Comparison of 2003 & 2017 Davidson River Habitat Inventories on the Pisgah District of the Pisgah National Forest, North Carolina

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

Report prepared by:
Brandon Fair, Colin Krause, and Craig Roghair
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USDA Forest Service
Southern Research Station
Center for Aquatic Technology Transfer
1710 Research Center Dr.
Blacksburg, VA 24060

Table of Contents

List of Figures

List of Tables

Introduction

The Davidson River watershed has a rich history of forest stewardship that began in 1898 at the Biltmore Forest School, the present-day Cradle of Forestry, and continues today through the Pisgah National Forest (PNF). The Biltmore Forest School was established to teach sustainable forestry and became the first educational facility of its kind. Prior to its opening, the land surrounding the school was severely damaged by fire, grazing, and logging practices typical of late 19th and early 20th century. Today, the Cradle of Forestry is an important site for public outdoor education and environmental awareness (Beanblossom 2017). The lands of the Davidson River watershed are largely managed by the PNF for multiple uses, including recreation and draws over 40,000 visitors each year for activities including photography, camping, hiking, mountain biking, swimming, fishing, and tubing (McKissok 2012).

The Davidson River hosts a diverse coldwater community including Rainbow Trout (*Oncorhynchus mykiss*), Brown Trout (*Salmo trutta*), and Brook Trout (*Salvelinus fontinalis*), and a population of the imperiled Eastern hellbender (*Cryptobranchus alleganiensis*). All of these species require clean, cold water with high levels of dissolved oxygen (Spoor 1990), low percentages of fine substrate (sand, silt, or clay), and complex habitat features such as large rocks, boulders, and large wood. Trout, hellbenders, and other aquatic organisms (Pitt et al. 2017) are negatively influenced by a lack of deep pools, insufficient large wood (LW), and increased amounts of fine sediment from natural and anthropogenic sources (Hopkins and Durant 2011).

The PNF inventoried stream habitat in the Davidson River in 2003 and found relatively low amounts of pool habitat, high percent fine sediment in pools, and low densities of desirable large wood (LW). The PNF inventory also found a large number of rock dams built by visitors to increase water depth and velocity. Moving rocks can be damaging to stream habitat, particularly for hellbenders, which utilize large rocks for diurnal and seasonal refugia and nesting habitat (Pitt et al. 2017). Based on the 2003 inventory results, the PNF took several management actions to improve stream habitat. These actions included a "Don't Move the Rocks!" campaign (an initiative to reduce the movement of stream rocks by people for the creation of swimming holes; Gillespie 2015), habitat restoration, and stream bank stabilization projects.

In the early 2000's, eastern hemlocks (*Tsuga canadensis*) in the watershed were infested by the invasive hemlock wooly adelgid (HWA) (*Adelges tsugae*). The HWA infestation of Pisgah National Forest's (PNF) watersheds has resulted in a rapid decline of hemlock trees, a major component of streamside vegetation. With seedling hemlock trees unable to reach maturity in the presence of the HWA dead hemlock trees located in riparian areas are only a temporary source of large wood for these streams. Dead or dying hemlocks may be allowed to recruit through natural processes, or may be intentionally

added to stream channels. Large wood additions encourage pool formation and sediment scour, thereby increasing the amount of spawning and rearing habitat, particularly for trout (Ryan et al. 2014, Faustini and Jones 2003, Thompson 1995), as well as the Eastern hellbender.

In 2017, the PNF requested that the USDA Forest Service, Southern Research Station, Center for Aquatic Technology Transfer (CATT) replicate the 2003 inventory with the objective of assessing stream habitat composition changes over time. Since the 2003 survey, a variety of factors have altered the watershed such as the addition of stream habitat enhancement structures, ongoing infestation by the HWA and the implementation of the "Don't Move The Rocks!" campaign for the imperiled Eastern hellbender. Our objectives were to: 1) quantify stream habitat conditions; and 2) describe hemlock abundance and condition within the riparian area. In this report we present both the 2003 and 2017 BVET results.

Methods

Reach Selection

Lorie Stroup (PNF Zone Fisheries Biologist) and personnel from the PNF selected a 17 km section of the Davidson River in 2003 to quantify stream habitat characteristics. The reach runs from the PNF boundary line near Brevard, NC to the upper headwaters, and passes through/by campgrounds, trails, roads, stream access points, and a fish hatchery/education center.

Habitat Inventory

A basinwide visual estimation technique (BVET) habitat inventory was completed on the Davidson River in 2003 and 2017 (Figure 1, Table 1) (Dolloff et al. 1993). The BVET is a two-stage visual estimation technique used to quantify stream habitat. During the first stage, habitats are classified based on naturally occurring habitat features as pools (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), or riffles (fast water, turbulent, gradient <12%; shallow reaches characterized by water flowing over or around rough bed materials that break the surface during low flows). Glides (slow water, no surface turbulence, gradient <1%; shallow with little to no flow and flat bottom profile) were identified during the inventory, but were grouped with pools for some data analysis. Runs (fast water, non-turbulent, gradient <12%; deeper than riffles with little or no surface agitation or flow obstructions and a flat bottom profile) and cascades (fast water, turbulent, gradient >12%; highly turbulent series of short falls and small scour basins, with very rapid water movement) were grouped with riffles for some data analysis.

Habitat in each section of stream was classified and inventoried by a 2 or 3 person team. One team member identified each habitat unit by type (pool, glide, riffle, run, or cascade), estimated average

wetted width, average and maximum depth, riffle crest depth (RCD), substrate composition, and percent fines. The length of each habitat unit was measured with a hip chain. Average wetted width was visually estimated. Average and maximum depth of each habitat unit were estimated by taking depth measurements at various places across the channel profile with a graduated staff marked in 5 cm increments. The RCD was estimated by measuring water depth at the deepest point in the hydraulic control between riffles and pools. The RCD was subtracted from average pool depth to obtain an estimate of residual pool depth which could occur during low flow conditions. Substrates were assigned to one of nine size classes (Appendix A). Dominant substrate (covered greatest amount of surface area in habitat unit) and subdominant substrate (covered 2nd greatest amount of surface area in habitat unit) were visually estimated. Percent fines is the percent surface area of the stream bed consisting of sand, silt, or clay substrate particles (particles < 2 mm diameter).

Where encountered, the distance at the upstream end of channel features, as well as additional attributes described in Appendix A, were recorded for waterfalls, tributaries, side-channels, braids, seeps, landslides, and 'other' miscellaneous features encountered (e.g. campsites, fish habitat structures, etc.). One type of "other" feature of particular interest are man-made rock dams built to increase water depth and velocity by moving and piling stream rocks into rows (typically done by visitors recreationally floating the river). In addition, a photograph and GPS coordinates (as well as additional attributes described in Appendix A) were recorded for waterfalls and crossing features (bridges, fords, dams, and culverts).

The second team member classified and inventoried large wood (LW) within the bankfull channel and recorded all data. LW was assigned to one of four size classes (Appendix A). All wood less than 1.0 m long and less than 10 cm in diameter were omitted from the inventory.

The first unit of each habitat type selected for intensive (second stage) sampling (e.g. accurate measurement of wetted width) was determined randomly. Additional units were selected systematically; every 10th unit. The wetted width of each systematically selected habitat unit was measured with a meter tape across at least three transects and averaged. For the reach between each second stage fast water habitat unit, we estimated the abundance and condition of hemlock trees within the riparian area; this assessment was performed only in 2017 (Appendix A).

The ratio of measured to visually estimated area was used to calibrate all estimates, which enabled the calculation of total stream area by habitat type (Hankin and Reeves 1988). The BVET calculations were computed with a Microsoft Excel spreadsheet using formulas found in Dolloff et al. (1993). Data were summarized using MS Access and Excel. See Appendix A for detailed field methods.

Results

Davidson River stream habitat was inventoried from May 19th - September 13th 2003 (17.48 km) and June 5th - 12th 2017 (17.40 km) (Figure 1, Table 1). See Table 2 for GPS coordinates for the start and end location of the BVET inventory.

Depth and Width

In 2017, mean average, maximum, and residual depths were deeper, mean maximum pool depths were more uniform throughout the 17 km reach, and average wetted widths were narrower than they were in 2003 (Figure 2, Table 3).

Habitat Area

In 2017, total habitat area declined 2.2 hectares, glide habitat declined 2.8 hectares (-10.6%), and riffle habitat increased 1.0 hectare (+9.2%) while pool, run, and cascade habitat remained largely the same as in 2003 (Figure 3, Table 4). Pool and glide habitat area was significantly less in 2017, while there was no difference for riffle, run, and cascade habitat area (Figure 4). Discharge, which influences stream wetted width and thus habitat area, was 9 cfs less on average during the inventory in 2017 than in 2003 (Table 5).

% Fines and Substrate

Average percent fines in pools declined 7% between 2003 (28%) and 2017 (22%), while percent fines in riffles remained the same (8%) (Table 3). Percent fines in pools were highest from inventory distance 3-12 km, whereas in riffles they were much more consistent throughout the entire inventory distance (Figure 5). The percentage of pools with fines exceeding 35% declined in 2017 (15%) compared to 2003 (23%) (Appendix B).

