DRIGGS RIVER RESTORATION WITHIN SENEY NATIONAL WILDLIFE REFUGE: AN 18-YEAR REVETMENT CONDITION ASSESSMENT

Ellen Comes
Applied Sciences Program Intern
Seney National Wildlife Refuge
1674 Refuge Entrance Rd.
Seney, MI 49883
Refuge Contact/Project Lead: Greg Corace (Refuge Forester): 906.586.9851x14,
Greg_Corace@fws.gov

I. Overview

1. Project Justification and Expected Benefits

Revetments are installations placed in a river or stream and are used to maintain channel alignment or stabilize banks that are subject to erosion. They are commonly used in meandering streams on the concave side of the bends, parallel to the flow. Most revetments are built of rock riprap, stone-fill pilings, articulated concrete mattress, and other materials (Sandheinrich et al. 1986), such as whole trees.

The use of whole tree revetments creates habitat structure, shelter, patchiness of habitat, and increased food resources for aquatic and terrestrial wildlife species (Steel et al. 2003), in addition to helping to stabilize stream banks. A lack of woody debris in streams is thought to cause a loss of habitat for invertebrates (Benke & Wallace 2003) and other organisms (Steel et al. 2003). The periodic monitoring of tree revetments is important to ensure that they are continuing to stabilize banks, provide habitat, and maintain ecological complexity (Gurnell et al. 2005). Assessing decay rates will help to determine how long tree revetments can last and if new revetments are needed to be placed in the river to stabilize the banks, and prevent erosion.

2. Project Objectives and Hypothesis

The overall objective of this project is to organize past work and conduct an 18-year assessment of the condition of the tree revetments placed within the Driggs River flowing through Seney National Wildlife Refuge (NWR). **The central hypothesis is that portions of tree revetments that are more consistently submerged beneath the river surface will be significantly more stable and less decayed than the portions that are less consistently submerged beneath the river surface.**

II. Methods

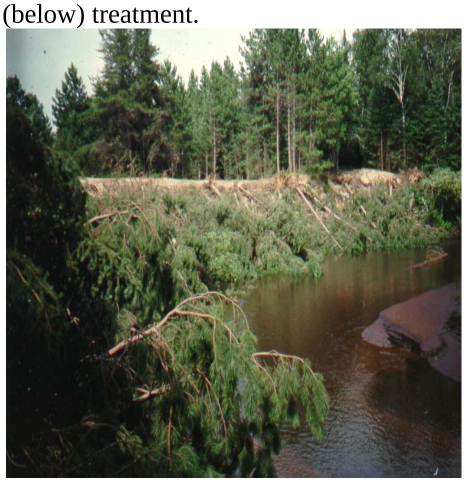
1. Study Site

In August of 1992, the Manistique River Watershed Partnership was formed to develop and implement a course of action to restore and protect the Manistique River Watershed in the Michigan's eastern Upper Peninsula. The cooperative effort included members from three federal agencies, two state agencies, a variety of county and local agencies, private industry, and local citizens. The total watershed is

Fig. 1. Installation of a revetment at an erosion site along the Driggs River.

474,350 ha, of which 38,627 ha are within Seney NWR. A major tributary of the Manistique River is the Driggs River that flows and meanders through the center of the refuge for ~23 kilometers. The Driggs River had been severely degraded as a result logging during the late 19th and early 20th centuries. The initial goal of the Driggs River Restoration project, led by former manager Michael Tansy, was to restore to the Driggs the diversity of aquatic life that was lost when it was cleared of woody debris and scoured by logs during logging. Restoration of the Driggs would also reduce the high sand sediment load entering the Manistique River. It is thought that the loss of large-diameter (mostly older) trees within the floodplain of the Driggs River had caused little woody debris to enter the river banks and that the younger, second growth forest had not matured enough to the point where trees along the floodplain edge were able to naturally fall into the river banks (i.e., the Driggs River was not recruiting woody debris from the adjacent forests). With nothing along the riverbanks to stabilize the soil, the sandy banks were susceptible to heavy erosion by the river current. The lack of woody debris in the river was also assumed to have caused a loss of habitat for invertebrates and other aquatic organisms; by installing tree revetments in banks of severe erosion, aquatic habitats could (in theory) be reestablished and sediment loading of the Manistique River could be reduced.

Fig. 2. Experimental tree revetments were used at 46 erosion sites along the Driggs River. Site 46 before (above) and after (below) treatment.



