STATUS REPORT #7 for the DES MOINES AND RACCOON RIVERS OF IOWA

NITRATE NITROGEN and *ESCHERICHIA COLI*

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For

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WEATHER AND HYDROLOGIC CONDITONS IN THE DES MOINES RIVER WATERSHED, 4th QUARTER of 2007

Precipitation this quarter alternated between extremes. October was the 4th wettest on record with most of the rain failing on October 14 in SW Iowa (fig 1). November was the 3rd driest on record at 0.17 inches. December was characterized by cycles of rain and freezing rain early in the month followed by cycles of heavy snowfall. Overall, December was the 2nd wettest month on record.

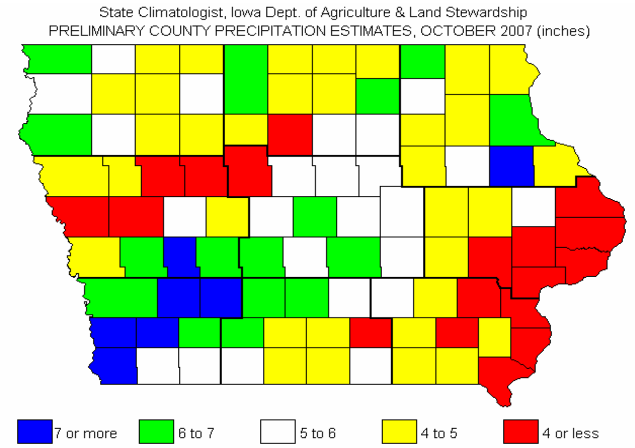


fig 1. October 2007 precipitation

December temperatures averaged 2.0° below normal. Very little of the snow melted in the rural areas while in urban areas ice and snow removal activities contributed to runoff into storm sewers. Total monthly precipitation at Guthrie Center, Sac City, and Des Moines (table 1) provide information on key locations in the South Raccoon, North Raccoon, and Des Moines area watersheds.

Table 1. Monthly Precipitation 4th Quarter 2007

	Guthrie Center	Sac City	Des Moines
Oct	6.46	3.76	4.45
Nov	0.46	0.05	0.28
Dec	2.46	0.83	1.6
total	9.38	4.64	6.33

Rainfall events were widely distributed over the entire study area with the South Raccoon receiving the heaviest rainfall during each of these events. (fig 2). The heaviest rainfall fell October 14 with Guthrie Center reporting 2.4 inches. Runoff was more prevalent in the South Raccoon watershed. The heavy rainfall and hilly terrain of the Southern Iowa Drift Plain created a sharp spike in flow at the Redfield Gauging Station on the South Raccoon. Extensive impervious services and storm sewers in the urban Des Moines area promoted discharge into local streams. Landform terrain, land use, soil, and surface characteristics play an important role in stream flow dynamics and water quality.

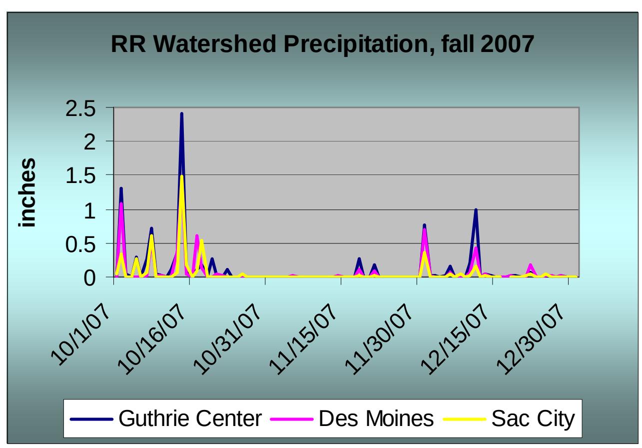


fig 2. Precipitation events

Beaver Creek contribution to flow in the Des Moines River

The mid-October rainfall and more local runoff caused Beaver Creek to rise before the Des Moines River (fig 3). This created a disproportionately high contribution to flow (>10%) in the Des Moines River for four days. Flow in the Des Moines River steadily declined through November to a base flow of <1000 CFS through most of December. Two spikes in Beaver Creek flow recorded on December 7 and 9 are likely due to ice jams as no precipitation fell on these dates. The flow data is provisional and subject to revision.

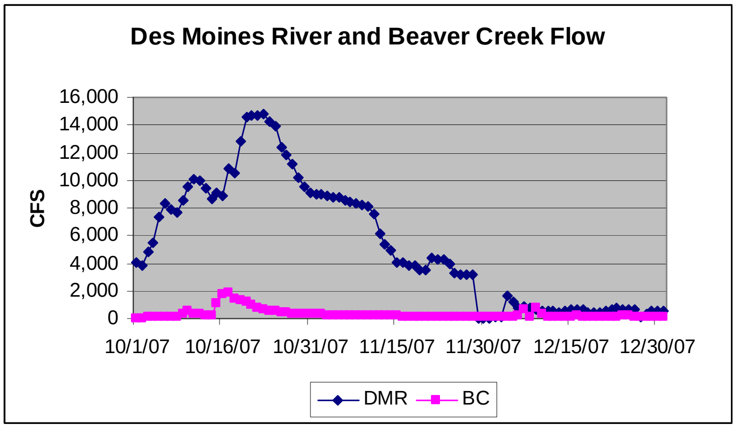


fig 3. Beaver Creek contribution to Des Moines River flow

Tributary contributions to flow in the Raccoon River

Walnut Creek

Walnut Creek is small tributary that contributes little to total flow in the Raccoon River (2.2% median contribution). However it is of particular interest because much of its watershed is in the urban landscape where impervious surfaces promote runoff. Storm sewers quickly drain urban streets and flush contents in the storm sewers to local streams. These storm sewers are known to provide temporary shelter to wildlife such as raccoons. The large human population within the urban area increases the risk of a large scale fecal discharge should the sanitary sewer systems fail. The close proximity of Walnut Creek to the DMWW intake and short time of travel accentuates this contribution as discharge from Walnut Creek arrives at the Raccoon River intake before elevated flow from the Raccoon River.

The Walnut Creek gauging station shows four spikes in flow that occurred on October 3, 8, 15, and 18 (fig 4). On October 2, approximately 1 inch of rain fell in Des Moines and parts of the South Raccoon Watershed. Little increase in flow occurred in the Raccoon River while Walnut Creek showed a prominent spike in flow. This is likely due to infiltration in the relatively dry

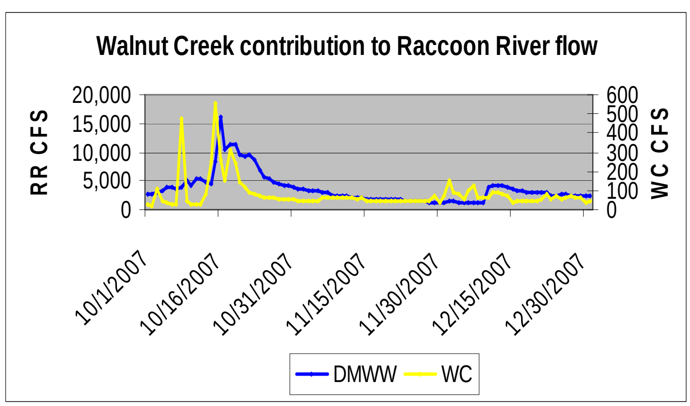


Fig 4. Walnut Creek and Raccoon River flow

rural area while city streets and storms sewers discharged much of the rain into Walnut Creek. The one-half inch rain on October 8 again produced a sharp spike in flow in Walnut Creek that was not observed in the Raccoon River. Runoff from the heavy rain on October 14 and 15 was essentially masked by the spike in flow from the South Raccoon that dominated flow in the Raccoon River downstream. On October 8, Walnut Creek contributed 12% of the flow in the Raccoon River compared to 5.6 and 6.6% on October 14 & 15 respectively.

