United States Department of the Interior
U.S. GEOLOGICAL SURVEY
Western Ecological Research Center
San Diego Field Station
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4/23/2020

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Dear Ms. Smith and Dr. Preston,

This letter transmits the U.S. Geological Survey (USGS) Western Ecological Research Center's Draft Final: Associations Between Arroyo Toads, Nonnative Species, Drought, and Impervious Surfaces in San Diego County. This work was completed under agreement number 5004597. We expect to publish these data in a synthesis paper in 2021 as part of a synthesis on status and threats to the arroyo toad.

Please note that this information is preliminary or provisional and is subject to revision. It is being provided to meet the need for timely best science. The information has not received final approval by the USGS and is provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the unauthorized use of this draft data for interpretation or resource decision-making.

Please direct any questions to me at (619) 206-5686.

Sincerely,

Robert Fisher

Principal Investigator

Draft Final: Associations Between Arroyo Toads, Nonnative Species, Drought, and Impervious Surfaces in San Diego County

Data Summary

Draft Final: Associations Between Arroyo Toads, Nonnative Species, Drought, and Impervious Surfaces in San Diego County

By: Chris Brown[1], Emily Perkins[1], Cynthia Hitchcock[2], Angelica Aguilar Duran[1], Lizzie Grolle[1], Elise Watson[1], and Robert N. Fisher[1]

U.S. GEOLOGICAL SURVEY
WESTERN ECOLOGICAL RESEARCH CENTER

Data Summary

Prepared for:
San Diego Association of Governments
and
San Diego Management and Monitoring Program

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List of Authorized Individuals:
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California Department of Fish and Wildlife
Scientific Collecting Permit (Entity) and MOU: SCP838

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Cover Photographs: Arroyo toad (*Anaxyrus californicus*) from San Diego River (photo by C. Brown), Western bullfrog (*Lithobates catesbieanus*) and crayfish (*Procambaris* sp.) (photos by C. Brown), and San Dieguito Creek habitat (photo by C. Brown).

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Executive Summary

Our research is focused on understanding the demography of amphibian taxa in southern California. Specifically, we investigate responses of these taxa to large scale threats, such as drought, wildfire, nonnative taxa, and loss or degradation of habitat. Our data provide land managers with results that inform their decision making. This document summarizes data collected for the purpose of understanding arroyo toad population persistence in seven major watersheds in southern California. Data were collected between 2015 and 2016 to compare with observations and records of arroyo toad locations documented in past years (before and up to 2010). Being a stream-breeding habitat specialist, this species has likely been negatively impacted by the persistent drought conditions between 2011 and 2014 in southern California. The arroyo toad also has specific aquatic habitat requirements for breeding; therefore, effects of upland urban development were examined, water temperature and relative conductivity were continually logged, and the presence/absence of non-native species was recorded. The scope of this document is not to provide a comprehensive report and interpretation of the data but to present a short narrative of our findings with the data itself in graphical or cartographic form for the reader to interpret as needed. As such, there are extensive appendices presenting maps, toad locations, site photos, and graphs of the water quality measured over time at each of 75 surface water monitoring locations. We also provide a protocol of how to program, install, and download data from the water quality loggers we used.

Introduction

Southern California has experienced more drought years in the last two decades than in the past century (Diffenbaugh et al. 2015). As a result, aquatic systems in San Diego County have experienced an increasing rain debt (i.e., the accumulated deficit in rainfall compared with the average; Savtchenko et al. 2015). Drought can exacerbate existing threats to native species; therefore, the potential consequences of the most recent drought (2011 through 2014) were considered in the San Diego Management and Monitoring Program's (SDMMP) Management and Monitoring Strategic Plan (MSP; see SDMMP and The Nature Conservancy (TNC) 2017). This plan included many conserved lands with riparian habitat, some of which also happened to have been impacted by the wildfires of 2007. In addition to drought and wildfires, two predominant potential threats to native species in this area include invasive nonnative species, and the effects of urbanization altering natural habitats downstream. We investigate these potential threats.

The taxon we address in detail as part of this research program is the arroyo toad (*Anaxyrus californicus*), which was federally listed as endangered in 1994 (USFWS 1994). The arroyo toad historically occurred along low gradient sandy streams in coastal California and Mexico from Monterey County, California, to Rio Santo Domingo in Baja California del Norte, Mexico (Sweet and Sullivan 2005). In San Diego County, the arroyo toad has been affected by loss of habitat to development, roads, introduced predatory fish and bullfrogs, and habitat degradation due to prolonged drought or aseasonal hydrology associated with urban runoff (Sweet and Sullivan 2005; Miller et al. 2012; Clark et al. 2013; Brehme et al. 2018). Observations of arroyo toads in San Diego County between 1990 and 2015 that were documented in the U.S. Fish and Wildlife Service Arroyo Toad Occurrence database indicate that arroyo toad populations have been restricted to the upper portions of all major coastal watersheds, except the Otay River watershed where it no longer occurs and the Carlsbad watershed where there were no previous records (USFWS 2015; Figure 1).

The USGS has been conducting various arroyo toad studies and conservation efforts throughout southern California in collaboration with many agency and academic partners for several decades. Previous work mostly focused on monitoring, inventory, and conservation of the arroyo toad. In 2015 and 2016, we began to systematically assess arroyo toad populations within the Management Strategic Plan Area (MSPA; SDMMP and TNC 2017) in support of their region-wide monitoring and management strategy. All known occupied or historically occupied areas within the MSPA were included in the study. However, we also included sampling in the MSPA's Management Unit 8 (MU8; upper Santa Margarita and San Luis Rey watersheds; Figures 1 and 2) which had no currently known occurrences with recruitment of arroyo toad within Conserved Lands. For these sites, we present data on hydroperiod, upland urbanization, and nonnative species which could be important to the life history and persistence of arroyo toads.

Hydroperiod is important for determining if surface water is available for the duration it takes for arroyo toads to breed and larvae to metamorphose (Madden-Smith et al. 2003). Upland urbanization affects hydroperiod because it is associated with increased surface water runoff due to impervious surfaces indicative of urbanized areas. Impervious surface is known to increase stream flow by reducing both soil infiltration and evapotranspiration (Trimble 1997; SDMMP and TNC 2017 Volume 2B Sec 3). This decrease in soil infiltration also causes streams in watersheds with more impervious surfaces to get up to maximum flow faster. These streams then dry out more quickly after a precipitation event because the stream lacks inputs from water that infiltrated through soil. Impervious surface can be a good indicator of human water use which prolongs the stream hydroperiod by causing stream flow during non-precipitation periods. Urban areas are also a source for nonnative species as permanent water could help invasive aquatics persist. Finally, impervious surfaces also impact stream geomorphology by increasing erosion along the bottom of the channel, making channels deeper and more incised (Dunne and Leopold 1978; Trimble 1997; Taniguchi and Biggs 2015). Data from this study provide a more in-depth understanding of the relationships between arroyo toads, nonnative species, drought, and impervious surface due to upland urbanization which can affect hydroperiod.

This summary presents the preliminary results from the first year of data collection (2015–2016). We summarize data on arroyo toad locations and which potential threats to the species were present at each site. Data from this study will not only inform managers at the local level for the SDMMP and MSP but also provide detailed information about this species that can be applied to the arroyo toad's broader geographic range.

Study Area

Our study area included riparian areas along the coastal streams of San Diego County within the MSPA (outside of Marine Corps Base Camp Pendleton: MCBCP; Figure 2). The MSPA is divided into 11 management units (SDMMP and TNC 2017). Within these 11 units, seven coastal watersheds in this study area are currently or were historically occupied by arroyo toads.

From north to south these seven are: Santa Margarita River, San Luis Rey River, San Dieguito River, San Diego River, Sweetwater River, Otay River, and Tijuana River (Figure 1; Table 1). We focused on conserved lands within these watersheds.

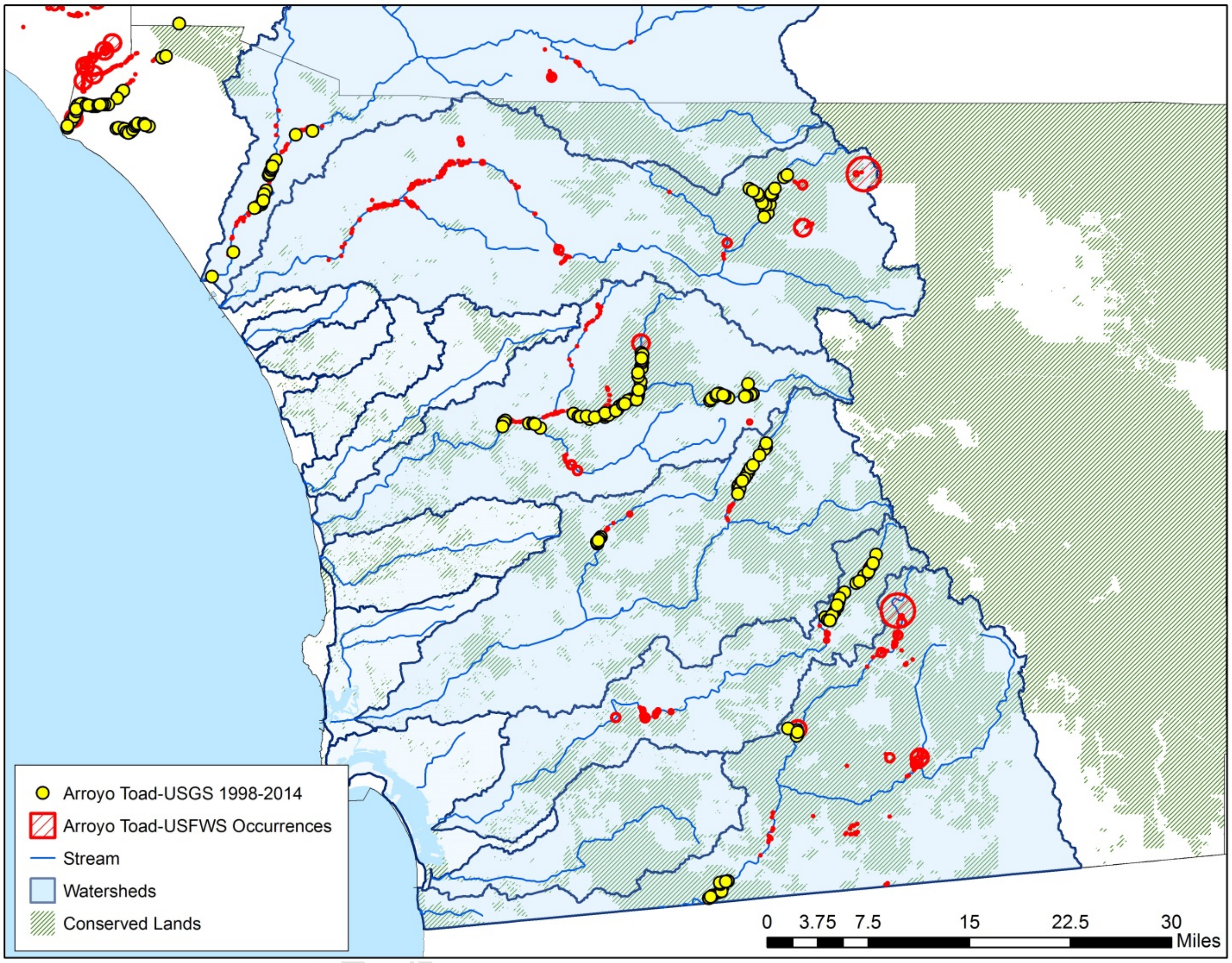

Figure 1. Arroyo toads in San Diego County, CA. Historic and recent records of arroyo toads within San Diego County. The red polygons and lines are occurrences listed in the USFWS Carlsbad Field Office database. The yellow dots are USGS arroyo toad observations recorded between 1998 and 2015.

Several of these populations are those we have previously studied for ongoing long-term monitoring and management programs mentioned above (Figure 1). These include a long-term monitoring program on MCBCP which began in 2005 and continues today (Miller et al. 2012; Brehme et al. 2014). Also within this program, the upper San Luis Rey watershed is continuously being studied for the Navy Base Coronado Remote Training Site, Warner Springs (Clark et al. 2013), while conserved lands within the MSCP region have been examined for impacts from wildfires (Brown et al. 2013).

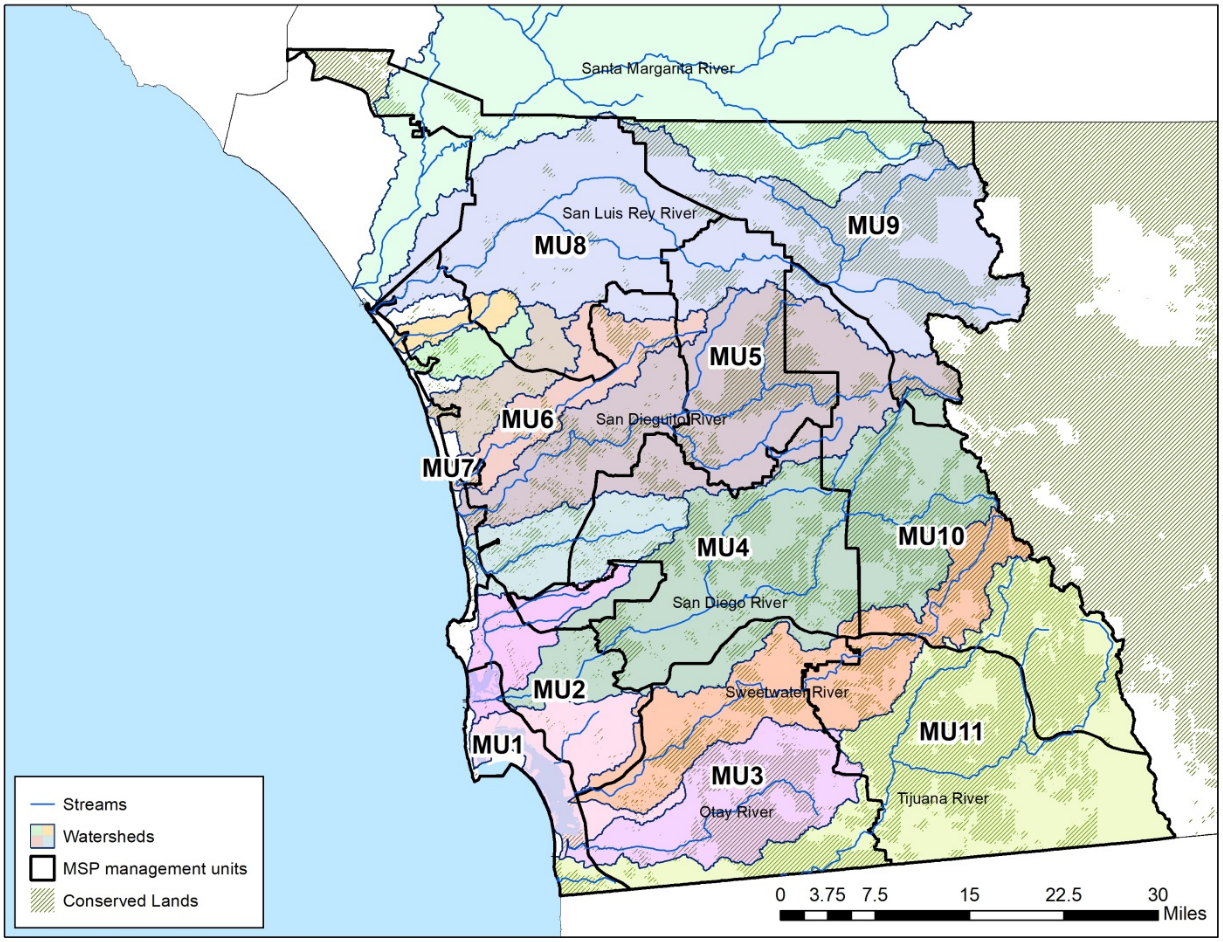

Figure 2. Arroyo toad study area overview, San Diego, CA. The study area includes 11 management units in the MSPA and 7 watersheds that are currently or were historically occupied by arroyo toad.

Table 1. Watersheds for this study from north to south with approximate area in hectares and percent area conserved. Values for the Santa Margarita and Tijuana rivers are given first for the entire watershed, then for San Diego County only. Number of surface water monitoring stations (STIC Sites) per watershed are included.

Watershed	Total Area (Ha)	Conserved Area (Ha)	Conserved (%)	Number of STIC Sites
Santa Margarita River	191,918 (50,787)	-na- (19,679)	-na- (39%)	11
San Luis Rey	144,835	40,235	28%	6
San Dieguito River	89,422	26,715	30%	32
San Diego River	112,078	43,821	39%	9
Sweetwater River	56,407	23,655	42%	3
Otay River	36,764	16,663	45%	7
Tijuana River (in California)	453,248 (120,998)	-na- 71,662	-na- 59%	8

Methods

Site Selection and Overview

All current known and historical locations for the arroyo toad within conserved lands in San Diego County were included, plus MU8 which has conserved lands within the MSCP but was not known for having arroyo toad recruitment. Since MU8 was lacking known arroyo toad history, we first conducted surveys for habitat that could be suitable for arroyo toads. Specifically, this included habitat having low gradient, ephemeral streams with sandy substrates and open banks for basking and foraging (USGS 2006a). Therefore, within this study there were some locations that were already monitored for arroyo toad by USGS from previous and continual work, other locations on conserved lands that were known to be occupied by arroyo toads but previously not monitored for this species by USGS, and some sites (such as in MU8) that were potentially suitable but previously unsurveyed locations on conserved lands (see Miller et al. 2012; Brown et al 2013; Clark et al 2013; Brehme and Matsuda et al. 2014).

Regardless of whether previous surveys had occurred or not, each stream was subdivided into 250-meter reaches using TOPO! and ArcGIS. Where the conserved lands boundaries permitted, we added several reaches beyond the known extent of the population to ensure we captured the entirety of potentially suitable habitat. Adjacent reaches were combined into 1.5 kilometer segments. We surveyed three 250-meter reaches that were randomly selected within each 1.5 kilometer segment. In accordance with the USGS aquatic species and habitat assessment protocols for the south coast region of California (USGS 2006a, 2006b), the selected coordinates for the start and end of each 250-m stream reach were mapped and placed into the USGS Stream Survey Database as predefined sites for ease and consistency of repeated surveys (Figure 3). The stream reaches were organized into 19 study sites based on watershed, land ownership, and access (Table 2).

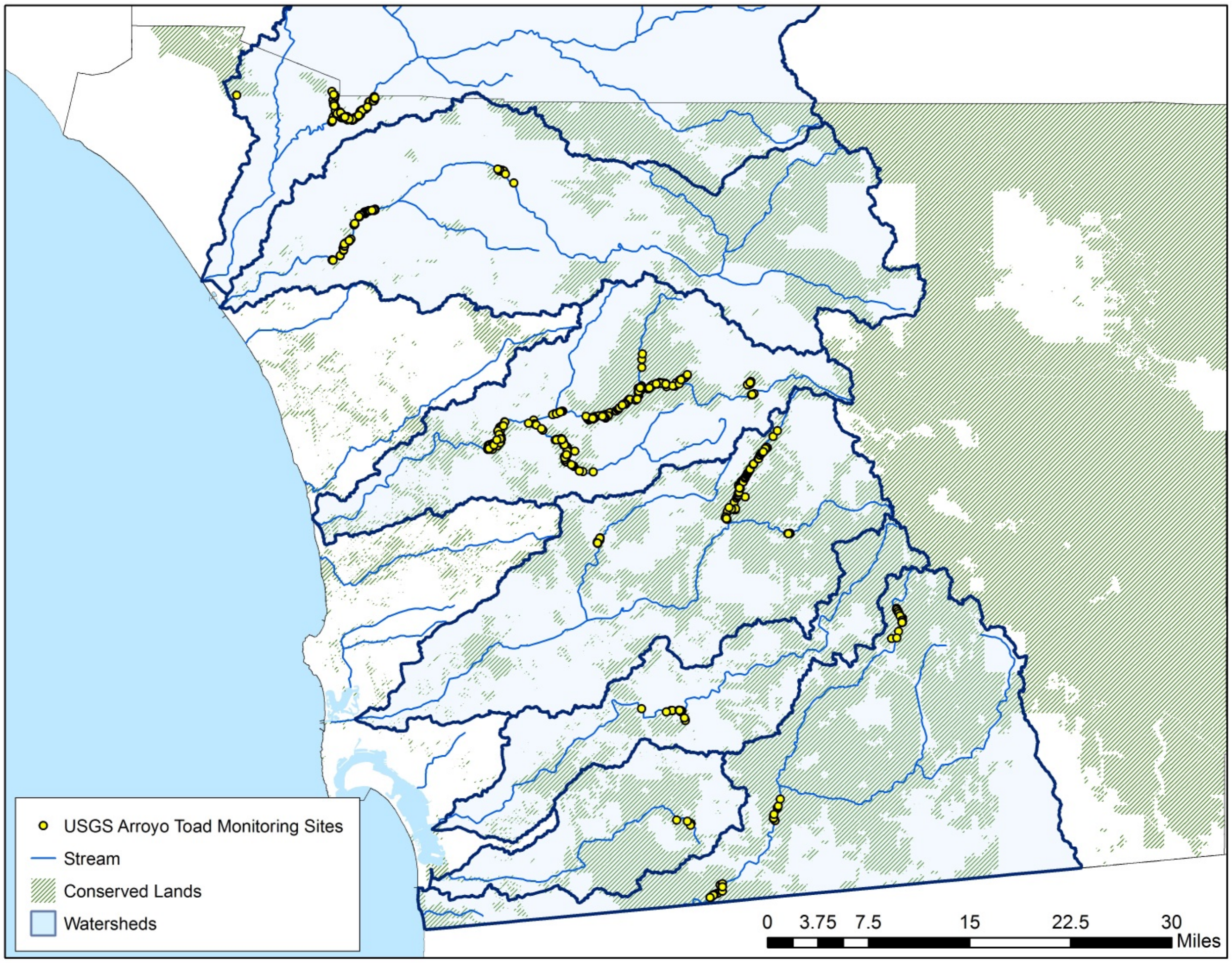

Figure 3. Arroyo toad monitoring locations, San Diego, CA. The 173 yellow dots represent the midpoints of 250-m stream reaches surveyed for arroyo toads and potentially suitable toad habitat as part of the monitoring program.

Table 2. Study sites and associated streams. Study sites by watershed from north to south with associated stream names (block), general location (decimal degrees, WGS84) and major landowners. Coordinates for specific reaches are provided in Appendix A.

Watershed	Study Site	Stream Names	General Location	Land Owners
Santa Margarita	Sandia Canyon	Sandia Canyon	33.417573°, -117.247702°	Falbrook Public Utilities District
	Middle Santa Margarita River	Santa Margarita River	33.406983°, -117.231017°	Fallbrook Public Utilities District, County of San Diego
San Luis Rey	Middle San Luis Rey	Middle San Luis Rey River	33.352926°, -117.033689°	County of San Diego
	Lower San Luis Rey	Lower San Luis Rey River	33.293351°, -117.229569°	County of San Diego
San Dieguito	Temescal Creek	Temescal Creek (Santa Ysabel)	33.149546°, -116.851209°	City of San Diego
	Upper Santa Ysabel Creek	Upper Santa Ysabel Creek Trib 11A, Upper Santa Ysabel Creek	33.117336°, -116.714073°	County of San Diego, San Dieguito River Park
	Middle Santa Ysabel Creek	Lower Santa Ysabel Creek, Black Canyon, Boden Canyon	33.109297°, -116.855343°	City of San Diego, US Forest Service, CDFW
	Lower Santa Ysabel Creek	Lower Santa Ysabel Creek, Upper San Dieguito River	33.081668°, -117.010680°	City of San Diego
	Santa Maria Creek 1	Santa Maria Creek	33.074978°, -116.982573°	City of San Diego
	Santa Maria Creek 2	Santa Maria Creek	33.046968°, -116.946619°	County of San Diego
	Santa Maria Creek 3	Santa Maria Creek	33.026431°, -116.916920°	County of San Diego
San Diego	Upper San Diego River	Upper San Diego River, Temescal Creek	33.033340°, -116.711270°	US Forest Service
	Cedar Creek	Cedar Creek	32.988904°, -116.733018°	US Forest Service
	San Vicente Creek	San Vicente Creek, West Branch San Vicente Creek	32.958313°, -116.906776°	City of San Diego, County of San Diego
Sweetwater	Middle Sweetwater River	Middle Sweetwater River	32.769531°, -116.818993°	CDFW
Otay Watershed	Dulzura Creek	Dulzura Creek, Pringle Canyon	32.662500°, -116.814128°	County of San Diego CDFW
	Jamul Creek	Jamul Creek	32.658079°, -116.871581°	CDFW
Tijuana	Pine Valley Creek	Pine Valley Creek	32.861746°, -116.520913°	US Forest Service
	Lower Cottonwood Creek	Lower Cottonwood Creek	32.589724°, -116.730888°	City of San Diego, US Forest Service

Visual Surveys

The 250-meter predefined sites were downloaded to handheld GPS units (Trimble Juno SB, Garmin eTrex 20, or Pro GPS and Avenza Maps for iPhone). We navigated to the coordinate using GPS, to get as close to the survey start point as possible. If the selected coordinate was off channel, we moved to the channel and collected a new coordinate by GPS to use as the survey start point. At the start of the survey, geotagged site photos were taken using either a Canon PowerShot D30, Apple iOS device, or Samsung Android device.

Daytime visual surveys were conducted at the selected predefined survey sites within each stream to determine presence of water and aquatic species (both native and nonnative) following USGS Stream Survey Protocols (USGS 2006a, 2006b). Two biologists walked upstream examining the water, stream bottom, and shoreline for aquatic species along the 250-meter reach. Care was taken to examine underneath overhangs and floating material. All stream-associated reptiles and amphibians, fish, and nonnative invertebrates and mammals were recorded.

Nighttime visual surveys were conducted for arroyo toads at a subset of sites within each stream system to determine timing of breeding activity and to collect genetic material (i.e., toe tips) for future analysis (not part of this study). Nighttime visual surveys were conducted in accordance with USGS Stream Survey Protocols (USGS 2006c). Two biologists with headlamps walked upstream examining the water, stream bottom, and shoreline for native and nonnative aquatic species along the 250-meter reach. All amphibians and reptiles encountered were recorded.

During each survey, data were collected on stream morphology, riparian habitat, upland habitat, water quality and flow (when present), and weather. Field data, including survey and species coordinates, were collected into a Trimble Juno SB and uploaded to the USGS Stream Survey Database upon returning from the field. Representative site and species photos were uploaded to the centralized repository and labeled by survey. Individual site descriptions, photos, maps and information for all survey areas were compiled (Appendix B).

Stream Morphology

We examined stream morphology at all study sites. We looked for low stream gradients and open banks as potential arroyo toad basking and foraging habitat. We also recorded substrate (e.g., silt, sand, gravel, cobble, boulder) and entrenchment ratio (calculated as the average bank full width over average flood prone width). Arroyo toads are most often found in low gradient streams with a sand or gravel substrate (Sweet and Sullivan 2005). High entrenchment ratios, indicating wide flood plains, have been associated with suitable arroyo toad habitat (Brehme and Matsuda et al 2014). We compared these features with average hydroperiods at the same sites to examine water availability in combination with suitable streambed structure for arroyo toads.

Stream Temperature, Intermittency, and Conductivity Loggers (STICs)

STIC Deployment and Data Collection

We established surface water monitoring sites approximately every 1.5 kilometers (Figure 4). Stream temperature, intermittency and conductivity (STIC) loggers were used to monitor surface water (Chapin et al. 2014). Additional surface water monitoring stations were added when atypical permanent pooling occurred (e.g., large bedrock plunge pools, artificial impoundments, etc.), which may have facilitated persistence of nonnative aquatic species. These surface water monitoring stations were configured for data collection compatible with the USGS surface water monitoring sites used in separate but related studies; (i.e., the Urban Aseasonal Flow study program; [Brown et al. 2016; Figure 4] and the California Water Quality Control Board surface flow monitoring stations, San Diego Region [SDRWQCB unpub. data]). We combined logger records from these studies to provide a summary of data on surface water availability and temperatures from coastal San Diego to the foothills of the Cuyamaca, Palomar, and Santa Margarita mountain ranges (Figure 4).

STICs are Onset Hobo Pendant temperature and light data loggers (Model UA-002-64) that have been modified to collect relative conductivity when submerged (Chapin et al. 2014). The modification, launch, deployment, and data upload were conducted according to the USGS STIC Protocol (Appendix C). STICs were configured and launched in the lab to record data at 30-minute intervals. Prior to deployment, the STIC number and coordinates were recorded into the Trimble Juno SB for upload to the USGS Stream Survey Database. A photo of the STIC number, serial number, and current GPS reading was also taken.

We used STIC conductivity readings as a surrogate for the availability of surface water because when the STIC was dry it recorded a conductance of zero. This allowed us to determine the hydroperiod of each site and compare it with the time needed for arroyo toads to breed and metamorphose. STICs were placed as close to the predefined location as possible. When the predefined location was outside of the stream channel, a new location in the stream channel adjacent to the predefined site was selected and the coordinates taken. Two STICs were deployed when uncharacteristic stream features were present, such as large bedrock pools within a typically sandy wash. This allowed for continual collection of water temperature and relative conductivity while also indicating the presence of permanent pooling water which could facilitate persistence of nonnative aquatic species within the system.

STIC Data Reduction

Data retrieved from STICs were compiled and analyzed in a Microsoft Excel template developed by Brown and Aguilar Duran (2017) derived from Chapin et al (2014). Each site had its own associated spreadsheet. From here, conductivity data were corrected for temperature and standardized for each site, and the maximum hydroperiod was determined. For most cases, stream was determined to be wet when temperature-corrected percent relative conductivity (%RC) was greater than 10%. Maximum hydroperiod was defined as the maximum number of consecutive data points where the percent relative conductivity was greater than 10% and recorded as the maximum number of consecutive wet days. This was determined automatically using the confines set up in the excel template. Data for each site were checked manually against site photos for anomalous records. Conductivities used to determine maximum hydroperiod were corrected for ringing (i.e., oscillations between the measured conductivity and zero or near zero values) and anomalies due to the STIC being buried by sediment. In these cases, site photos and changes in temperature variation were used along with the conductivity to determine the maximum hydroperiod.

For each STIC site, we graphed temperature (degrees celsius) and relative conductance (percent), overlaying each other on the X axis and date on the Y axis (see Appendix B). Graphs show how temperature and conductivity fluctuated throughout the duration of the study. Comparisons can be made between watersheds and STIC locations.

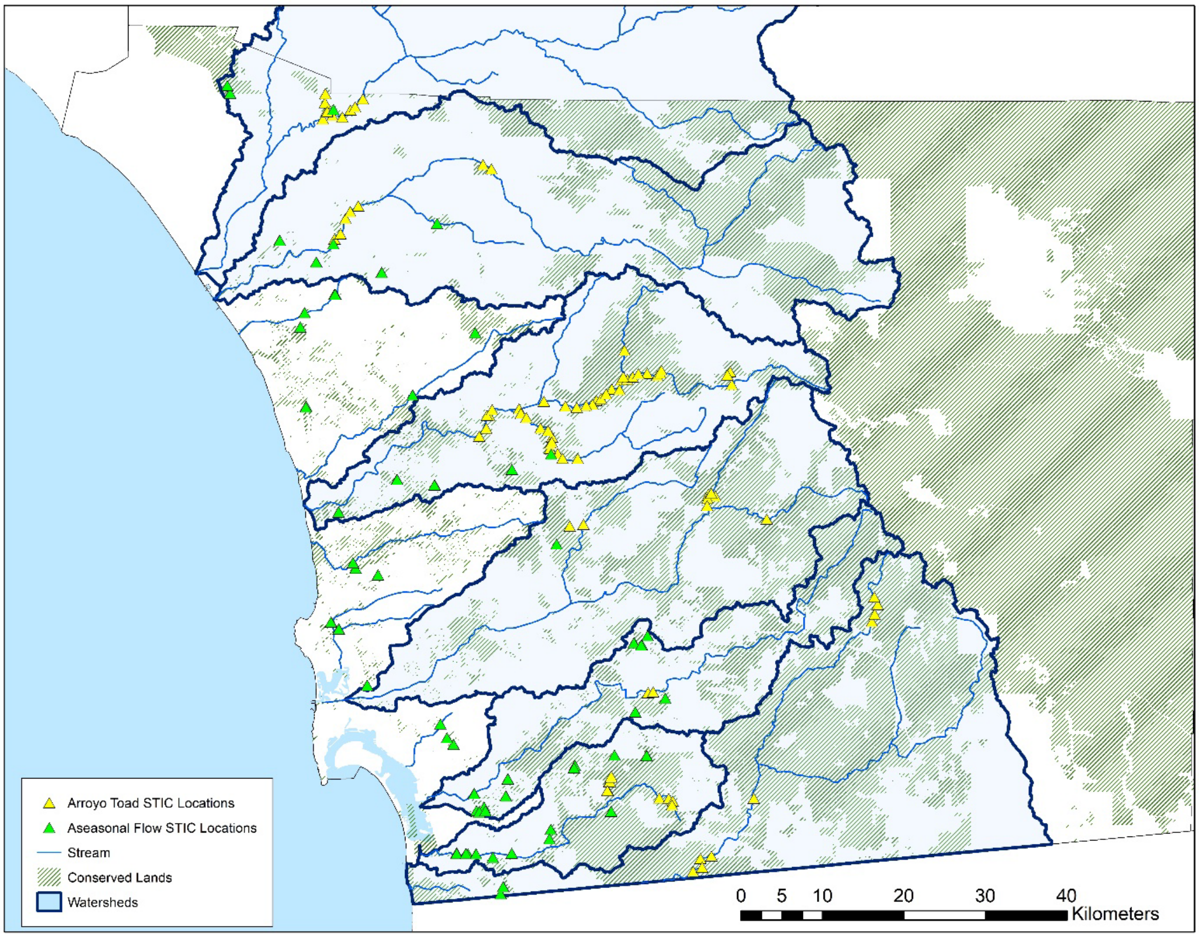

Figure 4. Stream surface water monitoring sites, San Diego, CA. There are 75 stream surface water monitoring sites (STIC sites) for the arroyo toad monitoring study (yellow triangles). There are 64 additional water monitoring sites from our related but separate aseasonal flow study throughout coastal San Diego County (green triangles; Brown et al. 2016).

Watershed Characteristics (GIS)

Watershed size and area of conserved lands per watershed were calculated in ArcGIS. Watershed size calculations were based on 8, 10, or 12 level Hydrologic Unit Codes (HUC; USGS 2013) and conserved lands calculations were based on the SANDAG Conserved Lands Database (SanGIS 2015). Watersheds were delineated using standard methods in ArcGIS (http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/how-watershed-works.htm). A

USGS Digital Elevation Model (DEM) from the National Elevation Dataset was used to create flow direction and flow accumulation rasters using the model below (Figure 5). This DEM has a horizontal spatial resolution of 10 meters and was created in 2013.

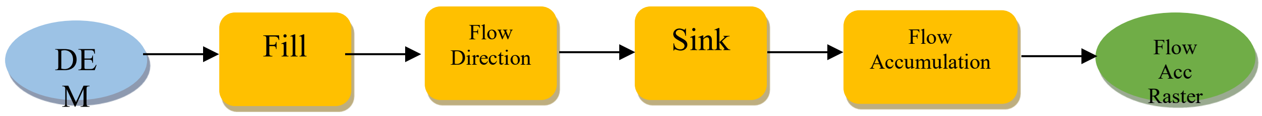

Figure 5. GIS flow accumulation model. Using ArcGIS to calculate stream flow accumulation. The tools used are in yellow boxes. The input and output are listed in ovals.

Using ArcGIS and the flow rasters created, each STIC location was snapped to the DEM derived stream line, using the tool, "Snap Pour Points" at a distance of 76.2 meters. Several locations were manually snapped where the point fell outside of the 76.2 meter snap distance or was very near a confluence of two stream lines. For each STIC location, a watershed was delineated and converted to a polygon.

For each watershed, several characteristics were calculated to describe the conditions draining to each STIC site. Using the SanGIS Land use layer from 2012, percent urban, percent agriculture, and percent open space were calculated for each watershed (summarized in Table A1). The total area of each watershed was calculated using GIS. The percent of each watershed covered with impervious surface was calculated from the National Land Cover Database (NLCD) for 2011 (https://catalog.data.gov/dataset/usgs-national-land-cover-dataset-nlcd-downloadable-data-collection) (Figure 6). Finally, the percent of each vegetation category was calculated using the Fire Resource and Assessment Program (FRAP) vegetation layer. This vegetation data is a compilation of the most recent vegetation data available throughout the county. It includes the AECOM 2014 vegetation map, preserve mapping where available, and CALVEG data in the gaps. Unified vegetation classes were calculated and can be found in SDMMP's MSP Volume 1 section 3 (SDMMP and TNC 2017).

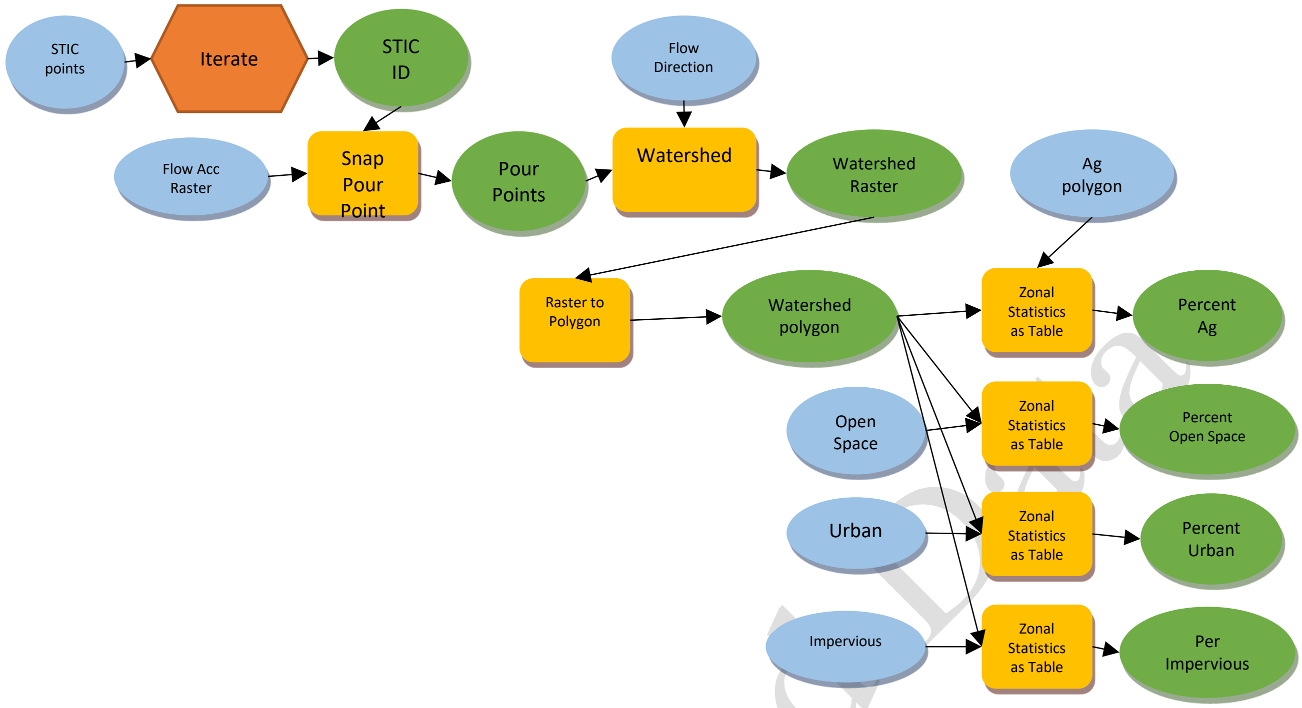

Figure 6. GIS land cover statistics model. Using ArcGIS to calculate watershed characteristics.

Impervious Surfaces

Impervious surfaces in this model consist of anthropogenic surfaces which are generally impervious to liquids (water). The impervious surface layers were developed using Landsat and high resolution imagery and modeled synthetic impervious surfaces (Homer et al. 2011). The change in impervious surfaces has been used to monitor land use changes over large geographic areas (Yang et al. 2003). We calculated the percent of impervious surfaces within the watershed above the surface water monitoring sites to examine the relationship between impervious surfaces and native and nonnative species.

Results

Visual Surveys

During the summer of 2015 and spring of 2016, 661 visual encounter surveys (survey visits) were conducted across the 19 study sites at a total of 173 arroyo toad monitoring stream reaches (stream reach = one 250-meter stream segment). During our surveys, 153 of these monitoring sites had detectable surface water during at least one site visit. Five native amphibians and two native stream-associated reptiles were detected along with two nonnative amphibian, one nonnative reptile, eight nonnative fish, two nonnative aquatic invertebrates, and one nonnative mammal species (Table 3).

Table 3. Results of visual surveys 2015–2016. Aquatic species observations (number of survey visits a species was detected) by watershed and site. Sites are grouped by watershed and listed from north to south; species are listed as native or nonnative. Five native amphibian and two native aquatic reptile species were detected including arroyo toads. Fourteen nonnative aquatic species were detected including two amphibian, one reptile, eight fish, two invertebrate, and one mammal species.

			Native Aquatic Species							Nonnative Aquatic Species															
Year	Site	Number of Survey Visits	Arroyo Toad	Western Toad	Western Spadefoot	California Treefrog	Pacific Treefrog	Western Pond Turtle	Two-striped Gartersnake	Bullfrog	African Clawed Frog	Red-eared Slider	Largemouth Bass	Redeye Bass	Green Sunfish	Bluegill Sunfish	Common Carp	Goldfish	Bullhead Catfish	Mosquitofish	Crayfish	Asian clam	Beaver	Total Species Observed
2015	Sandia Canyon	11				3				1					1						4			4
	Middle Santa Margarita River	26		7		3		2		4		2	4	3	4		4			10	6		1	12
	Middle San Luis Rey	9								4		1					1							3
	Lower San Luis Rey	9					1			2		1								1	1			5
	Temescal Creek	6																						0
	Upper Santa Ysabel Creek	9							1											2				2
	Middle Santa Ysabel Creek	26				4	10													1				3
	Lower Santa Ysabel Creek	9																						0
	Santa Maria Creek 1	3																						0
	Santa Maria Creek 2	19				7	6		2	4										4				5
	Santa Maria Creek 3	3																						0
	Upper San Diego River	-																						-
	Cedar Creek	-																						-
	San Vicente Creek	3																						0
	Middle Sweetwater River	5																						0
	Dulzura Creek	15															1							1
	Jamul Creek	2																						0
	Pine Valley Creek	-																						-
	Lower Cottonwood Creek	9																						0
	2015 Total:	164	0	7	0	17	17	2	3	15	0	4	4	3	5	0	6	0	0	18	11	0	1	
2016	Sandia Canyon	12				1	5			1			1	2						2	10	1		8
	Santa Margarita River	38		1			4	2		31		1		18	8		10		3	20	22	8	1	13
	Middle San Luis Rey	10	1	2						3										1				4
	Lower San Luis Rey	32		2	1	2	27			5					1					6	20			8
	Temescal Creek	9	1	1			3			1														4
	Upper Santa Ysabel Creek	11	1	4		1	10			1										1				6
	Middle Santa Ysabel Creek	87	19	7		38	44		7							2		1		6				8
	Lower Santa Ysabel Creek	42				4	4																	2
	Santa Maria Creek 1	14		1																				1
	Santa Maria Creek 2	50	19	19		8	24	1		25										14	4			8
	Santa Maria Creek 3	8																						0
	Upper San Diego River	60	23	6		39	11	7		2					3					1				8
	Cedar Creek	10	9			7	4		1						1									5
	San Vicente Creek	6				4	6			5										1	3			5
	Middle Sweetwater River	7				3	4				4				1		2				4			6
	Dulzura Creek	8																						0
	Jamul Creek	4						4		4											2			3
	Pine Valley Creek	27	9	1		7	9		7															5
	Lower Cottonwood Creek	62	2				3			3														3
	2016 Total:	497	84	44	1	114	158	14	15	81	4	1	1	20	14	2	12	1	3	52	65	9	1	

Native and Nonnative Aquatic Species

All watersheds in the study area contained both native and nonnative aquatic species. Native aquatic species observed included the two-striped gartersnake (*Thamnophis hammondii*), western pond turtle (*Emys marmorata*), western toad (*Anaxyrus boreas*), western spadefoot (*Spea hammondii*), California treefrog (*Pseudacris cadaverina*), and Pacific treefrog (*Pseudacris regilla*). In spite of very low rainfall levels, many nonnative aquatic species which rely on permanent water were also observed during visual surveys, including red-eared slider (*Trachemys scripta*), bullfrog (*Lithobates catesbeianus*), African clawed frog (*Xenopus laevis*), carp (*Cyprinus carpio*), mosquitofish (*Gambusia affinis*), green sunfish (*Lepomis cyanellus*), redeye bass (*Micropterus coosae*), largemouth bass (*Micropterus salmoides*), goldfish (*Carassius auratus*), bullhead catfish (*Ameiurus* sp.), crayfish (*Procambarus* sp.), Asian clam (*Corbicula* sp.), and beaver (*Castor canadensis*; Table 3; Figures 7–9).

Number of native species ranged from no native species per site to a total of of five per site (Pine Valley and Santa Maria creeks; Table 3; Figures 7–9). The Santa Margarita River had by far the largest number of nonnative aquatic species detections during the study (Table 3; Figures 10–14). Of the 14 aquatic nonnative species observed during this study, 11 were present at the Santa Margarita River (the exceptions being the African clawed frog, goldfish, and bluegill sunfish).

