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Monitoring of Vegetation along the San Joaquin River

2017 Report

Reach 2B, San Joaquin River

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

February 2018

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Monitoring of Vegetation along the San Joaquin River

2017 Report

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Executive Summary

Vegetation transects were sampled in 2017 to inventory riparian vegetation along select reaches of the San Joaquin River. Previous surveys were generally scheduled in the spring or early summer to coincide with potential recruitment and flowering stages, but extended flood flows of 2017 pushed the survey date to August when sites were accessible. This timing was not ideal to observe early recruitment or overall vegetative state, but did provide an opportunity to capture early post-flooding colonization and other potential changes to vegetative conditions shortly after flood conditions had receded. This study was a continuation of previous vegetation monitoring conducted from August 2011 through May 2015. The original study provided historical data for vegetation in river reaches that were revisited in 2017, including Reaches 2B and 4B2 and the Middle East Side and Mariposa Bypasses; additional transects were also established in the Middle East Side Bypass in 2017. The focus of the 2017 study was to provide current vegetative conditions for these reaches and present temporal trends from historical data.

Vegetation data were collected at 15 permanent transects. Plant cover, species composition, woody stem density, and overstory height were collected along each transect. Transect lengths were determined by the extent of the floodplain and varied from 30 to 100 meters (m).

Herbaceous species dominated the majority of the floodplain shortly after the 2017 flood releases. Reaches 2B and 4B2 were the only sites in which woody species were detected in all years from 2011 to 2017. No woody species were detected in Mariposa Bypass. Woody species cover and density were historically low in the East Side Bypass although transects that included Goodding's willow were added in 2017. Many willows were observed but generally occurred within the river channel and therefore outside of transects, but are observable in photos taken from the transect endpoints.

Trends in vegetation that were generally consistent between all surveyed reaches were:

- Highest total understory cover estimates in 2011 and 2017
- Highest species richness values in 2017
- Introduced understory species dominant in 2015
- Plant species composition most similar in 2011 and 2017

Introduction

Background

In 2006, the Department of the Interior entered into the San Joaquin River Settlement (Settlement) in *NRDC et al., v. Kirk Rodgers et al*. The Settlement was subsequently approved by the Court in October 2006 and the San Joaquin River Restoration Settlement Act, Public Law 111-11, authorized and directed the Secretary of the Interior to implement the Settlement. The San Joaquin River Restoration Program (SJRRP) is a comprehensive long-term effort to restore flows and a self-sustaining Chinook salmon population to the San Joaquin River from Friant Dam to the confluence of Merced River, while reducing or avoiding adverse water supply impacts.

Historically, riparian vegetation in California's Central Valley was typical of a dynamic system largely driven by annual flooding and a long summer drought (Stillwater Sciences 2003a). The natural hydrograph for unmanaged rivers in California is an inverted U-shape, with peak flows in the winter and spring (November through June; Griggs 2009). The slowing or reduction in magnitude of flows during late spring and early summer as rainfall tapers out is biologically important to most plants that grow in the riparian zone.

Natural vegetation recruitment and survival are maintained through annual flooding via floodplain inundation, scour, and sediment/propagule deposition. Water availability during the summer dry period is the primary factor for vegetation establishment and distribution. This cycle of flooding and drought is important to pioneer woody plant species, primarily willows (*Salix* spp.) and cottonwoods (*Populus* spp.), which have adapted timing of seed-release, dispersal, and seedling establishment to coincide with the historical annual hydrographic cycle to provide bare seed beds, water, and nutrients (Griggs 2009). These species produce rapid root growth to reach permanent water tables and a secure bank footing to resist subsequent floods (Stillwater Sciences 2003a).

The frequency and duration of flood events over time shapes the physical habitat which in turn influences species composition and community structure (Griggs 2009). Riparian forests require periodic seedling recruitment and establishment to maintain populations over time (Stillwater Sciences 2003a). A mature riparian zone typically consists of a mosaic of vegetation types of various ages and species. Commonly, mixed riparian forests occupy mid-elevation floodplain sites, while valley oak woodland and savannah occupy the oldest and driest floodplain sites, such as high terraces and cut banks.

Along geomorphically active streams, cottonwoods and willows are typically among the first species to colonize bare stream banks and bars. These species, which are characterized by high seed output and rapid growth rates, typically establish in bands parallel to the channel, with the youngest stands occurring closest to the active channel (Stillwater Sciences 2003a). Each band of vegetation represents a separate recruitment event. Over time, pioneer vegetation traps sediment and adds litter and nutrient inputs to floodplain soils (Stillwater Sciences 2003a). As the floodplain develops and the riparian stand ages, changes in microclimate (depth to groundwater, shade, temperature, and relative humidity) occur which often facilitates establishment of other riparian species such as Oregon ash (*Fraxinus latifolia*), box elder (*Acer negundo*), and valley oak (*Quercus lobata*). These "later successional" species typically produce larger seeds and are more shade-tolerant than the early pioneer species, allowing them to persist in the seedbank and germinate under the forest canopy when soil temperature and moisture conditions are adequate. Recruitment of these species is less dependent on flow and sediment conditions compared to willows and cottonwoods.

The San Joaquin River historically supported a much wider riparian corridor than is present under current conditions. Riparian vegetation between Friant Dam and the Merced River confluence has been significantly modified by agricultural development, hydrologic changes from operations of Friant Dam, and the construction and operation of the flood control levees and bypass systems. River regulation has resulted in decreased peak flows, increased summer base flows, and reduction of physical processes such as scour and sediment deposition, compared with historical conditions. Riparian pioneer tree populations that evolved with pre-regulation cycles of flooding and drought have decreased recruitment and altered topographic distributions relative to bank elevation and proximity to the channel. The reduction in riparian tree recruitment is compounded by human development on floodplains that has simultaneously removed over 90 percent of the historical riparian forests for fuel wood, agricultural and urban expansion, and floodplain mining (Stillwater Sciences 2003a).

Reduced riparian vegetation along streambanks has decreased shaded riverine cover, organic inputs, water temperature control, and habitat structure (including inputs of large woody debris to aquatic habitats in the river), thus degrading aquatic habitat and fishery health. Important functions of the floodplain have also been reduced or eliminated, including flood flow retention and the ability for the channel to meander, which in turn increases both the risk of flooding and the amount of sediment deposited by flood flows.

Reclamation's Technical Service Center (TSC) in Denver, CO sampled vegetation transects in August 2017 to inventory riparian vegetation following extended flood releases that occurred in the San Joaquin River in winter and spring of 2017 (e.g. flows between 8,000 and 9,000 cubic feet per second (cfs) from January through June – peaking at 22,700 cfs in early June – below Friant Dam; and flows between 7,000 and 8,000 cfs from January through June – peaking at 12,500 cfs in early March – in the East Side Bypass near El Nido, California). This study was based on previous vegetation monitoring conducted from August 2011 through May 2015 (hereafter "original study") in order to evaluate the establishment and development of riparian vegetation on the San Joaquin River and bypasses. The original study included sampling sites in river reaches 1A through 5 and the East Side Bypass (ESB) and Mariposa Bypass (MB). Historical data were used to examine trends in vegetation development over time.

Sampling locations were revised in 2017 to include only transects in river reaches 2B, 4B2, the Middle East Side and Mariposa Bypasses from the original study, with additional transects established in the Middle East Side Bypass. The focus on the ESB area (i.e. both bypasses and Reach 4B2) was to provide information on current vegetative conditions for Reach 4B, Eastside Bypass, and Mariposa Bypass Channel and Structural Improvements Project (Reach 4B Project). Improvements identified in the project include modifications to bypass structures to allow anadromous fish passage on an interim basis and modifications to the bypass channel that are necessary to support anadromous fish migration. Transects in Reach 2B were retained from the original study to provide long-term data for channel realignment and revegetation associated with the Reach 2B Project currently underway.

Project Area

A location map of the entire SJRRP Restoration Area is shown in Figure 1 with the vegetation monitoring transect locations and the nearest stream gauges shown in Figure 2. Of the areas sampled in 2017, Reach 2B is the furthest upstream.

The Middle East Side Bypass is identified as Reach 2 of the Bypass in the map in Figure 1, and includes part of the Merced National Wildlife Refuge (NWR). Reach 4B2 is located within the San Luis NWR.

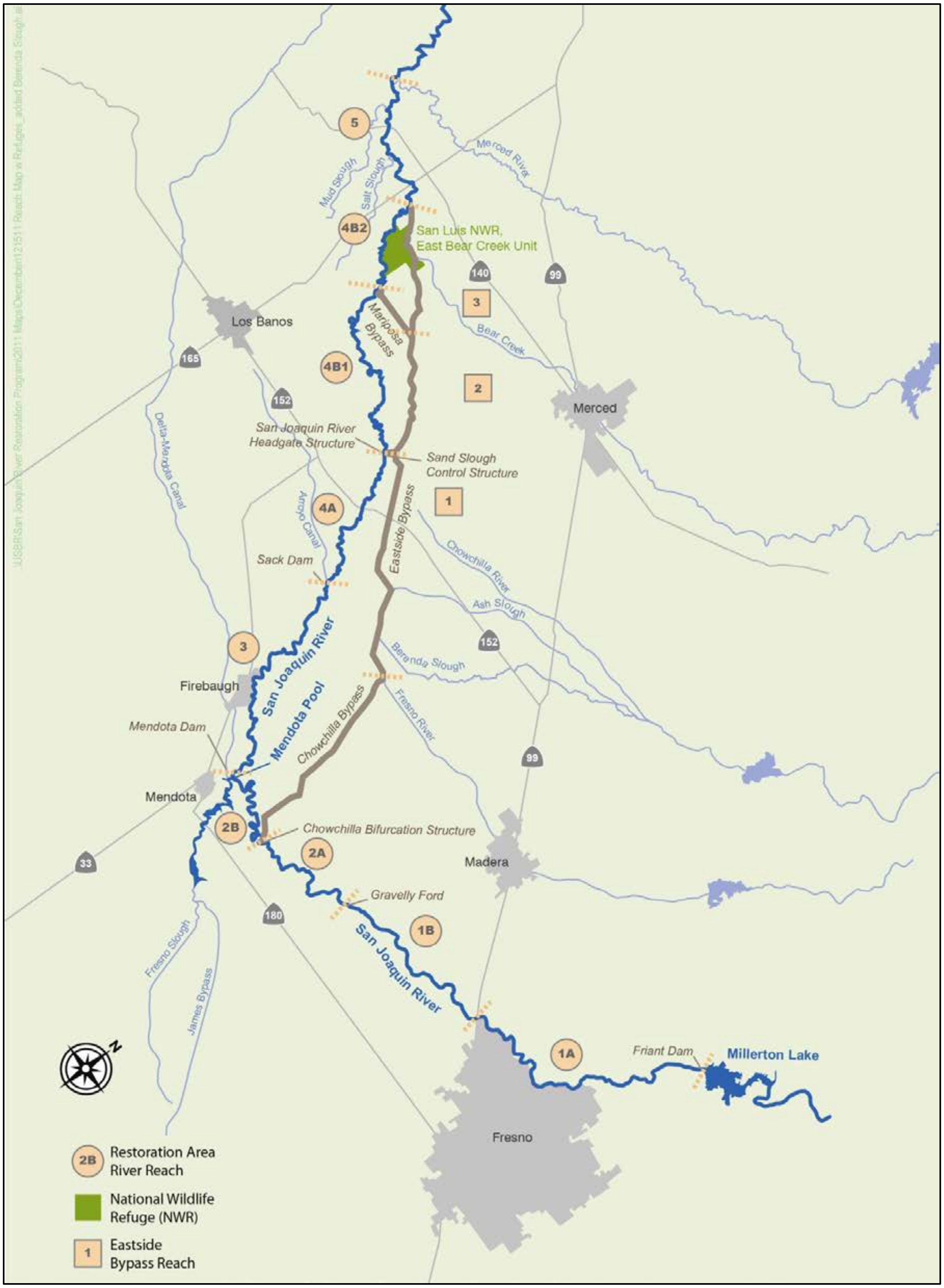


Figure 1. SJRRP Project Area.

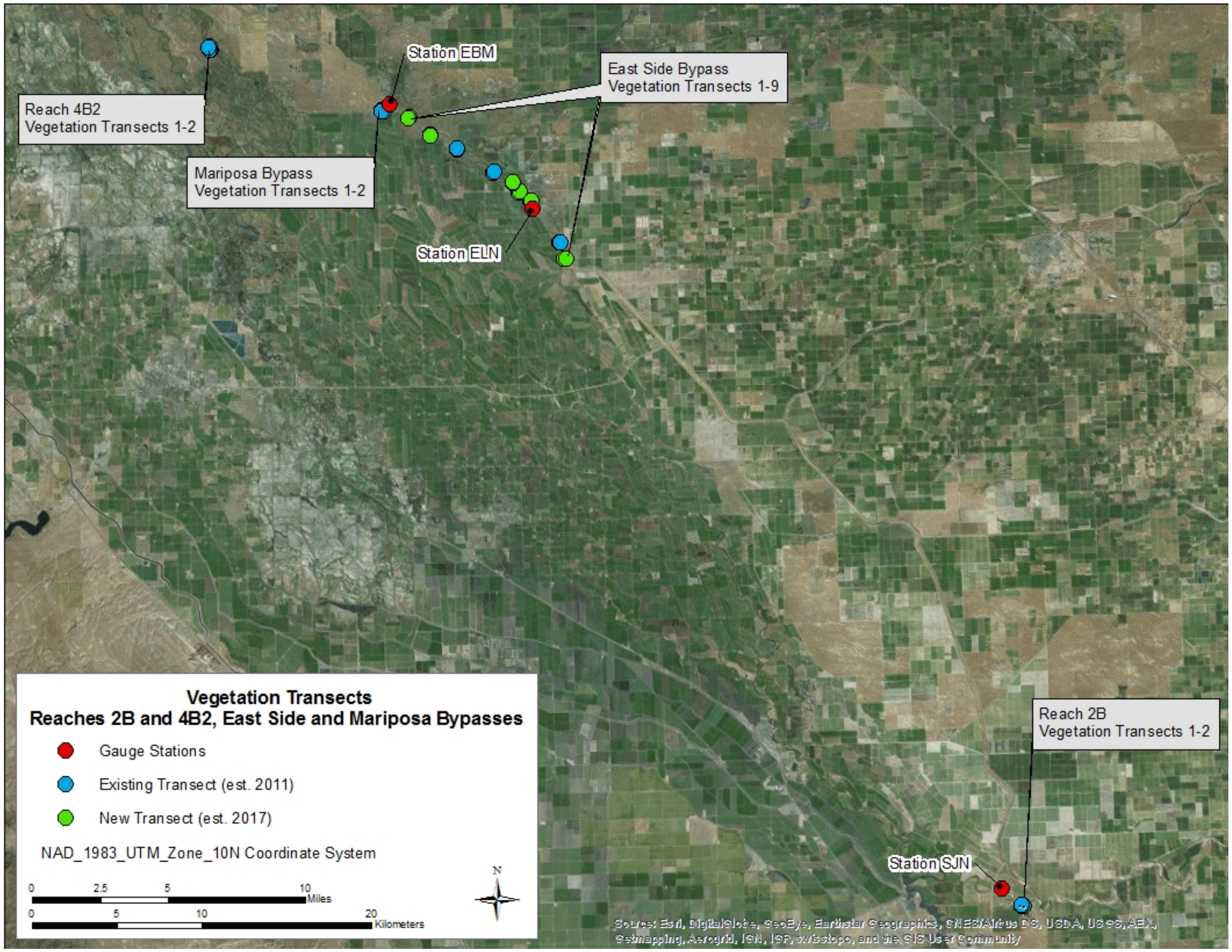


Figure 2. Vegetation monitoring transect and stream gauge station locations.

Methods

Vegetation Transects

In 2017, vegetation data were collected at 15 permanent vegetation transects (mapped by river reach in Appendix A). In reaches 2B, 4B2 and MB, 2 previously established transects from each reach were retained for monitoring; in the ESB 3 existing transects were also retained with an additional 6 transects established/sampled in 2017. Transects were placed adjacent to the river channel within the historically active floodplain. These sites are subject to seasonal changes in water and nutrient input, scour, and sediment deposition. Transects are not comprehensibly representative of vegetation populations across the entirety of reaches, but were located based on best potential to capture vegetation changes over time resulting from overbank flows.

Plant cover, species composition, woody stem densities, and overstory heights were collected at regular intervals along each transect. The length of each transect was determined by the extent of the floodplain and varied from 30 to 100 meters (m). Observation intervals were calculated based on transect length to include approximately 100 data points per transect. Waypoints for each end of transects are listed in Appendix B; forms used to collect data are included in Appendix C.

Survey Timing

Monitoring was conducted during spring or summer months depending on flow levels, with the objective of collecting data at similar river phases and comparable stages of vegetation development each year.

Understory Vegetation

For understory measurements, cover and species composition were measured either every 0.5 or 1 m depending on the length of the transect. The point-intercept method was used, which entailed recording species presence by the first vertical "hit" at each sample point along the transect. This method was used for all herbaceous species and woody plants under 1 m tall. Bare soil, litter, rock, or water were recorded when no vegetation was intercepted. General location and extent of invasive weed species were also documented when encountered.