North and South Raccoon

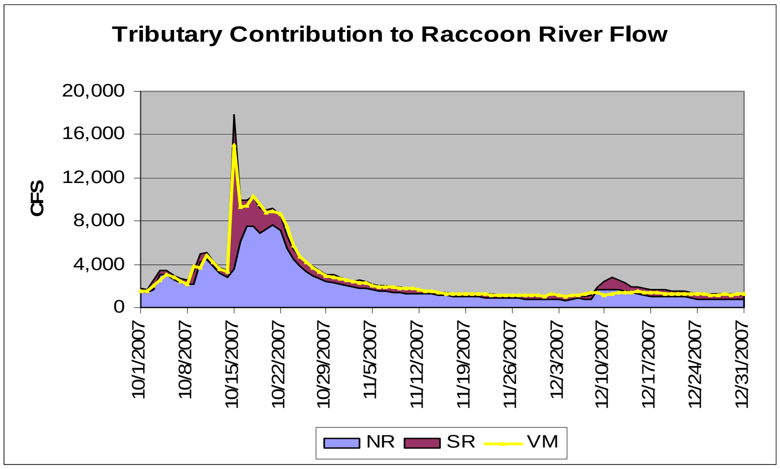


fig 5. Flow in the Raccoon River and upstream tributaries

The North Raccoon tributary provided most of the flow except for a very prominent spike in flow from the South Raccoon on October 15 (fig 5). This chart adds flow from the South Raccoon at Redfield to the North Raccoon at Perry. The combined flows are in very close agreement to the flow recorded at their confluence at Van Meter.

WATER QUALITY AT THE DES MOINES RIVER INTAKE

The Des Moines River exceeded the E. coli water quality standard seven (7) of the fifty four (54) sampling dates this quarter. Five (5) of the occurrences happened when flow in Beaver Creek exceeded 1000 CFS and constituted more than 9% of the total flow in the Des Moines River (fig 6). As in previous reports, E. coli counts in the Des Moines River correlated much more positively to Beaver Creek flow ($r^2 = 0.68$) than to Des Moines River flow ($r^2 = 0.20$). Assuming the source of E. coli counts to be from Beaver Creek, count concentration in Beaver Creek would be approximately ten times greater than that found at the Des Moines River Intake due to the dilution effect of Saylorville Lake discharge.

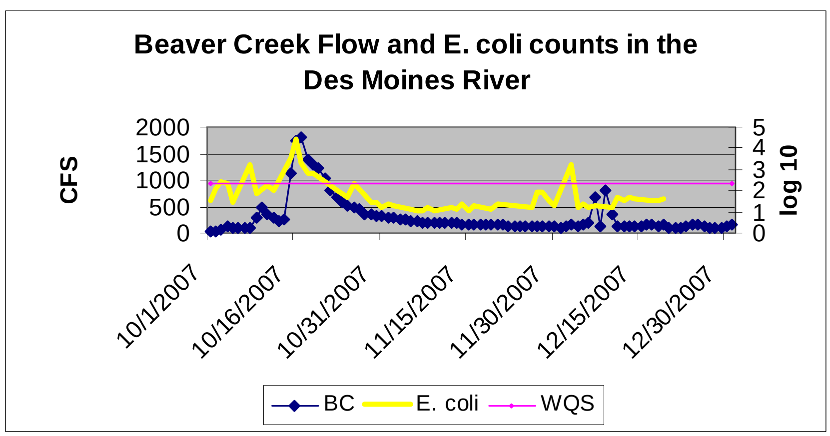


fig 6. Beaver Creek flow & E. coli counts in the Des Moines River

Water chemistry in the Des Moines River changed little during this period. This would be expected as most of the water flowing past the Des Moines River intake was discharged from Saylorville Lake. Water chemistry in Beaver Creek varies little relative to E. coli counts. Nitrate values remained below the water quality standard throughout this quarter (Table 1). Approximately 9000 metric tons of NO3-N flowed past the DMR intake this quarter.

Table 1. DMR Water Quality 4th Quarter 2007

Sample Date	E.coli_QT	Turb	Cl	NO3-N
10/01/07	35	21.9	22.4	5.4
10/02/07	127	20.4	21.9	5.2
10/03/07	240	26.6	22.2	5.2
10/04/07	206	24.3	21.8	5.2
10/05/07	27	24.2	22.8	6.0
10/08/07	1733	28.2	20.3	6.5
10/09/07	74	13.4	21.6	6.5
10/10/07	0	26.5		
10/11/07	183	30.5	19.3	7.4
10/12/07	98	23.6	19.3	7.4
10/15/07	3790	77.2	18.6	7.2
10/16/07	28600	79.1	17.2	7.1
10/17/07	2200	46.4		
10/18/07	630	35.4	18.5	7.6
10/19/07	690	31.9	18.8	7.5
10/22/07	194	27.7	19.0	8.1
10/23/07	98	25.2	18.5	8.0
10/24/07	73	23.8		
10/25/07	52	18.6	18.0	7.9
10/26/07	224	21.5	17.7	8.0
10/29/07	27	19.5	18.0	8.1
10/30/07	28	18.8	18.4	8.1
10/31/07	22	17.8		
11/01/07	23	20.2	18.3	8.1
11/02/07	20	17.4	18.5	8.1
11/05/07	14	15.6	19.2	8.1
11/06/07	11	21.3	19.9	7.9
11/07/07	12	14.7		
11/08/07	17	17.2	20.4	7.8
11/09/07	11	13.7	20.6	7.9
11/12/07	15	11.8	21.5	7.6
11/13/07	14	12.2	21.2	7.7
11/14/07	25	12.6		
11/15/07	11	24.1	21.9	7.5
11/16/07	18	18.5	22.1	7.5
11/19/07	14	11.9	22.7	7.5

Table 1 cont. DMR Water Quality 4th Quarter 2007

Sample Date	E.coli_QT	Turb	Cl	NO3-N
11/20/07	26	7.5	22.0	7.5
11/21/07		18.1	23.2	7.5
11/26/07	17	8.7	23.2	7.3
11/27/07	93	7.6	23.4	7.3
11/28/07	79	7.6		
11/29/07	36	14.3	24.3	7.0
11/30/07	18	10.7	25.4	6.9
12/03/07	1790	10.4	27.1	6.8
12/04/07	15	8.2	25.1	7.1
12/05/07	26	10.2	25.4	7.1
12/06/07	17	6.0	29.7	6.9
12/07/07	18	7.2	26.6	6.8
12/10/07	16	3.1	26.7	6.9
12/11/07	50	4.9	27.4	6.9
12/12/07	34	4.9		
12/13/07	51	8.7	32.5	7.1
12/14/07	41	5.9	31.3	7.2
12/17/07	36	5.8	27.8	6.9
12/18/07	33	5.3	29.0	7.2
12/19/07	40	4.8		
12/20/07		4.4	29.7	7.5
12/21/07		4.2	29.5	7.4
12/26/07		3.2	30.8	7.2
12/27/07		2.6	31.3	7.0
12/28/07		3.1	30.6	7.1
12/31/07		4.0		
Median	34	15	22	7.27

WATER QUALITY AT THE RACCOON RIVER INTAKE

Water quality at the Raccoon River intake is primarily a function of land use and hydrologic contributions in the North and South Raccoon in response to weather conditions in their respective watersheds. Land use determines to a considerable extent the quantity of fecal material deposited on the surface of the landscape while landform and hydrology affect transport of fecal material into streams and continued discharge downstream. The North Raccoon Watershed lies entirely within the glaciated Des Moines Lobe landform. The relatively flat landscape is highly suited to row crop agriculture. There are fewer animal livestock units (141) per square mile than in the South Raccoon Watershed (165) and livestock operations tend toward confinement operations and swine production to maximize production of valuable farm ground. Management requirements for these operations include incorporation which further reduces the amount of fecal material left on the surface while the flat terrain decreases the energy of transport during a rain event. Furthermore, some of the overland flow is trapped in the numerous prairie potholes and subsequently drained by extensive tile systems.

