Appendices

MUDDY CREEK RESTORATION PARTNERSHIP

Final Project Report
Section 319 Grant Project Number EW06043

September 2008

Appendix A

Members of the MCRP Technical Committee

Members of the Muddy Creek Restoration Partnership Technical Committee

Jim Borawa, Supervisor, Watershed Enhancement Group – N.C. Wildlife Resources Commission
Andy Brown, President and Environmental Planner – Equinox Environmental, Inc.
Tom Kenney, Lands Protection – Foothills Conservancy of North Carolina
Dan McClure, Coordinator - Carolina Lakes Resource Conservation and Development Council
Steve Melton, Field Biologist – Equinox Environmental, Inc.
Albert Moore, District Conservationist – USDA Natural Resources Conservation Service
Dan Smith – N.C. Cooperative Extension Service, McDowell County
Michael "Squeak" Smith, Board of Trustees – Trout Unlimited
Gene Vaughan, Senior Scientist - Duke Energy Corporation

Appendix B

Compilation of Project Stream Data

Notes for Tables B.1 and B.2

- Site ID refers to the ID numbers given in Table 1.1 and Figure 1.2 of main text
- BEHI = Bank Erosion Hazard Index
- D_{50} = median riffle particle size from pebble count
- % silt-sand = % silt + % sand from pebble count
- VASOS = Virginia Save Our Streams benthic macroinvertebrate protocol
- Temp = water temperature
- DO = dissolved oxygen
- Sp Cond = specific conductance (conductivity in µmhos/cm adjusted to 25ºC)
- Some observations are missing due to lack of appropriate riffles (e.g. VASOS) or water quality field meter malfunction.

Table B.1. Summary of Annual Monitoring Data Collected by Equinox Environmental in the Muddy Creek Watershed

Site ID	Stream	Date	Habitat Score	% Embeddedness	BEHI Average	D_{50} Riffle (mm)	% Silt-Sand	VASOS Score	Temp (°C)	DO (mg/L)	Sp Cond (µmhos/cm)
1	Catawba River	9/30/2005	76	60	22.9	3	42		19.4	8.4	59
1	Catawba River	7/28/2006	82	60	18.5	28	25		20.9		62
1	Catawba River	10/10/2007	94	25	17.8	59	15		18.8	9.2	54
2	Catawba River	9/30/2005	77	50	22.3	11	39		19.8	8.3	58
2	Catawba River	7/28/2006	82	55	19.1	57	24		21.2		61
2	Catawba River	10/10/2007	92	30	13.9	67	14		18.0	8.6	51
3	Catawba River	9/30/2005	87	60	19.2	10	40		21.1	7.6	47
3	Catawba River	7/28/2006	82	55	18.7	64	23	10	17.6		51
3	Catawba River	10/10/2007	95	25	18.3	88	17		20.0	8.8	54
4	Old Catawba River	8/25/2005	84	40	21.7	35	34	5	21.2	5.7	66
4	Old Catawba River	10/25/2006	80	30	15.3	26	25	5	9.5	9.5	68
4	Old Catawba River	9/17/2007	82	5	17.9	58	15	5	17.6	7.1	72
5	Muddy Creek	10/25/2005	33	70	26.1	0.99	72		11.1	9.6	65
5	Muddy Creek	10/25/2006	28	45	28.6	0.39	73		7.5	13.2	68
5	Muddy Creek	9/17/2007	33		27.1		0		16.3	12.2	52
6	South Muddy Creek	10/20/2005	52	50	25.2	2	50	8	15.3	9.1	49
6	South Muddy Creek	10/4/2006	40	70	22.1	2	54	6	15.8	8.0	52
6	South Muddy Creek	8/22/2007	47	60	20.2	9	33	5	24.2	8.1	50
7	Patten Branch	10/4/2005	17		23.0	0.14	100		15.9	8.7	42
7	Patten Branch	11/10/2006	46		22.5	0.079	100	7	14.8	8.5	46
7	Patten Branch	11/7/2007	41		8.8	0.094	100		10.4	11.5	16
8	South Muddy Creek	10/28/2005	59	45	26.5	42	27	7	11.5	10.2	46
8	South Muddy Creek	1/26/2007	58	40	24.7	47	17	10	5.4	11.7	43
8	South Muddy Creek	11/14/2007	57	55	23.4	37	33	7	11.6	10.7	34
9	Hoppers Creek	6/23/2005	32	10	26.7	0.14	79	9	21.8	7.5	13
9	Hoppers Creek	7/17/2006	23	80	25.4	0.096	87	4	58.3		25
9	Hoppers Creek	7/20/2007	35	40	19.8	8	41	8	23.8	8.1	52
10	S Fork Hoppers Ck.	6/23/2005	37	60	33.7	8	44	11	17.3	8.5	41
10	S Fork Hoppers Ck	8/9/2006	64	65	17.0	22	44	4	25.4		43
10	S Fork Hoppers Ck	7/4/2007	70	40	14.2	2	51	8	20.6	9.0	41
11	S Fork Hoppers Ck	6/21/2005	55	50	17.8	2	51	11	15.5	8.4	37
11	S Fork Hoppers Ck	7/17/2006	45	65	20.3	10	37	10	20.1		38
11	S Fork Hoppers Ck	7/20/2007	45	70	19.2	1	53	10	20.4	8.0	38
12	South Muddy Creek	10/20/2005	42	75	23.0	2	59	10	17.6	8.6	44
12	South Muddy Creek	8/2/2006	42	65	20.0	6	34	7	22.6		49
12	South Muddy Creek	10/3/2007	42		21.8		0	6	18.4	8.9	46

(Table continued on next page)

Table B.1. Continued.

Site ID	Stream	Date	Habitat Score	% Embeddedness	BEHI Average	D_{50} Riffle (mm)	% Silt-Sand	VASOS Score	Temp (°C)	DO (mg/L)	Sp Cond (µmhos/cm)
13	South Muddy Creek	10/5/2005	93	35	18.6	2	53	5	18.2	9.1	43
13	South Muddy Creek	9/15/2006	86	40	21.8	0.46	59	8	18.0	8.4	46
13	South Muddy Creek	7/20/2007	84	40	21.8	46	23	8	22.5	9.4	44
14	High Shoals Creek	10/5/2005	78	40	26.7	12	29	9	18.0	8.8	36
14	High Shoals Creek	10/25/2006	81	8	24.2	9	36	11	10.6	8.9	37
14	High Shoals Creek	8/31/2007	83	40	19.0	15	17	8	21.1	8.0	39
15	Ut to South Muddy	10/25/2005	75	40	23.4	21	29	10	11.5	9.6	44
15	Ut to South Muddy	9/12/2006	77	55	21.0	17	32	12	19.9		48
15	Ut to South Muddy	8/7/2007	80	40	23.8	1	54	11	24.3	7.2	49
16	North Muddy Creek	10/4/2005	52	30	28.2	7	43	5	18.5	7.8	76
16	North Muddy Creek	10/4/2006	56	70	27.7	14	23	6	16.9	8.1	81
16	North Muddy Creek	8/7/2007	54	60	30.1	14	32	6	23.0	8.0	81
17	Ut to North Muddy	10/4/2005	30	65	32.7	1	66		18.6	7.1	57
17	Ut to North Muddy	8/10/2006	33	80	28.3	0.71	63		23.6		58
17	Ut to North Muddy	8/7/2007	34	100	31.5	0.33	73		22.2	7.3	54
18	Thompsons Fork	10/12/2005	39	25	29.9	7	47	7	20.2	8.7	62
18	Thompsons Fork	8/10/2006	54	35	31.2	6	45	9	25.4		72
18	Thompsons Fork	9/17/2007	53	35	35.2	6	44	7	20.4		73
19	North Muddy Creek	11/8/2005	84	25	23.7	16	43	5	12.8	10.8	69
19	North Muddy Creek	9/27/2006	79	45	21.5	20	35	5	17.0	8.3	84
19	North Muddy Creek	8/22/2007	83	40	21.9	32	25	5	23.5	7.7	100
20	Big Camp Branch	8/4/2005	45	25	28.7	8	41	10	21.5	7.7	54
20	Big Camp Branch	9/27/2006	39	40	39.0	8	28	12	16.3	8.4	57
20	Big Camp Branch	10/3/2007	42	40	26.8	9	28	8	17.7	9.7	55
21	Bledsoe Branch	7/27/2005	42	50	38.5	2	57	8	19.6	4.3	62
21	Bledsoe Branch	9/12/2006	35	65	34.9	10	33	11	17.5		66
21	Bledsoe Branch	12/18/2007	68	25	27.9	20	29	9	7.6	11.2	65
22	Youngs Fork	8/25/2005	65	65	30.8	11	38	4	20.5	8.2	109
22	Youngs Fork	8/9/2006	58	75	23.7	17	20	5	23.5		106
22	Youngs Fork	8/22/2007	80	50	26.8	19	19	5	23.5	9.1	112
23	Jacktown Creek	10/12/2005	60	55	31.4	14	39	6	17.6	9.2	90
23	Jacktown Creek	11/10/2006	46	70	29.5	10	35	7	15.8	7.9	91
23	Jacktown Creek	11/7/2007	59	50	30.2	3	49	8	10.1	11.4	33
24	North Muddy Creek	6/23/2005	71	35	22.4	20	23	5	21.5	7.8	52
24	North Muddy Creek	8/3/2006	69	35	21.3	25	11	7			
24	North Muddy Creek	8/31/2007	64	30	25.8	25	5	7	21.8	9.3	62

(Table continued on next page)

Table B.1. Continued.

Site ID	Stream	Date	Habitat Score	% Embeddedness	BEHI Average	D_{50} Riffle (mm)	% Silt-Sand	VASOS Score	Temp (°C)	DO (mg/L)	Sp Cond (µmhos/cm)
25	Bob's Creek	6/21/2005	48	55	13.5	2	50	9	18.4	8.4	41
25	Bob's Creek	9/15/2006	52	65	12.7	8	42	10	17.8	8.7	48
25	Bob's Creek	8/6/2007	62	50	13.2	9	36	8	21.6	8.1	46
27	Goose Creek	8/4/2005	31	55	16.2	9	43	7	22.9	9.3	49
27	Goose Creek	8/10/2006	53	40	15.5	21	22	8	25.6		50
27	Goose Creek	9/11/2007	60	40	16.9	23	26	8	22.7	8.6	51
28	Ut to Goose Creek	7/27/2005	76	45	20.8	11	46	6	24.8	6.7	67
28	Ut to Goose Creek	8/3/2006	71	50	22.0	13	39	11	23.5		73
28	Ut to Goose Creek	9/11/2007	73	15	21.8	24	30	9	22.7	7.4	74
29	North Muddy Creek	10/28/2005	55	70	28.7	8	39	5	10.8	10.1	65
29	North Muddy Creek	9/28/2006	61	75	29.8	10	31	4	17.3	7.5	68
29	North Muddy Creek	9/5/2007	64	65	24.7	8	34	4	21.6	8.7	72

Table B.2. Summary of Quarterly Monitoring Data Collected by Equinox Environmental in the Muddy Creek Watershed

