2012 Riparian Protocol Testing Summary and Recommendations

Prepared for
Dr. David Merritt
Stream Systems Technology Center
USDA Forest Service
Rocky Mountain Research Station
Suite 368 2150 Centre Avenue, Bldg. A
Fort Collins, CO 80526

Prepared by
Christopher Peltz
Research Services /Mountain Studies Institute
cdpeltz.researchservices@gmail.com
PO Box 873
Silverton, CO 81433
970.691.6351

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Summary

In the summer of 2012 the Mountain Studies Institute (MSI) entered into a cost share agreement with the U.S. Forest Service Stream Systems Technology Center. The purpose of that agreement was to evaluate the draft riparian monitoring protocol: U.S.D.A. Forest Service National Riparian Vegetation Monitoring Core Protocol: Western U.S. (hereafter Protocol) and field test and apply the protocol to stream reaches in the San Juan and Gunnison National Forests and other sites as identified in Southwestern Colorado. Testing and evaluation of the protocol in the San Juan mountain region will allow for application of the Protocol to multiple and varied stream and valley types as identified in previous work conducted by the Forest Service and collaborators. The results from this testing and evaluation will serve to allow Forest Service managers to better evaluate whether this protocol is applicable and effective for the riparian resources they manage, as well, the Forest Service will benefit from the collected data and information about the condition of riparian resources on the San Juan and Gunnison National Forests. As part of this contract MSI was responsible for:

1. Assemble a field crew capable of applying the Protocol to selected stream segments.
2. In conjunction with SST staff, select a subset of rivers in the SJM region to conduct testing of the Protocol.
3. Apply the Protocol to a minimum of forty (40) stream sites located on San Juan and Gunnison National Forests.
4. Provide all survey data in digital form to SST staff at regular intervals.
5. Develop reports at the completion of the field season (Dec 31, 2012) using parameters developed with USFS SST staff and will contain at a minimum, data analysis for riparian vegetation composition, character, and distribution of species

As part of completing these activities for 2012 this report summarizes data collected during July of 2012 and provides data analysis for those sites, insights gained from application of the protocol and suggestions for improving the protocol and integrating it into other, alternative and emerging field data collection techniques.

The data presented in this report summarizes the channel topography and vegetation communities found at each of sampled sites. Sites were identified in consultation with Forest Service staff and spanned the range of channel types and regional ecotypes (i.e. Montane, Foothills and High Desert). Sites were located along river reaches on the Animas, Piedra, San Juan, and Rio Grande Rivers, and spanned an elevation range of 3317 – 1904 meters and included a range of geomorphic settings from confined high gradient streams to low gradient meandering streams.

As part of the sampling efforts fifty (50) vegetation and channel topography transects were established, with the locations of transect endpoints included in Appendix 1. Sampling methods followed the Riparian Monitoring protocol with a minimum of 100 vegetation point-intercept measurements taken at each site along five transects that included overstory measurements in 10 meter width belt transects and all shrubs within a 2 meter belt transect centered upon transect lines. The most common vegetation surveyed was willow (Salix exigua and Salix monticola) with Carex, Bromus, Achillea, Bryophytes, Taraxacum, Populus, Oreochrysum, Potentilla, Fragaria, Trifolium, Shepardia, and Astragalus comprising 80% of the total cover for all sites combined. Overstory vegetation dominated by Narrowleaf cottonwood and Engelmann spruce. In addition to vegetation measurements, transect topographic profiles and the longitudinal profile along the thalweg of the channel was measured, with channel slopes ranging from 0.011 – 0.031 m/m.

The following report and appendices outlines the equipment and staffing requirements, the methods used and suggestions for refinement, data analysis on a site by site and geomorphic surface basis, and the results of this analysis and conclusions about the application of the Protocol and suggestions for future application of the protocol.

Field sampling team (from left, Alan T., Tim Cutter, Zach Gallien, Bree McClenning)

Locations

From July 1 – July 27 we applied the U.S.D.A. Forest Service National Riparian Vegetation Monitoring Core Protocol: Western U.S. (hereafter "Protocol") at ten sites in the San Juan Mountain region of Southwest Colorado (**Figure 1**). The ten sites included reaches along the Animas, San Juan, Rio Grande, and Piedra rivers. Sampling was conducted on a range of sites that comprised mainly of "mountain" and "moderate-energy gravel" rivers (Carlson, 2009).

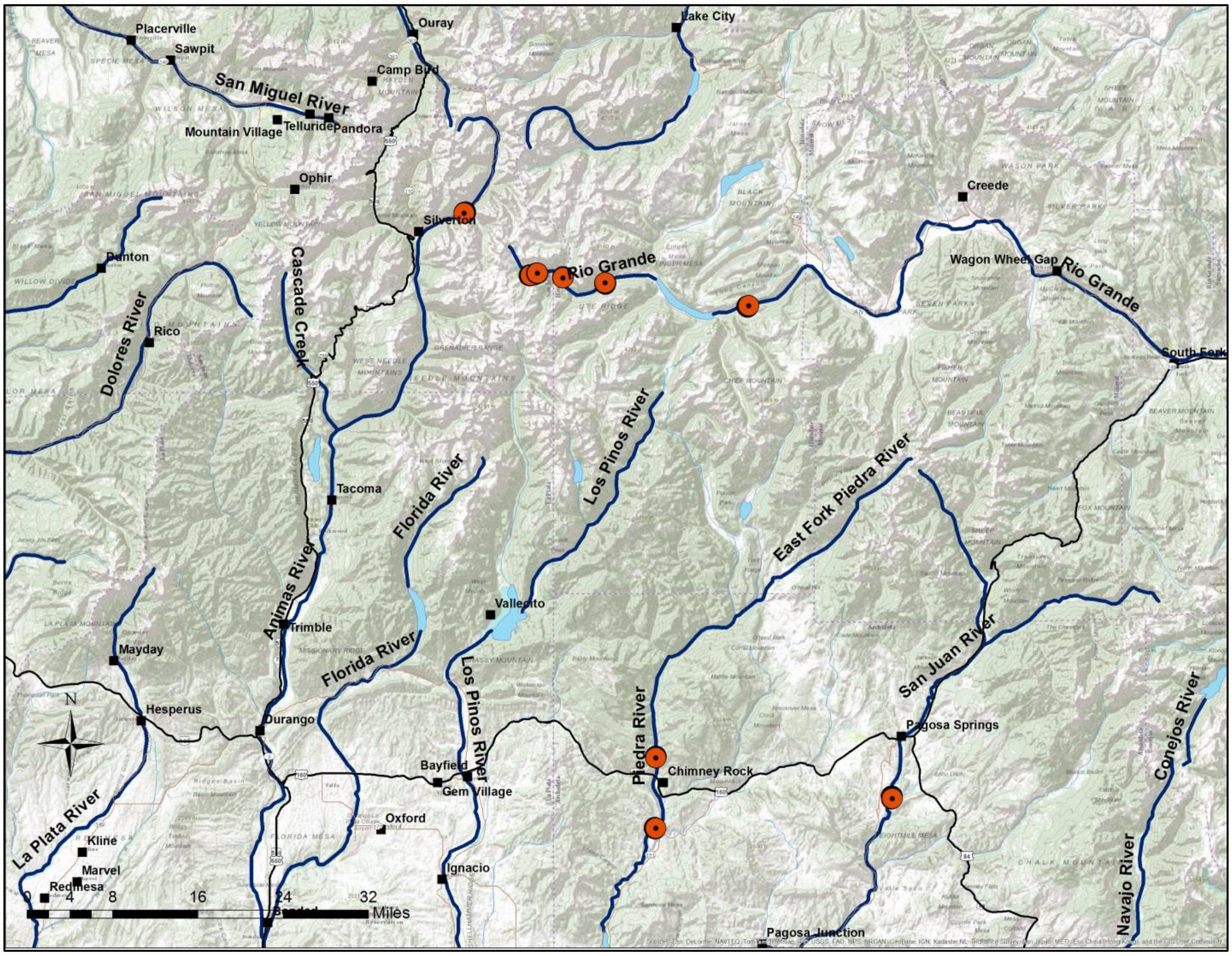


Figure 1. Riparian sampling locations

Table 1. Site locations and channel types

Site Name	UTM (NAD 83, 13)	Elevation (m)	Slope (m/m)	Channel Type
Animas 1	271096 4190439	2854	0.015	Moderate-energy Gravel
Piedra 1	292200 4124933	2015	0.017	Steep Mountain River
Piedra 2	291803 4116323	1940	0.011	Low-energy
Rio Grande 1	278517 4182679	3317	0.029	Steep Mountain River
Rio Grande 2	279085 4182835	3300	0.031	Moderate-energy Gravel
Rio Grande 3	279444 4182953	3296	0.024	Moderate-energy Gravel
Rio Grande 5	282560 4182372	3192	0.022	Moderate-energy Gravel
Rio Grande 7	287577 4181432	3027	0.025	Moderate-energy Gravel
Rio Grande 10	304451 4178368	2814	0.015	Low-energy
San Juan 1	320459 4119464	2090	0.011	Moderate-energy Gravel

Methods

We followed the methods outlined in the Core Protocol with the exception of conducting the belt transects using a 2 meter width for the shrub survey, and a ten meter belt for the overstory measurements (**Figure 2**).

