Santa Fe River

Riparian Vegetation Monitoring

Report 2003-2005

The University of New Mexico

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Santa Fe River Riparian Vegetation Monitoring[1]

Report 2003-2005

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Abstract

The Taos Field Office of the Bureau of Land Management (BLM), in cooperation with Natural Heritage New Mexico, has initiated a riparian vegetation monitoring program for its lands along the lower Santa Fe River just west of La Cienega, New Mexico. The intent of this program is to detect long-term trends in riparian plant communities within a two-mile reach of the river that is to be excluded from livestock grazing. Nine monitoring transects were established in September of 2003. Sampling was focused on riparian and wetland vegetation within the active floodplain. Transects averaged 26 meters in length, but varied depending on the width of the floodplain, and extend from the edge of the high terrace above the river channel across the active floodplain to the opposite terrace. Percent vegetation cover and height of all species was measured using 20 x 50 cm quadrat frames laid lengthwise end to end along the upstream side of each transect. Vegetation was measured in September of 2003 and 2004, and in late July 2005. Vegetation zones were delineated across each transect using Sliding Window Boundary Analysis and cluster analysis. Five hierarchically arranged zones and 10 subzones (excluding water) were defined by dominant species or species complexes. The active floodplain was divided into four subzones: Water, Aquatic Vegetation, Mesic Herbaceous Wetland, and Sparse Mesic Herbaceous Wetland. The bank slope between the active floodplain and the upper terraces was divided into Dense Upper Herbaceous Wetland, Yerba-Mansa Dense Upper Herbaceous Wetland, and Sparse Upper Herbaceous. The rarely flooded terraces were partitioned into Woody Riparian and Arroyo Riparian zones.

To help characterize the fluvial geomorphology of the site and to support future hydrological modeling, the topography of all nine transects was surveyed in 2005. The cross-sections, in combination with the vegetation zone analysis, will provide the foundation for tracking changes in vegetation and channel morphology following the removal of livestock.

A total of 102 plant species were identified along the transects during the three years of surveys. The majority of woody cover was from exotic species and over half of all herbaceous cover was also comprised of exotics. Across all vegetation zones the average height of herbaceous vegetation (grasses and forbs) was eight centimeters or less in 2003, reflecting the high livestock utilization throughout the reach. The average height of herbaceous vegetation

[1] Final report Cooperative agreement No. GDA-010009, Task Order No. 7

increased to 12 cm in 2004 and 2005, following a small reduction in livestock use during those years. In succeeding years this monitoring system, with the removal of livestock, will provide an opportunity to accurately gauge the response of the riparian system to the absence of grazing and its implications for wildlife and fisheries habitat.

Cover: Transect No. 03SF001 along the Santa Fe River.

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Introduction

The Taos Field Office of the Bureau of Land Management (BLM) has initiated a riparian vegetation monitoring program for its lands along the lower Santa Fe River just west of La Cienega. The intent of this program is to detect long-term trends in abundance, diversity, and distribution of riparian plant communities within a two-mile reach of the river that has been recently excluded from livestock grazing. Historically, the allotment was subject to livestock grazing year round while under BLM management, which continued through the spring of 2004. In 2003, Natural Heritage New Mexico (NHNM) established a set of vegetation transects to determine baseline conditions under grazing for comparison to later surveys following livestock removal. The vegetation sampling was designed in the context of breeding bird surveys that were begun within the same riparian zone in 2002, with the intent of providing data on the relationship between bird densities and vegetation structure and composition through time[2]. The transects established in 2003 were read again in 2004 and 2005. Although livestock grazing was somewhat restricted in 2004 and 2005, cattle were still present on the allotment for several months each summer. Thus, the three years of data reported here represent a baseline dataset of the allotment riparian zone under grazing that can be used to analyze future trends following livestock removal. The dataset also provides details of the current vegetation condition for use in the revision of the allotment management plan. We report here on the project design, methodologies, and the data collected from 2003 through 2005.

Methods

Study area

The study area is located 26 km (16 miles) southwest of Santa Fe within the lower portion of the Santa Fe River Area of Critical Environmental Concern (ACEC) managed by the BLM (Figure 1). The study reach is approximately 3.5 km (2.2 miles) long with elevations that range from 1768 m (5800 ft) upper end to 1737 m (5700 ft) at the lower end resulting a gentle stream gradient (approximately 1%). The floodplain averages only about 100 m in width and is constrained within a deep canyon, bounded by mesas capped with ancient basalt lava flows. The river has a perennial flow sustained by a combination of natural discharge from a drainage basin of 45.5 km^2 (18.20 sq. miles) and from the city of Santa Fe sewage treatment facility south of town. Stream flow peaks in May following snowmelt at 21 ft^3/s (cfs) on average in the post regulation period after 1926 (Figure 2). Yearly peak daily discharges have averaged over 80 cfs in recent decades (1980-1999) with a maximum of 119 cfs on 7/18/1992. The majority of the local precipitation arrives during late summer and early fall (Table 1) and, hence, in a given year, there can be secondary peaks in stream flow between August and September in response to large monsoonal rainstorms. In contrast, winter time precipitation is low and monthly base flows typically dip to below 5 cfs. At the same time, average temperatures are below freezing through the winter months, and the growing season typically does not begin until late March and concludes by the end of September.

[2] Hawks Aloft Inc. of Albuquerque, NM is conducting the breeding bird surveys on behalf of the Bureau of Land Management.

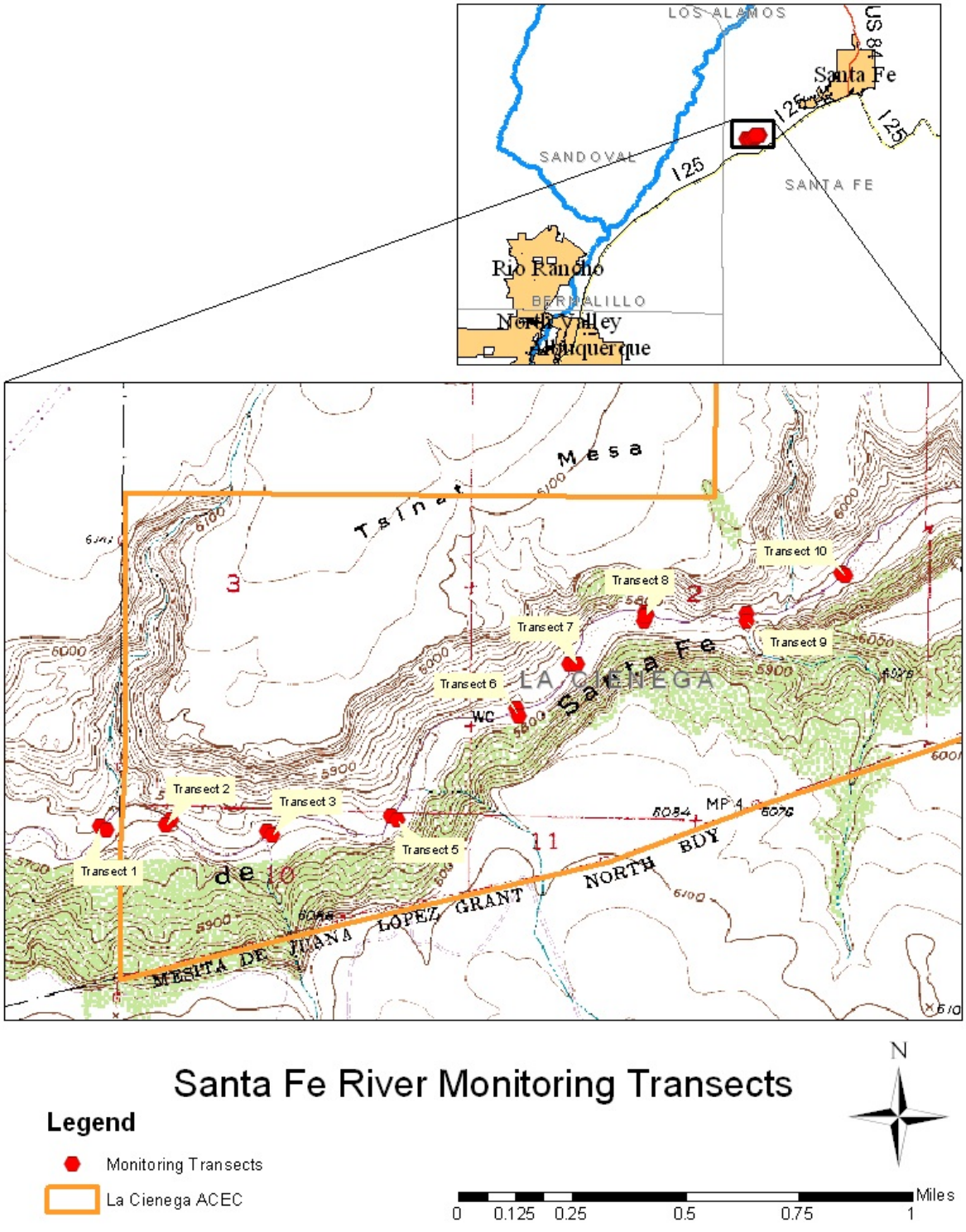

Figure 1. Study area for the Santa Fe River ACEC riparian monitoring program.

Table 1. Summary temperature and precipitation data from 1972 through 2003 for weather station Santa Fe 2 (298085), approximately 20 km north of the study area (source: www.wrcc.dri.edu/).

	Temperature Averages (° F)			Precipitation (in)		
	Max.	Min.	Mean	Mean	High	Low
Winter	44.9	20	32.4	1.77	5.24	0.18
Spring	64.2	34.2	49.2	2.78	7.4	0.13
Summer	84.2	53.6	68.9	5.41	10.66	2.04
Fall	65.6	36.8	51.2	3.83	7.71	0.78
Annual	64.7	36.2	50.4	13.79	20.09	7.23

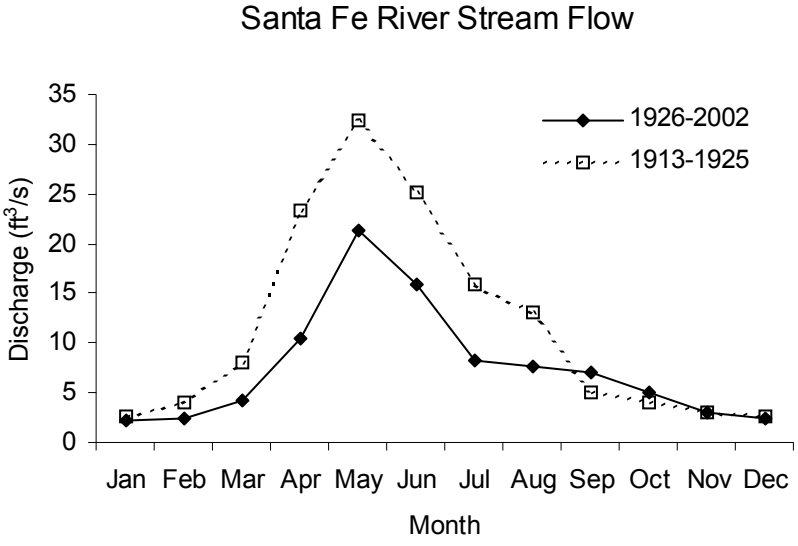

Figure 2. Average monthly discharge of the Santa Fe River near Santa Fe (Gage Station 08316000). The years 1913-1925 represent pre-regulation and 1926-2002 post-regulation flows (source: US Geological Survey at http://waterdata.usgs.gov/nm/nwis/peak).

The study area has a long history of human use as evidenced by numerous archeological sites within the canyon. Over the past century, livestock grazing has been the primary land use, typically on a year-round basis, and the site is part of an active BLM grazing allotment. At the time sampling began in 2003, cattle had been heavily using the site through the summer season since forage elsewhere in the allotment was in short supply due to drought conditions. An attempt was made to limit grazing within the allotment in 2004 and 2005. However, for several months during both summers cattle were present on the allotment and there was grazing within the active floodplain, again because of limited forage elsewhere.

Sampling design

Nine monitoring transects were established in September 2003 along the lower two-mile stretch of the Santa Fe River within the ACEC (Figure 1). Sampling was focused on riparian and wetland vegetation within the active floodplain with the intent of detecting major changes in species composition and structure. Hence, transects were more or less evenly distributed along the reach and generally across straight reaches between river bends where the widest zones of riparian vegetation occurred.

Transects averaged 26 m (85 ft) in length, but varied, depending on the width of the channel, from 16.8 to 38.2 m (55 to125 ft). All transects started on the right (northern) bank terrace above the river channel and the active floodplain, and extended perpendicularly across the river and up onto the left bank terrace. Three to five meters of terrace were included on either side of the active channel. Rebar stakes tagged with aluminum tags were used to monument both ends of the transect on the terraces, with two additional tagged stakes located along the transect within the active floodplain to improve repeatability. The locations of the end-point stakes were recorded with a Garmin GPS with an accuracy of +/- 3 m (Appendix A). Each year four monitoring photographs were taken along each transect: one from the start stake to end stake and vice-versa, then two more photographs, one looking upstream and one looking downstream, were taken from a point upstream of the transect at a distance measured and recorded off the right bank floodplain stake. A complete set of digital monitoring photographs is provided on the CD included with this report.

Vegetation cover was measured using 20 x 50 cm quadrat frames laid lengthwise end to end along the upstream side of each transect starting at the first stake (rebar 1, at 0 m) and continuing until there was no longer room for a complete quadrat along the line. (i.e., if the transect line ended at 23.4 m, the last quadrat was from 22.5 to 23 m.). In each quadrat, canopy cover of all species was evaluated to the nearest percent and with some smaller-sized species, to one tenth of a percent. In addition, average height for each species was measured to the nearest cm. Ground cover components of litter, exposed soil, gravel, rock, water, cryptogams and total herbaceous canopy cover were also recorded to the nearest percent. Vascular aquatic vegetation was identified to species and measured as canopy cover whether it was submerged or emergent. However, algae, which was not identified to species, was measured as part of the ground cover components and was only measured when not submerged (i.e.: submerged algae was not recorded and was simply part of the total area assigned to water for quadrats in which it

occurred.). Additionally, the start and end points of the major vegetation zones were recorded for each transect.

