) miles SE of Guthrie Center. The headwaters area has long gentle slopes with predominantly row crop agriculture. The watershed soon changes to a prominent valley with its surrounding hillsides. There are numerous pastures and livestock feeding operations in the valley and surrounding hillsides. The stream is relatively straight but has many pools and areas of slow moving water due to beaver activity and artificial impoundments (fig 12). For much of the summer, there was little flow so there was considerable detention time in these pools. These pools were shallow with a thick layer of black muck

**fig 12. Pool area in upper Brushy Creek**

and sediment. Filamentous algae proliferated upstream as the summer progressed, both in the stream attached to structures (Cladophora sp) and on the surface of pool areas as well.

**Landuse and registered livestock operations:**

The DNR interactive map (fig 13) which shows the number and distribution of registered livestock operations is inconclusive as to the cause of the relatively elevated E. coli counts.

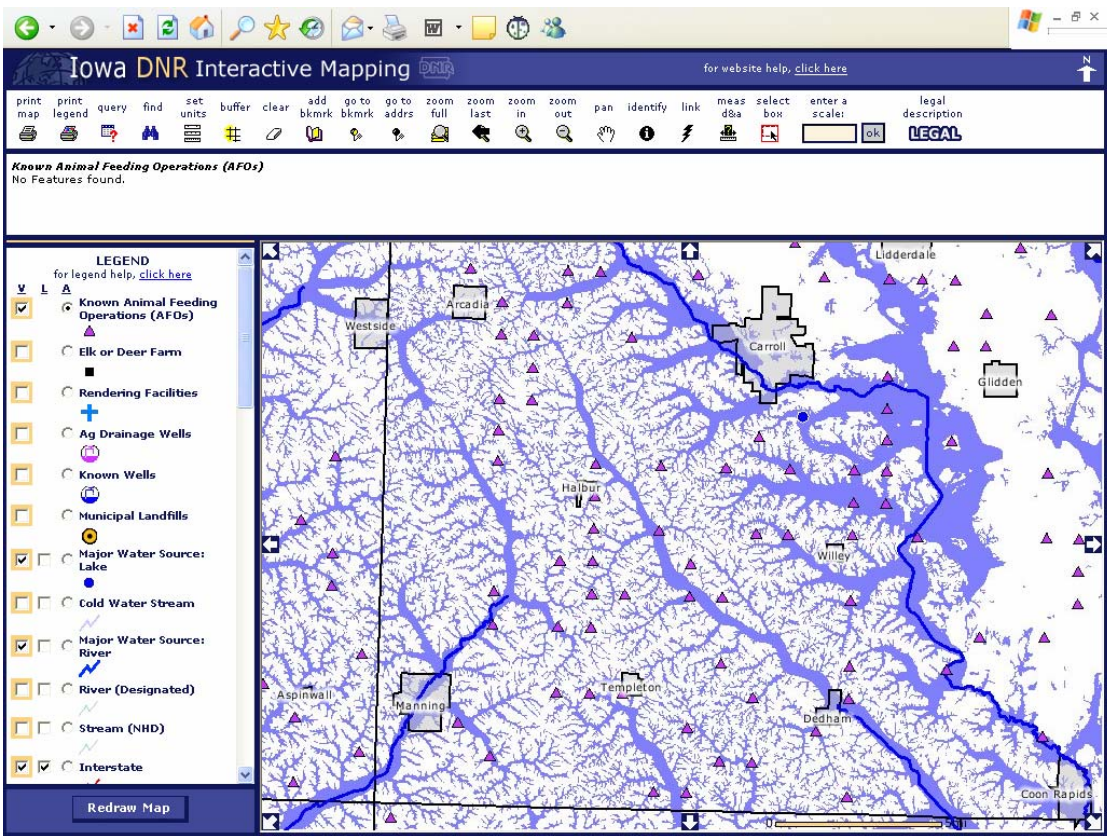


**fig 13. Registered AFO in the upper Brushy Creek Watershed**

The map does not indicate the size of operations nor record smaller units that are not required to register. It does show the sudden change in drainage from the relatively flat, poorly drained Des Moines Lobe landform seen in the upper right corner of fig 13 to the hilly, highly dissected watershed of Brushy Creek and the SIDP landform. The change in topography makes runoff of fecal material during a rain event much more likely unless extra precautions and controls are in place.