At the time of testing field sheets had yet to be developed, therefore we developed field data sheets based on prior experience. The assembled field data collection sheets, with separate sheets devoted to the point-intercept data, shrub and overstory, and topographic survey data are provided in (**Appendix 1**). In addition to developing field data sheets we explored various sequences for conducting the field sampling with the below series of steps being the most efficient.

Steps followed once arriving to site:

1. Break into two teams
    a. Team 1 – Begins to set up transect cross-sections following protocol methods for end point location, ***This process is helped when one person is identifying transect end points and taking GPS measurements ahead of the team installing transect end points.
    b. Team 2 – Begin to develop species list, general botanizing and site familiarity. Should not exceed the time it takes to set up two transects. Team 2 should be taking detailed notes and lots of pictures of the site.
2. Team 1 – Begin topographic survey, and if *optimal, shrub and tree measurements.
    a. *Optimal conditions would be present if there are limited shrub stem numbers (<500 total at site, or they are short and do not impede walking), and few trees > than 10DBH (cm). These conditions were found typically at the higher montane and sub-alpine streams, these streams were also on average narrower and had fewer tall shrubs than sites in the foothills (e.g., Upper Animas, Upper Rio Grande).
3. Team 2 – Begin vegetation line-intercept survey, and shrub and overstory survey.
    a. Worked well when line intercept was done going one direction (RR –>>RL) and the shrub and overstory was done walking back (RL ->>RR).
4. Once Team 1 completes transect installation and topographic survey (typically about the time when veg survey was on Transect 4 or 5), set up and conduct longitudinal survey.
    a. Important to select a location to set tripod and auto-level so the survey pole will be visible for the entire length of the study reach.
5. Once Team 2 completes veg survey, begin to dismantle transects, ideally completing 2-3 transects by the time the longitudinal survey is near completion.

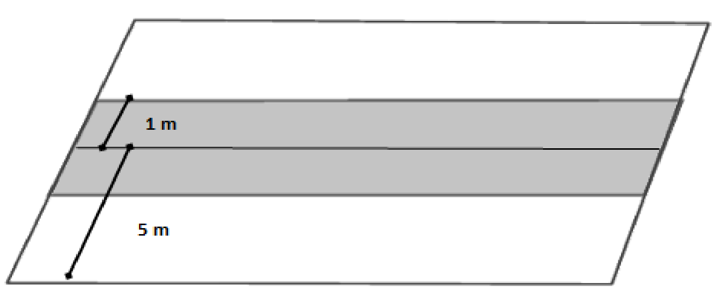


Figure 2. Belt Transect: Record species and number stems <10 DBH in 2 m belt, record all species and DBH in 10 m belt

Transect end point

High willow stem count

Belt transect measurements of stem counts

Belt transect measurements of DBH and Crown %

Channel longitudinal and lateral topography measurments

Sampling Equipment

The list of sampling equipment was developed in conjunction with the USFS Stream Team and is listed below and shown in **Figure 3**. We made use of all the equipment listed as well as some additional equipment including a Bosch laser range finder, tree diameter measurement caliper, and short range radios. The most expensive pieces of equipment purchased included a laser point intercept measurement device from Synergy Resources ($270), Auto level kit ($700) and a Trimble JUNO GPS with ArcPad ($1,100).

We found that the Auto level was very useful, the GPS was indispensable, and the laser intercept tool was useful, however, we found that there were probably good alternatives for all of these devices that would have been much lower cost, particularly the laser intercept tool. Once we used this device a number of times we found that had we constructed something similar using PVC and a small hand held laser pointer would have been just as good and most likely would have cost <$40. The Auto level probably could have been substituted with a dumpy level or other hand held device, and having a field mapping GPS was great, however had we used an Apple IPad© with a GPS receiver and ArcPad application (<$1,000 total) we probably would have had a easier to use system that would have required much less training. Additionally, we found that Keeson survey ropes were better (more durable/less expensive) than metal meter tapes or tag lines. Additionally, we found that using a plastic sleeve, similar to those used to collect baseball cards would have been optimal for collecting unknown plant examples. In addition to the equipment listed in **Table 2**, we list additional equipment needed in **Table 3**.

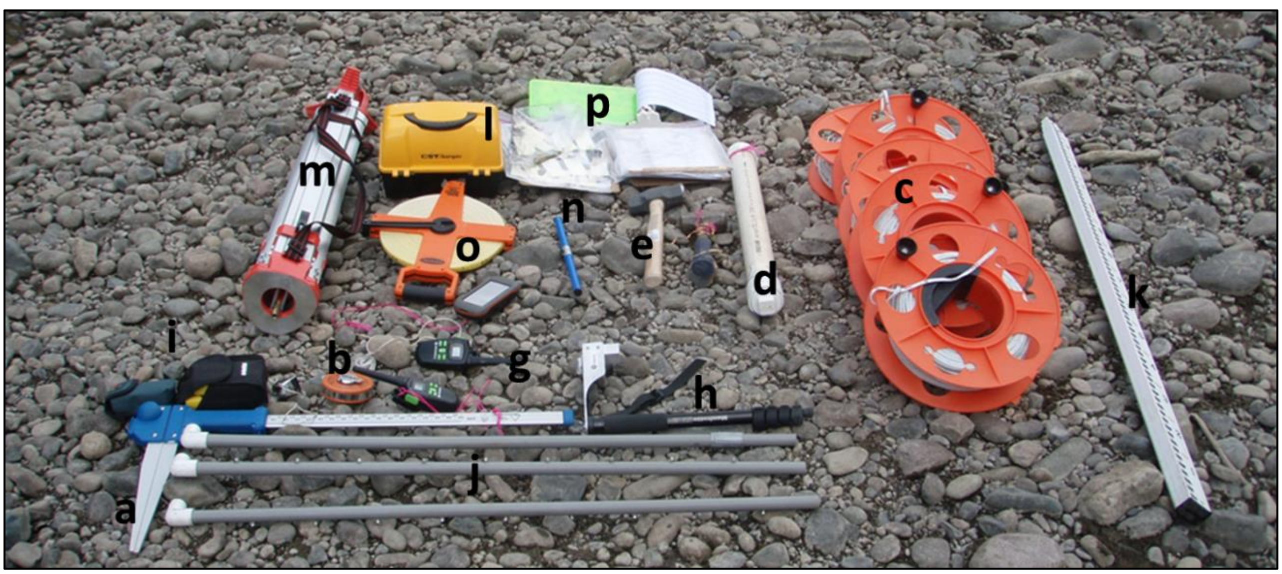


Figure 3. Sampling equipment

Sampling equipment included:

1 Hagloff tree diameter caliper (a)
1 DBH tape (steel) (b)
5 Surveyors tapes (100 meters) (c)
12 2 ft sections of rebar (in PVC sleeve) (d)
1 Small sledge hammer (e)
1 GPS (f)
2+ field radios (g)
1 Laser point intercept tool (h)
1+ laser range finder(i)
2+ 1 meter sections of PVC pipe (j)
1 Survey pole (5 meters) (k)
1 Auto level (24x magnification) (l)
1 Survey tripod (m)
1 10 inch Hagloff increment borer (n)
1 200 meter tape (o)
1 Set of site maps, data sheets, and references

Table 2. Equipment, costs and potential suppliers

Equipment	# needed	($)	Supplier
Hagloff tree diameter caliper (50 cm)	1	160	Forestry Suppliers
DBH tape (steel)	2	50	Forestry Suppliers
Kenson Surveyors Rope (100 meters)	5	37	CSP Outdoors
2'-3' sections of rebar	12	2	Home Depot
Sledge Hammer	1	30	Home Depot
Laser point intercept tool	1	262	Synergy Resources
Walkie Talkies	4	25	Forestry Suppliers
Auto level (24x), tripod and survey rod	1	800	Forestry Suppliers
Meter tape (200 meters)	1	60	Forestry Suppliers
GPS with ArcPad*	1	1100	ESRI
GPS with GPX file transfer*	1	600	Garmin
Hagloff increment borer (10 inch)	1	100	Forestry Suppliers
Laser range finder	2	100	Home Depot
PVC pipes	4	2	Home Depot
Field maps, and other supplies	1	200	
Fuel and Travel expenses	1	500	
Total		4,429	

Table 3. Additional equipment and associated costs

Equipment	#	Cost/project/year
High Clearance 4x4 vehicles	2	800-1,500
ESRI ArcGIS	2	100
Statistical software	1	250
Computer	1	900
Office space	1	2,500
~Total Annual cost ($)		3,600
10-20% of total annual		360 - 720

Training

Training for the field crews involved reviewing the Protocol and collective discussions about its contents with quizzes and role playing on what people would be doing and how it relates to the overall goal. Practicing and getting familiar with the equipment, computer systems, data plan and analysis software, familiarity with field sites by looking at air photos, and field preparation logistics. Office and non-field training took ~4 days for the entire crew. While in training, field crew was housed at MSI field station ($20/day x 4 people x 4 days = $320). Field stipends were provided to each field crew member ($25 X 4 = $100) for food assistance.