Approximately 50% of the South Raccoon Watershed is located in the Southern Iowa Drift Plain landform which is not recently glaciated. It is highly dissected with relatively steep slopes. A much higher percentage of the land is uncultivated (36.2 % in grasses and woodlands vs. 14.2% for the North Raccoon). Cattle operations are more common which include open feedlots and grazing. Six (6) percent of the land is in permanent pasture compared to 2.9% in the North Raccoon. The landscape is much more subject to runoff and transport of exposed fecal material to streams than in the North Raccoon Watershed.

Two unique landscape features provide exception to this pattern and can potentially alter water quality at the Raccoon River intake: the urban landscape of Walnut Creek and Lake Panorama on the Middle Raccoon. The amount of impervious surfaces and proximity of Walnut Creek to the Raccoon River intake presents special concerns as noted in the flow section while Lake Panorama functions as a stabilization lagoon for bacterial contaminants and buffers rapid changes in water quality from upstream sources.

The spike in E. coli counts on October 3 & 4 was of short duration and occurred with little increase in Raccoon River flow. Counts correlated best to spikes in flow and contribution from Walnut Creek. Heavy rain and subsequent runoff in mid-October in the South Raccoon especially contributed to exceptionally high E. coli counts (Table 2). Counts were highest on Oct 15-17 when flow in the Raccoon was dominated by contributions from the South Raccoon and to a much lesser extent Walnut Creek on the 15th.

Table 2. Raccoon River Intake, 4th Quarter 2007

Sample Date	E.coli_QT	Turb	Cl	NO3-N
10/01/07	456	46.8	21.9	8.9
10/02/07	15	39.5	21.3	8.9
10/03/07	9850	97.1	20.9	7.2
10/04/07	10860	152.0	18.8	7.2
10/05/07	740	102.0	20.7	9.3
10/08/07	6488	74.7	19.1	8.2
10/09/07	7030	337.0	16.8	6.4
10/10/07	4350	174.0		
10/11/07	8840	164.0	17.1	8.2
10/12/07	1730	89.8	17.4	8.3
10/15/07	17230	237.0	15.7	6.3
10/16/07	15420	409.0	10.4	4.3
10/17/07	25820	192.0		
10/18/07	8080	140.0	16.7	7.6
10/19/07	2680	124.0	17.0	7.9
10/22/07	865	94.7	17.7	8.7
10/23/07	436	78.6	17.8	8.7
10/24/07	550	67.8		

Table 2. Raccoon River Intake, 4th Quarter 2007

Sample Date	E.coli_QT	Turb	Cl	NO3-N
10/25/07	264	75.3	18.6	8.9
10/26/07	233	56.0	19.0	8.9
10/29/07	185	38.9	20.0	9.0
10/30/07	123	33.9	20.3	9.1
10/31/07	121	34.6		
11/01/07	203	31.5	20.7	9.1
11/02/07	86	28.6	21.0	9.1
11/05/07	99	25.5	21.0	9.1
11/06/07	61	21.7	21.0	9.0
11/07/07	58	18.6		
11/08/07	64	23.1	22.3	9.1
11/09/07	62	16.3	21.9	9.0
11/12/07	39	13.9	22.0	9.0
11/13/07	44	14.5	22.6	9.0
11/14/07	30	12.2		
11/15/07	21	20.7	23.0	8.9
11/16/07	16	13.2	23.0	8.7
11/19/07	89	9.5	24.0	8.6
11/20/07	19	7.0	22.4	8.4
11/21/07		11.3	23.5	8.5
11/26/07	25	7.8	23.3	8.5
11/27/07	34	6.4	23.2	8.5
11/28/07	18	8.4		
11/29/07	22	7.7	23.9	8.6
11/30/07	14	9.7	23.8	8.4
12/03/07	6035	12.6	21.8	6.8
12/04/07	236	15.9	25.6	7.3
12/05/07	115	11.7	27.2	7.8
12/06/07	62	8.4	25.7	7.3
12/07/07	41	7.4	27.0	8.1
12/10/07	12	7.5	29.2	8.7
12/11/07	138	7.4	42.5	8.3
12/13/07	34	28.6	36.7	8.2
12/14/07	8	16.8	33.3	8.0
12/17/07	10	10.4	28.5	8.5
12/18/07	7	7.4	28.1	8.6
12/19/07	6	8.4		
12/20/07	6	7.5	27.0	8.5
12/21/07		5.9	26.0	8.2
12/28/07		6.0	25.6	7.7
12/31/07		8.6		
Median	99	20.7	22	8.5

The single sample water quality standard for E. coli was exceeded this quarter on 20 of the 55 sampling dates, nearly all of which (18) occurred in October. The highest count (25820) occurred on October 17 when flow from the South Raccoon dominated flow at the Raccoon River intake. Nitrate concentrations never exceeded the water quality standard of 10 mg/l but remained close during most of the quarter.

WATERSHED CONTRIBUTIONS

Most of the watershed sampling was conducted in October during rain events. Relatively few grab samples were collected during the remainder of this quarter in part due to dry weather in November and freezing conditions in December. Much of the effort later in the quarter focused on evaluating the efficacy of grab samples for E. coli enumeration. High variability in E. coli counts at the same sampling site during apparently static conditions raised the question of whether a single grab sample can be used to represent bacteria water quality in the stream. Multiple samples were collected by ISCO samplers during base flow at multiple sites with differing land use characteristics for variability analysis. All composite samples were analyzed for E. coli using Idex Quantitrays to determine the most probable number (MPN). Field studies were supplemented with laboratory analyses of E. coli counts in various matrices and stream simulation experiments to experimentally model E. coli dynamics in the watershed.

<u>Beaver Creek:</u>

No samples were collected in Beaver Creek during wet weather flow this quarter. An ISCO sampler was triggered to composite three (3) samples every half hour over a 24 hour period during dry weather base flow to determine variability in E. coli counts during static conditions (Table 3). The ISCO sampler, located at the Grimes stream gauging station, is at the lower end of the watershed where there was little evidence of direct livestock access to the stream for many river miles. Grazing was observed however in the upper portion of the watershed earlier in the fall.

E. coli counts varied little over a 24 hour period at this site. No sample exceeded the water quality standard of 235 counts/100 ml at this site.

Table 3. Time Study on E. coli Counts at Beaver Creek

Sample Date	Client Id	E. coli	Turbidity
11/8/2007 00:00	BC04-01	85	18.9
	BC04-02	52	9.62
	BC04-03	85	5.14
	BC04-04	31	8.35
	BC04-05	52	8.93
	BC04-06	10	6.85
	BC04-07	74	7.33
	BC04-08	52	8.3
	BC04-09	110	8.8
	BC04-10	63	7.73
11/9/2007 00:00	BC04-11	86	7.2
	BC04-12	135	6.26
	BC04-13	134	7.74
	BC04-14	20	7.05
	BC04-15	109	6.74
	BC04-16	74	8.8

Raccoon River and tributaries:

Walnut Creek

Sampling conducted by the Agriculture Clean Water Alliance (ACWA) at two sites on Walnut Creek has demonstrated high nitrate concentrations coming from the rural landscape that was diluted by urban stream contributions. E. coli data however gave mixed results (Table 4). Median and third quartile results indicate than on most days, E. coli counts from the rural area is greater than the urban contribution.

Table 4. Water Quality in Walnut Creek

	E.coli		Nitrate-N	
	40 Urban	70 Rural	40 Urban	70 Rural
Average	1413	1309	7.49	11.22
Min	101	100	0.22	0.25
Max	10860	4352	14.11	19.56
Median	462	970	8.61	14.09
First Quartile	242	223	3.48	4.72
Third Quartile	952	1733	11.10	15.99

The highest counts (32550 cfu/100 ml) at site 40 occurred on November 13, 2006 when only ¼ inch of rain fell in the Des Moines and flow in Walnut Creek increased from only 20 CFS to 30 CFS.

