CC

Ancycronyx sp.
Argia sp.
Boyeria sp.
Brachycentrus sp.
Calopteryx sp.
Cambaridae
Centroptilum sp.
Chironomidae
Cyphon sp.
Dineutus sp.
Dromogomphus sp.
Dubiraphia sp.
Gyrinus sp.
Hagenius sp.
Hydropsyche sp.
Neureclipsis sp.
Polycentropus sp.
Progomphus sp.
Sialis sp.
Stenelmis sp.
Stenonema sp.
Tabanus sp.
Tipula sp.
Trepobates sp.

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HC

Ancycronyx sp.
Bezzia sp.
Boyeria sp.
Calopteryx sp.
Cambaridae
Chironomidae
Cordulegaster sp.
Cyphon
Dineutus sp.
Dromogomphus sp.
Dubiraphia sp.
Estigmene sp.
Gammarus sp.
Gerris sp.
Gyrinus sp.
Hexagenia sp.
Hydropsyche sp.
Mooreobdella sp.
Noctuidae
Progomphus sp.
Sialis sp.
Stenelmis sp.
Tipula sp.

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NC

Argia sp.
Boyeria sp.
Calopteryx sp.
Cambaridae
Centroptilum sp.
Cordulegaster sp.
Corixidae
Corydalydus
Dineutus sp.
Dromogomphus sp.
Dubiraphia sp.
Gyrinus sp.
Hexagenia sp.
Hydropsyche sp.
Perlesta sp.
Progomphus sp.
Sialis sp.
Stenelmis sp.
Stenonema sp.
Trepobates sp.

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SAC

Ancycronyx sp.
Bezzia sp.
Boyeria sp.
Calopteryx sp.
Cambaridae
Centroptilum sp.
Chironomidae
Cordulegaster sp.
Dineutus sp.
Dixa sp.
Dromogomphus sp.
Dubiraphia sp.
Estigmene sp.
Gammarus sp.
Gomphus sp.
Gyrinus sp.
Hexagenia sp.
Perlesta sp.
Progomphus sp.
Sialis sp.
Simulium sp
Stenelmis sp.
Stenonema sp.
Stylurus sp.
Tipula sp.

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CC	HC	NC	SAC
Ancycronyx sp.	*Argia sp.*	*Argia sp.*	*Bittacomorpha sp.*
Argia sp.	*Asellus sp*	*Berosus sp.*	*Boyeria sp.*
Boyeria sp.	*Bezzia sp.*	*Bezzia sp.*	*Calopteryx sp.*
Calopteryx sp.	*Bittacomorpha sp.*	*Boyeria sp.*	Cambaridae
Cambaridae	*Boyeria sp.*	Cambaridae	*Centroptilum sp.*
Centroptilum sp.	*Caenis sp.*	*Centroptilum sp.*	Chironomidae
Chironomidae	*Calopteryx sp.*	Chironomidae	*Cordulegaster sp.*
Cordulegaster sp.	Cambaridae	*Cordulegaster sp.*	*Dixa sp.*
Corydalus sp.	Chironomidae	*Dineutus sp.*	*Dromogomphus sp.*
Dineutus sp.	*Cordulegaster sp.*	*Gyrinus sp.*	*Dubiraphia sp.*
Dromogomphus sp.	*Dineutus sp.*	*Hydropsyche sp.*	Gammarus sp.
Dubiraphia sp.	*Dromogomphus sp.*	*Perlesta sp.*	*Gelastocoris sp.*
Eurylophella sp.	*Gammarus sp.*	*Progomphus sp.*	*Gyrinus sp.*
Gammarus sp.	*Gerris sp.*	*Stenelmis sp.*	*Hexagenia limbata*
Gyrinus sp.	*Gyrinus sp.*	*Stenonema sp.*	*Hyallela azteca*
Hagenius sp.	*Hexagenia limbata*	*Trepobates sp.*	*Hydropsyche sp.*
Hexagenia limbata	*Hydroporus sp.*		*Perlesta sp.*
Hyallela azteca	*Libellula sp.*		*Polycentropus sp.*
Lirceus sp.	*Neophylax sp.*		*Progomphus sp.*
Macromia sp.	*Pachydiplax*		*Sialis sp.*
Neophylax sp.	*Progomphus sp.*		*Stenelmis sp.*
Neureclipsis sp.	*Simulium sp.*		*Stenonema sp.*
Perlesta sp.	*Stenelmis sp.*		*Tipula sp.*
Polycentropus sp.	*Tabanus sp.*		*Trepobates sp.*
Progomphus sp.			
Simulium sp.			
Stenelmis sp.			
Stenonema sp.			
Stylurus sp.			
Tipula sp.			
Trepobates sp.			
31	24	16	24

Ameiurus natalis
Aphredoderus sayanus
Cyprinella venusta
Erimyzon sucetta
Esox americanus vermiculatus
Etheostoma asprigene
Etheostoma chlorosomum
Etheostoma gracile
Etheostoma parvipinne
Etheostoma whipplei
Fundulus notatus
Fundulus olivaceus
Gambusia affinis
Ichthyomyzon gagei
Lepomis cyanellus
Lepomis megalotis
Lepomis punctatus
Lythurus umbratilis
Lythurus fumeus
Micropterus punctulatus
Minytrema melanops
Moxostoma poecilurum
Notimegonus chrysoleucas
Notropis atrocaudalis
Noturus nocturnus
Percina sciera
Semotilus atromaculatus

Ameiurus melas
Ameiurus natalis
Aphredoderus sayanus
Cyprinella venusta
Erimyzon sucetta
Esox americanus vermiculatus
Etheostoma asprigene
Etheostoma chlorosomum
Etheostoma gracile
Etheostoma parvipinne
Etheostoma whipplei
Fundulus notatus
Fundulus olivaceus
Gambusia affinis
Ichthyomyzon gagei
Lepomis cyanellus
Lepomis marginatus
Lepomis megalotis
Lepomis punctatus
Lythrurus fumeus
Lythrurus umbratilis
Micropterus punctulatus
Micropterus salmoides
Minytrema melanops
Moxostoma poecilurum
Notropis atrocaudalis
Noturus nocturnus
Opsopoedus emilae
Percina sciera
Semotilus atromaculatus

Site ID	Sample Date	Activity	Conductivity (m	Flow (cfs)	Water Temp (C)	Turbidity (NTU)	DO
CCA	9/13/2006	Grab	0.0344	0.285	21.96	2.5	7.26
CCA	9/19/2006	Storm				21.0	
CCA	10/10/2006	Grab	0.0381	0.385	17.81	3.1	7.41
CCA	10/12/2006	Storm					
CCA	10/18/2006	Storm				11.0	
CCA	10/20/2006	Storm				9.2	
CCA	10/27/2006	Storm				31.0	
CCA	11/7/2006	Storm					
CCA	11/20/2006	Grab	0.0441	0.937	9.62	5.1	9.01
CCA	12/12/2006	Storm					
CCA	12/14/2006	Grab	0.0514	1.246	10.60	5.9	9.97
CCA	12/21/2006	Storm				7.1	
CCA	12/26/2006	Storm					
CCA	1/2/2007	Storm				18.0	
CCA	1/5/2007	Storm				40.0	
CCA	1/8/2007	Storm					
CCA	1/18/2007	Storm				45.0	
CCA	1/22/2007	Storm				11.0	
CCA	1/26/2007	Grab	0.0533	2.592	7.12	8.2	11.16
CCA	2/14/2007	Storm				26.0	
CCA	2/19/2007	Grab	0.0510	1.920	9.69	7.9	10.89
CCA	3/9/2007	Grab	0.0432	1.537	14.66	11.0	9.71
CCA	3/16/2007	Storm				15.0	
CCA	3/29/2007	Storm					
CCA	4/17/2007	Habitat	0.0408	0.916	14.17	8.3	8.67
CCA	4/27/2007	Storm					
CCA	4/30/2007	Grab	0.0412	0.530	18.13	11.0	7.85
CCA	4/30/2007	Grab-Duplicate					
CCA	5/4/2007	Storm				25.0	
CCA	5/25/2007	Storm				40.0	
CCA	5/31/2007	Grab	0.0463	2.157	19.57	14.0	7.98
CCA	6/1/2007	Storm					
CCA	6/18/2007	Storm				24.0	

pH (SU)	TSS (mg/L)	TP (mg/L as P)	TN (mg/L as N)	TKN (mg/L as N	AnaLab Report
6.67	1.50	0.0500	0.5000	0.2800	857075
	50.00	0.1820	0.5000	1.2000	858635
6.56	0.50	0.0500	0.5000	0.0990	863690
	11.00	0.0500	0.5000	0.7970	865471
	23.30	0.0500	0.5000	0.9880	865481
			0.5000	0.6700	867120
	94.70	0.0500	0.5000	1.4200	868569
	36.00	0.0500	0.5000	0.7300	870290
6.65	2.50	0.0500	0.5000	0.4560	873158
			0.5000	0.1760	878766
6.12	2.50	0.0500	0.5000	0.3000	879799
			0.5000	0.2420	881522
	6.00	0.0500			881520
	26.00				883072
	66.70	0.3490	0.5000	1.0800	884614
	6.00				884605
	22.00	0.0500	0.5000	1.0800	886372
	16.00	0.0500	0.5000	0.4580	887610
6.05	0.50	0.0500	0.5000	0.3620	888019
	28.00	0.0500	0.5000	0.6600	892855
6.13	2.20	0.0500	0.5000	0.5340	894569
6.11	8.00	0.0500	0.5000	0.0250	899759
	6.70	0.0500	0.5000	0.6070	901470
	14.00				903975
5.91					
	14.00				911481
6.90	9.00	0.0250	0.5000	0.5560	911486
	4.00	0.0250	0.5000	0.4120	911487
	30.00	0.0500	0.5000	0.8080	913401
	88.00	0.1410	0.5000	0.8280	357893
5.92	9.00	0.2910	0.5000	0.5950	358507
		0.0500			358501
	36.00	0.0334	0.5000	0.6600	360678

Site ID	Sample Date	Activity	Conductivity (m	Flow (cfs)	Water Temp (C)	Turbidity (NTU)	DO
CCA	6/28/2007	Storm					
CCA	6/29/2007	Grab	0.0445	0.716	22.68	13.0	6.97
CCA	7/9/2007	Storm				38.0	
CCA	7/11/2007	Grab	0.0437	1.727	24.56	15.0	6.87
CCA	7/16/2007	Storm				60.0	
CCA	8/2/2007	Storm					
CCA	8/6/2007	Grab	0.0420		25.00	9.7	6.02
CCA	8/7/2007	Grab-Duplicate					
CCB	9/13/2006	Grab	0.0347	0.205	22.03	3.5	7.51
CCB	9/19/2006	Storm				19.0	
CCB	10/10/2006	Grab	0.0380	0.310	17.36	3.2	8.92
CCB	10/18/2006	Storm				15.0	
CCB	11/20/2006	Grab	0.0464	0.943	8.93	5.3	10.39
CCB	12/14/2006	Grab-Duplicate					
CCB	12/14/2006	Grab	0.0530	1.362	10.29	5.5	10.30
CCB	12/21/2006	Storm					
CCB	12/26/2006	Storm					
CCB	1/2/2007	Storm				18.0	
CCB	1/5/2007	Storm				95.0	
CCB	1/18/2007	Storm				45.0	
CCB	1/22/2007	Storm				17.0	
CCB	1/26/2007	Grab	0.0533	2.718	6.83	9.0	10.66
CCB	2/14/2007	Storm				29.0	
CCB	2/19/2007	Grab	0.0521	2.098	8.91	9.2	11.30
CCB	3/9/2007	Grab	0.0441	1.628	14.45	19.0	9.88
CCB	3/13/2007	Storm				14.0	
CCB	3/16/2007	Storm				18.0	
CCB	3/29/2007	Storm				29.0	
CCB	4/17/2007	Habitat	0.0415	0.780	13.10	9.1	9.20
CCB	4/27/2007	Storm				19.0	
CCB	4/30/2007	Grab	0.0428	0.465	17.81	11.0	8.29
CCB	5/4/2007	Storm				50.0	
CCB	5/25/2007	Storm				29.0	

