Final Investigators Report
Stable isotope tracers of water use by riparian vegetation in Chaco Culture National Historical Park, NM

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Introduction:

Chaco Culture National Historical Park, first designated as Chaco Canyon National Monument on March 11, 1907, was established to preserve the significant archaeological features located in Chaco Canyon. In addition to the renowned "Chacoan greathouse" sites, nearly 4,000 archaeological sites have been recorded within the park boundary. Chaco Canyon is eroded into Cretaceous sandstone and shale outcrops exposed in the center of the San Juan Basin in northwestern New Mexico. Elevation within the park ranges from ~1800 to 2100 m, and the park encompasses three prominent land forms: (1) the alluvium-filled valley floor of Chaco Canyon, with its prominent drainage features; (2) expansive sandstone mesas, topped by slickrock outcrops and gently rolling hills; and, (3) a number of smaller side canyons (locally known as "rincons") eroded into the sandstone faces adjacent to the main canyon floor. The park is listed in the National Register of Historic Places, and was also designated a UNESCO World Heritage Site in 1987.

Although established primarily for its archaeological resources, the park encompasses an appreciable natural area within the San Juan Basin Region. The park is one of only two protected areas in the region, and as such could be considered an "island" of biodiversity which harbors plants and wildlife that are otherwise sensitive to grazing, mineral extraction, and other land-use activities. The native flora and fauna of Chaco Canyon and the surrounding San Juan Basin have been influenced by human activities reaching back in time to the Chacoan occupation over 1,100 years ago. The canyon then had centuries to recover from intensive prehistoric land-use activities. Anecdotal historic evidence, available vegetation histories, and fire chronologies suggest that, as recently as 200 years ago, the canyon was predominately a healthy grassland, with abundant pinyon & juniper woodland, and with more reliable springs and seeps.

Beginning in the mid-1800's, land-use activities again began altering the stability of vegetation and geomorphic surfaces. Livestock overgrazing seriously reduced grassland vegetation cover and topsoil, leading to the onset of catastrophic erosion within the park watershed in the early part of this century. During the last 140 years, an arroyo measuring 100 feet wide by as much as 30 feet deep formed along the entire reach of Chaco Wash within the canyon. A number of extensive erosion control projects were undertaken by the National Park Service between the 1930's and 1960's to prevent numerous archaeological sites from washing away. These efforts, in combination with fencing the park boundary in 1948 and improved range management practices enacted since the 1940's, have led to some recovery from erosion within the watershed, and the arroyo has filled in to only 15 feet deep at present. The shallow alluvial aquifer elevation underlying Chaco Wash continues to decline which may threaten native floodplain and riparian vegetation. This is a major concern to park managers because the condition of the Chaco Canyon watershed remains paramount to preserving the original canyon floor and the many thousand cultural sites it contains (Vincent et. al. in progress).

Riparian vegetation in the deserts of the Southwestern United States performs many valuable ecosystem services: providing wildlife habitat, stabilizing stream channels, preventing erosion, and improving water quality (Busch et al. 1992, Horton and Clark 2000, Horton et al. 2002). Native riparian forests in the southwest, typically dominated by *Populus fremontii*, have declined. Anthropogenic alterations of hydrologic processes have been suggested as the primary cause for this decline (Busch et al. 1992, Horton et al. 2002). The exotics *Tamarix ramosissima* and *Tamarix chinensis* now dominate many riparian ecosystems in the Western United States, threatening the biological integrity of many areas (Lesica and Miles 2004). *Tamarix* alters both ecosystem and hydrologic processes (Busch et al. 1992).

While both *Populus* and *Tamarix* have been termed phreatophytes, *Populus* species are obligate phreatophytes, with limited capacity to draw water from sources other than groundwater, and *Tamarix* has been identified as a facultative phreatophyte, able to draw water from unsaturated soil (Busch et al. 1992, Horton et al. 2002). Declining water tables are responsible for physiological stress and even death of phreatophytes. Because they are less able to utilize soil water, *Populus* are more susceptible to stress. Conversely, *Tamarix* are less prone to stress because of their ability to extract soil water (Busch et al. 1992, Horton et al. 2002).

The ability to extract soil water can be quantified using plant water potential measurements. Water potential is defined as the free energy of water in a substance, in relation to the free energy of pure water (Barbour et al. 1987). Many things can be inferred from plant water potential measurements such as susceptibility to cavitations or internal solute concentration, which ultimately determine the ability of a plant to extract soil water. Water potential has been shown to vary significantly within and among species and is driven primarily by water availability (Koide et al. 1989). Such variability has been demonstrated in *Tamarix*, which is able to maintain relatively low water potentials (likely a result of high internal solute concentrations). The ability to maintain low water potentials allows for *Tamarix* to extract soil water from relatively dry soils (Greis et al. 2003). Cottonwood, on the other hand, is susceptible to cavitation at high (negative) water potentials, and crown dieback has been documented when predawn water potential falls below -0.8 MPa (Cooper et al. 2003).

Naturally occurring stable isotopes of hydrogen (deuterium) have been utilized to determine the environmental water sources of vegetation (Busch et al. 1992, Dawson and Ehleringer 1998, Horton et al. 2002). It has been determined that isotopic fractionation in suberized stems is limited. Isotopic analysis of stem water and environmental water sources allows for tracing sources of plant water use (Dawson and Ehleringer 1998).

The goals of this research are to identify the water sources, and how they change during the growing season, for five xeric and riparian species, cottonwood, (*P. fremontii*), tamarisk (*Tamarix chinensis*), greasewood (*Sarcobatus vermiculatus*), rabbit brush (*Ericameria nauseosa var. glabrata*), and big sagebrush (*Artemisia tridentata*). Primary methods include analysis of stable isotopes of hydrogen and field water potential measurements. From these, potential competitive interactions among riparian species will be identified. It was hypothesized that cottonwood and tamarisk will have similar isotopic signatures, suggesting that both are utilizing similar water sources, at least during part of the growing season. Similarly, cottonwood and tamarisk may have isotopic signatures similar to alluvial groundwater, indicating ground water is the primary water source of these species. It was also hypothesized that cottonwood will have higher water potential than tamarisk indicating increased dependence on alluvial groundwater by cottonwood.

Specific objectives as identified in the Scope of Work include Objective 1: Determine the contribution of summer and winter precipitation and stream flow to groundwater recharge. Objective 2: Identify water sources and competitive interactions of specific plant species located within riparian areas and how they change over the growing season. Objective 3: Apply an isotopic mass balance approach to estimate the proportions of alluvial groundwater and unsaturated soil water used by different plant species. Objective 4: Develop a groundwater management strategy to minimize aquifer drawdown and spread of tamarisk while protecting archeological resources. Objective 5: Prepare a progress report for fiscal year 2005 and a final report in 2006.

Methods:

Study Area

This study was conducted during the growing seasons of 2004 and 2005 at Chaco Culture National Historical Park (CCNHP) in northeast New Mexico (Figure 1; map provided by Brad Shattuck). A preliminary sampling trip occurred in May, 2003. Mean annual precipitation is 22.5 cm and mean annual air temperature is 19.5°C (National Climatic Data Center, Station 291647; URL: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?nmchac). Sampling was conducted in or adjacent to Chaco Wash, an ephemeral stream with flowing or standing water present only after large precipitation events. Ongoing groundwater monitoring has been conducted at the following wells: Historic Masonry Wells (HM), Shabikaschee Wells (SH), Casa Chiquita Wells (CC) and Fajada View Wells (FV) (Figure 1). Three wells were present at each site located within the wash while two wells were present at the Fajada View site located out of the wash. The Global Positioning System (GPS) was used to determine exact well-head locations with a GeoExplorer3 receiver referenced to NAD83 (Table 1).

Four plant sampling sites were established close to the well locations. At the three sites located in Chaco Wash (CC, HM and SH), 3 individuals of cottonwood, greasewood, rabbit brush, sagebrush and tamarisk were selected. At FV, on a stream terrace above the floodplain level, greasewood was the only shrub species present, and therefore the only species sampled. Individuals were marked and re-sampled for each growing season of the study. An additional deep sediment core (to 7m depth) was augered by hand in the streambed near Pueblo Del Arroyo ruin for water sampling in May, 2003. Soils were classified as coarse-loamy, mixed, superactive, calcareous, mesic Typic Torrifluvents in the Yelives fine sandy loam series (Soil Survey Staff, 2002).

Field Sampling

Plant, soil, and groundwater samples were collected for isotope analysis on six occasions, in June, July, and August of 2004, and in June, August and September of 2005. Sampling was limited to the summer season because this is the time of active plant water uptake and (approximately) steady-state transpiration during daytime. Winter sampling was not attempted because the plant xylem water would not reflect the source water isotopic composition, rather it would slowly evaporate and thus become isotopically enriched. At each site, a suberized section of stem was removed. The phloem, cambium, and bark were removed and the stem section was then placed in a scintillation vial and sealed with parafilm. Soils were sampled from a soil pit or by augering at a central location at each site during each sampling period. Soil was sampled at 20, 40, 60, and 80-cm depths in 2004, and down to 180-200 cm in 2005, placed in a scintillation vial and sealed with parafilm. Soil and stem samples were then frozen. Well depth was measured at each of the wells using a Solinist water level recorder from the top of the PVC casing to the water level (0.01 ft accuracy). Well water was collected from the middle well at each site during each sampling period. Well water samples were stored at 4°C. Shoot water potential of each individual at the Historic Masonry Well (HM) site was measured at predawn and midday using a Scholander-type pressure chamber (PMS Instruments). Precipitation samples were collected throughout the year, after each precipitation event, at a rain gauge located at the visitor center as well as at various locations when standing or flowing water was present. However, several winter precipitation samples were inadvertently lost or not collected.

