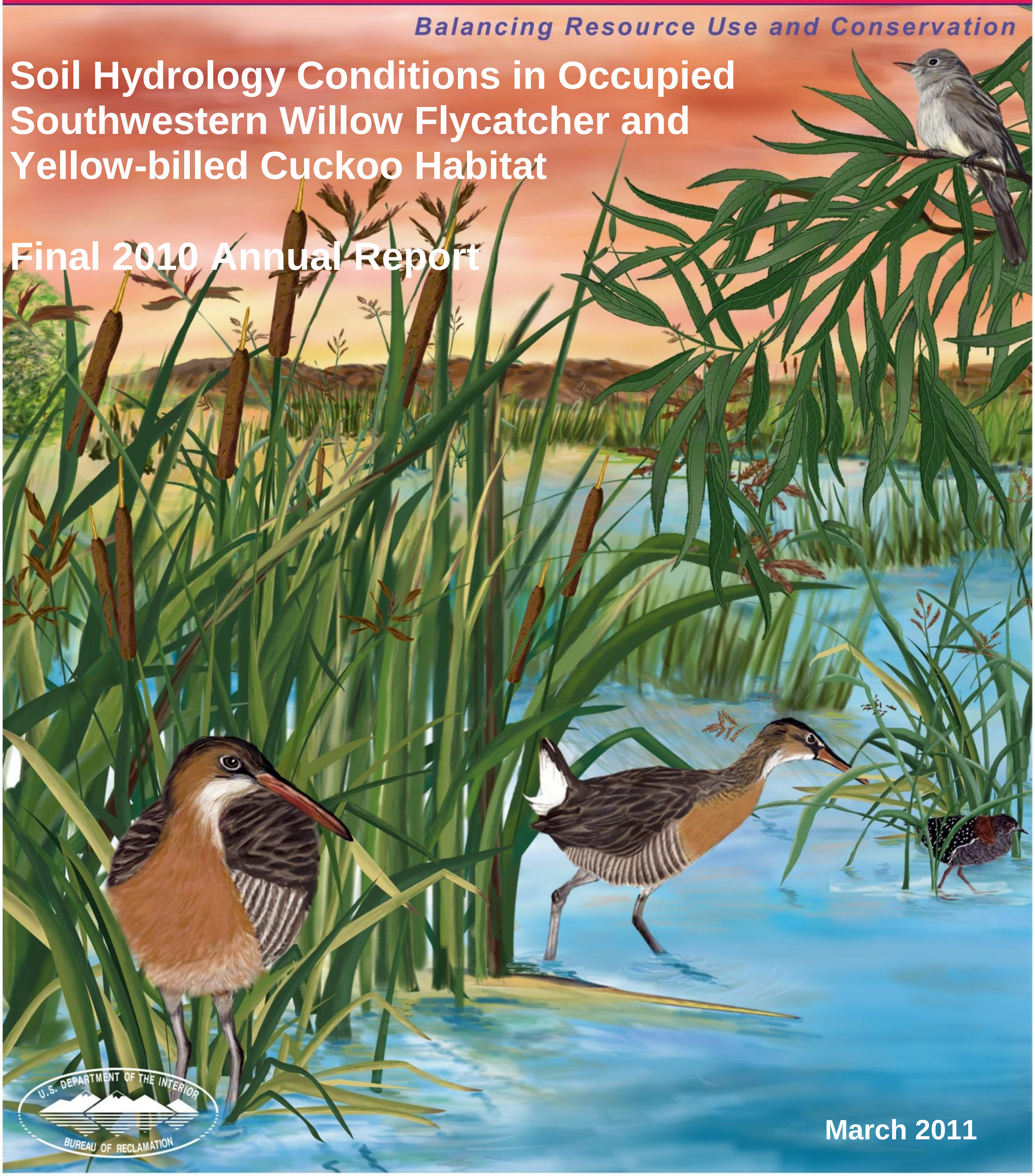
Lower Colorado River
Multi-Species Conservation Program

Balancing Resource Use and Conservation

Soil Hydrology Conditions in Occupied Southwestern Willow Flycatcher and Yellow-billed Cuckoo Habitat

Final 2010 Annual Report



U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

March 2011

Lower Colorado River Multi-Species Conservation Program
Steering Committee Members

Federal Participant Group

Bureau of Reclamation
U.S. Fish and Wildlife Service
National Park Service
Bureau of Land Management
Bureau of Indian Affairs
Western Area Power Administration

Arizona Participant Group

Arizona Department of Water Resources
Arizona Electric Power Cooperative, Inc.
Arizona Game and Fish Department
Arizona Power Authority
Central Arizona Water Conservation District
Cibola Valley Irrigation and Drainage District
City of Bullhead City
City of Lake Havasu City
City of Mesa
City of Somerton
City of Yuma
Electrical District No. 3, Pinal County, Arizona
Golden Shores Water Conservation District
Mohave County Water Authority
Mohave Valley Irrigation and Drainage District
Mohave Water Conservation District
North Gila Valley Irrigation and Drainage District
Town of Fredonia
Town of Thatcher
Town of Wickenburg
Salt River Project Agricultural Improvement and Power District
Unit "B" Irrigation and Drainage District
Wellton-Mohawk Irrigation and Drainage District
Yuma County Water Users' Association
Yuma Irrigation District
Yuma Mesa Irrigation and Drainage District

Other Interested Parties Participant Group

QuadState County Government Coalition
Desert Wildlife Unlimited

California Participant Group

California Department of Fish and Game
City of Needles
Coachella Valley Water District
Colorado River Board of California
Bard Water District
Imperial Irrigation District
Los Angeles Department of Water and Power
Palo Verde Irrigation District
San Diego County Water Authority
Southern California Edison Company
Southern California Public Power Authority
The Metropolitan Water District of Southern California

Nevada Participant Group

Colorado River Commission of Nevada
Nevada Department of Wildlife
Southern Nevada Water Authority
Colorado River Commission Power Users
Basic Water Company

Native American Participant Group

Hualapai Tribe
Colorado River Indian Tribes
Chemehuevi Indian Tribe

Conservation Participant Group

Ducks Unlimited
Lower Colorado River RC&D Area, Inc.
The Nature Conservancy

Lower Colorado River
Multi-Species Conservation Program

Soil Hydrology Conditions in Occupied Southwestern Willow Flycatcher and Yellow-billed Cuckoo Habitat

Final 2010 Annual Report

Prepared by:

Tricia Balluff
EcoPlan Associates, Inc.
701 W. Southern Ave., Suite 203
Mesa, AZ 85210

Lower Colorado River
Multi-Species Conservation Program
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada
http://www.lcrmscp.gov

March 2011

EXECUTIVE SUMMARY

Federal and non-Federal actions related to the operations of the Lower Colorado River (LCR) water delivery and power systems have been determined to affect species listed as threatened or endangered under the Endangered Species Act (ESA) and their critical habitat. The LCR Multi-Species Conservation Program (MSCP) was created to address the needs of these species and to comply with the ESA. The LCR MSCP intends to avoid jeopardy, support the conservation of listed species, and reduce the potential for future listings of additional species as a result of ongoing operations. Two key avian species included in the LCR MSCP are the endangered Southwestern willow flycatcher *(Empidonax traillii extimus)* (SWFL) and the candidate Western yellow-billed cuckoo *(Coccyzus americanus occidentalis)* (YBCU). These species utilize riparian habitat along the LCR.

SWFL and YBCU breeding habitats have been studied in terms of canopy density, canopy height, patch size, plant species composition, and other vegetation characteristics. However, there is less information available on the underlying soil hydrology and microclimate conditions that characterize breeding habitat for these species. The objective of this study is to identify and describe the range of soil hydrology conditions that are present in occupied SWFL and YBCU habitat along the LCR. This information can then be used to aid the creation of breeding habitat for these species.

Study sites were selected using information from the 2009 SWFL and YBCU surveys, associated vegetation surveys, and through consultation with the Bureau of Reclamation and its biological consultants. Originally, 21 sites were selected for study for each species. After the first month of field visits, the number of sites was reduced to 19 for each species due to several considerations.

Identical data sampling methods were employed at all SWFL and YBCU sites. Measurements of litter depth, soil moisture, air temperature, relative humidity, and soil texture were taken at subplots. Any standing water that crossed the transect was also measured. At select sites, piezometers were installed to measure depth to ground water. Distance to flowing water was determined by overlaying the sites on Geographic Information Systems map and on aerials. Data from 2009 vegetation surveys completed in previous studies also were compared with measurements taken at the same sites for this study.

Results indicated significant differences between SWFL and YBCU sites in a number of measured environmental variables. Generally, YBCU sites had lower percent soil moisture, sandier soil texture, less area of standing water, deeper depth to ground water, higher air temperature, lower relative humidity, and lower percent canopy closure compared with SWFL sites.

Due to the amount of precipitation in spring 2010, many of the study sites had higher levels of flow in March and April than in later months, as shown on page 16. Therefore, data collected for the spring 2010 months are likely on the high range of soil hydrology conditions utilized by these species. Data collection will occur again in 2011 from March through August, and the results will be combined with the 2010 field season data to increase sample size and further inform the range of conditions that characterize breeding habitat for these two species. The data collected in 2011 will also provide information on the variability in conditions between years.

CONTENTS

APPENDICES

TABLES

FIGURES

1.0 INTRODUCTION

The Endangered Species Act (ESA) of 1973 provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of the ecosystems on which they depend. Federal and non-Federal actions related to the operations of the Lower Colorado River (LCR) water delivery and power systems have been determined to affect species listed as threatened or endangered and their critical habitat. The LCR Multi-Species Conservation Program (MSCP) was created to address the needs of listed species and to comply with the ESA. The LCR MSCP intends to avoid jeopardy, support the conservation of listed species, and reduce the potential for future listing of additional species as a result of ongoing operations.

Riparian areas provide habitat for a number of listed and candidate species, but they are rare on the landscape and have declined or been degraded due to human activities. Two key avian species included in the LCR MSCP are the endangered Southwestern willow flycatcher (SWFL) *(Empidonax traillii extimus)* and the candidate Western yellow-billed cuckoo (YBCU) *(Coccyzus americanus occidentalis).* These species utilize riparian habitat along perennial stretches of water as nesting areas.

Riparian areas are the transition zones between an aquatic system and the surrounding uplands. As such, riparian zones occupy a relatively small area in the natural landscape but are highly productive, provide unique communities, and are key habitat for many species of wildlife (Bechtold and Naiman 2006, Kelsey and West 1998, Naiman et al. 1993, Naiman et al. 2000, Pase and Layser 1977). Riparian habitat has decreased or become degraded in many areas in the southwestern United States due to various factors, including urban development, water diversion and impoundment, overgrazing by livestock, and increasing numbers of decadent riparian stands due to lack of natural succession (Brinson et al. 1981, Busch and Smith 1995). Decadent stands have resulted from increased fire suppression activities over the past 100 years and the construction of dams that change the historic hydrologic regime of the area (U.S. Forest Service 2000).

Historically, riparian systems in the southwestern United States were dynamic and subject to frequent change due to annual periods of spring/summer flooding and, as a result, supported plant species adapted to this particular hydrologic regime. These flooding events cleared decadent vegetation, added soil nutrients, created space, and carried seed for new growth (U.S. Forest Service 2000). Many common riparian tree species adapted to this hydrologic regime, including various willow (*Salix* spp.) and cottonwood (*Populus* spp.) species. One example of this is Goodding's willow *(Salix gooddingii),* which has the ability to withstand long periods of inundation without long-term injury, which aided its survival during these historic annual floods (Green and Balluff 2005). In addition, Goodding's willow seed release occurred as these flood flows started to recede and expose sediment, thus providing the seeds with moist, bare soil on which to germinate (Roelle and Gladwin 1999, Sprenger et al. 2002, Tallent-Halsell and Walker 2002). With rivers in the southwestern United States increasingly regulated, many rivers no longer accommodate the historic hydrologic regime to which native riparian tree species are adapted.

Regulation of flows has changed the plant species composition of riparian areas and has affected the wildlife species that use these habitats. Willow/cottonwood stands are historically the preferred habitat of SWFL and YBCU, though these species have now been observed to use stands of the invasive saltcedar (*Tamarix* spp.) and other nonnative species such as Russian olive *(Elaeagnus angustifolia)* (Ellis et al. 2008, U.S. Forest Service 2000). These invasive plant species are promoted by the regulated nature of most rivers in the Southwest. For example, saltcedar cannot withstand long periods of inundation; thus the historic hydrologic regime would likely have made establishment of saltcedar more challenging (Tallent-Halsell and Walker 2002). Saltcedar also has a competitive advantage in seeding. Whereas cottonwood and willow seed for relatively short periods of time in the early summer (timed to occur after summer floods start to recede), saltcedar has an extended seeding period lasting from approximately April to September (Siegel and Brock 1990, Sprenger et al. 2002).

Soil hydrologic conditions, including soil texture, moisture, depth to ground water, and the amount of standing water, may influence vegetation composition, structure, and density, and the microclimate conditions that may influence habitat selection by breeding birds, including SWFL and YBCU. These conditions can rapidly change temporally and spatially in the semi-arid Southwest, creating a range of soil hydrology through the course of one season, from year to year, and from the river channel toward the uplands (Paxton et al. 2007, U.S. Forest Service 2000). This results in varying habitat conditions available for breeding birds across temporal and spatial scales.

1.1 Southwestern Willow Flycatcher (SWFL)

The willow flycatcher is widely distributed across the United States (Ellis et al. 2008). The Southwestern subspecies of interest in this study has breeding grounds along the LCR and its tributaries, arrives in late April or early May, and departs in September (Ellis et al. 2008, Paxton et al. 2007, USFWS 2010).

As noted previously, SWFL select breeding habitat with a variety of vegetation characteristics. Plant species composition of SWFL breeding habitat can consist of native, nonnative, and mixed tree and shrub communities (Ellis et al. 2008, Paxton et al. 2007, U.S. Forest Service 2000). In addition to plant species composition, breeding habitat selected by SWFL also varies in canopy height and structure, and size and shape of breeding patch. It can range from monotypic to diverse stands of vegetation and from single-canopy strata to multiple-canopy strata (U.S. Forest Service 2000).

The Arizona Game and Fish Department (AGFD) found that areas with dense riparian vegetation showed greater breeding activity and nest density for SWFL (AGFD 2004). Breeding SWFLs have been observed to use patch sizes ranging from 0.6 hectare up to 100 hectares or more (Sogge et al. 1997, Spencer et al. 1996). Generally, preferred breeding habitat consists of dense stands with high or midstory canopy closure with multiple small openings (AGFD 2004, Ellis et al. 2008, Paxton et al. 2007, U.S. Forest Service 2000). The U.S. Forest Service (2000) noted that no long-term data are available to determine optimal breeding habitat, though SWFL do not appear to use cottonwood/willow galleries that lack understory and are not known to use riparian patches less than 10 meters (m) wide for breeding purposes.

Little data exist in the literature regarding soil hydrology and microclimate requirements of SWFL breeding habitat beyond noting that the species is an obligate riparian breeder that requires surface water or saturated soil conditions to breed (Ellis et al. 2008, McLeod and Koronkiewicz 2010, Paxton et al. 2007, Sogge and Marshall 2000, U.S. Forest Service 2000, USFWS 2010). A report by the U.S. Forest Service (2000) noted that because of diverse temporal hydrologic conditions in the semi-arid Southwest, breeding habitat may be saturated for the entire breeding season one year but may be several hundred meters from water in dry years. The report noted that the nesting SWFL may persist in the same area for several years even with these varying conditions, but it is not known how long they would persist given continuing dry conditions. SWCA Environmental Consultants has conducted SWFL surveys along the LCR and its tributaries and has noted sites to which SWFL consistently return through varying conditions over several years (McLeod and Koronkiewicz 2010).

1.2 Western Yellow-billed Cuckoo (YBCU)

The yellow-billed cuckoo occurs as two subspecies whose combined range extends across the continental United States from southern Canada to northern Mexico. The only currently known breeding populations of the western subspecies are in California, Arizona, and New Mexico (U.S. Geological Survey [USGS] 2010a). The YBCU breeds along the LCR and its tributaries, arriving in mid- to late May and departing in September, with the peak breeding activity occurring in mid-July to early August (Corman and Magill 2000, USGS 2010a).

Characteristics of YBCU breeding habitat may vary in plant species composition across its geographic range. The YBCU breeds in large blocks of dense, mature cottonwood/willow stands along streams and in stands with varying concentrations of cottonwood, willow, velvet ash, Arizona walnut, mesquite, and saltcedar (USFWS 2010, USGS 2010a). The stands selected for breeding tend to have multilayer canopy structure with tall trees and dense understory (USGS 2010a). YBCU are more likely to use saltcedar stands for foraging rather than breeding (USGS 2010a) and the Johnson et al. (2006) study found that YBCU had a low occupancy rate in stands with 75 percent saltcedar cover. Other studies suggest that use of saltcedar stands by YBCU may vary by geographic region, likely due to temperature changes (Howe 1986, Hunter 1987). YBCUs have been observed nesting in saltcedar in New Mexico but do not appear to utilize monotypic saltcedar stands along the LCR (Howe 1986, Hunter 1987). Surveys for YBCU within the LCR MSCP area found that the average size of occupied sites was 33.9 hectares and that unoccupied sites were smaller, with an average of 19.5 hectares (Halterman et al. 2009).

A few studies have investigated the importance of hydrologic and microclimate features in YBCU habitat. These studies found that distance to water and high humidity near the nest are important habitat elements (Gaines 1974, Hamilton and Hamilton 1965). Standing water in cottonwood/willow stands may positively influence the microclimate of the breeding habitat and protect eggs from extreme temperatures (USGS 2010a).

1.3 Study Purpose

Though there is quite a bit of information regarding the vegetation requirements for SWFL and YBCU breeding habitat in terms of canopy density, patch size, and species composition, there is less information available for the underlying soil hydrology and microclimate conditions that characterize breeding habitat for these species. The Bureau of Reclamation (Reclamation) is seeking information for its efforts to support the conservation of listed and candidate species.

The purpose of this study is to identify and describe the range of soil hydrology conditions that are present in occupied SWFL and YBCU habitat along the LCR. This information can then contribute to the development and protection of habitat for these species along the LCR.

2.0 METHODS

Sites were selected using information from SWFL and YBCU surveys and associated vegetation surveys completed by researchers contracted by Reclamation in 2009. Site selection for this soil hydrology study involved a four-step process. First, Reclamation and its biological consultants were consulted to determine which general areas (e.g., Bill Williams River National Wildlife Refuge) would be most appropriate to use for the soil hydrology study. Because the purpose of this study is to identify the range of soil hydrologic conditions in habitat utilized by these two species, the second step was to identify habitat patches within these general areas that had bird or nest sightings in 2009. The third step narrowed the list of possible soil hydrology sites further by finding sites that also had vegetation survey plots in order to minimize the spatial disparity between the soil hydrology measurements and vegetation measurements. Though the majority of sites selected had vegetation measurements, a few sites included in the soil hydrology study were not associated with vegetation plots. These sites are noted in Section 3.0. Fourth, within this final list of appropriate habitat patches, soil hydrology sample sites were randomly selected.

Originally, 21 sites were selected for study for each species. During the first data collection visit in March 2010, it was discovered that two SWFL sites (WF15 and WF18) overlapped SWFL sites WF14 and WF17. The two overlapping sites (WF15 and WF18) were removed from the project, which decreased the number of sites for the 2010 field season from 21 to 19. Also along the Bill Williams River, two of the YBCU sites were inaccessible due to high water conditions. This reduced the YBCU sites included in this field season from 21 to 19.

The final locations of the SWFL sites are shown in Figures 2.1 through 2.4 and are listed in Table 2.1. The YBCU sites are shown in Figures 2.3 through 2.5 and are listed in Table 2.2.

The same measurements were taken at all SWFL and YBCU sites. At each site, a site center was identified using the 2009 vegetation plot locations, where applicable, and a site center was randomly determined on the sites with no associated vegetation plot. From each site center, four 20-m transects were laid out, one in each cardinal direction. Measurements of litter depth, soil moisture, air temperature and relative humidity (as indicators of evapotranspiration), and soil texture were taken at 12 approximately 0.25 m^2 subplots located at 5 m, 12 m, and 20 m along each of the four transects. The total surface area and depth of any standing water that crossed the transect also were measured. At select sites, piezometers were installed to measure depth to ground water (refer to Table 2.3). These sites were selected as representative of multiple other sites located a similar distance from the same body of water. No piezometers were installed along the Bill Williams River because previously installed wells were available for measurement. Following discussions with Reclamation, it was determined that not all sites would have a piezometer installed due to the difficulty in accessing many of the sites and due to the close proximity of some of the sites to others. As a result, piezometers were installed at sites that were determined to be representative of several sites based on factors such as irrigation status and distance to the nearest flowing water.

Table 2.1. Final site locations for SWFL for the 2010 soil hydrology field season.

SWFL Site Name	Nearest Water Body	Landowner/ Manager	Latitude/Longitude (decimal degrees)	Associated 2009 Bird Survey Area
WF01	Beaver Dam Wash	Private	36.90286N/113.93580W	Littlefield Poles 20A
WF02	Beaver Dam Wash	Private	36.90250N/113.93473W	Littlefield Poles 105A
WF03	Virgin River	Nevada Department of Wildlife	36.61676N/114.32585W	Virgin River #1 South 63A
WF04	Virgin River	Nevada Department of Wildlife	36.61720N/114.32645W	Virgin River #1 South T2
WF05	Virgin River	Nevada Department of Wildlife	36.61833N/114.32644W	Virgin River #1 South 28A
WF06	Virgin River	Nevada Department of Wildlife	36.61928N/114.32620W	Virgin River #1 North 40A
WF07	Topock Marsh	Havasu NWR	34.82466N/114.51699W	Topock Pipes #3 2A
WF08	Topock Marsh	Havasu NWR	34.82246N/114.51577W	Topock Wallows F23
WF09	Topock Marsh	Havasu NWR	34.81261N/114.51883W	In Between T6
WF10	Topock Marsh	Havasu NWR	34.81229N/114.52247W	Pierced Egg 30A
WF11	Topock Marsh	Havasu NWR	34.80599N/114.53029W	Topock IRFB04 F5
WF12	Topock Marsh	Havasu NWR	34.79899N/114.53097W	Topock 250M F36
WF13	Topock Marsh	Havasu NWR	34.79447N/114.53382W	Topock Glory Hole 9A
WF14	Bill Williams River	Bill Williams River NWR	34.25795N/113.97449W	Bill Williams River NWR upstream from Site 8 47B
WF16*	Bill Williams River	Bill Williams River NWR	34.28081N/114.06678W	Bill Williams River NWR #3 8A
WF17	Bill Williams River	Bill Williams River NWR	34.28081N/114.06752W	Bill Williams River NWR #3 31B
WF19*	Bill Williams River	Bill Williams River NWR	34.28210N/114.06733W	Bill Williams River NWR #3 12A
WF20	Bill Williams River	Bill Williams River NWR	34.28181N/114.06814W	Bill Williams River NWR #3 66A
WF21	Bill Williams River	Bill Williams River NWR	34.28279N/114.06980W	Bill Williams River NWR #4 F24

NWR = National Wildlife Refuge

* WF15 and WF18 were dropped from the study during the March field visit. These two sites overlapped sites WF14 and WF17, respectively.

Table 2.2. Final site locations for YBCU for the 2010 soil hydrology field season.

YBCU Site Name	Nearest Water Body	Landowner/ Manager	Latitude/Longitude (decimal degrees)	Associated 2009 Bird Survey Area
YB01	Topock Marsh	Havasu NWR	34.83775N/114.52580W	Havasu NWR North Dike
YB02	Topock Marsh	Havasu NWR	34.78732N/114.55590W	Havasu NWR Topock Platform
YB03	Bill Williams River	Planet Ranch (City of Scottsdale)	34.25368N/113.95785W	Bill Williams River NWR Cottonwood Patch
YB04	Bill Williams River	Planet Ranch (City of Scottsdale)	34.25459N/113.96634W	Bill Williams River NWR Cave Wash
YB05	Bill Williams River	Bill Williams River NWR	34.25460N/113.98517W	Bill Williams River NWR Honeycomb Bend
YB06	Bill Williams River	Bill Williams River NWR	34.25409N/114.00124W	Bill Williams River NWR Mineral Wash
YB07	Bill Williams River	Bill Williams River NWR	34.25993N/114.01771W	Bill Williams River NWR Esquerra Ranch
YB08	Bill Williams River	Bill Williams River NWR	34.26307N/114.02626W	Bill Williams River NWR Cougar Point
YB09	Bill Williams River	Bill Williams River NWR	34.25966N/114.03259W	Bill Williams River NWR Kohen Cliff
YB10	Bill Williams River	Bill Williams River NWR	34.26011N/114.03635W	Bill Williams River NWR Gibraltar Rock
YB11	Bill Williams River	Bill Williams River NWR	34.27584N/114.05034W	Bill Williams River NWR Sandy Wash
YB12	Bill Williams River	Bill Williams River NWR	34.27644N/114.05551W	Bill Williams River NWR Borrow Pit
YB13	Bill Williams River	Bill Williams River NWR	34.27988N/114.06429W	Bill Williams River NWR Mosquito Flats
YB16*	Colorado River	Cibola Valley Conservation Area	33.41016N/114.65888W	Cibola Valley Conservation Area 1
YB17[†]	Colorado River	Cibola Valley Conservation Area	33.40530N/114.66013W	Cibola Valley Conservation Area 2
YB18	Colorado River	Cibola Valley Conservation Area	33.40378N/114.69425W	Cibola Valley Conservation Area 3
YB19	Colorado River	Cibola NWR	33.37434N/114.67970W	Cibola NWR North Plantation
YB20	Colorado River	Cibola NWR	33.36716N/114.67690W	Cibola NWR Nature Trail
YB21	Colorado River	Cibola NWR	33.27972N/114.68617W	Cibola NWR South Restoration

NWR = National Wildlife Refuge

* YB14 and YB15 were dropped from the study during the March field visit. These sites were inaccessible.

† YB17 did not have any YBCU observations in 2009. However, YB16 and YB18 (both of which are restoration sites in the same general area) had YBCU observations. YB17 was included in the study because it was expected that YBCU would be present in 2010.

Distance to flowing water was determined by overlaying the sites on aerials. Due to the extremely thick vegetation along the Bill Williams River, it was not always possible to see the river channel on aerials. A 2005 Geographic Information Systems (GIS) map of the Bill Williams River channel, marsh area, and river bars obtained from the U.S. Fish and Wildlife Service (USFWS) was used to determine the distance of sites to the nearest braid of the Bill Williams River. Though this map was the most detailed available, it was likely not representative of flowing water conditions along the Bill Williams River in March and April 2010 due to the high releases of water from Alamo Dam in March 2010.

Stream discharge was obtained from the online record of the closest upstream USGS station on the same body of water on which the study sites were located. The level of flow in a river was obtained because it can impact the soil hydrology in the adjacent riparian zone, including soil moisture, depth to ground water, and standing water. Data from the following USGS stream discharge stations were used for analysis purposes: Beaver Dam Wash at Beaver Dam, Arizona (USGS ID 09414900), Virgin River Above Lake Mead Near Overton, Nevada (USGS ID 09415250), Topock Marsh Inlet Near Needles, California (USGS ID 09423550), Bill Williams River Below Alamo Dam, Arizona (USGS ID 09426000), and Colorado River Below Palo Verde Dam, Arizona–California (USGS ID 09429100).

Soil samples to a depth of approximately 8 inches were collected for texture analysis in April 2010. Soil texture samples were only collected once during the field season as soil texture would not be expected to change over the course of one season. One soil sample was collected at each subplot, and a 200-gram subsample of each was transported to Olsen Laboratories for texture analysis. The results for the 12 subplots were averaged to obtain an overall average soil texture per site.

The soil organic layer, including litter and decomposing organic matter, can affect soil moisture and contributes to the water-holding capacity of soil. Therefore, the depth of organic material was measured using a metric ruler directly adjacent to the transect line at each of the 12 subplots.