pH (SU)	TSS (mg/L)	TP (mg/L as P)	TN (mg/L as N)	TKN (mg/L as N	AnaLab Report
	16.00	0.0427	0.5000	1.0800	361976
6.26	12.00	0.1820	0.5000	0.5180	361975
	52.00	0.0482	0.5000	1.1500	363030
5.80	12.00	0.0279	0.5000	0.5260	363028
	50.00	0.1150	0.5000	0.2960	363828
	36.00	0.2070	0.5000	0.9400	365876
6.40	8.00	0.0353	0.5000	0.5620	366255
	10.00	0.0732	0.5000	0.5420	366255
6.48	2.50	0.2020	0.5000	0.5260	857074
	40.00	0.1500	0.5000	0.9700	858636
6.34	0.50	0.0500	0.5000	0.0250	863689
	19.00	0.0500	0.5000	0.8760	865488
6.54	3.00	0.0500	0.5000	0.2800	873157
	0.50	0.0500	0.5000	0.2410	879801
5.85	3.00	0.0500	0.5000	0.1870	879800
			0.5000	0.4470	881523
			0.5000	0.5230	881521
	12.00				830573
	72.00	0.0500	0.5000	1.1500	886377
	17.50	0.0500	0.5000	0.4470	887611
5.82	0.50	0.0500	0.5000	0.3580	888018
	30.00	0.0500	0.5000	0.6690	892854
5.83	5.70	0.0500	0.5000	0.3380	894568
6.16	2.40	0.0500	0.5000	0.0250	899760
	16.00	0.0500	0.5000	0.3240	899763
	5.30	0.0500	0.5000	0.6570	901471
	28.00	0.2290	0.5000	1.5200	903976
6.37					
	14.00	0.0250	0.5000	0.6450	911482
6.68	5.00	0.0250	0.5000	0.1470	911488
	38.20	0.0500	0.5000	0.9830	913400
	82.00	0.2740	0.5000	1.4800	357893

Site ID	Sample Date	Activity	Conductivity (m	Flow (cfs)	Water Temp (C)	Turbidity (NTU)	DO
CCB	5/31/2007	Grab	0.0460	2.576	19.44	16.0	8.24
CCB	6/28/2007	Storm				18.0	
CCB	6/29/2007	Grab	0.0452	0.659	22.97	14.0	7.15
CCB	7/9/2007	Storm				37.0	
CCB	7/11/2007	Grab	0.0497	1.798	24.77	16.0	7.07
CCB	8/7/2007	Grab	0.0339		25.03	10.0	6.55
HCA	9/20/2006	Grab	0.0698		20.78	9.9	6.79
HCA	10/13/2006	Grab	0.0767	0.025	17.46	7.4	7.73
HCA	10/20/2006	Storm				11.0	
HCA	10/27/2006	Storm				65.0	
HCA	11/7/2006	Storm				360.0	
HCA	11/15/2006	Grab	0.0778	0.228	16.30	9.6	6.68
HCA	11/29/2006	Storm				9.9	
HCA	12/12/2006	Storm				7.5	
HCA	12/15/2006	Grab	0.0814	0.173	13.35	6.5	7.68
HCA	12/26/2006	Storm					
HCA	1/2/2007	Storm				18.0	
HCA	1/5/2007	Storm				21.0	
HCA	1/18/2007	Storm				50.0	
HCA	1/24/2007	Grab	0.0692	0.948	10.01	17.0	10.02
HCA	2/14/2007	Storm				23.0	
HCA	2/19/2007	Grab	0.0702	0.443	9.18	7.8	10.62
HCA	3/9/2007	Grab	0.0640	0.281	13.39	7.2	9.24
HCA	3/16/2007	Storm				16.0	
HCA	3/28/2007	Storm				32.0	
HCA	4/23/2007	Grab	0.0699	0.131	18.40	10.0	6.71
HCA	5/4/2007	Storm				31.0	
HCA	5/31/2007	Grab-Duplicate					
HCA	5/31/2007	Grab	0.0617	0.287	21.49	21.0	7.35
HCA	6/1/2007	Storm					
HCA	6/18/2007	Storm				95.0	
HCA	6/19/2007	Grab	0.0665	0.393	24.79	21.0	5.72
HCA	7/9/2007	Storm				50.0	

pH (SU)	TSS (mg/L)	TP (mg/L as P)	TN (mg/L as N)	TKN (mg/L as N	AnaLab Report
6.02	11.00	0.1180	0.5000	0.3550	358507
	28.00	0.0889	0.5000	0.9800	361976
6.23	13.30	0.1000	0.5000	0.6990	361975
	126.00	0.0667	0.5000	1.1000	363030
5.95	12.00	0.0667	0.5000	0.4460	363028
6.35	10.00	0.2350	0.5000	0.4960	366255
6.09	9.00	0.0500	0.5000	0.2700	858643
6.24	3.00	0.0500	0.5000	0.2000	865467
	10.70	0.1490	0.5000	0.4030	867112
	135.00	0.0500	0.5000	1.4400	868570
	444.00	0.2390	0.5000	2.9000	870291
5.71	22.00	0.0500	0.5000	0.0674	872001
	20.00	0.0500	0.5000	0.5000	874972
	5.50		0.5000	0.2380	878768
5.95	7.30	0.0500	0.5000	0.1990	879797
	16.00	0.0500			881519
	24.00	0.0500	0.5000	0.3110	883070
	33.30				884602
	78.00	0.0500	0.5000	1.2300	886376
5.57	6.00	0.0500	0.5000	0.1450	887600
	60.00	0.0500	0.5000	0.3710	892856
5.75	8.00	0.0500	0.5000	0.2860	894571
5.73	6.00	0.0500	0.5000	0.0829	899761
	7.30	0.0500	0.5000	0.4550	901469
	12.00	0.0500	0.5000	0.9500	903977
5.72	20.00	0.0500	0.5000	0.3750	910181
	36.40	0.0500	0.5000	0.7480	913398
	18.20	0.1850	0.5000	0.6290	358507
5.67	22.00	0.2330	0.5000	0.5980	358507
	36.00				358501
	152.00	0.1630	0.5000	1.2100	360678
5.71	11.40	0.0926	0.5000	0.4530	360684
		0.1300	0.5000	0.8790	363030

Site ID	Sample Date	Activity	Conductivity (m	Flow (cfs)	Water Temp (C)	Turbidity (NTU)	DO
HCA	7/16/2007	Storm				50.0	
HCA	7/24/2007	Grab	0.0673		20.65	23.0	7.22
HCA	8/8/2007	Grab	0.0690		24.57	37.0	7.04
HCA	8/20/2007	Storm					
HCB	9/20/2006	Grab	0.0702	0.104	20.52	9.5	8.02
HCB	10/13/2006	Grab	0.0741	0.159	16.15	9.0	9.43
HCB	10/18/2006	Storm				25.0	
HCB	10/27/2006	Storm				260.0	
HCB	11/7/2006	Storm				600.0	
HCB	11/15/2006	Grab	0.0805	0.604	16.07	8.6	8.09
HCB	11/29/2006	Storm				18.0	
HCB	12/12/2006	Storm				55.0	
HCB	12/15/2006	Grab	0.0834	0.549	13.62	5.5	8.70
HCB	12/26/2006	Storm				19.0	
HCB	1/2/2007	Storm				16.0	
HCB	1/5/2007	Storm				20.0	
HCB	1/18/2007	Storm				110.0	
HCB	1/24/2007	Grab	0.0740	1.736	10.35	14.0	10.15
HCB	1/24/2007	Grab-Duplicate					
HCB	2/19/2007	Grab	0.0743	0.921	8.99	7.5	10.77
HCB	2/26/2007	Storm				15.0	
HCB	3/9/2007	Grab	0.0679	0.637	12.33	6.1	9.76
HCB	3/28/2007	Storm					
HCB	4/23/2007	Grab	0.0736	0.423	17.78	7.9	7.66
HCB	5/4/2007	Storm				31.0	
HCB	5/31/2007	Grab	0.0644	0.763	20.66	16.0	8.20
HCB	6/1/2007	Storm					
HCB	6/18/2007	Storm				50.0	
HCB	6/19/2007	Grab	0.0707	0.836	24.01	21.0	6.82
HCB	7/9/2007	Storm				45.0	
HCB	7/16/2007	Storm				85.0	
HCB	7/24/2007	Grab	0.0735		21.25	19.0	7.82
HCB	8/8/2007	Storm					

pH (SU)	TSS (mg/L)	TP (mg/L as P)	TN (mg/L as N)	TKN (mg/L as N	AnaLab Report
	78.00				363828
6.27	6.00	0.1190	0.5000	0.3990	364579
6.19	14.00	0.1220	0.5000	1.1500	366255
	46.00	0.1090	0.5000	1.3700	368060
6.04	5.00	0.0500	0.5000	0.1200	858642
6.13	4.00	0.0500	0.5000	0.1300	865468
	24.00		0.5000	0.7490	865478
	528.00	0.3500	0.5000	3.1800	868571
	516.00	0.4030	0.5000	5.5300	870289
5.85	14.00	0.0500	0.5000	0.5700	872003
	90.00	0.0500	0.5000	0.1500	874973
	80.00	0.1400	0.5000	0.6190	878767
5.74	5.00	0.0500	0.5000	0.0250	879798
	20.00	0.2760	0.5000	1.3500	881517
	24.00	0.0500	0.5000	0.4000	883071
	127.00	0.4100	0.5000	1.1200	884612
	152.00	0.0500	0.5000	1.0000	886375
6.09	6.00	0.0500	0.5000	0.3420	887601
	6.00	0.0500	0.5000	0.2320	887602
5.94	6.40	0.0500	0.5000	0.1350	894570
	45.50	0.0500	0.5000	0.3010	896129
5.72	6.10	0.0500	0.5000	0.0250	899762
	132.00				903978
6.13	12.00	0.0500	0.5000	0.2980	910182
	28.00	0.0500	0.5000	0.5920	913402
5.68	22.00	0.1670	0.5000	0.5720	358507
	88.00				358501
	68.00	0.1220	0.5000	0.5410	360678
5.68	17.00	0.0316	0.5000	0.3770	360684
	16.40	0.1180	0.5000	0.8280	363030
	76.00	0.3850	0.5000	0.1150	363828
5.84	5.00	0.0649	0.5000	0.3110	364579