The largest changes in percent occurrence of dominant substrate between 2003 and 2017 were for sand (-8% in pools), cobble (-9% in pools and -6% in riffles), and bedrock (+24% in pools and +7% in riffles) (Table 6). In pools, the dominate substrate was most frequently cobble and boulder in 2003, and cobble and bedrock in 2017; the substrate types silt, sand, small gravel, and large gravel were also present, but more often as subdominant substrates (Figure 6, Table 6). In riffles, the dominant substrate was most frequently cobble and boulder in both 2003 and 2017; the substrate types sand, large gravel, and bedrock were also present, but most often as a subdominant substrates (Figure 7, Table 6).

Large Wood

Total LW/km and LW quantity declined by 50% between 2003 and 2017 (Figure 8, Table 7). The majority of LW was small diameter size classes (LW1 and LW3 with 10-55 cm diameter) (Figure 8, Table 7). In 2003 and 2017, LW is distributed relatively evenly throughout the inventory; there are occurrences of log jams resulting in higher counts within an individual habitat unit (Figure 9).

Hemlock Abundance and Condition

In the riparian area, hemlock trees were present in high abundance and showed signs of infestation and/or mortality from hemlock wooly adelgid throughout the majority of the 2017 inventoried reach (Figure 10).

Rock Dams

There was a 91% decrease in quantity of constructed rock dams between 2003 (n=32) and 2017 (n=3) (Figure 11). In 2003, rock dams were clustered at inventory distances 1-4 km, 7-8 km, and 14-17 km (Figure 12).

Discussion

Noteworthy stream habitat differences between 2003 and 2017, discussed herein, include decreases in LW/km, decreased number and frequency of man-made rock dams, decreased glide habitat area, and change in fine sediments. The Nantahala and PNF's plans specify that the desired LW condition is 322 to 161 LW/Km, respectively (USDA 1994). The PNF's desired LW condition was just being met in 2003 (168 LW/km), however in 2017, we found it had decreased by half (84 LW/km); the cause of the decline warrants further investigation. The large-scale loss of hemlocks from hemlock wooly adelgid infestation, though tragic, also presents a new opportunity as the PNF addresses impacts on the Forest from late 19th century land use. The riparian area of the Davidson River, which contains infested or dead hemlock trees, will over time shed limbs and tops, and/or fall entirely into the stream channel. This natural recruitment of a variety of LW sizes, as well as any deliberate felling of hemlocks into the river, will add channel complexity and provide improved habitat in high priority management areas. Researchers have not found an upper limit on the amount of large wood that is beneficial to fish, so most often the upper limit will be determined by social factors rather than fish habitat objectives (Richards and Hollingsworth 2000), particularly in areas managed for multiple uses. Interactions between recruitment of hemlocks to the stream channel and the popular recreational activity of visitors floating the river could present safety concerns in the future.

The PNF began a "Don't Move the Rocks!" campaign a little over a decade ago to address negative impacts of recreational visitors on Eastern hellbenders and other aquatic organisms in the Davidson River (Gillespie 2015). Research has shown that habitat disruption likely contributes to the diminishing range of the hellbender (Williams et al. 1981). We observed a large decrease in the quantity of rock dams built by recreating visitors in 2017 compared to the 2003 inventory, indicating that the continuation of the anti-habitat disturbance campaign is having a successful effect (continued monitoring particularly during peak recreation times in mid-summer will help to confirm the effectiveness of the campaign). This decrease in rock dams may also be a driving factor in the 10.6% glide habitat area reduction we observed. These decreases along with narrower stream widths and less discharge are all contributing factors to the total habitat area decline observed in 2017.

The Eastern hellbenders in the Davidson River also require interstitial spaces between rocks that are not clogged with fine sediments for successful spawning and recruitment (Hopkins and Durant 2011). And likewise, trout reproduction can decrease in the rivers where fines exceed 35% in spawning areas (Everest et al. 1987). In the first 12 km of our inventory, and particularly from inventory km 6 to 12, fine sediments exceeded 35% in some pools and sand was occasionally the dominant or subdominant substrate. Fine sediments can be reduced in spawning gravel by salmonids building redds, flushing flows from storm events, and large wood improving stream habitat though pool creation and habitat complexity. Newly formed plunge pools from LW can help flush out fine sediments and expose additional patches of spawning gravel (Ryan et al. 2014, Faustini and Jones 2003, Thompson 1995).

Land management practices initiated by the Cradle of Forestry after 1898, such as native tree planting, creation of permanent management roads, and wildlife population improvement projects, have contributed to a healthier overall habitat structure within the Davidson River watershed (Beanblossom 2017). Recreational impacts on stream ecology and aquatic organisms, as well as high mortality rates of Eastern hemlocks will most likely become the major points of concern for future management. In the long run, it will prove cost-effective to manage riparian zones specifically around stream access locations to prevent the erosion of stream banks. Eventually, riparian LW recruitment to the river will decrease after all the dead/dying hemlocks fall, necessitating planning for future LW natural recruitment. Efforts to improve stream habitat by adding designed structures to protect stream banks and preventing recreating visitors from disturbing rocks where hellbenders and other organisms live will continue to enhance habitat conditions. Clearly, decisions made by today's land managers will impact LW recruitment and retention, and sediment transport and deposition for decades to come. New challenges may present fresh opportunities and we encourage the PNF and its partners to continue their work to improve stream habitat.

Data Availability

Stream habitat inventory data from 2003 and 2017 reside in a MS Access database, which is managed by the CATT, and a copy has been provided to Lorie Stroup (PNF Zone Fisheries Biologist).

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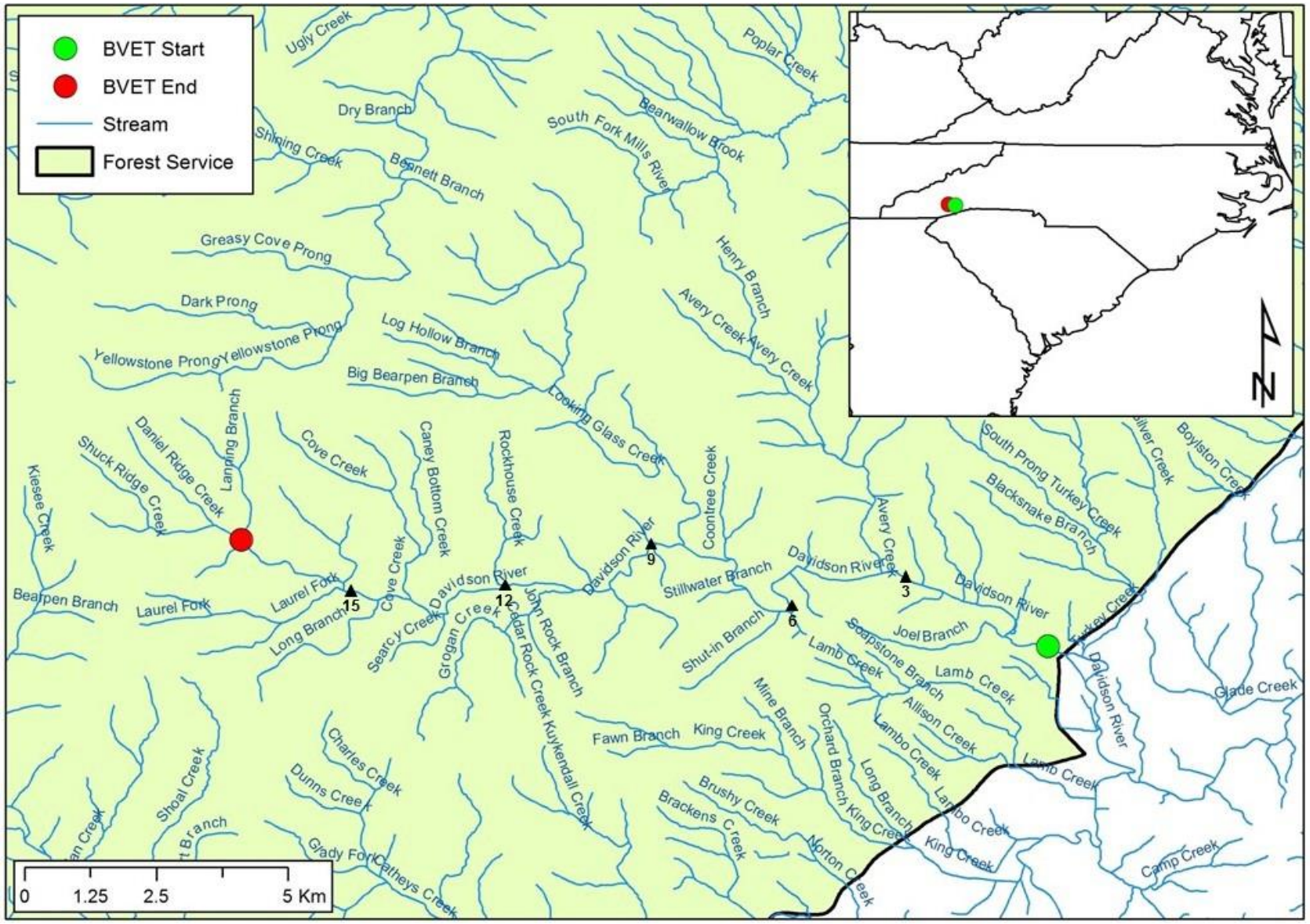

Figure 1. BVET inventory start (green circle) and end (red circle) locations, as well as every 3 river kilometers marked with black triangles, on the Davidson River, Pisgah National Forest, North Carolina, 2003 and 2017.

