Upper Brushy Creek Water Quality Monitoring Report

July through December 2010

Prepared by Gordon Brand M.A.

Des Moines Water Works

For

Watershed Improvement Review Board

Jan 2011

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.

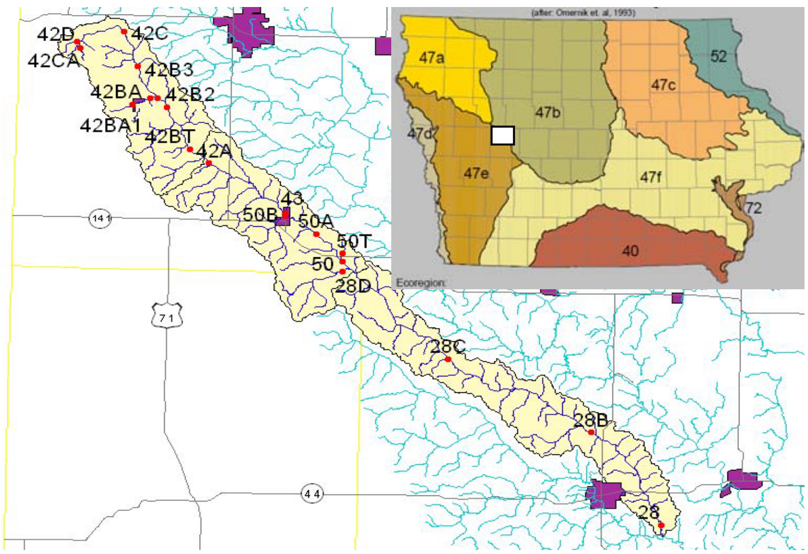

Fig 1. Brushy Creek Watershed

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 typically takes several years to develop an expected response to weather and rain events. 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 through re-suspension during elevated flows. Improvements in land management practices which reduce the transport of these contaminants to the stream will reduce the load within sediments and therefore potential to bias runoff indicators during rain events. Interpretation of stream monitoring must 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

The summer months of 2010 at Carroll, Iowa were especially wet. Total precipitation was nearly double the long term monthly average (Table 1). The remainder of the year had near normal amounts.

Table 1.	NOAA records for Carroll	
Month	**L.T. Average**	**2010**
Jan	0.87	1.84
Feb	0.86	1
Mar	2.28	1.75
Apr	3.43	2.67
May	4.43	2.97
Jun	4.55	10.88
Jul	4.84	7.34
Aug	3.49	5.05
Sep	3.3	3.67
Oct	2.48	0.18
Nov	1.75	1.67
Dec	0.97	0.61
Total	33.25	39.63

The above average rainfall in July and August applied to already saturated soils from the June rains contributed to runoff and elevated stream flow in July and August with local flooding (fig 2).

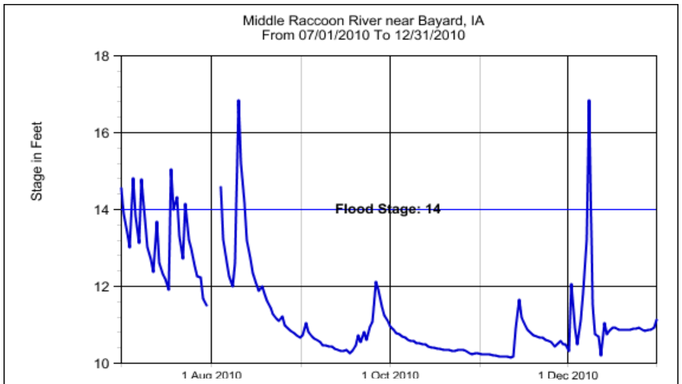

Fig 2. Flow in Middle Raccoon near Brushy Creek

The high total precipitation in July came from frequent rains while most of the August precipitation was concentrated in early August which caused considerable runoff and near record level stream flow in early August. The high frequency of rain increased the probability of sampling during rain events (fig 3). Four of the first nine sampling events occurred during a rain event.

