Summary of Stream Inventories on the Daniel Boone National Forest, 2005-2018

United States Department of Agriculture Forest Service
Southern Research Station
Center for Aquatic Technology Transfer
1710 Research Center Drive
Blacksburg, VA 24060

C. Andrew Dolloff, Team Leader

Report prepared by:
Colin Krause and Craig Roghair
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Introduction

In March 2005, resource specialists from the Center for Aquatic Technology Transfer (CATT), Daniel Boone National Forest (DBNF), National Forests in North Carolina (NFNC), George Washington-Jefferson National Forest (GWJNF), and Southern Region Office (RO) met with Southern Research Station (SRS) scientists to develop the framework for a Southern Region stream monitoring program. All parties acknowledged that existing monitoring programs (e.g. Hixson et al. 2004, Walker and Bishop 1991) were not appropriate or sustainable for Forest-level stream monitoring in the Southern Region. The team outlined a sampling design and discussed specific sampling protocols.

Recommendations from the meeting were compiled into a field guide by the CATT (Appendix A). The DBNF volunteered to test the new strategy and initiated a pilot monitoring program. The CATT and DBNF field teams completed stream habitat, macroinvertebrate, and fish assemblage inventories on the DBNF each summer from 2005 – 2010, 2012 – 2014, and 2017 – 2018 (Table 1).

Methods

Reach Selection

Random site selection is an important component of the monitoring program. The DBNF requested random sites from the Environmental Protection Agency (EPA), which has an existing random site selection program for the state of KY (Olsen, 2005). All sites had to meet two criteria: 1) watershed greater than 13 km^2; 2) depth shallow enough for backpack electrofishing.

At each site we measured the wetted width of 1 – 2 fast water (riffle or run) habitat units and calculated the average wetted width. If the average wetted width was less than or equal to 3.0 m or greater than or equal to 7.5 m, the sample reach length was 120 m or 300 m, respectively (Appendix A). In all other cases sample reach length was 40-times the average wetted width.

Macroinvertebrate Inventory

We collected macroinvertebrates using riffle sample and multi-habitat sample methods described by Pratt (2002). Macroinvertebrates were collected at least one day before fish sampling. See Appendix A for detailed field methods.

Pebble Count Inventory

Fish sampling teams (see below) conducted pebble counts (Wolman heel-to-toe steps protocol; Wolman, 1954) in riffle habitat units to characterize the substrate in sample reaches. Team members measured the intermediate axis of a minimum of 200 pebbles per riffle as described in Bunte and Abt (2001) and Kappesser (2002). In addition to pebble counts, bar counts were conducted by measuring the

intermediate axis of 30 dominant large particles residing on a bar or similar depositional feature within the sample reach. See Appendix A for detailed field methods.

Habitat Inventory

Two-person teams performed abbreviated stream habitat inventories (Roghair and Nuckols, 2005) based on the basinwide visual estimation technique (BVET) (Dolloff et al. 1993). For each habitat unit contained wholly or partially within the sample reach, the team visually estimated or measured the following attributes:

All Habitat Units	Sub-Sample of Habitat Units
Type of habitat	Bankfull channel width
Length and width	Channel gradient
Maximum and average depth	Water temperature
Riffle crest depth	Photographs
Dominant and subdominant substrate	GPS coordinates
Rosgen channel type (Rosgen, 1996)	
Percent fines	
Large wood counts	

When possible, the team sub-sampled at least 3 fast water and 3 slow water units within each reach.

In addition, the team noted stream features including:

- Waterfalls
- Tributaries
- Side channels
- Braided channels
- Seeps (springs)
- Landslides
- Bridges
- Fords
- Dams
- Culverts

See Appendix B for detailed field methods.

Fish Inventory

A four-person team using a DC backpack electrofisher collected fish from the same stream reach inventoried for stream habitat (see above). The team attempted to apply standard effort of approximately 1 sec/m^2 of wetted stream habitat, and recorded the following data:

- Species name
- Counts of adult, age-0, and voucher specimens
- Sample reach length, electrofishing time (sec), and voltage
- GPS coordinates of start and end location

See Appendix A for detailed field methods.

Results

The CATT and DBNF personnel completed habitat inventories on a total of 127 sites (30.6 km) between 2005-2018 (Tables 1-9). We did not sample fish at 18 sites due to the potential presence of Blackside Dace (*Chrosomus cumberlandensis*) or Cumberland Darter (*Etheostoma susanae*), Federally Threatened and Endangered species; additional sites were not sampled due to dry stream, large streams with deep water, or access issues (Tables 2-9). We collected a total of 76 fish species on the DBNF between 2005-2018 (Table 10). These data can be used to describe stream condition on the DBNF and serve as a baseline for future comparisons. In addition, the data will be used to test the effectiveness of the proposed Southern Region stream monitoring program.

Data Availability

Summer 2005-2018 habitat, fish, and pebble count data are stored in a MS Access database, which is maintained at the CATT offices and a copy has been provided to the DBNF. We are working with the DBNF to develop custom queries and reports for the MS Access database. Queries already developed include stream width corrections (visually estimated vs. measured), stream area calculations, summary of fish captures, and summary of inventories. Jon Walker, DBNF Forest Hydrologist, received a copy of all data in electronic format.

Literature Cited

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Figure 1. Sample site locations (2005-2018) within the Daniel Boone National Forest, Kentucky.

Table 1. Inventory summary by year, including the timeframe and number of days to complete sampling as well as the number inventories completed for habitat (BVET), electrofishing (Efish), and riffle stability index (RSI).

				# Sites	# Inventories Completed			Inventory
Year	Dates	Days	Crew Size	Visited	BVET	Efish	RSI	Distance (km)
2005	June 7-17	11	8	26	20	12	20	5.1
2006	July 18-27	10	9	43	34	34	34	8.7
2007	July 13-19	7	7	12	12	10	12	2.9
2008	July 15-19	5	6	5	5	5	5	1.3
2009	July 10-22	13	4	12	10	10	10	2.6
2010	September 14-16	3	5	7	2	2	7	0.4
2012	June 20 - September 27	20	4	17	15	12	15	3.1
2013	July 23-25	3	6	4	3	3	3	0.9
2014	June 3-11	9	8	10	7	6	7	1.9
2017	July 19-26	8	6	9	9	9	9	1.7
2018	May 15-23	8	4	10	10	5	10	2.0
			Total:	155	127	108	132	30.6

Table 2. Summary of parameters inventoried at stream sample locations in 2005.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
1	Rock Creek	collected	75	52	299	2,747	none	collected	
9	Marsh Creek	--	--	--	--	--	--	present	Not inventoried, too large
14	Pine Creek	collected	86	42	226	1,408	none	present	
17	Rock Creek	collected	85	38	305	2,566	none	collected	
21	Roaring Paunch Creek	--	--	--	--	--	--	--	Not inventoried, too large
33	Rock Creek	collected	73	58	311	3,356	collected	collected	
34	Bunches Creek	collected	19	680	218	--	--	present	Not efished, blackside dace stream
38	Cane Creek	collected	58	92	305	3,877	none	collected	
41	Jellico Creek	collected	75	34	173	745	collected	collected	
42	Big Clifty Creek	collected	84	8	299	2,037	none	present	
45	Beaver Creek	collected	96	14	143	--	--	--	Not efished, blackside dace stream
53	Laurel Creek	collected	90	70	253	1,638	none	present	Efish mistake, blackside dace stream
61	Beaver Creek	--	--	--	--	--	--	--	Not inventoried, tick hazard
62	Horse Lick Creek	collected	75	54	297	1,620	collected	collected	
65	Rock Creek	collected	64	118	279	2,805	none	collected	
66	Beaver Creek	--	--	--	--	--	--	--	Not inventoried, too large
75	Indian Creek	--	--	--	--	--	--	--	Not inventoried, stream dry, karst area
78	Hawk Creek	collected	85	30	261	--	--	--	Not efished, water too turbid
85	Roaring Paunch Creek	collected	69	82	325	3,000	collected	present	
90	Craig Creek	collected	NA*	1024	302	--	--	--	Not efished, blackside dace stream
93	Middle Fork (Beaver Cr)	collected	68	14	200	--	none	present	Not efished, blackside dace stream
97	Roaring Paunch Creek	--	--	--	--	--	--	--	Not inventoried, too large
98	Dog Slaughter Creek	collected	NA*	1024	163	--	none	present	Not efished, blackside dace stream
105	Capuchin Creek	collected	62	38	325	2,611	collected	collected	
109	Kilburn Fork	collected	69	34	141	--	--	--	Not efished, blackside dace stream
117	Laurel Creek	collected	74	44	311	--	--	--	Not efished, blackside dace stream
				Total	5,136				

*Riffle Stability Index (RSI) not available because no bars were present for bar count.