Overstory Vegetation

The line-intercept method was used for measuring woody overstory cover. Overstory cover was measured along the transect by noting the point along the tape where the canopy began and the point at which it ended for each woody species over 1 m tall. Because species overlapped in some cases, the sum of the cover for all species did not necessarily reflect the actual percentage of overstory cover along the tape. The percentage of the tape covered by overstory was also calculated. The height of the tallest vegetation within each continuous stretch of the same species was measured.

Woody Stem Density

Woody stem densities were determined within one meter perpendicular to the transect on the upstream side. All woody stems within this one meter wide belt transect were counted and recorded by size into 4 classes for each species encountered (see Figure C-3 in Appendix C for descriptions of size classes).

Statistical Analysis

Total cover and density data were compared between sampling periods for all reaches to evaluate any statistically significant changes in vegetation over time. A general linear model (GLM) was applied to test for relationships between cover or density and year, while Tukey's honest significant difference (HSD) procedure was used as a multiple comparison test to evaluate statistically significant differences between years (alpha=0.05) utilizing StatGraphics statistical software. The Tukey’s HSD analysis is a post-test to the GLM and provides a more focused analysis of individual years.

Primer (Plymouth Routines in Multivariate Ecological Research; see www.primer-e.com) statistical software was used to create a Bray-Curtis similarity matrix and Multi-dimensional Scaling (MDS) ordination to examine plant species composition between reaches and years.

Photo Stations

Two digital photographs were taken at each end of transects – one facing toward the transect and one facing outward. These photos provide visual documentation of vegetation height, density, species composition, and general site development for comparison over time.

Groundwater Monitoring

Reclamation installed two piezometers to measure groundwater levels in association with vegetation transects in Reach 2B in 2013. Groundwater recession rates have been closely tied to riparian vegetation establishment and survival in the San Joaquin Valley and elsewhere (Stillwater Sciences 2003b). Causal relationships between flows, groundwater and vegetation are not addressed in this report; these data are presented as a primer for a more comprehensive analysis in the future.

Results

Vegetation Transects

This report includes data from 2011 to 2017, but is limited only to reaches monitored in 2017 (2B and 4B2, MB and ESB) to accurately present temporal trends. Newly established transects in the ESB in 2017 include only one year of data. Sampling was discontinued in the MB in 2014, and therefore historical data for this reach includes only 2011 to 2013. Historical data that exists from other reaches in previous years are not included. The sampling schedule for those sites monitored in 2017 is summarized in Table 1.

Table 1. Historical sampling schedule for all sites monitored in 2017.

Sample Sites	Years Sampled						
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Reach 2B (n=2))	X	X	X	X	X	X	X
East Side Bypass Original Study Transects (n=3)	X	X	X	X	X	X	X
East Side Bypass Additional Transects (n=6)							X
Mariposa Bypass (n=2)	X	X	X				X
Reach 4B2 (n=2)	X	X	X	X	X	X	X

See Appendix D for a plant list of all herbaceous and woody species detected in transects within the current study over 6 years of monitoring.

Survey Timing

In order to compare vegetation data over time, sampling schedules were kept as consistent as possible from year to year. The goal was to sample in spring when flows had receded and vegetation was identifiable. Sampling was conducted in June 2012 and 2013, but was shifted to May in 2014 and 2015 when drought conditions were declared by the State of California. Water Years 2011 and 2017 were the wettest of the years within the study period. Friant Dam was in flood operations through mid-July both of these years, and monitoring was not feasible until August due to high river levels and inundated sites.

Hydrology

River levels directly influenced survey timing. Figure 3 shows hydrographs at 4 points along the San Joaquin River and demonstrates the differences in river discharge between years. River gauge stations SJF, SJN, and ELN provide data for all years of the vegetation monitoring period (2011 to 2017); station EBM began collecting data in May 2013. Data presented in Figure 3A at Station SJF were collected downstream of Friant Dam and represents flows that were most influenced by dam operations and releases. Extreme differences in river flows in 2011 and 2017 (peak flows averaging between

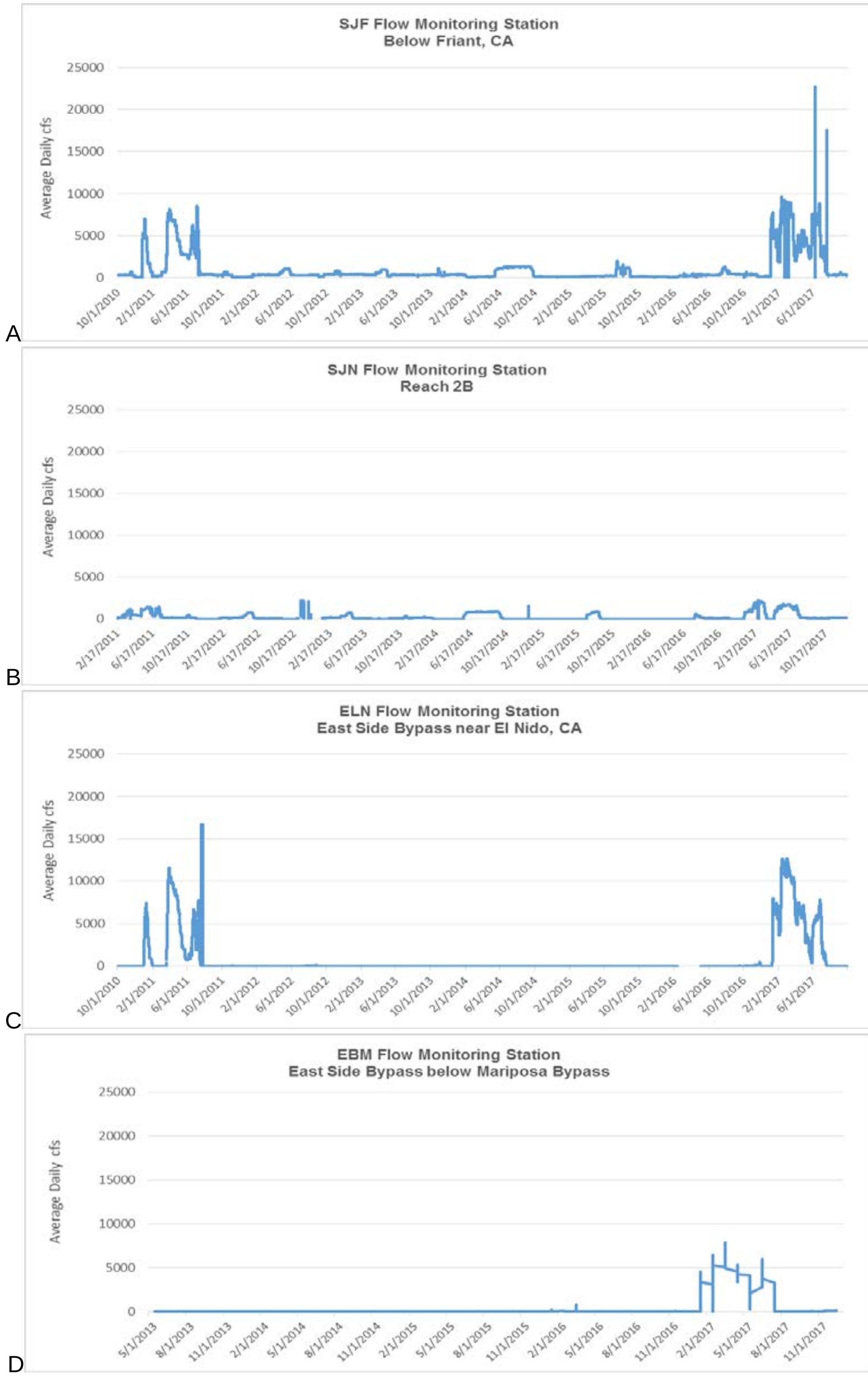


Figure 3. San Joaquin River discharge (cfs) measured at A) Station SJF, B) Station SJN, C) Station ELN, D) Station EBM from 2011-2017 (A-C) and 2013-2017 (D). Source: CA Dept of Water Resources.

8,000 and 9,000 cfs) compared to other years (mostly between 1,000 and 2,000 cfs) were evident. Figure 3B graphs data from Station SJN (Figure 2), located just upstream of vegetation transects in Reach 2B. Peak flows were not as high in 2011 and 2017 (around 2,200 cfs) as those measured at the other stations and variability between years was not as extreme. Hydrographs in Figures 3C and D show data from stream gauges EBM and ELN in the East Side Bypass (Figure 2), located just upstream and downstream of vegetation transects. Again, differences in flows were obvious between 2011 and 2017 (peak flows between 11,000 and 13,000 cfs at ELN and around 8,000 cfs at EBM in 2017 where no 2011 data is available) as compared to the other years when the channel was typically dry.

Understory Vegetation

Seventy-seven annual and perennial species were identified while measuring understory vegetation along transects over 6 years of monitoring. The average total percent cover by individual species, life-form (*i.e.* native or introduced shrubs < 1m, grasses, and forbs) and cover type (*i.e.* plant, litter, bare ground, water) found in the understory layer are listed in Appendix E. A summary of total percent cover in the understory layer is presented in Figure 4 by reach.

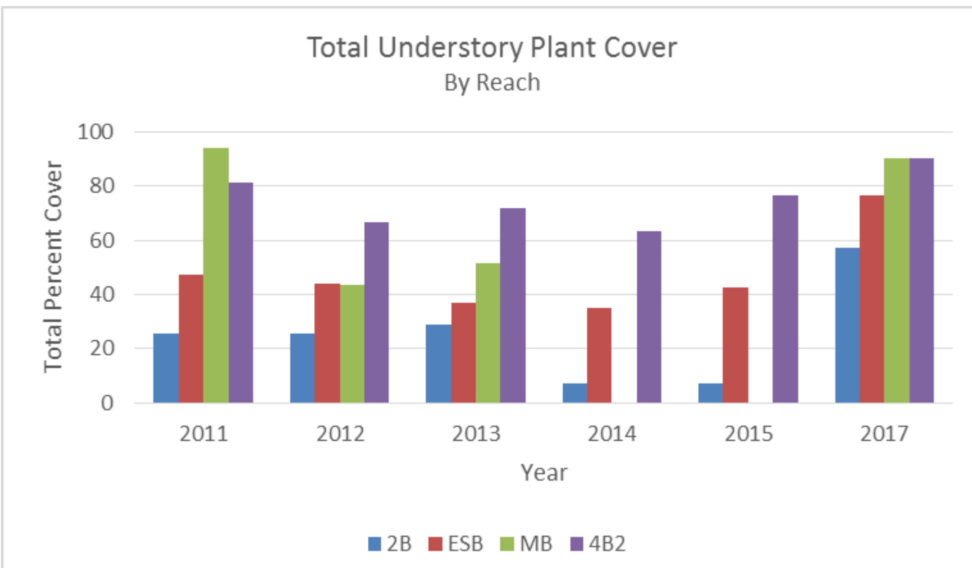
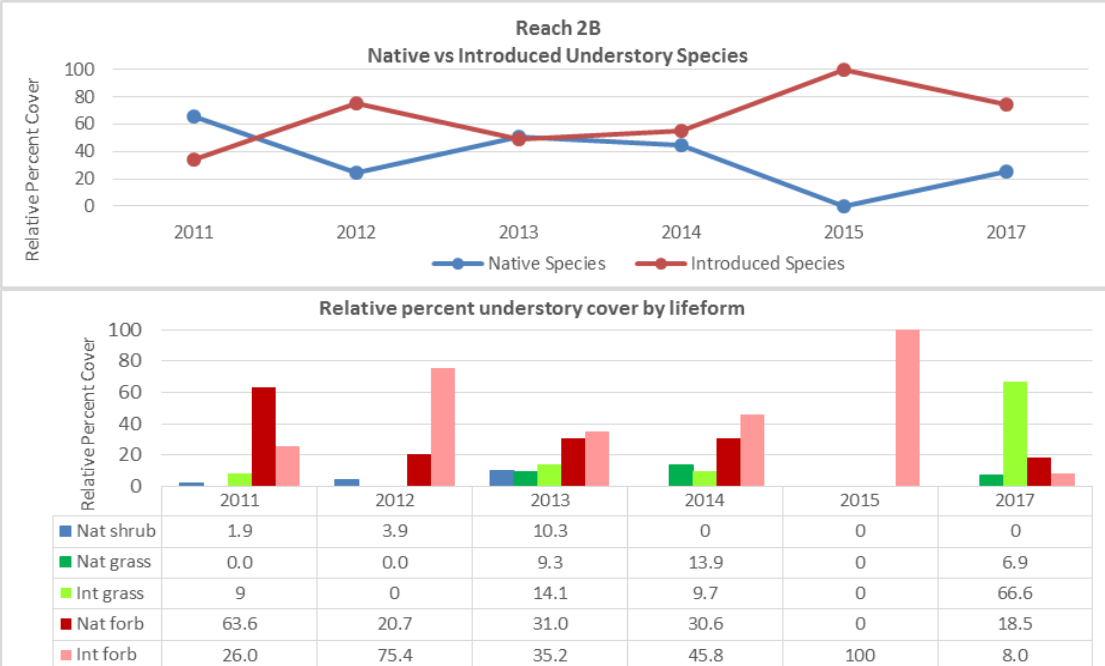


Figure 4. Average total percent cover in the understory layer of vegetation transects along the San Joaquin River by reach from 2011 to 2015 and 2017.

Trends in understory cover were variable among reaches over the monitoring period from 2011 to 2017, although plant cover within reaches generally decreased from 2011 to 2015 and increased in 2017.

Total understory plant cover in Reach 2B was lowest among reaches, varying from 7.1 percent in 2015 to 57 percent in 2017 (Figure 4) with introduced species dominant relative to native species in all years except 2011 (Figure 5). Dominant lifeforms shifted



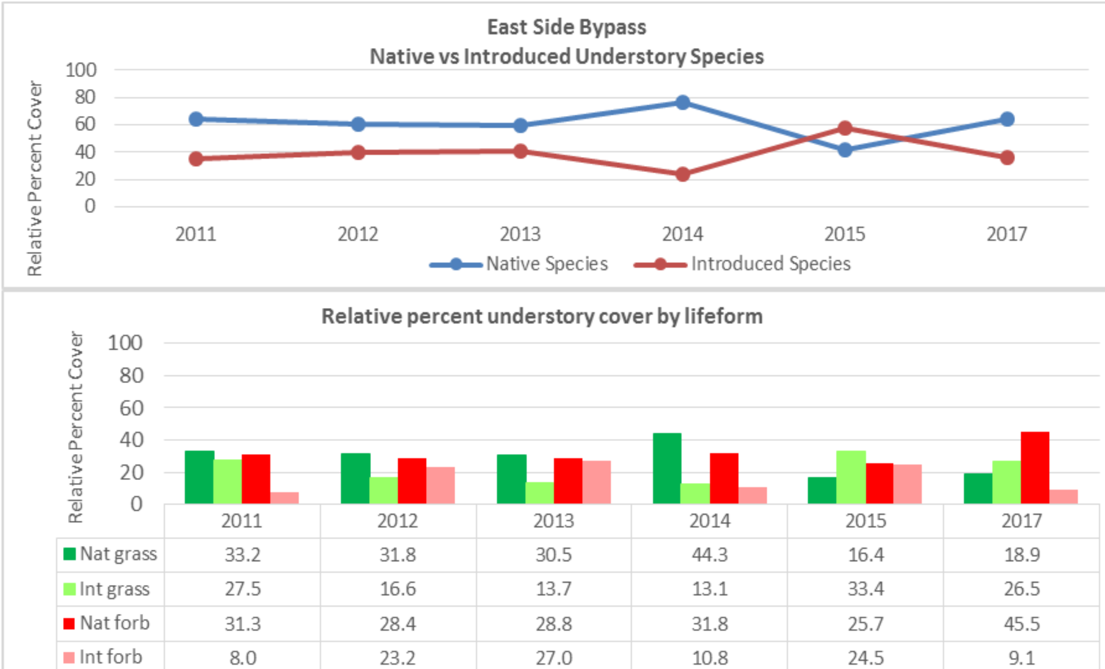
	2011	2012	2013	2014	2015	2017
Nat shrub	1.9	3.9	10.3	0	0	0
Nat grass	0.0	0.0	9.3	13.9	0	6.9
Int grass	9	0	14.1	9.7	0	66.6
Nat forb	63.6	20.7	31.0	30.6	0	18.5
Int forb	26.0	75.4	35.2	45.8	100	8.0

Figure 5. Relative percent understory cover by native vs. introduced species and by lifeforms in vegetation transects in Reach 2B along the San Joaquin River from 2011 to 2015 and 2017.

from native forbs in 2011 to introduced forbs from 2012 to 2015; introduced grasses were dominant in 2017 within Reach 2B.