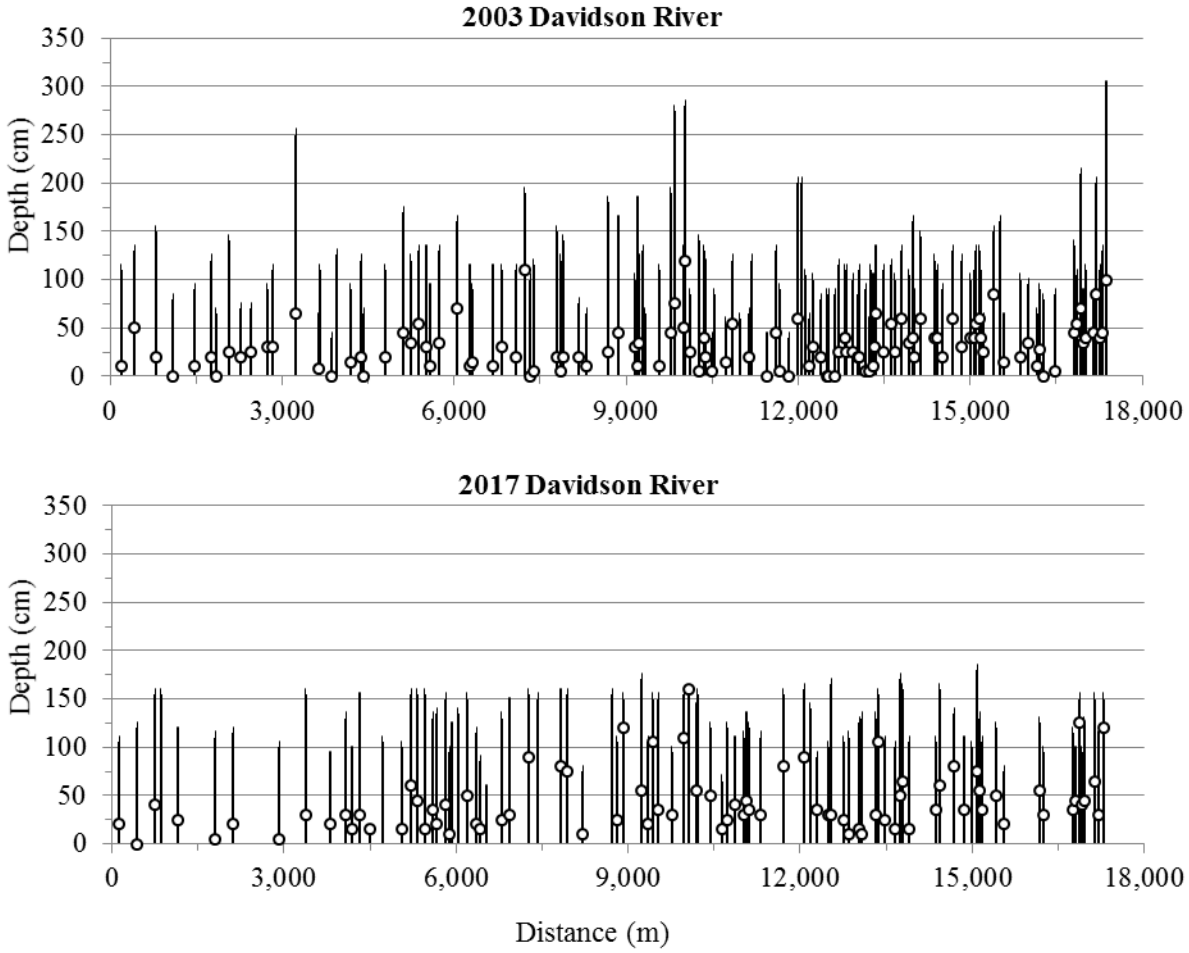

Figure 2. Maximum pool depth (bars) and residual pool depth (circles) shown longitudinally for each stream inventory.

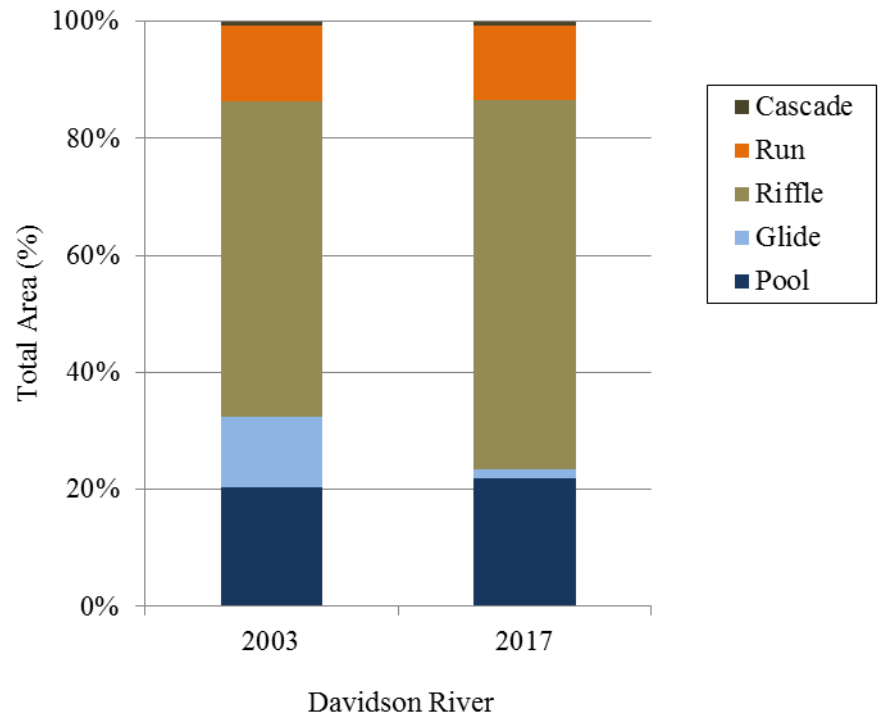

Figure 3. Percent pool, glide, riffle, run, and cascade habitat area.

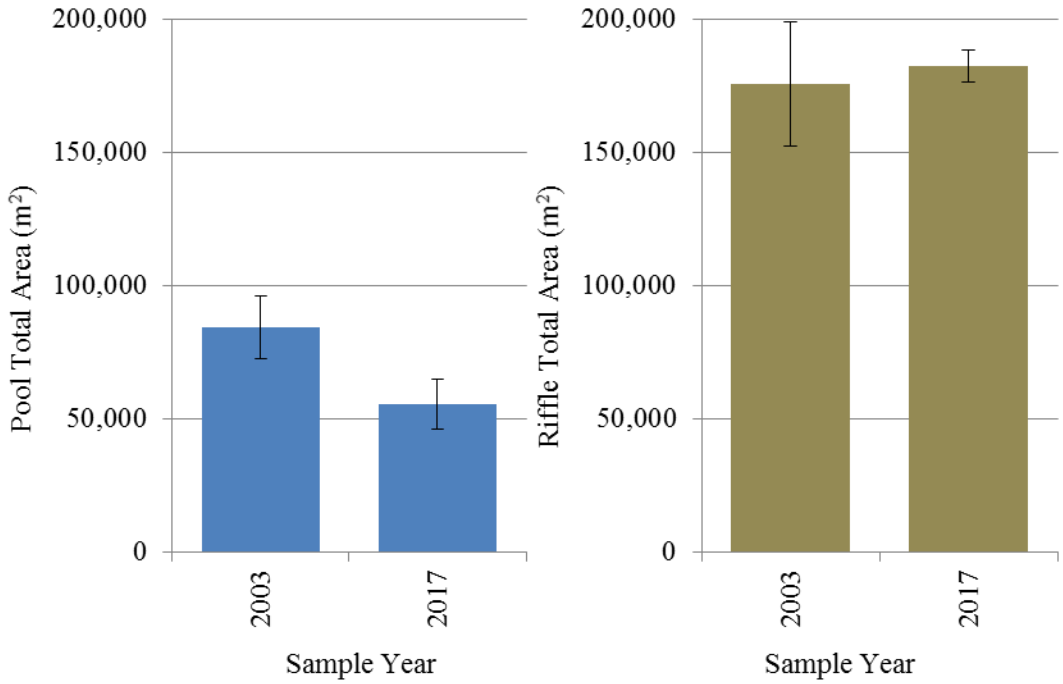

Figure 4. Pool (includes glide) and riffle (includes run and cascade) total habitat area.