This suggests storm sewers as both a potential source of E. coli and an efficient conduit of E. coli transport from urban landscapes. On November 6, lab staff conducted a hydrant flushing experiment to directly measure E. coli counts flushed off city streets and storm sewers. Study results are presented in Appendix A. High E. coli counts were observed for a short period of time which is consistent with November 13, 2006 event and supports the hypothesis that runoff from impervious surfaces and storm sewer discharges during small rain events transport high concentrations of E. coli. Larger rain events soon flush the storm sewers of their contents and thereafter serve as conduits for urban runoff.

High E. coli counts in Waveland Creek during the July 2007 storm sewer study prompted investigation of upstream sources during this quarter. Three storm sewers were located within Waveland Golf course (SS7C, SS7E, and SS7F) and one in the Glendale cemetery (SS7G) that discharged into a pond frequented by ducks and geese. Sample collection sites are labeled in fig 7.

fig 7. Sample sites in the Waveland Creek tributary

Two rounds of sampling were performed in the Waveland area with similar results (Table 5). The observation of flow from these sewers in the absence of a rain event and elevated E. coli counts suggested contribution from a leaking sanitary sewer. However, chemistry data indicates the source of slow to be local groundwater. Phosphorus and nitrogen nutrients were very low as was fluoride, an inorganic substance added to drinking water. Elevated chloride can be attributed to road salt application as similar concentrations were observed at sites NWC3 and 40A on the urban North Walnut Creek.

Table 5. Water Quality in Walnut Creek and Contributing Sources

Sample Date	Site Id	Chloride	E. coli	Fluoride	Nitrate as N	Phos-O as P	TN	Turb
12/05/07	70B	21.5	41	0.11	10.61			5.36
	70A	28.2	135	0.21	10.50	0.10		2.97
	70	22.5	142	0.18	9.96			5.62
	LWC	35.6	480	0.23	8.96			4.36
	NWC3	170.8		0.09	2.45			4.69
	WC2	42.0		0.19	6.80			2.88
	40A	193.7	448	0.13	2.27			3.05
	40B	54.2	203	0.27	6.28			3.6
	40	85.3	134	0.20	5.25			2.69
	WCrSS7	135.8	4570	0.18	1.06		1.1	5.21
	WCrSS7a	138.7	>2400	0.17	1.06		1.2	7.44
	WCrSS7b	142.1	>2400	0.17	1.15		1.3	5.69
	WCrSS7c	75.4	>2400	0.09	1.06		0.7	7.76
	WCrSS7d	187.4	2419	0.17	0.57		1.4	5.09
	WCrSS7e	235.2	1046	0.15	2.13	0.10	2.1	3.21
	WCrSS7f	88.0	1120	0.19	0.74		1.4	5.21
	WCrSS7g	45.7	921	0.26	1.60		1.2	0.68
12/17/07	WCrSS7	122.4	717	0.18	1.13			5.26
	WCrSS7a		20					1509
	WCrSS7b	118.2	990	0.43	1.11			5.53
	WCrSS7c	73.2	1789	0.24	0.97			9.79
	WCrSS7d	157.7	7701	0.39	0.81			4.12
	WCrSS7e	267.5	794	0.32	2.04			3.29
	WCrSS7f	85.0	12033	0.41	0.78			5.31
	WCrSS7g	43.4	327	0.43	1.46			0.52

The source of elevated E. coli is unknown but wildlife is prevalent in this area and contamination from these sources is probable. Large numbers of ducks and geese were frequenting the Glendale Cemetery pond that discharged into Waveland Golf Course at site WCrSS7F. Deer droppings at this site and a marsh a few yards downstream provide at least anecdotal evidence of abundant wildlife and contributions from these sources to the E. coli counts in Waveland Creek and storm sewers.

Main-stem tributaries

E. coli counts were higher in the South Raccoon than either the Middle or North Raccoon during the four area wide sampling dates this quarter (Table 6). Highest counts occurred on the receding limb of the South Raccoon hydrograph on October 16 when turbidity dropped to less than 10% of the previous day (Table 7).during the mid-October rain event.

Table 6. E. coli Counts in the Mainstem Tributaries

	NR	SR (VM)	MR	SR Redfield	RR (VM)
10/15/07	17200	29090	5380	41060	17230
10/16/07	17230		3740	86640	15420
10/17/07					25820
10/23/07	529	547	238	1086	436
11/27/07	10	20	52	120	34

Table 7. Turbidity in the Mainstem Tributaries

Sample Date	NR	SR (VM)	MR	SR
10/15/07	142	1551	231	1387
10/16/07	154		107	106
10/23/07	71	46	29	50
11/27/07	6	7	8	5

This suggests that the most contaminated source is at the upper portion of the watershed such as upper Brushy Creek as it has the greatest time of travel. Exceptionally high counts in this region were indeed observed as noted in the next section.

Sub-watershed water quality
South Raccoon and Brushy Creek

There are many small streams in the south fork of the South Raccoon as its watershed lies entirely within the hilly highly dissected Southern Iowa Drift Plain landform. High *E. coli* counts are typically found throughout this watershed, especially during runoff events. Brushy Creek is the largest tributary of this branch and therefore has a dominant impact on water quality in the South Raccoon at site 32. The South Raccoon just upstream of the Brushy Creek confluence is very similar in landform but with a higher percentage of land in pasture. DNR mitigated manure containment structures have been recently installed at several open feedlots operations in Brushy Creek but problems clearly remain. As noted in a previous report, this may be due in part to heavily contaminated sediments and the legacy of prior runoff events. E. coli are known to survive for months in a suitable matrix. The observation that organic matter and E. coli counts in the sediments are decreasing suggests these control measures are effective in reducing feedlot runoff.

During this quarter, E. coli counts during the mid-October rain event where high throughout the watershed with several sites exceeding the entire dilution series for a maximum of >241020. Rainfall was especially heavy which promoted runoff and possibly overwhelmed manure containment structures. Discharge from a pipe at site 28C was very turbid with high E. coli counts (Table 8). This point source location has been brought to the attention of IDNR staff for further investigation.

Table 8. Water Quality in the South Raccoon and Tributaries

Sample Date	Creek Name	Site Id	Chloride	E. coli	Turbidity
10/15/2007	Brushy Creek	28	6.16	>241920	334
		28C	15.72	198630	417
	South Raccoon	28A	2.78	120330	1103
		28AA	6.17	>241920	107
		32A	4.45	>241920	896
		32	4.98	41060	1387
10/16/2007	South Raccoon	32	2.07	86640	106
10/23/2007	Brushy Creek	28	11.14	3448	27.6
		28C	15.61	2909	36
		42A	14.5	1333	15.6
		42B2	13.93	601	11.8
		42B3	12.99	616	17.1
		43	15.41	2613	16.4
		50	17.44	3448	18.6
	Halbur Creek	42BA	15.35	443	5.82
	South Raccoon	28A	7.94	733	46.7
		28A1	8.51	683	17.8
		32A	9.44	1674	41.1
		32	7.63	1086	50.2
11/27/2007	Brushy Creek	28	11.27	175	11.5
	South Raccoon	28A	6.92	107	12.3
		32	8.27	120	5.2

Counts in late November were below the water quality standard. No rain fell in the watershed and there was little flow. Most of the cattle had also been removed from pasture.

A 24 hour time series sampling with the ISCO sampler was conducted on Brushy Creek at site 50 on November 12 and 13, several weeks after the stream had returned to base flow. This section of Brushy Creek is quite straight. The velocity of flow is relatively high and the stream bed is sandy with little organic matter. E. coli counts in the sediments are much lower than the pool areas upstream. Pasture land is present adjacent to the stream but with restricted access. Cattle were not in the pasture at the time of sampling. It is therefore assumed that the presence of E. coli is from upstream sources rather than from local inputs and disturbances (Table 9).

All samples exceeded the water quality standard for E. coli with counts ranging from a low of 644 to a high of 3448. The median value was 1565 and standard deviation 905. Turbidity varied from a low of 13.7 to a high of 54.2. These results provide a range of values that could be expected from grab samples collected during this time period.