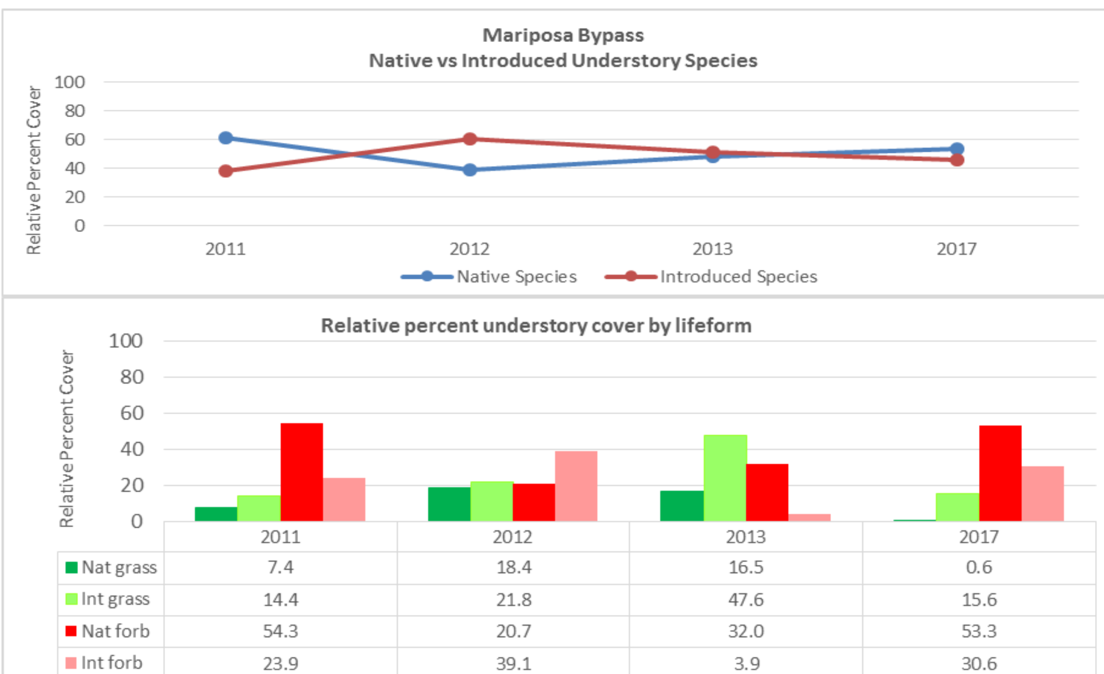
Total understory plant cover ranged from 35.2 percent in 2014 to 76.6 percent in 2017 in the ESB (Figure 4); the sample size in 2017 was 9 transects versus 4 prior to that although percent cover was comparable (72.0 percent) when averaging only existing transects in 2017. The proportion of total plant cover composed of native species was greater than that of introduced species in all years except 2015 when introduced species were dominant in the understory (Figure 6). Dominant lifeforms varied and were generally equally represented over the years in the ESB.

Total understory plant cover was relatively high in MB, ranging from 43.5 percent in 2012 to 94 percent in 2011 (Figure 4). The proportion of native to introduced species was approximately even over the years (Figure 7). Native forbs were the dominant lifeform in 2011 and 2017 and variable in the other 2 years of monitoring in this reach.
Total understory plant cover was consistently high in Reach 4B2 relative to other reaches, fluctuating from 63.5 percent in 2014 to 90.0 percent in 2017 (Figure 4). Native and introduced species were more or less equally represented except in 2015 when introduced species were dominant (Figure 8). Grasses (both introduced and native) were the most common lifeform until 2017 when native forbs became dominant.



	2011	2012	2013	2014	2015	2017
Nat grass	33.2	31.8	30.5	44.3	16.4	18.9
Int grass	27.5	16.6	13.7	13.1	33.4	26.5
Nat forb	31.3	28.4	28.8	31.8	25.7	45.5
Int forb	8.0	23.2	27.0	10.8	24.5	9.1

Figure 6. Relative percent understory cover by native vs. introduced species and by lifeforms in vegetation transects in the Middle East Side Bypass along the San Joaquin River from 2011 to 2015 (n=4) and 2017 (n=9).



	2011	2012	2013	2017
Nat grass	7.4	18.4	16.5	0.6
Int grass	14.4	21.8	47.6	15.6
Nat forb	54.3	20.7	32.0	53.3
Int forb	23.9	39.1	3.9	30.6

Figure 7. Relative percent understory cover by native vs. introduced species and by lifeforms in vegetation transects in the Mariposa Bypass along the San Joaquin River from 2011 to 2013 and 2017.

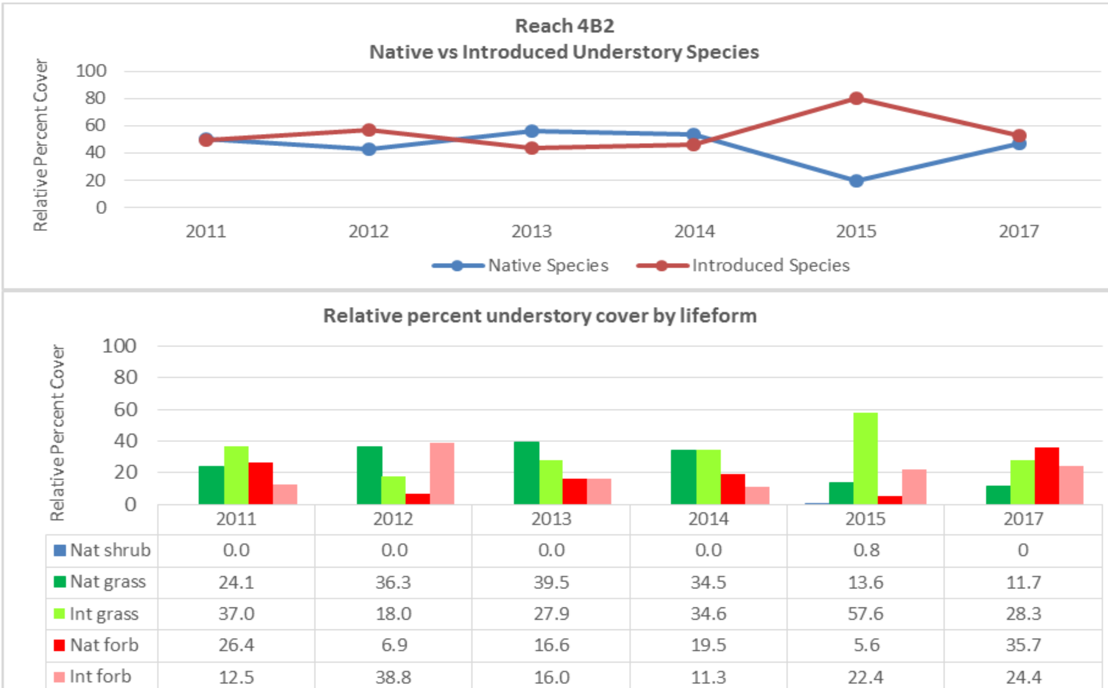
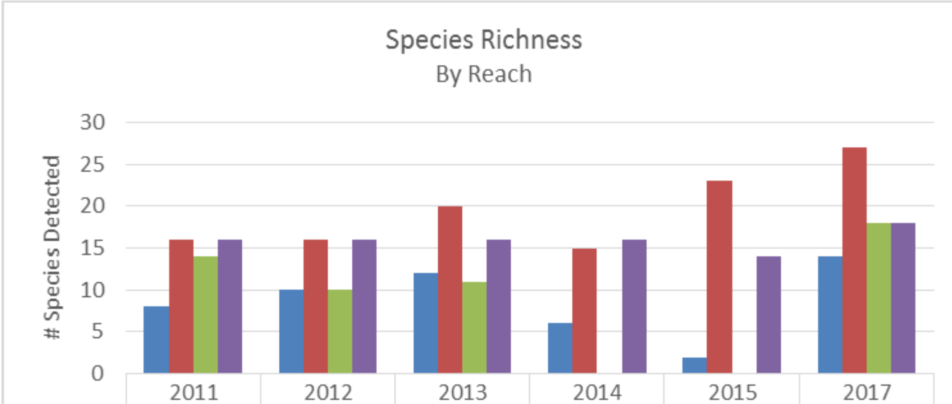


Figure 8. Relative percent understory cover by native vs. introduced species and by lifeforms in vegetation transects in Reach 4B2 along the San Joaquin River from 2011 to 2015 and 2017.

Species richness is the total number of species detected and is an indicator of plant diversity. Herbaceous plant species richness was often highest in the ESB, with 20 or more species recorded in 3 of 6 years (Figure 9). The higher sample size in this reach may have influenced species richness numbers since the opportunity to detect more plant species is greater with more transects, particularly in 2017 (species richness in 2017 was 20 when only counting transects from original study vs 27 when including additional transects). Values were relatively consistent within Reach 4B2, where 14 to 18 species were detected over the years. Reach 2B had the lowest plant diversity among the reaches samples, ranging from 2 to 14 species detected.



	2011	2012	2013	2014	2015	2017
2B	8	10	12	6	2	14
ESB	16	16	20	15	23	27
MB	14	10	11			18
4B2	16	16	16	16	14	18

Figure 9. Plant species richness (number of herbaceous species detected) by reach along the San Joaquin River from 2011 to 2015 and 2017.

Overstory Vegetation

Only native overstory species (woody species > 1m in height) were detected in reaches sampled in August 2017; no introduced overstory species were identified. The timing of the survey in the fall and within a short period after flood flows had receded was not suitable for observation of new woody species recruitment, but changes from historical conditions at existing transects were detected as well as acquisition of baseline data at newly established transects.

Table 2 lists total cover of the overstory layer in Reach 2B, ESB, and Reach 4B2, the only monitoring sites in which overstory species were detected. The average height of the tallest overstory shrubs/trees within each stretch by species is also shown. A total of 4 woody species were detected in the overstory of transects within Reach 2B from 2011 to 2017, however Fremont cottonwood was only documented from 2013 to 2015 (Figure 10). Goodding's willow was the only overstory species detected in ESB and in Reach 4B2. No overstory was recorded in MB in any year.

There was little change in total overstory canopy cover from 2011 to 2015 in any reach except 2B, where cover increased from 7.2 to 17.4 percent (peaking at 21.4 percent in 2014; Table 2 and Figure 10). During this period, overstory species were only detected in 2011 in the ESB (with only 0.2 percent cover) and decreased marginally from 9.3 percent in 2011 to 8.6 percent cover in 2015 in Reach 4B2 (Table 2).

Table 2. Total percent cover and average height of woody overstory species (>1 m) detected in vegetation transects within reaches along the San Joaquin River from 2011 to 2015 and 2017.

Species	Year	2011	2012	2013	2014	2015	2017
Reach 2B							
Fremont cottonwood	Tot % cov	0	0	0.2	0.2	0.2	0
	Avg. Ht. (m)				1.6	1.6	
Sandbar willow	Tot % cov	0	0	0.7	0.9	0.2	1.5
	Avg. Ht. (m)				1.7	1.0	1.2
Gooding's willow	Tot % cov	4.4	12.5	10.3	13.0	12.6	13.3
	Avg. Ht. (m)	5.9	6.0	3.0	2.7	3.8	6.8
Black elderberry	Tot % cov	2.8	6.9	7.3	7.3	4.6	3.9
	Avg. Ht. (m)	4.2	4.8	5.7	5.5	5.1	5.1
Total native & total canopy		7.2	19.4	18.5	21.4	17.6	5.4
Middle East Side Bypass							
Species	**Year**	**2011**	**2012**	**2013**	**2014**	**2015**	**2017**
Gooding's willow	Tot % cov	0.2	0	0	0	0	0.8
	Avg. Ht. (m)	1.0					1.6
Total native & total canopy		0.2	0.0	0.0	0.0	0.0	0.8
Reach 4B2							
Species	**Year**	**2011**	**2012**	**2013**	**2014**	**2015**	**2017**
Gooding's willow	Tot % cov	9.3	8.5	9.5	10.5	8.6	12.7
	Avg. Ht. (m)	8.6	10.5	10.2	9.9	8.6	11.6
Total native & total canopy		9.3	8.5	9.5	10.5	8.6	12.7

*Total canopy may not equal sum of all species due to overlap

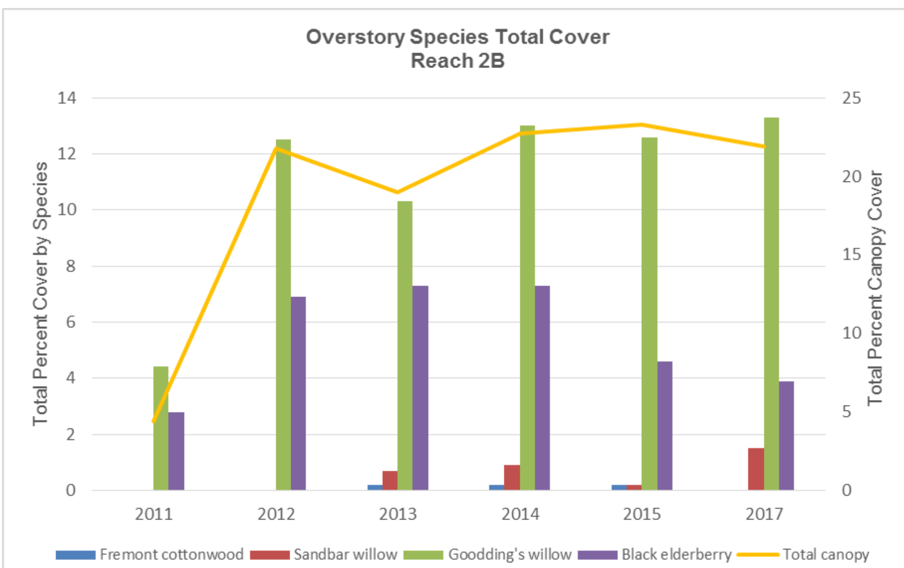


Figure 10. Total percent cover by overstory species detected in transects within Reach 2B from 2011 to 2015 and 2017.

By 2017, total percent overstory cover had dropped to 5.4 percent within Reach 2B transects, had slightly increased to 12.7 percent cover in Reach 4B2, and increased to 0.8 percent cover in the East Side Bypass. The increase in the East Side Bypass was due to the addition of transects in 2017 that included Goodding's willow.

Woody Stem Density

Density of woody plants by size class and species is listed in Table 3. No stems were detected in the one meter belt associated with transects in Reach 4B2 and MB. No woody stems were detected within transects in the ESB until 2017 with the addition of new transects, although a number of Goodding's willow stems were documented in an existing transect adjacent to a wetland depression in 2017.

Woody stems were counted in Reach 2B in all years. Densities in Reach 2B decreased somewhat substantially in 2013 from 3.62 to 1.32 stems/m^2 (mostly reductions in the number of Goodding's willow stems), although densities increased to 2.23 stems/m^2 in 2014 (mostly related to increases in size class 2 Goodding's willow).

Table 3. Density of woody plant species by size class and species in San Joaquin River reaches from 2011 to 2015 and 2017.

Average # stems/m^2													
		Reach											
	Size class*	2B						ESB					
Species		2011	2012	2013	2014	2015	2017	2011	2012	2013	2014	2015	2017
Fremont cottonwood	1	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0.07	0.02	0.13	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0
Sandbar willow	1	0.01	0.02	0.01	0	0.01	0	0	0	0	0	0	0
	2	0	0.11	0.06	0	0.12	0	0	0	0	0	0	0
	3	0	0.05	0.17	0.11	0.08	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0
Goodding's willow	1	1.56	0.80	0	0	0	0	0	0	0	0	0	0.02
	2	0	1.78	0.38	1.43	0.20	0.01	0	0	0	0	0	0.01
	3	0.06	0.68	0.46	0.38	0.48	0.03	0	0	0	0	0	0.01
	4	0	0	0	0	0	0	0	0	0	0	0	0
Black elderberry	1	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0
	3	0.32	0.10	0.21	0.18	0.16	0.16	0	0	0	0	0	0
	4	0	0	0	0	0.03	0.02	0	0	0	0	0	0
Total by size class	1	1.57	0.82	0.01	0.00	0.01	0.00	0	0	0	0	0	0.02
	2	0.00	1.96	0.47	1.56	0.32	0.01	0	0	0	0	0	0.01
	3	0.38	0.83	0.84	0.67	0.72	0.19	0	0	0	0	0	0.01
	4	0.00	0.00	0.00	0.00	0.03	0.02	0	0	0	0	0	0.00
TOTAL stems/m^2		**1.95**	**3.62**	**1.32**	**2.23**	**1.08**	**0.22**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.05**

*Size class:
1= Seedling; 2= <1 m in ht; 3= >1 m in ht and <10 cm DBH; 4= >10 cm DBH

Statistical Analysis

Vegetation Transects

Various parameters associated with total cover and stem density were statistically compared between years by reach; no data were collected in 2016 in any reach and no data exists from 2014 to 2016 for the MB reach. There were no significant changes identified over time for any of the parameters tested in Reaches 2B and 4B2 (see Table 4 for test statistics).

Significant differences were found in total understory cover within both of the bypasses and were for the most part associated with years 2011 and 2017 (Table 4).

In the ESB, total understory plant cover was found to be significantly higher in 2017 than in any other year and litter cover was significantly less in 2017 and 2011 compared to other years (Table 4).