Table 3. Summary of parameters inventoried at stream sample locations in 2006.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
7	South Fork Kentucky River	--	--	--	--	--	--	--	Not inventoried, too large
32	Yocum Creek	collected	90	78	304	2,108	none	present	
35	Red Bird River	--	--	--	--	--	--	--	Not inventoried, too large
40	Open Fork	--	--	--	--	--	--	--	Not inventoried, too large
48	North Fork Licking River	collected	94	72	276	2,824	collected	collected	
55	Bullskin Creek	collected	81	66	268	772	none	collected	
59	Cavanaugh Creek	collected	93	54	293	1,480	none	collected	
64	Minor Creek	collected	92	56	213	1,300	none	collected	
67	Rock Lick Creek	--	--	--	--	--	--	--	Not inventoried, private land
68	Chimney Top Creek	collected	99	38	218	764	none	present	
72	Beaver Creek	collected	97	24	415	1,842	none	present	
79	Sand Lick Fork	collected	97	50	193	953	none	present	
84	Swift Camp Creek	collected	74	88	322	2,479	none	present	
99	Upper Jacks Creek	collected	84	60	300	1,739	none	collected	
123	Ross Creek	collected	70	80	124	427	none	collected	
135	Red Bird River	--	--	--	--	--	--	--	Not inventoried, too large
136	Beaver Creek	collected	96	24	374	2,700	none	collected	
148	Red River	--	--	--	--	--	--	--	Not inventoried, too large
159	Middle Fork Red River	collected	82	60	215	1,000	none	collected	
160	Upper Lick Fork Creek	collected	93	54	129	336	none	collected	
175	Red River	--	--	--	--	--	--	--	Not inventoried, too large
176	Craney Creek	collected	89	8	377	2,252	none	collected	
179	Red Bird River	--	--	--	--	--	--	--	Not inventoried, too large
183	Leatherwood Creek	collected	52	112	230	998	none	present	
191	East Fork Indian Creek	collected	88	66	256	1,061	none	collected	

Table continued on next page.

Table 3, continued. Summary of parameters inventoried at stream sample locations in 2006.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
192	Clear Fork	collected	78	126	223	1,002	none	collected	
195	Collins Fork	--	--	--	--	--	--	--	Not inventoried, too deep
196	Gladie Creek	collected	93	48	443	2,456	none	present	
199	Bowen Creek	collected	90	58	124	413	none	collected	
200	Brushy Fork	collected	84	88	200	707	none	collected	
207	Right Fork Buffalo Creek	collected	76	60	198	788	none	collected	
224	North Fork Licking River	collected	98	40	357	2,403	collected	none	
239	Indian Creek	collected	93	50	251	1,398	none	collected	
240	Slabcamp Creek	collected	99	40	213	751	none	collected	
251	Big Sinking Creek	collected	77	160	320	1,796	none	collected	
275	Phillips Fork	collected	59	96	277	1,165	none	collected	
283	War Fork	collected	88	66	463	2,137	none	present	
288	Craney Creek	collected	99	20	322	2,965	collected	collected	Live Corbicula clams
307	Hector Branch	collected	58	114	268	1,910	none	collected	
NA	Gilberts Big Creek	collected	92	52	105	290	none	collected	site # DBF04052007
NA	Katies Creek	collected	75	58	195	823	none	collected	site # DBF04051009
NA	Sugar Creek	collected	92	46	109	362	none	collected	site # DBF04052030
NA	Upper Bear Creek	collected	45	210	158	654	none	collected	site # DBF04052701
				Total	8,730				

Table 4. Summary of parameters inventoried at stream sample locations in 2007.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
117	Laurel Creek	collected	54	106	190	956	none	collected	
133	Big Creek	collected	55	104	265	1,669	none	collected	
137	Barren Fork	collected	78	32	279	--	none	--	Not efished, blackside dace stream
178	Bark Camp Creek	collected	15	1024	225	1,392	none	collected	
201	Indian Creek	collected	69	80	277	--	none	--	Not efished, blackside dace stream
218	Lick Creek	collected	94	18	189	728	none	collected	
258	Mill Creek	collected	73	80	232	1,146	none	collected	
278	Cane Creek	collected	59	88	260	1,222	none	collected	
290	Bark Camp Creek	collected	42	380	252	1,542	none	collected	
293	Bridge Fork	collected	50	126	201	868	none	collected	
305	Wolf Creek	collected	54	108	181	738	none	collected	
314	Sinking Creek	collected	37	140	300	2,056	present	collected	
				Total	2,851				

Table 5. Summary of parameters inventoried at stream sample locations in 2008.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
4	Chimney Top Creek	collected	72	64	241	1,786	none	collected	
20	Swift Camp Creek	collected	70	60	258	1,735	none	none	
63	Indian Creek	collected	90	36	302	2,098	none	collected	
100	Gladie Creek	collected	82	52	270	1,850	none	collected	
255	East Fork Indian Creek	collected	84	50	205	1,063	none	collected	
				Total	1,276				

Table 6. Summary of parameters inventoried at stream sample locations in 2009.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
15	Big Sinking Creek	--	--	--	--	--	--	--	Not inventoried, stream dry
16	Middle Fork Red River	collected	69	80	210	1,120	none	collected	
34	McCammon Branch	collected	81	62	184	796	none	collected	
51	Hector Branch	collected	78	52	219	1,118	none	collected	
180	Red River	--	--	--	--	--	--	--	Not inventoried, no access
235	War Fork	collected	88	46	305	2,526	none	collected	
244	Red River	collected	51	100	338	2,762	none	collected	
254	Laurel Fork	collected	80	38	303	2,929	none	collected	
277	Bridge Fork	collected	NA*	130	304	2,211	none	none	
289	White Oak Creek	collected	59	78	145	500	none	present	
301	Beaver Creek	collected	58	98	320	2,233	none	collected	
315	Big Sinking Creek	collected	66	70	305	2,473	none	collected	
				Total	2,633				

*Riffle Stability Index (RSI) not available because no bars were present for bar count.

Table 7. Summary of parameters inventoried at stream sample locations in 2010.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
925	Ross Creek	collected*	81	60	--	--	--	--	Not inventoried, stream dry
927	Big Sinking Creek	collected*	37	1,024	279	1,696	none	present	
928	Little Sinking Creek	collected*	53	98	--	--	--	--	Not inventoried, stream dry
929	Tickey Fork	collected*	51	90	--	--	--	--	Not inventoried, stream dry
931	Willow Branch	collected*	52	114	--	--	--	--	Not inventoried, stream dry
932	Little Willow Branch	collected*	73	48	--	--	--	--	Not inventoried, stream dry
933	Upper Lick Fork	collected*	94	44	128	407	none	present	Isolated pools, partially dry
				Total	407				

*Macroinvertebrates were collected by DBNF personnel in April-June, 2010; CATT collected the other parameters in September.

Table 8. Summary of parameters inventoried at stream sample locations in 2012.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
47	White Oak	collected	81	46	287	1,977	--	--	
56	Unnamed	--	--	--	--	--	--	--	Not inventoried, stream dry
67	Cogur Fork	collected	66	78	119	324	--	--	
81	Left Fork Island Creek	collected	53	128	217	1,124	--	--	
82	Laurel Fork	collected	80	84	194	945	--	--	
90	Big Creek	collected	82	62	234	1,346	--	--	
91	Bob's Fork	collected	74	86	121	348	--	--	
100	Elisha Creek	collected	64	110	161	640	--	--	
101	Flat Creek	collected	93	68	160	NA	--	--	No efish sec, timer malfunction
103	Otter Creek	collected	76	58	152	555	--	--	
124	Lower Lick Fork	--	--	--	--	--	--	--	Not inventoried, too deep
934	Swift Camp Creek*	collected	77	82	351	1,728	--	--	Wide, deep, and mostly bedrock
935	Swift Camp Creek*	collected	25	100	300	3,690	--	--	Spots too deep to efish throughout
936	Cooperas Creek	--	69	70	120	60	--	--	Mostly dry, some pools
937	Freeman Fork*	collected	52	64	133	--	--	--	Not efished, listed Cumberland darter
938	Hurricane Creek*	collected	64	82	238	--	--	--	Not efished, listed Cumberland darter
939	Middle Fork*	collected	41	36	309	--	--	--	Not efished, listed Cumberland darter
				Total	3,096				

*Non-random site location; located in USFS Wilderness.

Table 9. Summary of parameters inventoried at stream sample locations in 2013.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
456	Hector Branch	collected	84	34	276	NA	--	--	No efish sec., timer malfunction
965	Roaring Paunch Creek	collected	25	490	317	2,672	--	--	Spots too deep to efish throughout
1580	Rock Creek	collected	92	34	300	NA	--	--	site # DBF02008719; Sec. data lost
4003	Wolf Creek	--	--	--	--	--	--	--	Not inventoried, very low flow
				Total	893				

Table 10. Summary of parameters inventoried at stream sample locations in 2014.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
73	Swift Camp Creek	collected	87	44	320	2,951	present	--	Lots of bank erosion, corbicula
189	Upper Lick	collected	97	34	177	635	none	--	
204	Craney Creek	--	--	--	--	--	--	--	Not inventoried, too large
512	Clear Fork	collected	52	126	347	3,183	present	--	
523	Indian Creek	--	--	--	--	--	--	--	Not inventoried, no access, private
1055	Big Sinking Creek	--	--	--	--	--	--	--	Not inventoried, stream dry
1100	Brushy Fork	collected	42	220	240	1,444	none	--	Concrete slab ford 20 m upstream
1115	Big Sinking Creek	collected	92	24	226	--	--	--	Not efished, very turbid from rain
1365	Swift Camp Creek	collected	82	46	318	2,772	present	present	campsites; corbicula
1449	Clear Fork	collected	58	80	280	1,865	none	--	almost entirely bedrock
				Total	1,908				

Table 11. Summary of parameters inventoried at stream sample locations in 2017.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
1868	Upper Lick Fork	collected	96	32	209	1,018	none	present	
CFD05036502	Stonecoal Branch	collected*	67	46	127	383	none	present	
DBF05016	North Fork Licking R.	collected	86	--	315	2340	present	present	mussel relics & Corbicula
DBF05017	Upper Lick Fork	collected	97	24	136	440	none	present	
DBF05018	Craney Creek	collected	93	18	247	1504	none	present	
DBF05021	Passenger Branch	collected*	87	20	138	442	none	present	
DBF05022	Minor Creek	collected	96	30	136	320	none	present	
DBF05023	Slabcamp Creek	collected	97	30	120	404	none	present	
DBF05036710	Craney Creek	collected	98	3	235	1,032	present	present	mussel relics
				Total	1,663				

*Macroinvertebrates collected by Jon Walker (DBNF Forest Hydrologist) in June 2017; collection was by CATT in July at all other sites.