2. Previous Site Work

In the summer of 1993, 80 erosion sites were identified; biological surveys and experimental restoration work on 46 sites with severe erosion problems began in 1994. One of the restoration treatments was the placement of whole tree revetments (mostly red pine, *Pinus strobus*, but also jack pine, *P. banksiana*) at the base of the eroded bank in order to stabilize the riverbank, divert the river channel, and enhance microhabitat diversity. Pre-treatment data collected in the stream bank erosion inventory of 1993 included physical characteristics of the riverbank, such as bank condition, vegetative cover, cause of erosion, amount of erosion (bank slope, length, and mean height), river depth and width, soil type, and recommended treatment (Appendix II), riverbed topography of select sites using cross-sectional measurements (Appendix IV), invertebrate species composition (Appendix III), and river temperature at the northern and southern intersections of the river with the refuge boundary. Post-treatment cross sectional measurements were then taken annually by Dr. Richard Urbanek (past Refuge Biologist) until 1998 to assess the physical changes of the river (Appendix IV). In a 1998 report, the measurements collected from the six cross sections indicated desirable results of "insignificant additional bank erosion, beneficial silting in the revetments, and some diversion of current into inner sandbars" (Appendix I).

The sites were again revisited and assessed in

2002, 2003, and 2007; not all of the sites were revisited and assessed in 2003 and 2007. These post-treatment measurements and assessments included vegetative cover on once eroded bank, vegetation type, presence of gravel or sand bottom, river width and depth, and any biological observations (Appendix V).

3. Evaluation of Past Data (Pre- and Post-Treatment): Problems and Solutions

- **Inconsistency of site numbering –** each site visited in 2012 is being renumbered from 1-46 from north to south using GPS points (UTM, NAD83) from 2007 data. GPS points will also be converted to decimal degrees, NAD83. This data will then be used with data from previous years to attempt to match up sites which have inconsistent numbering.
- **Inconsistency with revetment location description –** past work seemed to inconsistently “define” east and west. During 2012, the location of the revetment will be determined using E to indicate “east side of the river” and W to indicate “west side of the river.”

4. Sampling Design, Field Measurements, and Materials

For the collection of data and to conduct the assessment, the Driggs River was canoed from north the south. A GPS unit (decimal degrees, NAD83) was used to locate each of the 46 revetment sites. These sites were then marked with rebar and/or flagging along the river, and the river side location of the revetment was noted (E: east side; W: west side). For a sub-sample, a coarse woody debris (CWD) decay class or other decay-class will be assigned for the revetments; two classes will be assigned for each revetment site: one for revetments below the water surface and one for revetments above the water surface at the time of the data collection. The species of the tree revetment will also be noted, if possible, along with any other notes concerning the condition of the revetments and erosion sites. Other possible measurements could involve relative wood density

5. Data Analysis and Materials

The data will be used to calculate if there is a significant difference in the decay class between the revetments above the water surface and the revetments below the water surface. The data will also be analyzed in order to assess how the revetments have decayed since they were put in place nearly a decade ago. Based on the condition of the revetments, it may be advisable to implement more revetments. If the species of the tree revetments are identifiable, differences in the decay class of *P. strobus* and *P. banksiana* should be analyzed as well. This could be used to determine if a certain tree species is preferential as a tree revetment.

III. Project Duration and Timeline

This project will take place during the 2012 field season, with potential follow-up in future years.

Table 1. Project Timeline

Date	Project Stage - Description
May-June 2012	Past data on erosion sites and revetments are reviewed and digitized
early June 2012	Revetment sites visited on foot and marked with rebar and/or flagging
late June - July 2012	Revetment sites visited in canoe and data collected
July 2012	Data analysis and report writing
August 2, 2012	"Science and Seney" presentation

IV. Literature Cited

Benke, A.C., & Wallace, J.B. (2003). Influence of wood on invertebrate communities in streams and rivers. *The Ecology and Management of Wood in World Rivers, 37*, 149-177.

Gurnell, A.M., Tockner, K., Edwards, P., & Petts, G. (2005). Effects of deposited wood on biocomplexity of river corridors. *Frontiers in Ecology and the Environment, 3*, 377-382.

Sandheinrich, M.B., Atchison, G.J., United States., U.S. Army Engineer Waterways Experiment Station., & Environmental & Water Quality Operational Studies. (1986). *Environmental effects of dikes and revetments on large riverine systems*. Vicksburg, Miss: U.S. Army Engineer Waterways Experiment Station.

Steel, E.A., Richards, W.H., & Kelsey, K.A. (2003). Wood and wildlife: benefits of river wood to terrestrial and aquatic vertebrates. *The Ecology and Management of Wood in World Rivers*, *37*, 235-247.

Appendix I. Annual Report Summary (1993-1998). Annual reports were written verbatim and edited to be read as one compilation report.

