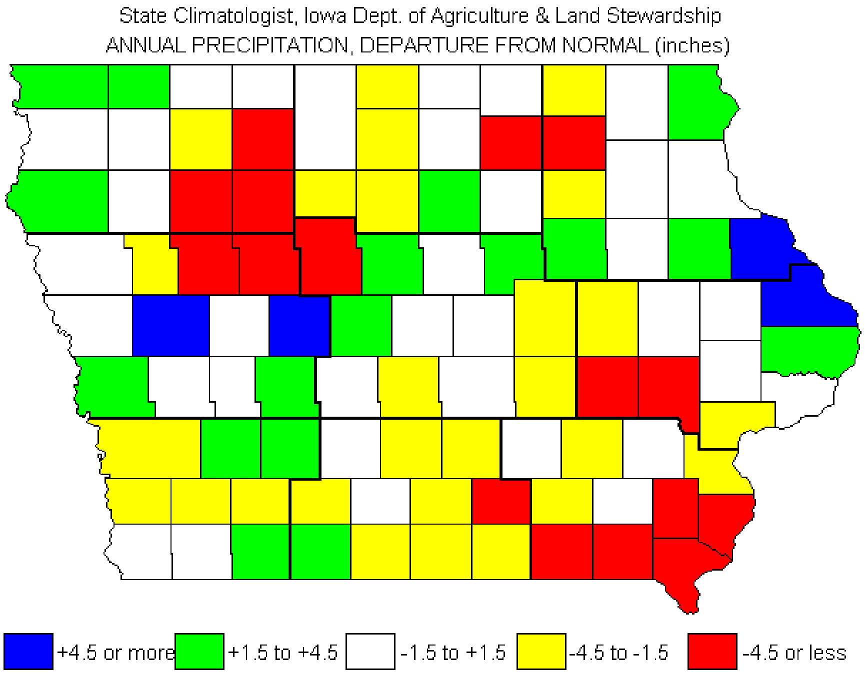
WEATHER AND HYDROLOGIC CONDITONS IN THE DES MOINES RIVER WATERSHED 2006

Annual precipitation state-wide totaled slightly above the long-term mean (Hillaker 2006). The rainfall distribution however was quite spotty with atypical seasonal distribution. Rainfall in the northern portion of the North Raccoon was four (4) inches below normal while rainfall in Greene County was more the four (4) inches above normal. Most of the precipitation occurred in March and April but with atypically high amounts occurring in the South Raccoon Watershed, southern portion of the North Raccoon, and Beaver Creek in September. May, June, and July were very dry, nearly the driest months on record. The above average rainfall in March and April provided enough soil moisture for good crop production and uptake of nutrients during the growing season. This distribution of rainfall had a profound effect on runoff and transport of fecal material to the main stem tributaries as well as nutrient loading.



Flow in the Des Moines River and Beaver Creek

The mean annual flow rate of the Des Moines River at the 2nd Avenue Bridge in Des Moines was 3380 ft^{3}s^{-1} in 2006 compared to the 10 year mean of 3396 ft^{3}s^{-1}. Most of the flow (53%) occurred in April and May (fig 1) compared to the more normal distribution observed in the 10 year period of record. A small increase was observed in September due to unusually high rainfall in the south portion of the watershed.

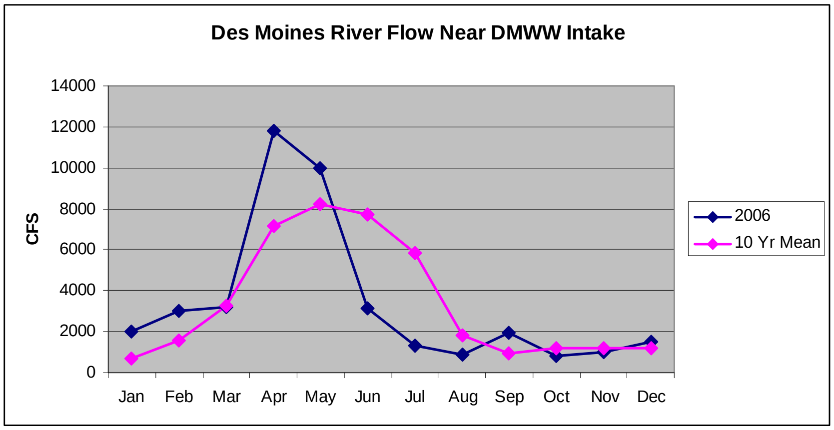


Fig 1. DMR flow in 2006 compared to the 10 year period of record

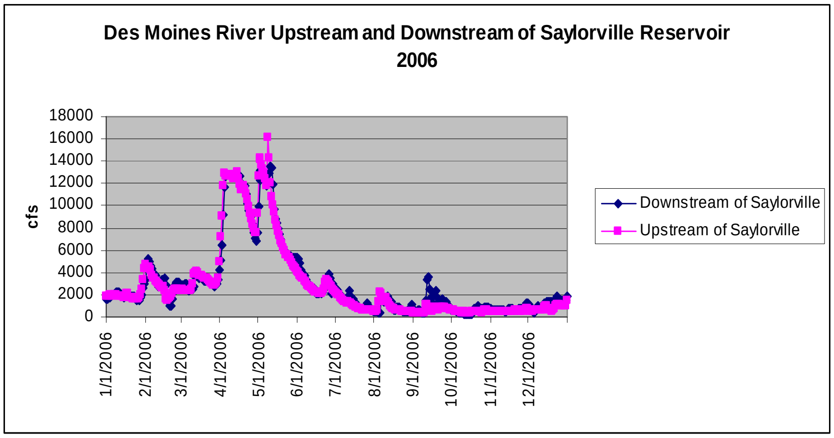


fig 2. Des Moines River flow through the Saylorville Reservoir

Pool levels in Saylorville Lake were kept relatively constant is 2006 so downstream discharge closely mirrored flow into the Saylorville Reservoir (fig 2). Water quality in the discharge, however, is that of stored reservoir water rather than inflow into the reservoir (Lutz 2006). Flow from Beaver Creek was generally minimal relative to flow in the Des Moines River through June. Beginning in July, however, percentage flow from Beaver Creek increased substantially (fig 3) indicating much higher rainfall amounts and runoff conditions in this watershed. Up to 50% of the total flow in September and October came from Beaver Creek. Water quality in the Des Moines River therefore was heavily influenced by Beaver Creek through this time period.

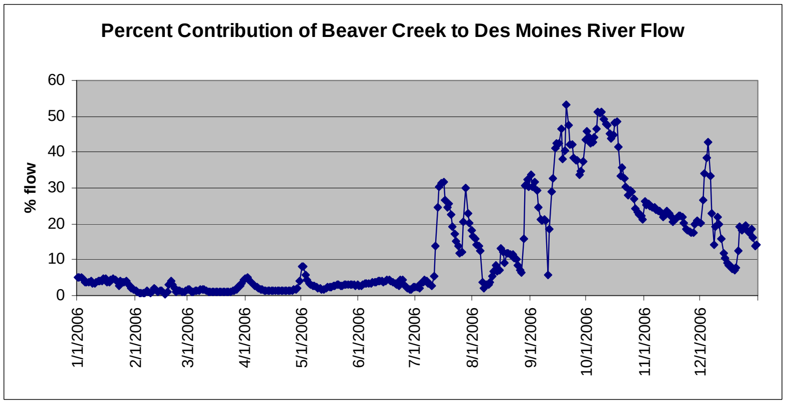


Fig 3. contribution of Beaver Creek to Des Moines River flow

Flow in the Raccoon River and tributaries

The mean annual flow in the Raccoon River in 2006 was 1182 cfs compared to the 10 year mean of 1865 cfs, most of the difference due to the dry summer (fig 4). The contribution of the North and South Raccoon tributaries to total flow in the remaining months differed considerably. Heavy April and May rain in the North Raccoon Watershed contributed

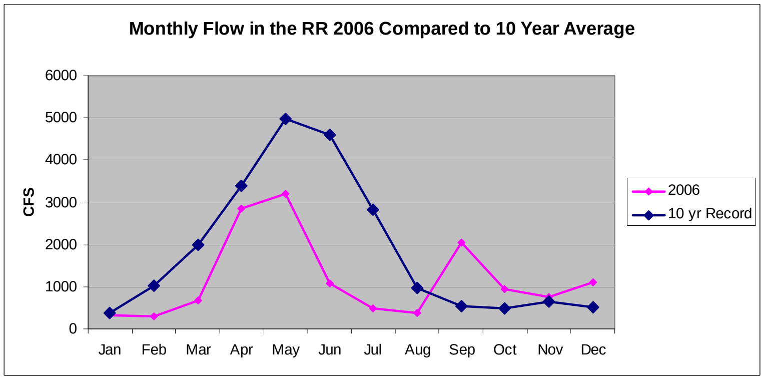


fig 4 Raccoon River flow in 2006 compared to 10 year mean

approximately 80% of the flow in the Raccoon while heavy fall rain in the South Raccoon Watershed contributed over 90% of the September flow (fig 5).

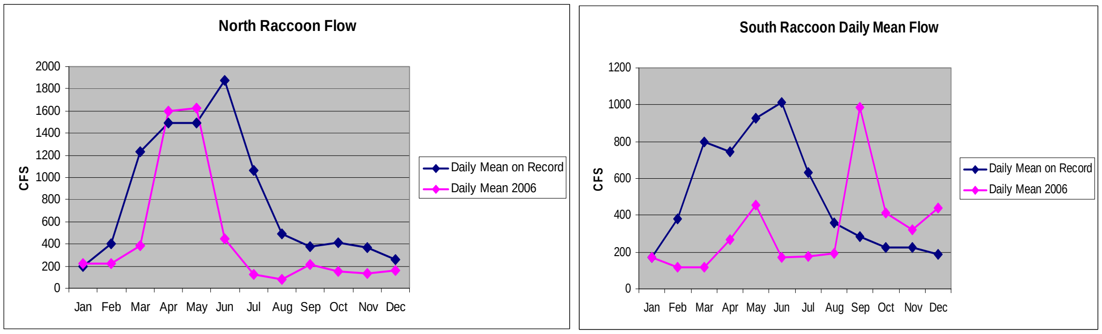


fig 5. Comparison of the North and South Raccoon flow in 2006 compared to 10 year mean

The superposition of flow from the two main stem tributaries to flow in the Raccoon River graphically shows illustrates this change in source of flow (fig 6.)