In-field training involved three steps and took ~1 day with "refreshers" done periodically throughout the summer:
1 – Identification of appropriate field sites
2 – Setting up transects and surveying
3 – Vegetation and forestry surveys

Training was reinforced each day by conducting a "huddle" before we began for the day – outlining roles and goals, and re-convening after each site was completed. Re-convening involved a gear check-in, notes about the site, and any discussion about challenges and options to overcome them at the next site.

Staffing

In order to successfully complete the field sampling and analysis required in the Core Protocol a number of aptitudes and experience is needed. **Table 4,** outlines the expected staffing levels and estimated costs, based on non-profit wages with a 25% overhead. The number of days listed in the table does not include the time required to hire and train field crews or time spent on data analysis and reporting. Additional time would be needed for both the Project Manager, Field Crew Leader, and support staff. Given the level of understanding and aptitude needed to implement the Protocol and number of years' experience needed, some specific skills are recommended, and are listed below Table 4.

Table 4. Staffing levels and estimated costs

Personnel*	Experience (yrs.)	Cost/day ($)	# of Days	Total
Project Manager (GS-9)	5	200	40	8,000
Field Crew Leader (GS-7)	2-3	144	25	3,600
Vegetation Specialist (GS-9)	1-3	144	25	3,600
Field Tech 1 (GS-5)	0-2	80	20	1,600
Field Tech 1 (GS-5)	0-2	80	20	1,600
Botanist Contractor (GS-12)	10+	300	3	900
Support (ED and Finance) (GS-12)	5+	300	5	1,500
Total Personnel				20,800

*Based on non-profit wages and 25% Taxes and Benefits, values in parentheses are the Government Service equivalent pay grades - https://www.opm.gov/oca/12tables/pdf/gs_h.pdf

Project Manager: Should have minimum 5 years of experience conducting and leading field ecological investigations with experience in riverine and forest environments. PM should have broad working knowledge of basic hydrologic principles, atmospheric processes, plant physiology, geomorphology, plant identification, data and geographic analysis, project management/staffing, and safety. This person will most likely have an advanced degree, MS or greater equivalent.

Field Crew Leader: Should have 2-3 years field experience with progressively increasing levels of responsibility. FCL should have most of the qualifications of the PM, with the exception of having increased understanding of plant identification and ecophysiology. This person may have a bachelor's of science degree, but most likely has a MS or is in the process of achieving an advanced degree.

Vegetation Specialist: The Vegetation Specialist will be primarily responsible for plant identification and should have had college level instruction in botany and >1 year of field experience as a botanist. These positions are typically difficult to staff, with many summer field botanists jobs offering rates >$20/hour.

Field Tech: The Field Techs do not need any special training prior to hiring; however a number of characteristics of the individual will predispose them to success in this job. These characteristics, include physically fitness, determination, attention to detail, ability to work long days in the elements. Based on the author's experience, many people will say that they like to camp and hike and "love field work" however this love can wear off quickly when the monotony of field work sets in. Thus, it is important to hire field techs that see the job as a step towards their professional or scholastic goals, this additional incentive they have to conduct the work at a high level will, hopefully supplement the low relative pay they may receive. However, doing this requires more of an investment in time and relationship building on the part of the PM, and this most likely is not reflected in the direct project costs. Of all the positions, the field techs, in many ways are the most important, as the ability of the FT's and their enthusiasm and flexibility can be the critical factors in collecting accurate and robust data sets.

Results

Overall, we identified 89 individual species, with 5 species unknown. The most common plants found were Salix, Carex, and Bromus species, accounting for 47% of all point intercept counts (**Table 2**). The number of uncommon plants (<5 instances) was 34 different plants; however these plants only accounted for ~3% of total counts. Community level data is presented below, with species occurrences in **Table 5 and Figure 4.** Species occurrences from the belt transects for all sites combined is presented in **Figure 5**. Herbaceous vegetation was analyzed on a site by site and geomorphic surface basis, with the results presented in **Table 5** and **Figure** 6-9.

The data was also analyzed using community similarity analyses (PCA and PCoA) as well as classification and regression tree analyses. The results of these analyses are presented in **Figure 10** which illustrates a two-way dendrogram of species groupings as limited by site, and **Figures 11** and **12** which present the results of a principal components analysis (11) and principal coordinates analysis (12) for individual species and site. **Figure 13** presents a two-way dendrograms for each geomorphic surface with **figures 14** and **15** illustrating the PCA and PCoA for geomorphic surface.

Table 5. Community analysis for each site and geomorphic surface. Richness (S – sum of non-zero elements), Diversity (H – sum (Pi*Ln(Pi) = Shannon's diversity index, Evenness (E – H/ln (Richness), Simpsons Diversity Index (D – 1- sum(Pi*Pi). Pi = importance probability in element i.

Site	S	E	H	D`
Animas 1	20	0.82	2.45	0.88
Piedra 1	22	0.84	2.60	0.90
Piedra 2	24	0.67	2.12	0.81
Rio_1	22	0.77	2.39	0.86
Rio_10	17	0.80	2.26	0.85
Rio_2	21	0.73	2.22	0.83
Rio_3	24	0.70	2.22	0.82
Rio_5	15	0.82	2.22	0.87
Rio_7	14	0.76	2.01	0.79
SJAC_1	27	0.80	2.63	0.89
Average	20.6	0.77	2.312	0.85

Surface	S	E	H	D`
AC	23	0.76	2.39	0.86
BC	27	0.85	2.79	0.91
FP	50	0.76	2.98	0.92
T1	81	0.76	3.36	0.94
T2	35	0.88	3.11	0.93
Average	43.2	0.80	2.93	0.91

Table 5. Plant genus list with individual counts, relative %, and cumulative % occurrence for each point intercept instance.

Genus	Count	%	Additive %
Salix	629	25.4%	25%
Carex	392	15.8%	41%
Bromus	145	5.9%	47%
Achillea	137	5.5%	53%
Bryophyte	108	4.4%	57%
Taraxacum	101	4.1%	61%
Populus	97	3.9%	65%
Oreochrysum	92	3.7%	69%
Potentilla	91	3.7%	72%
Fragaria	78	3.1%	75%
Trifolium	52	2.1%	78%
Shepardia	36	1.5%	79%
Astragalus	35	1.4%	80%
Equisetum	29	1.2%	82%
Rosa	26	1.0%	83%
Juniperus	21	0.8%	84%
Melilotus	21	0.8%	84%
Picea	20	0.8%	85%
Acer	17	0.7%	86%
Betula	17	0.7%	87%
Veronica	17	0.7%	87%
Apocynum	16	0.6%	88%
Heterotheca	16	0.6%	89%
Oreoxis	16	0.6%	89%
Centaurea	15	0.6%	90%
Geranium	14	0.6%	90%
Pseudotsuga	13	0.5%	91%
Epilobium	11	0.4%	91%
Prunus	11	0.4%	92%
Sedum	11	0.4%	92%
Calamagrostis	11	0.4%	93%
Oxyria	11	0.4%	93%
Arnica	10	0.4%	94%
Clematis	10	0.4%	94%
Poa	9	0.4%	94%
Pinus	9	0.4%	95%
Rhus	9	0.4%	95%
Cornus	8	0.3%	95%
Medicago	8	0.3%	96%
Verbascum	8	0.3%	96%
Berberis	7	0.3%	96%

Genus	Count	%	Additive %
Leucanthemum	7	0.3%	97%
Ribes	7	0.3%	97%
UNK4	5	0.2%	97%
Agrostis	5	0.2%	97%
Caltha	5	0.2%	97%
Pedicularis	4	0.2%	98%
Aconitum	4	0.2%	98%
Juncus	4	0.2%	98%
Pascopyrum	4	0.2%	98%
Senecio	4	0.2%	98%
Critesion	3	0.1%	98%
Erigerion	3	0.1%	98%
Scirpus	3	0.1%	99%
UNK1	2	0.1%	99%
UNK3	2	0.1%	99%
UNK9	2	0.1%	99%
Alnus	2	0.1%	99%
Cercocarpus	2	0.1%	99%
Hippochaete	2	0.1%	99%
Pinus	2	0.1%	99%
Quercus	2	0.1%	99%
Rhamus	2	0.1%	99%
Sphaeralcea	2	0.1%	99%
Sporobolus	2	0.1%	99%
UNK8	1	0.0%	100%
Alyssum	1	0.0%	100%
Artemisia	1	0.0%	100%
Hordeum	1	0.0%	100%
Distegia	1	0.0%	100%
Distichlis	1	0.0%	100%
Glycyrrhiza	1	0.0%	100%
Ligularia	1	0.0%	100%
Lonicera	1	0.0%	100%
Mertensia	1	0.0%	100%
Ranunculus	1	0.0%	100%
Rubus	1	0.0%	100%
Stellaria	1	0.0%	100%
Total # counts	**2,477**		