About a century ago, logs were floated to mill down the Driggs River, which now flows about 14 miles through the center of the refuge. Deposition of sand into the river from the badly eroding banks has resulted. In August 1993, an inventory of streambank erosion along the Driggs River was performed and 36 sites needing possible treatment were identified. Biological surveys and experimental restoration work began in 1994. Cuttings of willow (SPP), alder, red-osier dogwood, and sweet gale were planted along eroded banks in May 1994 and then checked in August 1994. All four species demonstrated good viability; however, 84% of willow cuttings disappeared, primarily as a result of removal by herbivores, probably beaver. Sweet gale exhibited the best overall success rate, but few cuttings of this species were tested. During August-September 1994, 13 eroded bank sites along the upper portion of the river were rehabilitated with tree revetments. Cross-sections of the river at each of the 13 eroded bank sites were measured before rehabilitation and during October 1994 to provide comparative data to evaluate effects of treatment on channel diversion. Also, Biological Intern Heather Luff performed habitat structure mapping and invertebrate sampling during June-August 1994.

During 1995, 33 sites with severely eroded banks were rehabilitated with tree revetments. Revetments were constructed by placing whole red pine (SPP) trees (also jack pine (SPP) if needed) into the riverbed at the base of the eroded bank. Sites with undercut banks were then graded, fertilized, and reseeded with jack pine. This completed treatment began in 1994 to restore 46 problem sites accounting for 5,320 linear feet of eroded riverbank. In 1995, 12 channel cross-sections (8 new sites and 4 checks of 1994 sites) were measured to provide comparative data for future evaluation of the revetments on bank stabilization. The cross-sections indicated little short-term change in channel diversion. In October 1995, a sand trap was excavated off the north and south sides of the C-3 bridge. The pit volume, calculated from linear and cross-sectional measurements, was approximately 1,514 cubic yards. The sandtrap will be monitored to determine the rate of sedimentation from upstream and be emptied as needed. Cuttings of willow, alder, red-osier dogwood, and sweet gale were again planted along eroded banks in May 1995 and then checked in July 1995. The summer evaluation had to be completed before August in 1995 because the sites were scheduled for treatment with revetments. Depredation was not a serious problem in 1995, perhaps because the cuttings were checked earlier in the season or because sandbar willow (*S. inexigua*), which may be less palatable to beaver, was the willow species used that year. Sweet gale exhibited the best overall survival rate, but plantings of none of the species tested were successful beyond the first year. Because of substantial bank instability, most cuttings either washed out or were buried. From June 5 to October 19, 1995, two water temperature monitoring stations were operated near the north and south intersections of the Driggs River and the refuge boundary. Summer temperatures were too warm to provide optimal brook trout habitat. Also, notable were the high daily ranges in water temperature: means of 7.9°F north and 4.5°F south and maximum recorded ranges of 15.9°F north and 9.3°F south.

The rehabilitated banks proved to be stable, except for site no. 26, just south of M-2 Pool, which collapsed during spring runoff. In 1996, this site was repaired, and 4 additional sites were identified for treatment. One of these latter sites had been identified in the original survey but was missed during the restoration work in 1995. That site and one of the newly identified sites were rehabilitated in 1996. Six sites (nos. 1, 6, 12, 15, 18, and 26) were selected for annual cross-section measurement to evaluate success of revetments on bank stabilization. The two northernmost sites, nos. 1 and 6, showed some silting in the revetment and diversion of current inward; others demonstrated no conclusive effect on channel morphometry. In October 1995, a 1,500 cubic yard sandtrap was excavated off the north and south sides of the Driggs River bridge east of C-3 Pool. The sandtrap was completely filled by the end of spring runoff and may be impractical to maintain. From May 22 to November 7, 1996, two water temperature monitoring stations were operated near the north and south intersections of the Driggs River and refuge boundary. Unfortunately, a corroded cable resulted in loss of the sensor at the north station.

In 1997, the annual cross-section measurements were collected for the six selected sites (nos. 1, 6, 12, 15, 18, and 26) to continue to evaluate success of revetments on bank stabilization. Significant additional bank erosion was not found at five sites in 1997. Site 18 could not be evaluated because of data discrepancies. The four northernmost sites (nos. 1-15) showed beneficial silting in the revetment and some diversion of current into inner sandbars. In 1998, these cross-sectional measurements indicated desirable results of insignificant bank erosion, beneficial silting in revetments, and some diversion of current into inner sandbars.