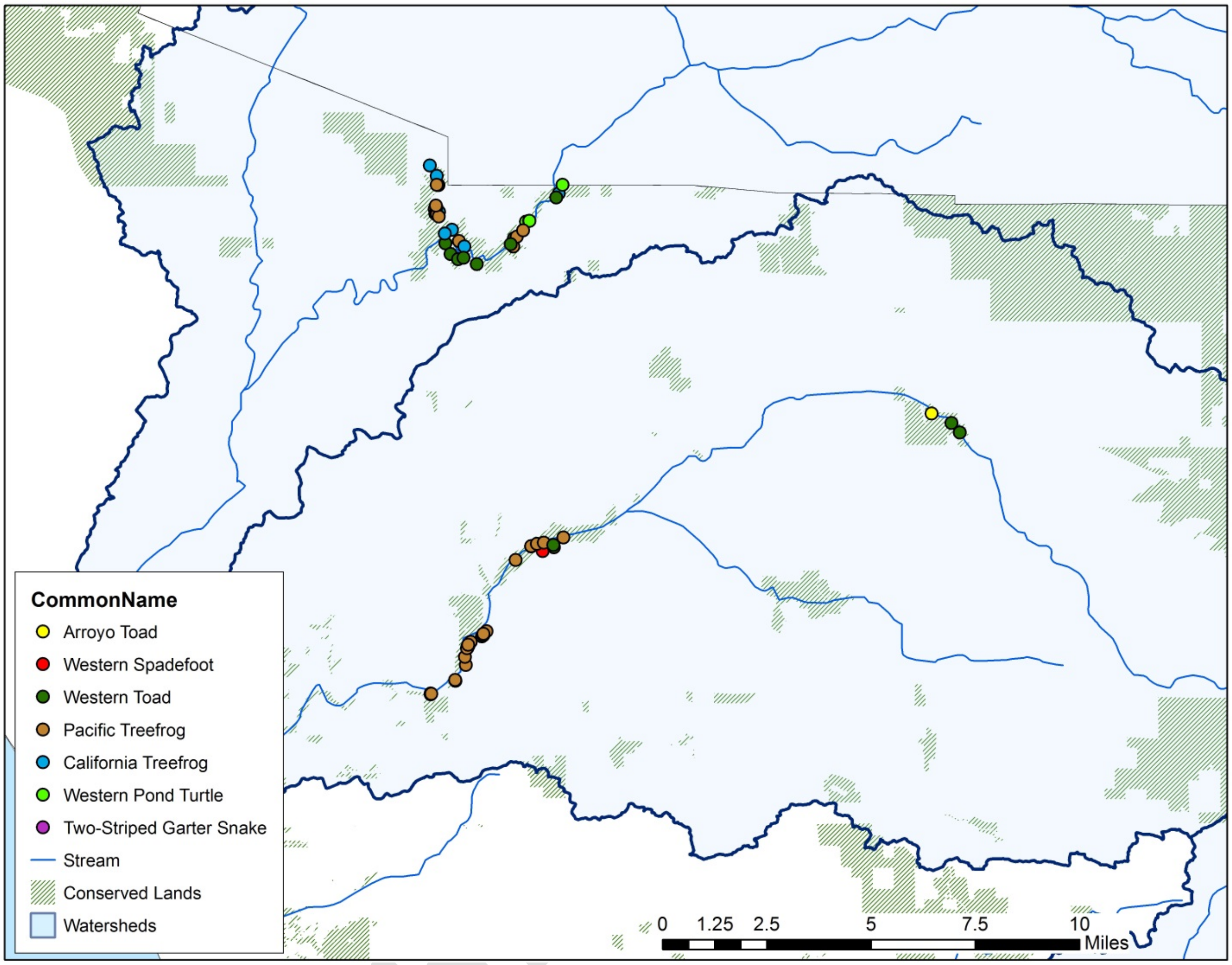

Figure 7. Map of native aquatic species observations in the Santa Margarita and San Luis Rey watersheds during 2015 and 2016. Six native aquatic species were observed in addition to the arroyo toad. See table A2 for complete list of species observations by watershed, stream/river, and/or reach number.

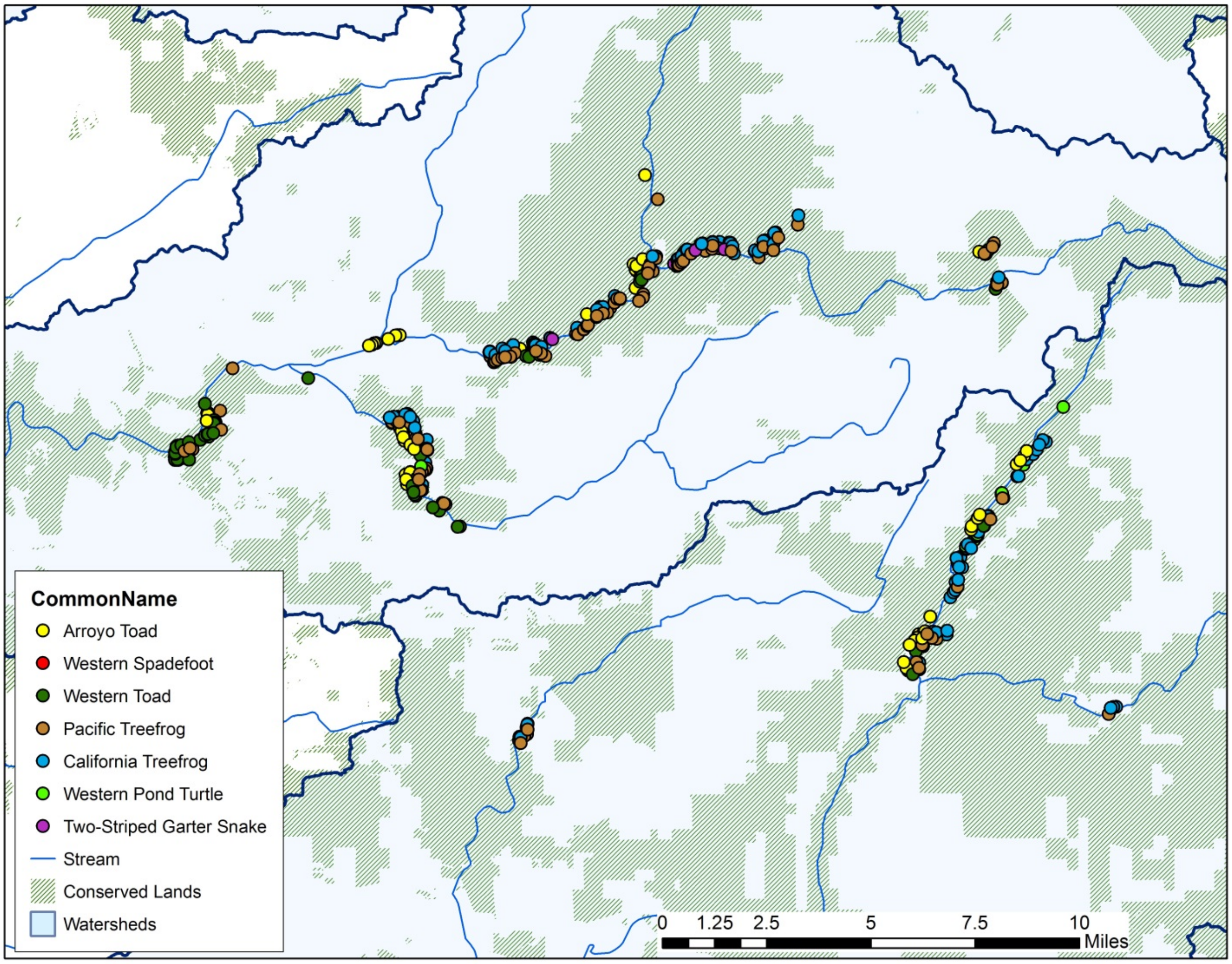

Figure 8. Map of native aquatic species observations in the San Dieguito and San Diego watersheds during 2015 and 2016. Six native aquatic species were observed in addition to the arroyo toad. See table A2 for complete list of species observations by watershed, stream/river, and/or reach number.

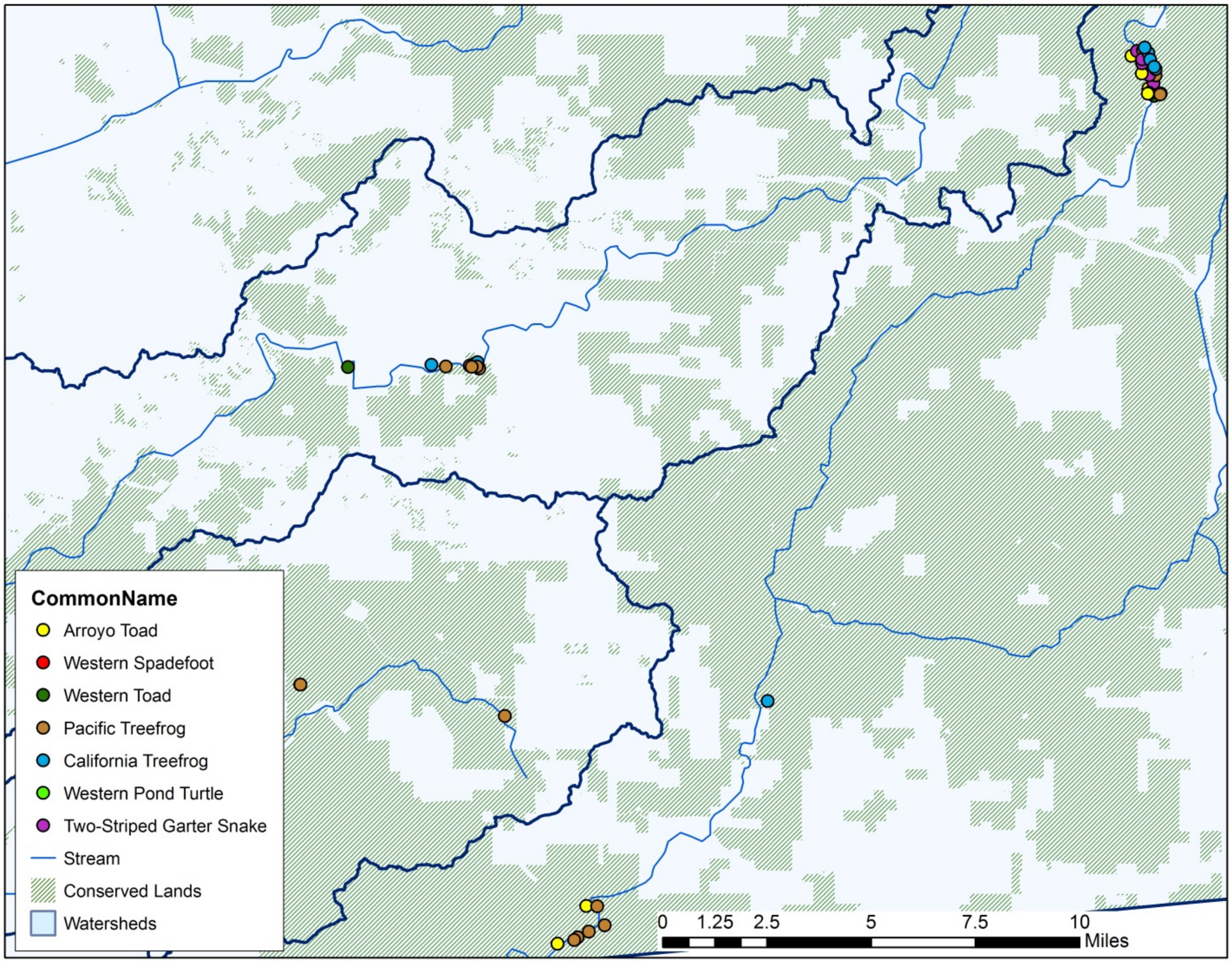

Figure 9. Map of native aquatic species observations in the Sweetwater, Otay, and Tijuana watersheds during 2015 and 2016. Six native aquatic species were observed in addition to the arroyo toad. See table A2 for complete list of species observations by watershed, stream/river, and/or reach number.

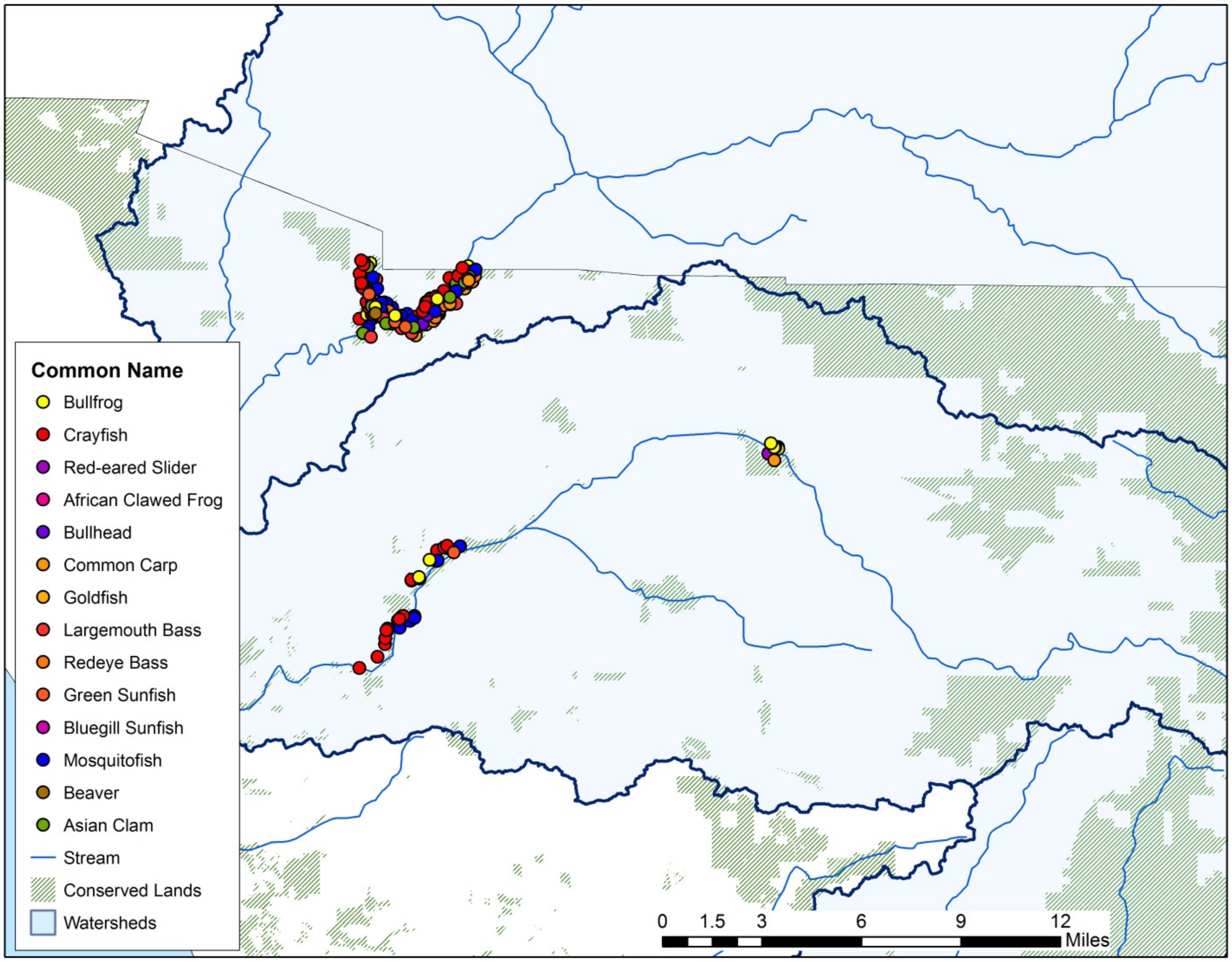

Figure 10. Map of nonnative aquatic species observations in Santa Margarita and San Luis Rey watersheds during 2015 and 2016. Eleven nonnative aquatic species were detected during the 2015–2016 stream surveys. See table A2 for complete list of species observations by watershed, stream/river, and/or reach number.

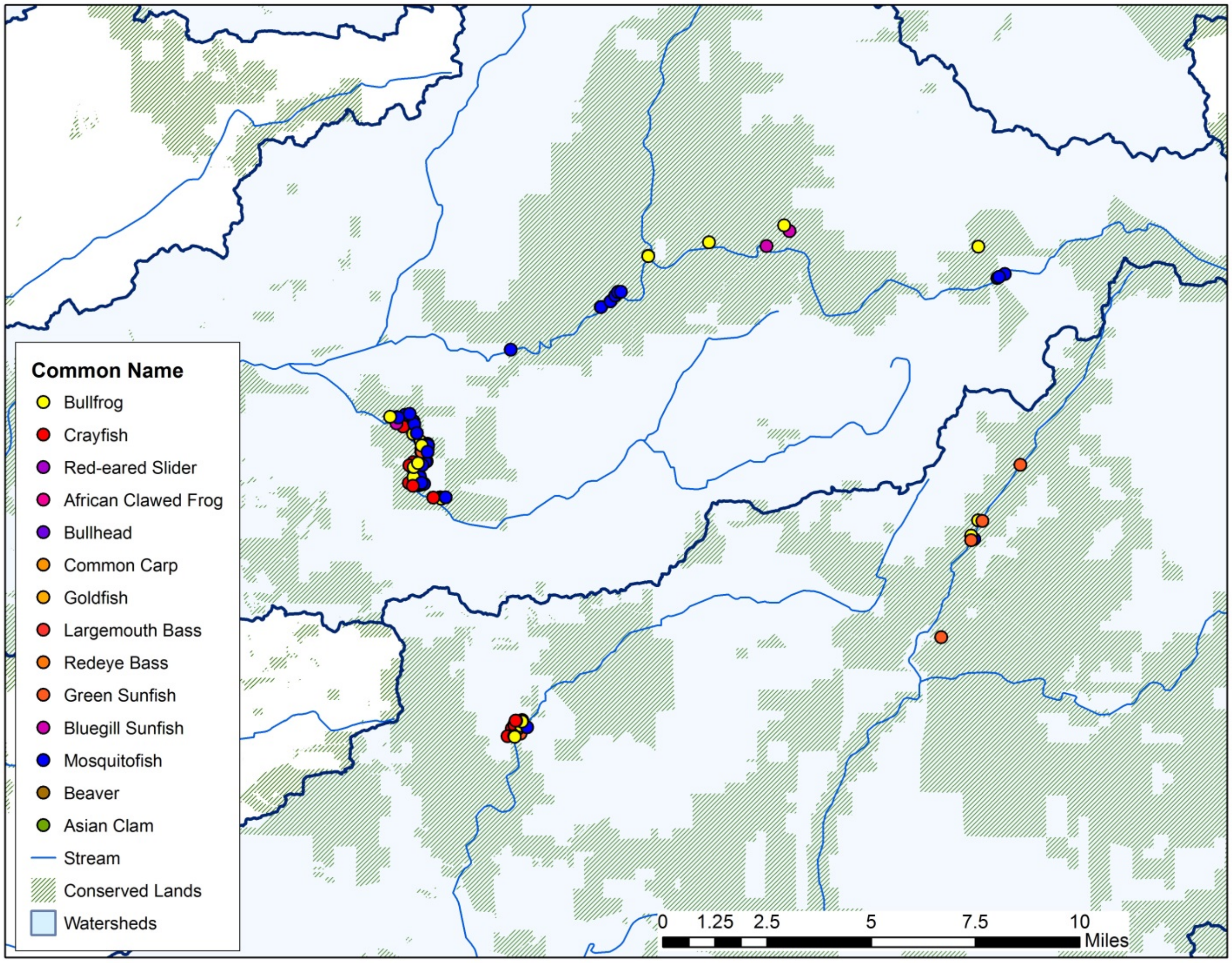

Figure 11. Map of nonnative aquatic species observations in the San Dieguito and San Diego watersheds during 2015 and 2016. Seven nonnative aquatic species were detected during the 2015–2016 stream surveys. See table A2 for complete list of species observations by watershed, stream/river, and/or reach number.

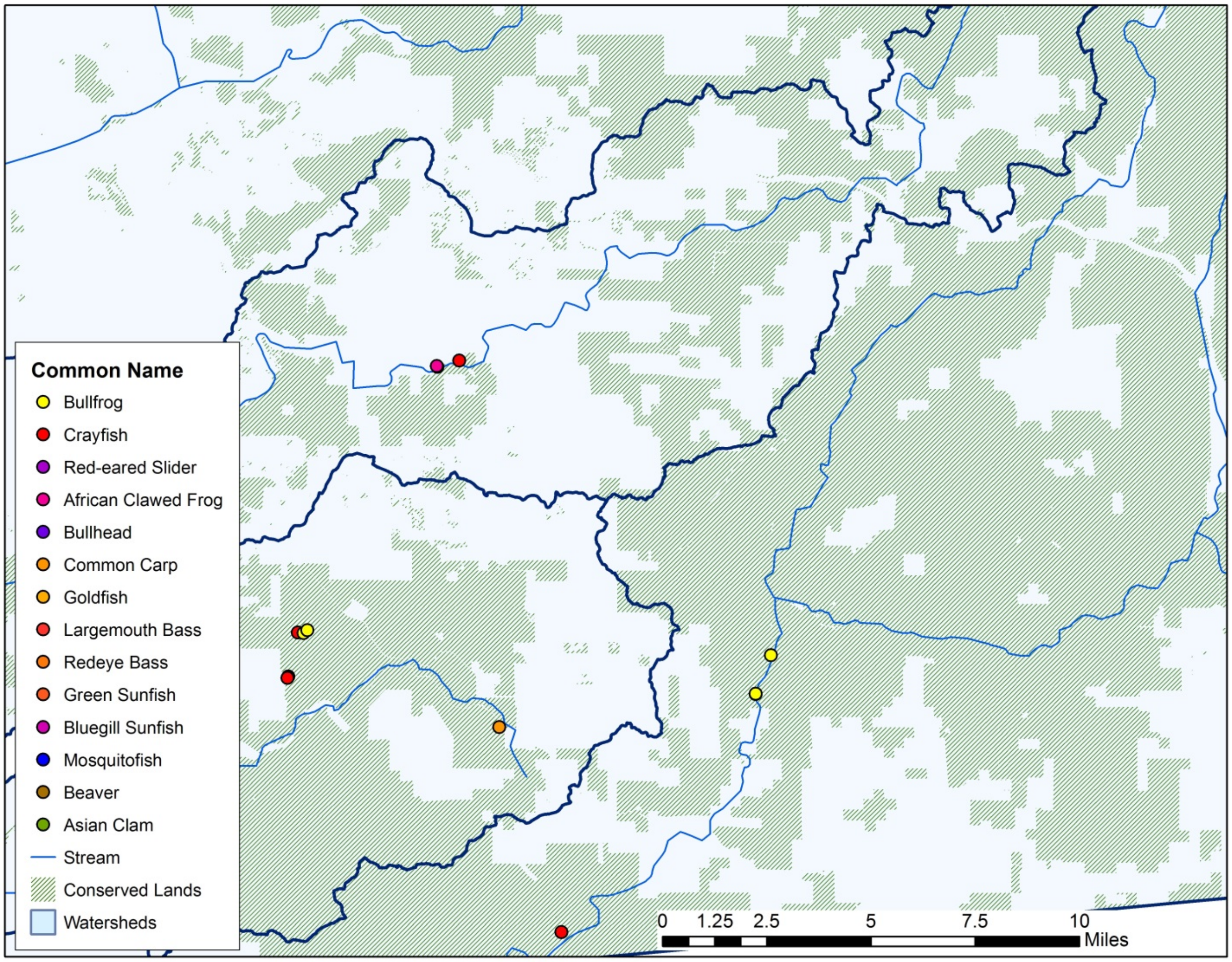

Figure 12. Map of nonnative aquatic species observations in the Sweetwater, Otay, and Tijuana watersheds during 2015 and 2016. Five nonnative aquatic species were detected during the 2015–2016 stream surveys. See table A2 for complete list of species observations by watershed, stream/river, and/or reach number.

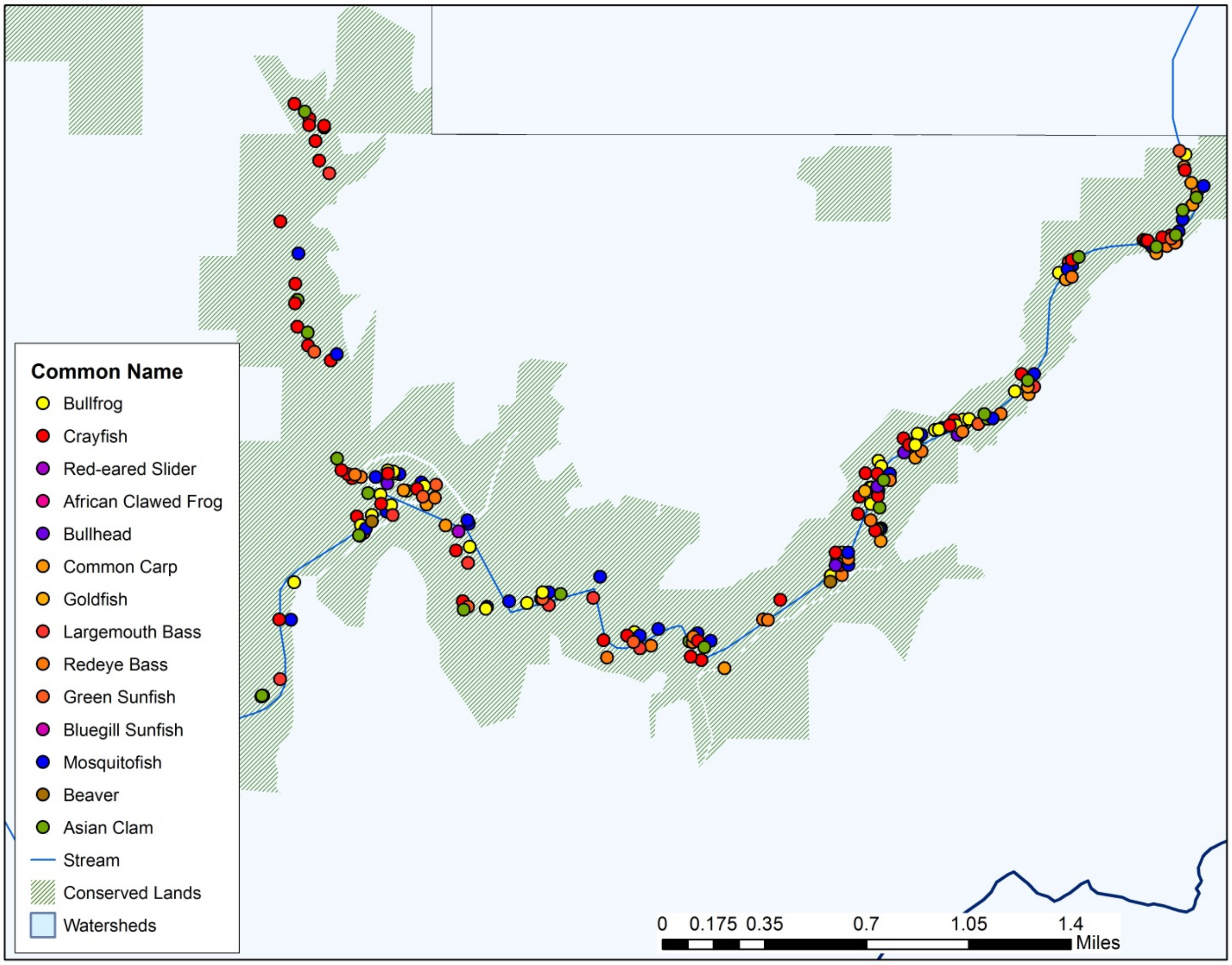

Figure 13. Map of nonnative aquatic species observations in the Santa Margarita River watershed 2015–2016. The Santa Margarita River has high flow perennial water, and all but three of the nonnative aquatic species were detected during the surveys.

Figure 14. Map of nonnative aquatic species observations in the Santa Maria Creek during 2015 and 2016. Santa Maria Creek has perennial pooling water within the stream channel and large pond adjacent to the creek. Santa Maria Creek contained large numbers of bullfrogs, crayfish, and mosquitofish during the surveys.

Arroyo Toad Observations

No arroyo toads were detected in summer of 2015, but in 2016 arroyo toads were detected in 22 streams at 38 of the 173 250-m predefined segments (Figure 15), which also included 10 of our 75 surface monitoring sites (see STIC results). Recruitment, however, was detected in only five of the 22 streams. Collectively, arroyo toads were observed in a total of four watersheds. Arroyo toad recruitment was detected in the San Dieguito watershed along Santa Maria, Santa Ysabel, and Temescal creeks. Recruitment was also observed in the San Diego River and Pine Valley Creek (upper Tijuana River watershed; Figure 15). Only adults were detected in the middle San Luis Rey River and Cottonwood Creek. While prolonged drought rendered some of the sites dry at the time of our surveys (Figure 16), several still had arroyo toad adults but no recruitment. We also documented a new site (not previously surveyed), that happened to be dry but still had arroyo toad adults. No arroyo toads were detected in the Santa Margarita River watershed outside of MCBCP or within the Sweetwater and Otay River watersheds during the 2015–2016 surveys.

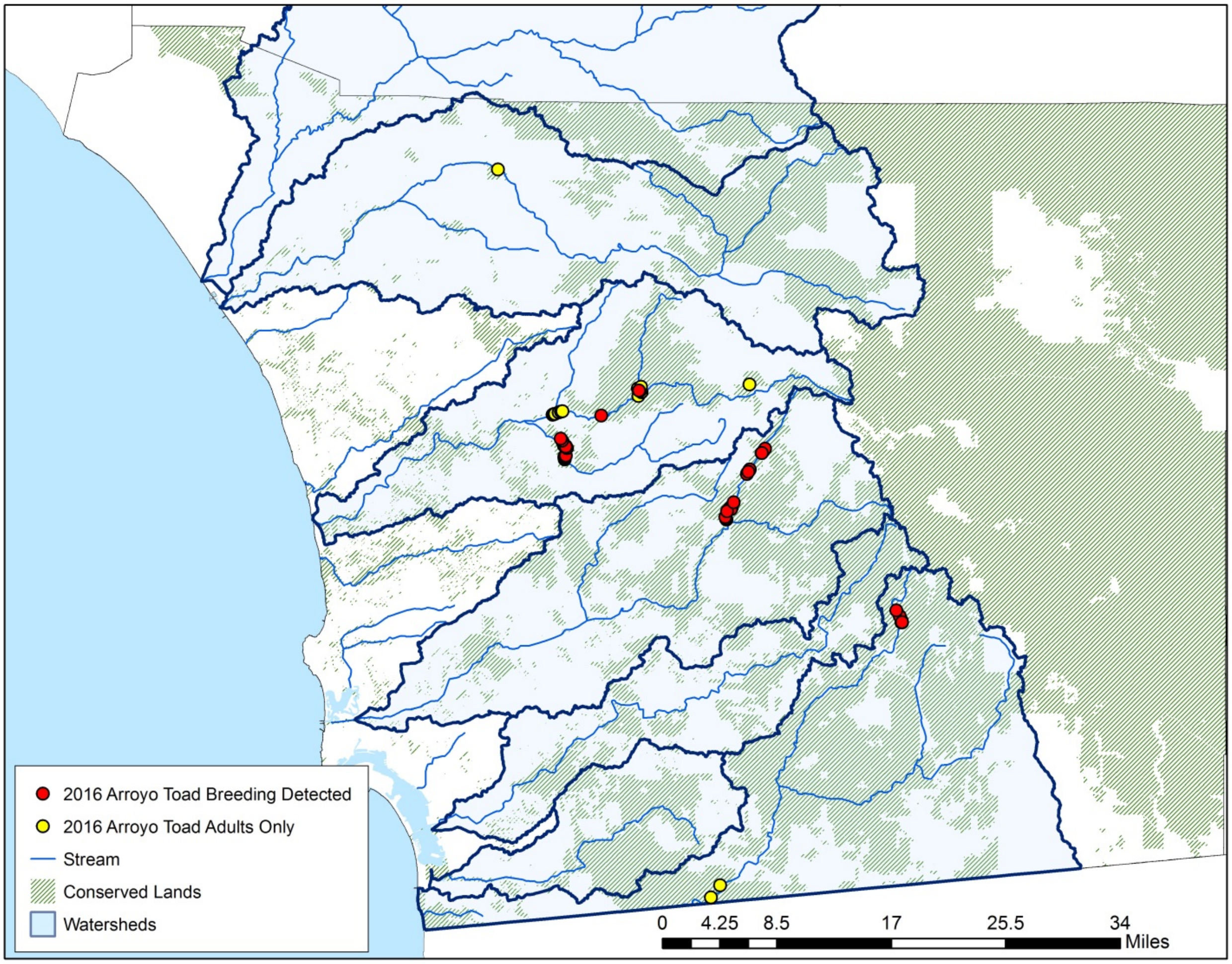

Figure 15. Map of arroyo toad observations within each watershed in 2016. Red dots represent where arroyo toad larvae and/or metamorphs were detected and yellow dots represent sites where only adults were detected.

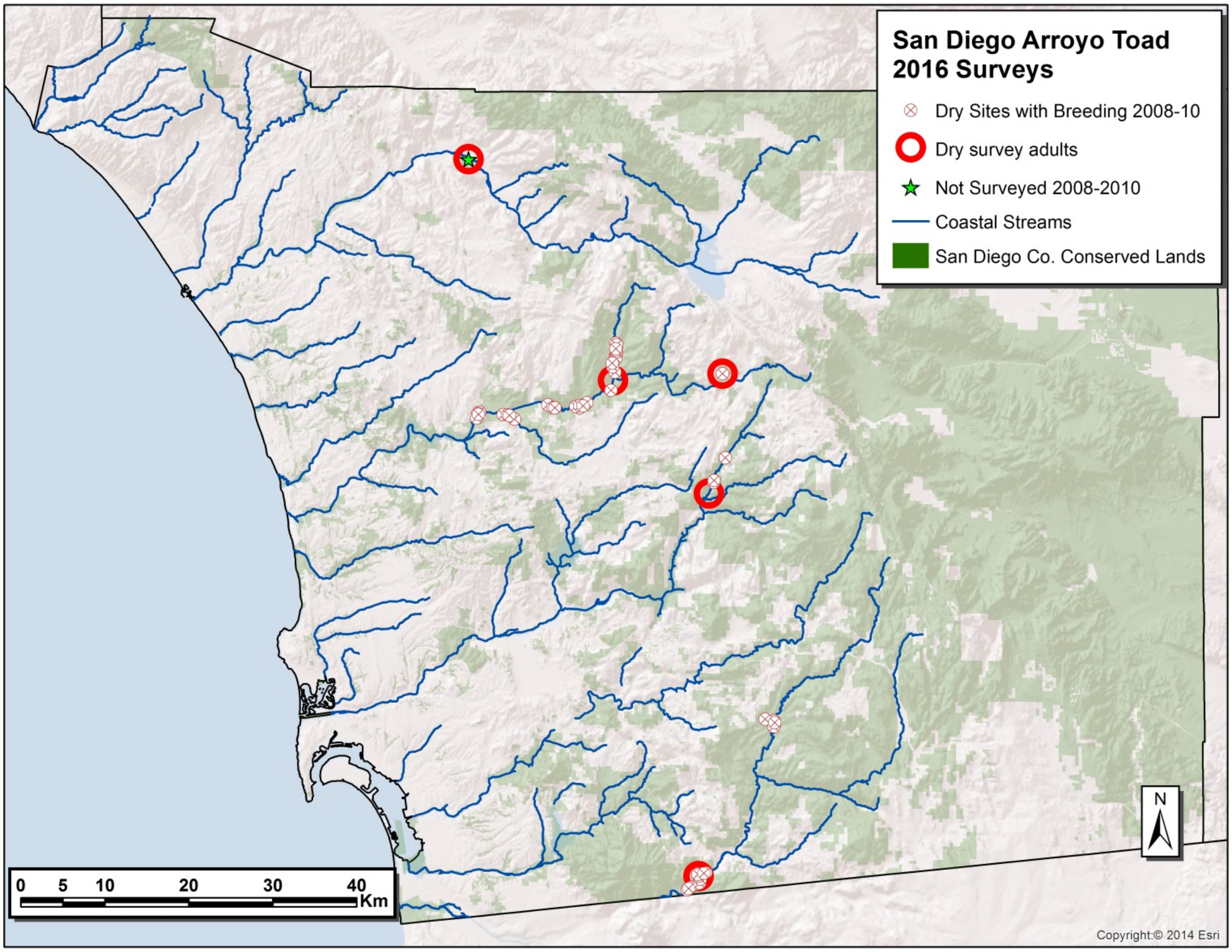

Figure 16. Map of dry survey observations in 2016. The small red circles with a red "X" represent monitoring sites that had arroyo toad recruitment during 2008 to 2010 surveys but were dry during all surveys in 2016. The large red circles indicate the dry sites where adults were observed during 2016 nighttime surveys. The green star marks a new monitoring site for 2015 where USGS had no previous observations but detected an arroyo toad in 2016.

Stream Morphology

We found that, where recruitment was observed, sites may have lower entrenchment ratios compared to other sites with toads but no recruitment detected (Table 3). Sites with recruitment had an average entrenchment ratio of 2.5 (bankfull width in meters/flood prone width in meters), and sites without observed recruitment had an average ratio of 5.8. One site, Upper Santa Ysabel Creek Tributary, had a much higher entrenchment ratio than the other sites and was largely responsible for the higher entrenchment ratio average of non-recruiting sites.

Stream Temperature, Intermittancy, and Conductivity loggers (STIC)

We did not have complete data for all sited for the entirety of the survey period due to technical problems with the STICs (e.g., dead batteries, problems recording or offloading data, lost STICs, and or late initial deployment dates). Because of this, the data used for analysis were confined to records between January 4th, 2016 and September 19th, 2016. This date range also incorporated the breeding season of the arroyo toad and included seasonal rain events. The first major rain of the season occurred on January 4, 2016, and by September 19, 2016, 250 days later, the arroyo toad breeding season was complete. By this time the 2016 cohort of toads, if present, should have metamorphosed and dispersed to the upland.

Data were extensive for STIC loggers; therefore, we present the detailed graphs for each STIC logger in an appendix with the site photos (Appendix B). These graphs present relative conductivity and temperature over the duration of the data logger deployment. Some logger measurements fluctuated more than others indicating variability in hydroperiod and temperatures across sites. Relative conductivity was calibrated to range between 0 and 100%. Readings of 0 indicated that several of the STIC locations became dry at some point during the study (see Appendix B). Temperatures for all creeks ranged from 0˚C (lower limit) to 62.5˚C (dry streambed).

Hydroperiod and Arroyo Toad Breeding Cycle

We summarize hydroperiod measurements across 12 streams currently or recently occupied (according to our past work) by arroyo toads in both graphical and tabular form (Table 4; Figure 17). Table 4 illustrates young of the year found in 2016 versus 2008–2010 and shows whether or not bullfrogs were also present. Since the average breeding cycle of arroyo toads requires ~70–80 days from egg-laying through metamorphosis, beginning as early as March and metamorphosing as late as October (Madden-Smith et al. 2003), measurements indicate several sites were unlikely to have enough water to sustain a new cohort in 2016. Figure 17 shows hydroperiod by reach for all of the 75 surface water monitoring stations.

Site hydroperiods ranged from 2 days to 228 days, the latter being the total sample period for presumed breeding and larval development phases. Five sites had a smaller hydroperiod than is required for the arroyo toad breeding cycle, and while most had arroyo toads present, there was no recruitment at these sites. There were seven sites having an average hydroperiod of over 80 days and these all had arroyo toads present. Recruitment was documented at five of these seven sites.

Table 4. Hydroperiod, stream morphology, and presence of arroyo toad and bullfrog. Average hydroperiod across the study sites measured in days, Bold sites indicate where arroyo toads have been documented recently and highlighted sites indicate where recruitment was detected in 2016.

Watershed	Site	Number of Sites with STICs	Avg. Meas. Hydroperiod 11/1/15-9/19/2016	Avg. Julian Day Until Dry	Max. Julian Day Until Dry	Avg. Bank Width (meters)	Avg. Flood Prone Width (meters)	Avg. Entrenchment Ratio	Arroyo Toad YOY 2016	Arroyo Toad YOY 2008-2012	Bullfrogs Present 2016
Santa Margarita	Sandia Canyon	3	Perennial	Perennial	Perennial	3.24	5.89	1.92	0	NS	Present
	Middle Santa Margarita River	7	Perennial	Perennial	Perennial	12.71	19.17	1.53	0	NS	Present
San Luis Rey	**Middle San Luis Rey**	**2**	**3**	**0**	**0**	**21.03**	**29.00**	**2.50**	**0**	**NS**	**Present**
	Lower San Luis Rey	5	Perennial	Perennial	Perennial	6.42	14.29	3.09	0	NS	Present
San Dieguito	**Temescal Creek**	**2**	**57**	**110**	**116**	**13.31**	**26.93**	**2.97**	**0**	**Present**	**Present***
	Upper Santa Ysabel Creek	**3**	**180**	**173**	**173**	**3.14**	**17.32**	**8.51**	**0**	**Present**	**Present***
	Middle Santa Ysabel Creek	**9**	**76**	**79**	**155**	**6.93**	**16.45**	**4.10**	**Present**	**Present**	**Present***
	Lower Santa Ysabel Creek	**9**	**9**	**10**	**42**	**19.51**	**40.01**	**3.14**	**0**	**Present**	**Present***
	Santa Maria Creek 1	**2**	**56**	**60**	**60**	**8.36**	**21.08**	**5.64**	**0**	**NS**	**0**
	Santa Maria Creek 2	**7**	**69**	**114**	**177**	**8.25**	**12.84**	**2.06**	**Present**	**NS**	**Present**
	Santa Maria Creek 3	2	2	0	0	9.17	15.33	1.71	0	NS	0
San Diego	**Upper San Diego River**	**3**	**46**	**133**	**171**	**6.26**	**13.78**	**2.68**	**Present**	**Present**	**0**
	Cedar Creek	**2**	**75**	**156**	**156**	**6.05**	**14.75**	**8.18**	**Present**	**NS**	**0**
	San Vicente Creek	**2**	**228**	**181**	**181**	**7.59**	**14.61**	**2.50**	**0**	**Present**	**Present**
Sweetwater	**Middle Sweetwater River**	**3**	**176**	**95**	**167**	**4.00**	**5.00**	**1.25**	**0**	**NS**	**0**
Otay	Dulzura Creek	4	157	149	178	3.14	4.72	1.56	0	NS	Present
	Jamul Creek	3	234	158	172	4.13	7.88	1.84	0	NS	Present
Tijuana	**Pine Valley Creek**	**3**	**43**	**143**	**174**	**2.92**	**6.17**	**2.67**	**Present**	**NS**	**0**
	Lower Cottonwood Creek	4	27	102	102	7.70	23.34	3.79	0	Present	0

*Observed bullfrogs may have migrated into the site from nearby adjacent ponds

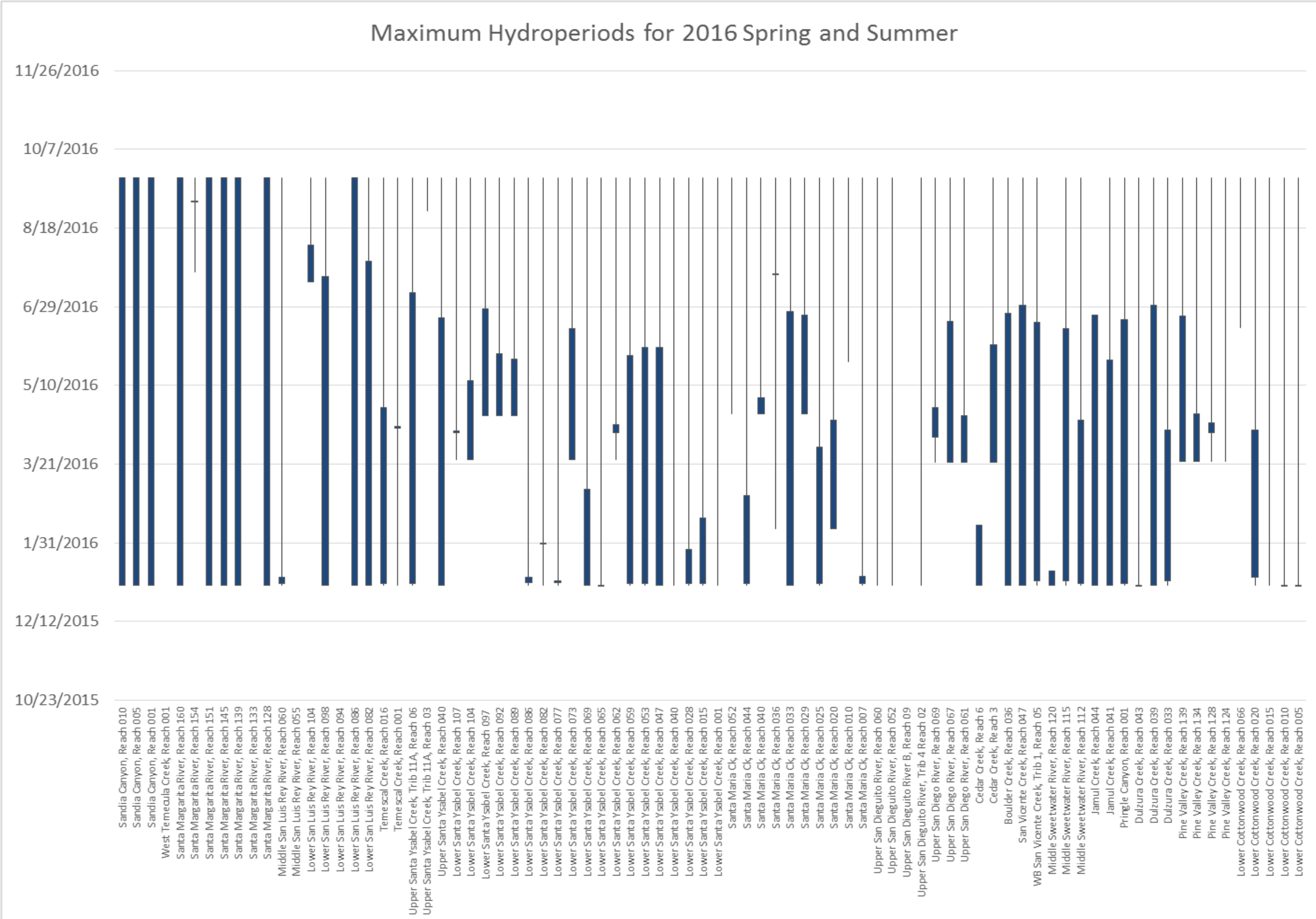

Figure 17. 2016 hydroperiod data for surface water monitoring sites, represented from north to south by stream name and reach name.