**Sampling conditions and results**

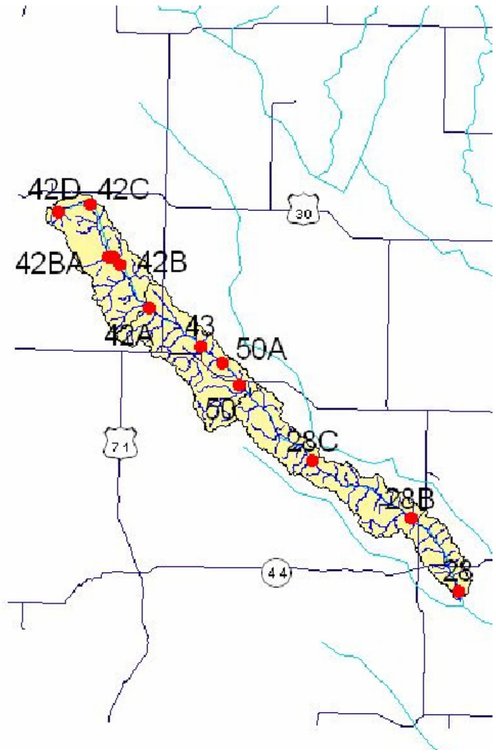

**fig 14. Sample sites in the Brushy Creek Watershed**

Sampling within the Brushy Creek Watershed initially followed a survey approach to identify which section(s) of the tributary are more heavily contaminated and guide subsequent sampling efforts to locate specific sources of contamination. During base flow conditions (ground water contribution), water quality is relatively static so that sources of nitrate contamination could be identified through scheduled sampling. This sampling showed exceptionally high *E. coli* counts in the upper regions of the watershed. Based in part on experience with North Raccoon tributaries, chronically high E. coli counts not attributed to wastewater discharge indicates a highly contaminated source(s) upstream. Therefore, sample collection during the first runoff event was more concentrated in the upper region of the watershed. This was supported by subsequent sampling events. The spacial location of these sample sites is shown in fig 14 which provides a visual frame of reference for data in Table 9.

Sample sites are ordered according to flow down the tributary. An additional site at the upper end of the South Raccoon (site 28A1) is included as a reference point. Result records painted in yellow denote sampling during a runoff event. Results in red are averaged results from the event sampler at site 50.

**Table 9. Water Quality Within the Brushy Creek Watershed**

| Site Id | Sample Date | Nitrate as N | Nitrite as N | TN | o-Phos as P | Turbidity | E. coli |
|---|---|---|---|---|---|---|---|
| 42CA | 07/06/06 | 29.3 | | | | | 31 |
| | 07/20/06 | 28.2 | | | | 0.42 | |
| | 07/26/06 | 28.8 | | 24.1 | | 12 | 171 |
| | 08/03/06 | 28.8 | | | | 7.6 | 310 |
| 42CA1* | 08/07/06 | 30.4 | | | | 0.69 | <10 |
| | 08/17/06 | 27.5 | | 24.42 | | 0.9 | <100 |
| 42CA2* | 08/07/06 | 28.3 | | | | 0.33 | 11199 |
| | 08/17/06 | 30.5 | | 28.32 | | 0.8 | <100 |