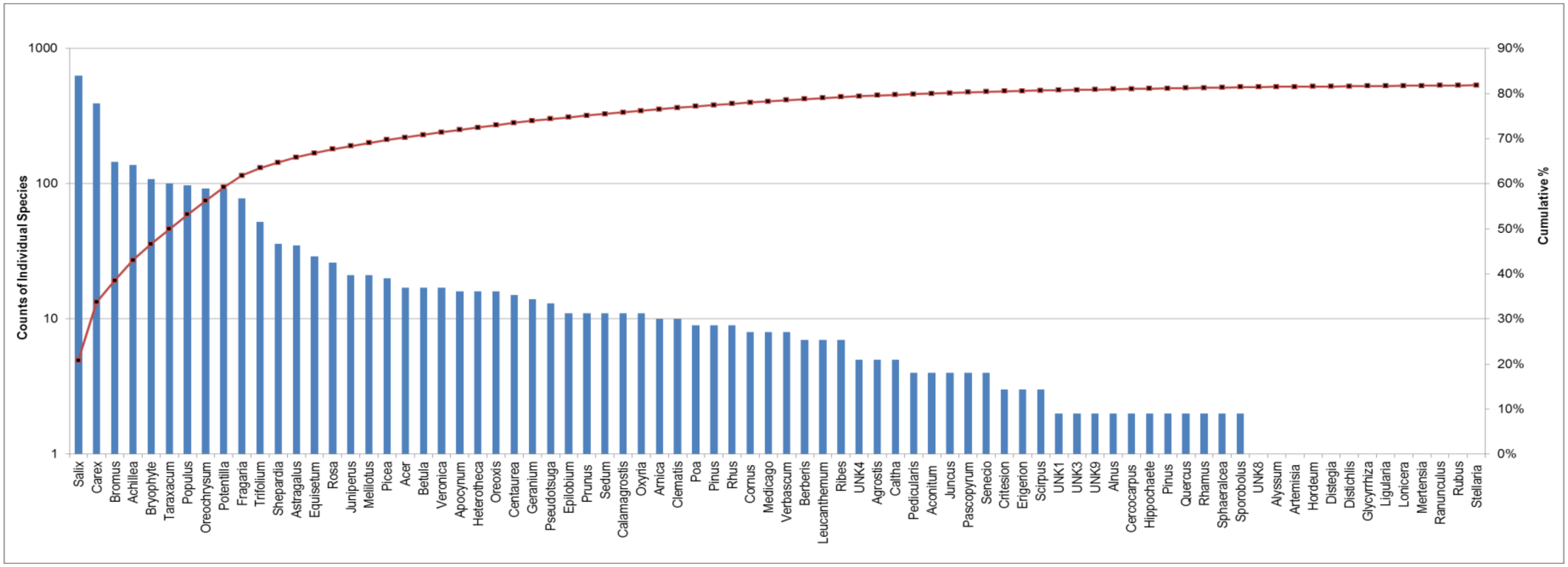


Figure 4. Point Intercept Genus Counts and Relative Percent (%) all sites

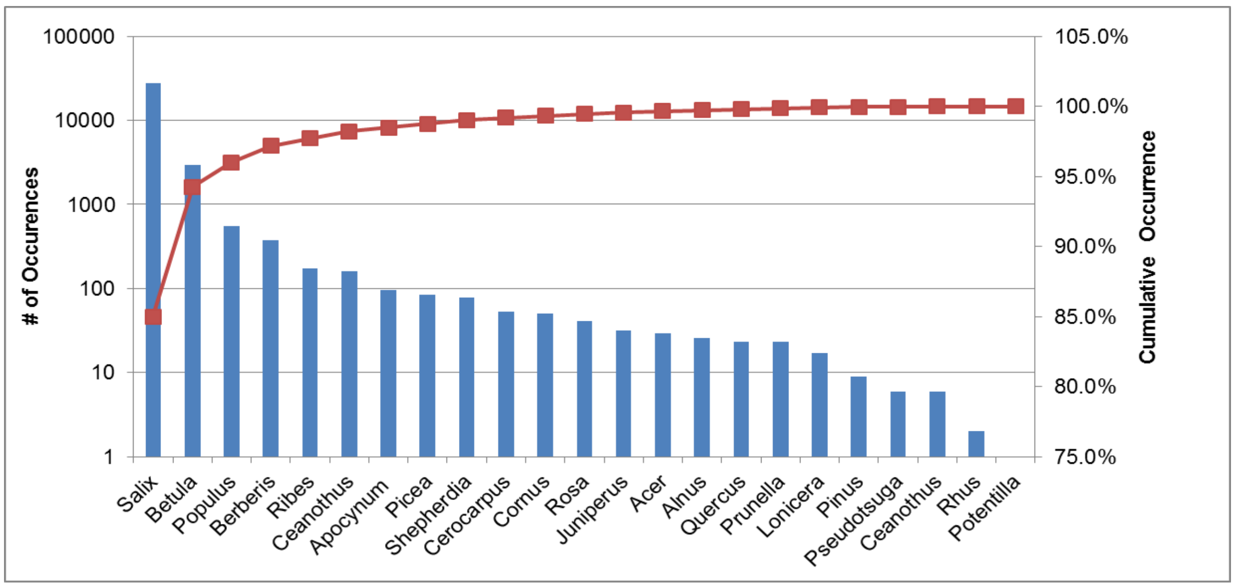


Figure 5. Belt Transect Genus Counts and Relative Percent (%) all sites

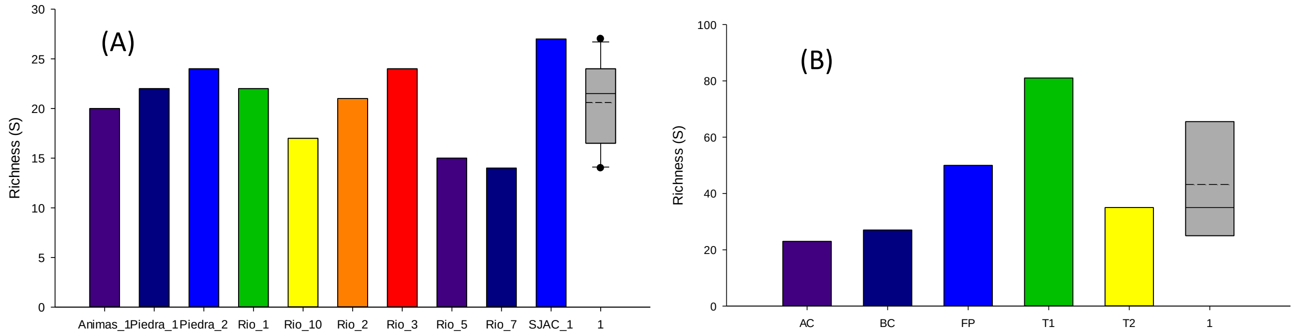


Figure 6. S = Richness = number of unique Genus found at each site (A) and each geomorphic surface (B), AC-Active Channel, BC-Back Channel, FP-Floodplain, T1 – Terrace 1, T2-Terrace 2.

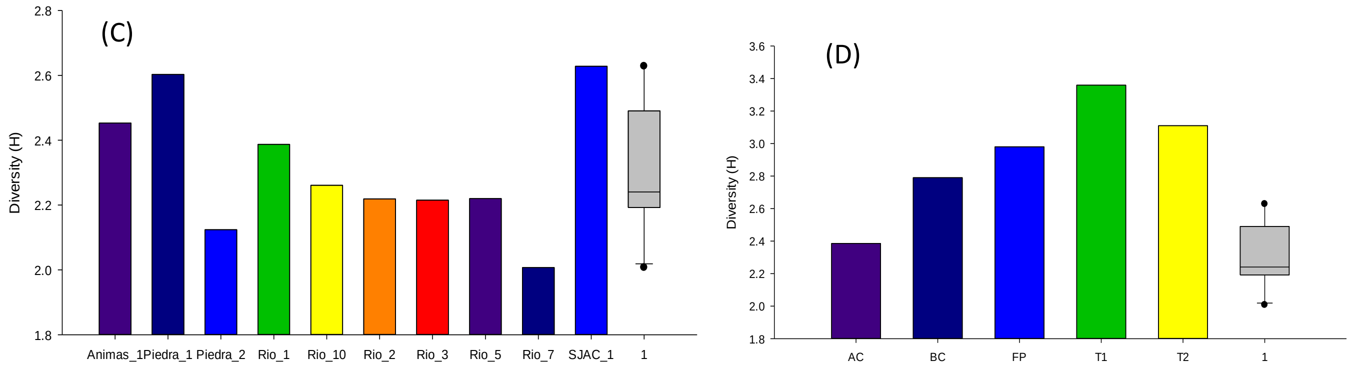


Figure 7. H = Diversity = - sum (Pi*ln(Pi)) = Shannon`s diversity index for each site (C) and each geomorphic surface (D)