Appendix II. Streambank Erosion Inventory (1993): Pre-Treatment Data (Duszynsik, T. Teets, Tempel, M. Tansy, R. Urbanek)

				Condition of Bank				Amount of Erosion			River Conditions			Soil Type/Texture		
Possible 2012 Site Number	1993 Old Site Number	Date	Bank (right or left, looking downstream)	Condition of Bank	Vegetative cover on bank slope (%)	Problem Trend	Apparent cause(s) of erosion	Side slope of bank	Length of eroded bank (ft.)	Mean height of eroded bank (ft.)	Approx. depth of river at point of erosion (ft.)	Approx. width of river (ft.)	Current	Soil type	Stratified	Recommended treament(s)
1	1	8/16/1993	left	toe undercutting	50-100	somewhat increasing	bend in river	--	20	0-5	3-4	25-30	fast	sand, loam	N	fencing
2	2	8/16/1993	right	toe stable, upper bank eroding	0-10	increasing	bend in river, bank seepage	1:1	100-120	5-10	3	20-25	fast	sand	N	rock rip rap, bank seeding
3	3	8/16/1993	right	toe stable, upper bank eroding	0-10	somewhat stable	obstruction in river, bend in river, bank seepage	50-70%	10	5-10	2	40	slow	sand	N	fencing
4	4	8/16/1993	left	toe stable, upper bank eroding	0-10	somewhat stable	bend in river, bank seepage	50-70%	65	0-5	<1	45	fast	sand, loam	N	brush replacement, planting of willow, etc
5	5	8/16/1993	right	toe stable, upper bank eroding	0-10	increasing	bend in river, bank seepage	60-70%	60	10-20	3-4	25-30	slow	sand	N	rock rip rap
6	6	8/16/1993	left	toe stable, upper bank eroding	0-10	--	bend in river, bank seepage	45-70%	40	5-10	4-5	30	fast	sand	N	rock rip rap
7	7	8/16/1993	left	toe stable, upper bank eroding	10-50	stable to somewhat stable	bend in river	60-70%	35-40	5-10	4-5	30-25	slow	sand	N	log jam structure, bank seeding, fencing
8	8	8/16/1993	left	toe and upper bank eroding	0-10	increasing	bend in river	45-60%	20	5-10	3-4	35-40	fast	sand	N	rock rip rap, fencing
9	9	8/16/1993	left	toe stable, upper bank eroding	10-50	increasing	gullying by side channels	45-60%	25-45	10-20	1-3	35	slow	sand	N	fencing
10	10	8/17/1993	left	toe stable, upper bank eroding	0-10	increasing	bend in river	1:1	120	5-10	1	40	fast	sand	N	rock rip rap, log jam structure
11	11	8/17/1993	left	toe stable, upper bank eroding	0-10	increasing	bend in river	1:1	60	5-10	3	40	fast	sand	N	rock rip rap, log jam structure
12	12	8/17/1993	left	toe and upper bank eroding	0-10	increasing	bend in river	1:1	120	0-5	3	40	fast	sand	N	rock rip rap
13	13	8/17/1993	right	toe and upper bank eroding	10-50	somewhat stable	bend in river	1:1	70	0-5	2	50	fast	sand	N	brush replacement, planting of willow, etc.

Possible 2012 Site Number	1993 Old Site Number	Date	Bank (right or left, looking downstream)	Condition of Bank	Vegetative cover on bank slope (%)	Problem Trend	Apparent cause(s) of erosion	Side slope of bank	Length of eroded bank (ft.)	Mean height of eroded bank (ft.)	Approx. depth of river at point of erosion (ft.)	Approx. width of river (ft.)	Current	Soil type	Stratified	Recommended treament(s)
14	14	8/17/1993	right	toe and upper bank eroding	10-50	somewhat stable	bend in river	1:1	100	5-10	2	50	fast	sand, rock bottom at toe	N	log jam structure, brush replacement, planting of willow, etc.
15	15	8/18/1993	left	toe and upper bank eroding	0-10	increasing, somewhat stable	bend in river	1:1	300	5-10	2	50	slow	sand	N	rock rip rap
16	16	8/18/1993	left	toe and upper bank eroding	0-10	increasing, somewhat stable	bend in river	1:1	50	5-10	2	35	slow	sand	N	rock rip rap
17	17	8/18/1993	right	toe and upper bank eroding	0-10	increasing	bend in river, deer trails	1:1	110	5-10	2	40	slow	sand	N	brush replacement, planting of willow, etc., fencing
18	18	8/18/1993	left	toe and upper bank eroding	--	increasing	bend in river	1:1	300	10-20	2	50	slow	sand	N	rock rip rap
19	19	8/18/1993	right	toe and upper bank eroding	10-50	somewhat stable	bend in river	1:1	300 (some nat. bank reclamation)	5-10	2	25	slow	sand	N	brush replacement, planting of willow, etc.
20	20	8/18/1993	right	toe and upper bank eroding	0-10	increasing	bend in river	1:1	150	5-20	2	50	slow	sand	N	rock rip rap, brush replacement, planting of willow, etc.
21	21	8/18/1993	left	toe and upper bank eroding	10-50	increasing, somewhat stable	bend in river	1:1	45	0-5	2	30	slow	sand	N	rock rip rap
22	22	8/18/1993	left	toe and upper bank eroding	0-10	--	bend in river	2:1	200	5-10	2	25	slow	sand	N	rock rip rap, brush replacement, planting of willow, etc.
23	23	8/18/1993	left	toe and upper bank eroding	0-10	increasing	bend in river	2:1	200	5-10	2	30	slow	sand	N	rock rip rap
24	24	8/18/1993	left	toe and upper bank eroding	10-50	increasing, somewhat stable	bend in river, deer trails	2:1	300 (about 80% nat. reclam. w/ veg at toe)	10-20	2	50	slow	sand	N	rock rip rap, bank seeding, brush replacement, planting of willow, etc.