Watershed Characteristics (GIS)

Vegetation classifications and land use classifications for each watershed are summarized in tabular form (Tables 5–6). The majority of the areas were classified as having chaparral as the primary vegetation category (Table 5). Most of the landuse was classified as open space (Table 6). Locations with arroyo toad recruitment are highlighted.

Table 5. Watershed, site, and vegetation classifications. Total watershed size and amount of habitat for each vegetation classification in acres. Bold sites indicate where arroyo toads have been documented recently and highlighted sites indicate where recruitment was detected in 2016.

Watershed	Site	Total Hectares	Riparian Forest %	Chaparral %	Grassland %	Coastal Sage %	Other Natural %
Santa Margarita	Sandia Canyon	5,407	2.45	23.36	2.99	11.70	8.33
	Middle Santa Margarita River	156,082	1.35	44.17	6.06	15.57	25.46
San Luis Rey	**Middle San Luis Rey River**	**82,167**	**2.31**	**51.71**	**13.01**	**5.65**	**19.88**
	Lower San Luis Rey River	122,409	3.10	41.75	11.21	8.82	15.41
San Dieguito	**Temescal Creek**	**16,710**	**4.95**	**46.05**	**16.25**	**5.62**	**25.31**
	Upper Santa Ysabel Creek	**2,441**	**19.56**	**9.64**	**28.68**	**3.35**	**36.13**
	Middle Santa Ysabel Creek	**23,420**	**6.29**	**38.46**	**19.53**	**7.30**	**26.59**
	Lower Santa Ysabel Creek	**56,239**	**4.06**	**39.43**	**16.82**	**9.89**	**17.14**
	Santa Maria Creek 1	**16,257**	**1.62**	**24.34**	**17.31**	**12.40**	**6.74**
	Santa Maria Creek 2	**14,280**	**1.53**	**24.50**	**18.17**	**10.52**	**6.97**
	Santa Maria Creek 3	11,714	1.45	25.26	13.75	10.57	6.76
San Diego	**Upper San Diego River**	**14,805**	**5.54**	**31.88**	**12.44**	**22.05**	**25.47**
	Cedar Creek	**6,582**	**5.97**	**38.09**	**5.35**	**16.80**	**32.57**
	San Vicente Creek	**9,320**	**1.32**	**61.52**	**6.34**	**7.66**	**4.79**
Sweetwater	**Middle Sweetwater River**	**29,186**	**0.94**	**72.10**	**6.95**	**2.09**	**13.46**
Otay	Dulzura Creek	3,084	0.31	43.18	7.77	37.00	8.20
	Jamul Creek	3,783	1.57	27.42	20.34	38.33	1.94
Tijuana	**Pine Valley Creek**	**5,233**	**0.17**	**62.10**	**6.18**	**0.04**	**31.28**
	Lower Cottonwood Creek	**79,279**	**0.55**	**72.60**	**4.55**	**10.72**	**10.19**

Table 6. Watershed, site and land use classifications. Total watershed size in acres and percent of watershed by land use category including open space (O.S.), developed O.S., urban, industrial, commercial, and residential. Bold sites indicate where arroyo toads have been documented recently and highlighted sites indicate where recruitment was detected in 2016.

Watershed	Site	Impervious %	Open Space %	Developed O. S. %	Urban %	Industrial %	Commercial %	Residential %
Santa Margarita	Sandia Canyon	1.14	53.16	0.00	19.77	0.00	0.00	3.38
	Middle Santa Margarita River	3.79	88.64	0.00	7.52	0.00	0.00	1.22
San Luis Rey	**Middle San Luis Rey River**	**0.20**	**86.18**	**0.18**	**6.74**	**0.01**	**0.67**	**6.12**
	Lower San Luis Rey River	1.09	71.99	0.41	14.88	0.13	0.58	13.20
San Dieguito	**Temescal Creek**	**0.06**	**90.39**	**0.00**	**2.24**	**0.00**	**0.01**	**2.64**
	Upper Santa Ysabel Creek	**0.08**	**92.91**	**0.00**	**1.13**	**0.01**	**0.02**	**1.27**
	Middle Santa Ysabel Creek	**0.11**	**82.53**	**0.00**	**3.96**	**0.01**	**0.02**	**4.25**
	Lower Santa Ysabel Creek	**0.73**	**75.03**	**0.15**	**12.42**	**0.05**	**0.51**	**12.01**
	Santa Maria Creek 1	**2.30**	**40.89**	**0.32**	**41.69**	**0.22**	**1.25**	**39.05**
	Santa Maria Creek 2	**2.52**	**38.83**	**0.27**	**44.17**	**0.25**	**1.38**	**40.90**
	Santa Maria Creek 3	2.78	36.07	0.04	46.99	0.29	1.09	43.83
San Diego	**Upper San Diego River**	**0.32**	**82.21**	**0.01**	**13.29**	**0.07**	**0.15**	**14.38**
	Cedar Creek	**0.18**	**84.05**	**0.00**	**13.96**	**0.00**	**0.00**	**15.46**
	San Vicente Creek	**2.37**	**76.54**	**0.75**	**21.24**	**0.01**	**0.40**	**20.09**
Sweetwater	**Middle Sweetwater River**	**0.85**	**80.54**	**0.00**	**16.34**	**0.00**	**0.20**	**15.19**
Otay	Dulzura Creek	0.36	69.86	0.00	26.75	0.00	0.01	29.88
	Jamul Creek	1.70	68.74	0.02	27.88	0.00	0.15	26.30
Tijuana	**Pine Valley Creek**	**0.39**	**96.12**	**0.00**	**3.88**	**0.00**	**0.02**	**3.51**
	Lower Cottonwood Creek	**0.51**	**91.36**	**0.00**	**6.79**	**0.00**	**0.02**	**6.08**

Impervious Surface

We found that impervious surface was a better indicator for arroyo toad and bullfrog presence than land use because the urban land use category includes a diverse range of urban types. While impervious surface is related to land use, some urban areas have much higher impervious surface percentages than others. For example, rural residential areas may have small impervious surface cover with several acres of open space surrounding it. The land use mapping methods varied by jurisdiction but generally included the entire parcel as urban even where the actual urban footprint was small. This caused an overestimation of urban land cover in rural residential areas. This relationship became more complicated when looking at the amount of irrigation in rural residential areas as well as the size of the watershed.

Our graphs show that we did not find arroyo toads when the percent of impervious surface was above 2.5% (Figure 18). Bullfrogs were found at up to a slightly higher percent of impervious surface (~8%; Figure 19), and other nonnative aquatic species tolerated up to ~59% impervious surface (Figure 20). Interestingly, both arroyo toads and bullfrogs tolerated a similar percent of urban area at ~44%, whereas other nonnative aquatic species tolerated space that was up to ~89% urbanized (Figures 18–20).

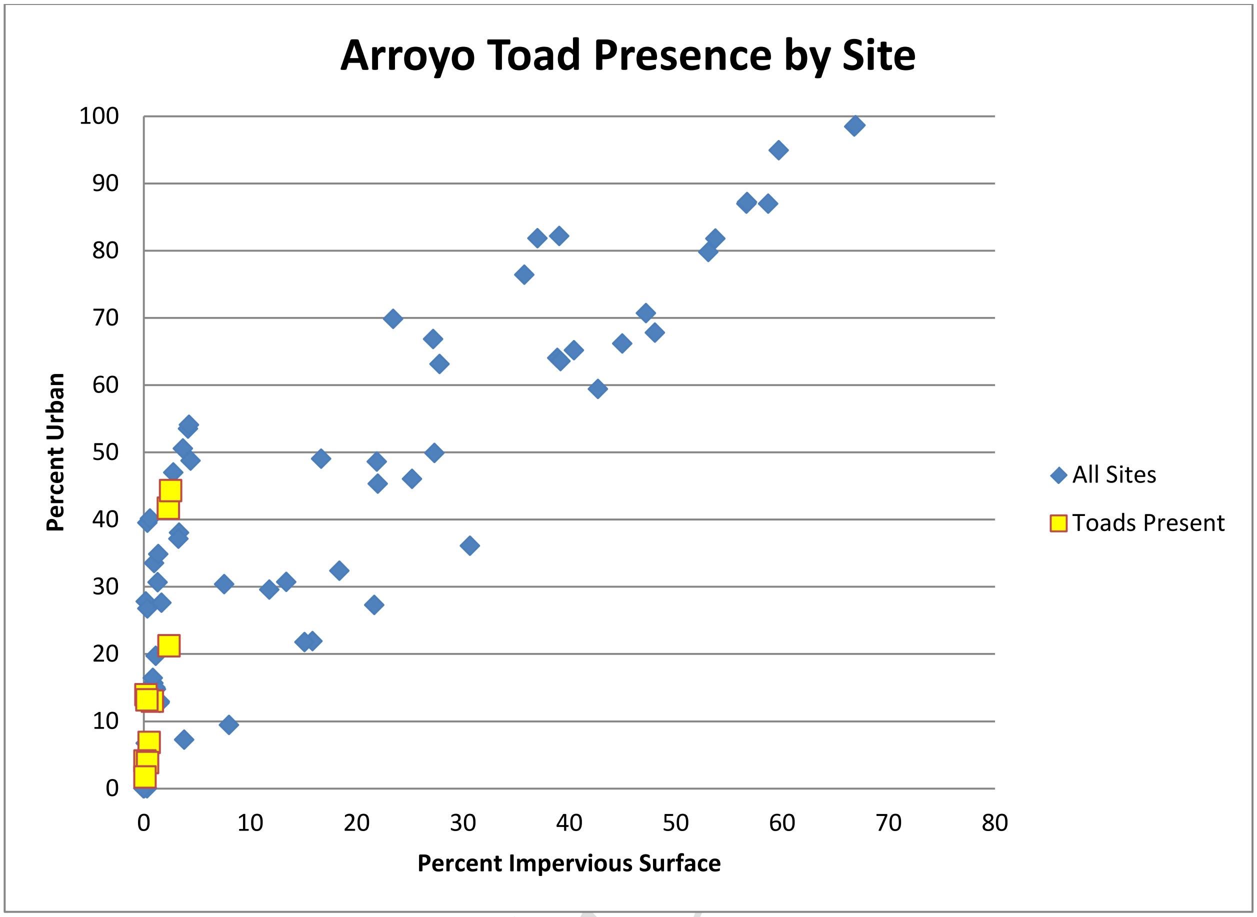

Figure 17. Arroyo toad presence by percent urban and percent impervious. Arroyo toads were observed at 10 out of 75 USGS surface water monitoring sites in conserved lands in San Diego County. Of these sites, the maximum percentof impervious surface within the watershed above the site where arroyo toads were detected was 2.51%, and the maximum percent of urban was 44.33% (at the same site).

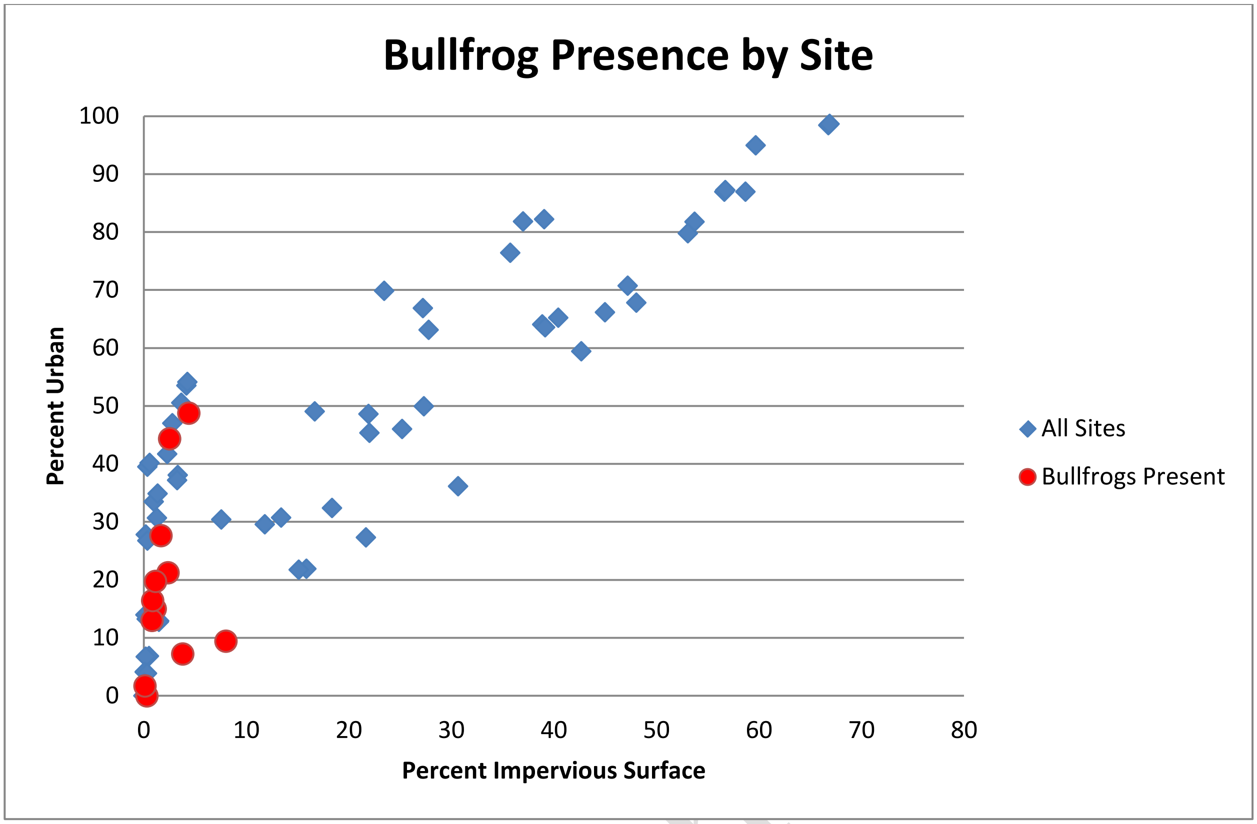

Figure 18. Bullfrog presence by percent urban and percent impervious. Bullfrogs were observed at 12 out of 75 USGS surface water monitoring sites in conserved lands in San Diego County. Of these sites, bullfrogs were detected at sites with as much as 8.01% impervious surfaces (over three times the what we were able to find for the arroyo toad) and up to 48.73% urban.

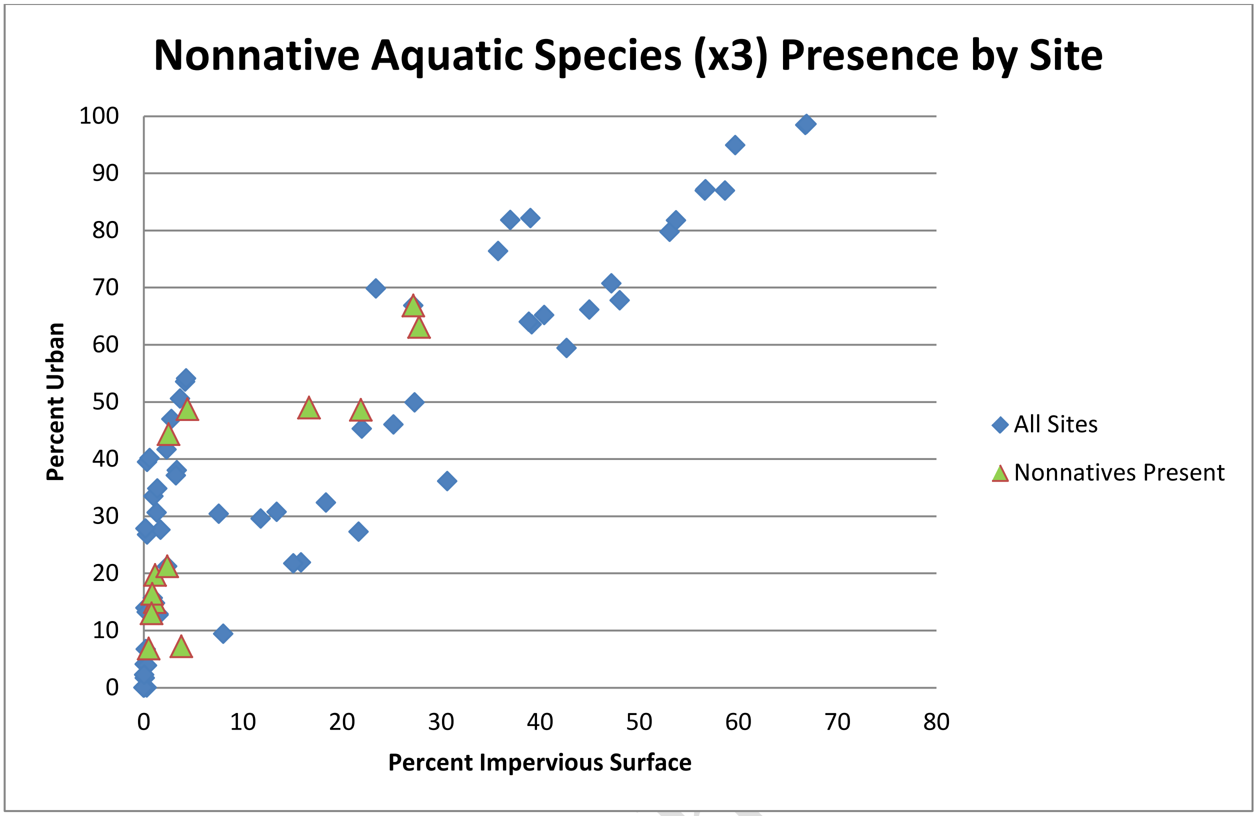

Figure 9. Sites with three or more nonnative species by percent urban and percent impervious. Twenty sites had three or more nonnative aquatic species. Of these sites, the maximum percentof impervious surface within the watershed above the site was 27.8% and the maximum percent of urban was 63.1%. All sites with less than 6.7% urban land use had less than three nonnative aquatic species.

Discussion

This two year study built upon previously collected data and covered conditions and species observations during very dry years with accumulated drought debt. Even with prolonged drought, several sites held permanent water and these sites, such as the Santa Margarita River, had large numbers of nonnative aquatic species, as predicted. Permanent water may be due to runoff from urban upland areas that have impervious surfaces.

Past research on stream channels in Southern California shows a shift in stream morphology from large sandy washes to deep incised channels (Trimble 1997; Tanaguchi and Biggs 2015). This allows for invasive aquatics to persist (Ficetola et al. 2010) and reduces breeding habitat for arroyo toads. In this study, we used the entrenchment ratio as a measure of arroyo toad recruitment habitat. However, data did not show that stream reaches with a larger entrenchment ratio had more arroyo toad recruitment, as we expected. There are a number of reasons this could have occurred. First, this study was done during a dry period and focused on drought debted reaches. Dry conditions may not promote typical behavior. Additionally, we did not calculate the statistical significance of this information and it appears that a single site may be a large driver of the apparent difference. Further investigations could focus on statistical relationships and add data from wetter periods. They could also identify indicators of stream morphology erosion and suggest management action that might mitigate these changes.

Though entrenchment ratio was not a predictor of arroyo toad breeding habitat in this particular study, we did find that increased upland development correlated with higher numbers of nonnative species and absence of arroyo toads. Many of the survey sites were impacted by upland development with high impervious surfaces percentages (Figure 20). Sites impacted by upland development also had altered stream morphology, with much more incised, vegetation-lined stream channels and less sandy shoreline available for breeding. These degraded sites had large numbers of bullfrogs and crayfish. Therefore, nonnative species appeared to have a higher tolerance to upstream urban disturbance than arroyo toads. This was evident in both the watershed impervious surface coverage and land use classification. Specifically, arroyo toads were absent from sites where the draining area had over 2.5% impervious while invasives tolerated sites with up to 30% impervious cover. Similarly with upstream urban land use, arroyo toads were only found in areas with less than 44% urban upstream whereas other invasives tolerated as much as 70% urban disturbance. Additionally, nonnatives tended to be found with other nonnatives. Twenty sites had three or more species of nonnatives. Overall, nonnative species were found at 42 of 75 USGS surface water monitoring locations. Twelve sites had bullfrogs. Furthermore, nonnative bullfrogs were found at several sites where they were previously unknown to occur. Nonnative aquatic species, including bullfrogs and crayfish, directly prey upon arroyo toads and their larvae and can have a significant impact on arroyo toad presence (Brehme et al. 2014).

Interestingly, bullfrogs appear to be more sensitive than other invasive aquatic species. Bullfrogs were not present at sites with watersheds with impervious surface area above 8% and urban land cover above 44%. This suggests that bullfrogs can tolerate higher levels of stream flow than arroyo toads but not as much as other invasives found in the area. It would be of interest to investigate any association between percent of urban development, the percent of impervious surfaces, and native vs. nonnative species diversity in normal rainfall years as it appears to be very strong during dry years. It could be modeled further to determine what specific parameters are acting on the system. In addition to site management activities, percent of impervious surface in the watershed may be a strong predictor of native and nonnative diversity at a given site.

Finally, another interesting outcome of the study was finding western pond turtle in Santa Maria Creek within Ramona Grasslands Preserve (Table 2). This species had not been recorded from this preserve prior to our data collection. With the large geographic scope and random site selection, this study demonstrated the potential to verify presence of species beyond known distributions and within preserves where they had not previously been detected.

Overall, arroyo toads were only found within 38 of the 173 predefined reaches, some of which are adjacent to other stream reaches within the same study site. From a management standpoint at a larger scale, a more appropriate representation of arroyo toad presence might be to look at toad presence as occurring in 10 of the 75 surface water monitoring sites, allowing the data to be used at different scales depending on management needs and funding. Toads were not found at several sites where they were present in 2008–2010. As our data may indicate this may be because of drought, upland urbanization causing increased runoff, the introduction of nonnative aquatic species, and/or changes in the stream geomorphology. While arroyo toad populations could have been negatively affected by one or a combination of these factors, we were able to detect arroyo toads in environments and sites in which swe did not expect to find them (i.e., sites without permanent water). Through our systematic surveys, we were also able to extend the known distribution of arroyo toads at Santa Maria Creek, Santa Ysabel Creek, and San Diego River.

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Site Access

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APPENDIX A

Site information, characteristics, habitat suitability, and aquatic species observed.

Table A1. Land cover per watershed for each of the arroyo toad surface water monitoring study sites with percent urban cover and total watershed size.

					Acres of Land Coverage for Watershed											
Watershed	Block	Reach Number	Latitude	Longitude	RIPARIAN	CHAPARRAL	CSS	GRASS	CONIFER	MONT_HW	OAK	Other	AG	URBAN	PercUrban	Grand Total
Santa Margarita River	Sandia Canyon	Reach 001	33.41402400000	-117.24518500000	5,306.10	163,164.24	58,626.62	22,021.50	482.49	5,183.60	10,700.19	18,306.15	35,449.12	80,662.67	20%	399,902.69
Santa Margarita River	Sandia Canyon	Reach 005	33.42195333330	-117.24869400000	260.63	1,441.21	1,741.22	289.48			1,096.63	598.15	6,064.23	2,260.65	16%	13,752.20
Santa Margarita River	Sandia Canyon	Reach 010	33.43223200000	-117.24821633300	208.84	1,278.65	1,685.56	289.04			1,094.03	447.31	5,342.50	2,129.15	17%	12,475.07
Santa Margarita River	Santa Margarita River	Reach 128	33.40392700000	-117.25103000000	5,383.94	163,380.02	58,685.22	22,022.12	482.49	5,183.60	10,706.81	18,397.61	35,572.69	81,074.00	20%	400,888.51
Santa Margarita River	Santa Margarita River	Reach 133	33.41204900000	-117.24554000000	5,313.04	163,203.65	58,629.21	22,021.50	482.49	5,183.60	10,700.19	18,313.13	35,447.47	80,675.57	20%	399,969.85
Santa Margarita River	Santa Margarita River	Reach 139	33.40825166670	-117.23866900000	4,940.17	161,244.01	56,648.68	21,701.66	482.49	5,183.60	9,580.41	17,620.44	29,063.76	78,149.65	20%	384,614.88
Santa Margarita River	Santa Margarita River	Reach 145	33.40585700000	-117.22553250000	4,869.23	161,145.24	56,636.95	21,701.70	482.49	5,183.60	9,567.03	17,523.43	28,931.73	77,814.12	20%	383,855.51
Santa Margarita River	Santa Margarita River	Reach 151	33.41373750000	-117.21471900000	4,724.39	160,393.89	56,489.95	21,679.25	482.49	5,183.60	9,524.68	17,047.24	28,503.09	76,197.20	20%	380,225.77
Santa Margarita River	Santa Margarita River	Reach 154	33.41803300000	-117.20801300000	4,696.14	160,261.27	56,467.16	21,679.25	482.49	5,183.60	9,520.63	17,025.32	28,393.11	76,103.95	20%	379,812.92
Santa Margarita River	Santa Margarita River	Reach 160	33.42820700000	-117.19924000000	4,648.37	159,972.72	56,466.17	21,678.79	482.49	5,183.60	9,499.69	16,911.46	28,346.07	76,003.50	20%	379,192.85
San Luis Rey River	Lower San Luis Rey River	Reach 082	33.27167150000	-117.23391800000	5,130.40	113,308.86	21,456.34	22,056.66	1,861.59	23,403.71	14,651.84	11,143.52	53,051.12	58,435.30	18%	324,499.34
San Luis Rey River	Lower San Luis Rey River	Reach 086	33.27686500000	-117.22656900000	5,057.09	113,308.86	21,310.08	22,009.88	1,861.59	23,403.71	14,651.84	11,143.52	52,967.27	58,247.37	18%	323,961.23
San Luis Rey River	Lower San Luis Rey River	Reach 094	33.29356800000	-117.22042500000	4,384.45	109,812.43	19,695.81	21,590.15	1,861.59	23,403.71	14,262.41	10,587.53	44,625.15	43,786.91	15%	294,010.14
San Luis Rey River	Lower San Luis Rey River	Reach 098	33.30205350000	-117.21459400000	4,175.05	109,810.00	19,310.07	21,487.20	1,861.59	23,403.71	14,195.22	10,441.77	43,119.50	38,709.91	14%	286,514.04
San Luis Rey River	Middle San Luis Rey River	Reach 054	33.35521300000	-117.03931700000	1,718.47	95,737.43	10,331.39	19,883.27	1,861.59	21,985.38	12,445.77	7,094.98	18,090.76	14,389.42	7%	203,538.48
San Luis Rey River	Middle San Luis Rey River	Reach 061	33.35027300000	-117.02821600000	1,630.73	95,437.29	10,302.84	19,879.33	1,861.59	21,985.38	12,437.45	7,094.98	17,809.30	14,381.39	7%	202,820.30
San Dieguito River	Lower Santa Ysabel Creek	Reach 001	33.08217000000	-117.02230550000	2,011.43	55,497.36	12,520.20	14,087.92		6,835.92	18,107.56	1,705.09	21,652.96	25,686.52	16%	158,104.97
San Dieguito River	Lower Santa Ysabel Creek	Reach 015	33.08440800000	-116.98905150000	1,726.93	51,578.83	10,031.37	13,665.61		6,834.37	17,337.32	1,692.92	19,179.97	23,281.75	16%	145,329.08
San Dieguito River	Lower Santa Ysabel Creek	Reach 028	33.09286100000	-116.95695650000	915.10	36,465.48	6,623.83	6,353.72		6,835.92	13,295.98	735.45	9,750.01	4,294.33	5%	85,269.84
San Dieguito River	Lower Santa Ysabel Creek	Reach 040	33.08762550000	-116.92804300000	869.53	35,681.47	6,222.84	6,346.84		6,840.69	13,292.59	715.75	9,399.40	4,010.37	5%	83,379.48
San Dieguito River	Lower Santa Ysabel Creek	Reach 047	33.08653150000	-116.91341500000	830.32	34,948.65	5,982.60	6,179.45		6,840.69	13,273.53	675.11	9,261.66	3,964.10	5%	81,956.10
San Dieguito River	Lower Santa Ysabel Creek	Reach 052	33.06140300000	-117.03699700000	2,206.13	55,504.81	12,843.29	14,216.71		6,835.92	18,129.82	1,712.99	22,012.51	26,338.67	16%	159,800.85
San Dieguito River	Lower Santa Ysabel Creek	Reach 053	33.08875750000	-116.90127750000	802.78	34,702.25	5,629.63	6,144.83		6,840.69	13,268.66	675.11	9,261.66	3,960.58	5%	81,286.20
San Dieguito River	Lower Santa Ysabel Creek	Reach 059	33.09012450000	-116.89280650000	482.85	30,111.72	4,920.06	5,732.28		6,835.92	13,087.01	672.91	8,748.59	2,907.12	4%	73,498.47
San Dieguito River	Lower Santa Ysabel Creek	Reach 065	33.09649700000	-116.88150800000	439.42	29,565.17	4,912.01	5,731.72		6,835.92	13,087.01	672.91	8,748.59	2,890.39	4%	72,883.14
San Dieguito River	Lower Santa Ysabel Creek	Reach 068	33.10169500000	-116.87502350000	416.23	29,258.01	4,912.01	5,731.72		6,835.92	13,087.01	672.91	8,748.59	2,890.39	4%	72,552.78
San Dieguito River	Lower Santa Ysabel Creek	Reach 077	33.10650500000	-116.85744600000	362.73	28,436.71	4,664.91	5,729.48		6,835.92	13,080.55	672.91	8,748.59	2,890.39	4%	71,422.20
San Dieguito River	Lower Santa Ysabel Creek	Reach 083	33.11730450000	-116.85476500000	287.99	26,274.61	4,324.98	5,675.34		6,835.92	12,987.42	672.91	8,744.74	2,507.28	4%	68,311.20
San Dieguito River	Lower Santa Ysabel Creek	Reach 087	33.11802500000	-116.84741250000	125.17	13,993.28	2,487.66	4,452.75		6,638.16	9,644.75	627.99	8,457.07	2,332.75	5%	48,759.59
San Dieguito River	Santa Maria Creek	Reach 007	33.07963900000	-116.98685100000	232.43	6,996.21	2,264.63	2,669.99			1,066.29	773.52	7,511.72	18,354.73	46%	39,869.52
San Dieguito River	Santa Maria Creek	Reach 020	33.06327725000	-116.96088125000	212.34	6,438.18	1,944.29	2,661.04			1,051.86	662.99	6,803.53	18,006.34	48%	37,780.58
San Dieguito River	Santa Maria Creek	Reach 025	33.06051066670	-116.95111066700	211.30	6,065.30	1,924.79	2,657.97			1,050.30	597.09	6,799.98	17,989.26	48%	37,295.98
San Dieguito River	Santa Maria Creek	Reach 032	33.04650700000	-116.94802200000	202.11	5,693.14	1,760.60	2,276.45			1,040.84	366.86	6,227.81	17,524.05	50%	35,091.85
San Dieguito River	Santa Maria Creek	Reach 034	33.04647800000	-116.94806800000	183.73	5,597.48	1,761.13	2,196.78			1,036.78	224.26	5,895.25	17,286.89	51%	34,182.28
San Dieguito River	Santa Maria Creek	Reach 036	33.04071333330	-116.94848933300	3.30	20.43		15.53			0.83	2.16	97.53	129.58	48%	269.37
San Dieguito River	Santa Maria Creek	Reach 044	33.03016500000	-116.93205266700	34.41	539.72	28.22				50.71		396.20	1,034.90	50%	2,084.16
San Dieguito River	Temescal Creek	Reach 01	33.22331233330	-116.96744233300	157.48	9,099.89	973.30	876.30		170.18	2,998.92		284.45	128.16	1%	14,688.67
San Dieguito River	Temescal Creek	Reach 16	33.15043550000	-116.85133150000	2,204.74	55,504.81	12,842.64	14,200.49		6,835.92	18,129.82	1,712.99	22,012.21	26,338.67	16%	159,782.29
San Dieguito River	Upper San Dieguito River	Reach 52	33.06211150000	-117.03460750000	2,154.24	55,501.56	12,806.78	14,173.51		6,835.92	18,129.82	1,712.99	21,929.57	26,244.05	16%	159,488.44
San Dieguito River	Upper San Dieguito River	Reach 60	33.06896766670	-117.03495400000	2,054.15	55,497.36	12,557.68	14,112.35		6,835.92	18,123.23	1,707.41	21,764.26	25,918.81	16%	158,571.18
San Dieguito River	Upper San Dieguito River B	Reach 09	33.07705150000	-117.02877750000	185.93	816.70	2,020.01	48.35			120.85	1,541.83	1,227.14	2,449.85	29%	8,410.67
San Dieguito River	Upper San Dieguito River Trib 4	Reach 02	33.05369800000	-117.04151700000	11.69	1,481.16	640.20	2,505.10		5,692.93	2,335.45	57.36	2,940.93	574.64	4%	16,239.45
San Dieguito River	Upper Santa Ysabel Creek	Reach 040	33.11299350000	-116.70950500000		105.30	19.23	277.38		2.33	612.49		0.02		0%	1,016.74
San Dieguito River	Upper Santa Ysabel Creek Trib11A	Reach 03	33.12341300000	-116.71568450000		102.61	16.24	213.55		2.33	519.33				0%	854.05
San Dieguito River	Upper Santa Ysabel Creek Trib11A	Reach 06	33.12694550000	-116.71188500000		222.48		58.99			37.64	129.90	0.01	47.43	10%	496.46
San Diego River	Boulder Creek	Reach 36	32.96382100000	-116.66290650000	12.57	4,599.72	260.03	2,348.37	360.95	5,685.34	517.69	999.66	47.96	345.54	2%	15,177.83
San Diego River	Cedar Creek	Reach 06	32.98989650000	-116.73049500000		6,444.92	869.70	533.67	9.17	4,728.39	1,046.15	10.49	327.76	2,283.02	14%	16,253.29
San Diego River	San Vicente Creek	Reach 047	32.95690666670	-116.90364400000	255.88	11,684.13	1,081.43	1,086.19			748.68	2,087.39	546.31	5,556.23	24%	23,046.23
Sweetwater River	Middle Sweetwater River	Reach 112	32.77084800000	-116.81762000000	593.44	45,556.21	1,576.43	1,833.12	1,893.09	2,597.38	2,935.05	1,348.55	2,309.00	12,060.93	17%	72,703.21
Sweetwater River	Middle Sweetwater River	Reach 115	32.77157100000	-116.81102833300	584.24	45,162.08	1,503.99	1,833.12	1,893.09	2,597.38	2,930.10	1,348.55	2,309.00	12,060.93	17%	72,222.49
Sweetwater River	Middle Sweetwater River	Reach 120	32.77233000000	-116.80087650000	559.36	44,711.82	1,393.67	1,833.12	1,893.09	2,597.38	2,928.77	1,348.55	2,309.00	12,021.36	17%	71,596.11
Otay River	Dulzura Creek	Reach 033	32.65393750000	-116.80220400000	42.14	3,975.63	2,396.19	361.43			372.49	260.03	324.72	2,852.79	27%	10,585.42
Otay River	Dulzura Creek	Reach 039	32.65354600000	-116.79009850000	26.11	3,967.05	2,131.99	334.50			372.43	260.03	323.61	2,746.86	27%	10,162.59
Otay River	Dulzura Creek	Reach 043	32.64644300000	-116.78534000000	9.80	1,350.15	1,080.36	247.84			69.56	255.70	290.59	928.50	22%	4,232.51
Otay River	Jamul Creek	Reach 014	32.67772000000	-116.86539200000	104.07	1,750.51	2,423.45	1,699.09			54.59	17.28	435.53	2,702.32	29%	9,186.83
Otay River	Jamul Creek	Reach 041	32.67183800000	-116.86766500000	109.63	1,776.30	2,674.25	1,752.20			54.96	17.57	435.55	2,701.70	28%	9,522.17
Otay River	Jamul Creek	Bedrock P	32.66184700000	-116.87023800000	125.78	1,870.87	3,457.71	2,026.61			63.10	18.15	435.55	2,703.11	25%	10,700.88
Otay River	Jamul Creek	Pump Pond	32.67705300000	-116.86486200000	104.93	1,750.51	2,429.05	1,706.87			54.59	17.28	435.53	2,702.32	29%	9,201.08
Otay River	Pringle Canyon	Reach 001	32.65058650000	-116.78443250000	17.01	3,959.01	1,814.31	334.50			370.86	260.03	323.61	2,719.74	28%	9,799.07
Tijuana River	Lower Cottonwood Creek	Reach 005	32.57304800000	-116.75738000000	434.09	144,020.43	11,717.35	6,074.84	4,808.15	4,210.30	5,886.11	3,683.06	3,855.88	13,921.34	7%	198,611.55
Tijuana River	Lower Cottonwood Creek	Reach 010	32.57753900000	-116.74577766700	427.05	143,782.01	10,629.01	5,986.54	4,808.15	4,210.30	5,874.06	3,682.35	3,855.88	13,869.66	7%	197,125.02
Tijuana River	Lower Cottonwood Creek	Reach 015	32.58704100000	-116.74788150000	416.84	143,261.91	10,200.88	5,957.17	4,808.15	4,210.30	5,873.09	3,682.35	3,855.88	13,869.66	7%	196,136.23
Tijuana River	Lower Cottonwood Creek	Reach 020	32.58983850000	-116.73357600000	405.03	142,111.62	8,792.99	5,812.22	4,808.15	4,210.30	5,795.93	3,654.98	3,780.68	12,966.74	7%	192,338.65

Table A3. Results of visual surveys 2015 and 2016. Aquatic species observations (number of site visits during which a species was detected) by watershed, stream name (block), and site (reach number). Sites are listed by watershed from north to south; species are listed as native or nonnative. Percent of upstream urban development is listed by site. Five native amphibian species were detected including arroyo toads.

				Native Aquatic Species							Nonnative Aquatic Species												
Watershed	Study Site	Stream/River	Reach Number	Arroyo Toad	Western Toad	Western Spadefoot	California Treefrog	Pacific Treefrog	Western Pond Turtle	Two-striped Gartersnake	Bullfrog	African Clawed Frog	Red-eared Slider	Common Carp	Largemouth Bass	Redeye Bass	Green Sunfish	Bluegill Sunfish	Bullhead Catfish	Mosquitofish	Crayfish	Asian Clam	American Beaver
Santa Margarita River	Sandia Canyon	Sandia Canyon	1				1				1										2		
			2													1					1		
			3													1					1		
			4				1	2									1			1	2		
			5				1	2													3	1	
			6					1												1	1		
			9								1				1						2		
			10																		2		
			12				1																
	Middle Santa Margarita River	Santa Margarita River (CPN)	128																	1			
			130								1									1	1		
			133								2					1				1			
			134								1										1		
			135		1		1				4		3	2			1		1	3	1		
			136								1			1		1	1				1		
			137		1			1			1				1					2	1		
			139		1		1				1						1			2	1		
			140		1						2				1	1	1			2		1	
			143		1						1				1	1	1			2	2	1	
			145											1		2				2	2	1	
			147													2					1		
			149					1			3					2			1	2	2	1	1
			150		1						1			1		2				1	2	1	
			151		1			1			4					2			1	2	3		1
			152					1	1		1			1		1					1		
			153						2		6					1	1		1	2	2		
			154								3					1	1		1	1	1	1	
			155											2	1					1	1		
			158								1			1		1	1			2	1	1	
			160				1				1			1		2	3			3	3	1	
San Luis Rey River	Middle San Luis Rey	Middle San Luis Rey River	55	**1**							1												
			56								3		1	1									
			58		1																		
			60		1																		
			67																				
	Lower San Luis Rey	Lower San Luis Rey River	45					1			1										1		
			46				2	2			2						1				1		
			47								1												
			71					3													1		
			76					2													1		
			79					1													1		
			80					1													1		
			82					6												1	3		
			85					4												3	4		
			86					2												2	4		
			94								2		1								2		
			98					1			1												
			99																				
			101																				
			102					3												1	1		
			103																		1		
			104																				
			105																				
			106		2	1		2															

				Native Aquatic Species							Nonnative Aquatic Species												
Watershed	Study Site	Stream/River	Reach Number	Arroyo Toad	Western Toad	Western Spadefoot	California Treefrog	Pacific Treefrog	Western Pond Turtle	Two-striped Gartersnake	Bullfrog	African Clawed Frog	Red-eared Slider	Common Carp	Largemouth Bass	Redeye Bass	Green Sunfish	Bluegill Sunfish	Bullhead Catfish	Mosquitofish	Crayfish	Asian Clam	American Beaver
San Dieguito River	Temescal Creek	Temescal Creek (Santa Ysabel)	1	1	1			2			1												
			12					1															
			19																				
	Upper Santa Ysabel Creek	Upper Santa Ysabel Creek Trib11A	3					1			1												
			4	1																			
			5		1			2															
			6		1			1															
		Upper Santa Ysabel Creek	40		1		1	2												2			
			41		2			4		1										1			
	Middle Santa Ysabel Creek	Black Canyon	1				1											1					
			3				2	1															
			5								1							1					
			7				1	1															
			4																				
		Boden Canyon	1					1															
			13																				
		Lower Santa Ysabel Creek	71					2												1			
			72				1	2												1			
			73					4												2			
			76					1															
			77																				
			78																				
			79	1																			
			81	1	2			1															
			82	6	2			4															
			83				1																
			87					2															
			88				3	5		1													
			89				5	1		1													
			92				5	1		2													
			95				1																
			96				1	1		1													
			97				3	1		1													
			99				1																
			102				2																
			103				1	1															
			105				1	1															
			107				1																
	Lower Santa Ysabel Creek	Lower Santa Ysabel Creek	24	1																			
			25	3																			
			26																				
			27																				
			28	1																			
			29	5																			
			42																				
			43																				
			44				3	1															
			45				1	2															
			46					1															
			47				2	3															
			48				2	2												1			
			49				1	2															
			51																				
			53	1	2		4	5															
			54					1															
			56		1																		
			57				2																
			58																				
			59																				
			60							1													
			63					1															
			64				1	1															
			65					2															
			66					2															
			68				2	3															
			69				2	5												2			

				Native Aquatic Species							Nonnative Aquatic Species												
Watershed	Study Site	Stream/River	Reach Number	Arroyo Toad	Western Toad	Western Spadefoot	California Treefrog	Pacific Treefrog	Western Pond Turtle	Two-striped Gartersnake	Bullfrog	African Clawed Frog	Red-eared Slider	Common Carp	Largemouth Bass	Redeye Bass	Green Sunfish	Bluegill Sunfish	Bullhead Catfish	Mosquitofish	Crayfish	Asian Clam	American Beaver
San Dieguito River	Santa Maria Creek 1	Santa Maria Creek	3																				
			4		1																		
			6																				
			7																				
			10																				
			11																				
	Santa Maria Creek 2	Santa Maria Creek	20					2												1			
			21				1	1															
			22				1	1															
			23	**1**			7	3												3			
			24	**2**			2	1												1			
			25	**2**			1	4			1									1	1		
			26	**5**			1	3			2									1			
			27	**1**																			
			28	**1**	1																		
			29	**1**	1			4			5									3			
			30								2									1			
			31																				
			32	**2**	4		1	4			4									2	1		
			33	**2**	3			2	1		2												
			34	**1**	3			1												1			
			35	**1**	1						2												
			36		2		1	2		2	9									3	1		
			39		1																		
			40					1			2												
	Santa Maria Creek 3	Santa Maria Creek	41		1			1												1	1		
			44		2																		
			49																				
San Diego River	Upper San Diego River	Temescal Creek	1				1																
		Upper San Diego River	61	**4**	1		1	3															
			62	**1**	1			3															
			65	**1**	1		1	1															
			69	**2**																			
			71	**1**																			
			73				1																
			74				1																
			75				1																
			76				2	1															
			79				4																
			80				2																
			81				3																
			82																				
			83				3		1														
			84				2																
			85						1											1			
			86				3		2		1						1						
			88	**2**	1																		
			89	**1**							1												
			90	**2**	2		2	1									1						
			91	**1**																			
			94				4	2	1														
			98				2																
			100				1		1														
			101	**3**			1										1						
			102	**1**			1																
			103	**1**			1																
			104	**3**			1																
			105				1																
			111						1														
			116																				
	Cedar Creek	Cedar Creek	1	**1**			1	1															
			2	**1**																			
			3	**7**			3	3		1													
			5				3										1						
			6																				
	San Vicente Creek	San Vicente Creek	44				2	3			2										1		
			46					2			1									1	1		
			47				2	1			2										1		

				Native Aquatic Species							Nonnative Aquatic Species												
Watershed	**Study Site**	**Stream/River**	**Reach Number**	**Arroyo Toad**	**Western Toad**	**Western Spadefoot**	**California Treefrog**	**Pacific Treefrog**	**Western Pond Turtle**	**Two-striped Gartersnake**	**Bullfrog**	**African Clawed Frog**	**Red-eared Slider**	**Common Carp**	**Largemouth Bass**	**Redeye Bass**	**Green Sunfish**	**Bluegill Sunfish**	**Bullhead Catfish**	**Mosquitofish**	**Crayfish**	**Asian Clam**	**American Beaver**
Sweetwater River	Middle Sweetwater River	Middle Sweetwater River	112				1																
			115					1				2											
			120				1	1	2			2									4		
			121				1	2	2								1		2				
Otay River	Dulzura Creek	Dulzura Creek	33																				
			39																				
			42											1									
		Pringle Canyon	1																				
	Jamul Creek	Jamul Creek	35					2													1		
			39																				
			40																				
			41								9										1		
			42					1															
			43																				
			44						2		19			1							12		
			45								1										1		
Tijuana River	Pine Valley Creek	Pine Valley Creek	37				1		1	2													
			59						1														
			60				1		1														
			61				1		1														
			62				1																
			124																				
			133	**5**				4															
			134	**2**	1																		
			135							1													
			137	**1**			2	1		1													
			139				2	1		2													
			140	**1**			2			2													
			141				1	3		1													
	Lower Cottonwood Creek	Lower Cottonwood Creek	3																				
			4	**1**																			
			5																				
			6					1															
			7					1															
			12																				
			14	**1**				1															
			67								1												
			68																				
			69								1												
			72																				
			73																				
			74								1												
			77																				

APPENDIX B

Site descriptions, maps, STIC data, and site photos organized by watershed.