| Site Id | Sample Date | Nitrate as N | Nitrite as N | TN | o-Phos as P | Turbidity | E. coli |
|---|---|---|---|---|---|---|---|
| | 08/31/06 | 26.3 | | | | | |
| 42D | 06/22/06 | 12.0 | | 12.1 | | 6.4 | 1414 |
| | 07/06/06 | 10.8 | | | | | 1956 |
| | 07/26/06 | 6.5 | 0.16 | 6.5 | 0.07 | 13.7 | 12740 |
| | 08/03/06 | 4.8 | 0.07 | | 0.07 | 18.9 | 1350 |
| | 08/17/06 | 3.5 | 0.07 | 3.8 | | 7.9 | 630 |
| 42C | 06/22/06 | 17.6 | 0.08 | | | 8.8 | 179 |
| | | | | | | | |
| | 07/06/06 | 15.8 | | | | | 624 |
| | 08/03/06 | 8.6 | 0.05 | | 0.10 | 7 | 200 |
| 42B3 | 07/20/06 | 11.4 | 0.08 | | 0.12 | 5.68 | 1789 |
| | 08/03/06 | 8.7 | 0.11 | | 0.19 | 11.8 | 1600 |
| | 08/31/06 | 12.0 | 0.11 | | 0.2 | 8.02 | 26460 |
| | 09/21/06 | 16.3 | 0.08 | | 0.1 | 6 | 12755 |
| 42BA1 | 07/06/06 | 12.4 | | | | | 393 |
| | 08/31/06 | 10.2 | | | 0.13 | 2.88 | 3140 |
| | 09/21/06 | 12.2 | | | | 8.7 | 310 |
| 42BA | 06/22/06 | 12.6 | 0.10 | | | 13.3 | 980 |
| | 07/06/06 | 10.6 | 0.09 | | 0.11 | | 565 |
| | 08/03/06 | 7.9 | 0.17 | | 0.15 | 7.08 | 970 |
| | 08/17/06 | 6.5 | 0.11 | 6.2 | | 6.6 | 2430 |
| | 08/31/06 | 9.2 | 0.08 | | 0.12 | 2.47 | 6570 |
| | 09/21/06 | 12.2 | 0.05 | | 0.16 | 7.9 | 4500 |
| 42B2 | 06/22/06 | 14.0 | 0.15 | 12.8 | 0.07 | 7.5 | 613 |
| | 07/06/06 | 11.9 | 0.09 | | | | 816 |
| | 07/26/06 | 1.3 | 3.17 | 15 | 3.6 | 209 | >241920 |
| | 08/03/06 | 7.1 | 0.08 | | 0.33 | 5.33 | 2260 |
| | 08/17/06 | 6.1 | | 5.6 | | 5.6 | 960 |
| 42B | 06/22/06 | 13.2 | 0.59 | | 0.08 | 8.4 | 291 |
| | 08/03/06 | 4.7 | 0.24 | | 0.49 | 2.31 | 1100 |
| | 09/21/06 | 14.2 | 0.08 | | 0.11 | 6 | 11805 |
| 42BT* | 08/07/06 | 11.1 | | | | 0.1 | <10 |
| | 08/17/06 | 10.9 | | 10.6 | | 6.8 | <100 |
| | 08/31/06 | 9.4 | | | | | |
| stream | 09/21/06 | 14.1 | 2.54 | | | 10.7 | 4210 |
| 42A | 06/22/06 | 11.3 | 0.16 | | 0.15 | 11 | 248 |
| | 07/06/06 | 7.9 | 0.64 | | 0.48 | | >24192 |
| | 07/20/06 | 4.9 | 0.33 | | 0.4 | 2.52 | 520 |
| | 07/26/06 | 0.9 | 1.89 | 11 | 1.49 | 119 | >241920 |
| | 08/03/06 | 3.6 | 0.41 | | 0.62 | 3.56 | 850 |
| | 08/17/06 | 4.6 | 0.17 | 10 | | 5.6 | 410 |
| | 09/21/06 | 14.1 | 8.04 | | 24 | 6.4 | 4520 |
| 43 | 04/20/06 | 8.0 | 0.10 | | | 4.89 | 261 |
| | 05/04/06 | 15.5 | 0.15 | | 0.16 | 22.3 | **3255** |
| | 05/18/06 | 12.0 | 0.08 | | | 15 | **2481** |
| | 06/01/06 | 11.9 | 0.11 | | 0.11 | 23.8 | **8212** |
