**LOWER SANTA CRUZ RIVER**
**RIPARIAN VEGETATION 2014 SURVEY REPORT**

***FINAL***

**SUBMITTED TO:**
**PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT**
**TUCSON, ARIZONA 85701**

**SUBMITTED BY**
**HARRIS ENVIRONMENTAL GROUP, INC.**
**DECEMBER 2014**

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# RIPARIAN VEGETATION ASSESSMENT
# 2014 SURVEY REPORT

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**SUBMITTED TO:**

**PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT**
**97 EAST CONGRESS, 3RD FLOOR**
**TUCSON, ARIZONA 85701**

**SUBMITTED BY:**

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**DECEMBER 2014**

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## ACRONYMS

DBH: Diameter at Breast Height
EPA: Environmental Protection Agency
FAC: Facultative
FACU: Facultative Upland
FACW: Facultative Wetland
GIS: Geographic Information Systems
GPS: Global Positioning System
NITRO#: Nitrogen Affinity Score
OBL: Obligate (wetland)
PCRFCD: Pima County Regional Flood Control District
SEINet: Southwest Environmental Information Network
SOW: Statement of Work
UPL: Upland
WIS#: Wetland Indicator Score
WRF: Wastewater Reclamation Facility

## INTRODUCTION

Harris Environmental Group, Inc. (Harris Environmental) is under contract with Pima County Regional Flood Control District (PCRFCD) to conduct vegetation surveys along the Santa Cruz River in the Tucson, Arizona area. The purpose of this study is to determine the effects of facility upgrades at two Wastewater Reclamation Facilities (WRF) on native riparian vegetation. This study is part of a comprehensive, Environmental Protection Agency (EPA)-funded assessment of ecological impacts of improved water quality and changes in effluent volume.

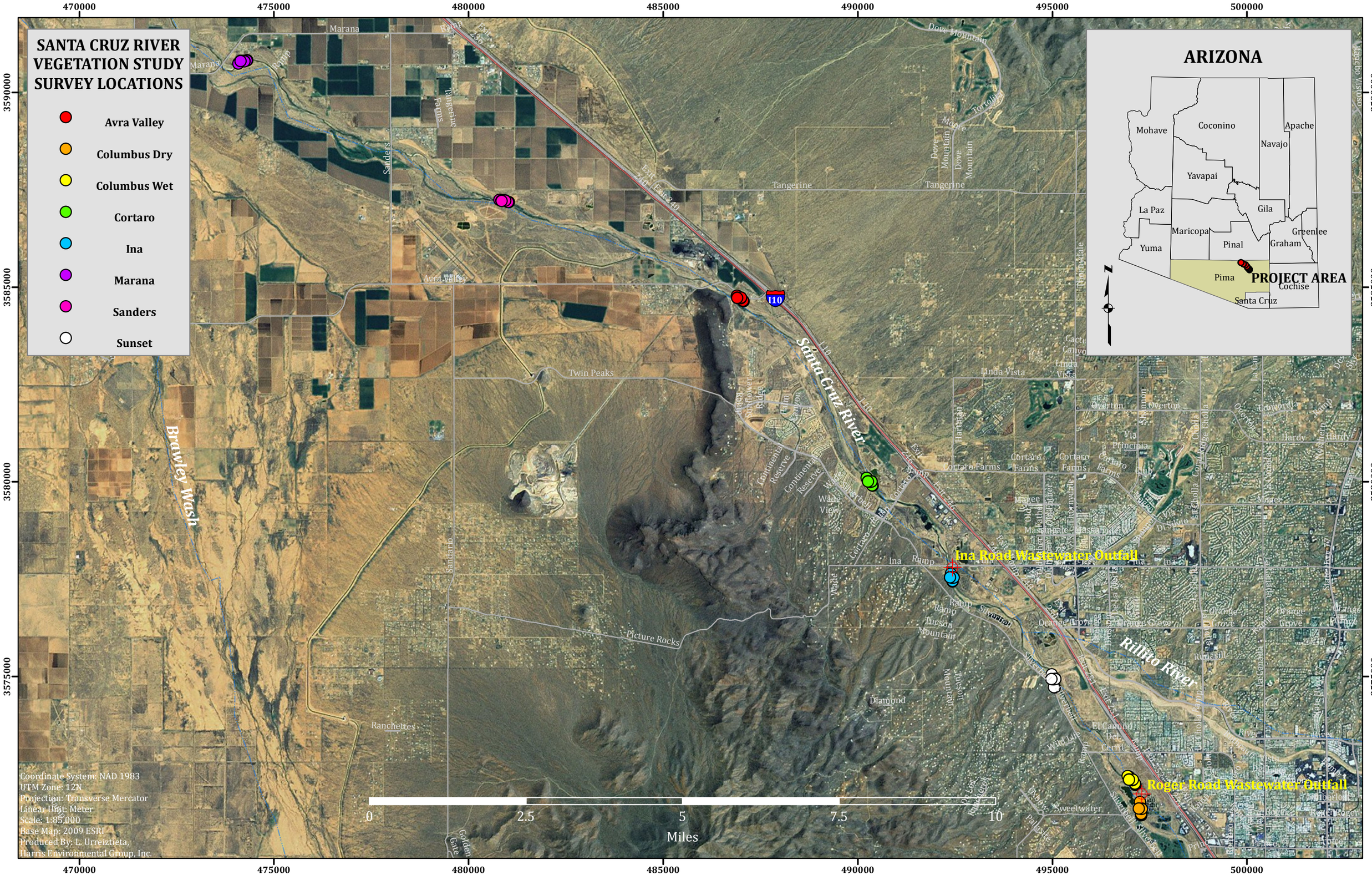
Pima County is investing $660 million for facility upgrades for two WRFs that discharge into the Santa Cruz River. The construction of a new WRF was completed mid-December of 2013 to replace the 60-yr old Roger Road WRF that was decommissioned on January 8, 2014. The new WRF, Agua Nueva, is just north of the Roger WRF. While Agua Nueva improves the quality of water discharged at the Roger outfall (i.e., the point-source where treated wastewater enters the Santa Cruz River), the total discharge may decrease from its historical volume due to less overall water being treated as well as increased use of recycled water for municipal purposes. The Ina Road WRF upgrade, Tres Rios, was completed on October 11, 2013 and handles more total metropolitan sewage than Agua Nueva, which increases the total volume of treated water discharged from the Ina outfall.

This report summarizes the second year of vegetation data collected from eight sample sites along the Santa Cruz River. This data is the first year of post-treatment data, and gives insight to initial and immediate impacts to streamside herbaceous vegetation. A secondary purpose of

this study is to compare results with research along other riparian reaches across the region. The surveys are designed to measure vegetation during the growing season when precipitation is most limited and vegetation is most dependent on effluent flows. Therefore, surveys were conducted from May 19-23 2014 after spring leaf out, but before summer monsoon rainfall.

**PROJECT LOCATION**

The Santa Cruz River flows from south-to-north extending from the US-Mexico international border to the south to the confluence of the Gila River to the north. This project is located along the Lower Santa Cruz River and surveys were conducted from the city of Tucson to the town of Marana in Pima County, AZ (Figure 1). Specifically, we examined a 40-kilometer [km] (25-mile [mi]) stretch of the lower Santa Cruz River spanning from a reach adjacent to Christopher Columbus Park (12S 0497161 m E, 3571679 m N) to a reach downstream, just south and east of Trico-Marana Rd (12S 0473698 m E, 3590743 m N). Within the project area, the width of the main channel ranges from 8-20 meters[m] (26-66 feet [ft]) with the floodplain ranging anywhere from 80-500+ m (262-1640+ ft) wide. Stabilized embankments, typically consisting of man-made soil cement, are common along this stretch of the river and often constrain the width of the floodplain to ~100 m. The channel is free to meander independently throughout many river miles; however, an edge of the main channel's low-flow often abuts these stabilized banks.


SANTA CRUZ RIVER VEGETATION STUDY SURVEY LOCATIONS
Avra Valley
Columbus Dry
Columbus Wet
Cortaro
Ina
Marana
Sanders
Sunset
ARIZONA
Mohave
Coconino
Apache
Navajo
Yavapai
La Paz
Gila
Maricopa
Greenlee
Yuma
Pinal
Graham
Pima
PROJECT AREA
Cochise
Santa Cruz
Ina Road Wastewater Outfall
Roger Road Wastewater Outfall
Santa Cruz River
Brawley Wash
Rillito River
Coordinate System: NAD 1983
UTM Zone: 12N
Projection: Transverse Mercator
Linear Unit: Meter
Scale: 1:85,000
Base Map: 2009 ESRI
Produced By: L. Urreiztieta,
Harris Environmental Group, Inc.
0
2.5
5
7.5
10
Miles
470000
475000
480000
485000
490000
495000
500000
3590000
3585000
3580000
3575000

## ENVIRONMENTAL SETTING

The lower Santa Cruz River is within the basin and range topography typical of southern Arizona. Most of the study area is within the Arizona Upland subdivision of the Sonoran Desertscrub biotic community, but a few areas are characteristic of vegetative zones of the Lower Colorado River subdivision (Brown, 1994). Historically, perennial stretches were more common in the 19$^{th}$century; however, shallow groundwater and seasonal rainfall often produced baseflow for many weeks of the year until the mid-20$^{th}$ century (Wood et al., 1999). In the mid-1900s, factors such as groundwater and surface water pumping, excessive wood-cutting, and overgrazing drastically impacted dense riparian gallery forests of cottonwood (*Populus* spp.), willow (*Salix* spp.), and mesquite (*Prosopis* spp.;Rea, 1983; Bahr, 1991). These negative impacts reduced the overall distribution of riparian gallery forests, reduced tree height and diameter, and altered species composition. Today, native vegetation along the Santa Cruz River includes abundant velvet mesquite (*Prosopis velutina*) and Goodding's willow (*Salix gooddingii*) while non-native species include two tamarisk species (*Tamarix ramosissima* and *T. aphylla*). Streamside herbaceous vegetation consists of obligate and facultative wetland plants, including mixed native and non-native grasses, and encroaching upland vegetation. Current river conditions and associated vegetation communities reflect current management strategies including flood control and prevention, and an altered hydrological regime consisting of treated wastewater discharge at varying volumes throughout the day and year.

## SURVEY SITES

Eight survey sites were selected using information provided by the PCRFCD (Figure 1). Between significant winter rains and monsoon rains, 100% of the baseflows within the Santa Cruz River are supported by two outfalls that discharge treated wastewater from the Roger Road and Ina Road WRFs. The Roger outfall provides baseflows to the entire river reach from Columbus Park to its confluence with the Ina outfall just south of Ina Rd. One survey site (Veg_1), not influenced by reclaimed water, was located upstream from the Roger outfall and served as the control site; three sites were located downstream from the Roger outfall, but upstream from the Ina outfall (Veg_2, Veg_3, Veg_4); and the remaining four locations were downstream from the Ina outfall and were potentially influenced by both the Roger and Ina outfalls (Veg_5, Veg_6, Veg_7, Veg_8; Figure 1). The following sections describe each site in upstream to downstream order.

**Site 1 (Veg_1), Columbus Park Dry**

The first survey site serves as the control site. It is the only location that is not influenced by treated wastewater. This site is located southeast of Christopher Columbus Park and slightly less than 200 m upstream of the Roger outfall. This reach has stabilized banks to the east and the west of the main channel and the width from bank to bank is less than 100 m. Singlewhorl burrobrush (*Hymenoclea monogyra*) is the most abundant species at this site and upland vegetation dominates the landscape.