The percent soil moisture was measured using two different methods over the course of the field season. Soil moisture was recorded below the surface rather than at the soil surface. Collecting deeper soil moisture measurements would be expected to provide more useful information because it will provide information on conditions closer to the tree root zone (Balluff 2007). Initially, soil moisture measurements were obtained via direct measurement in the field at a 0.6 m depth using an AquaTerr M300 Soil Moisture Meter at each of the 12 subplots. Due to various problems with the M300 in the first three months of data collection, the data collection method was switched to measuring gravimetric soil moisture by collecting and oven-drying soil samples from the same 0.6 m depth at each of the 12 subplots. Soil samples for gravimetric soil moisture determination were collected at all but two sites in April 2010, at five sites in May 2010, and at all sites in June through August 2010. The M300 was used exclusively in March 2010, part of April 2010, and almost entirely in May 2010.

These two methods of soil moisture measurement are not directly comparable and had no predictive relationship, according to a regression analysis ($R^2 = 0.461$, $p = 0.054$). Because of the problems associated with the M300, these data were dropped from further statistical analysis and only gravimetric data were carried forward in quantitative analyses. Further details regarding the relationship between the M300 and gravimetric soil moisture are discussed in Section 3.0.

Air temperature and relative humidity were collected during the time of each field visit using a handheld digital thermo-hygrometer to compare these microclimate conditions between YBCU and SWFL sites. Measurements were collected at approximately 1.5 m above the soil surface at each of the 12 subplots and were averaged for each site as a measure of habitat microclimate. Additional temperature data will be acquired to estimate evapotranspiration. Evapotranspiration is difficult to measure directly, but it can be correlated to atmospheric temperature, net radiation, and soil heat flux using the Priestley-Taylor estimation method. Samani et al. (2007) found that variables in the Priestley-Taylor methods, such as net radiation and soil heat flux, can be estimated using remote sensing. In addition to the temperature data from permanent data loggers placed by researchers contracted by Reclamation, this is the method that will be used following the 2011 field season to estimate potential evapotranspiration for the study sites.

Standing water was measured using a variation of the line intercept method. Whenever a pool of standing water crossed one of the 20-m transects, the width, length, and average depth of the pool were noted. These measurements did not include the depth or width of water in a flowing river and included only the dimensions of standing water within the limits of the site (e.g., the 40 m by 40 m or 1,600 m^2 area determined by the lateral extent of the four transects). The areas of each pool of standing water at one site were totaled to acquire the total square meters of standing water in each site. Where the site was inundated, the total area of the site (e.g., 1,600 m^2) was noted.

Eight existing wells were measured once per month along the Bill Williams River to obtain depth to ground water. These wells were located at varying distances from the river. In addition to these eight wells, three-quarter-inch-diameter piezometers were installed to a depth of 15 feet at nine sites in March 2010. Table 2.3 lists the locations of all the piezometers, including the existing wells measured along the Bill Williams River.

Following installation, the wells were allowed to fill and the depth to ground water was measured using a battery-operated Solinst water level meter. The wells were then hand-bailed and allowed to refill to ensure that no clogging or blockage due to piezometer installation had occurred. Depth to ground water was then measured again to ensure that the measurement was consistent and not skewed by the recent installation. For each well/piezometer, the height of the piezometer above ground level was measured and subtracted from the total depth to water to obtain a depth to ground water from ground level. The distance of each well to the nearest flowing water was determined using 2005 aerial photography, with the exception of the wells along the Bill Williams River, where this distance was determined using the 2005 GIS map provided by the USFWS. Not all wells were within a soil hydrology site. Wells were assigned to one or more soil hydrology sites based on similar distances to the nearest flowing water. Therefore, a well assigned to a site may be some distance from the site but would have a similar distance from flowing water.

Table 2.3. Location of wells and piezometers used to measure depth to ground water.

Piezometer Name	Existing or New	Landowner	Latitude/Longitude (decimal degrees)
PZ WF02	New	Private	36.90254N/113.93474W
PZ WF04	New	Nevada Department of Wildlife	36.61715N/114.32644W
PZ WF08	New	Havasu National Wildlife Refuge	34.82245N/114.51577W
PZ WF12	New	Havasu National Wildlife Refuge	34.79896N/114.53102W
PZ YB01	New	Havasu National Wildlife Refuge	34.83778N/114.52586W
PZ YB02	New	Havasu National Wildlife Refuge	34.78741N/114.55599W
PZ BW250	Existing	Bill Williams River National Wildlife Refuge	34.27962N/114.06563W
PZ BW248	Existing	Bill Williams River National Wildlife Refuge	34.27542N/114.05100W
PZ BW240	Existing	Bill Williams River National Wildlife Refuge	34.26040N/114.03123W
PZ BW233	Existing	Bill Williams River National Wildlife Refuge	34.25990N/114.01834W
PZ BW230	Existing	Bill Williams River National Wildlife Refuge	34.25349N/114.00617W
PZ BW225	Existing	Bill Williams River National Wildlife Refuge	34.25732N/113.97834W
PZ PR3B	Existing	Planet Ranch	34.25376N/113.96306W
PZ PR3C	Existing	Planet Ranch	34.25399N/113.96606W
PZ YB16	New	Cibola Valley Conservation Area	33.41020N/114.65892W
PZ YB19	New	Cibola National Wildlife Refuge	33.37433N/114.67964W
PZ YB21	New	Cibola National Wildlife Refuge	33.27972N/114.68617W

Vegetation data, including canopy height, percent canopy closure, and percent ground cover, were collected by SWCA in 2009 at approximately the same location as many of the SWFL sites and by the Southern Sierra Research Station (SSRS) in 2009 at approximately the same location as the YBCU sites. The vegetation measurement plots were smaller than the soil hydrology site, but they were encompassed in the area measured for soil hydrology. All references to canopy height, percent canopy closure, and percent ground cover in this report refer to the 2009 data from SSRS or SWCA (SSRS 2009, SWCA 2009).

W/09-285/NEPA/HYDRO/Fig2.1

Figure 2.1. Site locations along Beaver Dam Wash in Littlefield, Arizona.

Figure 2.2. Site locations along the Virgin River near Overton, Nevada.

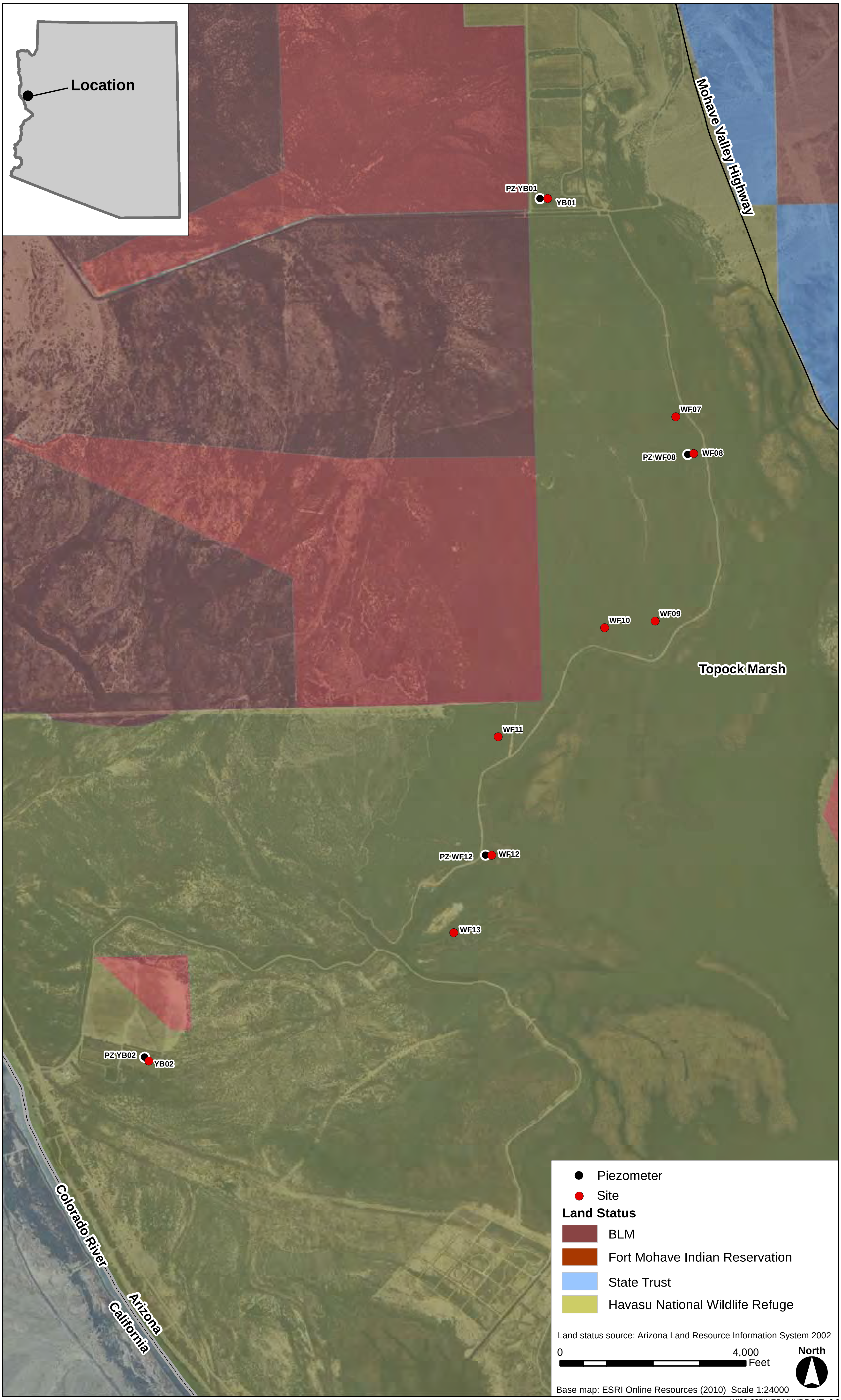


Figure 2.3. Site locations near Topock Marsh in Havasu National Wildlife Refuge, Arizona.

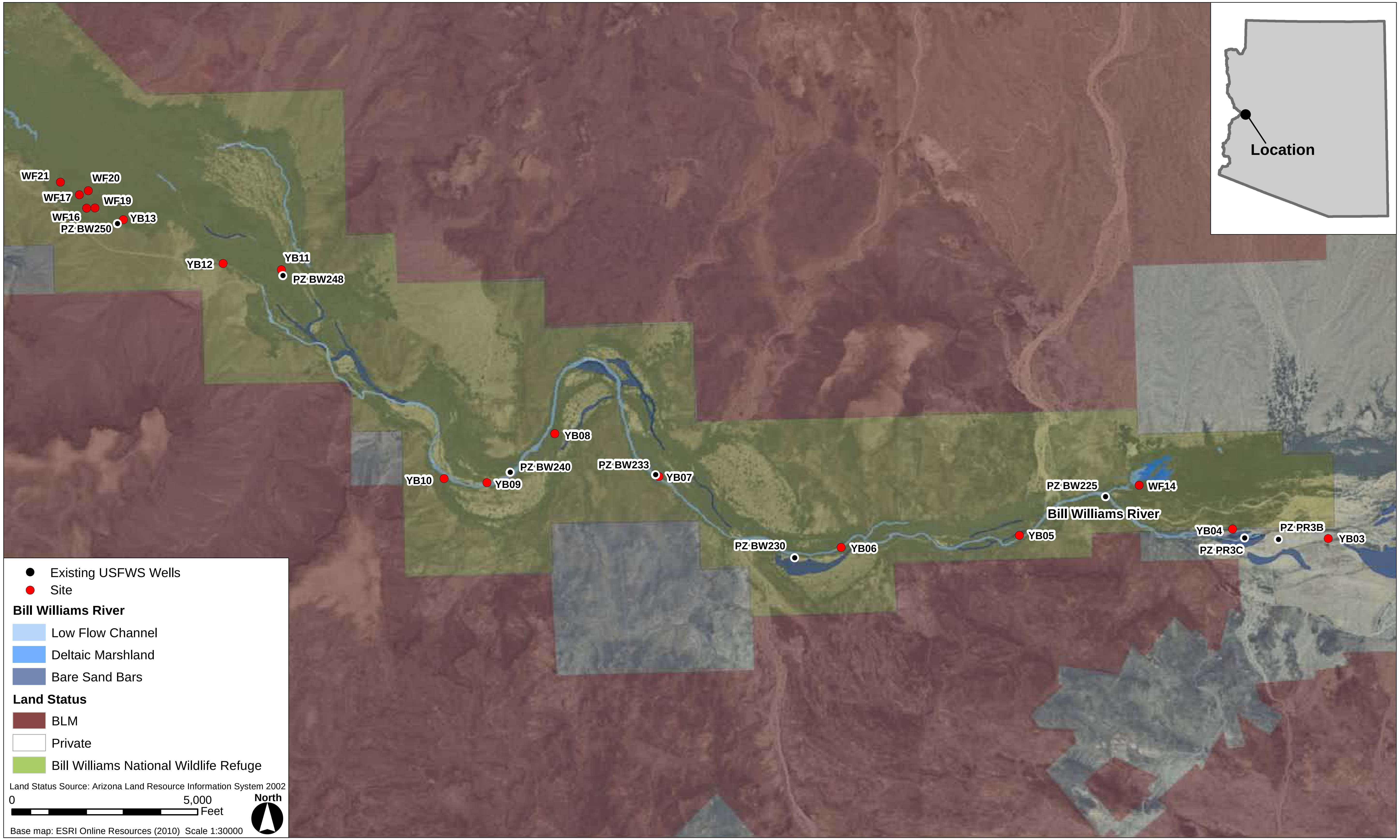


Figure 2.4. Site locations along the Bill Williams River downstream of Alamo Dam, Arizona.

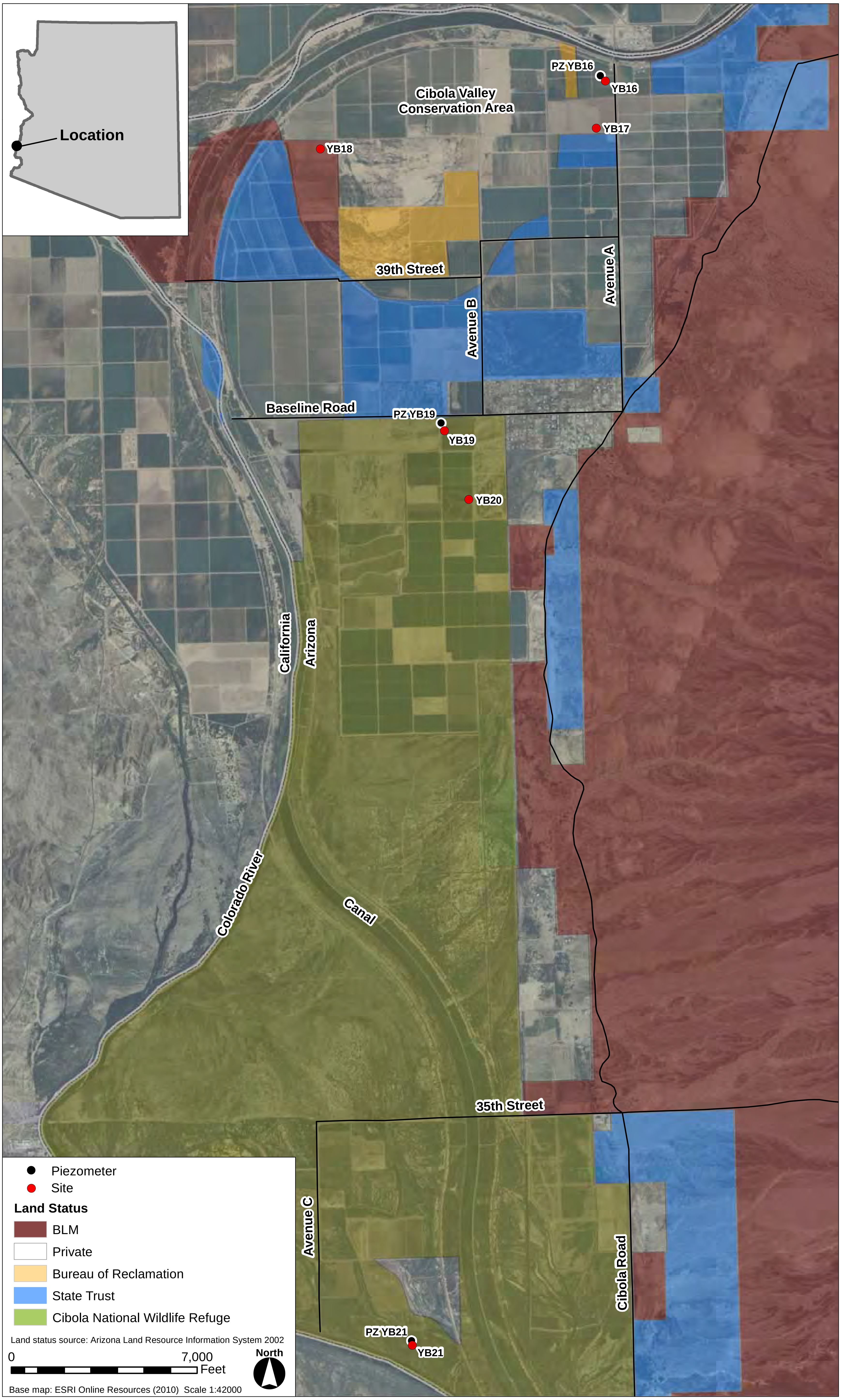


Figure 2.5. Site locations at restoration sites near Colorado River at the Cibola Valley Conservation Area and the Cibola National Wildlife Refuge, Arizona.

3.0 RESULTS

The results of this study are discussed in three main sections: SWFL results, YBCU results, and a comparison between SWFL and YBCU results. Within the SWFL and YBCU sections, results are further broken down by study site in tables followed by a cumulative results discussion for all study sites within that section. Results of statistical analysis are discussed in each of the respective cumulative sections. A more detailed text description of each site and its results are presented in Appendix A. A representative photo log of the sites is available in Appendix B.

Due to high winter precipitation, discharge along nearby streams tended to be higher in March and April than in later months of the field season. This was most noticeable for the Bill Williams River. Alamo Dam along the Bill Williams River is upstream of the study sites and had high storage levels as a result of this winter precipitation. This necessitated large releases in March, slowly subsiding through April. The effect of high precipitation followed by snowmelt was also observed on Beaver Dam Wash and the Virgin River and, to a lesser extent, on the Colorado River, which is heavily regulated. The Virgin River is the only unregulated river in this study. Very little variation in discharge occurred at Topock Marsh. Flow is tightly regulated through the marsh. A slight rise in discharge was seen in April through June, but this was minimal, a difference of a maximum of approximately 28 cubic feet per second. The discharge at each stream is discussed in the individual SWFL and YBCU results in sections that follow.

As discussed in the Methods section, soil moisture data were collected using two methods at varying times in the field season: the M300 direct field measurement and the soil samples collected to calculate gravimetric soil moisture. The M300 estimates percent soil moisture by measuring the ratio of water to air in the soil, whereas the soil samples were oven-dried to obtain the gravimetric percent soil moisture. These two methods are not directly comparable, so duplicate data were collected in April and part of May so a regression could be run to determine whether there was a predictive relationship (e.g., Can the M300 percent moisture predict what the gravimetric percent moisture would be?). The resulting low regression coefficient ($R^2 = 0.461$, $p = 0.054$) suggested there is no appropriately powerful predictive relationship between the two moisture measurements.

Because of the lack of a predictive relationship, multiple problems with the M300—including the need to constantly recalibrate due to unusual readings—and because the majority of data use the gravimetric method, the M300 data were dropped from the overall statistical analysis. As a result, no percent soil moisture data were analyzed for the months with only M300 data available, including all sites in March and all sites in May. However, the M300 results are discussed here qualitatively. For example, though the soil moisture percentages cannot be compared directly quantitatively, it was noted whether the M300 measurements were generally high, moderate, or low percent moisture. Though two months of data are not included in the quantitative analysis, this was the appropriate course to take to ensure that the analyses are valid and to use comparable data. The 2011 field work will only include collecting soil samples for gravimetric percent soil moisture. The soil moisture measurements for the 12 subplots were averaged to obtain the average percent soil moisture per site.

3.1 SWFL Results

3.1.1 SWFL Individual Site Results

The following tables show the range of conditions for each environmental variable measured during the 2010 field season. Table 3.1 shows the range of soil hydrology measurements at each SWFL site, and Table 3.2 shows the microclimate measurements at each SWFL site, including the vegetation measurements from 2009. Following the tables, Figures 3.1 through 3.6 chart the discharge at the nearest USGS (2010b) stream gauge compared with depth to ground water at each well/piezometer.

The air temperature and relative humidity measurements recorded on-site, as noted in Table 3.2, were taken at varying times of day. Analysis of the data is hindered by the potential for error created by the disparity in measurement time. The vegetation data on canopy height, canopy closure, and ground cover were taken from SWCA's 2009 data (SWCA 2009).

Table 3.1 Soil hydrology results for individual SWFL sites across the 2010 field season (March through August).

Site Name	Average Distance to Flowing Water (m)	Range of Area of Standing Water (m^2)/Depth of Standing Water (m)	Range of Depth to Ground Water (m)/ Piezometer Used	Range of Soil Moisture (%)*	Soil Texture Classes Present	Months Standing/ Flowing Water Present
WF01	0	0.0/0.0	0.69–0.46/ WF02	4.0–35.0	Sandy loam	March through August
WF02	0	0.0/0.0	0.69–0.46/ WF02	23.0–28.0	Sand, sandy loam, loamy sand	March through August
WF03	348	283–1,150/ 0.04–0.07	0.2–0.0/ WF04	37–50	Silt loam	March through June
WF04	170	33–1,600/ 0.0–0.13	0.2–0.0/ WF04	29–44	Silt loam	March through June, August
WF05	289	1.46–286/ 0.01–0.04	0.2–0.0/ WF04	38–43	Silt loam	March, May, June**
WF06	240	34–51.75/ 0.02–0.04	0.2–0.0/ WF04	32–36	Silt loam, sandy loam	March and May**
WF07	96	3.7–9/ 0.21	1.21–0.85/ WF12	31–46	Loam	March and April
WF08	111	7.6–107/ 0.05	0.28–0.0/ WF08	38–57	Silt loam, clay loam, loam	April and May
WF09	226	77–180/ 0.05	0.28–0.0/ WF08	29–36	Sandy loam and loam	March and April
WF10	165	28.2–150.8/ 0.04	0.28–0.0/ WF08	33–42	Sandy loam, loam	March and April
WF11	202	0.0/0.0	0.28–0.0/ WF08	24–32	Loam, sandy loam, silt loam	NA
WF12	61	0.0/0.0	1.21–0.85/ WF12	20–24	Loamy sand	NA
WF13	214	0.0/0.0	1.21–0.85/ WF12	4.9–9.8	Sand, loamy sand	NA
WF14	8	10–550/ 0.04–0.14	2.08–1.73/ PZ BW225	33.7–40.2	Silt loam, sandy loam, loam	April through August***

Table 3.1 Soil hydrology results for individual SWFL sites across the 2010 field season (March through August).

Site Name	Average Distance to Flowing Water (m)	Range of Area of Standing Water (m^2)/Depth of Standing Water (m)	Range of Depth to Ground Water (m)/ Piezometer Used	Range of Soil Moisture (%)*	Soil Texture Classes Present	Months Standing/ Flowing Water Present
WF16	446	15–520/ 0.04–0.21	2.8–1.1/ PZ BW250	39.6–50.3	Silt loam	March through June
WF17	331	180–755/ 0.15	2.8–1.1/ PZ BW250	30.5–42.6	Silt loam	March through June
WF19	430	34–64/ 0.04	2.8–1.1/ PZ BW250	34.7–51.0	Silt loam	March through May
WF20	290	20–27.5/ 0.02	2.8–1.1/ PZ BW250	31.2–47.5	Silt loam	March through June
WF21	250	63.5/0.04	2.8–1.1/ PZ BW250	32.8–47.3	Silt loam	March

NA = Not applicable

* Represents gravimetric soil moisture measurements collected in April and June–August 2010.

** Due to rising water in the Virgin River (in response to precipitation), no data were collected at this site in April.

*** Due to high water levels, this site was inaccessible in March and no measurements were taken.

Table 3.2. Microclimate results for individual SWFL sites across the 2010 field season (March through August) and 2009 vegetation plot data.

Site Name	Range of Relative Humidity (%)	Range of Air Temperature (ºC)	Canopy Height (m)	Canopy Closure (%)	Ground Cover (%)
WF01	28.0–88.0	14.5–28.5	5.4	88.5	4.8
WF02	24.0–81.0	14.5–24.2	NA	NA	NA
WF03	23.0–74.0	17.3–32.6	3.7	92.2	11.8
WF04	23.0–74.0	12.4–32.2	2.8	92.7	3.5
WF05	20.0–85.0	20.2–26.2	5.5	50.5	11.3
WF06	20.0–76.0	16.7–28.1	4.5	92.7	7.8
WF07	22.0–82.0	16.7–37.0	6.0	95.8	42.5
WF08	29.5–73.0	18.3–33.7	NA	NA	NA
WF09	31.0–81.0	21.4–30.1	7.0	98.4	14.0
WF10	25.0–87.0	24.4–29.9	7.5	92.7	13.3
WF11	19.0–78.0	25.8–36.4	NA	NA	NA
WF12	17.3–73.4	23.2–33.6	NA	NA	NA
WF13	29.0–77.0	16.1–27.8	5.2	94.8	41.3
WF14	23.0–87.0	14.1–29.4	16.5	88.5	35.0
WF16	20.0–91.0	24.5–35.2	5.2	96.9	46.3
WF17	29.0–87.0	19.3–30.6	6.9	94.3	15.8
WF19	35.0–87.0	15.7–30.2	13.7	96.9	38.8
WF20	35.0–93.0	12.9–30.7	NA	NA	NA
WF21	35.0–82.0	10.0–31.1	NA	NA	NA

NA = Not available. These sites were not associated with vegetation plots.

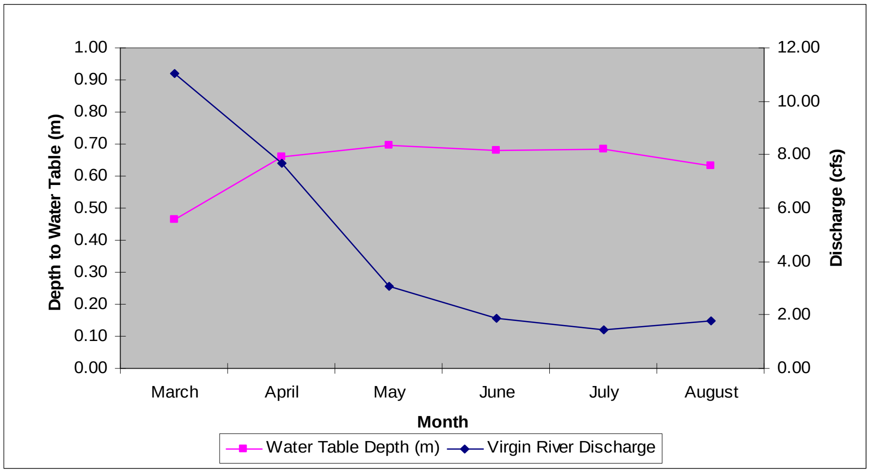


Figure 3.1. Depth to ground water at WF02 piezometer and discharge at Beaver Dam USGS station.