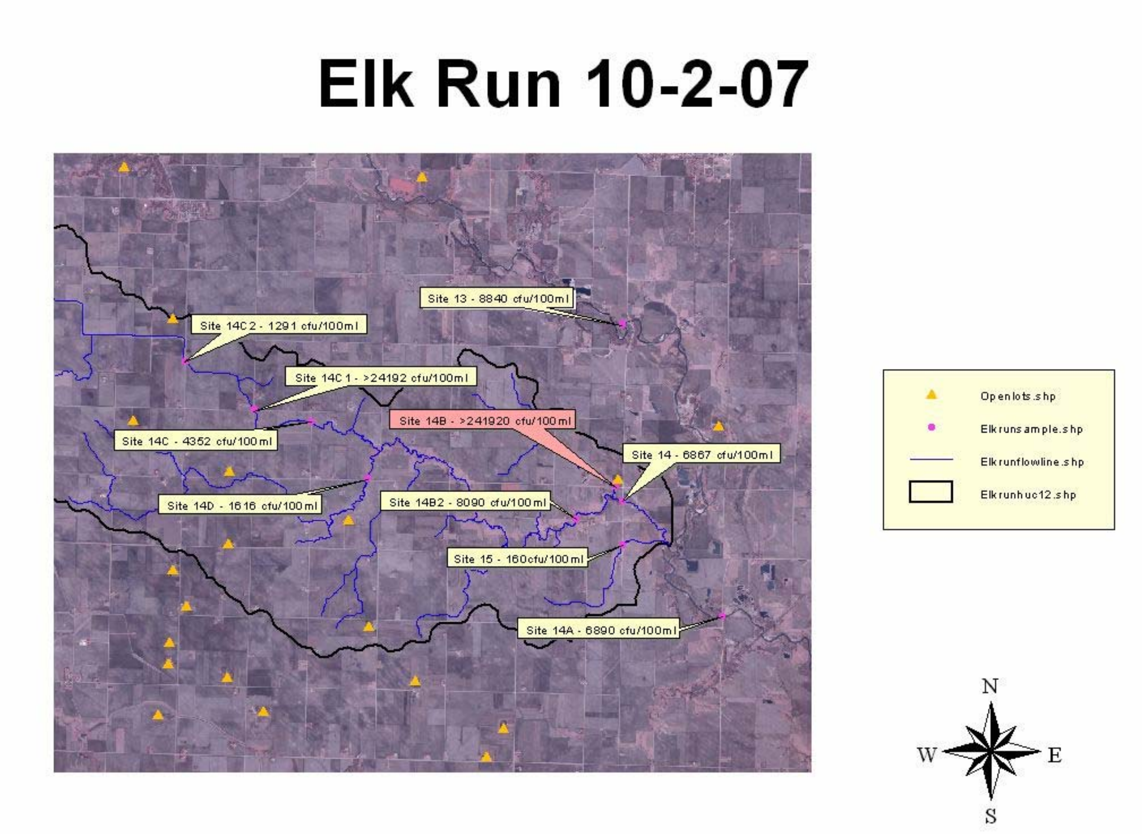
Table 9. Time Series Sampling in Brushy Creek, Site 50

Sample Date	Sample	E. coli	Turbidity
11/12/2007	1	3448	49.3
	2	2909	54.2
	3	1789	30.4
	4	2481	24.2
	5	684	21.3
	6	865	26.4
	7	1565	19.4
	8	1989	19.2
	9	1918	29
11/13/2007	10	1354	33.5
	15	933	20.4
	16	644	26.6
	17	676	13.7

The counts are remarkably high for base flow conditions with no runoff contribution. There is very limited potential of point source contribution other that direct defecation from cattle and wildlife upstream. This observation contributed to laboratory investigation of E. coli counts in the feces of cattle and survival in various matrices and stream environments.

North Raccoon and Tributaries, Elk Run Creek

E. coli counts in the North Raccoon exceeded the water quality standard during runoff events as well, by orders of magnitude. Since there are few streams within the study area, a foray was made into Elk Run Creek futher upstream which the ACWA sampling demonstrated to be chronically high in E. coli. Site 14B below an open feedlot was especially contaminated. This site was investigated by IDNR staff and cited for corrective action.



It should also be noted that these are count concentrations and not fecal load. The sample was collected from a very small tributary just downstream of a small drainage ditch. The contribution of this source to total counts in Elk Run Creek however may be insignificant. Counts in the receiving stream above the confluence of this source (site 14B2) were higher than at the site downstream (14). Also, counts in the Raccoon River upstream of Elk Run Creek were higher than discharge from Elk Run Creek at the time of sampling. Few conclusions can be made however because E. coli counts within the watershed were quite variable (Table 10) and likely a function time of time of collection and position on the stream hydrograph. This is especially true for small watersheds where time of travel is very short and hydrographs are compressed. Whether corrective action will materially improve water quality in Elk Run and the Raccoon River is speculative but it is reasonable to assume that such action will encourage other producers in the watershed to take measures to reduce manure runoff in their operations.

Table 10. Elk Run Creek

Sample Date	Creek Name	Client Id	Chloride	E. coli	Turbidity
10/2/2007	Elk Run	14	23.08	6867	20.2
		14B	71.55	>241920	915
		14C		4352	8.76
		14C1	22.15	>24192	8.16
		14D	26.61	1616	4.37
	Elk Run Creek	14A	20.84	4350	85
		14A (2 hr later)	20.76	6890	102
		14B2	22.76	8090	17.3
		14C2	22.27	1291	4.09
	Elk Run South	15	27.18	160	3.55
	North Raccoon	13	18.9	8840	101

Purgatory Creek

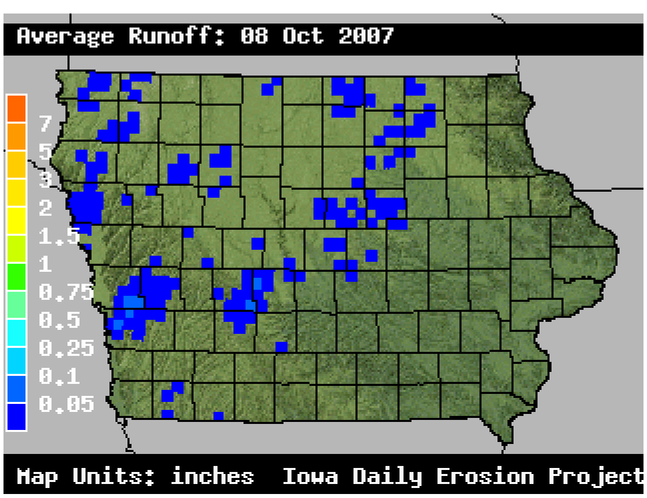


fig 8. Runoff contribution to flow, Oct 8, 2007

Widespread rain events on October 8 and 14 caused sufficient rise in flow to trigger the ISCO sampler on Purgatory Creek. The two rain events however differed considerably from each other. The October 8 rain was much smaller and followed a period of dry weather in late September. Little surface runoff contributed to the elevated flow (fig 8). In contrast, the October 14 rain event was much larger and fell on already hydrated soils. This resulted in widespread surface runoff, especially toward the southern section of the Watershed (fig 9).

