Upper Brushy Creek Water Quality Monitoring Report

January through June 2011

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Des Moines Water Works

For

Watershed Improvement Review Board

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SITE DESCRIPTION

The Brushy Creek Watershed is located on the eastern edge of the Loess Hills and Rolling Prairie Ecoregion (47e) in Southwestern Iowa (fig 1). The thick layer of loess which defines the landscape along the Missouri River thins out further east to expose pre-Illinoisan glacial till topography. Erosion of the highly erodible loess from the hillsides has produced a landscape of loess mantled hills. This produced a unique hydrology of highly permeable soils along the ridge tops overlying weathered and less permeable till. The watershed is shaped like a ribbon that parallels the Middle Raccoon River. It is 42.9 miles long with an effective width of 3.3 miles. There are 104 first order streams in this 141 sq mi watershed which gives a drainage frequency of 0.73/square mile. The average basin slope is 6.08%. All areas of the landscape are close to a stream. The main channel is 50.2 miles long with a slope of 6.65 ft/mile.

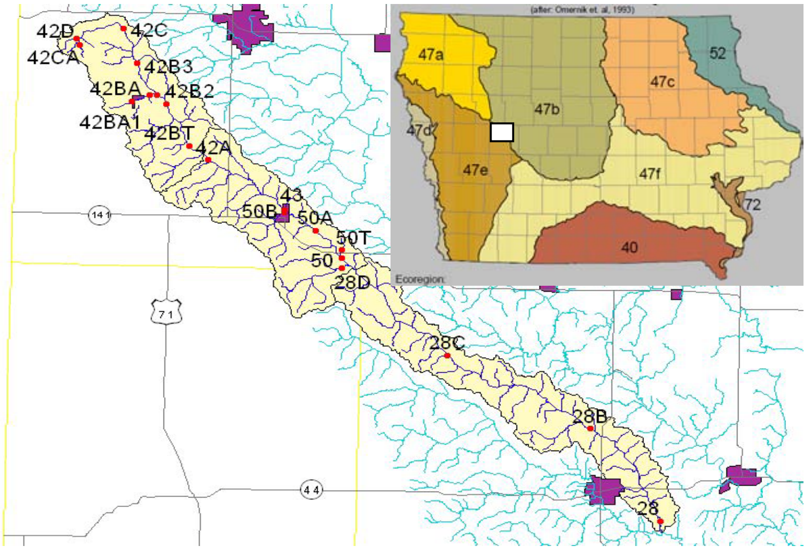


Fig 1. Brushy Creek Watershed

The stream begins at the loess mantled Missouri - Mississippi divide and flows easterly until it discharges into the South Raccoon River near Guthrie Center. The WIRB management area is in the upper region of the watershed, above site 43 and the community of Dedham (fig 1). Urban influences are limited to the small communities of Halbur and Roselle. Agricultural activities include tillage on the loess mantled ridge tops and protected slopes with pasture common on steeper slopes or near streams. Most producers are engaged in livestock operations, most of which are cattle in open feedlots. Tile drainage is common in areas more suited to row crop agriculture. Several small sedimentation basins are located between sites 42B and 42A.

Previous studies in the Raccoon River watershed conducted over an eight year period identified Brushy Creek as contributing a disproportionate load of fecal material and nutrients to the Raccoon River (Brand 2007). WIRB activities designed to reduce this

load to defined water quality standards began in 2008. Activities include inventorying what is present on the landscape as well as methods to keep the contaminants from being transported into the stream. Reduction in bacterial loading focuses primarily on improved manure containment and erosion control measures while nutrient reduction focuses on optimizing nutrient application to crop demand. Specific activities and practices are provided in a separate section. Assistance is provided by various state and professional organizations. This includes working with producers to select management options most compatible with producer needs and water quality. These practices are generally based on extensive research at a variety of sites. However, no two sites are identical so design and operational modifications may be necessary. Monitoring is conducted primarily to test and demonstrate effectiveness. Outliers in water quality may indicate areas needing further attention.

Demonstrating an improvement in water quality as a function of WIRB activities is challenging as highly variable weather plays such a large role in the transport of contaminants to the stream. It takes years to develop sufficient data to characterize discharge off the landscape under a variety of weather and hydrological conditions. The uncharacteristic stream morphology (which includes several sedimentation basins) further complicates evaluation. Models (such as SWAT) may accurately predict transport to the stream but not necessarily what is occurring within the stream. Sediment analyses below the catchment basins in 2007 indicated high fecal contamination (2.4E+7 *E. coli* counts/100ml) while counts downstream under faster flowing water was 1.4E+5 counts/100ml. These basins serve as both a catchment of fecal contaminants during low to moderate runoff and a source of counts during both base flow and elevated flow through re-suspension. Improvements in land management practices which reduce the transport of these contaminants to the stream will reduce the load within these sediments and therefore potential contribution during rain events. Interpretation of stream monitoring must therefore consider these in-stream processes as well as landscape contributions. The amount of time required to establish an improvement in water quality as a result of these practices is uncertain.

WEATHER CONDITIONS

Overall weather conditions during this period were near normal. A short January thaw occurred in early January providing minor runoff. A major blizzard on February 1 provided most of the winter precipitation. Temperatures remained below freezing after the blizzard until mid-February when temperatures rose to the upper 50s to low 60s creating extensive snow melt. Runoff from snowmelt was sampled on February 17. Total precipitation through April was 1.3 inches below average and evenly distributed which allowed soils to dry and crops to be planted. Frequent rains began in late May through June with three major storms dropping nearly 2 inches of rain each. These three rain events triggered the auto-samplers but only May 26 and June 20 events were collected for runoff data. Figure 2 shows weather and hydrological conditions where precipitation events in Brushy Creek are superimposed on USGS recorded flow in the Middle Raccoon near Brushy Creek. Figure 3 displays scheduled samples in relationship to flow to provide context to the results.