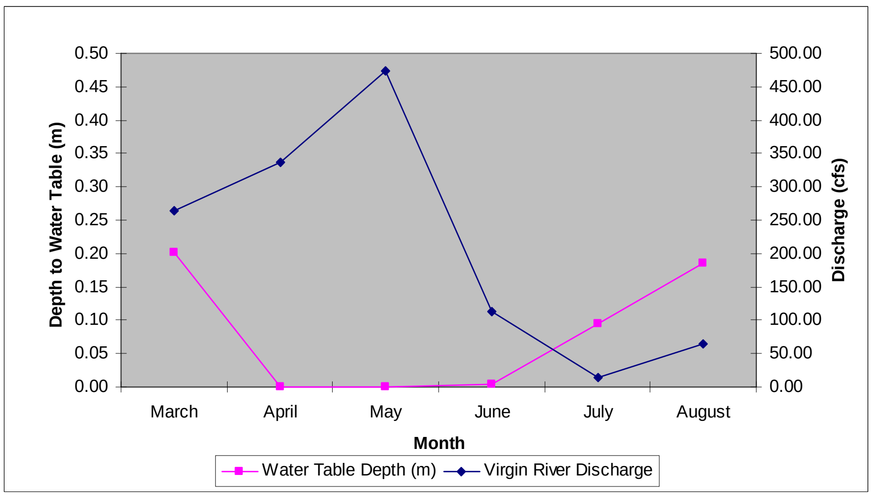


Figure 3.2. Depth to ground water at WF04 piezometer and discharge at Virgin River USGS station.

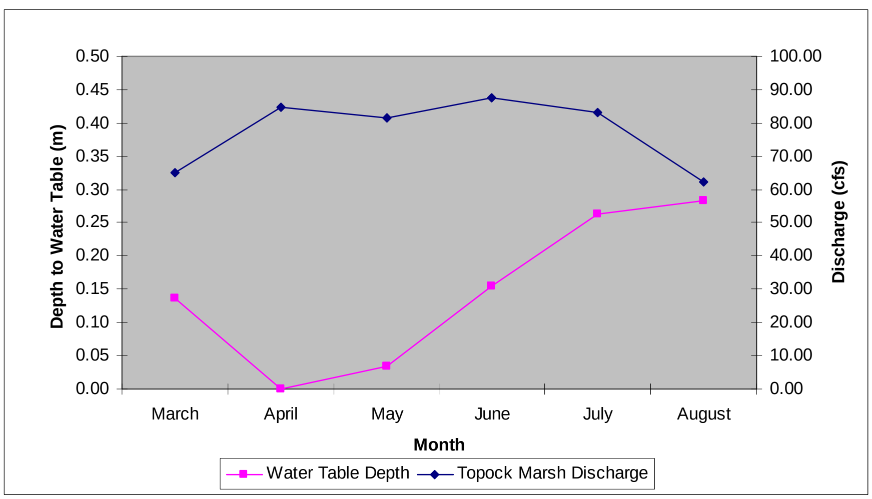


Figure 3.3. Depth to ground water at WF08 piezometer and discharge at Topock Marsh Inlet USGS station.

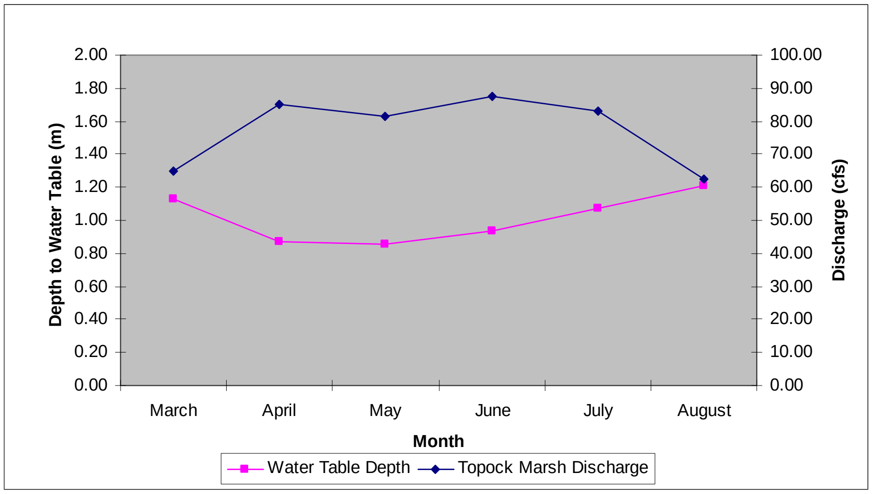


Figure 3.4. Depth to ground water at WF12 piezometer and discharge at Topock Marsh Inlet USGS station.

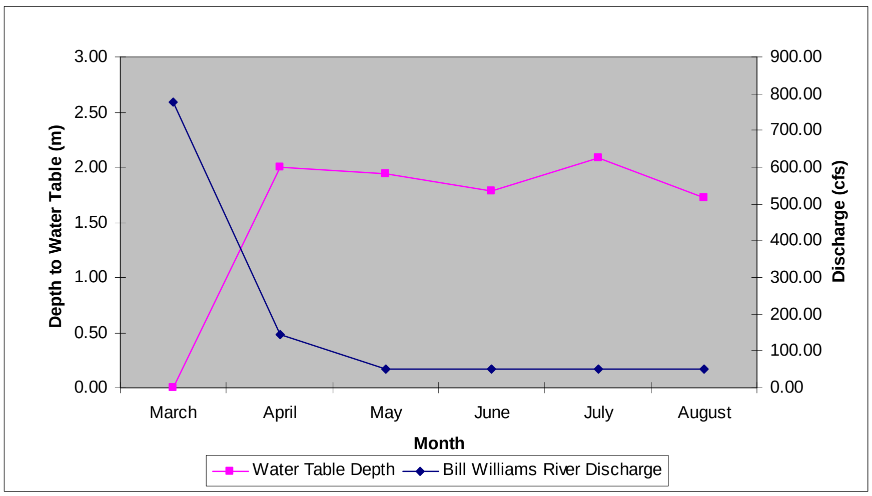


Figure 3.5. Depth to ground water at PZ BW225 and discharge at Bill Williams River below Alamo Dam USGS station.

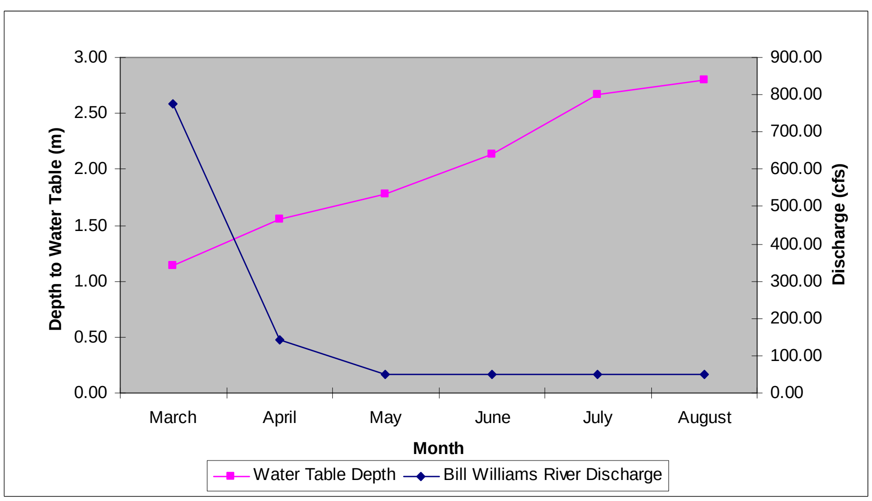


Figure 3.6. Depth to ground water at PZ BW250 and discharge at Bill Williams River below Alamo Dam USGS station.

3.1.2 Cumulative SWFL Results

The range of conditions measured at the SWFL sites in 2010 are detailed in Table 3.3. The range of soil moisture conditions only reflect gravimetric measurements obtained in April, June, July, and August and do not include measurements in inundated soils. Sixteen of 19 SWFL sites had inundated/saturated soil conditions in at least part of the site for one or more months and would have higher levels of soil moisture. The range of percent soil moisture as described in Table 3.3 is an underestimate if considered alone but gives an idea of the range of conditions when combined with the area of standing water (saturated soil conditions).

Table 3.3. Total range of conditions measured at all SWFL sites in 2010.

Measurement	Mean	Median	Range (minimum/ maximum)	Standard Error/Standard Deviation	Notes
2010 Soil Hydrology Measurements					
Percent soil moisture	34.1	36.1	4.3/58.6	1.3/11.8	Does not include measurements in inundated soils
Soil texture (% sand)	43.6	46.5	20.6/84.3	5.0/22.0	Soil textures ranged from sand to silt loam
Standing/flowing water area (m^2)	284	1.5	0.0/2100	49.9/525.6	16 of 19 sites had standing or flowing water at least two months of the field season
Standing/flowing water depth (m)	0.06	0.0	0.0/0.5	0.01/0.1	
Depth to ground water (m)	0.88	0.68	0.0/2.8	0.08/0.87	
Distance to flowing water (m)	210.6	226	0/446	31.0/135.3	Per aerial measurements and 2005 Bill Williams River GIS map
Air temperature ºCelsius (within site)	24.9	25.4	10.1/37.0	0.5/5.8	
Percent relative humidity (within site)	54.7	55.4	17.0/93.0	2.2/22.6	
2009 SWCA Vegetation Measurements					
Canopy height (m)	6.9	5.5	2.8/16.5	1.1/3.9	13 of 19 soil hydrology sites had 2009 SWCA vegetation data spatially associated
Percent canopy closure	90.4	92.7	50.5/98.4	3.4/12.4	
Percent ground cover	22.0	14.0	3.5/46.3	4.4/16.0	

Regression analysis was used to determine relationships between variables measured across all SWFL sites. Identifying the relationships between variables may provide valuable information when determining what conditions may be important for breeding habitat. For all statistical analyses, significance was inferred at a p-value less than 0.05.

Percent soil moisture was compared with month of collection, stream discharge, distance from flowing water, area of standing water, soil texture, and depth to ground water using linear regression to identify any significant relationships between soil moisture and these variables. Because the distance to flowing water was obtained via measurement from aerial photographs and from a 2005 USFWS GIS map (for the Bill Williams River), the measurements do not reflect precise river channel conditions in 2010. For example, the Bill Williams River had high flows due to dam releases in March, resulting in a wider channel with multiple flowing braids over several months. An effort was made via the use of the 2005 low-flow channel and channel bar layers and the most recent aerials available to identify the closest braids to the sites; however, this use of aerial photography and mapping introduces some potential for error in calculating the distance to flowing water. In addition, distance to flowing water was calculated for the average flow over the course of the field season.

Soil moisture at SWFL sites was best predicted by soil texture, distance from standing water and, to a lesser degree, time of year, stream discharge, and area of standing water. There was a fairly wide range of soil moisture across the SWFL sites, from 4.3 percent to nearly 60 percent, and this was associated with soil texture, as indicated by the results of a linear regression using percent sand as the quantitative representative of soil texture ($R^2 = 0.57$, $p<0.01$). Percent soil moisture decreased with increasing sand levels. Sand allows water to infiltrate more rapidly, resulting in lower soil moistures in sandy soils. Results of the regression between soil moisture and distance to flowing water indicated that there is a significant relationship between soil moisture and distance to flowing water and that approximately 27 percent of the variation is accounted for by a linear relationship ($R^2 = 0.27$, $p = 0.02$). Unexpectedly, percent soil moisture tended to be lower at sites closer to flowing water than sites farther away, though this was likely the result of higher percent sand (more highly drained soils) closer to active channels as a result of sediment deposition on overbank or floodplain areas.

For all the remaining relationships with soil moisture, except depth to ground water, the p-values suggest that a relationship exists, but the resulting regression coefficients are low, only explaining a small percentage of the variation. These relationships are (1) percent soil moisture and time of year measurements were taken ($R^2 = 0.06$, $p = 0.04$), (2) soil moisture and stream discharge ($R^2 = 0.06$, $p = 0.03$), and (3) soil moisture and the area of standing water ($R^2 = 0.09$, $p<0.01$). Finally, soil moisture was compared with depth to ground water. The regression did not show a significant relationship between percent soil moisture and depth to ground water ($R^2 = 0.01$, $p = 0.3$).

Air temperature and percent relative humidity were compared with 2009 percent canopy closure, canopy height, and percent ground cover. Because the air temperature and relative humidity measurements were taken in 2010 and are being compared with 2009 vegetation data, there is a temporal disparity that may lead to error. Though sites were located as close to the 2009 vegetation plots as possible, there is a possibility that the sites do not cover the precise spatial area measured in the 2009 vegetation plots. The soil hydrology sites also covered a larger area than the 2009 vegetation plots.

It was hypothesized that vegetation characteristics such as canopy density would have an impact on the microclimate under the canopy through shading and evapotranspiration and thereby influence microclimate conditions that may be important in breeding habitat selection. Comparisons of 2009 vegetation data and 2010 air temperature and relative humidity data at the same approximate locations only yielded a significant result when comparing relative humidity with the height of the canopy ($R^2 = 0.67$, $p<0.01$). Taller canopy heights had a generally higher percent relative humidity in the site. The remaining comparisons (air temperature and canopy height [$R^2 = 0.009$, $p = 0.7$], air temperature and canopy closure [$R^2 = 0.02$, $p = 0.6$], air temperature and ground cover [R^2 = 0.14, p = 0.2], relative humidity and canopy closure [R^2 = 0.01, p = 0.7], and relative humidity and ground cover [R^2 = 0.18, p = 0.14]) did not indicate significant relationships between the variables. Figure 3.7 plots the measured average air temperature at each site with the average canopy closure and average ground cover, and Figure 3.8 plots the measured percent relative humidity with the average canopy closure and average ground cover.

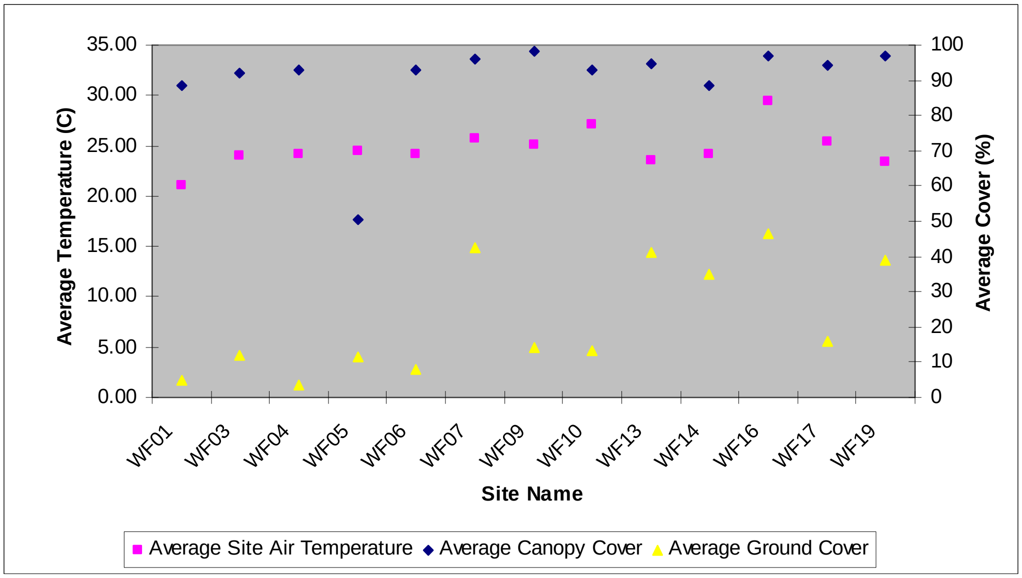


Figure 3.7. Average air temperature at 2010 SWFL sites and average percent canopy closure and ground cover at 2009 vegetation SWFL sites.

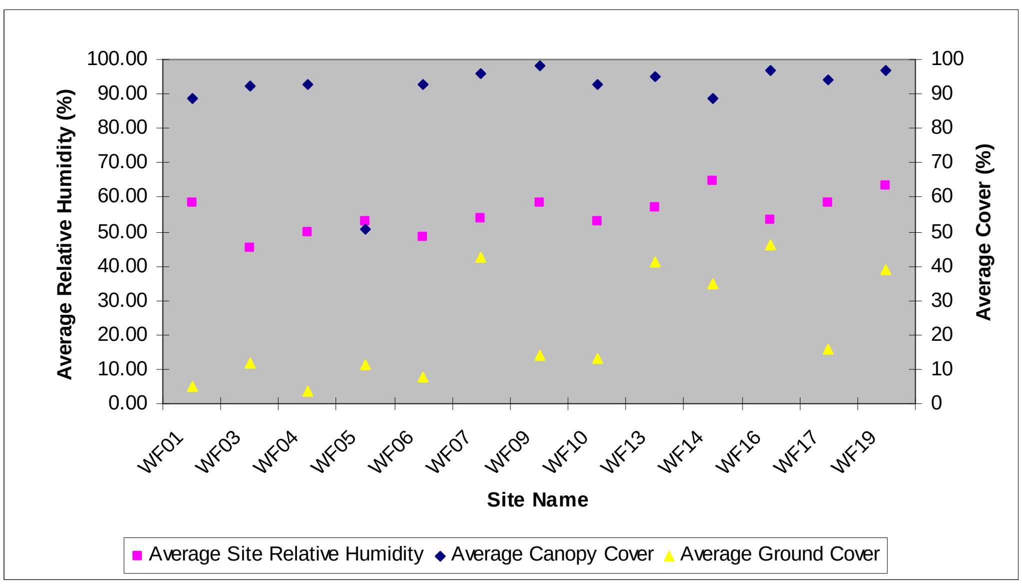


Figure 3.8. Average percent relative humidity at 2010 SWFL sites and average percent canopy closure and ground cover at 2009 vegetation SWFL sites.

At SWFL sites in this study, soil moisture was best predicted by soil texture and distance from flowing water, and relative humidity was best predicted by vegetation canopy height. Sites with lower percent sand had higher percent soil moisture, and sites closer to flowing water had generally lower percent soil moisture. Relative humidity was higher in sites with higher canopy height. Many of these variables are interrelated, and any conclusions about interrelated variables would be preliminary at this stage. Conclusions about conditions to consider for habitat creation efforts will be provided after the 2011 field season. It is likely, however, that soil texture will be an important variable in the selection of sites for habitat creation.

3.2 YBCU Results

3.2.1 YBCU Individual Site Results

The following tables show the range of conditions for each environmental variable measured during the 2010 field season. Table 3.4 shows the range of soil hydrology measurements at each YBCU site, and Table 3.5 shares the microclimate measurements at each YBCU site, including vegetation measurements. Following the tables, Figures 3.9–3.20 chart the discharge at the nearest USGS (2010b) stream gauge compared with depth to ground water at each well/piezometer.

The air temperature and relative humidity measurements recorded on-site, as noted in Table 3.4, were taken at varying times of day. Analysis of the data is hindered by the potential for error created by the disparity in measurement time. The vegetation data on canopy height, canopy closure, and ground cover, as noted in Table 3.5, were taken from SSRS 2009 data (SSRS 2009).

Table 3.4. Soil hydrology results for individual YBCU sites across the 2010 field season (March through August).

Site Name	Average Distance to Flowing Water (m)	Range of Area of Standing Water (m^2)/Depth of Standing Water (m)	Range of Depth to Ground Water (m)/ Piezometer Used	Range of Soil Moisture (%)*	Soil Texture Classes Present	Months Standing/Flowing Water Present
YB01	450	0.0/0.0	1.32–0.88/YB01	16–24	Loam, sand, silt loam	NA
YB02	700	0.0/0.0	2.4–1.9/YB02	0.47–3	Sand, loamy sand	NA
YB03	144	0.0/0.0	0.94–0.0/ PZ PR3C	3.9–14.8	Sand	NA
YB04	28	0.0/0.0	1.4–0.9/ PZ PR3B	3.5–6.1	Sand	NA
YB05	5	0.0/0.0	2.08–1.73/ PZ BW225	4.6–9.2	Sand	NA**
YB06	5	0.0/0.0	2.43–2.21/ PZ BW233	9.6–16.7	Loam, sandy loam, loamy sand	March through August (flowing water)
YB07	11	0.0/0.0	2.43–2.21/ PZ BW233	12.9–15.1	Sand, loamy sand, sandy loam	March through August (flowing water)
YB08	49	0.0/0.0	1.96–1.37/ PZ BW230	4.5–12.3	Sand	NA**
YB09	32	0.0/0.0	1.81–1.52/ PZ BW240	1.6–7.2	Sand	NA**
YB10	30	0.0/0.0	1.81–1.52/ PZ BW240	9.0–19.2	Sand	NA**

Table 3.4. Soil hydrology results for individual YBCU sites across the 2010 field season (March through August).

Site Name	Average Distance to Flowing Water (m)	Range of Area of Standing Water (m^2)/Depth of Standing Water (m)	Range of Depth to Ground Water (m)/ Piezometer Used	Range of Soil Moisture (%)*	Soil Texture Classes Present	Months Standing/Flowing Water Present
YB11	207	0.0/0.0	2.2–0.9/ PZ BW248	2.3–8.7	Sand, loam, loamy sand, sandy loam	NA
YB12	215	0.0/0.0	2.2–0.9/ PZ BW248	1.2–3.9	Sand, loamy sand, sandy loam	March and April (flowing water)
YB13	433	0.96–700/0.03–0.07	2.08–1.73/ PZ BW250	38.9–53.5	Sand, loamy sand, silt loam	March through June
YB16	254	0.0/0.0	4.71–4.18/YB16	4.2–11.6	Sandy loam, loam	NA (flood irrigation occurred throughout field season)
YB17	754	0.0/0.0	4.71–4.18/YB16	9.7–23.8	Silt loam, loam	NA (flood irrigation occurred throughout field season)
YB18	680	1,600 (flood irrigated in August)	4.71–4.18/YB16	7.9–29.8	Silt loam	August (flood irrigation occurred throughout field season)
YB19	2100	1,600 (flood irrigated in June)	2.91–1.02/YB19	3.6–26.6	Loam, sandy loam	June (flood irrigation occurred throughout field season)
YB20	2000	0.0/0.0	2.91–1.02/YB19	17.8–29.0	Loam, sandy loam, silt loam	NA (flood irrigation occurred throughout field season)
YB21	200	0.0/0.0	1.45–0.89/YB21	26.9–33.1	Sandy loam, loam	NA (flood irrigation occurred throughout field season)

NA = Not applicable

* Represents gravimetric soil moisture measurements collected in April and June–August.

** Site was inaccessible in March due to high flows. No measurements taken.

Table 3.5. Microclimate results for individual YBCU sites across the 2010 field season (March through August).

Site Name	Range of Relative Humidity (%)	Range of Air Temperature (°C)	Canopy Height (m)	Canopy Closure (%)	Ground Cover (%)
YB01	14–74	16.8–44.5	5	58.5	90
YB02	13–28	27.6–47.4	8	72.8	10
YB03	15–87	9.5–40.2	9	56.0	31.0
YB04	14–85	12.5–40.8	14	60.3	0.0
YB05	17–64	25.5–37.8	9	69.7	12.5
YB06	23–95	17.7–33.0	10.5	57.5	3.5
YB07	25–91	22.8–30.9	9	79.8	87.5
YB08	31–93	19.6–28.2	10.5	62.5	5.0
YB09	23–83	19.0–35.5	8.0	73.8	6.3
YB10	37–87	15.9–33.1	8.0	60.3	0.0
YB11	31–91	7.8–31.4	5.3	91.0	0.0
YB12	20–91	11.4–40.2	6.4	53.0	0.0
YB13	31–95	16.7–29.3	19.0	59.0	33.5
YB16	24–50	21.7–37.2	10.0	90.3	19.3
YB17	24–87	18.3–35.0	8.0	88.3	3.3
YB18	15–57	21.5–44.7	7.0	67.8	37.0
YB19	20–62	13.8–37.5	10.5	78.3	4.5
YB20	17–87	16.4–30.8	12.8	81.3	23.8
YB21	19–96	22.2–27.6	5.2	68.8	0.0

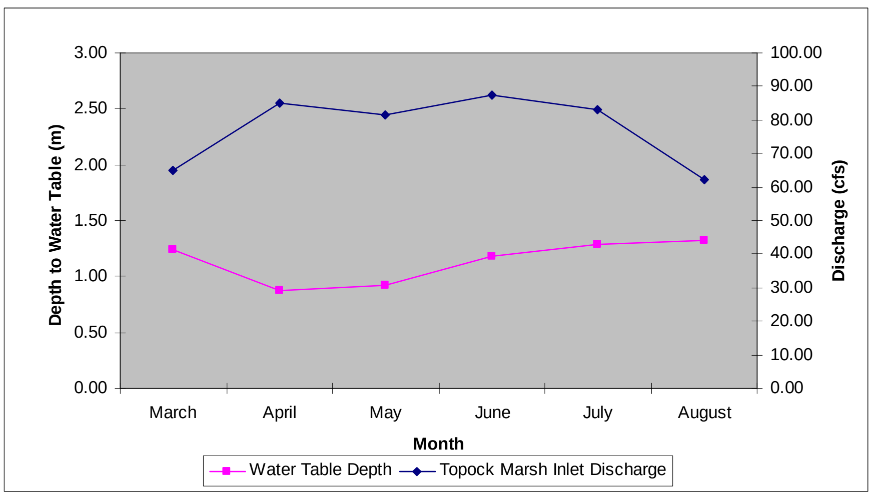


Figure 3.9. Depth to ground water at YB01 piezometer and discharge at Topock Marsh Inlet USGS station.

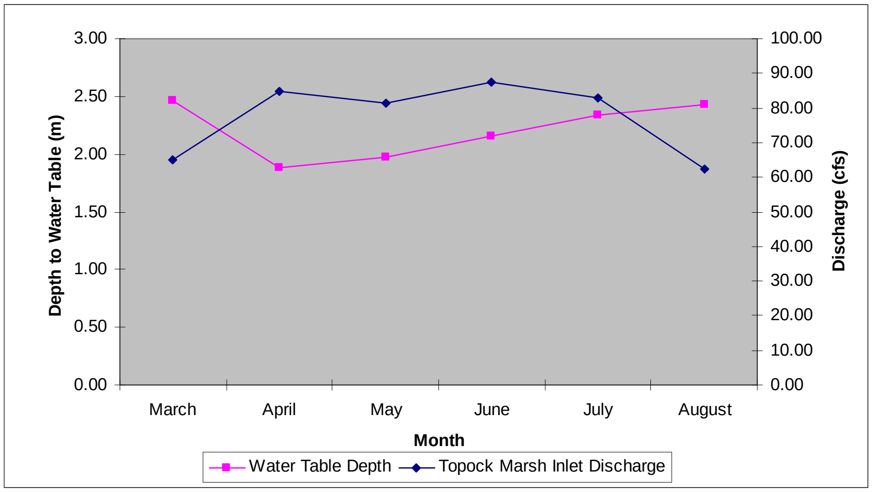


Figure 3.10. Depth to ground water at YB02 piezometer and discharge at Topock Marsh Inlet USGS station.

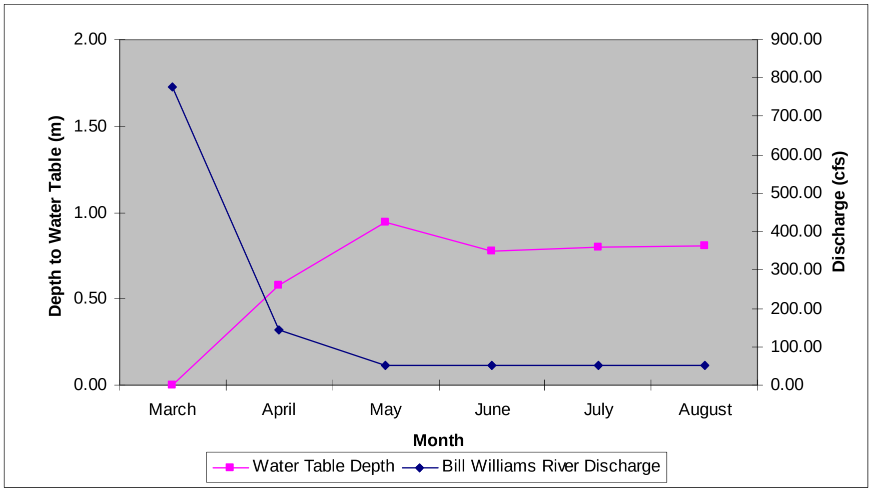


Figure 3.11. Depth to ground water at PZ PR3C and discharge at Bill Williams River below Alamo Dam USGS station.