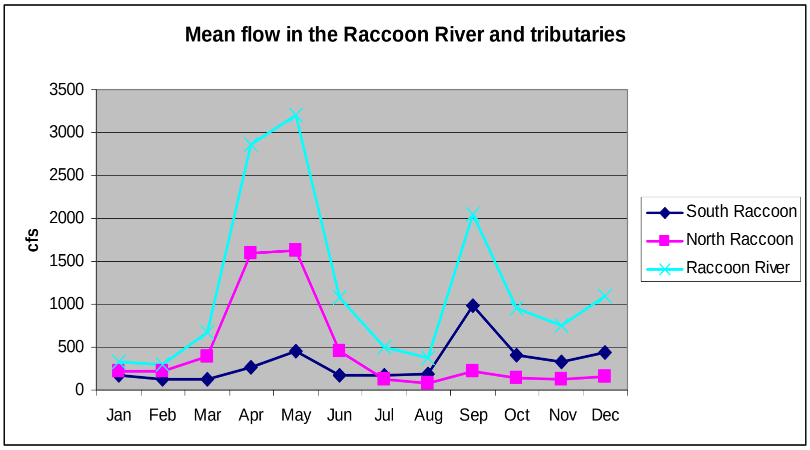


fig 6 Contribution of main stem tributaries to Raccoon River flow

The relative impact of the tributaries to water quality in the Raccoon River should change accordingly. Both water quality in the tributaries and contribution to flow must be known in order to understand the cause of impairment in the Raccoon River. This principle must be extended to tributaries of each stream in order determine the impact of a contaminant source on the receiving waterbody.

WATER QUALITY AT THE DES MOINES AND RACCOON RIVER INTAKE

Extensive sampling at the intake location on the Des Moines River and Raccoon River provides data-rich analyses of these two rivers. Daily samples were collected from the Des Moines and Raccoon River, excluding weekends and holidays. *E. coli* and turbidity analysis were performed on all river samples. Nitrate analysis was performed daily when nitrate-N concentrations approached or exceeded the water quality standard of 10 mg/l. On-line nitrate analyzers provided water production staff with real time data on combined source water flowing through the plant. An on-line nitrate analyzer installed on the Raccoon River near Van Meter provided early warning of high-nitrate water approaching Des Moines. Total anion scans were performed daily when nitrate-N concentrations in the rivers approached or exceeded the water quality standard of 10 mg/l. The frequency of analyses was reduced when nitrate concentrations fell well below the water quality standard.

Des Moines River

The total number of *E. coli* analysis performed on the Des Moines was 244 and total anion scans was 213 (Appendix A). The highest *E. coli* count was 8280 counts/100ml which occurred October 16, 2006. *E. coli* counts in the Des Moines River showed no correlation to flow in the Des Moines River (r2=-0.03929) but had a positive correlation to turbidity (r^2=0.41). The months with lower mean flow in the Des Moines River were more likely to exceed the *E. coli* water quality standard (fig 7). The frequency of *E. coli* impairment coincides remarkably l to the increase in relative contribution of Beaver Creek flow to the Des Moines River. The heavy late summer and early fall rain in the Beaver Creek watershed created runoff conditions for sediment and *E. coli* transport to the stream. High *E. coli* counts and turbidity were observed in Beaver Creek simultaneous to low counts just below Saylorville Reservoir (Lutz, Des Moines River Water Quality Network), flow that has been stabilized by the impoundment. *E. coli* counts in the Des Moines River were positively correlated (r2=0.41) to Beaver Creek flow though it contributed only 6.4% of the Des Moines River flow in 2006. Limited data on *E. coli* counts in Beaver Creek further implicates Beaver Creek as a primary source of *E. coli* and turbidity in the Des Moines River during elevated Beaver Creek flow. During three of the four sample dates in which the Des Moines River exceeded the *E. coli* standard, contribution from Beaver Creek alone would have caused impairment (Table 1).

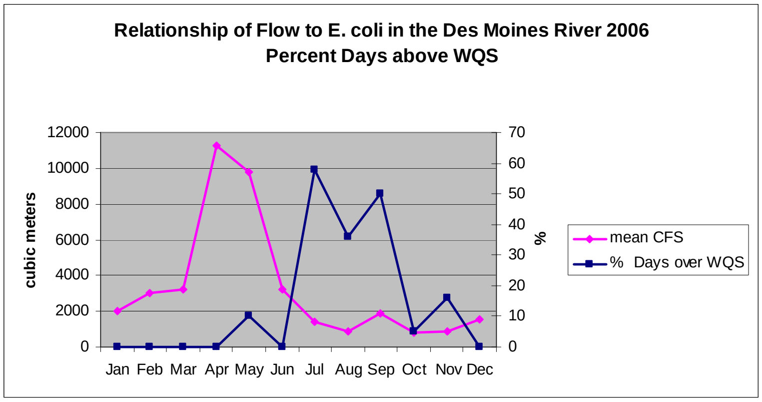


fig 7. Relationship of Des Moines River flow and *E. coli* Impairment

Table 1. Influence of Beaver Creek on Des Moines River *E. coli* Counts

Date	BC flow (CFS)	BC *E. coli* counts	DMR flow	DMR *E. coli* counts	% flow from BC	% *E. coli* load from BC	Contribution of BC to *E. coli* counts
6/22/2006	64	770	2500	74	2.6	26.6	20
7/6/2006	70	833	1830	82	3.8	38.9	32
7/12/2006	324	1850	2330	315	13.9	81.7	257
7/26/2006	159	8300	1310	3730	12.1	27.0	1007
8/3/2006	70	520	463	91	15.1	86.4	79
8/17/2006	80	6380	659	583	12.1	132.8	775
8/24/2006	52	410	519	43	10.0	95.5	41
11/16/2006	12	66	1020	30	1.2	2.6	1
11/29/2006	12	342	1460	576	0.8	0.5	3
12/7/2006	11	51	946	19	1.2	3.1	1
12/21/2006	21	411	1800	162	1.2	3.0	5

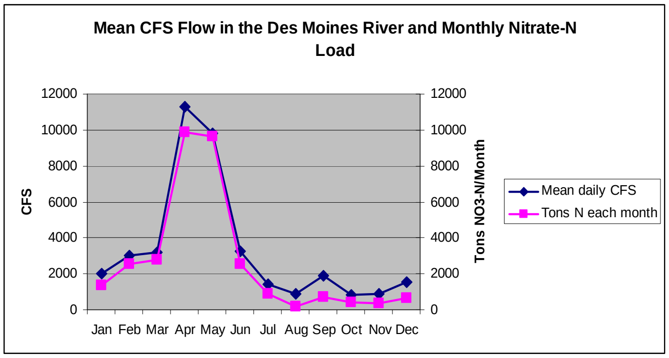


Figure 8 mean daily flow and nitrate loading

Nitrate loading in the Des Moines River is closely related to flow (fig 8) and to a lesser extend nitrate concentration. Highest concentrations generally occurred during high base flow. High nitrate concentration with elevated flow contributed to the high loading in April and May. Total 2006 nitrate load as N was 31944 tons, of which 19493 tons (61%) flowed past the intake in April and May (Table 2). Nitrate values between sampling events (such as weekends) were estimated from pre and post sampling events. When compared to the typical anhydrous ammonia application on corn acreage (approximately 150 lbs/acre), the annual load in the river was 10.7% (16 lbs/acre).

Table 2. Nitrate-N Loading in the Des Moines River

Month	Mean daily CFS	Mean NO3-N mg/l	monthly lbs/acre	Tons N each month
Jan	1983	8.52	0.69	1375
Feb	3010	11.9	1.27	2537
Mar	3221	10.48	1.38	2763
Apr	11277	10.82	4.93	9853
May	9812	11.46	4.82	9640
Jun	3242	8.75	1.28	2562
Jul	1414	6.28	0.44	878
Aug	905	2.62	0.09	184
Sep	1873	4.46	0.35	704
Oct	800	6.33	0.21	420
Nov	899	5.3	0.19	372
Dec	1522	5.45	0.32	656
Sum				31944
% of load in April and May				61.02241422

<u>Other associated nutrients</u>

Nitrite-N was somewhat elevated during the summer months. Soluble o-Phosphorus was detected with regularity in September during higher flow and fecal loading from Beaver Creek.

Chloride concentrations varied little during the year (mean = 27.9 mg/l, SD = 3.79) but a discernable drop is observed during high flow and runoff conditions (fig. 9) giving an R^2 = -0.70. Chloride concentration in the major rivers provided an invaluable reference point for detecting either raw fecal contamination or treated wastewater upstream during low flows. Chloride is not subject to bio-transformations, so it can be detected some distance from the source.

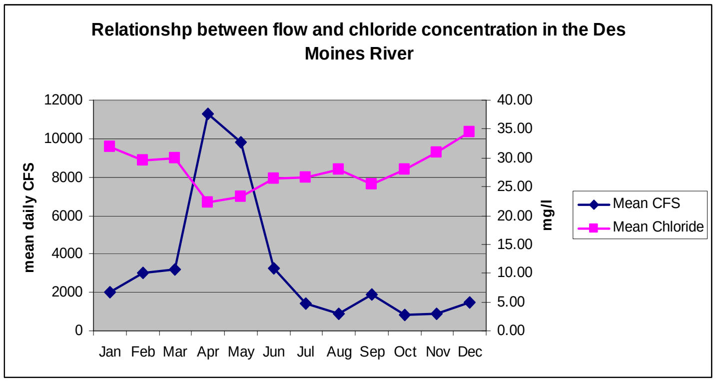


fig 9 chloride and flow in the Des Moines River

Raccoon River

The Raccoon River at the DMWW intake near Fleur Drive in Des Moines was also extensively monitored as it historically is the primary source of drinking water for the utility. A total of 247 samples were analyzed for *E. coli* and 210 for anions in 2006 (Appendix B). Water quality is more dynamic in the Raccoon River without a large reservoir upstream to buffer changes in upstream water quality. *E. coli* counts ranged from non-detect to 23820 counts /100ml on August 28, 2006. Nitrate-N concentrations ranged from 18.7 on May 5 to <0.05 in August. The annual median concentration was 8.8 mg/l with a standard deviation of 4.2 mg/l.