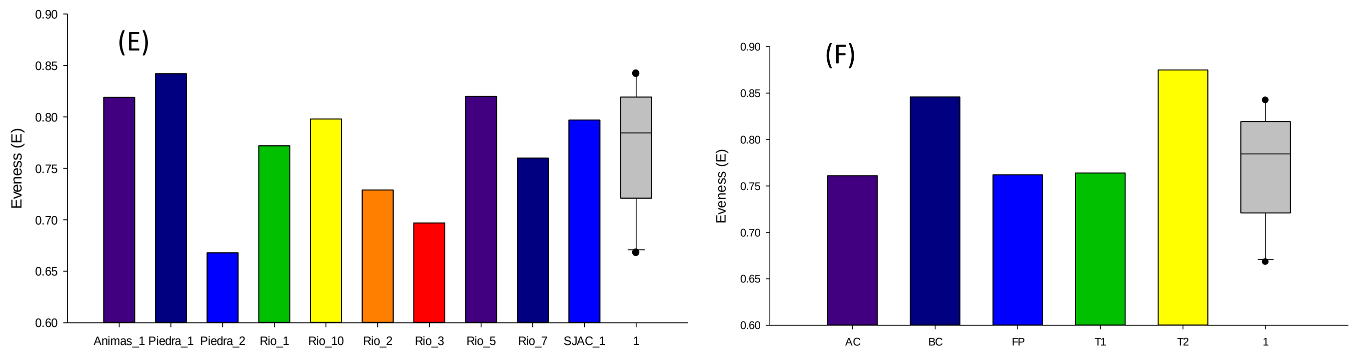


Figure 8. E = Evenness = H / ln (Richness) for each site (E) and each geomorphic surface (F)

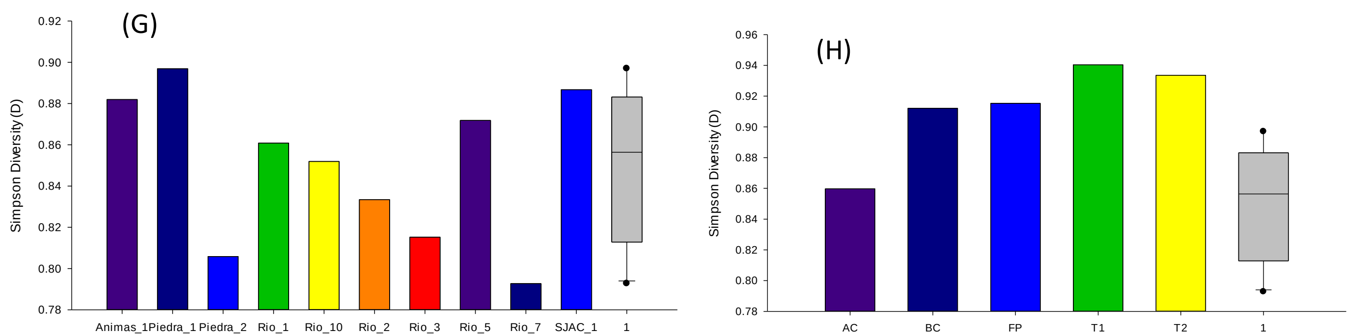


Figure 9. D = Simpson`s diversity index for infinite population = 1 - sum (Pi*Pi) for each site (G) and each geomorphic surface (H)

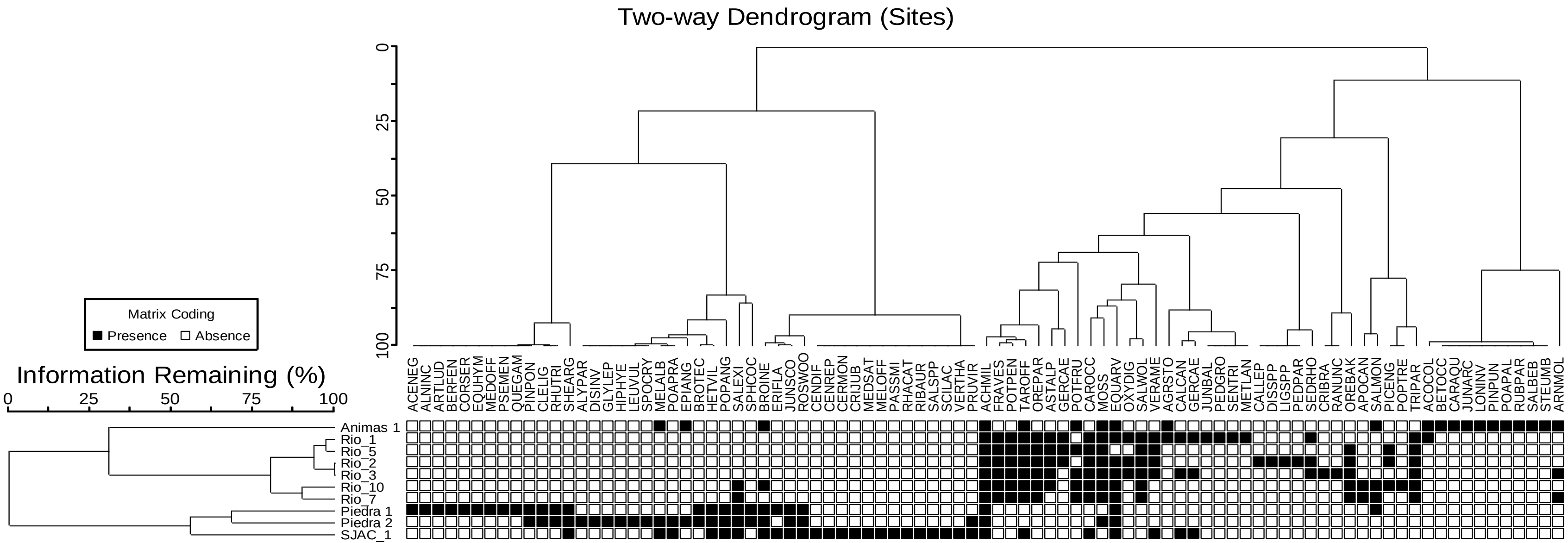


Figure 10. Two-way dendrograms split along species groupings for each site.

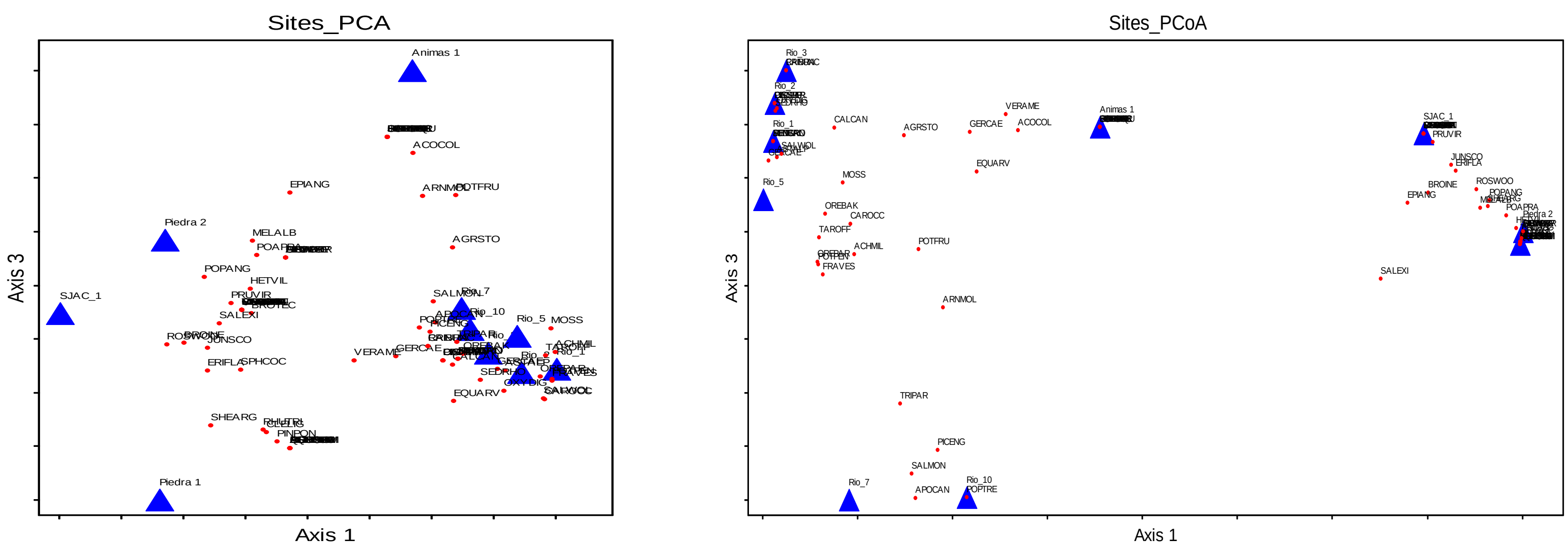


Figure 11. Principal Components Analysis (A) and Principal Coordinates Analysis with each site (blue) and species (red) listed