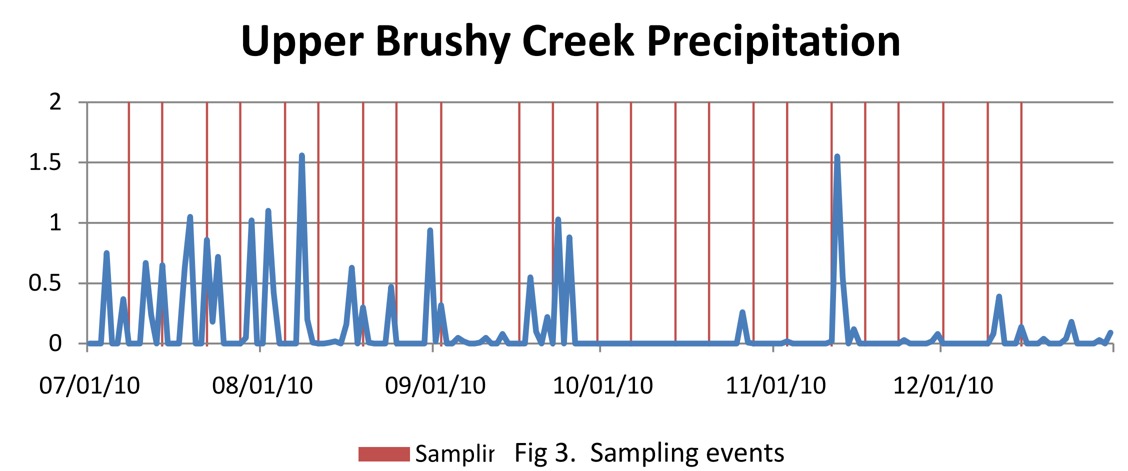

Fig 3. Sampling events

METHODS

Grab samples were collected from eight sites on a weekly basis to provide contaminant distribution data across the watershed over a variety of flow and weather conditions. No event triggered samples were collected during this period. All analyses were performed by the DMWW laboratory.

RESULTS

Table 1. Water quality data July-December 2010.

Sample Date	Site	Turbidity Ntu	*E. coli* counts/100ml	Nitrate as N mg/l	o-Phos as P mg/l	Ammonia as N mg/l
7/8/10	42A	15.9	5460	16.18	0.1	
	42B2	13.2	1320	17.46	<0.05	
	42B2.5	11.6	740	18.59	<0.1	
	42B3	9.18	>241920	18.22	<0.1	
	42BA	13.6	1970	15.04	<0.1	
	42BT	22.6	6370	16.67	0.08	
	42C	8.84	310	18.92	<0.1	
	43	132	13540	12.96	0.11	
7/14/10	42A	15.2	34480	15.77	<0.1	
	42B2	14.3	13130	16.58	<0.1	
	42B2.5	11.7	18600	17.69	<0.1	
	42B3	10	8160	17.39	<0.1	
	42BA	17.3	8160	14.46	<0.1	
	42BT	14.6	18500	15.98	<0.1	
	42C	9.91	2400	18.23	<0.1	
	43	36.5	36540	13.63	<0.1	
7/22/10	42A	100	>241920	12.33	0.19	
	42B2	145	173290	11.17	0.46	
	42B2.5	161	141360	11.26	0.62	
	42B3	184	198630	12.30	0.58	
	42BA	59.3	155310	10.42	0.46	
	42BT	163	>241920	10.72	0.65	
	42C	79.7	10140	12.04	0.2	
	43	218	>241920	11.10	0.13	
7/28/10	42A		860	14.46	<0.05	0.02
	42B2		630	15.09	<0.05	0.01
	42B2.5		100	16.17	<0.05	0.01
	42B3		100	15.79	<0.05	0.01
	42BA		2310	13.27	<0.05	0.02
	42BT		1090	14.54	<0.05	0.03
	42C		200	16.76	<0.05	0.01
	43		1300	12.62	<0.05	0.01
8/5/10	42A	23.9	2330	14.13	0.08	
	42B2	13.6	1750	14.99	<0.05	