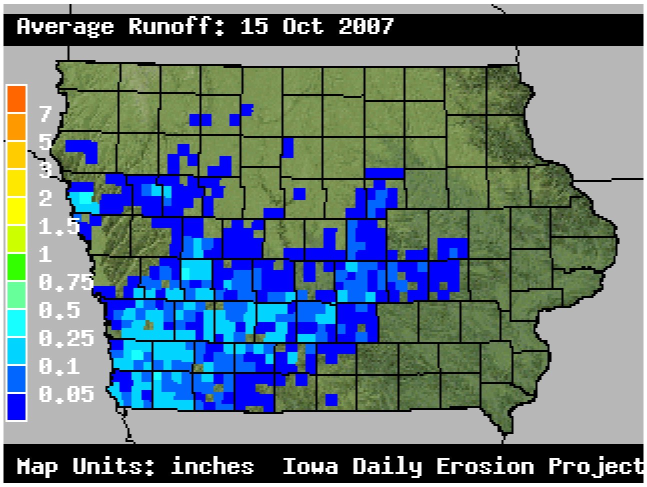


fig 9. Runoff contribution on Oct 14, 2007

The differences in water quality observed (Table 11) may be due to unique local land use at the sampler location and differences area wide runoff amounts. The ISCO sampler is located in a pasture where cattle have unrestricted access to the stream. During the October 8 rain event the highest E. coli counts occurred in the first two samples when flow was just beginning to increase (fig 10). This indicates local contribution as time of travel is minimal. The local pasture however was well protected with vegetation so runoff from the pasture is unlikely. Cattle were observed in the stream however and direct defecation into the stream is a probable. Disturbance of fecal contaminated sediments by aquatic organisms, terrestrial wildlife, or livestock trampling in the stream will dislodge E. coli from the matrix into the flowing water. The observation that cattle more frequently enter streams during dry weather to drink or cool off suggests greater direct contribution of fecal material to the stream during low flow when there is little energy to dislodge and transport of E. coli from the fecal matrix. During low flow, fecal contamination may continue to accumulate until elevated flow flushes the sediments. Kicking stream sediments to simulate trampling activity of cattle in stream and collecting samples downstream results in E. coli counts in numbers generally attributed to runoff from the landscape (unpublished lab activity). These disturbances however are sporadic and of short duration relative to sediment disturbance and transport caused by elevated flow.

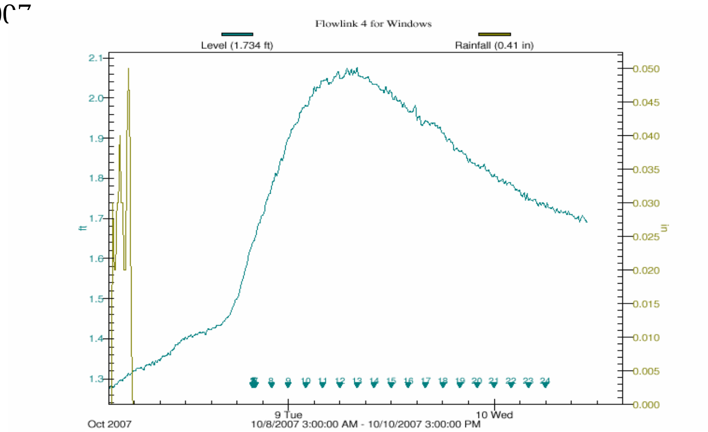


fig. 10. Purgatory Creek 10/8/07 hydrograph

The larger October 14 rain event created greater surface runoff from the landscape. Counts are considerably higher and corresponded to changes in turbidity and flow, indicating erosion and transport of E. coli from the entire landscape and stream sediments. No analyses of the stream sediments were performed at this location however to quantify in stream stores of E. coli and potential contribution during elevated flow.

Table 11. Purgatory Creek Water Quality During Rain Events

Sample Date	Creek Name	Client Id	Chloride	E. coli	Turbidity
10/8/2007	Purgatory Creek	Purgatory 01	22.59	4350	83.5
		Purgatory 04	23.17	5980	93.2
		Purgatory 08	23.36	2780	101.9
		Purgatory 09			119
10/9/2007	Purgatory Creek	Purgatory 10			130
		Purgatory 11			122
		Purgatory 12	23.67	1870	114
		Purgatory 13			103
		Purgatory 14	23.92	1210	103
		Purgatory 15			88.1
		Purgatory 16	23.63	1200	88.9
		Purgatory 17			81.2
		Purgatory 18			76.5
		Purgatory 19			73.5
		Purgatory 20	23.65	1220	72.8
		Purgatory 21			68.7
10/10/2007	Purgatory Creek	Purgatory 22			66.7
		Purgatory 23			70.3
		Purgatory 24	24.06	1210	64.5
10/14/2007	Purgatory Creek	Purg -2	22.37		104
10/15/2007	Purgatory Creek	Purg -6	21.65	17329	187
		Purg -8	20.11	32550	205
		Purg -11	18.57	21870	205
		Purg -15	16.56	6500	150

Potential impairment of water quality due to cattle activity within the stream was tested by collecting samples ever ½ hour over a 24 hour period during base flow (Table 12). Spikes in E. coli counts and turbidity would be considered evidence of sediment disturbance. Large spikes in E. coli counts with little increase in turbidity would be interpreted as a defecation event. The results were inconclusive. Median counts were higher than at other sites and counts more variable. The highest counts occurred at 2 AM when there was also a small increase in turbidity. It is doubtful whether livestock would be active in the stream at this time but disturbance by wildlife is possible. Beaver were observed in the area and are active at night. Counts ranged from a low of 20 cfu/100 ml to a high of 1153. Eighty nine percent (89%) of the samples exceeded the E. coli water quality standard. Activities such a collecting a kick sample or gathering a sample downstream of observed stream activity at or near this site may help data interpretation but was not performed. Data collected from other sites with different sediments and stream flow may be very different. No sediment analyses were performed at this site to provide comparative data.

Samples collected upstream of the pasture (site 19 up) at the beginning and end of the time study sampling were little different from pasture site samples. However, the upstream site may not have isolated in stream influences by cattle as pasture land was present further upstream.

Table 12. Time Study of Water Quality in Purgatory Creek, Base Flow

Sample Date	Creek Name	Client Id	Chloride	E. coli	Turbidity
10/31/2007	Purgatory Creek	19-1		677	50.7
		19-2		143	31.3
		19-3		404	28.9
		19-4		305	27.4
		19-5		278	31.6
		19-6		663	26.3
		19-7		350	29.1
		19-8		295	26.4
		19 Up	23.5	359	24.2
11/1/2007	Purgatory Creek	19-9		262	26.2
		19-10		529	28.1
		19-11		1153	32.7
		19-12		813	32.9
		19-13		697	31.8
		19-14		594	32.3
		19-15		651	29.6
		19-16		20	26.8
		19 Up	23.57	259	17.7

Several laboratory experiments were performed to test count contribution potential of both fresh and stored fecal matter and define source and environmental conditions that simulate water quality dynamics observed in small streams.

Laboratory Experiments:

Fresh bovine and porcine feces and samples from various stages of manure storage were analyzed primarily for viable E. coli concentrations (Table 13). Counts in the fresh feces compared favorably to the literature values used for the TMDL calculations. Two bovine samples were analyzed, the first from a feedlot and the second from a pasture. The second bovine sample yielded lower counts (0.6 billion vs. 2.4 billion/100ml) but it was uncertain whether it was fresh or related to diet or other causes. Comparison of fresh feces to stored manure uses values from the first sample as it is known to be fresh.

Table 13. E. coli Counts/100 ml in Fresh and Stored Manure

Source	Fresh	1 week [a]	3 months [b]	Lagoon [c]	1 year [d]
Bovine	2.4 E+9	6.5 E+7	4.1 E+4	1.1 E+5	
Porcine	2.5 E+9				6.6 E+4

a Estimated age of manure bladed off a dirt feedlot and stored on concrete slab.
b Estimated age of manure pile.
c Lagoon that captured runoff below the concrete slab
d Pit below swine confinement. Collected at time of land application

Assuming a pat volume of 500 ml and 12 pats per day, each cow produces 144 billion E. coli per day. This compares favorably to 104 billion/day used for TMDL calculations.

The common supposition that the source of high E. coli counts in the Raccoon River necessarily comes from large quantities of fecal matter is fundamentally flawed. E. coli counts are based on numbers of viable E. coli not mass of fecal material. The following examples illustrate the potential impact of fresh fecal matter on water quality.