Site ID	Sample Date	Activity	Conductivity (m	Flow (cfs)	Water Temp (C)	Turbidity (NTU)	DO
HCB	8/8/2007	Grab	0.0748		23.22	28.0	7.69
HCB	8/20/2007	Storm				29.0	
NCA	9/7/2006	Grab	0.0585	0.020	23.02	12.5	6.51
NCA	10/4/2006	Grab	0.0578		21.43	13.0	6.03
NCA	10/4/2006	Grab-Duplicate					
NCA	10/18/2006	Storm				190.0	
NCA	10/20/2006	Storm				230.0	
NCA	10/27/2006	Storm				180.0	
NCA	11/3/2006	Grab	0.0360	4.011	12.12	16.0	10.21
NCA	11/7/2006	Storm				65.0	
NCA	12/5/2006	Grab	0.0428	1.671	6.27	9.9	12.18
NCA	12/13/2006	Storm				75.0	
NCA	1/5/2007	Storm				70.0	
NCA	1/18/2007	Storm				65.0	
NCA	1/22/2007	Storm				26.0	
NCA	1/23/2007	Grab	0.0355	7.700	9.22	18.0	10.53
NCA	2/14/2007	Storm				170.0	
NCA	2/20/2007	Grab	0.0371	5.006	12.95	13.0	10.22
NCA	2/26/2007	Storm				29.0	
NCA	3/16/2007	Storm					
NCA	3/20/2007	Grab	0.0438	2.186	17.47	13.0	9.31
NCA	4/2/2007	Storm				45.0	
NCA	4/9/2007	Grab	0.0409	1.830	13.16	11.0	8.51
NCA	4/16/2007	Storm				160.0	
NCA	4/27/2007	Storm					
NCA	5/24/2007	Grab	0.0522	0.494	21.73	8.7	8.08
NCA	6/5/2007	Grab	0.0480	0.181	23.76	11.0	8.15
NCA	6/5/2007	Grab-Duplicate					
NCA	6/18/2007	Storm				100.0	
NCA	7/18/2007	Storm				130.0	
NCA	7/25/2007	Grab	0.0465		23.18	26.0	8.10
NCA	7/25/2007	Storm				170.0	
NCA	7/30/2007	Storm				160.0	

pH (SU)	TSS (mg/L)	TP (mg/L as P)	TN (mg/L as N)	TKN (mg/L as N	AnaLab Report
5.90	14.00	0.2330	0.5000	0.5040	366255
	44.00	0.1440	0.5000	0.7460	368060
6.71	6.00	0.0500	0.5000	0.3340	855716
6.69	18.60	0.0500	0.5000	0.4900	861949
	8.80	0.0500	0.5000	0.5060	861950
	392.00	0.3600	0.5000	1.4000	865476
	54.00	0.0500	0.5000	2.0000	867122
	39.20	0.0500	0.5000	1.6000	868566
6.03	4.00	0.0500	0.5000	0.2000	870287
	84.00	0.0500	0.5000	0.6600	870294
5.46	4.00	0.0500	0.5000	0.1700	876814
	96.00	0.0500	0.5000	0.5340	878770
	107.00	0.2960	0.5000	0.6980	884616
	62.50	0.0500	0.5000	0.7600	886373
	34.00	0.0500	0.5000	0.3160	887608
7.06	10.70	0.0500	0.5000	0.1790	887603
	123.00	0.0500	0.5000	0.6520	892850
6.38	2.50	0.0500	0.5000	0.2420	894574
			0.5000	0.5540	896130
	12.00	0.0500	0.5000	0.3420	901473
6.17	4.00	0.0500	0.5000	0.2560	901475
	32.00		0.5000	0.3360	903971
6.75	5.90	0.0500	0.5000	0.4290	905938
	237.00	0.1690	0.5000	1.2000	908448
	20.00		0.5000	0.4690	911483
6.61	4.50	0.0891	0.5000	0.4260	357895
6.46	10.00	0.2520	0.5000	0.4140	358965
	4.00	0.2090	0.5000	0.3920	358965
	148.00	0.0963	0.5000	0.7690	360678
	124.00	0.5190	0.5000	0.3680	363828
6.37	3.50	0.0741	0.5000	0.4170	364579
	356.00	0.1440	0.5000	1.6300	364580
	180.00	0.3640	0.5000	0.8260	365349

Site ID	Sample Date	Activity	Conductivity (m	Flow (cfs)	Water Temp (C)	Turbidity (NTU)	DO
NCA	8/2/2007	Storm				110.0	
NCA	8/6/2007	Grab	0.0449		28.36	17.0	7.02
NCB	9/7/2006	Grab	0.0530	0.024	21.86	15.0	4.15
NCB	10/4/2006	Grab	0.0576		21.15	14.0	4.82
NCB	10/13/2006	Storm				40.0	
NCB	10/18/2006	Storm				230.0	
NCB	10/20/2006	Storm				950.0	
NCB	10/27/2006	Storm				250.0	
NCB	11/3/2006	Grab	0.0355	4.472	11.77	17.0	10.30
NCB	11/7/2006	Storm				80.0	
NCB	12/5/2006	Grab	0.0432	1.691	6.30	9.7	12.22
NCB	12/13/2006	Storm				85.0	
NCB	12/26/2006	Storm				35.0	
NCB	1/2/2007	Storm				270.0	
NCB	1/5/2007	Storm				120.0	
NCB	1/18/2007	Storm				110.0	
NCB	1/22/2007	Storm					
NCB	1/23/2007	Grab	0.0375	8.031	9.28	16.0	10.64
NCB	2/14/2007	Storm				240.0	
NCB	2/20/2007	Grab-Duplicate					
NCB	2/20/2007	Grab	0.0368	5.371	12.84	13.0	10.20
NCB	2/26/2007	Storm				33.0	
NCB	3/16/2007	Storm					
NCB	3/20/2007	Grab	0.0439	2.279	17.14	13.0	9.38
NCB	4/2/2007	Storm				26.0	
NCB	4/9/2007	Grab	0.0412	1.696	12.52	11.0	9.13
NCB	4/16/2007	Storm				120.0	
NCB	4/27/2007	Storm					
NCB	5/24/2007	Grab	0.0526	0.365	21.08	8.7	8.20
NCB	6/5/2007	Grab	0.0496	0.356	22.50	12.0	8.12
NCB	6/18/2007	Storm				45.0	
NCB	7/18/2007	Storm				85.0	
NCB	7/25/2007	Storm				65.0	

pH (SU)	TSS (mg/L)	TP (mg/L as P)	TN (mg/L as N)	TKN (mg/L as N	AnaLab Report
	122.00	0.1110	0.5000	0.9550	365876
6.41	7.50	0.1560	0.5000	0.4560	365877
6.64	7.30	0.0500	0.5000	0.4100	855717
6.18	8.60	0.0500	0.5000	0.4980	861951
	69.20				865470
	568.00	0.3410	0.5000	1.6300	865477
	1,750.00	0.1490	0.5000	3.4000	867121
	760.00	0.0500	0.5000	2.0900	868568
6.21	8.70	0.0500	0.5000	0.0949	870288
	156.00	0.0500	0.5000	0.3650	870293
6.55	3.00	0.0500	0.5000	0.2300	876815
	86.00	0.0500	0.5000	0.3520	878769
	32.00	0.0500	0.5000	0.9060	881518
	360.00	0.0500	0.5000	1.6000	883061
	180.00	0.3960	0.5000	1.0400	884617
	64.00	0.0500	0.5000	0.9200	886371
			0.5000	0.4240	887609
6.38	8.00	0.0500	0.5000	0.1980	887604
	570.00	0.0500	0.5000	1.3900	892851
	5.30	0.0500	0.5000	0.2820	894572
5.98	4.50	0.0500	0.5000	0.2020	894573
	50.00				901474
6.44	6.00	0.0500	0.5000	0.2800	901476
	28.00	0.3450	0.5000	0.3410	903972
6.70	10.00	0.0500	0.5000	0.3990	905939
	187.00	0.1910	0.5000	0.9440	908447
			0.5000	0.4420	911475
6.67	4.50	0.0780	0.5000	0.4170	357895
6.69	5.00	0.7970	0.5000	0.3020	358965
	56.00	0.0769	0.5000	0.6790	360678
	132.00	0.0704	0.5000	0.5150	363828
	96.00	0.3790	0.5000	1.6000	364580

Site ID	Sample Date	Activity	Conductivity (m	Flow (cfs)	Water Temp (C)	Turbidity (NTU)	DO
NCB	7/25/2007	Grab	0.0456		22.51	20.0	8.36
NCB	7/30/2007	Storm				65.0	
NCB	8/2/2007	Storm				85.0	
NCB	8/6/2007	Grab	0.0446		27.87	19.0	7.25
SACA	9/6/2006	Grab	0.0291	0.051	22.79	5.5	7.35
SACA	9/19/2006	Storm				18.0	
SACA	10/6/2006	Grab	0.0344	0.037	22.66	7.8	8.29
SACA	10/13/2006	Storm				70.0	
SACA	10/18/2006	Storm				80.0	
SACA	10/27/2006	Storm				140.0	
SACA	11/13/2006	Storm				23.0	
SACA	11/16/2006	Grab	0.0353	0.420	12.69	6.3	9.87
SACA	11/16/2006	Grab-Duplicate					
SACA	12/13/2006	Storm				28.0	
SACA	12/13/2006	Grab	0.0363	0.523	11.72	6.1	10.46
SACA	12/22/2006	Storm				21.0	
SACA	1/2/2007	Storm				110.0	
SACA	1/18/2007	Storm				500.0	
SACA	1/23/2007	Grab	0.0246	1.720	10.41	14.0	10.34
SACA	2/14/2007	Storm				170.0	
SACA	2/20/2007	Grab	0.0262	0.983	13.32	9.8	10.07
SACA	2/26/2007	Storm					
SACA	3/16/2007	Storm					
SACA	3/21/2007	Grab	0.0273	0.601	19.56	12.0	8.82
SACA	3/28/2007	Storm					
SACA	4/19/2007	Grab	0.0288	0.520	15.43	11.0	9.53
SACA	4/27/2007	Storm				18.0	
SACA	5/8/2007	Grab	0.0323	0.324	21.81	13.0	8.37
SACA	6/1/2007	Storm					
SACA	6/6/2007	Storm					
SACA	6/6/2007	Grab	0.0298	0.300	21.85	12.0	7.68
SACA	6/18/2007	Storm				190.0	
SACA	7/9/2007	Storm				55.0	

pH (SU)	TSS (mg/L)	TP (mg/L as P)	TN (mg/L as N)	TKN (mg/L as N	AnaLab Report
6.76	5.30	0.0778	0.5000	0.3840	364579
	64.00	0.4110	0.5000	0.7120	365349
	96.00	0.3260	0.5000	0.9490	365876
6.44	7.50	0.1260	0.5000	0.3890	365877
6.73	0.50	0.0500	0.5000	0.1500	855714
	34.70		0.5000	0.3450	858634
6.27	6.50	0.0500	0.5000	0.1740	863688
	41.70		0.5000	0.7440	865469
	308.00	0.1580	0.5000	0.3740	865474
	340.00	0.2660	0.5000	1.4800	868572
	58.00	0.0500	0.5000	0.8570	871994
6.07	9.20	0.0500	0.5000	0.2040	873161
	4.60	0.0500	0.5000	0.2490	873160
	36.00	0.0500	0.5000	0.3860	878771
5.83	6.00	0.0500	0.5000	0.0250	878764
	28.00	0.0500	0.5000	0.1100	881516
	180.00	0.2220	0.5000	2.0700	883068
	724.00	0.1720	0.5000	2.3900	886378
7.05	10.50	0.0500	0.5000	0.0676	887605
	260.00	0.1090	0.5000	1.0200	892852
6.61	3.00	0.0500	0.5000	0.1460	894576
	37.10	0.0500			896131
	20.00		0.5000	0.4140	901472
6.25	5.00	0.0500	0.5000	0.2780	901477
	28.00		0.5000	0.7420	903973
6.51	6.00	0.0500	0.5000	0.2680	908445
	8.00		0.5000	0.2370	911484
6.63	3.00	0.0500	0.5000	0.2340	913399
	352.00	0.6120	0.5000	1.3800	358501
	93.30	0.0500			358964
6.60	8.00	3.3100	0.5000	0.4820	358965
	268.00	0.0982	0.5000	0.6550	360678
	62.00	0.1000	0.5000	0.6530	363030

