

ASSESSING RIPARIAN VEGETATION CONDITION

CHACO CULTURE NATIONAL HISTORIC PARK

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INTRODUCTION

Resource Management personnel at Chaco Culture National Historic Park (CHCU) have identified a critical need to characterize the current condition of vegetation in Chaco Wash, the major drainage that bisects the Park. Chaco Wash is approximately 20 km in length, supporting critical habitat for birds, reptiles, and mammals. Since the late 1800's the wash has cut a deep arroyo which may carry flowing water several months of the year. Steep arroyo walls, sometimes exceeding 7 meters, characterize the drainage. These changes have been, in part, due to livestock grazing in the canyon. Livestock were first introduced into the Chaco Canyon area of New Mexico in the last couple decades of the seventeenth century by Pueblo Indians fleeing from the Spanish onto Navajo lands. Navajo and Jicarilla Apache grazed their sheep, horses, and goats in the area for over a hundred years before Anglo cattle were introduced in 1878. Large-scale cattle and sheep operations began in 1878 or 1879 (Judd, park records, 1954). Grazing by unknown numbers of sheep, goats, and to a lesser degree, cattle continued in the area well into the twentieth century. Chaco Canyon National Monument was established in 1907, but did not affect grazing practices—in fact, the prehistoric ruins of the canyon were often used as sheep corrals. In 1933 Park Custodian Julien noted that lands in the monument were overgrazed, and that livestock should be excluded. It was noted in Monument records, by comparing current vegetation with historic records, that grasses and herbaceous forbs were degraded by the 1920's. Such degraded riparian vegetation may contribute to sequential degradation of stream channels (Belsky et al. 1999) such as has occurred in Chaco Canyon. In efforts to stem erosion, cottonwoods, willows, and tamarisk were planted from the 1930's to the 1950's. Today, between the steep arroyo walls, scattered stands of *Populus angustifolia* and hybrid *P. angustifolia* X *P. fremontii* (cottonwoods) persist among dense woody shrubs, including *Artemisia tridentata* (sagebrush), *Chrysothamnus nauseosus* (rabbitbrush), *Sarcobatus vermiculatus* (greasewood), and *Atriplex canescens* (saltbush). The understory consists of the native grasses *Hilaria jamesii*, *Oryzopsis hymenoides*, *Sporobolus aeroides* and *S. cryptandrus*.

The National Park Service began fencing the boundaries of the monument (8600 ha) in 1936, and completed the task in 1948 (NPS 1995, 1998). In 1980 the monument was expanded, becoming Chaco Culture National Historic Park. Fencing of the four new parcels (amounting to 5000 ha) has been completed from 1995 to the present. Consequently, Chaco currently is one of the largest grazing exclosures in western North America. There are 8600 ha that have been protected from grazing for 50+ years,

including the entire riparian area, and an additional 5000 ha that have been protected for 5 years or less, including upland sagebrush and piñon-juniper woodlands. The entire 13,600 ha exclosure is surrounded by lands that continue to be grazed by Navajo ranchers. Post-grazing trends differed among six habitats after 50 years of release from grazing: the two riparian sites either favored grasses or low shrubs (Floyd et al. in press). But grazing history is only part of the story of vegetative change in Chaco wash. Water table fluctuations are being studied concurrently by the USGS (Vincent, personal communication), and those data will be relevant to vegetation changes.

In 1974, Dr. Loren Potter and associates from University of New Mexico established line transects across the arroyo in order to characterize vegetation and set a baseline for monitoring vegetation change. Along these transects, they measured woody and herbaceous vegetation cover in 1 meter segments of the reach. These data augmented geomorphological studies carried out by Dr. Harold Malde. The vegetation data (Potter) and a photographic series (Potter and Malde) provide the basis for a comparative study of vegetation change that has occurred along Chaco Wash during the last 26 years. Malde's work provided the baseline for the current USGS study.

Background Information

Our initial reconnaissance suggested that two problems seemed to be occurring in cottonwood stands in CHCU—there appeared to be little recruitment into the population and the adults were experiencing canopy die-back. The stands appeared to consist of *Populus fremontii* and hybrids with *P. angustifolia*. Vegetation dynamics in riparian areas in northwestern New Mexico are not well understood, but inferences can be drawn from other areas of the southwest where *Populus angustifolia* and hybrids with *P. fremontii* occur. Hybridization between these two species creates hybrid swarms, such as seen in Chaco Wash, that exhibit similar fitness to parental populations, similar seed viability, and up to twice as many asexual ramets. It has been proposed that introgression of genes from *P. angustifolia* enhances asexual reproductive traits, while the genetic influx of *P. fremontii* genes promote traits that enhance seed viability (Schweitzer et al 2002). In some cases, hybrids of these two species are more susceptible to herbivory such as that of the poplar bud gall mite *Aceria parapopuli*. Hybrids supported low mite extinction rates and increased population growth rates (McIntyre and Whitham 2003), which in turn can affect the relative vigor of hybrid and parent cottonwoods. Hybrid zones, such as found in Chaco Wash, have important implications for supporting biodiversity at other trophic levels. For example *Chrysomela confluenta*, a beetle that feeds on *Populus*, is far more abundant and fecund

on hybrid trees than on parents; this means greater herbivory on hybrids, and this trend is exhibited in other arthropods as well (Floate et al. 1993). It has also been documented that avian nesting increases in cottonwood hybrids relative to parent populations (Martinsen and Whitham 1994). Thus the vigor of parents and hybrids in Chaco Wash, while of interest from the tree health standpoint, becomes more critical as we view hybrid zones such as occur in CHCU in light of their effects on evolution and biodiversity (Whitham et al 1999).

Inter-relationships among life forms in Wyoming may provide another relevant model for riparian dynamics in Chaco. There, a typical successional progression ranges from cottonwood (*Populus deltoides*) and sandbar willow (*Salix exigua*) seedlings in early seres, to cottonwood galleries accompanied by shrub understory (similar to that seen in Chaco today), giving way ultimately to grasslands (Boggs and Weaver 1992). Declining tree density gave way to dramatic increases in shrubs, and these transitions are in part due to successive declines in water availability. While small riparian trees in the Wasatch Mountains, Utah, use summer precipitation and stream water, large riparian trees do not, relying rather on subsurface groundwater (Flanagan et al. 1991). To assist resource managers in CHCU in understanding the status of the riparian vegetation of Chaco wash, this study addresses the following objectives.

Project Objectives

In 2001, the first year of this study, we addressed the following objectives:

1. Interpret vegetation changes since 1974 in riparian vegetation structure
2. Develop methods to describe the heterogeneity of dominant woody species across the range of stream channel environments
3. Develop methods to assess cottonwood population structure and health and perform a pilot study

In 2002, we built on these pilot studies and addressed the following:

4. Map the spatial extent of dominant tree and woody shrub populations along Chaco, Fajada, and Gallo Washes
5. Map locations for stands of the noxious invasive shrub *Tamarisk chinensis* (tamarisk, taxonomy according to Allred 2002) in Chaco Wash. This objective was prioritized in 2002 by resource management personnel (Jim Ramakka and Brad Shattuck, pers. Comm.)
6. Determine woody shrub community composition
7. Evaluate the health and reproductive status of *Populus* stands in Chaco Wash

In 2003, we completed the study by improving the mapping of the mixed shrub associations that occur within the inner arroyo. Additional remote sensing and field methods were brought to bear in an effort to better characterize the cover and distribution of shrubs. A final map was created depicting the current spatial distribution of plant communities in Chaco Wash.

METHODS

Vegetation Change- 1974-2001

We located transects B1, B2, B4, B7, B8, B9, and B10 originally established by Loren Potter in 1974 (Figure 1). Each transect had been marked by rebar on two ends and spanned the wash. A 100-meter tape was stretched between the rebar ends, and the beginning and end-points of each woody plant encountered by the line was recorded. Stream channel geomorphology was defined by the "General Cross Section Profile of Chaco Wash", established by CHCU Resource Manager Paul Whitefield (Appendix A). For each 1 meter transect segment, a stream channel environment was assigned. Cover data were summed by species for each transect.

In addition, we added two field sampling techniques not previously used by Potter. At right angles to each line transect, we established a series of 20 m transects, one in each of the dominant "stream environments". The cover of woody vegetation was recorded, as above, along these transects. A point-frame was placed at 5 m intervals, and the relative frequency of grasses, forbs, shrubs, dung, and bare soil were recorded (Mueller-Dombois and Ellenburg 2002).

Data were stored in Excel spreadsheets and analyzed in SPSS statistical package. It is difficult to perform meaningful statistics on the repeat data because each transect was characterized by the cover of each plant species, and there was only one transect per sampling point (i.e. there is no within site variation in the sampling design originated by Potter). Therefore, we simply calculated the total cover of each woody species and compared each transect during the 1974-2001 period in a qualitative manner.

Mapping of Riparian Vegetation in Chaco and Fajada Washes

Satellite Imagery:

In April, 2002, the Park obtained a set of IKONOS satellite imagery from Space Imaging Corporation, Thornton, Colorado. These included a pan-chromatic image and

a multi-spectral image set, orthorectified from the vendor with an accuracy reported as 4.1m CE90 and meeting National Map Accuracy Standards (NMAS) of 1:4800 (Space Imaging, 2003). Images were acquired on 11 August, 2001. The spectral ranges of each band are presented in Table 1. All images were provided to the Park as Geotiff images referenced to the Universal Transverse Mercator map projection, zone 12N, NAD27.

Table 1. Spectral characteristics of IKONOS imagery used I this study as reported by Space Imaging (2003).

Band	Spectral Range (nm)	Color
B&W	0.45-.90	Pan
1	445-516	Blue
2	506-595	Green
3	632-698	Red
4	757-853	NIR

Initial mapping:

Because this study focused on the vegetation found within the deeply incised arroyo in Chaco wash, it was important to develop an accurate map of the boundaries of the arroyo. This would provide a frame of reference for the remaining field work and image processing procedures. The arroyo edges were visually interpreted from the IKONOS imagery and digitized on-screen. This preliminary map was then adjusted through field verification as the study progressed

False-color composite images were created to facilitate visual interpretation of the vegetation within the arroyo of chaco wash. The 432 (RGB) false-color composite proved to be most useful in delineating probable *Populus* stands as well as tamarisk, willow, and mixed woody shrub communities. Field maps were generated for the entire wash for 1km increments corresponding with the reaches defined for sampling purposes (see below). These maps were printed at an approximate scale of 1:5000 (Figure 2). In order to map the overstory vegetation (i.e. *Populus*, *Tamarix*, and *Salix*) stands, we walked the entire length of Chaco Wash with Trimble Geoexplorer 3 GPS units. The dominant overstory vegetation was field verified by comparing the false color composite imagery to the actual stands of vegetation in the wash. A polygon for each stand was drawn on the field map and labeled. From these field maps, a digital map was generated through "heads-up" digitizing of the polygons. Small polygons were

mapped directly with the GPS and combined with the digitized map. Throughout the field seasons individual plant species of note were located using the GPS. This field-based map then formed the basis for further sampling of the riparian shrub associations. For sampling convenience, Chaco Wash was broken into 1-km long strata called "reaches". There are 23 reaches within the park. They are labeled 1 through 2 from the upper end of the wash to the lower end (See figure 3). In addition, the arroyo polygon described above was subdivided into these reaches for future use.