| | 06/15/06 | 10.0 | 0.08 | 10.1 | | 6.21 | 365 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 06/22/06 | 8.5 | 0.25 | | | 12.5 | 225 |
| | 06/29/06 | 7.8 | 0.09 | 8.0 | | 4 | 179 |
| | 07/06/06 | 3.4 | 0.28 | | 0.65 | | 1539 |
| | 07/13/06 | 7.0 | 0.08 | | 0.19 | 16.3 | 100 |
| | 07/20/06 | 4.1 | 0.11 | | 0.2 | 12.7 | 171 |
| | 07/26/06 | 3.9 | 0.21 | 5.3 | 0.27 | 112 | >241920 |
| | 07/27/06 | 0.2 | | | 1.29 | 39.2 | >241920 |
| | 08/03/06 | 2.7 | 0.26 | | 0.32 | 3.49 | 1100 |
| Site Id | Sample Date | Nitrate as N | Nitrite as N | TN | o-Phos as P | Turbidity | E. coli |
| | 08/10/06 | 2.4 | 0.16 | | 1 | 223 | >2419200 |
| | 08/17/06 | 2.8 | 0.09 | 3.5 | | 32 | 2130 |
| | 08/24/06 | 4.8 | 0.18 | | 0.29 | 77.4 | 5830 |
| | 09/07/06 | 6.9 | 0.06 | | 0.11 | 21.5 | 2430 |
| 50T* | 07/26/06 | 3.0 | 0.18 | 3.5 | 0.23 | 125 | >241920 |
| | 08/03/06 | 18.0 | | | 0.07 | 0.743 | 100 |
| | 08/07/06 | 18.0 | | | 0.07 | 1.06 | 1017 |
| 50A | 06/22/06 | 7.2 | 0.18 | | 0.09 | 2.51 | 461 |
| 50T1* | 08/17/06 | 16.8 | 0.12 | 16.4 | | 4.6 | >241920 |
| 50T2* | 08/17/06 | 10.4 | | 9.5 | | 2 | 520 |
| | 08/31/06 | 13.0 | | | | | |
| 50 | 06/22/06 | 7.0 | 0.10 | | | 4.9 | 261 |
| | 08/17/06 | 2.3 | 0.05 | 2.8 | | 30 | 2560 |
| | 08/28/06 | 2.8 | 0.29 | 4.2 | 0.49 | 369 | 248969 |
| | 09/11/06 | 4.6 | 0.18 | | 0.65 | | >2419200 |
| | 09/21/06 | 11.5 | 4.03 | | 0.2 | 186 | 1843 |
| 28C | 06/22/06 | 5.2 | | | 0.07 | 10 | 291 |
| * tile | 07/26/06 | 3.6 | 0.13 | 9.9 | 0.16 | 193 | >241920 |
| * tile | 08/31/06 | 40.2 | 0.17 | | 0.64 | 42 | 48840 |
| 28B | 06/22/06 | 4.1 | 0.06 | 5.2 | | 33.6 | 166 |
| 28 | 05/04/06 | 10.0 | 0.17 | | 0.11 | 44 | **2247** |
| | 05/18/06 | 7.2 | | | 0.11 | 25 | 295 |
| | 06/01/06 | 5.6 | | | 0.16 | 63.8 | 1120 |
| | 06/15/06 | 4.4 | | 4.8 | 0.12 | 29.6 | |
| | 06/22/06 | 3.1 | | 3.9 | | 28.5 | 345 |
| | 06/29/06 | 2.7 | | 3.0 | | 14 | |
| | 07/13/06 | 3.2 | | | 0.13 | 23.4 | |
| | 07/20/06 | 1.8 | | | 0.12 | 18.1 | 1145 |
| | 07/26/06 | 1.5 | | 1.5 | | 10.7 | >24192 |
| | 07/27/06 | 1.8 | | | 0.1 | 11.4 | 100 |
| | 08/10/06 | 1.6 | | | 0.12 | 12.3 | 100 |
| | 08/24/06 | 3.2 | | | 0.25 | 29.5 | 1340 |
| | 09/07/06 | 4.4 | | | 0.2 | 29.3 | 2400 |
| 28A | 04/20/06 | 3.4 | | | 0.11 | 14.9 | |
| | 05/04/06 | 6.3 | | | 0.22 | 53.4 | **2098** |
| | 05/18/06 | 3.8 | | | | 20.4 | 265 |
| | 06/01/06 | 5.0 | | | 0.11 | 79.3 | 517 |
| | 06/15/06 | 2.9 | | 3.4 | | 26.5 | |
| | 06/29/06 | 2.3 | | 2.6 | | 25 | |