Site ID	Sample Date	Activity	Conductivity (m	Flow (cfs)	Water Temp (C)	Turbidity (NTU)	DO
SACA	7/17/2007	Storm				45.0	
SACA	7/31/2007	Grab-Duplicate					
SACA	7/31/2007	Grab	0.0326		24.69	9.9	7.98
SACA	8/15/2007	Grab	0.0337		24.78	9.6	7.63
SACA	8/20/2007	Storm				200.0	
SACB	9/6/2006	Grab	0.0324	0.015	20.84	5.9	7.46
SACB	10/6/2006	Grab	0.0384	0.018	22.12	11.0	8.67
SACB	10/18/2006	Storm				150.0	
SACB	10/27/2006	Storm				340.0	
SACB	11/7/2006	Storm				28.0	
SACB	11/13/2006	Storm				11.0	
SACB	11/16/2006	Grab	0.0408	0.621	12.90	6.3	10.02
SACB	12/13/2006	Grab	0.0410	0.689	9.96	6.6	10.84
SACB	12/13/2006	Storm				27.0	
SACB	12/22/2006	Storm				28.0	
SACB	1/2/2007	Storm				400.0	
SACB	1/5/2007	Storm				40.0	
SACB	1/18/2007	Storm				550.0	
SACB	1/22/2007	Storm				75.0	
SACB	1/23/2007	Grab	0.0273	2.614	10.11	13.0	10.47
SACB	2/14/2007	Storm				280.0	
SACB	2/20/2007	Grab	0.0296	1.298	12.96	10.0	10.10
SACB	2/26/2007	Storm				18.0	
SACB	3/21/2007	Grab-Duplicate					
SACB	3/21/2007	Grab	0.0312	0.902	18.59	10.0	8.89
SACB	3/28/2007	Storm					
SACB	4/19/2007	Grab	0.0322	0.618	13.12	9.5	10.05
SACB	4/27/2007	Storm				19.0	
SACB	5/8/2007	Grab	0.0361	0.457	21.66	14.0	8.45
SACB	6/1/2007	Storm					
SACB	6/6/2007	Grab	0.0350	0.492	21.29	12.0	8.18
SACB	6/6/2007	Storm					
SACB	6/18/2007	Storm				900.0	

pH (SU)	TSS (mg/L)	TP (mg/L as P)	TN (mg/L as N)	TKN (mg/L as N	AnaLab Report
	68.00	0.2260	0.5000	0.1280	363828
	10.00	0.0408	0.5000	0.0250	
6.31	11.70	0.0926	0.5000	0.0250	365348
6.37	8.00	0.0131	0.5000	0.0766	367107
	240.00	0.1720	0.5000	1.7500	368060
6.88	1.50	0.0500	0.5000	0.0250	855715
7.25	3.50	0.0500	0.5000	0.0250	863691
	320.00	0.4270	0.5000	1.1400	865475
	488.00	0.1590	0.5000	2.1000	868573
	54.00	0.0500	0.5000	0.2690	870292
	10.00	0.0500	0.5000	0.0250	871996
6.12	5.30	0.0500	0.5000	0.3040	873159
6.37	9.30	0.0500	0.5000	0.0250	878765
	34.00	0.0500	0.5000	0.2830	878772
	34.00	0.0500	0.5000	0.1600	881515
	580.00	0.0500	0.5000	0.4200	883069
	26.70	0.0500	0.5000	0.3120	884615
	624.00	0.1030	0.5000	1.6600	886374
	306.00	0.0500	0.5000	0.3950	887607
7.04	11.50	0.0500	0.5000	0.0831	887606
	320.00				892853
6.72	2.50	0.0500	0.5000	0.1500	894575
	31.00	0.0500	0.5000	0.3490	896128
	5.00	0.0500	0.5000	0.1520	901479
6.34	7.00	0.0500	0.5000	0.1190	901478
	34.00				903974
6.62	7.00	0.0500	0.5000	0.1380	908446
	18.00		0.5000	0.3070	911476
6.81	3.80	0.0500	0.5000	0.2050	913397
	116.00	0.1980	0.5000	0.6880	358501
6.02	7.50	0.4270	0.5000	0.2880	358965
	56.70	0.0371	0.5000	0.4960	358964
	1,040.00	0.3940	0.5000	2.5500	360678

Site ID	Sample Date	Activity	Conductivity (m	Flow (cfs)	Water Temp (C	Turbidity (NTU)	DO
SACB	7/9/2007	Storm				130.0	
SACB	7/31/2007	Grab	0.0372		25.30	11.0	8.03
SACB	8/2/2007	Storm					
SACB	8/15/2007	Grab	0.0379		24.67	15.0	7.89
SACB	8/20/2007	Storm				400.0	

pH (SU)	TSS (mg/L)	TP (mg/L as P)	TN (mg/L as N)	TKN (mg/L as N	AnaLab Report
	178.00	0.0982	0.5000	0.8030	363030
6.63	10.00	0.0050	0.5000	0.1280	365348
	2.00	0.1560	0.5000	0.5830	365876
6.56	9.00	0.0050	0.5000	0.1190	367107
	353.00	0.1590	0.5000	1.4700	368060




EVALUATING THE EFFECTIVENESS OF TEXAS FORESTRY BEST MANAGEMENT PRACTICES

Results from the Texas Silvicultural BMP Effectiveness Monitoring Project 2003-2007

TEXAS FOREST SERVICE
A Member of the Texas A&M University System

December 2008

TEXAS FOREST SERVICE
The Texas A&M University System

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December 2008

By

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Best Management Practices Project
Texas Forest Service
Lufkin, Texas

PREPARED IN COOPERATION WITH THE
TEXAS STATE SOIL AND WATER CONSERVATION BOARD
AND
U.S. ENVIRONMENTAL PROTECTION AGENCY

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EXECUTIVE SUMMARY

Four perennial streams on intensively managed silvicultural sites in East Texas were monitored from September 2003 until September 2007 to evaluate the effectiveness of Texas forestry Best Management Practices (BMPs) in protecting water quality. This was done to test the hypothesis that forestry operations, using properly applied BMPs, would not have a significant impact on water quality.

This project followed the BACI study design. Reference and test sections were established upstream and downstream of the treatment area, respectively. Biological (benthic macroinvertebrates, fish, and habitat) and physiochemical (grab and stormwater) monitoring was conducted on these sections for one year prior to the treatment (regeneration harvest, site preparation, and reforestation) to obtain a baseline. Data collection continued for three years after the initial treatment. Treatments were conducted in accordance with the state recommended BMP guidelines.

Weather conditions varied over the course of the project from extremely wet to extremely dry. Average rainfall for this area is approximately 46 inches. In 2004, the project sites received almost 70 inches of rain, while only 32 inches of rain fell in 2005.

Statistical analyses (ANOVA) were conducted to test for significant differences among the project results at each section (upstream vs. downstream), time period (pre- vs. post-treatment), and their interaction (section vs. time period). The interaction analysis was used to determine if a treatment effect had occurred at $\alpha = 0.05$. The physiochemical data showed no significant differences in the interaction analysis. The biological data showed significant differences in habitat results at two sites (Cherokee and San Augustine) and in fish results at one site (Houston). In all three cases, the post-treatment section/period interaction was higher than its pre-treatment counterpart, indicating the treatment had no negative effect on these parameters. Therefore, this project showed that BMPs, when applied properly, are effective in protecting water quality during forestry operations.

INTRODUCTION

Forestry BMPs have been developed and implemented for almost 20 years in Texas. Texas Forest Service promotes these practices and monitors their implementation. Published reports have shown that these guidelines have been embraced by the forestry community, noting significant improvement in BMP implementation rates over the years to the current all time high of 91.7% (Simpson et al., 2005). However, this approach only addresses the presence and functionality of BMPs, not their actual effectiveness in protecting water quality. A controlled, holistic stream biological and physiochemical monitoring approach would be critical to determine the effectiveness of Texas forestry BMPs.

Numerous studies have been conducted in the South to determine the effects of specific forest practices on water quality, both with and without the use of BMPs (Jackson et al., 2004). Similar studies designed to look at more of a holistic approach of the entire operation are not as common. There has only been one project to take the latter approach (Vowell, 2000). However, it was not conducted under the conditions found in the Western Gulf region, and only included a biological monitoring component.

Monitoring BMP effectiveness is also mandated by federal law. The reauthorization of the Clean Water Act (CWA) of 1987 required that "states develop methods for determining BMP effectiveness," something Texas has not done for its forestry BMP guidelines.

The Texas BMP Effectiveness Monitoring Project, funded by a FY03 CWA Section 319(h) grant from the Environmental Protection Agency (EPA) through the Texas State Soil and Water Conservation Board (TSSWCB), was designed to determine the effectiveness of BMPs in reducing nonpoint source (NPS) pollution from silvicultural activities. This report documents the findings of this monitoring project.

SELECTION OF PROJECT SITES

The site selection criteria that were used for this project were extremely restrictive. Project sites had to be under intensive, operational forest management and adjacent to perennial streams. These streams had to originate on and flow through commercial timberlands, as well as have comparable fluvial conditions above and below the proposed treatment area. This limited the effects any non-silvicultural activities (poultry, cattle, agriculture, construction, urban, etc.) could have on the project, facilitated a clearer analysis of the project results, and provided additional quality assurance/control.

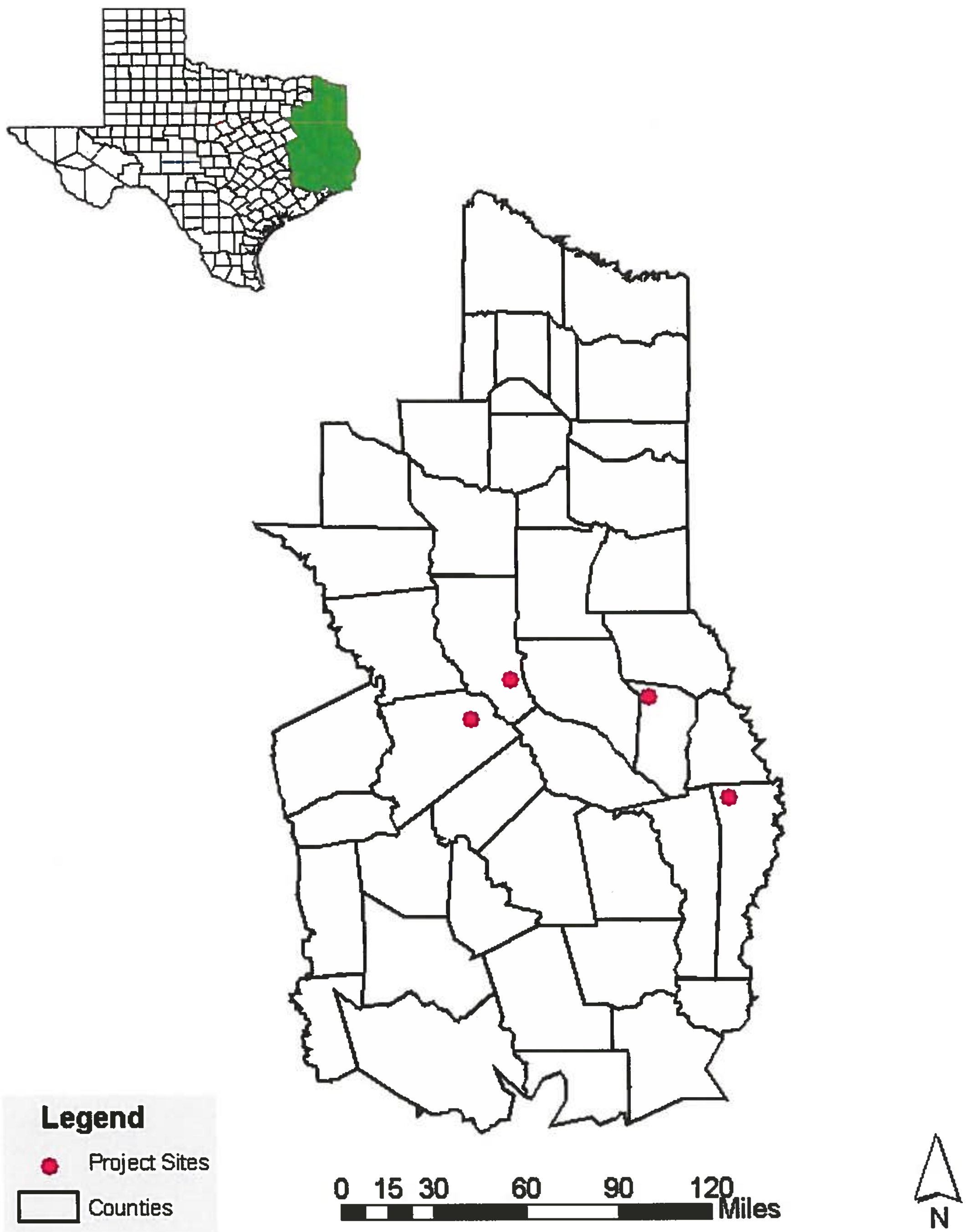
Sites were also selected to include significant topography and erodibility. These conditions were chosen on the basis that if BMPs can protect water quality on these "worst case scenario" tracts, then they should be able to protect water quality on other East Texas tracts with less severe topography and erodibility. Finally, to facilitate data collection, the sites had to be located within an hour's drive of Lufkin, Texas, and scheduled for harvest in 2004 through 2005.