Multi-spectral classifications:

Field mapping provided an accurate base map of the dominant overstory species growing within the wash. These stands are found growing within a matrix of mixed shrubs consisting of *Chrysothamnus nauseosus*, *Chrysothamnus viscidiflorus*, *Artemisia tridentata*, *Atriplex canescens*, *Sarcobatus vermiculatus* and others. We used a combination of unsupervised and supervised classifications of the IKONOS imagery to map the distribution of these species. All image processing procedures were implemented using IDRISI for Windows v.2.0 GIS software. Using the arroyo boundary polygon and the field mapped overstory species, the 4m IKONOS imagery was masked to show only the areas of mixed shrub communities within the arroyo. Due to the aridity of the region, we created a transformed soil adjusted vegetation index (TSAVI) to use in this classification (Eastman, 1997, Baret et.al., 1989). This input to the classification helped adjust for the significant soil reflectance signals in Chaco canyon. The classification was run using the TSAVI image and bands 1,3, and 4 of the IKONOS set using an iterative isocluster algorithm as implemented in Idrisi. This classification produced 5 clusters, one of which was the obvious masked area outside of the arroyo. The remaining 4 clusters were used to guide field sampling in January, 2003.

Sixty field relevés (Figure 4a) were sampled in January, 2003 in order to define vegetative categories to the matrix of shrubs within the arroyo. This included approximately 15 samples in each of the 4 spectral classes defined in the unsupervised classification. Each relevé consisted of a 10m x 10m plot within which all species were recorded and assigned a value using the Braun-Blanquet scale of cover and abundance (Mueller-Dombois and Ellenburg, 2002). These data were analyzed using a multi-variate cluster analysis (SPSS statistical package) and resulted in 4 vegetative associations. Training sites for these four vegetation classes were defined using GPS and by digitizing onscreen from visual interpretation of the imagery. A supervised classification was then run using these training classes and the 4 spectral bands of IKONOS imagery. This produced a map showing the distribution of the shrub associations within the arroyo.

In May of 2003, 120 additional field releve plots (Figure 4b) were established using the procedure described above. These releves were assigned to one of the 4 vegetation classes and used for an accuracy assessment of the vegetation map resulting from the supervised classification. A cross-tabulation analysis was performed to test the accuracy of the classification. The spatial results of the shrub mapping and the overstory mapping procedures were merged in the GIS to create the final map of vegetative cover within the inner arroyo of Chaco Wash.

Size structure of *Populus* stands

In 7 of the 20 1-km reaches, we numbered the *Populus* polygons. We drew random numbers to select the stands to be surveyed. We sampled roughly 5 *Populus* stands per reach, but increased the sample size if the reach was characterized by heterogeneous stands, or decreased it if the reach was particularly homogenous. We set a point at one end of the stand, and ran a transect parallel to the wash, establishing 10 X 10m plots on either side of the transect. The number of plots depended on the heterogeneity of the site—we continued to add plots until additional data did not alter the pattern of seedlings, saplings, and adult trees (in other words, we had reached a point of diminishing returns in the sampling). At each transect we designated the channel environment and recorded the distance to stream channel, as well as the slope and soil characteristics (texture).

For each tree encountered, the following data were recorded:

- species was recorded for each individual—*Populus angustifolia* or hybrids with *P. fremontii*
- basal diameter
- vigor was estimated using an ordinal scale

Value	% live crown
0	Dead
1	< 25
2	26-50
3	50-75
4	75=100

Woody shrub vegetation assessment

Using the map created with IKONOS imagery and field reconnaissance, zones of woody shrub cover were identified. Cover of shrubs was compared across the various channel environments (Appendix A). In each of the 7 sampled reaches, we randomly established between 3 and 8 points, the number depending on the heterogeneity of the shrubland. At each point, the channel environment was recorded and a 25m line intercept transect was established parallel to the wash to evaluate cover of each shrub species.

To further distinguish the shrub communities and attempt to classify differences in floristics and structures, in 2003 we sampled approximately 160 points and

established releve plots in which a semi-quantitative scale of cover/abundance was assigned to each shrub species (Mueller-Dombois and Ellenburg 2002). These floristic and cover data augmented the woody vegetation cover data gathered in line transects during the previous year, and helped clarify the spatial patterns of shrub vegetation in the arroyo bottom. These are the same samples used in the multi-spectral classification procedures described above.

RESULTS

Vegetation Change- 1974-2001

Table 2 provides summaries of woody cover along the Potter transects. Locations of the Potter points are permanently recorded with GPS (Figure 1).

Changes in woody plant cover: The total cover of each woody species was compared between 1974 (Potter data) and 2001 (Table 2). Potter data were not available for B1. Transect B2 was characterized by a 6-fold increase in woody cover; there was more *Sarcobatus vermiculatus* (greasewood) than in 1974, and both *Chrysothamnus nauseosus* (rabbitbrush) and *Artemisia tridentata* (sagebrush) have become dominant in this area after 1974.

At transect B4, there was a 3-fold decline in woody cover during the last 26 years; *Chrysothamnus viscidiflorus* and *C. nauseosus* dropped in cover and *Atriplex canescens* (saltbush) became established. *Artemisia dracunculus* also increased.

Transect B7 was characterized by a doubling of woody species since 1974; while the cover of greasewood did not change, saltbush and *Artemisia dracunculus* increased, and both *Chrysothamnus* species declined.

An opposite trend characterized B8, where woody species declined overall to about half the cover present in 1974. Remarkably, both *Chrysothamnus* species had identical cover to the values measured in 1974. The site declined in sagebrush and greasewood, and willows are no longer present.

B9 demonstrated a 4-fold decline in woody species; it is significant that *Populus* was represented in 1974 but was absent in 2001. Greasewood and saltbush dropped in cover, and both *Chrysothamnus* species were gone.

At B10, like B8, woody vegetation declined by one-half. Saltbush remained at the same cover, but sagebrush increased. Greasewood declined sharply. Willows were dominant in 1974 and are no longer present at this site.

Table 2. Cover of woody species, as measured by line intercept sampling. Data were collected in 1974 by Loren Potter and colleagues, and repeated in 2001.

Transect	Woody Species	1974 Cover (cm)	2001 Cover (cm)
B2	<i>Atriplex confertifolia</i>	50	0
	<i>Chrysothamnus nauseosus</i>	0	241
	<i>Sarcobatus vermiculatus</i>	43	231
B4	<i>Atriplex canescens</i>	0	64
	<i>Artemisia dracunculus</i>	48	220
	<i>Chrysothamnus nauseosus</i>	1129	211
	<i>C. viscidiflorus</i>	561	0
	<i>Sarcobatus vermiculatus</i>	701	316
B7	<i>Atriplex canescens</i>	0	157
	<i>Artemisia dracunculus</i>	0	42
	<i>Chrysothamnus nauseosus</i>	362	0
	<i>Sarcobatus vermiculatus</i>	475	663
B8	<i>Artemisia nova</i>	136	0
	<i>Chrysothamnus nauseosus</i>	182	182
	<i>C. viscidiflorus</i>	438	438
	<i>Salix exigua</i>	200	0
	<i>Sarcobatus vermiculatus</i>	116	0
B9	<i>Atriplex canescens</i>	415	74
	<i>Artemisia tridentata</i>	0	85
	<i>Chrysothamnus nauseosus</i>	192	0
	<i>C. viscidiflorus</i>	149	0
	<i>Populus fremontii</i>	305	0
	<i>Sarcobatus vermiculatus</i>	406	183
B10	<i>Atriplex canescens</i>	156	164
	<i>Artemisia tridentata</i>	0	515
	<i>Artemisia dracunculus</i>	0	121
	<i>Chrysothamnus nauseosus</i>	365	401
	<i>C. viscidiflorus</i>	187	0
	<i>Salix exigua</i>	809	0
	<i>Sarcobatus vermiculatus</i>	298	9
	<i>Tamarix pentandra</i>	68	0

Changes in grass cover: It is possible to compare, in general, the percent cover of grasses in 1974 and 2001, although they were collected in different ways (Potter included grasses in the line intercept, and in the current study, we used the point frame and separated native and non-native invasive species). Despite these differences, we are confident that grass cover increased at B2, B4, B7 and B9, and declined at B8 and B10 (Table 3).

Table 3. The cover of grasses at 6 sample transects, Chaco Canyon. The cover in 1974 represents one value, taken from the line intercept sampling described in Potter, 1974. The 2001 values represents the average of n=12 sample points per transect.

Transect	1974 % cover	2001 ave. % cover
		native species, non-native species
B2	0	8.5 ± 1.6, 2.5 ± 1.5
B4	0.7	19.1 ± 10.2, 0
B7	4.2	6.3 ± 2.8, 9.0 ± 3.2
B8	44.6	11.4 ± 3.2, 1.0 ± .7
B9	14.9	30.5 ± 8.9, 4.2 ± 2.5
B10	23.6	7.4 ± 1.9, 5.7 ± 2.1

Mapping of Riparian Vegetation in Chaco and Fajada Washes

Figure 3 provides an overview of Chaco Wash and the 23 "reaches" defined for the arroyo within Chaco wash. Multi-variate clustering of the releve data defined a total of 6 vegetation associations characterized by the dominant tree or shrub species. These include the following *Salix*, *Populus*, *Chrysothamnus*-grass, *Artemisia/Atriplex* – grass, *Tamarix*, and a bare soil class. Vegetation classes defined by a single genus were mapped as overstory species in the field and were noted as priority species by resource management personnel. Table 4 summarizes the area (ha) of each of these vegetation cover types. Across Chaco Wash, *Populus* stands occupy 10.46 hectares (4.8 % of the total area); *Salix* stands occupy 2.8 hectare (1% of the total area); mixed woody shrubs occupy 121 hectares (56% of the total area) and the invasive *Tamarix* occupies 12 hectares (6% of the total area). Figure 5 illustrates two section of the vegetation map near Pueblo Bonito and adjacent to Wijiji Ruin.

The results of the accuracy assessment of multi-spectral imagery classification for woody shrub mapping are presented with a cross-tabulation in Table 5. Although the general accuracies range in the 30 and 40 percentiles, it is felt that the map still provides a workable representation of the arroyo. The *Populus* class was not sampled in the field as part of this analysis as it was effectively mapped using the field techniques described above. The miss classifications in this category are a result of undifferential GPS navigation in the field. The accuracy assessment was focused on the mixed shrub groups where accuracies are highest and when combined (note the values in the red oval) the accuracy increases to 83%. It suggest that much of this discrepancy may be accounted for in the fact that the vegetation sampling plots represented ground sample distances 6.25 times larger than the ground sample distance of the imagery. Thus, it would be important to sample the woody shrub vegetation at a spatial scale comparable to that of the multi-spectral imagery used to

develop the map. Despite the 30-40% accuracies reported here, based on field observations, the authors feel that the map itself does give a effective portrayal of the spatial distribution of woody shrub associations and the spatial variation among them.