Laboratory Procedures

Water was extracted from plant stems and soil using cryogenic vacuum distillation. Extracted water was then stored at 4°C. Water samples were prepared using the zinc reduction method (Coleman, 1982). The samples were then analyzed for hydrogen isotopes on a Micromass Optima duel inlet mass spectrometer. Hawaiian Spring Water and GLEES standards were used to normalize δD values. Precision of analyses was ± 1.9‰ based on replicate standards. Raw data from all isotopic analyses are provided in the Appendices at the end of the report. Soil water content was measured gravimetrically for each set of samples. Soil moisture release curves were developed on a subset of samples using a dew-point hygrometer system (WP4, Decagon Devices, Pullman, Washington), and soil water potential values were estimated for each sample from a power function fit to the moisture release data.

Data Analysis

Raw hydrogen isotope values from the mass spectrometer were corrected using two known standards and a linear relationship (Mark Larson, personal communication, 2004). All data were analyzed using SAS (v. 9.1). Repeated measures ANOVA (Mixed Procedure) were used to test differences in the mean plant water potential for species, site, time and species-time interactions, as well as xylem δD for species, site, species-site, and species-site-time interactions. Factorial ANOVA (GLM Procedure) were used to test differences in the plant water potential and xylem water δD values for species, site, and species-site interactions. Post-hoc means separations were adjusted using Tukey's groupings.

Results:

Precipitation, Groundwater and Runoff

The two study years received just below the average amount of precipitation, with 194 mm falling in 2004 and 219 in 2005. However, the seasonal patterns of rainfall were different. Nearly 60 mm of rain fell in April, 2004, but after that the growing season was quite dry, whereas no rain fell in April, 2005 (Figure 2). The growing season (June through August) of 2005 received about 60 mm of rain, more than twice as much as in 2004 (25 mm). These contrasts in moisture supply allow us to evaluate the effects of summer rain on plant water use.

Rain from several individual precipitation events was analyzed for hydrogen isotopic composition (δD value) (Figure 3). Precipitation received in January to March, 2004, had lower δD values than that received during the growing season, which is a typical pattern. The pre-monsoon drought was more apparent during May-June, 2004 than in 2005, and the monsoon rains were sparse in 2004. Precipitation δD values had similar ranges in early and late growing seasons in both years (Figure 3). All precipitation isotope and amount data are presented in Appendix 1.

The δD value of precipitation was weighted by the amount of each rainstorm for each month with available samples (Figure 4). This gives an indication of the influence of the precipitation on groundwater; for example, a trace of rain will not count as much toward the weighted average δD as a large thunderstorm. Groundwater collected from all wells was averaged for each month of the study period for comparison. It can be seen that the δD of groundwater is intermediate between summer and winter precipitation, and that it does not change much over the growing season. It is likely that the groundwater remains near -80‰ for much of the year (Figure 4). Detailed groundwater isotopic composition data are presented in Appendix 2, and well level readings are presented in Appendix 3.

Three runoff events were sampled and analyzed in 2004, with mean δD values of -76.4‰ on 3 April 2004, -32.2‰ on 18 July 2004, and -84.8‰ on 26 July 2004. Runoff events were collected only sporadically in 2005 and samples were not analyzed for isotopic composition.

Gravimetric water content of the sandy alluvial soils in CCNHP was always very low (≤11 %), and water potential was frequently too low to be used by plants (≤-6 MPa; Appendix 4). The isotopic composition of soil water varied with depth, time and site (Figures 5-10). In general, deeper soil water was isotopically similar to groundwater, except for at CC in August 2004 (Figure 7). We expected the upper soil water to be isotopically similar to precipitation, but this was not generally the rule. In July, 2004 and June, 2005, soil water δD values were much lower than recent precipitation, probably because the rainfall did not infiltrate sufficiently to alter the soil water (Figures 6 and 8). By August of those years, the upper soil water was more similar to precipitation (Figures 7 and 9).

Xylem Water Isotopic Composition

Stable hydrogen isotope values for stem xylem water (“sap”) varied significantly among sites and species in both 2004 and 2005, and by time (sampling date) in 2005 (Table 1). Significant interactions among almost all the fixed effects were observed, indicating complex and somewhat inconsistent patterns in δD values for the different species. Sap δD values ranged from about –70 to –90‰ in 2004 and 2005 (Figures 5-10 and Table 2). On most sampling dates, there were significant differences in δD values among sites and species (Table 2). The CC site tended to have highest sap δD values, and FV and HM had relatively lower values. Cottonwood sap was different than tamarisk sap on 4 of the 6 sampling dates, and was in general more similar to sap of the other species. Surprisingly, cottonwood sap was not different from that of greasewood on 5 of the 6 dates (Table 2). Species were most similar to each other in July, 2004, and August, 2005. However, in August, 2005, an accident occurred during transport of the samples back to the laboratory, and several samples were lost, preventing a full comparison among sites and species (Table 2).

Plant Water Potential

Several significant differences were found in plant water potential among riparian species that will help distinguish depth of water use by the species of interest (Table 3). Low (more negative) values indicate more drought stress or ability to remove water from drier soil, and higher values (closer to zero) indicate less drought stress. Water potential was always higher at predawn than at mid-day because plants were less water stressed in early morning. Predawn and mid-day water potential in cottonwood was always higher than other species, reflecting its reliance on adequate soil or groundwater, and was significantly different from tamarisk on all but two occasions (June 2004 mid-day and June 2005 predawn). Greasewood and sagebrush had consistently the lowest water potentials, reflecting their drought-tolerance. Rabbitbrush and tamarisk always had similar water potential (Table 3).

Estimating Depth of Water Use

Stable isotope values and water potential status can be compared graphically to qualitatively estimate the depth of water use by the different species. In June, 2004, cottonwood and greasewood tended to have the lowest δD values, most similar to deep soil water (≥80-cm depth) and groundwater at all sites (Figure 5). Rabbitbrush, sagebrush and tamarisk all had higher δD values, suggesting use of shallower soil water (≤20-cm depth), although at CC sagebrush and tamarisk were outside the measured source water values. Soil water potential in June, 2004, at the SH site were all too low for plant water use, suggesting that plants were acquiring water from unmeasured sources (Appendix 4). In July, 2004, all species at all sites could have been using water from any depth measured (Figure 6), except that at SH the soil water potential was again too low for plant water use (Appendix 4). At CC and HM, soil water potential was high enough for plant water use. In August, 2004, at CC all species were likely using deep soil moisture or ground water, because soil water potential was too low in the upper profile (Figure 7 and Appendix 4). At HM, all species were likely using moisture from the middle soil profile, and at SH, cottonwood, rabbitbrush and sagebrush appeared to be using shallow soil moisture, and greasewood and tamarisk deep soil moisture (Figure 7). However, soil water potential at SH remained very low in August, 2004.

In June, 2005, at CC, cottonwood and rabbitbrush were probably using shallow soil water, while greasewood, sagebrush and tamarisk were likely using deeper soil water (Figure 8). At HM, all species appeared to be using shallow soil water, but soil water potential at 20-cm depth was too low for plant water use. At SH, cottonwood xylem sap was lower than measured source water, but the other species were likely using deep soil water, because shallow soil water potential was too low for plant water use (Figure 8). In August, 2005, at CC and HM sites all species were probably using water from the middle of the soil profile (~40-80 cm). At SH, cottonwood, rabbitbrush and tamarisk were likely using deep soil water or groundwater (Figure 9). In September, 2005, at CC, cottonwood and tamarisk may have been using very shallow soil water (≤20-cm), similar to precipitation, because soil water potential in the deeper soil was too low (Figure 10 and Appendix 4). At HM, tamarisk xylem sap was lower than measured source water, but the other species were likely using water from the middle of the soil profile. At SH, cottonwood and rabbitbrush were likely using water from the middle of the profile, while greasewood, sagebrush and tamarisk were likely using deep soil water or ground water (Figure 10).

Discussion:

Plant Competition for Water

We can qualitatively estimate competitive relations among species living in close proximity on stream terraces in the Chaco Canyon, NM, area using stable isotopes and plant water potential data collected in the growing seasons of 2004 and 2005. The 2004 season was drier than the 2005 season, especially in mid- to late-summer, leading to differences in plant water relations over the growing seasons. However, when the data for all six sampling dates are combined, some patterns emerged. Cottonwood and tamarisk δD values were significantly different in early and late growing seasons, but they were not different in mid-summer (Table 2). This suggests that more competition between cottonwood and tamarisk occurs during the pre-monsoon drought, after spring moisture is depleted. Predawn water potential indicates that water stress was greatest in early August, 2005, during the time of greatest overlap of δD values and probably greatest competition for limited water. Following this, precipitation events likely alleviated water stress in 2005. Cottonwood xylem sap δD were consistently distinct from tamarisk, sagebrush and rabbitbrush in early summer of both years, suggesting less competition for water in general at that time.

The CCNHP study area is hydrologically complex, with variations among all the sites studied. In general, the SH site had lowest soil water content and water potential, possibly reflecting its position furthest upstream (Figure 1). Cottonwood trees at this site appeared to have the most die-back, although this was not quantified. The Fajada View wells silted in during the study, making continued sampling impossible. Because only greasewood was collected at this site, it was not included in the statistical analysis.