Table 12. Summary of parameters inventoried at stream sample locations in 2018.

Site	Stream Name	Macro-inverts	Pebble Count RSI	Pebble Count D50 (mm)	BVET habitat (m)	Efish (sec)	Mussels	Crayfish	Comments
CFD02008502	Negro Creek	collected	50	130	123	410	none	present	
DBF02006707	Cave Creek	collected	89	42	224	1,076	none	present	
DBF02006708	Cave Creek	collected	71	64	189	879	none	present	
DBF02006714	Big Creek	collected	67	66	142	545	none	present	
DBF02006719	Middle Fork Beaver	collected	48	140	306	--	--	--	No efish, T&E species present
DBF02006720	Little Hurricane	collected	66	42	182	--	--	--	No efish, T&E species present
DBF02006721	Freeman Fork	collected	92	16	120	--	--	--	No efish, T&E species present
DBF02008716	Wolf Creek	collected	31	1,024	187	--	--	--	No efish, T&E species present
DOW02006032	Beaver Creek	collected	84	40	271	--	--	--	No efish, T&E species present
Lick_Creek	Lick Creek	collected	74	66	298	1,714	none	present	
				Total	2,042				

Table 13. Fish species captured on the DBNF, 2005-2018.

Family	Scientific Name	Common Name
Atherinidae	*Labidesthes sicculus*	Brook Silverside
Catostomidae	*Catostomus commersoni*	White Sucker
	Hypentelium nigricans	Northern Hog Sucker
	Moxostoma anisurum	Silver Redhorse
	Moxostoma carinatum	River Redhorse
	Moxostoma erythrurum	Golden Redhorse
	Moxostoma macrolepidotum	Shorthead Redhorse
Centrarchidae	*Ambloplites rupestris*	Rock Bass
	Lepomis auritus	Redbreast Sunfish
	Lepomis cyanellus	Green Sunfish
	Lepomis gibbosus	Pumpkinseed
	Lepomis gulosus	Warmouth
	Lepomis macrochirus	Bluegill
	Lepomis megalotis	Longear Sunfish
	Lepomis microlophus	Redear Sunfish
	Micropterus dolomieu	Smallmouth Bass
	Micropterus punctulatus	Spotted Bass
	Micropterus salmoides	Largemouth Bass
Clupeidae	*Dorosoma cepedianum*	Gizzard Shad
Cottidae	*Cottus bairdi*	Mottled Sculpin
	Cottus carolinae	Banded Sculpin
Cyprinidae	*Campostoma anomalum*	Central Stoneroller
	Chrosomus erythrogaster	Southern Redbelly Dace
	Clinostomus elongatus	Redside Dace
	Clinostomus funduloides	Rosyside Dace
	Cyprinella galactura	Whitetail Shiner
	Cyprinella spiloptera	Spotfin Shiner
	Cyprinella whipplei	Steelcolor Shiner
	Cyprinus carpio	Carp
	Hybopsis amblops	Bigeye Chub
	Luxilus chrysocephalus	Striped Shiner
	Lythrurus fasciolaris	Scarlet Shiner
	Lythrurus umbratilis	Redfin Shiner
	Nocomis micropogon	River Chub
	Notemigonus crysoleucas	Golden Shiner
	Notropis atherinoides	Emerald Shiner
	Notropis boops	Bigeye Shiner
	Notropis buccatus	Silverjaw Minnow
	Notropis photogenis	Silver Shiner
	Notropis rubellus	Rosyface Shiner
	Notropis stramineus	Sand Shiner
	Notropis telescopus	Telescope Shiner

Table continued on next page.

Table 13, continued. Fish species captured on the DBNF, 2005-2018.

Family	Scientific Name	Common Name
Cyprinidae	*Notropis volucellus*	Mimic Shiner
	Pimephales notatus	Bluntnose Minnow
	Pimephales promelas	Fathead Minnow
	Rhinichthys obtusus	Western Blacknose Dace
	Semotilus atromaculatus	Creek Chub
Ictaluridae	*Ameiurus natalis*	Yellow Bullhead
	Ameiurus nebulosus	Brown Bullhead
	Noturus flavus	Stonecat
	Noturus miurus	Brindled Madtom
Percidae	*Ammocrypta pellucida*	Eastern Sand Darter
	Etheostoma baileyi	Emerald Darter
	Etheostoma blennioides	Greenside Darter
	Etheostoma caeruleum	Rainbow Darter
	Etheostoma camurum	Bluebreast Darter
	Etheostoma chlorosomum	Bluntnose Darter
	Etheostoma flabellare	Fantail Darter
	Etheostoma kennicotti	Stripetail Darter
	Etheostoma nigrum	Johnny Darter
	Etheostoma obeyense	Barcheek Darter
	Etheostoma rufilineatum	Redline Darter
	Etheostoma sagitta sagitta	Cumberland Arrow Darter
	Etheostoma sagitta spilotum	Kentucky Arrow Darter
	Etheostoma spectabile	Orangethroat Darter
	Etheostoma susanae	Cumberland Darter
	Etheostoma variatum	Variegate Darter
	Etheostoma virgatum	Striped Darter
	Etheostoma zonale	Banded Darter
	Percina caprodes	Logperch
	Percina maculata	Blackside Darter
	Percina sciera	Dusky Darter
	Percina stictogaster	Frecklebelly Darter
Petromyzontidae	*Lampetra aepyptera*	Least Brook Lamprey
	Lampetra appendix	American Brook Lamprey
Salmonidae	Oncorhynchus mykiss	Rainbow Trout

Appendix A: Field Methods for Stream Inventory

Sampling Strategy

Day 1 – Macroinvertebrate collection & BVET Inventory

- All team to first site to learn site documentation, site layout, and macroinvertebrate and habitat sampling methods
- While 2 team members conduct the BVET inventory and site layout, 2 or more other team members can collect macroinvertebrates
- Split into several teams (depending on team size) to visit and document other sites, layout sites, and sample macroinvertebrates and habitat

Day 2 – Efish & Pebble Counts

- Perform efish, pebble, and bar-count sampling at sites visited on day 1
- If the team is large enough, the team can split so that two teams are continuing with site documentation, site layout, macroinvertebrate, and habitat sampling methods

Day 3

- Continue with approach from day 2, allowing at least 1 day between macroinvertebrate and fish sampling
- If the fish sampling team catches up with the layout team, then take a day to split into several layout teams as during day 1
- When layout team finishes all sites they can rejoin fish sampling team

This approach should maximize team efficiency and prevent biases associated with sampling fish and macroinvertebrates within the same site in the same day.

Site Documentation

Objective - Record location and description of site for reporting purposes

Methods

- Directions to site
    - Record roads taken to parking area
    - Record trails walked to site
    - Document route to site on quadrangle map

- GPS
    - Record GPS coordinates at start and end of inventory

- Photos
    - Take digital photo from downstream end looking up, upstream end looking down
    - Photograph any pertinent features within the site that may influence habitat and fauna, example, road or trail crossings, erosion, etc.

- Written description
    - Record comments on land use in the site area, for example private land with mowed lawns, all forested, pasture lands, etc.
    - Record comments on other features that may be influencing stream conditions

Site Layout

Objective - Use consistent method to lay out site for fish and macroinvertebrate sampling

Methods

- Locate 1 – 2 riffles or runs and determine the average wetted width by making several measurements and computing the average. Measure width perpendicular to thalweg.

    - If the average wetted width is less than or equal to 3.0 m, then the site length will be 120 m
    - If the average wetted width is greater than or equal to 7.5 m, then the site length will be 300 m
    - If the average wetted width is between 3.0 and 7.5 m, then site length is 40-times the average wetted width, example: average wetted width = 5 m; site length = 5 x 40 = 200m

- Hang a double orange flag at the downstream end of the site . Attach topofil from a hipchain and walk to the midpoint of the site, hang a single orange flag, then continue to the end of the site and hang another single orange flag (hanging the flags to layout the site can be done while performing the BVET inventory)

- Record the average wetted width and site length on the datasheet

- Sites will not be moved to avoid road or trail crossings – moving sites violates the assumptions of the stratified random sample design and invalidates statistical analysis. Document these features fully with photos and written descriptions

- Always begin sites at the downstream end of a defined habitat unit, end points should be at the exact distance as described above

- In large streams make sure the site includes all of a fast water habitat unit and all of a slow water habitat unit

Habitat Inventory (BVET)

Objective – Characterize stream habitat attribute within the sample site.

Methods

- Collect attribute as described in Section 2 of Roghair and Nuckols (2005) (Appendix B)

- Increase frequency of paired (sub-) samples to include at least 3 fast and 3 slow water units within each site
    - Where less than 3 fast or slow occur, sub-sample all units

- Start and end data collection at habitat unit breaks
    - This may extend habitat data collection slightly beyond end of sample site (however, still hang site-end flag at calculated distance, not at the upper end of habitat unit)

Macroinvertebrates Inventory

Objective - Collect assemblage sample

Methods

- Using D-frame nets and a seine collect macroinvertebrates using the riffle sample and multi-habitat sample methods described by KDOW (2011)

- Where possible, keep macroinvertebrate samples within designated sites. If this is not possible be sure to indicate on datasheet.