Table 4. Summary of the cover (hectares) of each vegetation cover type as mapped for Chaco wash arroyo.

Reach ID	Chrsythamnus	Artemisia	Bare Soil	Populus	Tamarix	Salix	Total
1	1.85	2.22	0.34		0.13	0.71	5.25
2	2.74	2.19	0.71	0.15	0.10	0.74	6.63
3	2.64	2.06	0.62	0.03	0.19	0.59	6.13
4	2.42	3.17	1.31	0.04	0.14	0.18	7.26
5	3.89	2.58	0.96	0.24	0.06	0.03	7.76
6	4.64	2.18	1.09	0.90	0.03		8.84
7	2.73	2.62	1.52	0.55	0.10		7.52
8	1.97	2.23	1.37	0.59	0.12	0.00	6.28
9	1.37	1.63	0.61	0.15	0.08		3.84
10	2.07	2.13	1.38	0.91	0.05	0.01	6.55
11	3.05	2.59	0.82	0.86	0.40		7.72
12	2.46	3.18	0.75	0.69	0.40		7.48
13	3.69	3.30	0.67	0.68	0.14		8.48
14	2.84	3.52	1.61	1.16	0.25		9.38
15	4.21	0.73	0.68	0.55	0.58		6.75
16	1.94	2.39	0.88	0.56	0.28	0.00	6.05
17	2.57	2.54	2.36	0.66	1.02	0.03	9.18
18	2.96	3.14	2.86	1.07	2.02	0.19	12.24
19	2.67	3.99	2.32	0.40	0.91	0.13	10.42
20	5.10	3.06	2.50	0.27	1.13	0.19	12.25
21	2.22	1.90	7.15		3.87		15.14
22	0.27	0.06	29.08				29.41
23	0.00		8.28				8.28
24	4.45	3.03	0.48		0.06		8.02
Total	64.75	56.44	70.35	10.46	12.06	2.80	216.86

Table 5. Cross-tabulation results

Mapped categories	Ground-truthed categories					
		Chryso-grass	Artemisia-grass	Bare Soil		Populus
	Chrsyo - grass	16	25	5	2	48
	Artemisia-grass	12	25	5	1	43
	Bare Soil	6	2	6	1	15
	Populus	1				1
	Tamarix	6	1			7
	Salix			2		2
	Total		41	53	18	4
% correct		39	47	33	0	

Woody shrub vegetation assessment

With field sampling we tested if clusters of shrub species might be related to the distance from the surface water and geomorphic position occupied in the wash. The woody populations are a mosaic of *Artemisia tridentata*, two species of *Chrysothamnus*, and *Sarcobatus vermiculatus* (Figure 8). A Two-Way Analysis of Variance was run to determine if the cover differed significantly among species and portions of the channel in which they were located (Table 6). There was no difference in the cover of shrubs across channel designations (partial $F=1.4$, $p>.05$) but there was a significant differences in cover across species (partial $F=3.3$, $p=.01$). *Artemisia tridentata* (big sagebrush) and *Chrysothamnus viscidiflorus* (rabbitbrush) were present across the wash (channel B-G); *Salix* species (willows) tend to cluster near the inner channel (channel H) and very likely requires surface water from the active channel. *Sarcobatus* tends to grow nearer the arroyo walls; it was frequently observed growing along the arroyo bank erosion fans (channel B). We obtained a quantitative measure of this trend upon completion of the vegetation map (Figure 5). There was a significant difference in the distance to the arroyo wall between releve plots with and without *Sarcobatus*. *Sarcobatus* plots had a mean distance to arroyo bank of 15.02 m while plots without *Sarcobatus* had a mean distance of 26.75 m ($T=5.9$, $p= 0.00$)

Size structure of *Populus* stands

Basal diameter was used to estimate the approximate time since cottonwoods have established themselves in Chaco Wash. While determination of ages from ring structures in the wood would be ideal, it is difficult to obtain increment cores from cottonwoods, which often have rotten heartwood. Also, because cottonwoods occur in an environment where water fluctuates considerably, ring counts are not reliably annual. The trees were planted between 1930 and 1950, so it is assumed that the largest (i.e. oldest) trees are approximately 60 years old. Growth of cottonwoods after this time is apparent in a series of repeat photographs taken by Harold Malde.

The stands also showed considerable variation in size structure across the 7 reaches sampled in 2002 (Figure 6). The mean diameter was significantly different among reaches ($F=132.9$, $p<.05$); post-hoc tests show, however, no significant difference in the mean diameters of reaches 2 and 3 that were located in the eastern portion of the Wash and within 3-4 m of the active channel.; both reaches supported hybrid cottonwoods with numerous saplings, most of which originated as vegetative sprouts from older trees. These reaches had older trees up to 50 cm diameters as well. In contrast to the vigorous re-sprouting in these eastern reaches there was virtually no regeneration in reach 7 and 13, where the majority of the *Populus fremontii* trees were between 10 and 35 cm diameters and a few older trees were 65 cm. The largest trees

were found at reach 10. Here trees of all size classes are represented in what appears to be a healthy sustainable population. Reach 10, 15 and 18 have broad distributions of size classes as well, with numerous re-sprouting saplings and trees in mid and larger size classes.

How are the *Populus* stands positioned relative to the channel environments (Appendix A)? Is there any evidence that reproduction or health of established individuals can be attributed to position in the wash? There is a significant difference in mean diameters of *Populus* between channel categories ($F=121.7$, $p<.05$); the greatest mean diameter (34 cm) is found in Channel "D", high floodplain terrace. The lowest mean diameter, suggestive of re-sprouting stands, occurred on Channel "B", arroyo bank erosion fans, and Channel "H", the inner channel slope. There is no statistical correlation in the size (diameter) of trees and distance to channel ($r=-.028$, $p>.05$). It is likely that large cottonwoods are accessing subsurface water and that distance to the channel is not relevant to the spatial distribution of older individuals; however, younger saplings access surface flow (Flanagan et al. 1992) so their success might be influenced by proximity to the active channel.

Cottonwoods in Chaco Wash are either broad-leaved *Populus fremontii*, or they show leaf characteristics that suggest hybridization of *Populus angustifolia* and *Populus fremontii*. While the taxa have not been confirmed, we observed that stands with intermediate and variable leaf shapes (hybrids) are the more vigorous re-sprouting stands. *Populus fremontii* trees, characterized by consistently broad leaves, did not display active vegetative reproduction in the reaches sampled in 2002.

How healthy are the *Populus* trees? A cursory look at the stands can be alarming; dead branches persist on most of the larger and many of the smaller trees. We developed a simple ordinal scale of crown health and applied it to each tree surveyed. Most of the stands have a mean vigor of 2 (25-50% live crown cover); only reach 18 in the far western portion of the wash had a significantly greater mean value of 3 (50-75%). As the trees get larger, their vigor class declines ($r=-.22$, $p<.05$). This supports our initial observations that the larger, presumably older, trees are suffering from canopy die-back while the younger trees and saplings are maintaining healthier crowns. An extremely weak (and therefore meaningless) positive correlation between the distance to the channel and vigor (see below) category ($r=.083$, $p<.05$) was detected. No relationship was detected between relative canopy die-back in parents or hybrid populations. However, hybrids appear to produce ramets by asexual cloning more vigorously than parents. As the adults are not dependent on surface flow, it is more likely that frost damage, insect infestation, and other extrinsic factors are affecting vigor. Studies occurring in tandem with this investigation by Kirk Vincent, USGS,

suggest that the ground water is stable after dropping to about 25 feet since around 1940 (perhaps due to acquisition by the riparian plants) and that indeed cottonwoods are accessing this ground water (Vincent, personal communication). Thus, it is unlikely that water availability significantly influences adult *Populus* vigor despite the drought that has prevailed over the area for the last 4 years. However, sapling trees utilize surface flow in other areas, and it is likely that if the drought continues, these younger trees may become affected by decreasing water availability.

Vegetation association distribution

We have outlined 12 hectares of the invasive *Tamarix chinensis* (Figure 5). This woody perennial forms dense stands throughout the wash. While tamarisk is clearly widespread, it is interesting to note that its expansion was not detected by re-visiting the Potter study locations from 1974. This suggests that while isolated permanent transects are valuable in detecting shifts in dominance of many species, they are not sufficient to detect widespread changes in native/non-native shrub composition. A more comprehensive picture of the distribution of all the shrubs is obtained from the GIS-based map (Figure 5). The percent cover of each vegetation class was calculated in each reach to assess changes in vegetation along the elevation gradient of the wash. A comparison of these results are presented in figure 7a,b. Cover of each major overstory species (*Populus*, *Tamarix* and *Salix*) are compared across the length of the arroyo (Figure 7a). Note that *Salix* is present both in the upper and lower reaches of the arroyo, but is virtually absent in the middle reaches. *Tamarix* shows a fairly steady increase in percent cover from the upper to the lower ends of the arroyo. A similar comparison of the two mixed shrub components that are dominated by *Artemisia* associations and those dominated by *Chrysothamnus* associations is presented in Figure 7b. It can be seen that there are no significant trends between these two associations along the elevation gradient of the wash.

DISCUSSION

Using high resolution IKONOS satellite imagery, we mapped the spatial extent of woody vegetation communities throughout Chaco, Gallo, and Fajada Washes. Today *Populus* stands occupy 10.46 hectares, or 4.8 % of the total area of Chaco Wash. *Salix* stands occupy 2.8 hectare or 1% of the total area, mixed woody shrubs occupy 121 hectares, or 56% of the total area and the invasive *Tamarix* occupies 12 hectares or 6% of Chaco Wash. Within the last 27 years, the riparian vegetation in 8 transects has changed considerably, however those trends are site-specific and generalizations are difficult to make. We predicted that grass cover would increase in the sandy riparian bottomland, especially since cattle and sheep grazing was removed excluded from these sites since 1940 and post-grazing recovery is underway. Grass cover increased at five of the six sites for which 1974 grass cover data were available, but in the widest expanses of wash near the junction of Clys Canyon and Chaco Canyon, grass cover decreased. We also noted considerable cover of non-native grasses, primarily *Bromus tectorum*, but because the 1974 study did not distinguish native and non-native grasses it is difficult to evaluate if this is a significant increase. However, it is more difficult to characterize changes in woody shrub populations in the wash during the last 27 years. In some areas, woody shrubs have gained dominance, e.g. *Artemisia* and *Atriplex* at one site, while at others they have declined, e.g. *Sarcobatus* at four sites. *Tamarix* was present at only one Potter transect in 1974, but it was absent at that site in 2001. These seemingly inconsistent data may reflect differences in the physical characteristics of the wash; the western portion becomes much wider and the profile (Appendix A) contains more varied habitats than in the eastern portion of the wash.

Tamarisk now occupies 6% of Chaco Wash and we have provided an accurate map of the current location of each stand. From numerous other studies it is known that tamarisk competes aggressively with native willows in inner channel habitats; we recommend that all of these tamarisk stands be evaluated for mitigative treatment by Resource Management.