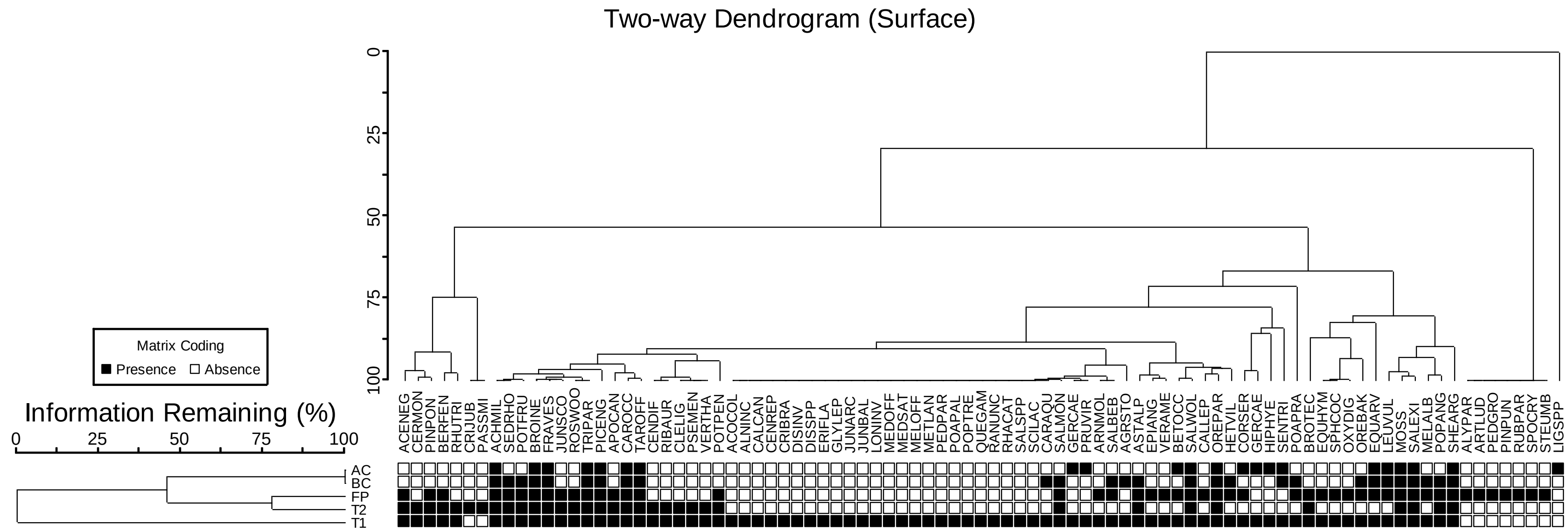


Figure 12. Two-way dendrograms split along species groupings for each surface.

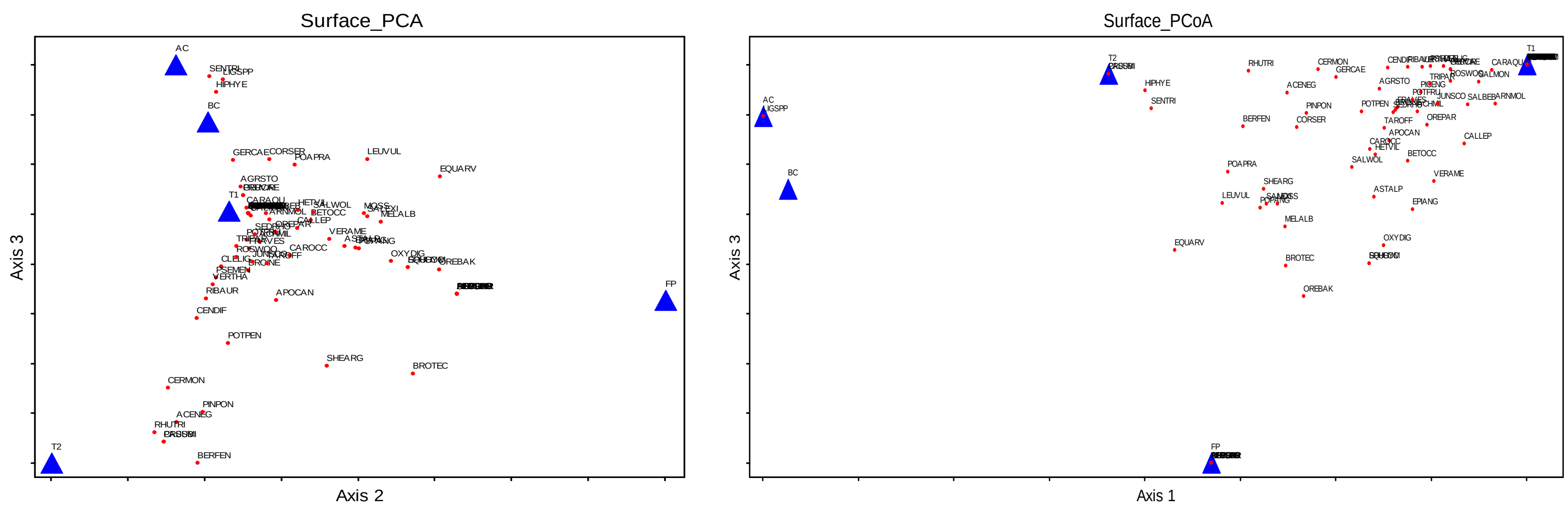


Figure 13. Principal Components Analysis (A) and Principal Coordinates Analysis with each surface (blue) and species (red) listed

Overstory and Shrub Data Summary

Overstory and shrub data were collected in 2 meter and 10 meter belt transect centered along the topographic transect lines. Data are summarized below and present the data from six of the sites as there were no overstory data for Rio_1, Rio_2, Rio_3, and Rio_7. Counts of individual stems are presented in **Table 6**, average DBH in **Table 7**, and average crown condition in **Table 8**. The most common species with DBH >10 cm were Narrowleaf cottonwood and Spruce. Four sites (**Table 8**) had species that were analyzed for crown condition.

Table 6. Counts of individual species found in the 10 meter belt and whose DBH was greater than 10 cm.

	ACENEG	CEASPP	JUNCOM	JUNSCO	PICPUN	PICSPP	PINPON	POPANG	PSEMEN	QUEGAM	SHEARG
Piedra 1	15		4				8	2	6	8	1
Piedra 2								29			1
SJAC_1		6		7				30			
Rio_5						5					
Rio_10						37					
Animas 1					1						
Total Counts	15	6	4	7	1	41	8	61	6	8	2

Table 7. Average DBH (cm) found in the 10 meter belt.

	ACENEG	CEASPP	JUNCOM	JUNSCO	PICPUN	PICSPP	PINPON	POPANG	PSEMEN	QUEGAM	SHEARG
Piedra 1	16.2		16.0				31.9	16.3	37.6	13.7	13.0
Piedra 2								14.2			10.0
SJAC_1		11.3		19.1				34.1			
Rio_5						23.6					
Rio_10						18.4					
Animas 1					14.0						

Table 8. Average crown condition by species for each site with trees that had a crown condition status.

	ACENEG	CEASPP	JUNCOM	JUNSCO	PICPUN	PINPON	POPANG	PSEMEN	QUEGAM	SHEARG
Piedra 1	100		100			100	100	100	100	100
Piedra 2							83			100
SJAC_1		96		64			78			
Animas 1					100					

Conclusions

Our original field crew included five people (1 botanist, 2 vegetation recorders, 2 conducting the transect topography and longitudinal survey). Ultimately we found that four field technicians were adequate to complete the survey as long as at least one person was familiar with plant identification.

Locating and installing transects typically was the most difficult task and took the longest time, and might not be practical for large riparian areas >100 meters, lots of line sag. We used surveyor's ropes (graduated in 0.1 m increments).

We also realized that it might be more efficient to collect each GPS point as the vegetation and transect topography data was being collected. Additionally, we found that if each site had a summary for field use that included:

a. Site map and directions/notes on access
b. Coordinates of transect end points and transect lengths
c. Species list with images of each species
d. Species composition from last sampling for each transect
e. Summary of species composition with most common species and rare species identified

One of the biggest questions we had regarding the application of the Protocol was to what extent was the consideration of new technologies to survey and map forested areas included in the conceptualization and final application of the methods.

The stated purpose of the Protocol is to "provide guidance on measuring riparian vegetation characteristics along wadeable stream channels and floodplains."

This objective from the Protocol text would often prompt our group to ask why are we measuring X, and I could usually explain that the reason for measuring channel topography (setting up transects, systematically measuring elevations, recording plant species, etc.) is to be able to understand and quantify the character and configuration of the geomorphic surfaces and the vegetation community and its condition. However the deeper question of why are we doing this, in this way, kept coming up. In other words, the group kept asking why would the Forest District Ranger, Hydrologist, Wildlife Specailist, Ecologist…need this information, and what would they do with it, and when.

The sampling team was primarily made up of young adults (<25) who all came with varying GIS and remote sensing experience, and all of them realized quickly that what we were doing was essentially a spatial data collection exercise, and, that the field data we were collecting could be overlaid on air photos or elevation models of the ground and vegetation surface. This realization lead to conversations about the information we were collecting and why, and how we were going about collecting it. Based on our groups perspective and recent university experience there was recurring discussions of how one might, and how people are, using active and passive digital sensors to record environmental conditions.

We made the assumption that data collection strategies for forested areas specifically (environmental/ecological data generally) are undergoing a rapid and fundamental shift from traditional methods where humans directly take more and more discrete and diverse information and catalog it in a way that served to help understand and classify the encountered environment to methods and techniques where the primary agents are machines. These machines use knowledge algorithms and spatial self-autonomy (ability to move freely in three dimensions for some period of time) become primary agents of data collection using sensor networks which enable the development of a model of the encountered environment with more sensible characteristics than humans using sight are able to perceive (physical and chemical).