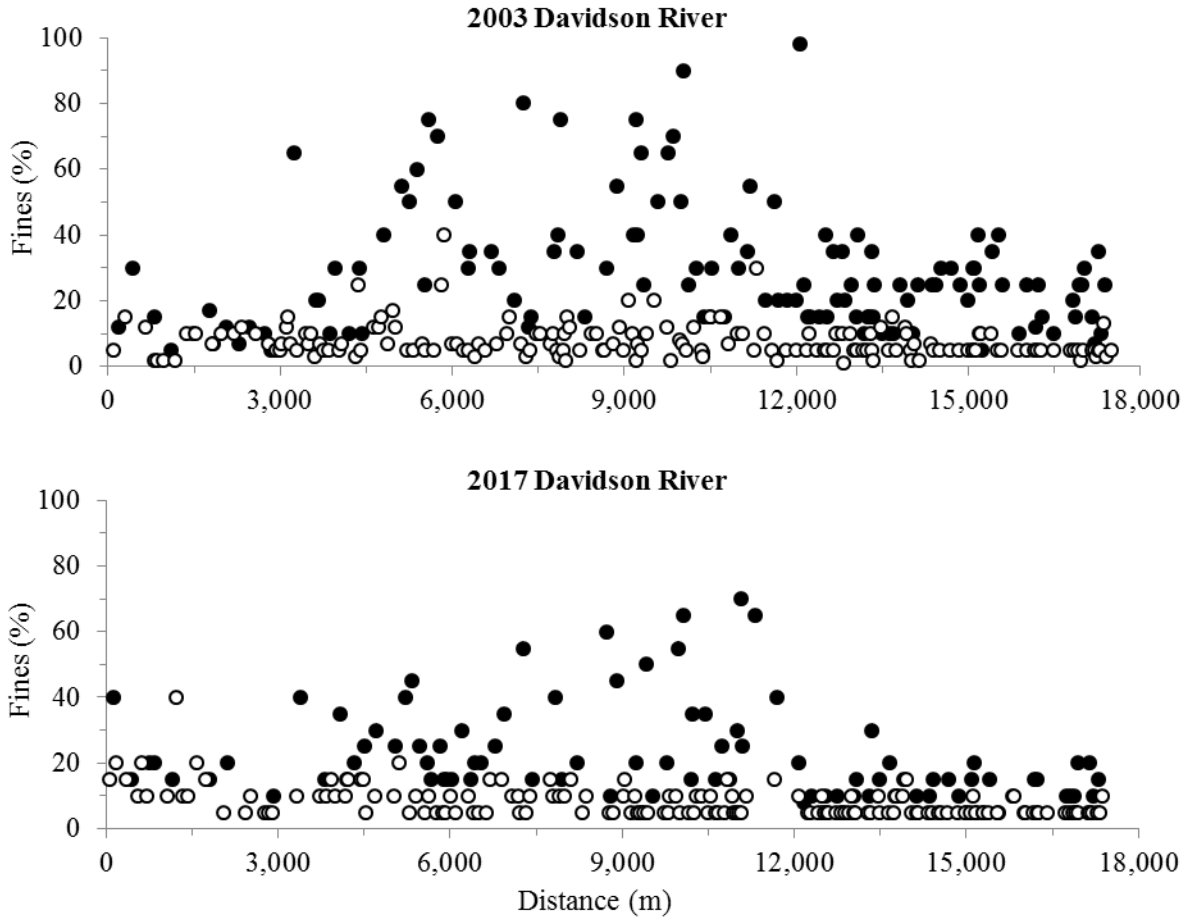

Figure 5. Percent of each pool (solid circles) and riffle (open circles) channel bottom comprised of fine sediment (sand, silt, and/or clay).

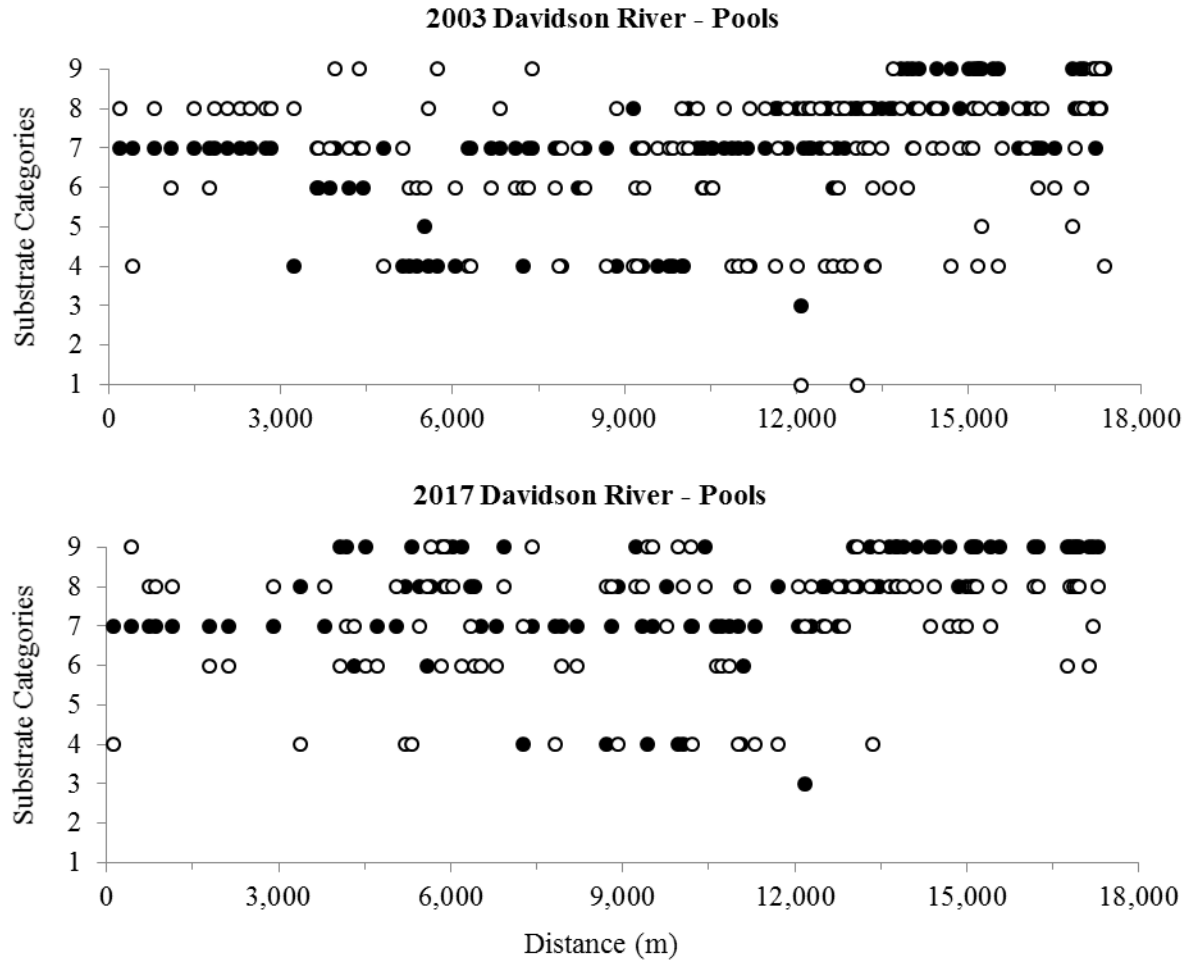

Figure 6. Dominant (solid circles) and subdominant (open circles) substrate category present in pools. Substrate size categories: 1 Organic Matter = dead leaves, detritus, etc.; 2 Clay = sticky, holds form; 3 Silt = slippery, doesn't hold form; 4 Sand = silt-2 mm; 5 Small Gravel = 3-16 mm; 6 Large Gravel = 17-64 mm; 7 Cobble = 65-256 mm; 8 Boulder = >256 mm; 9 Bedrock = solid rock.