We sampled 2065 *Populus* trees in 25 transects scattered among 7 reach strata. While two of the seven reaches exhibited recruitment of saplings we did not detect any recruitment by seed germination. Most of the vegetative recruitment was in hybrid stands (*Populus angustifolia* X *P. fremontii*). The populations characterized by larger trees (highest average diameters) were found on high floodplain terraces (Channel "D").

Our data suggests that the most abundant sapling re-sprouting occurred close to the inner channel (reaches 2 and 3) although this trend cannot be verified statistically. Dead limbs characterize the largest trees and crown die-back is common. Browsing of leaves, probably by elk, was evident throughout all size classes. Most of the trees, with the exception of those in reach 18—maintained only 25-50% crown cover. The cause of this die-back is unknown, but it may include insects, frost and possibly for the younger trees that access surface water, stress caused by the recent regional drought. The status of sub-surface water levels (accessed by large, established trees) is being investigated currently in Chaco Wash by the USGS; preliminary data suggest that the subsurface water level is stable at about 25 feet (Vincent personal communication). These data will no doubt contribute to our understanding of cottonwood decline. Future studies on cottonwood decline in CHCU might focus on the genetic structures of the hybrid and parent populations as they influences fecundity and health.

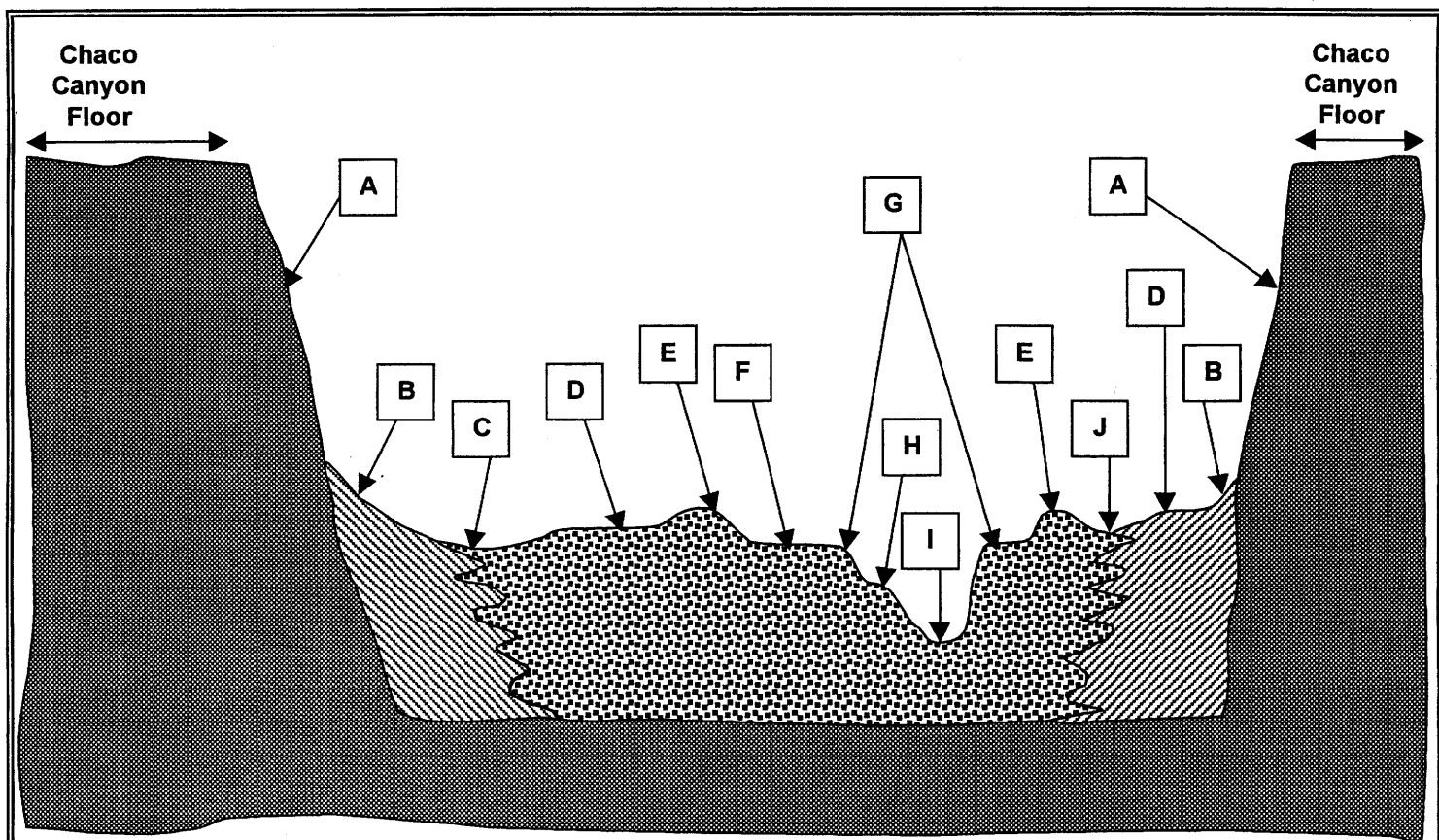
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Table 6. The average cover of woody shrub species sampled in randomly place locations. Chaco wash, Chaco Culture National Historic Park. Data were collected using line intercept sampling in 2003. See text for description of sampling design. N = sample size.

Reach	Species	mean cover +/- SE	N				
18	Chrys vis	.25 +/- 0	1	18	Artem trid	.8 +/- .27	4
	Artem drac	.16 +/- .04	7		Artem drac	.01 +/- .01	3
	Chrys vis	.75 +/- .25	5		Chrys nau	.5 +/- 0	1
	Artem trid	1.15 +/- .7	2		Artem trid	1.22 +/- .27	8
	Artem drac	.2 +/- 0	1		Chrys nau	.46 +/- 0	1
	Tama pent	.4 +/- 0	1	10	Atrip can	.59 +/- 0	1
	Chrys vis	.71 +/- 0	1		Artem trid	.76 +/- .23	2
	Artem drac	.12 +/- .03	7		Sarco verm	3.8 +/- 0	1
	Chrys vis	.08 +/- .04	3		Artem trid	.5 +/- .1	3
	Chrys vis	.94 +/- .23	7		Chrys nau	.39 +/- .22	4
	Chrys vis	.4 +/- .13	5		Atrip can	1.2 +/- 0	1
	Chrys vis	.18 +/- .03	11		Artem trid	.93 +/- .03	2
	Artem trid	.36 +/- .08	10		Artem drac	.25 +/- 0	1
	Sarco verm	.72 +/- .34	5		Chrys nau	.42 +/- .01	2
	Artem trid	.58 +/- .25	7		Artem trid	.71 +/- .18	14
	Sarco verm	.81 +/- .41	3		Chrys nau	.23 +/- .06	3
	Tama pent	.21 +/- 0	1		Chrys nau	.14 +/- .02	4
	Artem trid	.96 +/- .23	13	15	Chrys vis	.1 +/- .02	23
2	Chrys vis	.95 +/- .47	4		Artem drac	.18 +/- 0	1
	Artem trid	.25 +/- 0	1		Chrys vis	.23 +/- .06	12
	Chrys vis	.63 +/- .1	12		Artem trid	.37 +/- .25	5
	Artem trid	.9 +/- 0	1		Chrys vis	.13 +/- .02	4
	Chrys vis	.97 +/- .23	12		Atrip can	.26 +/- .12	5
	Salix exig	.37 +/- .17	2		Chrys vis	.28 +/- .13	9
	Atrip can	1.41 +/- .26	5		Salix exig	.15 +/- .03	2
	Artem trid	1.03 +/- .26	7		Chrys vis	.32 +/- .05	9
13	Artem trid	.31 +/- .08	15		Artem drac	.20 +/- 0	1
	Atrip can	.18 +/- .05	2		Chrys vis	.31 +/- .11	3
	Artem trid	.41 +/- .11	11		Artem drac	.33 +/- 0	1
	Chrys nau	.28 +/- 0	1		Chrys vis	.4 +/- .14	5
	Chrys vis	.16 +/- .06	5		Artem trid	.05 +/- 0	1
	Artem drac	.09 +/- 0	2		Artem drac	.09 +/- 0	1
	Chrys vis	.07 +/- 0	1		Chrys vis	.48 +/- 0	1
	Artem trid	.82 +/- .07	2		Artem trid	.36 +/- .03	2
	Artem drac	.2 +/- .07	3		Artem drac	.37 +/- .10	3
	Chrys nau	.22 +/- .17	2		Chrys vis	.37 +/- .28	2
	Artem trid	.94 +/- .24	6		Artem trid	.29 +/- .12	9
	Artem trid	.59 +/- .18	5		Sarco verm	.21 +/- 0	1
	Chrys nau	.24 +/- .18	3		Chrys vis	.51 +/- .12	11
	Artem trid	1.64 +/- .40	7		Atrip can	.34 +/- .16	4
	Atrip can	.34 +/- .03	2		Artem trid	.46 +/- .1	9
	Artem trid	.33 +/- .24	2		Artem drac	.14 +/- 0	1
	Atrip can	1.6 +/- 0	1		Chrys vis	.47 +/- .12	2
	Artem trid	.66 +/- .12	14		Artem trid	.55 +/- .06	12
	Chrys nau	.12 +/- .04	2		Tama pent	3.9 +/- 2.1	4
18	Atrip can	.47 +/- 0	1		Chrys vis	.41 +/- .12	6
					Atrip can	.01 +/- 0	1
					Sarco verm	.30 +/- .12	8
					Sarco verm	.66 +/- .10	28



Appendix B. **GENERAL CROSS SECTION PROFILE OF CHACO WASH**
(NOT TO SCALE)

LEGEND:

-  CHACO CANYON ALLUVIAL FILL (> 70 YEARS OLD)
-  CHACO WASH ARROYO BANK EROSION DEPOSITS (< 70 YEARS OLD)
-  CHACO WASH FLOODPLAIN DEPOSITS (< 70 YEARS OLD)

Common Stream Channel Environments:

- A Arroyo Wall
- B Arroyo Bank Erosion Fan
- C Broad Floodplain Swale
- D High Floodplain Terrace
- E Levee
- F Low Floodplain Terrace
- G Inner Channel Bank
- H Inner Channel Slope (sand bench also shown mid-slope)
- I Inner Channel Bottom
- J Narrow Floodplain Channel

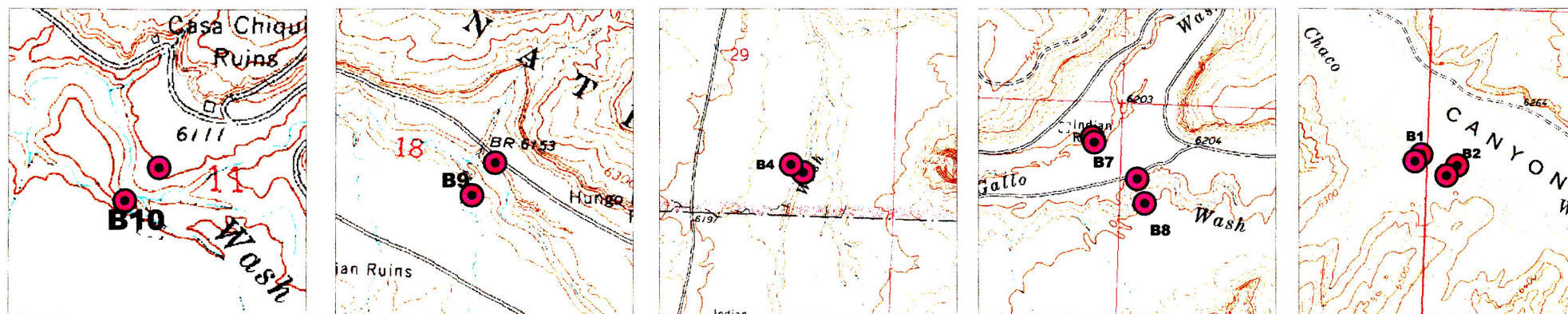
Figure 6. The average cover of woody shrub species sampled in randomly place locations. Chaco wash, Chaco Culture National Historic Park. Data were collected using line intercept sampling in 2003. See text for description of sampling design. N = sample size.