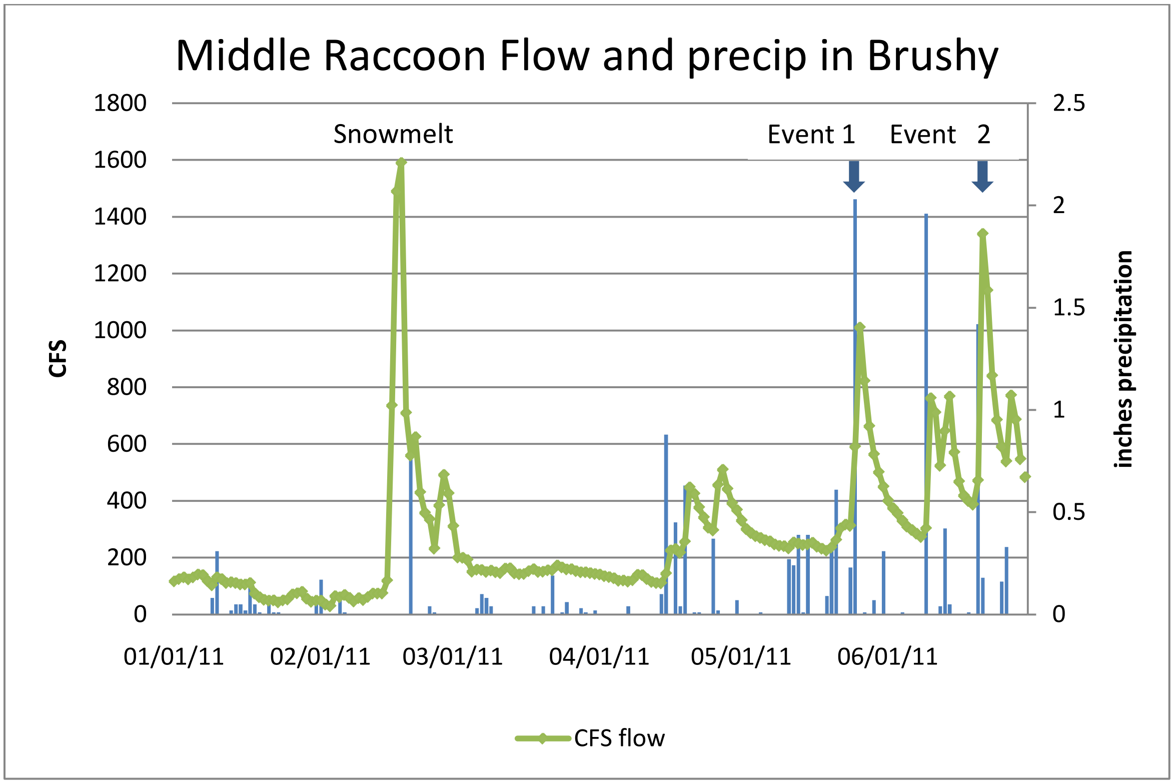


Fig 2. Precipitation events in upper Brushy Creek and flow response in the Middle Raccoon

METHODS

Samples were collected from eight sites on a weekly basis from March through June to provide contaminant distribution data across the watershed over a variety of flow and weather conditions (fig 3). One round of samples was collected from flow under the ice in January. A second set was collected during snowmelt runoff in February. All analyses were performed by the DMWW laboratory.