Sample Date	Site	Turbidity Ntu	*E. coli* counts/100ml	Nitrate as N	o-Phos as P	Ammonia as N
8/5/10	42B2.5	13.5	630	16.05	<0.05	
	42B3	10	100	15.50	<0.05	
	42BA	18.5	1850	12.98	<0.05	
	42BT	22.1	1480	14.29	<0.05	
	42C	18.4	410	15.96	<0.05	
	43	50	3130	12.55	0.09	
8/11/10	42A	52.1	2590	12.49	<0.05	
	42B2	29.1	2330	14.08	<0.05	
	42B2.5	23.1	1730	14.11	<0.05	
	42B3	25.8	1480	14.12	<0.05	
	42BA	339	28510	13.72	<0.05	
	42BT	63.6	3090	12.41	<0.05	
	42C	193	16070	13.87	<0.05	
	43	62.6	3130	12.50	<0.05	
8/19/10	42A	19.2	4280	13.78	0.06	
	42B2	15.2	3140	14.58	<0.05	
	42B2.5	10.3	8090	15.73	<0.05	
	42B3	9.26	3540	15.04	<0.05	
	42BA	15.7	3050	12.48	0.08	
	42BT	17.7	13540	13.72	<0.05	
	42C	14.4	410	15.78	<0.05	
	43	31		12.12	0.06	
8/25/10	42A	17.8	4130	13.28	0.05	
	42B2	10.4	1340	14.29	<0.05	
	42B2.5	13.3	980	15.48	<0.05	
	42B3	12.1	860	15.22	<0.05	
	42BA	18.7	3010	12.35	<0.05	
	42BT	14.7	3230	13.65	<0.05	
	42C	3.73	>241920	15.76	<0.05	
	43	19.3	8390	11.86	<0.05	
9/2/10	42A	10.3	26130	12.96	0.10	
	42B2	70.6	38730	12.48	0.08	
	42B2.5	28.1	120330	14.54	0.11	
	42B3	14.4	6090	14.74	<0.05	
	42BA	96.7	91390	6.73	0.11	
	42BT	20.7	18600	13.11	0.08	
	42C	9.03	1210	15.40	<0.05	
	43	26.8	51720	10.80	0.10	
9/8/10	42A	15.7	2030	13.26	<0.05	
	42B2	16	2130	13.76	<0.05	
	42B2.5	10.9	1450	15.02	<0.05	
	42B3	16.5	630	14.84	<0.05	
	42BA	10.5	1850	11.62	<0.05	
	42BT	18	1340	13.20	<0.05	
	42C	12.7	630	15.41	<0.05	
	43	18	1580	11.41	<0.05	

Sample Date	Site	Turbidity Ntu	*E. coli* counts/100ml	Nitrate as N	o-Phos as P	Ammonia as N
9/16/10	42A	14.2	630	12.94	0.05	
	42B2	14.2	2460	13.30	<0.05	
	42B2.5	11.1	3270	14.67	<0.05	
	42B3	9.04	1190	14.53	0.05	
	42BA	14.9	2280	10.87	<0.05	
	42BT	10.1	1220	12.85	<0.05	
	42C	10.4	520	15.18	<0.05	
	43	17.2	1750	11.01	<0.05	0.04
9/22/10	42A	3.56	740	11.72	<0.05	
	42B2	7.1	310	11.39	0.23	
	42B2.5	6.29	740	11.38	<0.05	
	42B3	11	1730	10.73	<0.05	
	42BA	4.44	970	9.40	<0.05	
	42BT	6.31	740	11.35	<0.05	
	42C	3.76	1450	9.69	<0.05	
	43	12.5	1710	10.72	<0.05	0.03
9/30/10	42A	22.8	1090	13.07	0.06	
	42B2	18.8	1460	13.58	0.07	
	42B2.5	17.1	860	14.93	0.05	
	42B3	17.4	1480	13.42	<0.05	
	42BA	13.7	860	11.09	<0.05	
	42BT	21.4	1460	13.06	0.06	
	42C	18.1	1430	14.93	0.06	
	43	23	1580	11.24	0.07	0.02
10/6/10	42A	19.4	850	13.10	0.05	
	42B2	16	630	13.40	<0.05	
	42B2.5	15.2	310	14.82	0.05	
	42B3	9.5	100	14.84	<0.05	
	42BA	7.6	860	10.93	<0.05	
	42BT	15.8	1480	13.04	<0.05	
	42C	12	730	15.56	<0.05	
	43	12	630	11.31	<0.05	0.01
10/14/10	42A	14.8	100	12.92	<0.05	
	42B2	13.5	620	13.43	<0.05	
	42B2.5	16.3	740	14.93	<0.05	
	42B3	12.8	200	14.89	<0.05	
	42BA	10.8	980	11.00	<0.05	
	42BT	17.8	630	12.93	0.05	
	42C	12.6	100	15.56	<0.05	
	43	9.5	410	10.98	<0.05	0.01
10/20/10	42A	15	200	12.39	<0.05	
	42B2	19.5	9070	12.93	<0.05	
	42B2.5	17.4	2180	14.82	<0.05	
	42B3	15	410	14.91	<0.05	
	42BA	20.5	4810	10.41	0.1	
	42BT	19.1	520	12.49	<0.05	