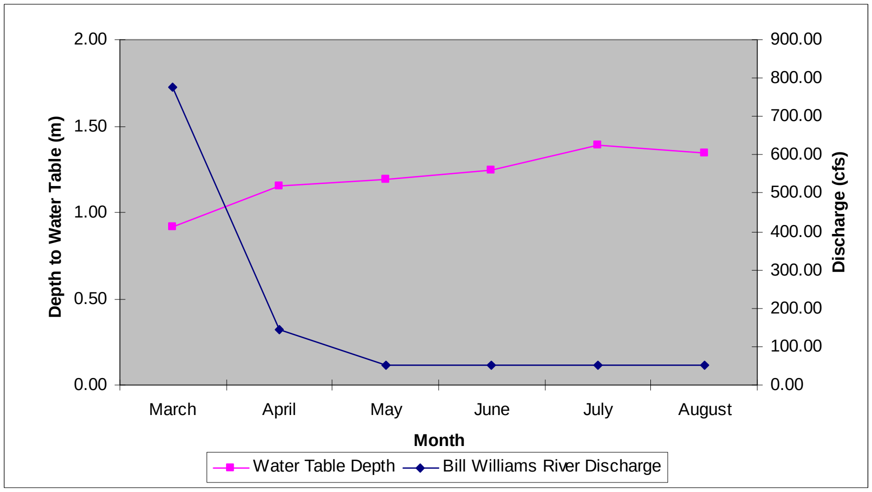


Figure 3.12. Depth to ground water at PZ PR3B and discharge at Bill Williams River below Alamo Dam USGS station.

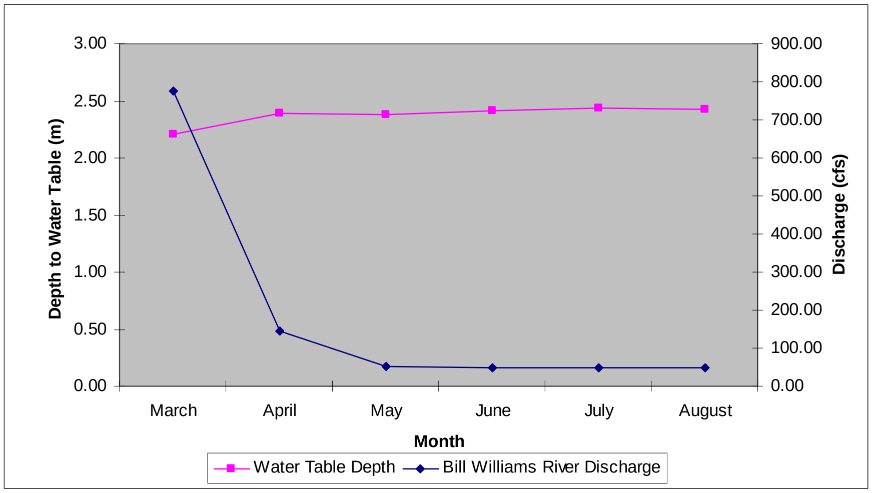


Figure 3.13. Depth to ground water at PZ BW233 and discharge at Bill Williams River below Alamo Dam USGS station.

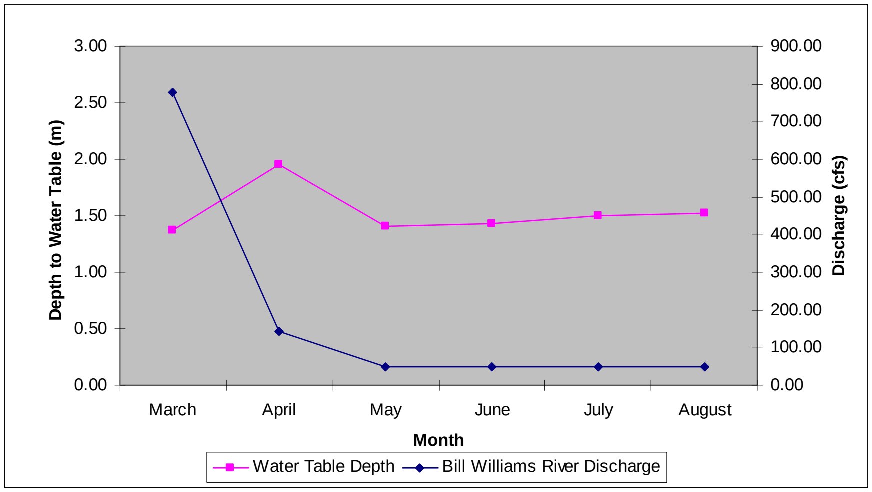


Figure 3.14. Depth to ground water at PZ BW230 and discharge at Bill Williams River below Alamo Dam USGS station.

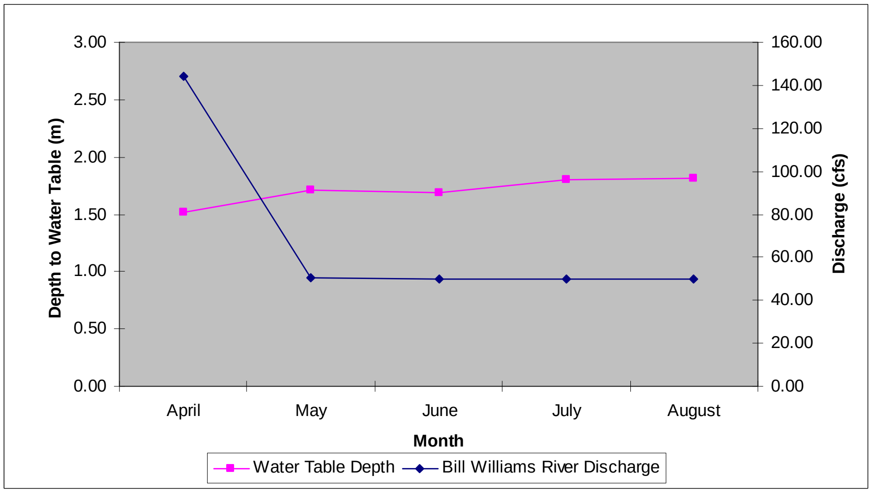


Figure 3.15. Depth to ground water at PZ BW240 and discharge at Bill Williams River below Alamo Dam USGS station

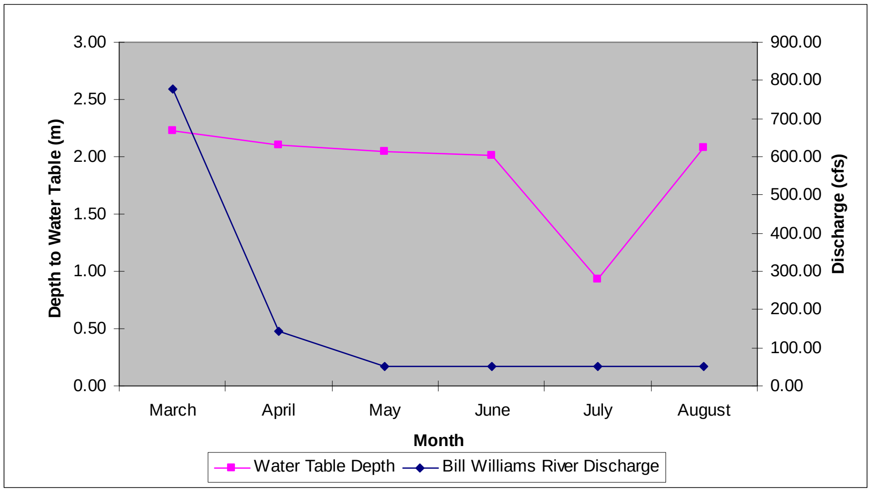


Figure 3.16. Depth to ground water at PZ BW248 and discharge at Bill Williams River below Alamo Dam USGS station.

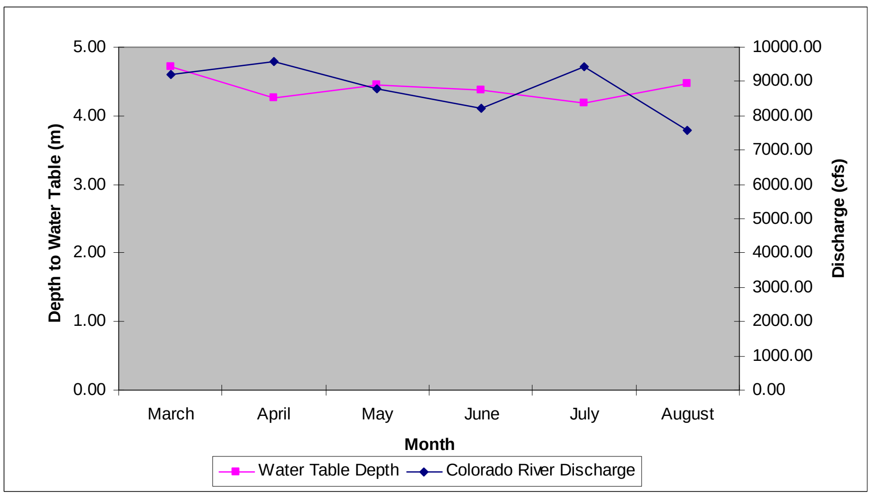


Figure 3.17. Depth to ground water at YB16 piezometer and discharge at Colorado River below Palo Verde Dam USGS station.

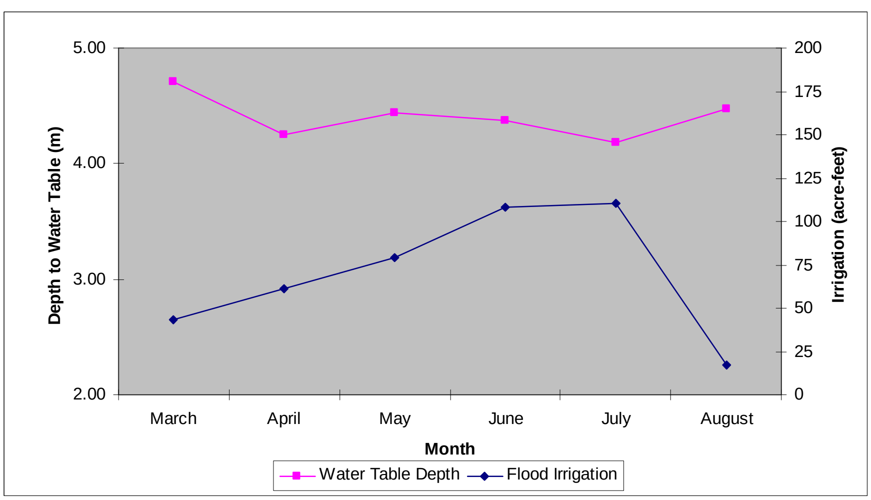


Figure 3.18. Depth to ground water at YB16 piezometer and flood irrigation at YB16.

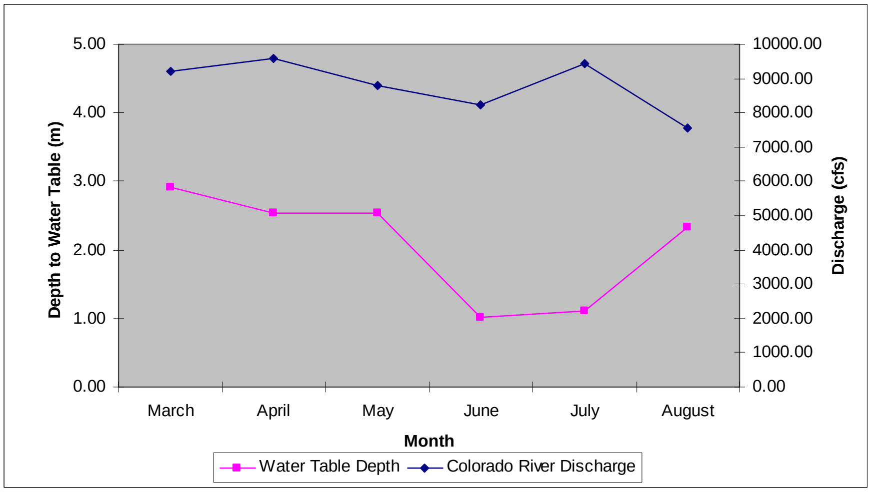


Figure 3.19. Depth to ground water at YB19 piezometer and discharge at Colorado River below Palo Verde Dam USGS station.

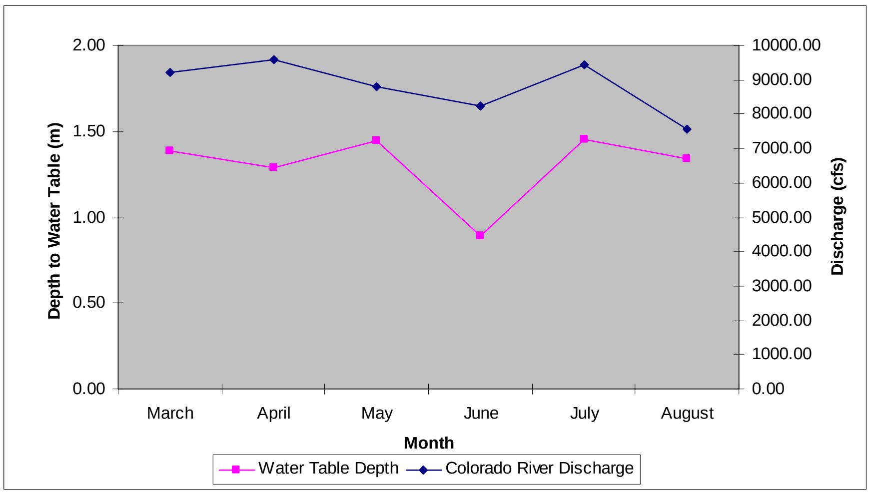


Figure 3.20. Depth to ground water at YB21 piezometer and discharge at Colorado River below Palo Verde Dam USGS station.

3.2.2 Cumulative YBCU Results

The range of conditions measured at the YBCU sites in 2010 are detailed in Table 3.6. The range of soil moisture conditions only reflect gravimetric measurements obtained in April, June, July, and August, as discussed previously. As with the SWFL sites, the percent soil moisture does not include measurements in saturated soils, which may lead to an underestimation of soil moisture. However, this effect would be less in the YBCU sites because very few sites had saturated soil conditions, and those that did have saturated soil on at least part of the site did not have those conditions for the entire field season.

Table 3.6. Total range of conditions measured at all YBCU sites in 2010.

Measurement	Mean	Median	Range (minimum/ maximum)	Standard Error/Standard Deviation	Notes
2010 Soil Hydrology Measurements					
Percent soil moisture	13.2	9.6	0.47/53.5	1.3/11.4	Does not include measurements in inundated soils
Soil texture (% sand)	66.3	73.3	21.8/94.8	5.6/24.6	Soil textures ranged from sand to silt loam
Standing/flowing water area (m^2)	156.3	0	0.0/3120	44.3/470.9	6 of 19 sites had standing or flowing water at least one month of the field season
Standing/flowing water depth (m)	0.02	0	0.0/0.3	0.006/0.06	
Depth to ground water (m)	2.2	1.8	0.0/4.7	0.1/1.2	
Distance to flowing water (m)	453	215	5/2182	150.1/654.4	Per aerial measurements and 2005 Bill Williams River GIS map
Air temperature ºC (within site)	27.2	26.6	7.8/47.4	0.8/8.1	
Percent relative humidity (within site)	46.7	37.9	13.4/9.6	2.4/24.7	
2009 SSRS Vegetation Measurements					
Canopy height (m)	9.2	9.0	5.0/19.0	0.8/3.4	All soil hydrology sites had 2009 SSRS vegetation data spatially associated
Percent canopy closure	69.9	68.8	53.0/91.0	2.8/12.1	
Percent ground cover	19.3	6.3	0.0/90.0	6.3/27.3	

Regression analysis was used to determine relationships between variables across all YBCU sites. Identifying the relationships between variables may provide valuable information when determining what conditions may be important for breeding habitat and selecting sites for habitat creation efforts. Significance was inferred at a p-value less than 0.05.

Percent soil moisture was compared with month of collection, stream discharge, distance from flowing water, area of standing water, soil texture, and depth to ground water using linear regression to identify any significant relationships between soil moisture and these variables. Because the distance to flowing water was obtained via measurement from aerials and from a 2005 USFWS GIS map (for the Bill Williams River), the measurements do not reflect precise river channel conditions in 2010. This use of aerial photographs and mapping introduces some potential for error in calculating the distance to flowing water. In addition, distance to flowing water was calculated for the average flow over the course of the field season and did not attempt to include March high flows.

For YBCU sites, percent soil moisture was significantly correlated with soil texture and, to a lesser extent, with stream discharge and area of standing water but was not related to time of year, distance to flowing water, or any of the other measured variables. There was a fairly wide range of soil moisture across the YBCU sites—from 0.47 percent to nearly 54 percent—associated with soil texture, as indicated by the results of a linear regression using percent sand as the quantitative representative of soil texture (R^2 = 0.51, p<0.01). As with the SWFL sites, as percent sand increased, soil moisture decreased at these sites. A relationship was observed between soil moisture and stream discharge, with higher soil moisture generally occurring at times of higher stream discharge; however, the regression coefficient was low, with stream discharge only explaining 7 percent of soil moisture results (R^2 = 0.07, p = 0.02). The area of standing water was also compared with soil moisture via linear regression. Results indicated that there is a relationship between soil moisture and area of standing water, with soil moisture generally higher in sites with standing water, but only a small amount of the variation is explained by the regression (R^2 = 0.08, p = 0.01). No significant relationship was observed between percent soil moisture and the time of the year (R^2 = 0.004, p = 0.6), distance from flowing water (R^2 = 0.06, p = 0.3), and depth to ground water (R^2 = 0.0003, p = 0.9).

Air temperature and percent relative humidity were compared with 2009 percent canopy closure, canopy height, and percent ground cover. Because the air temperature and relative humidity measurements were taken in 2010 and are being compared with 2009 vegetation data, there is a temporal disparity that may lead to error. Though sites were located as close to the 2009 vegetation plots as possible, there is a possibility that the sites do not cover the precise spatial area measured in the 2009 vegetation plots. In addition, the soil hydrology sites covered a larger area than the 2009 vegetation plots.

It was expected that vegetation characteristics such as canopy density would have an impact on the microclimate under the canopy through shading and evapotranspiration and thereby influence microclimate conditions that may be important in breeding habitat selection. Comparisons of 2009 vegetation data and 2010 air temperature and relative humidity data at the same approximate locations did not yield any significant results: air temperature and canopy height (R^2 = 0.05, p = 0.4), air temperature and canopy closure (R^2 = 0.07, p = 0.3), air temperature and ground cover (R^2 = 0.08, p = 0.2), relative humidity and canopy height (R^2 = 0.07, p = 0.3), relative humidity and canopy closure (R^2 = 0.04, p = 0.4), and relative humidity and ground cover (R^2 = 0.03, p = 0.5). Figure 3.21 plots the measured average air temperature at each site with the average canopy closure and average ground cover, and Figure 3.22 plots the measured percent relative humidity with the average canopy closure and average ground cover.

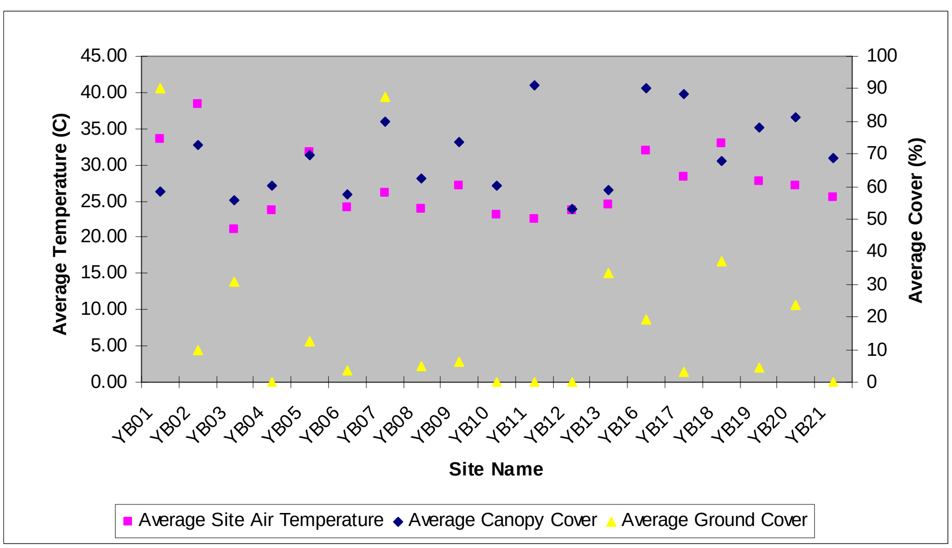


Figure 3.21. Average air temperature at 2010 YBCU sites and average percent canopy closure and ground cover at 2009 vegetation YBCU sites.

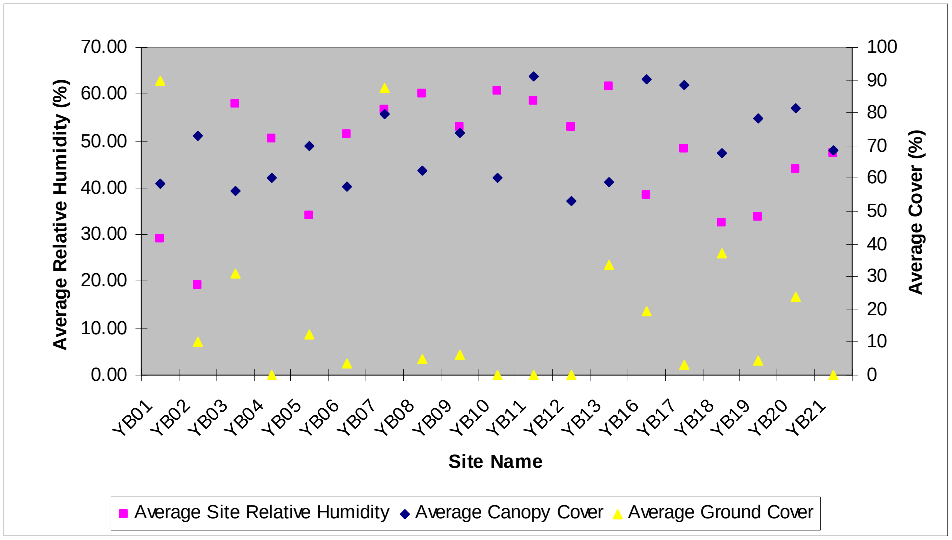


Figure 3.22. Average percent relative humidity at 2010 YBCU sites and average percent canopy closure and ground cover at 2009 vegetation YBCU sites.

At YBCU sites in this study, soil moisture was best predicted by soil texture. Sites with lower percent sand had higher percent soil moisture. No significant relationships were identified between vegetation characteristics and the other measured environmental variables. Many of these variables are interrelated, and any conclusions would be preliminary at this stage. Conclusions about site conditions to consider for habitat creation efforts will be provided after the 2011 field season. It is likely, however, that soil texture will be an important variable in this regard.

3.3 Results of SWFL and YBCU Site Conditions Comparison

Two sample t-tests were conducted to identify significant differences between SWFL and YBCU sites. As in the previous sections, soil moisture was only analyzed for the months of April and June through August. Percent sand was used as a representative of soil texture. Distance to water used measurements on the 2005 USFWS GIS map for sites on the Bill Williams River and measurements from aerials for the remainder of the sites. These measurements do not reflect the higher March flows along the Bill Williams River. Only standing water was included in the analysis for area of water on-site. Several sites also had flowing water in March and April during high flows, particularly along the Bill Williams River. These areas of flowing water were not included in the comparison between SWFL sites and YBCU sites. Results of the two sample t-tests are shown in Table 3.7.

Table 3.7. Results of two sample t-tests comparing SWFL sites with YBCU sites.

Environmental Variable	SWFL and YBCU T-test Results				
	Sites	Mean	Standard Deviation	T-value	P-value
Soil moisture (%)	SWFL	33.5	11.7	10.78	<0.01
	YBCU	13.0	11.4		
Soil texture (% sand)	SWFL	43.6	22.0	2.99	<0.01
	YBCU	66.3	24.6		
Depth to ground water (m)	SWFL	0.89	0.87	9.07	<0.01
	YBCU	2.12	1.16		
Distance to water (m)	SWFL	211	135	1.58	0.13
	YBCU	453	654		
Area of standing water on-site (m^2)	SWFL	130	308	3.72	<0.01
	YBCU	18.3	88.2		
Depth of water on-site (m)	SWFL	0.065	0.11	3.65	<0.01
	YBCU	0.021	0.06		
Air temperature (C)	SWFL	24.87	5.8	2.49	0.01
	YBCU	27.23	8.1		
Relative humidity (%)	SWFL	54.7	22.6	2.51	0.01
	YBCU	46.7	24.8		
2009 canopy height	SWFL	6.92	3.9	1.73	0.09
	YBCU	9.22	3.4		
2009 canopy closure	SWFL	90.4	12.4	4.63	<0.01
	YBCU	69.9	12.1		
2009 ground cover	SWFL	22.0	16.0	0.35	0.73
	YBCU	19.3	27.3		

As noted in Table 3.7, significant differences ($p \leq 0.05$) between SWFL sites and YBCU sites were identified in the following areas: soil moisture, soil texture, depth to ground water, area of standing water on-site, depth of standing water on-site, air temperature, relative humidity, and canopy closure. The results of the t-tests did not identify a significant difference in the distance of SWFL sites compared with YBCU sites to flowing water. There was also no significant difference in canopy heights or ground cover between SWFL and YBCU sites. Boxplots for each environmental variable showing the comparison between SWFL sites and YBCU sites are included in Appendix C.

Average percent soil moisture was more than twice as high at SWFL sites (34.1 percent) as at YBCU sites (13.2 percent). Soils at YBCU sites had more sandy textures generally than SWFL sites, which may have factored into lower soil moisture content. The number of sites with standing water at least one month of the field season was higher in SWFL sites than in YBCU sites. Sixteen SWFL sites had standing water at least one month of the year (and tended to have standing water for a minimum of two or three months), with flowing water crossing seven sites at least one month of the field season, whereas only three YBCU sites had standing water present at least one month of the field season, four had flowing water crossing the sites, and two were inundated by flood irrigation during at least one site visit. For those sites with standing water, a larger portion of the SWFL sites were covered by standing water than on YBCU sites. These areas of standing water also tended to be slightly deeper at SWFL sites than at YBCU sites.

In line with these observations of standing water, depth to ground water was generally shallower at SWFL sites than at YBCU sites, with means of 0.88 m and 2.2 m, respectively. Though the mean distance to flowing water was greater for YBCU sites (453 m) than for SWFL sites (211 m), this difference was not statistically significant. The distance to water was skewed higher for YBCU sites due to the location of some YBCU study sites within restoration areas at Cibola Valley Conservation Area and Cibola National Wildlife Refuge, some of which were more than 2 kilometers away from the nearest flowing water.

The SWFL sites had lower average air temperatures, higher average relative humidity, and higher percent canopy closure compared with the YBCU sites. There were no significant differences in the height of the canopy or the percent ground cover between SWFL and YBCU sites.

4.0 DISCUSSION

The range of conditions observed for SWFL and YBCU sites had some overlap, though many of the environmental variables also showed significant differences. The overall ranges measured at SWFL and YBCU sites for all environmental variables are noted in Table 3.3 and Table 3.6, respectively.

The SWFL sites had significantly higher levels of soil moisture at a 0.6 m depth than YBCU sites. These measurements did not include inundated or saturated soils, which would likely have made this difference greater because there were more SWFL sites with saturated soils than YBCU sites. In both site types, most sites were only inundated in the first one to three months of the field season and became generally dry in the latter months.