STREAMS

Second and third order perennial streams were selected for this project in order to facilitate biological monitoring, mainly fish assemblages. Watersheds ranged in size from 500 to 2300 acres.

Four sites were selected: Walker Creek in Cherokee County, Johnson Creek in Houston County, East Prong of McKim Creek in Newton County, and an unnamed creek in San Augustine County. See Figure 1.

Figure 1. Location of project sites.



SITE LAYOUT

Project sites were divided into two sections. The reference was located upstream of the treatment area and the test was located downstream of the treatment area. Five, evenly spaced stream transects, 125 feet apart, were established at each section, and constituted the monitoring reach (500 feet) for the biological assessment. Monitoring stations, consisting of an automatic water sampler and flow meter housed in a metal box, were installed at each section along the monitoring reach of the project sites. A standard National Weather Service rain gauge and a tipping bucket rain gauge were installed at each site to obtain precipitation data. The standard gauge measured the total precipitation, while the tipping bucket recorded start/stop time and intensity. The treatment area encompassed up to 25% of the watershed. See Figures 2 and 3.

Figure 2. Typical project site layout.

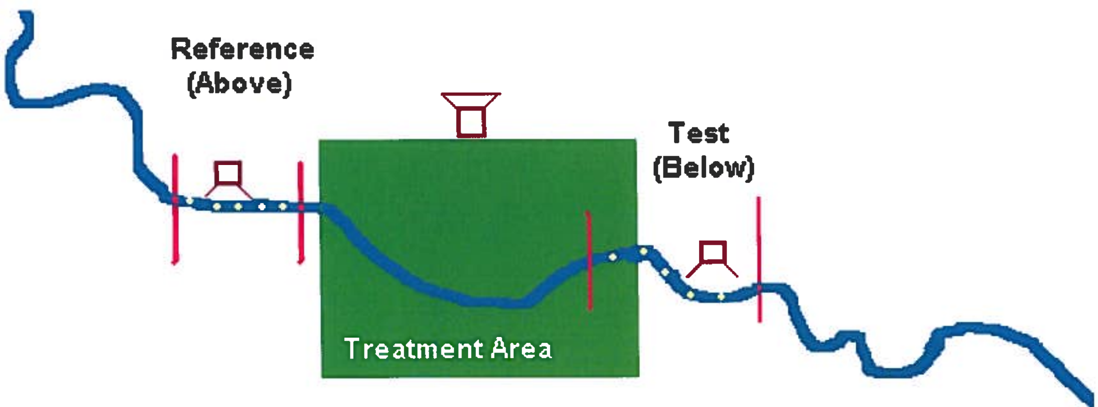
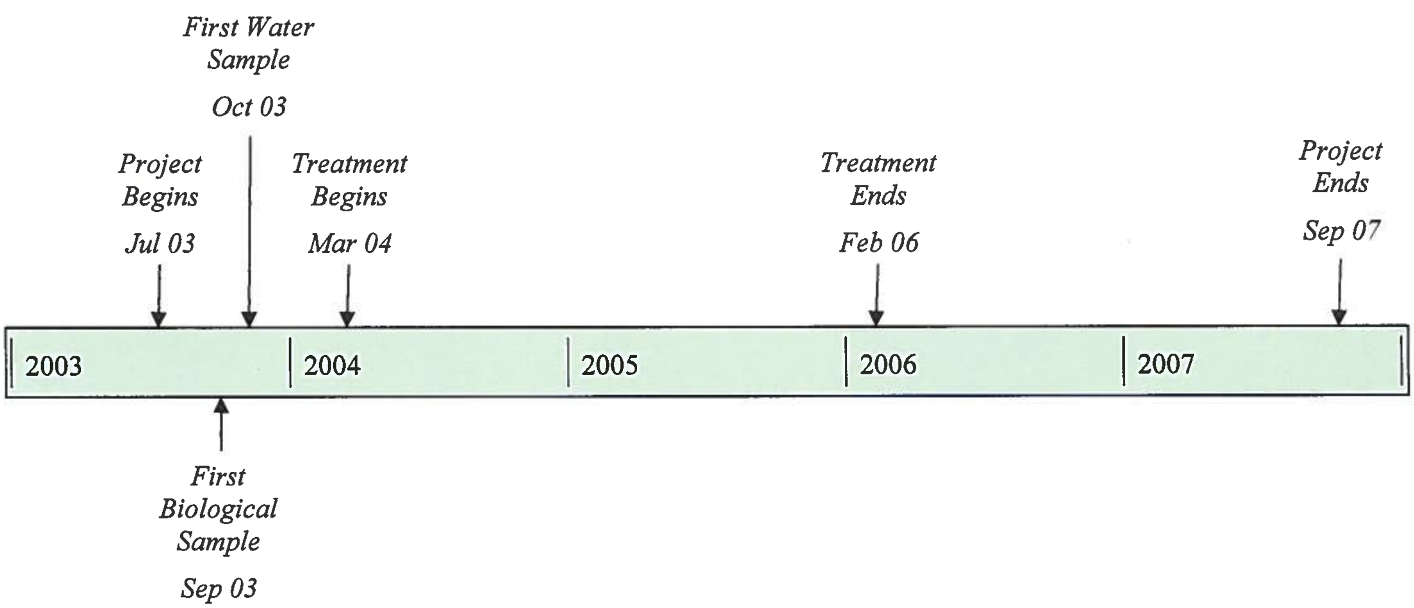


Figure 3. Monitoring station and rain gauges.

SCHEDULE

The project began in July 2003 and was completed in September 2007. Biological sampling was conducted twice a year, during spring (April – May) and late summer (August – September). Grab samples were collected monthly, while stormwater samples were collected based on weather (approximately 40 times per year). Treatments began in March 2004 and concluded in February 2006. See Figure 4.

Figure 4. Project timeline.



TREATMENTS

Operational treatments were conducted at all sites in accordance with state recommended BMPs. Project sites underwent a commercial timber harvest, site preparation, and machine planting of loblolly pine. All harvest contractors were trained in BMPs and had a current "Pro Logger" certificate.

SAMPLING PARAMETERS

Grab samples were monitored for the following parameters: dissolved oxygen (DO), potential hydrogen (pH), specific conductance, total nitrogen (TN), total phosphorous (TP), total suspended solids (TSS), turbidity, water temperature, and stream flow. Stormwater samples were monitored for the following parameters: TN, TP, TSS, and turbidity. Biological monitoring consisted of a habitat assessment, benthic macroinvertebrate sampling, and fish sample collection. See Table 1.

Table 1. Summary of biological and physiochemical sampling parameters.

Parameter	Biological	Grab	Stormwater
Dissolved Oxygen		X	
pH		X	
Specific Conductivity		X	
Temperature		X	
Stream Flow		X	
Total Nitrogen		X	X
Total Phosphorous		X	X
Total Suspended Solids		X	X
Turbidity		X	X
Rainfall Amount			X
Rainfall Intensity			X
Benthic Macroinvertebrates	X		
Fish	X		
Habitat	X		

SAMPLING METHODS / DATA COLLECTION

Sampling methods were conducted in accordance with the protocols established by the Texas Commission on Environmental Quality (TCEQ) in *Surface Water Quality Monitoring Procedures*, Volumes 1 and 2. Test sections were always monitored before reference sections to prevent contamination of downstream water quality samples. Appropriate scientific collection permits from Texas Parks and Wildlife Department (TPWD) were obtained prior to biological sampling. Data from the monitoring stations and rain gauges were downloaded monthly to a laptop.

Biological Monitoring – Benthic Macroinvertebrates

A D-frame kick net was used to collect benthic macroinvertebrates along the monitoring reach. This net was swept across the stream bed along riffles, runs, and glides to dislodge organisms. After "sweeping" for five minutes, the contents of the net were emptied into a dishpan. Benthic macroinvertebrates were then removed using forceps and placed in a collection jar with 70% isopropyl alcohol. Sampling continued, keeping record of the number of "sweeps" that were made, until 100 individual macroinvertebrates were collected. Organisms were also collected from submerged leaf and twig samples. Crawfish were counted and released. Samples were then labeled and sent to a taxonomist for identification and enumeration. See Figure 5.

Figure 5. Sampling for benthic macroinvertebrates.

Biological Monitoring – Fish

A backpack electrofisher, operated by a TPWD fisheries biologist, was used to sample fish species. This equipment emits an electrical current in the water, temporarily stunning fish and causing them to float to the surface so they can be collected. This was done for a minimum of 15 minutes, or longer if new species were still being collected, starting from the bottom of the monitoring reach and working upstream.

A seine was also used because of its effectiveness in collecting smaller fish in riffles and deep pools that may have been missed by the electrofisher. This large net was stretched across the water and pulled upstream parallel to the bank, ensuring that the lead line remained firmly on the stream bottom. This process was continued until a minimum of six effective hauls were completed along the monitoring reach, covering a minimum of 60 meters. See Figure 6.

Fish samples were separated based on the collection method employed. The TPWD fisheries biologist field identified the samples, releasing any known specimens into the stream after monitoring was completed. Results were reported on the appropriate biological monitoring form.

Two representative samples of each species per site and monitoring period were reserved for reference. Digital photographs were taken as reference vouchers in some cases. Any samples that were not easily field identified, along with reference samples, were preserved in a 90% formalin solution and returned to the lab for identification.

Figure 6. Collecting fish specimens.

Biological Monitoring – Habitat Assessment

General physical characteristics of the stream along the entire monitoring reach were determined from field observations. Direct measurements were also taken at each of the five stream transects and in the area extending three meters on either side of the transect line. Data collected from these observations and measurements were reported on the habitat assessment form to calculate the Habitat Quality Index. See Figure 7.

Figure 7. Conducting habitat assessment.

Physiochemical Monitoring – Grab Water Samples

Grab samples were collected immediately upstream of monitoring stations at each section on a monthly basis. Water was collected from the stream and placed in pre-preserved sample bottles for analysis of TN, TP, and TSS. A duplicate sample was collected at a different site each month for quality control purposes. Bottles were labeled and placed on ice until delivered to the contract lab, ensuring all holding times were met.

Turbidity was measured using a portable turbidity meter. Water was collected from the stream and allowed to reach ambient air temperature before placing it in the meter for analysis. Water temperature, pH, specific conductivity, and dissolved oxygen were measured *in-situ* with a Hydrolab multiprobe datasonde.

Stream flow was measured using a Marsh-McBirney portable flowmeter at designated areas located near the monitoring station for each section. Velocity and depth measurements were taken at regular intervals across the stream cross section. Average velocity and cross sectional area were then used to calculate stream flow. All physiochemical data was recorded on the water quality monitoring data sheet.