In 2005, the relative elevations along all transects were surveyed using a laser level (seven transects), or a transect (two transects) and a tape and rod. Measurements were taken at significant topographic breaks and major changes in vegetation zones. The measurements were then used to create cross section profiles of each transect that indicate the elevation of each vegetation zone or landform relative to the channel bottom and bordering terraces (Appendix B).

Vouchers of all plant species were taken, identified, and have been archived at the herbarium of the University of New Mexico Museum of Southwest Biology. The vegetation data was entered using Microsoft Access into the NHNM's Ecology database with tables specifically designed for this project. Over the past decade the NHNM ecology database has been developed and populated with over 7,000 plot records from around the state and Southwest. Accordingly, there is a set of data entry protocols that have been implemented that ensure data quality including independently proofreading the data for accuracy. All of the raw data has been made available in an Access database form on compact disk along with appropriate exported ASCII files of the data, photo point files, and this report.

Using the quadrat data, preliminary vegetation zones were defined along each transect using sliding window boundary analysis (Ludwig and Cornelius 1987). These preliminary zones were then grouped by similarity of vegetation using cluster analysis (SAS 2001) to generate a revised set of hierarchically arranged zones and subzones that form the foundation for the interpretation of changes across transects and throughout the study area.

Results

Vegetation zones

The transects were hierarchically classified into five zones and 10 subzones (excluding water) as defined by their dominant species or species complex (Table 2). The active channel was broken into an Open Water zone with little or no vegetation and an Aquatic Vegetation zone dominated by rooted vascular aquatic species such as the exotic watercress (*Rorippa nasturtium-aquaticum*), and native water speedwell (*Veronica anagallis-aquatica*). There were significant changes in the Aquatic vegetation zone between 2003 and 2005. Watercress and speedwell declined 98% and 54% in cover, respectively, while knotgrass (*Paspalum distichum*) increased 34% and became the dominant (Figure 3; Table 3).

The Mesic Herbaceous Wetland Zone was a complex of two subzones that are intermixed on the frequently flooded alluvial bars adjacent to the active channel. The predominant subzone was the Creeping Bentgrass-Knotgrass (*Agrostis stolonifera-Paspalum distichum*) Mesic Herbaceous Wetland (Table 4). Creeping bentgrass, an introduced European pasture grass, had a slight increasing trend in cover between 2003 and 2005. Knotgrass is a native obligate wetland species found across the southern United States and it had a slight downward trend. Besides the two characteristic dominants, this relatively luxuriant subzone had a wide assortment of other

Table 2. Riparian vegetation zone and subzones along river cross-sections of the BLM Santa Fe River ACEC. Codes are NHNM acronyms for the scientific names or physical elements of the subzone name. Channel location refers to the primary landscape position of the subzones. Active Channel is the location of the current river and is usually filled with water; the Floodplain adjacent to the channel is typically flooded every one to two years up to ten; the Terrace is upper alluvial terraces that are only rarely flooded (> 10 years return interval).

Vegetation Zone	Sub-Vegetation Zone Name	Code	Channel Location
Active Channel	Open Water - little or no vegetation	OPEN WATER	Active Channel
	Watercress-Water Speedwell Aquatic Vegetation (*Rorippa nasturtium-aquaticum-Veronica anagallis-aquatica*)	RORAQU-VERANA	Active Channel
Mesic Herbaceous Wetland	Creeping Bentgrass-Knotgrass Mesic Herbaceous Vegetation (*Agrostis stolonifera-Paspalum distichum*)	AGRSTO-PASDIS	Active Floodplain
	Common Threesquare Sparse Herbaceous Wetland (*Schoenoplectus pungens*)	SCHPUN	Active Floodplain
Upper Herbaceous Wetland	Tall Fescue-Alkali Muhly Upper Herbaceous (*Festuca arundinaceae-Muhlenbergia asperifolia*)	FESARU-MUHASP	Terrace slope
	Yerba Mansa/Alkali Muhly Upper Herbaceous (*Anemopsis californica-Muhlenbergia asperifolia*)	ANECAL/MUHASP	Terrace slope
	Sparse Upper Herbaceous	SPARSE UPPER HERB	Terrace slope
Woody Riparian	Russian Olive Riparian Woodland (*Elaeagnus angustifolia*)	ELAANG	Terrace
	Russian Olive/Rubber Rabbitbush Riparian Woodland (*Elaeagnus angustifolia/Chrysothamnus nauseosus*)	ELAANG/CHRNAU	Terrace
	Saltcedar Riparian Shrubland (*Tamarix ramosissima*)	TAMRAM	Terrace
Arroyo Riparian	Rubber Rabbitbush Riparian Shrubland (*Chrysohamnus nauseosus*)	CHRNAU	Terrace

Table 3. Watercress-Water Speedwell Aquatic Vegetation zone summary table. Cov = average percent cover over 46 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Trees						
Elaeagnus angustifolia - seedling					0.09	10
Elaeagnus angustifolia - yng regen			0.87	36		
Elaeagnus angustifolia - mature			10.22	600	10.87	600
Shrubs						
Rhus trilobata					0.15	6
Tamarix ramosissima - seedling	0.07	4				
Graminoids						
Agrostis stolonifera	4.26	8	31.50	11	29.93	9
Cyperus spp.	0.11	14				
Distichlis spicata	0.11	12				
Echinochloa crus-galli	3.89	10	2.63	20	1.41	10
Eleocharis palustris	0.05	9	2.52	14	5.97	11
Elymus repens					0.65	18
Eragrostis pectinacea	1.22	8	0.33	14		
Festuca arundinaceae	0.22	4	3.61	14	4.33	13
Juncus arcticus var. balticus					0.11	9
Muhlenbergia asperifolia	0.11	10	0.13	7	0.24	12
Paspalum distichum	16.78	12	18.78	21	25.24	15
Polypogon monspeliensis			1.46	9	0.17	8
Schoenoplectus pungens	1.42	9	3.38	24	3.19	16
Forbs						
Argentina anserina	0.11	4	0.11	10	0.17	8
Calibrachoa parviflora	0.22	5	0.11	11	0.41	6
Chenopodium incanum					0.01	3
Cirsium vulgare			0.33	15		
Conyza canadensis			0.05	27		
Melilotus officinalis			0.17	17		
Mimulus glabratus	1.57	3	2.11	10	0.24	3
Polygonum aviculare	0.07	3	0.26	24		
Polygonum persicaria	0.72	14	2.57	17	3.21	9
Portulaca oleracea			0.04	2		
Ranunculus cardiophyllus	0.14	3				
Ranunculus cymbalaria					0.26	4
Rorippa nasturtium-aquaticum	28.87	6	34.87	10	0.05	2
Rumex crispus	0.33	14	1.02	30	0.70	22
Sonchus asper	0.11	6				
Trifolium fragiferum	1.50	5	1.33	10	0.54	6
Veronica anagallis-aquatica	3.74	6	1.70	15	0.78	6
Xanthium strumarium	0.17	9	1.63	65	7.00	18

Table 4 . Creeping Bentgrass-Knotgrass Mesic Herbaceous Vegetation zone summary table. Cov = average percent cover over 117 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Trees						
Elaeagnus angustifolia - seedling	0.02	6	0.20	6	0.03	9
Elaeagnus angustifolia - yng regen	0.17	10	0.94	60	0.02	20
Elaeagnus angustifolia - mature	5.98	1200	3.44	1200	8.29	1200
Shrubs						
Chrysothamnus nauseosus			0.00	5		
Rhus trilobata					0.04	3
Salix exigua	0.00	12				
Tamarix ramosissima - seedling	0.14	5				
Tamarix ramosissima- yng regen	0.10	57	0.09	120	0.04	190
Graminoids						
Agrostis stolonifera	31.79	5	42.50	8	47.89	8
Bromus catharticus	0.57	5	0.00	10		
Bromus tectorum					0.00	7
Cenchrus spinifex	0.04	5	0.03	10		
Cynodon dactylon			0.21	2	0.51	6
Distichlis spicata	0.04	4	0.13	20	0.07	7
Echinochloa crus-galli	3.55	6	3.06	8	0.38	7
Eleocharis palustris	0.80	6	0.34	14	1.32	9
Eragrostis pectinacea	0.05	4	0.10	7		
Festuca arundinaceae	3.79	6	7.40	11	8.27	12
Hordeum jubatum ssp. intermedium			0.04	15		
Hordeum murinum ssp. glaucum					0.02	13
Juncus arcticus var. balticus					0.19	17
Muhlenbergia asperifolia	0.91	6	2.97	9	2.44	9
Paspalum distichum	10.09	8	8.29	15	5.79	12
Poa annua			1.29	7	0.55	7
Polypogon interruptus					0.01	
Polypogon monspeliensis			0.04	10	0.19	6
Schoenoplectus pungens	10.59	10	12.74	16	8.93	15
Sporobolus cryptandrus	0.05	10	0.02	15		
Unidentified grass	0.01	2				
Forbs						
Almutaster pauciflorus			0.09	8		
Amaranthus hybridus			0.02	4		
Ambrosia acanthicarpa			0.01	9	0.04	8
Anemopsis californica	0.03	3	0.02	5	0.09	6
Argentina anserina			0.09	4	0.11	7
Berula erecta			0.57	19	0.13	5
Bidens cernua			0.05	17		
Calibrachoa parviflora	0.05	4				
Chamaesyce serpyllifolia	0.26	5	0.07	3		
Chamaesyce serrula	0.00	1				
Equisetum laevigatum					0.00	8
Grindelia nuda var. aphanactis	0.02	3			0.02	5
Kochia scoparia			0.05	10		
Melilotus officinalis	0.01	6	0.35	13	0.09	24
Mimulus glabratus	0.09	6	0.21	18	0.00	2
Polygonum aviculare	0.05	2	0.21	7	0.04	4
Polygonum persicaria	0.01	10	0.10	22	0.32	13
Portulaca oleracea	0.04	2	0.39	4		
Ranunculus cardiophyllus	0.00	3				
Ranunculus cymbalaria					0.02	3
Rorippa nasturtium-aquaticum	1.44	7	1.67	10	0.00	2
Rumex crispus			0.09	10		
Salsola tragus			0.00	10		
Schkuhria multiflora			0.02	7		
Taraxacum officinale	0.01	2	0.14	5	0.12	4
Tribulus terrestris			0.03	3		
Trifolium fragiferum	21.48	3	20.77	4	14.33	4
Veronica anagallis-aquatica	0.10	5			0.09	5
Xanthium strumarium	1.01	10	10.77	42	5.12	17

grass-like species (graminoids) and forbs, among which the most common were the introduced strawberry clover (*Trifolium fragiferum*) and tall fescue (*Festuca arundinaceae*), and common threesqaure (*Schoenoplectus pungens*), a native obligate wetland species. Common threesquare was the dominant in the Common Threesquare (*Schoenoplectus pungens*) Sparse Herbaceous Wetland subzone which occurs on sandier soils, usually above the Creeping bentgrass-Knotgrass vegetation zone (Table 5). Per its name it was less species rich and has a lower overall vegetative cover. Common threesquare cover shifted little between 2003 and 2005 (+/- 2%) and had an average cover of 14%, while alkali muhly, the next most common graminoid at 9% cover, was somewhat more dynamic (+/- 5% cover over the years). Other graminoids and forbs averaged less than 2% cover.

Figure 3. Typically, vegetation zones extend laterally from the open water of the channel through a narrow Aquatic Vegetation zone to Herbaceous Wetlands on the adjacent bars. The upper terraces support a Woody Riparian zone (dominated by Russian olive on the left side of the photo) or an Arroyo Riparian zone (the rubber rabbitbush on the right side of the photo) [photo: Transect 6 2005].

The Upper Herbaceous Wetland Zone was found on the slope between the active floodplain and upper terraces that are flooded infrequently relative to the active floodplain (soils may become saturated during high flows). These herbaceous vegetation zones can have an overhanging canopy of Russian olives, shrubs and trees extending from the upper terrace. Three subzones were identified. The most mesic subzone was the Tall Fescue-Alkali Muhly (*Festuca arundinaceae-Muhlenbergia asperifolia*) Upper Herbaceous Wetland. Tall fescue is an introduced pasture grass while alkali muhly is a native facultative wetland species. This was a fairly luxuriant subzone with total herbaceous cover generally greater than 60% (Table 6). While *F. arundinaceae* cover remained relatively high between 2003 and 2005, *M. asperifolia* cover fell 50% in 2005.

The Yerba Mansa/Alkali Muhly (*Anemopsis californica-Muhlenbergia asperifolia*) Upper Herbaceous Wetland subzone tended to occur higher on the terrace slope than the Tall Fescue-Alkali Muhly subzone, and was only present on two transects (03SF005 and 03SF008). While grasses such as *M. asperifolia, Sporobolus airoides,* and *Distichlis spicata* can be well represented, the subzone was characterized by a high cover (average of 40%) of the native obligate wetland forb, yerba mansa (Table 7). In contrast, the Sparse Upper Herbaceous subzone, while high in diversity, had no clear dominant species (Table 8). It tended to occur high on steep terrace slopes, and the soils were sandy and drier. Most species within the zone had less than 2% cover and, with the exception of occasional annual species proliferation, total herbaceous cover was usually less than 5%. Generally this zone occurred in the transition between the more mesic herbaceous vegetation zones and the dry arroyo riparian vegetation zone.