I personally have worked for 7 years collecting forestry and hydrogeomorphic related data in habitats that range from desert intermittent streams to large rivers (Missouri) medium sized (Rio Grande), mountain streams, as well as various upland forest and grassland habitat types. I have experience with areal measurements of forest and understory composition using modified Whitaker plots and fixed radius circular plots, I have used plotless methods for forest composition (Point –centered quarter method). These methods were often used in conjunction with herbaceous understory measurements of species composition (community composition and dominance) and sometimes growth form.

From a practical, applied, and financial perspective all of these methods have different strengths, however they all have a common drawback. Most often a minimum of three (more typically 4) people were needed to complete a survey of 1-4 hectares (difficult conditions) to 5-10 hectares in (optimal conditions) in a single day (two sites). This is mostly due to the time it takes to set up a systematic survey in an area of dense vegetation, running water, rapidly varying topography and often other physical and environmental impediments to measuring (in a systematic fashion) the variables of interest.

Recently, more attention has been focused on using hyperspatial (<25 cm) multi-band imagery and LiDAR applications to map and monitor forest and riparian areas, with increasing numbers of these applications placed on unmanned aerial vehicle platforms. For example, papers by Dunford et al. (2009) examined the potentials and constraints for using UAVs to map riparian forests in France, and Wallace et al. (2012) evaluated using small UAVs with LiDAR and imagery collection as a forest measurement tool (**Figure 14**). And while the overall number of reviews using small UAV's for terrain and vegetation mapping ,the increasing commercial availability, durability, ease of use, and decreasing costs of UAVs' will most likely become an increasingly common method for acquiring environmental information: "Studies such as these suggest that through the combination of low-cost, high resolution data capture, UAV platforms are likely to be the next tool of choice for optimizing detailed small area surveys within forests." (Wallace et al. 2012).

Figure 14. Different UAV platforms for natural resource data acquisition

Below are a number of videos of UAV platforms (research and commercial) as well as listed in the references a number of papers that outline both the technology and its application forestry and riparian mapping. Furthermore, being that the evolution of UAV's is still in its formative stages, with relatively limited commercial options, it is expected that the future of using these platforms is unpredictable, though given the highly cost favorability of using UAV's to collect information relative to trained field technicians, the likelihood of these platforms being adopted by resource managers is high.

There are currently a number of obstacles to the introduction of these systems, including, and primarily due to the need for fundamental change in how natural resource information is collected and analyzed. The near future most likely will include systems that are primarily actively guided and managed. However, a number of platforms and research projects are listed below, particularly the USGS program, which whose contact is Leanne Hansen of the USGS Fort Science program in Fort Collins.

USGS Program using UAVs for natural resource management and monitoring
http://rmgsc.cr.usgs.gov/UAS/

UAV's to monitor river change on the Elwa River
http://rmgsc.cr.usgs.gov/UAS/BoRriverSedimentMonitoring.shtml

The Draganflyer X4 is an affordable, reliable unmanned aerial vehicle (UAV) that's been designed to carry wireless video and still cameras. Radio control allows for piloting the UAV remotely, and an advanced autopilot helps you fly. http://www.draganfly.com/uav-helicopter/draganflyer-x4/

The RQ-84Z AreoHawk The glider-style shape of the AreoHawk and its overpowered nature allow it to comfortably climb to safe operating altitude post takeoff in even the most adverse conditions.
http://www.hawkeyeuav.com/aerial-systems

Great description of how drones are being used and some of the potentials
https://www.youtube.com/watch?v=kwkxx84wXNo

World Wildlife Foundation Conservation Drones
http://conservationdrones.org/

University of Alaska Fairbanks using UAVs for wildlife monitoring
http://www.youtube.com/watch?v=LKDFw4Wsxao

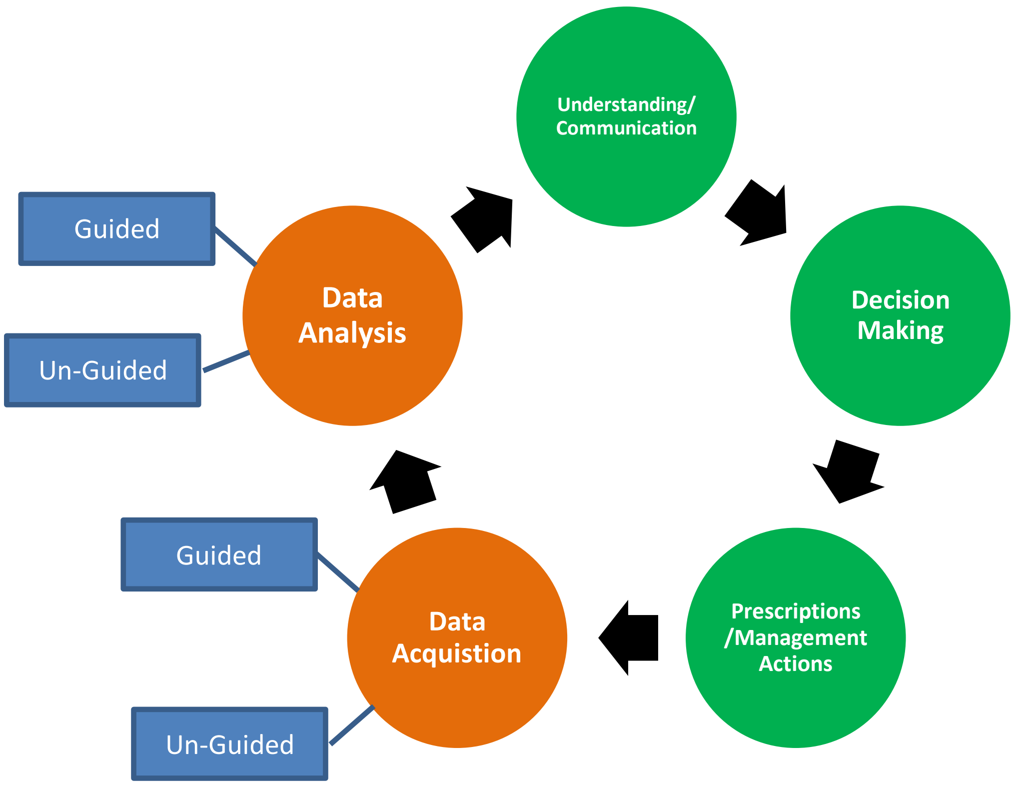
Swallow Systems – Skimmer UAV
https://www.youtube.com/watch?v=ijCFxul6LN8

Team BlackSheep – incredible UAV imagery of New York City and San Francisco
http://www.youtube.com/channel/UCAMZOHjmiInGYjOplGhU38g?sub_confirmation=1 – Main page
http://www.youtube.com/watch?v=M9cSxEqKQ78 - New York City
http://www.youtube.com/watch?v=7k_viLj3avE – San Francisco




Most likely the future of field ecosystem monitoring will look like the above, probably not below


Over the longer term, systems will be developed and deployed that will be able to “find” and “perch” at a site and passively monitor a range of physical and biogeochemical phenomenon. As these systems come on line a re-thinking about the human roll in the “loop” of data acquisition and analysis will be necessary. And consideration will most likely be needed to determine the optimum level of guided versus unguided data collection and analysis. As there will be trade-offs regarding the level of human direction needed to complete these tasks a re-evaluation of where financial resources can be applied may be needed.



Loop of decision making and responding, and monitoring environmental conditions, where and how to optimize human and machine interactions is an unknown quantity.

A note about costs

This project benefitted from using as a contractor, a non-profit, the Mountain Studies Institute (MSI). There are many benefits of using a non-profit as a contractor on projects, and include; relatively low overhead (25-30%), low administrative costs, and the ability to hire students and temporary workers as interns, providing these workers with "stipends" as opposed to salary.

For example, MSI summer interns are hired for a 10 week period beginning the first week of June and finishing by the second week of August (so students may return to college). For their ten week service interns are paid $2,000 and provided with a $750 living stipend. Most interns work between 35-55 hours a week, for an effective wage rate of $6.88/hour for a 40 hour work week (Federal minimum wage standard is $7.25/hour, Colorado $7.64/hour). Interns that worked on this project often worked in excess of 50 hours a week when travel and overnight stays are included. **Table 9** outlines the general staffing costs directly related to the Riparian project, and does not include the time spent advertising, hiring and training field crews, and in general are a very conservative estimate of the personnel costs directly related to the project. As the table below, along with the equipment costs indicate the total costs for a single year equal >$25,000, which exceeds the FS contribution. The ability of non-profits to use "cost-share" agreements where there is a financial match is a benefit that may only be available under limited circumstances. Most likely either the protocol will be conducted by FS personnel or for-profit contractors.

The ability of a non-profit being able to hire at intern/volunteer wages (i.e., below minimum wage standards), along with the ability to leverage funds from other projects and utilize non-profit discounts, (e.g., $100/year ESRI license vs. $5,000 for a for-profit license) is a benefit and will most likely become more so as Federal Agency budgets are re-evaluated. The ability to pay below market prices for equipment and labor would most likely be much different for a for-profit entity. For example, see Arizona project with estimated project costs for 25 sites at 70k, also compare with Federal wage rates, even at lowest Step ratings, the non-profit rate is ~4,000 less than the equivalent Federal estimated costs for personnel, this does not include the potential much higher overhead costs that both for profit entities and Federal entities would be paying for equipment, facilities, insurance, training, retirement, etc.