Reach	Species	mean cover +/- SE	N				
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	Artem drac	.16 +/- .04	7			Artem drac	.01 +/- .01 3
	Chrys vis	.75 +/- .25	5			Chrys nau	.5 +/- 0 1
	Artem trid	1.15 +/- .7	2			Artem trid	1.22 +/- .27 8
	Artem drac	.2 +/- 0	1			Chrys nau	.46 +/- 0 1
	Tama pent	.4 +/- 0	1		10	Atrip can	.59 +/- 0 1
	Chrys vis	.71 +/- 0	1			Artem trid	.76 +/- .23 2
	Artem drac	.12 +/- .03	7			Sarco verm	3.8 +/- 0 1
	Chrys vis	.08 +/- .04	3			Artem trid	.5 +/- .1 3
	Chrys vis	.94 +/- .23	7			Chrys nau	.39 +/- .22 4
	Chrys vis	.4 +/- .13	5			Atrip can	1.2 +/- 0 1
	Chrys vis	.18 +/- .03	11			Artem trid	.93 +/- .03 2
	Artem trid	.36 +/- .08	10			Artem drac	.25 +/- 0 1
	Sarco verm	.72 +/- .34	5			Chrys nau	.42 +/- .01 2
	Artem trid	.58 +/- .25	7			Artem trid	.71 +/- .18 14
	Sarco verm	.81 +/- .41	3			Chrys nau	.23 +/- .06 3
	Tama pent	.21 +/- 0	1			Chrys nau	.14 +/- .02 4
	Artem trid	.96 +/- .23	13		15	Chrys vis	.1 +/- .02 23
2	Chrys vis	.95 +/- .47	4			Artem drac	.18 +/- 0 1
	Artem trid	.25 +/- 0	1			Chrys vis	.23 +/- .06 12
	Chrys vis	.63 +/- .1	12			Artem trid	.37 +/- .25 5
	Artem trid	.9 +/- 0	1			Chrys vis	.13 +/- .02 4
	Chrys vis	.97 +/- .23	12			Atrip can	.26 +/- .12 5
	Salix exig	.37 +/- .17	2			Chrys vis	.28 +/- .13 9
	Atrip can	1.41 +/- .26	5			Salix exig	.15 +/- .03 2
	Artem trid	1.03 +/- .26	7			Chrys vis	.32 +/- .05 9
13	Artem trid	.31 +/- .08	15			Artem drac	.20 +/- 0 1
	Atrip can	.18 +/- .05	2			Chrys vis	.31 +/- .11 3
	Artem trid	.41 +/- .11	11			Artem drac	.33 +/- 0 1
	Chrys nau	.28 +/- 0	1			Chrys vis	.4 +/- .14 5
	Chrys vis	.16 +/- .06	5			Artem trid	.05 +/- 0 1
	Artem drac	.09 +/- 0	2			Artem drac	.09 +/- 0 1
	Chrys vis	.07 +/- 0	1			Chrys vis	.48 +/- 0 1
	Artem trid	.82 +/- .07	2			Artem trid	.36 +/- .03 2
	Artem drac	.2 +/- .07	3			Artem drac	.37 +/- .10 3
	Chrys nau	.22 +/- .17	2			Chrys vis	.37 +/- .28 2
	Artem trid	.94 +/- .24	6			Artem trid	.29 +/- .12 9
	Artem trid	.59 +/- .18	5			Sarco verm	.21 +/- 0 1
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	Artem trid	1.64 +/- .40	7			Atrip can	.34 +/- .16 4
	Atrip can	.34 +/- .03	2			Artem trid	.46 +/- .1 9
	Artem trid	.33 +/- .24	2			Artem drac	.14 +/- 0 1
	Atrip can	1.6 +/- 0	1			Chrys vis	.47 +/- .12 2
	Artem trid	.66 +/- .12	14			Artem trid	.55 +/- .06 12
	Chrys nau	.12 +/- .04	2			Tama pent	3.9 +/- 2.1 4
18	Atrip can	.47 +/- 0	1			Chrys vis	.41 +/- .12 6
						Atrip can	.01 +/- 0 1
						Sarco verm	.30 +/- .12 8
						Sarco verm	.66 +/- .10 28

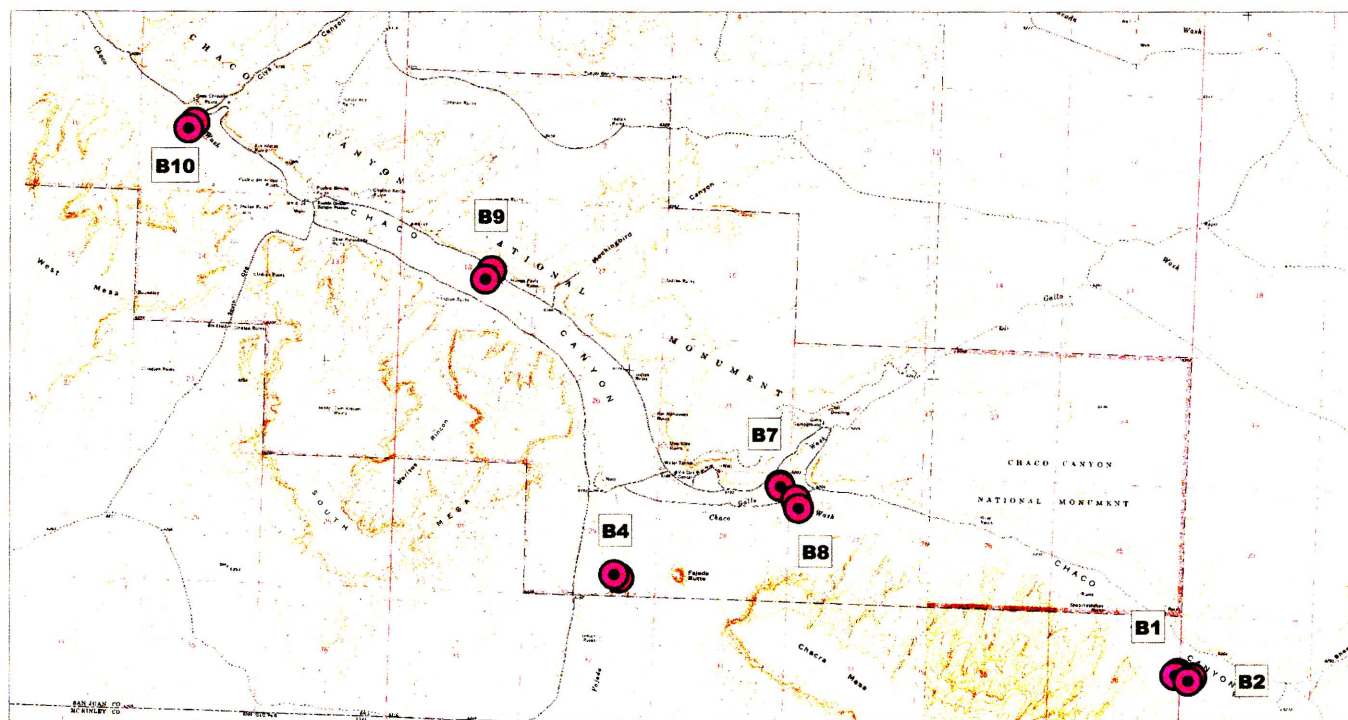
Figure 1.

27 Year Repeat Transect Locations

(Potter, 1974 - Hanna and Floyd-Hanna,2001)



Details of transect locations



Overview of locations within Chaco Canyon



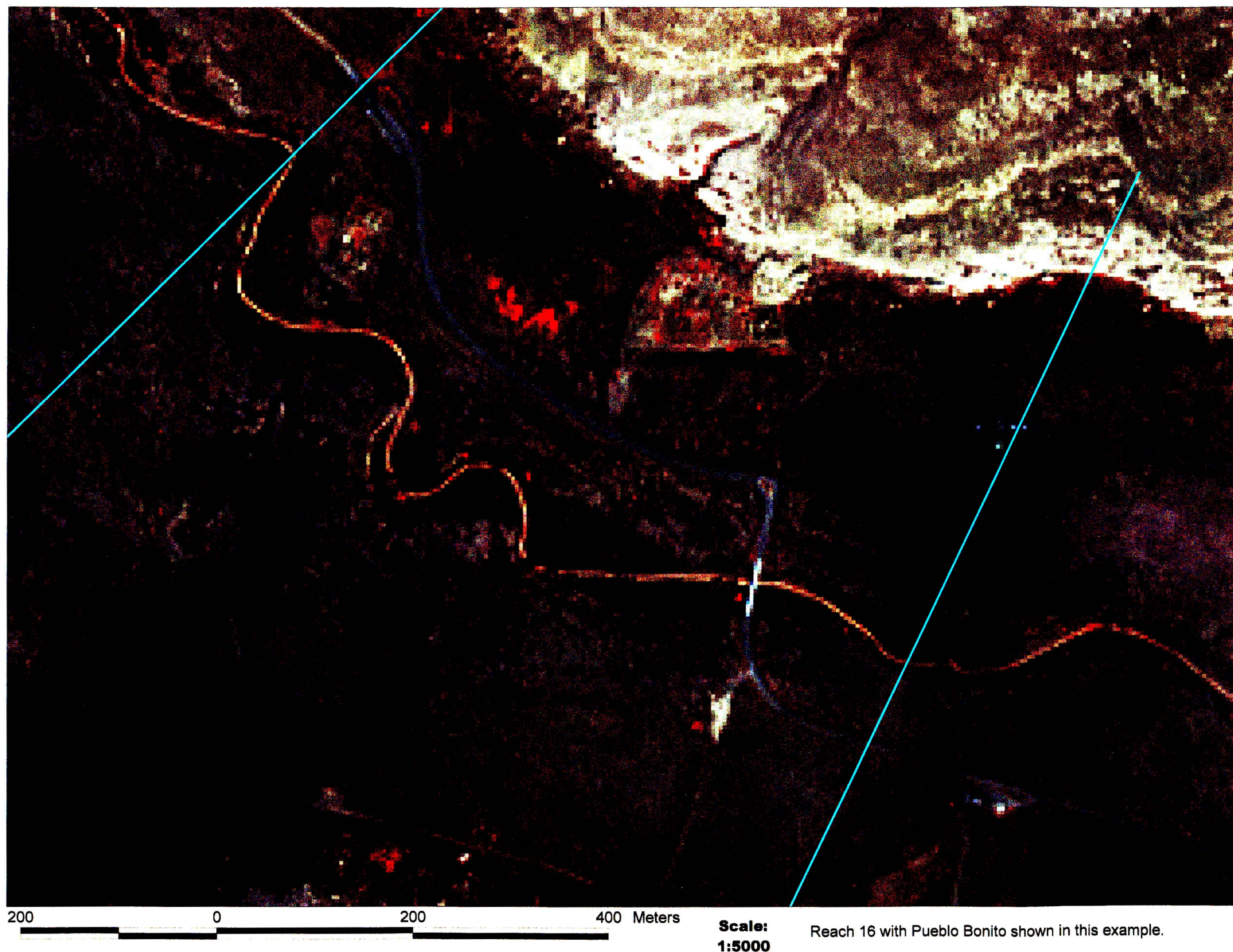
The line intercept transects sampled at these locations were initially sampled in 1974 by Loren Potter of the University of New Mexico. They were resampled as part of this study in 2001.