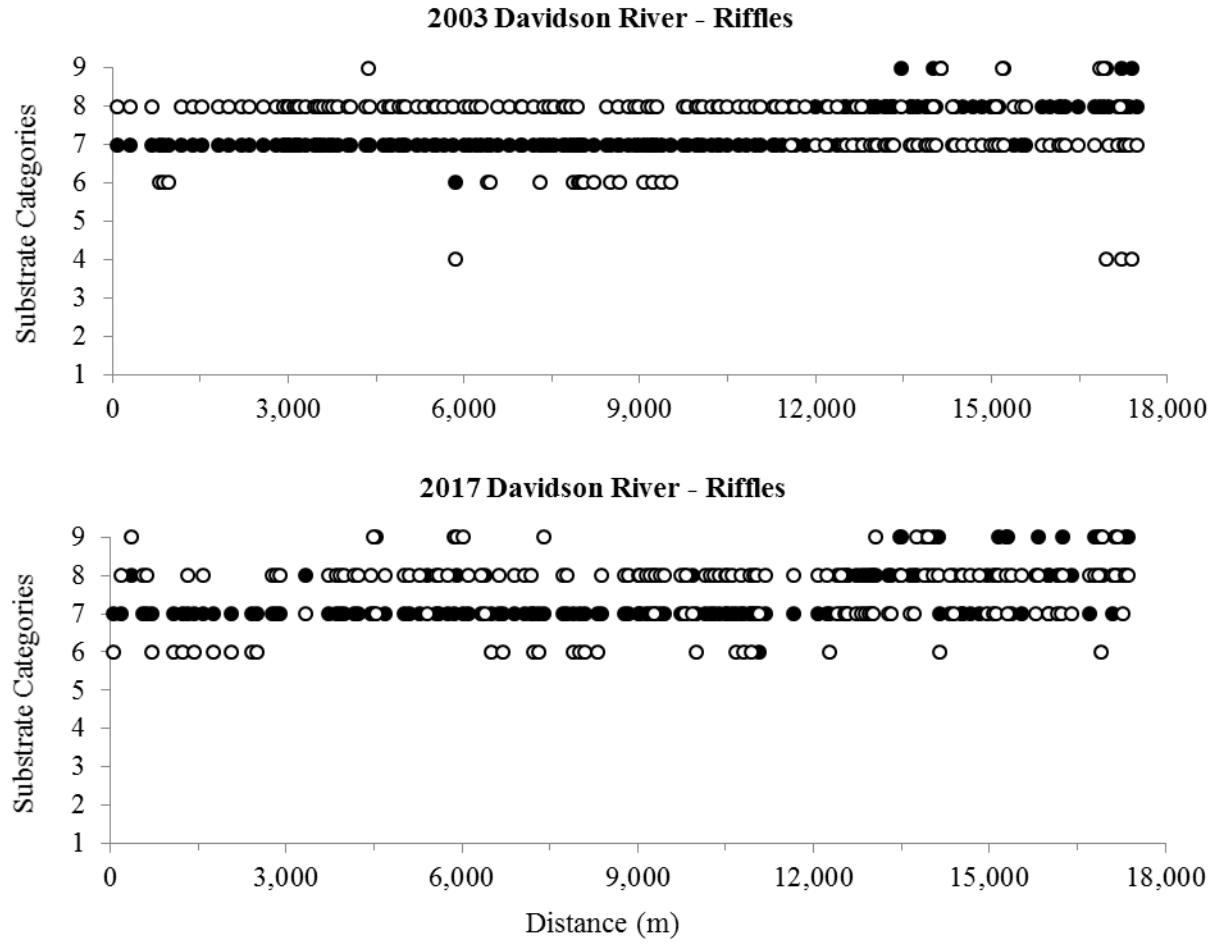

Figure 7. Dominant (solid circles) and subdominant (open circles) substrate category present in riffles. Substrate size categories: 1 Organic Matter = dead leaves, detritus, etc.; 2 Clay = sticky, holds form; 3 Silt = slippery, doesn't hold form; 4 Sand = silt-2 mm; 5 Small Gravel = 3-16 mm; 6 Large Gravel = 17-64 mm; 7 Cobble = 65-256 mm; 8 Boulder = >256 mm; 9 Bedrock = solid rock.

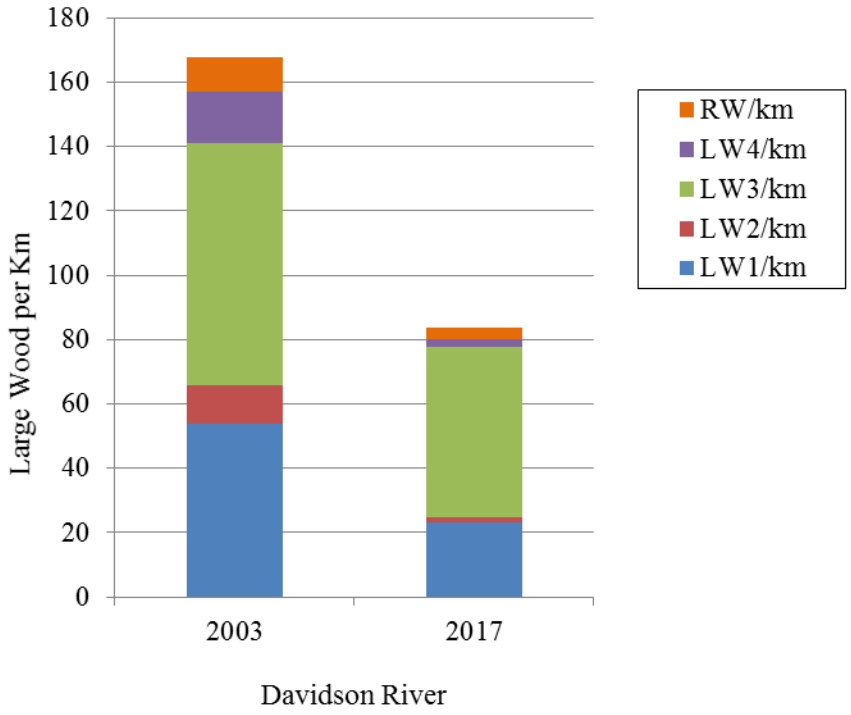

Figure 8. Quantity of large wood (LW; dead and down, any part within bankfull channel) per kilometer. LW size classes: LW1 = 1-5 m length, 10-55 cm diameter; LW2 = 1-5 m length, >55 cm diameter; LW3 = >5 m length, 10-55 cm diameter; LW4 = >5 m length, >55 cm diameter; RW = rootwad.

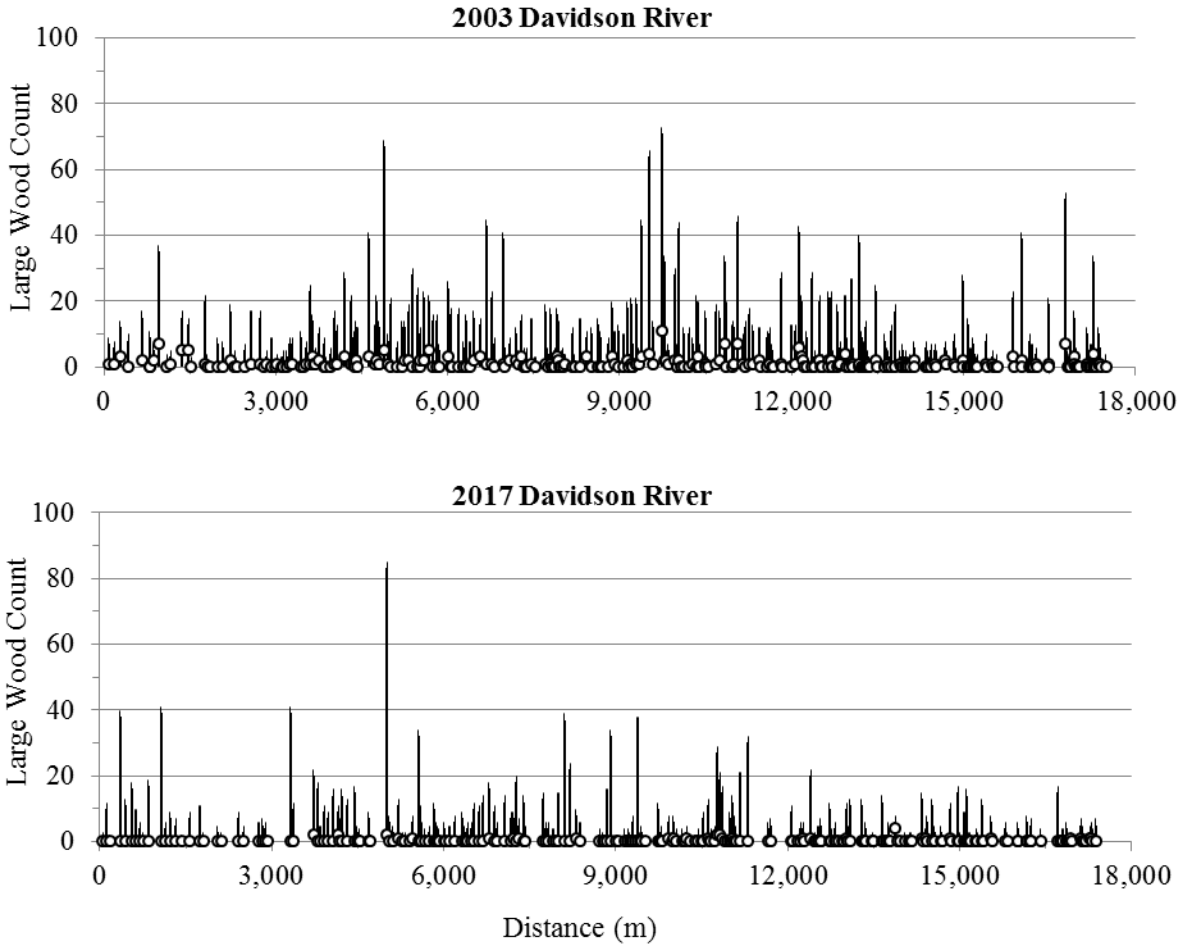

Figure 9. Count of large wood (bars = size classes 1, 2, 3, 4, and rootwad combined; open circles = size 4 only) within individual habitat units in each year inventoried. 2003 Davidson River LW n=2934 and habitat unit n=295, 2017 Davidson River LW n=1456 and habitat unit n=244.