Kentucky Division of Water (KDOW). 2011. Methods for sampling benthic macroinvertebrate communities in wadeable waters. Kentucky Department for Environmental Protection. Division of Water, Frankfort, KY.

Electrofishing Inventory

Objective - Determine relative abundance and determine catch-per-unit-effort (CPUE). Note: we are not attempting to estimate population size or density for individual species, only assessing the fish assemblage

Methods (based on sampling strategies discussed and approved by R8 and SRS personnel in 3/2005)

- Electrofishing starts in same location as habitat inventory

- Electrofishing ends at location designated in site layout process
    - Habitat inventory may extend beyond end of designated site
    - DO NOT extend electrofishing sample beyond end of designated site

- Single-pass DC backpack electrofishing

- One shocker, 3 netters (a net on the probe can be the 3rd net)

- No blocknets

- Electrofishing effort will be equal to 1.0 seconds for each 1.0 m^2 of wetted area
    - note: this will standardize our effort and remove the potentially confounding effect of changes in wetted width relative to the bankfull channel width in wet or dry years
    - derived Warren et al. data on electrofishing effort in MS streams

- Fish will be counted and released at the site, except for a voucher specimen for each species; endangered species lists will be reviewed before sampling

- Record age-0 fish and all fish older than age-0 separately for each species

- Keep all relic mussel shells encountered

- Record number of crayfish captured (don't actively net crayfish, but bucket any that end up in the net). If also vouchering fish then keep a couple crayfish specimens (ideally Form I & II males)

Pebble Count Inventory

Objective - Determine the riffle stability index (RSI), bar sample geometric mean, and median particle sizes.

Methods

- Pebble count data is collected using methods modified from those in Kappesser (2002) to characterize the substrate composition of sample sites

- Pebble counts are performed in riffles designated for electrofishing by walking transects perpendicular to the flow within the bankfull channel (Harrelson et al. 1994)

- Walk the transect beginning at the edge of the bankfull channel on one side of the stream and walk heel-to-toe across the stream channel to the opposite bank

- At each step pick up the pebble at the tip of your toe and measure its intermediate axis with a ruler to the nearest millimeter

- For very large particles, the same particle is counted as many times it is encountered

- These procedures are repeated until at least 200 measurements are recorded; Transects are not terminated until the opposite bank is reached even if this results in more than 200 measurements

- Transects are distributed throughout the riffle; If detritus, LW, or other organic materials are encountered the rock substrate found directly below them is sampled

- For the bar sample, measure 30 freshly moved dominant large particles residing on a bar or similar depositional feature to estimate the largest particle size transported at flows of bankfull and above; Freshness is evaluated by lack of growing vegetation and lack of embeddedness of the particles

- The depositional feature must be in close proximity to the riffle being examined, and can include laterally attached bars, side bars, and central bars; The entire bar should be visually inspected to identify the dominant large size of particle present; If a bar deposit cannot be found, trained field personnel may select the large mobile particles from within the riffle; For each particle, measure the intermediate axis to the nearest millimeter

Bunte, K. and S. R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. General Technical Report RMRS-GTR-74. Fort Collins, CO: U. S. Deparment of Agriculture, Forest Service, Rocky Mountain Research Station.

Harrelson, Cheryl C., Rawlins, C. L., and Potyondy, John P. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61p.

Kappesser, G. B. 2002. A riffle stability index to evaluate sediment loading to streams. Journal of the American Water Resources Association. 38:1069-1081.

Appendix B: Field Methods for Habitat Inventory

Guide to Stream Habitat Characterization using the BVET Methodology on the Daniel Boone National Forest, KY

United States Department of Agriculture Forest Service
Southern Research Station
Center for Aquatic Technology Transfer
1710 Research Center Drive
Blacksburg, VA 24060-6349

C. Andrew Dolloff, Team Leader

Document prepared by:
Colin Krause

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Introduction

The Basinwide Visual Estimation Technique (BVET) is a versatile tool used to assess streamwide habitat conditions in wadeable size streams and rivers. A team of two individuals performs the inventory using two-stage visual estimation techniques described in Hankin and Reeves (1988) and Dolloff et al. (1993). In its most basic form the BVET combines visual estimates with actual measurements to provide a calibrated estimate of stream area with confidence intervals, however the team may inventory any number of other habitat attributes as they walk the length of the stream. Experienced teams can inventory an average of 2-3 km per day, but this will vary depending on stream size and the number of stream attributes inventoried.

Before a team begins a BVET inventory they must receive adequate training, both in the classroom and in the field. Estimating and measuring a large number of habitat attributes can confuse and overwhelm an inexperienced team. Individuals must have an understanding of the basic concepts behind the BVET and be familiar with habitat attributes before they can effectively and efficiently perform an inventory.

In summer 2004, resource managers on the Daniel Boone National Forest (DBNF) requested that the USFS Center for Aquatic Technology Transfer (CATT) implement modified BVET inventories to inventory stream sites previously inventoried in the 1990's. The 1990's inventories followed methods detailed in the 'Daniel Boone National Forest Stream Inventory Work Plan and Sampling Techniques Manual', which were similar in nature to the BVET habitat inventory. After discussion with resource managers from the DBNF, we scaled down the original protocol, eliminating several attributes and modifying others to maximize inventory efficiency during our limited time on the Forest. In summer 2005 the DBNF opted to use identical BVET methods as National Forests in Virginia and North Carolina, which are only slightly different from methods used in Kentucky in 2004.

This document was developed to serve as a guide for classroom and field instructions specific to the ONF BVET habitat inventory and to provide a post-training reference for field teams. It includes an overview of the BVET inventory, defines habitat attributes, instructs how and when to measure attributes, and provides reference sheets for use in the field. Each trainee should receive a copy of this manual and is encouraged to take notes in the spaces provided.

We used an abbreviated version of the BVET to sample habitat within sample sites only. Paired samples were collected more frequently then described here because sample sites were short. Stream attributes were collected as described in Section 2.

References cited in this manual:

Armantrout, N. B., compiler. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, Maryland.

Bunte, K., and S. R. Abt. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. General Technical Report RMRS-GTR-74. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Dolloff, C. A., D. G. Hankin, and G. H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. General Technical Report SE-83. Asheville, North Carolina: U.S. Department of Agriculture, Southeastern Forest Experimental Station.

Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45:834-844.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.

Rosgen, D.L., and L. Silvey. 1998 Field Guide for Stream Classification, Wildland Hydrology Books, Pagosa Springs, Colorado.

Outline of BVET Habitat Inventory

1. Enter 'Header' information on the data sheet: --- 'Header' information includes date, stream, start location, team, etc. and is **vitally** important to record for future reference.

2. Enter downstream of the starting point, then move upstream and begin the inventory. Tie off the hipchain, proceed upstream to the starting point, reset the hipchain to zero, and proceed upstream estimating parameters and recording data in every habitat unit.

3. At the paired sample units perform visual estimates, then perform measurements. Pair a minimum of 3 fast and 3 slow-water units; pair more if possible.

4. Progress upstream estimating attributes for every unit until the next paired sample unit is reached, then repeat step 4.

The team should also take care to record roads, trails, tributaries, dams, waterfalls, road crossing types, riparian features (wildlife openings, trails, campsites, roads, timber harvest, etc.), and other pertinent stream features as they progress upstream. Be sure to record hipchain distances when noting such features. Some features may also require a picture number to be associated with them.

The following sections describe the BVET habitat inventory in detail:

Section 1: Getting Started – equipment, header info, random numbers, starting the inventory
Section 2: Habitat Attributes – definitions, how to estimate or measure, when to record
Section 3: Wrapping Up – what to do when the inventory is completed
Section 4: Summary
Section 5: GPS Instructions
Appendix: field guide, random number tables, equipment checklist

Section 1: Getting Started

Equipment List

- ☐ Hipchain
- ☐ Extra string for hipchain
- ☐ Wading rod
- ☐ 50 m tape measure
- ☐ Clinometer
- ☐ Datalogger
- ☐ Thermometer
- ☐ GPS unit
- ☐ Topographic map w/NHD_ID
- ☐ Cell Phone
- ☐ First Aid Kit
- ☐ Rain Gear (optional)
- ☐ Camera
- ☐ Backpack
- ☐ Pencils
- ☐ Flagging
- ☐ Markers
- ☐ Waterproof backup datasheets
- ☐ Clipboard
- ☐ BVET field guide on waterproof paper
- ☐ Felt bottom wading boots or waders
- ☐ Water
- ☐ Water Filter
- ☐ Toilet Paper

The BVET team consists of two individuals, the 'observer' and the 'recorder'. The observer wears the hipchain and carries the wading rod. The recorder wears the data logger and carries other equipment in the backpack. The duties of each individual are listed below.

Duties

Observer	Recorder
Designate habitat units	Locate changes in NHD_ID
Measure distance	Record data
Estimate width	Determine paired sample location
Estimate depths	Classify and count Large Wood (LW)
Classify substrates	Photo-documentation
Locate features	Document features
Estimate percent fines	GPS-documentation

Both team members are needed to measure actual widths, channel widths, riparian areas, gradient, and water temperature at designated units. Although the team has assigned duties, they should not hesitate to consult with each other if they have questions or feel that a mistake may have been made. Working as a team will provide the best possible results.

Header Information

Header information is **vitally important** for future reference. Take the time to record all categories completely and accurately.