Progress on Objectives

Progress on the specific objectives as identified in the Scope of Work has been made as follows: Objective 1: Determine the contribution of summer and winter precipitation and stream flow to groundwater recharge. This objective was not entirely met because CCNHP personnel were not able to collect a full complement of precipitation samples. The contribution of precipitation to groundwater was estimated from the available precipitation samples collected between January and September. Stream flow events were likewise sampled somewhat sporadically, preventing a full analysis. Objective 2: Identification of water sources of specific plant species located within riparian areas and how they change over the growing season has been accomplished for the 2004 and 2005 growing seasons. We increased the number and depth of soil samples for water extraction, improving our confidence in plant water use below 80-cm depth. We developed an extensive suite of soil moisture characteristic curves, enabling us to calculate soil water potentials for all samples. This allowed more direct comparison with plant water potentials, improving our ability to estimate competition and water sources. Objective 3: An isotopic mass balance approach was used in 2004 to estimate the proportion of alluvial groundwater and water from the unsaturated soil above the water table is used by plant species. Because it was clear that plants were accessing water from more than two sources, we plan to implement a modeling approach, incorporating both isotope and water potential measurements, for more accurate estimation of water sources. Objective 4: A groundwater management strategy will be developed by Brad Shattuck, CCNHP. Future work will be conducted to complete this objective with the goals of minimizing aquifer drawdown and spread of tamarisk while protecting archeological resources. Objective 5: This report constitutes the final report for the project.

Acknowledgements:
This study was made possible by financial support from the National Park Service Colorado Plateau Cooperative Ecosystem Studies Unit. We are grateful to Brad Shattuck for overall project support, Kirk Vincent for introducing us to the hydrologic and geomorphic context of the study area, to Coy Miller for field assistance and to Joanne Newcomb for laboratory assistance.

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Figure 1. Map of site locations, prepared by Brad Shattuck, CCNHP. (Following page).

Isotope Sample Sites Chaco Culture NHP

National Park Service
U.S. Department of the Interior

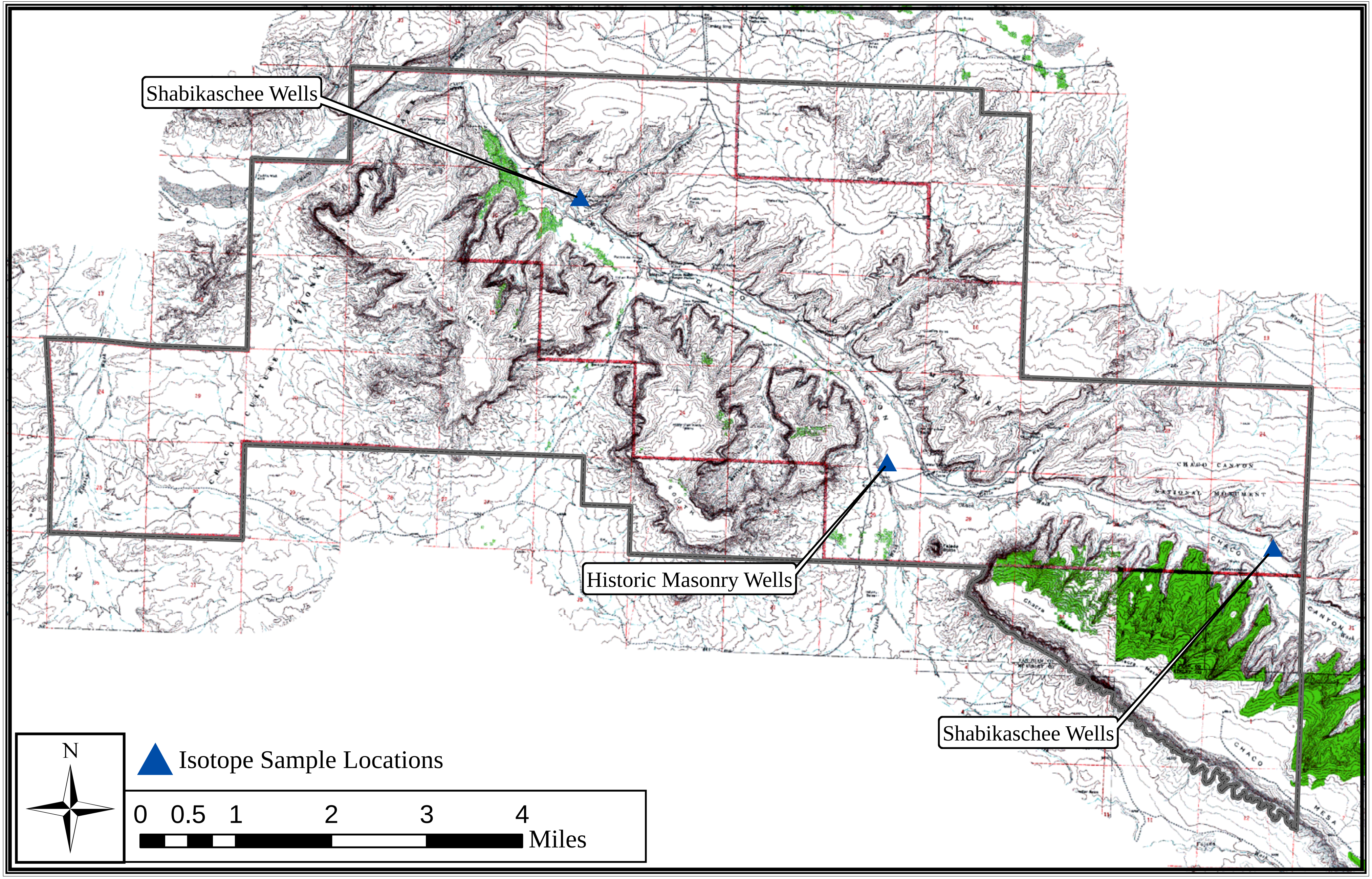

Figure 2. Monthly precipitation data from Chaco Canyon, NM. Mean is long-term mean from 1922-2005, error bars reflect standard error.

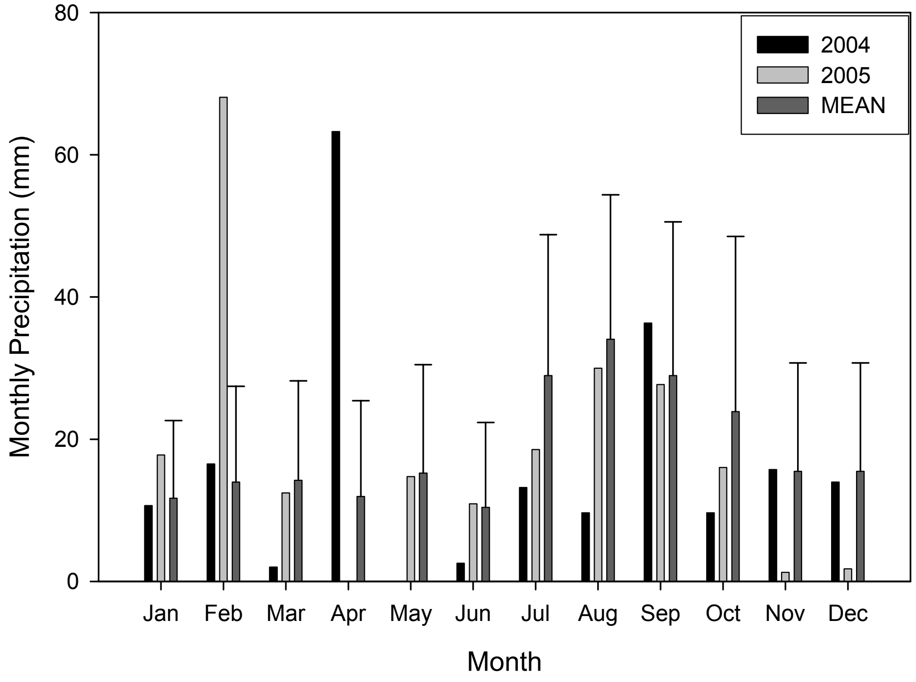

Figure 3. Precipitation amount (bars) and isotopic composition (circles) for each sample collection, 2004 and 2005. Precipitation was not collected during the winter months of 2004-2005.

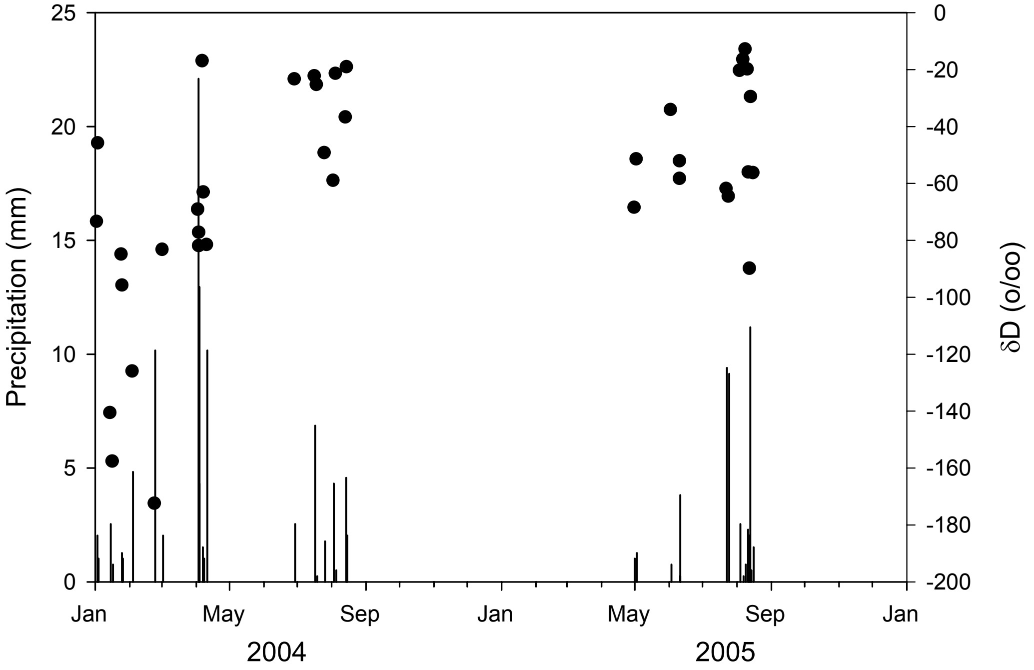

Figure 4. Hydrogen isotopic composition of precipitation and groundwater samples averaged by month over the study. Precipitation collected at CCNHP Visitor's Center, and groundwater collected at CC, HM and SH wells.