Physiochemical Monitoring – Stormwater Samples

Flow-weighted composite stormwater samples were collected from monitoring stations. An ISCO 4230 bubbler flowmeter was used to measure stage (flow depth) continuously at 15-minute intervals. A stage-discharge relationship was established at each site by measuring flow rate (discharge) using the Marsh-McBirney flowmeter at a variety of stages. This information was programmed into the bubbler flowmeter, allowing constant flow rate and volume measurements to be taken on the project streams. Upon detecting a 0.3 foot rise in stream level, the bubbler flowmeter activated the ISCO 3700 water sampler. Samples were automatically collected at one millimeter intervals (volumetric depth based on runoff from the watershed) while the bubbler flowmeter was enabled.

Water was retrieved from the sampler, measured, and placed in pre-preserved sample bottles for analysis of TN, TP, and TSS. First priority was given to TSS, TP, and then TN when minimum sample analysis volumes were not met. Turbidity was measured on any remaining sample volume. Bottles were labeled and placed on ice until delivered to the contract lab, ensuring all holding times were met.

DATA ANALYSIS

Biological metrics (see Table 2) were used to calculate the Aquatic Life Use (ALU) and Habitat Quality Index (HQI) for each section based on the protocols established by TCEQ in *Surface Water Quality Monitoring Procedures*, Volume 2. Metrics were assigned a numerical value based on where they scored in a given range. The individual values were summed to obtain a total score for each section, which related to a general ALU or HQI (Exceptional, High, Intermediate, or Limited).

Physiochemical parameters measured *in-situ*, along with grab sample concentrations, were analyzed to establish baseflow conditions before and after silvicultural treatments. Non-detectable laboratory results were assigned a value equal to one half of the method detection limit. Precipitation and streamflow relationships were also developed to determine possible treatment effects. Stormwater sample concentrations were converted to loads (kg/ha) for analysis. This was done by multiplying the storm event flow volume by the sample concentration and dividing by the watershed area. Correlations between TSS and turbidity were also analyzed. Annual sediment and nutrient losses for the project sites were computed.

Statistical analyses (ANOVA) were conducted to test for significant differences among the project results at each section (upstream vs. downstream), time period (pre- vs. post-treatment), and their interaction (section vs. time period) at $\alpha = 0.05$. The interaction analysis was used to determine if a treatment effect had occurred.

Table 2. Summary of biological metrics.

Benthic Macroinvertebrates	Fish	Habitat
Taxa richness	Total # of species	Available instream cover
EPT taxa abundance	# of Native cyprinid species	Bottom substrate stability
Biotic Index (HBI)	# of Benthic invertivore species	# of Riffles
% Chironomidae	# of Sunfish species	Dimensions of largest pool
% Dominant taxon	# of Intolerant species	Channel flow status
% Dominant FFG	% of Individuals as tolerant	Bank stability
% Predators	% of Individuals as omnivores	Channel sinuosity
Ratio of intolerant to tolerant taxa	% of Individuals as invertivores	Riparian buffer vegetation
% of Trichoptera as Hydropsychidae	% of Individuals as piscivores	Aesthetics of reach
# of Non-insect taxa	# of Individuals in sample	
% Collector/Gatherers	# of Individuals/seine haul	
% of Total as Elmidae	# of Individuals/min. electrofishing	
	% Individuals non-native	
	% Individuals with disease	

RESULTS AND DISCUSSION

Over the course of the project, nine biological assessments were conducted at each section (three pre-treatment, six post-treatment); grab samples were taken once a month at each section for 47 months; and stormwater samples were collected on 139 dates where needed.

Biological Monitoring – Benthic Macroinvertebrates

Project streams proved to be extremely diverse in benthic macroinvertebrate populations, with 115 different species being collected, 31 of which were found at all sites. Common species included damsel/dragonflies, mayflies, caddisflies, water beetles, midges, and crawfish. The majority of organisms collected were in the Ephemeroptera and Odonata orders, while the predominant functional feeding group (FFG) was predator. The least common order and functional feeding group was Diptera and shredder, respectively.

ALU scores ranged from 18 (Limited) to 36 (High), with most falling in the Intermediate to High classification. Mean post-treatment results decreased at all but one section (San Augustine upstream). Statistical analysis showed these section/period interaction declines were not significant. A potential cause may be linked to the weather. In 2004 (pre-treatment), East Texas experienced one of the wettest years on record, while 2005 (post-treatment) was one of the driest, even with Hurricane Rita dropping 10 inches of rain on some of the project sites. This weather pattern began in March 2005 and at some sites lasted until field data collection ended in September 2007. Droughty, low flow stream conditions are not conducive to benthic macroinvertebrate survival and reproduction (Wiseman and Matthews, 2000).

Several individual metrics played integral roles in determining the resulting ALU score. The percent of predators and percent of Trichoptera as Hydropsychidae consistently provided lower scores than other metrics, while the percent of Elmidae scored higher. Trends associated with seasonal and sectional differences were not found. See Tables 3 and 6 and Figures 8 and 9.

Table 3. Benthic macroinvertebrate Aquatic Life Use scores across all project sites.

Season	Cherokee		Houston		Newton		San Augustine	
	Above	Below	Above	Below	Above	Below	Above	Below
Fall 03	28	28	27	33	27	27	28	30
Spring 04	36	28	25	31	29	30	26	24
Fall 04	32	31	28	27	31	27	30	30
Spring 05	33	32	26	23	28	31	25	29
Fall 05	34	25	27	29	27	25	26	28
Spring 06	29	23	24	32	28	28	31	27
Fall 06	28	18	21	30	20	23	26	26
Spring 07	31	34	23	28	23	20	33	31
Fall 07	27	25	27	25	25	24	33	24

Ratings (per TCEQ):
> 36 = Exceptional
29 – 36 = High
22 – 28 = Intermediate
< 22 = Limited

Figure 8. Mean benthic macroinvertebrate Aquatic Life Use scores across all sites.

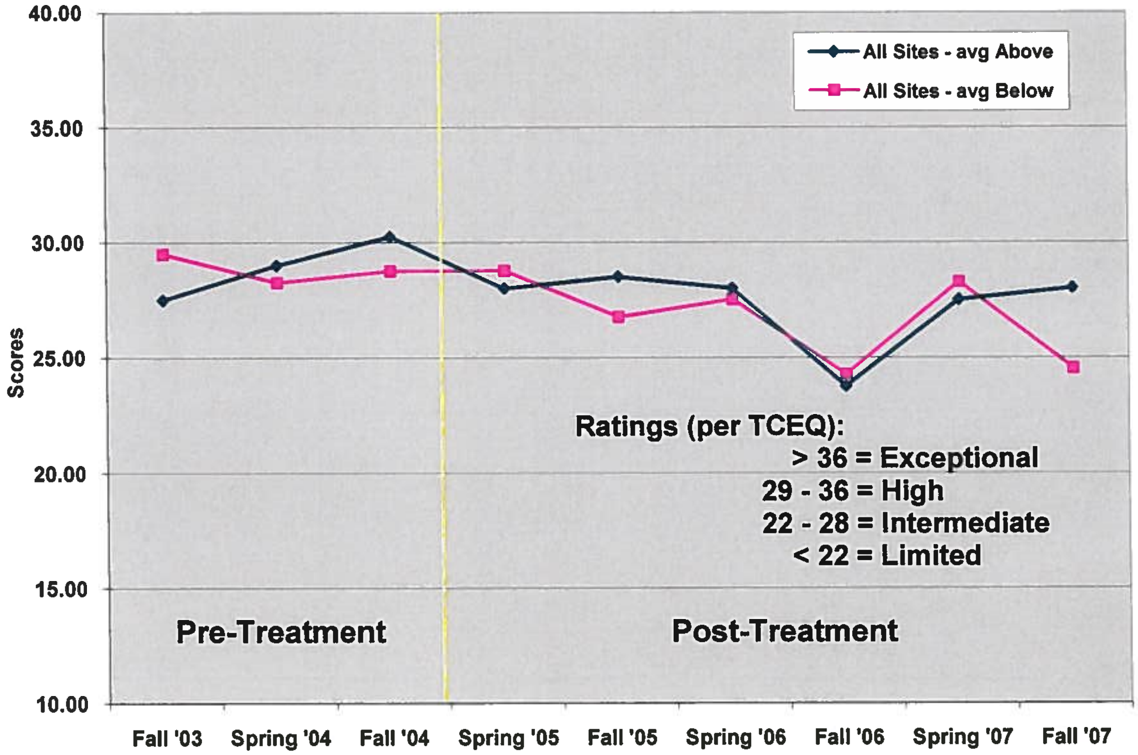


Figure 9. Common benthic macroinvertebrates collected during the project.

Dragonfly larva

Stonefly larva

Mayfly larva

Biological Monitoring – Fish

Project streams also proved to be very diverse in fish populations, with 38 different fish species being sampled, 14 of which were found at all sites. Common species included shiners, chubs, topminnows, darters, sunfish, and lampreys, with the majority being classified as cyprinids (shiners, chubs). The predominant functional feeding group was invertivore (shiners, sunfish, darters), while the least common was omnivore (catfish). Only one percent of all fish sampled were considered tolerant of pollution, most of which (73%) were found in the reference sections of the project sites.

ALU scores ranged from 33 (Limited) to 58 (Exceptional), with most falling in the High classification. Mean post-treatment results increased at all test sections, while decreasing at all but one reference section (Cherokee), indicating that the treatment had no negative effect on fish species. One explanation could be the transient nature of fish over the course of this project. Downstream sections were expected to have higher fish populations due to draining larger watersheds. Statistical analysis indicated the post-treatment section/period interaction was significantly different (higher) than the pre-treatment section/period interaction at the Houston County project site.

Several individual metrics played integral roles in determining the resulting ALU score. The percent of individuals as non-native species and percent of individuals as tolerant species were consistently low, providing a higher score than the other metrics, while the number of sunfish species was usually low, contributing a lower score. There was a slight seasonal trend in fish ALU scores. Five of the eight sections had higher average scores during the late summer sampling period than the spring. See Tables 4 and 6 and Figures 10 and 11.

Table 4. Fish Aquatic Life Use scores across all sites.

Season	Cherokee		Houston		Newton		San Augustine	
	Above	Below	Above	Below	Above	Below	Above	Below
Fall 03	44	48	44	48	58	55	45	45
Spring 04	45	49	44	39	51	46	46	49
Fall 04	43	51	41	39	58	54	40	45
Spring 05	46	50	39	51	52	55	47	43
Fall 05	47	51	42	42	49	51	42	48
Spring 06	50	51	40	48	51	55	41	45
Fall 06	47	53	44	48	55	55	43	51
Spring 07	49	47	33	43	50	54	42	43
Fall 07	47	49	40	48	54	52	48	48

Ratings (per TCEQ): $\geq$ 52 = Exceptional
42 – 51 = High
36 – 41 = Intermediate
< 36 = Limited

Figure 10. Mean fish Aquatic Life Use scores across all sites.