Possible 2012 Site Number	1993 Old Site Number	Date	Bank (right or left, looking downstream)	Condition of Bank	Vegetative cover on bank slope (%)	Problem Trend	Apparent cause(s) of erosion	Side slope of bank	Length of eroded bank (ft.)	Mean height of eroded bank (ft.)	Approx. depth of river at point of erosion (ft.)	Approx. width of river (ft.)	Current	Soil type	Stratified	Recommended treament(s)
25	25	8/18/1993	right	toe and upper bank eroding	10-50	somewhat stable	bend in river	1:1	50	10-20	2	25	slow	sand	N	bank seeding, brush replacement, planting of willow, etc.
26	26	8/18/1993	right	toe and upper bank eroding	10-50	increasing, somewhat stable	bend in river	1:1	400 (half nat. revegetated)	10-20	2	30	slow	sand	N	rock rip rap, bank seeding, brush replacement, planting of willow, etc.
27	27	8/18/1993	left	toe and upper bank eroding	10-50	somewhat stable	bend in river	1:1	150 (about half or more nat. revegetation	5-10	2	25	slow	sand	N	rock rip rap, brush replacement, planting of willow, etc.
28	27a															
29	27b															
30	28	8/18/1993	left	toe and upper bank eroding	10-50	somewhat stable	bend in river	1:1, 2:1	50 (complete veg at toe), 15 (recent-worst)	10-50, 5-10	2	25	slow	sand	N	bank seeding, brush replacement, planting of willow, etc., fencing
31	28a															
32	28b															
33	28c															
34	28d															
35	29	8/18/1993	left	toe and upper bank eroding	10-50	somewhat stable	bend in river	2:1	50	10-20	3	25	slow	sand	N	rock rip rap, bank seeding, brush replacement, planting of willow, etc.
36	30	8/18/1993	right	toe stable, upper bank eroding	10-50	somewhat stable	bend in river, deer trails	1:1	200 (80% of toe reveg.)	10-50	2	50	slow	sand	N	rock rip rap, bank seeding, brush replacement, planting of willow, etc.

Possible 2012 Site Number	1993 Old Site Number	Date	Bank (right or left, looking downstream)	Condition of Bank	Vegetative cover on bank slope (%)	Problem Trend	Apparent cause(s) of erosion	Side slope of bank	Length of eroded bank (ft.)	Mean height of eroded bank (ft.)	Approx. depth of river at point of erosion (ft.)	Approx. width of river (ft.)	Current	Soil type	Stratified	Recommended treament(s)
37	31	8/18/1993	right	toe and upper bank eroding	10-50	somewhat stable	bend in river	1:1	25	10-50	2	25	slow	sand	N	rock rip rap, brush replacement, planting of willow, etc.
38	32	8/18/1993	left	toe and upper bank eroding	10-50	somewhat stable	bend in river	1:1	50	--	2	50	slow	sand	N	fencing
39	33	8/18/1993	right	toe and upper bank eroding	0-10	--	bend in river	1:1	300	10-50	2	30	slow	sand	N	rock rip rap
40	34	8/20/1993	left	toe undercutting, upper bank eroding	10-50	somewhat stable	bend in river	1:1	60-80	5-10	2-3	30	fast	sand	N	rock rip rap, fencing
41	34a															
42	34b															
43	34c															
44	35	8/20/1993	right	toe and upper bank eroding	10-50	increasing	bend in river, bank seepage	1:1	80-100	5-10	2	30	fast	sand	N	rock rip rap, fencing
45	35a															
46	36	8/20/1993	left	toe undercutting, toe and upper bank eroding	0-10	increasing	bend in river, bank seepage	1:1	100-125	10-20	2	35	fast	sand	N	rock rip rap, brush replacement, planting of willow, etc., fencing

Appendix III. Macroinvertebrate data and compiled species list.

A Survey of Macroinvertebrates in the Driggs River,
Seney National Wildlife Refuge

Heather Luff, M.S.