| | | | | | |
|---|---|---|---|---|---|
| | 07/13/06 | 2.8 | | 70.3 | |
| | 07/27/06 | 3.0 | 0.09 | 43.7 | 510 |
| | 08/10/06 | 2.6 | 0.1 | 14.7 | 100 |
| | 08/24/06 | 2.9 | 0.08 | 52.6 | 1750 |
| | 09/07/06 | 3.2 | 0.07 | 28.1 | 300 |
| 28A1 | 07/20/06 | 18.6 | | 3.86 | 341 |

**Nitrogen dynamics in Brushy Creek**

The highest nitrate concentration observed (40.2 mg/l) was from a drainage pipe near 28C. The intermittent flow, high *E. coli* counts, and nutrient-rich discharge indicate fecal contaminated surface drainage. During dry weather there was little to no flow. During the July rain event, turbidity in the pipe discharge was higher than in the stream and *E. coli* counts were >241920/100 ml. Much of the total nitrogen concentration of 9.9 was in the TKN form as nitrate-N and nitrite-N concentrations were 3.6 and 0.13 mg/l respectively. The high nitrate concentration was collected a month later when there was little flow. E. coli counts were still high but measurable. The ortho-phosphorus concentration increased from 0.16 to 0.64. This data suggests mineralization and nitrification of fecal material as the source of high nitrate and phosphate. Total nitrogen analysis was not available at this time to check remaining amount of TKN nitrogen. The contribution to flow was small, however, so the impact of this specific source on water quality in Brushy Creek is likely small. Anecdotally this indicates a route of entry for fecal contamination to the stream that if commonly practiced in the watershed could seriously impair the stream.

All sampling events in Brushy Creek show Nitrate-N concentrations to progressively decrease along sampling points downstream throughout the summer (fig 15).

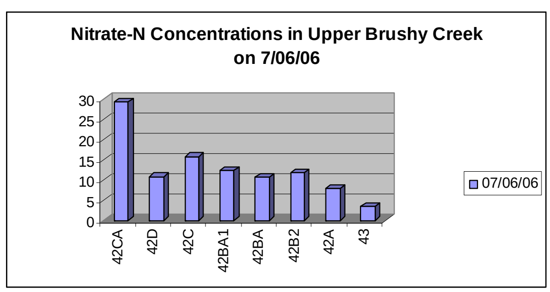


**fig 15. Nitrate concentration in Brushy Creek**

This is somewhat unique to Brushy Creek. The North Raccoon and its larger tributaries show little change downstream during normal flow. During low flow, influences from certain tributaries were apparent in the Raccoon River, e.g. Outlet Creek. Downstream of Outlet Creek, nitrate-N concentrations decrease as additional flow from tributaries and ground water dilute the nitrate concentration in the North Raccoon. There is some indication of denitrification as well which may be expected due to long retention times and near-wetland conditions. Denitrification within Lake Panorama is apparent from the reduction in nitrate-N concentration between inflowing water and discharge water. Brushy Creek has many pool areas before it discharges into the South Raccoon. Therefore the investigator examined both source and contribution of nitrate inputs to the stream as well as the potential role of in-stream de-nitrification processes to better account for the nitrate dynamics observed in Brushy Creek.