Table 5. Common Threesquare Sparse Herbaceous Vegetation zone summary table. Cov = average percent cover over 28 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Trees						
Elaeagnus angustifolia - yng regen					0.07	62
Ulmus pumila			0.07	4		
Shrubs						
Chrysothamnus nauseosus			0.04	10		
Tamarix ramosissima - seedling	0.04	4	0.07	10		
Tamarix ramosissima- yng regen			0.18	110	0.21	95
Graminoids						
Agrostis stolonifera	1.61	5	5.25	11	10.82	9
Bromus catharticus			0.18	15		
Bromus japonicus					0.11	12
Bromus tectorum					0.93	15
Cenchrus spinifex			0.25	5		
Distichlis spicata	0.57	5	0.71	12	0.18	8
Echinochloa crus-galli	2.79	7	1.86	12	0.11	7
Eleocharis palustris	6.50	7	4.93	18	1.70	12
Elymus repens					0.04	20
Eragrostis pectinacea	0.79	8				
Festuca arundinaceae	1.11	7	0.36	9	2.79	13
Hordeum jubatum ssp. intermedium			0.75	27		
Hordeum murinum ssp. glaucum					0.79	8
Juncus arcticus var. balticus	0.00	15	0.64	10	0.25	20
Muhlenbergia asperifolia	6.25	7	11.50	8	9.04	8
Paspalum distichum	1.18	3	0.80	12	0.54	24
Poa annua			0.46	10	0.55	12
Polypogon monspeliensis			3.08	12	2.11	10
Schoenoplectus pungens	15.90	9	12.48	14	13.41	14
Sporobolus cryptandrus	0.82	10			0.18	19
Forbs						
Almutaster pauciflorus	0.07	4	0.71	15	0.11	3
Ambrosia acanthicarpa			2.01	11	1.25	6
Argentina anserina	1.07	3	2.89	4	1.39	4
Bidens cernua			0.71	45		
Chamaesyce serpyllifolia	0.01	1				
Chamaesyce serrula			0.02	7		
Conyza canadensis	0.54	10	0.61	20	0.61	11
Gaura parviflora	0.00	7				
Kochia scoparia	0.71	6	5.23	9	0.46	4
Lactuca serriola					0.18	11
Melilotus officinalis			3.39	10		
Mimulus glabratus			0.07	22		
Polygonum aviculare	1.43	3	0.54	12	0.68	7
Polygonum persicaria			1.71	40	0.71	17
Portulaca oleracea	0.00	1				
Ranunculus cymbalaria	0.48	2	1.07	5	0.32	3
Rorippa nasturtium-aquaticum	2.32	16	5.00	18		
Taraxacum officinale	0.18	3			0.04	4
Tribulus terrestris	0.36	3	0.04	3		
Trifolium fragiferum	1.02	2	4.68	6	10.68	6
Xanthium strumarium	2.75	12	12.36	41	9.89	17

Table 6. Tall Fescue-Alkali Muhly Upper Herbaceous Vegetation zone summary table. Cov = average percent cover over 19 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Trees						
Elaeagnus angustifolia - seedling	0.03	4				
Elaeagnus angustifolia - mature	1.58	1000	7.37	1000	1.05	1200
Graminoids						
Agrostis stolonifera	2.95	4	5.32	9	9.00	10
Bouteloua barbata	0.01	1				
Bromus japonicus					0.11	15
Bromus tectorum					0.53	11
Cenchrus spinifex	0.05	3	0.05	6		
Cynodon dactylon	1.58	3	2.79	6	1.42	3
Distichlis spicata	3.53	7	2.79	6	0.53	8
Elymus repens					0.11	35
Eragrostis pectinacea	0.01	3	0.01	5		
Festuca arundinaceae	29.63	7	39.26	11	28.42	11
Hordeum jubatum ssp. intermedium			0.32	15		
Hordeum murinum ssp. glaucum					0.05	15
Juncus arcticus var. balticus					0.11	28
Muhlenbergia asperifolia	22.26	6	22.53	11	12.42	8
Pascopyrum smithii	0.45	15	1.16	14	3.26	17
Poa annua			0.06	10	0.05	2
Polypogon monspeliensis					0.11	7
Schoenoplectus pungens	2.87	8	4.98	15	2.08	18
Sporobolus cryptandrus	0.32	18	0.53	20	0.05	15
Forbs						
Amaranthus hybridus	0.03	2	0.01	2		
Ambrosia acanthicarpa			0.01	5	0.05	4
Conyza canadensis			0.05	20	0.18	5
Croton texensis					0.01	6
Kochia scoparia	0.05	7	0.79	9	0.11	1
Machaeranthera pinnatifida					0.01	9
Polygonum aviculare	0.03	3			0.01	5
Portulaca oleracea	0.21	1	0.59	3		
Taraxacum officinale	0.26	1	0.11	4		
Tribulus terrestris	0.27	2	0.69	3		
Trifolium fragiferum	13.26	2	6.00	5	9.95	3
Xanthium strumarium	0.89	13	3.27	31	2.16	14

Table 7. Yerba Mansa/Alkali Muhly Upper Herbaceous Vegetation zone summary table. Cov = average percent cover over 22 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Trees						
Elaeagnus angustifolia - seedling	0.23	12				
Elaeagnus angustifolia - mature	35.45	1200	37.73	1145	31.95	1000
Graminoids						
Agrostis stolonifera					2.50	6
Bouteloua barbata	0.00	1				
Bouteloua gracilis			0.05	5	0.23	6
Bromus japonicus			0.00	8		
Bromus tectorum					0.36	11
Chloris verticillata					0.05	7
Distichlis spicata	6.14	9	4.55	11	5.05	13
Eleocharis palustris	0.09	4				
Elymus elymoides			0.14	3		
Festuca arundinaceae	0.45	7	0.36	5	1.09	8
Hordeum murinum ssp. glaucum			0.01	7	1.02	8
Juncus arcticus var. balticus			0.00	22	0.36	16
Muhlenbergia asperifolia	9.91	7	13.36	8	7.00	8
Pascopyrum smithii	0.27	7	1.73	15	0.75	15
Poa annua			0.45	4	0.23	4
Poa compressa					0.55	6
Polypogon monspeliensis					0.82	8
Schoenoplectus pungens	2.09	12	1.45	13	2.14	13
Sporobolus airoides	4.09	8	3.41	14	6.64	14
Sporobolus cryptandrus	0.18	5	0.23	16	0.09	15
Forbs						
Almutaster pauciflorus	0.55	4	1.23	10	0.68	8
Amaranthus hybridus	0.02	3	0.00	2		
Anemopsis californica	43.05	3	49.91	4	45.09	8
Chamaesyce serpyllifolia	0.01	1	0.02	2		
Chenopodium atrovirens			5.55	6		
Chenopodium incanum	1.10	3	0.00	9		
Kochia scoparia	2.28	5	14.14	9	3.93	5
Polygonum aviculare	0.07	10	0.00	8	0.23	6
Portulaca oleracea	0.01	1	0.02	3		
Salsola tragus	0.05	6	0.03	16		
Solanum elaeagnifolium	0.09	2	0.36	7	0.18	5
Tribulus terrestris	0.02	3				
Trifolium fragiferum	0.09	3	0.23	2		
Unidentified forb	0.03	5				
Xanthium strumarium					0.45	16

Table 8. Sparse Upper Herbaceous Vegetation zone summary table. Cov = average percent cover over 54 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Trees						
Elaeagnus angustifolia - seedling			0.04	14		
Elaeagnus angustifolia - yng regen			0.74	75	3.00	104
Shrubs						
Chrysothamnus nauseosus	1.35	93	0.42	61	1.22	55
Tamarix ramosissima - seedling	0.70	21				
Tamarix ramosissima- yng regen	0.74	60	1.39	113	0.37	110
Tamarix ramosissima - adv regen			1.31	203	1.57	190
Gutierrezia sarothrae	0.06	13	0.44	21	1.06	33
Graminoids						
Agrostis stolonifera					0.41	6
Bouteloua barbata	0.05	2	0.77	4		
Bouteloua gracilis	0.50	5	0.65	6		
Bromus catharticus			0.19	15	1.28	10
Bromus japonicus	0.00	2	0.22	11	1.19	8
Bromus tectorum			0.01	7	3.64	11
Cenchrus spinifex	0.35	5	0.08	9	0.19	6
Cynodon dactylon	0.30	2	0.35	3	0.19	3
Distichlis spicata	0.95	8	1.54	9	4.87	10
Echinochloa crus-galli	0.72	5				
Elymus elymoides			0.09	7		
Elymus repens					0.71	13
Eragrostis pectinacea	0.01	2	0.02	7		
Festuca arundinaceae	1.64	6	3.15	10	0.22	9
Hordeum murinum ssp. glaucum	0.00	7	0.21	5	1.44	7
Juncus arcticus var. balticus					0.19	13
Muhlenbergia asperifolia	1.13	7	4.17	12	0.37	11
Munroa squarrosa	0.00	1				
Pascopyrum smithii	0.11	7	0.04	13	0.09	13
Paspalum distichum	0.37	5				
Poa annua					0.24	4
Polypogon monspeliensis					0.35	6
Schoenoplectus pungens	0.28	12	0.72	12	0.48	21
Sporobolus cryptandrus	1.68	7	1.66	10	0.41	17
Unidentified grass	0.09	1	0.00	2		
Vulpia octoflora	0.01	2			1.80	5
Forbs						
Amaranthus hybridus	0.04	2	0.00	3		
Ambrosia acanthicarpa	1.20	7	7.46	13	1.04	7
Argentina anserina			0.31	3	0.28	4
Chamaesyce serpyllifolia	0.02	2	0.00	3		
Chamaesyce serrula	0.02	1				
Chenopodium incanum	0.02	5	0.06	6		
Conyza canadensis	0.24	9	2.45	25	0.80	10
Croton texensis			0.89	36		
Cryptantha minima	0.02	1	0.02	2	0.67	4
Dalea candida var. oligophylla			0.00	10		
Descurainia spp.					0.04	27
Euphorbia exstipulata	0.01	4	0.00	5		
Kallstroemia hirsutissima	0.03	1				
Kochia scoparia	1.67	5	5.11	11	0.57	4
Lactuca serriola					0.20	22
Machaeranthera pinnatifida	0.40	4	0.05	6	0.31	10
Melilotus officinalis			1.19	11	0.50	23
Mentzelia multiflora					0.02	7
Plantago patagonica					0.11	9
Polygonum aviculare	0.95	3	1.01	4	2.04	6
Portulaca oleracea	0.79	1	1.71	3		
Ratibida tagetes	0.43	11	1.00	16	1.62	19
Rumex crispus	0.19	8	0.19	7	0.06	13
Salsola tragus	0.30	7	3.75	14	0.02	5
Schkuhria multiflora			0.02	14		
Solanum elaeagnifolium			0.06	16		
Sphaeralcea coccinea			0.02	4		
Stephanomeria pauciflora			0.43	18	0.22	30
Taraxacum officinale	0.04	5	0.04	4		
Tribulus terrestris	1.58	2	0.41	4		
Trifolium fragiferum	0.19	4			0.20	3
Xanthium strumarium	1.24	8	4.02	25	2.74	19

The rarely flooded terraces were characterized by a Woody Riparian Zone dominated by either Russian olive (*Elaeagnus angustifolia*) or saltcedar (*Tamarix ramosissima*), and an Arroyo Riparian zone dominated by rubber rabbitbush (*Chrysothamnus nauseosus*). There are three subzones in the Woody Riparian. The Russian Olive Riparian Woodland subzone was characterized by dense monotypic stands of Russian olive with little or no understory vegetation (Table 9). In contrast, the Russian Olive/Rubber Rabbitbush (*Elaeagnus angustifolia/Chrysothamnus nauseosus*) Riparian Woodland subzone had an open canopy with a shrubby understory dominated by rubber rabbitbush and limited herbaceous cover (Table 10). The Saltcedar (*Tamarix ramosissima*) Riparian Shrubland subzone was characterized by dense monotypic stands of saltcedar, with minimal understory (Table 11).

The Rubber Rabbitbush (*Chrysothamnus nauseosus*) Riparian Shrubland is an arroyo riparian type present on terraces throughout the canyon (Table 12). This type occurs on dry sandy soils that are likely only wetted during very high flows, particularly summer flash floods. The introduced weedy-annuals cheatgrass (*Bromus tectorum*), smooth barley (*Hordeum murinum* spp. *glaucum*) and common kochia (*Kochia scoparia*) were common during wet years, in all of woody riparian zones, but particularly prevalent in the saltcedar and Russian olive subzones. Within the Arroyo riparian zone native rubber rabbitbush declined during the study period while overhanging Russian olive cover increased.

Trends in species diversity

A total of 102 plant species were identified along the transects during the three years of surveys (Appendix C). Russian olive and oneseed juniper were the only trees recorded on the transects, although widely scattered mature Rio Grande cottonwoods (*Populus deltoides* var. *wislizeni*) occurred in the reach. There were four shrubs; the native rubber rabbitbush, coyote willow (*Salix exigua*), and broom snakeweed (*Gutierrezia sarothrae)*, and exotic saltcedar (*Tamarix ramosissima*). Exotic Russian olive and saltcedar dominate the woody species in the reach (Figure 4a). The majority of the woody cover in the Herbaceous Wetland zone and the Upper Herbaceous zone came from over hanging Russian olives. The native coyote willow was almost completely absent from the reach, with only one seedling being recorded on transect 2 in 2003. There are a few small patches of coyote willow downstream of the study area.