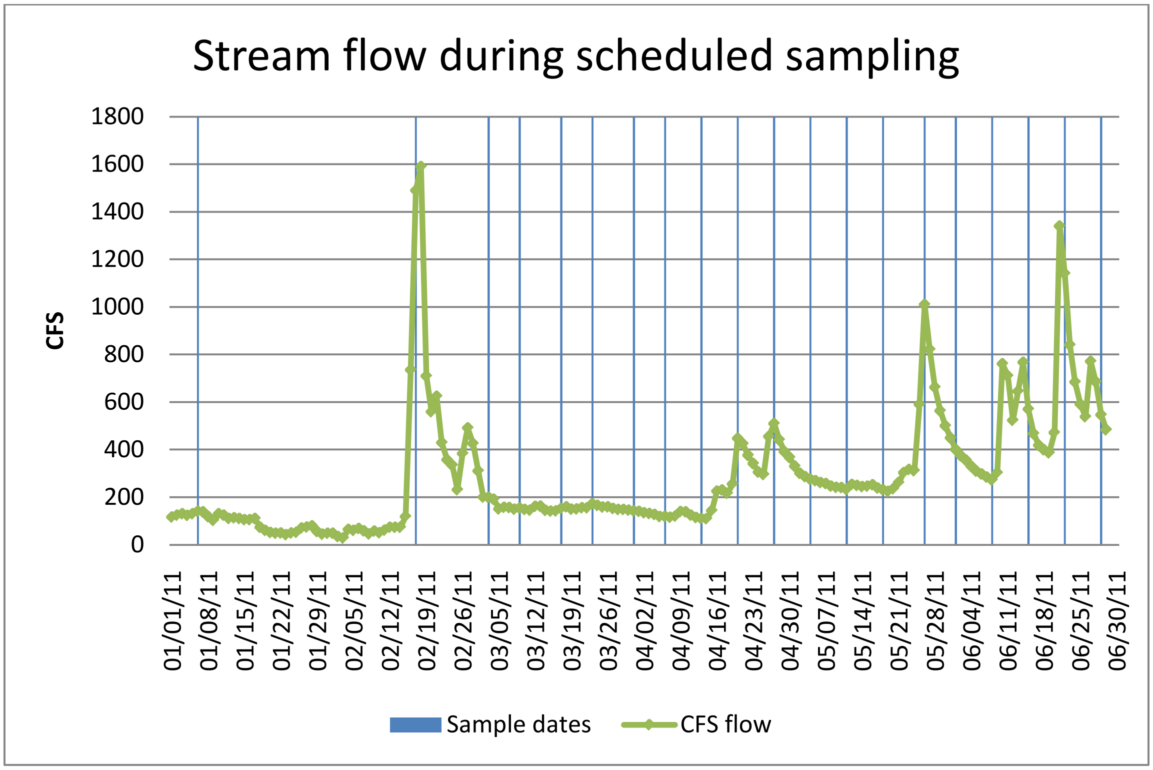


Fig 3. Flow in the Middle Raccoon during scheduled sampling

RESULTS

Tabulation of all data is provided in Appendix A. This report focuses on manure contamination and nutrients as these are the focus of WIRB activities.

<u>E. coli</u> **<u>counts</u> are highly variable with high counts associated primarily with runoff shown in bold font (Table 1). The winter sampling events occurred during snowmelt runoff over frozen ground. The January 6 event was minor as temperatures did not get above the mid-30s. The February 17 event was much more substantial due to the heavy snow from the February 1st blizzard and high temperatures in the upper 50s. Other high counts occurred following either during runoff from rain events or elevated**

flow in June when frequent rain fell on saturated the soils. During these conditions the distinction between runoff and elevated groundwater contribution becomes somewhat arbitrary.

Table 1. E. coli counts/100ml in Upper Brushy Creek

Date	42C	42B3	42B2.5	42BA	42B2	42BT	42A	43
01/06/11	**402**	**201**	**2755**	**3873**	**2382**	**313**	**272**	**8664**
02/17/11	**630**	**1480**	**980**	**5630**	**1100**	**3990**	**3730**	**4130**
03/03/11	<100	<100	<100	100	<100	<100	200	<100
03/09/11	<100	<100	<100	100	100	100	<100	<100
03/17/11	74	52	41	51	31	52	20	20
03/23/11	10	10	31	148	10	631	85	63
03/31/11	10	52	52	246	20	109	134	146
04/06/11	20	40	60	10	40	30	30	40
04/13/11	2	33	4	21	12	11	24	3
04/20/11	**8300**	**8000**	**6200**	**400**	**6300**	**17200**	**28500**	**68700**
04/27/11	200	400	400	<100	200	100	300	200
05/04/11	10	40	110	50	30	40	70	10
05/11/11	100	170	210	5170	1150	650	910	430
05/18/11	41	98	158	813	309	425	331	201
05/25/11	**18700**	**547500**	**770100**	**65000**	**613100**	**920800**	**1203300**	**1046200**
06/01/11	104	346	462	584	518	870	2290	1226
06/08/11	100	1210	1600	7230	970	1830	1850	3310
06/15/11	275	327	441	1259	2014	1989	2359	1460
06/22/11	**300**	**36540**	**27550**	**4100**	**20980**	**32550**	**21430**	**27550**
geomean	113.1646	376.7286	470.1677	527.8661	415.5178	632.9543	697.9876	684.8045

Geomean values show a reduction in counts over previous years, especially in the upper reaches of Brushy. This is a reversal to previous years in which counts generally increased upstream. Counts at site 43, the base of the WIRB area, show a downward trend during the project years (fig 4).

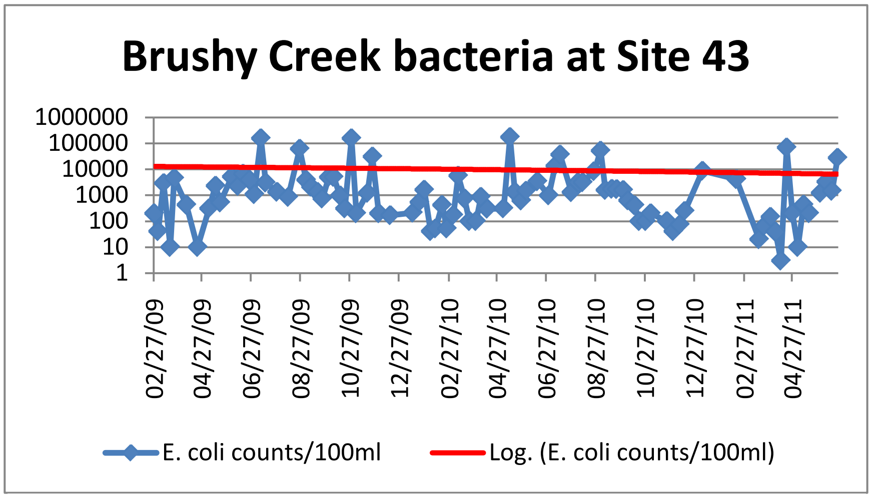


Fig 4. Trend in counts over the duration of the WIRB project

Counts during base flow may be a better indicator of improvement since lower counts would suggest a decrease in the amount of fecal material in the stream sediments and by inference amount of fecal material transported to the stream during runoff. Compared to previous years, the percentage of samples meeting the water quality standard of 210 counts/100 ml for *E. coli* has improved (Table 2). Very few samples were collected from this site in 2008 and are therefore not included in this table.