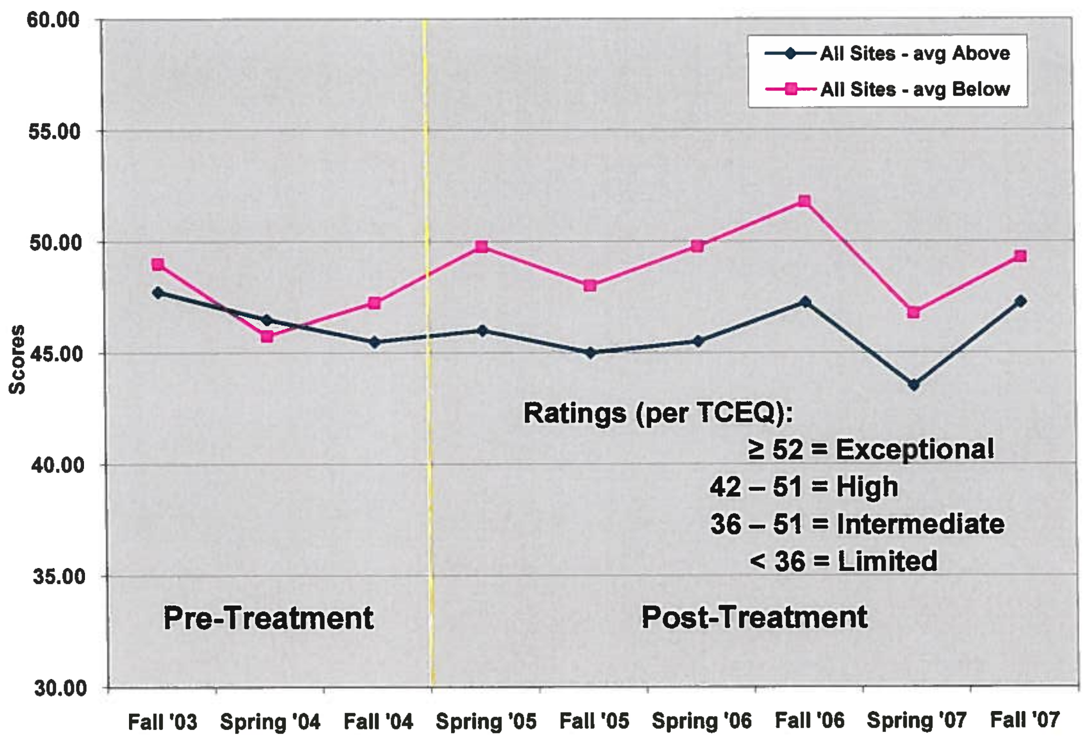


Figure 11. Examples of fish specimens collected.


Longear sunfish


Grass pickerel


Spotted bass


Redfin darter

Biological Monitoring – Habitat Assessment

Project streams generally provided good habitat for biological communities. HQI scores ranged from 16.5 (Intermediate) to 23.5 (High), with most falling in the High classification. Mean post-treatment results increased or remained the same at all sections but one reference (Cherokee), indicating the treatment had no negative effect. Statistical analysis indicated the post-treatment section/period interaction was significantly different (higher) than the pre-treatment section/period interaction at the Cherokee and San Augustine project sites.

Several individual metrics played integral roles in determining the resulting HQI score. The available instream cover consistently scored higher than the other metrics, while bank stability and bottom substrate stability scored lower. A seasonal trend was detected in HQI scores. The spring sampling periods produced higher habitat scores than those in the late summer, primarily because of low flow conditions found during the latter time period. See Tables 5 and 6 and Figure 12.

Table 5. Habitat Quality Index scores across all sites.

Season	Cherokee		Houston		Newton		San Augustine	
	Above	Below	Above	Below	Above	Below	Above	Below
Fall 03	*21.5*	*19*	*20*	*22*	*20.25*	*20*	*20*	*18.5*
Spring 04	*21.5*	*20.5*	*21*	*24*	*18*	*18.5*	*21.5*	*20.5*
Fall 04	*20.5*	*20*	*21.5*	*22*	*21.5*	*16.5*	*20.5*	*19.5*
Spring 05	*22*	*22*	*21.5*	*23.5*	*21.5*	*20*	*21.5*	*19*
Fall 05	*18.5*	*21*	*21*	*22.5*	*23*	*19.5*	*21.5*	*20.5*
Spring 06	*21*	*22*	*21.5*	*23.5*	*23*	*22.5*	*22*	*20*
Fall 06	*21.5*	*21.5*	*21*	*21.5*	*22.5*	*22*	*22*	*21*
Spring 07	*19.5*	*21*	*23*	*23.5*	*23.5*	*21.5*	*22.5*	*19.5*
Fall 07	*19.5*	*20*	*21.5*	*23*	*22*	*22*	*22*	*18*

Ratings (per TCEQ): 26 – 31 = Exceptional; 20 – 25 = High; 14 – 19 = Intermediate; ≤ 13 = Limited

Figure 12. Mean Habitat Quality Index scores across all project sites.

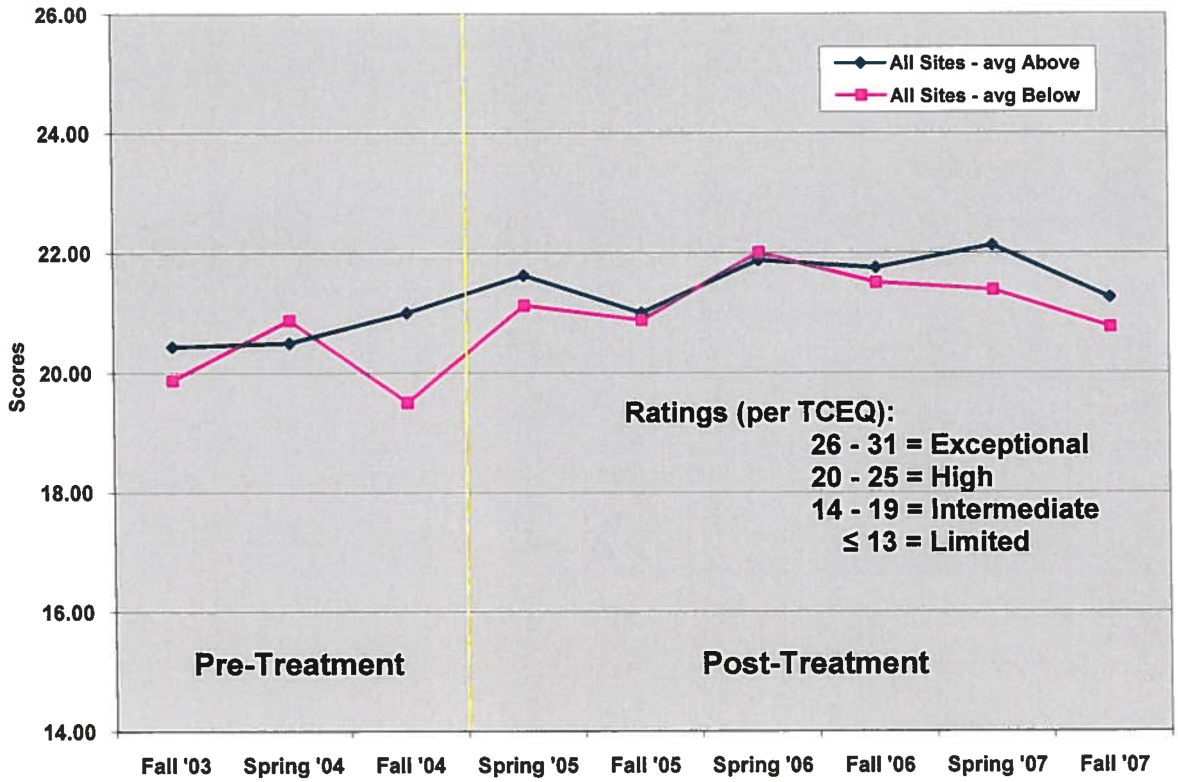


Table 6. Mean Habitat Quality Index and Aquatic Life Use scores of biological samples across all project sites (pre = pre-harvest; post = post-harvest).

Site	Section	Habitat			Benthics			Fish		
		HQI			ALU					
		Pre	Post	Sig[1]	Pre	Post	Sig[1]	Pre	Post[1]	Sig[1]
Cherokee	Upstream	21.17	20.33	A	32.00	30.33	A	44.00	47.67	A
	Downstream	19.83	21.25	**B**	29.00	26.17	A	49.33	50.17	A
Houston	Upstream	20.83	21.58	A	26.67	24.67	A	43.00	39.67	A
	Downstream	22.67	22.92	A	30.33	27.83	A	42.00	46.67	**B**
Newton	Upstream	19.92	22.58	A	29.00	25.17	A	55.67	51.83	A
	Downstream	18.33	21.25	A	28.00	25.17	A	51.67	53.67	A
San Augustine	Upstream	20.00	21.69	A	28.00	28.75	A	45.00	43.63	A
	Downstream	18.5	19.75	**B**	30.00	27.38	A	45.00	46.5	A

[1] Mean section/period interactions with the same letter are not significantly different at $\alpha = 0.05$.

Physiochemical Monitoring – Grab Water Samples

Results from grab samples collected indicated high water quality across all project sites (see Table 7). Parameters measured *in-situ* (conductivity, DO, pH, temperature, and turbidity) at each section closely paralleled each other, showing no treatment effect. DO ranged from 3.1 to 12.2 mg/l across all sites, exceeding the minimum criteria set by the 2000 Texas Surface Water Quality Standards for unclassified perennial streams (3.0 mg/l). The lowest reading occurred when stream flow fell below the seven-day, two-year low flow. Only eight out of 376 (2%) DO samples were below 5.0 mg/l. Conductivity ranged from 0.0003 to 0.0873 mS/cm, pH ranged from 4.67 to 10.56, and turbidity ranged from 2.5 to 37.0 NTU. As expected, DO and temperature were strongly correlated ($r^2 = 0.95$).

Laboratory analysis of grab samples (TN, TP, and TSS) also resulted in no significant treatment effect. TSS values ranged from non-detectable (assigned value 0.5) to 38.7 mg/l. TN and TP had much lower ranges, with results between 0.073 and 5.430 mg/l and non-detectable (assigned value 0.005) and 3.310, respectively. Over 86% of grab samples analyzed for TP were non-detectable, and only 1% (4 out of 376 samples) exceeded the TCEQ screening criteria for TP (0.69 mg/l). Less than 0.5% (1 out of 376) of TN samples exceeded the screening criteria for nitrate nitrogen (1.95 mg/l). Natural variability in lab parameters was noticeable. A comparison between grab and duplicate samples collected showed TSS values varying by 24%, TN by 18% and TP by 11%. See Table 8.

Table 7. Number of grab samples taken across all project sites.

Project Site	Pre-Treatment Samples	Post-Treatment Samples	Total Samples
Cherokee	13	34	47
Houston	14	33	47
Newton	17	30	47
San Augustine	5	42	47

Table 8. Mean sediment and nutrient (Total Nitrogen, Total Phosphorous) concentrations of grab samples across all project sites (pre = pre-harvest; post=post-harvest).

Site	Section	Total Nitrogen			Total Phosphorous			Sediment		
		mg / l								
		Pre	Post	Sig[1]	Pre	Post	Sig[1]	Pre	Post[1]	Sig[1]
Cherokee	Upstream	0.67	0.89	A	0.05	0.07	A	8.80	6.92	A
	Downstream	0.66	0.89	A	0.05	0.06	A	4.76	6.22	A
Houston	Upstream	0.44	0.83	A	0.05	0.06	A	7.13	10.63	A
	Downstream	0.80	0.78	A	0.05	0.06	A	7.04	8.70	A
Newton	Upstream	0.55	0.85	A	0.05	0.12	A	5.62	5.36	A
	Downstream	0.56	0.83	A	0.05	0.10	A	5.88	5.52	A
San Augustine	Upstream	0.34	0.64	A	0.05	0.14	A	5.50	6.02	A
	Downstream	0.28	0.65	A	0.05	0.06	A	6.16	6.45	A

[1] Mean section/period interactions with the same letter are not significantly different at $\alpha = 0.05$.

Physiochemical Monitoring – Stormwater Samples

Results from stormwater samples collected varied greatly among sites. Concentrations varied with storm event conditions and watershed physiographic characteristics. A total of 550 samples were collected throughout the course of this project. Approximately 60% of these samples represented a matched pair (data collected from both the upstream and downstream section during the same storm event), on which statistical analyses were conducted. See Table 9.