Site ID	Stream	Season	Date	Habitat Score	% Embeddedness	BEHI Average	D_{50} Riffle (mm)	% Silt-Sand	VASOS Score	Temp (°C)	DO (mg/L)	Sp Cond (µmhos/cm)
6	South Muddy Creek	Fall	10/20/2005	52	50	25.2	2	50	8	15.3	9.1	49
6	South Muddy Creek	Winter	3/8/2006	48	80	21.1	0.45	69	10	8.8	7.9	46
6	South Muddy Creek	Spring	6/13/2006	51	50	22.0	1	65	8	19.5		51
6	South Muddy Creek	Fall	10/4/2006	40	70	22.1	2	54	6	15.8	8.0	52
6	South Muddy Creek	Fall	12/19/2006	36	80	20.4	7	45	8	8.6	11.3	45
6	South Muddy Creek	Winter	3/8/2007	42	40	21.1	6	45		9.4	10.2	43
6	South Muddy Creek	Spring	6/19/2007	41		19.4	0.88	56		20.0	8.6	47
6	South Muddy Creek	Summer	8/22/2007	47	60	20.2	9	33	5	24.2	8.1	50
6	South Muddy Creek	Fall	12/13/2007	40		21.5	0.4	70		11.2	9.9	47
13	South Muddy Creek	Fall	10/5/2005	93	35	18.6	2	53	5	18.2	9.1	43
13	South Muddy Creek	Winter	3/16/2006	87	40	19.5	20	39	8	12.0	6.5	41
13	South Muddy Creek	Spring	6/14/2006	80	30	18.5	12	43	7	22.2		44
13	South Muddy Creek	Summer	9/15/2006	86	40	21.8	0.46	59	8	18.0	8.4	46
13	South Muddy Creek	Fall	12/7/2006	82	50	21.8	0.65	59	7	7.2	10.3	40
13	South Muddy Creek	Winter	3/7/2007	78	70	21.7	0.33	70	9	11.0	9.3	35
13	South Muddy Creek	Spring	5/30/2007	77	10	21.5	39	27	10	21.5	9.4	41
13	South Muddy Creek	Summer	7/20/2007	84	40	21.8	46	23	8	22.5	9.4	44
13	South Muddy Creek	Fall	11/13/2007	82	30	20.6	75	16	8	11.3	10.7	31
15	Ut to South Muddy	Fall	10/25/2005	75	40	23.4	21	29	10	11.5	9.6	44
15	Ut to South Muddy	Winter	3/16/2006	71	50	20.5	19	33	12	12.5	9.8	41
15	Ut to South Muddy	Spring	6/14/2006	84	30	16.1	17	30	12	18.0		46
15	Ut to South Muddy	Summer	9/12/2006	77	55	21.0	17	32	12	19.9		48
15	Ut to South Muddy	Fall	12/18/2006	76	45	24.4	11	37	9	7.2	11.6	38
15	Ut to South Muddy	Winter	2/22/2007	81	10	19.5	23	30	10	12.0	9.1	39
15	Ut to South Muddy	Spring	5/10/2007	81	35	22.3	26	23	12	19.4	7.9	43
15	Ut to South Muddy	Summer	8/7/2007	80	40	23.8	1	54	11	24.3	7.2	49
15	Ut to South Muddy	Fall	12/13/2007	84	35	25.2	30	20	9	12.8	8.5	43
16	North Muddy Creek	Fall	10/4/2005	52	30	28.2	7	43	5	18.5	7.8	76
16	North Muddy Creek	Winter	3/8/2006	59	50	28.2	7	43	6	8.6	11.7	68
16	North Muddy Creek	Spring	6/13/2006	43	50	28.1	9	33	5	20.7		79
16	North Muddy Creek	Fall	10/4/2006	56	70	27.7	14	23	6	16.9	8.1	81
16	North Muddy Creek	Fall	12/19/2006	46	65	31.1	8	41	6	9.7	11.4	63
16	North Muddy Creek	Winter	3/8/2007	42	35	31.8	10	32	9	9.0	10.8	61
16	North Muddy Creek	Spring	5/30/2007	46	60	30.0	13	31	9	19.1	9.1	72
16	North Muddy Creek	Summer	8/7/2007	54	60	30.1	14	32	6	23.0	8.0	81
16	North Muddy Creek	Fall	12/13/2007	49	40	30.8	15	20	5	10.8	11.2	77

(Table continued on next page)

Table B.2. Continued.

Site ID	Stream	Season	Date	Habitat Score	% Embeddedness	BEHI Average	D_{50} Riffle (mm)	% Silt-Sand	VASOS Score	Temp (°C)	DO (mg/L)	Sp Cond (µmhos/cm)
19	North Muddy Creek	Fall	11/8/2005	84	25	23.7	16	43	5	12.8	10.8	69
19	North Muddy Creek	Winter	3/16/2006	83	55	20.5	2	52	6	10.2	7.3	71
19	North Muddy Creek	Spring	6/13/2006	79	20	19.7	11	40	7	21.7		80
19	North Muddy Creek	Fall	9/27/2006	79	45	21.5	20	35	5	17.0	8.3	84
19	North Muddy Creek	Fall	12/18/2006	71	50	23.4	12	32	7	8.9	10.1	63
19	North Muddy Creek	Winter	3/7/2007	82	13	25.1	14	39	8	8.8	10.3	61
19	North Muddy Creek	Spring	6/19/2007	76	50	23.9	26	28	7	21.3	9.0	81
19	North Muddy Creek	Summer	8/22/2007	83	40	21.9	32	25	5	23.5	7.7	100
19	North Muddy Creek	Fall	12/18/2007	74	30	25.3	37	32	6	2.5		80
25	Bob's Creek	Summer	6/21/2005	48	55	13.5	2	50	9	18.4	8.4	41
25	Bob's Creek	Winter	3/8/2006	54	35	11.9	5	42	12	11.4	4.9	39
25	Bob's Creek	Spring	6/13/2006	58	45	12.4	12	25	11	18.7		45
25	Bob's Creek	Summer	9/15/2006	52	65	12.7	8	42	10	17.8	8.7	48
25	Bob's Creek	Fall	12/7/2006	55	70	12.2	10	35	6	7.5	10.0	41
25	Bob's Creek	Winter	2/22/2007	61	35	16.3	7	37	12	8.5	10.0	35
25	Bob's Creek	Spring	5/10/2007	55	45	15.0	14	29	7	16.6	8.0	37
25	Bob's Creek	Summer	8/6/2007	62	50	13.2	9	36	8	21.6	8.1	46
25	Bob's Creek	Fall	11/14/2007	59	40	16.2	12	19	6	11.5	10.5	33

Note: Cells shaded in grey indicate annual sampling dates for each site. Other dates represent supplemental quarterly sampling events.

Table B.3. Fecal Coliform Monitoring Results in the Muddy Creek Watershed, 2005-2007

B.3.1. 2005

Site ID	Stream Name	Date	Fecal Coliform (col/100/ml)
6	South Muddy Creek	9/6/2005	170
6	South Muddy Creek	9/14/2005	300
6	South Muddy Creek	9/19/2005	240
6	South Muddy Creek	9/21/2005	280
6	South Muddy Creek	9/28/2005	170
9	Hoppers Creek	9/6/2005	300
9	Hoppers Creek	9/14/2005	280
9	Hoppers Creek	9/19/2005	170
9	Hoppers Creek	9/21/2005	130
9	Hoppers Creek	9/28/2005	220
12	South Muddy Creek	9/6/2005	220
12	South Muddy Creek	9/14/2005	1600
12	South Muddy Creek	9/19/2005	130
12	South Muddy Creek	9/21/2005	280
12	South Muddy Creek	9/28/2005	170
16	North Muddy Creek	9/6/2005	170
16	North Muddy Creek	9/14/2005	240
16	North Muddy Creek	9/19/2005	240
16	North Muddy Creek	9/21/2005	240
16	North Muddy Creek	9/28/2005	300
22	Youngs Fork	9/6/2005	170
22	Youngs Fork	9/14/2005	500
22	Youngs Fork	9/19/2005	50
22	Youngs Fork	9/21/2005	130
22	Youngs Fork	9/28/2005	130
25	Bobs Creek	9/6/2005	130
25	Bobs Creek	9/14/2005	300
25	Bobs Creek	9/19/2005	300
25	Bobs Creek	9/21/2005	130
25	Bobs Creek	9/28/2005	70
26	Goose Creek	9/6/2005	300
26	Goose Creek	9/14/2005	240
26	Goose Creek	9/19/2005	130
26	Goose Creek	9/21/2005	80
26	Goose Creek	9/28/2005	220
29	North Muddy Creek	9/6/2005	110
29	North Muddy Creek	9/14/2005	300
29	North Muddy Creek	9/19/2005	220
29	North Muddy Creek	9/21/2005	240
29	North Muddy Creek	9/28/2005	500

B.3.2. 2006

Site ID	Stream Name	Date	Fecal Coliform (col/100/ml)
6	South Muddy Creek	8/2/2006	300
6	South Muddy Creek	8/8/2006	≥1600
6	South Muddy Creek	8/14/2006	900
6	South Muddy Creek	8/21/2006	300
6	South Muddy Creek	8/28/2006	280
9	Hoppers Creek	8/2/2006	220
9	Hoppers Creek	8/8/2006	1600
9	Hoppers Creek	8/14/2006	500
9	Hoppers Creek	8/14/2006	900
9	Hoppers Creek	8/21/2006	300
9	Hoppers Creek	8/21/2006	300
9	Hoppers Creek	8/28/2006	240
12	South Muddy Creek	8/2/2006	170
12	South Muddy Creek	8/8/2006	900
12	South Muddy Creek	8/14/2006	1600
12	South Muddy Creek	8/21/2006	300
12	South Muddy Creek	8/28/2006	240
12	South Muddy Creek	8/28/2006	240
16	North Muddy Creek	8/2/2006	300
16	North Muddy Creek	8/8/2006	240
16	North Muddy Creek	8/8/2006	170
16	North Muddy Creek	8/14/2006	900
16	North Muddy Creek	8/21/2006	500
16	North Muddy Creek	8/28/2006	170
22	Youngs Fork	8/2/2006	500
22	Youngs Fork	8/8/2006	900
22	Youngs Fork	8/14/2006	500
22	Youngs Fork	8/21/2006	900
22	Youngs Fork	8/28/2006	240
23	Jacktown Creek	8/2/2006	1600
23	Jacktown Creek	8/8/2006	300
23	Jacktown Creek	8/14/2006	900
23	Jacktown Creek	8/21/2006	500
23	Jacktown Creek	8/28/2006	900
25	Bobs Creek	8/2/2006	500
25	Bobs Creek	8/8/2006	≥1600
25	Bobs Creek	8/14/2006	300
25	Bobs Creek	8/21/2006	500
25	Bobs Creek	8/28/2006	300
26	Goose Creek	8/2/2006	500
26	Goose Creek	8/8/2006	130
26	Goose Creek	8/14/2006	300
26	Goose Creek	8/21/2006	240
26	Goose Creek	8/28/2006	110
29	North Muddy Creek	8/2/2006	1600
29	North Muddy Creek	8/8/2006	900
29	North Muddy Creek	8/14/2006	300
29	North Muddy Creek	8/21/2006	500
29	North Muddy Creek	8/28/2006	220

B.3.3. 2007

Site ID	Stream Name	Date	Fecal Coliform (col/100/ml)
6	South Muddy Creek	9/6/2007	580
6	South Muddy Creek	9/13/2007	450
6	South Muddy Creek	9/20/2007	330
6	South Muddy Creek	9/27/2007	1100
6	South Muddy Creek	10/4/2007	2900
9	Hoppers Creek	9/6/2007	300
9	Hoppers Creek	9/13/2007	248
9	Hoppers Creek	9/20/2007	>2600
9	Hoppers Creek	9/27/2007	300
9	Hoppers Creek	10/4/2007	570
12	South Muddy Creek	9/6/2007	>2600
12	South Muddy Creek	9/13/2007	280
12	South Muddy Creek	9/20/2007	224
12	South Muddy Creek	9/27/2007	330
12	South Muddy Creek	10/4/2007	1000
16	North Muddy Creek	9/6/2007	220
16	North Muddy Creek	9/13/2007	380
16	North Muddy Creek	9/20/2007	320
16	North Muddy Creek	9/27/2007	285
16	North Muddy Creek	10/4/2007	1980
22	Youngs Fork	9/6/2007	320
22	Youngs Fork	9/13/2007	1133
22	Youngs Fork	9/20/2007	410
22	Youngs Fork	9/27/2007	120
22	Youngs Fork	10/4/2007	>7467
25	Bobs Creek	9/6/2007	330
25	Bobs Creek	9/13/2007	375
25	Bobs Creek	9/20/2007	350
25	Bobs Creek	9/27/2007	260
25	Bobs Creek	10/4/2007	1500
26	Goose Creek	9/6/2007	350
26	Goose Creek	9/13/2007	360
26	Goose Creek	9/20/2007	221
26	Goose Creek	9/27/2007	212
26	Goose Creek	10/4/2007	390
29	North Muddy Creek	9/6/2007	222
29	North Muddy Creek	9/13/2007	410
29	North Muddy Creek	9/20/2007	390
29	North Muddy Creek	9/27/2007	285
29	North Muddy Creek	10/4/2007	1033

Appendix C

Field Forms

Appendix C
Table of Contents

Reach Log

Stream: ____________________ Date:_________________ Staff:__________________________

Reach Location:____________________________________ **Reach ID:**___________ **Drainage area:**___________

A. Reach Delineation

Downstream end of reach:

Location description____

WP #________ lat____________________ long______________________

Upstream end of reach:

Location description____

WP #________ lat____________________ long______________________

Reach direction:

station zero (tape) is ☐ downstream end of reach ☐ upstream end of reach

B. Transect Identification and Form Checklist

Site 1:

Type: ☐ riffle ☐ pool ☐ run Location (station or WP#)_________________________

Forms completed: BEHI____, Pebble Count____, Embeddedness____, VASOS____, XS____

Notes____

Site 2:

Type: ☐ riffle ☐ pool ☐ run Location (station or WP#)_________________________

Forms completed: BEHI____, Pebble Count____, Embeddedness____, VASOS____, XS____

Notes____

Site 3:

Type: ☐ riffle ☐ pool ☐ run Location (station or WP#)_________________________

Forms completed: BEHI____, Pebble Count____, Embeddedness____, VASOS____, XS____

Notes____

Site 4:

Type: ☐ riffle ☐ pool ☐ run Location (station or WP#)_________________________

Forms completed: BEHI____, Pebble Count____, Embeddedness____, VASOS____, XS____

Notes____

Reach scale: Habitat assessment completed for reach?_________

C. Water Quality and Flow Conditions

Water Quality:	*Flow Conditions*: ☐ high ☐ normal ☐ low
Temperature_________ ^{0}C DO _________mg/L	Date of last rain: _______________
Specific conductance ________µmhos/cm	
Location (if other than ds end of reach)____________	
____	

D. Invasive Species in Riparian Zone

	Present	*Dominant*		*Present*	*Dominant*
multiflora rose	☐	☐	kudzu	☐	☐
privet	☐	☐	honeysuckle	☐	☐
stilt grass	☐	☐	other (list below)	☐	☐
knotweed	☐	☐	____________________________		

Other Reach Information

*Photos (list photo no. and location)*____

____

Bankfull indicators, height above water surface: ____

____

Notes

Instructions for NCDWQ Habitat Assessment Field Data Sheet—Mountain/ Piedmont Streams

1. Select the reach to be assessed based on study objectives and site selection procedures.
2. A reach of at least 100 yards in length should be assessed.
3. The assessment should be conducted by a team by two or more observers.
4. The Field Data Sheet should be completed only after walking and observing the entire reach.
5. The assessment should reflect average or most typical reach conditions.
6. Complete the reach identification information.
7. Complete the assessment of the eight component metrics. For each metric, select the description which best fits the observed habitats and circle the score.
8. If the observed habitat falls between two descriptions, select an intermediate score.
9. The final score is determined by adding the scores of the component metrics.

Stream: ________________________ **Date:**____________ **Staff:**____________________

Reach Location: ______________________ **Reach ID:**__________ **Drainage area:**______________

Notes: ____

NCDWQ Habitat Assessment Field Data Sheet—Mountain/ Piedmont Streams
from BAU 3/01 Revision 6

I. Channel Modification

	Score
A. channel natural, frequent bends..	5
B. channel natural, infrequent bends (channelization could be old)........................	4
C. some channelization present (recent)...	3
D. more extensive channelization (recent), >40% of stream disrupted.......................	2
E. no bends, completely channelized or rip rapped or gabioned, etc........................	0

☐ Evidence of dredging ☐Evidence of desnagging=no large woody debris in stream ☐Banks of uniform shape/height

Remarks________________________________ Subtotal____

II. Instream Habitat: Consider the percentage of the reach that is favorable for benthos colonization or fish cover. If >70% of the reach is rocks, 1 type is present, circle the score of 17. Definition: leafpacks consist of older leaves that are packed together and have begun to decay (not piles of leaves in pool areas). Mark as **R**are, **C**ommon, or **A**bundant.

Detail breakdown (WAT) ____ ____ ____ ____

____Rocks ____Macrophytes ____Sticks and leafpacks ____Snags and logs ____Undercut banks or root mats

AMOUNT OF REACH FAVORABLE FOR COLONIZATION OR COVER

	>70% Score	40-70% Score	20-40% Score	<20% Score
4 or 5 types present.................	20	16	12	8
3 types present.........................	19	15	11	7
2 types present.........................	18	14	10	6
1 type present...........................	17	13	9	5
No types present.......................	0			

☐ No woody vegetation in riparian zone Subtotal_____

Remarks (characterize channel roughness, edge habitat, etc.): ______________________________

____

____

Page Total ____

III. Bottom Substrate (silt, sand, detritus, gravel, cobble, boulder) look at entire reach for substrate scoring, but only look at riffle for embeddedness.

	Score
A. substrate with good mix of gravel cobble and boulders	
1. embeddedness <20% (very little sand, usually only behind large boulders)........................	15
2. embeddedness 20-40%...	12
3. embeddedness 40-80%...	8
4. embeddedness >80%..	3
B. substrate gravel and cobble	
1. embeddedness <20%...	14
2. embeddedness 20-40%..	11
3. embeddedness 40-80%	6
4. embeddedness >80%...	2
C. substrate mostly gravel	
1. embeddedness <50%...	8
2. embeddedness >50%...	4
D. substrate homogeneous	
1. substrate nearly all bedrock...	3
2. substrate nearly all sand	3
3. substrate nearly all detritus..	2
4. substrate nearly all silt/ clay...	1

Subtotal ____

Remarks____

IV. Pool Variety Pools are areas of deeper than average maximum depths with little or no surface turbulence. Water velocities associated with pools are always slow. Pools may take the form of "pocket water", small pools behind boulders or obstructions, in large high gradient streams.

	Score
A. Pools present	
1. Pools Frequent (>30% of 100m area surveyed)	
a. variety of pool sizes...	10
b. pools same size (indicates pools filling in)...	8
2. Pools Infrequent (<30% of the 100m area surveyed)	
a. variety of pool sizes...	6
b. pools same size...	4
B. Pools absent..	0

Subtotal ____

Remarks____

☐ Pool bottom boulder-cobble=hard ☐ Bottom sandy-sink as you walk ☐ Silt bottom ☐ Some pools over wader depth

V. Riffle Habitats

Definition: Riffle is area of reaeration-can be debris dam, or narrow channel area.

	Riffles **Frequent** Score	Riffles **Infrequent** Score
A. well defined riffle and run, riffle as wide as stream and extends 2X width of stream....	16	12
B. riffle as wide as stream but riffle length is not 2X stream width	14	7
C. riffle not as wide as stream and riffle length is not 2X stream width	10	3
D. riffles absent....	0	
** riffle not as wide as stream but riffle length is 2X width of stream…score within range	10-14	3-7

Subtotal ____

Remarks____

Page Total ____

VI. Bank Stability and Vegetation

FACE DOWNSTREAM

	Left Bank Score	Rt. Bank Score
A. Banks stable		
1. no evidence of erosion or bank failure(except outside of bends), little potential for erosion....	7	7
B. Erosion areas present		
1. diverse **trees**, shrubs, grass; plants healthy with good root systems....................................	6	6
2. few trees or small trees and **shrubs**; vegetation appears generally healthy...........................	5	5
3. sparse **mixed** vegetation; plant types and conditions suggest poorer soil binding.................	3	3
4. mostly **grasses**, few if any trees and shrubs, high erosion and failure potential at high flow..	2	2
5. no bank vegetation, mass erosion and bank failure evident...	0	0

Subtotal ____

Remarks____

VII. Light Penetration (Canopy is defined as tree or vegetative cover directly above the stream's surface. Canopy would block out sunlight when the sun is directly overhead).

	Score
A. Stream with **good** shading with some breaks for light penetration	10
B. Stream with **full canopy** - breaks for light penetration absent..	8
C. Stream with **partial** shading - sunlight and shading are essentially equal...................................	7
D. Stream with **minimal** shading - full sun in all but a few areas..	2
E**. No shading**...	0

Subtotal ____

Remarks____

VIII. Riparian Buffer Width

Notes: *Riparian buffer* for this form is area of natural (woody) vegetation adjacent to stream (can go beyond floodplain). A *break* in the riparian buffer is any place on the stream banks which allows sediment or pollutants to directly enter the stream, such as paths down to stream, storm drains, uprooted trees, otter slides, etc.

Riparian zone is the area adjacent to and influenced by the stream (floodplain and terraces), and it is often larger than the *riparian buffer*.

Dominant vegetation in riparian zone: ☐ Trees ☐ Shrubs ☐ Grasses ☐ Weeds/old field ☐Exotics (kudzu,etc)

	Lft. Bank Score	Rt. Bank Score
A. Riparian buffer **intact** (no breaks)		
1. width > 18 meters..	5	5
2. width 12-18 meters...	4	4
3. width 6-12 meters..	3	3
4. width < 6 meters..	2	2
B. Riparian buffer **not intact** (breaks)		
1. breaks rare		
a. width > 18 meters..	4	4
b. width 12-18 meters...	3	3
c. width 6-12 meters...	2	2
d. width < 6 meters...	1	1
2. breaks common		
a. width > 18 meters..	3	3
b. width 12-18 meters..	2	2
c. width 6-12 meters...	1	1
d. width < 6 meters...	0	0

Subtotal____

Remarks:____
____

Page Total ____

TOTAL SCORE______

BEHI **Date**______________ **Stream**________________________________ **Reach ID**______________________ **Staff**___________________

		BEHI Parameters					**Index totals and adjustments**				**NBS**
Station and Bank (descending)	Measures (ft)	Bank ht/ bkf ht	Root depth/ bank ht	Root density (%)	Bank angle (degrees)	Surface protection	Index total	Adjust: bank materials	Adjust: stratifi-cation	Adjusted total	Near bank stress
Station location/description____											
☐ left bank ☐ right bank	bank ht:____ bkf ht:_____ root dpt:____	value:______	value:______	value:______	value:______	value:______					
		index:______	index:______	index:______	index:______	index:______					
☐ left bank ☐ right bank	bank ht:____ bkf ht:_____ root dpt:____	value:______	value:______	value:______	value:______	value:______					
		index:______	index:______	index:______	index:______	index:______					
Station location/description____											
☐ left bank ☐ right bank	bank ht:____ bkf ht:_____ root dpt:____	value:______	value:______	value:______	value:______	value:______					
		index:______	index:______	index:______	index:______	index:______					
☐ left bank ☐ right bank	bank ht:____ bkf ht:_____ root dpt:____	value:______	value:______	value:______	value:______	value:______					
		index:______	index:______	index:______	index:______	index:______					

Adjustments

Bank materials-- Bedrock: bank erosion potential always v. low
Boulders: bank erosion potential low
Cobble: decrease by one category unless mix of gravel/sand is >50%
Gravel: adjust values by 5-10 pts depending on composition of sand
Sand: adjust values up by 10 pts
Silt/clay: no adjustment

Stratification-- Adjust upwards by 5-10 pts depending on position of unstable layers in relation to bkf stage

Near bank stress Method is qualitative (low, med, high) judgment
low=stream velocity vectors pointing away from bank
med=stream velocity vectors parallel to bank
high=stream velocity vector pointing at bank

	very low		**low**		**moderate**		**high**		**very high**		**extreme**	
Parameter	**value**	**index**	**value**	**index**	**value**	**index**	**value**	**index**	**value**	**index**	**value**	**index**
bank ht/bkf ht	1.0-1.1	1.0-1.9	1.1-1.19	2.0-3.9	1.2-1.5	4.0-5.9	1.6-2.0	6.0-7.9	2.1-2.8	8.0-9.0	.>2.8	10
root depth/bank ht	1.0-0.9	1.0-1.9	0.89-0.50	2.0-3.9	0.49-0.30	4.0-5.9	0.29-0.15	6.0-7.9	0.14-0.05	8.0-9.0	<0.05	10
root density (%)	100-80	1.0-1.9	79-55	2.0-3.9	54-30	4.0-5.9	29-15	6.0-7.9	14-5	8.0-9.0	<5	10
bank angle (degrees)	0-20	1.0-1.9	21-60	2.0-3.9	61-80	4.0-5.9	81-90	6.0-7.9	91-119	8.0-9.0	>119	10
surface protection (%)	100-80	1.0-1.9	79-55	2.0-3.9	54-30	4.0-5.9	29-15	6.0-7.9	14-10	8.0-9.0	<10	10
TOTALS		**5.0-9.5**		**10-19.5**		**20-29.5**		**30-39.5**		**40-45**		**46-50**

Pebble Count

Site:	Date:
Names:	Reach:

Particle	Size (mm)	Type	# of Particles	Total #	%	Cum. %
Silt/Clay	< .062	S/C				
Very Fine	.062 -. 125	S				
Fine	.125 - .25	A				
Medium	.25 - .5	N				
Coarse	.5 - 1.0	D				
Very Coarse	1 - 2	S				
Very Fine	2 - 4					
Fine	4 - 6	G				
Fine	6 - 8	R				
Medium	8 - 12	A				
Medium	12 - 16	V				
Coarse	16 - 24	E				
Coarse	24 - 32	L				
Very Coarse	32 - 48	S				
Very Coarse	48 - 64					
Small	64 - 96	C				
Small	96 - 128	O				
Large	128 - 192	B				
Large	192 - 256	L				
Small	256 - 384	B				
Small	384 - 512	L				
Medium	512 - 1024	D				
Lrg/Vry Lg	1024 - 4096	R				
Bedrock		BDRK				
			TOTALS:			

Embeddedness Tally Sheet*

1	2	3	4	5	Median
6	7	8	9	10	
100% embedded (check) ☐					
No riffle (check) ☐					

*Record embeddedness for 10 particles in cells 1-10. Calculate median.