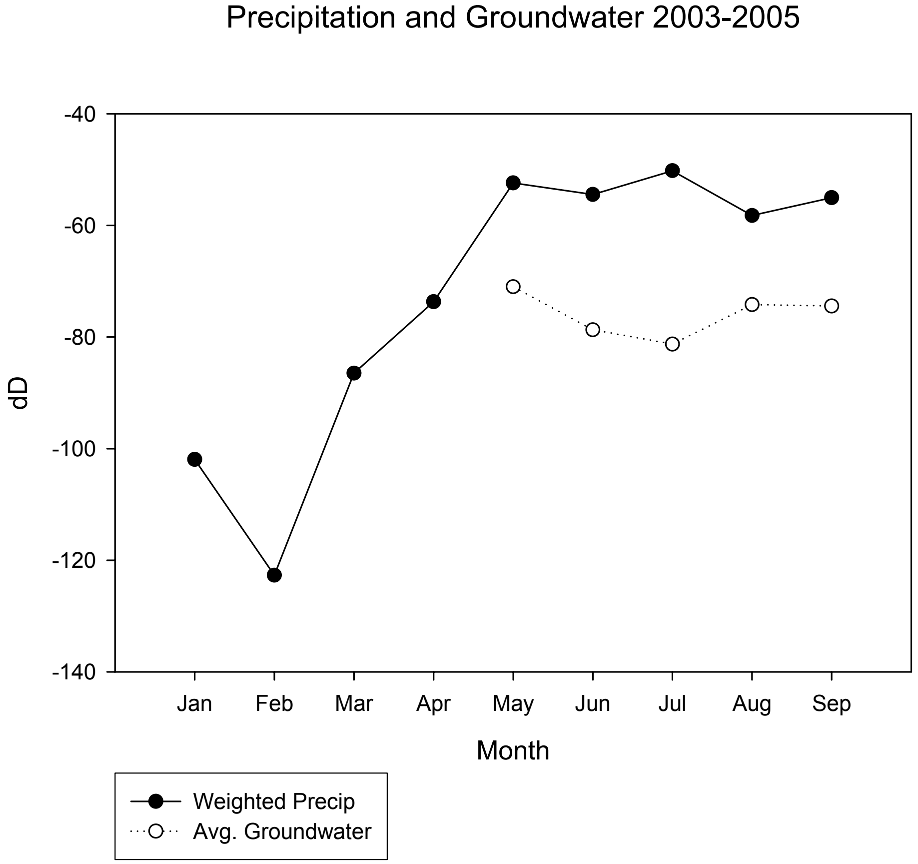

Figure 5. June, 2004 δD‰ values of xylem water for cottonwood (C), greasewood (G), rabbit brush (R), sagebrush (S), and tamarisk (T), and environmental source water including precipitation (Precip), soil water from four depths (20cm, 40cm, 60cm, 80cm), and groundwater (GW). CC, Casa Chiquita well site; HM, Historic Masonry well site; SH, Shibickeshee well site. Error bars reflect standard deviation of xylem water from three individual shrubs.

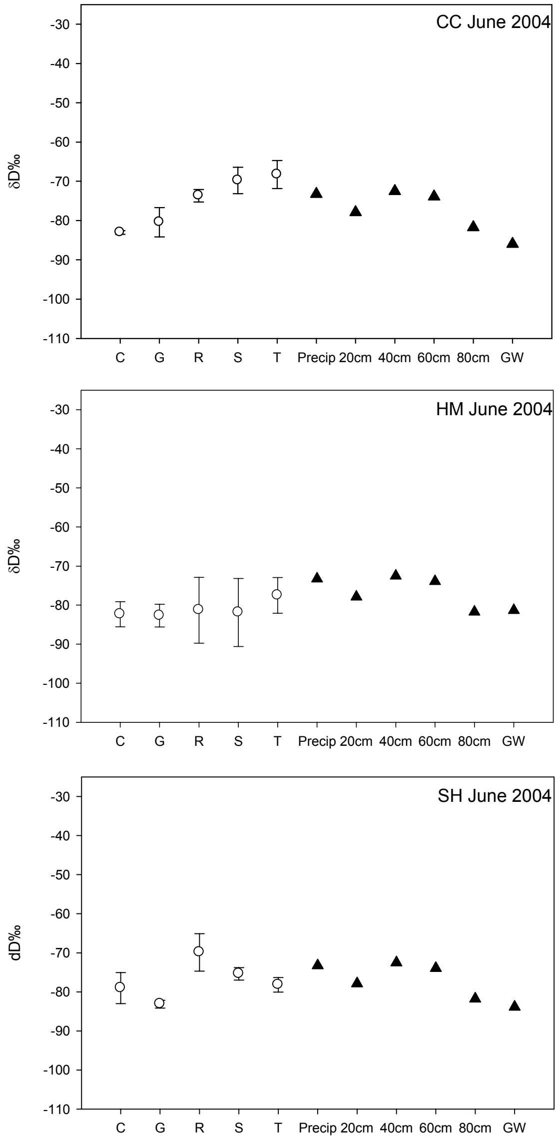

Figure 6. July, 2004 δD values for xylem water and environmental source water. For abbreviations see Figure 5 caption.

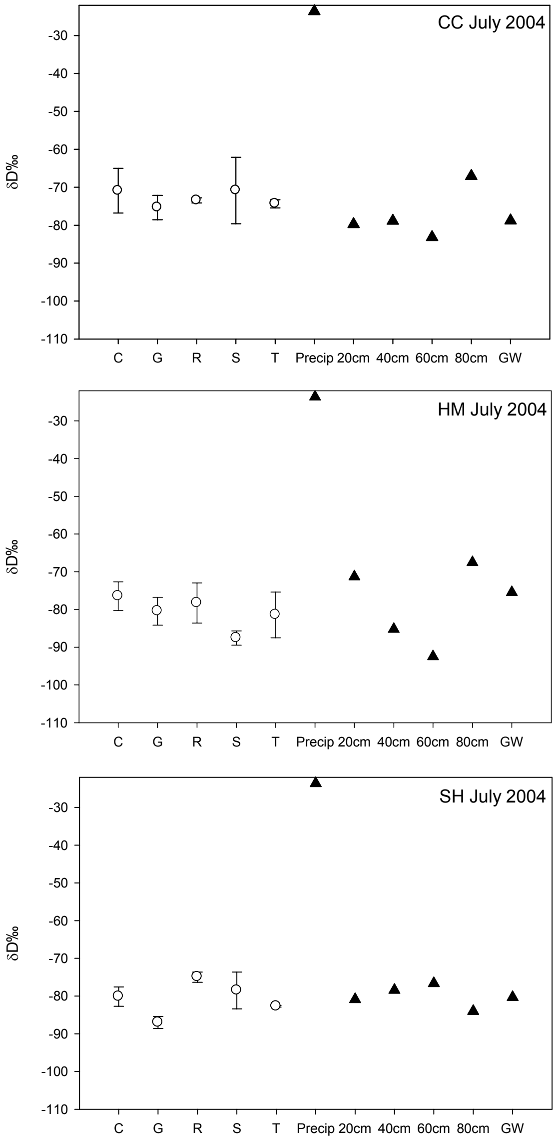

Figure 7. August, 2004 δD values for xylem water and environmental source water. For abbreviations see Figure 5 caption.

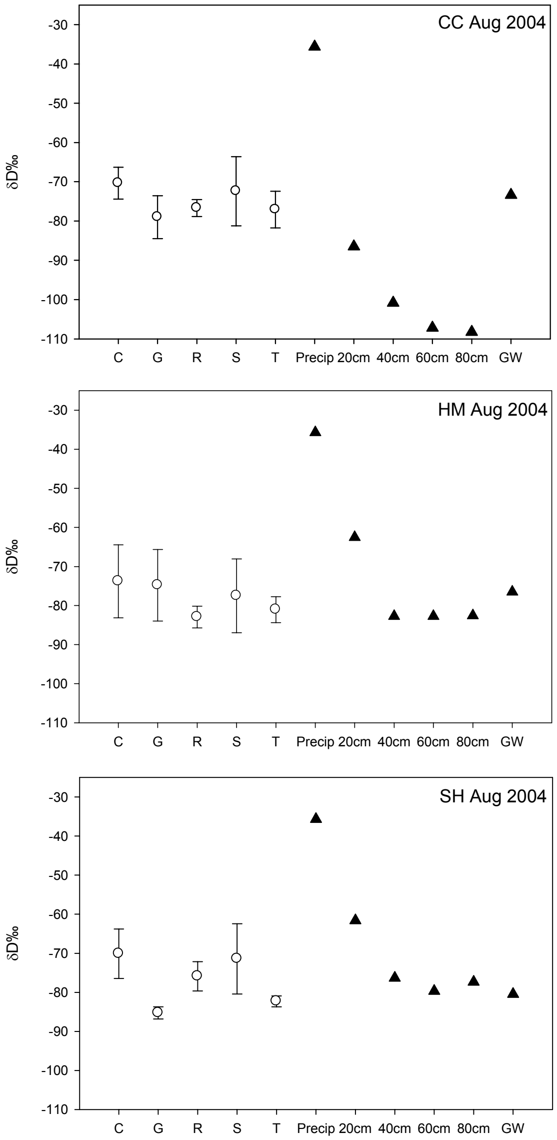

Figure 8. June, 2005 δD values for xylem water and environmental source water. For abbreviations see Figure 5 caption.