From 2003 to 2005 overall graminoid diversity was moderate at 33 species, with natives outnumbering exotics (19 versus 13 species, respectively). However, in both the Herbaceous Wetland zone and the Upper Herbaceous zone the number of native species decreased slightly by 3 to 5 species per zone from 2003 to 2005 while the number of introduced species more than doubled, increasing by 11 to 17 species per zone over the three years (Figure 5a). In addition, exotic cover was higher than native cover in all years (Figure 4b). Most of this exotic cover was due to introduced European pasture grasses including creeping bentgrass (*Agrostis stolonifera*), tall fescue, and barnyardgrass (*Echinochloa crus-galli*). In contrast, the Woody Riparian and Arroyo Riparian zones are dominated by native upland grasses such as alkali sacaton

Table 9. Russian Olive Riparian Woodland vegetation zone summary table. Cov = average percent cover over 49 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Trees						
Elaeagnus angustifolia - adv regen	0.22	333	9.39	400	11.02	400
Elaeagnus angustifolia - mature	57.55	1000	72.96	959	66.22	1033
Juniperus monosperma - mature	5.41	400	5.61	400	5.61	400
Shrubs						
Chrysothamnus nauseosus	7.55	94	3.73	75	0.86	77
Gutierrezia sarothrae	0.00	7				
Graminoids						
Agrostis stolonifera	0.10	12	1.22	11	1.65	9
Bouteloua barbata	0.01	2				
Bromus japonicus			0.00	8		
Bromus tectorum	0.18	7	0.43	8	4.29	17
Carex praegracilis	0.93	6	0.80	13	1.14	13
Cyperus spp.	0.01	7				
Distichlis spicata	2.91	9	4.51	13	3.88	12
Echinochloa crus-galli	0.10	5				
Elymus elymoides			1.02	6		
Elymus repens					1.20	12
Eragrostis pectinacea	0.02	14				
Festuca arundinaceae	6.09	8	10.72	12	3.80	12
Hordeum jubatum ssp. intermedium			0.46	11	0.31	23
Hordeum murinum ssp. glaucum	0.11	6	0.33	9	11.09	12
Juncus arcticus var. balticus	0.10	20	0.02	40	0.24	53
Muhlenbergia asperifolia	5.17	9	8.42	13	5.71	16
Pascopyrum smithii	0.84	16	1.24	25	2.10	22
Poa annua	1.31	7	0.57	7	0.28	7
Polypogon monspeliensis					0.31	21
Schoenoplectus pungens	0.84	11	0.12	15	0.70	20
Sporobolus airoides	0.71	7	1.02	12	1.02	10
Sporobolus cryptandrus	2.73	12	2.37	17	0.04	11
Forbs						
Amaranthus hybridus	0.01	2	0.00	4		
Ambrosia acanthicarpa	1.27	10	2.14	16	0.06	10
Anemopsis californica	2.36	3	3.27	7	1.86	10
Argentina anserina	0.47	3	0.49	5	0.53	3
Chamaesyce serpyllifolia	0.01	2	0.01	1		
Chamaesyce serrula	0.00	1				
Chenopodium atrovirens			0.06	15		
Chenopodium incanum	0.02	4	0.51	20		
Cirsium vulgare	0.14	3			0.04	44
Conyza canadensis	0.03	4	0.02	31	0.45	18
Croton texensis	0.01	1				
Dalea candida var. oligophylla	0.04	8	0.51	17		
Equisetum laevigatum					0.00	
Grindelia nuda var. aphanactis	0.10	8				
Heterotheca villosa			0.24	13	0.00	6
Ipomoea spp.	0.06	4				
Ipomopsis longiflora	0.00	3				
Kochia scoparia	7.64	5	21.12	12	4.56	4
Lactuca serriola	0.02	9			0.08	19
Malva neglecta	0.00	3				
Mirabilis linearis			0.10	8		
Polygonum aviculare	0.83	7	0.67	10	0.25	9
Portulaca oleracea	0.15	2	0.02	3		
Rumex crispus	0.04	3	0.02	7		
Salsola tragus	0.02	8	0.18	15	0.10	6
Schkuhria multiflora	0.00	3				
Scorzonera laciniata	0.35	5				
Solanum elaeagnifolium	0.02	5				
Sonchus asper			0.04	1		
Taraxacum officinale	1.20	3	0.20	5		
Tribulus terrestris	0.03	4				
Trifolium fragiferum	0.08	4	0.23	3	0.24	3
Unidentified forb	0.00	3				
Xanthium strumarium	0.02	6	1.80	34	0.00	12

Table 10. Russian Olive/Rubber Rabbitbush Riparian Woodland vegetation zone summary table. Cov = average percent cover over 22 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Trees						
Elaeagnus angustifolia - yng regen	0.36	38	5.00	75	7.05	184
Elaeagnus angustifolia - mature	44.45	1120	37.95	1086	47.77	1000
Shrubs						
Chrysothamnus nauseosus	44.09	103.23	32.82	88.87	26.59	113.36
Graminoids						
Agrostis stolonifera	0.14	17	0.45	5	0.91	7
Bromus catharticus			0.00	2	0.09	5
Bromus tectorum					2.05	25
Distichlis spicata	1.64	7.28	5.00	13.55	1.36	12.33
Elymus elymoides			2.59	5.8		
Eragrostis pectinacea	0.01	2				
Festuca arundinaceae					0.23	10
Hordeum murinum ssp. glaucum	0.09	5			16.91	9.18
Muhlenbergia asperifolia	4.73	5.66	3.41	6.8	3.00	15.75
Pascopyrum smithii	0.05	26	0.14	29	0.50	34.33
Paspalum distichum	0.09	25	0.09	16	0.14	16
Schoenoplectus pungens	0.23	4	0.14	15	0.23	12
Sporobolus cryptandrus	0.98	14.28	0.68			
Forbs						
Amaranthus hybridus	0.16	2.8	0.00	0.1		
Ambrosia acanthicarpa			0.64	13.33	0.00	6
Chamaesyce serpyllifolia	0.03	1.33	0.18	2		
Chenopodium atrovirens			0.77	75		
Chenopodium incanum			0.09	6		
Cirsium vulgare					0.68	5
Conyza canadensis					0.45	6
Kochia scoparia	6.00	7.46	18.36	11.17	8.14	9.38
Polygonum aviculare	0.18	7.66	0.14	10.5	0.09	4
Polygonum persicaria	0.45	20				
Portulaca oleracea	0.31	2	0.07	1.66		
Schkuhria multiflora	0.05	5				
Sisyrinchium demissum			0.23	7	0.68	30.5
Taraxacum officinale	0.36	1	0.68	5	0.68	4
Tribulus terrestris	0.09	3				
Trifolium fragiferum	0.95	5	0.09	2		
Xanthium strumarium			2.27	50		

Table 11. Saltcedar Riparian Shrubland vegetation zone summary table. Cov = average percent cover over 9 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Shrubs						
Tamarix ramosissima- yng regen					0.89	70
Tamarix ramosissima - adv regen					8.89	200
Tamarix ramosissima - mature	80.00	800	91.11	800	90.00	800
Graminoids						
Bromus tectorum	3.89	9	8.00	8	33.33	6
Hordeum murinum ssp. glaucum			3.44	6	9.56	5
Muhlenbergia asperifolia			0.44	5		
Pascopyrum smithii	0.22	31	0.67	15	1.22	18
Sporobolus cryptandrus	2.68	12	3.33	13	1.61	12
Vulpia octoflora					0.44	4
Forbs						
Amaranthus hybridus	0.11	1	1.67	6		
Chamaesyce serpyllifolia	0.01	1	0.33	4		
Erodium cicutarium			1.72	3		
Malva neglecta			0.56	5		
Portulaca oleracea	0.01	1	2.78	4		

Table 12. Rubber Rabbitbush Riparian Shrubland vegetation zone summary table. Cov = average percent cover over 56 quadrats; Ht = average height across all quadrats in which species was observed.

	2003		2004		2005	
Scientific Name	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**	**Cov (%)**	**Ht (cm)**
Trees						
Elaeagnus angustifolia - yng regen	1.16	48	5.66	105	5.45	113
Elaeagnus angustifolia - mature	0.36	800	0.18	800	0.36	800
Shrubs						
Chrysothamnus nauseosus	37.45	83	36.93	81	27.60	88
Tamarix ramosissima - adv regen					2.68	200
Tamarix ramosissima - mature	2.86	300	9.64	425	8.75	500
Gutierrezia sarothrae	0.09	12	0.04	36		
Graminoids						
Agrostis stolonifera	0.36	5	0.84	9	0.66	10
Bouteloua barbata	0.01	2				
Bromus catharticus	0.01	11	0.18	12	0.02	30
Bromus japonicus	0.09	10			0.23	17
Bromus tectorum	0.79	9	1.74	13	17.89	15
Cenchrus spinifex	0.01	4	0.02	5		
Distichlis spicata	1.04	10	0.45	11	0.30	10
Eragrostis pectinacea	0.02	5	0.43	8		
Festuca arundinaceae	0.36	5	0.41	10	0.77	15
Hordeum murinum ssp. glaucum	0.00	7	0.26	5	2.66	11
Juncus arcticus var. balticus					0.01	34
Muhlenbergia asperifolia	1.15	7	2.84	11	2.50	15
Munroa squarrosa	0.00	1				
Pascopyrum smithii	0.88	19	1.29	25	3.35	27
Poa annua					0.04	27
Polypogon monspeliensis					0.27	6
Schoenoplectus pungens	0.11	6	0.05	15	0.09	28
Sporobolus cryptandrus	3.85	14	6.70	24	1.88	24
Vulpia octoflora	0.05	6			0.00	9
Forbs						
Amaranthus hybridus	0.76	3	0.04	5		
Ambrosia acanthicarpa	0.64	8	2.40	16	0.15	6
Boerhavia spicata			0.14	11		
Chamaesyce serpyllifolia	0.19	1	0.28	3		
Chamaesyce serrula			0.14	6		
Chenopodium incanum	0.02	8				
Conyza canadensis					0.09	18
Cucurbita foetidissima			0.09	16		
Dalea candida var. oligophylla			0.09	10		
Descurainia spp.					0.01	29
Equisetum laevigatum					0.01	10
Gaura parviflora	0.04				0.27	240
Grindelia nuda var. aphanactis	0.02	5	0.21	33	0.68	17
Kallstroemia hirsutissima			0.07	3		
Kochia scoparia	2.15	5	6.73	10		
Lactuca serriola					0.04	16
Machaeranthera pinnatifida	0.25	7	0.32	12	0.22	8
Melilotus officinalis	0.01	8			0.30	47
Plantago patagonica					0.02	13
Polygonum aviculare	0.13	7	0.18	9	0.02	17
Portulaca oleracea	0.26	1	0.33	4		
Salsola tragus	0.06	5	0.56	14		
Schkuhria multiflora			0.00			
Taraxacum officinale			0.02	3		
Tidestromia lanuginosa			0.04	7		
Tribulus terrestris	1.32	3	1.07	4		
Verbascum thapsus	0.27	13	0.27	90		
Xanthium strumarium	0.16	17	0.21	38		

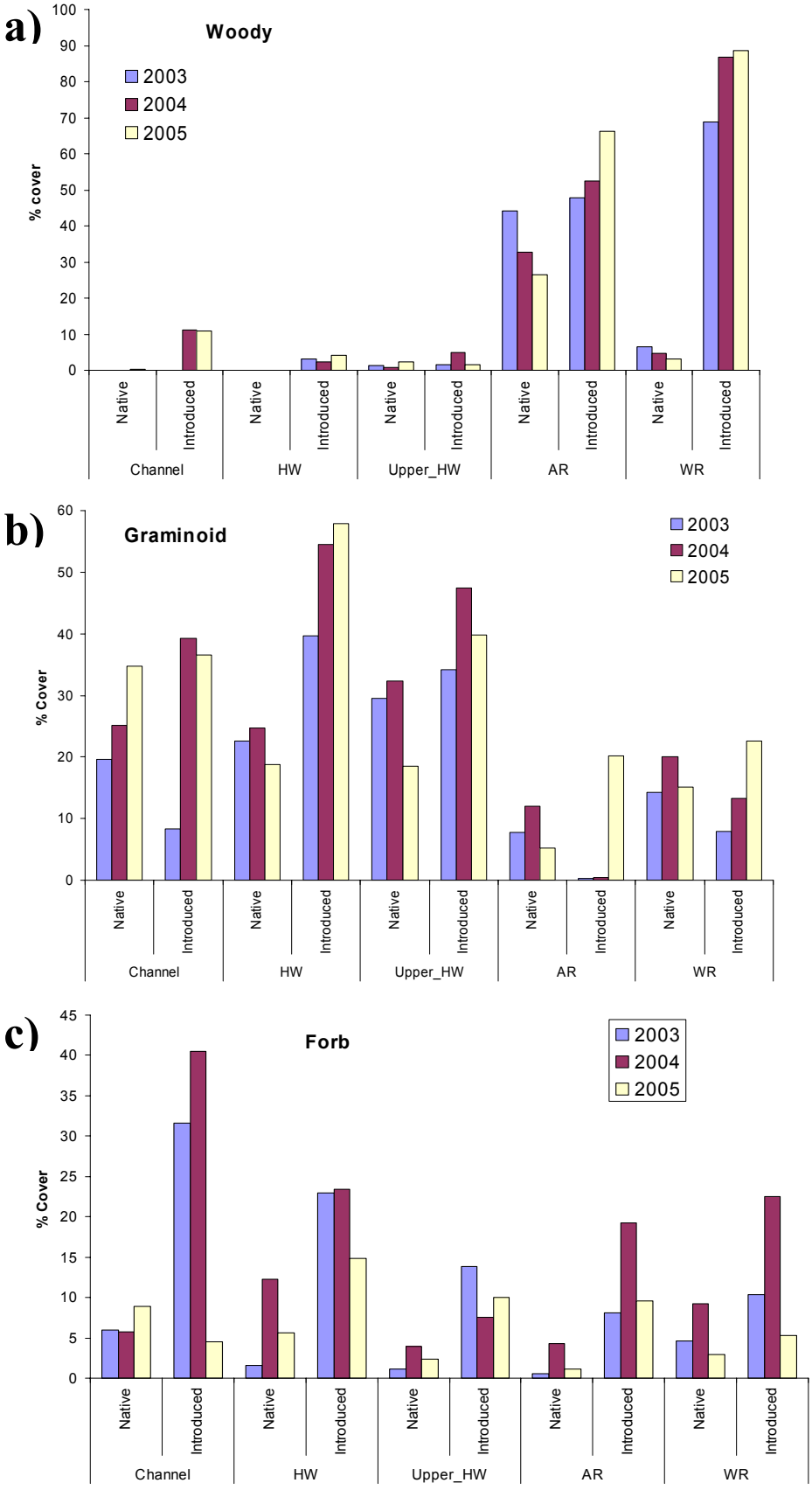

Figure 4. Average Woody (a), Graminoid (b), and Forb (c) cover by origin, year and vegetation zone.