Sample Date	Site	Turbidity Ntu	*E. coli* counts/100ml	Nitrate as N	o-Phos as P	Ammonia as N
	42C	11.8	310	15.82	<0.05	
	43	12.1	100	11.14	<0.05	
10/28/10	42A	13.8	980	10.76	0.11	
	42B2	10.7	200	14.78	<0.05	
	42B2.5	11.5	310	13.28	0.07	
	42B3	11.1	740	12.77	0.11	
	42BA	17.2	740	10.63	0.16	
	42BT	15.9	520	12.74	0.12	
	42C	14.5	310	12.95	0.05	
	43	9.55	100	11.22	<0.05	
11/3/10	42A	20	310	12.96	<0.05	
	42B2	18.8	520	13.35	<0.05	
	42B2.5	17.3	100	14.70	<0.05	
	42B3	8.4	100	14.76	<0.05	
	42BA	16	310	11.50	<0.05	
	42BT	20	<100	12.87	<0.05	
	42C	20.8	<100	15.28	<0.05	
	43	16	200	11.06	<0.05	
11/11/10	42A			12.93	<0.05	
	42B2			13.62	<0.05	
	42B2.5			13.68	<0.05	
	42B3			14.95	<0.05	
	42BA			11.78	<0.05	
	42BT			13.03	<0.05	
	42C			15.05	<0.05	
	43			11.12	<0.05	
11/17/10	42A			13.10	0.09	
	42B2			14.78	0.09	
	42B2.5			14.78	0.08	
	42B3			14.42	0.09	
	42BA			11.75	<0.05	
	42BT			12.84	<0.05	
	42C			14.97	<0.05	
	43			11.34	<0.05	
11/23/10	42A	10.4	100	13.51	<0.05	
	42B2	11.2	<100	15.18	<0.05	
	42B2.5	11.2	<100	15.26	<0.05	
	42B3	5.3	<100	15.17	<0.05	
	42BA	19.2	310	12.16	<0.05	
	42BT	11	100	13.52	<0.05	
	42C	8	<100	15.70	<0.05	
	43	22.5	100	11.64	<0.05	
12/1/10	42A	7.93	98	14.86	<0.05	
	42B2	23.2	199	15.06	<0.05	
	42B2.5	22.6	171	15.06	<0.05	
	42B3	17.9	52	15.67	<0.05	

Sample Date	Site	Turbidity Ntu	*E. coli* counts/100ml	Nitrate as N	o-Phos as P	Ammonia as N
12/1/10	42BA	36	379	12.78	<0.05	
	42BT	17.3	175	14.68	<0.05	
	42C	12.2	10	16.11	<0.05	
	43	10.6	41	12.78	<0.05	
12/9/10	42A	6.75	189	14.11	<0.05	
	42B2	12.1	384	14.16	<0.05	
	42B2.5	11.1	441	14.12	<0.05	
	42B3	10.8	74	15.23	<0.05	
	42BA	15.5	733	12.23	<0.05	
	42BT	12.6	213	13.64	<0.05	
	42C	13.5	97	15.27	<0.05	
	43	13.6	74	12.28	<0.05	
12/15/10	42A	8.29	185	13.50	0.09	
	42B2	12.3	249	13.38	0.06	
	42B2.5	18.4	462	12.72	<0.05	
	42B3	15.7	278	13.42	<0.05	
	42BA	23.8	520	13.50	0.08	
	42BT	13.5	243	11.51	<0.05	
	42C	10.6	145	14.02	0.07	
	43	53.6	246	12.27	0.09	

***E. coli* count data sorted in descending order shows highest counts occurring during rainfall events with lesser amounts during elevated flow. The small rain event on (9/2/2010) which contributed little to flow caused a much greater increase in counts than did the highest flow on August 11 (as observed at the Bayard gauging station on the Middle Raccoon). The two high counts at sites 42B3 and 42BT were "end of pipe" samples and must not be used as indicators of the stream at those locations. Counts at all other sites were well below the method threshold of 241920 except for July 22 when nearly an inch of rain contributed to already extensive runoff and flow from the July 19 storm (fig 3). The widespread occurrence of elevated counts and phosphorus concentrations was not unexpected.**