Stream Name	Full name of stream
District	National Forest District name
Quad	USGS 1:24,000 quadrangle name
Date	Record date(s) of inventory
Recorder	Full name of recorder
Observer	Full name of observer
GPS	Record at start and end locations, always use NAD83 CONUS, UTM
Location	**Detailed** written description of start point, include landmarks, road #, etc.
Comments	Record signs of activity in area, water conditions, other pertinent information

Starting the Inventory

After the team has organized their gear, determined their measurement interval, selected a random number, and recorded all the header information they are ready to begin the habitat inventory.

The observer should enter the stream slightly downstream of the starting point, tie off the hipchain, progress upstream to the starting point, reset the hipchain to zero and begin walking upstream through the first habitat unit. As the observer moves upstream they use the wading rod to measure depth at several locations in the habitat unit and make observations of unit type, width, substrates, and percent fines. When they reach the upstream end of the habitat unit they stop, turn to face the unit and report the unit type, maximum and average depth, riffle crest depth (where appropriate), dominant and subdominant substrate classes, percent fines, estimated width, and hipchain distance to the recorder.

As the observer moves upstream through the unit, the recorder follows behind, recording the amount of LW in the habitat unit. The recorder also assigns a number to the habitat unit. The recorder tells the observer if a unit is designated for measurements (i.e. if it is a ‘paired sample’ unit) only after they have recorded visual estimates.

The team continues upstream making estimates in every habitat unit and making estimates and measurements in every paired sample unit until the inventory endpoint is reached.

Definitions of habitat attributes, how to measure and when to record them, and what to do when the inventory is complete are covered in the following sections.

Section 2: Stream Attributes

Unit Type (see abbreviations)

Unit Type	Abbreviation	Definition
Riffle	R	**Fast water, turbulent, gradient <12%**; shallow reaches characterized by water flowing over or around rough bed materials that break the surface during low flows; also **include rapids** (turbulent with intermittent whitewater, breaking waves, and exposed boulders), **chutes** (rapidly flowing water within narrow, steep slots of bedrock), and **sheets** (shallow water flowing over bedrock) if gradient <12%
Cascade	C	**Fast water, turbulent, gradient ≥12%**; highly turbulent series of short falls and small scour basins, with very rapid water movement; also **include sheets** (shallow water flowing over bedrock) and **chutes** (rapidly flowing water within narrow, steep slots of bedrock) if gradient ≥12%
Run	RN	**Fast water, non-turbulent, gradient <12%**; deeper than riffles with little or no surface agitation or flow obstructions and a flat bottom profile
Pool	P	Slow water, surface turbulence may or may not be present, gradient <1%; generally deeper and wider than habitat immediately upstream and downstream, concave bottom profile; includes dammed pools, scour pools, and plunge pools
Glide	G	**Slow water, no surface turbulence, gradient <1%**; shallow with little to no flow and flat bottom profile
Underground	UNGR	Stream channel is dry or not containing enough water to form distinguishable habitat units

*modified from Armantrout (1998)

How to estimate:
Habitat units are separated by 'breaks'. Breaks can be obvious physical barriers, such as a debris dam separating two pools or a small waterfall separating a pool and riffle, or may be less obvious transitional areas. Questions often arise as to whether a break is substantial enough to split two habitat units and where the exact location of the break occurs. When in doubt, the observer should consult with the recorder and the team should 'think like a fish'. To determine if a break should be made, consider whether a fish would have to make an effort to move across the break and into the next habitat unit. If not, then it is probably a single habitat unit.

The channel may have both pool and riffle type habitat in the same cross-sectional area. Determine predominate habitat type and record it as the unit type. For example if an area contains both pool and riffle, but the majority of the flow is into and out of the pool habitat, then call the unit a pool.

Questions also often arise as to the minimum size of individual habitat units. Generally, if a habitat unit is not at least as long as the wetted channel is wide, then do not count it as a separate habitat unit. This rule may need to be adjusted for streams wider than 5 m. Use best professional judgment in such cases.

See the section 2.1 for a list of features that should also be recorded while performing the inventory.

When to record: every habitat unit

Unit Number (#)

Definition:
Count of habitat units of similar types, used to determine location of paired sample units

How to estimate:
When counting habitat units, group pools and glides (slow water) together, and group riffles, runs, and cascades (fast water) together. For example, consider the following sequence of habitat units:

Pool – Riffle – Pool – Pool – Riffle - Cascade – Riffle - Glide – Riffle – Pool – Run – Pool – Riffle

Habitat units in this sequence would be counted in the following manner (similar types are shaded same color):

Unit Type	Unit Number
P	1
R	1
P	2
P	3
R	2
C	3
R	4
G	4
R	5
P	5
RN	6
P	6
R	7

In the above example, the team has counted six slow water (pool/glide) units and seven fast water (riffle/run/cascade) units.

When to record: every habitat unit; not recorded for features

Distance (m)

Definition:
Number of meters (rounded to the whole meter) from the start of the inventory to the upstream end of the habitat unit or distance from the start of the inventory to upstream end of a feature, used as spatial reference for data analysis and to locate features in the future.

How to estimate:
The observer walks upstream in the middle of the stream channel with a hipchain measuring device. When they reach the upstream break between habitat units or the upstream end of a feature they stop and report the distance to the recorder.

Care should be taken to keep the hipchain string in the middle of the stream, especially around bends and meanders. If the hipchain should break, retreat to the location where the break occurred, tie off the hipchain, and continue. If the hipchain is reset for any reason be sure to note it in the comments.

When to record: every habitat unit and feature

Estimated Width (m)

Definition:
Average wetted width of the habitat unit as estimated visually (typically to half-meter accuracy), used to calculate stream area. Wetted width is the distance from the edge of the water on one side of the main channel to the edge of the water on the opposite side of the main channel.

How to estimate:
The observer notes the general shape and width of the unit while walking to the upstream end. When they reach the upstream end of the unit the observer stops, turns to face the unit, and estimates the average wetted width. Measure the wetted width of the stream before starting each day to calibrate yourself.

When to record: every habitat unit

Maximum and Average Depth (cm)

Definitions:
Maximum Depth – vertical distance from substrate to water surface at deepest point in habitat unit
Average Depth – average vertical distance from substrate to water surface in habitat unit

How to estimate:
The observer uses a wading rod marked in 5 cm increments to measure water depth as they walk upstream through the habitat unit. Water depth in deepest spot is recorded as the maximum depth. Average depth is the average of several depth measurements taken throughout the habitat unit.

When to record: every habitat unit

Riffle Crest Depth (cm)

Definition:
Vertical distance from the substrate to the water surface at the deepest point in the riffle crest. The riffle crest is the shallowest continuous line (usually not straight) across the channel where the water surface becomes continuously riffled in the transition area between a riffle (or a run or cascade) and a pool (or glide) (Armantrout 1998); think of it as the last place water would flow out of the pool if the riffle ran dry.

How to estimate:
When the observer reaches the upstream end of a riffle (or a run or cascade) leading into a pool (or glide), they use the wading rod to measure the deepest point in the riffle crest. Record the depth in the RCD column for the riffle habitat row.

When to record: at the upstream end of any riffle, run, or cascade leading into a pool or glide

Dominant and Subdominant Substrate (1-9)

Definitions:
Dominant Substrate – size class of stream bed material that covers the greatest amount of surface area within the wetted channel of the habitat unit.

Subdominant Substrate – size class of stream bed material that covers the 2nd greatest amount of surface area within the wetted channel of the habitat unit.

How to estimate:
The following size classes are used to categorize substrates*. The substrate 'Number' is entered into the dominant and subdominant substrate columns on the datasheet.

Type	***Number***	***Size (mm)***	**Description**
Organic Matter	1		dead leaves, detritus, etc. – **not live plants**
Clay	2		sticky, holds form when rolled into a ball
Silt	3		slippery, does not hold form when rolled into a ball
Sand	4	silt – 2	grainy, does not hold form when rolled into ball
Small Gravel	5	3-16	sand to thumbnail
Large Gravel	6	17-64	thumbnail to fist
Cobble	7	65-256	fist to head
Boulder	8	>256	larger than head
Bedrock	9		solid rock, parent material, may extend into bank

* these size classes are based on the modified Wentworth scale

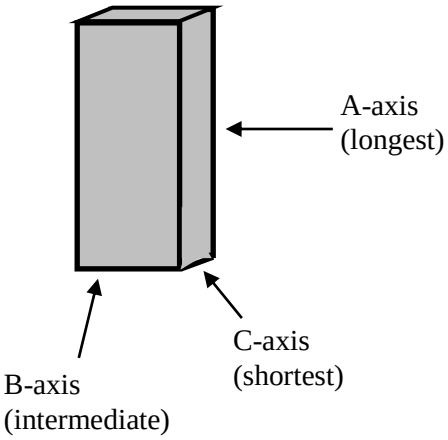
As the observer walks through the unit they scan the substrate. When they reach the upstream end of the unit they stop, turn to face the unit, and determine the dominant and subdominant substrate classes.

Estimate substrate size along the intermediate axis (b-axis). The b-axis is not the longest or shortest axis, but the intermediate length axis (see below). It is the axis that determines what size sieve the particle could pass through. Remember that your eyes are naturally drawn to larger size substrates. Be careful not to bias your estimate by focusing on the large size substrate.

Some units will contain a mixture of particle sizes. Consult with the recorder and use your best professional judgment to choose the dominant and subdominant sizes.

In units where the substrate is covered in moss, algae, or macrophytes classify the underlying substrate and make note of the plant growth in the comments. Only call organic substrate where there is dead and down leaves or other detritus covering the bottom of the unit.