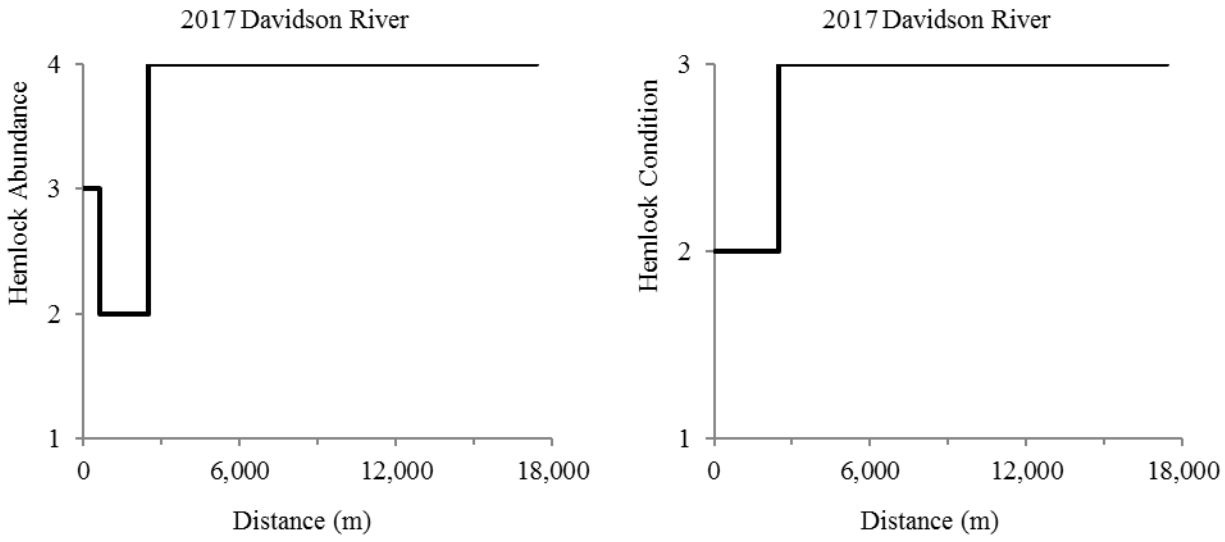

Figure 10. Hemlock abundance (1 = none; 2 = 1-10; 3 = 11-50, 4 = >50) and condition (1 = Healthy/Light Infestation, 2 = Infested, 3 = Dead) shown longitudinally for the 2017 stream inventory (see appendix A for detailed categories).

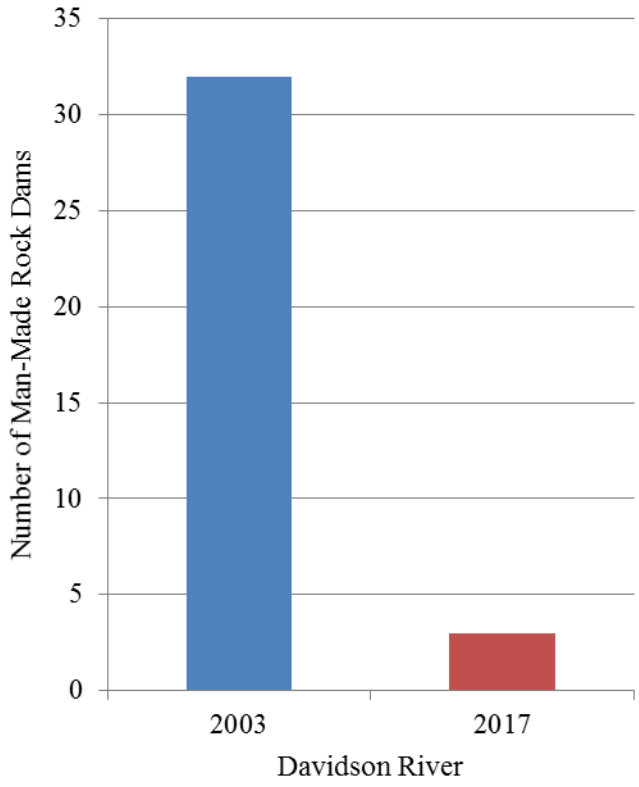

Figure 11. Quantity of man-made rock dams on the Davidson River.

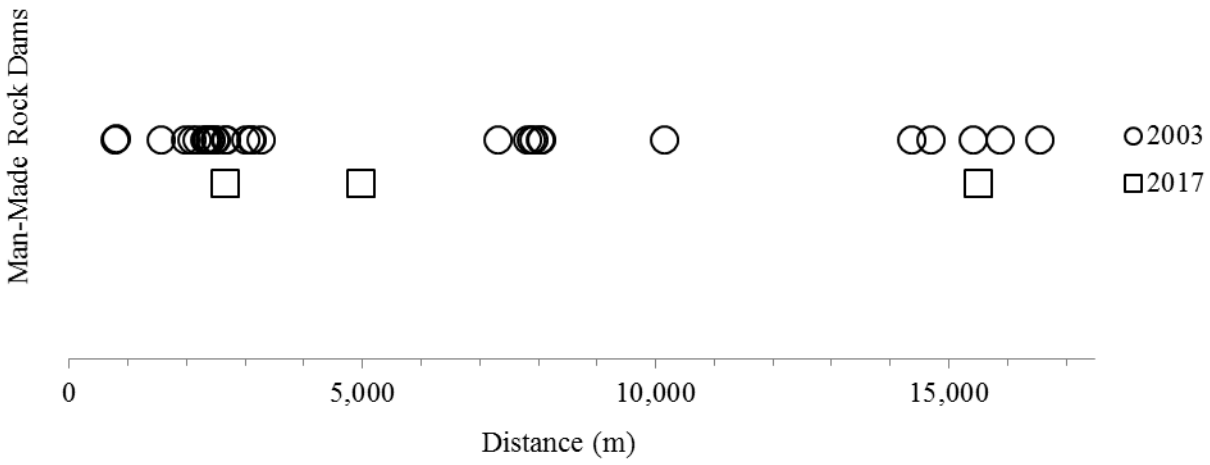

Figure 12. Location of man-made rock dams in 2003 and 2017 on the Davidson River.

Table 1. Summary of inventories on the Davidson River, Pisgah National Forest (Pisgah Forest and Shining Rock topo quad), 2003 & 2017.

	Date		BVET	
Year	Start	End	habitat (km)	Start Location/Comment
2003	05/19/03	09/13/03	17.48	Forest boundary beside rock gate post
2017	06/05/17	06/12/17	17.40	Across from stone gate at downstream end of small island

Table 2. GPS coordinates recorded at the downstream (start) and upstream (end) extent of Davidson River habitat inventories.

	GPS (NAD83)	
Year	Downstream Inventory Start	Upstream Inventory End
2003	none	none
2017	N35.27425 W82.70771	N35.29246 W82.84567

Table 3. Summary of BVET stream habitat attribute averages collected where Pools = pools+glides and Riffles = riffles+runs+cascades.

	Mean Avg. Depth (cm)		Mean Max. Depth (cm)		Mean Residual Pool Depth	Avg. Wetted Width (m)		Avg. % Fines		Unit Count (n)	
Year	Pools	Riffles	Pools	Riffles	(cm)*	Pools	Riffles	Pools	Riffles	Pools	Riffles
2003	67	35	114	62	30	15.7	14.6	28	8	128	167
2017	84	41	142	76	43	11.8	12.0	22	8	94	150
Difference	*17*	*6*	*27*	*14*	*12*	*-4.0*	*-2.6*	*-7*	*0*	*-34*	*-17*

**Residual pool depth = average pool depth – riffle crest depth*

Table 4. Stream habitat area and unit count of pool, glide, riffle, run, and cascade habitat as observed during BVET habitat inventories.

	Habitat Area (Hectares)						Percent Area							Unit Count (n)					
Year	Pool	Glide	Riffle	Run	Cas-cade	Total	Pool	Glide	Total	Riffle	Run	Cas-cade	Total	Pool	Glide	Riffle	Run	Cas-cade	Total
2003	5.3	3.2	14.0	3.4	0.2	26.0	20.3%	12.2%	32.5%	53.9%	12.9%	0.7%	67.5%	99	29	129	34	4	295
2017	5.2	0.4	15.0	3.0	0.2	23.8	21.8%	1.6%	23.4%	63.1%	12.7%	0.8%	76.6%	91	3	108	34	8	244
Difference	*-0.1*	*-2.8*	*1.0*	*-0.3*	*0.0*	*-2.2*	*1.5%*	*-10.6%*	*-9.1%*	*9.2%*	*-0.2%*	*0.1%*	*9.1%*	*-8*	*-26*	*-21*	*0*	*4*	*-51*

Table 5. Mean daily discharge (cfs) on BVET inventory dates in 2003 and 2017 (data is from USGS gage 03441000 on the Davidson River near Brevard, NC).

2003		2017	
Inventory Date	Mean Daily Discharge (cfs)	Inventory Date	Mean Daily Discharge (cfs)
5/19/2003	187	6/5/2017	144
5/20/2003	172	6/6/2017	127
8/4/2003	127	6/7/2017	118
8/5/2003	123	6/8/2017	126
8/6/2003	107	6/9/2017	113
8/12/2003	120	6/10/2017	105
8/13/2003	126	6/11/2017	100
8/14/2003	112	6/12/2017	98
8/18/2003	110		
9/13/2003	70		
Average	125	Average	116

Table 6. Percent occurrence of dominant and subdominant substrate size categories in pools (includes glides) and riffles (includes runs and cascades) in each stream inventoried. See appendix A for substrate size categories.