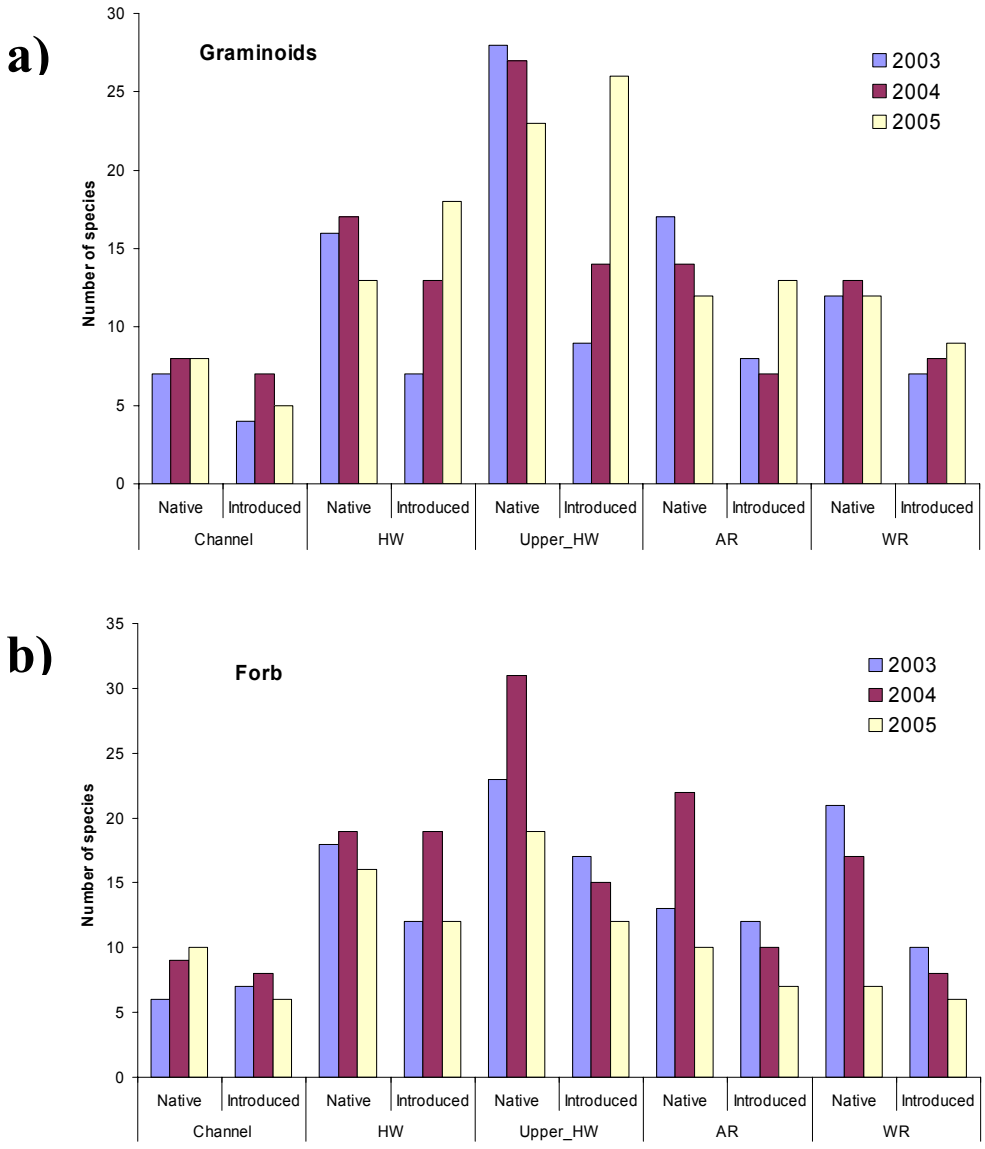

Figure 5. Species richness by origin and year for graminoids (a) and forbs (b) within each vegetation zone.

(*Sporobolus airoides*), sand dropseed (*Sporobolus cryptandrus*), and western wheatgrass (*Pascopyrum smithii*), along with alkali muhly, and inland saltgrass. However, in 2005, after a wet spring, the introduced annual grasses such as cheatgrass (*Bromus tectorum*) and smooth barley (*Hordeum murinum* ssp. *glaucum*) dominated the herbaceous cover in the Woody and Arroyo riparian zones.

With respect to forbs, 61 species were recorded over the three-year period with the majority (43) native (Figure 5b). While the number of native herbaceous species generally exceeded exotics, exotic herbaceous cover was clearly dominant in most zones (Figure 4c). For example, strawberry clover and watercress in the Herbaceous Wetland and Aquatic zones respectively, and kochia in the terrace zone (particularly prevalent in 2004).

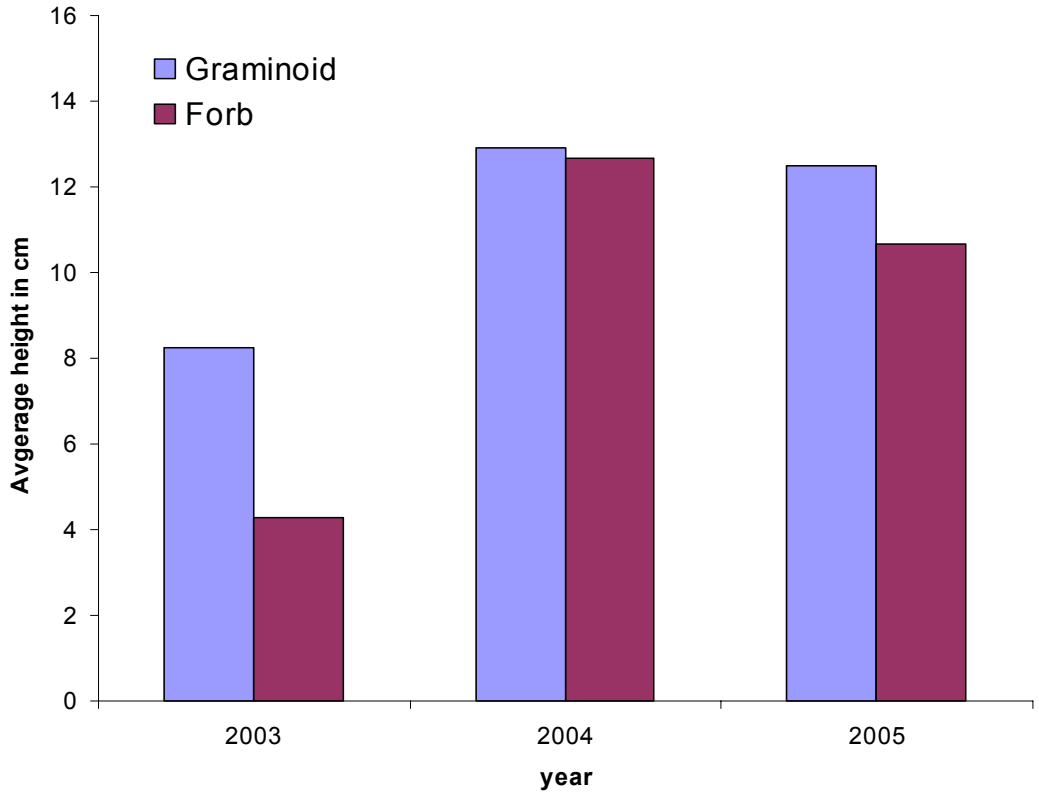

Figure 6. Average height of herbaceous vegetation by lifeform and year.

Utilization

In all vegetation zones the average height of herbaceous vegetation (grasses and forbs) was less than eight centimeters in 2003, likely reflecting the high livestock utilization throughout the reach during that year, but the severe drought of 2003 may have played a role directly (as well as indirectly as livestock gravitated to the riparian zone)(Figure 6). The average height of herbaceous vegetation increased to about 12 cm in 2004 and 2005 as precipitation increased to near normal and livestock use declined somewhat (the exact grazing level was not measured).. However, many of the grasses and forbs in these zones have the capacity to reach anywhere from 30 to 100 cm under normal moisture conditions. Hence, utilization is probably around 80% or more, and grazing is likely the most significant factor affecting standing crop biomass.

Discussion

In addition to the cropping by livestock, the large number and abundance of exotic herbaceous species may be driven by long-term grazing where natives are selectively removed and exotics brought in by the grazers. While factors in the success of Russian olive invasion of

southwestern riparian ecosystems are many, grazing likely plays a significant role, particularly through the removals of native tree and shrub reproduction.

With the removal of livestock in succeeding years we will have an opportunity to accurately gauge the response of the riparian system in the absence of intense grazing pressure. The sampling system that has been installed should allow the detection of subtle changes in species composition and abundance, major shifts in vegetation zones, and the restructuring of the floodplain. One expectation is that wetland and riparian vegetation zones will expand and enhance wildlife and fisheries habitat. Regardless, continued monitoring of this system is vital to establishing a good baseline of information on the current state of the system that will allow for clear and statistically defendable statements about change to support effective adaptive management.

Acknowledgements

We wish to thank Tara Plewa from the University of South Carolina for surveying the relative elevations along seven of the transects and sharing that elevation data with us. Rebecca Keeshen provided editorial assistance.

References

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Milford, E., E. Muldavin, Y. Chauvin, A. Browder and S. Sekscienski. Santa Fe River Riparian Vegetation Monitoring: Report 2003. Unpublished report submitted to: Taos Field Office, Bureau of Land Management.

SAS Institute Inc. The SAS system 8e for Windows, version 8.2. 1999-2001. Cary, NC, USA.

Appendix A

UTM coordinates for the end point rebar of all the transects.

UTM locations for transect end point rebars

Datum: NAD27 Zone: 13

Transect	Rebar #	Easting	Northing
03SF001	1	392051	3934550
03SF001	4	392073	3934538
03SF002	1	392302	3934572
03SF002	4	392286	3934558
03SF003	1	392643	3934534
03SF003	4	392662	3934518
03SF005	1	393083	3934587
03SF005	4	393102	3934574
03SF006	1	393524	3934969
03SF006	4	393532	3934941
03SF007	1	393711	3935125
03SF007	4	393739	3935123
03SF008	1	393982	3935310
03SF008	2b	393984	3935298
03SF008	3a	393981	3935293
03SF008	4	393979	3935275
03SF009	1	394340	3935302
03SF009	4	394339	3935279
03SF010	1	394674	3935447
03SF010	4	394688	3935437

Appendix B

Cross-section diagrams and site photos for transects in 2005.

Santa Fe River Monitoring 2005
Transect 03SF001

Figure 7: Transect 03SF001, 20m upstream of rebar 3 looking downstream, 2005.

Figure 8: Transect 03SF001, at 5m looking to 26m, 2005.

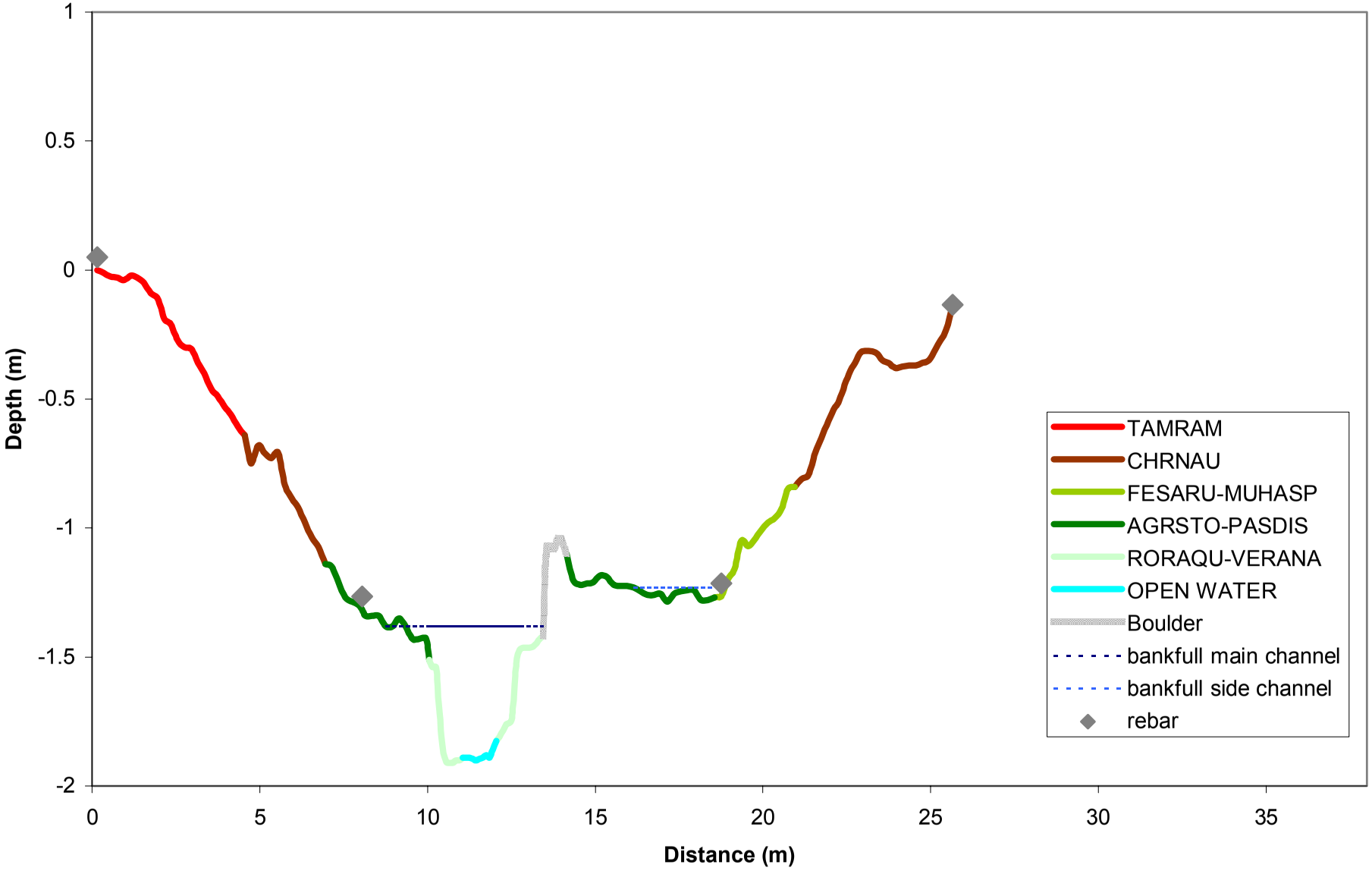

Figure 9: Cross-sectional diagram of transect 03SF001, from downstream looking upstream.