For the maps in this appendix, blue triangles represent the start of the arroyo toad monitoring survey locations and the green triangles represent the locations of the STIC surface water monitoring sites. Yellow triangles represent surface water monitoring sites for the aseasonal flow study (Brown et al. 2017).

Santa Margarita River Watershed

The Santa Margarita River Watershed occupies the northernmost region of our study area with approximately 73% of the watershed in Riverside County. The watershed area within San Diego County is approximately 50,787 hectares. The upper reaches of the watershed in San Diego County are on U.S. Forest Service (USFS) lands reaching an elevation of 2,076 meters. The middle reaches within San Diego County are surrounded by low urban and rural development. The lower reaches of the watershed are on MCBCP and drain into the Pacific Ocean. The watershed has approximately 19,679 hectares of conserved lands within San Diego County. This study includes three STIC locations in Sandia Canyon and eight STIC locations in Santa Margarita River between MCBCP and Riverside County. The open space land managers within the watershed are Fallbrook Public Utilities District, County of San Diego, and USFS.

Sandia Canyon

Sandia Canyon is a tributary to the Santa Margarita River with semi-permanent flow. The habitat consists of sycamore and willow riparian surrounded by thick chaparral. The streambed is a combination of sandy wash punctuated by boulder and bedrock runs and pools. This site is included in U.S. Fish and Wildlife Service's (USFWS) critical habitat designation for the arroyo toad (USFWS 2011?); however, arroyo toads were not known from this site prior to this study (USFWS 2015). This site is owned and managed by the Fallbrook Public Utilities District.

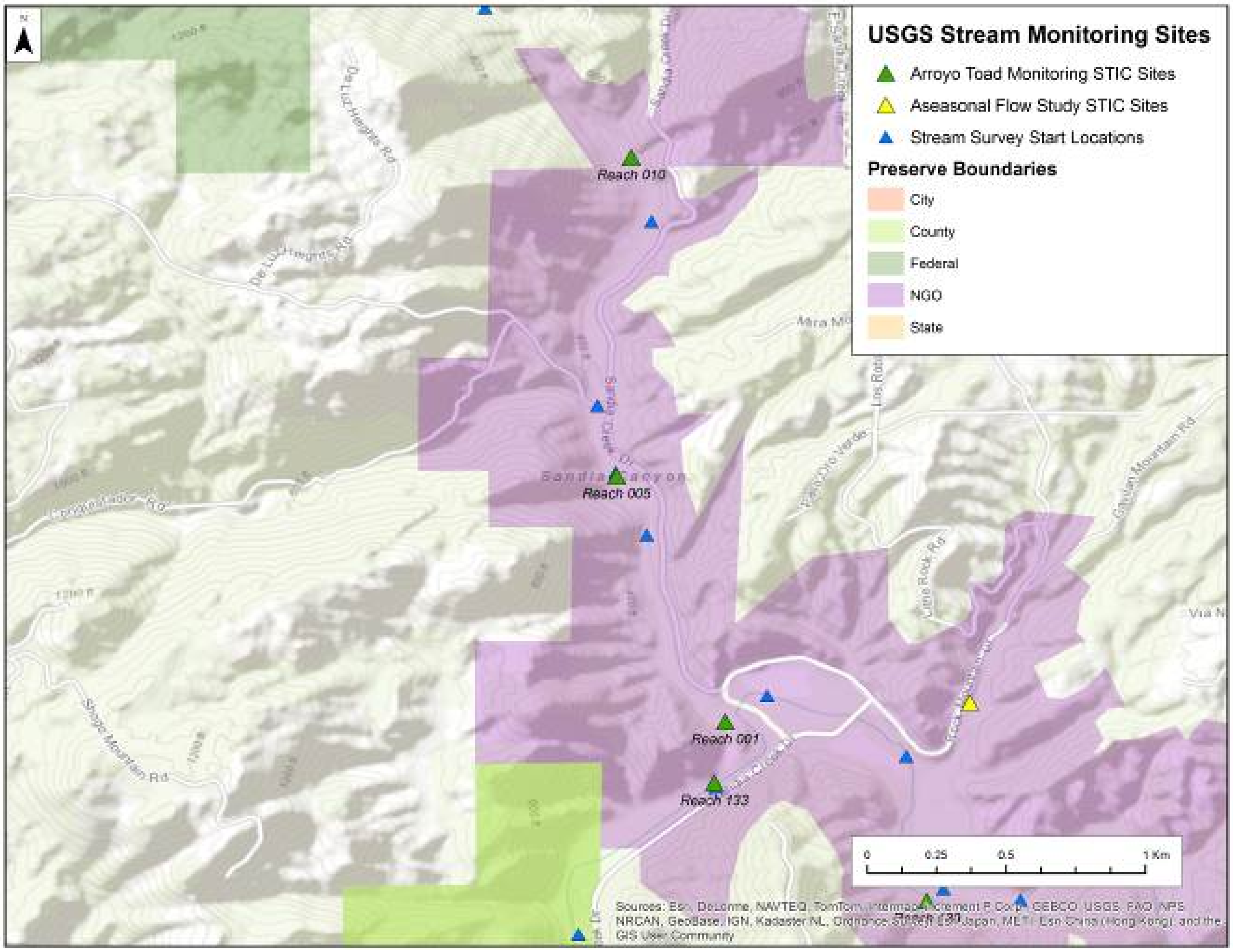

Figure B1. Sandia Creek, owned and managed by Fallbrook Public Utilities District Sandia Canyon 010.

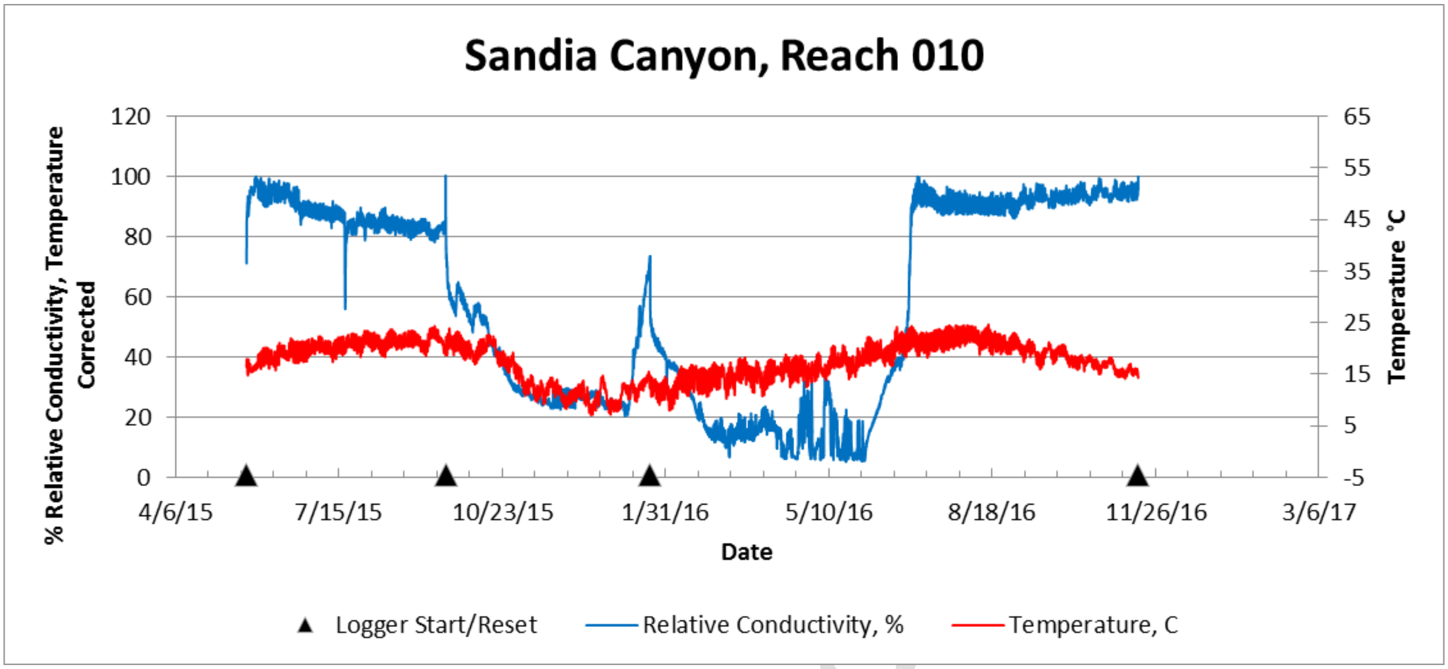

Figure B2. Relative conductivity and temperature graph of Sandia Canyon Reach 010.

Figure B3. Habitat at Sandia Canyon Reach 010 on 19 May 2015 downstream (left) and on 15 November 2016 upstream (right).

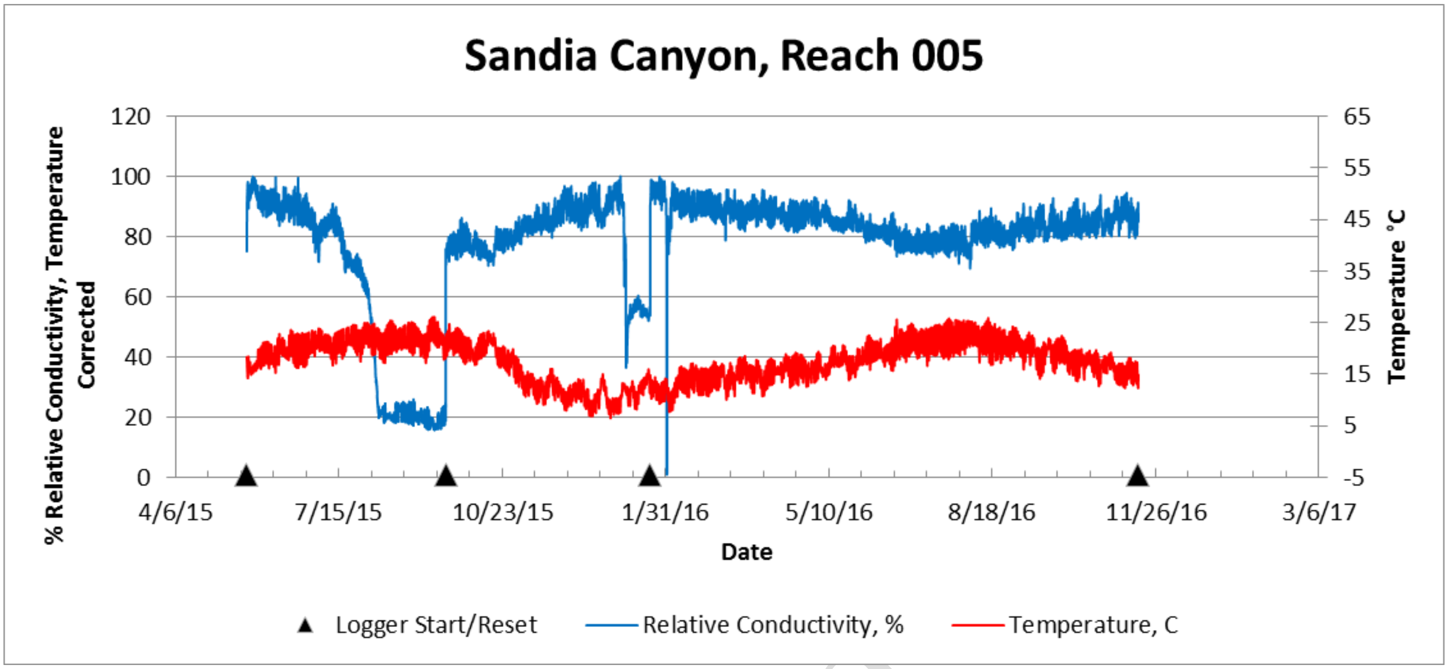

Figure B4. Relative conductivity and temperature graph of Sandia Canyon Reach 005.

Figure B5. Habitat at Sandia Canyon Reach 005 on 19 May 2015 (left) and on 15 November 2016 (right).

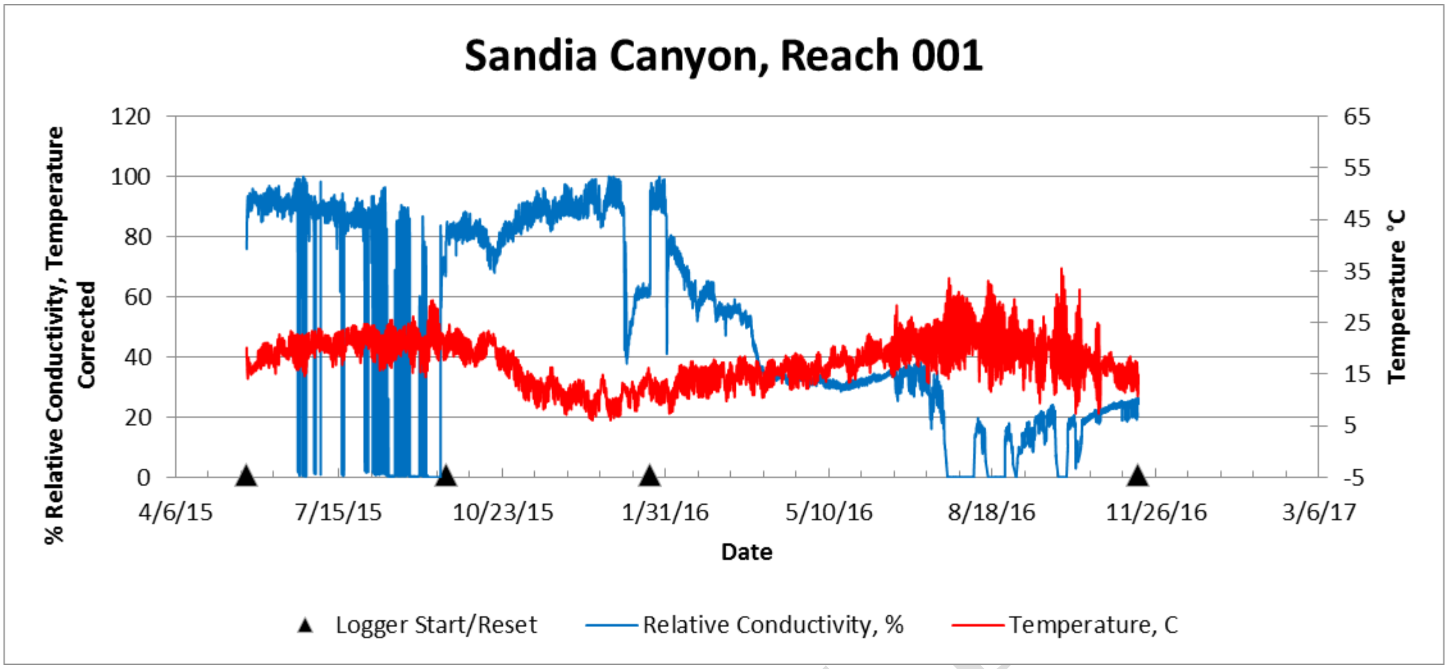

Figure B6. Relative conductivity and temperature graph of Sandia Canyon Reach 001.

Figure B7. Habitat at Sandia Canyon Reach 001 on 18 September 2015 (left) and on 15 November 2016 (right).

Santa Margarita River

The Santa Margarita River between MCBCP and Riverside County is predominantly sycamore riparian with permanent flow and with several large open pools surrounded by cattails, often created by beaver dams. This site is included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011); however, arroyo toads were not previously known from this site (USFWS 2015). This site is owned and managed by the Fallbrook Public Utilities District.

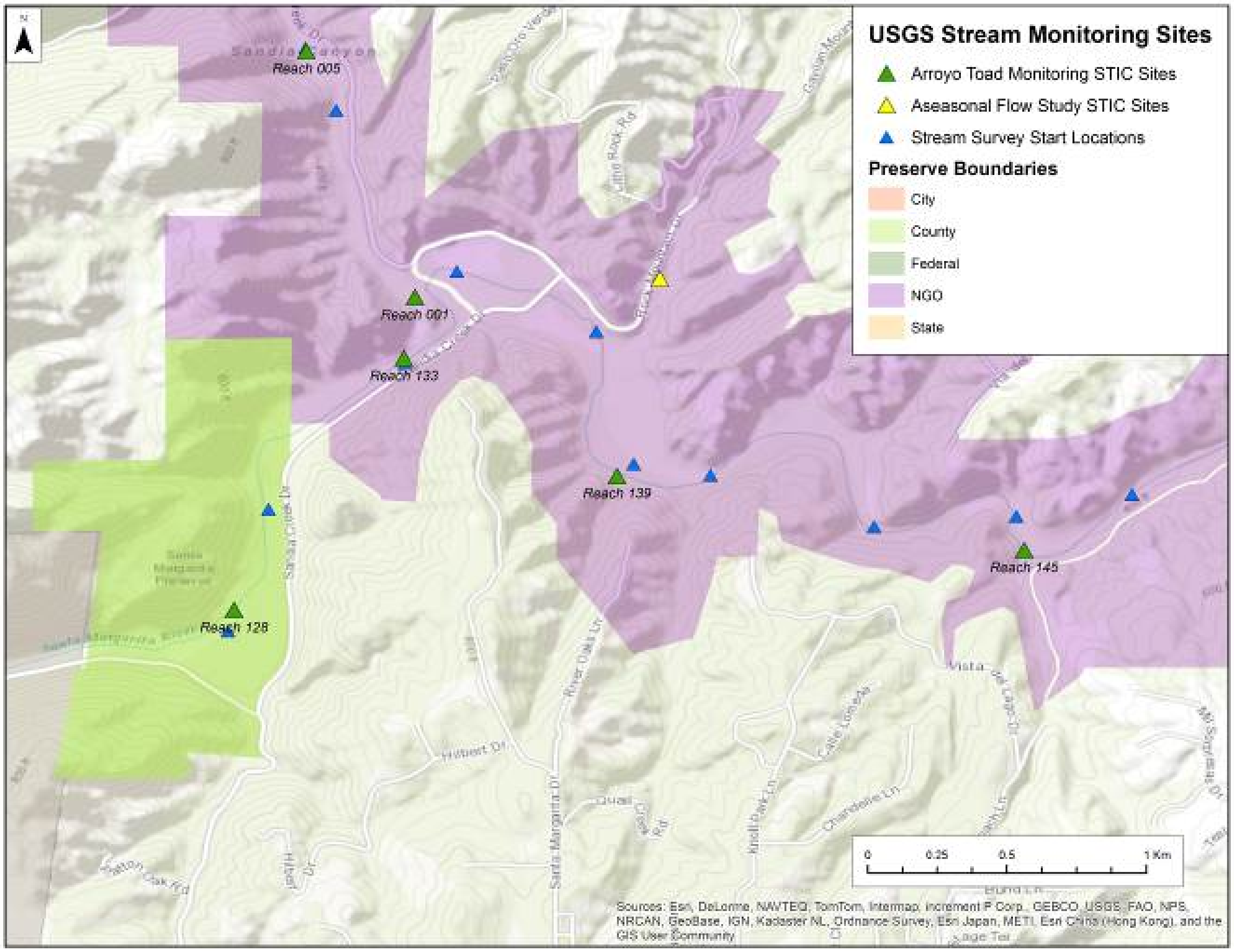

Figure B8. Santa Margarita River 1. Santa Margarita River reaches 128 to 145, owned and managed by County of San Diego Department of Parks and Recreation and Fallbrook Public utilities District.

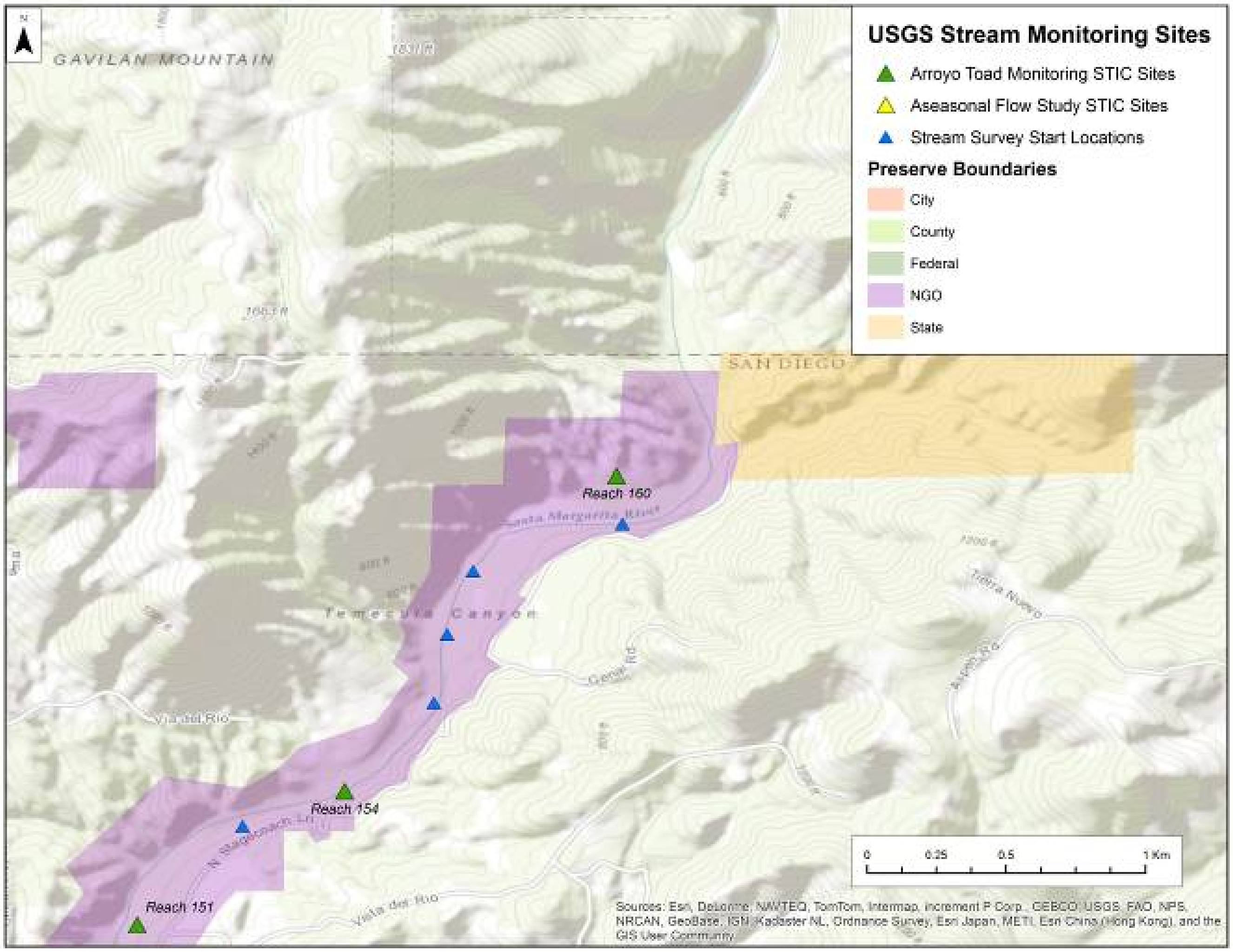

Figure B9. Santa Margarita River 2. Santa Margarita River reaches 151 to 160, owned and managed by Fallbrook Public utilities District.

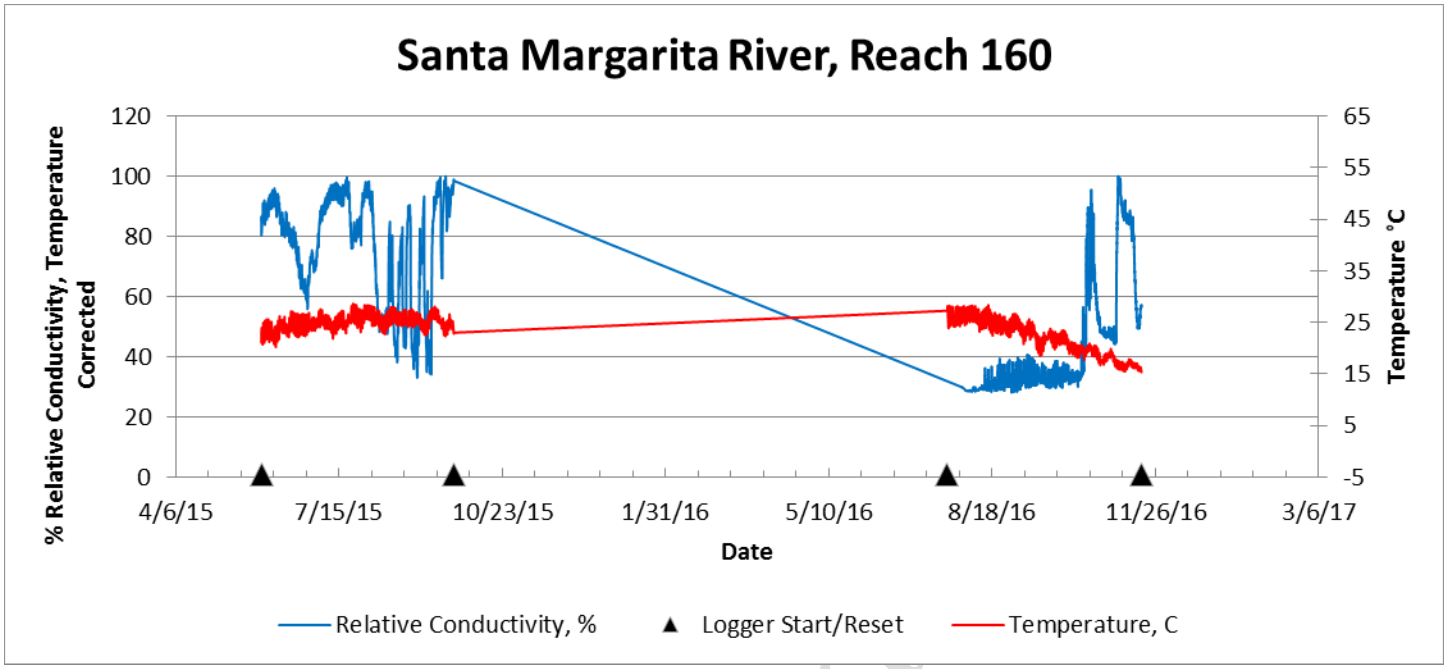

Figure B10. Relative conductivity and temperature graph of Santa Margarita River Reach 160.

Figure B11. Habitat at Santa Margarita River Reach 160 on 28 May 2015 (left) and on 17 November 2016 (right).

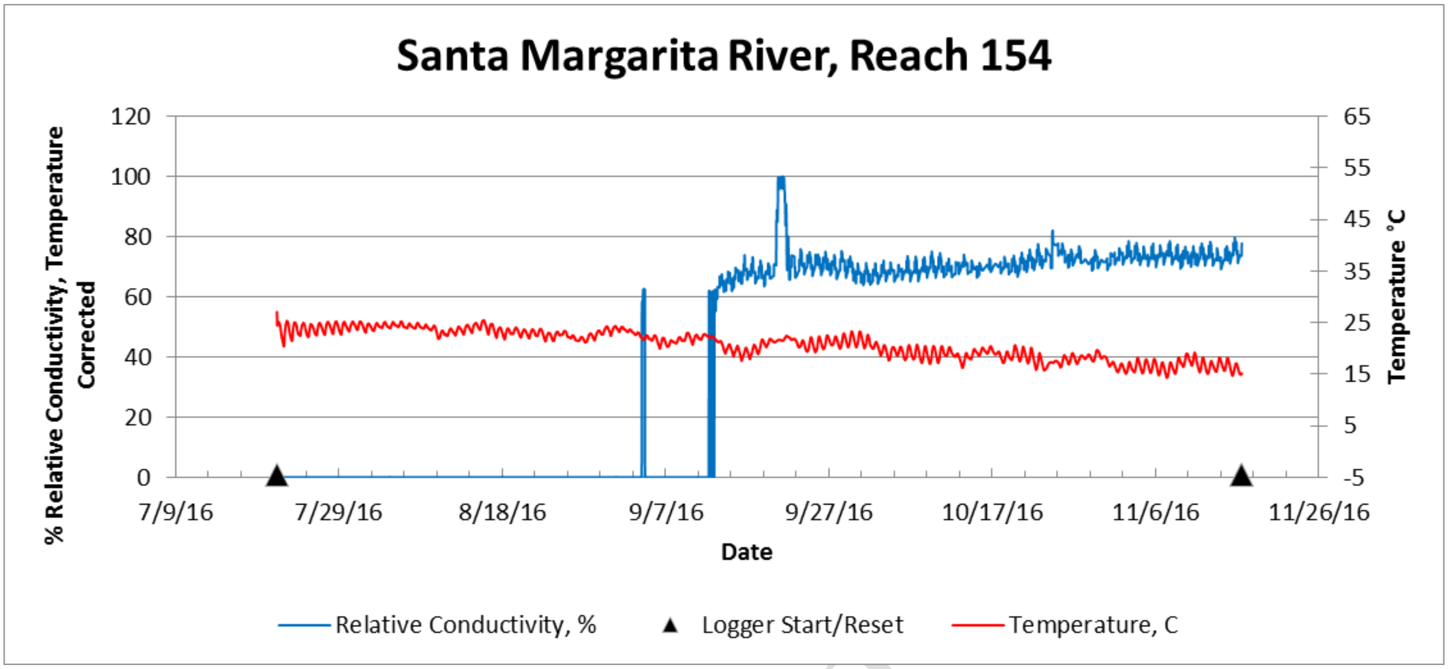

Figure B12. Relative conductivity and temperature graph of Santa Margarita River Reach 154.

Figure B13. Habitat at Santa Margarita River Reach 154 on 21 September 2015 (left) and on 21 July 2016 (right).

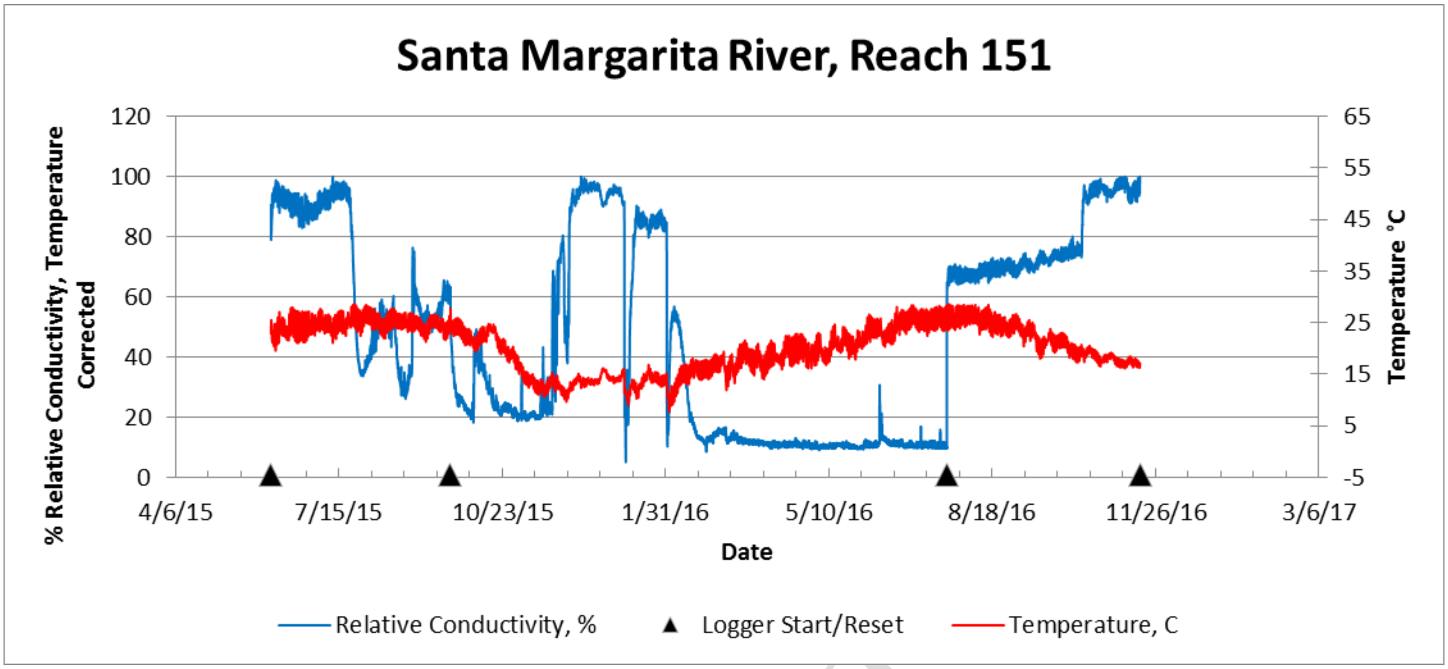

Figure B14. Relative conductivity and temperature graph of Santa Margarita River Reach 151.

Figure B15. Habitat at Santa Margarita River Reach 151 on 21 September 2015 (left) and on 21 July 2016 (right).

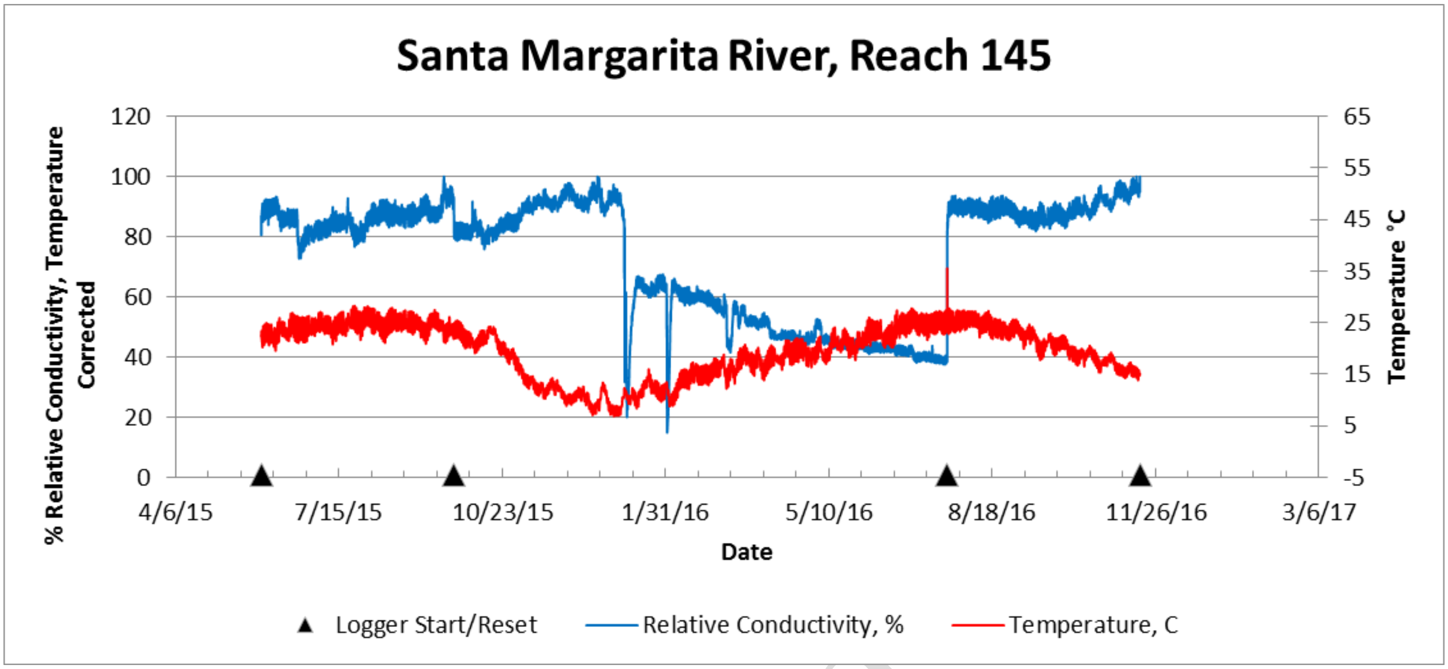

Figure B16. Relative conductivity and temperature graph of Santa Margarita River Reach 145.


Figure B17. Habitat at Santa Margarita River Reach 145 on 28 May 2015 (left) and on 23 September 2015 (right).

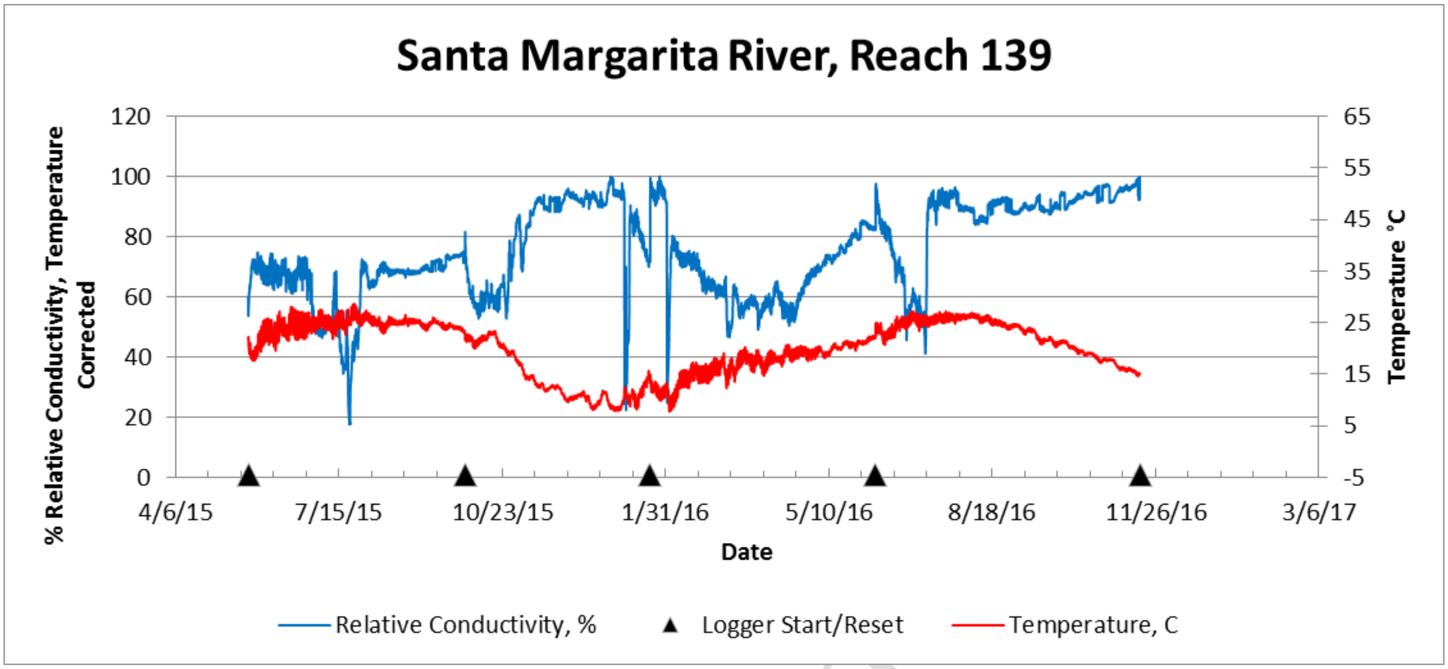

Figure B18. Relative conductivity and temperature graph of Santa Margarita River Reach 139.

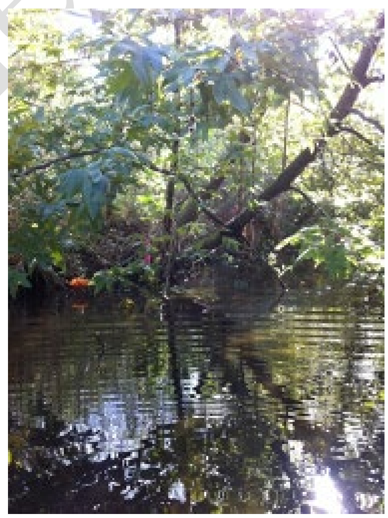

Figure B19. Habitat at Santa Margarita River Reach 139 on 20 May 2015 (left) and on 30 September 2015 (right).

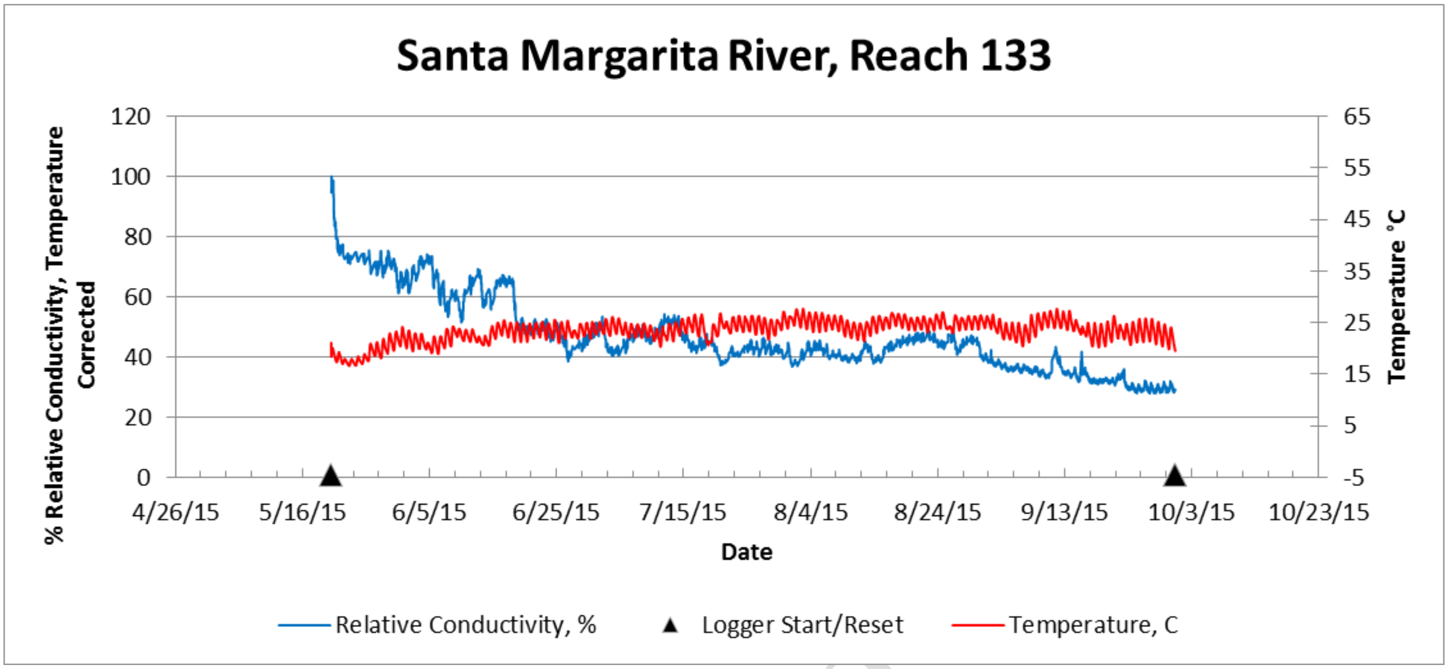

Figure B20. Relative conductivity and temperature graph of Santa Margarita River Reach 133.

Figure B21. Habitat at Santa Margarita River Reach 133 on 20 May 2015 (left) and on 17 November 2016 (right).