Table 2. Percent Samples over *E. coli* standard

2007	2009	2010	2011
94.1	76	72	47

<u>Turbidity</u>, a measure of cloudiness due to light scattering particles, is an indirect indicator of particle transport derived from the landscape or scour within the stream. Weather related runoff and transport that increase turbidity should also increase transport *E. coli* if present on the landscape. Spikes in turbidity occur on the same dates as spikes in counts. However, demonstrating this has been problematic. The distribution of *E. coli* counts precedes the turbidity distribution in the flow hydrograph. Furthermore, stream flow can segregate these particles. During declining flow the smaller, less dense bacteria remains in suspension while the heavier soil particles drop out as sediment. This contributes to high counts in the stream with low turbidity as observed during the elevated flow in June between rain events.

Table 3 Turbidity NTU in Upper Brushy Creek

Sample Date	42A	42B2	42B2.5	42B3	42BA	42BT	42C	43
01/06/11	9.71	10.7	11.3	13.1	12.3	15.8	14	9.39
02/17/11	**611**	**387**	**364**	**261**	**339**	**561**	**198**	**1211**
03/03/11	26.7	21.6	21.3	17.8	20.9	21.7	12.4	24.3
03/09/11	12.7	9.43	10	3.82	5	6.21	5.77	5.87
03/17/11	34.7	15.4	18.6	7.83	22.3	26	9.52	41.8
03/23/11	15.7	5.28	4.86	3.01	4.66	8.98	5.03	18.4
03/31/11	4.23	3.18	3.29	4.52	2.28	5.14	1.65	5.73
04/06/11	4.9	9.9	7.4	6.9	5	6.9	8.1	6.2
04/13/11	3.55	4.71	2.98	2.44	3.44	3.22	2.38	3.64
04/20/11	**21.6**	**16.9**	**17.4**	**18.6**	**12.2**	**18.8**	**19.4**	**37.9**
05/04/11	5.12	3.88	3.55	2.89	2.42	5.66	3.01	6.04
05/11/11	5.44	7	7.5	8	18.6	7.4	4.3	18.3
05/18/11	4.62	7.48	5.41	4.55	9.45	6.33	3	12.2
05/26/11	**710**	**322**	**313**	**223**	**226**	**436**	**103**	**1160**
06/01/11	19.8	20.6	18.2	13.4	18.8	22.5	13	49.8
06/08/11	23.7	15.9	10.9	13.1	91.9	29.1	10.9	44.7
06/15/11	7.74	17.3	13.9	10.7	40.3	13.5	8.43	55
06/22/11	**15**	**16**	**10.8**	**10.5**	**29.9**	**21.2**	**9.12**	**53**
06/29/11	13.9	5.81	6.76	5.26	28.6	15.9	7.27	40

Better manure containment should decrease manure runoff (counts) relative to total particles (turbidity). A more detailed examination on the change in manure runoff and potential impact of manure control structure will be provided at the end of the WIRB project.

Ammonia concentrations were highest during snowmelt runoff and to a lesser extent during storm events (Table 4). Essentially no detectable ammonia occurred in base flow samples. Therefore analysis was limited to site 43, the base of the watershed during base flow. Should an elevated concentration occur, analyses on the remaining samples would be performed.

Table 4 Ammonia-N (mg/l) in Brushy Creek January through June 2011

Sample Date	42A	42B2	42B2.5	42B3	42BA	42BT	42C	43
02/17/11	1.75	1.35	1.55	1.25	1.9	1.9	1.35	1.95
03/23/11	0.05	0.01	0	0.02	0.01	0.03	ND	0.05
04/20/11	0.21	0.05	0.07	0.09	0.04	0.09	0.4	0.36
04/27/11	0.01	0.09	0.02	0.09	0.05	0.04	0.09	0.07
05/18/11								0.06
05/25/11	1.13	0.95	1.0	0.52	0.3	1.1	0.08	0.86
06/08/11								0.08
06/15/11	0.05	0.05	0.05	0.05	0.05	0.06	0.03	0.05
06/22/11								ND
06/29/11	0.02	ND	0.01	ND	0.04	ND	0.02	0.02

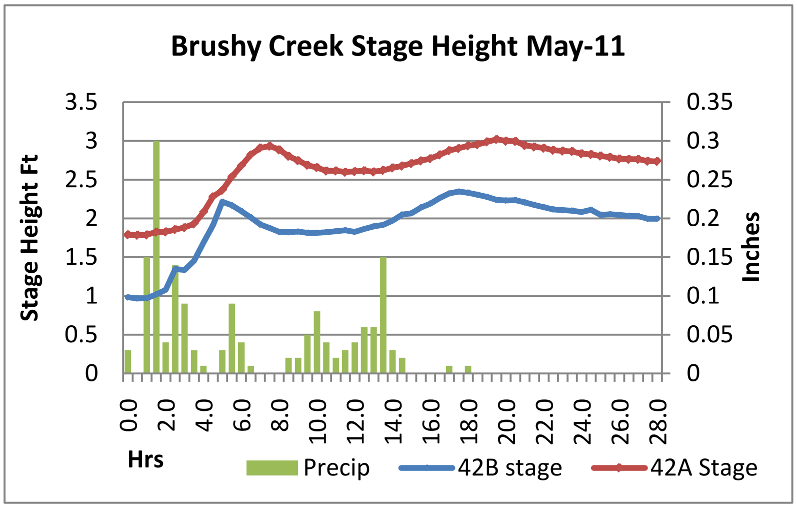
Nitrate-N concentrations were well above the water quality standard of 10 mg/l at all sites except when low nitrate surface runoff diluted the groundwater contribution. This is most apparent during snowmelt runoff over frozen ground. In fact, a dip in nitrate concentration has proven to be one of the most reliable indicators of surface runoff. Concentrations during base flow gradually decline downstream. This has been observed since monitoring began in Brushy Creek.