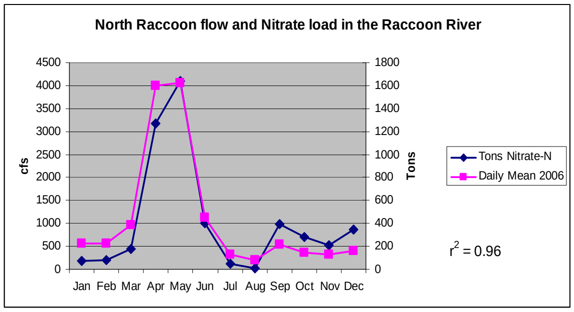


fig 10 N Raccoon flow to Raccoon nitrate load

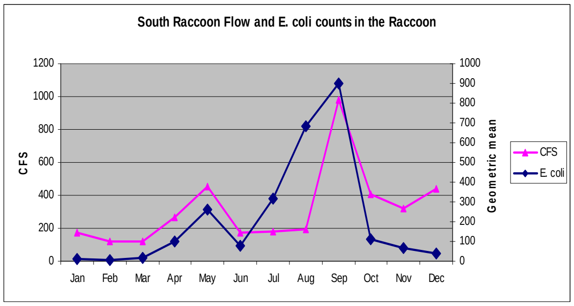


fig 11. S Raccoon flow and RR *E. coli* counts

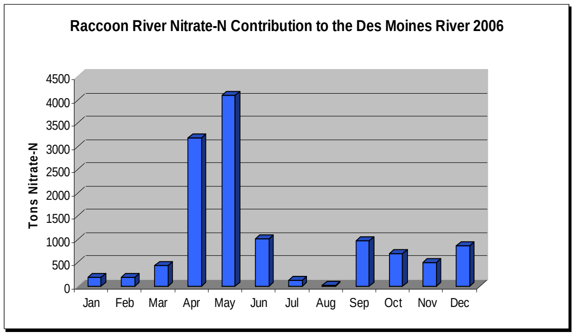


fig 12 Nitrate-N load in the Raccoon River

The change in tributary flow from the extensively-cultivated North Raccoon Watershed in the spring, to the more diverse South Raccoon Watershed in the fall best accounts for the dynamics in water quality in the Raccoon River. Nitrate loading in the Raccoon River closely correlates to flow (r^2=0.96) in the North Raccoon (fig 10) while *E. coli* counts correlates best to flow from the South Raccoon (fig 11). The relative contribution of these tributaries to nitrate-N and *E. coli* contamination is more than can be attributed by change in flow alone. Mean nitrate concentrations in the North Raccoon watershed were highest during the high April and May flow (15.8 and 18.9 respectively) while the South Raccoon had its highest mean count in September, the month with its highest flow. A nitrate-N load of 12323 tons flowed to the Des Moines River in 2006 of which April and May accounted for 59% of the total load in the Raccoon River (fig 12). This loss distributed over 2.3 million acres in the watershed is 10.6 lbs/acre.

E. coli loading was heavily influenced by the September flow from the South Raccoon. Nearly half the total *E. coli* load (49.4%) in the Raccoon River occurred in September.

WATERSHED DISTRIBUTION OF FECAL CONTAMINATION
And Chemical Indicators

Overview

Weekly samples were collected from select tributaries in the watershed. The main stem tributaries were sampled to provide a frame of reference to contributing streams. Feeder streams of tributaries with high *E. coli* counts were subsequently sampled and/or further subdivided to determine areas of highest concentration, source of contamination, and point or mode of entry to the stream. Sampling efforts focused on Brushy Creek during this quarter and to a lesser extent Beaver Creek and Walnut Creek. Brushy Creek had chronically-high counts during low flow and heavy fecal contamination during runoff conditions. It is the largest tributary of the South Raccoon and repeatedly demonstrated a disproportionate contribution of *E. coli* to the Raccoon River.

There is a high concentration of animal feeding operations in Carroll County (fig 13), near the headwaters of the Middle Raccoon and Brushy Creek. These sources do not necessarily contribute to high counts of *E. coli* to the streams and rivers. Much depends on manure management, adequacy of containment structures, manure age and stabilization, terrain, proximity to streams, amount and intensity of rainfall, method of application, and other factors. Natural and artificial impoundments such as beaver dams and sedimentation basins may at least temporarily trap and retain *E. coli* in the basin and sediment, allowing time for die-off and stabilization. Samples collected by the Agriculture Clean Water Alliance in the headwaters area of the Middle Raccoon were consistently above the *E. coli* standard while samples below Lake Panorama consistently met the water quality standard for *E. coli*. Samples from the Middle Raccoon near its confluence with the South Raccoon (site 31) consistently had low *E. coli* counts as well. Therefore no samples were collected up stream of that site on the Middle Raccoon. On-site observations in upper Beaver Creek and Brushy Creek indicated rather extensive stream-side pastures and grazing (fig 14).

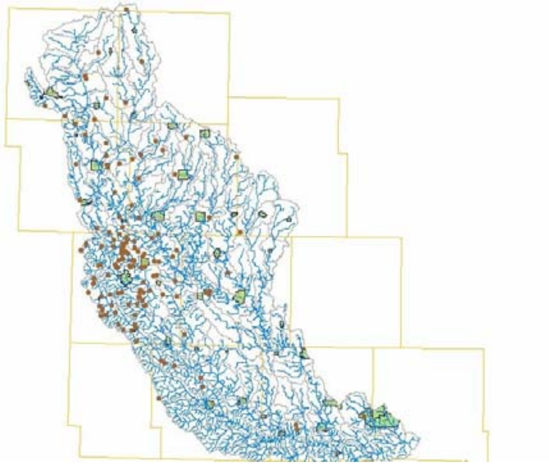


fig 13. open feedlots in the Raccoon

fig 14. Unrestricted grazing along Brushy Creek

In addition to grazing pressure, the dissected terrain of the southern Iowa drift plain landform causes nearly all producers to have some component of their operation on erosive slopes. This is especially true of Brushy Creek with its long narrow watershed. All operations are close to either permanent or temporal streams. This area was extensively sampled and nearly all sites in upper Brushy Creek had elevated *E. coli* counts.

High *E. coli* counts in Beaver Creek samples was evidence of high *E. coli* counts in the Des Moines River based on the relationship of flow contribution to the Des Moines River and *E. coli* counts. Walnut Creek had high *E. coli* counts came from both rural and urban areas. The urban streams however were highly variable and less predictable. Flow was very flashy because of extensive impervious surfaces.

Investigative approach

This quarter, more in-depth investigation was conducted in tributaries that had elevated *E. coli* counts in the first round of sampling and historical data. Flow data was gathered where possible to determine load contribution to the main stem tributaries. Composite samples on Beaver Creek, Brushy Creek, and Hardin Creek were programmed to initiate sampling when flow rate increased sufficiently to indicate runoff. Grab samples from various sites in these tributaries provided collaborative distribution data to the composite samples. Additional sample sites were selected in impaired areas as determined from the previous round of sampling to isolate specific sources.

This conceptually simple approach had several challenges:

1. The large size of the watershed created logistical challenges to comparative sampling when the goal is to isolate areas of high *E. coli* runoff. It is virtually impossible for a single sampler to collect samples under comparable hydrologic conditions.
2. Rainfall amounts and distribution were seldom uniform. Samples collected at similar times but different locations often displayed considerable turbidity differences, indicating differences in the amount and intensity of rain and subsequent *E. coli* runoff or position on the stream flow hydrograph.
3. The source of high *E. coli* counts is at least partially removed by the rain event associated with the high counts.
4. Rain events do not always conform to weekday schedules and daylight hours.

To counter these challenges, rain event sampling was generally focused on a single sub-watershed or region within the sub-watershed. The same sites were sampled repeatedly, supplemented with on-site observations of potential sources and changes in landscape activities. *E. coli* counts in pool and stream sediments were performed at several Brushy Creek sites to determine the potential relationship of high *E. coli* counts in the sediment to upstream source of *E. coli*. Benthic analysis was also performed to indicate aquatic health and evidence of chronic pollution. Laboratory bench scale experiments were conducted on sediments from impaired sites for *E. coli* viability and transport as well as de-nitrification potential under more controlled conditions. A complete tabulation of stream sampling data in this report is provided in Appendix C

Results: Beaver Creek Watershed

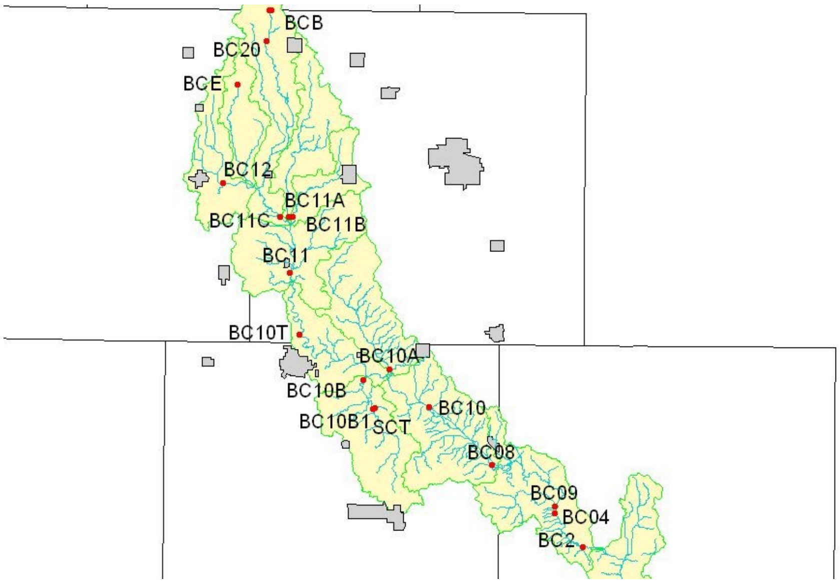


fig 15 Beaver Creek sample sites

Beaver Creek sample sites are represented by the red dots in the distribution map (fig 15). GPS lat long coordinates for these sites are presented in table 3. A composite ISCO sampler located near the USGS stream gauging at site BC04 was programmed to sample during a rain event.