**Site 2 (Veg_2), Columbus Park Wet**

The second survey site is located northeast of Columbus Park with the nearest transect beginning approximately 250 m north and downstream of the Roger outfall. The eastern edge of the main channel abuts a stabilized soil cement embankment. This is the first site downstream from the Roger outfall and upstream from the Ina outfall. This site supports larger, facultative phreatophytic trees (i.e., trees using both groundwater and the unsaturated zone for growth and survival) such as *S. gooddingii* and *Tamarix* spp., but soil cement along the eastern border limits growth to the west side of the main channel.

**Site 3 (Veg_3), Sunset Rd.**

The third survey site lies parallel to Silverbell Rd. and just north of the east-west plane of Sunset Rd. A gravel pit borders the site to the east and power lines cross the river in three separate areas. This is the second site downstream from the Roger outfall and upstream of the Ina outfall. Vegetation is mainly a mix of native species such as *S. gooddingii* and Mexican paloverde (aka. Jerusalem thorn, *Parkinsonia aculeata*), and a high terrace above the eroded western bank includes upland species such as wolfberry (*Lycium* spp.), creosotebush (*Larrea tridentada*), and cattle saltbush (*Atriplex polycarpa*).

**Site 4 (Veg_4), Ina Rd.**

The fourth survey site is over 200 m south of Ina Rd. and just over 100 m south and upstream of the Ina outfall. This is the furthest site downstream that receives water discharge from the Roger outfall alone. Depending on the management of the newly constructed WRF upstream, baseflows could be greatly reduced and may not reach this site in the future. Small to very large trees are prevalent at this site and include *Tamarix* spp. and *S. gooddingii*.

**Site 5 (Veg_5), Cortaro Rd.**

The fifth survey site is located just west of Marana Golf Continental Ranch and is over 600 m northwest of Cortaro Rd. This site is relatively open and is the first site to receive treated wastewater from the Ina WRF. A small sandbar is present at the first transect upstream, a large

channel bar encompasses most of the middle transect, and an embankment impacts the third transect downstream. Few trees exist at this site and shrubs such as *H. monogyra* and *Baccharis* spp. dominate the landscape.

**Site 6 (Veg_6), Avra Valley Rd.**

The sixth survey site lies parallel to Avra Valley Rd. and has a stabilized eastern bank made of soil cement. This site is unique in that the main channel is incised with steep slopes or banks on both sides ranging from three to eight meters. This is the second site to receive treated wastewater from the Ina WRF. Thick stands of non-native, shrubby *T. ramosissima* dominate this site with *B. salicifolia* common in the understory. This site also has large stands of *Arundo donax* that line the narrow channel.

**Site 7 (Veg_7), Sanders/Tangerine Rd.**

The seventh site, also referred to as "Sanders" (located upstream from and east of Sanders Rd) is located south and west of Tangerine Rd. This site also has an eastern bank stabilized with soil cement. Channel bars and sand bars are common at this site and also of note is a large drainage to the east of the middle transect which likely introduces high volume runoff through a culvert during large storm events. This is the third site to receive treated wastewater from the Ina WRF. The main channel runs roughly east-south-east to west-north-west with the most common woody species being *Tamarix* spp. and common aquatic plants including floating mats and grasses.

**Site 8 (Veg_8), Marana-Trico Rd.**

The eighth survey site is located south and east of Trico-Marana Rd. The main channel is sinuous along this reach heading east to west then meandering southwest. This is the fourth site to receive treated wastewater from the Ina WRF. Large *T. aphylla* dominate the site, but *T. ramosissima* and *S. gooddingii* are also common. This particular site is very remote and it is evident that cattle grazing and associated erosion is common in the area. Plants that are common at this site but are not as common upstream include cursed buttercup (*Ranunculus sceleratus*), false daisy (*Eclipta prostrata*, and sedge species (*Cyperus* spp).

## METHODS

The PCFCD provided site maps with GPS coordinates and restrictions (e.g., jurisdiction/right of entry) to eight survey areas for pre-treatment vegetation surveys conducted in 2013 (HEG 2013). The 2014 surveys were conducted at the same eight survey areas. Each site included three streamside herbaceous transects (Appendix A). We adapted surveys methods and analyses from protocols implemented by the Stromberg Research Group, Arizona State University. The metrics and indices used are amenable to other sites, thus a secondary goal was

to be able to compare results with research along other riparian reaches across the region. Woody shrub and tree belt-transects were not conducted in 2014, but will be continued in 2015 or 2016. Woody species are perennial species that may not show immediate impacts after facility upgrades, but long-term trends analyzed two or more years later can offer valuable information on growth, survival, and recruitment.

**Streamside Herbaceous Surveys**

We surveyed streamside herbaceous vegetation using four, 20-m transects spaced approximately 100-m apart and parallel to each streambank (Figure 2). Gridded, 1-m x 1-m sampling frames (i.e., quadrats) were used to estimate vegetation cover percentage (Figure 2). The 2014 survey increased the number of quadrats per transect from three to four to increase the sample size. While adding more samples minimally affects overall time and effort, more replications results in better representation of each study site as well as higher statistical power during analysis. If an edge of the low-flow channel abutted a stabilized embankment, then a total of eight randomized quadrats were placed along two, 20-m transects on the opposite bank.

We used a stopwatch to pick four random locations along each transect by separating the hundredths of seconds on the stopwatch into five, 20-interval categories to match 1-m intervals of a 20-m transect. For example; .05, .25, .45, .65, and .85 sec all represent a quadrat to be randomized at the 5-m position, whereas .17, .37, etc represent a randomized placement of 17 m. We also implemented a stratified random rule such that at least two quadrats would land in each of the two, 10-m halves of each transect (i.e., no three randomized quadrats could land in the first 10 m or second 10 m of the transect). On each side of the main channel, streamside vegetation was surveyed along the margin of low-flow perpendicular to the randomized transect locations. As suggested by PCRFC staff, the river was assumed to be near its low-flow during early morning surveys (e.g., between 05:00 A.M-11:00 A.M.); however, margins of low-flow were chosen to the best of our ability during late morning to afternoon surveys. Because placement was inherently subjective, the front edge (i.e., the edge closest to the main channel) of each quadrat was placed at the front edge of the first patch of vegetation influenced by channel moisture. We categorized the moisture at this interface as dry, moist, <3 cm, 3-10 cm, or >10 cm deep. This strategy allowed for obligate wetland plants to be included in the surveys when present, but also assessed vegetation reaching one meter onto a sandbar, channel bar, or the channel's edge.

A standard cover-abundance class approach was used to estimate cover of each species (FGDC 2008). Specifically, a modified Braun-Blanquet approach was used to assign a cover percentage to each species identified within each quadrat (Braun-Blanquet 1932). Herbaceous or woody species not originating in the quadrat but overhanging were included in the survey. Each cover

estimate corresponded to a midpoint value falling into one of five possible cover classes (Table 1). For example, if a species covered approximately 30% of the quadrat, then the species was given a value of 37.5, which represents the mid-point between the 25-50% cover class category.

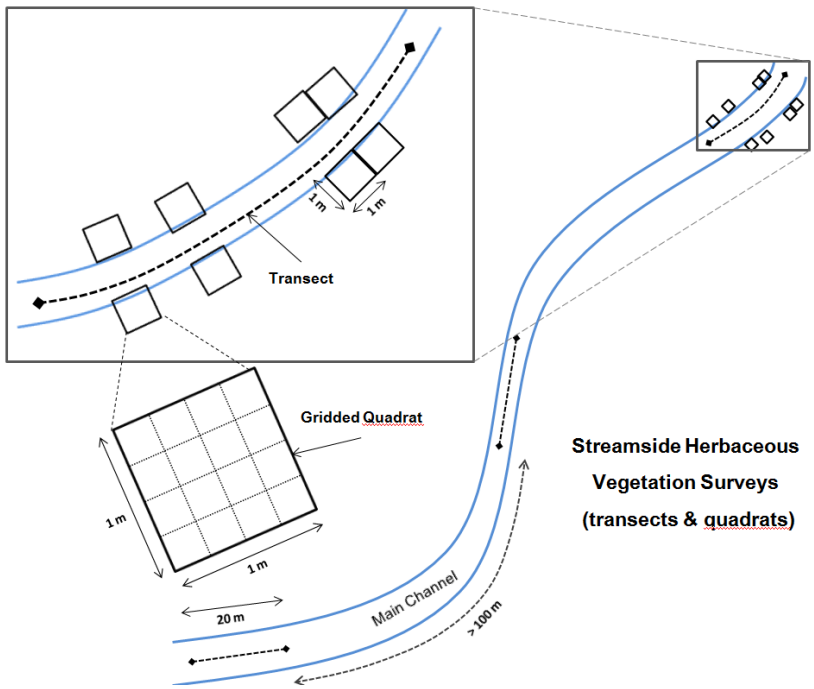



Figure 2. Streamside herbaceous survey design using stratified transects and randomized qudrats.

Table 1. Modified Braun-Blanquet classes used for data analyses.

| Cover Class Range | Midpoint |
|---|---|
| 76-100 | 87.5 |
| 51-75 | 62.5 |
| 26-50 | 37.5 |
| 6-25 | 15.0 |
| 1-5 | 3.0 |
| <1 | 0.5 |
| 0 | 0.0 |

## ANALYSIS

### Species Identification and Richness

All plants surveyed were identified to species using the USA Plants Database treatment (USDA 2013). Other resources used included SEINet (Southwest Environmental Information

Network,http://swbiodiversity.org/portal/index.php), the University of Arizona Herbarium, relevant regional plant identification books, and qualified regional botanists. All species were given a unique four-letter code using the first two letters of the genus and species. When necessary, some coded species were assigned a number to differentiate them from other similarly names species (e.g., *Baccharis salicifolia* and *B. sarathroides* were assigned BASA and BASA2, respectively). Species richness, the total number of individual species observed, was analyzed within each quadrat, transect (i.e., eight quadrats combined), and site (24 quadrats combined) as well as cumulatively for the entire project.

**Wetland Indicator Status**

A wetland indicator status (WIS) score (WIS#) was computed for each site. Using a list provided by Pima County and adapted from the National Wetland Plant List (Appendix B; USACE 2012), each species documented was assigned to one of five functional groups: 1) “1” obligate wetland species (OBL); 2) “2” facultative wetland (FACW); 3) “3” facultative (FAC); 4) “4” facultative upland (FACU); and 5) “5” upland (UPL). The list used in this project had updated WIS numbers for a number of species. For example, *T. ramosissima*, labeled as an upland plant in other regions, was given a WIS number of 4 instead of 5, indicating that the species functions as a facultative upland plant in the southwestern US. Similary, *Polygonum lapathifolium*, an upland plant in other regions, is considered a facultative wetland plant in desert riparian ecosystems; thus this species was given a WIS number of 2 instead of 5. Because this change was not implemented until 2014, the 2013 data was re-analyzed to provide direct comparisons between 2013 and 2014 using the same analysis. The 2013 Living River Report includes the original 2013 WIS values and the direct comparison between the two analysis methods is found in Appendix C. WIS# was computed for each site by weighting each species by their overall cover percentage and then using the functional group number as the multiplier. The WIS# is an index ranging from 1-5 with lower numbers representing sites with prevalent wetland species and higher numbers representing sites more characteristic of upland vegetation.