Virginia
Save Our Streams
Stream Quality Survey

For Office Use Only
Name of Reviewer________________
Date Reviewed________________
Data sent to________________
VA SOS Data Entry Date __________

The purpose of this form is to aid you in gathering and recording important data about the health of your stream. By keeping accurate and consistent records of your observations and data from your macroinvertebrate count, you can document changes in ecological condition. Refer to the Virginia Citizen *Monitor's Methods Manual* for instructions on how to collect and identify stream macroinvertebrates. *Please note, this method was designed and tested for conditions in the state of Virginia and may not be appropriate in other areas.*

Date__________

Stream____________________________ Station________ # of participants________

Group or individual____

Name of certified* monitor____

County_____________________ Latitude__________ Longitude___________

Location (please be specific) ____
____

Average stream width ____________ft Average stream depth __________________in

Flow rate: High______ Normal______ Low______ Negligible______

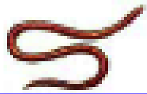
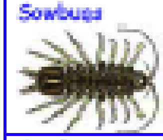
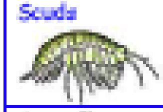
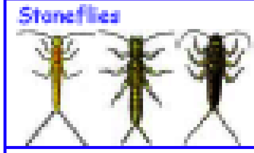
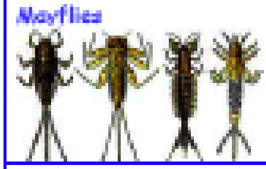
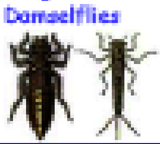
Weather last 72 hours ____
____

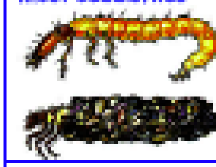
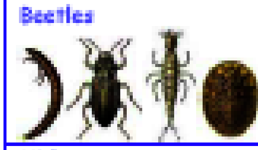
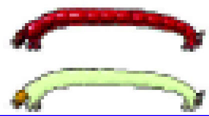
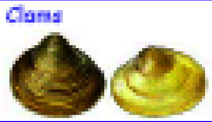
Water Temperature________°F (Please specify if reporting temperature in Celsius)

Collection Time:
Net 1:__________sec
Net 2:__________sec
Net 3:__________sec
Net 4:__________sec

Other comments:
____
____
____
____
____
____
____

Virginia Save Our Streams Macroinvertebrate Tally Sheet

Macroinvertebrates	Tally	Count
Worms 		
Flat Worms 		
Leeches 		
Crayfishes 		
Sowbugs 		
Scuds 		
Stoneflies 		
Mayflies 		
Dragonflies and Damselflies 		
Hellgrammites, Fishflies, and Alderflies 		

Macroinvertebrates	Tally	Count
Common Netspinners 		
Most Caddisflies 		
Beetles 		
Midges 		
Black Flies 		
Most True Flies 		
Gilled Snails 		
Lunged Snails 		
Clams 		
Other Subsurface organisms (please specify if possible – if you do not know if the organism is subsurface, please do not include in the total)		
Total number of organisms in the sample		

Illustrations from: Voshell, J. R., Jr. 2001. Guide to the Common Freshwater Invertebrates of North America. MacDonald and Woodward Publishing Co. With permission of the author.

Individual Metrics

Metric Number	Metric Organism Group	Number of metric organism		Total number of organisms in the sample		Percent (This is your value for this metric)
1	Mayflies + Stoneflies + Most Caddisflies		÷		Multiply by 100	%
2	Common Netspinners		÷		Multiply by 100	%
3	Lunged Snails		÷		Multiply by 100	%
4	Beetles		÷		Multiply by 100	%

Metric 5 - % Tolerant

Taxon	Number
Worms	
Flatworms	
Leeches	
Sowbugs	
Scuds	
Dragonflies and Damselflies	
Midges	
Black Flies	
Lunged Snails	
Clams	
Total Tolerant	
Total Tolerant divided by the total number of organisms in the sample	
Multiply by 100 This is your Value for Metric 5	

Metric 6 - % Non-Insects

Taxon	Number
Worms	
Flatworms	
Leeches	
Crayfish	
Sowbugs	
Scuds	
Gilled Snails	
Lunged Snails	
Clams	
Total Non-Insects	
Total Non-Insects divided by the total number of organisms in the sample	
Multiply by 100 This is your Value for this Metric 6	

Save Our Streams Multimetric Index

Write your metric value from the previous page in the 2nd column (Your Metric Value). Determine whether each metric should get a score of 2,1, or 0 - depending upon the range of your metric value. Put a check in the appropriate box for your metric value under 2,1, or 0. Count the total number of 2's, 1's, and 0's. Follow the multiplication at the bottom of the chart to determine your Save Our Streams Multimetric Index score and determine whether the site has acceptable or unacceptable ecological condition.

Metric Number	Metric Organism	Your Metric Value	2	1	0
1	% Mayflies + Stoneflies + Most Caddisflies		Greater than 32.2	16.1 - 32.2	Less than 16.1
2	% Common Netspinners		Less than 19.7	19.7 - 34.5	Greater than 34.5
3	% Lunged Snails		Less than 0.3	0.3 - 1.5	Greater than 1.5
4	% Beetles		Greater than 6.4	3.2 - 6.4	Less than 3.2
5	% Tolerant		Less than 46.7	46.7 - 61.5	Greater than 61.5
6	% Non-Insects		Less than 5.4	5.4 - 20.8	Greater than 20.8
			Total # of 2s:	Total # of 1s:	Total # of 0s:
		Subtotals:	Multiply by 2:	Multiply by 1:	Multiply by 0:

Now add the 3 subtotals to get the Save Our Streams Multimetric Index score:_______________

_____Acceptable ecological condition (7 to 12) _____Unacceptable ecological condition (0 to 6)

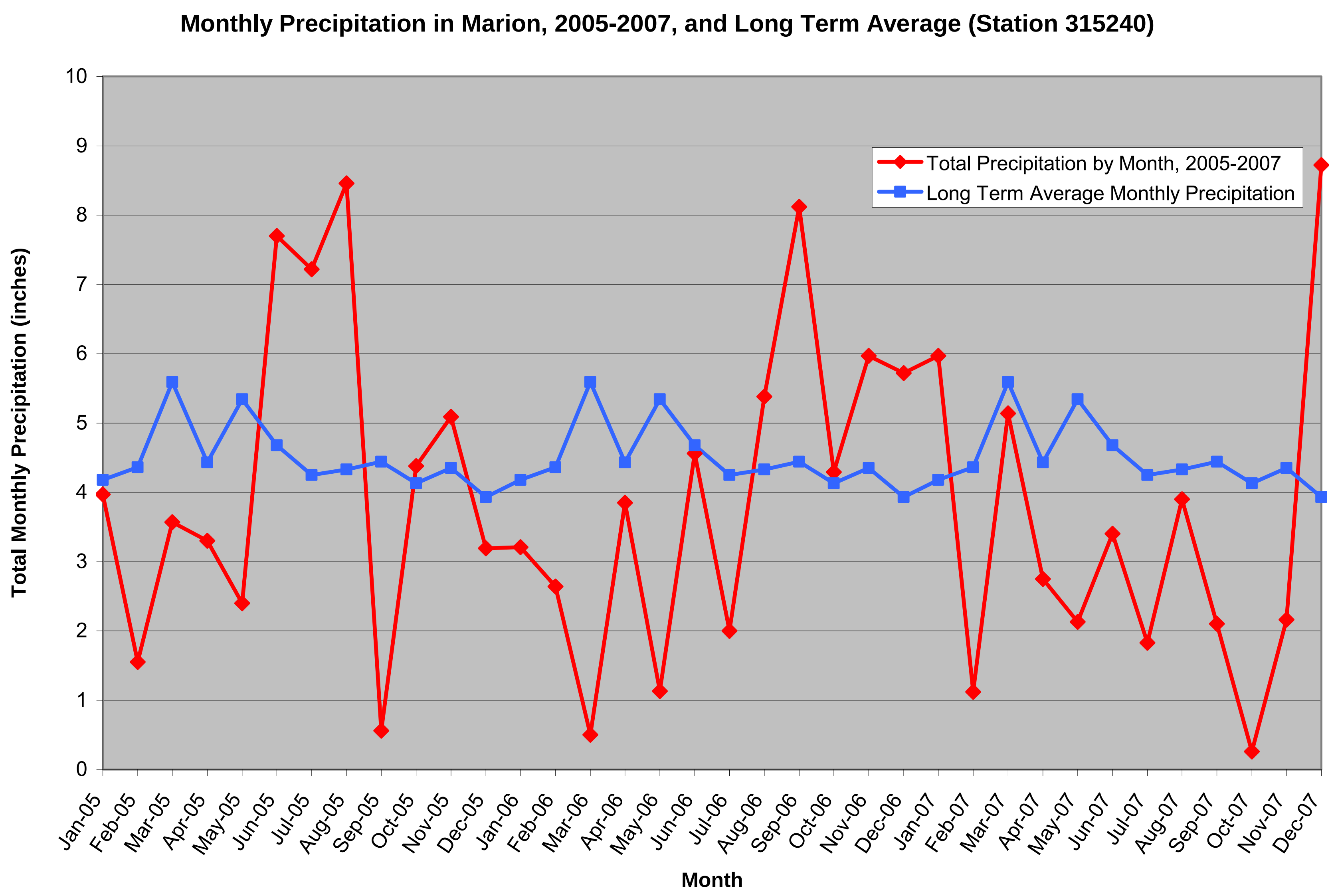
Please send data sheets to your regional coordinator or VA SOS, P.O. Box 8297, Richmond, Va 23226. If you have any questions about the modified method or this particular collection, please call 804-615-5036 or e-mail stacey@vasos.org

Appendix D

Ancillary Data

Appendix D
Table of Contents

Figure D.1.



Monthly Precipitation in Marion, 2005-2007, and Long Term Average (Station 315240)
Total Precipitation by Month, 2005-2007
Long Term Average Monthly Precipitation
Total Monthly Precipitation (inches)
0
1
2
3
4
5
6
7
8
9
10
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Jan-06
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Jul-06
Aug-06
Sep-06
Oct-06
Nov-06
Dec-06
Jan-07
Feb-07
Mar-07
Apr-07
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07
Nov-07
Dec-07
Month

Figure D.2. South Muddy Creek (Site 6): Maximum Daily Stage, May 2006 - December 2007