When to record: every habitat unit



Rosgen Channel Type (A-G)

Definitions:
Stream channel classification system described in Rosgen (1996) based on entrenchment, width/depth ratio, sinuosity, and percent slope

How to Measure:
Before the team begins the inventory they should make the measurements described below to determine the channel type. Channel types are based on the following channel characteristics:

	A	B	C	D	E	F	G
Entrenchment	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Sinuosity	1 – 1.2	> 1.2	>1.2	n/a	> 1.5	> 1.2	> 1.2
Slope (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

Although we record channel type for every unit, it was designed to describe a reach of stream. Our main objective here is to locate changes between channel types, which could either be abrupt (such as change from a B to a G near a road crossing) or less obvious transitional areas (such as a natural transition from a B to an A channel as you move upstream). If you think channel type may have changed take the time to make the calculations listed below to determine the channel type for the reach you are entering.

Full channel type descriptions and how to measure each of the channel characteristics in the table above can be found in Rosgen (1998). Never perform measurements in a pool, always attempt to find a run or deep riffle with well-defined bankfull indicators to perform measurements. A summary of each is listed below:

Entrenchment (page 31 & 32 in Rosgen field guide):
- locate suitable riffle or run area for bankfull measurement (page 24-25 in Rosgen field guide)
- measure the bankfull width the maximum bankfull depth
- stretch a tape across the channel at 2x the maximum bankfull depth (this is the flood prone area)
- divide the flood prone area width by the bankfull width to determine entrenchment ratio

Width to Depth Ratio (page 32 in Rosgen field guide):
- locate suitable riffle or run area for bankfull measurement (page 24-25 in Rosgen field guide)
- measure the bankfull width and the maximum bankfull depth
- divide bankfull width by depth to determine width to depth ratio

Sinuosity (need aerial photo to determine)

Slope (page 37 in Rosgen field guide):
- Measure riffle to riffle gradient using clinometer

When to measure: every paired fastwater habitat unit*

* record for every fastwater paired unit, but remember this is describing a site characteristic – see above

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.

Rosgen, D.L., and L. Silvey. 1998 Field Guide for Stream Classification, Wildland Hydrology Books, Pagosa Springs, Colorado.

Percent Fines (%)

Definition:
Percent of the total surface area of the stream bed in the wetted area of the habitat unit that consists of sand, silt, or clay substrate particles (i.e. particles < 2 mm diameter).

How to estimate:
As the observer walks through the habitat unit they note the amount of sand, silt, and clay in the habitat unit. When they reach the upstream end of the unit, they stop, turn to face the unit and estimate the amount of the total surface area within the wetted channel that consists of sand, silt, or clay.

Where to estimate: every habitat unit

Large Wood (1-4 and rootwad)

Definition:
Count of dead and down wood within the bankfull channel of a habitat unit

How to estimate:
The recorder classifies and counts LW as they walk through the habitat unit. LW counts are grouped by the size classes listed below:

Category	Length (m)	Diameter (cm)	Description
1	1-5	10-55	short, skinny
2	1-5	>55	short, fat
3	>5	10-55	long, skinny
4	>5	>55	long, fat
RW	rootwad	rootwad	roots on dead and down tree

Only count wood that is:
- 1 m in length and > 10.0 cm in diameter
- Within the bankfull channel
- Fallen, not standing dead

Additionally:
- Count rootwads separately from attached pieces of LW
- Estimate the diameter of LW at the widest end of the piece
- A piece that is forked, but is still joined counts as only one piece of LW
- Only count each piece one time, do not count a piece that is in two habitat units twice
- Enter the total count for each size category into the appropriate column on the datasheet

Where to estimate: every habitat unit

Actual Width (m)

Definition:
Average wetted width of the habitat unit as measured with 50 m tape, used to calculate stream area. Wetted width is the distance from the edge of the water on one side of the main channel to the edge of the water on the opposite side of the main channel.

How to measure:
Use a meter tape to measure the wetted width of the stream in at least three locations. Average the measurements to obtain the average wetted width.

Where to measure: paired sample habitat units

Bankfull Channel Width (m)

Definition:
Actual width of channel at bankfull elevation as measured with meter tape. Depending on channel type, bankfull may or may not be represented by the top of the banks. Use bankfull indicators to locate the top of the bankfull channel (Rosgen 1996).

How to measure:
Determine the location of bankfull water depth on both banks of the habitat unit and measure across the channel perpendicular to flow from bankfull to bankfull.

Where to measure: paired sample riffles, runs, or cascades

Riparian Width (m)

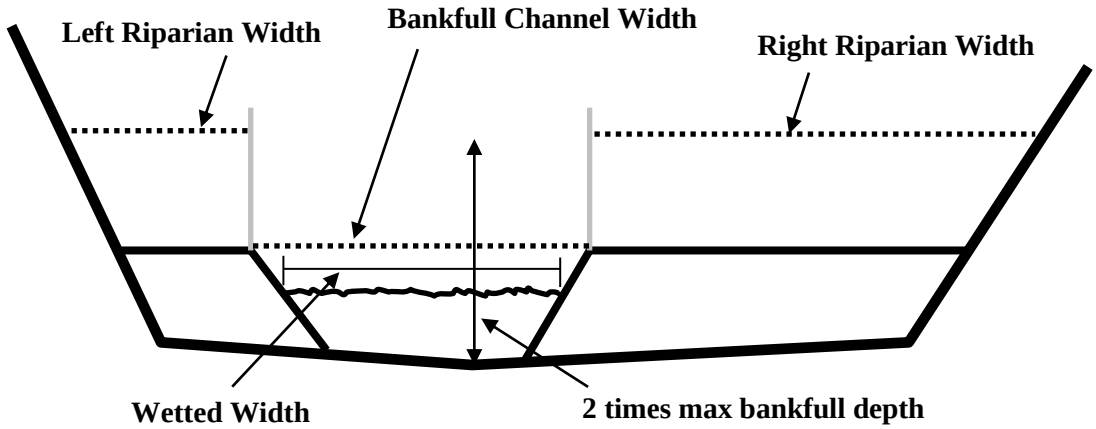
Definition:
Width of the riparian area at an elevation of two times the maximum bankfull depth, measured for both left and right banks (left and right as oriented facing upstream). Maximum bankfull depth is the greatest vertical distance from the substrate to the top of the bankfull channel across a bankfull transect.

How to measure:

- Stretch a measuring tape across the top of the bankfull channel – this is your bankfull transect
- Use a wading rod to find the maximum bankfull depth
- Place the clinometer against the wading rod at two-times the maximum bankfull depth
- Using the clinometer to maintain a slope of zero degrees, site perpendicular to the channel to the intersection with the nearest landform. It may be necessary to site to an intermediate point, move the wading and clinometer, and site again if the tape measure is too short or the view is obstructed
- Measure the distance from the edge of the bankfull channel to the landform – do this separately for the left and right (as facing upstream) riparian areas

Note: if riparian width is more than 50 m, record 51 as the riparian width and note in 'Comments' that riparian width was longer than meter tape

Where to measure: paired sample riffles, runs, or cascades



Gradient (%)

Definition:
Change in vertical elevation per unit of horizontal distance of the water surface (Armantrout 1998)

How to measure:
Gradient is measured in riffles with a clinometer using the following steps:

- Observer stands at upstream end of riffle, recorder stands at downstream end of riffle
- Recorder sites upstream to the height of their eye on the observer using clinometer
- Record the **percent** slope, **not the degrees** (tip the clinometer all the way back to determine which side of the scale is percent)

The recorder should determine the height of their eye on the observer at the beginning of the inventory. Be certain that the observer and recorder are standing with their feet in the same position (preferably with feet at top of water surface) within the stream channel. If the observer is standing on top of a boulder and the recorder is standing in a depression, the measured gradient will be incorrect.

Where to measure: paired sample riffles, runs, or cascades

Water Temperature (C)

Definition:
Temperature of the water in degrees Celsius.

How to measure:
Place the thermometer in moving water in an area not exposed to direct sunlight. Leave the thermometer sit for at least three minutes, then record the water temperature in degrees Celsius.

Where to measure: paired sample riffles, runs, or cascades

Photo (ID#)

Definition:
Photograph of habitat unit or crossing feature.

How to measure:
Take photo facing upstream with observer holding wading rod in picture. Be sure to get entire width (and length if possible) of habitat unit or crossing feature in the photo.

Where to measure: paired sample riffles, runs, or cascades and any crossing features encountered

Features

Definition: Points on a stream that could potentially serve as landmarks, may be natural or manmade.

How to measure: Record the distance to the upstream end of all features and take a photograph of all crossing features.

Where to record: wherever found

Channel Feature	Abbreviation	What to Record
Waterfall[1]	FALL	Distance, estimated height
Tributary	TRIB	Distance, average wetted width, into main channel on left or right (as facing upstream)
Side channel[2]	SCH	Distance, average wetted width, whether it is flowing into or out of main channel on left or right (as facing upstream)
Braid[3]	BRD	Distance at start and distance at end; continue with normal inventory up channel with greatest discharge
Seep (Spring)	SEEP	Distance, left or right bank (as facing upstream), size, coloration
Landslide	SLID	Distance, left or right bank (as facing upstream), estimated size
Other	OTR	Distance, description of feature, *example:* found water intake pipe going to house here; old burned out shack on side of stream; Big Gap campground on left; alligator slide here, etc.