1. Counts in a single fresh bovine pat weighing one pound (12 billion E. coli) are equivalent to counts in 146 tons of the three month old stored manure.
2. E. coli from one cow (144 billion) discharged in the Raccoon River at the 2006 average annual flow rate of 1000 CFS (2.44 E+9 liters/day) would increase E. coli counts in the Raccoon River at Des Moines by 6 counts/100 ml.
3. Defecation from 10 cows would cause impairment at a base flow of 250 CFS.

Several field observations can only occur with fresh fecal contribution. The highest counts in the Raccoon River in 2007 (123000/100ml) were higher than either of the lagoons or the stored fecal matter. Contribution from relatively fresh fecal sources with higher count concentrations would have to supplement the E. coli contribution from runoff or overflow of the lagoons to achieve this count concentration. Very high counts (2 million/100ml) occurred during dry weather with no runoff but where a small stream flowed through a small active feedlot just East of Lake City. Using an estimated flow of 0.1 CFS, this stream discharged 4.89E+12 E. coli in Lake Creek. Counts from this source alone could have caused water quality impairment in the Raccoon River at a 760 CFS flow as observed on that date. E. coli counts in Brushy Creek sediments (1.1 E+7 at site 42B2) are similar to freshly bladed feedlot manure even though a considerable amount of silt was mixed with the sample.

That E. coli counts are not higher than observed during low flow at Des Moines is somewhat problematic. This was also noted in the Raccoon River TMDL models which use E. coli counts in fresh fecal pats, number of grazing cattle and probability of direct defecation into the stream as point source contributions in the model that should be observed during base flow. The following experiments were conducted to determine what happens to a fecal pat that enters a stream and its influence on water quality through time.

The first experiment examined dispersion rate of E. coli out of a fecal pat matrix under various environmental conditions (Table 14). The fecal pat was collected from a pasture and had an E. coli count concentration of 0.6 billion/100 ml. Approximately 10 grams of fecal material was dropped into each 1 liter beaker containing treated water prior to chlorine addition. Simulated flow was provided with a Phipps and Bird 6 paddle mixer set at 10 rpm. Slow movement was simulated by attaching a paper clip rod to the paddle where only the rod had contact with the sample. Three hourly samples were collected from the top one centimeter for enumeration followed by a 24 hour sample. All samples, including "pool simulation" water exceeded the water quality standard within one hour of deposit. The observation of a turbidity plume as the sample fell through the water suggests that the resulting turbulence caused much of the initial dispersion. Dispersion in the field would be much greater however due to the greater height of drop. The results were not consistent but showed an overall trend on increased counts with time. The fecal material remained visually intact with relatively little of the total E. coli in the fecal pat dispersing into the water within three hours. The samples with greater agitation and surface area developed higher counts with time as expected. Counts 24 hours later exceeded 2.4 million except for the pool water. Visually, the fecal pats remained intact.

Table 14. Simulated Dispersion Rate of E. coli from Bovine Fecal Pat

Simulated stream conditions	Grams of fecal pat	1 hr	2 hr	3 hrs	24 hrs
Pool area	10.73			85000	689300
Slow moving	11.2	29090	63000	31000	>2419200
Moderate flow	10.2	44100	717000	488000	>2419200
Moderate flow HS *	10.3	2000	670000	1043000	>2419200

* HS (high surface) Fecal pat was separated into many small pieces to simulate splash separation such as on a hard surface.

The second experiment was a continuation of the first to observe the E. coli population dynamics through time (Table 15). Count concentration in the samples collected at the surface increased to nearly that of the original pat. This is nearly a 2 log increase in total numbers over the starting counts. Since the original pat concentration was 0.6 billion/100 ml, a 10 ml pat volume contains 60 million E. coli. When placed in 1 liter of water, the calculated count concentration is 60 million/liter or 6 million/100ml compared to a high of 580 counts/100 ml observed. Furthermore, these counts varied little with change through time. Fifty seven days (57) after the start of the experiment, the entire contents were uniformly dispersed through rapid mixing. With one exception, E. coli counts exceeded 242 million counts/100 ml, the maximum measurable value. This shows a net growth from 60 million to >2.4 billion E. coli counts in just under a two month period. The increase in E. coli counts with mixing indicates a very high concentration of E. coli remaining in the fecal matrix. This observation suggests a dynamic equilibrium between growth of E. coli in the fecal matrix with dispersion and mortality of E. coli in the overlying water column.

Table 15. Log value of E. coli Counts/100ml in Water Overlying a Fecal Matrix

Days	1	4	5	6	7	11	18	28	57*
Quiet	5.8	8.3	8.2	8.4	8.3	8.1	7.8	8.1	>8.4
Gentle	>6.4	8.5	8.3	8.2	8.1	7.0	8.2	7.7	>8.4
Moderate	>6.4	8.8		6.5	6.1	7.2	7.9	6.8	>8.4
Mod HS	>6.4	8.3	7.1	6.6	6.7	5.7	7.5	7.2	7.2

* Samples rapidly mixed to a uniform suspension

The third experiment studied long term changes in E. coli counts downstream of a fecal pat in a simulated stream environment. A ten (10) ml bovine pat was placed in a four (4) liter beaker into which treated chlorine free water continuously overflowed at a 1.2 liter/minute rate. Samples of the overflow water were analyzed for E. coli counts daily then longer increments of time until counts fell below 235 counts/100, the water quality standard for E. coli in streams. The experiment differed substantially from the previous experiment in that the continuously flowing water over the fecal continuously transported nutrients and E. coli away from the fecal pat and overlying water. Different results would be expected with differing flow rates.

Counts in the overflow water varied considerably with a minimum known value of 2924 in the first week to a maximum of >24192 counts (Table 16). The average of known counts was 3200. At this concentration and overflow rate, 0.4 billion E. coli were transported out of the beaker (downstream) in the one week period from a fecal pat containing initially 60 million E. coli. At a minimum, there was a 6.6 fold increase in E. coli counts in first week period with little indication of declining growth rate. This suggests a dynamic equilibrium between the reproductive rates of E. coli in the fecal matrix to transport downstream. After the initial week, the fecal pat lost its form and dispersed throughout the bottom of the beaker. Thereafter, counts declined.

Table 16. Overflow Experiment

Days	counts/100ml
1	2924
3	>2419
4	3255
5	>24192
7	3448
18	192
28	59

These results show that a fecal pats deposited into a stream are capable of creating sustained elevated E. coli counts in the stream for a least a week during base flow. Count values and variability are similar to that observed in streams were cattle were present. After a sustained period of time, the fecal pat disintegrated and counts declined. This decline in count concentration is also observed in Brushy Creek and upper South Raccoon after a sustained period of low flow and after cattle are removed from pasture.

The final experiment tested the influence of suspended particles in the stream to E. coli survival and sedimentation in pool areas. The high E. coli counts in the sediment relative to the overlying water at the pool sites in Brushy Creek suggested either settling of E. coli with stream sediments or possibly greater survival or even growth of E. coli on organic rich sediments.

Organic rich sediments from a pool area in Brushy Creek (site 42B2) were autoclaved to eliminate competition and predation by other organisms as well assuring uniform known E. coli concentrations from an inoculum. Varying amounts of the sediment (0, 1, 10, 100 ml) were placed into 1 liter beakers containing chlorine free treated water to constitute an experiment. High flow and base flow stream conditions were simulated using two paddle mixers, one set at 60 rpm to simulate high flow, the other at 5 rpm to simulate base flow.

Table 17. E. coli in Rapid Flow Environment

	Sediment volume			
Day	0	1	10	100
0	2400000	2400000	2400000	2400000
1	2419200	1732900	>2419200	1986300
2	1732900	>2419200	>2419200	>2419200
3	307600	980400	>2419200	>2419200
4	85700	1413600	>2419200	>2419200
12	36400	48000	344800	>2419200
End	36400	48000	344800	>2419200

Changes in E. coli counts through time in the rapid flow experiment show a clear relationship between E. coli counts to amount of sediment suspended in the water. Without sediment, E. coli counts rapidly declined. With increasing sediment volume, counts remain high for a longer period of time or even increased. The change in counts under base flow simulation was similar to the rapid flow experiment with one distinct difference, E. coli counts in the re-suspended matrix at the end of the experiment were higher that counts in the water matrix above the sediments (Table 18). It is unlikely that this is due to co-sedimentation since samples with the greater quantity of sediment would be expected to sweep more of the suspended E. coli to the bottom of the beaker than samples with lesser sediment volume. This was not observed. Also counts in the based flow simulation were similar to rapid flow suggesting processes independent of sedimentation.