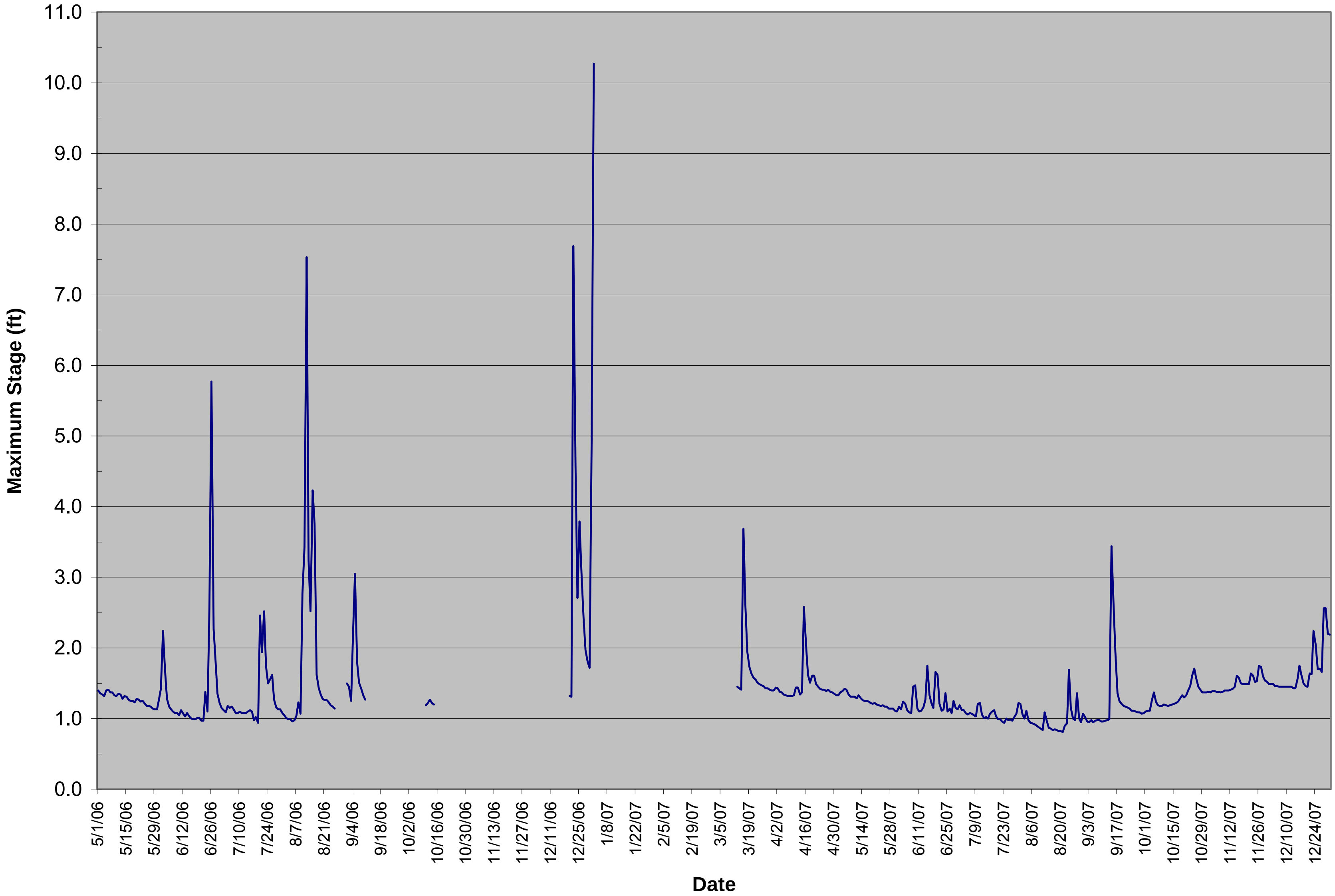


Figure D.3. Bobs Creek (Site 25): Maximum Daily Stage, May 2006 - December 2007

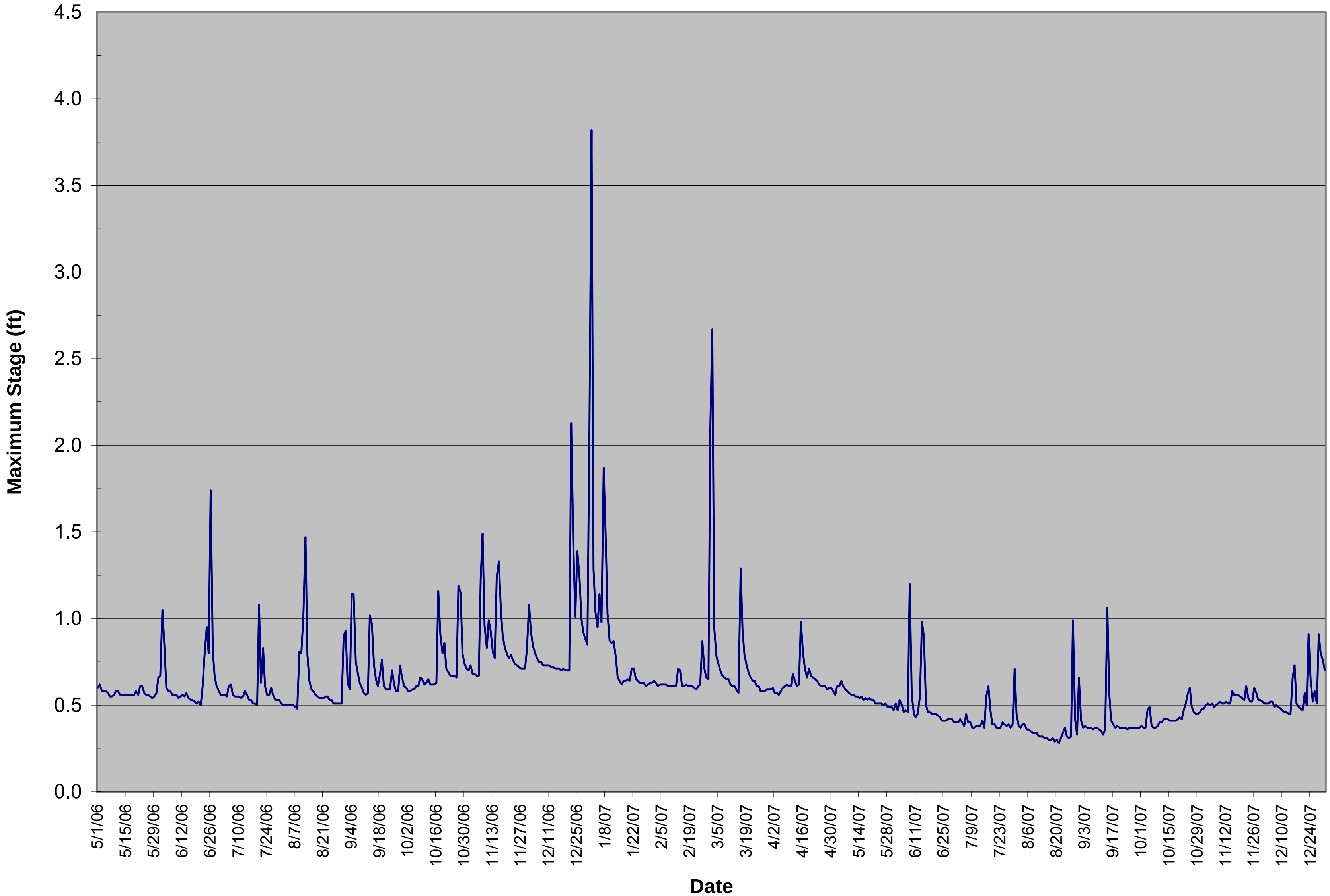


Table D.1. Land Cover by Sub-watershed (acres), 1998

Land Cover Classification	North Muddy Ck Drainage							South Muddy Ck Drainage					Lower Muddy Ck	
	NM-HW	GC	NM-U/BC	YF	NM-M	NM-L	TF	SM-HW	SM-U	SM-M	HC	SM-L	LM	OC/SD
Forested	**4,539.2**	**4,620.4**	**2,583.9**	**3,290.4**	**4,536.9**	**2,831.5**	**3,709.2**	**4,240.7**	**3,533.7**	**4,562.4**	**5,442.7**	**2,830.6**	**3,547.3**	**3,555.4**
Mixed Forest	3,900.1	3,460.8	1,891.5	2,738.5	3,335.5	2,230.8	3,256.5	2,541.0	2,349.2	2,854.5	3,476.7	1,912.9	1,612.3	2,084.3
Harvested 5-10	133.9	194.1	107.3	90.3	112.3	0.0	81.0	0.5	373.2	179.5	50.8	279.8	345.0	103.5
Harvested 0-5	226.2	649.0	238.5	216.5	347.0	189.9	124.4	614.0	460.7	325.8	460.9	309.9	890.3	104.5
Plantation	63.0	187.0	283.8	32.9	592.7	322.1	142.2	1,039.7	339.7	991.3	1,329.9	262.6	609.6	1126.7
Shrub/Scrub	215.9	129.4	63.0	212.3	149.4	88.6	105.0	45.4	11.0	211.2	124.3	65.4	90.1	136.4
Agricultural	**791.9**	**970.6**	**565.1**	**287.6**	**557.3**	**514.4**	**409.5**	**126.6**	**142.7**	**997.6**	**1,275.1**	**797.5**	**507.3**	**665.7**
Pasture	562.5	763.6	396.6	262.2	544.7	453.3	338.2	118.2	124.8	741.1	832.0	577.8	305.6	492.4
Cropland	223.1	207.0	107.1	25.4	12.7	56.2	59.6	8.4	5.4	122.6	298.5	204.4	181.0	48.4
Nursery	6.3	0.0	61.3	0.0	0.0	0.0	1.4	0.0	3.5	118.7	126.1	0.0	20.8	124.9
Poultry Operation	0.0	0.0	0.0	0.0	0.0	4.9	10.3	0.0	9.1	15.2	18.4	15.3	0.0	0.0
Urban/Built Up	**1,420.8**	**341.7**	**150.6**	**1,578.0**	**694.4**	**392.7**	**725.0**	**113.0**	**85.3**	**465.6**	**231.2**	**369.2**	**571.9**	**479.0**
Residential	1,072.0	311.4	101.5	941.7	635.6	298.9	653.9	107.7	83.4	443.1	212.1	306.7	506.0	409.5
Commercial	211.0	8.6	0.0	445.8	10.5	58.8	33.4	5.4	0.0	13.5	8.0	36.0	22.7	44.9
Transportation	121.9	16.1	12.7	101.0	47.9	31.9	27.2	0.0	1.9	9.0	11.1	26.6	33.2	24.5
Mixed Urban	15.8	0.0	36.4	83.8	0.4	3.1	10.5	0.0	0.0	0.0	0.0	0.0	10.0	0.0
Recreation	0.0	5.5	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	**91.9**	**48.9**	**38.9**	**208.3**	**74.9**	**10.5**	**37.7**	**3.3**	**33.0**	**33.8**	**117.9**	**5.0**	**41.3**	**10.6**
Altered Lands	66.1	21.6	37.2	197.0	65.8	5.7	21.3	2.7	19.6	14.3	12.5	3.3	36.7	9.3
Water	25.8	27.3	1.7	11.3	9.1	4.9	16.4	0.6	13.4	19.4	105.4	1.7	4.6	1.3
Total Area Acres	**6,844**	**5,982**	**3,338**	**5,364**	**5,863**	**3,749**	**4,881**	**4,484**	**3,795**	**6,059**	**7,067**	**4,002**	**4,668**	**4,711**
Sq. Miles	**10.7**	**9.3**	**5.2**	**8.4**	**9.2**	**5.9**	**7.6**	**7.0**	**5.9**	**9.5**	**11.0**	**6.3**	**7.3**	**7.4**

Table D.2. Land Cover by Sub-watershed (acres), 2005

Land Cover Classification	North Muddy Ck Drainage							South Muddy Ck Drainage					Lower Muddy Ck	
	NM-HW	GC	NM-U/BC	YF	NM-M	NM-L	TF	SM-HW	SM-U	SM-M	HC	SM-L	LM	OC/SD
Forested	**4,537.8**	**4,601.1**	**2,490.7**	**3,437.3**	**4,377.8**	**2,759.8**	**3,687.9**	**4,237.6**	**3,462.5**	**4,517.9**	**5,278.0**	**2,764.1**	**3,439.4**	**3,513.2**
Mixed Forest	3,287.4	2,883.0	2,027.0	2,583.5	3,076.6	2,092.7	3,071.6	2,062.5	1,822.2	2,746.6	3,075.3	1,692.5	1,566.7	2,372.3
Harvested 5-10	391.9	992.4	274.3	311.5	723.1	344.7	213.8	572.3	1,024.3	575.1	522.1	653.6	1,239.7	154.2
Harvested 0-5	549.0	307.7	25.3	148.1	137.5	23.1	137.5	876.5	360.2	377.6	934.1	150.3	154.8	260.0
Plantation	54.1	245.3	61.6	33.7	209.6	172.7	85.4	696.1	202.0	569.4	579.9	133.6	358.7	560.1
Shrub/Scrub	255.4	172.6	102.5	360.6	231.0	116.6	179.6	30.2	53.8	249.1	166.6	134.1	119.6	166.5
Agricultural	**692.9**	**864.5**	**504.0**	**260.7**	**498.0**	**425.2**	**326.2**	**102.5**	**129.9**	**889.1**	**1,180.6**	**768.3**	**539.9**	**642.9**
Pasture	571.6	698.9	334.7	223.6	477.5	334.6	257.4	93.9	112.7	659.6	917.7	419.9	301.8	409.9
Cropland	96.9	94.9	57.0	37.0	12.7	69.5	58.6	8.6	8.2	138.6	187.3	274.9	135.2	27.4
Nursery	24.4	70.7	112.3	0.2	7.8	14.3	0.0	0.0	0.0	77.7	57.3	61.1	102.9	205.6
Poultry Operation	0.0	0.0	0.0	0.0	0.0	6.8	10.3	0.0	9.1	13.2	18.3	12.3	0.0	0.0
Urban/Built Up	**1,584.2**	**464.9**	**210.9**	**1,649.6**	**954.1**	**554.9**	**830.2**	**143.6**	**185.5**	**614.4**	**460.9**	**457.2**	**635.6**	**548.0**
Residential	1,190.3	421.1	161.5	972.6	873.6	456.2	750.4	140.8	180.8	586.7	438.7	383.1	538.4	458.0
Commercial	244.1	19.3	0.4	432.5	30.1	63.7	40.1	2.2	2.8	18.8	10.7	47.6	56.2	60.0
Transportation	131.3	16.1	12.7	121.3	48.1	31.9	27.2	0.0	1.9	9.0	11.1	26.6	33.2	24.5
Mixed Urban	15.7	0.0	36.4	117.5	2.2	3.2	12.5	0.6	0.0	0.0	0.4	0.0	7.9	2.2
Recreation	2.9	8.3	0.0	5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
Other	**28.9**	**50.9**	**132.8**	**15.4**	**33.3**	**19.2**	**36.9**	**0.0**	**16.9**	**37.9**	**147.3**	**12.7**	**52.8**	**6.6**
Altered Lands	4.2	23.6	125.9	4.1	20.2	14.3	14.4	0.0	0.0	16.9	34.7	8.3	46.2	5.4
Water	24.7	27.3	7.0	11.3	13.2	4.9	22.6	0.0	16.9	20.9	112.7	4.4	6.6	1.3
Total Area Acres	**6,844**	**5,982**	**3,338**	**5,364**	**5,863**	**3,749**	**4,881**	**4,484**	**3,795**	**6,059**	**7,067**	**4,002**	**4,668**	**4,711**
Sq. Miles	**10.7**	**9.3**	**5.2**	**8.4**	**9.2**	**5.9**	**7.6**	**7.0**	**5.9**	**9.5**	**11.0**	**6.3**	**7.3**	**7.4**