**Nitrogen Affinity Scores**

Sites were also analyzed using a nitrogen affinity index. Each species was assigned a nitrogen number ranging from 1-9 representing low to high affinity to nitrogen. Similar to the WIS number analysis, the nitrogen score was weighted by cover percentages of species found at each site. Lower nitrogen numbers represented sites characteristic of species with low nitrogen affinity while higher scores represented sites with species having high tolerance to high nitrogen concentrations. Of note, was that the list of species provided did not have nitrogen numbers for all of the species. Any species not having a nitrogen number were excluded from the nitrogen affinity analysis. The 2013 analysis mistakenly assigned zeros to those species

without a nitrogen affinity score. The 2013 nitrogen affinity data were re-analyzed to provide direct comparisons between 2013 and 2014 results.

## RESULTS

### Species Identification and Richness

A total of 56 individual plant species were identified during the streamside herbaceous surveys (Appendix D). The average number of species documented was 17.75 per site, 11.46 per transect, and 3.31 per quadrat. Species richness varied greatly across the eight survey sites with the least number of species observed at the Columbus Dry site (Veg_1, 3) and the most observed at the Sunset Rd site (Veg_3, 23) and the Avra Valley Rd site (Veg_6, 23) (Table 2). The species observed the most often (i.e., most occurrences within quadrats) were as follows: 1) *Cynodon dactylon*, 2), *Polygonum lapathifolium*, 3) *Rumex obtusifolius*, 4) *Typha domingensis*, 5) *Polypogon monspeliensis*, and 6) *Conium maculatum*.

### Wetland Indicator Status

The average WIS# for all survey sites combined was 2.76. The Sunset Rd site (Veg_3) had the lowest WIS# at 1.88, representing the site with the most wetland species observed, while the Columbus Park Dry site (Veg_1) had a WIS# of 4.86, indicating the site with the most upland species present (Figure 3). All of the sites influenced by treated effluent were relatively wet ranging from 1.88 to 3.65. The 2014 average wetland indicator score across all sites was slightly lower, but did not differ significantly from 2013 ($p=0.31$, matched pairs analysis, Appendix E) (Figure 4). In fact, all but two sites (Veg_2 and Veg_6) had a lower WIS# in 2014 compared to 2013 (Figure 3).

### Nitrogen Affinity

The average NITRO# for all survey sites combined was 6.16. The lowest NITRO# was 3.38 computed for the Columbus Park Dry site (Veg_1) and the two highest NITRO#s, 6.90 and 6.89, were computed at the Cortaro Rd site (Veg_5) and the Sunset Rd site (Veg_3), respectively (Figure 3). The 2014 average nitrogen affinity score across all sites was slightly higher, but did not differ significantly from 2013 ($p=0.24$, matched pairs analysis, Appendix E)(Figure 5). Six of the eight study sites had a higher nitrogen value in 2014; however Avra Valley, the exception, had a much lower NITRO# in 2014.

Table 2. Species richness documented across each survey site. Summary statistics by column include: 1) average species richness per quadrat and average of all four quadrats combined (bold, left); 2) species richness within each transect as well as average per transect (bold, center); and 3) total number of species identified per site.

| | Species Richness (SR) | | | |
|---|---|---|---|---|
| | **Transects** | **Avg SR per Quadrat** | **Total SR per Transect** | **Total SR per Site** |
| **Veg_1** | **1** | 1.25 | 4 | |
| | **2** | 1.13 | 5 | |
| | **3** | 1.25 | 3 | |
| | **Avg** | ***1.21*** | ***4.00*** | ***3*** |
| **Veg_2** | **1** | 3.13 | 12 | |
| | **2** | 3.75 | 19 | |
| | **3** | 2.63 | 12 | |
| | **Avg** | ***3.17*** | ***14.33*** | ***16*** |
| **Veg_3** | **1** | 2.63 | 12 | |
| | **2** | 2.13 | 8 | |
| | **3** | 2.75 | 12 | |
| | **Avg** | ***2.50*** | ***10.67*** | ***23*** |
| **Veg_4** | **1** | 3.13 | 8 | |
| | **2** | 3.25 | 8 | |
| | **3** | 5.75 | 14 | |
| | **Avg** | ***4.04*** | ***10.00*** | ***17*** |
| **Veg_5** | **1** | 4.25 | 12 | |
| | **2** | 3.13 | 11 | |
| | **3** | 3.38 | 13 | |
| | **Avg** | ***3.58*** | ***12.00*** | ***19*** |
| **Veg_6** | **1** | 2.88 | 12 | |
| | **2** | 2.50 | 13 | |
| | **3** | 2.38 | 12 | |
| | **Avg** | ***2.58*** | ***12.33*** | ***23*** |
| **Veg_7** | **1** | 5.88 | 16 | |
| | **2** | 2.75 | 11 | |
| | **3** | 3.38 | 14 | |
| | **Avg** | ***4.00*** | ***13.67*** | ***19*** |
| **Veg_8** | **1** | 5.63 | 15 | |
| | **2** | 6.13 | 14 | |
| | **3** | 4.50 | 15 | |
| | **Avg** | ***5.42*** | ***14.67*** | ***22*** |

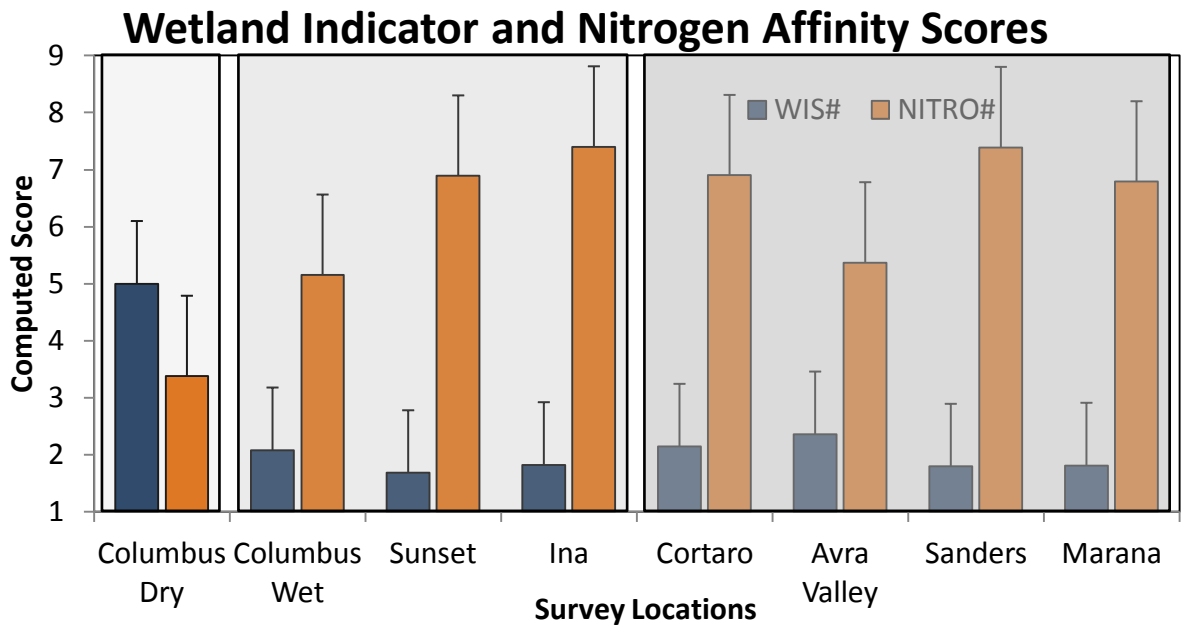



Figure 3. Computed wetland indicator scores (WIS#) and nitrogen affinity scores (NITRO#) for each survey site in 2014. Wetland Indicator Scores range from 1-5 with lower scores representing sites with more wetland species. Nitrogen Affinity Scores range from 1-9 with higher numbers indicating higher tolerance to nitrogen concentrations. Color gradients from left to right depict the influence of the Roger Rd and Ina Rd outfalls, respectively.

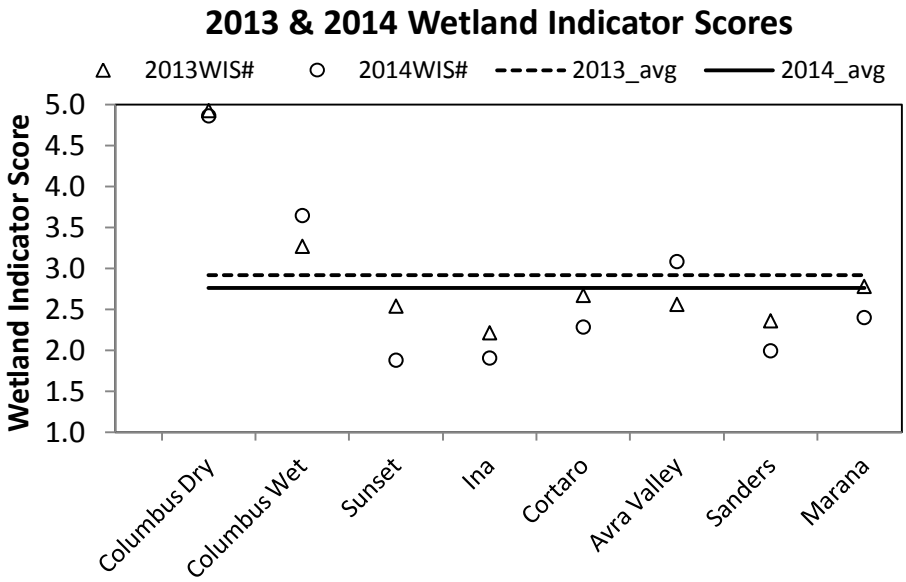



Figure 4. Computed Wetland Indicator Scores for Santa Cruz River vegetation surveys, 2013 and 2014.

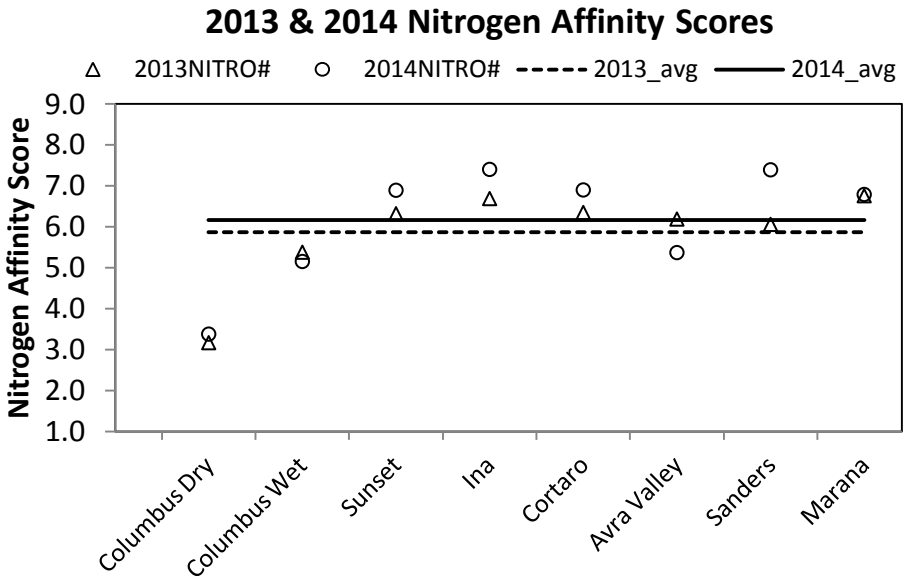



Figure 5. Computed Nitrogen Affinity Scores for Santa Cruz River vegetation surveys, 2013 and 2014.