Id		Northing
B1	243946.075250252	3988501.38026579
B1	243978.136097889	3988534.89381318
B10	231860.404394665	3995364.99282740
B10	231780.241046929	3995287.79159205
B2	244102.489136363	3988431.48221198
B2	244153.844627347	3988480.18045256
B4	237026.639738514	3989758.9385835
B4	237087.933553533	3989719.94363303
B7	239084.940393122	3990852.20437112
B7	239076.945867478	3990873.37901744
B8	239272.556396963	3990691.22274680
B8	239305.420280596	3990584.40405998
B9	235515.488655170	3993529.64417513
B9	235439.973094391	3993422.95134566

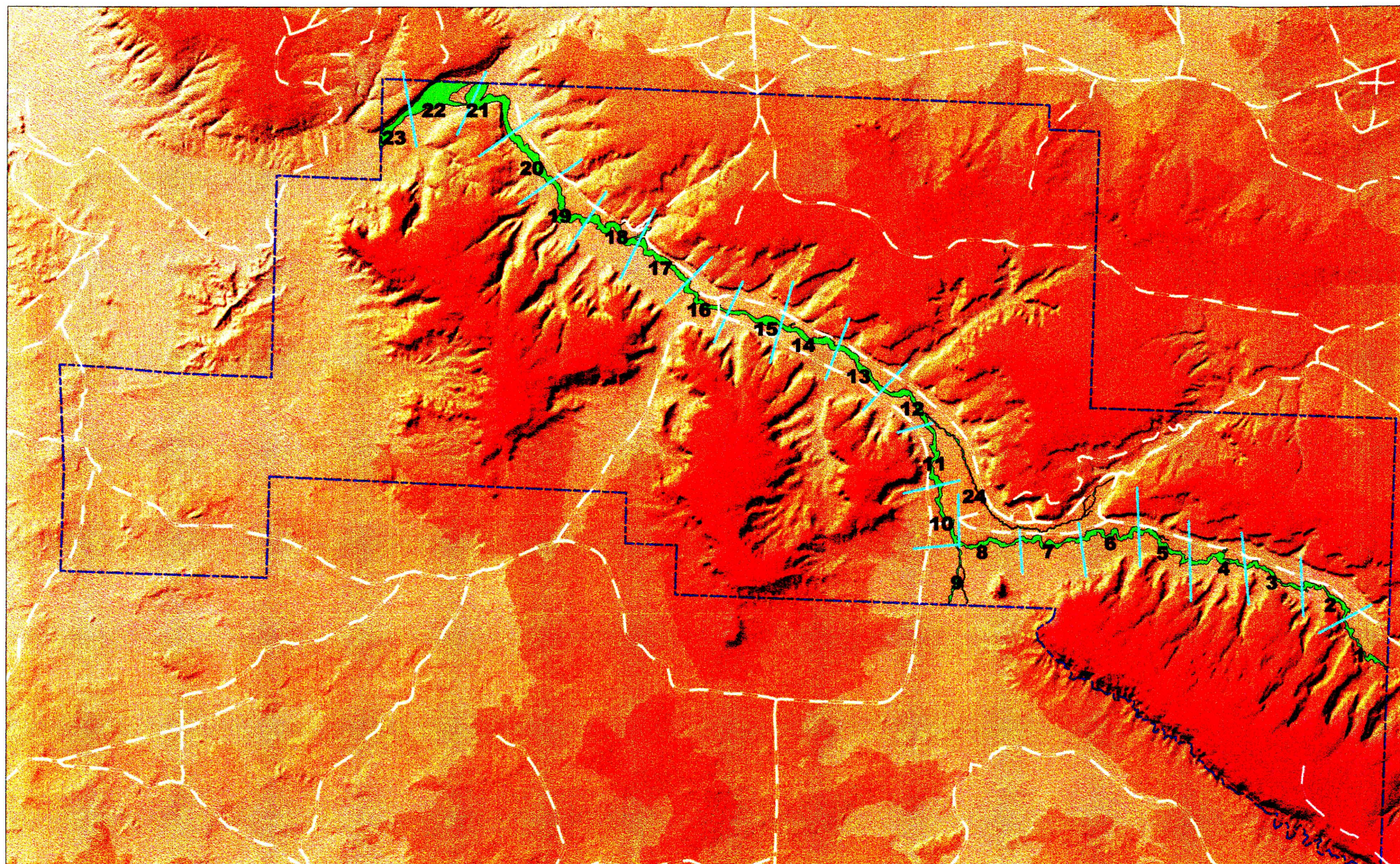
Geographic coordinates of transect endpoints.
Universal Transverse Mercator Projection
Zone 13, NAD27

Figure 2.

Sample of Field Maps created from IKONOS CIR Imagery

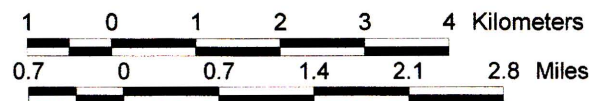


Overview of Riparian Vegetation Study Chaco Culture National Historic Park



Legend

- Roads
- Park Boundary
- Arroyo reaches
- Chaco Wash Arroyo



Scale 1:90000

UTM Coordinate System
Zone 13 North, NAD27



Figure 4a.

Training Relieve Plot Locations January 2003

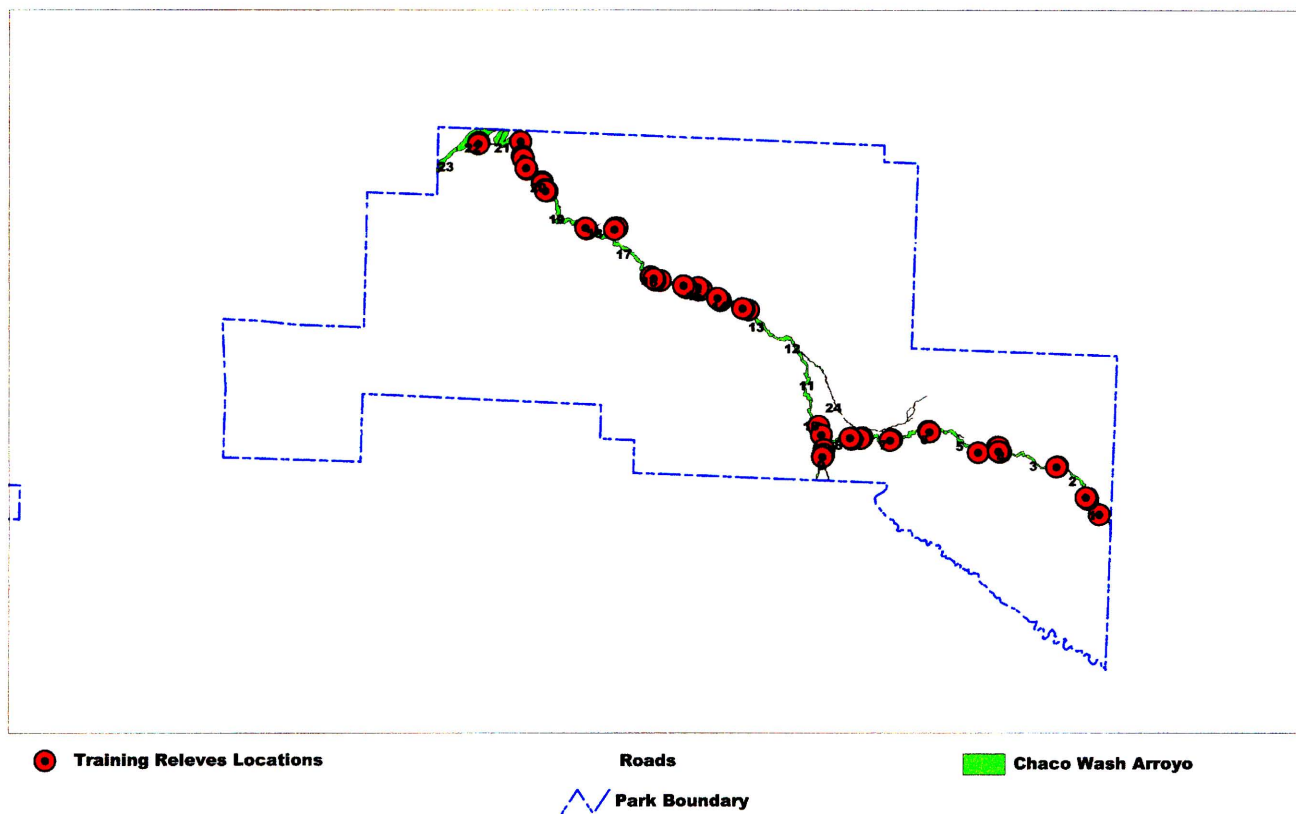
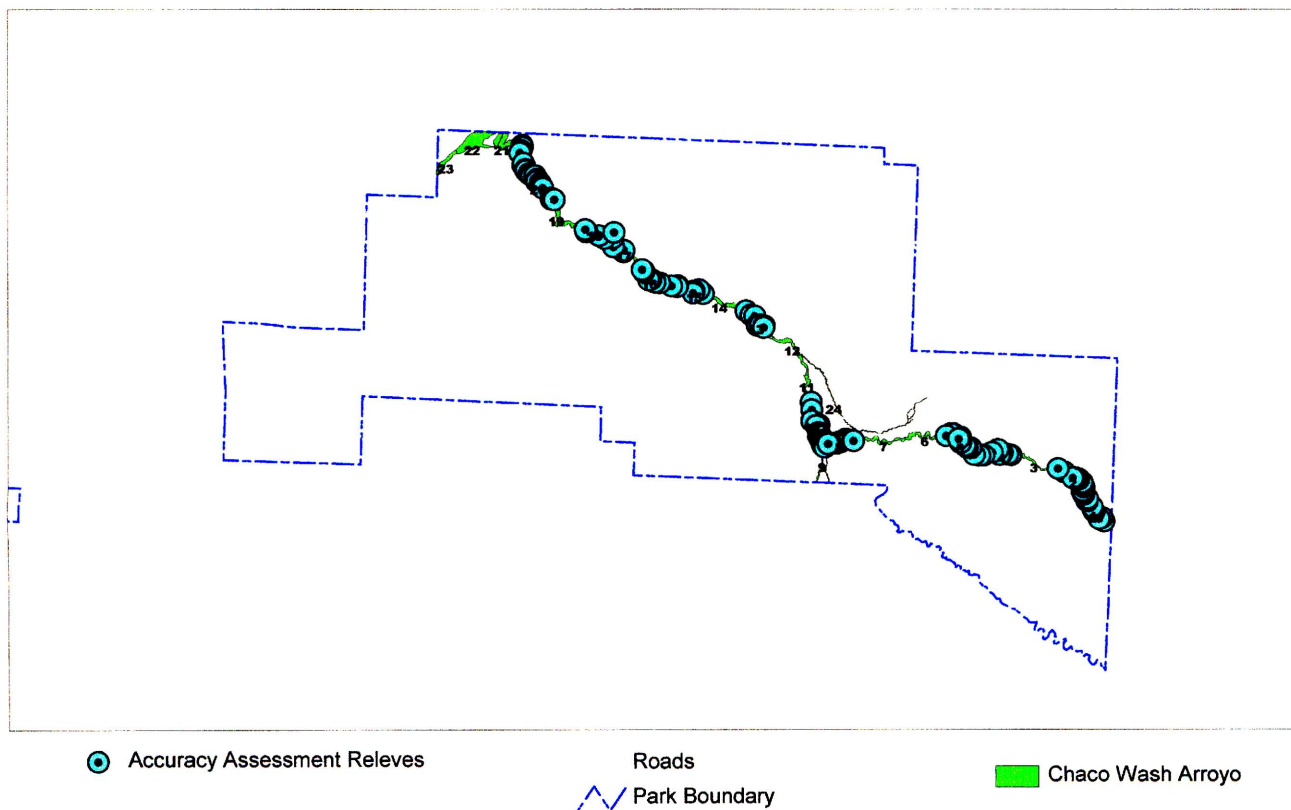