Nitrate concentrations in upper Brushy remained well above concentration in the Raccoon River at Des Moines (Table 5) with near average flows (288:338 cfs) in the Middle Raccoon at Bayard. This suggests disproportionately high losses from the landscape and an opportunity to refine nitrogen management. No soil testing was performed this spring and it is not known whether the producers reduced their application rates this spring in response to stalk testing last fall.

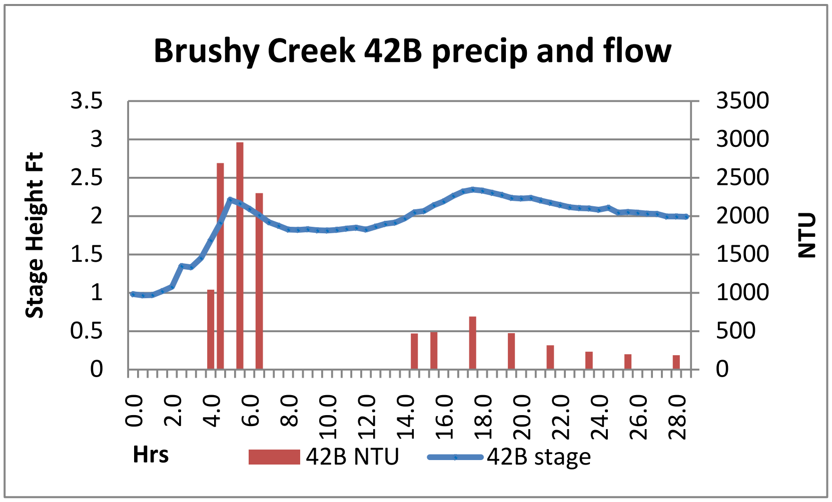
Table 5. Nitrate-N concentration (mg/l) in Brushy Creek and Raccoon River

Date	42C	42B3	42B2.5	42BA	42B2	42BT	42A	43	RR
01/06/11	12.6	12.8	13.9	14.1	13.3	12.6	12.6	15.8	7.6
02/17/11	6.6	6.7	6.6	5.2	6.6	6.0	5.8	5.6	4.2
03/03/11	14.9	14.3	14.3	11.4	14.3	13.0	12.9	11.2	6.7
03/09/11	13.0	14.0	11.9	11.1	12.5	12.5	12.4	12.2	5.6
03/17/11	0.3	0.3	4.8	4.8	4.8	3.0	3.8	5.7	5.6
03/23/11	14.1	13.5	13.4	10.1	13.4	11.7	11.6	9.9	4.5
03/31/11	14.0	13.2	13.2	10.1	13.2	11.6	11.8	10.0	7.0
04/06/11	11.5	11.5	11.7	9.8	11.7	11.3	11.7	11.4	6.4
04/13/11	13.4	12.8	12.7	9.5	11.4	10.9	11.0	8.9	4.9
04/20/11	14.7	14.7	13.7	12.0	13.7	13.2	13.1	11.6	6.3
04/27/11	9.9	9.8	9.9	8.8	10.4	8.6	9.9	10.6	7.8
05/04/11	14.4	14.4	13.4	11.7	13.3	12.9	12.6	11.1	9.0
05/11/11	14.9	13.8	13.6	10.1	12.1	11.5	11.2	10.1	8.0
05/18/11		14.1	14.1	11.0	12.9	12.4	12.0	10.6	7.8
05/26/11	17.5	16.9	16.1	14.4	16.1	14.2	13.1	9.4	8.2
06/01/11	17.1	16.7	16.7	13.9	15.6	15.2	15.1	13.6	11.2
06/08/11	16.8	16.3	16.5	13.5	16.3	16.0	16.0	15.3	10.4
06/15/11	16.4	15.9	16.0	13.3	15.0	15.0	15.0	13.4	7.2
06/22/11	16.4	15.8	16.0	13.9	15.2	15.0	14.9	13.1	6.9
06/29/11	16.3	16.2	16.4	14.2	14.4	15.4	15.2	14.2	10.8
mean	13.4	13.2	13.2	11.1	12.8	12.1	12.1	11.2	7.3

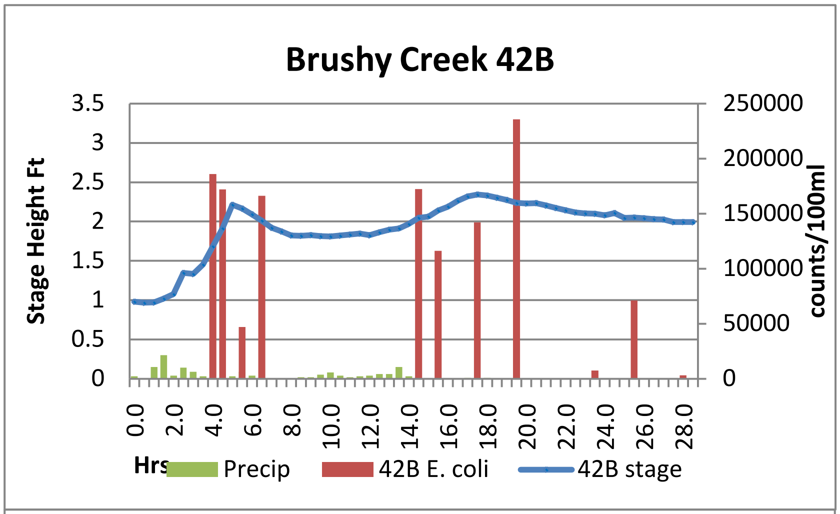
The two rain events samples provide very useful but complex data, especially the 5/25/11 event which was actually a composite of two cells that passed through within 12 hours of each other resulting in a hydrograph with split peaks. Runoff is rapid with a short distance to the stream. Peak flow at 42B occurs approximately four (4) hours after rainfall. Travel time to site 42A downstream is approximately three (3) hours.