Introduction

"In the summer of 1994 a biological inventory was carried out on this stretch of the Driggs River, concentrating on bank vegetation, the number and locations of downfalls in the river, aquatic vegetation and invertebrates; prior to a major rehabilitation project."

Methods

"The 14-mile stretch of the Driggs River that runs through Seney National Wildlife Refuge was canoed in the summer of 1993, and 36 sites were selected which showed moderate to severe bank erosion."

<u>Bank Vegetation and Downfalls</u>

"Bank vegetation was noted on a photocopied map while the river was being canoed. It was not so detailed that every tree was mentioned, but the general characteristic vegetation types were marked e.g. overhanging tag alder, large white pines. The number and exact localities of downfalls (trees fallen into the river channel) were also marked on the map."

<u>Aquatic Vegetation and Invertebrate Surveys</u>

"The more detailed aquatic vegetation and invertebrate surveys were conducted at the 36 sites of prime concern selected the previous summer, as this is where the river rehabilitation work was to begin.

Sites were defined as including the whole width of the river, extending the length of the eroded bank. The inventory conducted at each site was identical. First the site was sketched in detail, showing the curve of the river, marking the direction of water flow and the exact size and position of different microhabitats. The microhabitats at the site were then listed in order of size (area of the stream channel). Microhabitats included: sand, aquatic vegetation, overhanging trees and vegetation, gravel, and woody debris. A percentage value was estimated for the size of each microhabitat out of the total area of the site.

Aquatic vegeation was also studied at each site. A list was compiled of all the species present and the percentage of each (relative proportion) was estimated e.g. 80% *Vallisneria* sp., 20% *Potamogeton amplifolius*.

Emphasis on microhabitats within a river is important when conducting an invertebrate survey. Invertebrate species are often extremely habitat specific, so careful study of each microhabitat is required in order to compile an accurate species list. Detailed analysis of this kind also allows comparison between the invertebrate life in different microhabitats, so that species-rich microhabitats can be determined. This information is useful when deciding which microhabitats would be most beneficial to create during rehabilitation work, in order to increase the amount of life within the river. It also shows which invertebrate species would be encouraged by creating specific microhabitats e.g. adding more woody debris to the river.

Once the list of microhabitats was completed for the site, invertebrate sampling began. A 3 foot diameter invertebrate net was used. It was dragged across the microhabitat being studied and then lifted to identify any invertebrates that had been caught. This process was repeated until there were no new invertebrate species. By doing this it was hoped a complete species list for that microhabitat at that particular site could be compiled. In order to quantify the species list a scale of relative abundance, from 5 to 1, was used: 5 = extremely abundant, 4 = fairly abundant, 3 = moderately abundant, 2 = present, 1 = scarce.

The scale was identical for each species at every site, but varied between species according to biomass. Hundreds of *Baetis* sp. for instance may occur within a small area and be given a relative abundance (R.A.) value of 5, whereas just 15 crayfish would be awarded the same R.A. value.

As the relative abundance index was subjective, it was essential that it was carried out by the same person. A more standard quantitative method, e.g. Serber sampling, where a specific area of river gravel is kicked into a net, would have been impossible in this situation however where so many different microhabitats were studied. The relative abundance method also had the advantage of being fast and fairly reliable.

Invertebrates that could not be identified at the site were collected and stored in glass vials for late identification. There were still recorded in the species list for that habitat, with and abundance value. The correct species name was assigned to the list late.

All Odonata, Ephemeroptera, Plecoptera, and Tricoptera were classified to genus level. Chironimidae and Simulidae (Order = Diptera), were not classified beyond family level as this would have been a time-consuming process requiring a high power light microscope. Also further classification would not have yielded any more useful information. A reference collection for all classified invertebrates was built up."

Results

"The results of the biological inventory conducted on the 36 sites are shown in the appendix."

See Excel sheet "macro invertebrates_1994" which contains the data from the inventory as described under "Aquatic Vegetation and Invertebrate Surveys" of Methods, excluding site sketches.

Compiled Species List (2012)

Nematoda
Oligochaeta
Crustacea
Amphipoda
Gammarus sp.
Scud
Decapoda
Crayfish
Insecta
Odonata
(Zygoptera)

Calopterygidae
Calopteryx sp.
(Anisoptera)
Aeshnidae
Gomphidae
Ophiogomphus sp.
Cordulegaster sp.
Stylurus sp.
Plecoptera
Pteronarcidae
Pteronarcys sp.
Perlidae
Acroneuria sp.
Phasganophora sp.
Ephemeroptera
Heptageniidae
Stenonema sp.
Stenacron sp.
Baetidae
Baetis sp.
Caenidae
Brachycerus sp.
Oligoneuriidae
Isonychia sp.
Trichoptera
Brachycentidae
Brachycedntrus sp.
Asyea sp.
Phryganeidae
Agrypnia sp.
Hydropsychidae
Hydropsyche sp.
Philopotamidae
Dolophilodes sp.
Coleoptera
Dytiscidae
Gyrinidae
Hemiptera
Belostomatidae
Corixidae
Notonectidae
Diptera
Atericidae
Atherix sp.
Simuliidae
Chironomidae

Appendix IV. Cross sections data.