Figure 4b.

Accuracy Assessment Relieve Plot Locations May 2003



Chaco Arroyo Vegetation Associations (2 sample sections)

Figure 5.

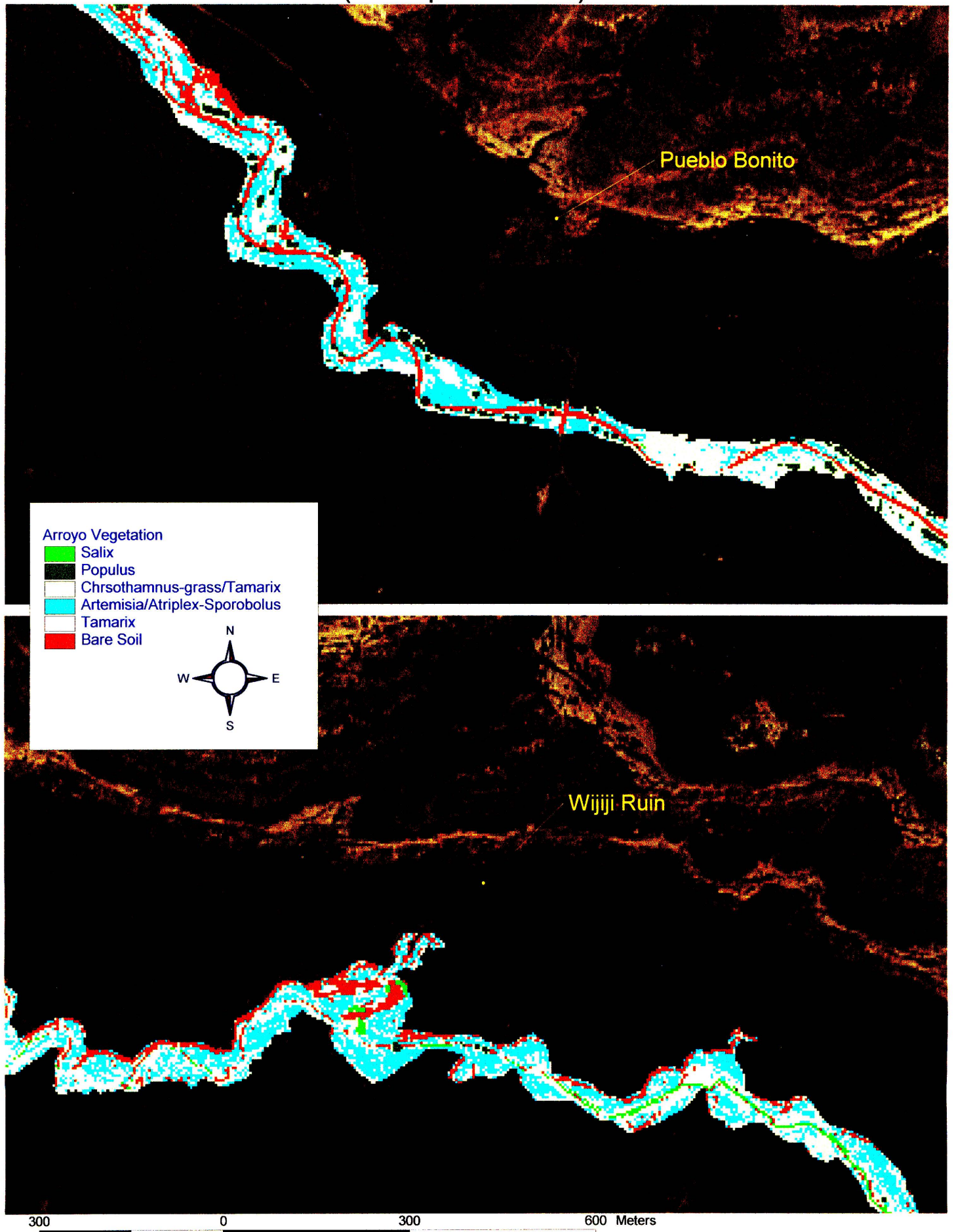


Figure 6 . Stand structure of Populus stands, Chaco Wash.
(Note: axes are not uniform to improve clarity of each histogram)

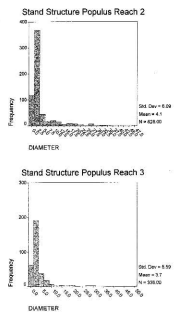


Figure 6 . Stand structure of Populus stands, Chaco Wash.
(Note: axes are not uniform to improve clarity of each histogram)

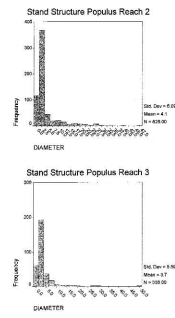


Figure 6 . Stand structure of Populus stands, Chaco Wash.
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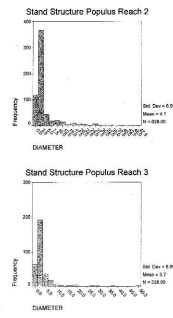


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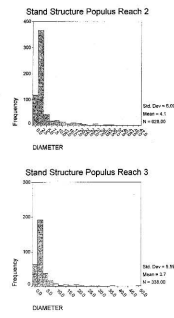
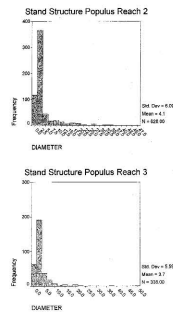
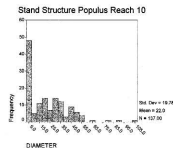
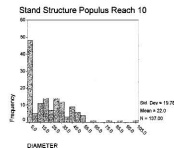
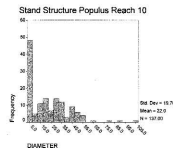
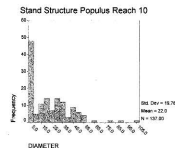
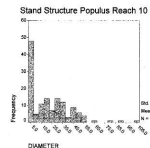
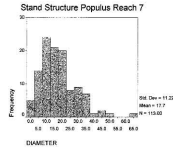
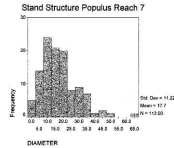
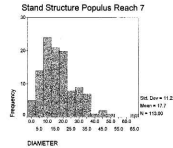
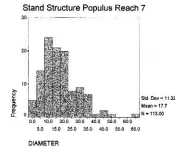
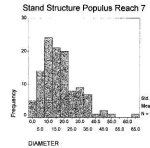
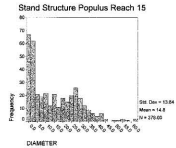
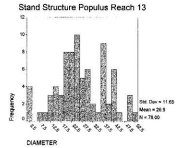
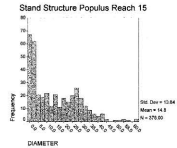
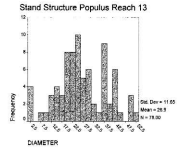
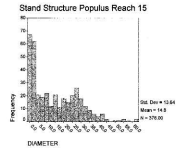
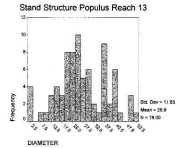
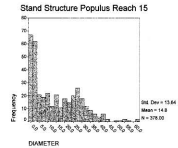
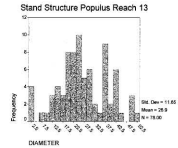
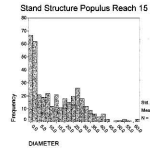
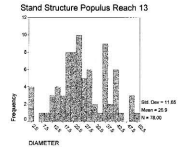
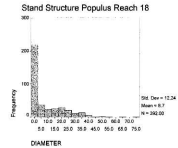


Figure 6 . Stand structure of Populus stands, Chaco Wash.
(Note: axes are not uniform to improve clarity of each histogram)

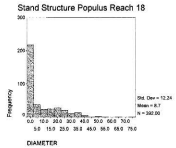




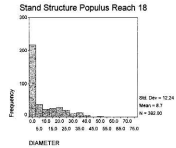




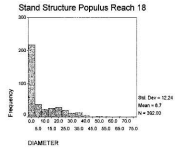
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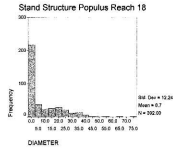
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Page 4