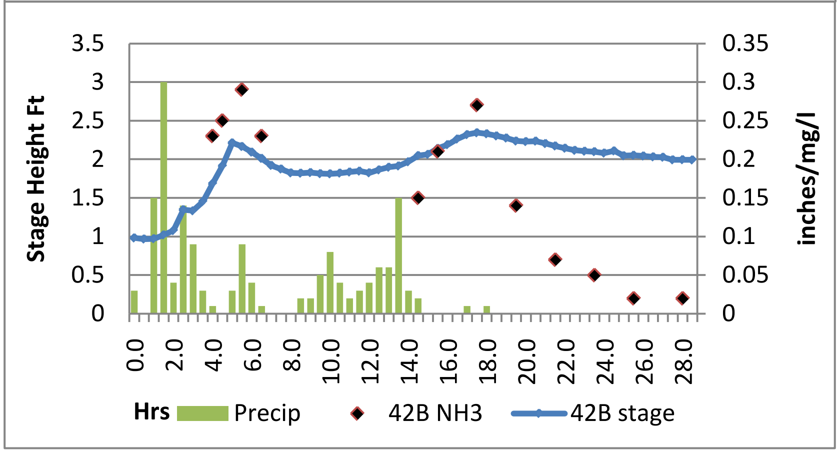


Surface runoff and stream response is greatly influenced by the intensity of the precipitation. The rain intensity of the first storm cell was much greater than the second cell which resulted in much greater overland flow and higher turbidity.



That the NTU values in the first peak are much higher than the second peak suggests the primary source of turbidity to be from erosion off the landscape rather than bank scour from increased stream flow velocity. High fecal counts would be expected from feedlots during these conditions if manure control structures were not in place. Though the counts are high following the initial runoff, counts are equally high following the second more gentle rain with highest counts on the descending limb of the second event. Ammonia concentrations followed a similar pattern. This suggests bacteria transport with the ammonia in the flow leaving the manure control structures. These are designed to retain the solids while allowing excess water to drain away through a filter strip. The second rain would further fluidize the manure creating additional liquid discharge from these structures - hence high ammonia and bacteria counts. It is highly probable that without these structures, much higher counts would have accompanied the transport of manure solids to the stream during the initial flush from the landscape. That counts during





base flow have decreased suggests less manure transport and deposition onto stream sediments during runoff events. A complete tabulation of event data is presented in Appendix B.

DISCUSSION AND SUMMARY

WIRB has applied a considerable amount effort and expense for improve manure management within the upper Brushy Creek watershed. Though it is impossible to know what counts would have been without these protective measures, collectively the evidence points to an improvement in stream water quality as a result of these activities. The geometric mean for *E. coli* is below the goal of 630 counts/100ml for most sites. Event data indicates retention of manure solids following a heavy rain. Counts during base flow are lower. There are fewer days in which the water quality standard is exceeded.

Nitrate-N concentrations however were well above the water quality standard of 10 mg/l except during runoff events when discharge of low nitrate surface water into the stream diluted high nitrate ground water. The magnitude of this loss to cannot be directly calculated without flow data. However, since flow in the Middle Raccoon near Bayard just a few miles north of Brushy Creek, it is probable that the flow/mi^2 in Brushy Creek is similar to that of the Middle Raccoon. Flow at the Bayard gauging station was close to the long term mean for this period. The high concentration with normal flow indicates considerable loss in nitrogen and an opportunity to save cost of application and losses to the stream. These losses also come with a human cost as it deteriorates water quality in the Raccoon River, a source of drinking water for 450,000 Iowans in central Iowa.

Appendix A. Scheduled Sampling Results

Sample Date	Site Id	Ammonia-N	E. coli	Nitrate as N	Phosphorus-O as P	Total Nitrogen as N	Turbidity
01/06/11	**42A**		272	12.6	0.07		9.71
	42B2		2382	13.28	0.06		10.7
	42B2.5		2755	13.91	ND		11.3
	42B3		201	12.76	ND		13.1
	42BA		3873	14.08	0.07		12.3
	42BT		313	12.59	0.07		15.8
	42C		402	12.61	ND		14
	43		8664	15.8	0.07		9.39
02/17/11	**42A**	1.75	3730	5.84	1.01		611
	42B2	1.35	1100	6.57	1.14		387
	42B2.5	1.55	980	6.55	1.17		364
	42B3	1.25	1480	6.74	1.07		261
	42BA	1.9	5630	5.17	1.02		339
	42BT	1.9	3990	5.97	1.05		561
	42C	1.35	630	6.63	0.96		198
	43	1.95	4130	5.62	0.72		1211
03/03/11	**42A**		200	12.93	0.07		26.7
	42B2		ND	14.26	ND		21.6
	42B2.5		ND	14.26	0.05		21.3
	42B3		ND	14.25	ND		17.8
	42BA		100	11.39	ND		20.9
	42BT		ND	12.96	ND		21.7
	42C		ND	14.89	ND		12.4
	43		ND	11.23	0.06		24.3
03/09/11	**42A**		ND	12.39	ND		12.7
	42B2		100	12.46	ND		9.43
	42B2.5		ND	11.88	ND		10
	42B3		ND	13.98	ND		3.82
	42BA		100	11.1	0.11		5