In MB, total plant cover was also significantly higher while litter cover was significantly less in 2011 and 2017 than in other years. Also in this reach, percent cover of native understory species was significantly higher in 2011 and 2017 than in 2012 and 2013, demonstrating a difference in species composition as discussed above.

Species Composition

MDS ordination of species composition similarities between reaches and across years is shown in Figure 7. MDS ordination ranks species similarities and the associated configuration can be interpreted in terms of relative similarity of samples to each other (Clarke et al 2014). Because it is difficult to satisfy the similarity ranking perfectly there will be some distortion in the configuration. Stress is the measure of distortion between the similarity ranks and the corresponding distance ranks in the ordination. A stress factor of <0.5 gives an excellent representation of the data. MDS analysis of this data had a 2-dimensional stress of 0.12. MDS ranks show that species composition in ESB was more similar to MB than to Reach 2B (Figure 7). MDS ranks also show that there was more change in the species composition from 2011 to 2017 within ESB than within Reach 2B. A 2-way statistical analysis examining species composition identified a significant difference between years across all reaches ($P<0.001$) and between reaches across all years ($P<0.001$). Pairwise testing indicated that species composition in 2011 and 2017 were significantly different from all other years while composition from 2012 to 2015 was found to be statistically equal.

Table 4. Statistical results comparing total plant cover and density over time for various parameters in San Joaquin River Reaches 2B, 4B2, Mariposa and Middle East Side Bypasses. Alpha = 0.05.

Parameter	Reach 2B (n=2) General Linear Model F-ratio (df), P-value	Reach 2B (n=2) Tukey HSD Sig. diff. between yrs.	East Side Bypass (n=4, 2011 to 2015; n=9, 2017) General Linear Model F-ratio (df), P-value	East Side Bypass (n=4, 2011 to 2015; n=9, 2017) Tukey HSD Sig. diff. between yrs.
Total cover (%)				
Plant	F(5)=1.33, P=0.364	No difference	F(5)=13.63, P<0.001	17 > all other years
Litter	F(5)=2.14, P=0.190	No difference	F(5)=15.94, P<0.001	17 < 12 to 15; 11 < 13 & 14
Bare	F(5)=0.12 , P=0.983	No difference	F(5)=1.36, P=0.277	No difference
Native understory	F(5)=0.89, P=0.542	No difference	F(5)=2.30, P=0.079*	No difference
Introduced understory	F(5)=0.98, P=0.497*	No difference	F(5)=1.32, P=0.290*	No difference
Native/Total overstory	F(5)=1.55 , P=0.302	No difference	NA	
Density (stems/m^2)				
Total	F(5)=0.34, P=0.870	No difference	NA	

Parameter	Mariposa Bypass (n=2) General Linear Model F-ratio (df), P-value	Mariposa Bypass (n=2) Tukey HSD Sig. diff. between yrs.	Reach 4B2 (n=2) General Linear Model F-ratio (df), P-value	Reach 4B2 (n=2) Tukey HSD Sig. diff. between yrs.
Total cover				
Plant	F(5)=15.80, P=0.011	11 & 17 > 12 & 13	F(5)=1.53, P=0.309	No difference
Litter	F(5)=14.74, P=0.013	11< 12 & 13; 17 < 12	F(5)=3.00, P=0.107	No difference
Bare	F(5)=11.00, P=0.021	13 > all other years	F(5)=1.79, P=0.249	No difference
Native understory	F(5)=21.63, P=0.006	12 < 11 & 17; 13 < 11	F(5)=1.65 , P=0.279	No difference
Introduced understory	F(5)=1.08, P=0.453	No difference	F(5)=2.18, P=0.186	No difference
Native/Total overstory	NA		F(5)=0.24, P=0.931	No difference
Density (stems/m^2)				
Total	NA		NA	

* Log transformed data
Highlighted boxes = significant difference at the 95% confidence level

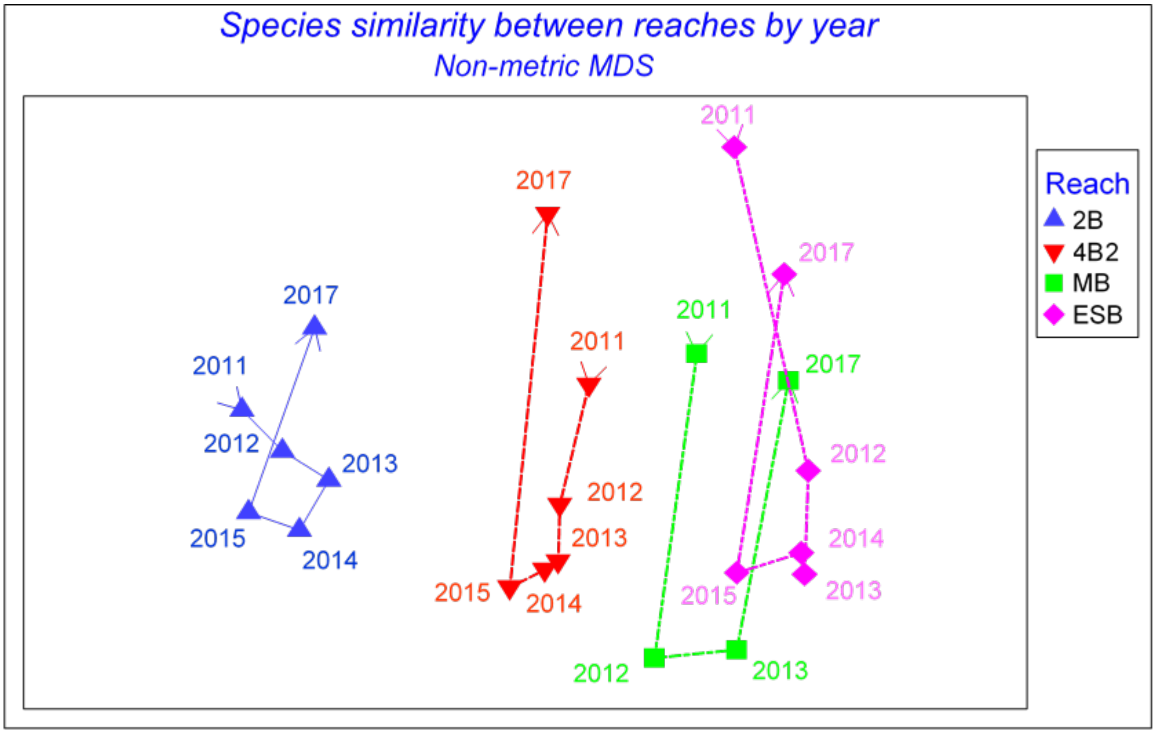


Figure 11. MDS ordination of sample sites (i.e. reaches) by year using Bray-Curtis similarities of plant species based on square root transformed cover data along the San Joaquin River from 2011 to 2015 and 2017 (2B, 4B2, ESB) and 2011 to 2013 and 2017 (MB). 2D Stress = 0.12.

Photo Stations

Photographs taken from the end of vegetation transects since 2011 for original study transects and from 2017 for new transects are shown in Appendix F. Some differences in vegetation can be observed when comparing the photos from 2011 and 2017 to photos from 2014 and 2015 when the channel was dry in a number of photos.

Groundwater Monitoring

Piezometers were installed in association with transects in Reach 2B in February 2013 (PZ-7 and PZ-8 in Figure 12). The hydrograph in Figures 13, 14, and 15 show groundwater depths at these piezometer sites from March through December 2013, from and May to November 2014, and from January 2016 to November 2017, respectively. Flow data included in the hydrographs were gathered at Station SJN (approximately 2 mi downstream). A correlation between flows and the depth of the water table is apparent, which indicates connectivity of the floodplain and river. In well PZ-7, which is located in the floodplain, the water table remained less than 4 ft from the surface when the channel held water and <1 ft when flows reached around 500 cfs or higher.

From March to December 2013, ground water within the floodplain (PZ-7) remained at a shallow enough depth (<4 ft) necessary to sustain established woody riparian plant species (Figure 13). In 2014, the river was completely dry in Reach 2B from mid-February to late May and groundwater levels reflected this, falling below piezometer sensor levels in the wells (sensors were placed at approximately 5.6 and 8.6 ft below surface level in wells PZ-7 and PZ-8, respectively; Figure 14). When irrigation flows were released in late May, discharge increased dramatically to between 750 to 900 cfs and groundwater remained at less than 1 ft until October of 2014. At that time, discharge returned to 0 cfs and groundwater again fell to near sensor levels. The water table in PZ8 – located on the upper terrace – rarely reached less than 5 ft from the surface. No data were collected at wells PZ-7 and PZ-8 in 2015, when flow releases were minimal and these wells were dry most of the time. Monitoring resumed in January 2016; flows remained quite low that year and the water table never reached less than 1 ft from the surface (Figure 15). In 2017, however, flows were greater than approximately 600 cfs from January through March and again from late April to mid-July at PZ-7, bringing ground water levels within 1 ft of the surface or less. During this period, when discharge was greater than 1200 cfs, the flood plain was inundated and the water table was less than 4 ft from the surface in PZ-8.

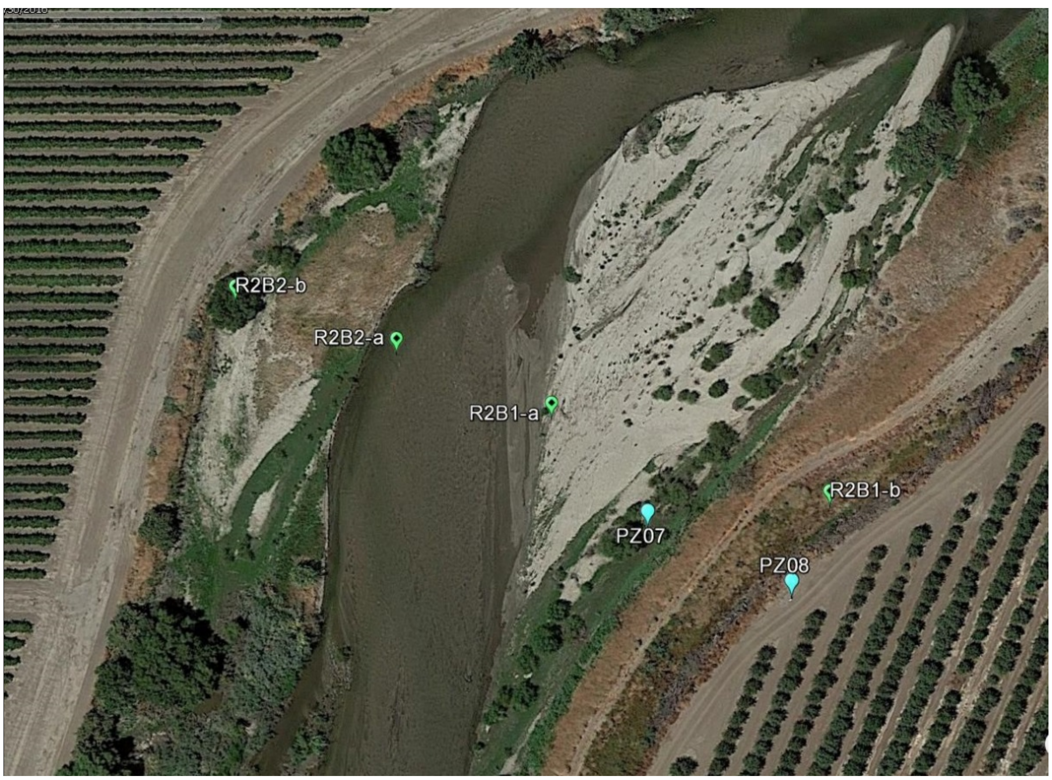


Figure 12. Locations of wells PZ-7 (floodplain) and PZ-8 (upper terrace) and endpoints of vegetation transects R2B-1 and R2B-2 within Reach 2B. Google Earth imagery December 2017.

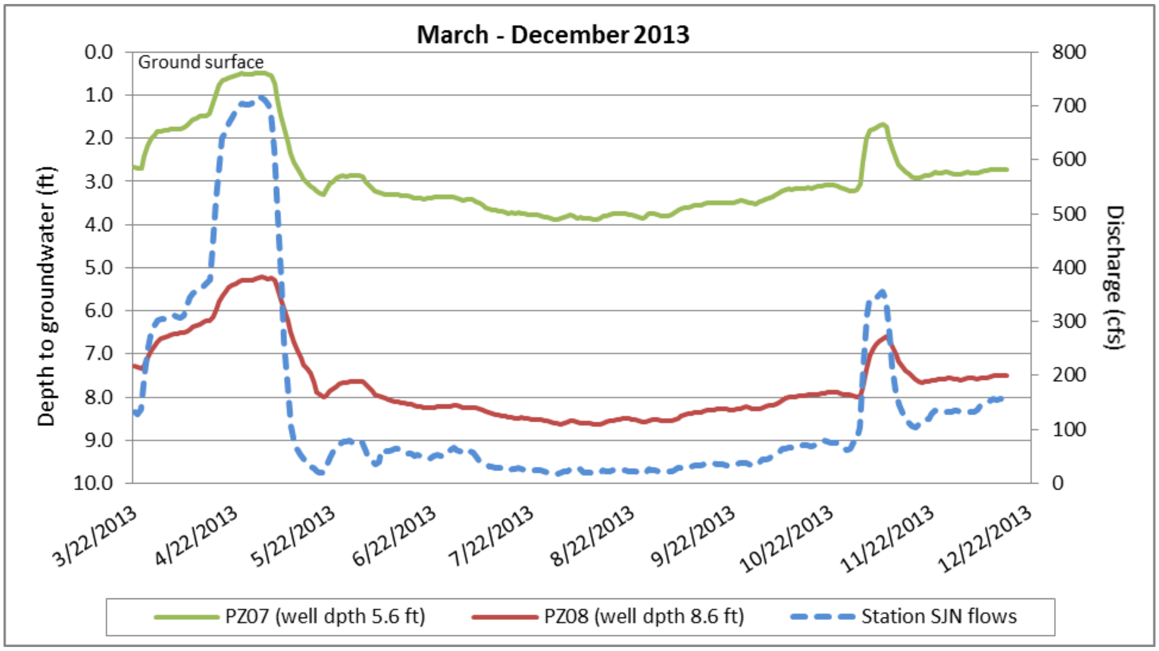


Figure 13. Depth to groundwater at wells PZ-7 and -8 and San Joaquin River discharge at gauge SJN from March to December 2013 in Reach 2B.

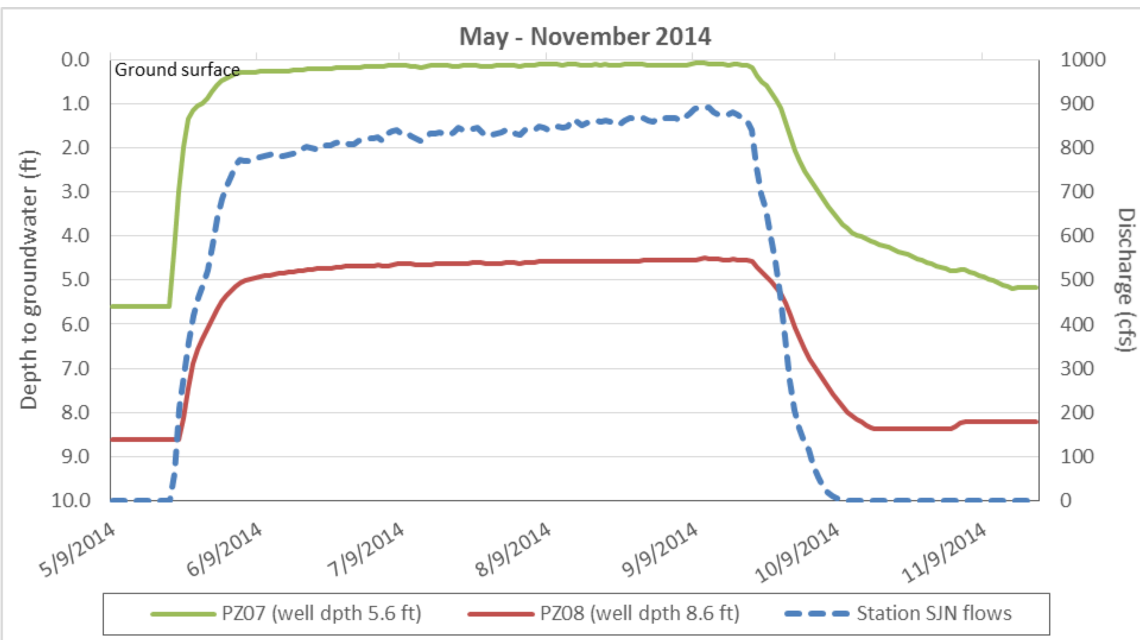


Figure 14. Depth to groundwater at wells PZ-7 and -8 and San Joaquin River discharge at gauge SJN from May to November 2014 in Reach 2B.