Table 3 GPS Latitude Longitude Coordinates for Beaver Creek Sample Sites.

Site ID	LAT	LONG	Stream Name
BC11A	41.99367595	-94.11139383	Middle Beaver Creek
BC11B	41.99362281	-94.10543078	East Beaver Creek
BC11C	41.99367662	-94.12347936	Beaver Creek
BC2	41.65344696	-93.69707443	Beaver Creek
BC11	41.93591081	-94.10814098	Beaver Creek
BC10	41.79728209	-93.91202766	Beaver Creek
BCD	42.20958040	-94.14139530	Beaver Creek
BCC	42.20958971	-94.14045988	Beaver Creek
BCB	42.20960210	-94.13921266	Beaver Creek
BCA	42.20961139	-94.13827724	Beaver Creek
BC20	42.17662032	-94.14516614	Beaver Creek
BC10A	41.83649780	-93.96762726	Little Beaver Creek (Dallas County)
BC10B	41.82458676	-94.00464641	Slough Creek
BC04	41.68819957	-93.73556702	Beaver Creek
BC09	41.69538111	-93.73657695	Little Beaver Creek (Polk County)
BC12	42.02849189	-94.20329639	West Beaver Creek
BC08	41.73722581	-93.82436496	Beaver Creek
BC10B1	41.79482376	-93.99040560	Slough Creek
BC10T	41.87148672	-94.09317386	Beaver Creek
BCE	42.13070774	-94.18453616	Little Beaver Creek (Greene County)
SCT	41.79544568	-93.98800483	Slough Creek

Highest *E. coli* counts consistently occurred in the middle to upper portion of the Beaver Creek watershed where pastures were common. The June-though-August samples were collected shortly after a rain event to capture runoff water. These areas typically had lower turbidity values than downstream sites. Other parameters associated with fecal contamination, such as soluble phosphorus and nitrite-N, were more common at these sites as well but at low concentrations. These observations are consistent with grazing as the source of *E. coli*. Pastures provide permanent cover to protect soil from erosion during runoff but would allow transport of fecal material to the stream during runoff (table 4). The November round of sampling, collected during base flow and low turbidity, still had elevated *E. coli* at these sites. If these low flows it is very unlikely that *E. coli* would be transported to the stream by overland flow or re-suspended from the sediments. The author's observation of cattle is that they tend frequent stream areas for water, shade, and forage. They usually gain access to the water in specific areas of the stream with easy access. Momentary bank-side grazing commonly occurs when taking a drink as does occasional direct discharge into the stream. This is consistent with downstream samples where *E. coli* counts were highly variable while phosphorus, chloride, and nitrite were present at low concentrations.

Site BC09 gave some indication of a point-source contribution from a waste treatment facility as both chloride and soluble phosphorus levels were well above other sites. *E. coli* counts were <1000 indicating treatment and stabilization. Because of the relatively low *E. coli* counts, this potential source was not further investigated.

Table 4 Beaver Creek Watershed

Sample Date	Site Id	*E. coli*	Turbidity	Chloride	Nitrate as N	Nitrite as N	Phosphorus-O as P
06/22/06	BC2	**770**	29.4	32.0	12.0		
	BC10	**488**	22.2	29.5	13.2	0.08	0.06
	BC11	**2419**	92.0	26.6	14.6	0.18	**0.15**
06/29/06	BC2			32.2	11.3		**0.07**
07/06/06	BC2	**833**	143.0	30.8	7.6		0.07
	BC11	**1529**	49.6	33.9	12.4		
	BC11A	**2851**	39.9	30.5	14.2		
	BC11B	**985**	26.0	56.0	12.7	0.08	**0.27**
07/12/06	BC2	**1850**	141.0	20.6	5.2		0.09
	BC10	**61310**	210.0	22.9	12.5		**0.12**
	BC11	**36540**	52.4	23.3	13.8		**0.22**
	BC11A	**92080**	34.0	21.9	14.0		**0.18**
	BC11B	**3180**	28.6	30.7	15.6	0.06	**0.10**
	BC11C	**27550**	54.9	28.3	14.1	0.08	**0.21**
07/26/06	BC2	**8300**	187.0	24.3	5.3		0.09
	BC8		180.0	19.0	6.4		
08/03/06	BC2	**520**	21.0	32.8	8.6		0.09
08/10/06	BC2		74.0	32.0	4.4		0.08
08/17/06	BC2	**6380**	104.0	20.9	3.9		
08/24/06	BC2	**410**		37.9	7.4		
09/07/06	BC2		24.4	33.3	10.0		
11/16/06	BC2	66		29.6	11.5	0.00	0.00
11/16/06	BC04	115		29.3	11.6	0.00	0.00
	BC09	196		**64.5**	10.6	0.05	**0.63**
	BC10			28.8	12.1	0.00	0.00
	BC10A	60		23.7	12.6	0.03	0.00
	BC10B	38		26.5	16.3	0.04	0.00

Sample Date	Site Id	*E. coli*	Turbidity	Chloride	Nitrate as N	Nitrite as N	Phosphorus-O as P
	BC11A	105		29.6	12.5	0.00	0.00
	BC11B	**1733**		30.1	11.7	0.00	0.00
	BC11C	71		30.1	11.7	0.00	0.00
	BC20	74		27.9	14.2	0.00	0.00
	BCA	194		27.2	13.1	0.00	0.00
	BCB	66		20.6	13.6	0.00	0.00
	BCC	128		27.2	13.8	0.00	0.00
11/29/06	BC2	**342**	11.9	28.8	10.2	0.00	0.00
	BC04	**626**	11.4	29.3	10.7	0.00	0.00
	BC09	**874**	6.1	37.1	11.3	0.05	**0.22**
	BC10	**748**	7.0	28.4	12.4	0.00	0.00
	BC10A	172	2.1	24.0	11.8	0.00	0.00
	BC10B	**462**	10.0	26.7	17.4	0.05	0.08
	BC11A	**700**	17.0	30.5	12.1	0.00	0.00
	BC11B	**4092**	6.2	40.0	11.7	0.06	**0.11**
	BC11C	**2582**	16.0	30.1	11.0	0.00	0.00
	BC12	**12976**	4.2	30.2	10.3	0.00	0.00
	BC20	220	1.3	28.4	13.3	0.00	0.00
	BCA	104	0.5	25.5	12.2	0.00	0.00
	BCB	**758**	0.2	27.9	13.3	0.00	0.00
	BCC	40	0.7	23.5	9.8	0.00	0.00
12/07/06	BC2	51	6.5	29.8	12.3		
12/21/06	BC2	**411**	27.7	28.1	8.6		
	BC04	200	25.6	28.2	9.3		

Nitrate concentrations were typical of samples collected throughout the Des Moines Lobe landform. Spring and early summer concentrations were well above the water quality standard and rapidly dropped in July and remained low through August. Nitrate concentrations increased again in September and remained high through most of December. Site BC10B (Slough Creek) consistently had the highest nitrate concentration in the Beaver Creek Watershed. This is consistent with the Beaver Creek snapshot survey conducted by the Steve Witmer group. The source and cause of high nitrate concentrations in this sub-watershed is being investigated.

Raccoon River Watershed (The Main stem tributaries)

The low *E. coli* counts at the Des Moines Water Works intake were also observed upstream on the Raccoon River and main stem tributaries as expected. (Table 5). Dry weather prevailed over most of the watershed from mid May until September. The South Raccoon generally had higher *E. coli* counts than the North Raccoon through the summer, even though drier weather prevailed in the South Raccoon Watershed. For logistical reasons, rain event sampling concentrated on sub-watersheds known to have high *E. coli* counts during a runoff event. The main stem tributaries were seldom sampled during a rain event giving some bias toward low flow conditions and *E. coli* counts.

Table 5. *E. coli* counts/100ml in the Raccoon River and Main-stem Tributaries

	38 (RR)		A (NR)		37(I SR)		31 (MR)		32 (SR)	
Sample Date	*E. coli*	Turb	*E. coli*	Turb	*E. coli_*	Turb	*E. coli_*	Turb	*E. coli_*	Turb
04/20/06		40	36	46	56	22			32	24
05/04/06		140	1340		498	80			980	
05/18/06	38	38	59	34	101	36			172	30
06/01/06	47	42	33	37	121	67			184	195
06/15/06		19	78	22	238	26			411	50
06/22/06			45	18	326	14	155	15		
06/29/06		14	41	19	246	10		24	146	30
07/06/06			63		323		52			
07/13/06		164	200	20	410	189		26	1220	194
07/20/06			30	25	63	31	93	30		
07/27/06		21	300	50	100	38		38		45
08/03/06			100	22	100	22		28		
08/10/06		22	200	22		22		22	1340	10
08/17/06			310	29	1430	30	310	36		
08/24/06		41	100	33	520	52		52		56
09/07/06		38		20	100	40		41		35
11/08/06			100							
11/09/06	10		5		5					
11/10/06		4		4						
11/13/06	15	3	30	3	8	3				
11/14/06	46		38		43					
11/21/06	3				5		24			
12/07/06	17	8	41	4	10	17	13	6	19	4
Average	25	42	157	24	224	39	108	29	500	61

High nitrate concentrations in the North Raccoon and high flow relative to the South Raccoon produced high nitrate concentrations in the Raccoon River through mid-July. Concentrations rapidly dropped to non-detectable levels in the North Raccoon in August were nearly non-detectable in the South Raccoon. Following September rains, nitrate concentrations rapidly increased in the Raccoon River. Similar flow both the North and South Raccoon hydrologic units suggested high nitrate concentrations in both sources. Samples collected from the South Raccoon unit in November and December were nearly as high as the North Raccoon. The Middle Raccoon tributary of the South Raccoon unit was higher than the South Raccoon as expected as part of its watershed is in the Des Moines lobe landform (Table 6).