Santa Fe River Monitoring 2005
Transect 03SF002

Figure 10: Transect 03SF002, 25m upstream from 13m looking downstream, 2005.

Figure 11: Transect 03SF002, from 0m looking to 23.4m, 2005.

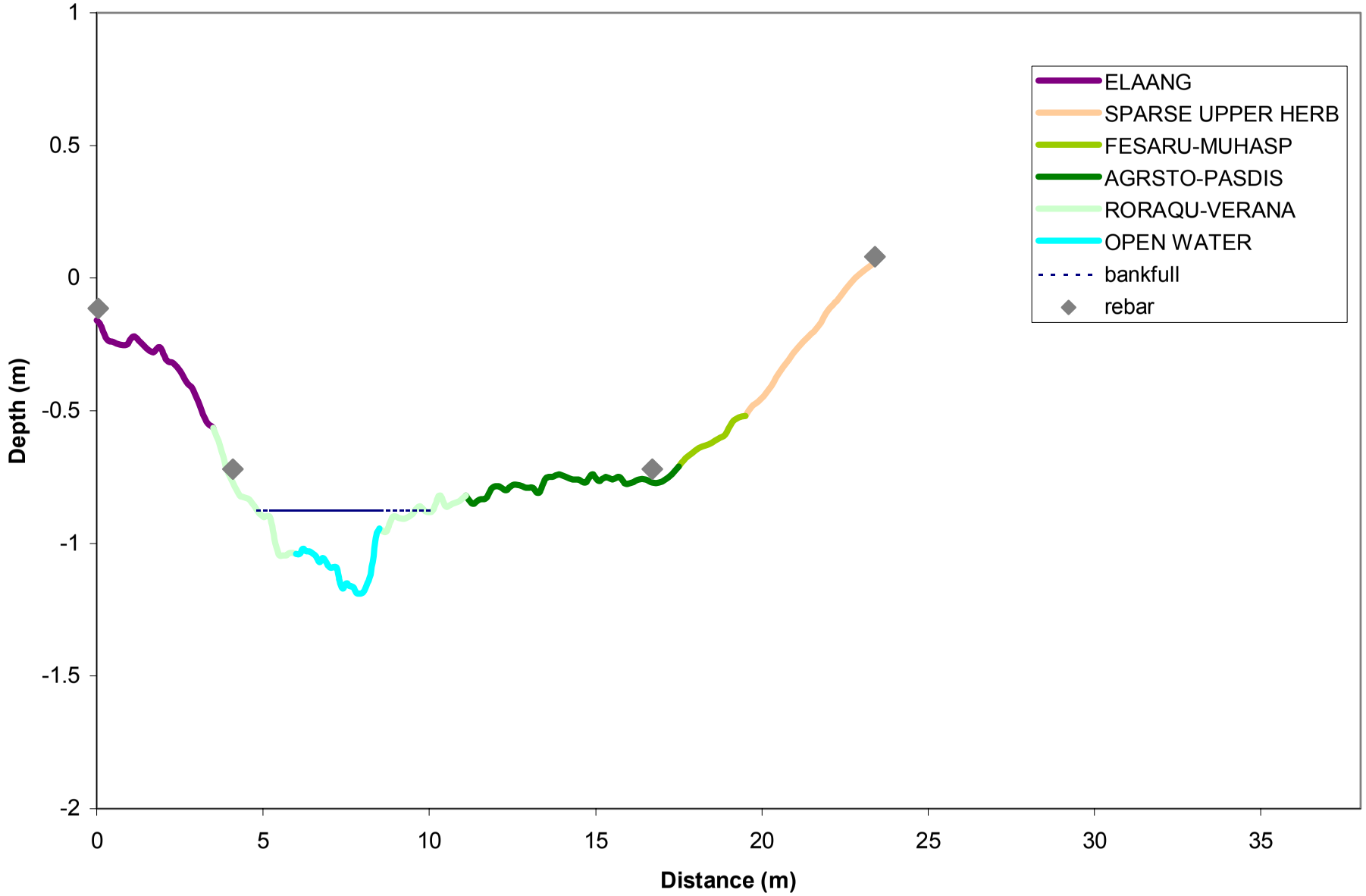

Figure 12: Cross-sectional diagram of transect 03SF002, from downstream looking upstream.

Santa Fe River Monitoring 2005
Transect 03SF003

Figure 13: Transect 03SF003, 20m upstream of rebar 3 looking downstream, 2005.

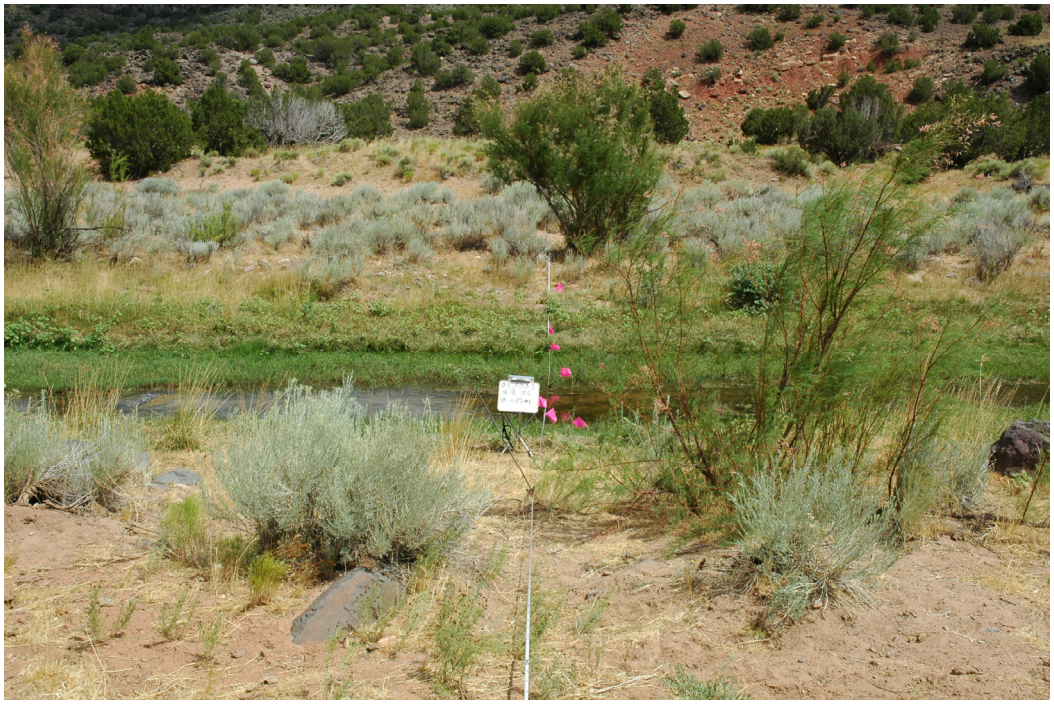

Figure 14: Transect 03SF003, from 0m looking to 25m, 2005.

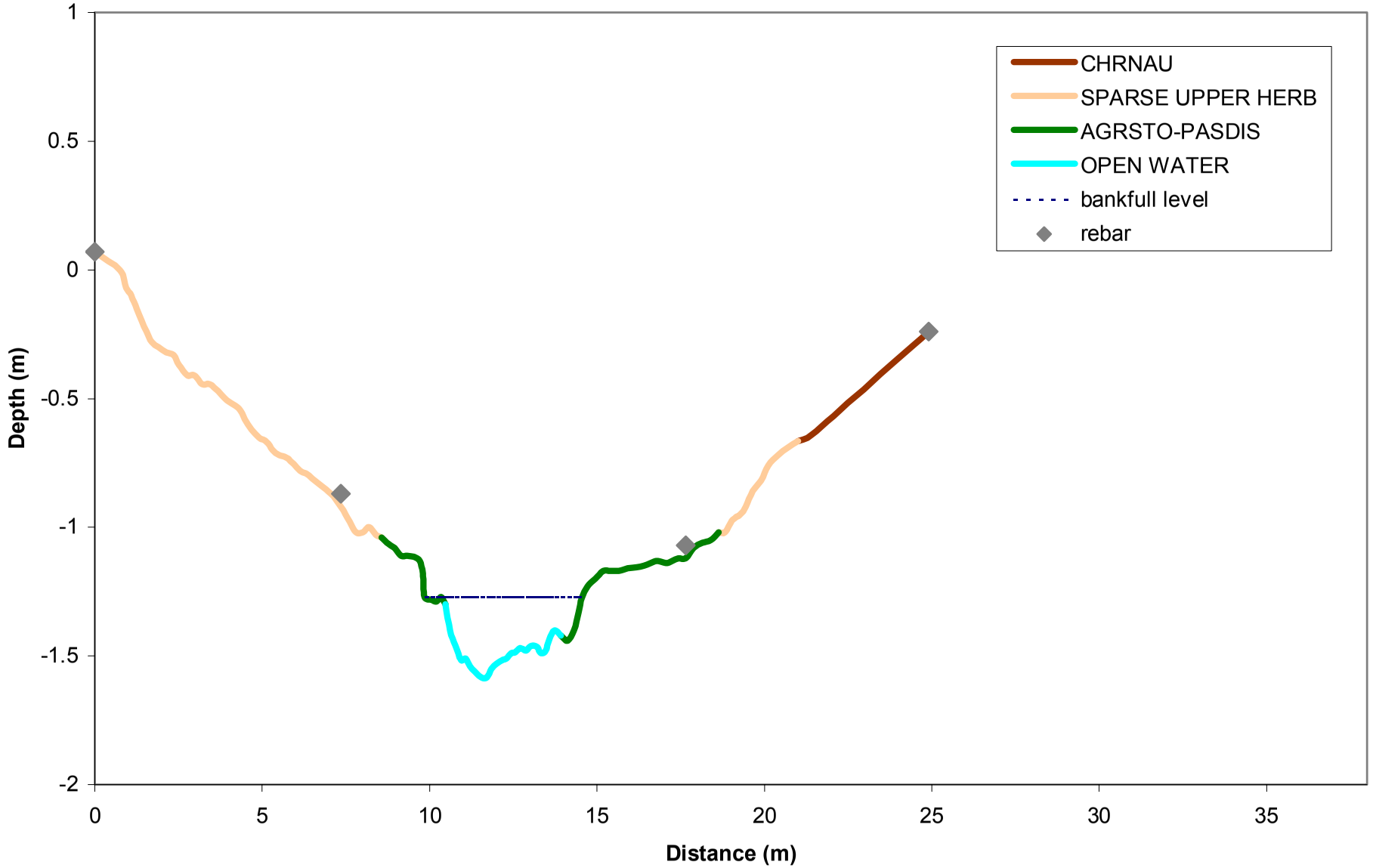

Figure 15: Cross-sectional diagram of transect 03SF003, from downstream looking upstream.

Santa Fe River Monitoring 2005
Transect 03SF005

Figure 16: Transect 03SF005, 25m upstream from 4m looking downstream, 2005.

Figure 17: Transect 03SF005, from 0m looking to 23.1m, 2005.

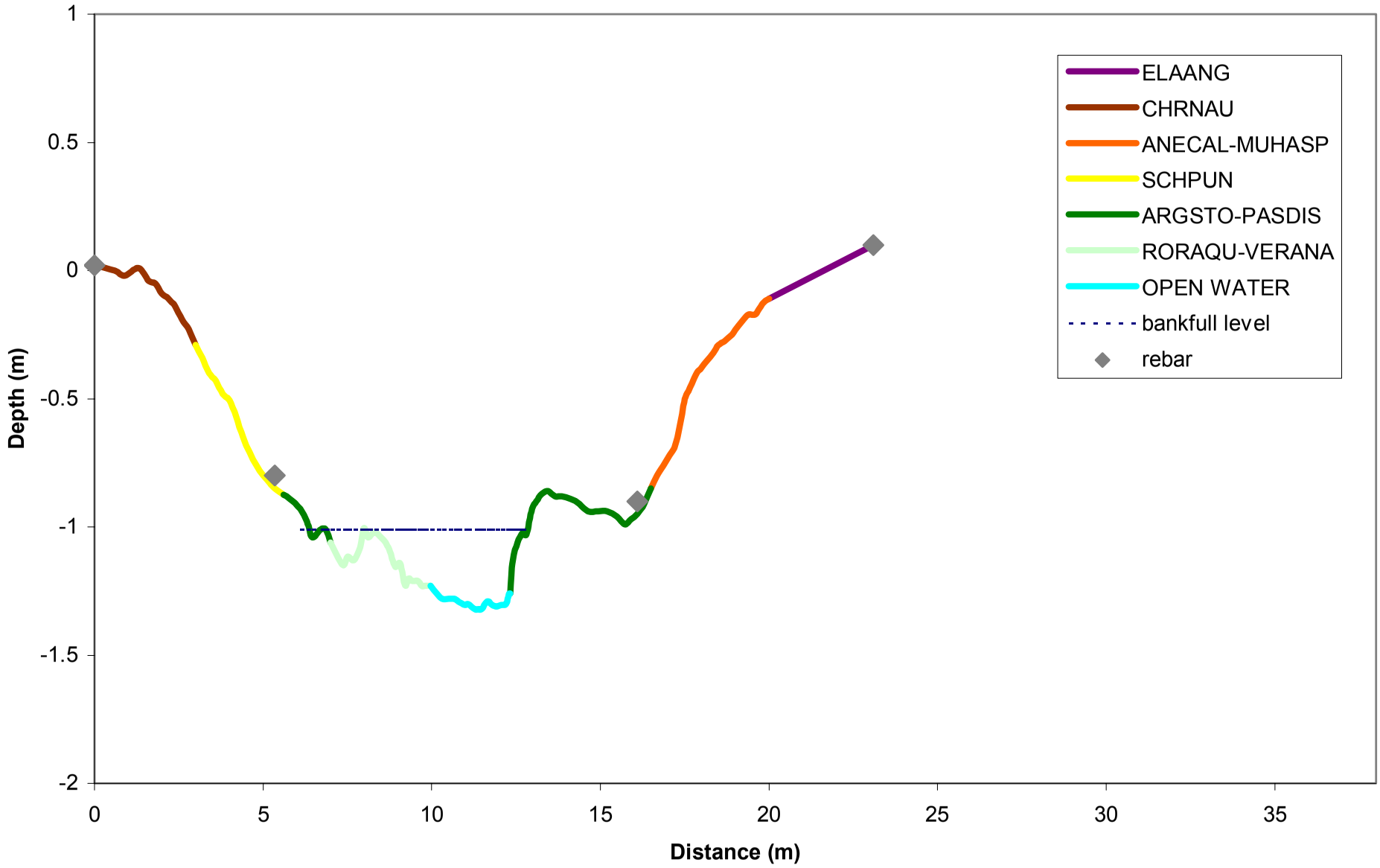

Figure 18: Cross-sectional diagram of transect 03SF005, from downstream looking upstream.