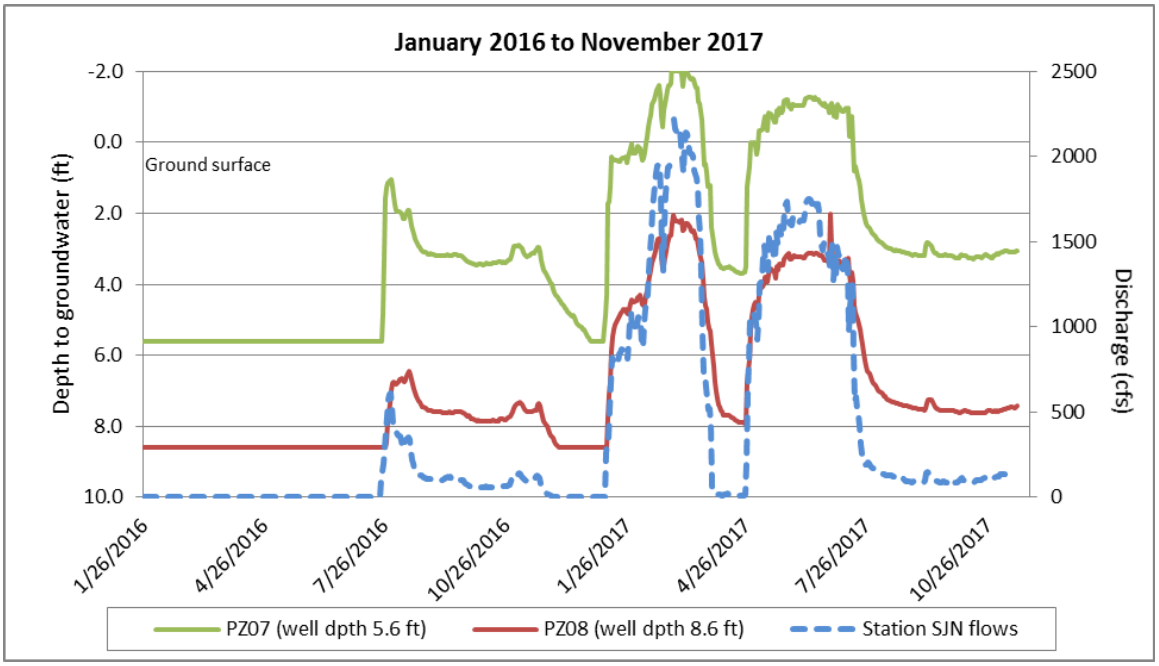


Figure 15. Depth to groundwater at wells PZ-7 and -8 and San Joaquin River discharge at gauge SJN from January 2016 to November 2017 in Reach 2B.

Discussion

A synopsis of vegetative conditions by reach follows.

Reach 2B

Total understory cover peaked in 2017 at 57.1 percent, which was a considerable increase from the previous monitoring period in 2015 when total cover was estimated to be 7.1 percent (Figure 4). The relatively high understory vegetative cover in 2017 was dominated by introduced grasses. This reach showed the largest increase in total overstory cover (7.2 to 20.0 percent from 2011 to 2014; Table 2), but overstory cover slightly decreased in 2015 to 17.6 percent. By 2017, overstory cover had decreased to 5.4 percent. Woody stem density followed a similar pattern, showing higher values through 2014 (1.32 to 3.62 stems/m^2) and dropping substantially by 2017 (0.22 stems/m^2; Table 3). Despite the decrease in overstory cover and stem density throughout the sandbar, a stand of Goodding’s willow developed over time at the base of the slope further from the channel (see photo for Transect 2B, 1a toward transect in August 2017 as compared to August 2011).

Woody species richness increased from 3 to 4 (all native species) from 2011 to 2015 and fell back to 3 species detected with the loss of cottonwood in the species composition. Within reach 2B, young willow and cottonwood seedlings established over the monitoring period, increasing in cover, size and richness. Severe drought conditions in 2014 and 2015 appeared to impact this site, however, with overall health of plants observed to be poor (see comparison photos in Appendix F; Reach 2B, Transect 1; 1A). Shallow-rooted understory species had a relatively large decrease in cover as well.

Piezometers installed at the site in 2013 indicated that groundwater was relatively shallow (< 4 ft) within the floodplain (Figures 13-15). When the river was dry, as it was from February to May and again in October in 2014, the water table fell to 5.6 ft (depth of sensor) or more from the surface. Flooding occurred within this reach when river discharge rates were greater than 1,200 cfs. A water table shallow enough to sustain saturated soil conditions for approximately 6-8 weeks following seed dispersal, as well as water table declines less than about 0.1 ft/day are generally necessary for recruitment of woody riparian species in the west (Segelquist et al. 1993, Lines 1999, Taylor 2000, Shafroth et al. 2000). Accurate assessment of the suitability of groundwater conditions and timing/duration for vegetative recruitment was not possible based on the limited and irregular available groundwater data collected at this site.

A native elderberry stand adjacent to the site was replaced with an almond orchard sometime between monitoring periods 2014 and 2015.

East Side Bypass

The addition of new transects within this reach in 2017 are included in the overall historical evaluation to provide further detail, although caveats for comparisons with mean reach historical trends should be made due to the location of the transects where they intersected previously un-sampled woody species. Temporal aspects are therefore more applicable to the herbaceous understory present throughout the ESB.

Total understory cover within transects in the ESB peaked in 2017 at an average of 76.6 percent, significantly greater than any other year (Figure 4, Table 4). Native understory species remained dominant relative to introduced species throughout most of the monitoring period; introduced species were only dominant in 2015 (Figure 6). Herbaceous species richness was relatively high in this reach ranging from 15 in 2014 to 27 in 2017 (Figure 9). The increase in sample size in this reach likely influenced these numbers since the opportunity to detect more plant species is greater with more transects, particularly in 2017 (species richness in 2017 was 20 when only counting transects from original study vs 27 when including additional transects).

From 2012 to 2015, transects in this reach fell within exclusively herbaceous habitat. In 2011, 0.2 percent overstory cover was documented (Table 2) but no woody species were detected in understory or stem density measurements. In 2017, no woody species were detected in total cover measurements but a stem density of 0.05 stems/m^2 was recorded (Table 3). The increase in woody stem density can be attributed to the addition of 2 transects that included Goodding's willow. However, one of the original transects was sampled prior to grazing or mowing in 2017, unlike other years, and a number of Goodding's willow seedlings were detected. All 4 transects in the original study and 6 of 9 transects in 2017 were located within the Merced NWR, where flows were more consistent year-round. Decreasing flows in the channel in 2014 and 2015 exposed substrates allowing willows to colonize in 2015 (see photos in Appendix F, ESB Transects 3a and 4a "away from transect"). In 2017, most of the Goodding's willow observed in this reach occurred within the channel (and outside of transects, Figure 15). Because sampling occurred soon after flows receded in 2017, woody plants established in association with overbank flows were unlikely to be detected yet.

The California State endangered delta button celery was detected in transects within the ESB in 2011 and 2017 only (Figure 16). This species was also detected in areas surrounding transects in 2011, 2012, 2017.

Figure 16. Goodding's willow (*Salix goodingii*) regeneration within the East Side Bypass channel, August 2017.

Figure 17. Delta button celery (*Eryngium racemosum*), a State-listed endangered plant, was detected in transects and surrounding areas within the East Side Bypass Reach, August 2017.

Mariposa Bypass

Transects in this reach were monitored from 2011 to 2013 and sampling was resumed in 2017. Of those years, total understory plant cover was significantly greater in 2011 and 2017 (94.0 and 90.0 percent, respectively) than in 2012 and 2013 (43.5 and 51.5 percent, respectively; Figure 4, Table 4). Native understory species (predominantly native forbs) were also significantly higher during 2011 and 2017 than other years. Species composition was most similar to the ESB (Figure 11). The East Side and Mariposa Bypasses were close in proximity and therefore similar results from analysis would not be surprising. No woody species were detected in any year in transects within the MB.

Reach 4B2

Reach 4B2 had relatively high total understory cover in all years (between 63.5 and 90.0 percent; Figure 4). Native and introduced understory species were generally evenly represented except in 2015 when introduced species (i.e. introduced grasses) made up a much greater proportion than native species (Figure 8). Herbaceous species richness remained relatively high over the monitoring period, averaging around 16 species detected (Figure 9).

Black mustard and poison hemlock, invasive species that are both given a ranking of “moderate” by the California Invasive Plant Council (Cal-IPC 2015), had relatively high coverage in Reach 4B2 in 2012. Percent cover decreased after 2012 and neither species was detected in 2017 (Appendix E). Milk thistle was detected in 2015, which is listed as “limited” by Cal-IPC, meaning that either there is not enough information to rank or that impacts are minor statewide, but may be problematic on a local level. The invasive perennial pepperweed was first detected in transects in 2012 and has increased slightly since then. This species is ranked as “high” by Cal-IPC, meaning it has severe ecological impacts. It is also included on the California Department of Food and Agriculture Noxious Weed List. Photos document the spread of pepperweed in Appendix F (see Transect 1 - both toward and away from transect - in 2014 and/or 2015).

While mature Goodding’s willow was measured in total overstory cover all years (averaging around 10 percent), no woody species were detected in understory cover or woody stem density measurements, suggesting that recruitment was low. This reach is located in the San Luis NWR and, like the Merced NWR in the East Side Bypass, has been supplied with year-round water and hydrologic conditions may not change considerably.

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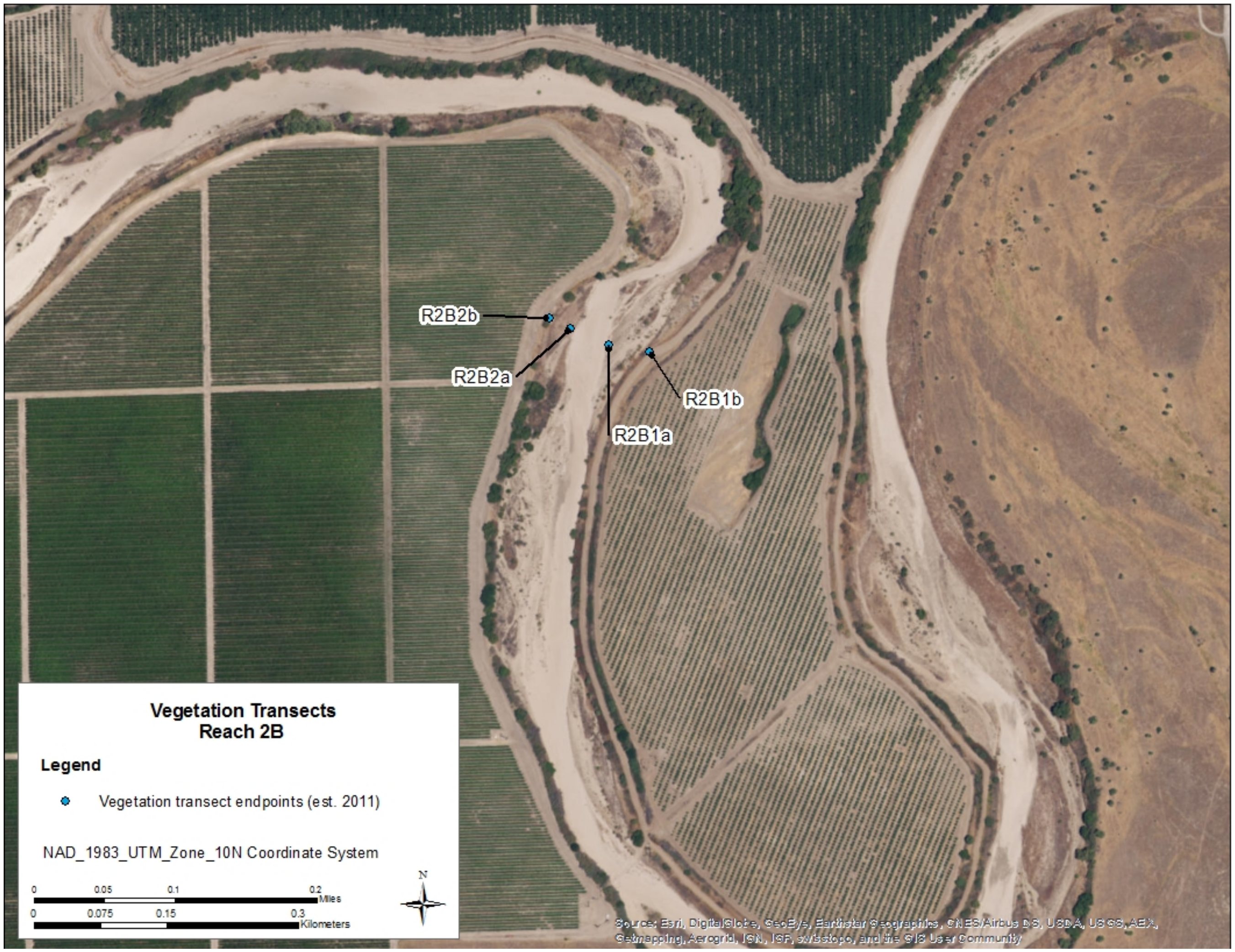
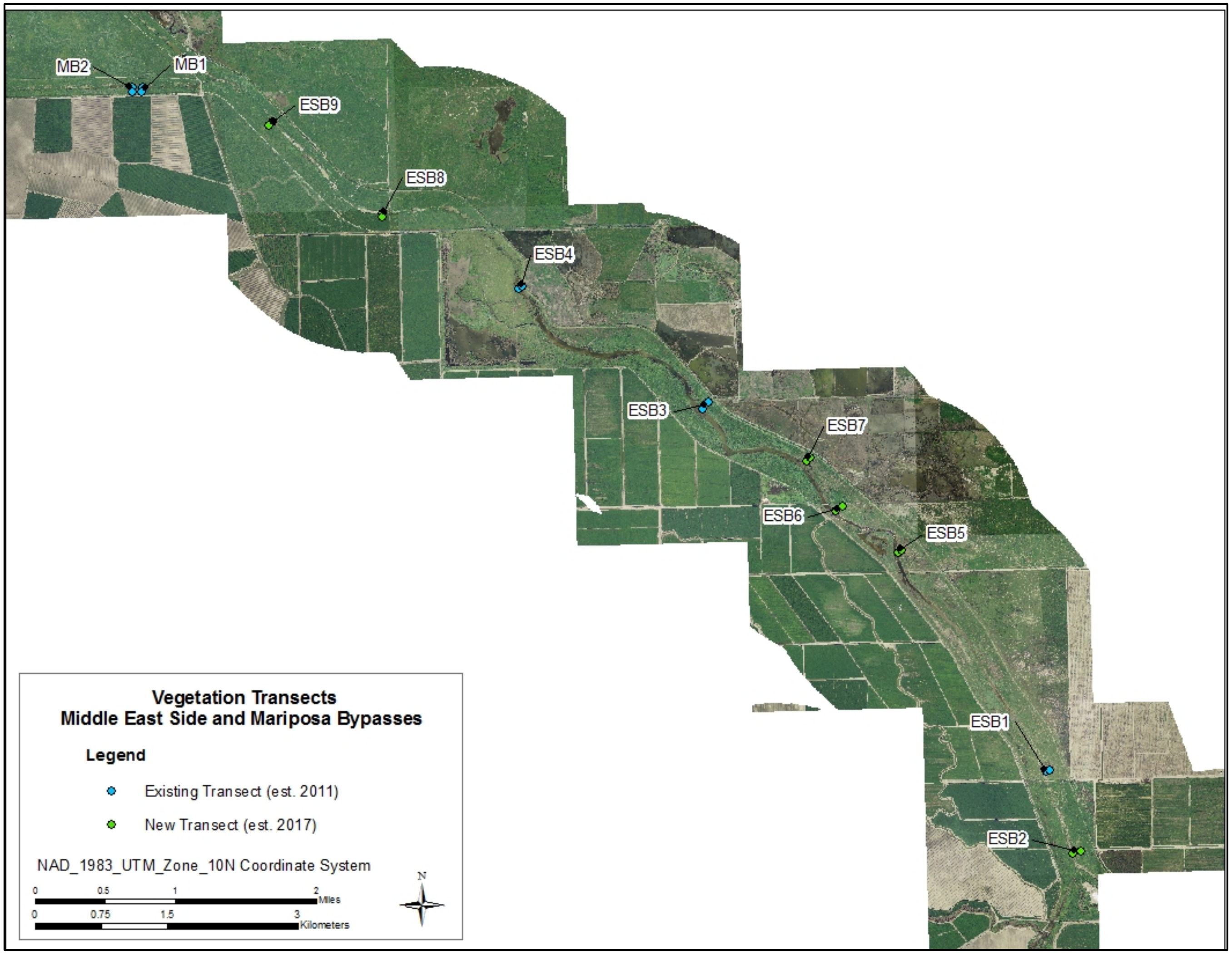
Appendix A