	42BT		100	12.47	ND	6.21
	42C		ND	12.95	ND	5.77
	43		ND	12.23	ND	5.87
03/17/11	**42A**		20	3.78	ND	34.7
	42B2		31	4.79	ND	15.4
	42B2.5		41	4.81	ND	18.6
	42B3		52	0.34	ND	7.83
	42BA		51	4.76	0.1	22.3
	42BT		52	2.98	ND	26
	42C		74	0.33	ND	9.52
	43		20	5.65	0.29	41.8
03/23/11	**42A**	0.05	85	11.64	ND	15.7
	42B2	0.01	10	13.37	ND	5.28
	42B2.5	0	31	13.38	ND	4.86
	42B3	0.02	0	13.51	ND	3.01
	42BA	0.01	148	10.14	ND	4.66
	42BT	0.03	631	11.71	ND	8.98
	42C	0	10	14.1	ND	5.03
	43	0.05	63	9.94	ND	18.4
03/31/11	**42A**		134	11.77	ND	4.23
	42B2		20	13.15	ND	3.18
	42B2.5		52	13.16	ND	3.29
	42B3		52	13.24	ND	4.52
	42BA		246	10.12	ND	2.28
	42BT		109	11.6	ND	5.14
	42C		10	14.02	ND	1.65
	43		146	9.97	ND	5.73
04/06/11	**42A**		30	11.71	ND	4.9
	42B2		40	11.68	ND	9.9
	42B2.5		60	11.67	ND	7.4
	42B3		40	11.49	ND	6.9
	42BA		10	9.8	ND	5
	42BT		30	11.27	ND	6.9

	42C		20	11.48	ND	8.1
	43		40	11.37	ND	6.2
04/13/11	**42A**		24	10.97	ND	3.55
	42B2		12	11.36	ND	4.71
	42B2.5		4	12.65	ND	2.98
	42B3		33	12.75	ND	2.44
	42BA		21	9.54	ND	3.44
	42BT		11	10.9	ND	3.22
	42C		2	13.38	ND	2.38
	43		3	8.92	ND	3.64
04/20/11	**42A**	0.21	28500	13.06	0.15	21.6
	42B2	0.05	6300	13.66	ND	16.9
	42B2.5	0.07	6200	13.69	ND	17.4
	42B3	0.09	8000	14.69	0.06	18.6
	42BA	0.04	400	11.99	ND	12.2
	42BT	0.09	17200	13.21	0.06	18.8
	42C	0.4	8300	14.67	ND	19.4
	43	0.36	68700	11.58	0.23	37.9
04/27/11	**42A**	0.01	300	9.9	ND	
	42B2	0.09	200	10.42	ND	
	42B2.5	0.02	400	9.93	ND	
	42B3	0.09	400	9.77	ND	
	42BA	0.05	0	8.82	ND	
	42BT	0.04	100	8.61	ND	
	42C	0.09	200	9.85	ND	
	43	0.07	200	10.64	ND	
05/04/11	**42A**		70	12.63	ND	5.12
	42B2		30	13.3	ND	3.88
	42B2.5		110	13.35	ND	3.55
	42B3		40	14.35	ND	2.89
	42BA		50	11.67	ND	2.42
	42BT		40	12.86	ND	5.66
	42C		10	14.39	ND	3.01

	43		10	11.05	ND	6.04
05/11/11	**42A**		910	11.19	ND	5.44
	42B2		1150	12.11	ND	7
	42B2.5		210	13.57	ND	7.5
	42B3		170	13.8	ND	8
	42BA		5170	10.13	ND	18.6
	42BT		650	11.54	ND	7.4
	42C		100	14.86	ND	4.3
	43		430	10.07	ND	18.3
05/18/11	**42A**		331	11.98	ND	4.62
	42B2		309	12.86	ND	7.48
	42B2.5		158	14.07	ND	5.41
	42B3		98	14.13	ND	4.55
	42BA		813	10.99	ND	9.45
	42BT		425	12.36	ND	6.33
	42C		41			3
	43	0.06	201	10.62	ND	12.2
05/25/11	**42A**	1.125	1203300	13.09	0.87	710
	42B2	0.95	613100	16.09	0.58	322
	42B2.5	1	770100	16.1	0.62	313
	42B3	0.52	547500	16.88	0.98	223
	42BA	0.3	65000	14.39	0.31	226
	42BT	1.1	920800	14.24	0.64	436
	42C	0.08	18700	17.53	ND	103
	43	0.86	1046200	9.37	0.38	1160
06/01/11	**42A**		2290	15.1	ND	19.8
	42B2		518	15.63	ND	20.6
	42B2.5		462	16.68	ND	18.2
	42B3		346	16.68	ND	13.4
	42BA		584	13.91	ND	18.8
	42BT		870	15.15	ND	22.5
	42C		104	17.1	ND	13
	43		1226	13.6	ND	49.8