Table D.3. Pre 2005 Benthic Community Data Collected by Duke Energy at Sites 6 and 16[1]

Site and Indicator	**Year**					
	1999	2000	2001	2002	2003	2004
Site 6 South Muddy Creek						
Total EPT Taxa	21	21	10	12	11	16
Biotic Index	5.49	5.57	5.06	6.27	5.22	5.24
Bioclassification [2]	GF	GF	F	F	F	F
Site 16 North Muddy Creek						
Total EPT Taxa	19	20	8	8	11	15
Biotic Index	5.57	5.33	5.79	6.15	5.26	5.45
Bioclassification [2]	F	GF	F	P	F	F

(1) Source: Duke Energy, 2008. *Muddy Creek Macroinvertebrate Bioassessment Project, 2007*. March.
Data were collected for earlier monitoring efforts and not as part of the current monitoring project.
(2) Bioclassification key: P=Poor, F=Fair, GF=Good-Fair, G=Good, E=Excellent. Classifications of Poor and Fair indicate impairment.

Table D.4. Benthic Community Data for Sites Monitored by NCDWQ on North and South Muddy Creeks, 2002- 2007

Site & Indicator	August 2002	July 2007
South Muddy Ck at SR 1764		
Total EPT Taxa	23	32
EPT Biotic Index	4.22	3.94
Bioclassification	Good-Fair	Good
North Muddy Ck at SR 1760		
Total EPT Taxa	32	25
Biotic Index	5.51	5.36
Bioclassification	Good-Fair	Good-Fair

Table D.5. Fish Community Data for Sites Monitored by NCDWQ on North and South Muddy Creeks, 2002- 2007

Site & Indicator	April-May 2002	May 2007
South Muddy Ck at SR 1764		
Total Species	14	16
NCIBI	48	52
Bioclassification	Good	Good
North Muddy Ck at SR 1760		
Total Species	19	23
NCIBI	48	54
Bioclassification	Good	Excellent

Appendix E

Analyzing Restoration Effects – A Review of Key Issues

Analyzing Restoration Effects – A Review of Key Issues

As noted in Section 5, identifying potential beneficial effects of stream improvement projects requires that:

- An improvement in environmental conditions has actually occurred;
- The improvement is measurable and distinguishable from normal variation in conditions; and
- It is reasonable to attribute the observed change to the intervention as opposed to other events or circumstances.

A comprehensive review of all of the issues involved is beyond the scope of this report. This Appendix provides a brief review of some of the key factors as they pertain to the Muddy Creek watershed.

E.1 Have Stream Conditions Improved?

Restoration efforts are unlikely to result in improved environmental conditions unless:

1. Project design is sound and projects are implemented properly;
2. At the sub-watershed and watershed scales, the extent of stream improvement activity is adequate to address the problem;
3. Improvements due to restoration are not obscured by the negative impacts of other activities; and
4. Sufficient time has elapsed for measurable changes to manifest themselves.

Sound design and implementation at the site scale. Inadequacies in design and construction can clearly affect the results of a stream project. For example, a channel restoration project is unlikely to produce a stable channel if the new channel is not sized properly or channel structures are not properly installed. A revegetation project may not result in the anticipated improvements in riparian function if specifications call for species that will not do well under conditions at the site, if poor quality stock are used, or if planting densities are inadequate.

Extent of stream improvement activity. With proper assessment, design and implementation, a particular project will likely be adequate to address on-site problems. However, when broader scale improvements are the focus, the situation is more complex. It is necessary to consider whether the projects implemented have addressed a sufficient portion of the problems in a drainage to improve conditions downstream, in reaches which have not themselves been a focus of restoration activity.

As discussed in Section 4, over 50,000 feet of stream improvement has been completed in the Muddy Creek watershed. While this is a substantial amount of work, it represents less than 3% of the total stream network and only about 9% of the stream length identified in the 2003 restoration plan as priority areas for restoration activities.

In considering whether this effort is sufficient for broad scale conditions to be reasonably expected, it is instructive to review some basic features of sediment transport. Excess sediment deposition at the watershed scale has occurred because sediment supply, from all sources, exceeds the capacity of the stream to transport it. Overall sedimentation will decrease when sediment supply is reduced below transport capacity and the stream can begin removing deposited materials.

Since neither transport capacity nor sediment loads have been quantified, there is no way to estimate whether any load reductions from stream projects completed to date might be sufficient to improve downstream channel conditions. It is clear, however, that a large majority of the stream and riparian deficiencies previously identified have yet to be addressed. From the perspective of projects completed, the sub-watershed for which impacts are most likely to be detectable may be Goose Creek, where completed restoration projects account for almost 10% of the total stream length and 24% of the priority stream length (see Table 4.3). A flood control facility is located on Goose Creek, but all completed projects are downstream of this impoundment.

It is also critical to realize that stream bank erosion, the primary sediment source addressed by stream improvement efforts being implemented in the Muddy Creek watershed, is not the only source of sediment in the watershed. The magnitude of sediment inputs from upland sources has not been quantified. If these sources are significant and sediment loading remains above stream transport capacity after stream bank sources have been substantially reduced, impacts from excessive deposition may remain.

Offsetting impacts. If sediment inputs from upland activities have actually increased during the monitoring period this could offset load reductions stemming from stream improvement projects. No data on this issue are available. While it appears that construction activity in McDowell County, as measured by building permits, has been increasing (see Section 2), it is not clear whether this trend is applicable to the Muddy Creek watershed or what the implications for sediment loading might be.

Elapsed time. As discussed in Section 4, some conditions at restored sites may (depending upon the nature of the restoration project) be expected to improve immediately upon project completion, while other conditions could take years to improve. Where monitoring occurs soon after a project has been completed, some site improvements will not have had time to develop. The issue is even more salient at the sub-watershed scale because of the time lag required for sediment transport, especially for bedload. Once sediment inputs are reduced at project locations, sediment impacts at downstream locations will not be reduced until some portion of the sediment already in the channel network has been flushed from the system. This process could take years, depending upon how far downstream the monitoring site is from the restoration project, the balance between transport capacity and supply, the sequence of storm events necessary to move the sediment, and other variables.

Given the recent nature of much of the restoration in Muddy Creek and the relatively low stream flows during 2007, it may be premature to expect that substantial reduction in downstream sediment deposition has yet occurred at broader scales. Seventy-five percent of the total linear extent of projects implemented was completed during the past three years, with the remaining twenty-five percent of the work completed during the second half of 2007. In the Goose Creek sub-watershed, where restoration has been most extensive relative to the size of the channel system and documented needs, more than half of the project length was completed immediately prior to the 2007 monitoring.

E.2 Are Stream Improvements Identifiable?

Where improvements have actually occurred, they must be reliably identified and measured. This will not be possible unless:

1. Data are collected for the appropriate indicators; and
2. Improvements are large enough to be distinguishable from background variability, considering the precision with which indicators are measured.

Indicators. The primary indicators used in this study should be sensitive to the types of impacts expected at the site scale, although it may take some time for improved conditions to develop. However, not all of these indicators are likely to be useful at broader scales. In particular, bank erosion potential at broad-scale sites is primarily influenced by site specific factors such as the height and steepness of banks, as well as the nature of bank materials and extent of vegetation. Bank erosion at these locations is unlikely to be highly sensitive to the types of upstream site improvements implemented in the watershed. Many of the metrics that comprise the aquatic habitat score are also not likely to be affected. The parameters most likely to be impacted at scales broader than the site level are those sensitive to changes in sediment supply, in particular embeddedness and sediment size measures.

Background Variability. The indicators used must be measured at a level of precision that makes it possible to distinguish actual change from normal environmental variation. This issue is partly one of sample size and monitoring frequency. Three years of annual monitoring data do not provide sufficient information to identify the extent of variability nor, in many cases, to draw confident conclusions for parameters for which variability is expected to be large. As discussed in Appendix F, the quarterly data available for several sites in the Muddy Creek watershed indicate large fluctuations in values for substrate parameters such as embeddedness and median substrate size (D_{50}), while variability is much smaller for aquatic habitat and bank erosion potential. Fluctuations in VASOS scores lie somewhere in between. This variability can be viewed as the background noise from which any signal due to restoration projects or other management actions must be distinguished. The quarterly data strongly suggest that it will be more difficult to reliably establish trends in embeddedness and median substrate size than for the other primary indicators, especially where only three years of annual data are available.

E.3 Can Identified Improvements Be Attributed to Restoration?

Where the extent of actual improvements can be reliably determined, one must determine whether observed changes can be reasonably attributed to restoration activities, or whether they may be due to other factors. Two such factors that must be considered are:

1. Changing hydrologic or meteorological conditions; and

2. Changes in watershed management and pollution inputs other than those related to the projects being evaluated.

Changing hydrologic conditions. As documented in Section 2, precipitation and stream discharge declined during the monitoring period, especially during the third year (2007). By and large, the three sets of annual monitoring events thus reflect the influence of differing hydrologic conditions. Lower storm frequency and magnitude will in theory be reflected in lower sediment inputs as well as reduced sediment transport. However, these impacts cannot be precisely specified.

Complications due to other watershed activity. Stream conditions are influenced by a wide variety of watershed activities. This is a factor even at the scale of individual restoration sites, since most projects have at least a small upstream area providing drainage. The issue becomes more complex at broader scales. While some data on land cover change are available, data on the extent of upstream disturbance during the course of the project do not exist. No information on changes in watershed management practices (e.g. construction site erosion control or forestry management) was systematically collected, although anecdotal information and informal observations made by project staff are available.

Specific events can also complicate interpretation of data. For example, during maintenance activities at a dam on South Muddy Creek in the summer of 2006, large amounts of accumulated sediment were released into the stream above Site 13. This had a significant impact on substrate indicators at the site and necessitated moving transects within the reach. In 2006, beavers constructed a dam on Bobs Creek downstream of the study reach (Site 25) that inundated much of the reach for a time. The dam was removed by the landowner and rebuilt by the beavers on several occasions.

Appendix F

Analysis of Quarterly Stream Data

Analysis of Quarterly Stream Data

F.1 Introduction

Because three years of annual data provide limited information on inherent variability in stream conditions, quarterly monitoring of selected physical parameters was conducted at six sites (Table F.1). The six sites were selected to represent a range of conditions across the watershed. At these locations, supplemental quarterly monitoring was conducted in the three seasons not covered by the annual monitoring, for a total of four monitoring events per year. Funding limitations precluded collecting seasonal data at all locations.

The quarterly data collected at these sites is limited to the following subset of primary indicators: pebble counts; riffle embeddedness; Bank Erosion Hazard Index (BEHI); NCDWQ stream habitat protocol; benthic macroinvertebrate community condition (Virginia Save Our Streams protocol, or VASOS). Water quality field parameters (dissolved oxygen, specific conductance and temperature) were also monitored.

Including the annual monitoring, each site was monitored on nine occasions, once in 2005 (summer-fall) and four times each (winter, spring, summer, fall) in 2006 and 2007. At several sites VASOS and embeddedness were not monitored during every event because riffles were not present in the reach.