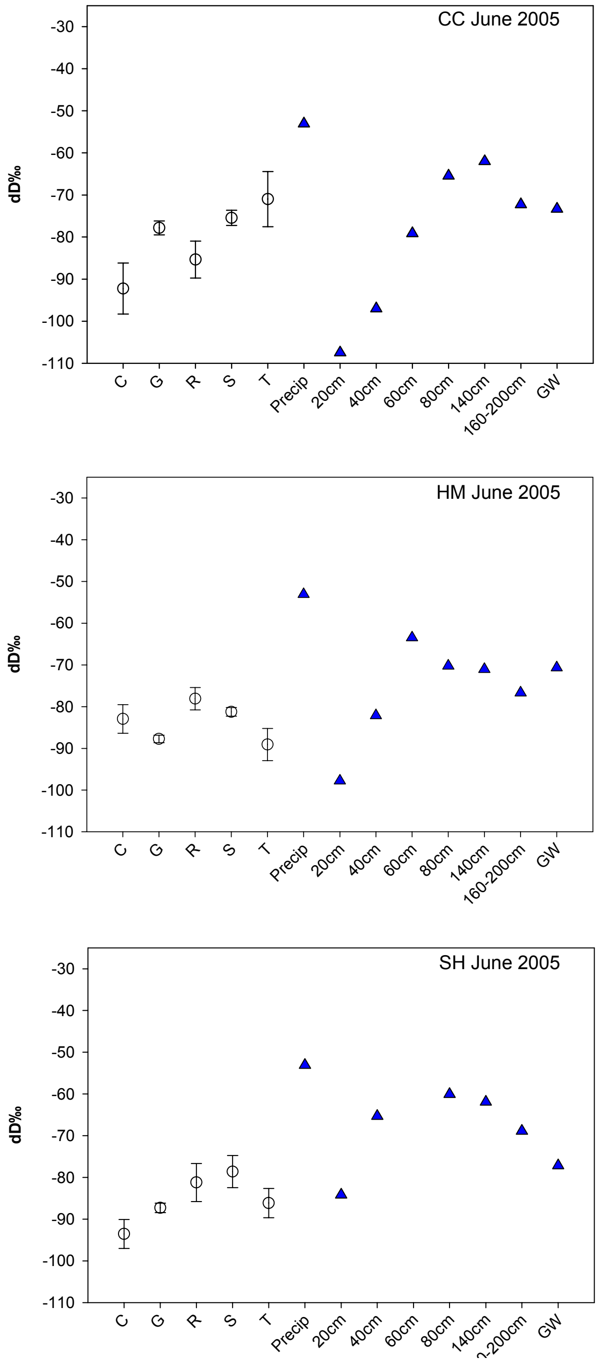

Figure 9. August, 2005 δD values for xylem water and environmental source water. For abbreviations see Figure 5 caption.

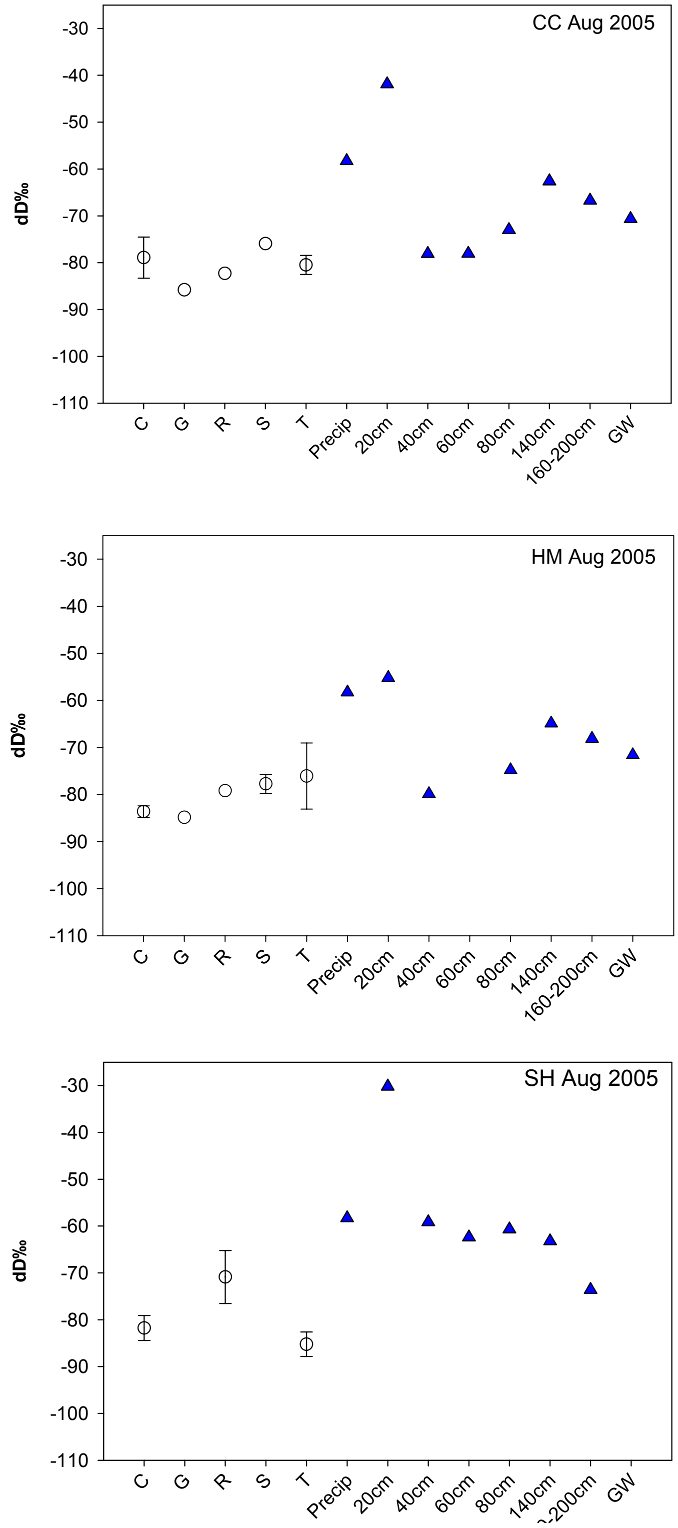

Figure 10. September, 2005 δD values for xylem water and environmental source water. For abbreviations see Figure 5 caption.

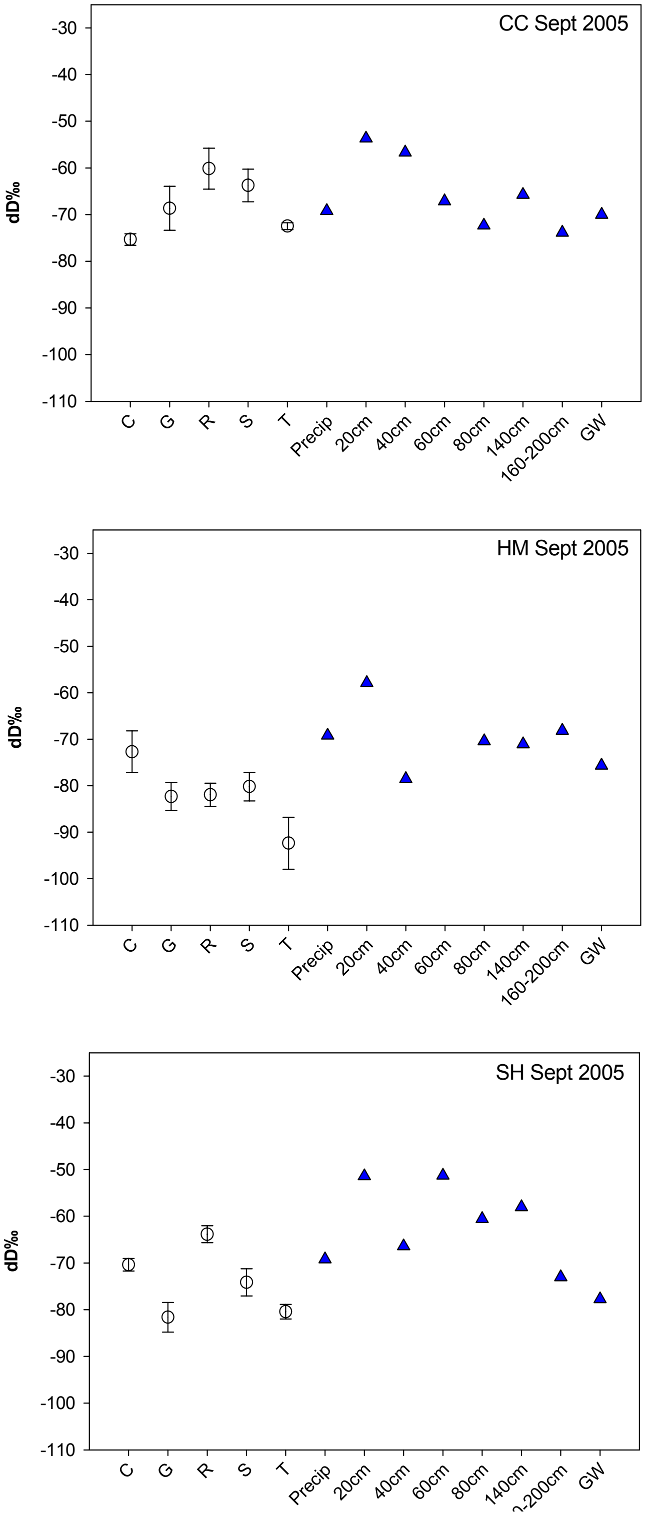

Table 1 Significant differences in xylem water δD values among sites, species and time for 2004 and 2005. Primary effects and interactions, degrees of freedom, and the probability of being greater than the F statistic from repeated measures ANOVA. (*Indicates significant effect). Results from the Fajada View site were not included in this analysis.