[1] must be vertical with water falling through air to be a waterfall and not a cascade, do not record unless >1m high
[2] two channels, continue with normal inventory up channel with most volume
[3] three or more channels intertwined, continue with normal inventory up channel with most volume

Crossing Feature	Abbreviation	What to Record*
Bridge	BRG	Distance, width, height, road or trail name and type (gravel, paved, dirt, horse, ATV, etc.), photo
Ford	FORD	Distance, road or trail name and type (gravel, paved, dirt, etc.), photo
Dam	DAM	Distance, type, condition, estimated height, dam use, name of road or trail, if applicable; include beaver dams, photo
Culvert	V	Distance, road or trail name, type, # of outlets, diameter/width, height, material, perch (distance from top of water to bottom lip of culvert, natural substrate (present or absent through length), photo

* photograph all crossing features with person and wading rod for scale, record 'Y' in 'Photo' column

We cannot stress enough the importance of fully and accurately describing features. This means getting out a quadrangle map and finding road, trail, and tributary names and recording them in 'Comments' and taking the time to describe the location of features in relation to landmarks found on quadrangle maps.

Take photos of all crossing features!

Section 3: Wrapping Up

End the inventory where:

- Forest Service property ends
- Stream is dry for more than 500 m
- Stream channel is < 1.0 m wide for more than 500 m

Record the following in the Comments:

- Time and date
- Reason for ending the inventory
- Detailed written description of location using landmarks for reference
- **Be sure the header information is completed – GPS, etc**

When you return to home base:

- Immediately download the data and check file to be sure all data downloaded
- Check header information to be sure it is complete
- Save to the computer and create a backup copy
- Document any photographs
- If using paper, make a photocopy of the data and store in secure location

Section 4: Summary

Before starting:

- fill in header information

Record for every habitat unit:

- Unit Type
- Unit Number
- Distance
- Estimated Width
- Maximum Depth
- Average Depth
- Dominant Substrate
- Subdominant Substrate
- Percent Fines
- Large Wood

Record for every riffle, run, or cascade leading into a pool or glide:

- Riffle Crest Depth

Record for every paired sample pool:

- Measured Width

Record for every paired sample riffle:

- Measured Width
- Bankfull Channel Width
- Riparian Width (left and right)
- Gradient
- Rosgen Channel Type
- Water temperature
- Photograph

Record features and full feature descriptions wherever they are encountered.

Photograph all crossings!

Section 5: GPS Instructions

Garmin BVET Waypoint Labels:

Garmin BVET Waypoint Label Examples:

S123	**Start** location of BVET survey
E123	**End** location of BVET survey

123 = Site identification number

How to Find a Waypoint on GPS:

- Turn Power On.
- On the main menu screen touch the **Where To?** icon with the magnifying glass.
- Touch the **Waypoints** icon with the red flag.
- At the bottom right of the next screen touch the **3-lines** button, then **Spell Search**.
- Start typing in the name of the desired waypoint. Once the waypoint name is identified by the GPS it will list the waypoints associated with that waypoint name.
- Touch the waypoint name you were looking for when the list pops up.
- To navigate to this location touch the big green **Go** button.

Changing Waypoints:

- To switch waypoints close the map screen by touching the **X** close button in the lower left corner of the screen.
- On the main menu screen touch the **Where To?** icon with the magnifying glass.
- Touch the Stop Navigation button and repeat the top process to get to a new waypoint.

Appendix: Field Guide, Equipment Checklist, Rosgen Worksheet

Record for every habitat unit:

- **Unit Type** – pool, riffle, run, cascade, glide, feature (see below)
- **Unit Number** – group pools & glides; group riffles, runs, cascades
- **Distance (m)** – at upstream end of unit
- **Estimated Width (m)** – visual estimate of average wetted width
- **Maximum Depth (cm)** – deepest spot in unit
- **Average Depth (cm)** – average depth of unit
- **Dominant Substrate (1-9)** – covers greatest amount of surface area in unit
- **Subdominant Substrate (1-9) –** covers 2nd most surface area in unit
- **Percent Fines (%)** – percent of bottom consisting of sand, silt, or clay
- **Large Wood (1-4, RW)** – count of dead and down wood in the bankfull channel

Record for every riffle, run, or cascade leading into a pool or glide:

- **Riffle Crest Depth (cm)** – deepest spot in hydraulic control between riffle type habitat and pool type habitat

Record for paired sample pools:

- **Measured Width (m)** – measurement of average wetted width

Record for paired sample riffles:

- **Measured Width (m)** – measurement of average wetted width
- **Channel Width (m)** – measurement of bankfull channel width
- **Riparian Width (m)** – L&R, measurement of floodplain
- **Gradient (%)** – clinometer measurement of riffle slope
- **Water Temperature (C)** – temperature of water in Celsius
- **Rosgen –** channel type classification
- **Photo (y or n)** – picture of habitat unit or crossing feature

Unit Types

- **Riffle (R)** – fast water, turbulent, gradient <12%; includes rapids, chutes, and sheets if gradient <12%
- **Cascade (C)** – fast water, turbulent, gradient ≥12%, includes sheets and chutes if gradient ≥12%
- **Run (RN)** – fast water, little to no turbulence, gradient <12%, flat bottom profile, deeper than riffles
- **Pool (P)** – slow water, may or may not be turbulent, gradient <1%, includes dammed, scour, and plunge pools
- **Glide (G)** – slow water, no surface turbulence, gradient <1%, shallow with little flow and flat bottom profile
- **Underground (UNGR)** – distance at upstream end, why dry

Features

- **Waterfall (FALL)** – distance, height
- **Tributary (TRIB)** – distance, width, in on L or R
- **Side Channel (SCH)** – distance, width, in or out on L or R
- **Braid (BRD)** – distance at downstream and upstream ends
- **Seep or Spring (SEEP)** – distance, on left or right, amount of flow
- **Landslide (SLID)** – distance, L or R, est. size and cause
- **Other (OTR)** – record distance, describe feature in comments
- **Crossing Features** – photograph and record the following:
- **Bridge (BRG)** – distance, height, width, road or trail name & type
- **Dam (DAM)** – distance, type, est. height, road or trail name &type
- **Ford (FORD)** – distance, road or trail name & type
- **Culvert (V)** – distance, type (pipe, box, open box, arch, open arch), size, material, natural substrate, perch, road or trail name

Substrates

- **Organic Matter** – dead leaves detritus, etc., not living plants
- **Clay** – sticky, holds form when balled
- **Silt** – slick, does not hold form when balled
- **Sand** – >silt-2mm, gritty, doesn't hold form
- **Small Gravel** – 3-16mm, sand to thumbnail
- **Large Gravel** – 17-64mm, thumbnail to fist
- **Cobble** – 65-256mm, fist to head
- **Boulder** – >256, > head
- **Bedrock** – solid parent material

Large Wood

- **#1** <5m long, 10-55cm diameter
- **#2** <5m long, >55cm diameter
- **#3** >5m long, 10-55cm diameter
- **#4** >5m long, >55cm diameter
- **RW** – rootwad, count separately from attached LW, record in comments, do not record wood <10cm diameter, <1m length

Rosgen Channel Types

Rosgen Channel Types	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Entrenchment	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Slope (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

Measuring Riparian Width (paired fast-water units only)

- Place clinometer against the wading rod at two times max bankfull depth
- Use the clinometer as a level – keep the slope at 0.0 – and site to the nearest landform perpendicular to the channel
- Measure the distance from the edge of the bankfull channel to the intersection with the landform
- Do this for both the left and right banks
- If riparian width in more than 50 m, record 51 as the riparian width and in 'Comments' note that riparian was > 50 m wide

End inventory

- End the inventory when the calculated sample distance has been inventoried.

Equipment Checklist

- ☐ hipchain
- ☐ extra string for hipchain
- ☐ wading rod
- ☐ 50 m tape measure
- ☐ clinometer
- ☐ thermometer
- ☐ datalogger
- ☐ GPS unit
- ☐ camera
- ☐ backpack
- ☐ pencils
- ☐ flagging
- ☐ markers
- ☐ waterproof backup datasheets
- ☐ clipboard
- ☐ BVET field guide on waterproof paper
- ☐ topographic maps
- ☐ water
- ☐ water filter
- ☐ lunch
- ☐ first aid kit
- ☐ radio/cell phone
- ☐ toilet paper
- ☐ felt bottom wading boots
- ☐ raingear

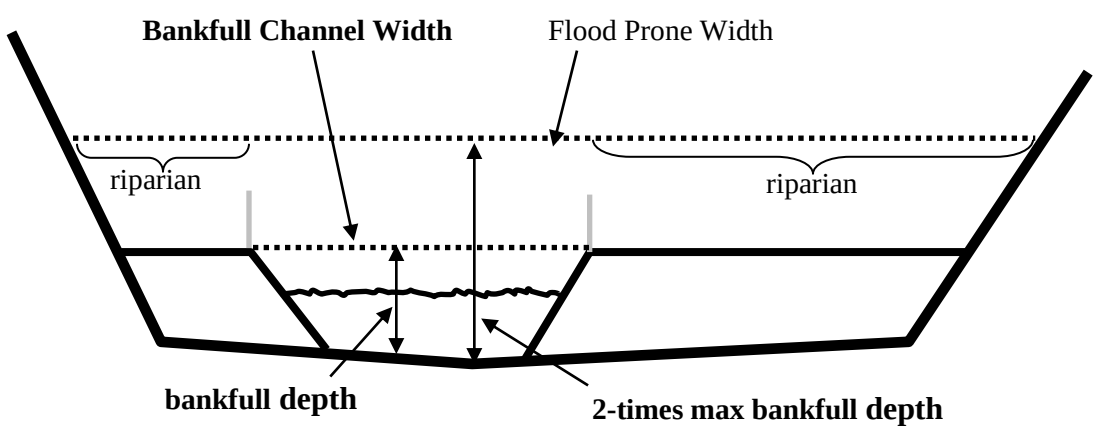
Rosgen Measurements

All measurements should be made across a transect in an area of uniform flow, specifically riffle or run sections with few irregularities in cross-sectional shape. **Avoid** areas influenced by culverts, bridges, tributaries, side-channels, etc.