Santa Fe River Monitoring 2005
Transect 03SF006

Figure 19: Transect 03SF006, 25m upstream from 10.5m looking downstream, 2005.

Figure 20: Transect 03SF006, from 0m looking to 25.2m, 2005.

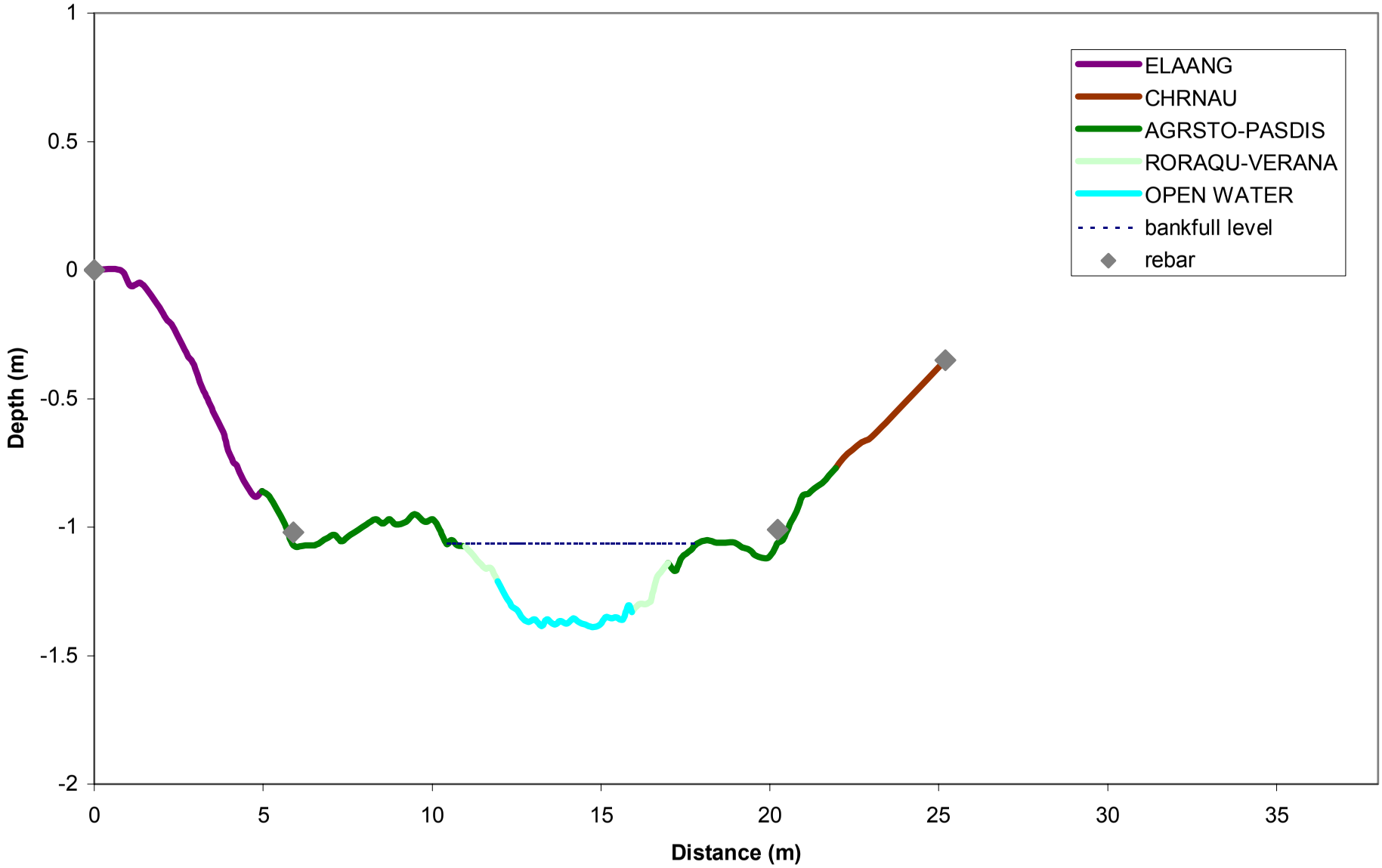

Figure 21: Cross-sectional diagram of transect 03SF006, from downstream looking upstream.

Santa Fe River Monitoring 2005
Transect 03SF007

Figure 22: Transect 03SF007, 20m upstream from rebar 3 looking downstream, 2005.

Figure 23: Transect 03SF007, from 2m looking to 28.3m, 2005.

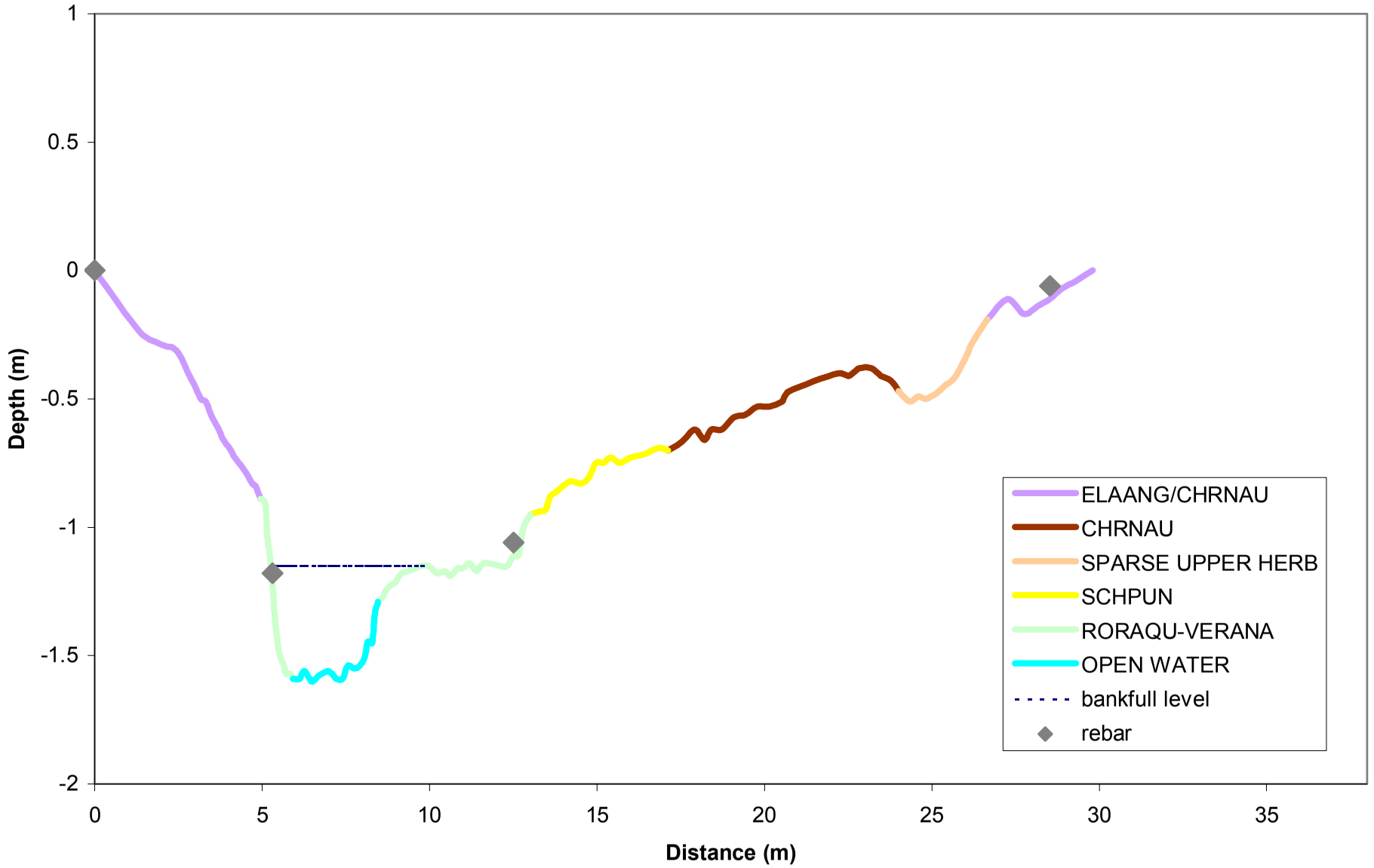

Figure 24: Cross-sectional diagram of transect 03SF007, from downstream looking upstream.

Santa Fe River Monitoring 2005
Transect 03SF008

Figure 25: Transect 03SF008, 41m upstream of rebar 3a looking downstream, 2005.

Figure 26: Transect 03SF008, from 0m looking to 38.2m, 2005.

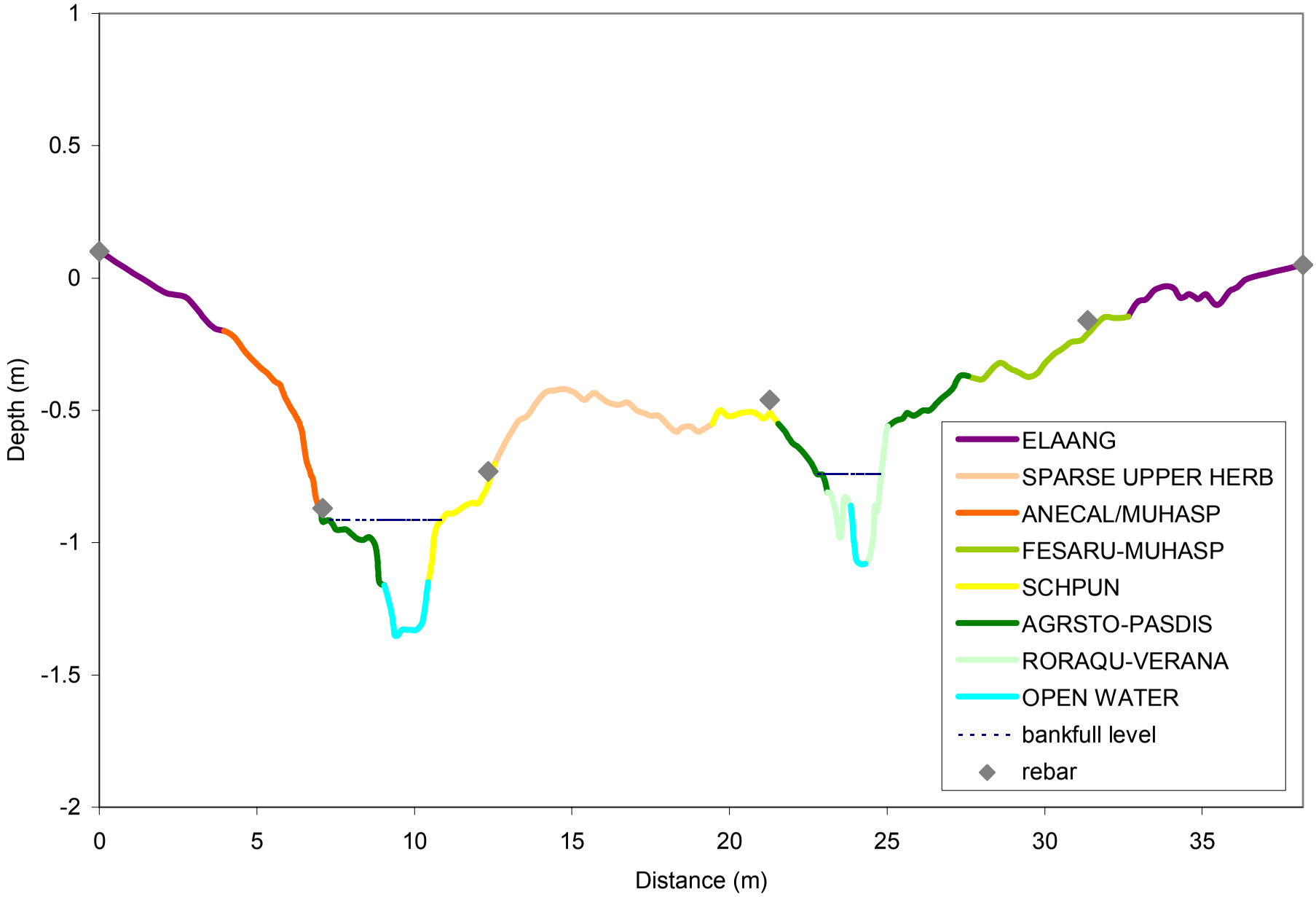

Figure 27: Cross-sectional diagram of transect 03SF008, from downstream looking upstream.

Santa Fe River Monitoring 2005
Transect 03SF009

Figure 28: Transect 03SF009, 20m upstream of rebar 2 looking downstream, 2005.

Figure 29: Transect 03SF009, from 2m looking to 28.4m, 2005.