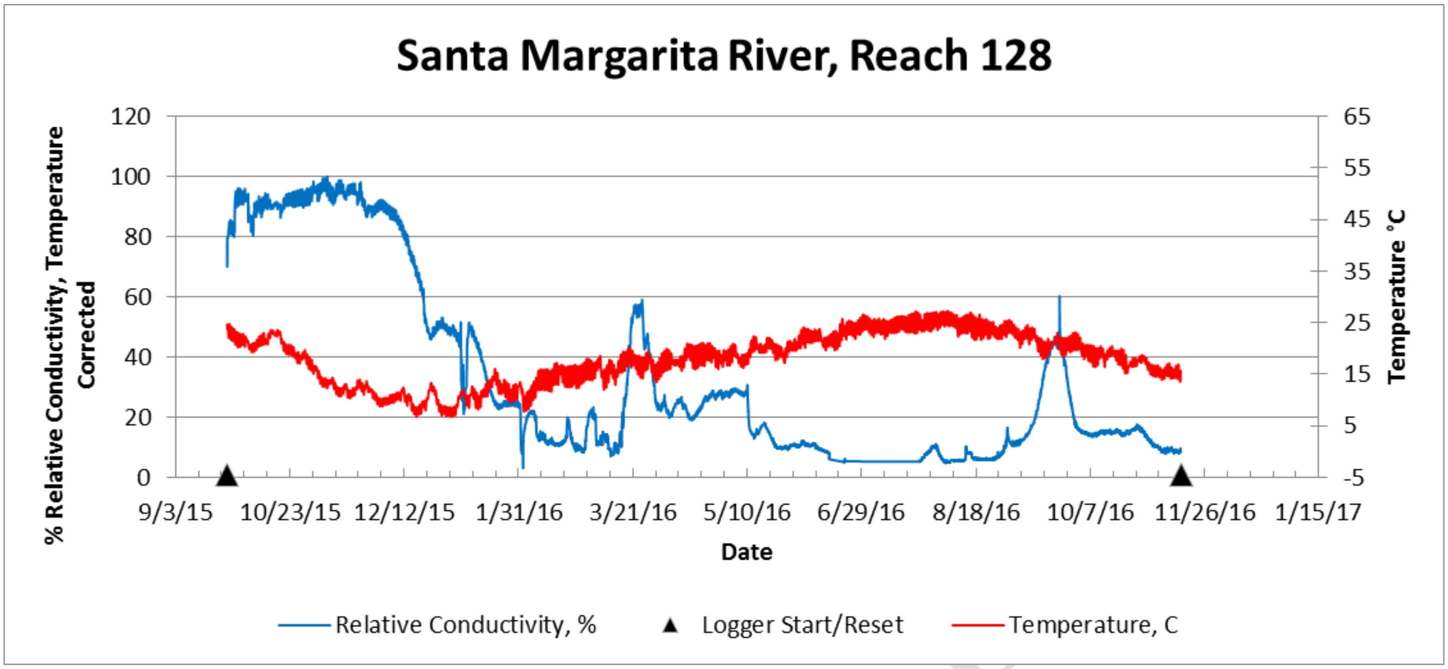

Figure B22. Relative conductivity and temperature graph of Santa Margarita River Reach 128.


Figure B23. Habitat at Santa Margarita River Reach 128 on 25 September 2015 (left) and on 15 November 2016 (right).

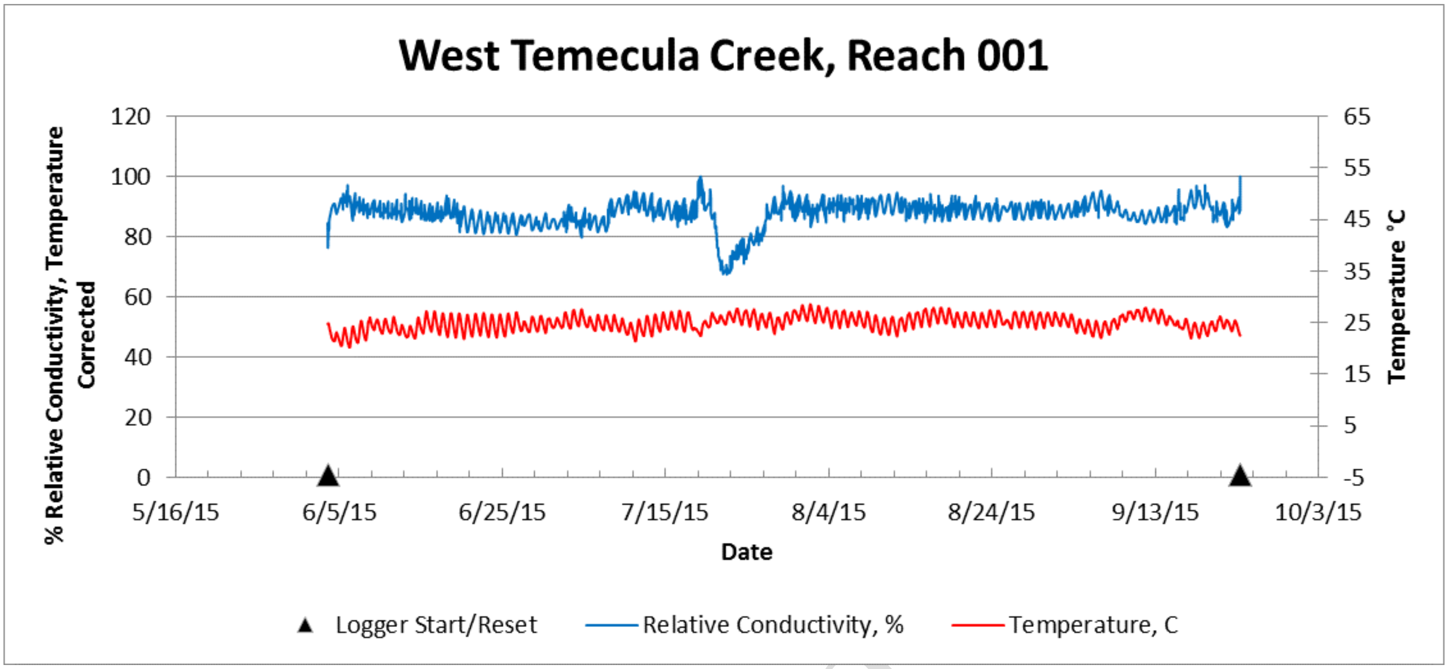

Figure B24. Relative conductivity and temperature graph of West Temecula Creek Reach 001.

Figure B25. Habitat at West Temecula Creek Reach 001 on 23 September 2015 (left) and on 17 November 2016 (right).

San Luis Rey River Watershed

The San Luis Rey River winds through northern San Diego County south of Santa Margarita River and is surrounded by development at the lower reaches and USFS and Tribal lands in the upper reaches. The watershed is approximately 144,835 hectares with approximately 40,235 hectares of conserved lands. The watershed runs from Palomar and Hot Springs Mountains at 1,991 meters to the Pacific Ocean south of MCBCP. Most of the San Luis Rey River, upstream from College Blvd in Oceanside and outside of Tribal lands, is included in USFWS's critical habitat designation for the arroyo toad (USFWS 2011). However, prior to our study, the status of the arroyo toad on conserved lands within the San Luis Rey River was unknown (USFWS 2015). This study includes six STIC sites along the main stem of the San Luis Rey River. The open space land managers within the watershed are California Department of Transportation (Caltrans), Center for Natural Lands Management (CNLM), City of Oceanside, and County of San Diego.

Wilderness Gardens Preserve

Wilderness Gardens Preserve is a San Diego County Park located along the main stem of the San Luis Rey River and downstream from Pauma Valley near the community of Pala. This section of the San Luis Rey River is characterized by a sandy wash with seasonal flow of water. A permanent pond lies adjacent to the main stem of river, providing a year-round water source. Recreation is limited to hiking within the 6.4 kilometers of trails surrounding and bordering the San Luis Rey River. This site was included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011); however, arroyo toads were not previously known from this site (USFWS 2015).

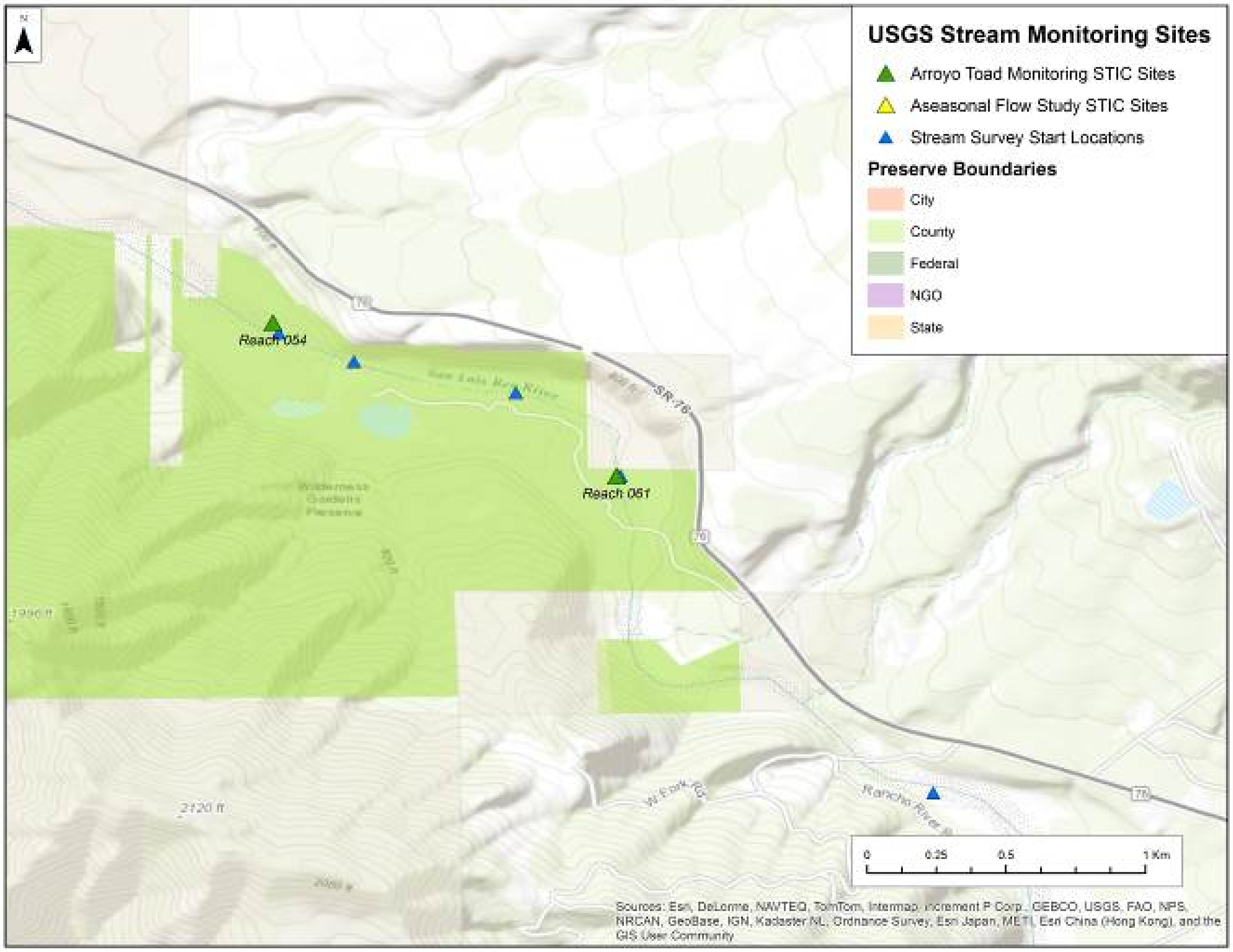

Figure B26. Wilderness Gardens. Middle San Luis Rey River reaches 54 through 61 owned and managed by County of San Diego Department of Parks and Recreation.

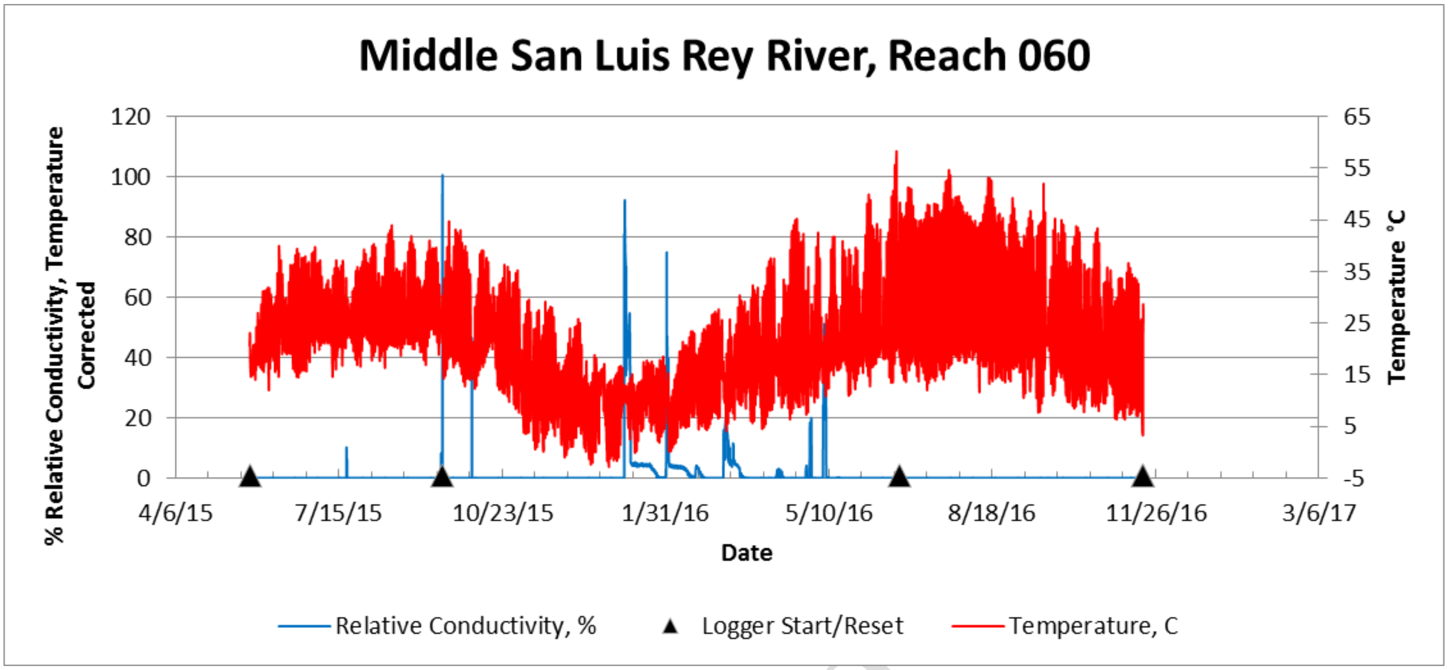

Figure B27. Relative conductivity and temperature graph of Middle San Luis Rey River Reach 060.

Figure B28. Habitat at Middle San Luis Rey River Reach 060 on 16 September 2015 (left) and on 22 June 2016 (right).

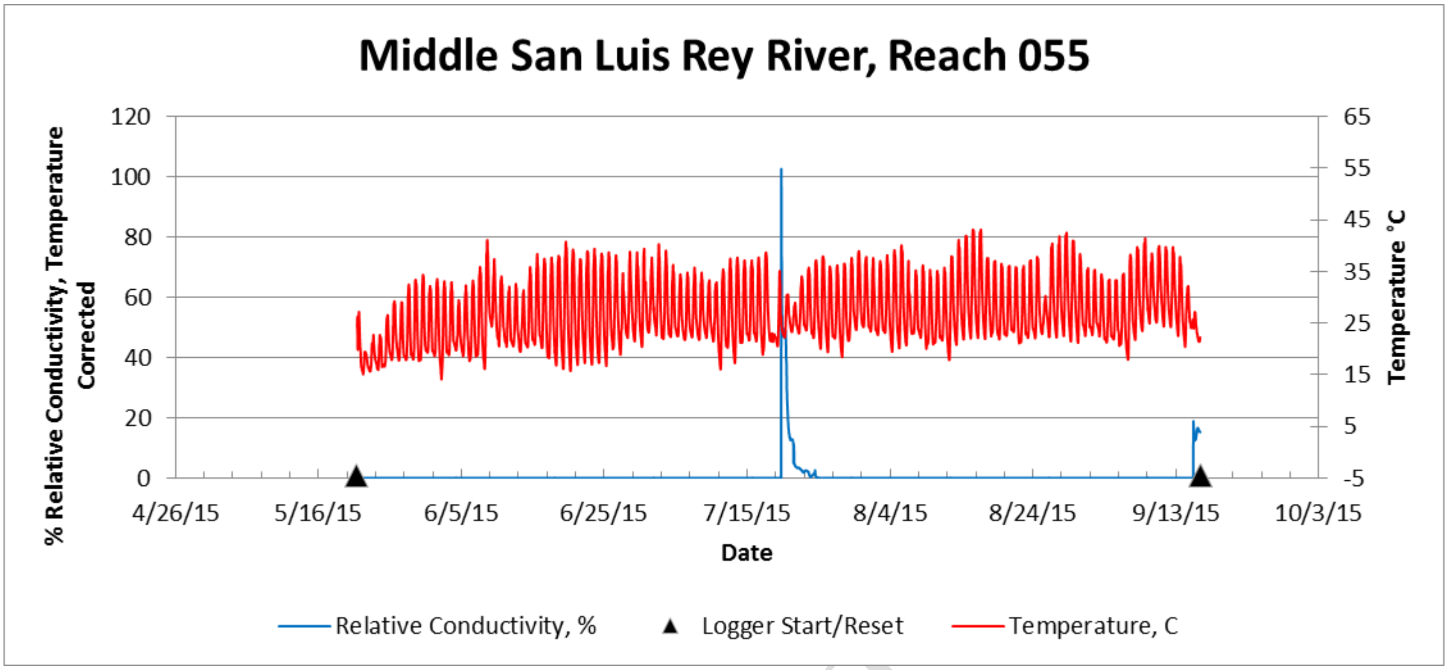

Figure B29. Relative conductivity and temperature graph of Middle San Luis Rey River Reach 055.

Figure B30. Habitat at Middle San Luis Rey River Reach 055 on 16 September 2015 (left) and on 22 June 2016 (right).

San Luis Rey River Park (ASF 29)

San Luis Rey River Park is owned and managed by City of Oceanside and contains dense riparian vegetation bordered to the east by Highway 76 and Old River Road to the west. Recreation is limited to hiking and horseback riding on trails surrounding and bordering the San Luis Rey River. This site was included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011), and arroyo toads were observed at this site in 2001 and 2006, but status between that time and this study was unknown (USFWS 2015).

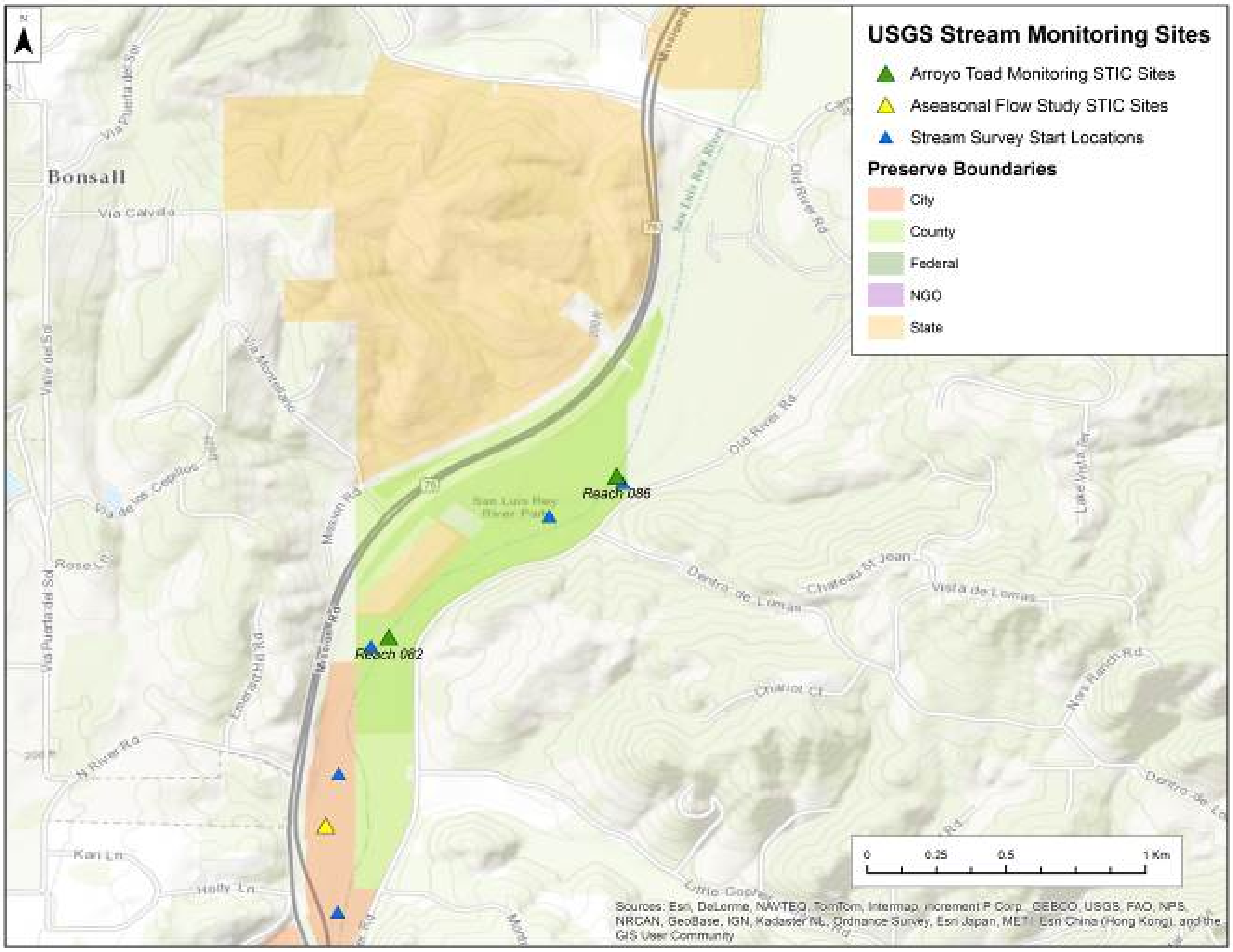

Figure B31. San Luis Rey River Park 2. Lower San Luis Rey River reaches 78 through 86 owned and managed by County of San Diego Department of Parks and Recreation.

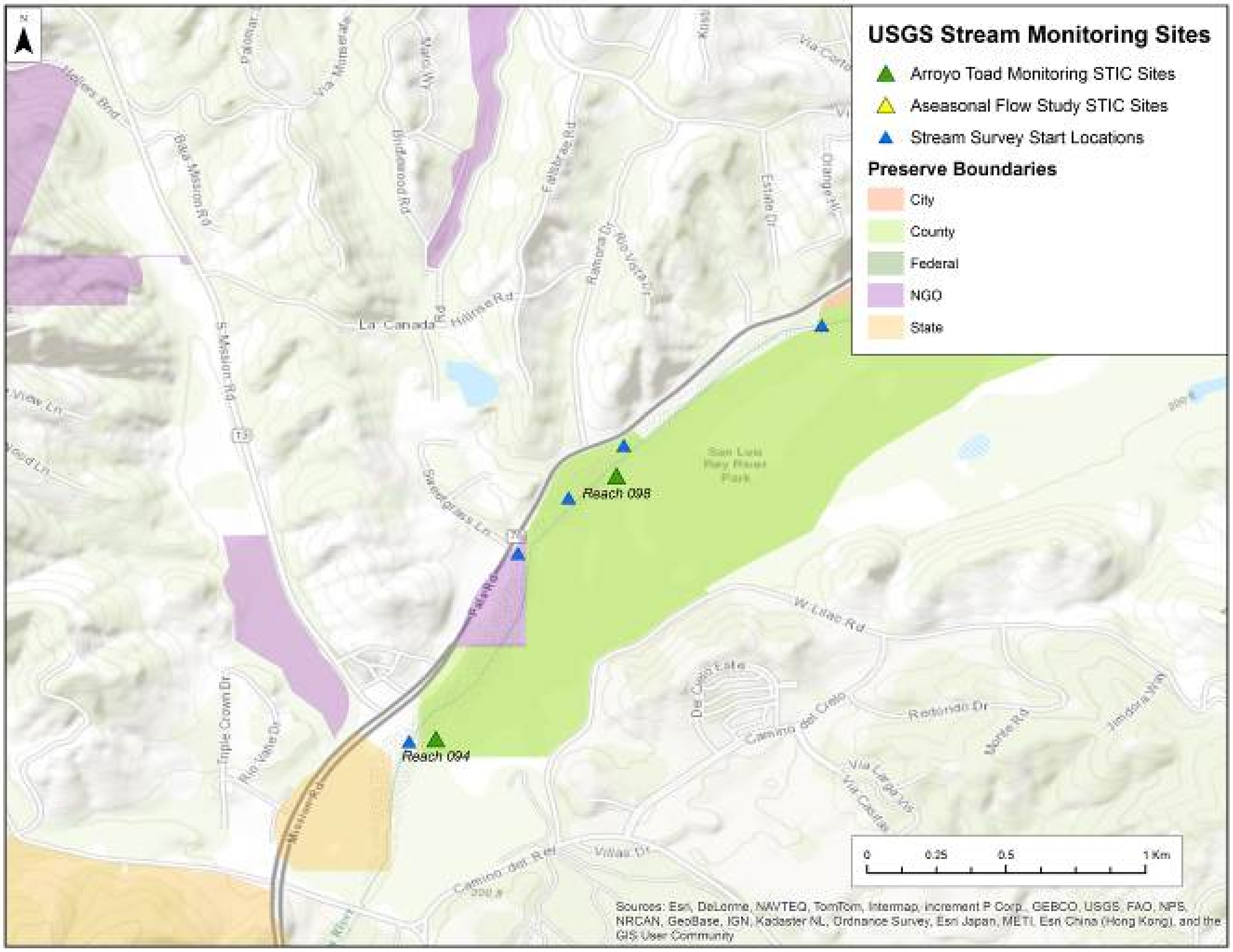

Figure B32. San Luis Rey River Park 1. Lower San Luis Rey River reaches 94 to 102 owned and managed by County of San Diego Department of Parks and Recreation.

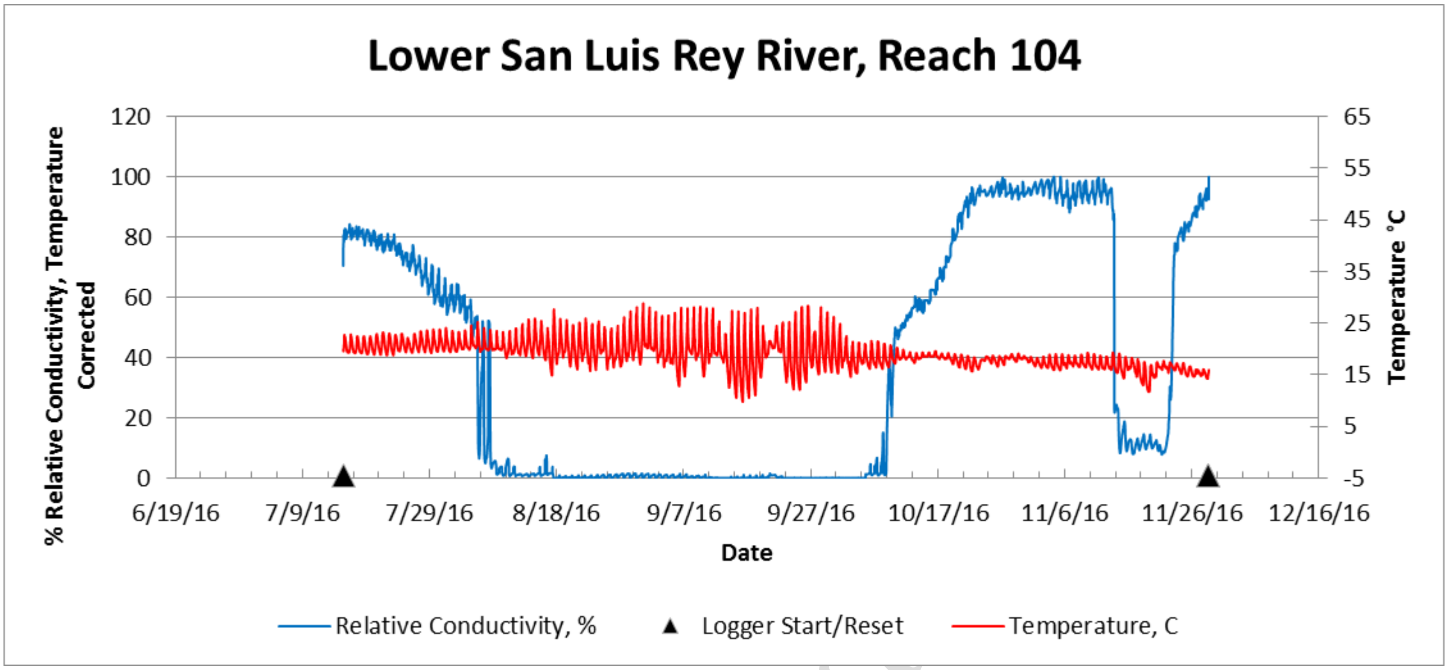

Figure B33. Relative conductivity and temperature graph of Lower San Luis Rey River Reach 104.

Figure B34. Habitat at Lower San Luis Rey River Reach 104 on 15 July 2016 (left) and on 28 November 2016 (right).

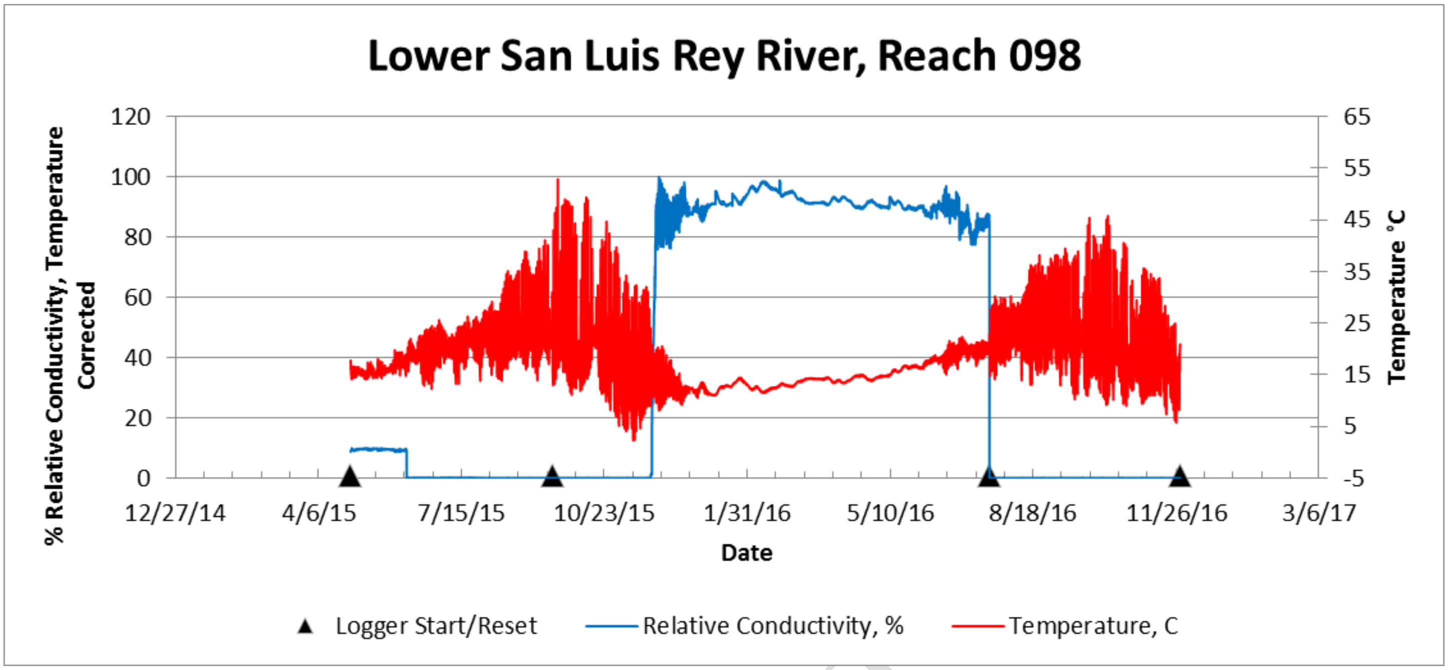

Figure B35. Relative conductivity and temperature graph of Lower San Luis Rey River Reach 098.

Figure B36. Habitat at Lower San Luis Rey River Reach 098 on 16 September 2015 (left) and on 28 November 2016 (right).

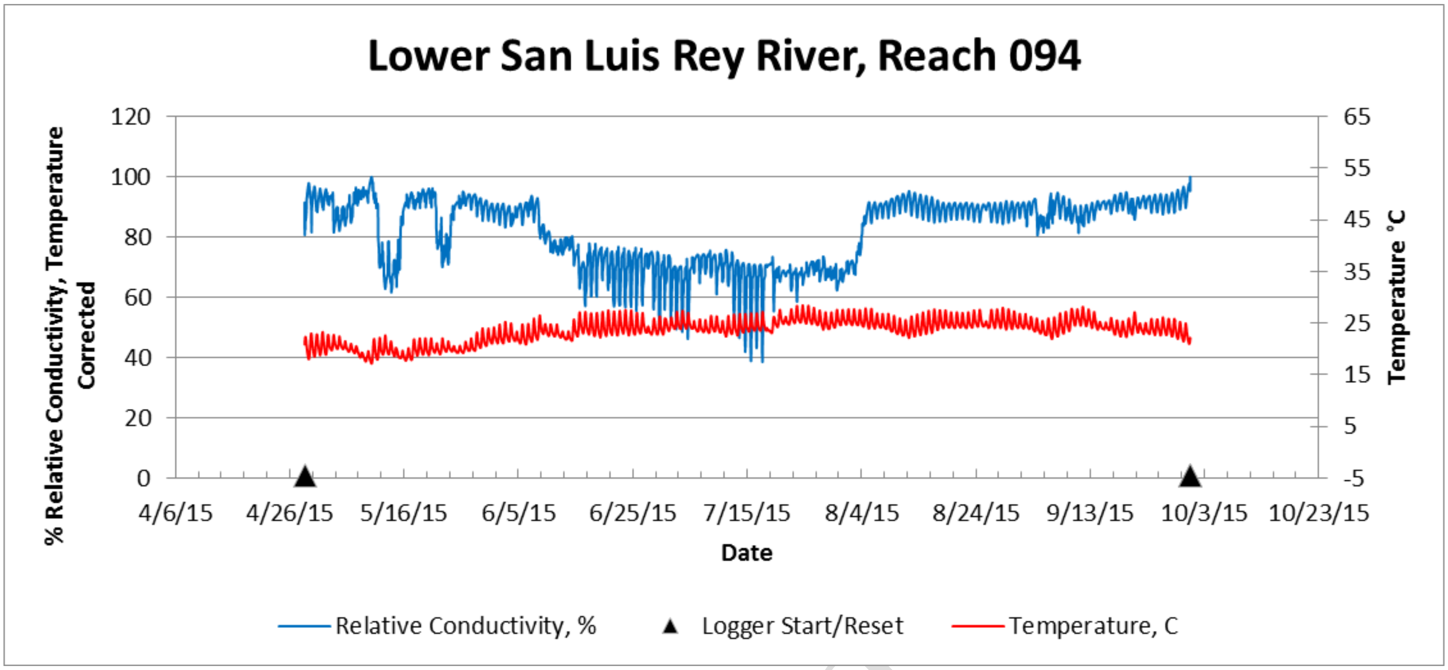

Figure B37. Relative conductivity and temperature graph of Lower San Luis Rey River Reach 094.

Figure B38. Habitat at Lower San Luis Rey River Reach 094 on 29 June 2016 (left) and on 28 November 2016 (right).

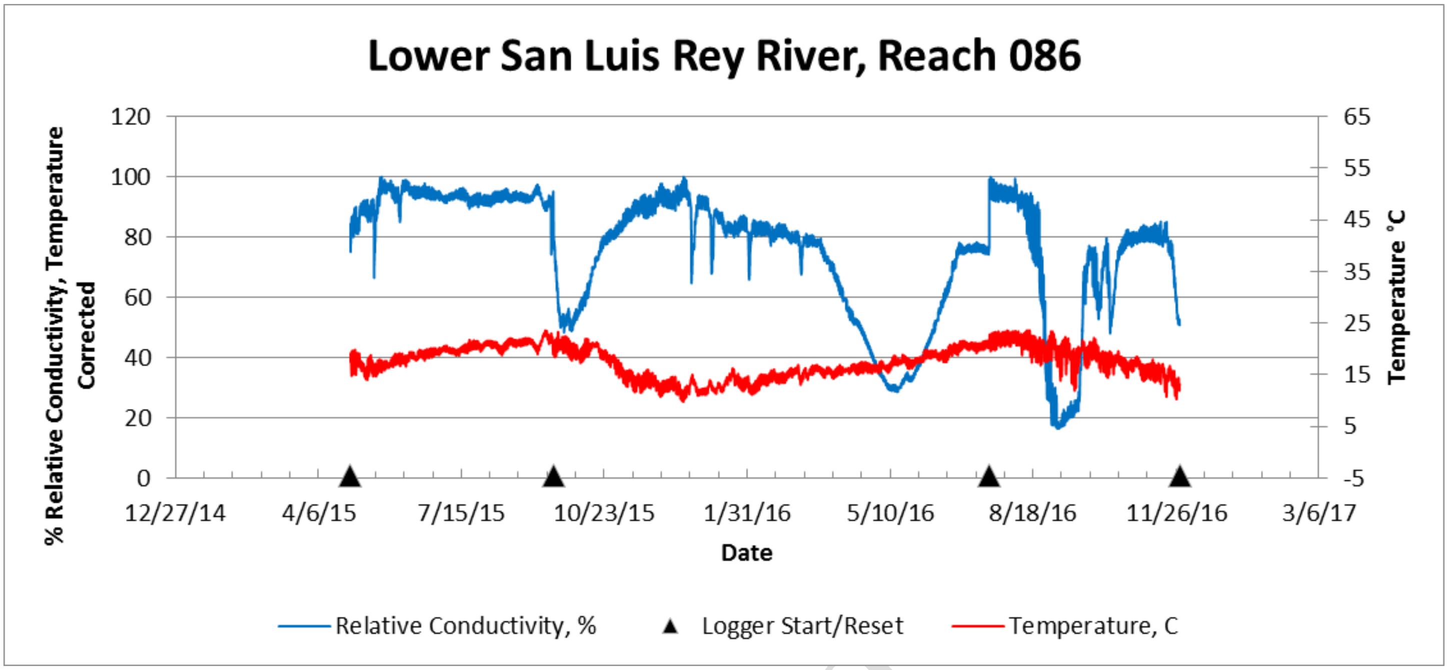

Figure B39. Relative conductivity and temperature graph of Lower San Luis Rey River Reach 086.

Figure B40. Habitat at Lower San Luis Rey River Reach 086 on 28 April 2015 (left) and on 28 November 2016 (right).

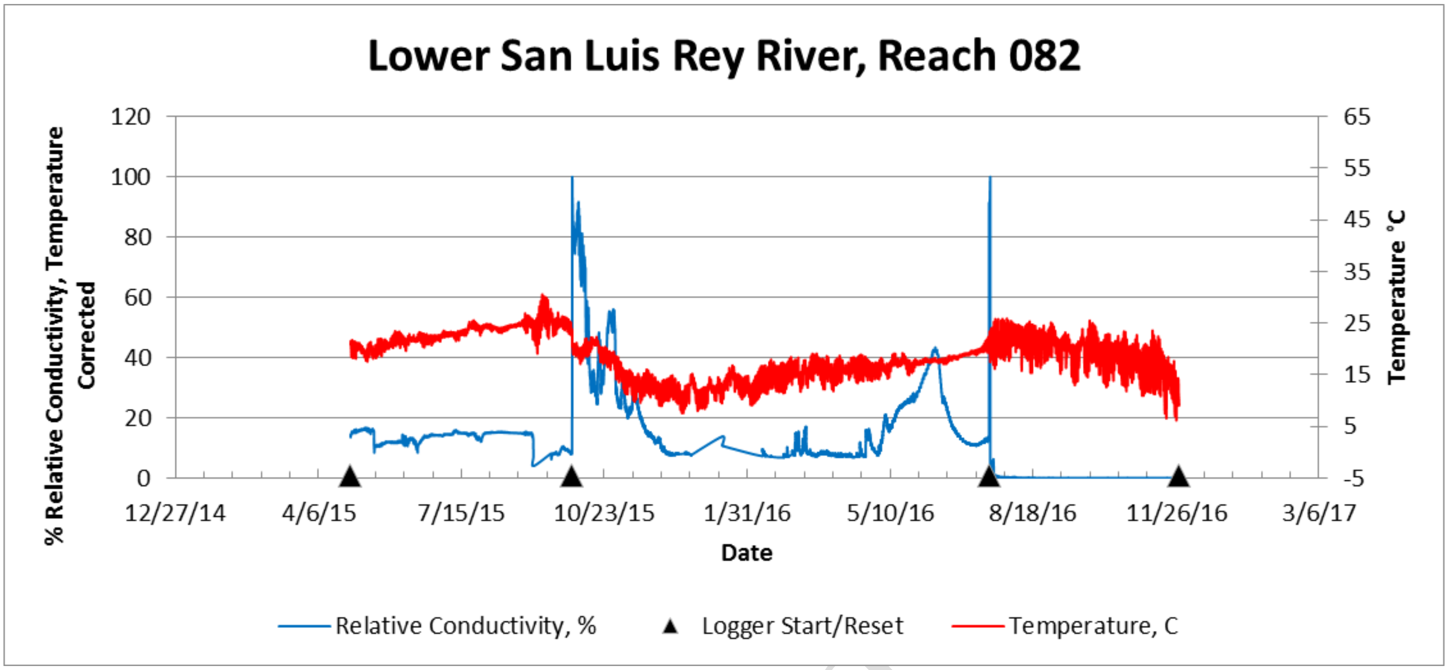

Figure B41. Relative conductivity and temperature graph of Lower San Luis Rey River Reach 082.


Figure B42. Habitat at Lower San Luis Rey River Reach 082 on 18 July 2016 (left) and on 28 November 2016 (right).

San Dieguito River Watershed

San Dieguito River watershed encompasses approximately 89,422 hectares. The San Diego River flows 88 kilometers from Volcan Mountain at 1,743 meters near Julian, CA, to the Pacific Ocean. Habitat within the watershed includes mixed conifer, oak woodland, chaparral, coastal sage scrub, and grasslands, as well as riparian. Including Santa Maria Creek, Santa Ysabel Creek, upper San Dieguito River, and Temescal Creek, we have 28 arroyo toad surface water monitoring locations. The conserved lands in this area total approximately 26,715 hectares and are primarily owned and managed by City of San Diego, County of San Diego, USFS, and San Dieguito River Conservancy. Much of the conserved land within San Dieguito River upstream from Lake Hodges, Santa Ysabel Creek, Santa Maria Creek, Boden Canyon, and Temescal Creek are within the USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

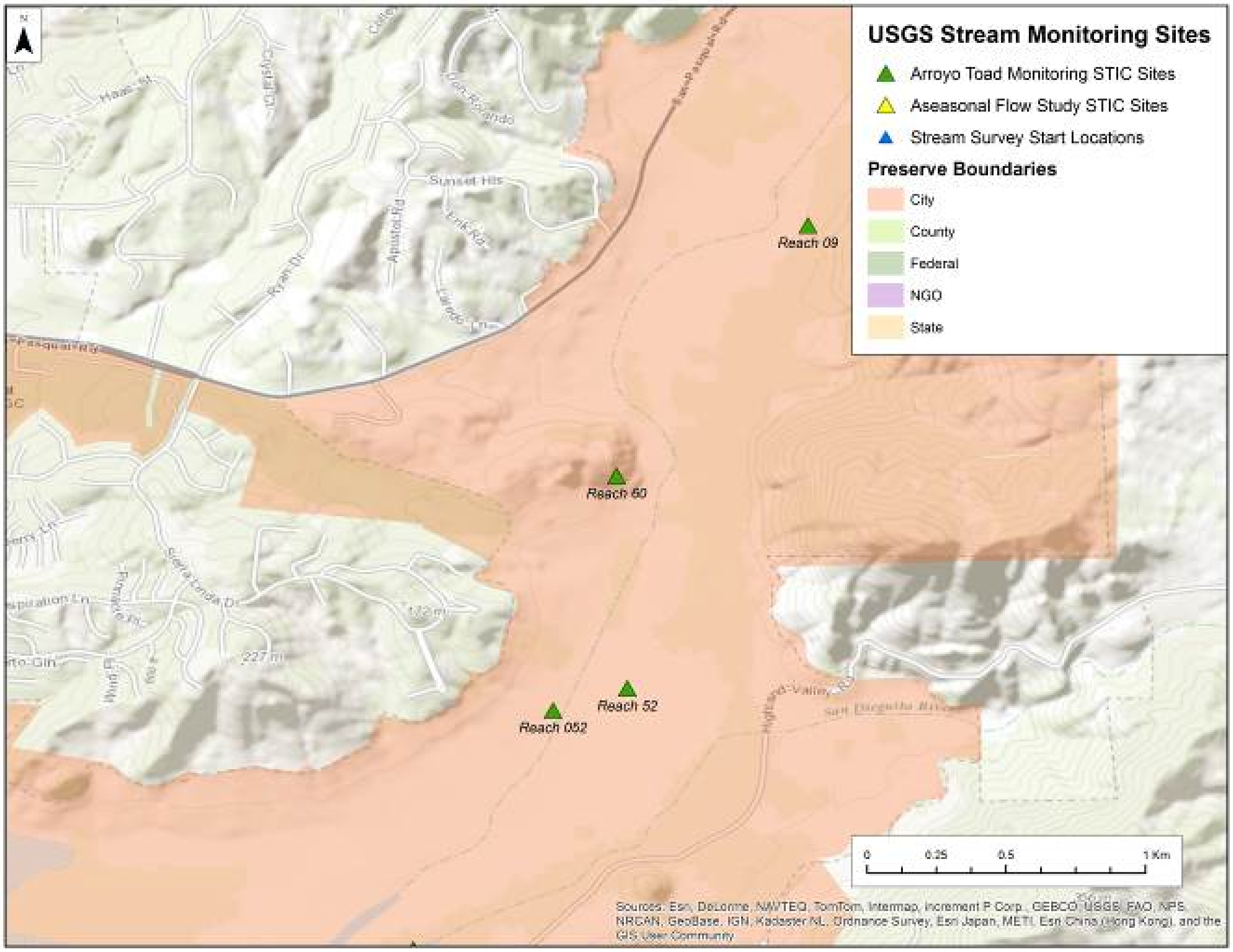

Figure B43. Upper San Dieguito River Reaches 52 through 60.