SWFL and YBCU habitat had flowing water running through some of the sites due to patch location or high flows as a result of precipitation. For example, two SWFL sites (WF01 and WF02) were partly within the flowing Beaver Dam Wash. High spring flows resulted in more braids of the Bill Williams River carrying water, some of which ran through SWFL and YBCU soil hydrology sites, before waters receded from many of the sites after the April field visit.

Percent soil moisture was significantly correlated with soil texture at SWFL and YBCU sites, and soil texture appears to have played a large role in the significant differences in soil moisture between these types of sites. The water holding capacity of soil in an area is dictated in large part by soil texture. The YBCU sites had a significant number of sites that were sandier than SWFL sites. Water infiltrates through sandy soils more quickly than in silt or clay soils, thereby resulting in lower soil moisture. The majority of the sandy YBCU sites occurred along the Bill Williams River. Almost twice as many YBCU sites were along the Bill Williams River as SWFL sites. However, it is unlikely that the difference observed in soil texture was simply a result of this difference in site frequency. Though seven of the 11 YBCU sites along the Bill Williams River had sandy soil and three others had at least part of the site classified as sand, all six SWFL sites along the Bill Williams River had soil classified as silt loam. Therefore, this appears to be a genuine difference in soil texture between SWFL and YBCU plots rather than a difference based on the sample size at one river. It may be that the SWFL selects sites with less sandy soil because the soil retains more moisture, thereby creating a preferred microclimate. On the other hand, the YBCU does not appear to select for sandy soils because seven YBCU study sites had soil textures of sandy loam, loam, or silt loam.

The depth to ground water at piezometers associated with YBCU sites was significantly deeper than at those associated with SWFL sites. The YBCU piezometers include two locations 250 m to 1,600 m farther from flowing water than the farthest SWFL piezometer—one at Topock Marsh, approximately 700 m from the Colorado River, and one at Cibola National Wildlife Refuge, approximately 2,100 m from the Colorado River. No restoration sites were included as study sites for SWFL. These greater distances from flowing water at YBCU sites may indicate differences in site selection between YBCU and SWFL, or the location of the restoration sites may have skewed the deeper ground water depths toward YBCU sites. There appeared to be a greater number of YBCU sites placed farther from flowing water than SWFL sites, though this difference was not statistically significant.

The area of standing water was greater in SWFL sites than in YBCU sites. In addition, 16 of 19 SWFL sites had standing water for one or more months of the field season while only three YBCU sites had standing water. These measurements of standing water did not include water flowing through the sites. Seven SWFL sites and four YBCU sites had water flowing through the site for at least one month. This difference in amount and presence of standing water was correlated to percent soil moisture according to the regression reported in Sections 3.1.2 and 3.2.2, though the amount of standing water had only weak predictive power with regard to soil moisture. This relationship would be expected to be stronger if soil samples were also taken at subplots covered by standing water.

Though not included as standing water, two YBCU sites had observed occurrences of flood irrigation, and flood irrigation reportedly occurs regularly at six of the YBCU sites. No SWFL sites received flood irrigation.

Observed high levels of standing water and saturated soils in this study support the conclusions of previous research that indicate SWFL requires surface water or saturated soil conditions to breed (Ellis et al. 2008, Paxton et al. 2007, Sogge and Marshall 2000, U.S. Forest Service 2000, USFWS 2010). However, only three of the YBCU sites had standing water present, which seems to indicate that this is not an important factor for this species. The USGS (2010b) suggests that standing water may positively influence the microclimate of YBCU breeding habitat and protect eggs from extreme temperatures. Though this study cannot speak directly to the latter, it cannot be concluded based on this year’s data that YBCU rely on standing water in their breeding habitat. However, given the difficulty in locating YBCU nests, data collection occurred in occupied patches rather than areas associated directly with nests. It is possible that standing water conditions in the area directly around the nest could be higher than in the general surrounding patch. Standing water does not appear to be an essential requirement in overall occupied habitat patches for YBCU.

The depth of standing water was significantly higher at SWFL sites than at YBCU sites. This is likely related to the observed differences in overall area of standing water. It is not surprising to find that sites with larger areas of standing water also have a slightly greater (0.04 m difference between the means) depth.

Air temperature and percent relative humidity were significantly different between YBCU and SWFL sites. The average temperature in YBCU sites was approximately 2.4ºC higher than in SWFL sites. However, this difference in air temperature likely is because YBCU site air temperatures were measured more frequently in the afternoon than SWFL sites. Relative humidity was higher at SWFL sites than at YBCU sites. Though relative humidity was measured at the same time as air temperature and, therefore, is subject to the same disparity in time of day, it is probable that observed higher relative humidity at SWFL sites was due to more standing water at these sites. SWFL sites also had denser tree canopy, which may also have contributed to the higher relative humidity measurements. If time of day was influencing the higher relative humidity, then YBCU sites would be expected to have a higher relative humidity than SWFL sites because relative humidity tends to be higher at higher temperatures.

Though there were no significant differences in canopy height or ground cover between YBCU and SWFL sites, there was a significant difference in percent canopy closure. The percent canopy closure at SWFL sites was higher than at YBCU sites. Previous studies indicate that YBCU and SWFL prefer dense canopy closure, with YBCU preferring multistory canopy structure and SWFL showing somewhat more tolerance for varying levels of canopy strata (U.S. Forest Service 2000, USFWS 2010, USGS 2010a). Sites for both species had fairly dense canopies, with a mean of 70 percent for YBCU (ranging from 53 percent to 91 percent) and a mean of 90 percent (ranging from 51 percent to 98 percent) for SWFL. Both of these species utilized a similar range of canopy densities, though YBCU were more likely to utilize less dense canopy than SWFL. It is important to note that the vegetation measurements were collected by different consultants (SSRS 2009, SWCA 2009), but similar vegetation sampling methods were used by both.

Due to the amount of precipitation in spring 2010, many of the study sites higher levels of flow in March and April than in later months of the field season. Therefore, the data collected for the spring 2010 months (for those sites directly influenced by river stage) are likely on the high range of soil hydrology conditions associated with these species. Data collection will occur again in 2011 from March through August, and the results will be combined with the 2010 field season to increase sample size and further inform the range of conditions associated with these two species. The data collected in 2011 will also provide information on the variability in conditions between years.

The purpose of this study is to provide data on the range of soil hydrology and microclimate conditions in habitat used for breeding by SWFL and YBCU. However, this is a two-year study, and conclusions on the range of site conditions would be premature at this point, particularly in light of high precipitation levels this year. Implications of the data with regard to potential future habitat creation efforts will be addressed in the final report after the 2011 field season, when year-to-year variation can be incorporated.

5.0 ACKNOWLEDGMENTS

EcoPlan Associates, Inc., would like to thank everyone who helped with this project, particularly the following people and organizations: Chris Dodge (Reclamation), Barbara Raulston (Reclamation), Theresa Olsen (Reclamation), Dick Gilbert (USFWS), Andrew Hautzinger (USFWS), Mike Oldham (USFWS), Linda Miller (USFWS), Brenda Zaun (USFWS), Murrelet Halterman (SSRS), Tom Koronkiewicz (SWCA), Mary Anne McLeod (SWCA), Steven Rimer (USFWS), Sonja Jahrsdoerfer (USFWS), Arizona Department of Water Resources, Nevada Division of Water Resources, and Mr. Bill Evans (Beaver Dam Station private landowner).

Special thanks to the field crew and EcoPlan staff members who also helped with this project, including Rob Klotz, Emily Peterson, Jerry Monks, T.J. McMichaels, William E. Davis, Ron van Ommeren, Thomas C. Ashbeck, Patrick E.T. Dockens, Ed Vergin, and Kathy Thielmann.

6.0 LITERATURE CITED

AGFD 2004. Mapping and monitoring Southwestern willow flycatcher breeding habitat in Arizona: A remote sensing approach. Technical Report 223. P.E.T. Dockens and C.E. Paradzick, editors.

Balluff, T. 2007. Small scale spatial variation and soil nutrient properties as site potential indicators in a semi-arid riparian community. Thesis, Arizona State University.

Bechtold, J.S., and R.J. Naiman. 2006. Soil texture and nitrogen mineralization potential across a riparian toposequence in a semi-arid savanna. *Soil Biology & Biochemistry* 38:1325–1333.

Brinson, M.M., B.L. Swift, R.C. Plantico, and J.S. Barclay. 1981. Riparian ecosystems: Their ecology and status. Eastern Energy and Land Use Team [and] National Water Resources Analysis Group, USFWS, Kearneysville, West Virginia.

Busch, D.E., and S.D. Smith. 1995. Mechanisms associated with decline of woody species in riparian ecosystems of the southwestern United States. *Ecological Monographs* 65:347–370.

Corman, T.E., and R.T. Magill. 2000. Western yellow-billed cuckoo in Arizona: 1998 and 1999 survey report. Nongame Branch, Wildlife Management Division Technical Report 150. AGFD.

Ellis, L.A., D.M. Weddle, S.D. Stump, H.C. English, and A.E. Graber. 2008. Southwestern willow flycatcher final survey and nest monitoring report. Research Technical Guidance Bulletin #10. AGFD.

Gaines, D. 1974. A new look at the nesting riparian avifauna of the Sacramento Valley, California. *Western Birds* 5:61–80.

Green, D. and T. Balluff. 2005. Impact of flooding on Goodding's willow at Horseshoe Reservoir, Arizona. 2005 Annual Report. Arizona State University. Report for Salt River Project, Phoenix, Arizona.

Halterman, M.D., E.T. Rose, S.E. McNeil, and D. Tracy. 2009. Yellow-billed cuckoo distribution, abundance and habitat use on the Lower Colorado River and tributaries: 2008 Annual Report. Southern Sierra Research Station. Report for Reclamation Lower Colorado Regional Office, Boulder City, Nevada.

Hamilton, W.J. III, and M.E. Hamilton. 1965. Breeding characteristics of the yellow-billed cuckoo in Arizona. Proceedings of the California Academy of Sciences, Fourth Series 32:405–432.

Howe, W.H. 1986. Status of the yellow-billed cuckoo *(Coccyzus americanus)* in New Mexico. New Mexico Department of Game and Fish, Santa Fe, New Mexico.

Hunter, W.C. 1987. Response to an exotic habitat by arid riparian breeding birds along an elevational gradient. Reclamation, Boulder City, Nevada.

Johnson, M.J., J.A. Holmes, R. Weber, and M. Dionne. 2006. Yellow-billed cuckoo distribution, abundance, and habitat use along the lower Colorado and Gila rivers in La Paz and Yuma counties, 2005. AGFD Heritage Program.

Kelsey, K.A., and S.D. West. 1998. Riparian wildlife. *In* River ecology and management: Lessons from the Pacific coastal ecoregion, edited by R.J. Naiman and R.E. Bilby. Springer-Verlag, New York.

McLeod, M.A., and T.J. Koronkiewicz. 2010. Southwestern Willow Flycatcher Surveys, Demography, and Ecology along the Lower Colorado River and Tributaries, 2009. SWCA Environmental Consultants. Report for Reclamation Lower Colorado Regional Office, Boulder City, Nevada.

Naiman, R.J., R.E. Bilby, and P.A. Bisson. 2000. Riparian ecology and management in the Pacific coastal rain forest. *BioScience* 50:996–1011.

Naiman, R.J., H. Decamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications* 3:209–212.

Pase, C.P., and E.F. Layser. 1977. Classification of riparian habitat in the southwest. *In* Importance, preservation and management of riparian habitat: A symposium, edited by R.R. Johnson and D.A. Jones. U.S. Forest Service, Tucson, Arizona.

Paxton, E.H., M.K. Sogge, S.L. Durst, T.C. Theimer, and J.R. Hatten. 2007. The ecology of the Southwestern willow flycatcher in Central Arizona: A 10-year Synthesis Report. Open File Report 2007-1381. USGS.

Roelle, J.E., and D.N. Gladwin. 1999. Establishment of woody riparian species from natural seedfall at a former gravel pit. *Restoration Ecology* 7:183–192.

Samani, Z., A.S. Bawazir, M. Bleiweiss, R.Skaggs, and V.D. Tran. 2007. Estimating daily net radiation over vegetation canopy through remote sensing and climatic data. *Journal of Irrigation and Drainage Engineering* 133 (4):291–297.

Siegel, R.S., and J.H. Brock. 1990. Germination requirements of key Southwestern woody riparian species. *Desert Plants* 10:3–8.

Sogge, M.K., and R.M. Marshall. 2000. A survey of current breeding habitats. *In* Status, ecology, and conservation of the Southwestern willow flycatcher, edited by D.M. Finch and S.H. Stoleson, pp. 43–56. U.S. Forest Service Rocky Mountain Research Station General Technical Report RMRS-GTR-60. Ogden, Utah.

Sogge, M.K., R.M. Marshall, T.J. Tibbitts, and S.J. Sferra. 1997. A Southwestern willow flycatcher natural history summary and survey protocol. National Park Service Technical Report NPS/NAUCPRS/NRTR-97.12.

Spencer, J.S., S.J. Sferra, T.E. Corman, J.W. Rourke, and M.W. Sumner. 1996. Arizona Partners in Flight 1995 Southwestern willow flycatcher survey. Nongame and Endangered Wildlife Program Technical Report 97. AGFD, Phoenix, Arizona.

Sprenger, M.D., L.M. Smith, and J.P. Taylor. 2002. Restoration of riparian habitat using experimental flooding. *Wetlands* 22:49–57.

SSRS. 2009. Excel file with vegetation measurement data collected by SSRS in 2009. File provided by the Bureau of Reclamation to EcoPlan Associates, Inc., September 2010.

SWCA. 2009. Excel file with vegetation measurement data collected by SWCA in 2009. File provided by the Bureau of Reclamation to EcoPlan Associates, Inc., August 2010.

Tallent-Halsell, N.G., and L.R. Walker. 2002. Responses of *Salix gooddingii* and *Tamarix ramosissima* to flooding. *Wetlands* 22:776–785.

U.S. Forest Service. 2000. Status, ecology, and conservation of the Southwestern willow flycatcher. General Technical Report RMRS-GTR-60, Rocky Mountain Research Station.

USFWS. 2010. Arizona Ecological Field Services threatened and endangered species. http://www.fws.gov/southwest/es/arizona/Listing.htm. Accessed November 12, 2010.

USGS. 2010a. Yellow-billed cuckoo. http://charlesvanriper.com/ybcu/default.htm. Accessed November 12, 2010.

_____. 2010b. Surface water statistics. http://waterdata.usgs.gov/nwis/dvstat/?referred_module=sw. Accessed November 2010.

APPENDIX A
Individual Site Descriptions and Results

This appendix contains descriptions and results for each Southwestern willow flycatcher (SWFL) and Western yellow-billed cuckoo (YBCU) site included in the 2010 field season. Information on site location and characteristics, soil hydrology, microclimate, and 2009 vegetation measurements are included. This is a more detailed supplement to the tables included in Section 3.

A1 SWFL Individual Site Descriptions and Results

A1.1 WF01 (Littlefield Poles 20A, Beaver Dam Wash, Arizona)

This site is within the active channel of Beaver Dam Wash. Because of this placement, the majority of the site was constantly inundated with flowing water throughout the field season (refer to Figure 2.1 and photos in Appendix B). Three beaver dams were observed in close proximity downstream of WF01 and WF02. Only subplots 12 North (N) and 20N, which are on increasingly higher ground, were not consistently inundated by water; soil samples were only collected at those subplots. Because site inundation was flowing water, it was not counted in the standing water measurements. During data collection, the percentage of soil moisture (measured in April and June through August 2010) at 12N ranged from 22 percent to 35 percent and at 20N ranged from 4 percent to 6 percent, with the remainder of the site inundated, resulting in saturated soil conditions. Soil texture was classified as sandy loam.

The piezometer was installed near the plot center at WF02, which was not as fully inundated as WF01. However, because WF01 was almost continuously inundated, the depth to ground water was, for all intents and purposes, 0. The WF02 piezometer and Beaver Dam discharge are discussed in detail in Section A1.2.

Relative humidity at WF01 ranged from a low of 28 percent in March to a high of 88 percent in August, at the height of the monsoon season. Air temperature ranged from a low of 14.5 degrees Celsius (ºC) in June to a high of 28.54ºC in March. However, in this and all other SWFL and YBCU results, air and relative humidity measurements were confounded by different measurement times across the field season. Provisional data on daily precipitation were available for locations near study sites through the National Oceanic and Atmospheric Administration National Climatic Data Center (NOAA NCDC 2010) (Beaver Dam station ID 020672). No precipitation was recorded at this station during any of the field visits to WF01 in 2010.

Vegetation data, including canopy height, average canopy closure, and average ground cover, were collected by SWCA in 2009 at approximately the same location as WF01. As with all sites discussed in this report, the vegetation measurement plot was smaller than the soil hydrology site, but it was encompassed in the area measured for soil hydrology. The canopy height at this approximate location was 5.4 meters (m), with an average canopy closure of 88.5 percent and an average ground cover of 4.8 percent.

A1.2 WF02 (Littlefield Poles 105A, Beaver Dam Wash, Arizona)

This site is partly within the active channel of Beaver Dam Wash. Because of this placement, approximately half the site was inundated with flowing water throughout the field season (refer to Figure 2.1 and photos in Appendix B). Three beaver dams were observed in close proximity downstream of WF01 and WF02. The plot center, the north transect, the east transect, and subplot 5 West were not inundated by the wash in April through August. Average percentage of soil moisture (measured in April and June through August) ranged from 23 percent in June to 28 percent in March. The inundated portion of the site had saturated soil and, therefore, percent moisture was not measured directly. The percentage of soil moisture measured by the M300 in March and May was high. The majority of the site had a soil texture of sand, with small areas of sandy loam and loamy sand.

The piezometer was installed near the plot center at WF02. The ground water level at the piezometer was consistent across the field season, only varying 0.23 m between the lowest and highest level. The ground water was lowest in May, with a depth of 0.69 m, and was highest in March, with a depth of 0.46 m. However, because half of WF02 was almost continuously inundated, the depth to ground water in this half of the site was, for all intents and purposes, 0. Because this inundation was flowing water, it was not counted in the standing water measurements. The depth of the flowing water was deeper at this site than at WF01, ranging from 0.2 m deep in July to a maximum depth of 0.5 m in May, though generally across the site, the depth of flowing water did not vary greatly between months—averaging approximately 0.35 m deep. According to stream gauge data at Beaver Dam (USGS 09414900), the average discharge ranged from a high of 11.02 cubic feet per second (cfs) in March to a low of 1.42 cfs in July (USGS 2010).

Relative humidity at WF02 ranged from a low of 24 percent in April to a high of 81 percent in August, at the height of the monsoon season. Air temperature ranged from a low of 14.5 C in May to a high of 24.2 in July. Provisional data on daily precipitation was available for locations near study sites through the NOAA NCDC (2010) (Beaver Dam station ID 020672). No precipitation was recorded at this station during any of the field visits to WF02 in 2010.

No vegetation data were collected by SWCA in 2009 at this site.

A1.3 WF03 (V1S63A 63A, Mormon Mesa, Virgin River, Nevada)

This site is east of the Virgin River and is in a generally marshy area (refer to Figure 2.2 and photos in Appendix B). Standing water was present in the study site from March through June and ranged from 283 m^2 in March to 1,150 m^2 in June. Depth of standing water averaged between 0.04 m and 0.07 m. Average soil moisture during the field season (measured in April and June through August) ranged from 37 percent in August to 50 percent in June. The percentage of soil moisture measured by the M300 in March and May was high. Soil texture on the site was classified as silt loam.

The piezometer was installed near the site center at WF04, approximately 170 m from the low-flow channel of the Virgin River. The site center of WF03 is approximately 348 m from the low-flow channel of the Virgin River. Both sites are within the marshy floodplain of the Virgin River. The details of the WF04 piezometer and Virgin River discharge are discussed in Section A1.4.

Relative humidity at WF03 ranged from a low of 23 percent in June to a high of 74 percent in August, at the height of the monsoon season. Air temperature ranged from a low of 17.3ºC in May to a high of 32.6ºC in July. The Overton NOAA NCDC station (ID 265846) was used to obtain general precipitation data (provisional) for the Virgin River area. No precipitation was recorded at this station during any of the field visits to WF03 in 2010; however, the field crew observed rainfall on-site during the April site visit. Though the NOAA NCDC record does not list precipitation in the area, light drizzle was observed on May 18, the day prior to the site visit.

The vegetation canopy height at this approximate location was 3.7 m, with an average canopy closure of 92.2 percent and average ground cover of 11.8 percent.

A1.4 WF04 (V1ST2 T2, Mormon Mesa, Virgin River, Nevada)

This site is east of the Virgin River and is in a generally marshy area (refer to Figure 2.2 and photos in Appendix B). Standing water covered the majority of the site in all months except July and ranged from 33 m^2 in August to the entire site area (1,600 m^2) in March. Depth of standing water averaged between 0.0 m and 0.13 m. Average soil moisture during the field season (measured in April and June through August) ranged from 29 percent in April to 44 percent in August. Only those subplots not inundated had soil samples collected. In April and June, almost the entire site was inundated. Therefore, the majority of the site had saturated soil moisture. The 29 percent soil moisture in April reflects only the one subplot that was not inundated. The percentage of soil moisture measured by the M300 in March and May was high. The average soil texture on the site was classified as silt loam.

The piezometer was installed near the site center at WF04, approximately 170 m from the low-flow channel and within the marshy floodplain of the Virgin River. The ground water level at the piezometer was consistently high across the field season, only varying 0.2 m between the lowest and highest level. The ground water was lowest in March, with a depth to ground water of 0.2 meter, and was highest in April and May, when water levels were on the surface and the piezometer had a reading of 0.0 meter. According to stream gauge data from the Virgin River near Overton (USGS 09415250), the average discharge ranged from a high of 474.5 cfs in May to a low of 13.3 cfs in July (USGS 2010).

Relative humidity at WF04 ranged from a low of 23 percent in June to a high of 74 percent in May (potentially due to observed precipitation the previous evening). The next-highest relative humidity reading was 68 percent in July during the monsoon season. Air temperature ranged from a low of 12.4ºC in May to a high of 32.2ºC in August. The Overton NOAA NCDC station (ID 265846) was used to obtain general precipitation data. No precipitation was recorded at this station during any of the field visits to WF04 in 2010; however, the field crew observed rainfall on-site during the April site visit, and non-measured precipitation was observed at the weather station near Overton the day before the May site visit.

The vegetation canopy height at this approximate location was 2.8 m, with an average canopy closure of 92.7 percent and average ground cover of 3.5 percent.

A1.5 WF05 (V1S28A 28A, Mormon Mesa, Virgin River, Nevada)

This site is east of the Virgin River and is in a generally marshy area (refer to Figure 2.2 and photos in Appendix B). Standing water covered the majority of the site in March, May, and June. Precipitation caused the Virgin River to rise in April, and the field crew had to leave the area; therefore, measurements were not taken at this site in April. It is expected that if data collection had occurred, standing water would have been observed in April as well. No standing water was observed at the site in July and August. The area of standing water in March, May, and June ranged from 1.46 m^2 in June to 286 m^2 in May. Depth of standing water for these months averaged between 0.01 m and 0.04 m. Average soil moisture during the field season (measured in June through August) ranged from 38 percent in August to 43 percent in July. The percentage of soil moisture measured by the M300 in March and May was high. The average soil texture on the site was classified as silt loam.

The piezometer was installed near the site center at WF04, as discussed in Section A1.4. The site center of WF05 is approximately 119 m farther east of the low-flow channel of the Virgin River than the piezometer location.

Relative humidity at WF05 ranged from a low of 20 percent in March to a high of 85 percent in July. Air temperature ranged from a low of 20.2ºC in June to a high of 26.2ºC in August. The Overton station (ID 265846) was used to obtain provisional general precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to WF05 in 2010; however, the field crew observed rainfall on-site during the April site visit, and non-measured precipitation was observed at the weather station near Overton the day before the May site visit.

The vegetation canopy height at this approximate location was 5.5 m, with an average canopy closure of 50.5 percent and average ground cover of 11.3 percent.

A1.6 WF06 (V1N40A 40A, Mormon Mesa, Virgin River, Nevada)

This site is east of the Virgin River in a generally marshy area (refer to Figure 2.2 and photos in Appendix B). Standing water was present at this site in March and May, though to a lesser extent than observed at the other Mormon Mesa sites. Precipitation caused the Virgin River to rise in April, and the field crew had to leave the area; therefore, measurements were not taken at this site in April. It is expected that if data collection had occurred, standing water would have been observed in April as well. No standing water was observed at the site in June, July, and August. The area of standing water in March and May totaled 51.75 m^2 and 34 m^2, respectively. Average depth of standing water in March and May was 0.04 m and 0.02 m, respectively. Average soil moisture during the field season (measured in June through August) ranged from 32 percent in July to 36 percent in June. The percentage of soil moisture measured by the M300 in March and May was high. The average soil texture on the site was classified as silt loam, with two subplots classified as sandy loam.

The piezometer was installed near the site center at WF04, as discussed in Section A1.4. The site center of WF06 is approximately 70 m farther east of the low-flow channel of the Virgin River than the piezometer location.

Relative humidity at WF06 ranged from a low of 20 percent in March to a high of 76 percent in July. Air temperature ranged from a low of 16.7ºC in June to a high of 28.1ºC in May. The Overton station (ID 265846) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to WF06 in 2010; however, the field crew observed rainfall on-site in April, and non-measured precipitation was observed at the weather station near Overton the day before the May site visit. The vegetation canopy height at this approximate location was 4.5 m, with an average canopy closure of 92.7 percent and average ground cover of 7.8 percent.

A1.7 WF07 (HPIPE 2A, Topock Marsh, Arizona)

This site is within the Havasu National Wildlife Refuge near Topock Marsh in Arizona, across the border from Needles, California. The general area consists of stands of vegetation separated by canals and dike roads (refer to Figure 2.3 and photos in Appendix B). Small areas of standing water were present at this site in March and April. No standing water was observed in May through August. The area of standing water in March and April totaled 3.7 m^2 and 9 m^2, respectively. Depth of standing water averaged 0.21 m. Average soil moisture during the field season (measured in April and June through August) ranged from 31 percent in August to 46 percent in April. The percentage of soil moisture measured by the M300 in March and May was high. The majority of the site had soil texture classified as loam.

A piezometer was installed near the site center at WF12, approximately 61 m west of Topock Marsh. The site center of WF07 is approximately 35 m farther from Topock Marsh than the piezometer location. The piezometer at WF12 is described further in Section A1.12.

Relative humidity at WF07 ranged from a low of 22 percent in April to a high of 82 percent in July. Air temperature ranged from a low of 16.7ºC in May to a high of 37ºC in August. The NOAA Needles station (ID 046115) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to WF07 in 2010.

The canopy height at this approximate location was 6.0 m, with an average canopy closure of 95.8 percent and average ground cover of 42.5 percent.

A1.8 WF08 (HWLW F23, Topock Marsh, Arizona)

This site is within the Havasu National Wildlife Refuge near Topock Marsh in Arizona, across the border from Needles, California. The general area consists of stands of vegetation separated by canals and dike roads (refer to Figure 2.3 and photos in Appendix B). Small areas of standing water were present at this site in April and May. No standing water was observed at the site in March or June through August. The area of standing water in April and May totaled 107 m^2 and 7.6 m^2, respectively. Depth of standing water averaged 0.05 m. Average soil moisture during the field season (measured in April and June through August) ranged from 38 percent in July to 57 percent in April. The percentage of soil moisture measured by the M300 in March and May was high. The majority of the site had soil texture classified as sandy loam, with some areas of silt loam, clay loam, and loam.

The piezometer was installed near the site center at WF08, approximately 111 m from Topock Marsh. This site is separated from Topock Marsh by a levee. The ground water level at the piezometer was consistently high across the field season, only varying 0.28 m between the lowest and highest level. The ground water was lowest in August, with a depth to ground water of 0.28 m, and was highest in April, when water levels were on the surface and the piezometer had a reading of 0.0 m. According to stream gauge data from Topock Marsh Inlet near Needles, California (USGS 09423550), the average discharge ranged from a high of 87.4 cfs in June to a low of 62.3 cfs in August (USGS 2010).