Table F.1. List of Sites in the Muddy Creek Watershed with Quarterly Data Collection

Station ID	Stream Name	Road Name	Drainage Area (sq mi)
06	South Muddy Ck.	Gilbert Byrd Road	39.7
13	South Muddy Ck.	Hwy NC 226	12.9
15	UT to S. Muddy Ck.	Brackett Town Road	0.5
16	North Muddy Ck.	Gilbert Byrd Road	56.3
19	North Muddy Ck.	Burma Road	42.8
25	Bobs Creek[2]	Marlowe Road	2.1

F.2 Results

A summary of trends and patterns for selected parameters is presented below, including all monitoring events for each site. Plots and statistical summaries of key parameters are included at the end of this Appendix (Figures F.1-F.5 and Tables F.3-F.7).

Trends. Based on a visual inspection of plots (Figures F.1-F.2), obvious temporal trends are generally not apparent.

- Habitat - Habitat in Bobs Creek (Site 25) appears to be improving. Habitat at other sites is either declining or remains unchanged.

- BEHI - No trend is apparent at most sites, though the lower North Muddy Creek (Site 16) and Bobs Creek appeared to show modest improvement during the latter portion of the monitoring period.
- Trends in the remaining parameters examined are difficult to discern because variability in the measurements is much greater. The VASOS scores appear to have declined in Bobs Creek and increased in upper South Muddy Creek (Site 13).

Variability. The plotted data indicated considerable fluctuation from event to event for some parameters. This variability is reflected in the coefficient of variation (CV), which is defined as the standard deviation (measure of the average deviation from the mean) expressed as a percentage of the mean. Aquatic habitat and bank erosion potential CVs are relatively low (<10% on average), indicating that measurements at individual sites do not vary much over time (Table F.2). This is consistent with the plotted data. This is not a surprising finding, as there is no reason to expect significant seasonal variation in overall habitat conditions and bank stability, though seasonal differences in the appearance of vegetation can make some habitat and BEHI metrics more difficult to evaluate.

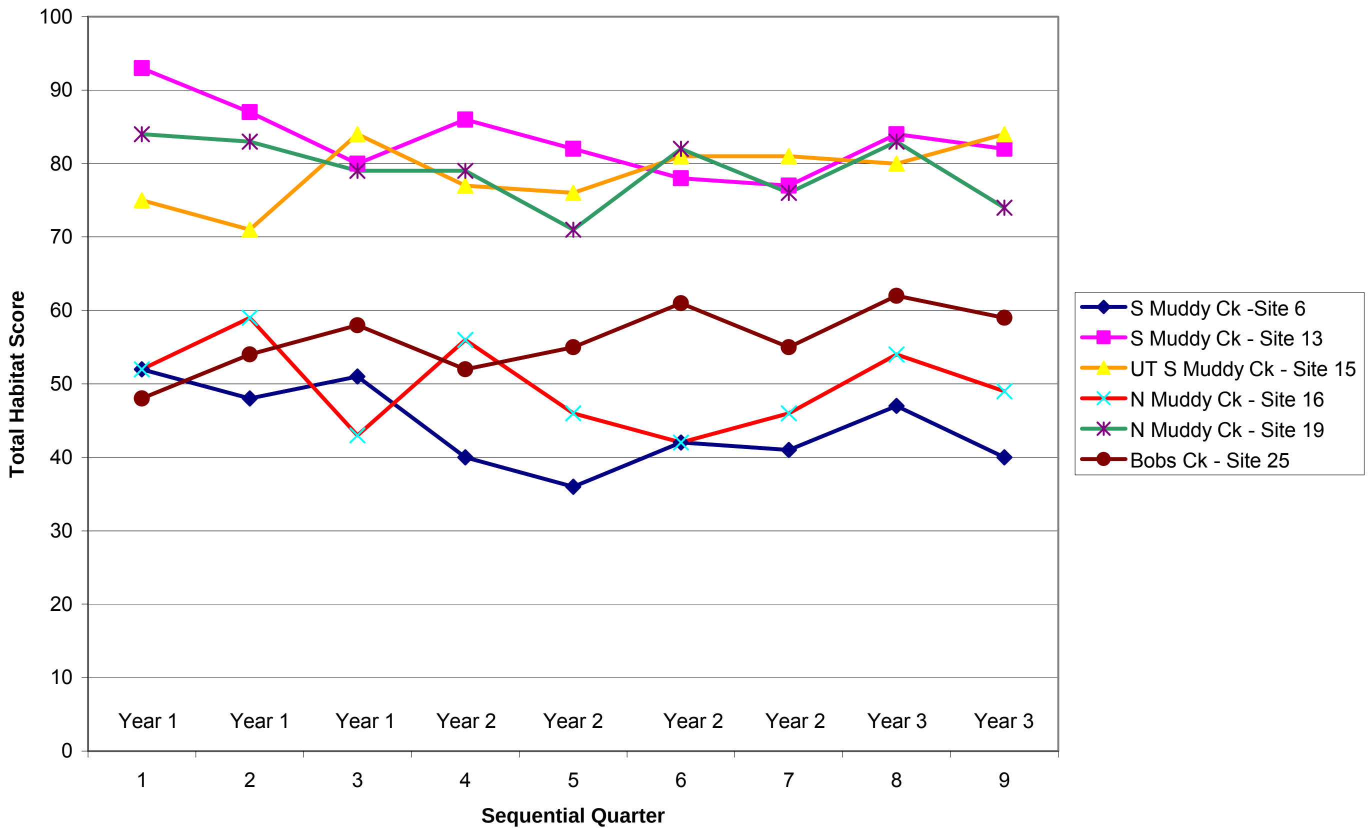
Variability in median riffle substrate size (D_{50}) and embeddedness are much higher (an average of 67% and 33%, respectively). This is rather consistent across sites. This also is not unexpected. Fluctuation in substrate parameters is likely due the episodic nature of bedload transport and variations in the magnitude and timing of flushing events. This is especially true in a dynamic system such as Muddy Creek.

Table F.2. Coefficients of Variation (CV) for Quarterly Monitoring Sites

Site ID	Indicator				
	Habitat	VASOS	% Embeddedness	BEHI	D_{50} (Riffle)
6	13%	23%	26%	8%	104%
13	6%	18%	42%	7%	122%
15	6%	12%	34%	13%	46%
16	12%	25%	27%	5%	30%
19	6%	18%	41%	9%	59%
25	8%	27%	25%	12%	41%
Mean CV	8%	20%	33%	9%	67%

Figure F.1.

Aquatic Habitat Scores at Quarterly Monitoring Sites



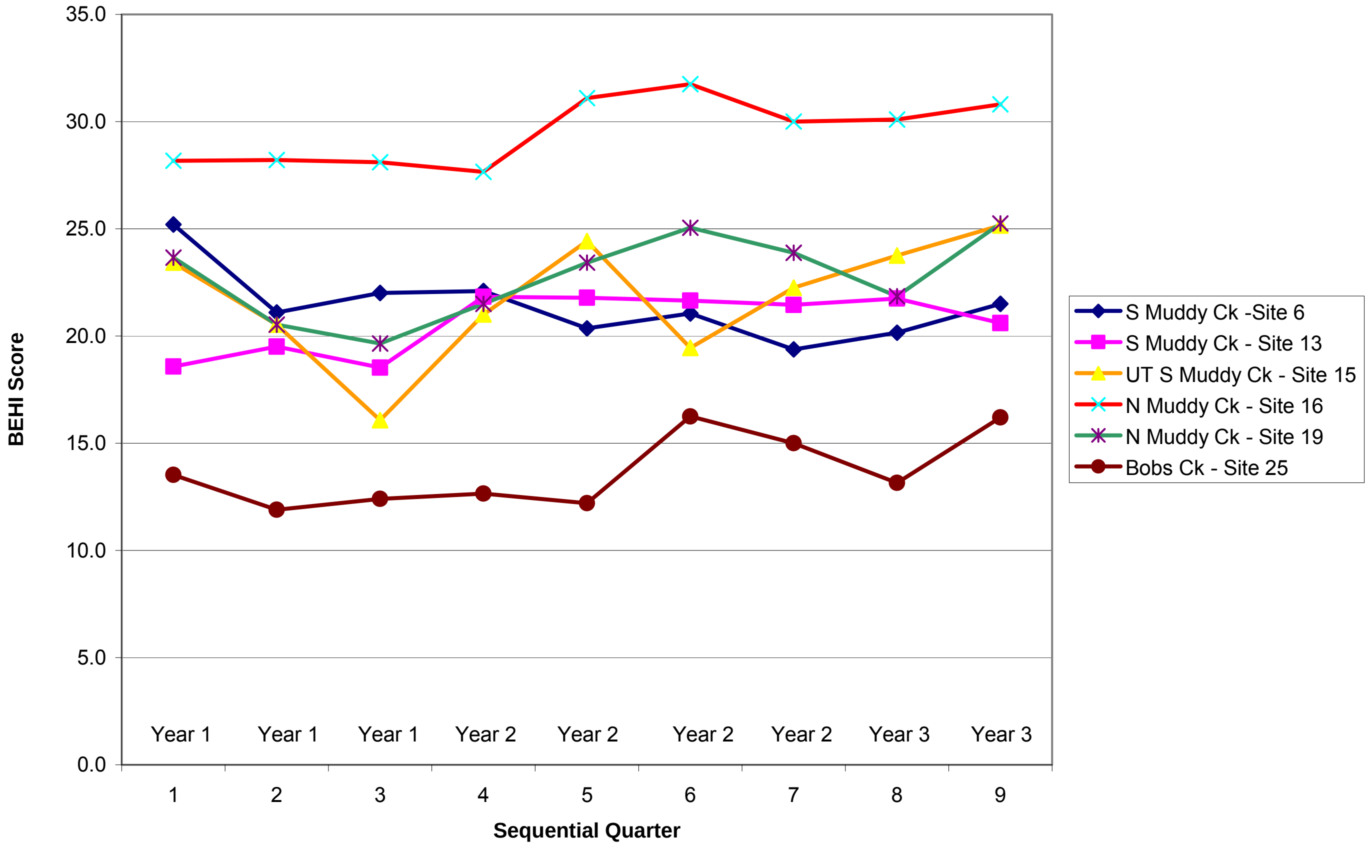
Note: Possible habitat scores range from 0 (worst habitat) to 100 (best habitat).

Table F.3. Summary of Seasonal Data - Aquatic Habitat Score

Indicator	Site					
	Site 6	Site 13	Site 15	Site 16	Site 19	Site 25
Mean	44.1	83.2	78.8	49.7	79.0	56.0
Median	42.0	82.0	80.0	49.0	79.0	55.0
Standard Deviation	5.6	5.0	4.4	5.9	4.5	4.5
Coefficient of Variation	13%	6%	6%	12%	6%	8%
Range	16	16	13	17	13	14
Minimum	36	77	71	42	71	48
Maximum	52	93	84	59	84	62
N	9	9	9	9	9	9

Figure F.2.