**Sources of nitrate, base flow conditions**

During base flow, water in the stream is supplied from alluvial and local ground water. Base flow predominated for much of July which gave opportunity to examine groundwater contribution to the stream. The highest nitrate concentration in Brushy Creek occurred at the headwaters where several tiles converge to discharge into a pool (42CA). Water quality in the two prominent tiles (42CA1, 42CA2) was similar to the receiving pool. These tiles continued to flow through August and the relative lack of *E. coli* contamination indicates groundwater drainage with little surface influence. Perhaps most remarkable is that these concentrations were observed in August when stream nitrate levels are typically very low. What the nitrate-N concentrations would have been in June is conjecture but based on the decrease observed in the other Raccoon River tributaries the concentrations would have been considerably higher.

Samples collected from a very small feeder stream adjacent to this site (42D) however was considerably lower in nitrate-N which suggests that site 42CA represents a localized area of high-nitrate groundwater rather than a more regional characterization related to soils and landform. A visual inspection of the local landscape did not reveal unusual land use practices or large AFO that may have caused the exceptionally high late summer nitrate concentrations. Other tile sources indicate widespread variability within the watershed (42BT, 50T). Tile site 42BT, approximately 10 linear miles SE of the headwaters sites, had nitrate concentrations near the nitrate water quality standard of 10 mg/l. The corn crop in the field drained by the tile showed yellowing and classic indicators of nitrogen deficiency. No other areas showing nitrogen stress were observed in the watershed. Tile discharge further downstream at site 50T in August had a nitrate concentration of 18 mg/l while the receiving stream at site 43 was less than 3 mg/l. The investigator is continuing to search for additional tiles and shallow wells to better define and characterize groundwater nitrate distribution in the Brushy Creek Watershed. The available evidence to date indicates that dilution from downstream groundwater sources alone can not account for either the rate nor extent of nitrate reduction as water travels down this tributary.

**Fecal contamination and runoff event sampling**

The first major runoff event occurred 7/26/06. The event sampler did not function properly so data is limited to grab samples collected throughout the watershed but concentrated in upper Brushy Creek. All sample sites except site 42D and 42CA at the headwaters had *E. coli* counts >241920, (the maximum counts that the method could measure at the dilution used). Nitrogen analyses though showed a very high TKN form of nitrogen at Site 42B that decreased downstream (fig 16). Ammonia was not analyzed separately to determine whether toxic concentrations indeed occurred. Also of note is the low nitrate concentration and elevated nitrite at this site which is located just a few miles downstream of 42CA. E. coli is known to chemically reduce nitrate to nitrite. The one upstream source of E. coli and TKN is implicated from an observation made weeks later at an upstream site near 42BA where manure runoff from a cattle yard was observed behind a terrace. One end of the terrace had broken