Within the North Raccoon, West Buttrick Creek had the highest nitrate concentration in the study area at 24.4 mg/l (Appendix C). The watershed has extensive buffer strips which may account for the relatively low *E. coli* counts. Elevated chloride and soluble phosphorus in July through early September suggests discharge from a waste treatment facility. Elevated *E. coli* and o-phosphorus occurred in Hardin Creek during the August 28 and September rain events. The composite sampler at the site triggered intermittently so that a plot of counts over the hydrograph was not possible. This illustrates the importance of collecting samples during runoff and the uncertainty of quantifying *E. coli* counts from single grab samples.

Table 6. Nitrate-N Concentration in the Raccoon River and Tributaries

Sample Date	38 (RR)	A (NR)	37 (lSR)	31 (MR)	32 (SR)
04/20/06	14.4	15.8	3.2		1.9
05/04/06	19.2	21.0	7.8		6.9
05/18/06	14.8	16.9	6.9		4.8
06/01/06	13.1	15.1	8.1		4.3
06/15/06	11.9	14.4	6.3		2.8
06/22/06		11.7	4.5	6.4	
06/29/06	7.1	9.2	3.3	5.3	1.5
07/06/06		5.9	1.9	4.4	
07/13/06	4.9	5.2	4.9	6.2	2.1
07/20/06		1.7	1.2	3.0	
07/27/06	1.2	0.6	1.5	2.4	1.5
08/03/06		0.4	0.4	1.7	
08/10/06	0.4	0.2	0.5	1.3	0.7
08/17/06		ND	0.3	0.8	
08/24/06	0.9	0.5	1.3	1.3	2.4
09/07/06	2.2	2.7	2.1	1.9	3.0
11/10/06	8.6	8.9			
11/13/06	8.6	8.8	8.6		
11/21/06	9.0		8.8	10.4	
12/07/06	10.4	11.5	9.7	10.6	6.4
Average	8.4		4.5	4.3	3.2

Raccoon River Watershed: Brushy Creek

Water quality in Brushy Creek near its confluence with the South Raccoon (site 28) gives little indication of the dynamics in water quality upstream (Table 7). Nitrate-N concentrations remained below the water quality standard during the entire period. Nitrite-N and o-phosphorus were seldom detected. *E. coli* levels typically exceeded the water quality standard even during low flow. During rain events, counts were very high, usually much higher than other tributaries. The headwaters region (site 42 series) consistently showed elevated nitrite and o-phosphorus concentrations during low flow and very high TKN nitrogen (TN-(nitrate+nitrite)) during high flow in addition to high *E. coli* counts. Therefore, sampling efforts were concentrated in this region with new sites added to isolate source(s) of fecal contamination.

The sample site distribution map (fig 16) and coordinates table shows extensive sampling near the headwaters where high *E. coli* counts occurred. Included are tile and end of pipe sites (those with a "T" extension and 28C). The composite sampler is located at site 50.

Brush Creek Watershed

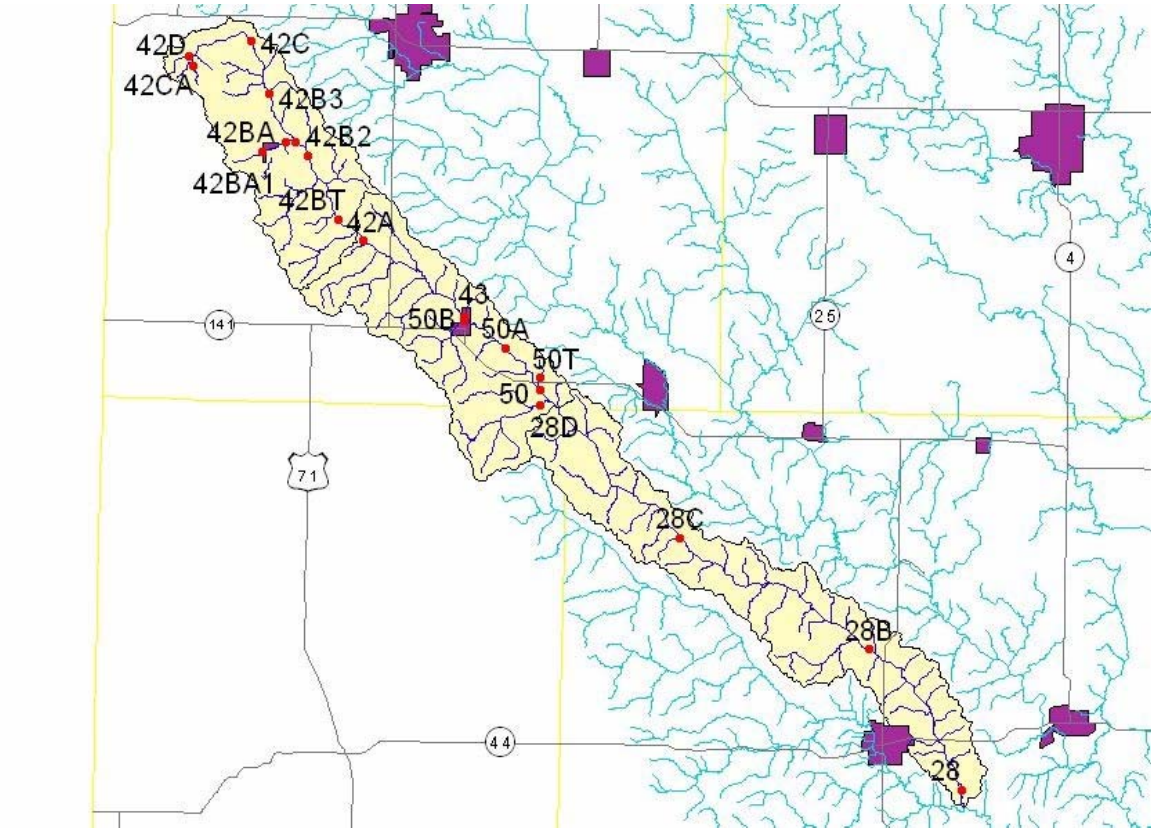


fig 16 Brushy Creek Sample Distribution Map

Site Coordinates for Brushy Creek

Site Id	LAT	LONG	Site description
28	41.65231481	-94.44139942	Brushy Ck outlet, Historical Data
42B3	42.03542839	-94.97221864	Brushy Ck upstream of Hbr Ck
50A	41.89548220	-94.79002381	
42BA	42.00792954	-94.95900365	Halbur Ck, downstream of Hbr
50	41.87232921	-94.76414435	Composite sampler, midpnt
43	41.91289343	-94.82203002	Dedham, Historical Data
42C	42.06443891	-94.98727882	
42D	42.05537380	-95.03387215	Headwaters
42B2	42.00824311	-94.95199772	Downstream of Halbur Ck
42B	42.00074659	-94.94199308	Historical Data
42A	41.95393693	-94.89878336	Historical Data
28C	41.79105844	-94.65610019	Intermittent Tile
28B	41.73044161	-94.51246689	
50T	41.87914256	-94.76394772	Tile
42BA1	42.00273394	-94.97625637	Hbr Ck, Upstream of Halbur
42BT	41.96537261	-94.91874344	Tile
42CA (T1,T2)	42.05008968	-95.03012108	2 tile pool at headwaters
28D	41.86373859	-94.76396613	
50B	41.91049897	-94.82221293	

During the initial quarter of sampling, the highest *E. coli* and nitrate concentrations were near the headwaters, indicating a possible relationship related to land-use and manure application. Nitrate concentration decreased remarkably in downstream sites during low flow. During a runoff event, very high *E. coli* counts were noted at all downstream sites. Water quality data at site 42B2 during the July 26 rain event showed heavily fecal contamination at that site. *E. coli* counts exceeded method capacity for the dilution range used (> 241920 counts/100ml), total nitrogen measured 15 mg/l, of which 10.5 mg/l was present as ammonia and organic nitrogen. Only 1.3 mg/l of nitrogen was in the nitrate form and 3.2 mg/l as nitrite-N. The soluble fraction of phosphorus was 3.64 mg/l. Only the single upstream site (42D) had measurable *E. coli* counts. This suggests a large upstream source near 42B2 as the principle contributor to downstream *E. coli*. Nitrogen upstream of this site was in the nitrate form and at a much higher concentration (6.5 mg/l). Soluble phosphorus was barely detectable at 0.07 mg/l.

Linking this source to *E. coli* counts in the Raccoon River is uncertain but potentially could cause the spike in observed counts. Assuming the increase in measured flow at the Redfield gauging station from Brushy Creek (50 CFS) and *E. coli* counts of >241920 as observed at site 43, the contribution to load in the Raccoon River would be >14080 compared to the 8160 counts observed on this date. However, time of travel to Des Moines is at least 24 hours, while the spike in Raccoon River *E. coli* on July 26 corresponds to flow from Walnut Creek.

Site 42B2 appears to be the focal point of fecal contamination. It is downstream of the first of several sedimentation basins in the site 42 area. These basins are shallow and nearly filled with sediment. Sediment analyses performed in October verified a large fecal component in these sediments. Extensive growth of filamentous algae (Cladophora sp) was colonizing the area, further increasing particle entrapment. During the July 26 rain event, stream velocity increased sufficiently to erode and re-suspend the fecal contaminated sediments and add to the *E. coli* loading from upstream. The occurrence of elevated nitrite and soluble phosphorus from these sites during warm weather and low flow is consistent with decomposition of trapped fecal material in the sediments. The organic rich sediments are functionally similar to wetlands substrate where denitrifying occurs.

Most of the sampling and study this second quarter focused on the upper section of the Brushy Creek Watershed to answer the following questions:

1. Where is the *E. coli* entering the stream and what is the source?
2. How much *E. coli* is trapped in stream sediments and what is its potential contribution during elevated flow?
3. Does the benthic community indicate chronic pollution and fecal contamination?
4. Is the decrease in nitrate levels downstream during low flow due primarily to dilution from low nitrate groundwater or in-stream processing (assimilation and denitrification)?