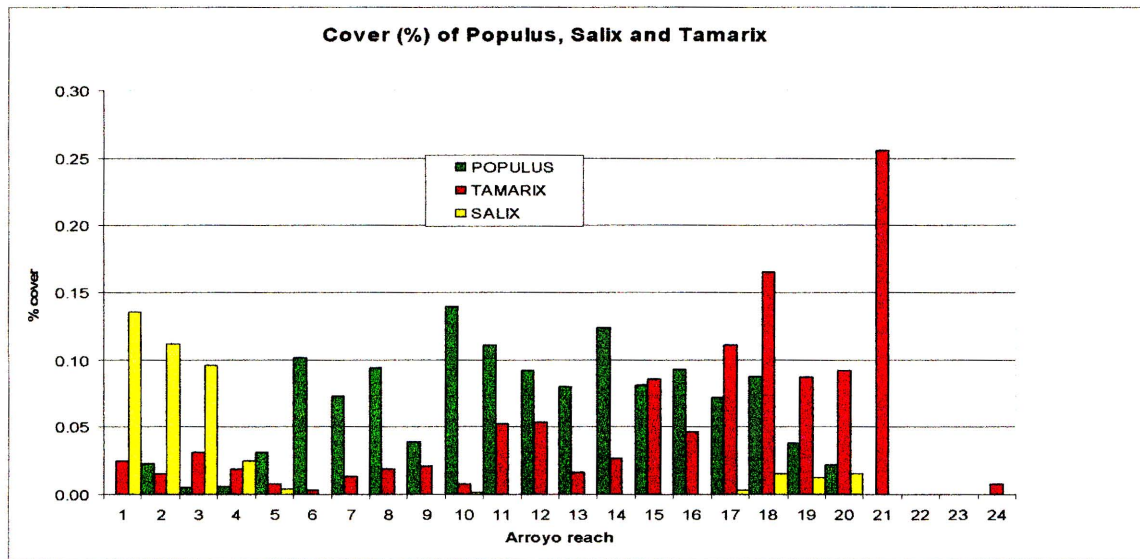


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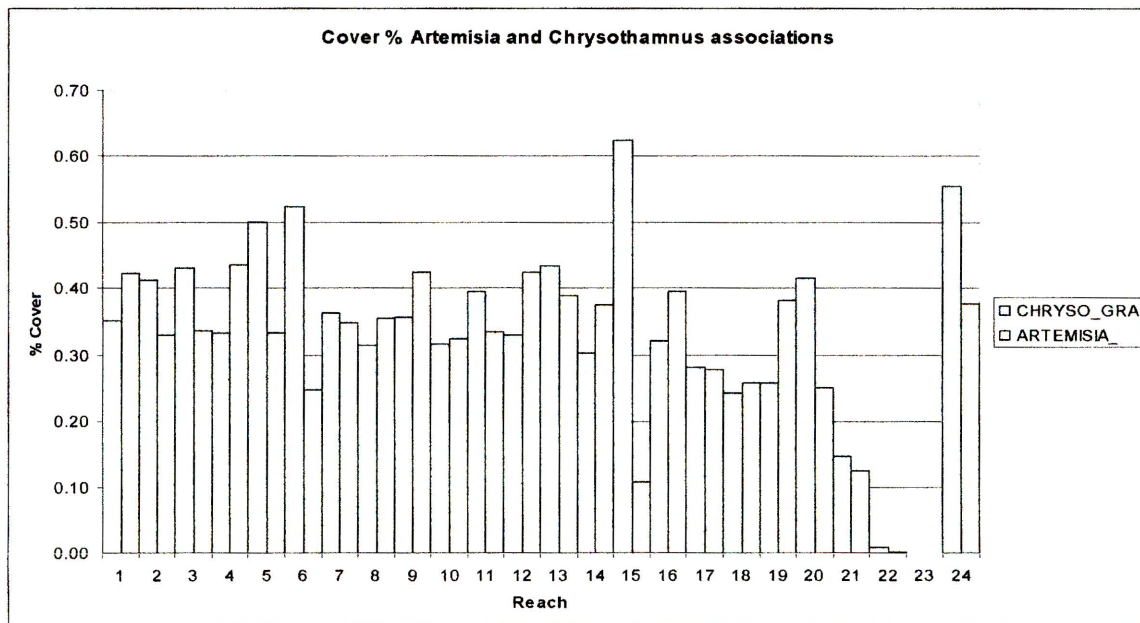
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Figure 7a. Comparison of the percent cover of *Populus*, *Tamarix* and *Salix* along the length of the arroyo. Arroyo reaches go from upstream to downstream, left to right.



upper end → Lower end

Figure 7b. Comparison of percent cover of *Artemisia* and *Chrysothamnus* associations along the elevation gradient of the arroyo.



upper end → Lower end

ATTACHMENT I: RECOMMENDED ATTRIBUTE DATA FOR WOODY RIPARIAN SPECIES	
I. Choose General Floodplain Location Relative To Inner Stream Channel & Arroyo Walls:	
(1) Inside of stream bend ("Point Bar")	
(2) Outside of stream bend ("Cut Bank")	
(3) Straight stream reach	
II. Identify Stream Channel Environment (refer to Figure 1):	
A. Arroyo Wall: Vertical or near vertical outer bank along Chaco Wash. Typically without much vegetation cover, or if present more representative of canyon floor communities than riparian communities. May be sampled at the discretion of the Principal Investigator.	
B. Arroyo Bank Erosion Fan: Fine clay derived from lateral erosion of arroyo wall and Chaco Canyon alluvial fill. Typically deposited immediately beneath the arroyo wall, with a radiating fan at the base of an eroded vertical face, gully, or groy. These deposits may also be inundating woody riparian species planted along the base of the arroyo walls during earlier erosion control programs.	
C. Broad Floodplain Swale: Wide, shallow swales in floodplain which do not readily drain after overbank flows. Usually closer to arroyo walls than inner flow channel. Typically accumulating dark, very fine, organically-rich clay.	
D. High Floodplain Terrace: Perhaps most common floodplain environment. Mostly level surface on arroyo floor which is not channelized & which readily drains after overbank flows.	
E. Levee: Linear, narrow sandy ridge deposit, parallel to inner channel banks. Multiple parallel levees have been observed in some reaches.	
F. Low Floodplain Terrace: Level terrace towards middle of arroyo. Locally, there may or may not be a clear distinction between this and the "High Floodplain Terrace" described above. However, in general, floodplain terraces proximal to the inner channel may be slightly lower than those proximal to arroyo walls. Therefore it may prove useful to compare vegetation differences on terraces between a levee and the inner channel to terraces between a levee and an arroyo wall.	
G. Inner Channel Bank: Horizontal area immediately adjacent to edge of inner channel. May be difficult to distinguish from a "Levee" or "Low Floodplain Terrace" which are also common features at this location.	

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H. Inner Channel Slope: Steep sided slopes of the inner channel. Typically devoid of vegetation, but often supports characteristic riparian species near the top of the bank and certain herbaceous species on the slope. Although not common, inner channel banks can have narrow, sandy benches 10 to 20% of the total distance above the channel base, even where the channel is straight. Wider benches also occur on the inside of channel bends similar to a classic "point bar". Most collection results have been observed in this environment, and the Principal Investigator may use over discretion in gathering more specific attribute data within this environment.	H. Inner Channel Slope: Steep sided slopes of the inner channel. Typically devoid of vegetation, but often supports characteristic riparian species near the top of the bank and certain herbaceous species on the slope. Although not common, inner channel banks can have narrow, sandy benches 10 to 20% of the total distance above the channel base, even where the channel is straight. Wider benches also occur on the inside of channel bends similar to a classic "point bar". Most collection results have been observed in this environment, and the Principal Investigator may use over discretion in gathering more specific attribute data within this environment.	H. Inner Channel Slope: Steep sided slopes of the inner channel. Typically devoid of vegetation, but often supports characteristic riparian species near the top of the bank and certain herbaceous species on the slope. Although not common, inner channel banks can have narrow, sandy benches 10 to 20% of the total distance above the channel base, even where the channel is straight. Wider benches also occur on the inside of channel bends similar to a classic "point bar". Most collection results have been observed in this environment, and the Principal Investigator may use over discretion in gathering more specific attribute data within this environment.	H. Inner Channel Slope: Steep sided slopes of the inner channel. Typically devoid of vegetation, but often supports characteristic riparian species near the top of the bank and certain herbaceous species on the slope. Although not common, inner channel banks can have narrow, sandy benches 10 to 20% of the total distance above the channel base, even where the channel is straight. Wider benches also occur on the inside of channel bends similar to a classic "point bar". Most collection results have been observed in this environment, and the Principal Investigator may use over discretion in gathering more specific attribute data within this environment.
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J. Narrow Floodplain Channel: More distinct, inner, shallow channel than the "Broad Floodplain Swale". These drain more readily after overbank flows and have coarser sediment deposits. May often develop straight across the inside of an inner channel bend, similar to a classic "cut-off shoot."	J. Narrow Floodplain Channel: More distinct, inner, shallow channel than the "Broad Floodplain Swale". These drain more readily after overbank flows and have coarser sediment deposits. May often develop straight across the inside of an inner channel bend, similar to a classic "cut-off shoot."	J. Narrow Floodplain Channel: More distinct, inner, shallow channel than the "Broad Floodplain Swale". These drain more readily after overbank flows and have coarser sediment deposits. May often develop straight across the inside of an inner channel bend, similar to a classic "cut-off shoot."	J. Narrow Floodplain Channel: More distinct, inner, shallow channel than the "Broad Floodplain Swale". These drain more readily after overbank flows and have coarser sediment deposits. May often develop straight across the inside of an inner channel bend, similar to a classic "cut-off shoot."
K. General Floodplain Terrace (not shown on Fig. 1): At sample sites which are difficult to distinguish, first attempt to generally choose between either "High Floodplain Terrace" or "Low Floodplain Terrace". However, when a clear environment cannot be discerned, this attribute may be assigned.	K. General Floodplain Terrace (not shown on Fig. 1): At sample sites which are difficult to distinguish, first attempt to generally choose between either "High Floodplain Terrace" or "Low Floodplain Terrace". However, when a clear environment cannot be discerned, this attribute may be assigned.	K. General Floodplain Terrace (not shown on Fig. 1): At sample sites which are difficult to distinguish, first attempt to generally choose between either "High Floodplain Terrace" or "Low Floodplain Terrace". However, when a clear environment cannot be discerned, this attribute may be assigned.	K. General Floodplain Terrace (not shown on Fig. 1): At sample sites which are difficult to distinguish, first attempt to generally choose between either "High Floodplain Terrace" or "Low Floodplain Terrace". However, when a clear environment cannot be discerned, this attribute may be assigned.
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M. Measure relationship of base of plant to Inner Flow Channel: (1) Distance to closest point at top of inner channel bank. (2) Height above lowest point at base of inner channel ("thalweg")	M. Measure relationship of base of plant to Inner Flow Channel: (1) Distance to closest point at top of inner channel bank. (2) Height above lowest point at base of inner channel ("thalweg")	M. Measure relationship of base of plant to Inner Flow Channel: (1) Distance to closest point at top of inner channel bank. (2) Height above lowest point at base of inner channel ("thalweg")	M. Measure relationship of base of plant to Inner Flow Channel: (1) Distance to closest point at top of inner channel bank. (2) Height above lowest point at base of inner channel ("thalweg")