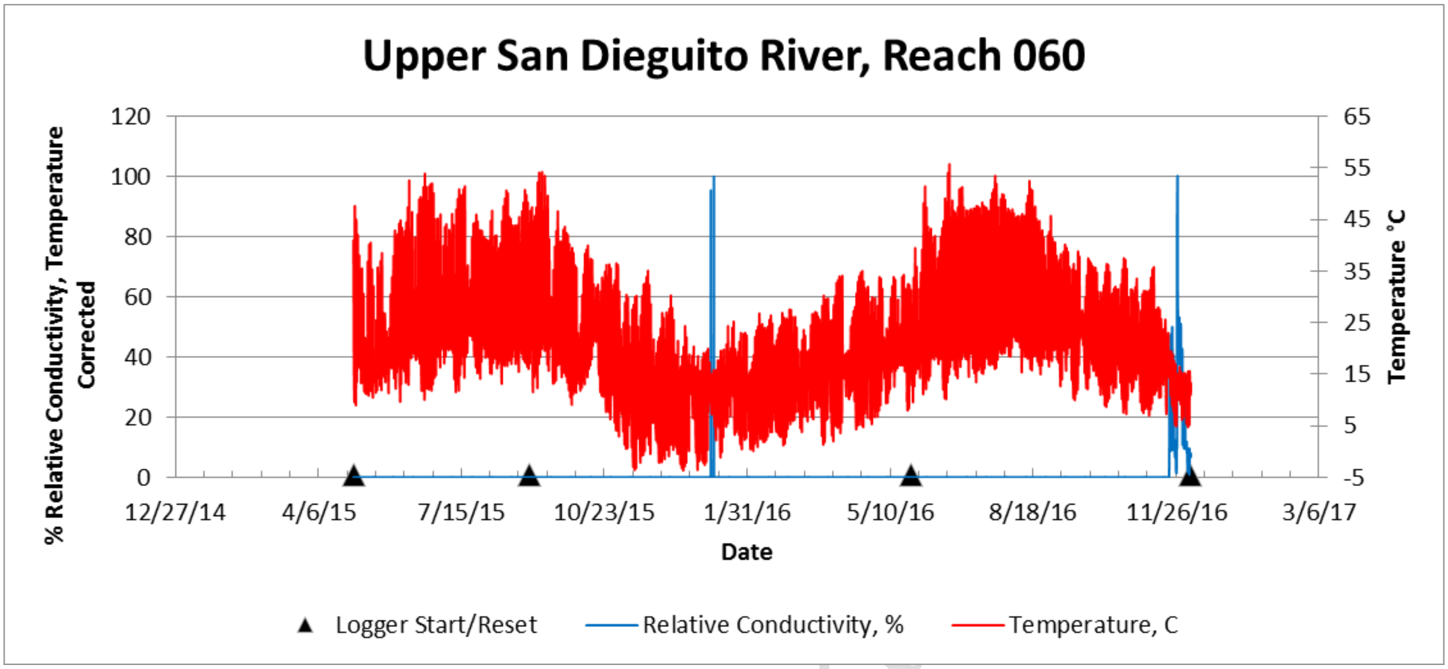

Figure B44. Relative conductivity and temperature graph of Upper San Dieguito River Reach 060.

Figure B45. Habitat at Upper San Dieguito River Reach 060 on 31 August 2015 (left) and on 06 December 2016 (right).

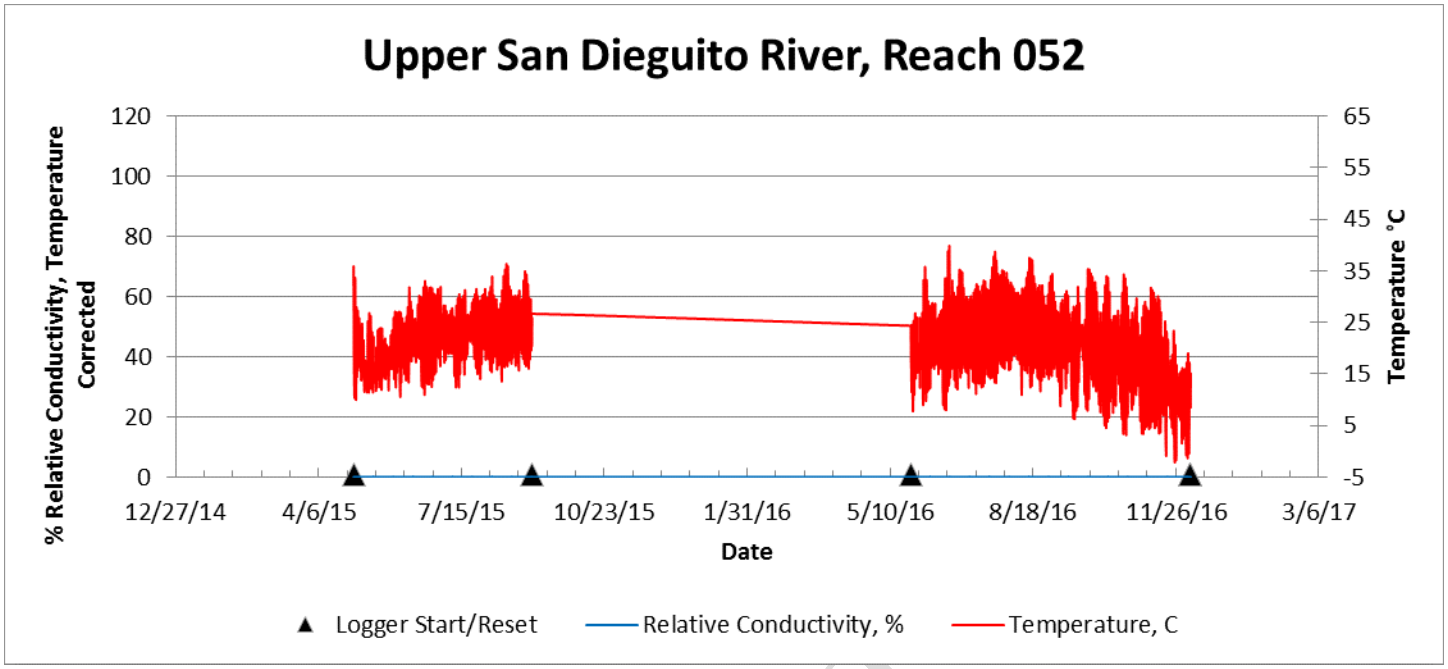

Figure B46. Relative conductivity and temperature graph of Upper San Dieguito River Reach 052.

Figure B47. Habitat at Upper San Dieguito River Reach 052 on 02 September 2015 (left) and on 06 December 2016 (right).

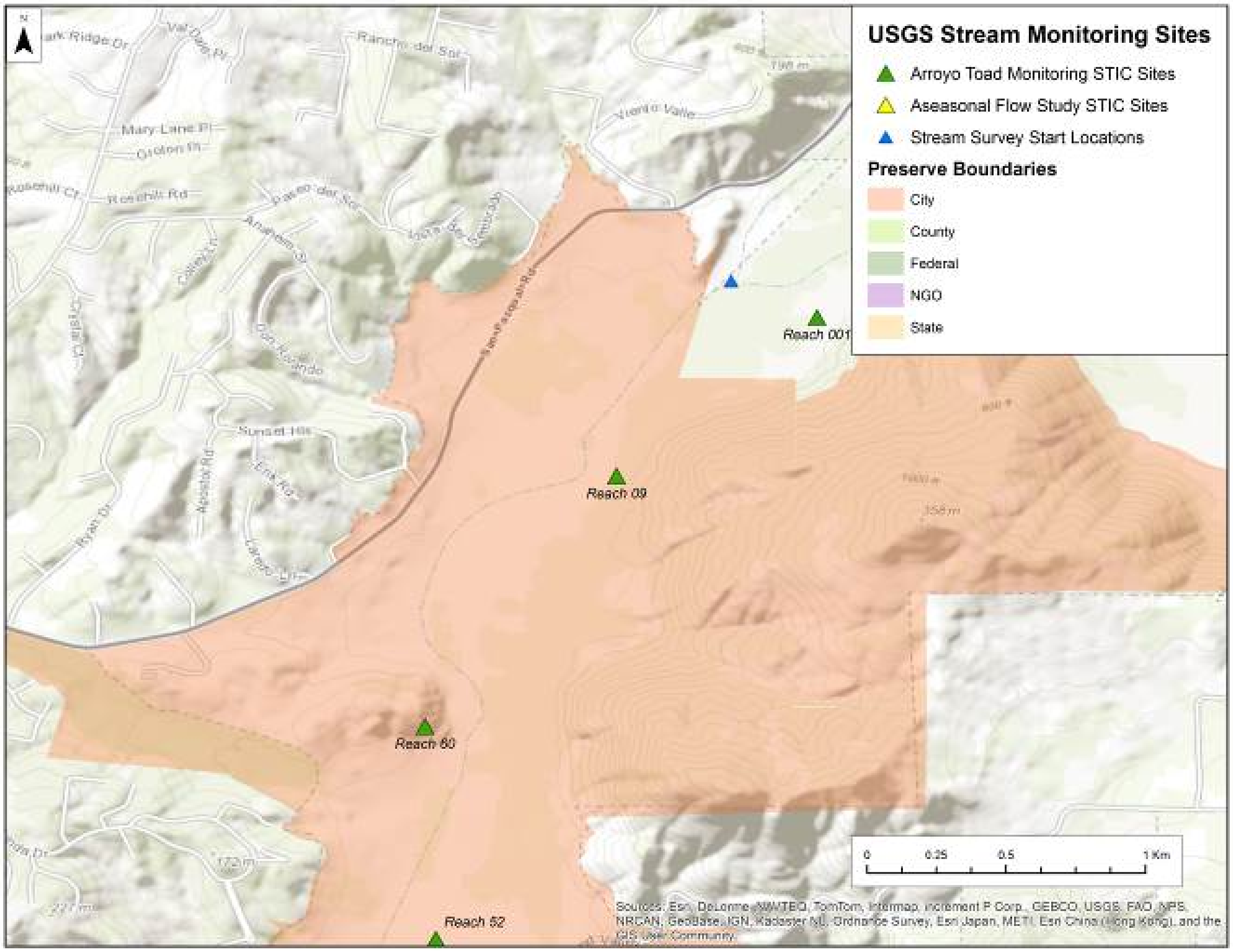

Figure B48. Upper San Dieguito River B Reach 9.

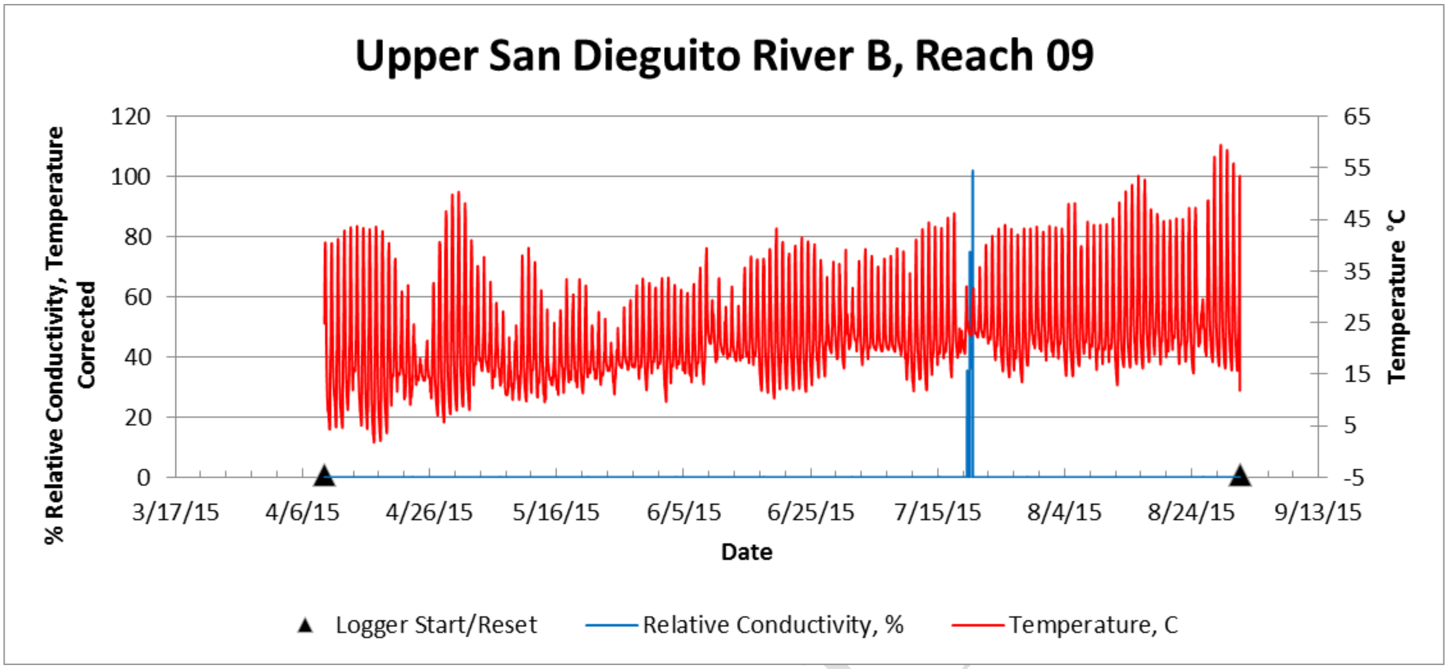

Figure B49. Relative conductivity and temperature graph of Upper San Dieguito River B Reach 09.

Figure B50. Habitat at Upper San Dieguito River B Reach 09 on 09 April 2015 (left) and on 19 May 2016 (right).

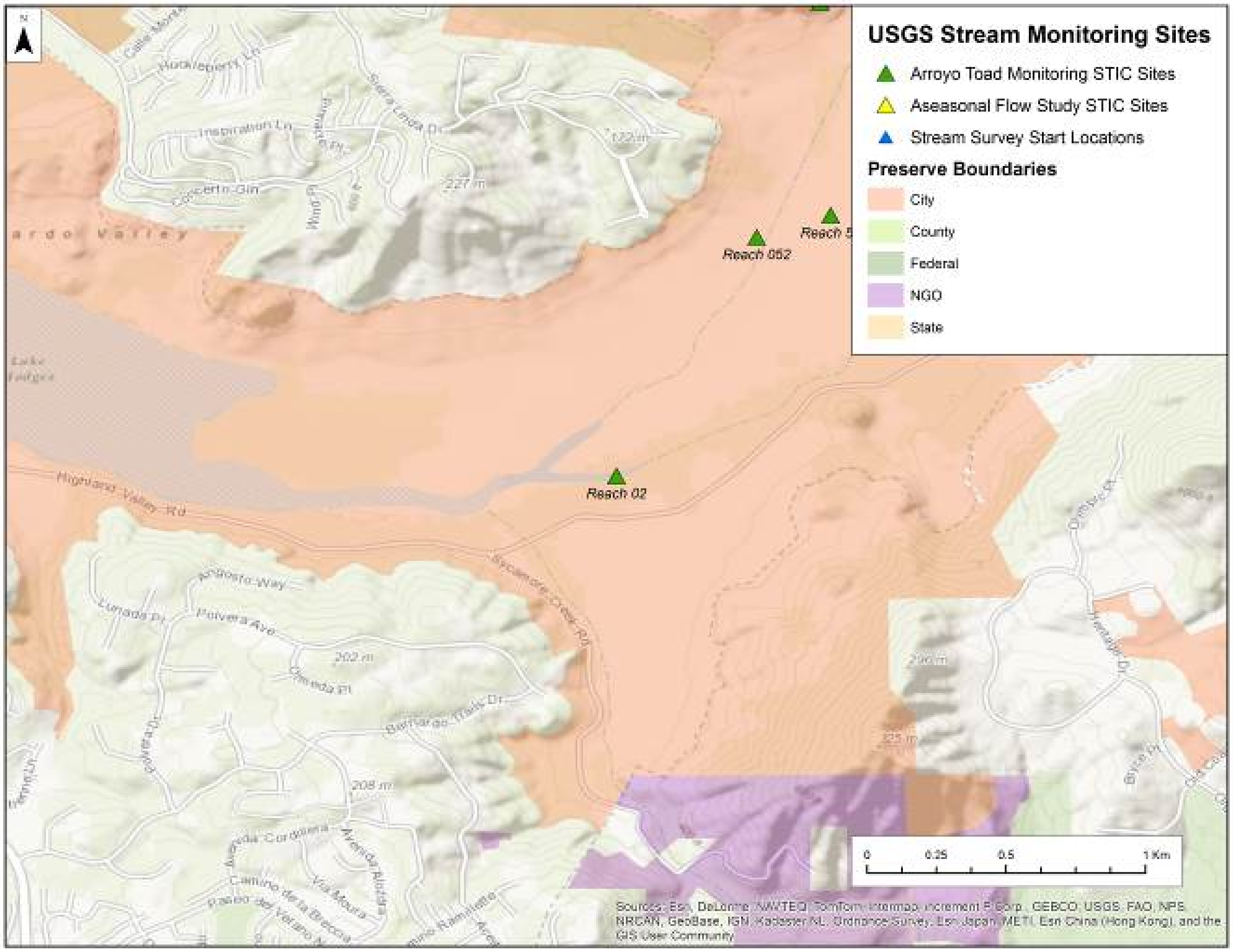

Figure B51. Upper San Dieguito River Tributary 4 Reach 2.

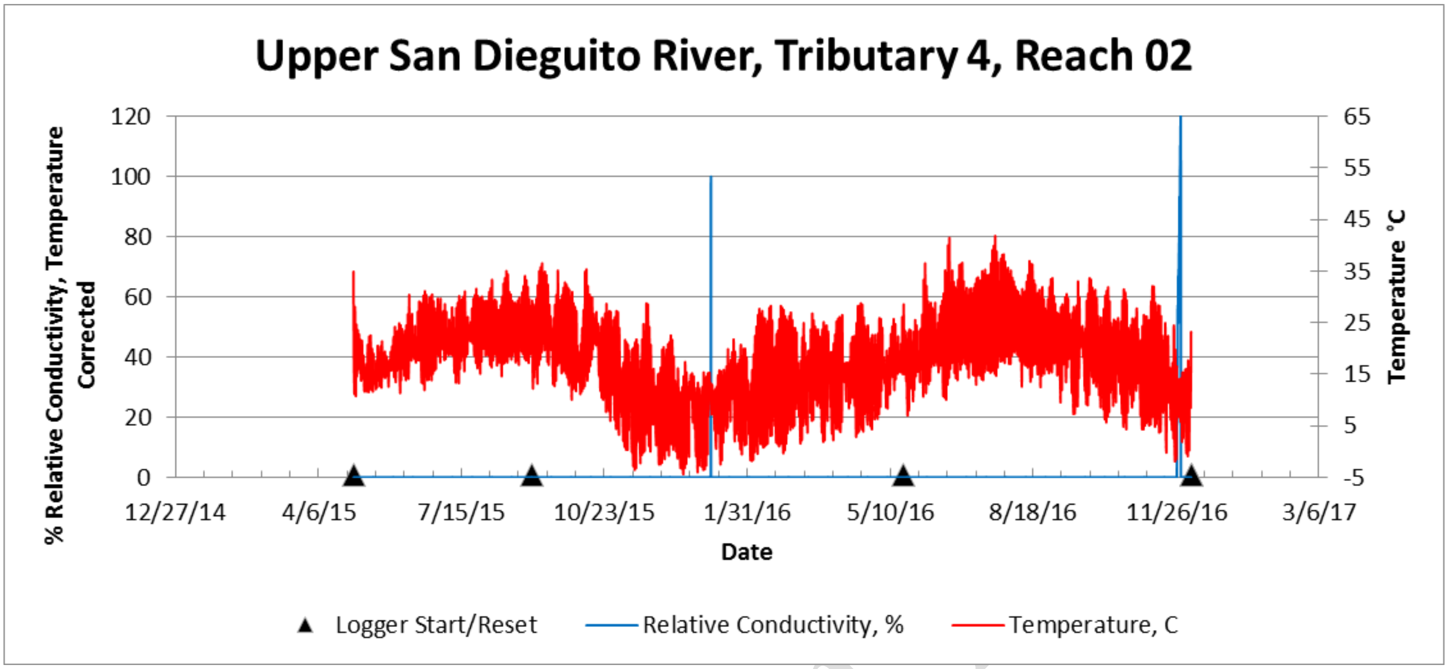

Figure B52. Relative conductivity and temperature graph of Upper San Dieguito River Tributary 4 Reach 02.

Figure B53. Habitat at Upper San Dieguito River Tributary 4 Reach 02 on 02 September 2015 (left) and on 19 May 2016 (right).

Santa Ysabel Ecological Preserve

This site includes a portion of Santa Ysabel Creek and one of its tributaries on the Santa Ysabel Ecological Preserve. The preserve is owned and maintained by County of San Diego and recreation is limited to hiking and equestrian use. Arroyo toads were previously known from this site (USFWS 2015), which is included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

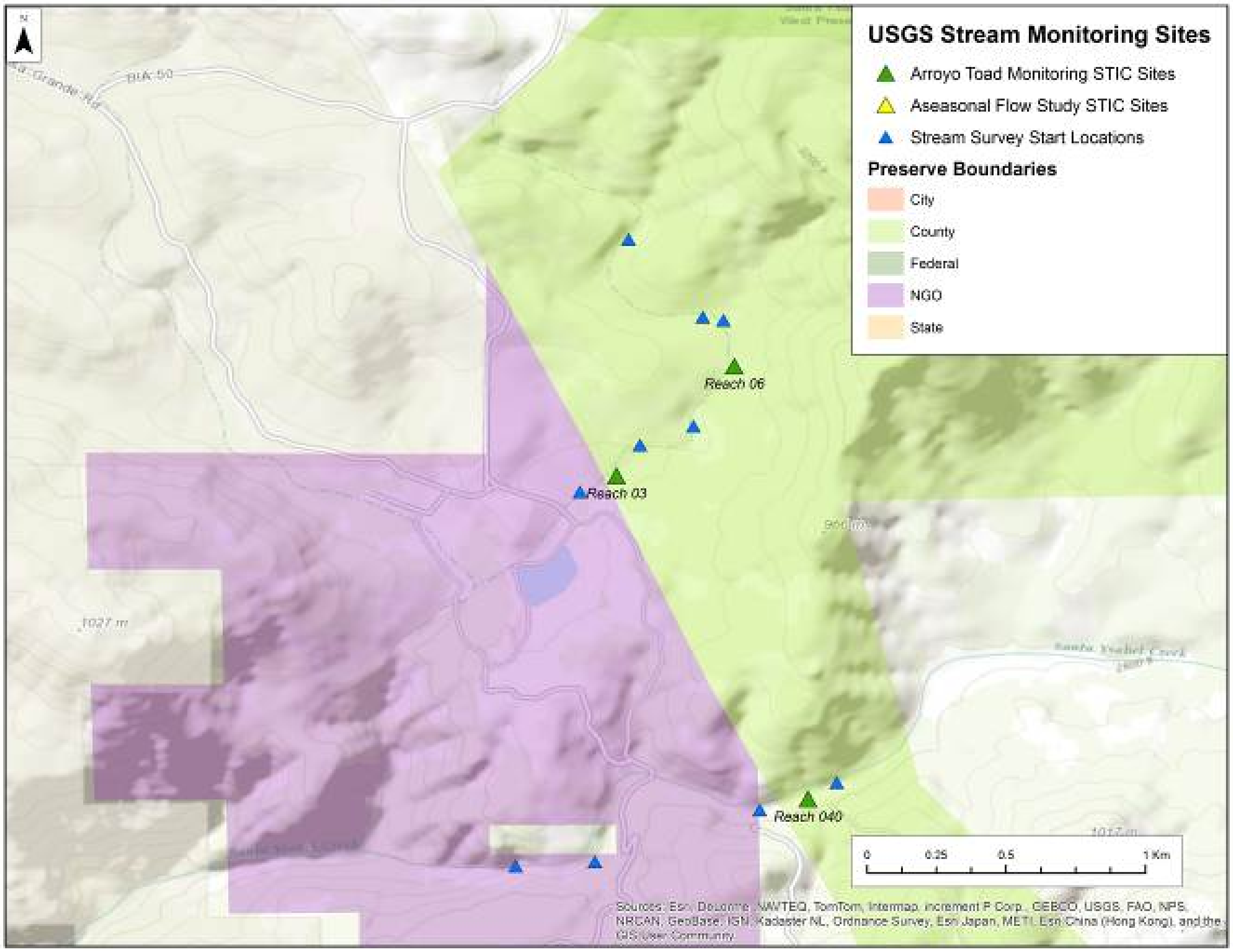

Figure B54. Upper Santa Ysabel Creek and Upper Santa Ysabel Creek Tributary 11A Santa Ysabel Ecological Preserve, owned and managed by County of San Diego.

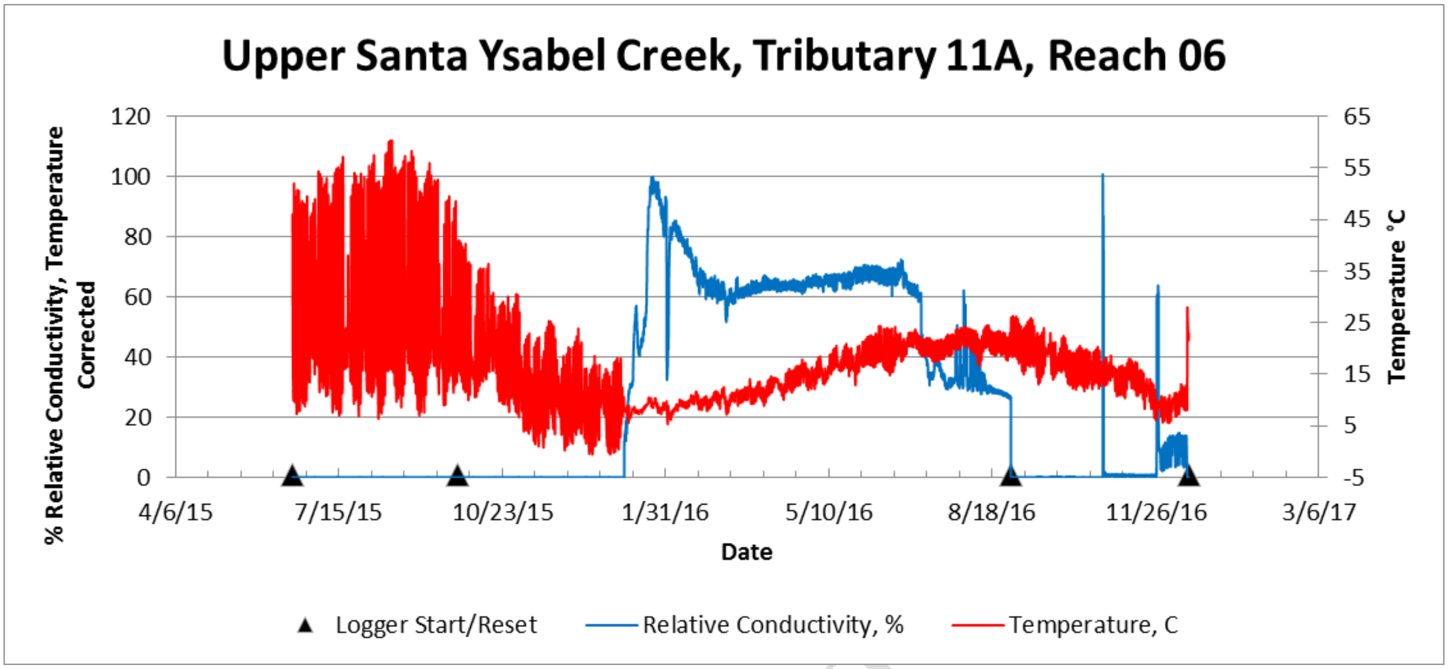

Figure B55. Relative conductivity and temperature graph of Upper Santa Ysabel Creek Tributary 11A Reach 06.

Figure B56. Habitat at Upper Santa Ysabel Creek Tributary 11A Reach 06 on 25 September 2015 (left) and on 15 December 2016 (right).

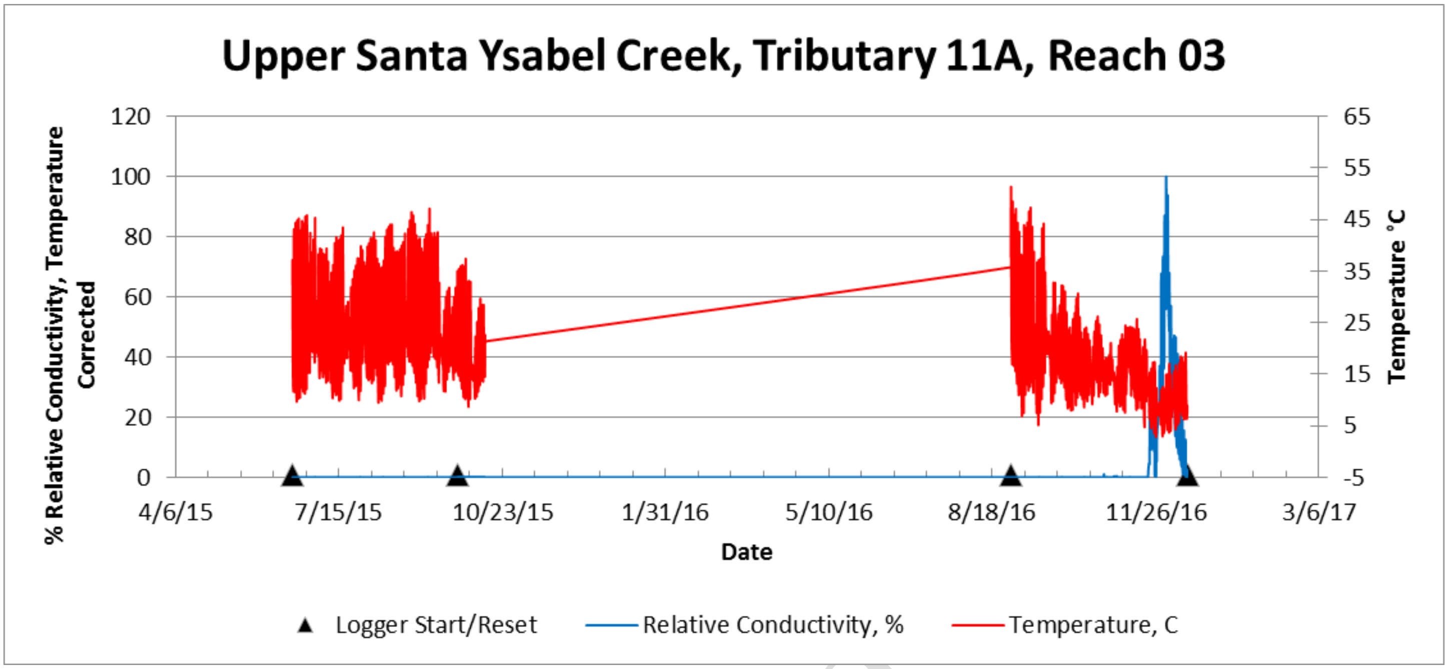

Figure B57. Relative conductivity and temperature graph of Upper Santa Ysabel Creek Tributary 11A Reach 03.

Figure B58. Habitat at Upper Santa Ysabel Creek Tributary 11A Reach 03 on 25 September 2015 (left) and on 15 December 2016 (right).

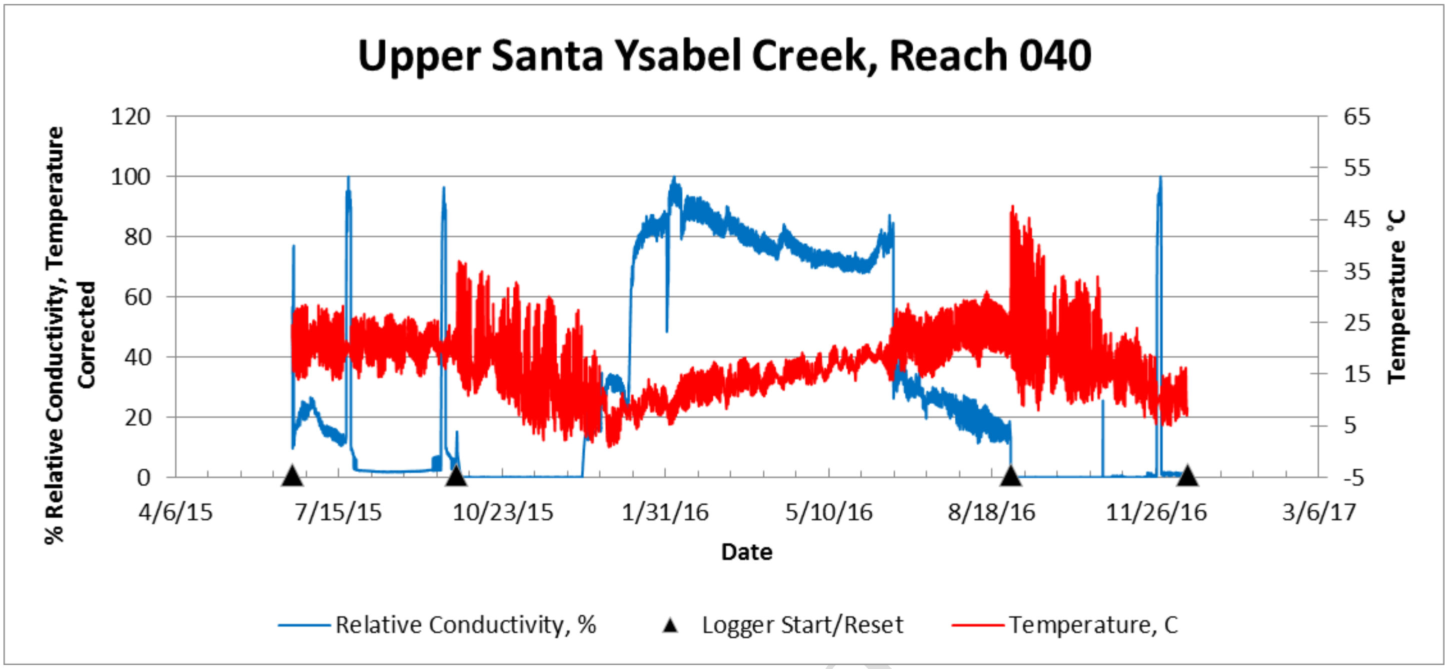

Figure B59. Relative conductivity and temperature graph of Upper Santa Ysabel Creek Reach 040.

Figure B60. Habitat at Upper Santa Ysabel Creek Reach 040 on 25 September 2015 (left) and on 29 August 2016 (right).

Santa Ysabel Creek

This site consists of Santa Ysabel Creek from Black Canyon to San Pasqual Valley. The habitat is a mixture of low gradient open wash punctuated by reaches of steep, narrow, boulder lined sycamore riparian. The site is owned and managed by City of San Diego, USFS, and California Department of Fish and Wildlife (CDFW). Recreation is limited to hiking and biking on City of San Diego property but also to hunting on USFS and CDFW property. Arroyo toads were previously known from this site (USFWS 2015), which is included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

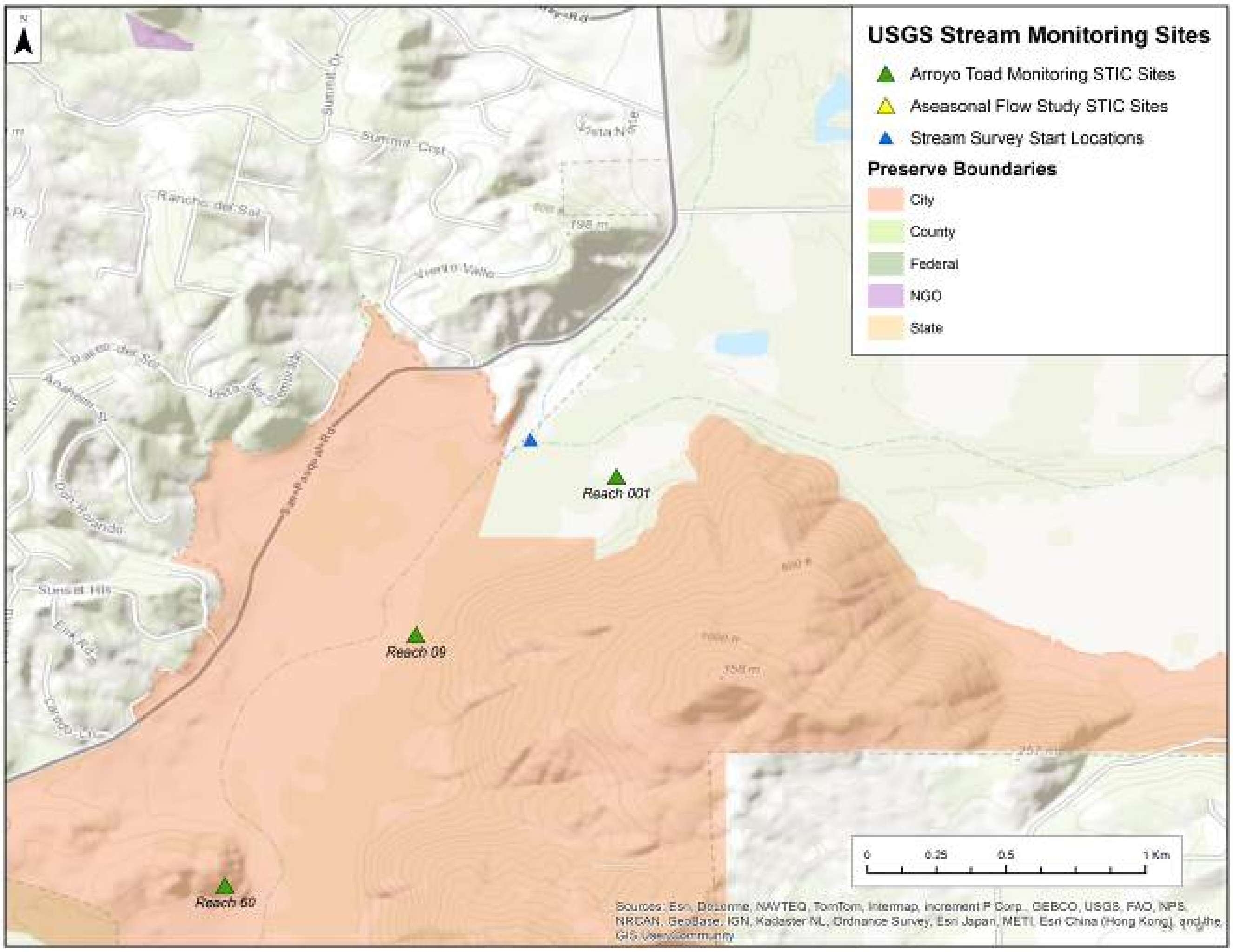

Figure B61. Lower Santa Ysabel Creek 1. Lower Santa Ysabel Creek Reach 1.

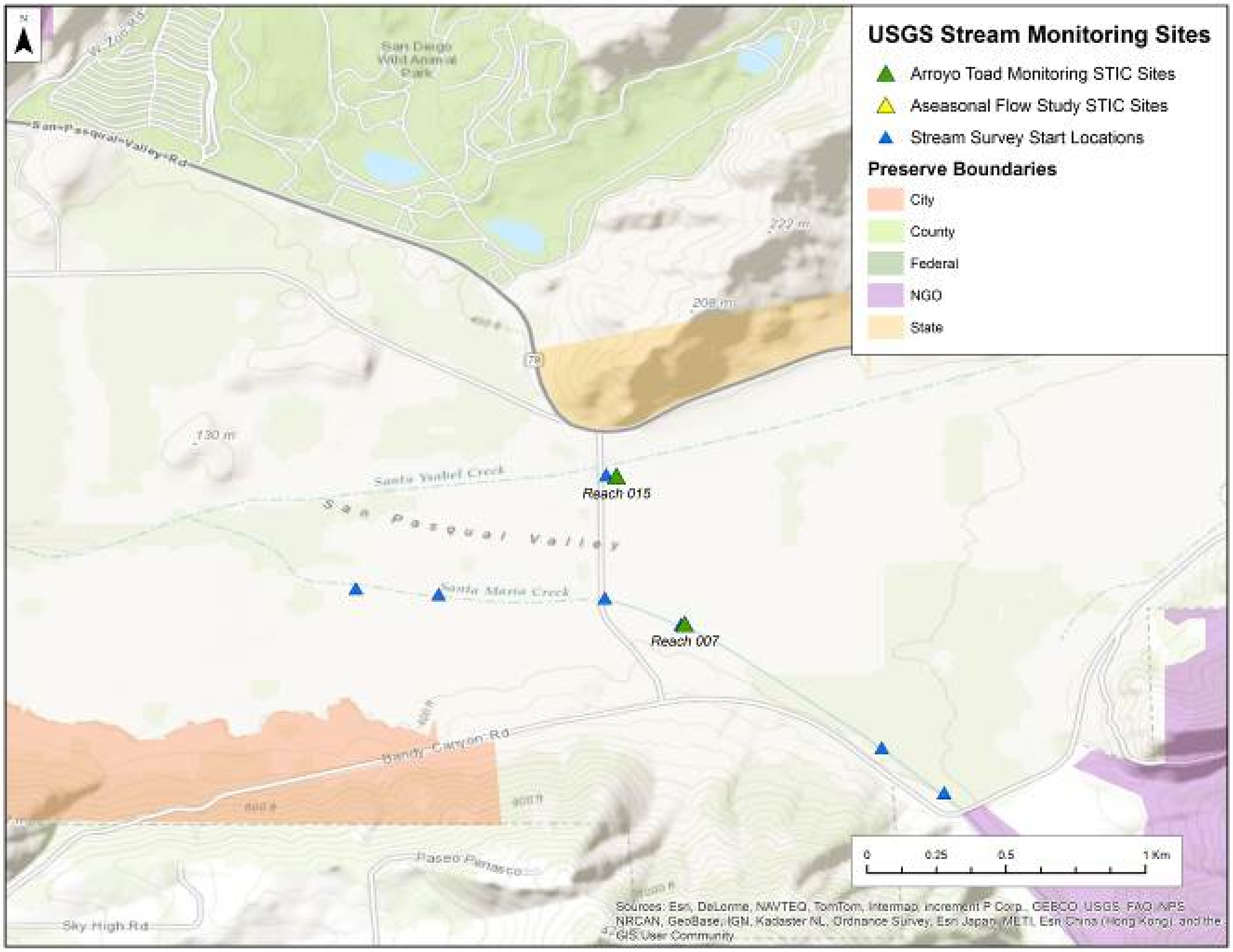

Figure B62. Lower Santa Ysabel Creek 2. Lower Santa Ysabel Creek Reach 15.

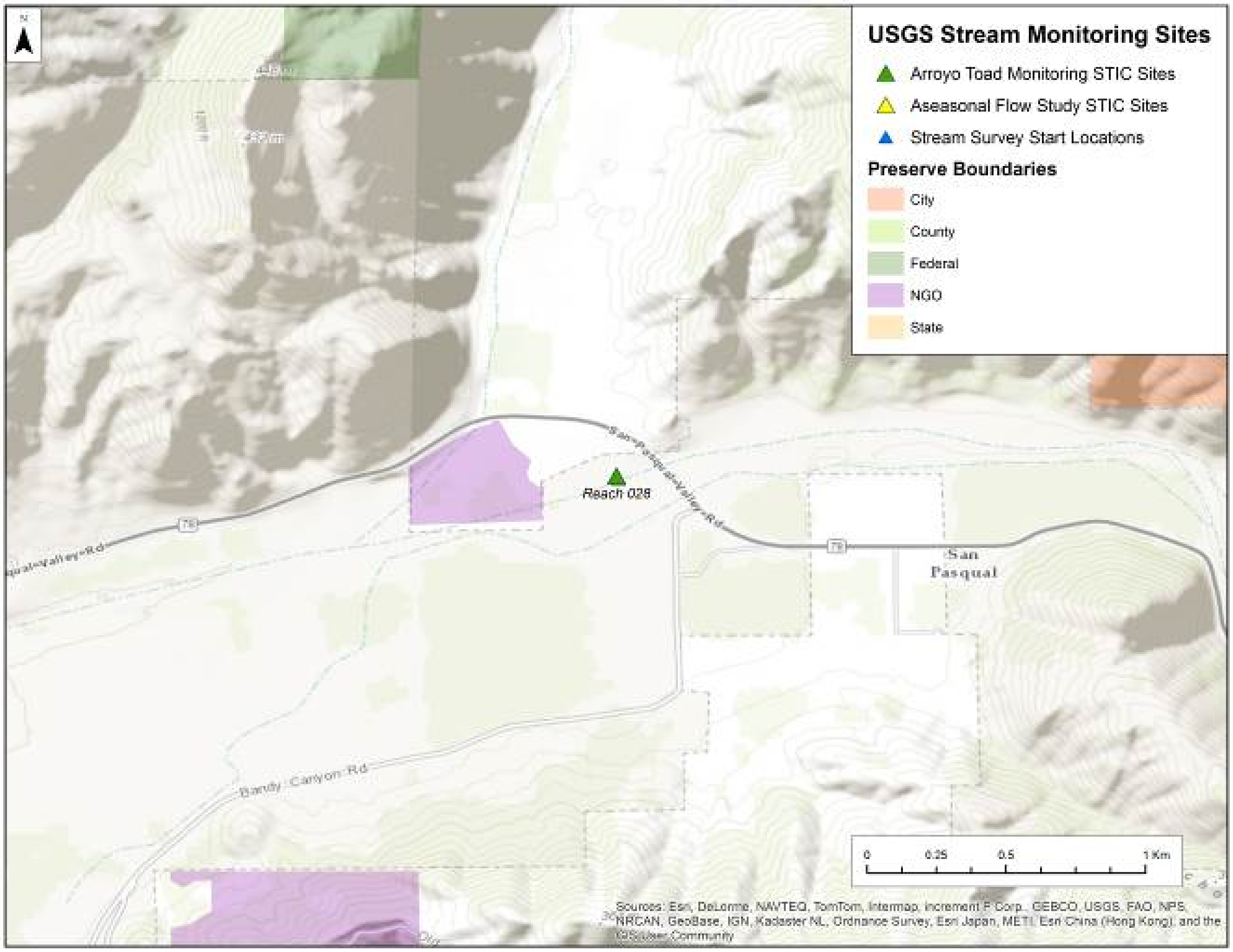

Figure B63. Lower Santa Ysabel Creek 3. Lower Santa Ysabel Creek Reach 28.