	2004		2005	
Effect	DF	Pr>F	DF	Pr>F
Site	2	*<0.0001	2	*0.0026
Species	4	*0.0085	4	*0.0009
Time	2	0.4534	2	*<0.0001
Site*Species	8	*0.0073	8	*0.0104
Site*Time	4	*0.0462	4	*0.0028
Species*Time	8	*0.0006	8	*0.0066
Site*Species*Time	16	0.6017	16	*0.0202

Table 2. Xylem water values collected from three shrubs averaged by site across species, and by species across sites, at each sampling date. Values within each column for site or species followed by the same letter are not significantly different (two-way ANOVA, $p<0.05$). All results reported in ‰. NA, not analyzed, samples lost.

	Date, 2004			Date, 2005		
Site	061104	0704	081104	060805	080305	090305
CC	-75^{a}	-73^{a}	-75^{a}	-80^{a}	-81^{a}	-68^{a}
HM	-81^{b}	-80^{b}	-78^{a}	-83^{ab}	-80^{a}	-82^{c}
SH	-77^{a}	-81^{b}	-77^{a}	-85^{b}	NA	-74^{b}
FV	NA	-83^{b}	-86^{b}	-76^{a}	NA	-82^{c}
Species	061104	0704	081104	060805	080305	090305
Cottonwood	-81^{a}	-76^{a}	-71^{a}	-90^{a}	-81^{a}	-73^{a}
Greasewood	-82^{a}	-81^{b}	-80^{b}	-84^{ab}	NA	-77^{ac}
Rabbit Brush	-75^{b}	-76^{a}	-79^{b}	-82^{b}	-77^{a}	-69^{ab}
Sagebrush	-76^{bc}	-79^{a}	-74^{a}	-78^{b}	NA	-73^{a}
Tamarisk	-75^{c}	-79^{a}	-80^{b}	-82^{b}	-81^{a}	-82^{c}

Table 3. Plant water potential measured at the HM site during the growing seasons of 2004 and 2005. P, predawn; M, mid-day. All values in MPa. Values within a column with the same superscript letters are not significantly different.

Date, 2004	061104-P		061104-M		081104-P		081104-M					
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD				
Cottonwood	-0.72^{a}	0.16	-1.88^{a}	0.66	-0.67^{a}	0.03	-1.60^{a}	0.05				
Greasewood	-1.18^{ab}	0.12	-2.03^{a}	0.40	-2.30^{b}	0.64	-3.60^{c}	0.35				
Rabbit Brush	-1.02^{ab}	0.06	-1.73^{a}	0.20	-1.70^{ab}	0.13	-2.23^{ab}	0.35				
Sagebrush	-1.15^{ab}	0.28	-1.97^{a}	0.60	-2.52^{b}	0.52	-3.30^{c}	0.53				
Tamarisk	-1.88^{b}	0.66	-2.62^{a}	0.42	-2.12^{b}	0.58	-2.87^{bc}	0.45				
Date, 2005	060805-P		060805-M		080405-P		080405-M		090305-P		090305-M	
Species	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cottonwood	-0.57^{a}	0.06	-1.23^{a}	0.13	-0.71^{a}	0.12	-1.37^{a}	0.05	-0.70^{a}	0.11	-1.38^{a}	0.03
Greasewood	-2.58^{b}	0.53	-4.12^{d}	0.14	-3.13^{bc}	0.59	-4.00^{c}	0.00	-2.34^{b}	0.65	-3.95^{c}	0.09
Rabbit Brush	-1.27^{ab}	0.35	-2.40^{b}	0.41	-2.07^{b}	0.64	-3.04^{b}	0.41	-2.89^{b}	0.22	-3.04^{b}	0.55
Sagebrush	-2.60^{b}	0.46	-3.37^{c}	0.35	-3.50^{c}	0.50	-4.01^{c}	0.08	-2.86^{b}	0.73	-3.78^{bc}	0.23
Tamarisk	-1.23^{ab}	0.94	-2.70^{bc}	0.10	-2.21^{b}	0.14	-3.16^{b}	0.25	-2.43^{b}	0.40	-3.43^{bc}	0.33

Appendix 1. Precipitation δD, 2003-2005.

Date	Amount (mm)	δD
2003		
2/14/2003	0.25	-136.50
2/19/2003	1.02	-109.10
2/21/2003	6.10	-106.53
2/24/2003	0.25	-204.69
2/25/2003	2.54	-83.58
2/25/2003	0.51	-68.76
2/26/2003	5.08	-81.89
2/28/2003	2.79	-85.30
3/17/2003	12.70	-79.56
3/18/2003	0.25	-175.24
3/21/2003	2.54	-118.59
3/24/2003	2.79	-75.82
3/27/2003	2.03	-94.25
4/24/2003	0.76	-104.87
5/4/2003	2.29	-45.53
2004		
1/3/2004	2.03	-73.69
1/4/2004	1.02	-46.06
1/15/2004	2.54	-140.89
1/17/2004	0.76	-157.92
1/25/2004	1.27	-85.17
1/26/2004	1.02	-96.11
2/4/2004	4.83	-126.23
2/24/2004	10.16	-172.71
3/2/2004	2.03	-83.49
4/3/2004	22.10	-69.40
4/4/2004	4.32	-82.20
4/4/2004	12.95	-77.51
4/7/2004	1.52	-17.22
4/8/2004	1.02	-63.34
4/11/2004	10.16	-81.79
6/29/2004	2.54	-23.62
7/17/2004	6.86	-22.55
7/19/2004	0.25	-25.56
7/26/2004	1.78	-49.49
8/3/2004	4.32	-59.28
8/5/2004	0.51	-21.71
8/14/2004	4.57	-36.98
8/15/2004	2.03	-19.37
2005		
5/1/2005	1.02	-68.76

5/3/2005	1.27	-51.74
6/3/2005	0.76	-34.45
6/11/2005	0.25	-52.45
6/11/2005	3.81	-58.60
7/23/2005	9.40	-62.14
7/25/2005	9.14	-64.84
8/4/2005	2.54	-20.58
8/7/2005	0.25	-16.73
8/9/2005	0.76	-13.10
8/11/2005	2.29	-20.15
8/12/2005	2.03	-56.33
8/13/2005	11.18	-90.13
8/14/2005	0.51	-29.86
8/16/2005	1.52	-56.56

Appendix 2. Groundwater δD, 2003-2005.

Date	**Well**	**δD (‰)**
May 2003		
	CC1	-71.08
	CC3	-67.74
	HM3	-69.74
	SH2	-75.46
June 2004		
	CC Middle	-85.98
	HM Middle	-81.33
	SH Middle	-83.85
July 2004		
	CC Middle	-78.78
	HM Middle	-75.46
	SH Middle	-80.28
	FVS	-68.43
August 2004		
	CC Middle	-73.40
	HM Middle	-76.51
	SH Middle	-80.48
	FVS	-72.66
June 2005		
	CC Middle	-73.31
	HM Middle	-70.69
	SH Middle	-77.17
August 2005		
	CC Middle	-70.67
	HM Middle	-71.64
	SH Middle	dry
September 2005		
	CC Middle	-69.99
	HM Middle	-75.67
	SH Middle	-77.73

Appendix 3. Ground water depth soundings

Date	Well	Level (feet)	Measured to:
6/15/04	CC S	30.08	top of cap (PVC)
6/15/04	CC M	28.95	top of cap (PVC)
6/15/04	CC N	30.01	top of cap (PVC)
6/16/04	SH W	34.19	top of pipe (cap off)
6/16/04	SH M	32.71	top of pipe (cap off)
6/16/04	SH E	33.73	top of pipe (cap off)
6/16/04	HM E	23.37	top of pipe (cap off)
6/16/04	HM M	25.57	top of pipe (cap off)
6/16/04	HM W	26.30	top of pipe (cap off)
6/16/04	FV S	52.00	
6/16/04	FV N		
7/14/04	CC S	30.05	
7/14/04	CC M	28.92	
7/14/04	CC N	29.97	
7/14/04	HM W	26.54	
7/14/04	HM M		
7/14/04	HM E	25.61	
7/14/04	FV S	52.10	
7/14/04	SH N	33.61	
7/14/04	SH M	32.59	
7/14/04	SH S	36.54	
8/11/04	SH N	33.66	top of PVC
8/11/04	SH M	32.81	top of PVC
8/11/04	SH S	35.98	top of PVC
8/11/04	HM W	26.93	top of PVC
8/11/04	HM M	24.91	top of PVC
8/11/04	HM E	24.85	top of PVC
8/11/04	CC S	30.26	
8/11/04	CC M	29.22	
8/11/04	CC N	31.52	
8/12/04	FV W	52.14	