Personnel**	Cost/day ($)	# days	Total ($)
Project Manager (GS-9) (19.92 – 25.89)	200	40	8,000 (10,356)
Field Crew Leader (GS-7) (16.28 -24.42)	162	25	4,070 (6,105)
Vegetation Specialist (GS-9)	200	25	5,000 (6,472)
Field Tech 1 (GS-5) (13.14 – 19.75)	131	20	2,628 (3,950)
Field Tech 1 (GS-5)	131	20	2,628 (3,950)
Botanist Contractor (GS-12) (28.88 – 32.9)	289	3	867 (987)
Support (ED and Finance) (GS-12)	289	5	1,455 (1,645)
Total - Step 1 (Step 10)			24,648 (33,465)

**Based on GS wage structure - https://www.opm.gov/oca/12tables/pdf/gs_h.pdf and 25% Taxes and Benefits. GS rate range (Step 1 – Step 10), used low value (Step 1) for all calculations.

State of Arizona Geomorphic Assessment Announcement (from Procure.AZ):
The purpose of this Contract is to obtain assistance from qualified geomorphologists/ hydrologists in conducting stream stability surveys, analyzing geomorphic data and making recommendations as to the best indicators for physical integrity of stream channel assessment. The contractor shall collect stream survey data from approximately 25-30 stream sites across 4-5 Rosgen stream types (B, Bc, C, E, F), to supplement an existing dataset of 28 samples (some are a-priori defined as reference or stressed). Then contractor shall enter the data into a database, conduct analyses and produce a report with recommendations for physical integrity assessment methods for streams. The estimated value of this project is $70,000.

References

Here are a few of the selected refrences on the topic --- a folder with all pdfs is included.

Breckenridge, R.P., Dakins, M., Bunting, S., Harbour, J.L., Lee, R.D. 2012. Using Unmanned Helicopters to Assess Vegetation Cover in Sagebrush Steppe Ecosystems. Rangeland Ecology and Management, 65 362-370.

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Grenzdorffer, G.J., Engel, A., Teichert, B. 2012. The Photogrammetric Potential of Low-Cost UAVs in Forestry and Agriculture.

Horcher, A., Visser, R. 2012. Unmanned Aerial Vehicles: Applications for Natural Resource Management and Monitoring

Irschara, A., Kaufmann, V., Klopschitz, M., Bischof, H., Leberl, L. 2010. Towards Fully Automatic Photogrammetric Reconstruction Using Digital Images Taken from UAVS.

Lin, Y., Hyyppa, J., Jaakkola, A. 2011. Mini-UAV-Born LIDAR for Fine-Scale Mapping. IEEE Geoscience and Remote Sensing Letters, 8-3.

Niethammer, U., James, M.R., Rothmund, S., Travelletii, J., Joswig, M. 2012. UAV-based remote sensing of the Super-Sauze landslide: Evaluation and results. Engineering Geology, 128 2-11.

Wallace, L., Lucieer, A., Watson, C., Turner, D. 2012. Development of a UAV-LiDAR System with Application to Forestry Inventory. Remote Sensing, 4, 1519-1543.

Xiang, H., Tian, L. 2011. Development of a low-cost agricultural remote sensing system based on an autonomous unmanned aerial vehicle. Biosystems Engineering, 108, 174-190.

Site Location

Date:	Observers:
Site Name:	UTM: Coordinate System, Zone
Site Id (River_#):	UTM_1 (RR)
Active Channel Width (m):	UTM_1 (RL)
Reach Length (m):	UTM_2 (RR)
Site description and directions:	UTM_2 (RL)
	UTM_3 (RR)
	UTM_3 (RL)
	UTM_4 (RR)
	UTM_4 (RL)
	UTM_5 (RR)
	UTM_5 (RL)

Site map (plan)

Stream Profile (thalweg) from upstream transect (10 m interval)

Elevation (m)	
Distance (m)	
Elev (cont)	
Dist (cont)	

Transect 1.	
Dist_______	
Int_________	
HT Ins_____	
Surface	
Elev (m)	
Interval	
Transect 2.	
Dist.______	
Int_______	
HT Ins_____	
Surface	
Elev (m)	
Interval	
Transect 3.	
Dist.______	
Int_________	
HT Ins_____	
Surface	
Elev (m)	
Interval	
Transect 4.	
Dist.______	
Int_________	
HT Ins_____	
Surface	
Elev (m)	
Interval	
Transect 5.	
Dist.______	
Int_________	
HT Ins_____	
Surface	

Features: Terrace 1 – n (T_#), Floodplain 1 – n (FP_#), Channel Shelf (CF), Bank (B_RR, B_RL), Active Channel (AC), Island (IS), Bar (BAR)

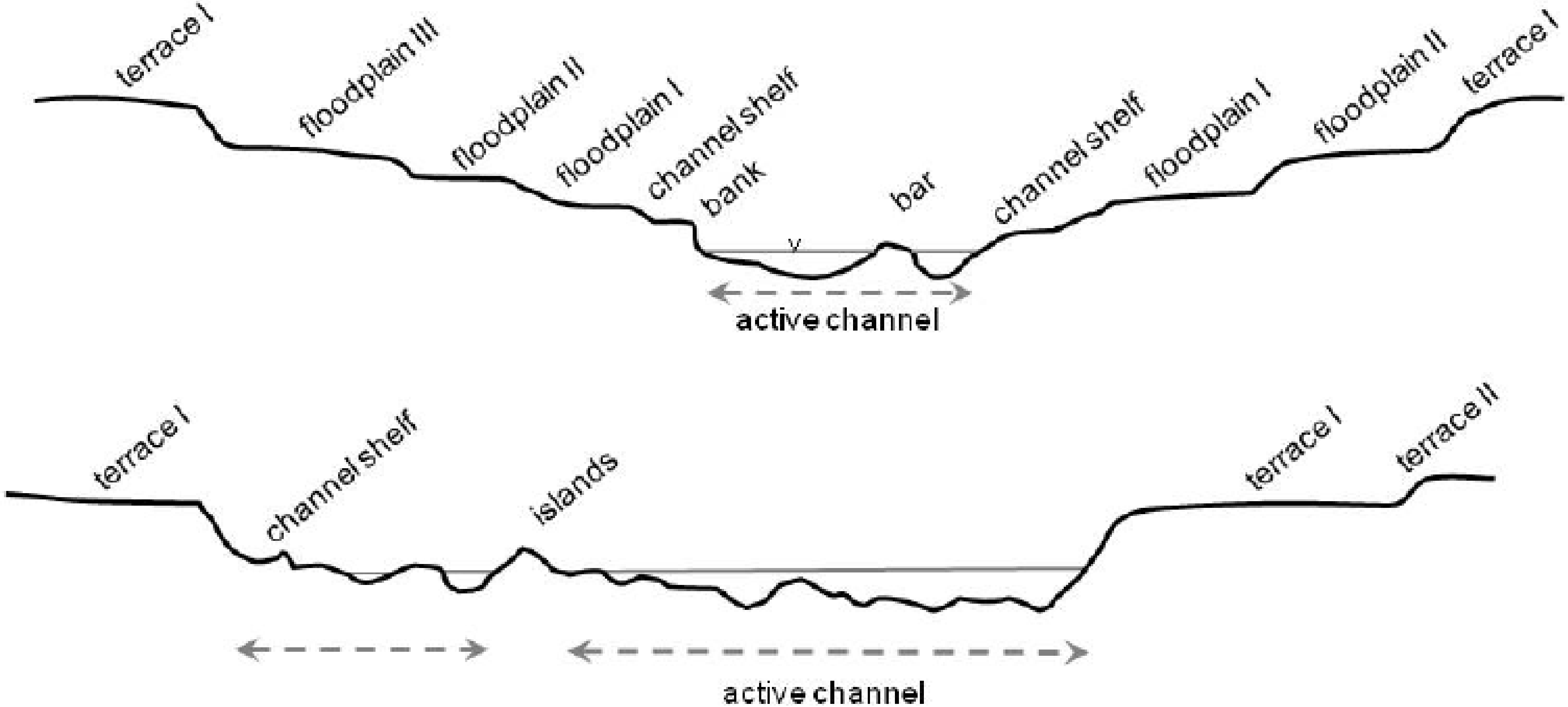

Figure 5. Idealized channel cross-sections showing active channel, islands and bars, channel shelf, floodplains, terraces and transitions. Meandering or straight stream in top frame; braided stream in lower frame. Islands are in channel features that are vegetated; bars are non-vegetated to partially vegetated and part of the active channel. Active channel in the lower frame –a braided channel– is the sum of the two principle active channels.

Riparian Vegetation
Data Sheet

Date: ______________________________ Azimuth: _________________________________
Observers ____________________________ Backsight: _______________________________
Site: ________________________________ Valley Centerline: __________________________
UTM: ________________________________ Active Channel Width: ______________________
Reach Type: ___________________________ Rip. Transect Width: _______________________

Name	Height	Point #	Name	Height	Point #	Name	Height	Point #

Page 1 of _