## DISCUSSION

This data is the first year of post-treatment data, and gives insight to initial and immediate impacts to streamside herbaceous vegetation; however, it may take several years to fully understand how sewage treatment improvements will affect riparian vegetation along the Santa Cruz River.

### Streamside Herbaceous Vegetation

Species richness did not dramatically change in the first year following WRF upgrades. A total of 56 species were observed in 2014 compared to 51 species in 2013. Most of the new species documented in 2014 were common grass species that did not land in a survey quadrat in 2013. However, two Asteraceae species, Thurber's sneezeweed (*Helenium thurberi*), an obligate native, and Maltese starthistle (*Centaurea melitensis*), an invasive facultative upland plant, landed in survey quadrats and were common along some reaches of the Santa Cruz River in 2014. Many factors other than treated effluent and its associated moisture downstream from their respective outfalls may influence the presence and/or shift of riparian species over time. Therefore, it is difficult to isolate whether climate, WRF management, or other human disturbances may contribute to changes in vegetation.

Excluding the Columbus Dry site (Veg_1), species richness was similar across all sites ranging from 16 to 23 species per site. The Columbus Dry site (3 species) was dominated by upland vegetation which was also indicated by a WIS# of 4.9. Two unknowns, an immature grass and a

legume species, were observed but did not have enough distinguishing characteristics to be identified via dichotomous keys, the University of Arizona herbarium, or by a professional botanist. In general, sites comprised of large stretches of southern cattail (*Typha domingensis*) or large mats of emergent vegetation such as marsh seedbox (*Ludwigia palustris*) tended to have lower species richness because these species dominated the survey area. As a result, sites with low WIS#s did not necessarily have more plant species than drier sites that were more open (see Appendix E).

The 2014 results take into account updated WIS values for the southwestern US. The 2013 analysis used the nominal functional groups (i.e.; OBL, FACW, FAC, FACU, UPL) to assign WIS numbers from 1-5 to represent wet to dry species, respectively. In 2014, plants were analyzed using the updated WIS numbers provided by Julie Stromberg, which account for overall function of species specific to the southwestern US (see Appendix B & Appendix C). This is important to note because common species such as *T. ramosissima* and curlytop knotweed (*Polygonum lapathifolium*) were reanalyzed with WIS values changing from 5 to 4 and 5 to 2, respectively. The 2013 data were reanalyzed to provide a side-by-side comparison between the first two years of data collection in this report. Overall, the 2013 re-analysis showed similar patterns to the original 2013 analysis; however, the WIS#s were reduced across most sites resulting in a lower overall average WIS# (see Appendix C).

Wetland Indicator Scores for 2013 and 2014 had a similar pattern when compared across sites. Some aquatic plants that tend to influence low WIS#s include *T. domingensis*, curlytop knotweed (*P. lapathifolium*) and rabbitsfoot grass (*Polypogon monspeliensis*), which have high abundance and low WIS values. On the other hand, singlewhorl burrobrush (*Hymenoclea monogyra*) and Bermuda grass (*Cynodon dactylon*), which have higher WIS values, tend to influence higher WIS#s when present in large quantities. While WIS and Nitro values for the plants observed during the study are not correlated, our findings showed that WIS#s were highly correlated with higher NITRO#s at each site (see Appendix E). This is explained, in part, by the common plants falling in our surveys, which include *T. domingensis* and *P. lapathifolium*, both of which have low WIS values and high nitrogen values, and *H. monogyra*, which has a high WIS value and low nitrogen value.

The average nitrogen score (NITRO#) across all sites was similar in 2014 compared to 2013, but the low Nitro# at Avra Valley was responsible for lowering the 2014 average. This is, in part, due to higher sand dropseed (*Sporobolis cryptandrus*) cover in 2014 compared to higher water hemlock (*Conium maculatum*) and *T. domingensis* cover in 2013, which have high values for nitrogen affinity. High NITRO#s were computed at the Sunset (Veg_3), Ina (Veg_4), and Cortaro (Veg_5) sites, which were due to large cover percentages of *T. domingensis*, *P. lapathifolium,* and bitter dock (*Rumex obtusifolius*) in the surveys. The lowest NITRO#s were computed for the

Columbus Park Dry (Veg_1) and Columbus Park Wet (Veg_2) sites, and were due to the high cover percentage of *H. monogyra* and *C. dactylon*, respectively.

**Notes Specific to Surveys**

Other than the Columbus Dry site that is always dry, two survey sites were dry upon arrival. The Trico-Marana Site (Veg_8) was surveyed on May 21, 2014 at 7:30a. The streambed was dry when we arrived, but a pulse of water arrived around 9:30a during the survey (see Appendix F). The Ina Site (Veg_4), just south of the Ina Rd bridge and Ina Outfall was also dry on May 22, 2014 at 7:30a. It was evident that water was close to the surface and that the lack of baseflow had little impact to the vegetation along the streamside. Cattails and other obligate plants were healthy and were not impacted by dry soils (see Appendix F).

**Notes Specific to Sites**

Wildlife was common during the surveys. Although garbage and human disturbance were common on the floodplain, the main channel was relatively isolated. Killdeer (*Charadrius vociferus*), an occasional duck (family Anatidae), and water turtles (e.g., red-eared sliders [*Trachemys scripta elegans*], spiny softshell turtle [*Apalone spinifera*], Sonora mud turtle [*Kinosternon sonoriense*]) were common. Small fish were abundant throughout the surveys, mostly comprised of schools of mosquito fish (*Gambusia* spp). Two large carp were observed at the Avra Valley Site (Veg_6) and a large tadpole, likely a bullfrog (*Rana catesbiana*), was observed within the pulse flow arriving at the Trico-Marana Site (Veg_8). Bullfrogs were heard during the early morning surveys. During the macroinvertebrate surveys conducted a week prior to the vegetation surveys, there was evidence of a dead juvenile catfish and catfish fry at the Cortaro Site (Veg_5).

The Avra Valley site (Veg_6) is unique in that the main channel is incised with steep slopes or banks on both sides ranging from three to eight meters. This results in faster streamflows and water is not likely to inundate the floodplain unless large tropical storms or monsoon events occur. Dense stands of tamarisk were observed at this site along the disconnected, incised banks. The Sanders site (Veg_7), in between the Avra Valley and Trico-Marana sites was perhaps the most natural looking site. It was common to find braided channels with point bars, backwaters, and a high diversity of plants and wildlife. The Marana Rd site (Veg_8) was clearly impacted by cattle grazing and many of the plants had evidence of mastication. While this site also had a high diversity of plants, it was evident that the area is often impacted by erosion during larger runoff events.

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## APPENDIX A – GPS Coordinates for All Transects

| FID | SiteName | Site # | Subsite | Info | UTM (NAD 83) | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| 1 | Columbus Dry | Veg_1 | 1E1 | start | 12S 0497291 3571431 | -111.028768 | 32.279624 |
| 2 | Columbus Dry | Veg_1 | 1E1 | end | 12S 0497286 3571451 | -111.028821 | 32.279805 |
| 3 | Columbus Dry | Veg_1 | 1E2 | start | 12S 0497286 3571451 | -111.028821 | 32.279805 |
| 4 | Columbus Dry | Veg_1 | 1E2 | end | 12S 0497282 3571470 | -111.028864 | 32.279976 |
| 5 | Columbus Dry | Veg_1 | 2 | start | 12S 0497276 3571594 | -111.028928 | 32.281095 |
| 6 | Columbus Dry | Veg_1 | 2 | end | 12S 0497274 3571612 | -111.028949 | 32.281257 |
| 7 | Columbus Dry | Veg_1 | 3W1 | start | 12S 0497265 3571736 | -111.029045 | 32.282376 |
| 8 | Columbus Dry | Veg_1 | 3W1 | end | 12S 0497261 3571756 | -111.029087 | 32.282556 |
| 9 | Columbus Dry | Veg_1 | 3W2 | start | 12S 0497261 3571756 | -111.029087 | 32.282556 |
| 10 | Columbus Dry | Veg_1 | 3W2 | end | 12S 0497258 3571778 | -111.029119 | 32.282755 |
| 11 | Columbus Dry | Veg_1 | 2 | NE | 12S 0497308 3571601 | -111.028588 | 32.281158 |
| 12 | Columbus Dry | Veg_1 | 2 | NW | 12S 0497229 3571607 | -111.029427 | 32.281212 |
| 13 | Columbus Dry | Veg_1 | 2 | SE | 12S 0497307 3571599 | -111.028598 | 32.281140 |
| 14 | Columbus Dry | Veg_1 | 2 | SW | 12S 0497229 3571604 | -111.029427 | 32.281185 |
| 15 | Columbus Wet | Veg_2 | 1W1 | start | 12S 0497142 3572206 | -111.030352 | 32.286616 |
| 16 | Columbus Wet | Veg_2 | 1W1 | end | 12S 0497134 3572224 | -111.030437 | 32.286778 |
| 17 | Columbus Wet | Veg_2 | 1W2 | start | 12S 0497134 3572224 | -111.030437 | 32.286778 |
| 18 | Columbus Wet | Veg_2 | 1W2 | end | 12S 0497125 3572245 | -111.030533 | 32.286967 |
| 19 | Columbus Wet | Veg_2 | 2W1 | start | 12S 0497065 3572332 | -111.031171 | 32.287752 |
| 20 | Columbus Wet | Veg_2 | 2W1 | end | 12S 0497051 3572346 | -111.031319 | 32.287878 |
| 21 | Columbus Wet | Veg_2 | 2W2 | start | 12S 0497051 3572346 | -111.031319 | 32.287878 |
| 22 | Columbus Wet | Veg_2 | 2W2 | end | 12S 0497038 3572360 | -111.031457 | 32.288005 |
| 23 | Columbus Wet | Veg_2 | 3W1 | start | 12S 0496972 3572424 | -111.032159 | 32.288582 |
| 24 | Columbus Wet | Veg_2 | 3W1 | end | 12S 0496954 3572432 | -111.032350 | 32.288654 |
| 25 | Columbus Wet | Veg_2 | 3W2 | start | 12S 0496964 3572427 | -111.032244 | 32.288609 |
| 26 | Columbus Wet | Veg_2 | 3W2 | end | 12S 0496936 3572439 | -111.032541 | 32.288717 |
| 27 | Columbus Wet | Veg_2 | 2 | NE | 12S 0497071 3572345 | -111.031107 | 32.287869 |
| 28 | Columbus Wet | Veg_2 | 2 | NW | 12S 0496975 3572352 | -111.032127 | 32.287932 |
| 29 | Columbus Wet | Veg_2 | 2 | SE | 12S 0497073 3572342 | -111.031086 | 32.287842 |
| 30 | Columbus Wet | Veg_2 | 2 | SW | 12S 0496972 3572346 | -111.032158 | 32.287878 |
| 31 | Sunset | Veg_3 | 1 | start | 12S 0495066 3574710 | -111.052413 | 32.309198 |
| 32 | Sunset | Veg_3 | 1 | end | 12S 0495047 3574723 | -111.052615 | 32.309315 |
| 33 | Sunset | Veg_3 | 2 | start | 12S 0495032 3574918 | -111.052775 | 32.311074 |
| 34 | Sunset | Veg_3 | 2 | end | 12S 0495033 3574938 | -111.052765 | 32.311255 |
| 35 | Sunset | Veg_3 | 3 | start | 12S 0494996 3575033 | -111.053158 | 32.312112 |
| 36 | Sunset | Veg_3 | 3 | end | 12S 0494986 3575050 | -111.053265 | 32.312265 |
| 37 | Sunset | Veg_3 | 2 | NE | 12S 0495080 3574936 | -111.052265 | 32.311237 |
| 38 | Sunset | Veg_3 | 2 | NW | 12S 0494982 3574931 | -111.053306 | 32.311191 |
| 39 | Sunset | Veg_3 | 2 | SE | 12S 0495081 3574930 | -111.052255 | 32.311183 |
| 40 | Sunset | Veg_3 | 2 | SW | 12S 0494982 3574928 | -111.053306 | 32.311164 |
| 41 | Ina | Veg_4 | 1 | start | 12S 0492444 3577432 | -111.080288 | 32.333739 |
| 42 | Ina | Veg_4 | 1 | end | 12S 0492438 3577451 | -111.080352 | 32.333911 |
| 43 | Ina | Veg_4 | 2 | start | 12S 0492431 3577525 | -111.080427 | 32.334578 |
| 44 | Ina | Veg_4 | 2 | end | 12S 0492431 3577546 | -111.080427 | 32.334768 |
| 45 | Ina | Veg_4 | 3 | start | 12S 0492408 3577613 | -111.080672 | 32.335372 |