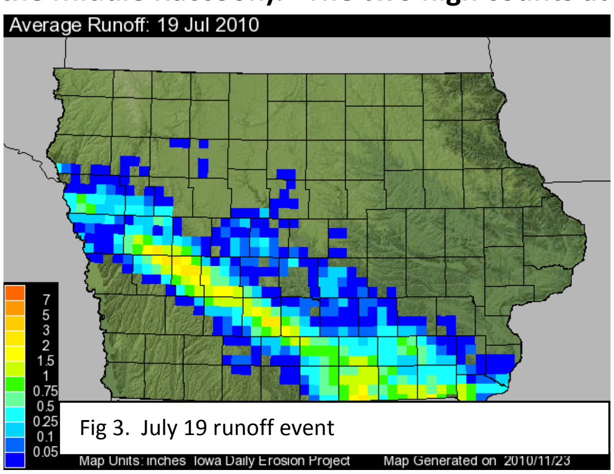

Fig 3. July 19 runoff event

The high density of open feedlots includes surface application of manure. Therefore high counts can come from many sources and should not be considered unequivocal evidence of faulty manure containment design. Erosion control and containment structures were simply overwhelmed and in some cases flooded. Data at Site 42A (Table 2) is presented to illustrate this relationship.

Table 2. *E.coli* Counts at Site 42A

Sample Date	Inches precip	counts/100ml	Turbidity	CFS Flow *	Flow trending
7/22/10	0.86	>241920	100	684	Down
7/14/10	0.65	34480	15.2	647	Down
9/2/10	0.32	26130	10.3	294	Up
7/8/10		5460	15.9	1340	Up
8/19/10	0.3	4280	19.2	448	Down
8/25/10		4130	17.8	332	Up
8/11/10		2590	52.1	1500	Down
8/5/10		2330	23.9	823	Down
9/8/10		2030	15.7	192	Steady
9/30/10		1090	22.8	305	Down
10/28/10		980	13.8	150	Steady
7/28/10		860		550	Down
10/6/10		850	19.4	232	Steady
9/22/10		740	3.56	254	Steady
9/16/10		630	14.2	167	Steady
11/3/10		310	20	135	Steady
10/20/10		200	15	167	Steady
12/9/10		189	6.75	388	Down
12/15/10	0.14	185	8.29	254	Steady
10/14/10		100	14.8	184	Steady
11/23/10		100	10.4	212	Steady
12/1/10		98	7.93	158	Steady

*Middle Raccoon at Bayard

High counts are obviously related to rainfall and runoff. Therefore higher counts during an especially wet year would be expected and should not be considered evidence of design failure. The more accurate question is whether water quality is better due to WIRB activity than it would otherwise have been without these activities and whether they are adequate. This is a difficult task at best, especially without flow data to establish a relationship to flow. Nonetheless, the relationship of counts to turbidity and change over time is consistent with better manure management and containment. The distribution of counts during pre-WIRB sampling is similar to 2010 even with the higher rainfall in 2010.

The turbidity distribution shows a slight increase over time as expected with greater rainfall. Assuming a positive relationship between flow, turbidity, and fecal runoff a reduction in counts per NTU turbidity unit (fig 4) suggests a decrease in fecal transport (better containment) during runoff events.