Table 7 Brushy Creek, Samples Sites from Mouth to Headwaters

Sample Date	Client Id	*E. coli*	Turbidity	Chloride	TN	Nitrate as N	Nitrite as N	o-Phos as P
06/22/06	28	345	28.5	12.1	3.9	3.1		
	28B	166	33.6	13.8	5.2	4.1	0.06	
	28C	291	10	14.2		5.2		0.07
	50	261	4.9	16.8		7.0	0.1	
	50A	461	2.5	16.7		7.2	0.18	0.09
	43	225	12.5	15.9		8.5	0.25	
	42A	248	11	13.5		11.3	0.16	0.15
	42B	291	8.4	14.6		13.2	0.59	0.08
	42B2	613	7.5	13.9	12.8	14.0	0.15	0.07
	42BA	980	13.3	15.3		12.6	0.1	
	42C	179	8.8	13.9		17.6	0.08	
	42D	1414	6.4	9.7	12.1	12.0		
06/29/06	28		14.0	11.4	3.0	2.7		
07/06/06	43	1539		18.9		3.4	0.28	0.65
	42A			14.6		7.9	0.64	0.48
	42B2	816		14.1		11.9	0.09	
	42BA	565		14.7		10.6	0.09	0.11
	42BA1	393		10.7		12.4		
	42C	624		12.3		15.8		
	42CA	31		13.9		29.3		
	42D	1956				10.8		
07/13/06	28		23.4	11.2		3.2		0.13
07/20/06	28	1145	18.1	12.2		1.8		0.12
	28A1	341	3.86	10.0		18.6		
	43	171	12.7	17.1		4.1	0.11	0.2
	42A	520	2.52	15.3		4.9	0.33	0.4
	42B3	1789	5.68	13.0		11.4	0.08	0.12
	42CA		0.42	18.4		28.2		
07/26/06	28	>24192	10.7	9.6	1.5	1.5		
	28C	>241920	193	15.4	9.9	3.6	0.13	0.16
	50T	>241920	125	17.5	3.5	3.0	0.18	0.23
	43	>241920	112	12.2	5.3	3.9	0.21	0.27
	42A	>241920	119	21.6	11	0.9	1.89	1.49
	42B2	>241920	209	55.3	15	1.3	3.17	3.64
	42CA	171	12	15.2	24.1	28.8		
	42D	12740	13.7	15.2	6.5	6.5	0.16	0.07
07/27/06	28	100	11.4	11.0		1.8		0.10
08/03/06	50T	100	0.7	48.6		18		0.07
	43	1100	3.5	19.8		2.7	0.26	0.32
	42A	850	3.6	17.3		3.7	0.41	0.62
	42B	1100	2.3	16.9		4.7	0.24	0.49
	42B2	2260	5.3	17.5		7.1	0.08	0.33
	42B3	1600	11.8	14.9		8.7	0.11	0.19
	42BA	970	7.1	18.7		7.9	0.17	0.15
	42C	200	7.0	13.9		8.6	0.05	0.10
	42CA	310	7.6	15.3		28.8		
	42D	1350	18.9	13.5		4.8	0.07	0.07

Sample Date	Client Id	*E. coli*	Turbidity	Chloride	TN	Nitrate as N	Nitrite as N	o-Phos as P
08/07/06	50T	1017	1.06	46.6		18.0		0.07
	42BT		0.10	5.4		11.1		
	42CA1		0.69	17.2		30.4		
	42CA2	11199	0.33	11.2		28.3		
08/10/06	28		12.3	10.4		1.6		0.12
08/17/06	50	2560	30.0	20.8	2.8	2.3	0.05	
	50T1		4.6	51.7	16.4	16.8	0.12	
	50T2	520	2.0	28.9	9.5	10.4		
	43	2130	32.0	18.4	3.5	2.8	0.09	
	42A	410	5.6	17.7	10.0	4.6	0.17	
	42B2	960	5.6	17.2	5.6	6.1		
	42BA	2430	6.6	18.8	6.2	6.5	0.11	
	42BT		6.8	5.5	10.6	10.9		
	42CA1		0.9	11.3	24.4	27.5		
	42CA2		0.8	17.5	28.3	30.5		
	42D	630	7.9	16.8	3.8	3.5	0.07	
08/24/06	28	1340	29.5	13.1		3.2		0.25
08/28/06	Brushy Ck 1	7080	93.7	17.5	3.2	3.2		0.17
	Brushy Ck 4			18.6		1.9	0.36	0.47
	Brushy Ck 6	29000		13.1		2.2		0.19
	Brushy Ck 7	28160	270	11.0	2.4	3.2		
	Brushy Ck 9	259940	315	18.8	2.5	2.3	0.07	0.28
	Brushy Ck 11		429	17.4	3.2	3.9	0	0.08
	Brushy Ck 13		565	22.1	4.9	0.5	0.6	0.87
	Brushy Ck 14		1393	21.4	6.0	0.4	0.54	1.22
	Brushy Ck 15	866400	662	16.1	4.2	0.4	0.49	0.84
	Brushy Ck 16		389	13.8		2.5	0.54	0.45
	Brushy Ck 17		316	13.8		3.2	0.24	0.35
	Brushy Ck 18		263	13.9		3.4	0.19	0.42
	Brushy Ck 19	290900		13.8	4.6	3.2	0.25	0.43
	Brushy Ck 20		215	14.4		3.2	0.28	0.52
	Brushy Ck 21		183	15.2		3.6	0.27	0.55
	Brushy Ck 22		158	17.4		4.4	0.2	0.55
	Brushy Ck 23	261300	154	16.1	6.7	4.6	0.17	0.5
	Brushy Ck 24		124	15.5		4.8	0.15	0.44
08/31/06	28C	48840	42	73.1		40.2	0.17	0.64
	50T2			25.1		13.0		
	42B3	26460	8.02	17.5		12.0	0.11	0.2
	42BA	6570	2.47	22.8		9.2	0.08	0.12
	42BA1	3140	2.88	14.8		10.2		0.13
	42BT			5.0		9.4		
	42CA2			11.0		26.3		
09/07/06	28	2400		13.7		4.4		0.20
09/10/06	Brushy Ck 1	1413600		23.4		3.8	0.13	0.32
	Brushy Ck 5			18.1		3.6	0.07	0.33
09/11/06	Brushy Ck 10			13.3		2.9	0.08	0.49
	Brushy Ck 17			15.6		3.7	0.11	0.63
	Brushy Ck 20			14.7		4.3	0.10	0.55

Sample Date	Client Id	*E. coli*	Turbidity	Chloride	TN	Nitrate as N	Nitrite as N	o-Phos as P
	Brushy Ck 24			19.5		5.8	0.24	0.74
	Brushy Ck grab			23.5		6.0	0.34	0.83
09/21/06	50	4710	14.5	17.7		11.5	0.06	0.2
	42A	4520	6.4	14.8		14.1	0.08	
	42B	4430	6	15.5		14.2	0.08	0.11
	42B3	3640	6	14.4		16.3	0.08	0.1
	42BA	4500	7.9	18.9		12.2	0.05	0.16
	42BA1	310	8.7	16.6		12.2		
	42BT pool	4430	10.7	15.2		14.1	0.08	
10/19/06	50	129970	8.7	18.8		11.5		
	43	68670	4.3	17.8		12	0.08	0.13
	42A	23330	4.3	15.2		14.2	0.08	0.08
	42B	3270	2.2	15.6		14.9		
	42CA	0	0.28	17.6		30.8		
11/10/06	28	310	21.4	12.0		7.5		
11/21/06	28	20		13.9		8.1		
	50	64		18.2		11.8		
	50T	115		27.5		18		
	43	3		16.1		12.6		
	42A	310		15.2		14.4	0.06	
	42B2	200		14.6		14.5		
	42CA	1		16.6		30.1		
	50B	72		25.5		10		
11/29/06	28	39726	32.3	11.9		7.1		
	28C	776	13.7	15.2		9.2		
	28D	832	4.3	10.8		7.3		
	50T	4718	1.8	28.5		17.5		
	43	19608	11.8	18.4		11.3	0.2	0.1
	42A	4564	4.4	16.0		13.1	0.15	0.11
	42B2	3570	6.7	16.7		14.0	0.07	
	42BA	2592	8.1	16.8		12.8		
	42CA	40	0.8	16.8		30.1		
	50B	190	4.6	25.6		9.5		
12/07/06	28	55	16.3	13.8		8.8		
	28C	55	9.1	14.9		10.6		
	50	81	8.13	18.3		12.4		
	50T			28.8		14.7	0.07	
	42A	228	4.23	15.9		15.3	0.07	
	42B2	727	7.79	16.1		15.5		
	42BA	727	10.2	17.2		14.1		
	42BA1	517	3.19	12.5		14.0		
	42BT	0						
	42C	99	4.48	14.0		17.3		
	42CA	4	2.02	16.4		30.0		
12/20/06	28C	42600	1442	388.1	96.2	17.6	7.84	10.95
	50	121	6.96	19.0		10.6		
	43	187	20.4	17.5		11.5		
	42A	171	7.24	16.9		13.7	0.05	

Sample Date	Client Id	*E. coli*	Turbidity	Chloride	TN	Nitrate as N	Nitrite as N	o-Phos as P
	42B	187	7.28	16.5	13.9	13.5		
	42B2 Up	3873	7.4	13.8	14.9	14.5		
	42B3	1376	6.5	13.1		14.9		
	42BA		11.6	26.9	11.8	11.3		
	42CA1	0	1.82	13.1				
	42CA2	0	0.71	19.4				

Potential Sources of *E. coli* in Brushy Creek:

Two sites upstream of 42B2 were selected for further sampling, one on a small tributary just south of Halbur (42BA), and the other on Brushy Creek just upstream of the Halbur tributary. Analyses showed both sites to be similarly contaminated.