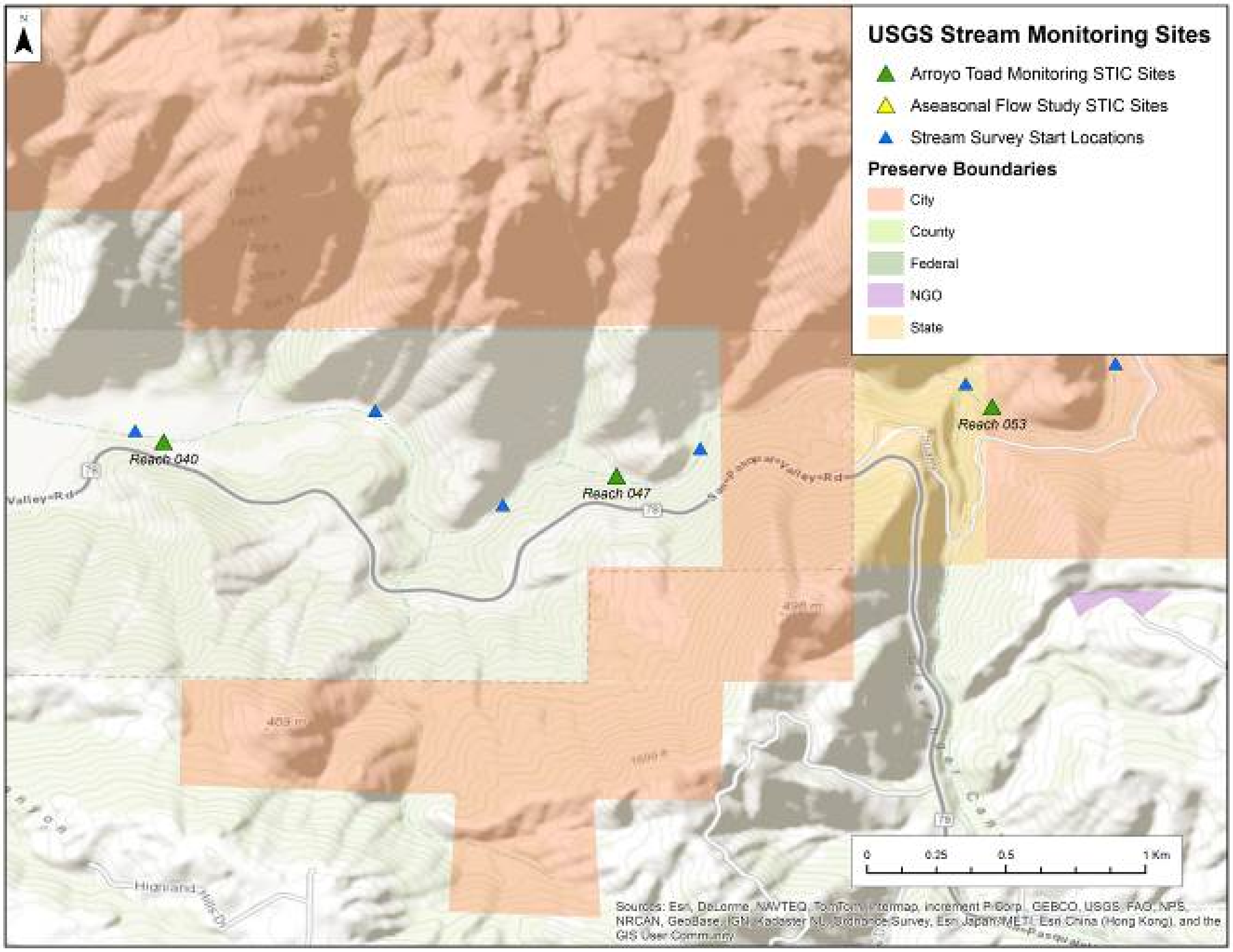

Figure B64. Lower Santa Ysabel Creek 4. Lower Santa Ysabel Creek Reaches 40 through 53.

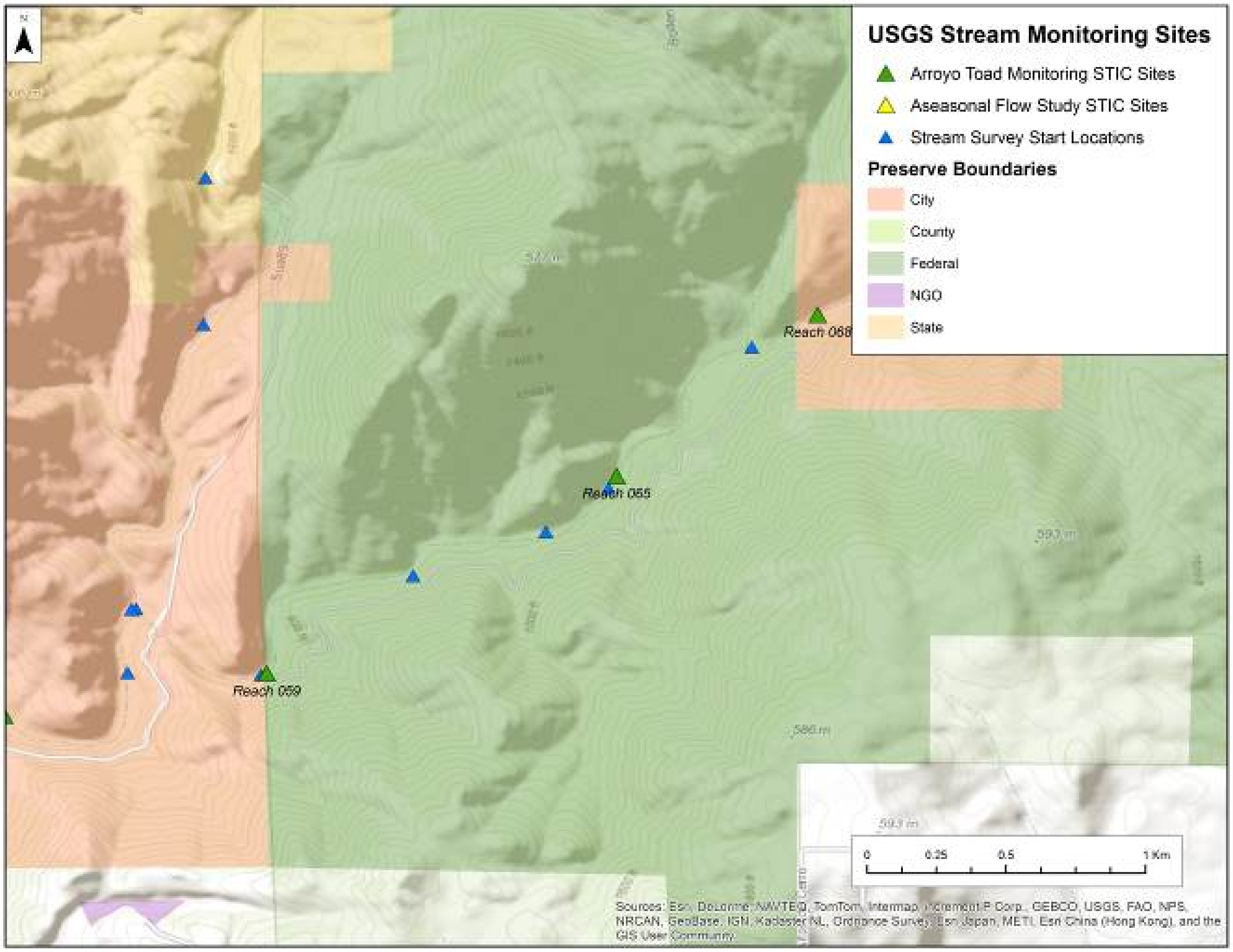

Figure B65. Lower Santa Ysabel Creek 5. Lower Santa Ysabel Creek Reaches 59 through 68.

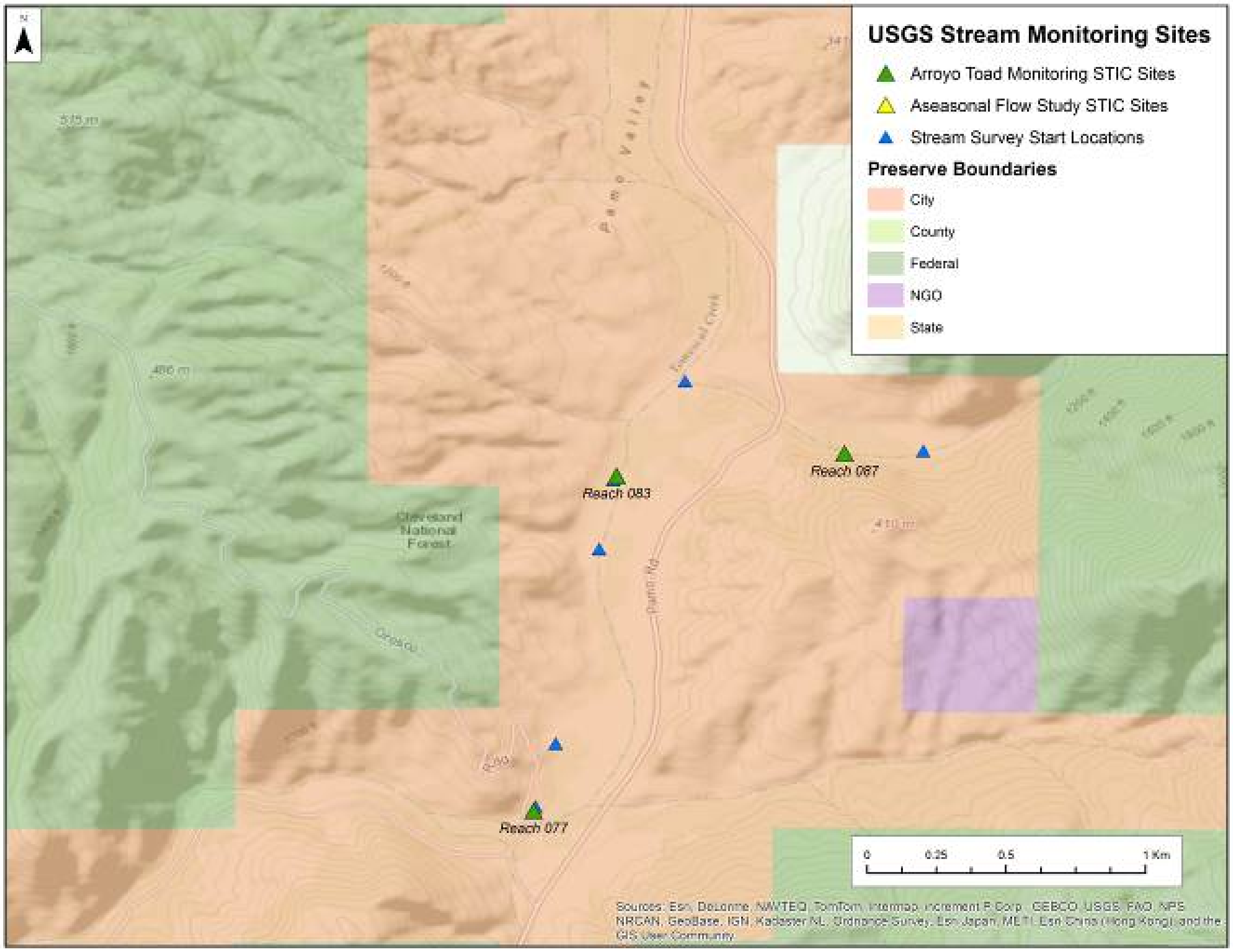

Figure B66. Lower Santa Ysabel Creek 6. Lower Santa Ysabel Creek Reaches 77 through 87.

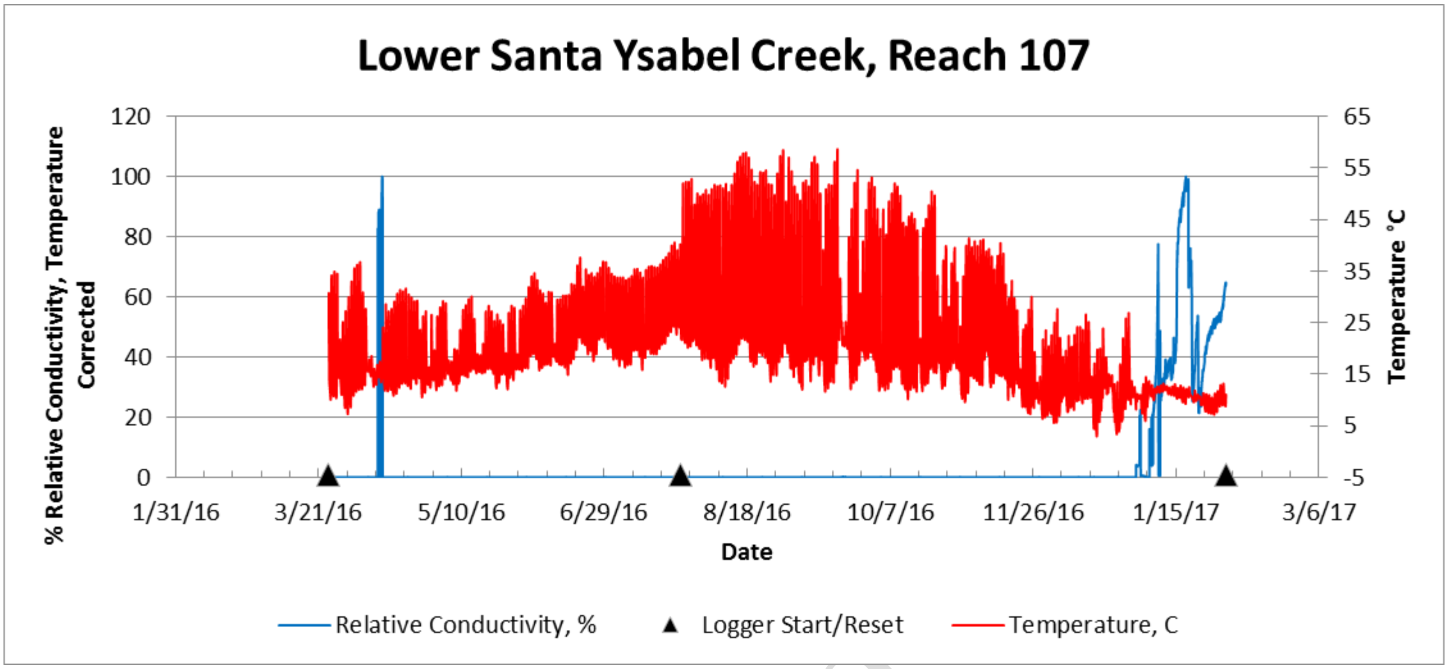

Figure B67. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 107.


Figure B68. Habitat at Lower Santa Ysabel Creek Reach 107 on 25 July 2016 (left) and on 01 February 2017 (right).

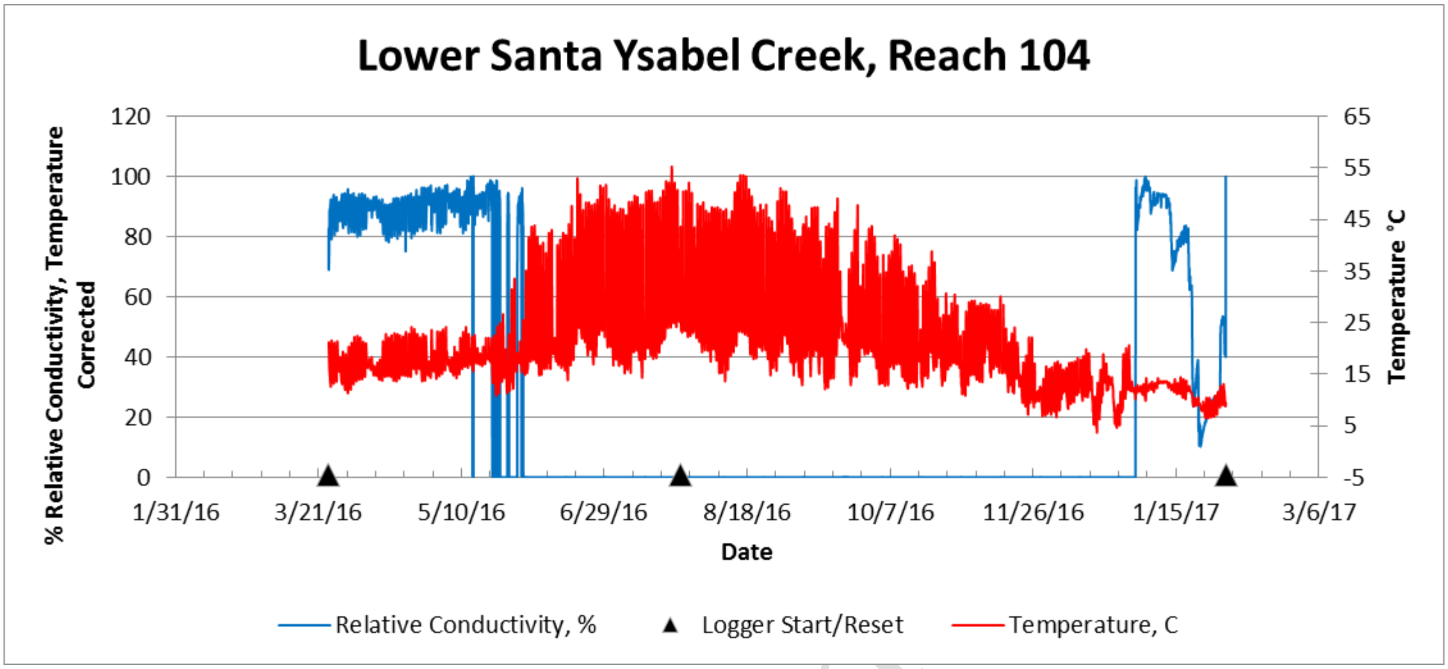

Figure B69. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 104.

Figure B70. Habitat at Lower Santa Ysabel Creek Reach 104 on 25 July 2016 (left) and on 01 February 2017 (right).

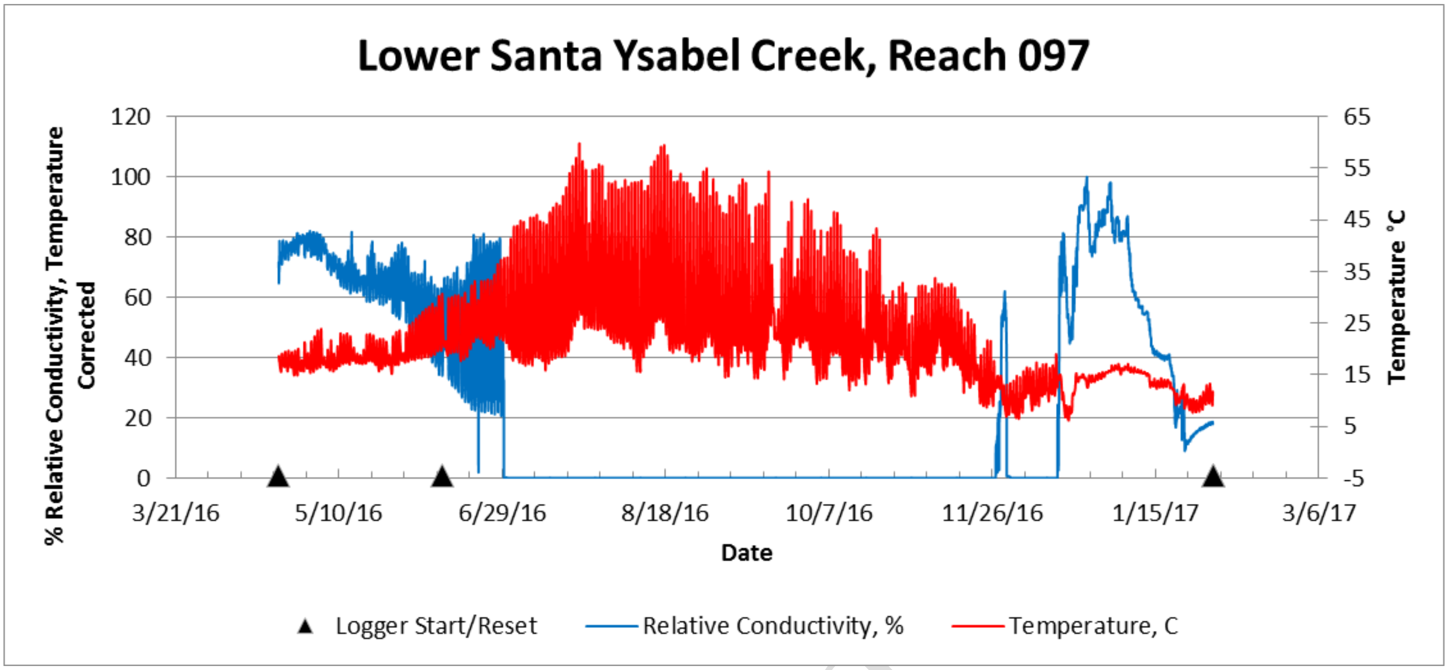

Figure B71. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 097.

Figure B72. Habitat at Lower Santa Ysabel Creek Reach 097 on 21 April 2016 (left) and on 01 February 2017 (right).

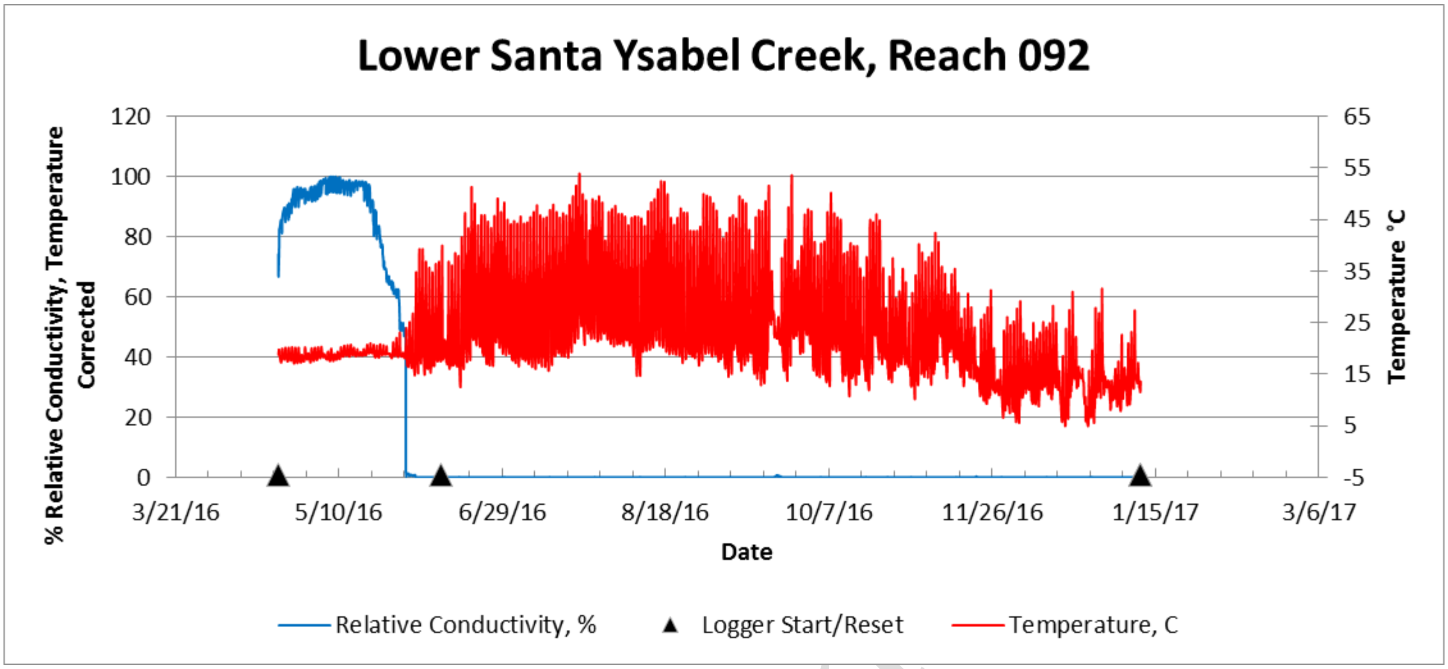

Figure B73. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 092.

Figure B74. Habitat at Lower Santa Ysabel Creek Reach 092 on 21 April 2016 (left) and on 10 January 2017 (right).

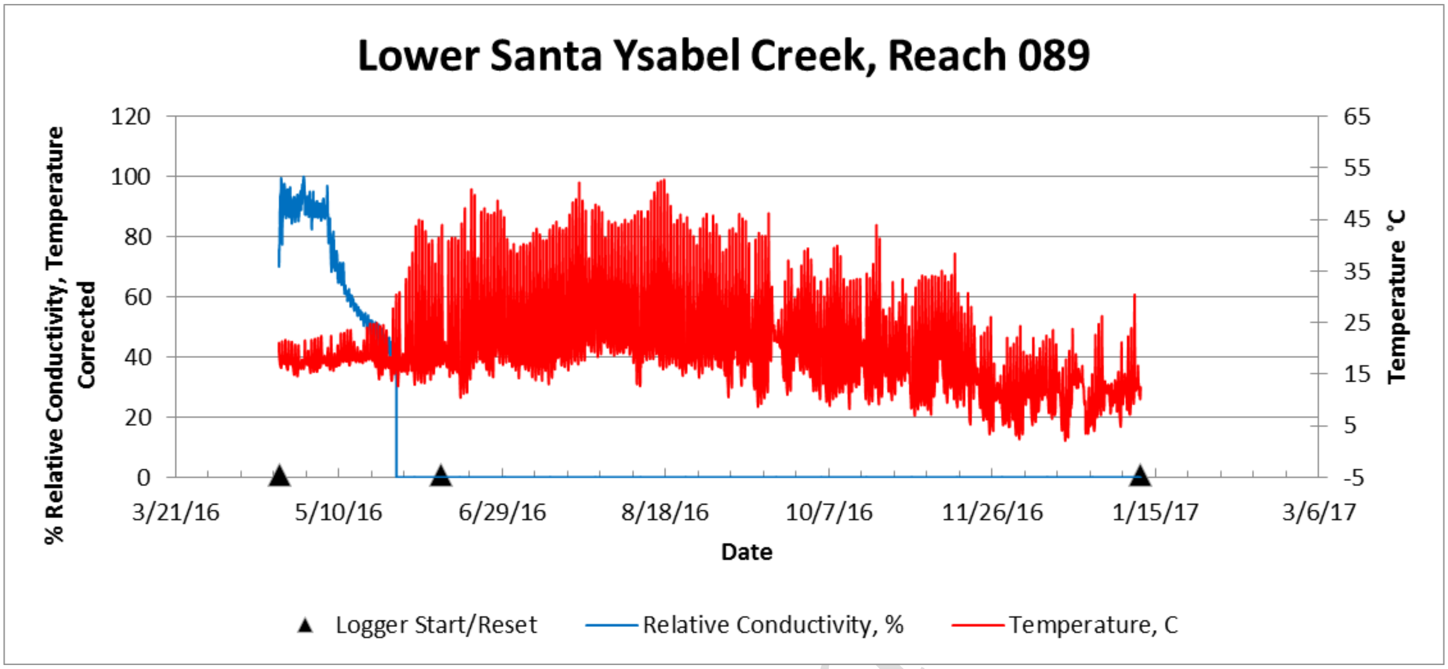

Figure B75. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 089.

Figure B76. Habitat at Lower Santa Ysabel Creek Reach 089 on 21 April 2016 (left) and on 10 January 2017 (right).

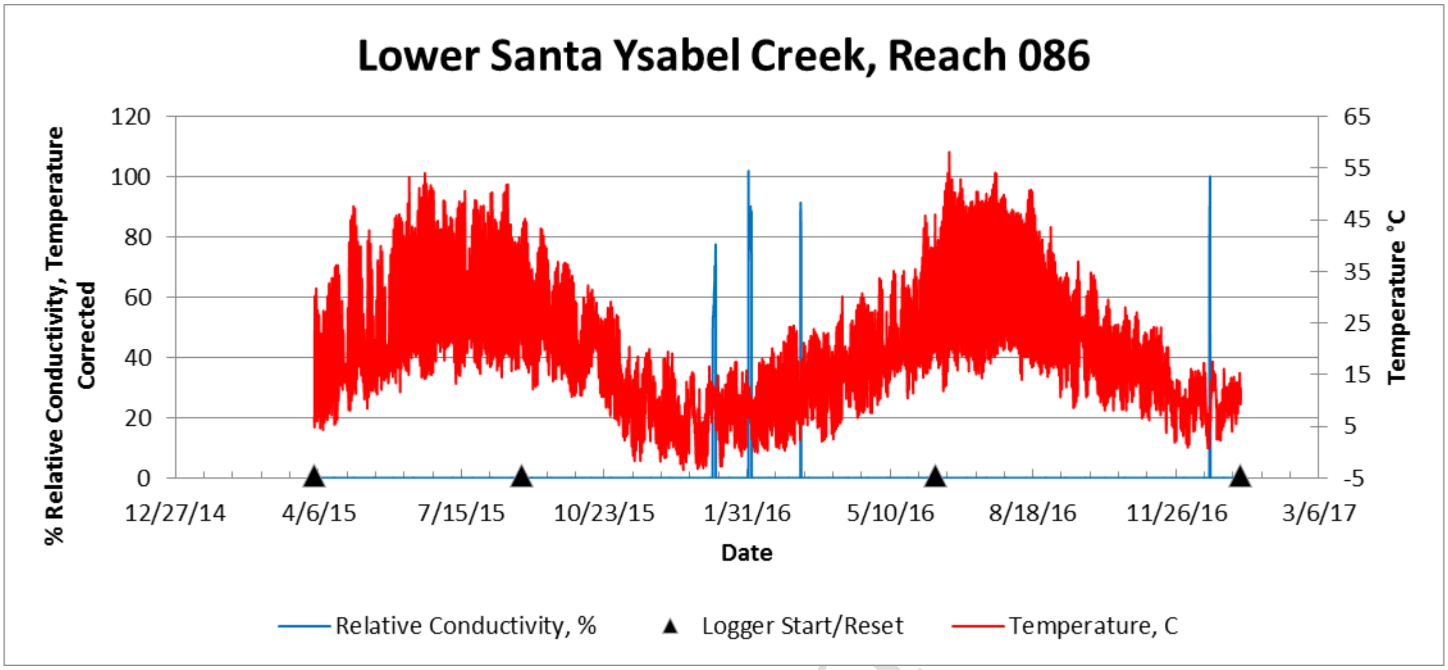

Figure B77. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 086.

Figure B78. Habitat at Lower Santa Ysabel Creek Reach 086 on 26 August 2015 (left) and on 10 June 2016 (right).

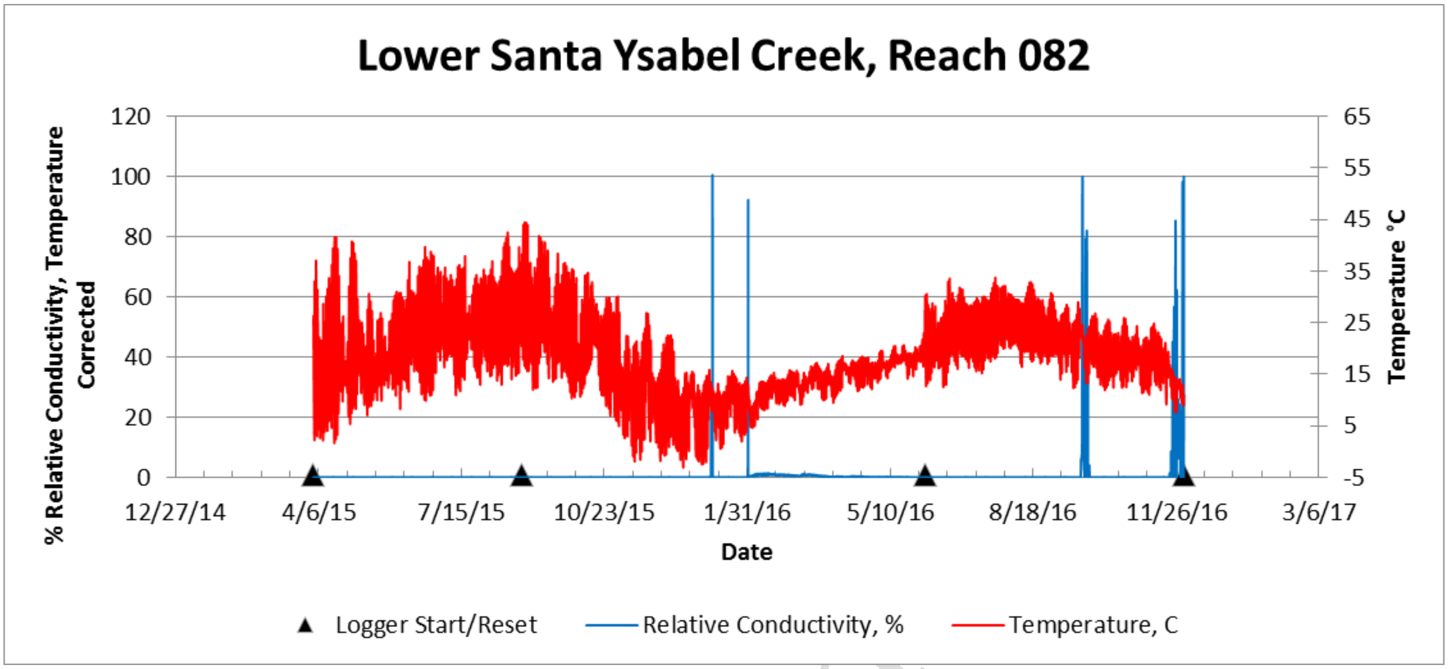

Figure B79. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 082.

Figure B80. Habitat at Lower Santa Ysabel Creek Reach 083 on 26 August 2015 (left) and on 01 December 2016 (right).

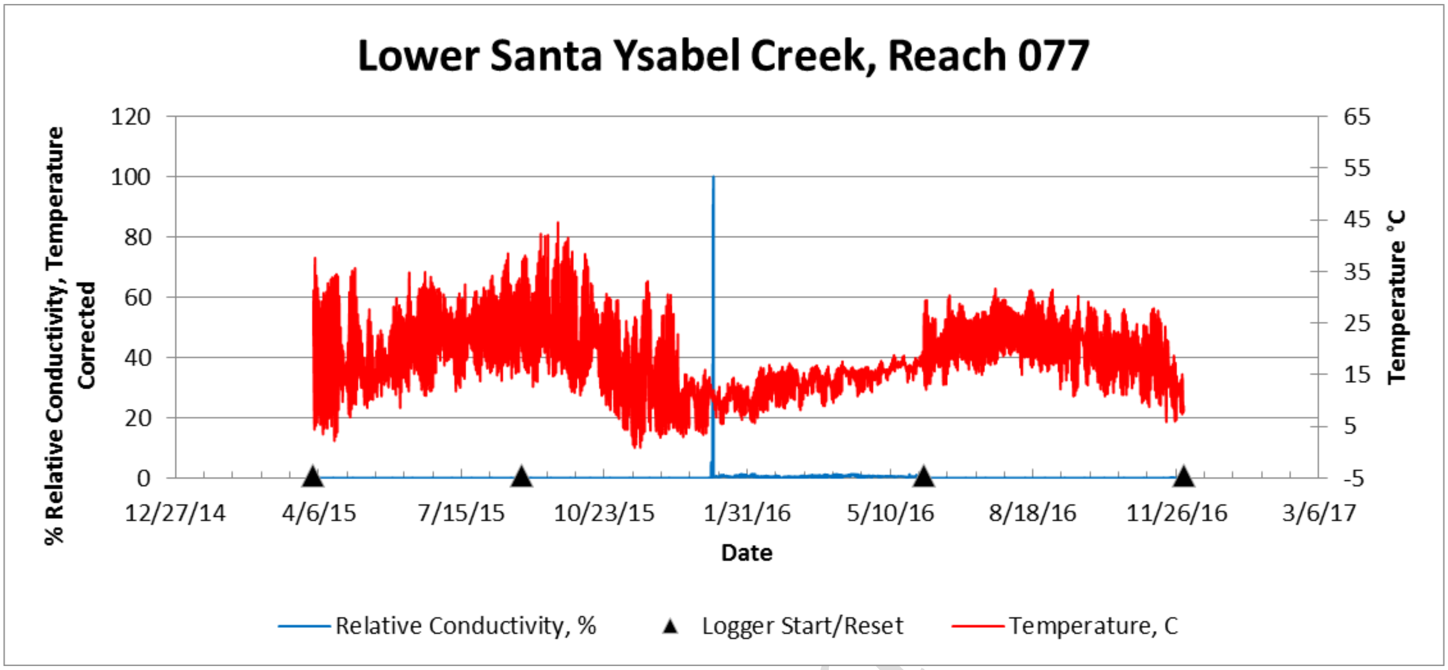

Figure B81. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 077.


Figure B82. Habitat at Lower Santa Ysabel Creek Reach 077 on 26 August 2015 (left) and on 01 December 2016 (right).

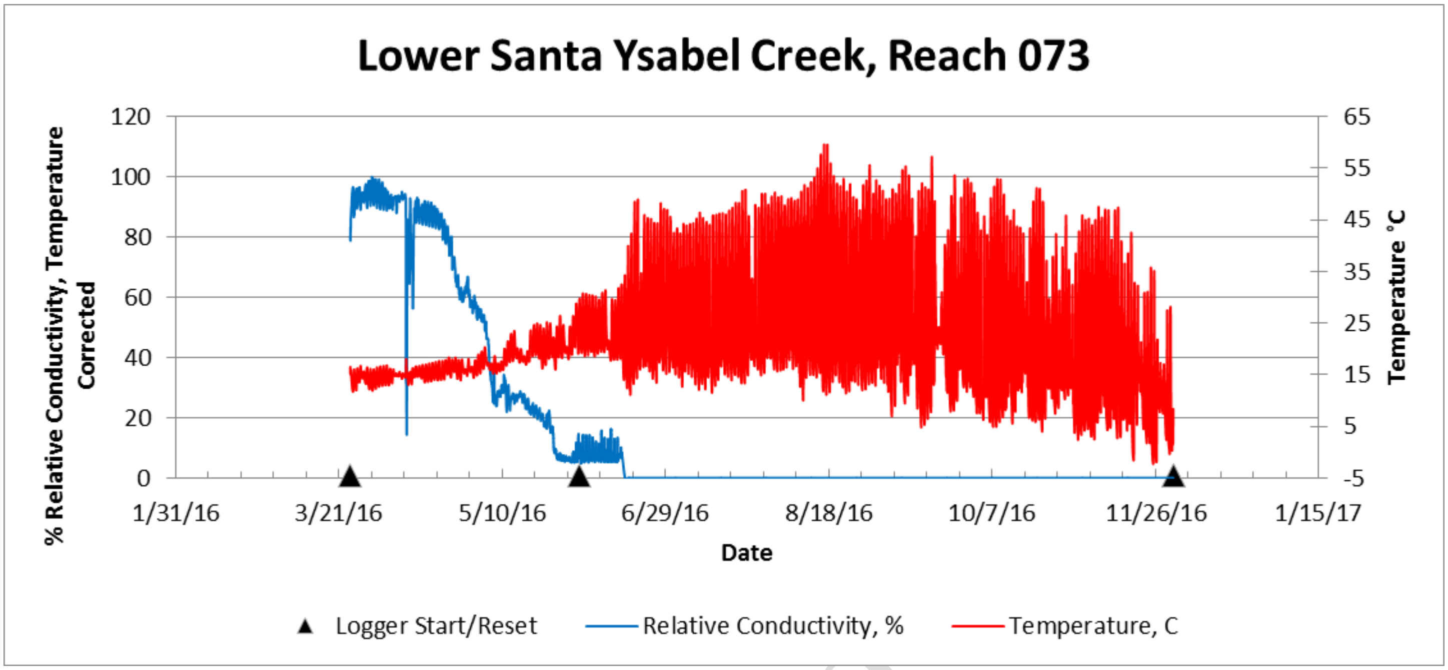

Figure B83. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 073.

Figure B84. Habitat at Lower Santa Ysabel Creek Reach 073 on 02 June 2016 (left) and on 01 December 2016 (right).

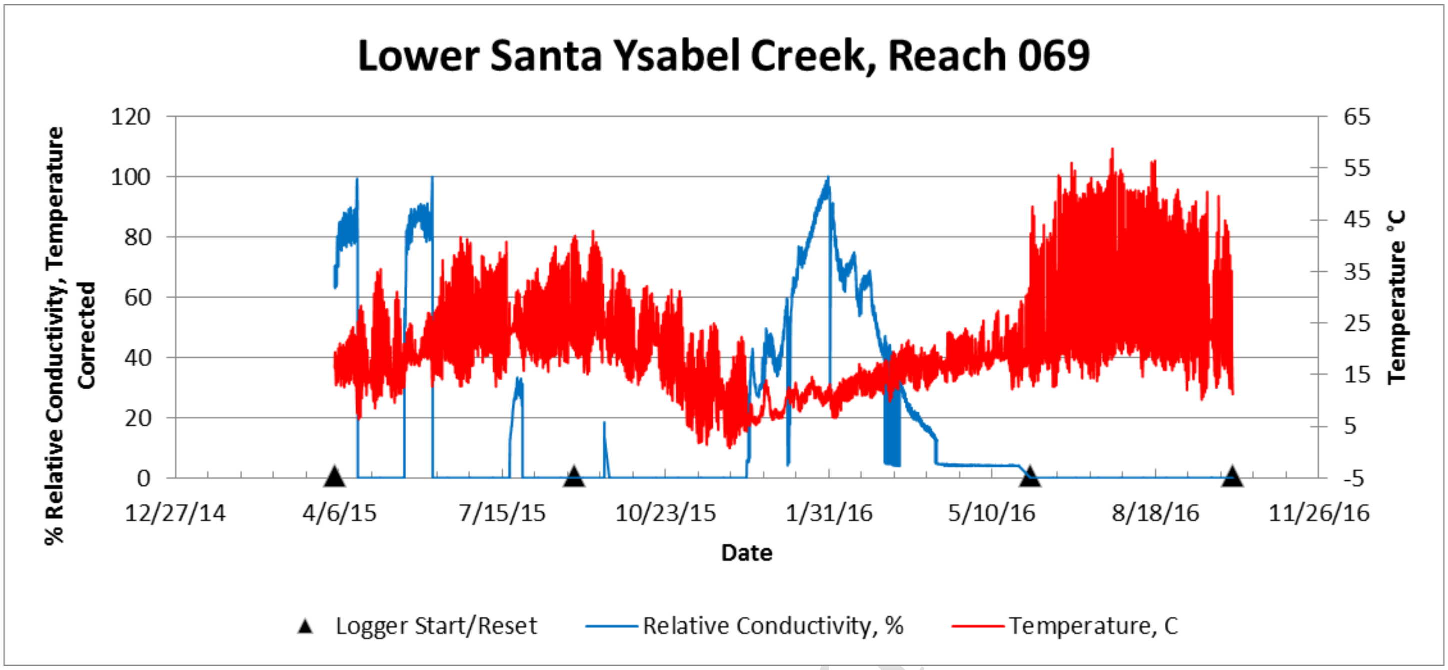

Figure B85. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 069.

Figure B86. Habitat at Lower Santa Ysabel Creek Reach 069 on 03 April 2015 (left) and on 02 June 2016 (right).

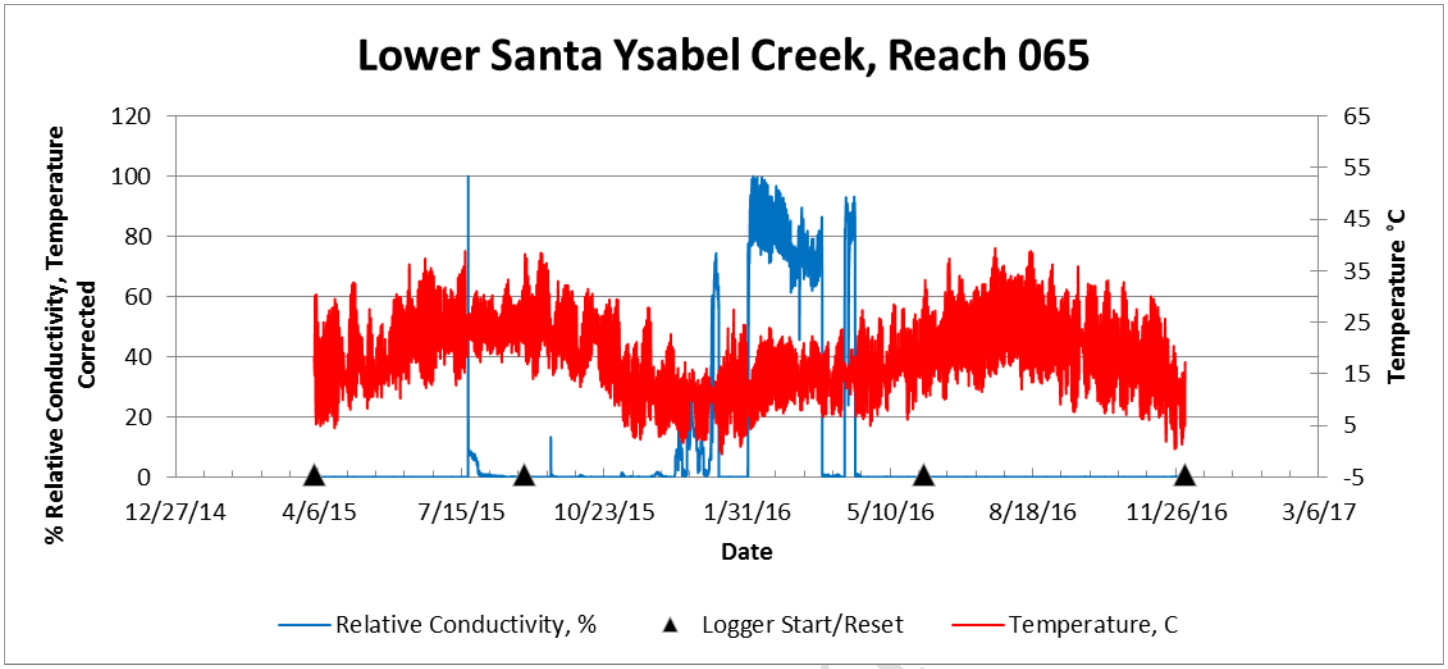

Figure B87. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 065.