Vegetation Transect Locations by River Reach

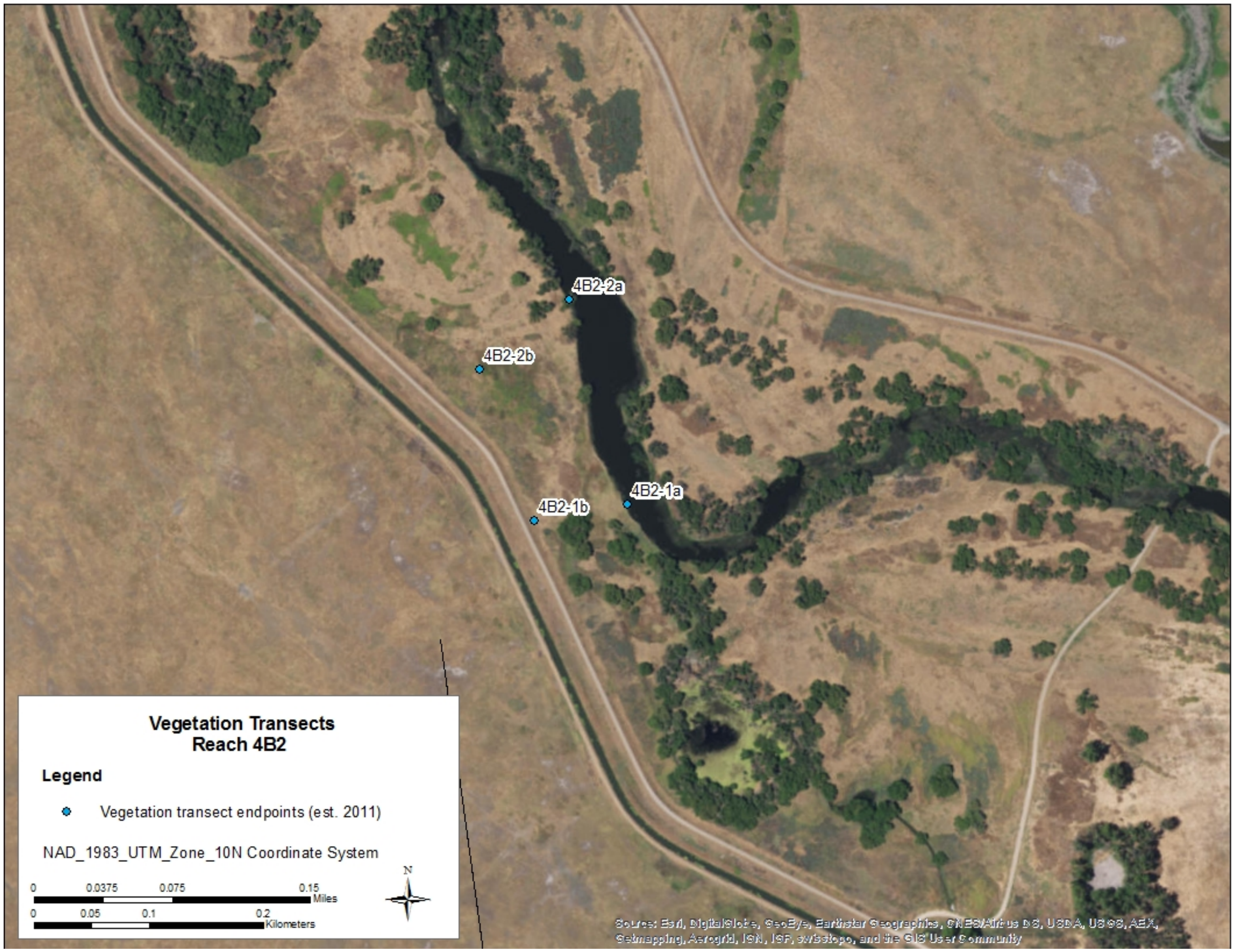


R2B2b
R2B2a
R2B1a
R2B1b
Vegetation Transects
Reach 2B
Legend
Vegetation transect endpoints (est. 2011)
NAD_1983_UTM_Zone_10N Coordinate System
0 0.05 0.1 0.2 Miles
0 0.075 0.15 0.3 Kilometers
N

Reach 2B



East Side and Mariposa Bypasses


4B2-2a
4B2-2b
4B2-1a
4B2-1b
Vegetation Transects
Reach 4B2
Legend
Vegetation transect endpoints (est. 2011)
NAD_1983_UTM_Zone_10N Coordinate System
0 0.0375 0.075 0.15 Miles
0 0.05 0.1 0.2 Kilometers
N

Reach 4B2

Appendix B

Vegetation transect waypoints

All datum in NAD83, Zone 10S.

Reach	Transect	Endpoint A		Endpoint B	
		x	y	x	y
R2B	1	741588	4072745	741635	4072737
	2	741545	4072764	741521	4072776
ESB	1	714247	4111883	714291	4111906
	2	714557	4110946	714649	4110981
	3	710327	4116028	710387	4116109
	4	708222	4117400	708260	4117430
	5	712553	4114394	712598	4114410
	6	711844	4114860	711922	4114923
	7	711516	4115437	711548	4115476
	8	706651	4118266	706654	4118220
	9	705396	4119310	705362	4119272
MB	1	703913	4119708	703909	4119657
	2	703796	4119709	703792	4119659
R4B2	1	693719	4123306	693638	4123291
	2	693669	4123485	693590	4123424

Appendix C

Data collection forms

San Joaquin Restoration Flows
Vegetation Monitoring
Herbaceous Cover

Date: ____________________ **Transect #:** ____________________

Observers: ____

Photo #s: A Toward transect: __________ B Toward transect: __________
Away from transect: __________ Away from transect: __________

Notes:

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50

Figure C-1.—Understory cover data form.

San Joaquin Restoration Flows
Vegetation Monitoring
Overstory Cover

Date: ______________________________ **Observers:** ______________________________

Transect: ______________________________

Species	Start	Stop	Height	Start	Stop	Height	Start	Stop	Height	Start	Stop	Height

Figure C-2.—Overstory cover data form

San Joaquin Restoration Flows
Vegetation Monitoring
Woody Stem Density

Date: ____________________

Transect: ____________________

Observers: ____________________

Size class	**Description**	**Species**				
1	Seedling					
2	< 1 m (3 ft) in height					
3	> 1 m (3 ft) in height and < 10 cm (4 in) DBH					
4	>10 cm (4 in) DBH					

Figure C-3.—Woody Stem Density data form.

Appendix D

Scientific Names and Locations of Plants Detected in Vegetation Transects
2011 to 2017

	SCIENTIFIC NAME	COMMON NAME	LIFE FORM	Reach 2B	ESB	MB	4B2
Tree/shrub							
POFR	*Populus fremontii*	Fremont cottonwood	NT	X			
SAEX	*Salix exigua*	Sandbar willow	NS	X			
SAGO	*Salix gooddingii*	Gooding's willow	NT	X	X		X
SANI	*Sambucus nigra*	Black elderberry	NT	X			
Graminoid							
AGEX	*Agrostis exarata*	Spike bent grass	NG	X			
ALAE	*Alopecurus aequalis var. aequalis*	Shortawn foxtail	NG		X		
BRDI	*Bromus diandrus*	Ripgut brome	IG		X	X	X
BRHO	*Bromus hordeaceus*	Soft chess brome	IG		X	X	X
BRMA	*Bromus madritensis*	Foxtail chess	IG	X	X		X
CRSC	*Cripsis schoenoides*	Swamp pricklegrass	IG		X	X	X
CYAC	*Cyperus acuminatus*	Tapertip flatsedge	NG	X	X		
CYDA	*Cynodon dactylon*	Bermuda grass	IG		X	X	X
CYES	*Cyperus esculentus*	Yellow nutgrass	NG		X	X	
CYST	*Cyperus strigosus*	Strawcolored flatsedge	NG		X		X
DISA	*Digitaria sanguinalis*	Hairy crabgrass	IG	X			
DISP	*Distichlis spicata*	Salt grass	NG		X	X	X
ECCR	*Echinochloa crus-galli*	Barnyard grass	IG	X	X		X
ELPA	*Eleocharis palustris*	Common spikerush	NG		X		
HOMA	*Hordeum marinum ssp gussoneanum*	Mediterranean barley	IG		X	X	X
HOMU	*Hordeum murinem*	Mouse barley	IG		X	X	X
JUAC	*Juncus acuminatus*	Tapertip rush	NG	X			
JUBA	*Juncus balticus*	Baltic rush	NG	X	X	X	X
LETR	*Leymus triticoides*	Creeping wildrye	NG		X		
PARI	*Panicum rigidulum*	Redtop panicgrass	IG	X	X		X
PADI	*Paspalum dilatum*	Dallis grass	IG		X	X	
PANO	*Paspalum notatum*	Bahia grass	IG		X		
POMO	*Polypogon monspeliensis*	Rabbitsfoot grass	IG	X	X		X
SCAC	*Schoenplectus acutis*	Hardstemmed bullrush	NG		X		X
SOHA	*Sorgham halapense*	Johnsongrass	IG		X		X
VUMY	*Vulpia myuros*	Rat-tail fescue	IG	X	X		X
Forb							
AMRE	*Amaranthus retroflexus*	Redroot pigweed	IF		X		X
AMRO	*Ammania robusta*	Grand redstem	NF		X		X
ANCO	*Anthemis cotula*	Dog fennel	IF		X		
ARDO	*Artemisia douglasiana*	California mugwort	NF	X			X
ASFA	*Asclepius fascicularis*	Narrowleaf milkweed	NF				X
BRNI	*Brassica nigra*	Black mustard	IF	X	X	X	X
CESO	*Centaurea solstitialis*	Yellow starthistle	IF		X	X	
CEPA	*Centromadia parryii ssp rudis*	Pappose tarweed	NF		X	X	X
CHCA	*Chenopodium californicum*	California goosefoot	NF			X	X
CRTR	*Cressa truxellensis*	Alkaliweed	NG		X		
EUOC	*Euthamia occidentalis*	Western goldentop	NF				X
CIVU	*Cirsium vulgare*	Bull thistle	IF		X	X	X
COMA	*Conium maculatum*	Poison hemlock	IF				X
COCA	*Conyza canadensis*	Horseweed	NF	X			
CUSP	*Cuscuta* sp.	Dodder	NF	X			
ERCI	*Erodium cicutarium*	Redstem storks bill	IF	X			
ERRA	*Eryngium racemosum*	Delta button celery	NF		X		
FRSA	*Frankenia salina*	Alkali seaheath	NF		X	X	X
GNPA	*Gnaphalium palustre*	Western marsh cudweed	NF			X	
GRCA	*Grindelia camporum*	Gum plant	NF		X	X	X
HEAN	*Helianthus annuus*	Sunflower	NF	X	X	X	X
HECU	*Heliotropium curassavicum*	Salt heliotrope	NF		X	X	
KOSC	*Kochia scoparia*	Kochia	IF	X	X		
LASE	*Lactuca serriola*	Prickly lettuce	IF		X	X	X
LELA	*Lepidium latifolium*	Perennial peppergrass	IF				X
LUPE	*Ludwigia peploides*	Water primrose	NF		X		
LOCO	*Lotus corniculatus*	Birdsfoot trefoil	IF		X		X
LOUN	*Lotus unifoliolatus*	American bird's-foot trefoil	NF	X			
MALE	*Malvella leprosa*	Alkali mallow	IF		X		X
MAPA	*Malva parviflora*	Cheeseweed mallow	IF		X		
MAVE	*Marsilea vestita*	Hairy water clover	NF		X		
MEAL	*Melilotus alba*	White sweetclover	IF		X	X	

MEAR	*Mentha arvensis*	Field mint	NF	X			
MOVE	*Mollugo verticillata*	Green carpetweed	IF	X	X		X
PHAN	*Physalis angulata*	Cutleaf groundcherry	NF				X
PHNO	*Phyla nodiflora*	Turkey tangle fogfruit	NF		X	X	X
POAV	*Polygonum aviculare*	Prostrate knotweed	IF		X	X	X
PELA	*Persicaria lapathifolium*	Curlytop knotweed	NF		X		
PSCA	*Pseudognaphalium californicum*	California cudweed	NF	X	X		
ROPA	*Rorippa palustris*	Yellow cress	NF	X			X
RUCR	*Rumex crispus*	Curly dock	IF		X	X	X
SATR	*Salsola tragus*	Russian thistle	IF		X		
SIMA	*Silybum marianum*	Milk thistle	IF		X	X	X
SOAM	*Solanum americanum*	American black nightshade	NF	X			X
SOAS	*Sonchus asper*	Prickly sow thistle	IF	X	X		
TRSP	*Trifolium sp.*	Clover		X	X		
URDI	*Urtica dioica*	Stinging nettle	IF	X			
XAST	*Xanthium strumarium*	Cocklebur	NF	X	X		X

*NT/IT=Native or Introduced tree; NS/IS=Native or Introduced shrub; NG/IG=Native or Introduced grass or grass-like specie; NF/IF=Native or Introduced forb

Appendix E

Total percent cover of individual plant species detected
in the understory layer of vegetation transects
from 2011 to 2017.

Average Total Percent Understory Cover																						
	River Reach																					
	Reach 2B						Eastside Bypass						Mariposa Bypass				Reach 4B2 (San Luis NWR)					
Species	n=2						n=4					n=9	n=2				n=2					
	2011	2012	2013	2014	2015	2017	2011	2012	2013	2014	2015	2017	2011	2012	2013	2017	2011	2012	2013	2014	2015	2017
Sandbar willow	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gooding's willow	0.5	1.0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seepwillow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0
Native trees/shrubs	0.5	1.0	3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0
Tapertip flatsedge	0	0	1	0	0	2.4	1.0	2.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow nutgrass	0	0	0	0	0	0	1.0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0
Salt grass	0	0	0	0	0	0	0	10.7	9.5	13.8	4.8	6.3	0	1.5	5.0	0	14.4	19.1	22.6	12.9	4.6	7.0
Baltic rush	0	0	1.5	1.0	0	0	0.7	0	0	0.8	0.5	1.0	6.5	6.5	3.5	0.5	5.2	5.1	5.7	9	5.8	0
Common spikerush	0	0	0	0	0	0	11.0	0	0	0	0	1.1	0	0	0	0	0	0	0	0	0	0
Creeping wildrye	0	0	0	0	0	0	0	1.0	1.5	1.0	0.5	0	0	0	0	0	0	0	0	0	0	0
Shortawn foxtail	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0	0	0
Strawcolored flatsedge	0	0	0	0	0	0	0	0	0	0	0	4.3	0	0	0	0	0	0	0	0	0	1.3
Hardstemmed bullrush	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0	0	0	0	0	2.3
Spike bentgrass	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified grasses*	0	0	0	0	0	0.5	2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Native graminoids	0.0	0.0	2.7	1.0	0.0	3.9	15.7	14.0	11.3	15.6	7.0	14.5	7.0	8.0	8.5	0.5	19.6	24.2	28.3	21.9	10.4	10.6
Swamp pricklegrass	0	0	0	0	0	0	0	0	0	0	0	0.9	5.5	0	0	3.0	1.0	0	0	0	0	0
Ripgut brome	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	1.5	0	0	0	3.8	7.8	20.4	0
Bermuda grass	0	0	0	0	0	0	2.7	3.0	0	0	3.7	16.1	3.0	0	0	9.0	2.0	4.0	3.5	2.0	0.5	1.9
Barnyard grass	0	0	0	0	0	1.7	0.3	0	0	0	0	0	0	0	0	0	26.1	0	0	0	0	18.9
Soft chess brome	0	0	0	0	0	0	0	0	0	0	1.5	0	0	2.0	0	0	0	5.5	11.2	8.5	22.0	0
Foxtail chess	0	0	3.4	0	0	0	0	0.3	0.5	0	3.2	0	0	0	0	0	0	0	0	0.7	0.6	0
Bahia grass	0	0	0	0	0	0	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dallis grass	0	0	0	0	0	0	4.5	1.7	3.5	2.3	0.3	0	0	0	1.5	0	0	0	0	0	0	0
Rat-tail fescue	0	0	0.7	0	0	0	0	0.3	0	0	0.5	0	0	0	0	0	0	0	0.5	0	0	0
Rabbitsfoot grass	0	0	0	0.7	0	0	0	1.4	0.8	0.8	0.3	0	0	0	0	0	0	0	0	0.5	0	0
Meditarrean barley	0	0	0	0	0	0	0	0	0.3	0	3.5	0	5.0	5.5	14.5	2.0	1.0	2.5	1.0	2.5	0	0
Mouse barley	0	0	0	0	0	0	0	0.3	0	1.5	1.3	0	0	2.0	7.0	0	0	0	0	0	0.6	0
Hairy crabgrass	0	0	0	0	0	2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Johnson grass	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	1.5
Redtop panicgrass	2.2	0	0	0	0	34.1	0.2	0	0	0	0	2.0	0	0	0	0	0	0	0	0	0	3.1
Introduced graminoids	2.2	0.0	4.1	0.7	0.0	38.0	13.0	7.3	5.1	4.6	14.3	20.3	13.5	9.5	24.5	14.0	30.1	12.0	20.0	22.0	44.1	25.4
California mugwort	1.4	2.9	2.1	1.7	0	3.1	0	0	0	0	0	0	0	0	0	0	0	1.6	0.6	1.9	1.8	0
California goosefoot	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0	3.5	1.3	4.0	1.0	0	8.8
Sunflower	0	0	0	0	0	1.0	0	0	0	0	0	0.1	3.0	0	0	11.5	7.1	0	0	0	0	17.4
American bird's-foot trefoil	9.3	0	4.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Field mint	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow cress	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0
American black nightshade	4.3	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	1.9	0	0	0	0	0
Cocklebur	0	0	1.2	0.0	0.0	4.1	7.3	2.7	0.3	0.3	0	8.5	12.0	0	0	13.0	7.1	0	0	0	0	0.6
Western goldentop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0