Relative humidity at WF08 ranged from a low of 29.5 percent in March to a high of 73 percent in July. Air temperature ranged from a low of 18.3ºC in April to a high of 33.7ºC in August. The

NOAA NCDC Needles station (ID 046115) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to WF08 in 2010.

No vegetation data were collected by SWCA in 2009 at this site.

A1.9 WF09 (HINBWN T6, Topock Marsh, Arizona)

This site is within the Havasu National Wildlife Refuge near Topock Marsh in Arizona, across the border from Needles, California. The general area consists of stands of vegetation separated by canals and dike roads with this particular site separated from Topock Marsh by a levee (refer to Figure 2.3 and photos in Appendix B). Small areas of standing water were present at this site in March and April. No standing water was observed at the site in May through August. The area of standing water in March and April totaled 180 m^2 and 77 m^2, respectively. Depth of standing water averaged 0.045 m. Average soil moisture during the field season (measured in April and June through August) ranged from 29 percent in August to 36 percent in June. The percentage of soil moisture measured by the M300 in March and May was high. The site was split between soil textures of sandy loam and loam.

The piezometer was installed near the site center at WF08, approximately 111 m west of Topock Marsh. The site center of WF09 is approximately 115 m farther west of Topock Marsh than the piezometer location. The piezometer at WF08 was described previously in Section A1.8.

Relative humidity at WF09 ranged from a low of 31 percent in March to a high of 81 percent in August. Air temperature ranged from a low of 21.4ºC in April to a high of 30.1ºC in July. The NOAA NCDC Needles station (ID 046115) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to WF09 in 2010.

The vegetation canopy height at this approximate location was 7.0 m, with an average canopy closure of 98.4 percent and average ground cover of 14.0 percent.

A1.10 WF10 (HEGG 30A, Topock Marsh, Arizona)

This site is within the Havasu National Wildlife Refuge near Topock Marsh in Arizona, across the border from Needles, California. The general area consists of stands of vegetation separated by canals and dike roads, with this particular site separated from Topock Marsh by a levee (refer to Figure 2.3 and photos in Appendix B). Small areas of standing water were present at this site in March and April. No standing water was observed at the site in May through August. The area of standing water in March and April totaled 28.2 m^2 and 150.8 m^2, respectively. Depth of standing water averaged 0.04 m. Average soil moisture during the field season (measured in April and June through August) ranged from 33 percent in July and August to 42 percent in April. The percentage of soil moisture measured by the M300 in March and May was high. The site was split between soil textures of sandy loam and loam with small areas of sand and silt loam.

A piezometer was installed near the site center at WF08, approximately 111 m west of Topock Marsh. The site center of WF10 is approximately 54 m farther west of Topock Marsh than the piezometer location. The piezometer at WF08 was described previously in Section A1.8.

Relative humidity at WF10 ranged from a low of 25 percent in March to a high of 87 percent in August. Air temperature ranged from a low of 24.4ºC in July to a high of 29.9ºC in August. The NOAA NCDC Needles station (ID 046115) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to WF10 in 2010.

The vegetation canopy height at this approximate location was 7.5 m, with an average canopy closure of 92.7 percent and average ground cover of 13.3 percent.

A1.11 WF11 (HIRFB F5, Topock Marsh, Arizona)

This site is within the Havasu National Wildlife Refuge near Topock Marsh in Arizona, across the border from Needles, California. The general area consists of stands of vegetation separated by canals and dike roads, with this particular site separated from Topock Marsh by two levees (refer to Figure 2.3 and photos in Appendix B). No areas of standing water were present at this site from March through August. Average soil moisture during the field season (measured in April and June through August) ranged from 24 percent in August to 32 percent in April. The percentage of soil moisture measured by the M300 in March and May was moderately high. The majority of the site has a soil texture of loam with small areas of sandy loam and silt loam.

A piezometer was installed near the site center at WF08, approximately 111 m west of Topock Marsh. The site center of WF11 is approximately 91 m farther west of Topock Marsh than the piezometer location. The piezometer at WF08 was described previously in Section A1.8.

Relative humidity at WF11 ranged from a low of 19 percent in April to a high of 78 percent in July. Air temperature ranged from a low of 25.8ºC in July to a high of 36.4ºC in June. The NOAA NCDC Needles station (ID 046115) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to WF11 in 2010.

No vegetation data were collected by SWCA in 2009 at this site.

A1.12 WF12 (H250M F36, Topock Marsh, Arizona)

This site is within the Havasu National Wildlife Refuge near Topock Marsh in Arizona, across the border from Needles, California. The general area consists of stands of vegetation separated by canals and dike roads, but this study site has no separation from Topock Marsh besides distance (refer to Figure 2.3 and photos in Appendix B). No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 20 percent in August to 24 percent in April. The percentage of soil moisture measured by the M300 in March and May was moderately high. The majority of the site had soil texture classified as loamy sand, with three subplots classified as either sandy loam or loam.

A piezometer was installed near the site center at this study site, approximately 61 m from Topock Marsh. No levee or other structure separates this site from the marsh. The ground water level at the piezometer was consistently high across the field season, varying 0.36 m between the lowest and highest level. The ground water was lowest in August, with a depth to ground water of 1.21 m, and was highest in May, with a depth to ground water of 0.85 m. According to stream gauge data from Topock Marsh Inlet near Needles, California (USGS 09423550), the average discharge ranged from a high of 87.4 cfs in June to a low of 62.3 cfs in August (USGS 2010).

Relative humidity at WF12 ranged from a low of 17.3 percent in April to a high of 73.4 percent in July. Air temperature ranged from a low of 23.2ºC in March to a high of 33.6ºC in April. The NOAA NCDC Needles station (ID 046115) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to WF12 in 2010.

No vegetation data were collected by SWCA in 2009 at this site.

A1.13 WF13 (HGH 9A, Topock Marsh, Arizona)

This site is within the Havasu National Wildlife Refuge near Topock Marsh in Arizona, across the border from Needles, California. The general area consists of stands of vegetation separated by canals and dike roads, with this particular site on an island with no structures separating the site from Topock Marsh (refer to Figure 2.3 and photos in Appendix B). No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 4.9 percent in August to 9.8 percent in April. The percentage of soil moisture measured by the M300 in March and May was moderate. The site was split between soil textures of sand and loamy sand.

A piezometer was installed near the site center at WF12, approximately 61 m west of Topock Marsh. The site center of WF13 is approximately 153 m farther away from Topock Marsh than the piezometer location. The piezometer readings for WF12 were applied to WF13 for analysis purposes because both of these sites do not have structural separations from the marsh. The piezometer at WF12 was described previously in Section A1.12.

Relative humidity at WF13 ranged from a low of 29 percent in March to a high of 77 percent in August. Air temperature ranged from a low of 16.1ºC in June to a high of 27.8ºC in July. No relative humidity or air temperature readings were taken at this site in May due to malfunctioning equipment. The NOAA NCDC Needles station (ID 046115) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to WF13 in 2010.

The vegetation canopy height at this approximate location was 5.2 m, with an average canopy closure of 94.8 percent and average ground cover of 41.3 percent.

A1.14 WF14 (BW 47B, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation (tamarisk, mesquite, cottonwood) along the braided Bill Williams River (refer to Figure 2.4 and photos in Appendix B). Areas of standing water were present at this site in April through August. The site was inaccessible in March due to high water levels at the Bill Williams River, and no measurements were taken for that month. The area of standing water at the site from April through August ranged from a low of 10 m^2 in May to a high of 550 m^2 in June. Depth of standing water ranged from an average of 0.14 m in April and August to an average of 0.04 m in July. Average soil moisture during the field season (measured in April and June through August) ranged from

33.7 percent in July to 40.2 percent in August. The percentage of soil moisture measured by the M300 in May was high. The site was split between soil textures of silt loam, sandy loam, and loam.

An existing well (PZ BW225) was in place about 360 m west of WF14. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 5 m from PZ BW225 and approximately 8 m from WF14. Therefore, the depth to ground water measured at PZ BW225 was applied to WF14 for analysis purposes. Depth to ground water at PZ BW225 varied only 0.35 m between the lowest and highest ground water level. Ground water was lowest in July, at a depth of 2.08 m, and was highest in August, at a depth of 1.73 m. According to stream gauge data from the Bill Williams River below Alamo Dam (USGS 09426000), the average monthly discharge ranged from a high of 776.4 cfs in March to a low of 50 cfs in June through August (USGS 2010). Due to high spring precipitation, storage levels above Alamo Dam were high. The high level of discharge in March and into April reflected releases to relieve the storage pressures on the dam. Generally, the level of discharge from Alamo Dam remains constant at around 50 cfs.

Relative humidity at WF14 ranged from a low of 23 percent in April to a high of 87 percent in August. Air temperature ranged from a low of 14.1ºC in June to a high of 29.4ºC in August. The NOAA NCDC Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, eight days prior to the site visit at WF14.

The vegetation canopy height at this approximate location was 16.5 m, with an average canopy closure of 88.5 percent and average ground cover of 35.0 percent.

A1.15 WF16 (BW 8A, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided Bill Williams River (refer to Figure 2.4 and photos in Appendix B). The site was within the flowing channel of the Bill Williams River in March during high flows from dam releases. Areas of standing water were present at this site in April, May, and June. No areas of standing water were observed in July or August. The area of standing water at the site from April through June ranged from a low of 15 m^2 in June to a high of 520 m^2 in April. Depth of standing water ranged from an average of 0.04 m in June to an average of 0.21 m in April. Average soil moisture during the field season (measured in April and June through August) ranged from 39.6 percent in August to 50.3 percent in June. The percentage of soil moisture measured by the M300 in March and May was high. Soil texture at the site was classified as silt loam.

An existing well (PZ BW250) was in place about 165 m east of WF16. According to the 2005 U.S. Fish and Wildlife Service (USFWS) Geographic Information Systems (GIS) map, the Bill Williams River is approximately 450 m from PZ BW250 and approximately 446 m from WF16. Therefore, the depth to ground water measured at PZ BW250 was applied to WF16 for analysis purposes. Depth to ground water at PZ BW250 varied 1.66 m between the lowest and highest ground water level. Ground water was lowest in August, at a depth of 2.8 m, and was highest in March, at a depth of 1.1 m. Due to high flows, WF16 was inundated by flowing water in March. According to stream gauge data from the Bill Williams River below Alamo Dam

(USGS 09426000), the average monthly discharge ranged from a high of 776.4 cfs in March to a low of 50 cfs in June through August (USGS 2010).

Relative humidity at WF16 ranged from a low of 20 percent in April to a high of 91 percent in August. Air temperature ranged from a low of 24.5ºC in May to a high of 35.2ºC in April. The NOAA NCDC Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, three days prior to the site visit at WF16.

The vegetation canopy height at this approximate location was 5.2 m, with an average canopy closure of 96.9 percent and average ground cover of 46.3 percent.

A1.16 WF17 (BW 31B, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided Bill Williams River (refer to Figure 2.4 and photos in Appendix B). The site was within the flowing channel of the Bill Williams River and near a beaver pond in March during high flows from dam releases. Areas of standing water were present at this site in April, May, and June. No areas of standing water were observed in July or August. The area of standing water at the site from April through June ranged from a low of 180 m^2 in June to a high of 755 m^2 in April. Depth of standing water averaged 0.15 m in April through June. Average soil moisture during the field season (measured in April and June through August) ranged from 30.5 percent in August to 42.6 percent in June. The percentage of soil moisture measured by the M300 in March and May was high. Soil texture at the site was classified as silt loam.

An existing well (PZ BW250) was in place about 218 m east of WF17. According to the 2005 USFWS GIS map, the Bill Williams River is approximately 450 m from PZ BW250 and approximately 331 m from WF17. Therefore, the depth to ground water measured at PZ BW250 was applied to WF17 for analysis purposes. Due to high flows, WF17 was inundated by flowing water in March. Specific data on PZ BW250 and discharge for the Bill Williams River were provided in Section A1.15.

Relative humidity at WF17 ranged from a low of 29 percent in April to a high of 87 percent in August. Air temperature ranged from a low of 19.3ºC in May to a high of 30.6ºC in April and August. The NOAA NCDC Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, three days prior to the site visit at WF17.

The vegetation canopy height at this approximate location was 6.9 m, with an average canopy closure of 94.3 percent and average ground cover of 15.8 percent.

A1.17 WF19 (BW 12A, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided Bill Williams River (refer to Figure 2.4 and photos in Appendix B). The majority of the site was within the flowing channel of the Bill Williams River in March during high flows from dam releases. Areas of standing water were present at this site in April and May. No areas of standing water were observed in June, July, or August. The area of standing water at the site in April and May was 64 m^2 and 34 m^2, respectively. A small flowing channel was also observed crossing the site in April. Depth of standing water averaged 0.04 m in April and May. Average soil moisture during the field season (measured in April and June through August) ranged from 34.7 percent in August to 51.0 percent in April. The percentage of soil moisture measured by the M300 in March and May was high. Soil texture at the site was classified as silt loam.

An existing well (PZ BW250) was in place about 315 m east of WF19. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 450 m from PZ BW250 and approximately 430 m from WF19. Therefore, the depth to ground water measured at PZ BW250 was applied to WF19 for analysis purposes. Due to high flows, WF19 was inundated by flowing water in March. Specific information on PZ BW250 and discharge for the Bill Williams River were provided in Section A1.15.

Relative humidity at WF19 ranged from a low of 35 percent in March to a high of 87 percent in July. Air temperature ranged from a low of 15.7ºC in April and May to a high of 30.2ºC in July. The NOAA NCDC Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, six days prior to the site visit at WF19.

The vegetation canopy height at this approximate location was 13.7 m, with an average canopy closure of 96.9 percent and average ground cover of 38.8 percent.

A1.18 WF20 (BW 66A, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided Bill Williams River (refer to Figure 2.4 and photos in Appendix B). The majority of the site was within the flowing channel of the Bill Williams River in March during high flows from dam releases. Small flowing channels crossed the site in April. Areas of standing water were present at this site in May and June. No areas of standing water were observed in July or August. The area of standing water at the site in May and June were 20 m^2 and 27.5 m^2, respectively. Depth of standing water averaged 0.02 m in May and June. Average soil moisture during the field season (measured in April and June through August) ranged from 31.2 percent in August to 47.5 percent in April. The percentage of soil moisture measured by the M300 in March and May was high. Soil texture at the site was classified as silt loam.

An existing well (PZ BW250) was in place about 334 m east of WF20. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 450m from PZ BW250 and approximately 290 m from WF20. Therefore, the depth to ground water measured at PZ BW250 was applied to WF20 for analysis purposes. Due to high flows, WF20 was inundated by flowing water in March and had flowing channels in April. Specific information on PZ BW250 and discharge for the Bill Williams River were provided in Section A1.15.

Relative humidity at WF20 ranged from a low of 35 percent in March to a high of 93 percent in July. Air temperature ranged from a low of 12.9ºC in May to a high of 30.7ºC in June. The NOAA NCDC Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, six days prior to the site visit at WF20.

No vegetation data were collected by SWCA in 2009 at this site.

A1.19 WF21 (BW F24, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided Bill Williams River (refer to Figure 2.4 and photos in Appendix B). A small flowing channel crossed the site in March and April—a result of high flows from dam releases. Areas of standing water were also present at this site in March. No areas of standing water were observed in April through August. The area of standing water at the site in March was 63.5 m^2, with an average depth of 0.04 m. Average soil moisture during the field season (measured in April and June through August) ranged from 32.8 percent in July to 47.3 percent in April. The percentage of soil moisture measured by the M300 was high in March and moderate in May. Soil texture at the site was classified as silt loam.

An existing well (PZ BW250) was in place about 490 m east of WF21. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 450 m from PZ BW250 and approximately 250 m from WF21. Therefore, the depth to ground water measured at PZ BW250 was applied to WF21 for analysis purposes. Due to high flows, WF21 had flowing water across the site in March and April. Specific information on PZ BW250 and discharge for the Bill Williams River were provided in Section A1.15.

Relative humidity at WF21 ranged from a low of 35 percent in March to a high of 82 percent in July. Air temperature ranged from a low of 10.0ºC in May to a high of 31.1ºC in August The NOAA NCDC Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, six days prior to the site visit at WF21.

No vegetation data were collected by SWCA in 2009 at this site.

A2 YBCU Individual Site Descriptions and Results

A2.1 YB01 (HAVND, Topock Marsh, Arizona)

This site is within the Havasu National Wildlife Refuge near Topock Marsh in Arizona, across the border from Needles, California. The general area consists of stands of vegetation separated by canals and dike roads, with this study site separated from Topock Marsh by a levee and canal (refer to Figure 2.3 and photos in Appendix B). No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 16 percent in June to 24 percent in July and August. The percentage of soil moisture measured by the M300 in March and May was moderate. The majority of the site had soil texture classified as loam, with small areas of sand and silt loam.

A piezometer was installed near the center of this study site, approximately 450 m from Topock Marsh. The ground water level at the piezometer was relatively consistent across the field season, only varying 0.44 m between the lowest and highest level. The ground water was lowest in August, with a depth to ground water of 1.32 m, and was highest in April, with a depth to ground water of 0.88 m. According to the stream gauge at Topock Marsh Inlet near Needles, California (USGS 09423550), the average discharge ranged from a high of 87.4 cfs in June to a low of 62.3 cfs in August (USGS 2010).

Relative humidity at YB01 ranged from a low of 14 percent in June to a high of 74 percent in August. Air temperature ranged from a low of 16.8ºC in May to a high of 44.5ºC in July. The Needles station (ID 046115) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to YB01 in 2010.

The vegetation canopy height at this approximate location was 5 m, with an average canopy closure of 58.5 percent and average ground cover of 90 percent.

A2.2 YB02 (HAVTPR, Topock Marsh, Arizona)

This site is within the Havasu National Wildlife Refuge near Topock Marsh in Arizona, across the border from Needles, California. The general area consists of stands of vegetation separated by canals and dike roads, with this study site separated from Topock Marsh by a levee and canal (refer to Figure 2.3 and photos in Appendix B). This site is closer to the Colorado River than it is to Topock Marsh. No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 0.47 percent in August to 3 percent in April. The percentage of soil moisture measured by the M300 in March was moderate and in May was low. The majority of the site had soil texture classified as sand with small areas of loamy sand.

A piezometer was installed near the site center at this study site, approximately 700 m from the Colorado River and approximately 1,400 m from Topock Marsh. The ground water levels at the piezometer were lower than the other piezometer readings in Havasu National Wildlife Refuge but were relatively consistent across the field season, only varying 0.59 m between the lowest and highest level. The ground water level was lowest in March and August, with a depth of 2.4 m, and highest in April, with a depth of 1.9 m. According to the stream gauge at Topock Marsh Inlet near Needles, California (USGS 09423550), the average discharge ranged from a high of 87.4 cfs in June to a low of 62.3 cfs in August (USGS 2010).

Relative humidity at YB02 ranged from a low of 13 percent in August to a high of 28 percent in March. Air temperature ranged from a low of 27.6ºC in March to a high of 47.4ºC in August. The Needles station (ID 046115) was used to obtain general provisional precipitation data (NOAA NCDC 2010). No precipitation was recorded at this station during any of the field visits to YB02 in 2010.

The vegetation canopy height at this approximate location was 8 m, with an average canopy closure of 72.8 percent and average ground cover of 10 percent.

A2.3 YB03 (BWCP, Bill Williams River, Arizona)

This site is within Planet Ranch upstream of Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 3.9 percent in July to 14.8 percent in April. The percentage of soil moisture measured by the M300 in March and May was low to moderate. Soil texture at the site was classified as sand.

An existing well (PZ PR3C) was in place about 750 m west of YB03. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 75 m from PZ PR3C and approximately 144 m from YB03. Therefore, the depth to ground water measured at PZ PR3C was applied to YB03 for analysis purposes. Depth to ground water at PZ PR3C varied 0.94 m between the lowest and highest ground water level. Ground water was lowest in May, at a depth of 0.94 m, and was highest in March, at 0.0 m at ground level. According to the stream gauge at Bill Williams River below Alamo Dam (USGS 09426000), the average monthly discharge ranged from a high of 776.4 cfs in March to a low of 50 cfs in June through August (USGS 2010).

Relative humidity at YB03 ranged from a low of 15 percent in June to a high of 87 percent in August. Air temperature ranged from a low of 9.5ºC in May to a high of 40.2ºC in June. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, eight days prior to the site visit at YB03.

The vegetation canopy height at this approximate location was 9 m, with an average canopy closure of 56 percent and average ground cover of 31 percent.

A2.4 YB04 (BWCW, Bill Williams River, Arizona)

This site is on the boundary of Planet Ranch and Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 3.5 percent in July to 6.1 percent in April. The percentage of soil moisture measured by the M300 in March was moderate and in May was low. Soil texture at the site was classified as sand.

An existing well (PZ PR3B) was in place about 300 m east of YB04. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 9 m from PZ PR3B and approximately 28 m from YB04. Therefore, the depth to ground water measured at PZ PR3B was applied to YB04 for analysis purposes. Depth to ground water at PZ PR3B varied 0.48 m between the lowest and highest ground water level. Ground water was lowest in July, at a depth of 1.4 m, and was highest in March, at a depth of 0.9 m. According to the stream gauge at Bill Williams River below Alamo Dam (USGS 09426000), the average monthly discharge ranged from a high of 776.4 cfs in March to a low of 50 cfs in June through August (USGS 2010).

Relative humidity at YB04 ranged from a low of 14 percent in June to a high of 85 percent in August. Air temperature ranged from a low of 12.5ºC in May to a high of 40.8ºC in June. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, eight days prior to the site visit at YB04.

The vegetation canopy height at this approximate location was 14 m, with an average canopy closure of 60.3 percent and average ground cover of 0.0 percent.

A2.5 YB05 (BWHB, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). This site was inaccessible in March due to high water releases from Alamo Dam. Measurements were only taken at this site from April through August. No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 4.6 percent in June to 9.2 percent in April. The percentage of soil moisture measured by the M300 in May was low. Soil texture at the site was classified as sand.

An existing well (PZ BW225) was in place about 650 m east of YB05. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 5 m from PZ BW225 and approximately 5 m from YB05. Therefore, the depth to ground water measured at PZ BW225 was applied to YB05 for analysis purposes. Specific information on PZ BW225 and discharge for the Bill Williams River were provided in Section A1.14.

Relative humidity at YB05 ranged from a low of 17 percent in April to a high of 64 percent in July. Air temperature ranged from a low of 25.5ºC in June to a high of 37.8ºC in August. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, eight days prior to the site visit at YB05.

The vegetation canopy height at this approximate location was 9 m, with an average canopy closure of 69.7 percent and average ground cover of 12.5 percent.

A2.6 YB06 (BWMW, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). No areas of standing water were present at this site; however, the Bill Williams River channel ran through this site. The entire site was inundated in March due to high water flows in the channel, and smaller braids ran through the site in April through August. Average soil moisture during the field season (measured in April and June through August) ranged from 9.6 percent in July to 16.7 percent in August. The percentage of soil moisture measured by the M300 was high in March and moderate to low in May. Soil texture across the site was equal parts loam, sandy loam, and loamy sand.

An existing well (PZ BW233) was in place about 1,700 m west of YB06. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 5 m from PZ BW233 and approximately 5 m from YB06. However, flowing channels were observed crossing the site throughout the field season, and the site was inundated in March due to high flows. Therefore, the depth to ground water measured at PZ BW233 was applied to YB06 for analysis purposes. Depth to ground water at PZ BW233 varied 0.22 m between the lowest and highest ground water level. Ground water was lowest in July and August, at a depth of 2.43 m, and was highest in March, at a depth of 2.21 m. According to the stream gauge at Bill Williams River below Alamo Dam (USGS 09426000), the average monthly discharge ranged from a high of 776.4 cfs in March to a low of 50 cfs in June through August (USGS 2010).

Relative humidity at YB06 ranged from a low of 23 percent in April to a high of 95 percent in August. Air temperature ranged from a low of 17.7ºC in May to a high of 33.0ºC in April. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data to compare with the specific measurements taken at YB06 (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, nine days prior to the site visit at YB06. Provisional precipitation data were not available for the date of the August site visit.

The vegetation canopy height at this approximate location was 10.5 m, with an average canopy closure of 57.5 percent and average ground cover of 3.5 percent.

A2.7 YB07 (BWER, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). No areas of standing water were present at this site; however, the Bill Williams River channel ran through this site. The entire site was inundated in March due to high water flows in the channel, and smaller braids ran through the site in April through August. A small backwater area (approximately 75 m^2) was also present on-site. Average soil moisture during the field season (measured in April and June through August) ranged from 12.9 percent in June to 15.1 percent in August. The percentage of soil moisture measured by the M300 was high in March and moderate in May. The majority of the site had a soil texture of sand, with small areas of loamy sand and sandy loam.

An existing well (PZ BW233) was in place about 18 m west of YB07. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 5 m from PZ BW233 and approximately 11 m from YB07, though, due to high flows in the river, YB07 was inundated in March. Smaller channels flowed across the site throughout the field season. The depth to ground water measured at PZ BW233 was applied to YB07 for analysis purposes. Specific information on PZ BW233 and discharge for the Bill Williams River were provided in Section A2.6.

Relative humidity at YB07 ranged from a low of 25 percent in March to a high of 91 percent in August. Air temperature ranged from a low of 22.8ºC in May to a high of 30.9ºC in March. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, nine days prior to the site visit at YB07. Provisional precipitation data were not available for the date of the August site visit.

The vegetation canopy height at this approximate location was 9.0 m, with an average canopy closure of 79.8 percent and average ground cover of 87.5 percent.

A2.8 YB08 (BWPT, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). No areas of standing water were present at this site. This site was inaccessible in March due to the high water levels in the Bill Williams River. Measurements were taken at this site in April through August. Average soil moisture during the field season (measured in April and June through August) ranged from 4.5 percent in July to 12.3 percent in April. The percentage of soil moisture measured by the M300 was low to moderate in May. The majority of the site had a soil texture of sand, with small areas of sandy loam.

An existing well (PZ BW230) was in place about 2,100 m east of YB08. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 33 m from PZ BW230 and approximately 49 m from YB08. Therefore, the depth to ground water measured at PZ BW230 was applied to YB08 for analysis purposes.

Depth to ground water at PZ BW230 varied 0.59 m between the lowest and highest ground water level. Ground water was lowest in April, at a depth of 1.96 m, and was highest in March, at a depth of 1.37 m. According to the stream gauge at Bill Williams River below Alamo Dam (USGS 09426000), the average monthly discharge ranged from a high of 776.4 cfs in March to a low of 50 cfs in June through August (USGS 2010).

Relative humidity at YB08 ranged from a low of 31 percent in April to a high of 93 percent in August. Air temperature ranged from a low of 19.6ºC in May to a high of 28.2ºC in August. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, five days prior to the site visit at YB08. Provisional precipitation data were not available for the date of the August site visit.

The vegetation canopy height at this approximate location was 10.5 m, with an average canopy closure of 62.5 percent and average ground cover of 5.0 percent.

A2.9 YB09 (BWKR, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). This site was inaccessible in March due to high water releases from Alamo Dam. Measurements were only taken at this site from April through August. No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 1.6 percent in July to 7.2 percent in April. The percentage of soil moisture measured by the M300 in May was low to moderate. The majority of the site had a soil texture of sand with a few areas of loamy sand.

An existing well (PZ BW240) was in place about 160 m east of YB09. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 23 m from PZ BW240 and approximately 32 m from YB09. Therefore, the depth to ground water measured at PZ BW240 was applied to YB09 for analysis purposes. Depth to ground water at PZ BW240 varied 0.29 m between the lowest and highest ground water level. Ground water was lowest in August, at a depth of 1.81 m, and was highest in April, at a depth of 1.52 m. According to the stream gauge at Bill Williams River below Alamo Dam (USGS 09426000), the average monthly discharge ranged from a high of 776.4 cfs in March to a low of 50 cfs in June through August (USGS 2010).