The 42BA tributary is approximately two (2) miles in length. Potential sources include pasture grazing, open feedlots, and the small community of Halbur. Halbur has no waste treatment system, nor is there a discharge pipe to the stream. However, this community is not on the DNR list of unsewered communities. Further upstream of Halbur and the pasture, a second site was selected (42BA1), as a control for these potential sources. The stream above 42BA1 was bordered by riparian woods and cropland.

E. coli counts from the 4 samples collected at site 42BA1 ranged from 310 to 3140 counts/100 ml. The highest turbidity was 8.7 NTUs, indicative of base flow and stabilized environment. The highest count occurred August 31 when crops were still in the field. Potential sources other than wildlife were not observed and appear limited. *E. coli* counts downstream at site (42BA) were consistently higher and ranged from 565 to 6500 counts/100ml during base flow. Contribution from grazing cattle is likely but linkage to increased counts during base flow is uncertain. In the author’s opinion, this source is too limited to create the heavy fecal loading observed at 42B2 during the July 26 rain event.

Reconnaissance of the landscape for large manure sources and routes of entry revealed a reservoir of fecal material trapped behind a terrace less than 100 yards from a ditch that drains into Halbur Creek (fig 17). One side of the terrace had degraded and a trail of dried fecal material was observed around this breach. The farmer has a manure containment structure on the lot but enough fecal material flowed through it to fill the back side of the terrace. No samples were collected from Halbur Creek during runoff to demonstrate heavy fecal loading from this source to site 42B2. This observation provided additional clues as to possible sources of large quantities of manure and routes of entry that otherwise are hidden from view. Observation of these potential sites however is limited. They are located on private property and most cannot be seen from public roads or driveways.

fig 17. Manure path around breached terrace near Halbur

E. coli counts in Brushy Creek upstream of Halbur Creek (42B3, 42C) generally exceeded the water quality standard although turbidity values were low. There are several open feedlots upstream as candidate sources and numerous drainage ditches which could transport waste, but no physical evidence was observed to date.

Site 28C, a discharge pipe in the lower section of the watershed, has characteristics of surface drainage. It only flows following a rain and can have high *E. coli* counts with heavy organic loading (July 26). The source of this flow is not readily apparent. No further investigation will be conducted as it would require access onto private property.

Benthic and sediment analysis:

Five (5) sediment grab were collected on 9/21/06 for *E. coli* analyses. Four of the sites were from pool sediments in the site 42 region, the fifth at the composite sampler location (Table 8). Samples were collected during base flow. Sediment at the pool sites were dark and odors indicated anaerobic activity. Sediment in the faster flowing area of site 50 was also dark but sandy in texture. *E. coli* counts in the sediments were much higher than in the overlying water. Site 42A was grossly contaminated with fecal matter with counts exceeding 24192000/100ml. Ten (10) ml of sediment was mixed into a 990 ml of distilled water for anion analyses. This 2 log dilution factor was problematic for low concentration anions but did provide useful information. No nitrate-N was detected but variable amounts of nitrite, soluble phosphorus, and large peaks of an undefined short chain organic acid were present. Simple organic acids are reportedly the ideal substrate for de-nitrifying bacteria.

Table 8. Sediment Analyses for *E. coli* and Anions in Samples Collected 9/21/06

Client Id	Chloride	Nitrate as N	Nitrite as N	Phosphorus-O as P	Turbidity	*E. coli*
42B	15.50	14.20	0.08	0.11	6.00	4430
42B sediment			ND	ND		1918000
42A	14.80	14.10	0.08	ND	6.40	4520
42A sediment			16.00	24.00		24192000
42BT pool	15.20	14.10	0.08	ND	10.70	4430
42BT pool sediment			5.00	ND		399000
42B3	14.40	16.30	0.08	0.10	6.00	3640
42B3 sediment			ND	ND		2187000
50	17.70	11.50	0.06	0.20	14.50	4710
50 sediment			8.00	ND		41000

Collectively, these pool sediments contained a large reservoir of *E. coli* which could re-suspend into the water column during elevated flow. Site 42A showed the greatest contamination, but the original source could be almost anywhere upstream. The pool furthest up-steam, site 42B3 had the next highest counts, indicating a major contributor from as yet undetermined source. The high fecal content of these sediments and frequent chemical and bacteriological indicators of fecal contamination would likely effect stream biota, especially the benthic community. Some organisms are known to be much more tolerant of chronic pollution than other organisms. A more comprehensive follow-up investigation was conducted using standard limnology equipment and methods on select sites on 10/19/06.

Benthic samples were collected with a standard 9” X 9” Ponar Dredge (0.05 m^2) at sites 42B2, 42A, and 50. Sediments were sorted for benthic organisms in the field using fine mesh nets for initial separation clay and other fine particles followed by swirl and decant of remaining sediments with entrapped organisms into large flat pans. Macro-benthic organism where picked out with a tweezers, identified and placed into vials for enumeration. A 250 ml portion of each sample was retained for sediment analyses and laboratory experiments.

The three sites were nearly void of macro-benthic organisms (Table 9). The few that were present were pollution-tolerant species except for a burrowing mayfly, Hexagenia limbata, at site 50.

Table 9. Macro-Benthos/m^2 at Three Sites on Brushy Creek 10/19/07

Site	Mayfly	Oligochaeta	Scuds	Midges	Leeches
42A		40		180	60
42B2		60		100	40
50	20	160	40	60	20

Given the low numbers and diversity of organism and anaerobic conditions of the sediment, it is probable that these organisms were either on the surface of the sediment or confined to a thin upper layer of sediment.

Qualitatively, sediments at site 42A and 42B2 were mucoid in texture (low solids) consistent with a high concentration of bacteria while site 50 was sandy, indicating greater energy of flow and transport (table 10). The pool sediments had a higher volatile solids component indicating more organic matter than stream sediments at site 50.

Table 10 Characterization of Brushy Creek Sediments 10/19/07

Site	*E. coli* (counts/100ml)	% Total Solids	% Volatile Solids
42A sediment	4611000	27.9	9.5
stream	72150		
42B2sediment	11199000	21.4	9.2
50 sediment	145000	55.8	3.3
stream	129970		

This round of sediment sampling included site 42B2, as this is generally the site with highest *E. coli* counts in the stream. *E. coli* counts in the sediments of this site were higher than any other site and suggest recent deposition of a large quantity of manure. *E. coli* counts at both downstream stream sites were very high. Counts in the sediments of site 50 were much lower and indeed similar to stream counts suggesting dynamic equilibrium between sediment and stream to flow from a chronic source upstream.

Laboratory Experiments:

A series of laboratory experiments was conducted to test the potential contribution of pool sediments to *E. coli* counts in Brushy Creek during elevated flow and to de-nitrification during low flow. It is important to know for this investigation whether high *E. coli* counts are indicative of current runoff or re-suspended from sediments upstream during elevated flow.

One hundred (100) ml aliquots of sediment from sites 42B2 and 50 were placed into 1000 ml beakers and filled to volume with de-chlorinated tap water spiked with $NaNO_3$ to a 30 mg/l nitrate-N concentration. Three different flow regimes were simulated on two substrates, stagnant, low flow, and rapid flow using 2, six-paddle mixers operating at 10 rpm (4 cm/sec) and 30 rpm (12 cm/sec) respectively. The simulated creek samples at two different sites were analyzed for *E. coli* after a 24-hour equilibration period. Another set was analyzed after eight (8) days of treatment to indicate effect of time on *E. coli* counts in a stream and substrate environment (Table 11).

Table 11. *E. coli* Re-suspension from Stream Sediments

Test period	42B2 Stagnant	42B2 Slow	42B2 Fast	50 Stagnant	50 Slow	50 Fast
1 day	6770	3880	77010	<100	<100	310
8 day	310	<100	11780	<100	<100	300

A 12 cm/sec flow over site 42B2 sediments during the 24 hour test resulted in suspended *E. coli* counts very similar to that collected from the pool at 42A. The longer test period of 8 days indicated substantial die-off and stabilization with time. High stream *E. coli* counts, evidently, can be due to re-suspension of recently deposited fecal material. Therefore time intervals between rain events are important factors in determining the cause of high *E. coli* counts in the stream. It also suggests that contributions from a small unmanaged operation, where cattle have direct access to the stream, contribute disproportionately higher counts of viable *E. coli* than large operations with containment structures.

The de-nitrification experiments demonstrated an interrelationship between nitrate concentration, organic content in the substrate supporting biological activity, and water movement (mixing rate). The highest rate of de-nitrification activity occurred in the 30 mg/l nitrate water overlying the organic rich sediments of 42B2 during low flow. Activity decreased proportionately to nitrate concentration for each test condition demonstrating first order kinetics. The higher organic content substrate of site 42B2 produced a much greater rate of de-nitrification than site 50 sediments during all test conditions. Slow moving water was marginally better than stagnant water for de-nitrification while faster moving water decreased activity. The addition of air reduced denitrification rates.

Table 12. Bench Scale De-nitrification Rates at Two Sites

De-nitrification rate mg/l/day

	Contact hours			
Substrate and flow	68 hrs	94 hrs	166 hrs	190 hrs
50 Stagnant	1.5	1.4	1.6	1.4
50 slow	1.7	1.7	1.5	1.4
50 rapid	1.3	1.3	1.4	1.4
42B2 Stag	6.0	5.4	4.4	4.0
42B2 Slow	6.1	5.7	4.3	3.8
42B2 Rapid	5.6	4.8	4.2	3.8
42B2 Rapid & air	3.6	3.9	4.1	3.9

The experimental conditions that promoted the greatest rate of de-nitrification exist in upper Brushy Creek. A continuous influx of high nitrate water from site 42CA (app 30 mg/l) slowly flows through pools overlying organic rich sediments. An abundance of fecal sources likely maintains these organic rich sediments. Nitrate concentrations in the stream do indeed rapidly decline in downstream sites during low flow, especially in upper Brushy Creek during warm weather when biological activity is highest. Other factors however could cause this decline in nitrate concentration as well, i.e. dilution by low nitrate water entering the stream and assimilation.