BEHI Scores at Quarterly Monitoring Sites



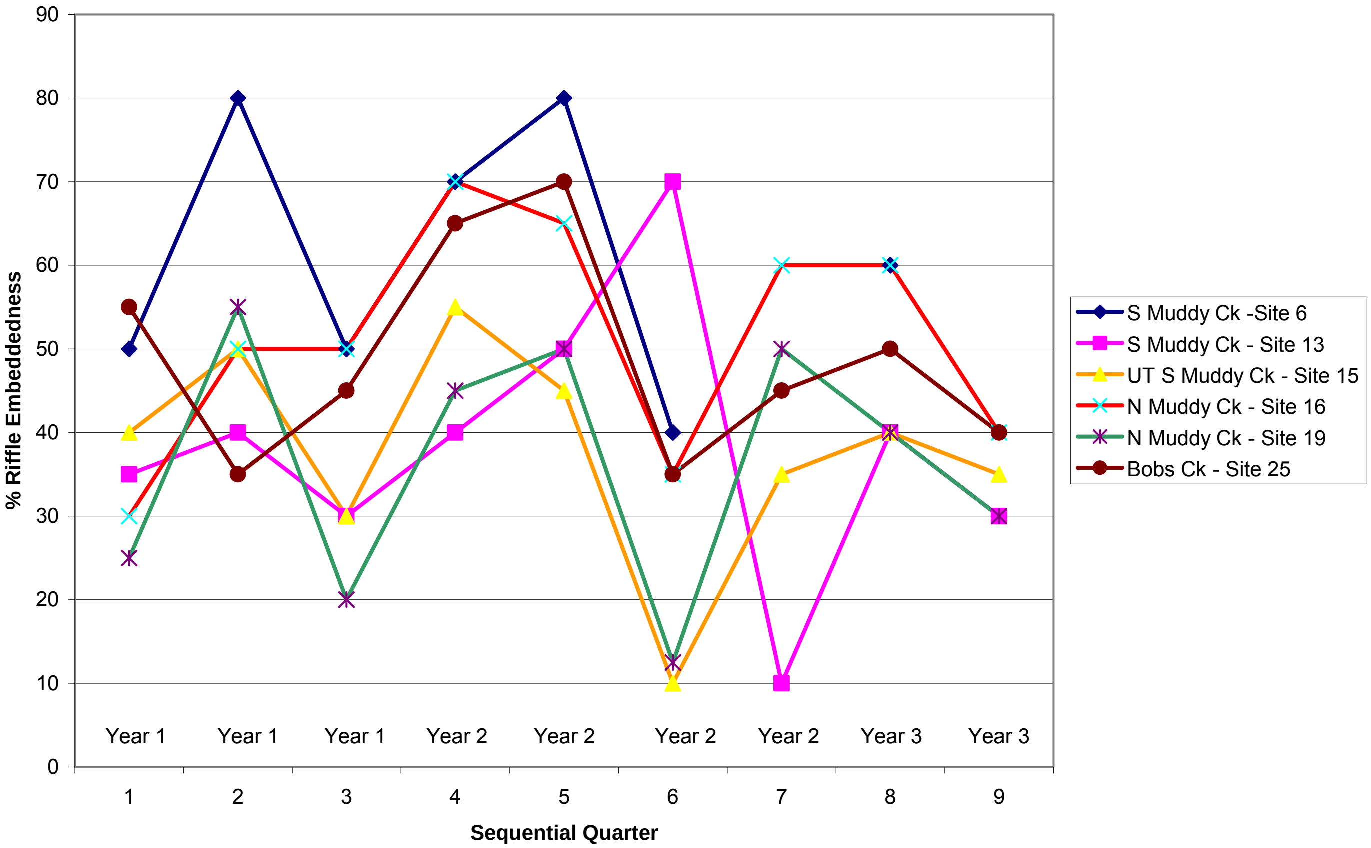
Note: Possible Bank Erosion Hazard Index (BEHI) scores range from 5 (extremely stable) to 50 (extremely unstable).

Table F.4. Summary of Seasonal Data - BEHI Score

Indicator	Site					
	Site 6	Site 13	Site 15	Site 16	Site 19	Site 25
Mean	21.4	20.6	21.8	29.5	22.8	13.7
Median	21.1	21.5	22.3	30.0	23.4	13.2
Standard Deviation	1.7	1.4	2.9	1.5	2.0	1.7
Coefficient of Variation	8%	7%	13%	5%	9%	12%
Range	6	3	9	4	6	4
Minimum	19	19	16	28	20	12
Maximum	25	22	25	32	25	16
N	9	9	9	9	9	9

Figure F.3.

Percent Riffle Embeddedness Scores at Quarterly Monitoring Sites



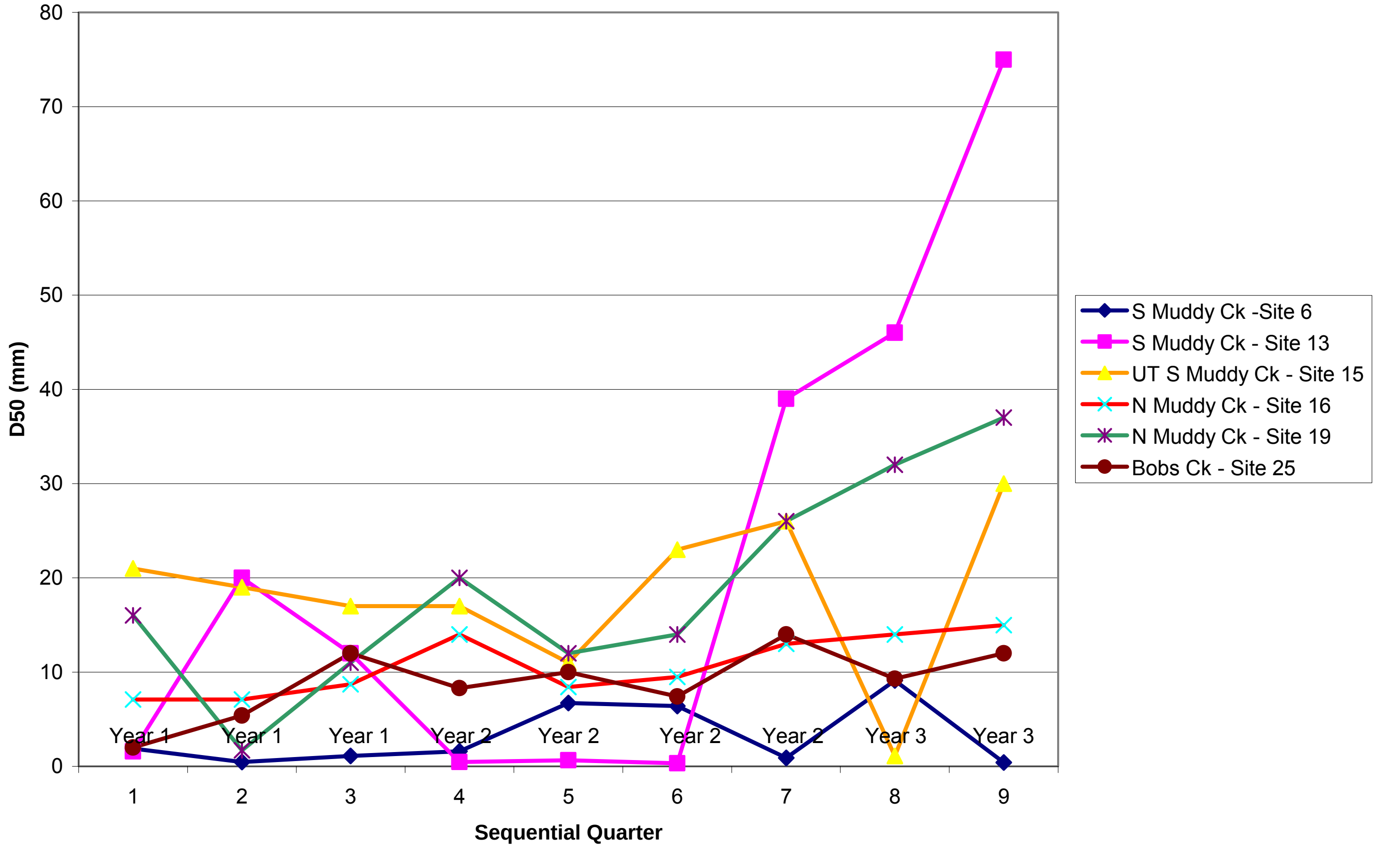
Note: Possible riffle embeddedness values range from 0% (not embedded) to 100% (completely embedded).

Table F.5. Summary of Seasonal Data - Embeddedness (%)

Indicator	Site					
	Site 6	Site 13	Site 15	Site 16	Site 19	Site 25
Mean	61.4	38.3	37.8	51.1	36.4	48.9
Median	60.0	40.0	40.0	50.0	40.0	45.0
Standard Deviation	15.7	16.2	13.0	13.9	15.1	12.4
Coefficient of Variation	26%	42%	34%	27%	41%	25%
Range	40	60	45	40	43	35
Minimum	40	10	10	30	13	35
Maximum	80	70	55	70	55	70
N	7	9	9	9	9	9

Figure F.4.

Riffle D50 at Quarterly Monitoring Sites



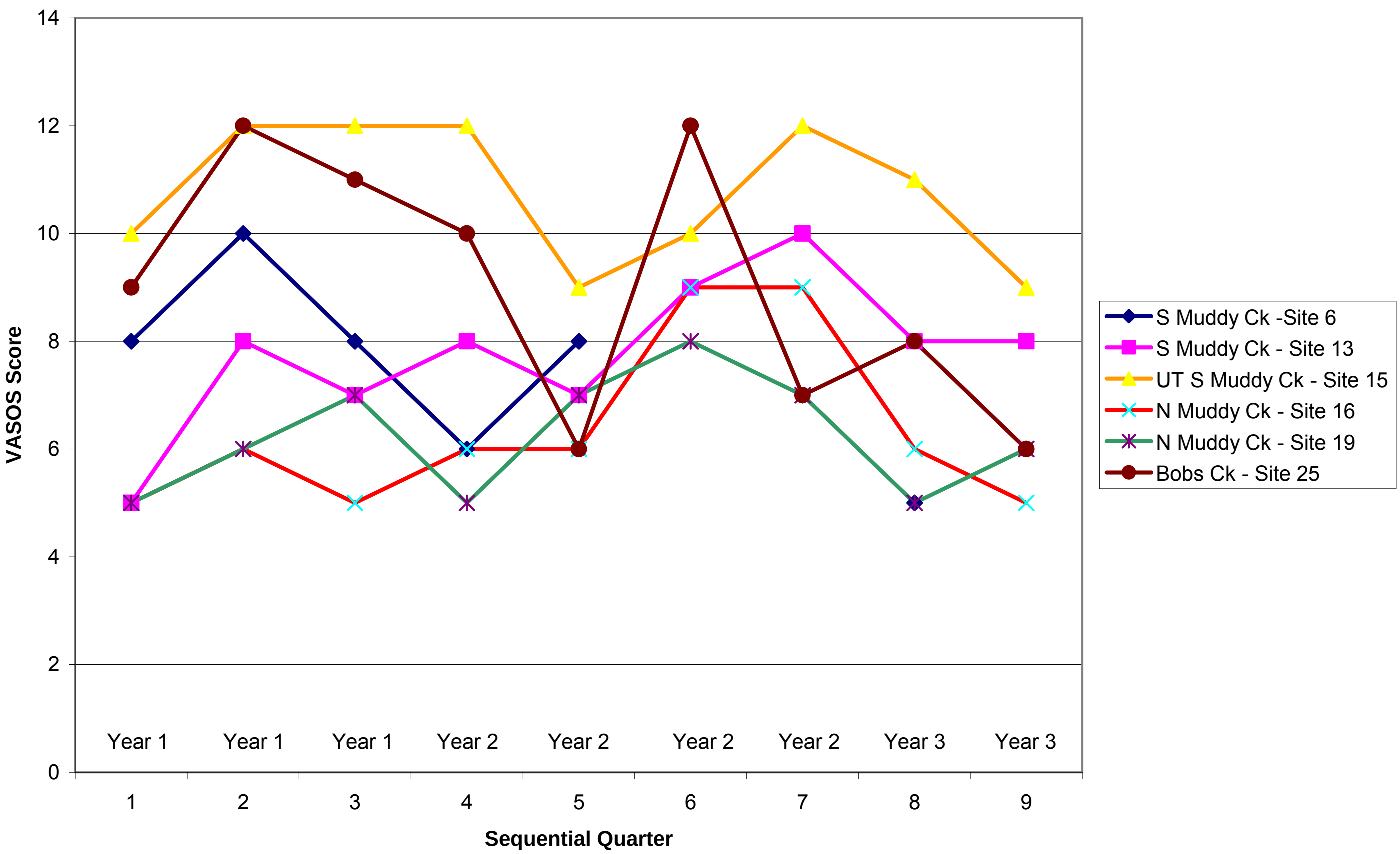
Note: D_{50} values reflect median riffle particle size in mm.

Table F.6. Summary of Seasonal Data – Riffle D_{50} (mm)

Indicator	Site					
	Site 6	Site 13	Site 15	Site 16	Site 19	Site 25
Mean	3.2	21.7	18.3	10.8	18.9	8.9
Median	1.6	12.0	19.0	9.5	16.0	9.3
Standard Deviation	3.3	26.4	8.5	3.2	11.1	3.7
Coefficient of Variation	104%	122%	46%	30%	59%	41%
Range	9	75	29	8	35	12
Minimum	0.4	0.3	1.1	7.1	1.7	2.0
Maximum	9	75	30	15	37	14
N	9	9	9	9	9	9

Figure F.5.

VASOS Scores at Quarterly Monitoring Sites



Note: Possible Virginia Save Our Streams (VASOS) benthic community scores range from 0 (worst) to 14 (best).

Table F.7. Summary of Seasonal Data - VASOS Score

Indicator	Site					
	Site 6	Site 13	Site 15	Site 16	Site 19	Site 25
Mean	7.5	7.8	10.8	6.3	6.2	9.0
Median	8.0	8.0	11.0	6.0	6.0	9.0
Standard Deviation	1.8	1.4	1.3	1.6	1.1	2.4
Coefficient of Variation	23%	18%	12%	25%	18%	27%
Range	5	5	3	4	3	6
Minimum	5	5	9	5	5	6
Maximum	10	10	12	9	8	12
N	6	9	9	9	9	9