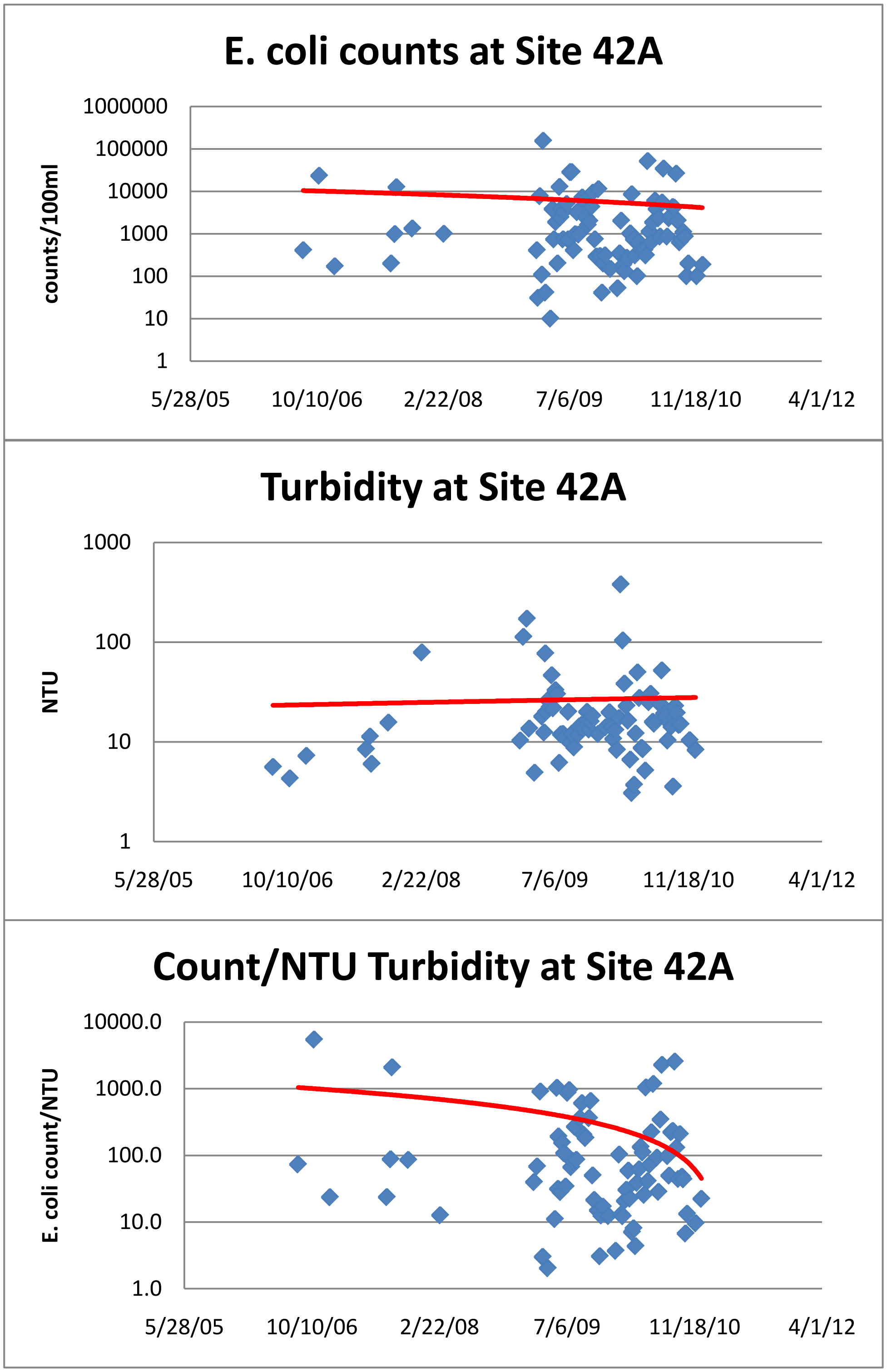

Fig 4. Time distribution of *E.coli* counts and turbidity in Brushy Creek.

A more detailed examination of the relationship of between counts, turbidity, and flow in conjunction with SWAT modeling is planned to help ascertain whether WIRB activities are effective in reducing fecal counts in Brushy Creek.

Nitrate concentrations remained well above the water quality standard of 10 mg/l for most sites through this entire period. With few exceptions, concentrations were highest near the headwaters (42C) and slowly decreased downstream. Halbur Creek (42BA), a tributary near the headwaters had lower nitrate concentrations than Brushy Creek sites upstream of their confluence. Downstream of its confluence (between sites 42B2.5 and 42B2) nitrate concentrations decreased approximately 1 mg/l (Table 3). This pattern is nearly identical to that observed during the first six months of 2010.

The progressive decline in nitrate concentrations indicates dilution by lower nitrate groundwater downstream. There was very little seasonal change in nitrate concentration in upper Brushy Creek during this period. Typically streams fall well below the water quality standard of 10 mg/l in late summer through early fall (mid July through mid October).