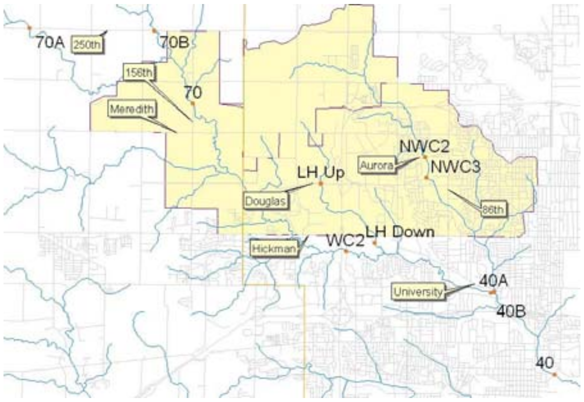
The potential of denitrification rates observed experimentally to reduce nitrate concentrations observed in Brushy Creek was tested using flow and surface area data collected at site 42A. The pool volume of 96000 ft^3 with discharge rate of 16cfs gives an average retention time of 1.67 hrs. The 48000ft^2 surface area with the de-nitrification capacity of 3 mg/ft^2/hr (determined experimentally at room temperature), removes

240480 mg of nitrate from 2722176 Kg of water during its 1.67 hr contact provides a 0.09 mg/l reduction in nitrate-N. There are at least four similar pools in upper Brushy Creek in addition to long stretches of very slow moving water which likely have similar substrates and denitrification potential. During the warmer and drier August with slower flow, accelerated denitrification and longer detention times would further reduce nitrate concentrations downstream. Dilution from lower nitrate sources does occur as seen in the tile samples. The results were quite variable. No estimate of average nitrate-N concentration from groundwater was attempted nor has an estimate been made of nitrogen assimilated into the extensive mats of filamentous algae.

Walnut Creek:
The Walnut Creek Watershed has a rural and urban component (Table 13 with map).

Table 13. Walnut Creek Site Locations

Site Id	LAT	LONG
40A	41.59906668	-93.71880083
40B	41.59870755	-93.72019723
40	41.57573120	-93.69591043
70	41.65181347	-93.83361216
70B	41.67255267	-93.84848369
70A	41.67280857	-93.89557048
NWC2	41.63713588	-93.74556033
NWC3	41.63133203	-93.74476756
WC2	41.61021580	-93.77508491
LH Down	41.61274721	-93.76415451
LH Up	41.62943781	-93.78476644
70AT	41.67280857	-93.89557047



The two watershed areas have similar *E. coli* counts and both typically exceed the water quality standard following a rain event as indicated by elevated turbidity (Table 13).

Table 13. Walnut Creek Watershed

Sample Date	Site Id	Turbidity	*E. coli*	Chloride	Nitrate as N
04/20/06	40	5.1	161	58.5	6.6
05/04/06	40	37.6	404	45.8	14.1
05/18/06	40	7.4	261	46.9	11.0
06/01/06	40	16.6	866	48.6	9.6
06/15/06	40	8.2	866	49.9	9.1
06/29/06	40	3.8	631	57.0	3.9
07/12/06	70A	13.3	970	45.7	8.3
	70B	34.1	9330	34.6	5.9
07/13/06	40	18.2	520	48.5	0.8
07/27/06	40	40.2	200	44.3	0.5
08/10/06	40	185.0	5040	21.2	0.6
08/17/06	40	142.0	7330	10.0	0.4
	40A	178.0	9880	9.4	0.4
	40B	136.0	10140	17.3	0.3
08/24/06	40	126.0	200	79.2	

Sample Date	Site Id	Turbidity	*E. coli*	Chloride	Nitrate as N
09/07/06	40	8.7	350	46.6	2.1
11/08/06	40		200		
11/09/06	40		86		
11/10/06	40	17.4	32550	46.6	3.7
11/13/06	40	3.1	4350	26.5	3.3
11/14/06	40		488		
11/15/06	40		310	46.4	5.0
	40A		200	67.4	1.1
	40B		200	41.4	6.2
	70		740	29.9	11.9
	LHCDN		1090	60.8	0.5
	LHCUP		200	97.8	1.6
	NWC2		100	78.9	1.4
	NWC3		100	74.8	1.3
	WC2		100	36.4	7.7
11/28/06	70	50.0	4260	25.3	4.8
	70A	47.0	2160	39.4	3.2
	70B	71.0	2590	27.8	11.1
	LHCUP	13.4	1730	33.4	2.3
	NWC3	30.6	2030	48.1	1.7
	WC2	74.2	3180	33.8	2.2
12/07/06	40	3.1	225	42.2	11.4
12/21/06	40	70.3	2280	31.4	2.3
	70	91.6	2310	27.8	12.5

Nitrate concentrations are consistently higher in the rural areas (site 70) than in urban sectors. Elevated chloride is occasionally observed in the urban sectors. No soluble phosphorus was detected and chloride was negatively correlated to *E. coli* ($R^2 = -0.31$) therefore septic discharge as the source of chloride is counter indicated. Fluoride concentrations were all less than 0.31 mg/l indicating a non-municipal source of water. The highest concentration occurred 11/15/06, which is before the first winter season salt application to city streets. No specific tributary has been identified for further investigation at this time.

Un-sewered Communities:

Table 14. Un-sewered Community Locations

Site Id	Community	LAT	LONG
URR	River Ridge	41.58695037	93.99375110
UA	Alcott	41.56655507	93.95162358
UT	Timber Valley	41.53747476	93.93910506
UC	Clarke	41.55468496	93.97840007
UT1	Timber Valley 1	41.56059832	93.93314573

Only one of the potential discharge sites from un-sewered communities (Timber Valley, site U-T) showed elevated fecal contamination but cattle were present upstream with access to the stream (Tables 14,15). A suitable site upstream was not available. Until otherwise discovered, it is assumed that these communities are using leach fields to discharge treated wastes.

Table 15 Water Quality at Sites Near Un-sewered Communities

Sample Date	Site Id	*E. coli*	Turbidity	Chloride	Nitrate as N	Phosphorus-O as P
11/13/06	U-A	100	0.3	49.9		
	U-C	310	36.3	7.3		
	U-RR	200	3.4	45.4	5.0	
	U-TV	64880	105.0	60.3	0.2	0.14
12/14/06	U-A	41	6.3	51.5	0.4	
	U-C	1169	120.0	9.0		
	U-TV	10462	58.0	53.3	0.4	0.10

Concerns have risen over the possibility of shallow wells within the leach field area. No information on water supply has been gathered to date.

DISCUSSION

Extensive sampling in the Beaver Creek and Raccoon River Watershed demonstrated the ubiquitous distribution of *E. coli* in the environment but several observations and patterns have emerged that indicate methods of *E. coli* transport to the stream and what happens once in the stream appears to be as important as landscape sources and distribution.

E. coli counts in the smaller tributaries and headwaters regions of the main stem tributaries generally have much higher *E. coli* counts than the lower sections of the main stem tributaries, especially during base flow. The reduction in *E. coli* counts is very pronounced below large impoundments such as Lake Panorama (site C of the ACWA annual report) and Saylorville Lake (Lutz 2005). Only one sample on the Middle Raccoon below Lake Panorama (site 31) exceeded the water quality standard for *E. Col,i* while *E. coli* counts flowing into Lake Panorama were consistently elevated. The Lutz report attributes the reduction in *E. coli* counts downstream of the main stem reservoirs to sedimentation and die-off. *E. coli* viability studies conducted at the Des Moines Water Works (D. Hill and M. Adams, unpublished report) demonstrated a daily die-off rate of 50% in a simulated river environment. Sediments were kept in suspension though gentle mixing to minimize the sedimentation factor. Die-off rates of *E. coli* on a terrestrial landscape subjected to desiccation is presumed higher but unknown.

E. coli counts in rivers and streams are much higher following a rain event where suspension and transported fecal material accompanies soil loss. Landscapes that are more subject to erosion therefore also have greater potential transport of *E. coli* to the streams. Tributaries within the hilly Southern Iowa Drift Plain Landform (SIDP) are more likely to have elevated counts following a rain event. Conservation practices such as grass buffer strips are especially important to erosion control and water quality in the SIDP.

The occurrence of elevated E coli counts during base flow can not be attributed directly to run-off. This requires either direct discharge of fecal material into the water or possibly re-suspension of *E. coli* from the sediments. The high *E. coli* counts in the Brushy Creek sediments show this to be a large potential reservoir. This large reservoir can only occur when more *E. coli* enters the pool areas and deposits onto the sediments than leaves the pool. This suggests the source to be upstream, but the distribution of *E. coli* counts in upper Brushy Creek is inconclusive. Increased numbers of *E. coli* as water passes through pasture lands to the stream are consistent with direct discharge of viable *E. Coli* into the stream, where it can either remain suspended downstream or deposited onto pool sediments. Long residence time in these pools would decrease the number of viable *E. coli*. All samples with elevated *E. coli* counts during base flow were located downstream of areas where animals have unrestricted access to the stream. Samples from protected watersheds with extensive grass buffer strips (e.g. Buttrick Creek) consistently showed low *E. coli* counts. Evidence to date shows count potential during base flow to be influenced by the number of animals with access to the stream, sedimentation potential, and time of travel. Tributaries such as Beaver Creek and Walnut Creek that have little travel time for die-off and no impoundments for sedimentation are especially subject to high counts.

Brushy Creek data shows that high *E. coli* counts during a rain event can come from re-suspension of fecal material in pool sediments as well as from the landscape. The high concentration of open feedlots and number of cattle in the area increases the amount of fecal material generated per unit area and potential run-off into the stream. Manure retention structures are diverse and include lagoons, terraces, and even bails of hay. Any of these can be overwhelmed during a large runoff event and evidence of one such event was presented.

Next phase:

Winter manure application on frozen snow-covered ground greatly increases runoff potential to rivers and streams. High *E. coli* counts and manure odor in the Raccoon River is occasionally observed during snow-melt events. Unusually high winter nitrate concentrations are occurring as well. Therefore, sampling of the main stem tributaries and sub-watersheds is continuing to characterize sources of *E. coli* and high winter nitrate concentrations. Tile samples have been collected and analyzed for *E. coli* as well as nitrate to better characterize distribution of nitrate and the potential relationship of nitrate to land use activity.

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