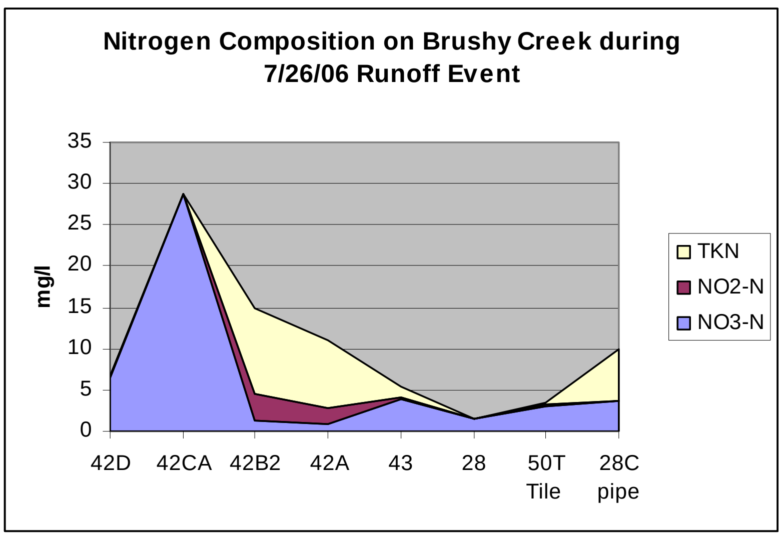


**fig 16. Nitrogen forms during rain event in Brushy Creek**

down. A path of manure could be observed from the trapped manure reservoir through the field to Brushy Creek. This indicates overland travel following a runoff event (fig 17). There are many terraces along Brushy Creek that are hidden from view by the corn crop. Note that the drainage pipe at site 28C had high E. coli and TKN. It is clearly draining a surface water source, perhaps a terrace. These are anecdotal evidences as to sources of fecal contamination and routes of entry. The investigators plan to conduct a more thorough search of these possibilities after the crops are out and visual inspection is more effective in identifying potential sites.

**fig 17. Manure trapped behind terrace**

Data from the composite event sampler is still being compiled and not available for this report.

# PLANS NEXT QUARTER

**Brushy Creek**

Flow measurements and time of travel especially during rain events are key elements in relating contamination load observed in the stream to contamination in the Raccoon River. Attempts have been made and will continue on determining flow.

Further work is planned to understand the decrease in nitrate concentration at downstream sites. Additional tile sites and or wells are needed to better characterize groundwater nitrate levels and distribution. Initial testing on sediment analyses has begun to characterize sediments for organic matter, fecal contamination and denitrifying activity. This may help further isolate sources of fecal contamination and determine the effect of denitrifying processes on water quality. Time of travel and surface coverage are also important elements in this determination.

A more thorough visual inspection of the landscape will be conducted after the crops are out to more easily identify specific sites and behaviors that contribute to high E. coli counts. This may be particularly important when farmers begin to apply manure to crop and pasture land this fall.

**Beaver Creek**

Beaver creek is the next target stream. A composite sampler is being placed near the stream gauging station so that load calculations can be made during a runoff event especially. During base flow conditions, the sampler will conduct additional survey-type sampling in the watershed to identify sections of stream or sub-watersheds that have higher levels of contamination. Results from the composite sampler should help determine the magnitude of fecal runoff and whether in-depth investigation is warranted.

**Walnut Creek**

The proximity of Walnut Creek to Beaver Creek may allow simultaneous survey sampling with Beaver Creek. Results will dictate the extent of further investigation.

**Un-sewered Communities**

We now have the locations of un-sewered communities in the watershed and will determine their proximity to streams that could be affected by inadequately treated sewage. Samples will be collected from candidate stream that are flowing and possibly drainage ditches following a rain event.

## SUMMARY

During low flow, point source contribution to streams becomes apparent. This is usually seen in elevated chloride levels and often ortho-phosphorus concentrations as well.

Nitrate and E. coli contribution is variable according to the characteristics of wastes treated and whether chlorination is practices.

Brushy Creek in the South Raccoon Watershed has an uncharacteristically high nitrate concentration in the upper reaches of the watershed. Tile discharge in this area indicates very high nitrate concentrations in the local ground water. Other tile discharges nearby are also above the water quality standard but variable. The cause of these differences is unknown. There is no obvious difference in land-use practice to account for the differences. The stream morphology is somewhat unique with many quiet pool areas. The high initial nitrate concentration, thick organic rich pool sediments, large surface areas, and low flow are all ideal conditions for de-nitrification. The decrease in nitrate concentration at downstream sites may at least in part be a function of de-nitrification rather than dilution below nitrate water downstream.

Brushy Creek has relatively high E. coli counts even during base flow and very high counts during runoff. Though there are many livestock operations in the watershed, the DNR interactive mapping of AFOs in Brushy Creek does not indicate a greater concentration of livestock operations than other tributaries. This may be a function of smaller operations that are not required to register. The hilly landscape in the watershed however makes fecal runoff a greater threat than in the North Raccoon Watershed and therefore contributes to the higher counts. Sources of fecal contamination can be hidden from view behind terraces or piped from a distant location. Fecal contamination in Brushy Creek appears most concentrated near Halbur. More runoff events are needed to better verify and pinpoint specific sources and practices.