06/08/11	**42A**		1850	16.01	ND		23.7
	42B2		970	16.27	ND		15.9
	42B2.5		1600	16.53	ND		10.9
	42B3		1210	16.34	ND		13.1
	42BA		7230	13.48	ND		91.9
	42BT		1830	15.97	ND		29.1
	42C		100	16.83	ND		10.9
	43	0.08	3310	15.26	ND		44.7
06/15/11	**42A**	0.05	2359	14.97	0.05	15.4	7.74
	42B2	0.05	2014	14.95	ND	15.6	17.3
	42B2.5	0.05	441	16.02	ND	16.9	13.9
	42B3	0.05	327	15.9	ND	16.2	10.7
	42BA	0.05	1259	13.3	0.08	14.1	40.3
	42BT	0.06	1989	14.96	ND	15.5	13.5
	42C	0.03	275	16.4	ND	17	8.43
	43	0.05	1460	13.43	0.07	14	55
06/22/11	**42A**		21430	14.85	0.08		15
	42B2		20980	15.2	0.06		16
	42B2.5		27550	15.97	ND		10.8
	42B3		36540	15.81	0.09		10.5
	42BA		4100	13.88	ND		29.9
	42BT		32550	14.99	0.09		21.2
	42C		300	16.4	ND		9.12
	43	0	27550	13.14	0.1		53
06/29/11	**42A**	0.02		15.15	ND		13.9
	42B2	0		14.38	ND		5.81
	42B2.5	0.01		16.4	ND		6.76
	42B3	0		16.2	ND		5.26
	42BA	0.04		14.18	ND		28.6
	42BT	0		15.36	ND		15.9
	42C	0.02		16.31	ND		7.27
	43	0.02		14.16	ND		40

Appendix B. May Rain Event Data

Site	Sample Date	IP_SampleTime	Ammonia as N	E. coli	Nitrate as N	Phosphorus-O as P	Turbidity
42A	05/25/11	5:19	0.57	727000	9.04	0.75	505
		6:05	0.5	579400	9.36	0.76	279
		7:05	2.5	488400	5.9	1.1	1025
		8:05	2.8	108100	8.81	0.65	923
		9:05	2	135400	9.92	0.69	868
		10:05	2.4	325500	11.18	0.68	1472
		11:05	2.7	435200	12.72	0.67	1287
		14:05	0.74	261300	13.85	0.59	323
		16:05	0.66	185000	14.16	0.67	260
		18:05	0.62		14.7	0.72	313
		20:05	0.67	235900	15.42	0.66	399
		22:05	0.62	160700	15.66	0.64	377
	05/26/11	0:05	0.32	4100	15.84	0.34	279
		2:05	0.23	27500	16.22	0.24	209
		4:05	0.15	12000	16.55	0.16	166
	06/20/11	23:23	0.06		12.23	0.13	169
	06/21/11	0:10	0.13	53800	9.28	0.19	725
		1:10	0.31	1986300	7.27	0.86	978
		2:10	0.24	1413600	8.21	0.51	926
		3:10	0.17	686700	9.13	0.42	722
		4:10	0.34	579400	7.28	0.61	834
		5:10	0.28	461100	7.87	0.4	967
		7:10	0.19	261300	8.81	0.43	586
42B	05/25/11	3:59	2.3	186000	11.31	0.31	1042
		4:32	2.5	172000	8.03	0.69	2689
		5:29	2.9	47100	11.49	0.61	2963
		6:29	2.3	166400	13.89	0.86	2300
		14:29	1.5	172500	15.73	0.81	470

		15:29	2.1	116200	16.08	0.79	484
		17:29	2.7	142100	15.85	1.03	691
		19:29	1.4	235900	16.53	0.54	474
		21:29	0.7		17.03	0.25	314
		23:29	0.5	7400	17.44	0.14	232
	05/26/11	1:29	0.2	71200	17.96	0.13	200
		4:29	0.2	3100	18.19	0.1	186
	06/20/11	23:47	0.1	104600	8.85	0.27	635
		23:17	0.1	95900	11.59	0.19	864
	06/21/11	1:11	0.19	387300	8.23	0.28	1619
		2:11	0.12	290900	8.03	0.35	1193
		3:11	0.17	461100	8.57	0.63	905
		5:11	0.14	686700	11.05	0.48	431
		0:17	1.325	1119900	9.59	0.72	1090

Appendix B: June 20 Event Data

Site Id	Sample Date	IP_Time	Ammonia as N	Nitrate as N	Nitrite as N	Phosphorus-O as P	Turbidity	E. coli
42A	**06/20/11**	23:23	0.06	12.23	0.06	0.13	169	
	06/21/11	0:10	0.13	9.28	0.06	0.19	725	53800
		1:10	0.31	7.27	0.08	0.86	978	1986300
		2:10	0.24	8.21	0.06	0.51	926	1413600
		3:10	0.17	9.13	0.09	0.42	722	686700
		4:10	0.34	7.28	0.1	0.61	834	579400
		5:10	0.28	7.87	0.07	0.4	967	461100
		7:10	0.19	8.81	0.07	0.43	586	261300
42B	**06/20/11**	23:17	0.1	11.59	0.05	0.19	864	95900
		23:47	0.1	8.85	0.05	0.27	635	104600
	06/21/11	0:17	1.325	9.59	0.08	0.72	1090	1119900
		1:11	0.19	8.23	0.05	0.28	1619	387300
		2:11	0.12	8.03	0.06	0.35	1193	290900
		3:11	0.17	8.57	0.08	0.63	905	461100
		5:11	0.14	11.05	0.11	0.48	431	686700