	Pool Dominant Substrate (%)									Riffle Dominant Substrate (%)								
Year	Organic Matter	Clay	Silt	Sand	Small Gravel	Large Gravel	Cobble	Boulder	Bedrock	Organic Matter	Clay	Silt	Sand	Small Gravel	Large Gravel	Cobble	Boulder	Bedrock
2003	0%	0%	1%	14%	1%	5%	41%	24%	14%	0%	0%	0%	0%	0%	1%	69%	26%	4%
2017	0%	0%	1%	6%	0%	3%	32%	19%	38%	0%	0%	0%	0%	0%	1%	63%	25%	11%
Difference	*0%*	*0%*	*0%*	*-8%*	*-1%*	*-2%*	*-9%*	*-5%*	*24%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*-6%*	*-1%*	*7%*
	Pool Subdominant Substrate (%)									Riffle Subdominant Substrate (%)								
2003	2%	0%	0%	18%	2%	20%	23%	30%	6%	0%	0%	0%	2%	0%	11%	26%	58%	3%
2017	0%	0%	0%	12%	0%	18%	17%	43%	11%	0%	0%	0%	0%	0%	16%	23%	54%	7%
Difference	*-2%*	*0%*	*0%*	*-6%*	*-2%*	*-2%*	*-6%*	*13%*	*5%*	*0%*	*0%*	*0%*	*-2%*	*0%*	*5%*	*-3%*	*-4%*	*4%*

Table 7. Large wood (LW) per kilometer and count of LW pieces observed during BVET habitat inventories. LW size classes: LW1 = 1-5 m length, 10-55 cm diameter; LW2 = 1-5 m length, >55 cm diameter; LW3 = >5 m length, 10-55 cm diameter; LW4 = >5 m length, >55 cm diameter; RW = rootwad.

	Large Wood per Km						Large Wood Count (n)						Inventory
Year	LW1	LW2	LW3	LW4	RW	Total	LW1	LW2	LW3	LW4	RW	Total	Dist. (km)
2003	54	12	75	16	11	168	944	206	1,315	279	190	2,934	17.48
2017	23	2	53	2	4	84	404	27	923	37	65	1,456	17.40
Difference	*-31*	*-10*	*-22*	*-14*	*-7*	*-84*	*-540*	*-179*	*-392*	*-242*	*-125*	*-1,478*	*-0.08*

Appendix A: Field Methods for Stream Habitat Inventory

Guide to Stream Habitat Characterization using the BVET Methodology in the Davidson River, Pisgah Ranger District, NC

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

Prepared by:

Prepared by: Colin Krause and Craig N. Roghair

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Table of Contents

Introduction

The Basinwide Visual Estimation Technique (BVET) is a versatile tool used to assess streamwide habitat conditions in wadeable size streams and rivers. A crew 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 crew may inventory any number of other habitat attributes as they walk the length of the stream. Experienced crews 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 crew 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 crew. 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.

This document was developed to serve as a guide for classroom and field instructions specific to the Chattahoochee National Forest BVET habitat inventory and to provide a post-training reference for field crews. 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.

References cited in this manual:

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

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.

Changes to BVET inventory in 2015

Attribute	Action	Reason
Hemlock LW	added	Quantify hemlock LW in bankfull channel
Hemlock Condition	changed	Combined categories 0 & 1; combined categories 4&5 from 2014 methods; now using 3 categories instead of 5
Hemlock Abundance	changed	Using same categories, but shifting category labels from 0-3 to 1-4 for consistency with BVET methods used in other National Forests

Other minor changes, mostly modifications in terminology and definitions to provide increased clarity, are found throughout the manual.

Outline of BVET Habitat Inventory

The inventory is comprised of the following steps:

1) Enter 'header' information in the data sheet
    - 'Header' information includes date, stream, start location, crew, etc. and is **vitally** important to record for future reference

2) Select an appropriate measurement interval and a random number
    - In streams < 1.0 km measure every 5th unit (random number 1-5), in streams > 1.0 km measure every 10th unit (random number 1-10)
    - The random number designates the first habitat unit (i.e. the paired sample unit) in which the crew will perform measurements

3) 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

4) At the paired sample unit perform visual estimates, then perform measurements
    - If the random number '3' were chosen, the crew would stop after making estimates in the 3rd pool (and 3rd riffle) and perform the necessary measurements

5) Progress upstream estimating attributes for every unit until the next paired sample unit is reached, then repeat step 4
    - In the above example, if the interval were 10 units, the crew would stop at the 13th, 23rd, 33rd, etc. pool (and 13th, 23rd, 33rd, etc. riffle) and repeat measurements done in pool 3 and riffle 3.
    - The crew 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.

Repeat steps 4 and 5 until the end of inventory reach.

The following sections describe the BVET habitat inventory in detail:

Section 1: Getting Started – equipment lists, header information, 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

Appendix: field guide, random number tables, equipment checklist

Section 1: Getting Started

Equipment List

Hipchain & extra string	Backpack
wading rod	Pencils
50 m tape measure	Flagging
Datalogger	Markers
GPS unit	waterproof backup datasheets
topographic map	BVET manual and field guide
camera	felt bottom wading boots or waders
Clinometer (for cascades)	Water Filter
Thermometer	1st Aid Kit & toilet paper

Other useful equipment: lunch, water, rain gear, radio/cell phone

The crew 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	Record data
Measure distance	Determine paired sample location
Estimate width	Classify and count LW
Estimate depths	Hemlock LW, abundance, condition
Classify substrates	Photo-documentation
Estimate percent fines	Document features

Both crew members are needed to measure actual widths, channel widths, riparian areas, gradient, and water temperature at designated units. Although the crew 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 NAD27 CONUS, UTM
Location	**Detailed** written description of start point, include landmarks, road #, etc.
Notes	Record signs of activity in area, water conditions, other pertinent information

Random Numbers

Before beginning the inventory, select a number from a random numbers table (see Appendix) to determine the first habitat unit at which to make measurements. For long inventories (> 1.0 km) select a random number between 1 and 10th (i.e. measure every 10 unit), for shorter streams use a number between 1 and 5 (i.e. measure every 5th unit). See the appendix for random numbers tables.

The crew needs to measure units more frequently during shorter inventories to provide enough 'paired samples' for data analysis. 'Paired samples' are habitat units in which both visual estimates and actual measurements are made. The more paired samples, the tighter the confidence intervals for stream area estimates.

After the crew records a paired sample they continue upstream making visual estimates and stopping to make additional measurements at the pre-determined interval. For example, if the random number was 3 and the crew was measuring every 5th unit, the crew would make measurements on the 3rd pool and 3rd riffle and then every 5th pool and riffle thereafter (8, 13, 18, 23, etc).

Starting the Inventory

After the crew has organized their gear, determined their measurement interval, selected a random number, recorded all the header information, and determined the start location 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, report the distance, then turn to face the unit and report the unit type, estimated width, maximum and average depth, riffle crest depth (where appropriate), dominant and subdominant substrate classes, and percent fines 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 crew 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)

Definitions:*

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 the 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 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 crew has counted six slow water (pool/glide) units and seven fast water (riffle/run/cascade) units.

If '3' were chosen as the random number and the measuring interval was every 10th unit, the crew would estimate and then measure habitat data for Pool 3 and Cascade 3 (i.e. Pool 3 and Cascade 3 are 'paired sample' units). When the crew reaches pool or glide 13 and riffle, run, or cascade 13, they would repeat procedures followed in the 3rd units.

When to record: every habitat unit; not recorded for features such as falls, tributaries, side channels, culverts, etc.

Distance (m)

Definition:
Number of meters 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, 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; also record RCD where short riffles break pools

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*

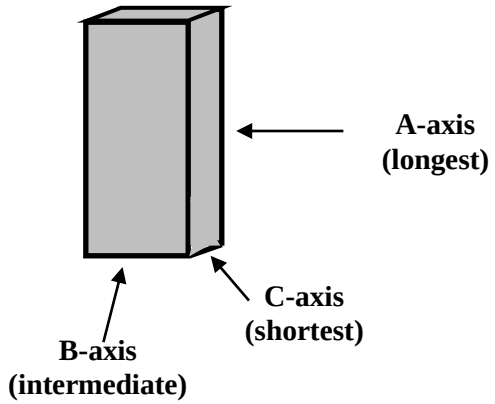
As the observer walks through the unit they scan the substrate. When they reach the upstream end of the unit they stop, turn to face the unit, and determine the dominant and subdominant substrate classes.

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



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 large wood that is:
- > 1.0 m in length and > 10.0 cm in diameter
- within the bankfull channel
- fallen, not standing dead

- 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

Hemlock Large Wood

Definition:
Count of dead and down wood within the bankfull channel of a habitat unit that is identifiable as hemlock (Hemlock LW is already counted in LW Data; this is a separate count of only Hemlock LW, all size classes combined).

How to estimate:
The recorder counts a total tally of all LW that is identifiable as hemlock as they walk through the habitat unit. Only count hemlock large wood that is > 1.0 m in length and > 10.0 cm in diameter, within the bankfull channel, and fallen, not standing dead.