Relative humidity at YB09 ranged from a low of 23 percent in April to a high of 83 percent in July. Air temperature ranged from a low of 19ºC in May to a high of 35.5ºC in August. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, five days prior to the site visit at YB09. Provisional precipitation data were not available for the date of the August site visit.

The vegetation canopy height at this approximate location was 8 m, with an average canopy closure of 73.8 percent and average ground cover of 6.3 percent.

A2.10 YB10 (BWGR, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). This site was inaccessible in March due to high water releases from Alamo Dam. Measurements were only taken at this site from April through August. No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 9.0 percent in June to 19.2 percent in April. The percentage of soil moisture measured by the M300 in May was moderate to high. The majority of the site had a soil texture of sand, with a few areas of loamy sand.

An existing well (PZ BW240) was in place about 530 m east of YB10. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 23 m from PZ BW240 and approximately 30 m from YB10. Therefore, the depth to ground water measured at PZ BW240 was applied to YB10 for analysis purposes. Specific information on PZ BW240 and discharge for the Bill Williams River were provided in Section A2.9.

Relative humidity at YB10 ranged from a low of 37 percent in May to a high of 87 percent in July. Air temperature ranged from a low of 15.9ºC in May to a high of 33.1ºC in August. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, five days prior to the site visit at YB10. Provisional precipitation data were not available for the date of the August site visit.

The vegetation canopy height at this approximate location was 8 m, with an average canopy closure of 60.3 percent and average ground cover of 0.0 percent.

A2.11 YB11 (BWSW, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). No areas of standing water were present at this site. Average soil moisture during the field season (measured in April and June through August) ranged from 2.3 percent in June to 8.7 percent in April. The percentage of soil moisture measured by the M300 was moderate in March and May. Soil texture at the site was a mix of sand, loam, loamy sand, and sandy loam.

An existing well (PZ BW248) was in place about 45 m southeast of YB11. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 200 m from PZ BW248 and approximately 207 m from YB11. Therefore, the depth to ground water measured at PZ BW248 was applied to YB11 for analysis purposes. Depth to ground water at PZ BW248 varied 1.29 m between the lowest and highest ground water level. Ground water was lowest in March, at a depth of 2.2 m, and was highest in July, at a depth of 0.9 m. According to the USGS (2010) stream gauge at Bill Williams River below Alamo Dam (USGS 09426000), the average monthly discharge ranged from a high of 776.4 cfs in March to a low of 50 cfs in June through August.

Relative humidity at YB11 ranged from a low of 31 percent in June to a high of 91 percent in August. Air temperature ranged from a low of 7.8ºC in May to a high of 31.4ºC in June. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, six days prior to the site visit at YB11. Provisional precipitation data were not available for the date of the August site visit.

The vegetation canopy height at this approximate location was 5.3 m, with an average canopy closure of 91.0 percent and average ground cover of 0.0 percent.

A2.12 YB12 (BWBP, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). No areas of standing water were present at this site; however, a braid of the Bill Williams River flowed through part of this site in March and April. Average soil moisture during the field season (measured in April and June through August) ranged from 1.2 percent in August to 3.9 percent in April. The percentage of soil moisture measured by the M300 was low in March and May. Soil texture at the site was a mix of sand, loamy sand, and sandy loam.

An existing well (PZ BW248) was in place about 450 m east of YB12. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 200m from PZ BW248 and approximately 215 m from YB12. Therefore, the depth to ground water measured at PZ BW248 was applied to YB12 for analysis purposes. Due to high flows, a portion of this site had flowing channels crossing it in March and April. Specific information on PZ BW248 and discharge for the Bill Williams River were provided in Section A2.11.

Relative humidity at YB12 ranged from a low of 20 percent in July to a high of 91 percent in August. Air temperature ranged from a low of 11.4ºC in May to a high of 40.2ºC in July. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, six days prior to the site visit at YB12. Provisional precipitation data were not available for the date of the August site visit.

The vegetation canopy height at this approximate location was 6.4 m, with an average canopy closure of 53.0 percent and average ground cover of 0.0 percent.

A2.13 YB13 (BWMF, Bill Williams River, Arizona)

This site is within the Bill Williams River National Wildlife Refuge, between Lake Havasu City and Parker, Arizona. The general area consists of dense stands of vegetation along the braided channel of the Bill Williams River (refer to Figure 2.4 and photos in Appendix B). Areas of standing water were present at this site in March through June. No areas of standing water were observed in July or August. Most of the site was within a flowing braid of the Bill Williams River in March; however, a small area of standing water measured 0.96 m^2. The area of standing water at the site from April through June ranged from a low of 283 m^2 in May to a high of 700 m^2 in April. Depth of standing water ranged from an average of 0.07 m in April to 0.03 m in June. Average soil moisture during the field season (measured in April and June through August) ranged from 38.9 percent in August to 53.5 percent in June. The percentage of soil moisture measured by the M300 was high in March and May. Soil texture at the site was a mix of sand, loamy sand, and silt loam.

An existing well (PZ BW250) was in place about 340 m west of YB13. According to the 2005 USFWS GIS map, the nearest braid of the Bill Williams River is approximately 450 m from PZ BW250 and approximately 433 m from YB13. Therefore, the depth to ground water measured at PZ BW250 was applied to YB13 for analysis purposes. Due to high flows, a flowing channel crossed this site in March. Specific data on PZ BW250 and discharge for the Bill Williams River were provided in Section A1.15.

Relative humidity at YB13 ranged from a low of 31 percent in April to a high of 95 percent in August. Air temperature ranged from a low of 16.7ºC in May to a high of 29.3ºC in July. The Alamo Dam station (ID 020100) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.57 inch) was recorded at this station on August 18, six days prior to the site visit at YB13. Provisional precipitation data were not available for the date of the August site visit.

The vegetation canopy height at this approximate location was 19.0 m, with an average canopy closure of 59.0 percent and average ground cover of 33.5 percent.

A2.14 YB16 (CVCA1, Colorado River, Arizona)

This site is within the Cibola Valley Conservation Area near Cibola, Arizona. The closest water body to this site is the Colorado River, approximately 260 m north. This site is a restoration area that receives irrigation (refer to Figure 2.5 and photos in Appendix B). No areas of standing water were present at this site during field measurements. However, the site was inundated for some period of time during each month of the field season according to the flood irrigation schedule. Flood irrigation ranged from 17.5 acre-feet in August to 108.5 acre-feet in July. Average soil moisture during the field season (measured in April and June through August) ranged from 4.2 percent in August to 11.6 percent in July. The percentage of soil moisture measured by the M300 was moderate in March and May. The majority of the site had a soil texture of sandy loam with a few areas of loam.

A piezometer was installed near the site center at YB16, approximately 254 m from the Colorado River. This site is separated from the Colorado River by a levee. The ground water level at the piezometer was fairly consistent across the field season, only varying 0.53 m between the lowest and highest level. The ground water was lowest in March, with a depth to ground water of 4.71 m, and was highest in July, the month with the highest level of flood irrigation, with a depth to ground water of 4.18 m. According to the stream gauge at the Colorado River below Palo Verde Dam, California–Arizona (USGS 09429100), the average discharge ranged from a high of 9,572.7 cfs in April to a low of 7,572.9 cfs in August(USGS 2010).

Relative humidity at YB16 ranged from a low of 24 percent in June to a high of 50 percent in August. Air temperature ranged from a low of 21.7ºC in March to a high of 37.2ºC in August. The Blythe, California, station (ID 040924) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.64 inch) was recorded at this station on March 7, one day prior to the site visit at YB16. Provisional precipitation data were not available for the date of the March site visit.

The vegetation canopy height at this approximate location was 10.0 m, with an average canopy closure of 90.3 percent and average ground cover of 19.3 percent.

A2.15 YB17 (CVCA2, Colorado River, Arizona)

This site is within the Cibola Valley Conservation Area near Cibola, Arizona. The closest water body to this site is the Colorado River, approximately 880 m north. This site is a restoration area that receives flood irrigation (refer to Figure 2.5 and photos in Appendix B). No areas of standing water were present at this site during field measurements. However, the site was inundated for some period of time during each month of the field season, according to the flood irrigation schedule. Flood irrigation ranged from 17.5 acre-feet in August to 108.5 acre-feet in July. Average soil moisture during the field season (measured in April and June through August) ranged from 9.7 percent in August to 23.8 percent in July. The percentage of soil moisture measured by the M300 was moderate in March and May. The majority of the site had a soil texture of silt loam, with a few areas of loam.

A piezometer was installed near the site center at YB16, approximately 500 m north of YB17 and 820 m from the Colorado River. Both YB17 and the piezometer at YB16 (PZ YB16) are separated from the Colorado River by a levee. Specific information on PZ YB16, discharge for the Colorado River, and flood irrigation levels were provided in Section A2.14.

Relative humidity at YB17 ranged from a low of 24 percent in May to a high of 87 percent in July. Air temperature ranged from a low of 18.3ºC in April to a high of 35.0ºC in August. The Blythe, California, station (ID 040924) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.64 inch) was recorded at this station on March 7, one day prior to the site visit at YB17. Provisional precipitation data were not available for the date of the March site visit.

The vegetation canopy height at this approximate location was 8.0 m, with an average canopy closure of 88.3 percent and average ground cover of 3.3 percent.

A2.16 YB18 (CVCA3, Colorado River, Arizona)

This site is within the Cibola Valley Conservation Area near Cibola, Arizona. The closest water body to this site is the Colorado River, approximately 800 m west. This site is a restoration area that receives flood irrigation (refer to Figure 2.5 and photos in Appendix B). The entire site was inundated with flood irrigation in May and August. No areas of standing water were present at this site during field measurements in March, April, June, or July. However, the site was inundated for some period of time during each month of the field season, according to the flood irrigation schedule. Flood irrigation ranged from 40 acre-feet in April to 109 acre-feet in August. Average soil moisture during the field season (measured in April and June through July) ranged from 7.9 percent in April to 29.8 percent in June. Soil samples were not collected in August; however, due to inundation by flood irrigation, the soil was saturated during this field visit. The percentage of soil moisture measured by the M300 was moderate in March and high in May. Soil texture at the site was classified as silt loam.

A piezometer was installed near the site center at YB16, north of YB18 and approximately 426 m closer to the Colorado River. YB18 and PZ YB16 are separated from the Colorado River by a levee. Specific information on PZ YB16, discharge for the Colorado River, and flood irrigation levels were provided in Section A2.14.

Relative humidity at YB18 ranged from a low of 15 percent in June to a high of 57 percent in July. Air temperature ranged from a low of 21.5ºC in March to a high of 44.7ºC in June. The Blythe, California, station (ID 040924) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.64 inch) was recorded at this station on March 7, 1 day prior to the site visit at YB18. Provisional precipitation data were not available for the date of the March site visit.

The vegetation canopy height at this approximate location was 7.0 m, with an average canopy closure of 67.8 percent and average ground cover of 37.0 percent.

A2.17 YB19 (CIBNTH, Cibola National Wildlife Refuge, Colorado River, Arizona)

This site is within the Cibola National Wildlife Refuge, south of the Cibola Valley Conservation Area near Cibola, Arizona. The closest water body to this site is the Colorado River, approximately 2,100 m west. This site is a restoration area that receives irrigation (refer to Figure 2.5 and photos in Appendix B). The entire site was inundated with flood irrigation in June. No areas of standing water were present at this site during field measurements in March through May, July, and August. However, the site was inundated multiple times over the course of the field season due to flood irrigation. The flood irrigation schedule for 2010 was not available for this area at the time of this report. Average soil moisture during the field season (measured April, July, and August) ranged from 3.6 percent in April to 26.6 percent in July. Soil samples were not collected in June; however, due to inundation by flood irrigation, the soil was saturated during this field visit. The percentage of soil moisture measured by the M300 was moderate in March and May. The majority of the site had a soil texture of loam with an area of sandy loam.

A piezometer was installed near the site center at YB19, approximately 2,100 m from the Colorado River. This site is separated from the Colorado River by a levee. The ground water levels at the piezometer varied by 1.89 m across the field season. The ground water was lowest in March with a depth to ground water of 2.91 m and was highest in June, the month with the flood irrigation during the site visit, with a depth to ground water of 1.02 m. According to the stream gauge at the Colorado River below Palo Verde Dam, California–Arizona (USGS 09429100), the average discharge ranged from a high of 9,572.7 cfs in April to a low of 7,572.9 cfs in August (USGS 2010).

Relative humidity at YB19 ranged from a low of 20 percent in June to a high of 62 percent in August. Air temperature ranged from a low of 13.8ºC in March to a high of 37.5ºC in July. The Blythe, California, station (ID 040924) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.64 inch) was recorded at this station on March 7, two days prior to the site visit at YB19. Provisional precipitation data were not available for the date of the March site visit.

The vegetation canopy height at this approximate location was 10.5 m, with an average canopy closure of 78.3 percent and average ground cover of 4.5 percent.

A2.18 YB20 (CIBCNT, Cibola National Wildlife Refuge, Colorado River, Arizona)

This site is within the Cibola National Wildlife Refuge, south of the Cibola Valley Conservation Area near Cibola, Arizona. The closest water body to this site is the Colorado River, approximately 2,000 m west. This site receives irrigation (refer to Figure 2.5 and photos in Appendix B). No areas of standing water were present at this site during field measurements. However, the site was likely inundated multiple times over the field season due to flood irrigation. The flood irrigation schedule was not available at the time of this report. Average soil moisture during the field season (measured in April, July, and August) ranged from 17.8 percent in August to 29.0 percent in June. The percentage of soil moisture measured by the M300 was moderate in March and May. Soil texture of the site is a mix of loam, sandy loam, and silt loam.

A piezometer was installed near the site center at YB19, approximately 2,100 m from the Colorado River, approximately 100 m farther from the Colorado River than YB20. This site is separated from the Colorado River by a levee. Specific information on PZ YB19, discharge for the Colorado River, and flood irrigation levels were provided in Section A2.17.

Relative humidity at YB20 ranged from a low of 17 percent in June to a high of 87 percent in August. Air temperature ranged from a low of 16.4ºC in March to a high of 30.8ºC in August. The Blythe, California, station (ID 040924) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.64 inch) was recorded at this station on March 7, two days prior to the site visit at YB20. Provisional precipitation data were not available for the date of the March site visit.

The vegetation canopy height at this approximate location was 12.8 m, with an average canopy closure of 81.3 percent and average ground cover of 23.8 percent.

A2.19 YB21 (CIBSTH, Cibola National Wildlife Refuge, Colorado River, Arizona)

This site is within the Cibola National Wildlife Refuge, south of the Cibola Valley Conservation Area near Cibola, Arizona. The closest water body to this site is the Colorado River approximately 200 m to the west. This site receives irrigation (refer to Figure 2.5 and photos in Appendix B). No areas of standing water were present at this site during field measurements. However, this site was likely inundated multiple times over the course of the field season due to flood irrigation. The flood irrigation schedule was not known at the time of this report. Average soil moisture during the field season (measured in April, July, and August) ranged from 26.9 percent in April to 33.1 percent in June. The percentage of soil moisture measured by the M300 was high in March and May. The majority of the site had a soil texture of sandy loam with two areas of loam.

A piezometer was installed near the site center at YB21, approximately 200 m from the Colorado River. This site is separated from the Colorado River by a levee. Ground water levels at the piezometer varied by 0.56 m across the field season. The ground water was lowest in May and July, with a depth to ground water of 1.45 m, and was highest in June, the month with the flood irrigation during the site visit, with a depth to ground water of 0.89 m. According to the stream gauge at the Colorado River below Palo Verde Dam, California–Arizona (USGS 09429100), the average discharge ranged from a high of 9,572.7 cfs in April to a low of 7,572.9 cfs in August (USGS 2010).

Relative humidity at YB21 ranged from a low of 19 percent in April to a high of 96 percent in August. Air temperature ranged from a low of 22.2ºC in March to a high of 27.6ºC in April. The Blythe, California, station (ID 040924) was used to obtain general provisional precipitation data (NOAA NCDC 2010). Precipitation (0.64 inch) was recorded at this station on March 7, two days prior to the site visit at YB21. Provisional precipitation data were not available for the date of the March site visit.

The vegetation canopy height at this approximate location was 5.2 m, with an average canopy closure of 68.8 percent and average ground cover of 0.0 percent.

Literature Cited

NOAA NCDC. 2010. National Climatic Data Center Satellite and Information Services. http://www.ncdc.noaa.gov/oa/ncdc.html. Accessed November 2010.

USGS. 2010. Surface water statistics. http://waterdata.usgs.gov/nwis/dvstat/?referred_module=sw. Accessed November 2010.

APPENDIX B
Representative Site Photos
(taken June 2010 unless otherwise noted)

Photos taken at Beaver Dam Wash, Arizona.

Photo 1. View north from site center at WF01.

Photo 2. View east from site center at WF01.

Photo 3. View south from site center at WF01.

Photo 4. View west from site center at WF01.

Photos taken at Beaver Dam Wash, Arizona.

Photo 5. View north from site center at WF02.

Photo 6. View east from site center at WF02.

Photo 7. View south from site center at WF02.

Photo 8. View west from site center at WF02.

Photos taken along Virgin River, Nevada.

Photo 9. View north from site center at WF03.

Photo 10. View east from site center at WF03.

Photo 11. View south from site center at WF03.

Photo 12. View west from site center at WF03.

Photos taken along Virgin River, Nevada.

Photo 13. View north from site center at WF04.

Photo 14. View east from site center at WF04.

Photo 15. View south from site center at WF04.

Photo 16. View west from site center at WF04.

Photos taken along Virgin River, Nevada.

Photo 17. View north from site center at WF05.

Photo 18. View east from site center at WF05.

Photo 19. View south from site center at WF05.

Photo 20. View west from site center at WF05.

Photos taken along Virgin River, Nevada.

Photo 21. View north from site center at WF06.

Photo 22. View east from site center at WF06.

Photo 23. View south from site center at WF06.

Photo 24. View west from site center at WF06.

Photos taken in Topock Marsh, Arizona.

Photo 25. View north from site center at WF07.

Photo 26. View east from site center at WF07.

Photo 27. View south from site center at WF07.

Photo 28. View west from site center at WF07.

Photos taken in Topock Marsh, Arizona.

Photo 29. View north from site center at WF08.

Photo 30. View east from site center at WF08.

Photo 31. View south from site center at WF08.

Photo 32. View west from site center at WF08.

Photos taken in Topock Marsh, Arizona.

Photo 33. View north from site center at WF09.

Photo 34. View east from site center at WF09.

Photo 35. View south from site center at WF09.

Photo 36. View west from site center at WF09.

Photos taken in Topock Marsh, Arizona.

Photo 37. View north from site center at WF10.

Photo 38. View east from site center at WF10.

Photo 39. View south from site center at WF10.

Photo 40. View west from site center at WF10.

Photos taken in Topock Marsh, Arizona.

Photo 41. View north from site center at WF11 (in May 2010).

Photo 42. View east from site center at WF11 (in May 2010).

Photo 43. View south from site center at WF11 (in May 2010).

Photo 44. View west from site center at WF11 (in May 2010).

Photos taken in Topock Marsh, Arizona.


Photo 45. View north from site center at WF12.


Photo 46. View east from site center at WF12.


Photo 47. View south from site center at WF12.


Photo 48. View west from site center at WF12.

Photos taken in Topock Marsh, Arizona.


Photo 49. View north from site center at WF13.


Photo 50. View east from site center at WF13.


Photo 51. View south from site center at WF13.


Photo 52. View west from site center at WF13.

Photos taken along Bill Williams River, Arizona.

Photo 53. View north from site center at WF14.

Photo 54. View east from site center at WF14.

Photo 55. View south from site center at WF14.

Photo 56. View west from site center at WF14.

Photos taken along Bill Williams River, Arizona.

Photo 57. View north from site center at WF16.

Photo 58. View east from site center at WF16.

Photo 59. View south from site center at WF16.

Photo 60. View west from site center at WF16.

Photos taken along Bill Williams River, Arizona.

Photo 61. View north from site center at WF17.

Photo 62. View east from site center at WF17.

Photo 63. View south from site center at WF17.

Photo 64. View west from site center at WF17.

Photos taken along Bill Williams River, Arizona.

Photo 65. View north from site center at WF19.

Photo 66. View east from site center at WF19.

Photo 67. View south from site center at WF19.

Photo 68. View west from site center at WF19.

Photos taken along Bill Williams River, Arizona.

Photo 69. View north from site center at WF20.

Photo 70. View east from site center at WF20.

Photo 71. View south from site center at WF20.

Photo 72. View west from site center at WF20.

Photos taken along Bill Williams River, Arizona.

Photo 73. View north from site center at WF21.

Photo 74. View east from site center at WF21.

Photo 75. View south from site center at WF21.

Photo 76. View west from site center at WF21.

Photos taken in Topock Marsh, Arizona.

Photo 77. View north from site center at YB01.

Photo 78. View east from site center at YB01.

Photo 79. View south from site center at YB01.

Photo 80. View west from site center at YB01.

Photos taken in Topock Marsh, Arizona.

Photo 81. View north from site center at YB02.

Photo 82. View east from site center at YB02.

Photo 83. View south from site center at YB02.

Photo 84. View west from site center at YB02.

Photos taken along Bill Williams River, Arizona.

Photo 85. View north from site center at YB03.

Photo 86. View east from site center at YB03.

Photo 87. View south from site center at YB03.

Photo 88. View west from site center at YB03.

Photos taken along Bill Williams River, Arizona.

Photo 89. View north from site center at YB04.

Photo 90. View east from site center at YB04.

Photo 91. View south from site center at YB04.

Photo 92. View west from site center at YB04.

Photos taken along Bill Williams River, Arizona.

Photo 93. View north from site center at YB05.

Photo 94. View east from site center at YB05.

Photo 95. View south from site center at YB05.

Photo 96. View west from site center at YB05.

Photos taken along Bill Williams River, Arizona.

Photo 97. View north from site center at YB06.

Photo 98. View east from site center at YB06.

Photo 99. View south from site center at YB06.

Photo 100. View west from site center at YB06.

Photos taken along Bill Williams River, Arizona.

Photo 101. View north from site center at YB07.

Photo 102. View east from site center at YB07.

Photo 103. View south from site center at YB07.

Photo 104. View west from site center at YB07.

Photos taken along Bill Williams River, Arizona.

Photo 105. View north from site center at YB08.

Photo 106. View east from site center at YB08.

Photo 107. View south from site center at YB08.

Photo 108. View west from site center at YB08.

Photos taken along Bill Williams River, Arizona.

Photo 109. View north from site center at YB09.

Photo 110. View east from site center at YB09.

Photo 111. View south from site center at YB09.

Photo 112. View west from site center at YB09.

Photos taken along Bill Williams River, Arizona.

Photo 113. View north from site center at YB10.

Photo 114. View east from site center at YB10.

Photo 115. View south from site center at YB10.

Photo 116. View west from site center at YB10.

Photos taken along Bill Williams River, Arizona.

Photo 117. View north from site center at YB11.

Photo 118. View east from site center at YB11.

Photo 119. View south from site center at YB11.

Photo 120. View west from site center at YB11.

Photos taken along Bill Williams River, Arizona.

Photo 121. View north from site center at YB12.

Photo 122. View east from site center at YB12.

Photo 123. View south from site center at YB12.

Photo 124. View west from site center at YB12.

Photos taken along Bill Williams River, Arizona.

Photo 125. View north from site center at YB13.

Photo 126. View east from site center at YB13.

Photo 127. View south from site center at YB13.

Photo 128. View west from site center at YB13.

Photos taken in the Cibola Valley Conservation Area, Arizona.

Photo 129. View north from site center at YB16.

Photo 130. View east from site center at YB16.

Photo 131. View south from site center at YB16.

Photo 132. View west from site center at YB16.

Photos taken in the Cibola Valley Conservation Area, Arizona.

Photo 133. View north from site center at YB17.

Photo 134. View east from site center at YB17.

Photo 135. View south from site center at YB17.

Photo 136. View west from site center at YB17.

Photos taken in the Cibola Valley Conservation Area, Arizona.

Photo 137. View north from site center at YB18.

Photo 138. View east from site center at YB18.

Photo 139. View south from site center at YB18.

Photo 140. View west from site center at YB18.

Photos taken at the Cibola National Wildlife Refuge, Arizona.

Photo 141. View north from site center at YB19.

Photo 142. View east from site center at YB19.

Photo 143. View south from site center at YB19.

Photo 144. View west from site center at YB19.

Photos taken at the Cibola National Wildlife Refuge, Arizona.

Photo 145. View north from site center at YB20.

Photo 146. View east from site center at YB20.

Photo 147. View south from site center at YB20.

Photo 148. View west from site center at YB20.

Photos taken at the Cibola National Wildlife Refuge, Arizona.

Photo 149. View north from site center at YB21.

Photo 150. View east from site center at YB21.

Photo 151. View south from site center at YB21.

Photo 152. View west from site center at YB21.

APPENDIX C
Boxplots from SWFL and YBCU T-tests

Boxplots provide basic information about the data visually. The box represents the middle 50 percent of the data range, the asterisks represent outliers, the whiskers represent the minimum and maximum data points (unless there are outliers, in which case the whiskers represent the data point 1.5 times the box range), the circle in the middle of the box represents the mean, and the line in the middle of the box represents the median. There is no specific statistical inference from the box plots, but they are useful as visual representations of the range of data.

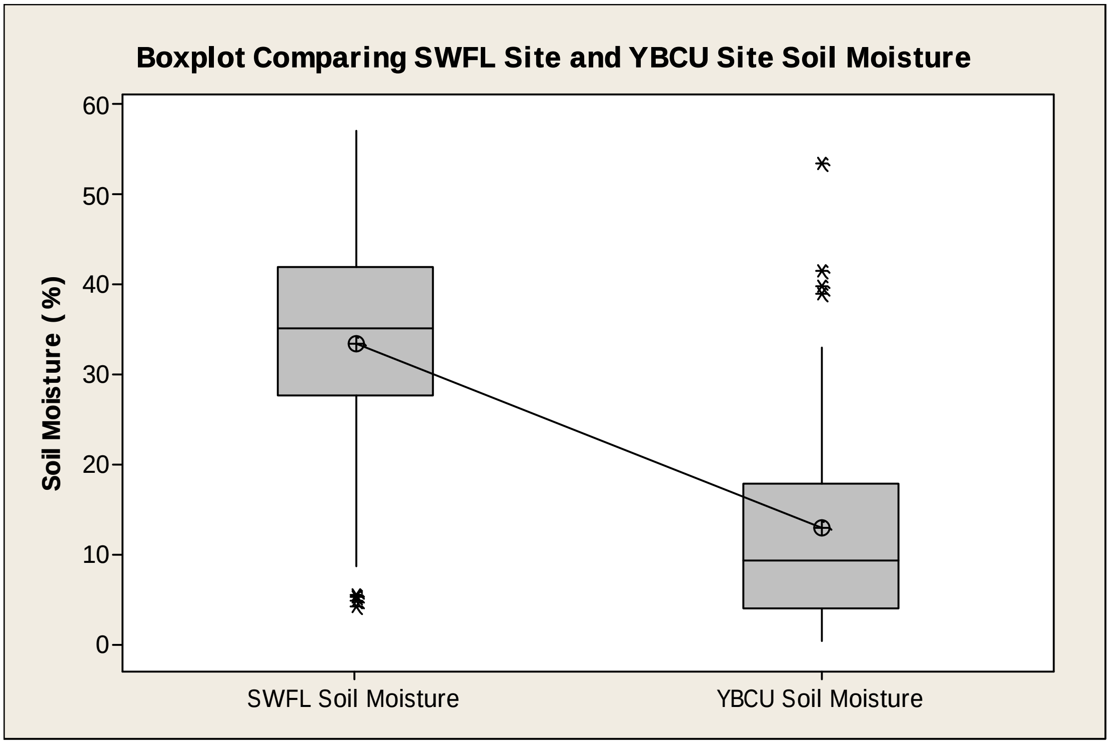


Figure C1. Comparison of percentage of soil moisture between Southwestern willow flycatcher (SWFL) sites and Western yellow-billed cuckoo (YBCU) sites. Data include gravimetric soil moisture measurements from April and June through August 2010.