*cont.*

| FID | SiteName | Site # | Subsite | Info | UTM (NAD 83) | Latitude | Longitude |
|---|---|---|---|---|---|---|---|
| 46 | Ina | Veg_4 | 3 | end | 12S 0492398 3577633 | -111.080778 | 32.335552 |
| 47 | Ina | Veg_4 | 2 | NE | 12S 0492472 3577544 | -111.079991 | 32.334750 |
| 48 | Ina | Veg_4 | 2 | NW | 12S 0492376 3577541 | -111.081011 | 32.334722 |
| 49 | Ina | Veg_4 | 2 | SE | 12S 0492473 3577537 | -111.079980 | 32.334687 |
| 50 | Ina | Veg_4 | 2 | SW | 12S 0492377 3577539 | -111.081000 | 32.334704 |
| 51 | Cortaro | Veg_5 | 1 | start | 12S 0490393 3579896 | -111.102106 | 32.355952 |
| 52 | Cortaro | Veg_5 | 1 | end | 12S 0490376 3579905 | -111.102287 | 32.356033 |
| 53 | Cortaro | Veg_5 | 2 | start | 12S 0490324 3579988 | -111.102840 | 32.356782 |
| 54 | Cortaro | Veg_5 | 2 | end | 12S 0490316 3580007 | -111.102925 | 32.356953 |
| 55 | Cortaro | Veg_5 | 3 | start | 12S 0490249 3580091 | -111.103638 | 32.357710 |
| 56 | Cortaro | Veg_5 | 3 | end | 12S 0490231 3580099 | -111.103830 | 32.357782 |
| 57 | Cortaro | Veg_5 | 2 | NE | 12S 0490364 3580005 | -111.102415 | 32.356935 |
| 58 | Cortaro | Veg_5 | 2 | NW | 12S 0490265 3580006 | -111.103467 | 32.356943 |
| 59 | Cortaro | Veg_5 | 2 | SE | 12S 0490365 3580000 | -111.102404 | 32.356890 |
| 60 | Cortaro | Veg_5 | 2 | SW | 12S 0490266 3580002 | -111.103457 | 32.356907 |
| 61 | Avra Valley | Veg_6 | 1 | start | 12S 0487071 3584629 | -111.137478 | 32.398616 |
| 62 | Avra Valley | Veg_6 | 1 | end | 12S 0487057 3584644 | -111.137627 | 32.398751 |
| 63 | Avra Valley | Veg_6 | 2 | start | 12S 0487000 3584712 | -111.138234 | 32.399364 |
| 64 | Avra Valley | Veg_6 | 2 | end | 12S 0486983 3584722 | -111.138415 | 32.399454 |
| 65 | Avra Valley | Veg_6 | 3 | start | 12S 0486919 3584769 | -111.139096 | 32.399877 |
| 66 | Avra Valley | Veg_6 | 3 | end | 12S 0486899 3584771 | -111.139308 | 32.399895 |
| 67 | Avra Valley | Veg_6 | 2 | NE | 12S 0487004 3584722 | -111.138191 | 32.399454 |
| 68 | Avra Valley | Veg_6 | 2 | NW | 12S 0486906 3584722 | -111.139233 | 32.399453 |
| 69 | Avra Valley | Veg_6 | 2 | SE | 12S 0487005 3584721 | -111.138181 | 32.399445 |
| 70 | Avra Valley | Veg_6 | 2 | SW | 12S 0486906 3584718 | -111.139233 | 32.399417 |
| 71 | Sanders | Veg_7 | 1 | start | 12S 0481040 3587174 | -111.201658 | 32.421489 |
| 72 | Sanders | Veg_7 | 1 | end | 12S 0481017 3587178 | -111.201902 | 32.421525 |
| 73 | Sanders | Veg_7 | 2 | start | 12S 0480915 3587214 | -111.202988 | 32.421848 |
| 74 | Sanders | Veg_7 | 2 | end | 12S 0480898 3587223 | -111.203169 | 32.421928 |
| 75 | Sanders | Veg_7 | 3 | start | 12S 0480818 3587235 | -111.204020 | 32.422035 |
| 76 | Sanders | Veg_7 | 3 | end | 12S 0480800 3587236 | -111.204211 | 32.422044 |
| 77 | Sanders | Veg_7 | 2 | NE | 12S 0480950 3587217 | -111.202616 | 32.421875 |
| 78 | Sanders | Veg_7 | 2 | NW | 12S 0480850 3587213 | -111.203679 | 32.421837 |
| 79 | Sanders | Veg_7 | 2 | SE | 12S 0480951 3587212 | -111.202605 | 32.421830 |
| 80 | Sanders | Veg_7 | 2 | SW | 12S 0480852 3587209 | -111.203658 | 32.421801 |
| 81 | Marana | Veg_8 | 1 | start | 12S 0474100 3590746 | -111.275568 | 32.453572 |
| 82 | Marana | Veg_8 | 1 | end | 12S 0474088 3590735 | -111.275696 | 32.453473 |
| 83 | Marana | Veg_8 | 2 | start | 12S 0474215 3590802 | -111.274346 | 32.454080 |
| 84 | Marana | Veg_8 | 2 | end | 12S 0474199 3590798 | -111.274516 | 32.454044 |
| 85 | Marana | Veg_8 | 3 | start | 12S 0474323 3590819 | -111.273198 | 32.454236 |
| 86 | Marana | Veg_8 | 3 | end | 12S 0474303 3590814 | -111.273410 | 32.454191 |
| 87 | Marana | Veg_8 | 2 | NE | 12S 0474249 3590797 | -111.273984 | 32.454036 |
| 88 | Marana | Veg_8 | 2 | NW | 12S 0474149 3590805 | -111.275049 | 32.454106 |
| 89 | Marana | Veg_8 | 2 | SE | 12S 0474249 3590793 | -111.273984 | 32.454000 |
| 90 | Marana | Veg_8 | 2 | SW | 12S 0474149 3590800 | -111.275049 | 32.454061 |

**APPENDIX B – Plant List Provided by Pima County**

| *Genus species* | ABBR | Family | Nitro # | Pre-2012 FG | Pre-2012 WIS | New FG | New WIS |
|---|---|---|---|---|---|---|---|
| *Acalypha neomexicana* | CHMI | Euphorbiaceae | 4 | N/A | 5 | UPL | 5 |
| *Acalypha neomexicana* | ACNE | Euphorbiaceae | | N/A | 5 | UPL | 5 |
| *Acalypha ostryifolia* | ACOS | Euphorbiaceae | | N/A | 5 | UPL | 5 |
| *Amaranthus fimbriatus* | AMFI | Amaranthaceae | 7 | N/A | 4 | UPL | 5 |
| *Amaranthus palmeri* | AMPA | Amaranthaceae | 7 | FACU | 4 | FACU | 4 |
| *Ambrosia ambrosioides* | AMAM | Asteraceae | 6 | N/A | 4 | UPL | 5 |
| *Ambrosia artemisiifolia* | AMAR | Asteraceae | 6 | FACU | 4 | FACU | 4 |
| *Ambrosia deltoidea* | AMDE | Asteraceae | 6 | N/A | 4 | UPL | 5 |
| *Ambrosia psilostachya* | AMPS | Asteraceae | 4 | FAC | 3 | FACU | 4 |
| *Ambrosia trifida* | AMTR | Asteraceae | 5 | FACW- | 2 | FAC | 3 |
| *Androsace occidentalis* | ANOC2 | Primulaceae | 2 | FACU | 4 | FACU | 4 |
| *Anoda cristata* | ANCR2 | Malvaceae | | FAC | 3 | FAC | 3 |
| *Apodanthera undulata* | APUN | Cucurbitaceae | | NI | 5 | UPL | 5 |
| *Argemone pleiacantha* | ARPL3 | Papaveraceae | | NI | 5 | UPL | 5 |
| *Aristida adscensionis* | ARAD | Poaceae | | N/A | 5 | UPL | 5 |
| *Arundo donax* | ARDO | Poaceae | 7 | FACW | 2 | FACW | 2 |
| *Astragalus thurberi* | ASTH | Fabaceae | 2 | N/A | 5 | UPL | 5 |
| *Baccharis salicifolia* | BASA | Asteraceae | 6 | FACW | 2 | FAC | 2 |
| *Baccharis salicifolia* | BASAd | Asteraceae | 6 | FACW | 2 | FAC | 2 |
| *Baccharis sarothroides* | BASA2 | Asteraceae | 6 | FAC- | 3 | FACU | 4 |
| *Bidens leptocephala* | BILE | Asteraceae | 8 | FAC | 3 | FAC | 3 |
| *Boerhavia coccinea* | BOCO | Nyctaginaceae | 2 | N/A | 5 | UPL | 5 |
| *Boerhavia coulteri* | BOCO2 | Nyctaginaceae | 2 | N/A | 5 | UPL | 5 |
| *Bouteloua aristidoides* | BOAR | Poaceae | 1 | N/A | 5 | UPL | 5 |
| *Bouteloua rothrockii* | BORO | Poaceae | 1 | N/A | 5 | UPL | 5 |
| *Bowlesia incana* | BOIN | Apiaceae | 2 | UPL | 5 | FACU | 4 |
| *Bromus catharticus* | BRCA | Poaceae | 4 | N/A | 5 | UPL | 5 |
| *Calibrachoa parviflora* | CAPA | Solanaceae | 1 | FACW | 2 | FACW | 2 |
| *Celtis laevigata var. reticulata* | CELAR | Ulmaceae | | FACU | 4 | FAC | 3 |
| *Cenchrus spinifex* | CESP | Poaceae | | NI | 4 | UPL | 5 |
| *Chamaecrista nictitans* | CHNI | Fabaceae | | NO | 4 | UPL | 5 |
| *Chamaesyce capitellata* | CHCA | Euphorbiaceae | 2 | N/A | 5 | UPL | 5 |
| *Chamaesyce florida* | CHFL | Euphorbiaceae | 2 | N/A | 5 | UPL | 5 |
| *Chamaesyce hyssopifolia* | CHHY | Euphorbiaceae | 2 | NI | 3 | FACU | 4 |
| *Chamaesyce setiloba* | CHSE | Euphorbiaceae | 2 | N/A | 5 | UPL | 5 |
| *Chenopodium ambrosioides* | CHAM | Chenopodiaceae | 7 | FAC | 3 | UPL | 5 |
| *Chenopodium berlandieri* | CHBE | Chenopodiaceae | 7 | N/A | 4 | UPL | 5 |
| *Chenopodium fremontii* | CHFR | Chenopodiaceae | 7 | UPL | 5 | UPL | 5 |
| *Chloris virgata* | CHVI | Poaceae | 2 | N/A | 5 | FACU | 4 |
| *Cirsium vulgare* | CIVU | Asteraceae | 8 | FACU | 4 | FACU | 4 |
| *Clematis drummondii* | CLDR | Ranunculaceae | 5 | N/A | 4 | UPL | 5 |
| *Clematis hirsutissima* | CLHI | Ranunculaceae | 5 | | 4 | UPL | 5 |