Date	Well	Level (feet)	Measured to:	Notes
6/8/05	SH N	34.65	top of metal cover	wet sand, no water sample
6/8/05	SH M	33.95	top of metal cover	H2O
6/8/05	SH S	37.90	top of metal cover	wet sand, no water sample
6/8/05	HM N	32.00	top of PVC	silted in, wet mud
6/8/05	HM M	32.30	top of PVC	
8/4/05	HM M	25.71	top of metal pipe	
8/4/05	HM W	24.25	top of metal pipe	
8/4/05	HM E			East Well closed and locked
8/4/05	SH M	34.08	top of metal pipe	no water, dry
8/4/05	SH N	34.75	top of metal pipe	no water, dry

8/4/05	SH S	34.58	top of metal pipe	no water, dry
8/4/05	CC S	30.63	top of metal well	
8/4/05	CC M	30.33	top of metal well	
8/4/05	CC N	30.67	top of metal well	
8/5/05	FV			Middle Well has probe.
9/3/05	SH N	34.63	top of metal pipe	* Wells cleaned since last sampling
9/3/05	SH M	34.21	top of metal pipe	* Wells cleaned since last sampling
9/3/05	SH S	35.54	top of metal pipe	* Wells cleaned since last sampling
9/3/05	CC N	30.71	top of metal pipe	
9/3/05	CC M	30.33	top of metal pipe	
9/3/05	CC S	30.67	top of metal pipe	
9/4/05	HM N	24.29	top of metal pipe	Wells cleaned since last sampling
9/4/05	HM M	25.71	top of metal pipe	Wells cleaned since last sampling
9/4/05	HM S			closed--out of commission
9/4/05	FV			two wells: one dry and one closed

Appendix 4. Soil water content, potential, and hydrogen isotopic composition in 2004 and 2005.

		2004			2005		
Site	Depth (cm)	Water content (% by weight)	Water Potential (MPa)	deltaD (‰)	Water content (% by weight)	Water Potential (MPa)	deltaD (‰)
Early Summer: June 15-16, 2004 and June 8-9, 2005							
CC	20	na	na	na	9.86	-0.39	-107.48
CC	40	na	na	na	4.76	-0.29	-97.01
CC	60	na	na	na	5.50	-0.23	-79.15
CC	80	na	na	na	5.52	-1.75	-65.48
CC	140	na	na	na	7.99	-0.59	-62.04
CC	200	na	na	na	5.68	-2.45	-72.24
HM	20	na	na	na	5.27	-8.59	-97.8
HM	40	na	na	na	4.68	-4.85	-82.15
HM	60	na	na	na	4.74	-3.13	-63.49
HM	80	na	na	na	4.79	-1.67	-70.24
HM	140	na	na	na	4.35	-2.25	-71.07
HM	180	na	na	na	5.12	-1.23	-76.68
SH	20	4.61	-11.2	-77.87	2.48	-5.66	-84.19
SH	40	1.36	-10.8	-72.5	1.48	-7.15	-65.33
SH	60	1.56	na	-73.94	na	na	na
SH	80	1.38	-19.3	-81.75	1.75	-4.73	-60.08
SH	140	na	na	na	2.29	-2.66	-61.93
SH	200	na	na	na	3.31	-0.52	-68.92
Pre-Monsoon: July 14-15, 2004 and August 4-5, 2005							
CC	20	3.43	-4.9	-79.75	4.23	-55.38	-41.87
CC	40	2.21	-4.7	-78.87	2.43	-86.04	-78.08
CC	60	1.73	-7.5	-83.17	3.12	-1.68	-78.05
CC	80	1.76	-18.8	-67.07	3.55	-2.89	-73.02
CC	140	na	na	na	2.62	-7.00	-62.61
CC	200	na	na	na	3.09	-42.28	-66.75
HM	20	1.24	-28.5	-71.3	2.80	-109.41	-55.2
HM	40	2.91	-5.0	-85.2	3.62	-7.05	-79.9
HM	60	2.7	-3.7	-92.44	3.93	-3.92	
HM	80	1.78	-8.2	-67.54	3.69	-4.86	-74.81
HM	140	na	na	na	3.17	-3.83	-64.89
HM	160	na	na	na	4.64	-1.87	-68.14
SH	20	1.86	-16.6	-80.86	3.53	-245.57	-30.2
SH	40	1.33	-11.0	-78.41	2.49	-5.60	-59.16

SH	60	2.01	na	-76.61	2.87	-1.31	-62.4
SH	80	1.8	-16.8	-84	2.92	-1.23	-60.7
SH	140	na	na	na	2.17	-2.94	-63.24
SH	200	na	na	na	3.25	-0.56	-73.6
Post-Monsoon: August 11-12, 2004 and September 3-4, 2005							
CC	20	1.99	-247.9	-86.48	11.36	-0.24	-53.68
CC	40	1.72	-194.3	-100.83	9.38	-0.26	-56.69
CC	60	1.86	-6.9	-107.22	2.95	-2.12	-67.13
CC	80	1.82	-17.4	-108.23	2.83	-4.54	-72.33
CC	140	na	na	na	2.65	-5.47	-65.75
CC	200	na	na	na	4.03	-5.93	-73.85
HM	20	1.4	-27.3	-62.51	4.54	-18.95	-57.91
HM	40	2.84	-5.1	-82.71	3.86	-6.56	-78.55
HM	60	2.64	-3.8	-82.73	na	na	na
HM	80	1.87	-8.0	-82.55	3.49	-4.36	-70.43
HM	140	na	na	na	3.29	-7.66	-71.09
HM	180	na	na	na	3.54	-3.32	-68.18
SH	20	3.23	-13.3	-61.63	5.42	-120.80	-51.43
SH	40	1.73	-9.7	-76.32	2.09	-11.68	-66.42
SH	60	1.22	na	-79.66	3.38	-5.36	-51.28
SH	80	1.75	-17.0	-77.35	1.73	-4.96	-60.56
SH	140	na	na	na	1.61	-7.11	-58.05
SH	200	na	na	na	1.64	-4.75	-73.05

Appendix 5. Xylem water δD, 2003-2005.

Date	**Sample**	**Species**	**δD**
May 2003			**avg. δD**
	CC	Cottonwood	-56.00
	CC	Greasewood	-63.33
	CC	Rabbit brush	-86.67
	CC	Sagebrush	-65.67
	CC	Tamarisk	-70.00
	PDA	Cottonwood	-77.33
	PDA	Greasewood	-73.33
	PDA	Rabbit brush	-77.67
	PDA	Sagebrush	-62.00
	PDA	Tamarisk	-77.33
	SH	Cottonwood	-74.00
	SH	Greasewood	-64.33
	SH	Rabbit brush	-64.67
	SH	Sagebrush	-63.00
	SH	Tamarisk	-63.67
June 2004			**δD**
	CCC1	Cottonwood	-83.04
	CCC2	Cottonwood	-83.49
	CCC3	Cottonwood	-82.59
	CCG1	Greasewood	-81.78
	CCG2	Greasewood	-76.18
	CCG3	Greasewood	-83.24
	CCR1	Rabbit brush	-72.13
	CCR2	Rabbit brush	-73.58
	CCR3	Rabbit brush	-75.32
	CCS1	Sagebrush	-71.07
	CCS2	Sagebrush	-65.95
	CCS3	Sagebrush	-72.28
	CCT1	Tamarisk	-71.22
	CCT2	Tamarisk	-69.29
	CCT3	Tamarisk	-64.33
	HMC1	Cottonwood	-79.48
	HMC2	Cottonwood	-85.80
	HMC3	Cottonwood	-81.77
	HMG1	Greasewood	-86.02
	HMG2	Greasewood	-81.49
	HMG3	Greasewood	-80.60
	HMR1	Rabbit brush	-73.44
	HMR2	Rabbit brush	-90.22
	HMR3	Rabbit brush	-80.28
	HMS1	Sagebrush	-90.04

	HMS2	Sagebrush	-82.88
	HMS3	Sagebrush	-72.75
	HMT1	Tamarisk	-72.75
	HMT2	Tamarisk	-81.90
	HMT3	Tamarisk	-77.87
	SHC1	Cottonwood	-83.37
	SHC2	Cottonwood	-75.60
	SHC3	Cottonwood	-78.10
	SHG1	Greasewood	-83.98
	SHG2	Greasewood	-83.46
	SHG3	Greasewood	-82.00
	SHR1	Rabbit brush	-64.37
	SHR2	Rabbit brush	-72.24
	SHR3	Rabbit brush	-73.05
	SHS1	Sagebrush	-73.58
	SHS2	Sagebrush	-75.99
	SHS3	Sagebrush	-76.57
	SHT1	Tamarisk	-80.31
	SHT2	Tamarisk	-76.90
	SHT3	Tamarisk	-77.40
July 2004			**δD**
	CCC21	Cottonwood	-64.12
	CCC22	Cottonwood	-74.76
	CCC23	Cottonwood	-73.85
	CCG21	Greasewood	-73.65
	CCG22	Greasewood	-73.35
	CCG23	Greasewood	-79.07
	CCR21	Rabbit brush	-73.45
	CCR22	Rabbit brush	-74.13
	CCR23	Rabbit brush	-72.76
	CCS21	Sagebrush	-63.87
	CCS22	Sagebrush	-68.03
	CCS23	Sagebrush	-80.63
	CCT21	Tamarisk	-73.24
	CCT22	Tamarisk	-75.40
	CCT23	Tamarisk	-74.43
	HMC21	Cottonwood	-80.36
	HMC22	Cottonwood	-72.80
	HMC23	Cottonwood	-76.21
	HMG21	Greasewood	-82.43
	HMG22	Greasewood	-76.19
	HMG23	Greasewood	-82.75
	HMR21	Rabbit brush	-73.42
	HMR22	Rabbit brush	-83.98
	HMR23	Rabbit brush	-77.42