Turbidity, measured *in-situ* from collected storm samples, ranged from 6.3 to 950.0 NTU. While this variance is high, no statistical difference was observed between the sections that could be attributed to the treatment. Laboratory analysis of stormwater samples (TN, TP, and TSS) also resulted in no significant treatment effect. TSS values ranged from 2.0 to 4,540.0 mg/l. TN and TP had much lower ranges, with results between 0.13 and 6.03 mg/l and non-detectable (assigned value 0.025) and 0.612 mg/l, respectively. It is important to note that no TP or TN samples exceeded their respective TCEQ screening criteria. Strong correlations between turbidity and TSS were established ($r^2 = 0.75$) at most sites. Seventy-five percent of the annual sediment and nutrient losses from each site were accounted for from five storm events. See Tables 10, 11, and 12.

Table 9. Number of stormwater samples collected, by parameter.

Project Site	# of Samples		Matched TSS		Matched TP		Matched TN	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Cherokee	21	79	20	41	19	33	19	35
Houston	17	49	14	31	10	23	10	24
Newton	25	48	23	32	20	25	20	32
San Augustine	7	67	7	38	5	34	7	32

Table 10. Mean stream flow and turbidity results of paired stormwater samples across all project sites (pre = pre-harvest, post = post-harvest).

Site	Section	Stream Flow			Turbidity		
		——— cm ———			——— NTU ———		
		Pre	Post	Sig[1]	Pre	Post	Sig[1]
Cherokee	Upstream	0.36	0.32	A	61.14	40.93	A
	Downstream	0.69	0.54	A	49.13	58.10	A
Houston	Upstream	0.56	0.79	A	79	51.03	A
	Downstream	0.36	1.07	A	81.14	98.77	A
Newton	Upstream	0.83	0.97	A	70.42	107.33	A
	Downstream	1.37	1.40	A	115	132.63	A
San Augustine	Upstream	1.51	1.20	A	53.8	182.88	A
	Downstream	1.08	1.77	A	41.6	221.08	A

[1] Mean section/period interactions with the same letter are not significantly different at $\alpha = 0.05$.

Table 11. Mean sediment and nutrient (Total Nitrogen, Total Phosphorous) losses of paired stormwater samples across all project sites (pre = pre-harvest; post = post-harvest).

Site	Section	Total Nitrogen			Total Phosphorous			Sediment		
		kg ha $^{-1}$								
		Pre	Post	Sig[1]	Pre	Post	Sig[1]	Pre	Post[1]	Sig[1]
Cherokee	Upstream	0.04	0.06	A	0.00	0.00	A	4.23	3.19	A
	Downstream	0.08	0.12	A	0.00	0.01	A	9.07	9.71	A
Houston	Upstream	0.08	0.11	A	0.00	0.01	A	7.85	4.22	A
	Downstream	0.07	0.14	A	0.00	0.01	A	8.65	11.08	A
Newton	Upstream	0.10	0.14	A	0.01	0.02	A	11.08	14.41	A
	Downstream	0.18	0.23	A	0.01	0.03	A	41.98	38.83	A
San Augustine	Upstream	0.09	0.20	A	0.01	0.02	A	40.59	67.92	A
	Downstream	0.06	0.29	A	0.02	0.03	A	13.76	74.57	A

[1] Mean section/period interactions with the same letter are not significantly different at $\alpha = 0.05$.

Table 12. Total annual rainfall, stream flow, sediment, and nutrient (Total Nitrogen, Total Phosphorous) losses of stormwater samples across all project sites.

Site	Upstream (reference)				Downstream (test)			
	2004	2005	2006	2007[1]	2004	2005	2006	2007[1]
Rainfall (cm)								
Cherokee	179.07	81.79	126.75	91.69	179.07	81.79	126.75	91.69
Houston	158.24	78.49	144.27	90.42	158.24	78.49	144.27	90.42
Newton	194.06	119.63	179.58	74.42	194.06	119.63	179.58	74.42
San Augustine	203.71	101.85	136.91	104.39	203.71	101.85	136.91	104.39
Flow (cm)								
Cherokee	11.22	7.05	4.60	5.99	21.92	9.96	6.51	10.71
Houston	8.91	8.19	11.67	10.00	7.56	11.94	15.03	11.97
Newton	14.46	13.31	19.44	9.03	23.58	17.07	32.83	20.13
San Augustine	26.23	16.41	19.80	14.25	29.55	18.26	28.32	24.08
Total Sediment (kg ha^{-1} yr^{-1})								
Cherokee	133.11	46.78	48.95	19.78	385.84	119.15	46.47	73.98
Houston	118.69	77.09	74.13	52.83	134.37	117.85	120.43	111.11
Newton	234.63	143.39	281.82	87.07	879.69	175.45	940.54	494.26
San Augustine	2337.80	237.77	214.83	357.29	1453.31	282.28	467.06	919.58
Total Nitrogen (kg ha^{-1} yr^{-1})								
Cherokee	1.30	0.79	0.60	0.76	2.56	1.45	0.94	1.45
Houston	0.97	0.99	1.27	1.19	1.09	1.00	2.01	1.31
Newton	1.40	1.72	3.00	1.06	2.93	2.03	5.29	3.14
San Augustine	2.99	1.52	1.31	2.37	3.24	1.57	3.65	3.34
Total Phosphorus (kg ha^{-1} yr^{-1})								
Cherokee	0.06	0.04	0.05	0.04	0.13	0.07	0.05	0.07
Houston	0.05	0.05	0.08	0.05	0.05	0.09	0.26	0.14
Newton	0.10	0.06	0.31	0.11	0.25	0.09	0.45	0.26
San Augustine	0.27	0.15	0.21	0.22	0.32	0.15	0.44	0.26

[1] Data through August 2007

Precipitation

Precipitation varied greatly over the course of the project. Average rainfall across the project area historically ranges from 44.5 to 54.6 inches annually. These averages were determined from 50 years of records at NOAA weather stations in close proximity to the project sites. In 2004, the project sites experienced one of the wettest years on record, receiving over 70 inches of rain. However, only 35 inches fell in 2005, even with Hurricane Rita dumping 10 inches on some of the project sites. This drought began in March 2005. Rainfall deficits peaked in December at 13 inches below normal, and did not start to recover until October 2006. The drought continued at some sites until July 2007. See Table 13.

Table 13. Total annual rainfall across all project sites.

Project Site	2004 Rain Gauge (in)	2005 Rain Gauge (in)	2006 Rain Gauge (in)	2007[1] Rain Gauge (in)	Historical NOAA (in)
Cherokee	70.5	32.2	49.9	36.1	44.5
Houston	62.3	30.9	56.8	35.6	44.5
Newton	76.4	47.1	70.7	29.3	54.6
San Augustine	80.2	40.1	53.9	41.1	53.8

[1] Data only through August 2007.

CONCLUSION

The results from this project indicated that Texas forestry BMPs, when implemented properly, are effective in protecting water quality and aquatic biological communities. The analysis of physiochemical and biological parameters resulted in no significant treatment differences between forest stands harvested and regenerated using BMPs and undisturbed forests. This demonstrates the value of and provides empirical justification for the continued use and implementation of forestry BMPs in Texas. These results further establish that forestry BMPs are the optimum means for minimizing silvicultural nonpoint source pollution.

APPENDIX

Benthic Macroinvertebrate Taxa List

Fish Taxa List

References

Benthic Macroinvertebrate Taxa List

Ablabesmyia sp.
Aedes sp.
Aeshna sp.
Anax sp.
Ancyronyx sp.
Anopheles sp.
Antocha sp.
Argia sp.
Argiogomphus sp.
Asellus sp.
Belostoma sp.
Bezzia sp.
Bittacomorpha sp.
Boyeria sp.
Caenis sp.
Calopteryx sp.
Cambarellus sp.
Cambaridae
Cambarus sp.
Cernotina sp.
Centroptilum sp.
Chauliodes sp.
Cheumatopsyche sp.
Dubiraphia sp.
Enallagma sp.
Ephemerella sp.
Erythrodiplax sp.
Estigmene sp.
Eurylophella sp.
Gelastocoris sp.
Gerris sp.
Gomphus sp.
Gyretes sp.
Gyrinus sp.
Hagenius sp.
Haliplus sp.
Hapoperla sp.
Helius sp.
Helleniella sp.
Helocordulia sp.
Hetaerina sp.
Hexagenia limbata
Hexagenia sp.
Hirundinea
Hyalella azteca
Hydaticus sp.
Mooreobdella sp.
Narpus sp.
Nematomorpha
Neureclipsis sp.
Notonecta sp.
Nyctiophylax sp.
Ochterus sp.
Oligochaeta
Orconectes sp.
Parachironomus sp.
Paraleptophlebia sp.
Paraplea sp.
Paratendipes sp.
Perithemis sp.
Perlesta sp.
Phylocentropus sp.
Placobdella sp.
Polypedilum sp.
Procambarus sp.
Procladius sp.
Progomphus sp.
Pseudochironomus sp.
Ranatra sp.

Chironomidae

Chironomus sp.

Chrysops sp.

Cordulegaster sp.

Corixidae

Corydalus cornutus

Corydalus sp.

Crangonyx. sp.

Cryptochironomus sp.

Culex sp.

Didymops sp.

Dimulium sp.

Dineutus sp.

Dixa sp.

Dixella sp.

Dromogomphus sp.

Hydrochus sp.

Hydroporus sp.

Hydropsyche sp.

Hydroptila

Isoperla sp.

Libellula sp.

Lipogomphus sp.

Lirceus sp.

Lumbricus sp.

Lype sp.

Macromia sp.

Macronychus sp.

Macrothemis sp.

Metrobates sp.

Micropsectra sp.

Rhagovelia sp.

Rheumatobates sp.

Sialis sp.

Simulium sp.

Stenacron sp.

Stenelmis sp.

Stenonema sp.

Stictochironomus sp.

Stylurus sp.

Tabanus sp.

Tanypus sp.

Tanytarsus sp.

Tipula sp.

Trepobates sp.

Trichocorixa sp.

Fish Taxa List

Black bullhead	*Ameiurus melas*
Blackspot shiner	*Notropis atrocaudalis*
Blackspotted topminnow	*Fundulus olivaceus*
Blackstripe topminnow	*Fundulus notatus*
Blacktail redhorse	*Moxostoma poecilurum*
Blacktail shiner	*Cyprinella venusta*
Bluegill	*Lepomis machrochirus*
Bluntnose darter	*Etheostoma chlorosomum*
Chestnut lamprey	*Ichthyomyzon castaneus*
Creek chub	*Semotilus atromaculatus*
Dollar sunfish	*Lepomis marginatus*
Dusky darter	*Percina sciera*
Freckled madtom	*Noturus nocturnus*
Golden shiner	*Notimegonus chrysoleucas*
Goldstripe darter	*Etheostoma parvipinne*
Grass pickerel	*Esox americanus vermiculatus*
Green sunfish	*Lepomis cyanellus*
Hybrid sunfish	
Lake chubsucker	*Erimyzon sucetta*
Largemouth bass	*Micropterus salmoides*
Longear sunfish	*Lepomis megalotis*
Mud darter	*Etheostoma asprigene*
Pirate perch	*Aphredoderus sayanus*

Pugnose minnow	*Opsopoedus emilae*
Redfin darter	*Etheostoma whipplei*
Redfin shiner	*Lythrurus umbratilis*
Ribbon shiner	*Lythrurus fumeus*
Sabine shiner	*Notropis sabinae*
Slough darter	*Etheostoma gracile*
Southern brook lamprey	*Ichthyomyzon gagei*
Spotted bass	*Micropterus punctulatus*
Spotted sucker	*Minytrema melanops*
Spotted sunfish	*Lepomis punctatus*
Tadpole madtom	*Noturus gyrinus*
Warmouth	*Lepomis gulosus*
Weed shiner	*Notropis texanus*
Western mosquitofish	*Gambusia affinis*
Yellow bullhead	*Ameiurus natalis*

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