California cudweed	0	0.5	0.7	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Horseweed	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pappose tarweed	0	0	0	0	0	0	0	0	2.5	0.0	1.3	0	33.0	0	1.0	13.0	1.3	0	0	0	0	0
Delta button celery	0	0	0	0	0	0	0.5	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0
Gum plant	0	0	0	0	0	0	0	0.3	1.7	0.5	0.5	0	0	4.5	6.5	0.5	0	1.1	6.2	7.8	1.5	0
Turkey tangle fogfruit	0	0	0	0	0	0	0	5.2	4.7	9.0	8.2	6.3	0	4.0	8.5	9.0	0	0	0.5	0	0	0
Grand redstem	0	0	0	0	0	0	3.0	0	0	0	0	10.7	0	0.5	0	0	0	0	0	0	0	0
Water primrose	0	0	0	0	0	0	0	0	0.5	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Narrowleaf milkweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0.5
Alkali seaheath	0	0	0	0	0	0	0	0	0	0.3	1.0	0.7	0	0	0	0.5	0	0	0	0	1.0	1.0
Salt heliotrope	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0.5	0	0	0	0	0	0	0
Alkaliweed	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0
Curlytop knotweed	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0
Cutleaf groundcherry	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0	1.3
Western marsh cudweed	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0
Alkali mallow	0	0	0	0	0	0	1.0	1.3	0.5	0.8	0	5.1	0	0	0	0	0.6	0	0	0	0	2.5
Hairy waterclover	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0
Unidentified forbs*	1.4	0	0	0.5	0	0.9	3.0	2.5	0.5	0	0	0.3	1.5	0	0	0.5	0	0	0	1.0	0	0
Native forbs	16.4	5.3	9.0	2.2	0.0	10.6	14.8	12.5	10.7	11.2	11.0	34.8	51.0	9.0	16.5	48.0	21.5	4.6	11.9	12.4	4.3	32.1
Prostrate knotweed	0	0	0	0	0	0	0	0.5	0	0	0	2.9	9.5	0	0	16.0	2.1	1.9	0	0	0	3.8
Black mustard	4.1	12.4	7.2	2.6	5.1	3.6	0	1.3	2.7	1.3	4.3	0	9.0	16.5	2.0	8.0	5.8	10.3	5.8	1.0	5.5	0
Prickly lettuce	0	0	0	0	0	0	0	0.3	1.0	0.5	0	0	1.0	0	0	1.5	1.0	0	0	0	0	0
Curly dock	0	0	0	0	0	0	0.5	3.0	0	0	0.2	0	3.0	0	0	0.5	1.3	0.6	0	0	0	0
Clover	2.1	4.3	0	0	0	0	3.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stinging nettle	0.5	0.5	0.5	0	2.0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Redstem storks bill	0	0.7	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Koschia	0	0.7	0	0	0	0	0	0	0.5	0	0	0.1	0	0	0	0	0	0	0	0	0	0
Prickly sowthistle	0	0.7	0	0	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White sweetclover	0	0	0	0	0	0	0	0.5	0	0	0.5	0	0	0	0	0.5	0	0	0	0	0	0
Bull thistle	0	0	0	0	0	0	0	0	1.8	0	0	0	0	0.5	0	0	0	1.3	1.3	0	0	0
Dodder	0	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poison hemlock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.3	1.9	3.1	5.5	0
Perennial pepperweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.9	2.5	3.1	2.5	5.6
Birdsfoot trefoil	0	0	0	0	0	0	0	0.5	1.5	0	0	0	0	0	0	0	0	0.6	0	0	0	0
Dog fennel	0	0	0	0	0	0	0	2.7	0	2.0	1.5	0	0	0	0	0	0	0	0	0	0	0
Milk thistle	0	0	0	0	0	0	0	0.7	0	0	1.0	0	0	0	0	0.5	0	0	0	0	3.6	0
Yellow starthistle	0	0	0	0	0	0	0	0	2.5	0	2.8	0	0	0	0	0.5	0	0	0	0	0	0
Cheeseweed mallow	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0
Green carpetweed	0	0	0	0	0	0.5	0	0	0	0	0	1.7	0	0	0	0	0	0	0	0	0	8.4
Russian thistle	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0
Redroot pigweed	0	0	0	0	0	0	0	0	0	0	0	1.9	0	0	0	0	0	0	0	0	0	4.1
Introduced forbs	6.7	19.3	10.2	3.3	7.1	4.6	3.8	10.2	10.0	3.8	10.5	7.0	22.5	17.0	2.0	27.5	10.2	25.9	11.5	7.2	17.1	21.9
Total Plant Cover	25.8	25.6	29.0	7.2	7.1	57.1	47.3	44.0	37.1	35.2	42.8	76.6	94.0	43.5	51.5	90.0	81.4	66.7	71.7	63.5	76.5	90.0
Litter	22.9	32.8	33.3	42.3	43.2	8.2	22.7	39.5	49.3	48.5	38.8	4.8	4.5	55.0	44.0	8.0	11.8	32.8	28.4	36.1	22.5	4.6
Bare	51.3	41.6	37.8	50.5	49.7	34.6	30.0	16.8	13.8	16.8	18.5	17.0	1.5	1.5	4.5	2.0	6.8	0.5	0	0.5	1.0	5.6
Water	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0
Total Cover	100	100	100	100	100	100	100	100	100	101	100	100	100	100	100	100	100	100	100	100	100	100

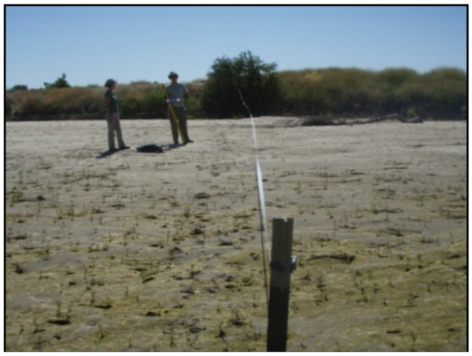
*Unidentified species may be either native or introduced

Appendix F

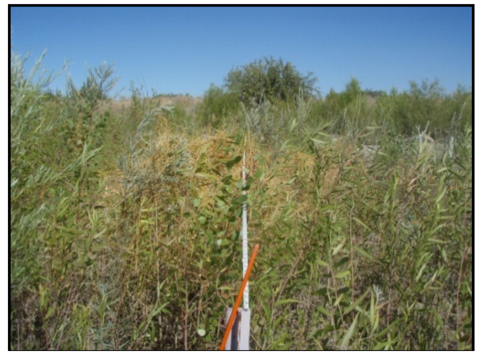
Photo Stations
August 2011 to August 2017

Reach 2B, Transect 1

1a – Toward transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

1a – Away from transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

1b – Toward transect


August 2011


June 2012


June 2013


May 2014


May 2015

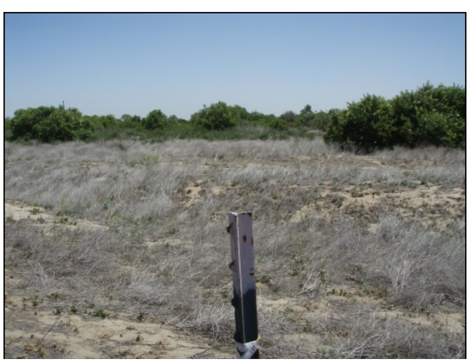

August 2017

1b – Away from transect


August 2011


June 2012


June 2013

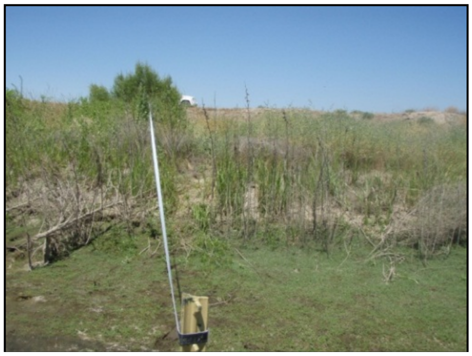

May 2014


May 2015


August 2017

Reach 2B, Transect 2

2a – Toward transect



August 2011

June 2012

June 2013

May 2014

May 2015

August 2017

2a – Away from transect

August 2011

June 2012

June 2013

May 2014

May 2015

August 2017

2b – Toward transect (taken from different angle in 2011)