	HMS21	Sagebrush	-86.34
	HMS22	Sagebrush	-89.76
	HMS23	Sagebrush	-86.63
	HMT21	Tamarisk	-82.06
	HMT22	Tamarisk	-87.12
	HMT23	Tamarisk	-75.06
	SHC21	Cottonwood	-77.85
	SHC22	Cottonwood	-82.90
	SHC23	Cottonwood	-79.63
	SHG21	Greasewood	-87.51
	SHG22	Greasewood	-85.21
	SHG23	Greasewood	-88.29
	SHR21	Rabbit brush	-76.37
	SHR22	Rabbit brush	-73.67
	SHR23	Rabbit brush	-74.85
	SHS21	Sagebrush	-77.67
	SHS22	Sagebrush	-83.77
	SHS23	Sagebrush	-74.05
	SHT21	Tamarisk	-82.71
	SHT22	Tamarisk	-82.93
	SHT23	Tamarisk	-82.49
	FVG21	Greasewood	-86.40
	FVG22	Greasewood	-86.92
	FVG23	Greasewood	-83.41
August 2004			**δD**
	CCC31	Cottonwood	-67.36
	CCC32	Cottonwood	-68.73
	CCC33	Cottonwood	-74.97
	CCG31	Greasewood	-81.75
	CCG32	Greasewood	-82.57
	CCG33	Greasewood	-72.70
	CCR31	Rabbit brush	-74.21
	CCR32	Rabbit brush	-78.02
	CCR33	Rabbit brush	-77.87
	CCS31	Sagebrush	-62.23
	CCS32	Sagebrush	-77.84
	CCS33	Sagebrush	-77.11
	CCT31	Tamarisk	-79.71
	CCT32	Tamarisk	-71.71
	CCT33	Tamarisk	-79.85
	HMC31	Cottonwood	-63.06
	HMC32	Cottonwood	-78.59
	HMC33	Cottonwood	-79.77
	HMG31	Greasewood	-78.61
	HMG32	Greasewood	-81.44

	HMG33	Greasewood	-64.38
	HMR31	Rabbit brush	-85.12
	HMR32	Rabbit brush	-79.84
	HMR33	Rabbit brush	-83.89
	HMS31	Sagebrush	-80.19
	HMS32	Sagebrush	-85.34
	HMS33	Sagebrush	-67.01
	HMT31	Tamarisk	-82.89
	HMT32	Tamarisk	-83.08
	HMT33	Tamarisk	-77.22
	SHC31	Cottonwood	-74.50
	SHC32	Cottonwood	-73.02
	SHC33	Cottonwood	-62.88
	SHG31	Greasewood	-86.14
	SHG32	Greasewood	-83.47
	SHG33	Greasewood	-86.22
	SHR31	Rabbit brush	-77.24
	SHR32	Rabbit brush	-78.75
	SHR33	Rabbit brush	-71.67
	SHS31	Sagebrush	-79.42
	SHS32	Sagebrush	-61.70
	SHS33	Sagebrush	-73.14
	SHT31	Tamarisk	-81.73
	SHT32	Tamarisk	-83.90
	SHT33	Tamarisk	-81.29
	FVG31	Greasewood	-78.93
	FVG32	Greasewood	-88.30
	FVG33	Greasewood	-82.73
June 2005			**δD**
	CCC1	Cottonwood	-104.3268
	CCC2	Cottonwood	-85.0037
	CCC3	Cottonwood	-87.3807
	CCG1	Greasewood	-79.4888
	CCG2	Greasewood	-74.5135
	CCG3	Greasewood	-79.4531
	CCR1	Rabbit brush	-82.9731
	CCR2	Rabbit brush	-93.8802
	CCR3	Rabbit brush	-79.2098
	CCS1	Sagebrush	-71.8847
	CCS2	Sagebrush	-76.6299
	CCS3	Sagebrush	-77.7950
	CCT1	Tamarisk	-80.4182
	CCT2	Tamarisk	-74.1728
	CCT3	Tamarisk	-58.3604
	HMC1	Cottonwood	-89.7394

	HMC2	Cottonwood	-80.7133
	HMC3	Cottonwood	-78.4446
	HMG1	Greasewood	-85.9414
	HMG2	Greasewood	-88.7591
	HMG3	Greasewood	-88.5862
	HMR1	Rabbit brush	-81.2042
	HMR2	Rabbit brush	-72.7728
	HMR3	Rabbit brush	-80.3001
	HMS1	Sagebrush	-83.3037
	HMS2	Sagebrush	-80.4532
	HMS3	Sagebrush	-80.0400
	HMT1	Tamarisk	-86.5637
	HMT2	Tamarisk	-84.0283
	HMT3	Tamarisk	-96.6358
	SHC1	Cottonwood	-89.4735
	SHC2	Cottonwood	-100.4608
	SHC3	Cottonwood	-90.7094
	SHG1	Greasewood	-87.4862
	SHG2	Greasewood	-89.1728
	SHG3	Greasewood	-85.2844
	SHR1	Rabbit brush	-88.4415
	SHR2	Rabbit brush	-82.5291
	SHR3	Rabbit brush	-72.7737
	SHS1	Sagebrush	-85.5738
	SHS2	Sagebrush	-72.2182
	SHS3	Sagebrush	-78.0814
	SHT1	Tamarisk	-87.9306
	SHT2	Tamarisk	-79.3779
	SHT3	Tamarisk	-91.1392
	FVG1	Greasewood	-79.8616
	FVG2	Greasewood	-85.6476
	FVG3	Greasewood	-88.1213
August 2005			**δD**
	CCC1	Cottonwood	-87.7203
	CCC2	Cottonwood	-74.2374
	CCC3	Cottonwood	-74.7839
	CCG2	Greasewood	-85.8068
	CCR2	Rabbit brush	-82.2955
	CCS2	Sagebrush	-75.9381
	CCT1	Tamarisk	-84.2142
	CCT2	Tamarisk	-80.0157
	CCT3	Tamarisk	-77.2229
	HMC1	Cottonwood	-82.4121
	HMC2	Cottonwood	-84.8516
	HMG3	Greasewood	-84.8576

	HMR2	Rabbit brush	-79.1936
	HMS1	Sagebrush	-79.7565
	HMS3	Sagebrush	-75.7578
	HMT1	Tamarisk	-83.1167
	HMT3	Tamarisk	-69.0226
	SHC1	Cottonwood	-76.8021
	SHC2	Cottonwood	-82.6345
	SHC3	Cottonwood	-85.8868
	SHR2	Rabbit brush	-65.2024
	SHR3	Rabbit brush	-76.5429
	SHT1	Tamarisk	-87.9451
	SHT2	Tamarisk	-80.0217
	SHT3	Tamarisk	-87.7324
September 2005			**δD**
	CCC1	Cottonwood	-73.3794
	CCC2	Cottonwood	-75.0081
	CCC3	Cottonwood	-77.6324
	CCG1	Greasewood	-63.0858
	CCG2	Greasewood	-64.7962
	CCG3	Greasewood	-78.0416
	CCR1	Rabbit brush	-68.1168
	CCR2	Rabbit brush	-59.3201
	CCR3	Rabbit brush	-53.0024
	CCS1	Sagebrush	-59.7472
	CCS2	Sagebrush	-60.7748
	CCS3	Sagebrush	-70.7069
	CCT1	Tamarisk	-72.0601
	CCT2	Tamarisk	-71.4620
	CCT3	Tamarisk	-73.9166
	SHC1	Cottonwood	-67.7737
	SHC2	Cottonwood	-71.1882
	SHC3	Cottonwood	-72.2300
	SHG1	Greasewood	-84.7978
	SHG2	Greasewood	-75.2986
	SHG3	Greasewood	-84.7687
	SHR1	Rabbit brush	-65.3054
	SHR2	Rabbit brush	-66.0037
	SHR3	Rabbit brush	-60.2444
	SHS1	Sagebrush	-70.9229
	SHS2	Sagebrush	-79.9248
	SHS3	Sagebrush	-71.6198
	SHT1	Tamarisk	-77.6760
	SHT2	Tamarisk	-80.6417
	SHT3	Tamarisk	-83.0302
	HMC1	Cottonwood	-79.5441

	HMC2	Cottonwood	-64.2142
	HMC3	Cottonwood	-74.3756
	HMG2	Greasewood	-79.3139
	HMG3	Greasewood	-85.3763
	HMR1	Rabbit brush	-80.1181
	HMR2	Rabbit brush	-78.8556
	HMR3	Rabbit brush	-86.8904
	HMS1	Sagebrush	-80.3631
	HMS2	Sagebrush	-74.7850
	HMS3	Sagebrush	-85.4358
	HMT1	Tamarisk	-91.6817
	HMT2	Tamarisk	-83.0526
	HMT3	Tamarisk	-102.3843
	FVG1	Greasewood	-72.3758
	FVG2	Greasewood	-80.2862
	FVG3	Greasewood	-76.4622