Compete data of cross sections are in files “DR Cross Sections_1994_1995” (13 sites measured, sites 12 and 34b collected in 1994, rest in 1995), “DR Cross Sections_1996” (4 sites measured), “DR Cross Sections_1997” (6 sites measured), and “DR Cross Sections_1998” (6 sites measured). At each site for cross section measurements, the elevation and water depth was measured for each distance away from the starting point.
Example of the cross sectional data collected at a revetment site:

Old Site Number	Date	Laser Line
18	8/24/1998	0.25 in above benchmark

Distance (m)	Elevation (ft)	Water Depth (ft)	Comments
0.00	13.18	0.00	at post, inside bank
1.70	13.93	0.00	top of vegetated bank
2.00	14.80	0.00	bottom/outside edge of sandbank
4.85	15.31	0.00	edge of water
5.40	15.73	0.58	in river
6.30	15.98	0.90	
10.40	16.33	1.15	
11.65	16.53	1.41	edge of hole
11.90	16.75	1.62	in hole
12.70	15.68	0.60	far end of hole / edge of sandbank
17.40	15.72	0.61	
19.60	15.96	0.85	
21.35	16.45	1.35	
22.45	16.95	1.80	edge of dropoff
23.20	17.38	2.25	
23.45	17.41	2.30	edge of logs
23.70	17.15	2.05	thick on bottom, in logs
24.30	16.12	1.00	
25.30	15.69	0.10	edge of bank, mud
25.80	14.80	0.00	outside bank (sandbank)
26.80	11.78	0.00	top of log
27.20	11.91	0.00	bank side of logs
27.80	10.41	0.00	
28.30	9.43	0.00	
28.70	8.71	0.00	edge of sandbank
28.80	7.80	0.00	edge of grass
31.70	4.30	0.00	at post

Appendix V. Driggs River Revetment Revisit and Assessment (2002).

Site Number	Old Site Number	Date	N GPS (UTM NAD83)	E GPS (UTM NAD83)	Bank Direction	Trend	Side Slope Degree	Slope Length (ft)	Slope Length (ft) other?	Slope Height (ft)	River Depth (ft)	River Width (ft)	Slope Width (ft)	Rating	Comments
1	1	7/10/2002	567340	5132601	L	stable	30	70	20	8	2.5	39	6	minor	veg. growing in nicely
2	2	7/10/2002	567378	5132503	R	stable	45	150	120	12	4	25	10	minor	tag alder growing in, little erosion
3	3	7/10/2002	567435	5132448	R	stable	30	40	10	10	1	40	8	minor	bank stable
4	4	7/10/2002	567642	5132287	L	stable		100	65	5	3	40	10	minor	vegetation established
5	5	7/10/2002	567611	5132195	R			50	60	12	3	30	10	minor	vegetation established
6	6	7/10/2002	567817	5132085	L	stable	20	50	40	6	2-3	30	10	minor	vegetation established
7	7	7/10/2002	567919	5131924	L	stable	20	30	40	8	1	45	6	minor	some bank erosion on tailing edge of revetment, trees may help stabilize
8	8	7/10/2002	567920	5131815	L	stable	60	100	20	15	2	35	15	minor	inside of bend - sand bank
9	9	7/10/2002	568589	5129599	L	stable	20	100	45	6	5	50	5	minor	vegetation established
10	10	7/10/2002	568675	5129431	L	stable	30	30	120	10	2.5	45	20	minor	vegetation well established
11	11	7/10/2002	568813	5129208	L	stable	45	100	60	10	3	35	10	moderate	upper bank may need to be planted, not quite as stable as bottom portion
12	12	7/12/2002	569251	5128035	L	stable	30	100	120	6	2	25	8	minor	veg. mostly established
13	13	7/12/2002	569102	5127909	R		30	60	70	10	2	35	15	minor	vegetation well established
14	14	7/12/2002	571103	5125445	R	stable	40	100	100	8	2	35	10	minor	herb. species established, very little erosion on latter edge of bank
15	15	7/12/2002	571564	5123689	L	stable	20	250	300	5	3	30	8	minor	veg. well established, some erosion, veg. looks to be establishing
16	16	7/12/2002	571460	5123518	L	stable	30	100	50	8	1	20	8	minor	veg. moderately established, some erosion persists, sand building on inside of bend
17	17	7/12/2002	571404	5123314	R	stable	45	150	110	8	3	40	8	minor	large sandbank on inside of bend, bank well established
18	18	7/12/2002	572133	5122763	L	stable	50	200	300	20-30	1	20	15	moderate	most veg. established, some parts still eroding - tailing edge of bank about 20 ft. long
19	19	7/12/2002	572584	5121969	R	stable	30	150	300	10	1-2	35	6	minor	mostly established, little erosion
20	20	7/12/2002	572642	5121831	R	stable	45	150	150	10	2.5	30	10	minor	bank covered with vegetation, inside of bank - large sand deposit