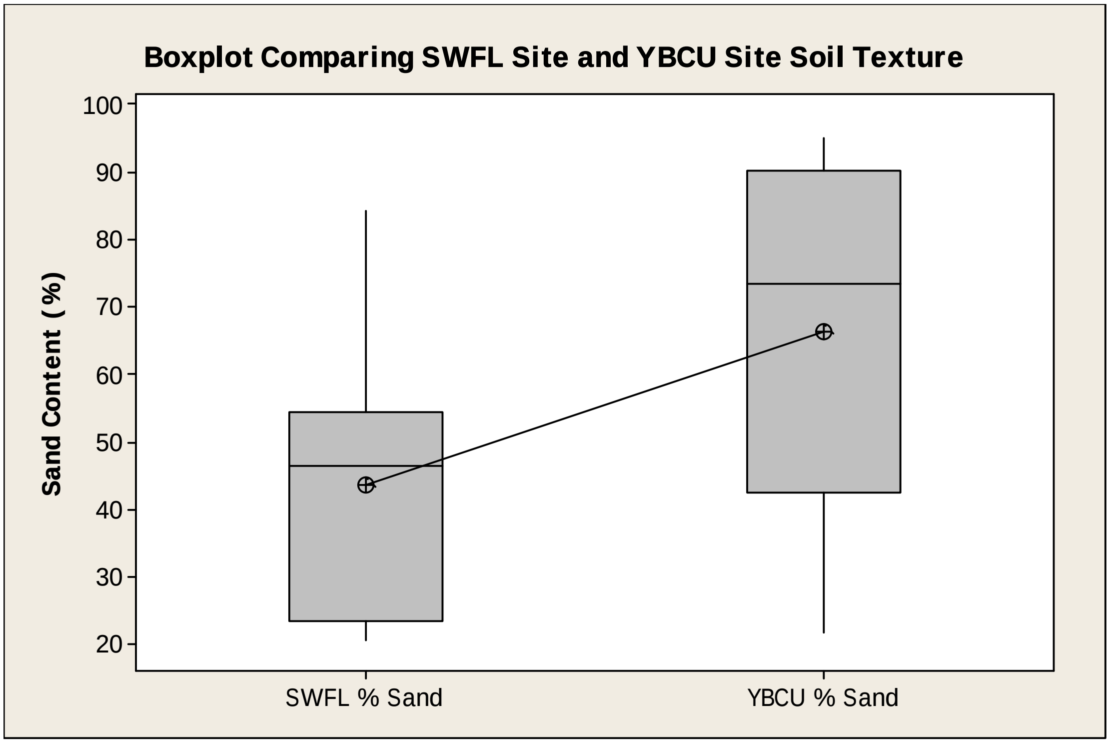


Figure C2. Comparison of percentage of sand (representative of overall soil texture) between SWFL sites and YBCU sites.

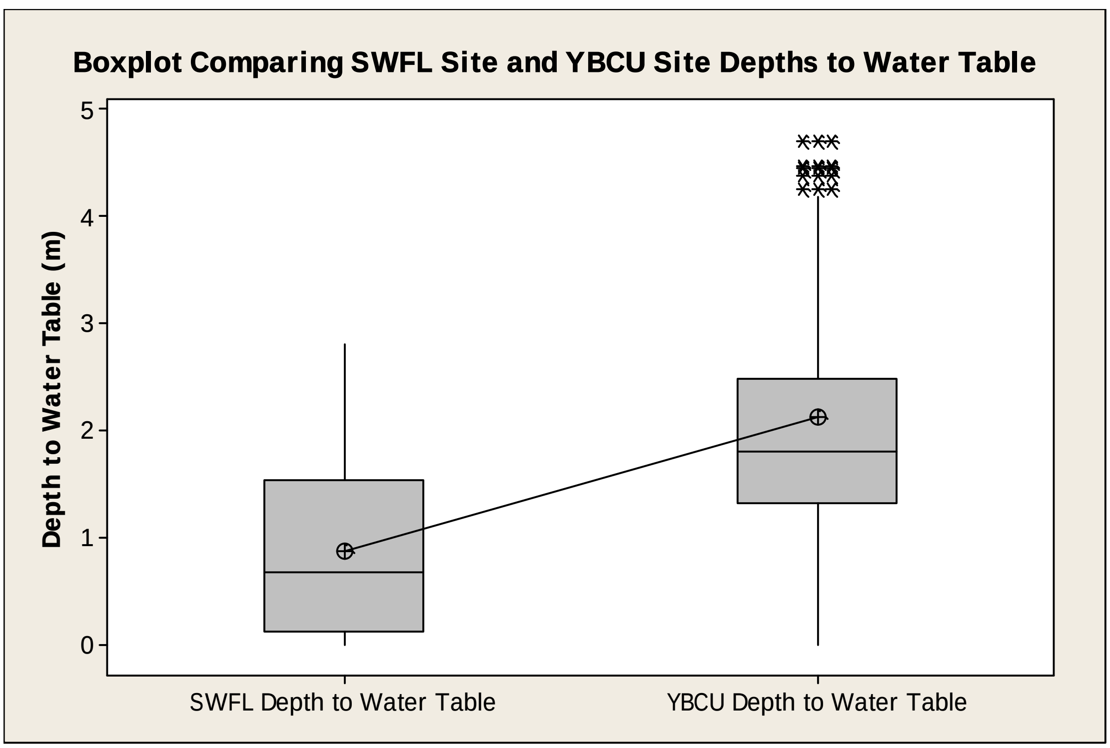


Figure C3. Comparison of depth to water table (meters [m]) between SWFL sites and YBCU sites.

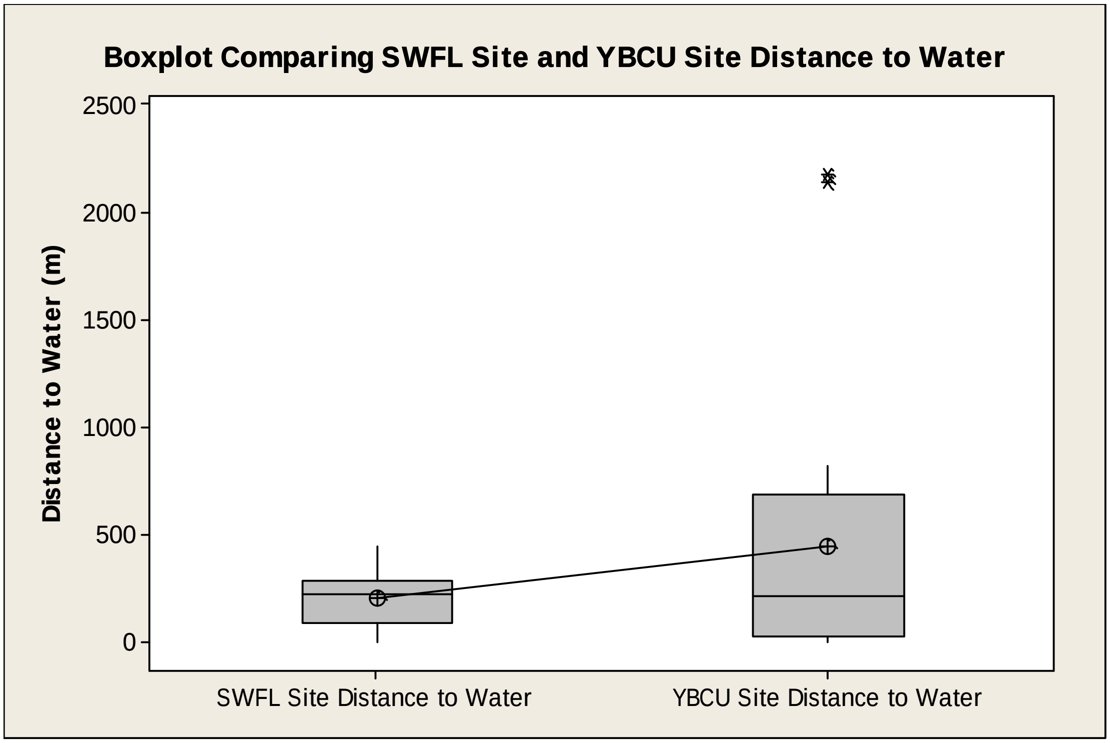


Figure C4. Comparison of site distance to water (m) between SWFL and YBCU sites.

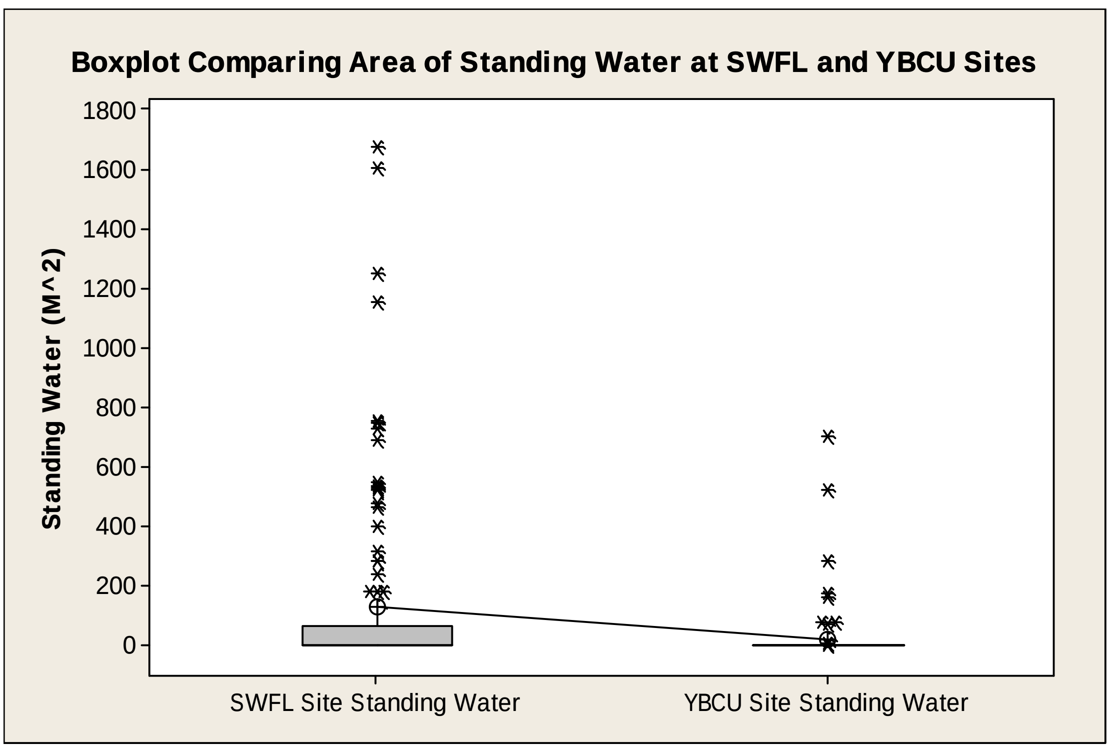


Figure C5. Comparison of the area of standing water (square meters [m^2]) between SWFL and YBCU sites. Comparison does not include any flowing water present across the site.

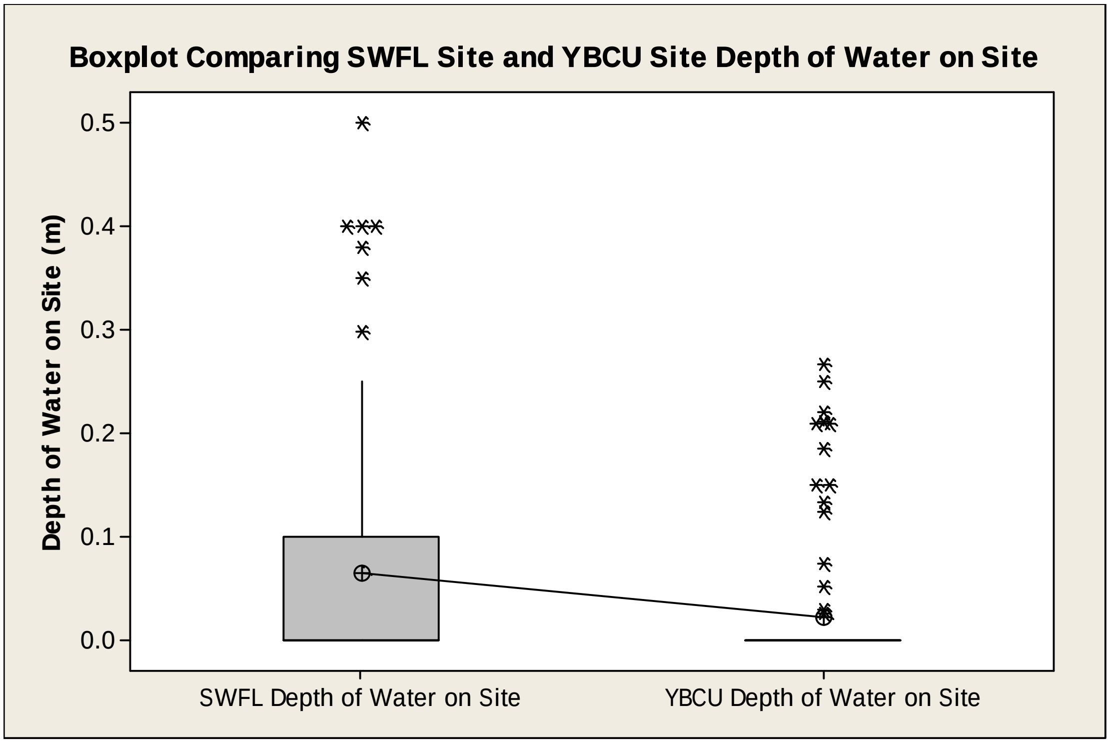


Figure C6. Comparison of depth of standing water (m) between SWFL and YBCU sites.

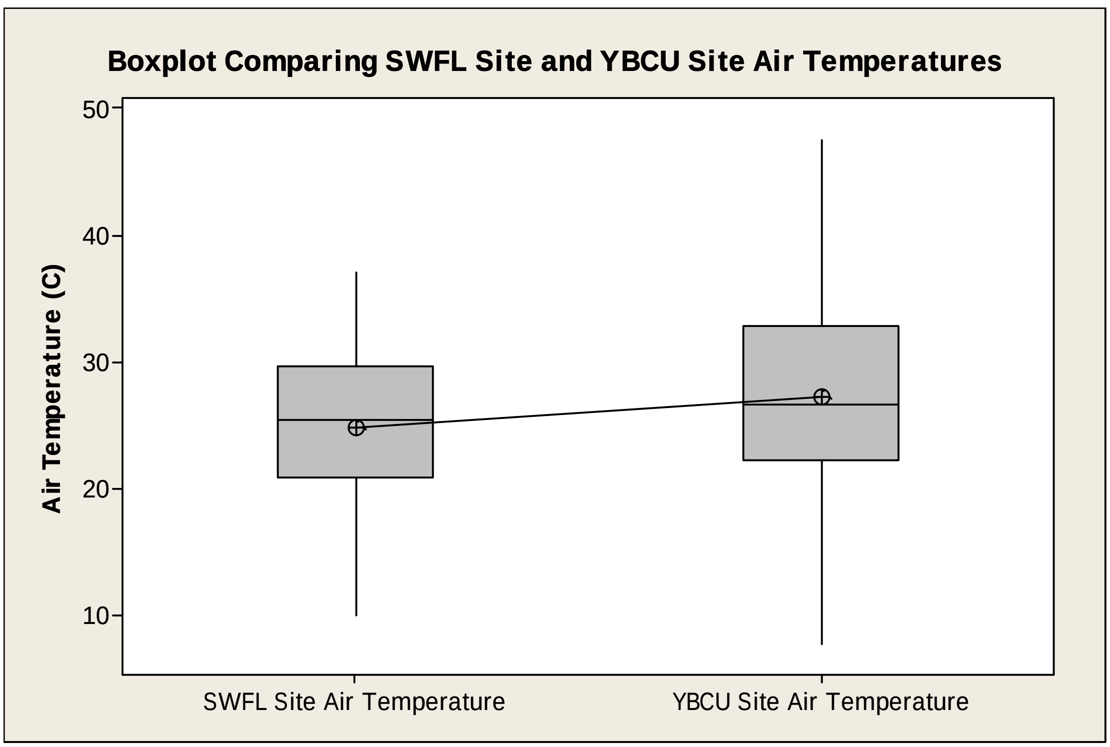


Figure C7. Comparison of air temperature (in degrees Celsius [C]) taken at 1.5-meter height between SWFL and YBCU sites.

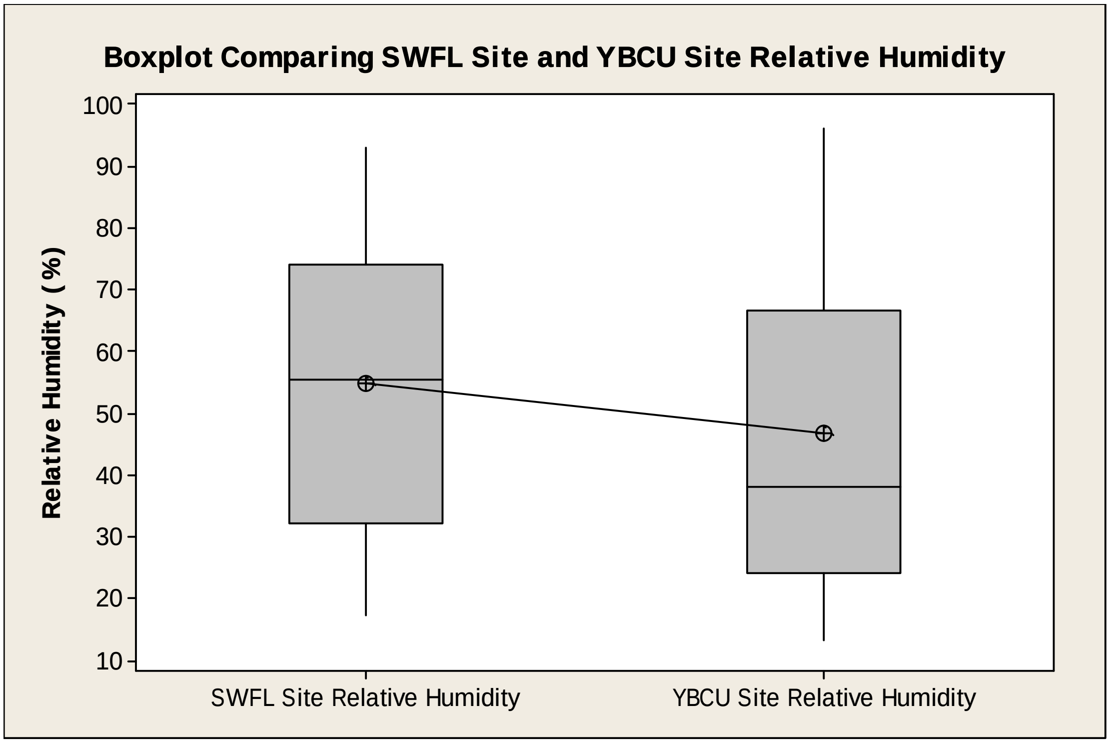


Figure C8. Comparison of relative humidity (percent [%]) taken at 1.5-meter height between SWFL and YBCU sites.

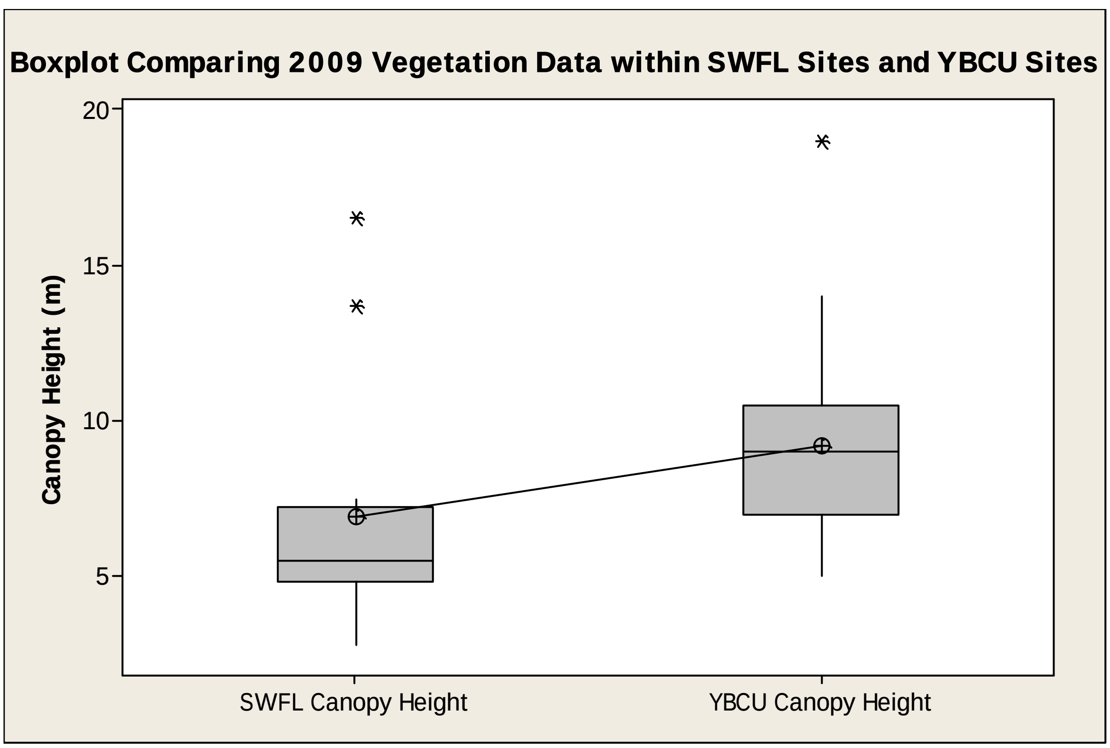


Figure C9. Comparison of canopy height (m) between SWFL and YBCU sites. Canopy height measurements were taken in 2009 by SWCA for SWFL sites and by the Southern Sierra Research Station (SSRS) for YBCU sites. Soil hydrology sites overlap the vegetation plots.

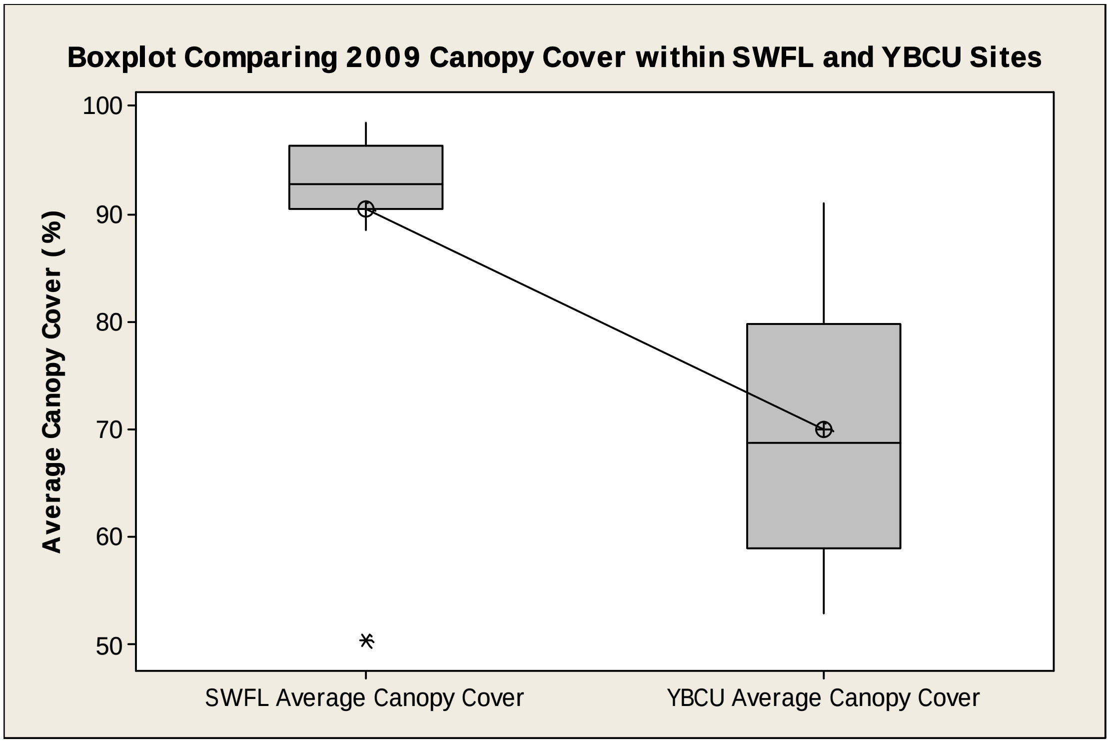


Figure C10. Comparison of canopy closure (%) between SWFL and YBCU sites. Canopy height measurements were taken in 2009 by SWCA for SWFL sites and by SSRS for YBCU sites. Soil hydrology sites overlap the vegetation plots.

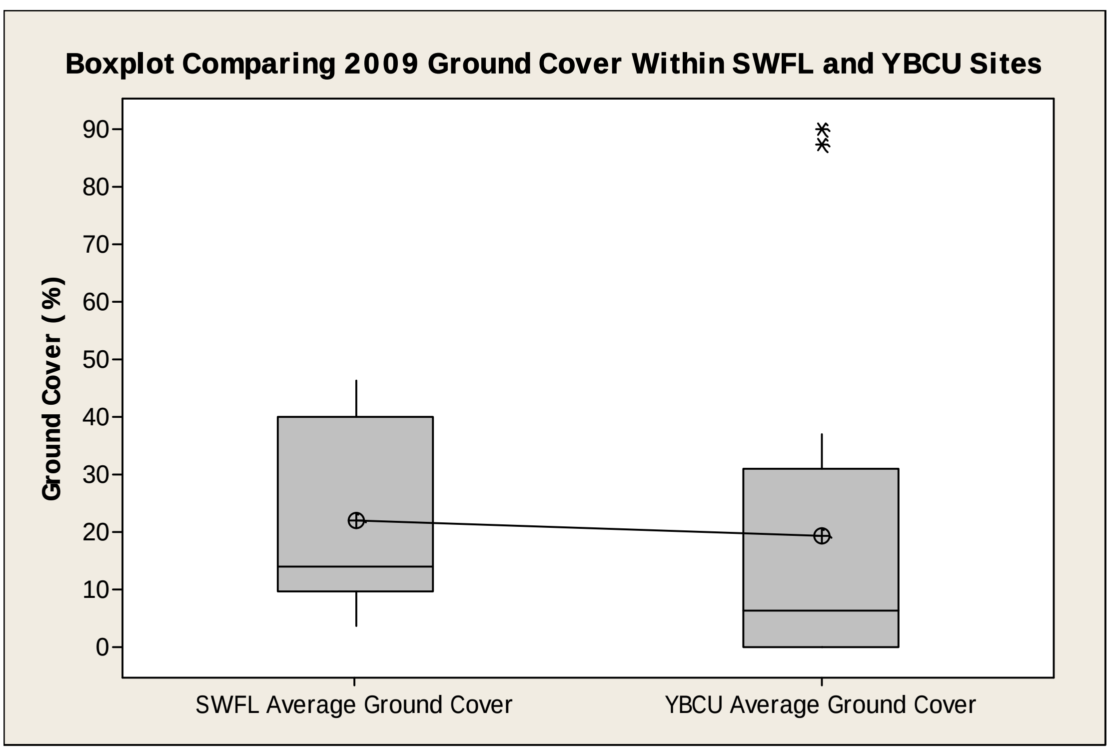


Figure C11. Comparison of ground cover (%) between SWFL and YBCU sites. Canopy height measurements were taken in 2009 by SWCA for SWFL sites and by SSRS for YBCU sites. Soil hydrology sites overlap the vegetation plots.