*cont…*

| ***Genus species*** | **ABBR** | **Family** | **Nitro #** | **Pre-2012 FG** | **Pre-2012 WIS** | **New FG** | **New WIS** |
|---|---|---|---|---|---|---|---|
| *Conium maculatum* | COMA | Apiaceae | 8 | OBL | 1 | FACW | 2 |
| *Conyza canadensis* | COCA | Asteraceae | 5 | FACU | 4 | UPL | 5 |
| *Crotalaria pumila* | CRPU | Fabaceae | | N/A | 5 | UPL | 5 |
| *Croton pottsii* | CRPO | Euphorbiaceae | | N/A | 5 | UPL | 5 |
| *Cryptantha angustifolia* | CRAN | Boraginaceae | 3 | N/A | 5 | UPL | 5 |
| *Cryptantha micrantha* | CRMI | Boraginaceae | 3 | N/A | 5 | UPL | 5 |
| *Cyclospermum leptophyllum* | CYLE | Apiaceae | 5 | UPL | 5 | FACU | 4 |
| *Cynodon dactylon* | CYDA | Poaceae | 5 | FACU | 4 | FACU | 4 |
| *Cyperus esculentus* | CYES | Cyperaceae | 5 | FACW | 2 | FACW | 2 |
| *Cyperus involucratus* | CYIN | Cyperaceae | 5 | NO | 2 | FACW | 2 |
| *Cyperus odoratus* | CYOD | Cyperaceae | 5 | FACW+ | 2 | FACW | 2 |
| *Cyperus strigosus* | CYST | Cyperaceae | 5 | FACW | 2 | FACW | 2 |
| *Dactyloctenium aegyptium* | DAAE | Poaceae | | N/A | 5 | UPL | 5 |
| *Datura wrightii* | DAWR | Solanaceae | 8 | N/A | 5 | UPL | 5 |
| *Daucus carota* | DACA | Apiaceae | 4 | N/A | 3 | UPL | 5 |
| *Descurainia pinnata* | DEPI | Brassicaceae | 6 | N/A | 5 | UPL | 5 |
| *Dicliptera resupinata* | DIRE | Acanthaceae | | N/A | 5 | UPL | 5 |
| *Digitaria sanguinalis* | DISA | Poaceae | 5 | FACU | 4 | FACU | 4 |
| *Distichlis spicata* | DISP | Poaceae | 2 | FACW | 2 | FAC | 3 |
| *Dysphania ambrosioides* | DYAM | Chenopodiaceae | | FAC | 3 | FAC | 3 |
| *Echinochloa colona* | ECCO | Poaceae | 8 | FACW | 2 | FAC | 2 |
| *Echinochloa crus-galli* | ECCR | Poaceae | 8 | FACW- | 2 | FACW | 2 |
| *Eclipta prostrata* | ECPR | Asteraceae | | FAC | 3 | FAC | 3 |
| *Equisetum laevigatum* | EQLA | Equisetaceae | 4 | FACW | 2 | FACW | 2 |
| *Eragrostis cilianensis* | ERCI | Poaceae | 3 | FACU+ | 4 | FACU | 4 |
| *Eragrostis lehmanniana* | ERLE | Poaceae | 3 | N/A | 5 | UPL | 5 |
| *Eragrostis pectinacea* | ERPE | Poaceae | 3 | FAC | 3 | FAC | 3 |
| *Erigeron divergens* | ERDI | Asteraceae | 4 | N/A | 5 | UPL | 5 |
| *Eriochloa acuminata* | ERAC | Poaceae | 3 | FACW | 2 | FACW | 2 |
| *Eriochloa aristata* | ERAR | Poaceae | 3 | FACW | 2 | FACW | 2 |
| *Eriogonum polycladon* | ERPO | Polygonaceae | | N/A | 5 | UPL | 5 |
| *Erodium cicutarium* | ERCI2 | Geraniaceae | 3 | N/A | 5 | UPL | 5 |
| *Eschscholzia californica* | ESCAM | Papaveraceae | 2 | N/A | 5 | UPL | 5 |
| *Euphorbia heterophylla* | EUHE | Euphorbiaceae | 4 | UPL | 5 | UPL | 5 |
| *Gaura mollis* | GAMO | Onagraceae | | NI | 4 | UPL | 5 |
| *Helianthus annuus* | HEAN | Asteraceae | 8 | FAC- | 3 | FACU | 4 |
| *Heliotropium curassavicum* | HECU | Boraginaceae | 6 | FACW | 2 | FACU | 4 |
| *Heterotheca subaxillaris* | HESU | Asteraceae | | UPL | 5 | UPL | 5 |
| *Hydrocotyle verticillata* | HYVE | Apiaceae | 2 | OBL | 1 | OBL | 1 |
| *Hymenoclea monogyra* | HYMO | Asteraceae | 3 | N/A | 5 | UPL | 5 |
| *Ipomoea barbatisepala* | IPBA | Convovulaceae | | N/A | 4 | UPL | 5 |
| *Ipomoea cristulata* | IPCR | Convovulaceae | 2 | N/A | 4 | UPL | 5 |
| *Ipomoea hederacea* | IPHE | Convovulaceae | 2 | FACU* | 4 | FACU | 4 |
| *Ipomoea purpurea* | IPPU | Convovulaceae | 2 | UPL | 5 | UPL | 5 |
| *Ipomoea ternifolia* | IPTE | Convovulaceae | 2 | N/A | 4 | UPL | 5 |

*cont…*

| ***Genus species*** | **ABBR** | **Family** | **Nitro #** | **Pre-2012 FG** | **Pre-2012 WIS** | **New FG** | **New WIS** |
|---|---|---|---|---|---|---|---|
| *Isocoma tenuisecta* | ISTE | Asteraceae | | N/A | 5 | UPL | 5 |
| *Kallstroemia parviflora* | KAPA | Zygophyllaceae | | N/A | 5 | UPL | 5 |
| *Lepidium thurberi* | LETH | Brassicaceae | 5 | N/A | 4 | FACU | 4 |
| *Ludwigia palustris* | LUPA | Onagraceae | 4 | OBL | 1 | OBL | 1 |
| *Lupinus concinnus* | LUCO | Fabaceae | | N/A | 5 | UPL | 5 |
| *Machaeranthera canescens* | MACA | Asteraceae | | UPL | 5 | UPL | 5 |
| *Malacothrix glabrata* | MAGL | Asteraceae | | N/A | 5 | UPL | 5 |
| *Malva parviflora* | MAPA | Malvaceae | | N/A | 5 | UPL | 5 |
| *Melilotus alba* | MEAL | Fabaceae | 4 | FACU+ | 4 | FACU | 4 |
| *Melilotus indicus* | MEIN | Fabaceae | 7 | FACU+ | 4 | FACU | 4 |
| *Melilotus officinalis* | MEOF | Fabaceae | 3 | FACU+ | 4 | UPL | 4 |
| *Mentzelia multiflora* | MEMU | Loasaceae | 4 | N/A | 5 | UPL | 5 |
| *Mimulus guttatus* | MIGU | Scrophulariaceae | 6 | OBL | 1 | OBL | 1 |
| *Mirabilis longiflora* | MILO | Nyctaginaceae | 3 | N/A | 4 | UPL | 5 |
| *Myosurus cupulatus* | MYCO | Ranunculaceae | | | | FAC | 3 |
| *Nama hispidum* | NAHI | Hydrophyllaceae | | N/A | 5 | UPL | 5 |
| *Nasturtium officinale* | NAOF | Brassicaceae | 7 | OBL | 1 | OBL | 1 |
| *Nicotiana glauca* | NIGL | Solanaceae | 6 | FAC | 3 | FAC | 3 |
| *Nicotiana obtusifolia* | NIOB | Solanaceae | 6 | FACU | 4 | FACU | 4 |
| *Panicum antidotale* | PAAN | Poaceae | 6 | N/A | 5 | UPL | 5 |
| *Parkinsonia aculeata* | PAAC | Fabaceae | | | | FAC | 4 |
| *Parkinsonia florida* | PASP | Fabaceae | | N/A | | FAC | 5 |
| *Paspalum dilatatum* | PADI | Poaceae | | FAC | 3 | FAC | 3 |
| *Pectis papposa* | PEPA | Asteraceae | | N/A | 5 | UPL | 5 |
| *Pectis prostrata* | PEPR | Asteraceae | | N/A | 5 | UPL | 5 |
| *Phacelia arizonica* | PHAR | Solanaceae | | N/A | 5 | UPL | 5 |
| *Physalis acutifolia* | PHAC | Solanaceae | 7 | N/A | 5 | UPL | 5 |
| *Polygonum lapathifolium* | POLA | Polygonaceae | 8 | OBL | 1 | UPL | 2 |
| *Polypogon monspeliensis* | POMO | Poaceae | 6 | FACW+ | 2 | FACW | 2 |
| *Populus fremontii* | POFR | Salicaceae | 6 | FACW | 2 | UPL | 2 |
| *Portulaca halimoides* | POHA | Portulaceae | 7 | NO | 4 | FAC | 3 |
| *Portulaca oleracea* | POOL | Portulaceae | 7 | FAC | 3 | FAC | 3 |
| *Portulaca suffrutescens* | POSU | Portulaceae | 7 | N/A | 4 | UPL | 5 |
| *Proboscidea parviflora* | PRPA | Pedaliaceae | | N/A | 5 | UPL | 5 |
| *Prosopis velutina* | PRVE | Fabaceae | | N/A | | FACU | 4 |
| *Pseudognaphalium canescens* | PSCA | Asteraceae | 2 | UPL | 5 | FACU | 4 |
| *Ranunculus sceleratus* | RASC | Ranunculaceae | 9 | OBL | 1 | OBL | 1 |
| *Rumex dentatus* | RUDE | Polygonaceae | 6 | NO | 1 | FACW | 2 |
| *Rumex obtusifolius* | RUOB | Polygonaceae | 9 | FACW | 2 | FAC | 3 |
| *Salix gooddingii* | SAGO | Salicaceae | 5 | OBL | 1 | FACW | 2 |
| *Salsola tragus* | SATR | Chenopodiaceae | 6 | FACU | 4 | FACU | 4 |
| *Schismus arabicus* | SCAR | Poaceae | 1 | N/A | 5 | UPL | 5 |
| *Schismus barbatus* | SCBA | Poaceae | 1 | N/A | 5 | UPL | 5 |