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

2b – Away from transect


August 2011


June 2012


June 2013


May 2014


May 2015

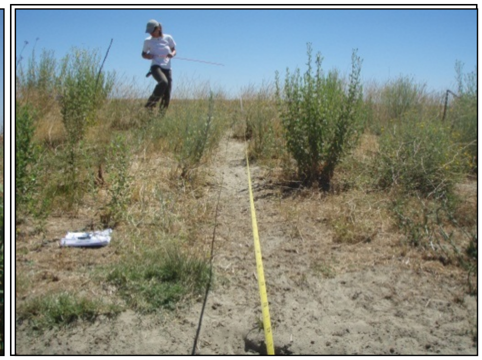

August 2017

East Side Bypass Original Study Transects
ESB Transect 1

1a – Toward transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

1a – Away from transect


August 2011


June 2012

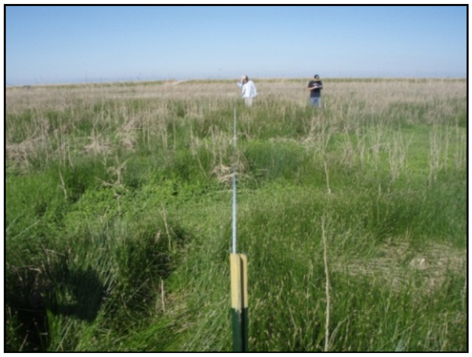

June 2013

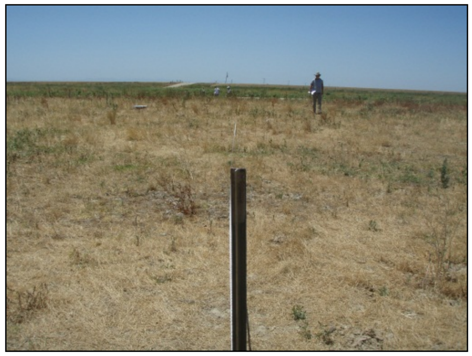

May 2014

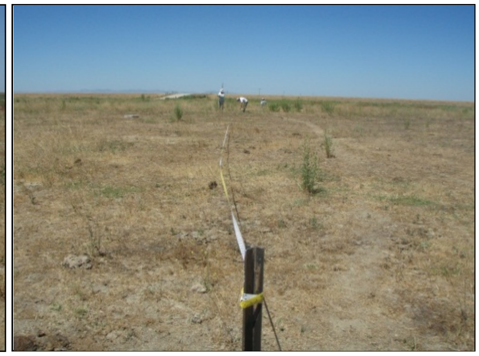

May 2015


August 2017

1b – Toward transect


August 2011


June 2012

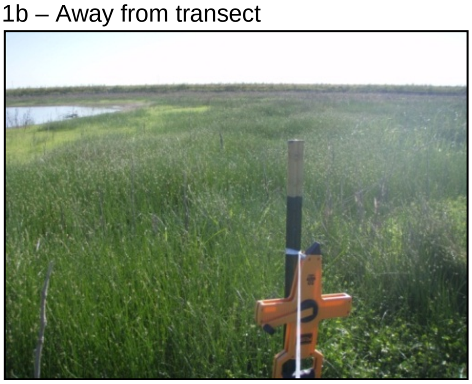

June 2013


May 2014

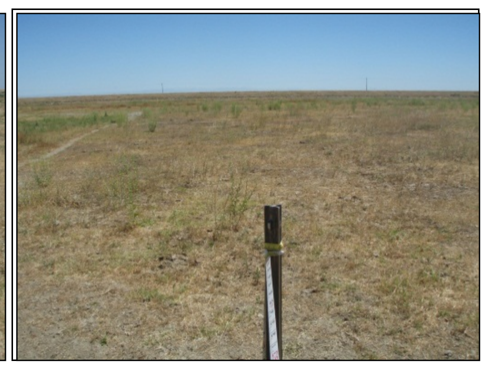

May 2015

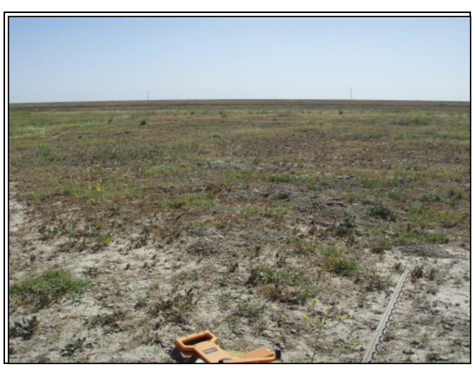
August 2017 Not Available

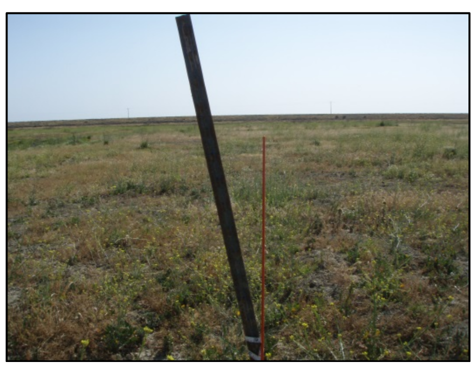
1b – Away from transect


August 2011


June 2012


June 2013


May 2014


May 2015

August 2017 Not Available

ESB Transect 2

2a – Toward transect


August 2011


June 2012


June 2013


May 2014

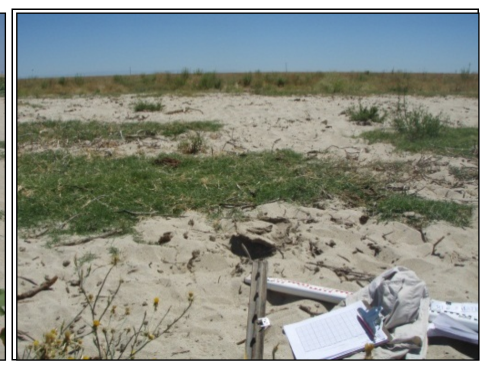

May 2015

August 2017 Discontinued

2a – Away from transect


August 2011


June 2012

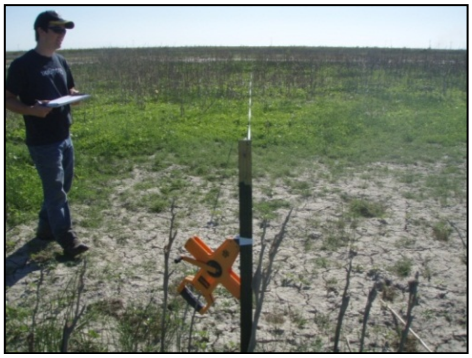

June 2013


May 2014


May 2015

August 2017 Discontinued

2b – Toward transect


August 2011


June 2012


June 2013


May 2014

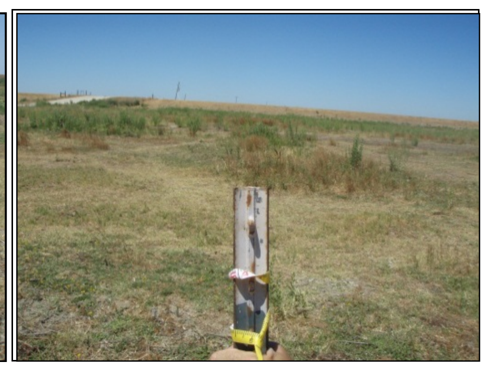

May 2015

August 2017 Discontinued

2b – Away from transect


August 2011


June 2012


June 2013


May 2014

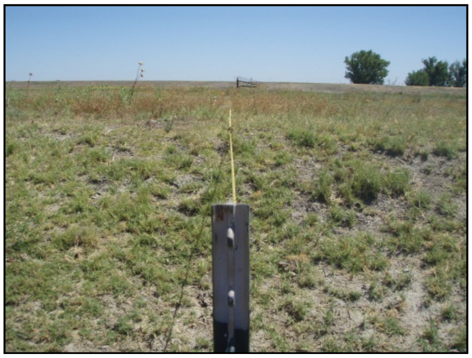

May 2015

August 2017 Discontinued

ESB Transect 3

3a – Toward transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

3a – Away from transect


August 2011


June 2012

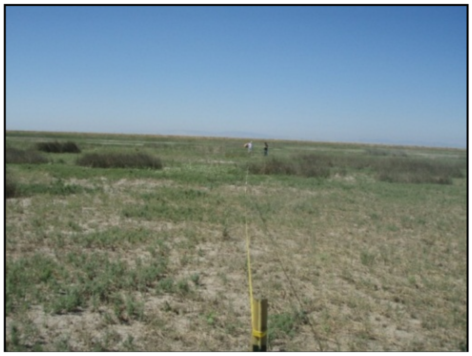

June 2013

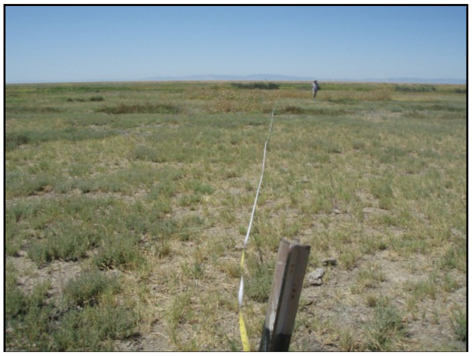

May 2014


May 2015

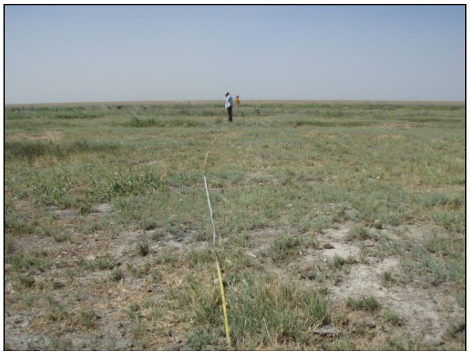

August 2017

3b – Toward transect


August 2011


June 2012


June 2013

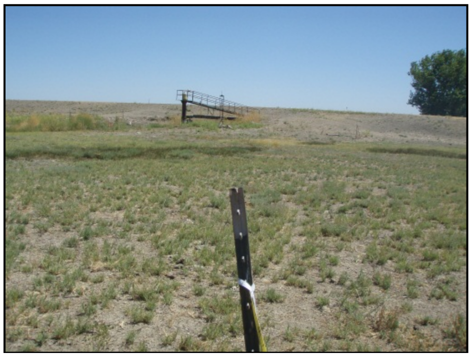

May 2014


May 2015

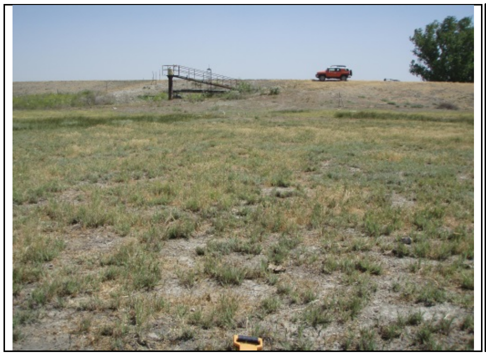

August 2017

3b – Away from transect


August 2011


June 2012


June 2013

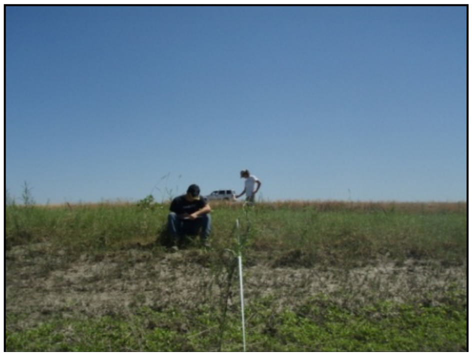

May 2014

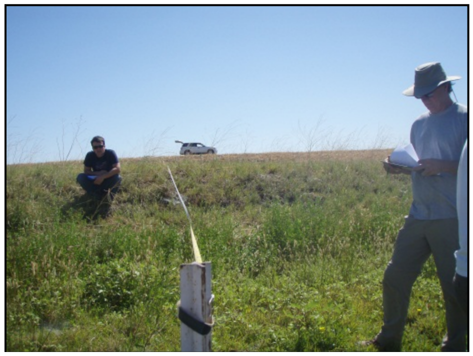

May 2015


August 2017

ESB Transect 4

4a – Toward transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

4a – Away from transect


August 2011


June 2012


June 2013

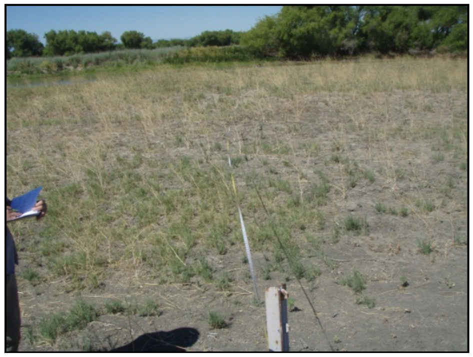

May 2014


May 2015


August 2017

4b – Toward transect


August 2011


June 2012


June 2013

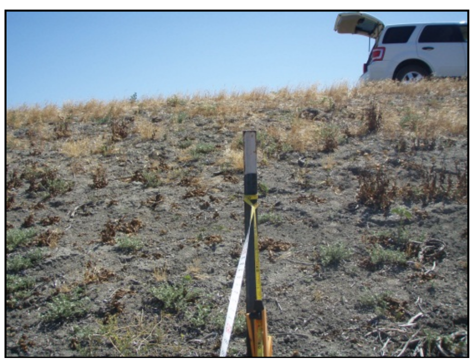

May 2014


May 2015


August 2017

4b – Away from transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

East Side Bypass New Transects
ESB Transect 2

2a – Toward transect

August 2017

2a – Away from transect

August 2017

2b– Toward transect

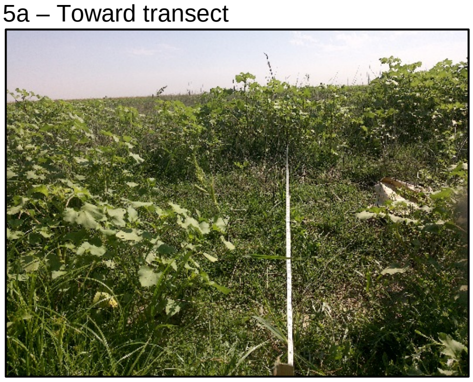
August 2017

2b – Away from transect

August 2017

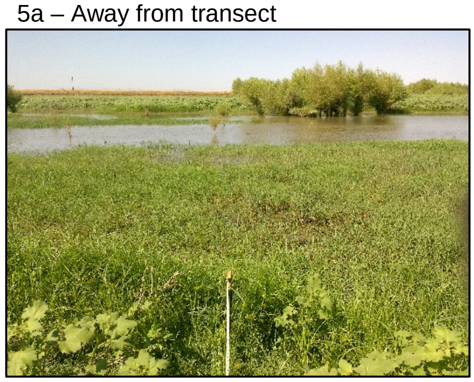
ESB Transect 5

5a – Toward transect



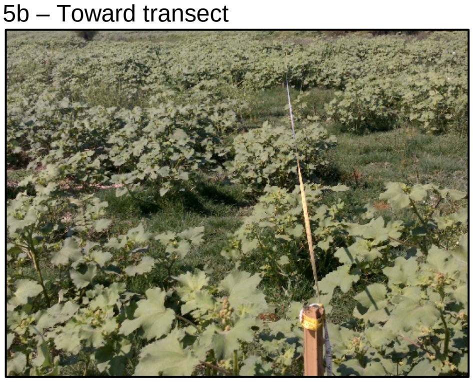
August 2017

5a – Away from transect



August 2017

5b – Toward transect



August 2017

5b – Away from transect

August 2017

ESB Transect 6

6a – Toward transect

August 2017

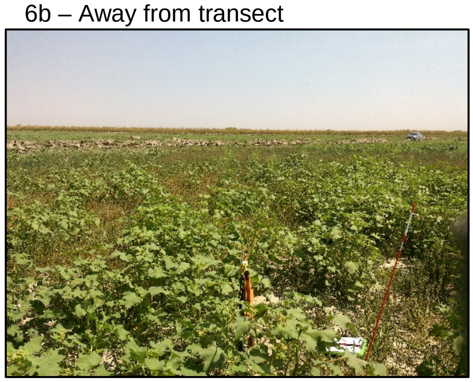
6a – Away from transect

August 2017

6b – Toward transect

August 2017

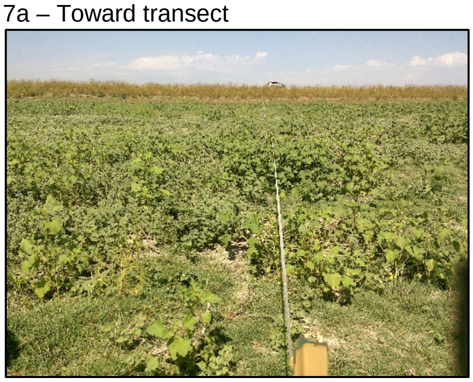
6b – Away from transect



August 2017

ESB Transect 7

7a – Toward transect

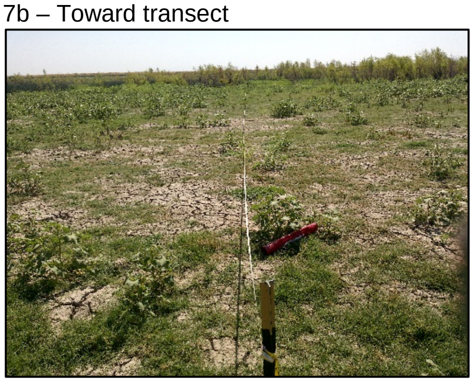


August 2017

7a – Away from transect

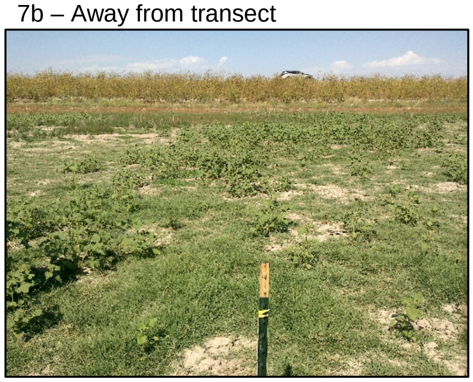
August 2017

7b – Toward transect



August 2017

7b – Away from transect



August 2017

ESB Transect 8

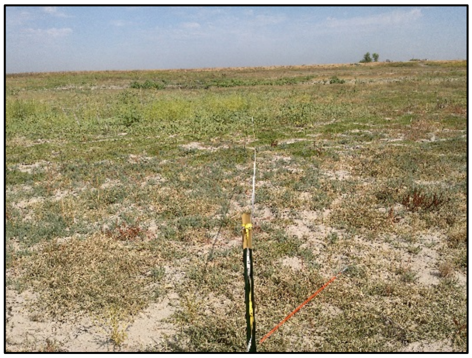
8a – Toward transect

August 2017

8a – Away from transect

August 2017

8b – Toward transect



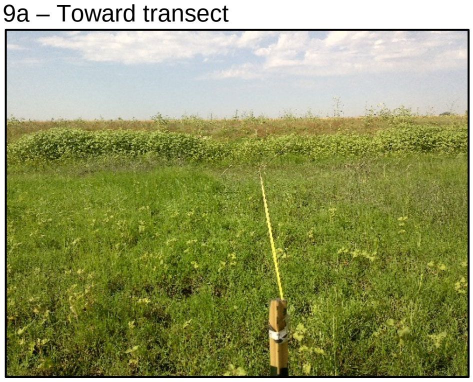
August 2017

8b – Away from transect

August 2017

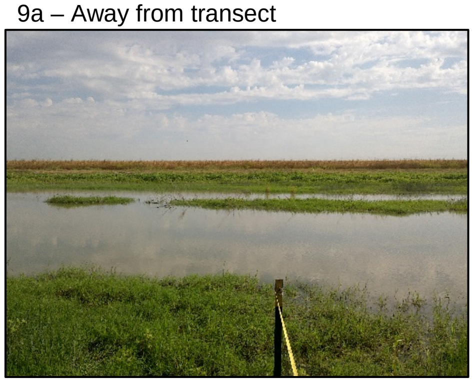
ESB Transect 9

9a – Toward transect



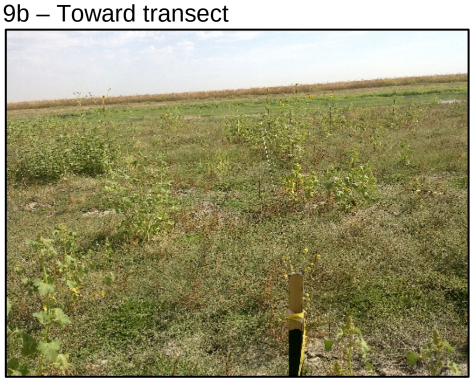
August 2017

9a – Away from transect



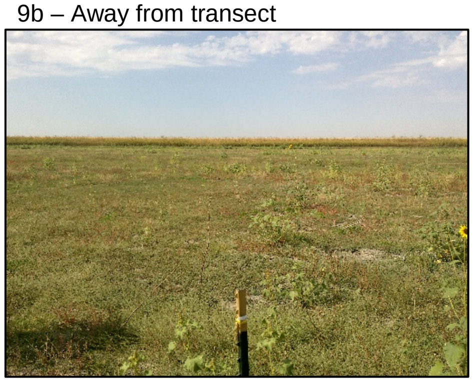
August 2017

9b – Toward transect



August 2017

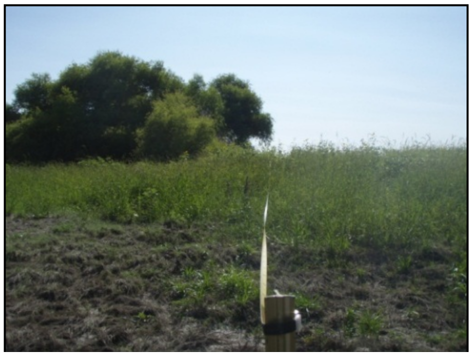
9b – Away from transect



August 2017

Reach 4B2, Transect 1

1a – Toward transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

1a – Away from transect


August 2011


June 2012


June 2013


May 2014

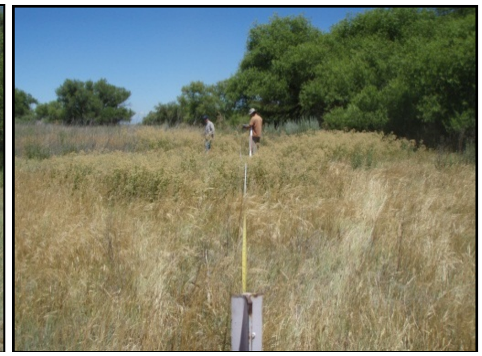

May 2015


August 2017

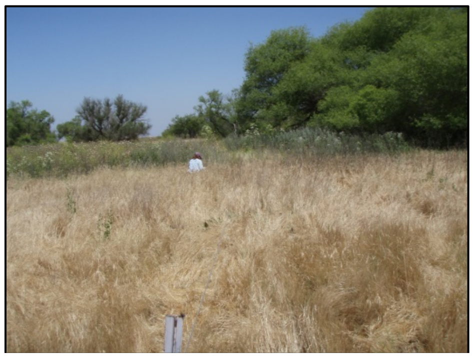
1b – Toward transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

1b – Away from transect


August 2011


June 2012


June 2013


May 2014


May 2015

August 2017 Not Available

Reach 4B2, Transect 2

2a – Toward transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

2a – Away from transect

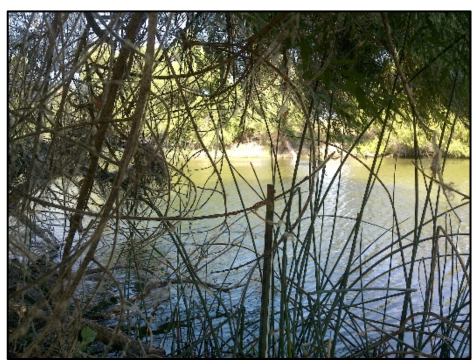

August 2011


June 2012


June 2013


May 2014


May 2015

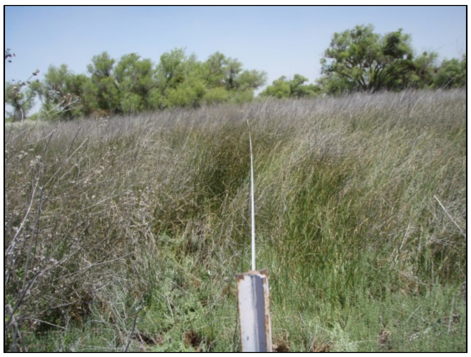

August 2017

2b – Toward transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

2b – Away from transect


August 2011


June 2012


June 2013


May 2014


May 2015


August 2017

PEER REVIEW DOCUMENTATION

PROJECT AND DOCUMENT INFORMATION

Project Name ___San Joaquin River Restoration Project__________________

WOID __FA660_____

Document _Vegetation Monitoring along the San Joaquin River_______________

Document Date _February 2018_________

Team Leader _____Blair Greimann__________________________

Document Author(s)/Preparer(s)__Rebecca Siegle, Scott O'Meara______________

Peer Reviewer _Blair Greimann______________________________
REVIEW CERTIFICATION

Peer Reviewer - I have reviewed the assigned Items/Section(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer: Blair Greimann Review Date: Feb 2018 Signature: ______________

I have discussed the above document and review requirements with the Peer Reviewer and believe that this review is completed, and that the document will meet the requirements of the project.

Team Leader: Blair Greimann Date: Feb 15, 2018 Signature: ______________