2012 Site Number	Old Site Number	Date	N GPS (UTM NAD83)	E GPS (UTM NAD83)	Bank Direction	Trend	Side Slope Degree	Slope Length (ft)	Slope Length (ft) other?	Slope Height (ft)	River Depth (ft)	River Width (ft)	Slope Width (ft)	Rating	Comments
21	21	7/10/2002	572881	5121783	L	stable	30	100	45	5	2	30	8	minor	little erosion
22	22	7/12/2002	573100	5121544	L	stable	30	250	200	10	2.5	35	15	minor	bank established
23	23	7/12/2002	573409	5121129	L	stable	10	100	200	4	2	30	4	minor	bank well established
24	24	7/12/2002	573520	5120980	L	stable	30	225		10	3	35	15	minor	
25	24a	7/12/2002	574041	5120654	L	stable	40	300	300	10	3-1	35	15	minor	very well established, large sand deposit on inside of bank
26	25	7/12/2002	574014	5120385	R	stable	75	110	50	20	3	35	10	minor	area before revetment is eroding away, needs work done, revetments seems to have been successful
27	26	7/13/2002	574256	5120190	R	stable	25	150	250	15	2	20	15	minor	bank just before revetment may need some attention
28	27	7/13/2002	574431	5120290	L	stable	45	150	150	15	2.5	35	15	minor	very little erosion
29	27a	7/13/2002	574562	5120203	R	stable	20	200	80	10	4	20	6	minor	nicely established
30	28	7/13/2002	574590	5120272	L	stable	60	100	60	30	2.5	35	20	minor	high slope - erosion stopped, large sand deposit on inside of bend
31	28a	7/13/2002	574705	5120148	L	stable	80	100	50	8	2	30	6	minor	well restored
32	28b	7/13/2002	574653	5120100	R	stable	45	125	85	10	2	35	15	minor	veg. established
33	28c	7/13/2002	574778	5120008	R	stable	30	50	190	10	2	35	15	minor	veg. established
34	28d	7/13/2002	574872	5119970	L	stable	60	30	60	15	3	30	10	minor	
35	29	7/13/2002	574922	5119881	L	stable	30	150	80	10	2	25	15	minor	
36	30	7/13/2002	574796	5119701	R	needs attention	75	150	200	40	2	50	15	moderate	tree falling, may help curb erosion
37	31	7/13/2002	574904	5119567	R	stable	10	50	50	30	2.5	25	25	minor	some erosion, will stabilize in time, may need some work now
38	32	7/13/2002	574967	5119532	L	stable	30	125	50	5	2	50	10	minor	
39	33	7/13/2002	574936	5119461	R	stable	60	200	300	25	2.5	40	12	minor	
40	34	7/13/2002	575261	5119556	L	stable	40	150	80	15	1	20	10	minor	well established
41	34a	7/13/2002	575346	5119530	L	stable	30	70	80	7	2	30	15	minor	well established, sand deposition on inside of bend

Site Number	Old Site Number	Date	N GPS (UTM NAD83)	E GPS (UTM NAD83)	Bank Direction	Trend	Side Slope Degree	Slope Length (ft)	Slope Length (ft) other?	Slope Height (ft)	River Depth (ft)	River Width (ft)	Slope Width (ft)	Rating	Comments
42	34b	7/13/2002	575545	5119487	L	stable	40	200	70	25	2	30	15	minor	sand deposition inside of bend, nicely restored, point between 34b-34c needs work (003) 0575659/5119221
43	34c	7/13/2002	575665	5119096	R	stable	60	100	100	10	2	40	5	minor	natural tree fall, high bank, erosion could be great, needs attention - pt 003
44	35	7/13/2002	575814	5118824	R	stable	45	200	100	10	3	30	6	minor	restored
45	35a	7/13/2002	576077	5118160	R	stable	75	75	40	20	2.5	30	10	minor	
46	36	7/13/2002	576368	5117911	L	stable	90	150	300	40	2	25	15	minor	sand deposition inside of bend, very stable

Bank directions are consistent with data collected in 2012, except for 2 sites (L indicates east, R indicates west).