Table 3. Nitrate Concentrations in Upper Brushy Creek

Date	42C	42B3	42B2.5	42BA	42B2	42BT	42A	43
07/08/10	18.9	18.2	18.6	15.0	17.5	16.7	16.2	13.0
07/14/10	18.2	17.4	17.7	14.5	16.6	16.0	15.8	13.6
07/22/10	12.0	12.3	11.3	10.4	11.2	10.7	12.3	11.1
07/28/10	16.8	15.8	16.2	13.3	15.1	14.5	14.5	12.6
08/05/10	16.0	15.5	16.1	13.0	15.0	14.3	14.1	12.6
08/11/10	13.9	14.1	14.1	13.7	14.1	12.4	12.5	12.5
08/19/10	15.8	15.0	15.7	12.5	14.6	13.7	13.8	12.1
08/25/10	15.8	15.2	15.5	12.4	14.3	13.7	13.3	11.9
09/02/10	15.4	14.7	14.5	6.7	12.5	13.1	13.0	10.8
09/08/10	15.4	14.8	15.0	11.6	13.8	13.2	13.3	11.4
09/16/10	15.2	14.5	14.7	10.9	13.3	12.9	12.9	11.0
09/22/10	9.7	10.7	11.4	9.4	11.4	11.4	11.7	10.7
09/30/10	14.9	13.4	14.9	11.1	13.6	13.1	13.1	11.2
10/06/10	15.6	14.8	14.8	10.9	13.4	13.0	13.1	11.3
10/14/10	15.6	14.9	14.9	11.0	13.4	12.9	12.9	11.0
10/20/10	15.8	14.9	14.8	10.4	12.9	12.5	12.4	11.1
10/28/10	13.0	12.8	13.3	10.6	14.8	12.7	10.8	11.2
11/03/10	15.3	14.8	14.7	11.5	13.4	12.9	13.0	11.1
11/11/10	15.1	15.0	13.7	11.8	13.6	13.0	12.9	11.1
11/17/10	15.0	14.4	14.8	11.8	14.8	12.8	13.1	11.3
11/23/10	15.7	15.2	15.3	12.2	15.2	13.5	13.5	11.6
12/01/10	16.1	15.7	15.1	12.8	15.1	14.7	14.9	12.8
12/09/10	15.3	15.2	14.1	12.2	14.2	13.6	14.1	12.3
12/15/10	14.0	13.4	12.7	13.5	13.4	11.5	13.5	12.3
1st quartile	15.0	14.3	14.1	10.9	13.4	12.8	12.9	11.1

median	15.4	14.9	14.8	11.8	13.9	13.1	13.1	11.4
3rd quartile	15.8	15.2	15.3	12.8	14.8	13.7	13.9	12.3

Nitrate concentrations in the WIRB area (including the upper Middle Raccoon at Carroll) were much higher than most sites in the Raccoon River Watershed, including the Brushy Creek outlet to the South Raccoon (site 28). This suggests common environmental factors of the local Loess Hills and Rolling Prairie Ecoregion (Table 4).

Table 4. Nitrate-N Distribution

Date	N R	M R	SR	SR at Brushy (28A)	Brushy Creek (28)	Brush Creek (43)	MR at Carroll
07/08/10	8.3	8.6	3.0	4.8	6.9	12.6	13.3
07/22/10	8.6	6.0	4.7			12.5	5.0
08/05/10	6.2	7.0	3.4	3.4	8.7	12.1	11.1
08/19/10	4.8	6.4	4.9	3.8	8.6	11.9	10.8

Ammonia was seldom detected this monitoring period, even during elevated flows. This indicator alone suggests improvement in manure management. However, the event samplers were not used during this period.

DISCUSSION AND SUMMARY

Heavy and frequent rains in July and August caused extensive and widespread runoff throughout the Brushy Creek watershed which contributed to high *E. coli* counts during the summer months. The near absence of ammonia and phosphorus suggests widespread discharge from the landscape rather than from stockpiled manure as observed during previous monitoring. Furthermore, the lower count to turbidity ratios during this period relative to pre-WIRB sampling suggests reduction in fecal runoff during similar runoff events. Further improvements are needed to meet the WIRB water quality goals. Pathways which bypass control and containment structures must be identified and eliminated.

Nitrate-N concentrations were well over the water quality standard of 10 mg/l during the entire monitoring period. This includes the peak growing season from mid July to late summer when crop uptake of nutrients is most rapid. That there was no observable reduction in nitrate during this time shows a great excess in nitrate availability over crop demand. That nitrate values remained high even after a large quantity of nitrate was lost from the soils shows that the soils still have high residual nitrate concentrations. This strongly suggests opportunities to reduce nitrogen application to the soils next year without reducing yields. These high nitrate concentrations have been observed every year since initial monitoring began in 1999 and indicates a systemic chronic condition. Perhaps tools used to determine optimum amounts of nitrogen to apply to soils for next year's crop needs to be re-examined.

A reduction in nitrogen application to what is needed by the crop will reduce both application costs and nitrogen export to Brushy Creek.

T