- What is the **entrenchment ratio**?
    - Entrenchment ratio = flood prone width / bankfull width
    - Floodprone width = width at two-times maximum bankfull depth

- What is the **width/depth ratio**?
    - Width/depth ratio = bankfull width / average bankfull depth
    - Be sure to use same units of measure (centimeters) for width and depth
    - Measure *bankfull* depth (**not** *water* depth) at several locations across transect to obtain average bankfull depth

- What is the **gradient**?
    - Measure riffle to riffle slope (%) with clinometer



Rosgen Worksheet

A. Bankfull Channel Width (m) _____

B. Maximum Bankfull Depth (cm) _____ *2 = _____

C. Average Bankfull Depth (cm) _____

D. Right Riparian Width (m) _____

E. Left Riparian Width (m) _____

F. Gradient (%) _____

Entrenchment Ratio = (A+D+E)/A

(_____ + _____ + _____) / _____ = _____

Width Depth Ratio = (100*A)/C

(100* _____) / _____ = _____

	A	B	C	D	E	F	G
Entrench. ratio	< 1.4	1.4 – 2.2	> 2.2	n/a	> 2.2	< 1.4	< 1.4
W/D ratio	< 12	> 12	> 12	> 40	< 12	> 12	< 12
Gradient (%)	4 – 9.9	2 – 3.9	< 2	< 4	< 2	< 2	2 – 3.9

*these are the dominant ranges, values may be slightly outside these ranges

Appendix C: Field Methods for Macroinvertebrate Sampling

Macroinvertebrate Equipment List

- ☐ Mesh wash bucket
- ☐ Rinse bucket
- ☐ Squirt bottle
- ☐ Seine
- ☐ D-Frame nets
- ☐ PVC ¼ sq meter quadrates
- ☐ Tweezers
- ☐ Collection jars
- ☐ Sample labels
- ☐ Pencils
- ☐ Markers
- ☐ Ethyl alcohol

Macroinvertebrate Sampling Methods

1. **Riffle Sample**
   - Take four 0.25 m^2 samples from midriffle or the thalweg (path of deepest thread of water).
   - For each of the 4 samples, place a seine (600 μm mesh, one meter wide) in moderate to fast current in areas with gravel to cobble substrate. Place some rocks on the bottom edge of the seine to hold it on the channel bottom.
   - Dislodge benthos by vigorously disturbing 0.25 m^2 (20 x 20 in.) in front of the net (use 0.25 m^2 PCV quadrate to sample correct area). Large rocks should be hand washed into the net.
   - After each of the 4 samples is collected wash the contents of the net into a mesh wash bucket to prevent loss of inverts when collecting the next sample. All four samples are composited in the bucket.
   - Find a suitable location on the side of the stream, spread the seine out on the ground, and wash the contents of the bucket onto the seine. With tweezers methodically sort through the sample picking out the invertebrates and placing them in a sample jar containing ethyl alcohol.
   - The picking process can easily take an hour to complete; be patient and thorough. When complete be sure there is a sample label inside the jar as well as one on the outside.
   - *This sample must be kept separate from all other subhabitat collections.*

2. **Multi-Habitat Sample**

   A. **Sweep Sample** - Involves sampling a variety of non-riffle habitats with the aid of an 800 x 900 μm mesh D-frame dipnet. Each habitat is sampled in at least three (3) replicates, where possible.

      1) *Undercut banks/root mats* - sampled by placing a large rootwad into the D-frame dipnet and shaken vigorously. The contents are removed from the dipnet and placed into a mesh wash bucket. Note: if undercut banks are present in both run and pool areas, each is sampled separately with three replicates.

2) *Marginal emergent vegetation* (exclusive of *Justicia americana* beds) – sampled by thrusting (i.e., "jabbing") the dipnet into the vegetation for ca. 1 m, and then sweeping through the area to collect dislodged organisms. Material is then rinsed in the wash bucket and any sticks, leaves and vegetation are thoroughly washed and inspected before discarding.

3) *Bedrock or slab-rock habitats* - sampled by placing the edge of the dipnet flush on the substrate, disturbing approximately 0.1 m^2 of area to dislodge attached organisms. Material is emptied into a wash bucket.

4) *Justicia americana (water willow) beds* - sampled by working the net through a 1 m section in a jabbing motion. The material is then emptied into a wash-bucket and any *J. americana* stems are thoroughly washed, inspected and discarded.

5) *Leaf Packs* - preferably "conditioned" (i.e., not new-fall material) where possible; samples are taken from a variety of locations (i.e., riffles, runs and pools) and placed into the wash-bucket. The material is thoroughly rinsed to dislodge organisms and then inspected and discarded.

B. Silt, sand, and fine gravel

1) *Netting* - a D-frame dipnet is used to collect sand and silt depositional areas by placing the net on the substrate and vigorously stirring the sediments in front of the net. An area of 0.1 m^2 is sampled for each replicate making sure, where possible, that replicates are taken from different depositional areas.

C. Aufwuchs sample - small invertebrates associated with this habitat are obtained by washing a small amount of rocks, sticks, leaves, filamentous algae and moss into a medium-sized bucket half filled with water. The material is then elutriated and sieved with the nitex sampler.

D. Rock Picking - invertebrates are picked from 15 rocks (large cobble-small boulder size; 5 each from riffle, run and pool). Selected rocks are washed in a bucket half filled with water, then carefully inspected to remove invertebrates with fine-tipped forceps.

E. *Wood Sample* - pieces of submerged wood, ranging from roughly 3 to 6 meters (10 to 20 linear feet) and ranging from 5–15 cm (2–6 inches) in diameter, are individually rinsed into the wash-bucket. Pieces of wood are inspected for burrowers and crevice dwellers. Large diameter, well-aged logs should be inspected and handpicked with fine-tipped forceps.

Macroinvertebrate Sampling Summary

	Sample	Sampling Device	Habitat	Replicates (composited)
1	Riffle*	Kick Seine/Mesh bucket/PVC Sq.	Riffle	4 - 0.25 m^2
2	Sweep - Undercut banks	Dipnet/Mesh Bucket	Undercut Banks/Roots	3
3	Sweep - Emergent vegetation	Dipnet/Mesh Bucket	Emergent Vegetation	3
4	Sweep - Bedrock	Dipnet/Mesh Bucket	Bedrock/Slabrock	3
5	Sweep - Justicia beds	Dipnet/Mesh Bucket	Justicia beds	3
6	Sweep - Leaf packs	Dipnet/Mesh Bucket	Riffle-Run-Pool	3
7	Silt,Sand, Fine Gravel	Dipnet/Mesh Bucket	Margins	3
8	Aufwuchs	Dipnet/Mesh Bucket	Riffle-Run-Pool	3
9	Rock Picking	Forceps	Riffle-Run-Pool	15 rocks (5-5-5)
10	Wood	Mesh Bucket	Riffle-Run-Pool	3-6 linear m

*Sample contents kept separate from other habitat samples.

Appendix D: Field Methods for Riffle Stability Index

Riffle Stability Index Field Methods

The Riffle Stability Index procedure is best applied to stream channels with gradients from 1.5 to 5 percent. The channel is best described as a Rosgen B-2, B-3, B-4or F-2, F-3, F-4 type. Three riffles are measured within each uniform Rosgen reach. Each riffle selected for measurement should be representative or typical within the reach. An ideal riffle is located in a straight section of reach, has uniform depth in the cross-section, and is at a point of thalweg crossover. Flow is evenly distributed across the channel and is not concentrated toward either bank. For each riffle, field data are gathered to determine the distribution of particle sizes present. An estimate of the common large size of particle capable of movement at bankfull flow is obtained by sampling a nearby bar deposit.

1. Pebble Count - Particle Size Distribution on the Riffle

A particle size distribution is obtained on the riffle by a bed material sampling procedure called a "Wolman Pebble Count". A sample size of at least 200 is necessary for RSI. The sample points are identified by establishing a sampling grid over the riffle, with transects across the channel from bankfull to bankfull over the entire length of riffle. Samples are taken every foot along the transect. Thus, bankfull width in feet will equal the number of samples per transect. Dividing 200 by the number of samples per transect and rounding up will determine the number of transects needed. Spacing between transects is determined by dividing the length of riffle by the number of transects needed. For each sample, the intermediate axis of the particle is measured using a metric caliper, and is tallied by size class. For very large particles, count the same particle as many times as you encounter it. The cumulative percent finer is then calculated for each size class, and plotted on the graph.

2. Bar (Cobble) Count - Dominant Large Particles on a Bar

Measure 30 of the freshly moved dominant large particles residing on a bar or similar depositional feature to estimate the largest particle size transported at flows of bankfull and above. Freshness is evaluated by lack of growing vegetation and lack of embeddedness of the particles. The depositional feature must be in close proximity to the riffle being examined, and can include laterally attached bars, side bars, and central bars. The entire bar should be visually inspected to identify the dominant large size of particle present. If a bar deposit cannot be found, trained field personnel may select the large mobile particles from within the riffle. When this is done, a sample size of at least 20 is needed. For each of the particles, the intermediate axis is measured and recorded to the nearest millimeter. Calculate the arithmetic mean of the sample, and compare this with the plotted cumulative particle size distribution for the riffle. On the X axis, find the mean bar sample grain size. Go up to the cumulative particle size distribution, and read from the Y axis the percentile this represents. This percentile is the Riffle Stability Index.