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

Hemlock Condition

Definition:
Visual estimate of the condition of standing hemlock trees (DBH >10 cm) in the riparian zone (water's edge to 30 m up the streambank; visually estimated) as you walk between paired fast-water units. For the first paired sample, the condition of riparian hemlocks is since the start of the inventory.

How to measure:
Observe the general condition of hemlocks in the riparian area as you walk between paired sample units. Select from one of the following categories for hemlock condition:

Category	Description	Wooly needles	Needle loss	Limb loss
Healthy/Light Infestation (1)	Healthy or early stages of infestation	None to some	0-25%	Rare
Infested (2)	Late stages of infestation	Yes	25 – 75%	Small, medium branches
Dead (3)	Mortality; majority of hemlocks are dead	Yes for the few remaining needles	> 75%	Small, medium, large branches and tree tops

Where to measure: assess throughout reach, but record only at paired fast-water units

Hemlock Abundance

Definition:
Category describing the total number of hemlocks encountered since the last paired fast-water unit.

How to measure:
Estimate the number of standing hemlock trees (live or dead with DBH >10 cm) in the riparian zone (water's edge to 30 m up the streambank; visually estimated) as you walk between paired fast-water units.

Select from one of the following categories for hemlock abundance:
None (1) = no hemlocks; **Few (2)** = 1-10; **Some (3)** = 11-50; **Many (4)** = >50 hemlocks

Where to measure: do counts throughout reach but record only at paired sample habitat units

Photo #

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. Record photo number shown on digital camera.

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

GPS (ID)

Definition:
Name of the point recorded to mark a waterfall, crossing feature or other location in the GPS unit.

How to measure:
Stand as close to the feature as possible and allow the GPS to have a clear view of the sky. Mark a waypoint on the GPS, then edit the waypoint name as follows:

S##	**Start** location of BVET survey
P##	**Pause** location of BVET survey if survey is not completed that day
T##	**Tributary** with name shown on quad map
E##	**End** location of BVET survey when survey is completed
W##b	**Waterfall**
B##b	**Bridge**
Fd##b	**Ford**
D##b	**Dam**
V##b	**Culvert**
O##b	**Other**, enter a brief description into the note section for the waypoint

= stream priority number – see stream list or map
b = use b, c, d, etc to create unique labels when more than 1 of a feature type are encountered on a stream; for example if 3 waterfalls are found on stream priority number 5 the first waterfall would be W5, the second would be W5b, the third W5c

Where to measure: all waterfalls, all crossing features, any other notable features encountered during the survey that we may want to locate in the future or that could serve as landmarks

See Section 5 below for additional information on GPS use.

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 a feature; record distance of **all features** (both stream and crossing features) in the regular habitat datasheet; also record additional measurements for crossing features in the crossing datasheet 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 and waterfalls!
Take GPS of all waterfalls!

Section 3: Wrapping Up

End the inventory where previous inventory ended or:

- 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 and Hemlock LW

Record for every riffle, run, or cascade (including breaks) 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
- Hemlock Condition and Abundance
- Photograph
- Water Temperature

Record features and full feature descriptions wherever they are encountered.

Photograph all crossings!

Section 5: GPS Instructions

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 of the next screen touch the 3 horizontal lines icon; then select 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

Garmin GPS Cheatsheet

Turn On

- Press Power button, wait for GPS to boot

Turn Off

- Press and hold Power button

Create New Waypoint

1. To create a waypoint of your current position press the waypoint button (larger button below the power button)
2. Touch the waypoint label's field, type desired label, touch checkmark, touch save

Calibrate compass

1. Touch Compass icon, touch 3 horizontal lines icon, touch calibrate compass
2. Touch Start, follow onscreen instructions

Data Fields

1. To change the data fields on the map page touch the Map icon
2. Touch the 3 horizontal lines icon, then unlock data fields, touch the data field you want to change, select new data field category, select data field, then relock data fields

Appendix: Field Guide, Random Numbers Table, Equipment Checklist

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
Hemlock Large Wood: count of dead and down Hemlock 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

Measured Width: (m) measurement of average wetted width
Hemlock Abun.: 1 None, 2 Few =1-10, 3 Some=1-50, 4 Many=>50
Hemlock Condition: 1 Healthy, 2 Infested, 3 Dead
Water Temperature: C, place thermometer in shaded area
Photo # : picture of habitat unit or crossing feature

Record for paired sample riffles:

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, GPS
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 (top of water to culvert) road or trail name

Substrates

1. **Organic Matter**, dead leaves detritus, etc., not living plants
2. **Clay**, sticky, holds form when balled
3. **Silt**, slick, does not hold form when balled
4. **Sand**, >silt-2mm, gritty, doesn't hold form
5. **Small Gravel**,3-16mm, sand to thumbnail
6. **Large Gravel**, 17-64mm, thumbnail to fist
7. **Cobble**, 65-256mm, fist to head
8. **Boulder**, >256, > head
9. **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 woody debris <10cm diameter, <1m length

End inventory

Where stream is less than 1.0 m wide for > 500 m, or channel runs dry for > 500 m, or where boundary is reached. Comment on why inventory was ended. Record time of day, detailed description of location, and GPS coordinates at endpoint, and be sure all header info is filled in on datasheets.

Random numbers for measuring every 5th unit

4	3	5	1	5	1	2	5	2	3
2	5	2	5	2	2	1	5	4	1
3	2	5	1	2	1	3	1	5	3
5	4	1	5	1	3	5	4	2	5
4	2	2	5	2	2	5	5	2	1
4	2	5	2	2	4	5	5	5	2
3	5	4	1	5	1	4	1	3	3
1	4	2	2	1	4	3	1	5	3
5	4	3	3	2	4	1	2	5	1
4	4	1	1	3	5	1	5	5	4

Random numbers for measuring every 10th unit

3	7	10	5	1	2	2	7	10	6
4	2	3	8	9	2	4	4	6	9
3	3	8	4	3	9	9	7	5	5
1	3	5	5	2	6	5	2	2	6
3	7	8	6	3	8	8	5	2	10
10	9	6	9	4	3	10	7	2	10
6	10	5	4	8	10	4	1	4	10
4	3	4	3	2	3	4	4	3	7
5	1	7	9	7	3	10	7	10	3
9	6	8	6	2	2	1	9	10	5

Choose a new random number at the beginning of each stream inventory
Use the number for the entire stream
Use the first table for streams < 1.0 km long, the second table for streams >1.0 km long

Equipment Checklist

- ☐ hipchain
- ☐ extra string for hipchain
- ☐ wading rod
- ☐ 50 m tape measure
- ☐ clinometer
- ☐ thermometer
- ☐ iPad
- ☐ handheld 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
- ☐ non-slip wading boots
- ☐ raingear

Remember the following for the start of each new stream or reach:

- Determine measuring interval
- Select a random number
- Fill in header information completely

Appendix B: BVET summary table for 2003 and 2017 inventories

Appendix B contains a summary table for the 2003 and 2017 inventories. The table contains BVET summary characteristics, the percent of pools and riffles having the specified dominant and subdominant substrates (%Dom,%Sub), and large wood per kilometer.

Stream	Davidson River	
District	Pisgah	
USGS Quadrangle	Pisgah Forest, Shining Rock	
Survey Dates	5/19 - 9/13/2003	6/5 - 6/12/2017
Comparison Distance (km)	17.5	17.4

Summary Characteristics	Pools		Riffles	
	2003	2017	2003	2017
% of Total Stream Area	32	23	68	77
Total Area (m^2)	84,413 ± 11,817	55,643 ± 9,299	17,5462 ± 23,297	182,373 ± 5,921
Correction Factor Applied	1.17	1.14	1.07	1.22
Number of Paired Samples	23	9	16	15
Total Count	128	94	167	150
Number per km	7	5	10	9
Mean Area (m^2)	659	592	1051	1216
Mean Max. Depth (cm)	114	142	62	76
Mean Average Depth (cm)	67	84	35	41
Mean Residual Depth (cm)	30	43	--	--
% Inventoried as Glides	23	3	--	--
% Inventoried as Runs	--	--	20	23
% Inventoried as Cascades	--	--	2	5
% with >35% Fines	23	15	1	1

Substrate (%Dom,%Sub*)	Pools		Riffles	
	2003	2017	2003	2017
Organic matter	0,2	0,0	0,0	0,0
Clay	0,0	0,0	0,0	0,0
Silt	1,0	1,0	0,0	0,0
Sand	14,18	6,12	0,2	0,0
Small gravel	1,2	0,0	0,0	0,0
Large gravel	5,20	3,18	1,11	1,16
Cobble	41,23	32,17	69,26	63,23
Boulder	24,30	19,43	26,58	25,54
Bedrock	14,6	38,11	4,3	11,7

Large Wood per Km	2003	2017
LW1 (1-5 m long, 10-55 cm diam.)	54	23
LW2 (1-5 m long, >55 cm diam.)	12	2
LW3 (>5 m long, 10-55 cm diam.)	75	53
LW4 (>5 m long, >55 cm diam.)	16	2
Rootwad	11	4
Total:	168	84

*percent of pools and riffles having the specified dominant and subdominant substrates