Table 18. E. coli and Turbidity in Base Flow Simulation Environment

	Sediment Volume			
Day	0	1	10	100
0	2400000	2400000	2400000	2400000
1	>2419200	>2419200	>2419200	>2419200
2	1773100	1553100	>2419200	>2419200
3	344800	146700		1732900
4	307600	119800	307600	>2419200
12	30500	195600	547500	>2419200
End	77600	686700	1732900	>2419200

	Turbidity (NTU)			
Day	0	1	10	100
0	5.3	116	2480	24900
1	2.3	10.6	39.3	388
2	2.2	8.1	28.5	197
3	4.5	10.7	12	114
4	0.87	2.44	3.76	29
12	0.55	1.18	1.58	122
End	3	120	1800	23000

The sediments used in this experiment contained a high percent of organic matter and a high E. coli counts before autoclaving. It is possible if not probable that much of the organic matter was of fecal origin and provided a favorable environment for E. coli growth and survival.

The settled sediments in this experiment should have similar characteristics so that E. coli present in these sediments would likely be in a more favorable matrix for growth and survival as well. Therefore suspension of E. coli in the sediments would result in higher E. coli counts at the end of the experiment.

These experiments were designed as a test of concept rather than for modeling source and fate of E. coli in the environment. They were instructive examining sources of high counts rather than mass of fecal material and that factors that effect E. coli growth and survival in stream sediments may be key ingredients to understanding E. coli dynamics in streams.

SUMMARY AND DISCUSSION

E. coli is ubiquitous in the Raccoon and Des Moines River watersheds, and its concentration within streams is the product of many factors. The study had been examining sources, transport, and fate of *E. coli* within watersheds to better understand the dynamics in *E. coli* counts observed in the Des Moines and Raccoon River at the Des Moines Water Works intake locations. This report includes potential contributions that tend to be overlooked or discounted as significant contributors to water quality impairments. Laboratory experiments suggest that age of fecal material and matrix are more important considerations to elevated E. coli in the stream than mass of fecal material. Large quantities of stored fecal material are often incapable of producing the high counts concentrations observed during runoff. Some fresh fecal matter must be present. The overflow experiment shows that low velocity flow over a fecal pat can produce sustained high E. coli counts. This observation is consistent with many field observations where high E. coli counts occur during base flow. The fecal matrix sustains high counts during base flow and contributes high counts during elevated flow and matrix erosion.

The 24 hour time study on the variability of E. coli counts during base flow shows a high variability in counts and the limitations of grab samples in characterizing water quality in the stream. Similar count variability was observed during controlled experiments. The fecal pat breaks up in a non-uniform manner so it should be expected that E. coli numbers would vary accordingly. from a pat would be expectedinto the stream. This sample collection time studies duriTdisruptionwhen turbulence re-suspends the E. coli counts seen in the Waveland Golf Course storm sewer discharge. fits the

Direct defecation in several select tributaries best fits the observations of high E. coli counts during base flow and in stream sediments. be explainedthe upper reaches reaches observed during E. coli within the right matrix can continue

to determinents of stream sediments may greatly effect E. coli numbers and survival rates. is in it Factors that effect E. coli survival on the landscape and in the sediments muand therefore counts observed in the streams. The matrix Sediment characteristics analysesanto e relative contribution of these factors is highly dynamic and differs according to landscape.

Chronically high E. coli counts during base flow are indicative of direct discharge of fecal wastes. With one possible exception, no untreated domestic point source was found. Direct defecation into the stream during base flow should also elevate E. coli counts and has been treated as a point source for TMDL calculations. The model suggests minimal contribution from grazing livestock. However, the rate at which E. coli disperses from the fecal pat and is transported downstream, dynamics of growth and mortality of E. coli within the pat, and disposition of the pat in the stream over time are virtually unknown. It should not be assumed that the E. coli of the entire fecal pat is dispersed into the water on the same day as deposition. The portion that is not dispersed and transported downstream increases the E. coli counts in the sediments that would be suspended during elevated flow associated with runoff. This results in lower observed counts relative to its contribution during low flow and higher contribution to observed counts during elevated flow and runoff. The assumption that the total “point source” contribution by grazing livestock would be observed during low flow was tested by a series of laboratory experiments and found to be invalid. The SWAT model used for the TMDL calculations makes no distinction between stream entry as a fecal pat from E. coli already dispersed in water and discharged from a pipe. As such, the expected values would be higher than observed during low flow and lower than observed during high flow as shown in the Raccoon River TMDL load calibration. The E. coli load calibration model however uses E. coli counts observed at Des Moines only and is not tested against streams where high counts and high contributions are observed and should not be considered uniform across the watershed. Modeling these dynamics where there is a paucity of data perhaps justifies this simplistic approach. Nevertheless, specific observations of counts and estimated load suggest a greater contribution from this source than indicated from the model. Highest counts are routinely located where cattle have direct access to the stream. Very high counts (2 million) occurred where a stream with an estimated flow of 0.1 CFS flowed through a small active feedlot just East of Lake City. Upper Brushy Creek and the South Raccoon upstream of Brushy Creek usually have the highest counts and also have the highest percentage of acreage in pasture. E. coli counts in the sediments are remarkably high, exceeding 11 million/100ml at site 42B2. That this count concentration could come from landscape runoff of stored manure is questionable. During runoff events, the turbulence of elevated flow keeps runoff material suspended and also erodes some of the stream sediments, especially lighter organic material. In contrast, direct deposition of fresh feces into a stream during low flow provides an E. coli source with very high numbers that is less subject to transport downstream.

In previous reports, an increase in *E. coli* could be linked to a runoff event as evidenced by increased flow from an upstream tributary. This linkage was not nearly as apparent during the Fall of 2007. However, rainfall distribution maps showed that every increase in *E. coli* counts occurred during a rainfall event within the local watershed where elevated *E. coli* was observed. This was especially true for urban streams that have a large percentage of impervious surfaces and their contributions to mainstem flow at gauging stations are often masked by the magnitude of flow in the mainstem rivers.

The South Raccoon continues to be the primary source of *E. coli* in the Raccoon River as evidenced by the relationship of South Raccoon flow to *E. coli* in the Raccoon River. This was somewhat unexpected as the North Raccoon Watershed received much more rain than did the South Raccoon. Differences in transport appear to be the primary reason for the differences observed in these two watersheds.

The decrease in *E. coli* and other fecal indicators in the stream and sediments of upper Brushy Creek indicate some reduction in fecal contributions. This is consistent with the manure containment structures that have been installed in this region of the watershed. Since the South Raccoon Watershed is more subject to runoff than the North Raccoon, containment structures will provide greater benefit to water quality in the South Raccoon watershed than in the North Raccoon.

<u>Activities next quarter:</u>

Variability in *E. coli* counts during base flow is difficult to interpret and raises several questions:

1. Are the samples representative?
2. How uniform is the distribution of E. coli within a stream?
3. How much does it vary through time?
4. What numeric resolution should be expected by the method?
5. Can fresh fecal matter deposited directly into a stream cause the variations observed in the stream?

ISCO samplers have been programmed to composite three samples every half hour over a 24 hour period during base flow at three different locations. This is designed to test the relationship between unrestricted access of cattle to streams and variability in E. coli counts associated with cattle activity. In conjunction with this, pats of bovine feces have been collected to determine the potential contribution of direct defecation into a stream and the influence of sediment particles on mortality rate and transport.