*cont…*

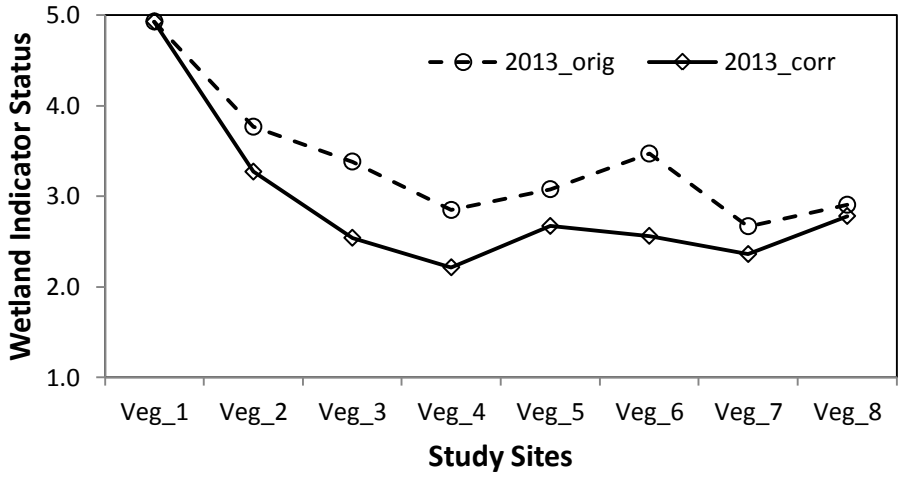
| ***Genus species*** | **ABBR** | **Family** | **Nitro #** | **Pre-2012 FG** | **Pre-2012 WIS** | **New FG** | **New WIS** |
|---|---|---|---|---|---|---|---|
| *Schoenoplectus americanus* | SCAM | Cyperaceae | 7 | OBL | 1 | OBL | 1 |
| *Setaria grisebachii* | SEGR | Poaceae | 7 | N/A | 4 | UPL | 5 |
| *Sida spinosa* | SISP | Malvaceae | | UPL | 5 | UPL | 5 |
| *Sisymbrium irio* | SIIR | Brassicaceae | 5 | N/A | 5 | UPL | 5 |
| *Solanum americanum* | SOAM | Solanaceae | 7 | FAC | 3 | FACU | 4 |
| *Solanum elaeagnifolium* | SOEL | Solanaceae | 7 | N/A | 5 | UPL | 5 |
| *Solanum lycopersicum* | SOLY | Solanaceae | 7 | N/A | 5 | UPL | 5 |
| *Sonchus asper* | SOAS | Asteraceae | 7 | FACW | 2 | FAC | 3 |
| *Sorghum halepense* | SOHA | Poaceae | 4 | FACU+ | 4 | FACU | 4 |
| *Sphaeralcea laxa* | SPLA | Malvaceae | 3 | NI | 5 | UPL | 5 |
| *Sporobolus contractus* | SPCO | Poaceae | 4 | N/A | 4 | UPL | 5 |
| *Sporobolus cryptandrus* | SPCR | Poaceae | 4 | FACU- | 4 | FACU | 4 |
| *Stemodia durantifolia* | STDU | Scrophulariaceae | | OBL | 1 | OBL | 1 |
| *Symphyotrichum ascendens* | SYAS | Asteraceae | | N/A | 5 | FAC | 3 |
| *Tamarix aphylla* | TAAP | Tamaricaceae | | FAC | 3 | FAC | 3 |
| *Tamarix ramosissima* | TARA | Tamaricaceae | | NI | | UPL | 4 |
| *Tidestromia lanuginosa* | TILA | Amaranthaceae | | N/A | 5 | UPL | 5 |
| *Trianthema portulacastrum* | TRPO | Aizoaceae | | NI | 2 | FAC | 3 |
| *Typha domingensis* | TYDO | Typhaceae | 8 | OBL | 1 | OBL | 1 |
| *Urochloa arizonica* | URAR | Poaceae | 1 | N/A | 5 | UPL | 5 |
| *Verbesina encelioides* | VEEN | Asteraceae | | FAC | 3 | FACU | 4 |
| *Veronica anagallis-aquatica* | VEAN | Scrophulariaceae | 5 | OBL | 1 | OBL | 2 |
| *Vulpia octoflora* | VUOC | Poaceae | 1 | NI | 5 | UPL | 5 |
| *Xanthium strumarium* | XAST | Asteraceae | 6 | NI | 4 | FAC | 3 |

## APPENDIX C – Re-analyses and Corrected Values for 2013 Data

Wetland Indicator Score 2013 Re-analysis

The Wetland Indicator Score (WIS) analysis in 2014 used updated WIS values that were more appropriate for the Sonoran desert region. The original list of WIS values was produced by expert opinion for plants of the US. These values do not take into account regional differences. Biologists in some regions have presented updated values that are more appropriate for their respective regions because they account for plant functional attributes. For example, a species in a wetter region or climate may be considered an upland plant, but may be restricted to riparian areas in desert regions. This impacted our analysis because common species such as *Tamarix ramosissima* and *Polygonum lapathifolium* were nominally labeled as UPL (upland) and given a value of 5 in 2013. The updated WIS scores give them values of 4 and 2, respectively. Below presents the values for various analyses including the 2013 Living River Report (LRR). Naturally, the original WIS scores decreased because the values changed from high to low.

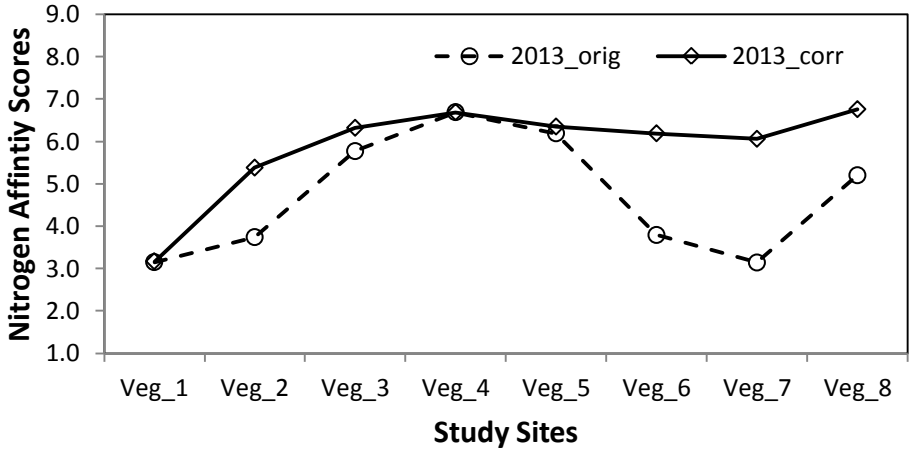
| Site Name | Code | 2013_LRR | 2013_orig | 2013_corr | 2014_new |
|---|---|---|---|---|---|
| **Columbus Dry** | Veg_1 | | 4.93 | 4.93 | 4.86 |
| **Columbus Wet** | Veg_2 | 3.8 | 3.77 | 3.27 | 3.65 |
| **Sunset** | Veg_3 | 3.4 | 3.38 | 2.54 | 1.88 |
| **Ina** | Veg_4 | 2.8 | 2.85 | 2.21 | 1.91 |
| **Cortaro** | Veg_5 | 3.1 | 3.08 | 2.67 | 2.28 |
| **Avra Valley** | Veg_6 | 3.5 | 3.47 | 2.56 | 3.08 |
| **Sanders** | Veg_7 | 2.7 | 2.67 | 2.36 | 1.99 |
| **Marana** | Veg_8 | 2.9 | 2.90 | 2.78 | 2.40 |



Nitrogen Affinity Score 2013 Re-analysis

The 2014 Nitrogen Affinity Score analysis also revealed an error in the 2013 analysis. The 2013 analysis mistakenly assigned zeros to those species without a nitrogen affinity score. Unlike the readily available WIS values, not all plant species have Nitrogen Affinity Scores. Plants in the master list (lookup table) that do not have a score have a blank in the cell. Any formulae (using Excel), like the one used to compute the Nitrogen Score, will automatically assign a value of 0 to the blanks. This happened to a few common plants such as *Tamarix ramosissima* and *Prosopis velutina*, thus the original 2013 results have values that are reduced from their actual, true nitrogen affinity. Naturally, the re-analysis of 2013 data resulted in the values increasing because values of 0 did not pull the averages down. Below presents the values for various analyses including the 2013 Living River Report (LRR).

| Site Name | Code | 2013_LRR | 2013_orig | 2013_corr | 2014_new |
|---|---|---|---|---|---|
| **Columbus Dry** | Veg_1 | | 3.15 | 3.17 | 3.38 |
| **Columbus Wet** | Veg_2 | 3.7 | 3.74 | 5.38 | 5.15 |
| **Sunset** | Veg_3 | 5.8 | 5.77 | 6.32 | 6.89 |
| **Ina** | Veg_4 | 6.7 | 6.69 | 6.69 | 7.40 |
| **Cortaro** | Veg_5 | 6.2 | 6.19 | 6.35 | 6.90 |
| **Avra Valley** | Veg_6 | 3.8 | 3.79 | 6.19 | 5.37 |
| **Sanders** | Veg_7 | 3.1 | 3.14 | 6.06 | 7.39 |
| **Marana** | Veg_8 | 5.2 | 5.2 | 6.76 | 6.79 |