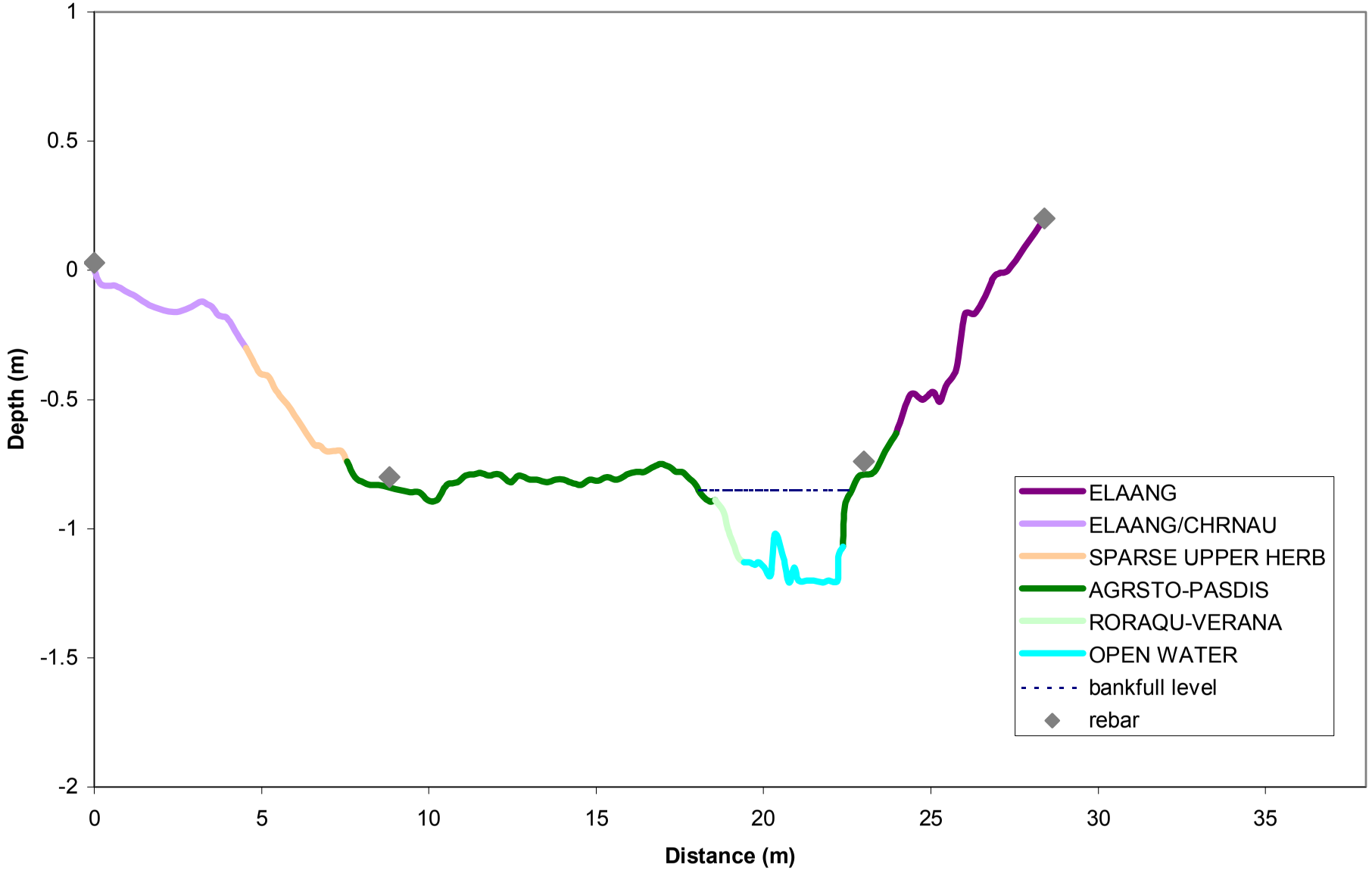

Figure 30: Cross-sectional diagram of transect 03SF009, from downstream looking upstream.

Santa Fe River Monitoring 2005
Transect 03SF010

Figure 31: Transect 03SF010, 20m upstream of 6m looking downstream, 2005.

Figure 32: Transect 03SF010, from 0m looking to 16.8m, 2005.

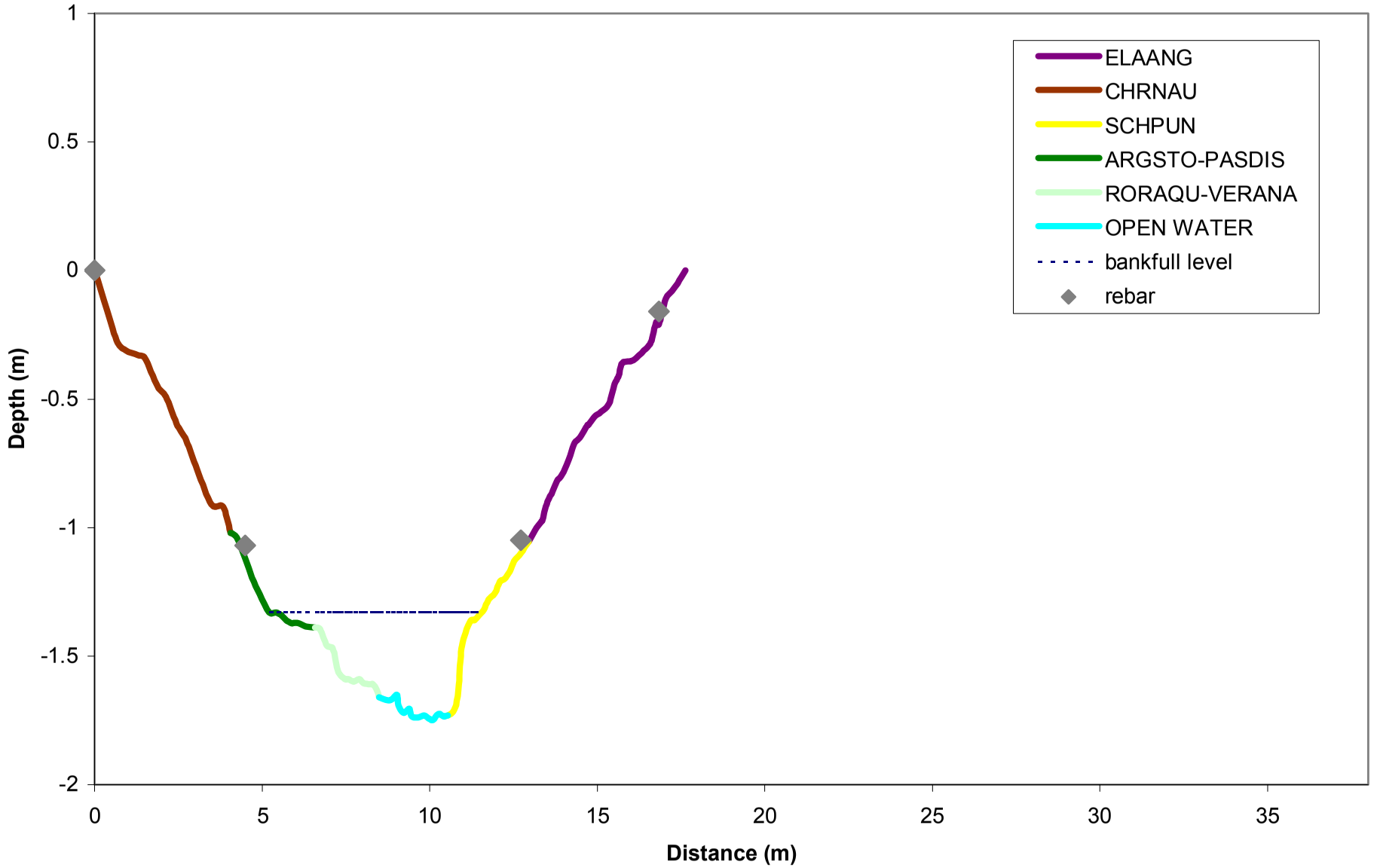

Figure 33: Cross-sectional diagram of transect 03SF010, from downstream looking upstream.

Appendix C

List of all species observed during Santa Fe River monitoring 2003-2005.

Scientific Name	Common Name	Origin	Wetland Status
Trees			
Elaeagnus angustifolia	Russian olive	Introduced	FACW-
Juniperus monosperma	oneseed juniper	Native	NI
Ulmus pumila	Siberian elm	Introduced	NI
Shrubs			
Chrysothamnus nauseosus	rubber rabbitbrush	Native	NI
Rhus trilobata	skunkbush sumac	Native	NI
Salix exigua	coyote willow	Native	OBL
Tamarix ramosissima	saltcedar	Introduced	NI
Sub-Shrubs			
Gutierrezia sarothrae	broom snakeweed	Native	NI
Graminoids			
Agrostis stolonifera	creeping bentgrass	Introduced	NI
Bouteloua barbata	sixweeks grama	Native	NI
Bouteloua gracilis	blue grama	Native	NI
Bromus catharticus	rescuegrass	Introduced	NI
Bromus japonicus	Japanese brome	Introduced	FACU
Bromus tectorum	cheatgrass	Introduced	NI
Carex praegracilis	clustered field sedge	Native	FACW+
Cenchrus spinifex	sandbur	Native	NI
Chloris verticillata	tumble windmill grass	Native	NI
Cynodon dactylon	bermudagrass	Introduced	FACU
Cyperus spp.	flatsedge		
Distichlis spicata	inland saltgrass	Native	FACW
Echinochloa crus-galli	barnyardgrass	Introduced	FACW-
Eleocharis palustris	common spikerush	Native	OBL
Elymus elymoides	bottlebrush squirreltail	Native	NI
Elymus repens	quackgrass	Introduced	FACU-
Eragrostis pectinacea	tufted lovegrass	Native	
Festuca arundinaceae	tall fescue or K-31	Introduced	NA
Hordeum jubatum ssp. intermedium	intermediate barley	Native	NI
Hordeum murinum ssp. glaucum	smooth barley	Introduced	
Juncus arcticus var. balticus	Baltic rush	Native	OBL
Muhlenbergia asperifolia	alkali muhly	Native	OBL
Munroa squarrosa	false buffalograss	Native	
Pascopyrum smithii	western wheatgrass	Native	NI
Paspalum distichum	knotgrass	Native	OBL
Poa annua	bluegrass	Introduced	
Poa compressa	Canada bluegrass	Introduced	FACU
Polypogon interruptus	ditch rabbitsfoot grass	Introduced	
Polypogon monspeliensis	annual rabbitsfoot grass	Introduced	FACW+
Schoenoplectus pungens	common threesquare	Native	OBL
Sporobolus airoides	alkali sacaton	Native	FAC
Sporobolus cryptandrus	sand dropseed	Native	FACU-
Vulpia octoflora	sixweeks fescue	Native	
Forbs			
Almutaster pauciflorus	alkali marsh aster	Native	FACW
Amaranthus hybridus	slim amaranth	Native	
Ambrosia acanthicarpa	flatspine burr ragweed	Native	
Anemopsis californica	yerba mansa	Native	OBL
Argentina anserina	silverweed cinquefoil	Native	OBL
Berula erecta	cutleaf waterparsnip	Native	OBL
Bidens cernua	nodding beggarstick	Introduced	OBL

Scientific Name	Common Name	Origin	Wetland Status
Forbs cont.			
Boerhavia spicata	creeping spiderling	Native	
Calibrachoa parviflora	seaside petunia	Native	FACW
Chamaesyce serpyllifolia	thymeleaf sandmat	Native	NI
Chamaesyce serrula	sawtooth sandmat	Native	
Chenopodium atrovirens	pinyon goosefoot	Native	
Chenopodium incanum	mealy goosefoot	Native	
Cirsium vulgare	bull thistle	Introduced	FACU
Conyza canadensis	Canadian horseweed	Native	FACU
Croton texensis	Texas croton	Native	NI
Cryptantha minima	little cryptantha	Native	
Cucurbita foetidissima	Missouri gourd	Native	NI
Dalea candida var. oligophylla	white prairieclover	Native	NI
Descurainia spp.	tansymustard		
Equisetum laevigatum	smooth horsetail	Native	FACW
Erodium cicutarium	redstem stork's bill	Introduced	NI
Euphorbia exstipulata	squareseed spurge	Native	
Gaura parviflora	velvetweed	Native	NI
Grindelia nuda var. aphanactis	curlytop gumweed	Native	
Heterotheca villosa	hairy goldenaster	Native	
Ipomoea spp.	morning glory	Native	
Ipomopsis longiflora	flaxflowered gilia	Native	NI
Kallstroemia hirsutissima	hairy caltrop	Native	
Kochia scoparia	common kochia	Introduced	FAC
Lactuca serriola	prickly lettuce	Introduced	FAC
Machaeranthera pinnatifida	lacy tansyaster	Native	
Malva neglecta	common mallow	Native	
Melilotus officinalis	yellow sweetclover	Introduced	FACU+
Mentzelia multiflora	manyflowered mentzelia	Native	
Mimulus glabratus	roundleaf monkeyflower	Native	
Mirabilis linearis	narrowleaf four o'clock	Native	
Plantago patagonica	woolly plantain	Native	NI
Polygonum aviculare	prostrate knotweed	Introduced	FACW
Polygonum persicaria	Lady's thumb	Introduced	FACW+
Portulaca oleracea	common purslane	Native	FAC
Ranunculus cardiophyllus	heartleaf buttercup	Native	OBL
Ranunculus cymbalaria	alkali buttercup	Native	OBL
Ratibida tagetes	green prairie coneflower	Native	NI
Rorippa nasturtium-aquaticum	watercress	Introduced	OBL
Rumex crispus	curly dock	Introduced	FACW
Salsola tragus	prickly Russian thistle	Introduced	
Schkuhria multiflora	manyflower false threadleaf	Native	
Scorzonera laciniata	cutleaf vipergrass	Introduced	
Sisyrinchium demissum	dwarf blue-eyed grass	Native	OBL
Solanum elaeagnifolium	silverleaf nightshade	Native	NI
Sonchus asper	spiny sowthistle	Introduced	NI
Sphaeralcea coccinea	scarlet globemallow	Native	NI
Stephanomeria pauciflora	brownplume wirelettuce	Native	
Taraxacum officinale	common dandelion	Introduced	FACU
Tidestromia lanuginosa	wooly tidestromia	Native	
Tribulus terrestris	puncturevine	Introduced	NI
Trifolium fragiferum	strawberry clover	Introduced	NI
Verbascum thapsus	common mullein	Introduced	NI
Veronica anagallis-aquatica	water speedwell	Native	OBL
Xanthium strumarium	rough cocklebur	Native	NI