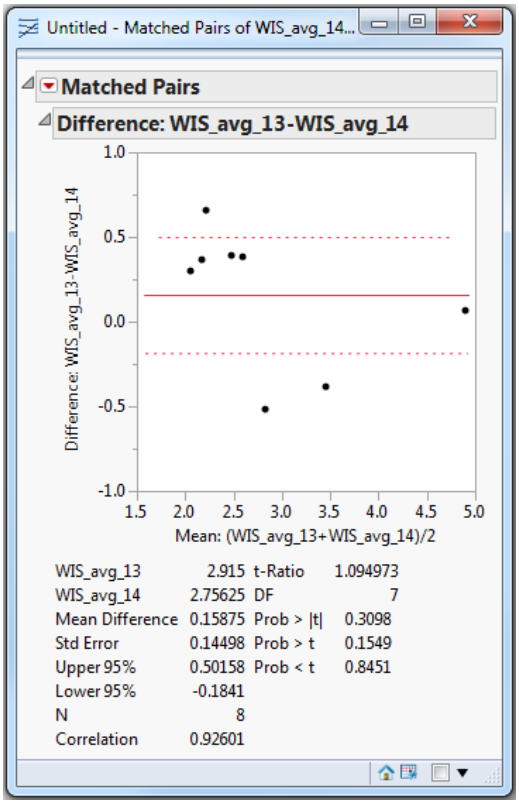


## APPENDIX D – Species Observed during Surveys

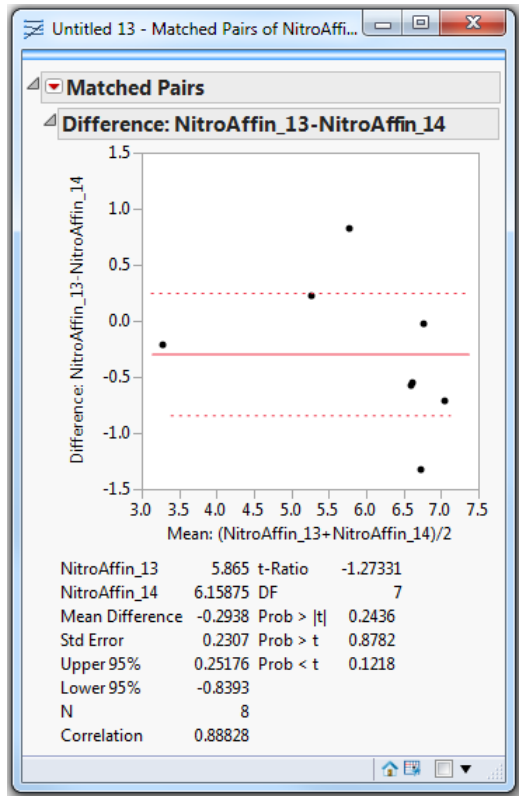
| Family | *Genus species* | Code | Common Names |
|---|---|---|---|
| Amaranthaceae | *Amaranthus palmeri* | AMPA | careless weed |
| Apiaceae | *Conium maculatum* | COMA | poison hemlock |
| Apiaceae | *Hydrocotyle ranunculoides* | HYRA | floating marsh pennywort |
| Asteraceae | *Ambrosia artemisiifolia* | AMAR | annual ragweed |
| Asteraceae | *Baccharis salicifolia* | BASA | mule fat, seep willow |
| Asteraceae | *Baccharis sarothroides* | BASA2 | desert broom |
| Asteraceae | *Centaurea melitensis* | CEME | Maltese star-thistle |
| Asteraceae | *Conyza canadensis* | COCA | Canadian horseweed |
| Asteraceae | *Eclipta prostrata* | ECPR | false daisy |
| Asteraceae | *Helianthus annuus* | HEAN | common sunflower |
| Asteraceae | *Helenium thurberi* | HETH | Thurber's sneezeweed |
| Asteraceae | *Hymenoclea monogyra* | HYMO | singlewhorl burrobrush |
| Asteraceae | *Lactuca serriola* | LASE | prickly lettuce |
| Asteraceae | *Pseudognaphalium canescens* | PSCA | Wright's cudweed |
| Asteraceae | *Sonchus asper* | SOAS | spiny sowthistle |
| Asteraceae | *Verbesina encelioides* | VEEN | cowpen daisy |
| Asteraceae | *Xanthium strumarium* | XAST | rough cocklebur |
| Brassicaceae | *Lepidium thurberi* | LETH | Thurber's pepperweed |
| Brassicaceae | *Nasturtium officinale* | NAOF | watercress |
| Brassicaceae | *Sisymbrium irio* | SIIR | London rocket |
| Chenopodiaceae | *Chenopodium ambrosioides* | CHAM | Mexican tea |
| Chenopodiaceae | *Chenopodium berlandieri* | CHBE | pitseed goosefoot |
| Chenopodiaceae | *Chenopodium fremontii* | CHFR | Fremont's goosefoot |
| Cyperaceae | *Cyperus esculentus* | CYES | yellow nutsedge |
| Cyperaceae | *Cyperus involucratus* | CYIN | umbrella sedge |
| Fabaceae | *Melilotus indicus* | MEIN | annual yellow sweetclover |
| Fabaceae | *Prosopis glandulosa* | PRGL | honey mesquite |
| Fabaceae | *Prosopis velutina* | PRVE | velvet mesquite |
| Fabaceae | | UNK2 | |
| Onagraceae | *Ludwigia palustris* | LUPA | marsh seedbox |
| Poaceae | *Arundo donax* | ARDO | giant reed |
| Poaceae | *Avena fatua* | AVFA | common wild oat |
| Poaceae | *Bromus catharticus* | BRCA | rescue grass |
| Poaceae | *Bromus rubens* | BRRU | red brome |
| Poaceae | *Cynodon dactylon* | CYDA | Bermuda grass |
| Poaceae | *Echinochloa crus-galli* | ECCR | barnyard grass |
| Poaceae | *Hordeum murinam* | HOMU | mouse barley |
| Poaceae | *Paspalum dilatatum* | PADI | dallisgrass |
| Poaceae | *Pennisetum ciliare* | PECI | buffelgrass |
| Poaceae | *Phleum pratense* | PHPR | Timothy grass |
| Poaceae | *Polypogon monspeliensis* | POMO | annual rabbitsfoot grass |
| Poaceae | *Setaria leucofila* | SELE | streambed bristlegrass |
| Poaceae | *Sorghum halepense* | SOHA | Johnsongrass |
| Poaceae | *Sporobolus cryptandrus* | SPCR | sand dropseed |
| Poaceae | | UNK1 | |

*cont…*

| Family | *Genus species* | Code | Common Names |
|---|---|---|---|
| Polygonaceae | *Polygonum lapathifolium* | POLA | curlytop knotweed |
| Polygonaceae | *Rumex obtusifolius* | RUOB | bitter dock |
| Ranunculaceae | *Ranunculus sceleratus* | RASC | cursed buttercup |
| Salicaceae | *Salix gooddingii* | SAGO | Goodding's willow |
| Scrophulariaceae | *Mimulus guttatus* | MIGU | seep monkeyflower |
| Scrophulariaceae | *Veronica anagallis-aquatica* | VEAN | water speedwell |
| Solanaceae | *Nicotiana obtusifolia* | NIOB | desert tabacco |
| Solanaceae | *Solanum americanum* | SOAM | American black nightshade |
| Tamaricaceae | *Tamarix aphylla* | TAAP | Athel tamarisk |
| Tamaricaceae | *Tamarix ramosissima* | TARA | saltcedar |
| Typhaceae | *Typha domingensis* | TYDO | southern cattail |

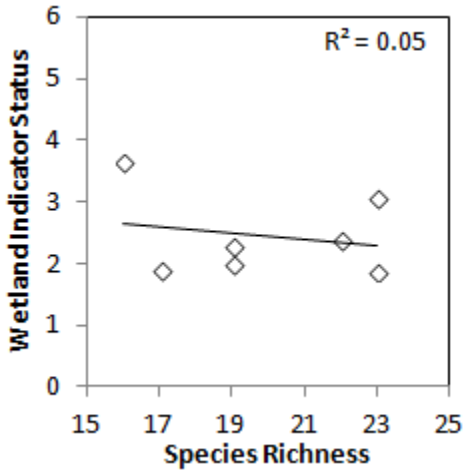


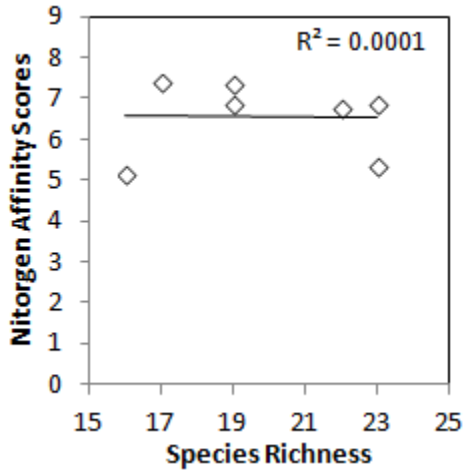

WIS Scores: Matched Pairs Analysis, JMP11



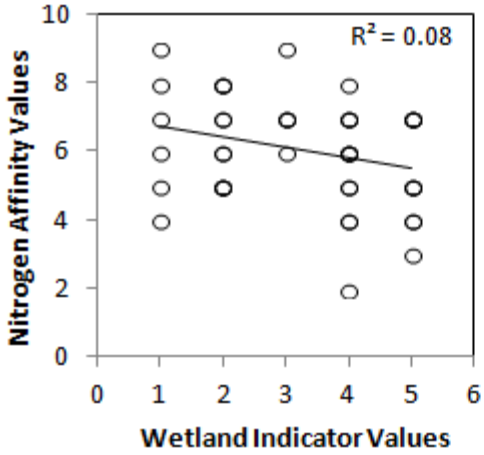

Nitro Scores: Matched Pairs Analysis, JMP11

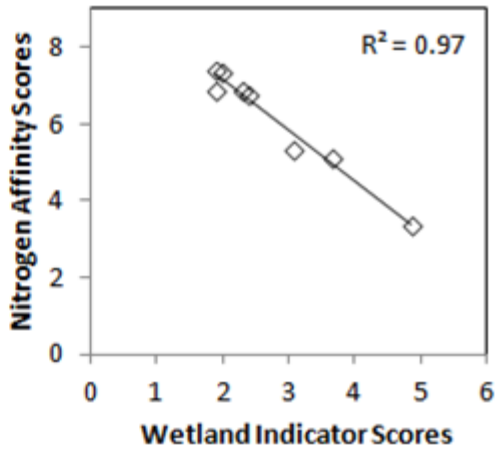
Using the standard deviation and standard error of the difference between 2013 and 2014, a matched pairs analysis tests whether the values are significantly different between 2013 and 2014. Above we see that neither WIS#s (p=0.31) nor Nitro#s (p=0.24) are significantly different between years. We can see data scattered outside the upper and lower confidence intervals, depicting large differences from the mean. While the mean differences for both WIS#s and Nitro#s tend away from zero, there is too much variance within the data to state significant differences. This is due mainly to two of the sites (Veg_2, Columbus Wet and Veg_6, Avra Valley) having an opposite pattern (i.e., higher WIS, lower Nitro) between 2013 and 2014 when compared to the other six sites.




Above, we find little relationship between Species Richness and WIS or Nitro Scores. In other words, although we might expect that wetter sites may have more species, we find that a lower WIS score does not correlate to increased numbers of species. As discussed in the report, one explanation could be that wet sites during this study often included large, homogenous mats of aquatic vegetation or stands of cattail that dominated the survey area.




Above, we find that Nitro Values are not correlated with WIS Values. For example, we see that the group of obligate plants (W=1) has a range of Nitro Values from 4-9 while facultative upland plants (W=4) range from 2-8. Interestingly, the project WIS Scores were highly correlated with Nitro Scores. This is explained by some of the more common plants documented during the survey having low WIS and high Nitro (e.g., TYPHA & POLA = 1,8) and high WIS and low Nitro (e.g., HYMO = 5,3) during the surveys. In general, this means that plants along the wetter reaches of the Santa Cruz tend to have higher nitrogen affinity, while plants in less wet areas tend to have lower nitrogen affinity.

**APPENDIX F - Ancillary Work Photographs**

Photo 1 - Dry streambed at Ina Site (Veg_4) just upstream of Ina Outfall.

Photo 2 - Quadrat placed at streamside edge of dry streambed at Ina Site (Veg_4).

Photo 3 - Dry streambed at Trico-Marana Site (Veg_8).

Photo 4 - Pulse flow arriving at Trico-Marana Site (Veg_8) at 9:30a.

Photo 5 - Sanders Site (Veg_7), perennial water with mats of watercress.

Photo 6 - Sanders Site (Veg_7), perennial water with mats of marsh seedbox and watercress.

Photo 7 - Goodding's willow seeding along the Santa Cruz River.

Photo 8 - Goodding's willow and saltcedar saplings within quadrat.

Photo 9 - Thick stand of giant reed at Avra Valley Site (Veg_6).

Photo 10 - Incised channel with 1-m quadrat for reference at Avra Valley site (Veg_6).

Photo 11 – Native Sonora mud turtle observed at Sanders Site (Veg_7).

Photo 12 - Carp at Avra Valley Site (Veg_6) and tadpole at Marana-Trico Site (Veg_8).