Figure B88. Habitat at Lower Santa Ysabel Creek Reach 065 on 02 June 2016 (left) and on 02 December 2016 (right).

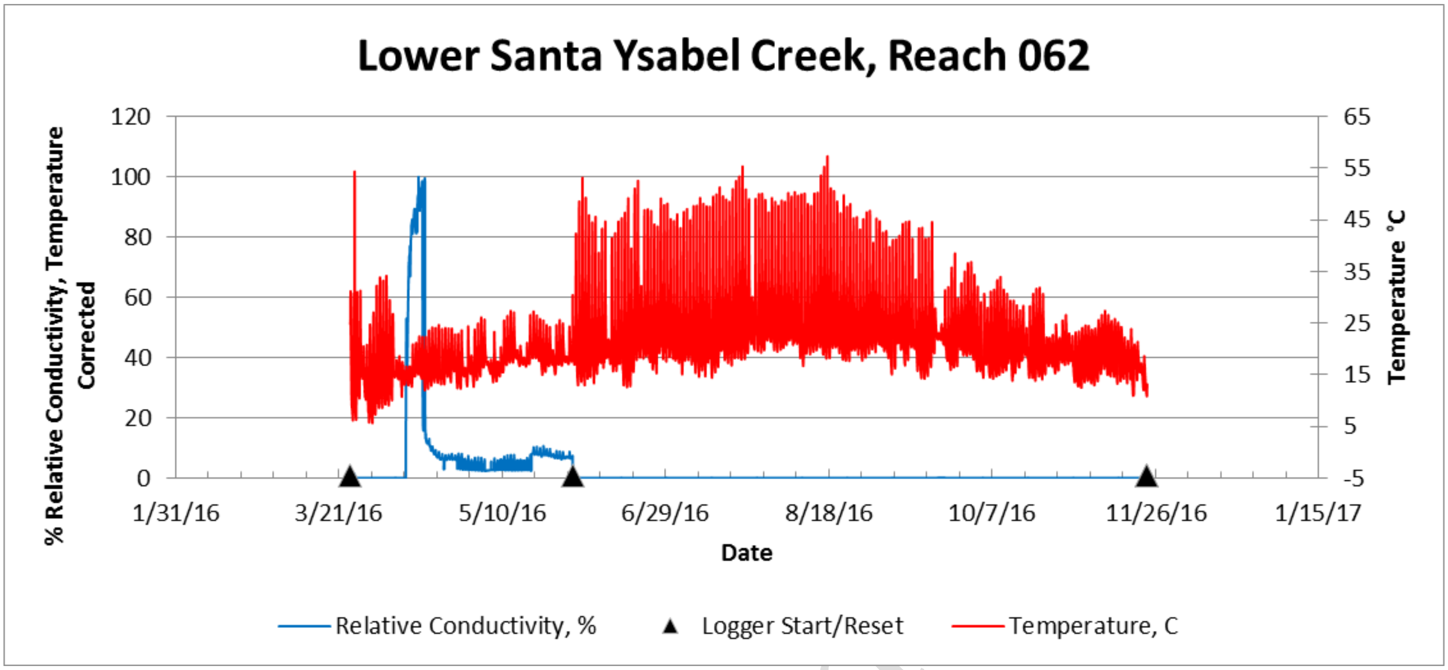

Figure B89. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 062.

Figure B90. Habitat at Lower Santa Ysabel Creek Reach 062 on 31 May 2016 (left) and on 02 December 2016 (right).

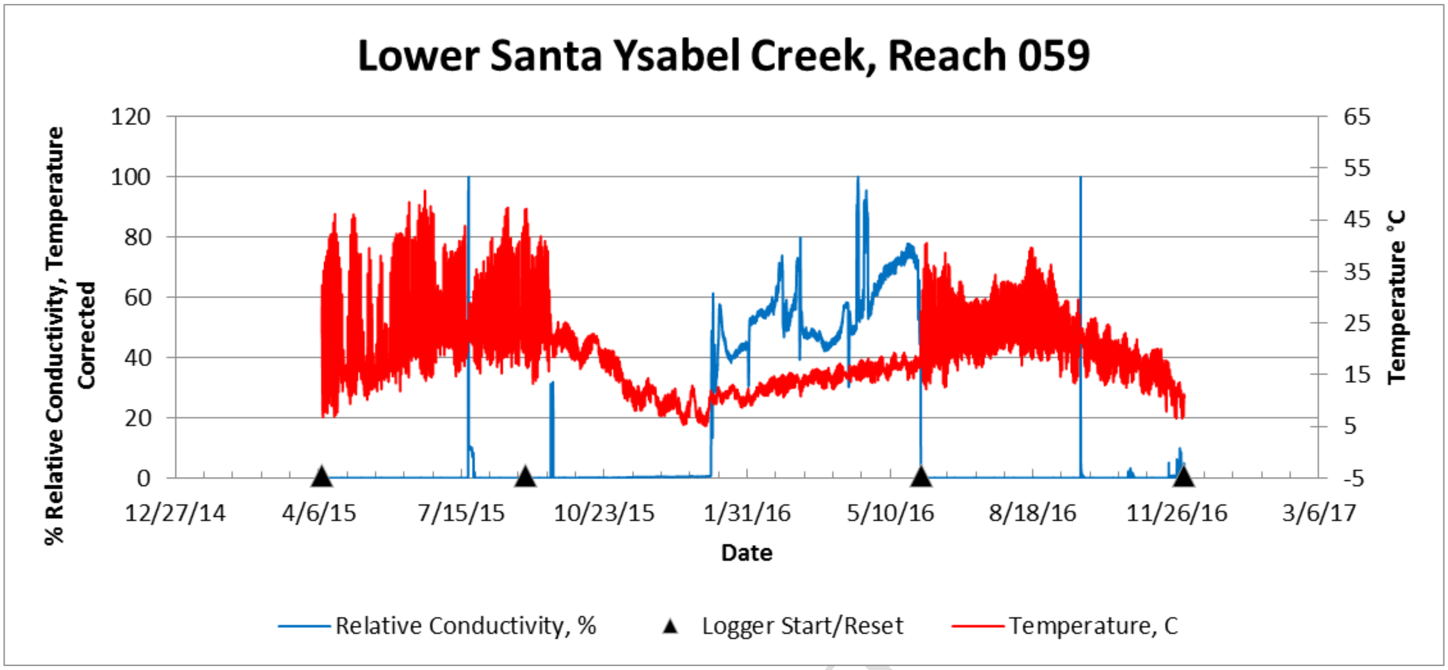

Figure B91. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 059.

Figure B92. Habitat at Lower Santa Ysabel Creek Reach 059 on 28 August 2015 (left) and on 02 December 2016 (right).

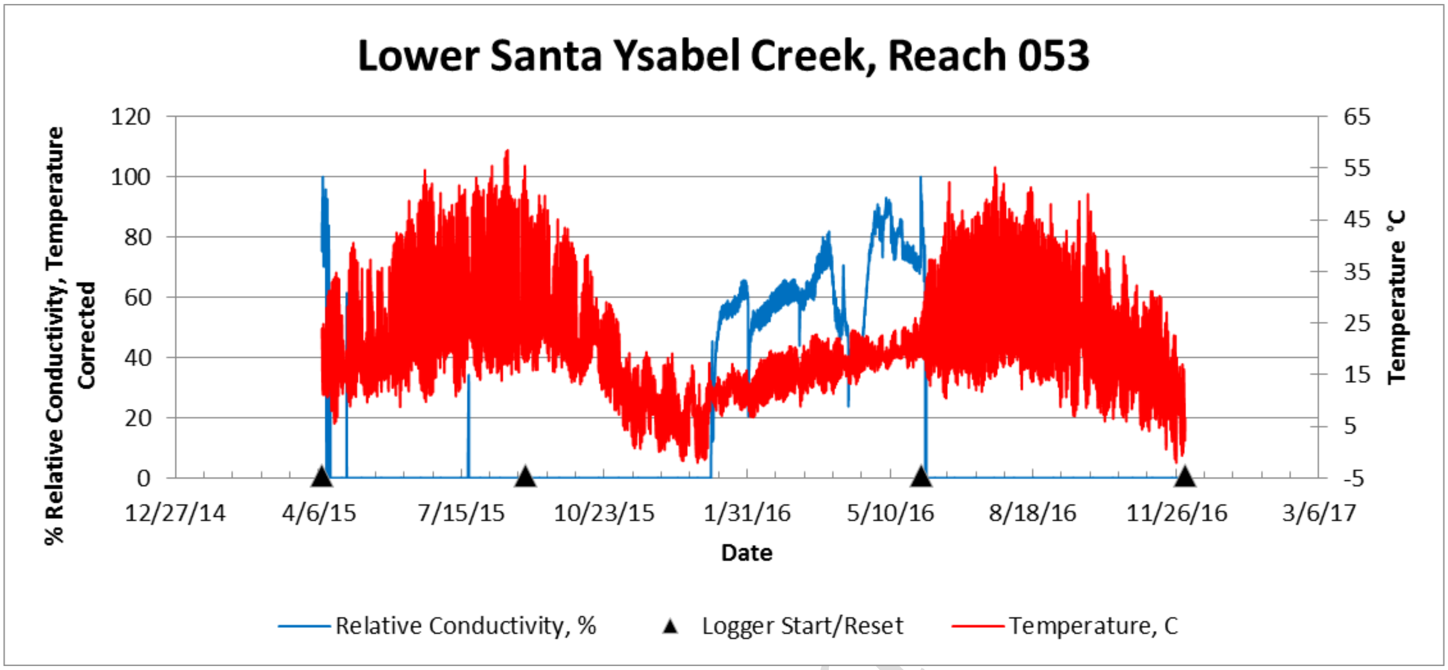

Figure B93. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 053.

Figure B94. Habitat at Lower Santa Ysabel Creek Reach 053 on 31 May 2016 (left) and on 02 December 2016 (right).

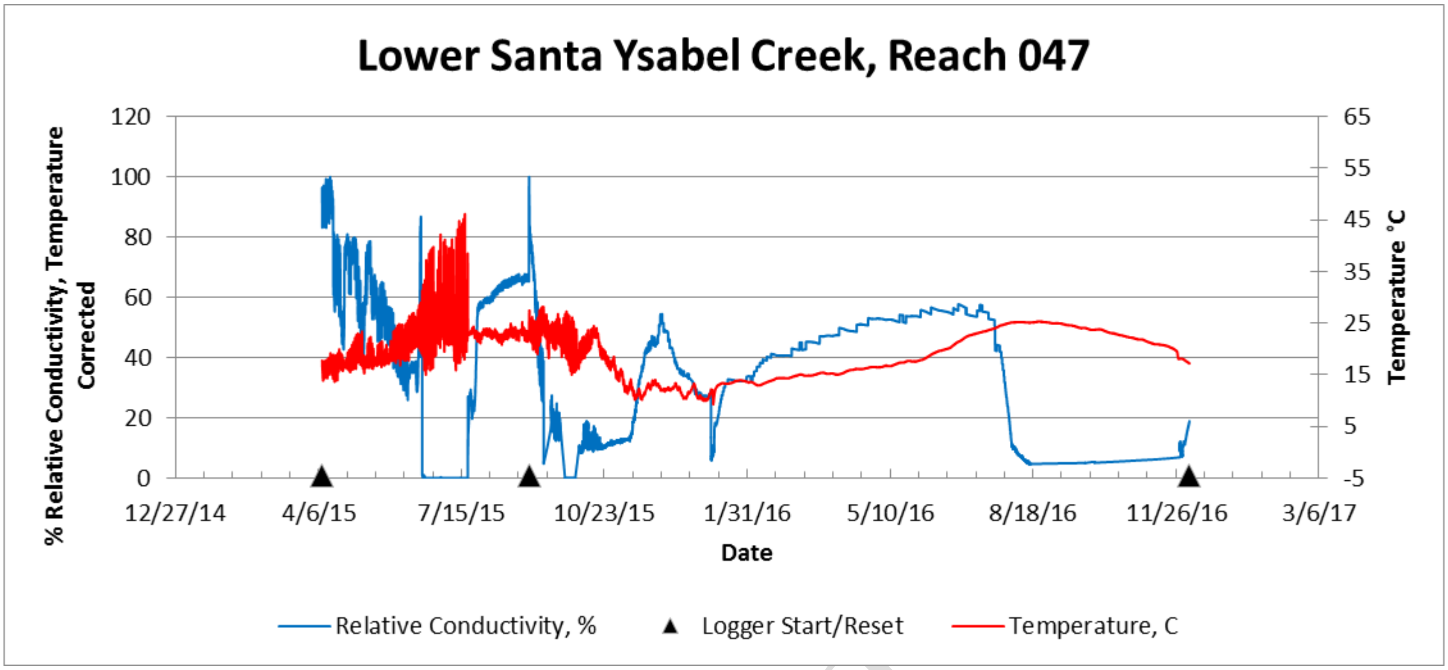

Figure B95. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 047.

Figure B96. Habitat at Lower Santa Ysabel Creek Reach 047 on 08 April 2015 (left) and on 31 August 2015 (right).

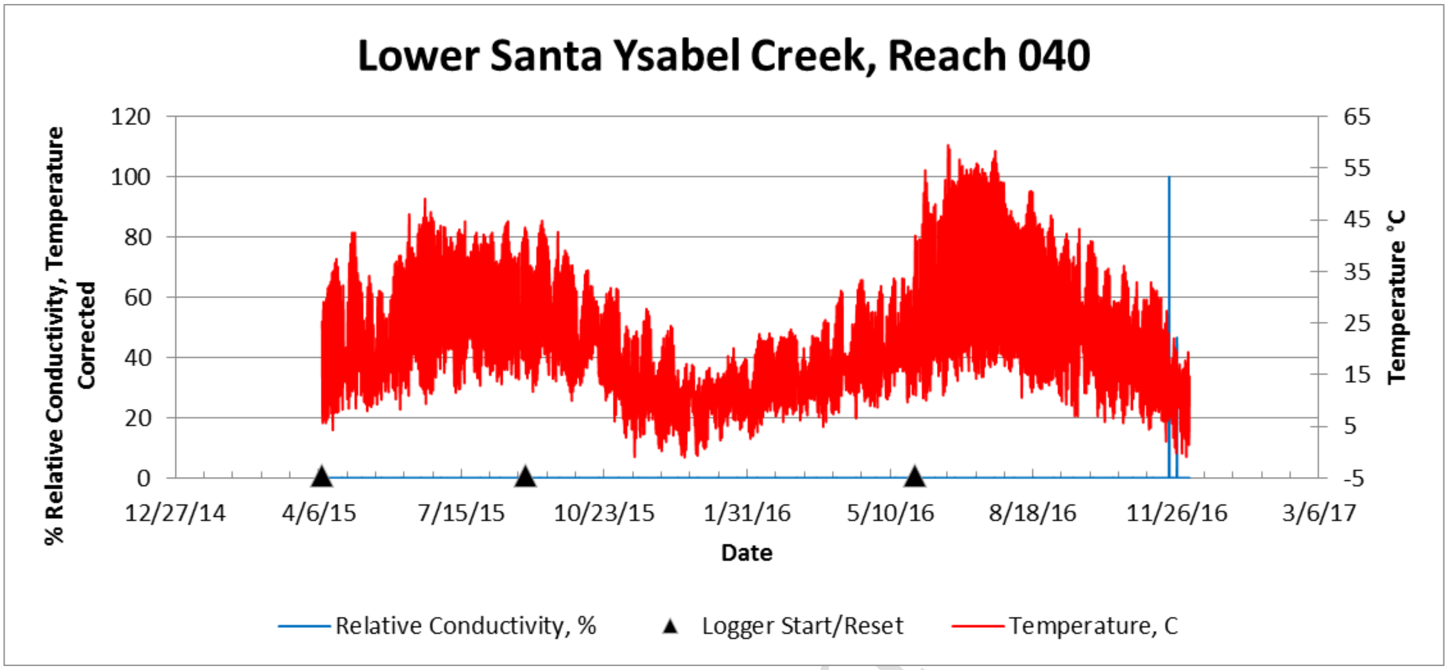

Figure B97. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 040.

Figure B98. Habitat at Lower Santa Ysabel Creek Reach 040 on 28 August 2015 (left) and on 05 December 2016 (right).

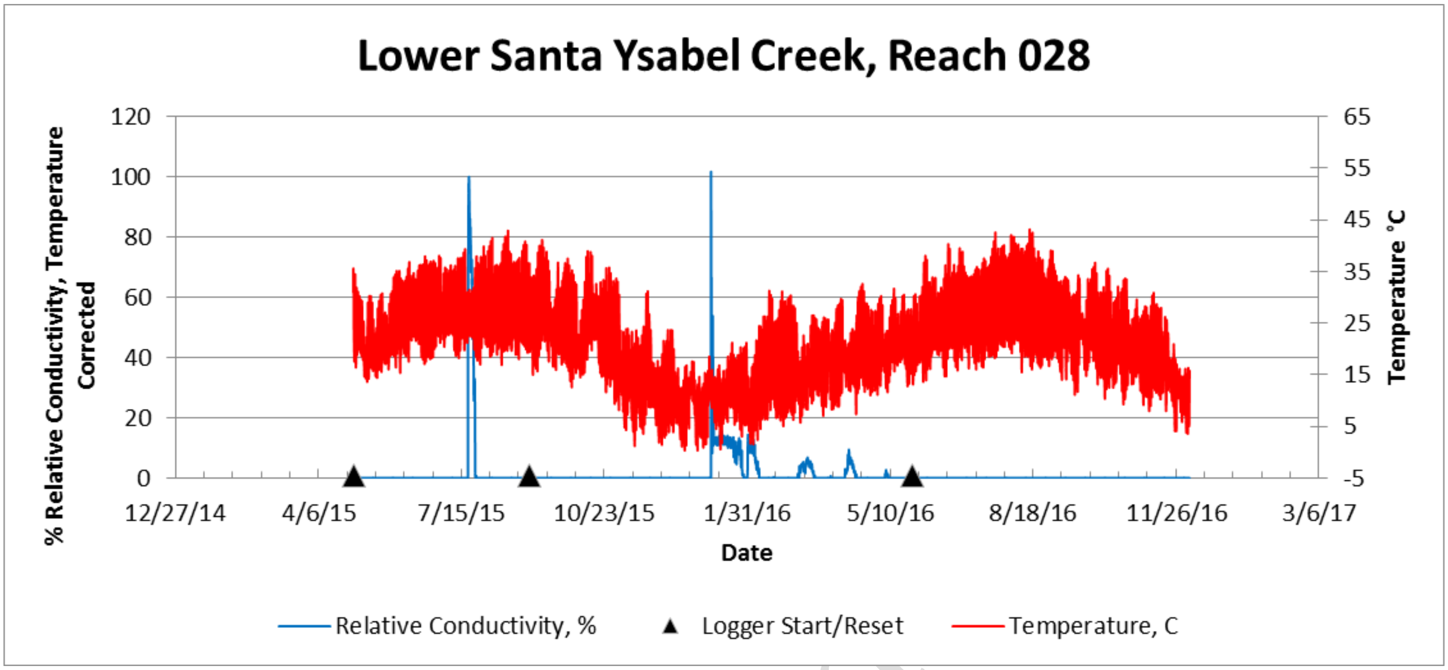

Figure B99. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 028.

Figure B100. Habitat at Lower Santa Ysabel Creek Reach 028 on 31 August 2015 (left) and on 05 December 2016 (right).

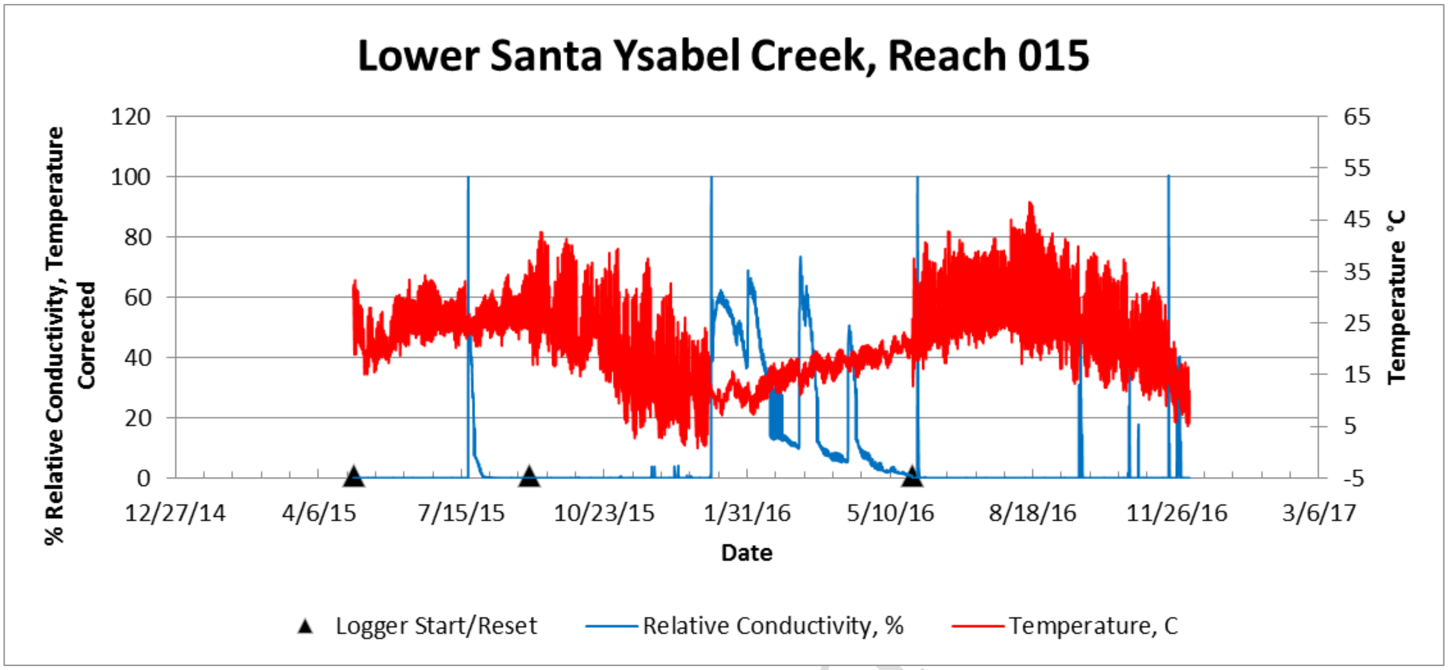

Figure B101. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 015.

Figure B102. Habitat at Lower Santa Ysabel Creek Reach 015 on 30 April 2015 (left) and on 02 August 2016 (right).

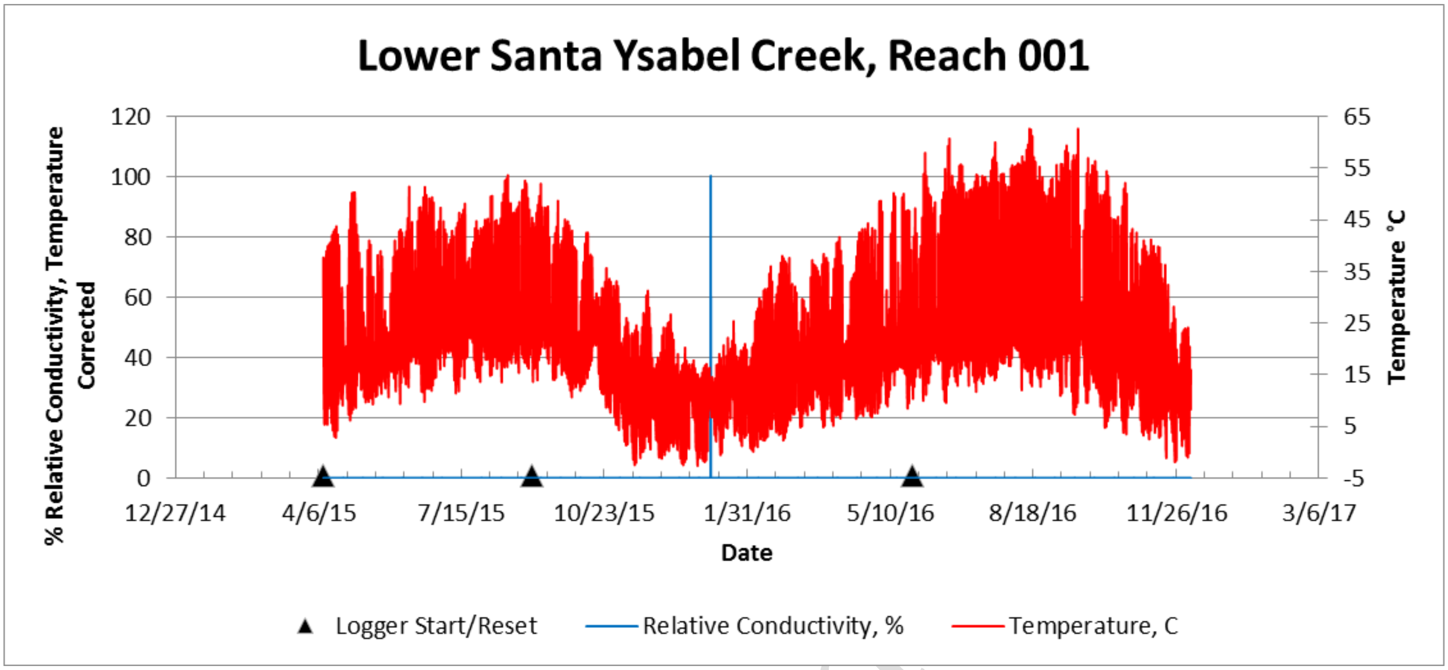

Figure B103. Relative conductivity and temperature graph of Lower Santa Ysabel Creek Reach 001.


Figure B104. Habitat at Lower Santa Ysabel Creek Reach 001 on 02 September 2015 (left) and on 06 December 2016 (right).

Pamo Valley

This site includes Temescal Creek and a portion of Santa Ysabel Creek. This is an agriculture preserve owned and managed by City of San Diego and recreation is limited to hiking and biking in a small portion of the preserve. This site consists of open sandy wash, grasslands, and coast live oak riparian. Arroyo toads were previously known from this site (USFWS 2015), which is included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

(No map available)

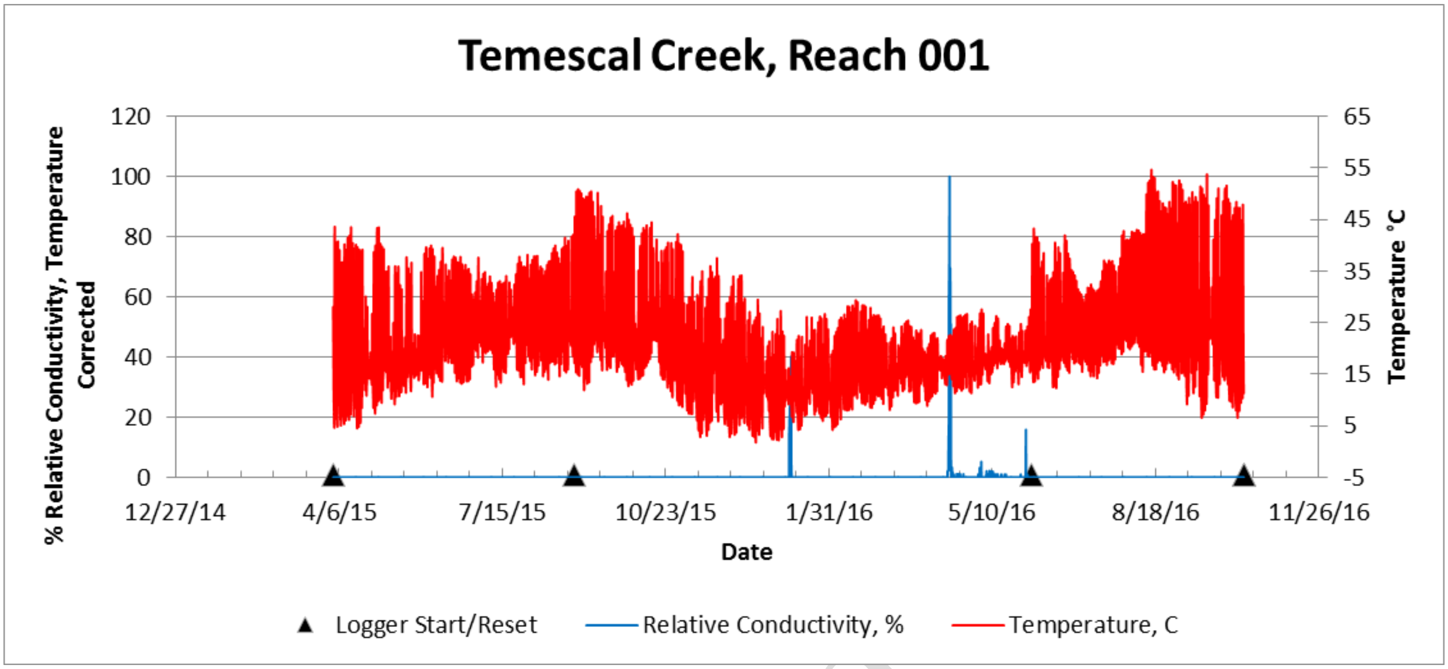

Figure B105. Relative conductivity and temperature graph of Temescal Creek Reach 001.

Figure B106. Habitat at Temescal Creek (Santa Ysabel) Reach 001 on 16 September 2015 (left) and on 03 June 2016 (right).

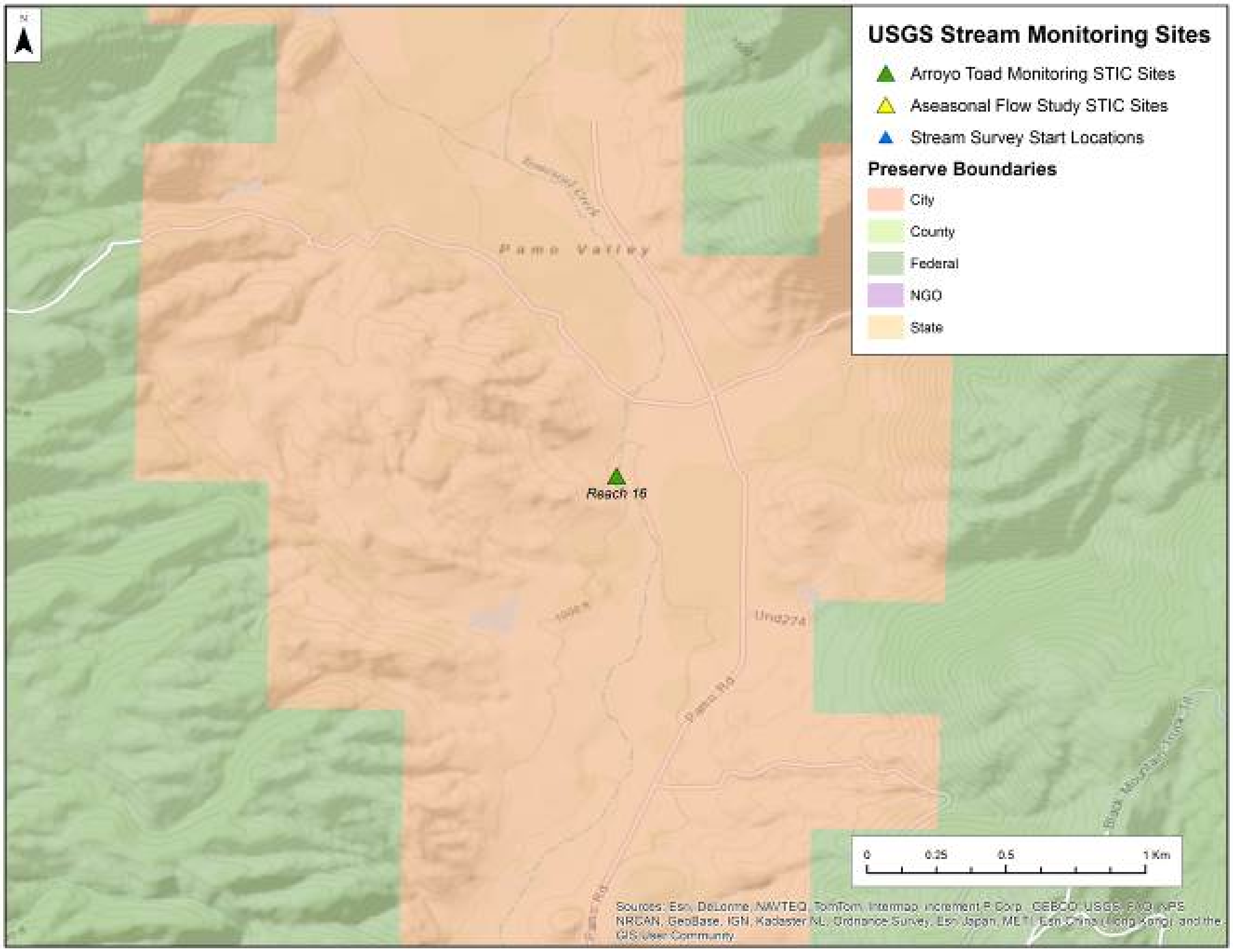

Figure B107. Temescal Creek 2. Temescal Creek Reach 016.

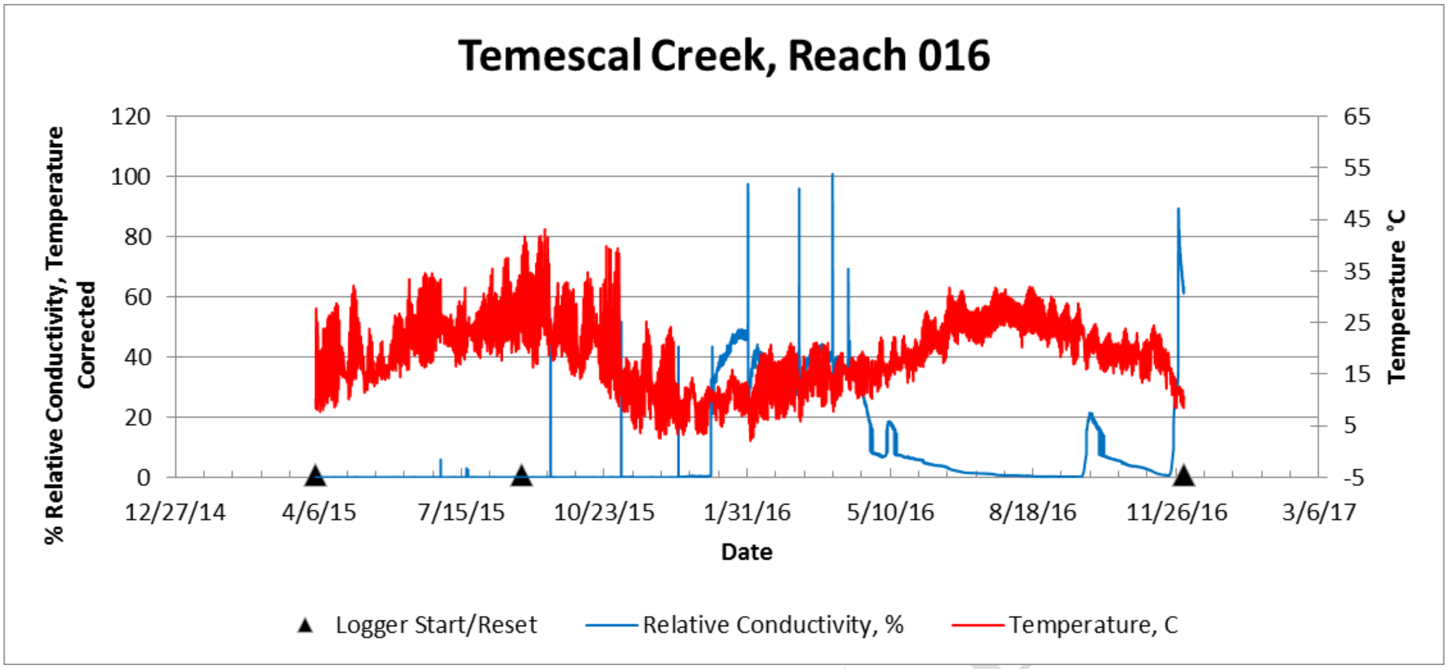

Figure B108. Relative conductivity and temperature graph of Temescal Creek Reach 016.


Figure B109. Habitat at Temescal Creek (Santa Ysabel) Reach 016 on 03 April 2015 (left) and on 01 December 2016 (right).

Boden Canyon

Boden Canyon is a tributary to Santa Ysabel Creek with historic populations of arroyo toads. The heavy rains after the 2007 wildfires caused large amounts of sediment to flow into the stream which reduced the amount of available surface water. Arroyo toads were not found to successfully breed at the site during surveys after the 2007 wildfires, but the site had not been surveyed since 2012, and it was unknown whether the habitat and arroyo toad population had recovered. The preserve is owned and maintained by CDFW and County of San Diego, and recreation is limited to hiking, biking, and hunting. This site was included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

San Pasqual Valley

This site includes the lower reaches of Santa Ysabel and Santa Maria creeks and the upper reaches of San Dieguito River. This relatively large valley consists primarily of low gradient sandy and often dry grassland and willow riparian. The preserve is owned and maintained by City of San Diego, and recreation is limited to hiking and biking. Arroyo toads were previously known from this site (USFWS 2015), which is included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

Santa Maria Creek

This section of Santa Maria Creek in Ramona Grasslands Open Space Preserve runs nearly six kilometers through low gradient grassland and oak riparian with some steeper boulder and bedrock lined stream reaches. It is owned and maintained by County of San Diego, and recreation is limited to hiking and biking. Arroyo toads were previously known from this site (USFWS 2015), which was included in USFWS' Critical Habitat Designation for the arroyo toad (USFWS 2011).

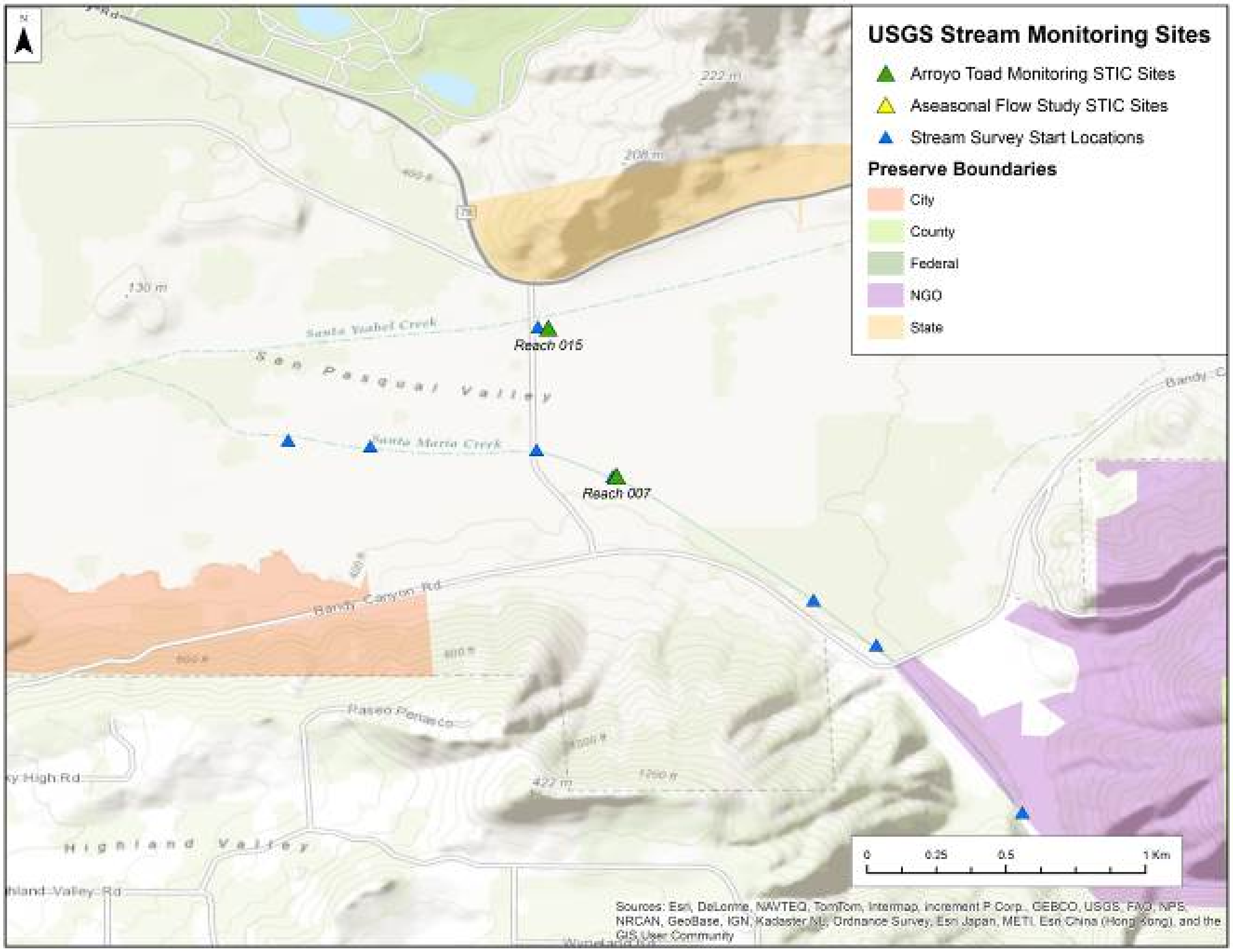

Figure B110. Santa Maria Creek 1. Santa Maria Creek Reach 7.

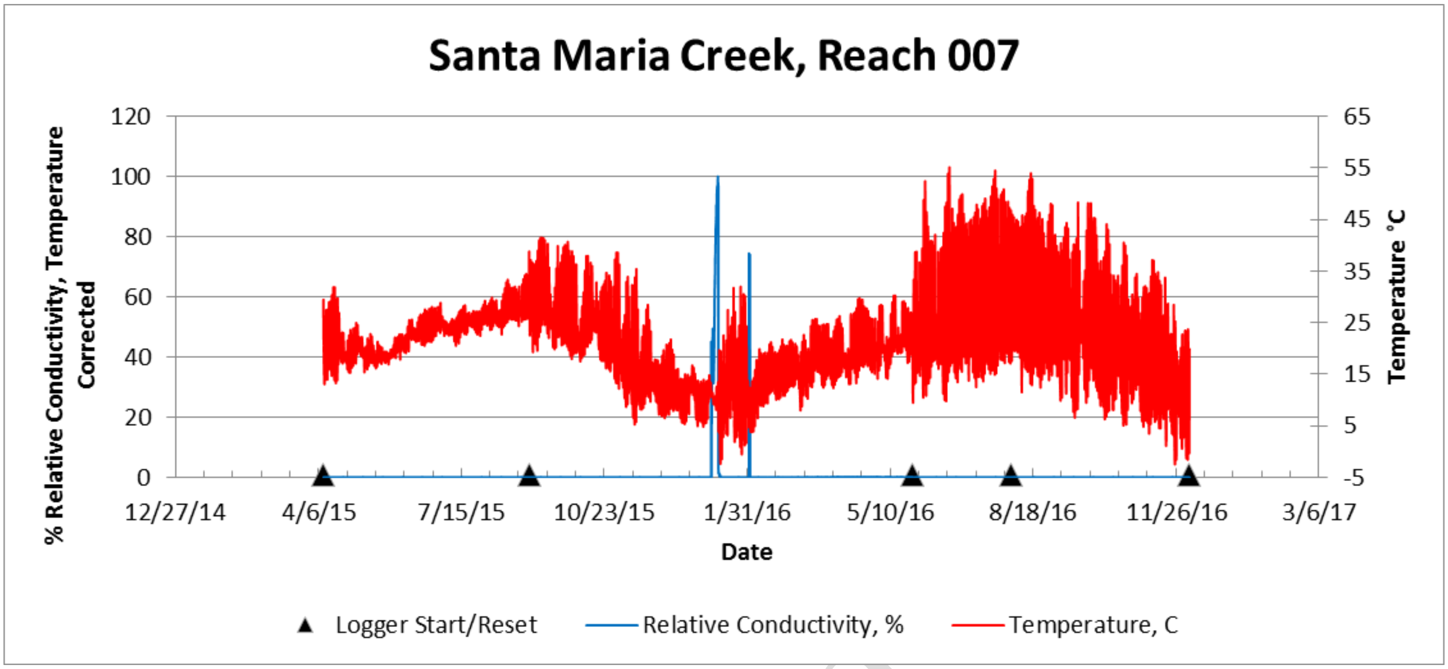

Figure B111. Relative conductivity and temperature graph of Santa Maria Creek Reach 007.

Figure B112. Habitat at Santa Maria Creek Reach 007 on 09 April 2015 (left) and on 05 December 2016 (right).

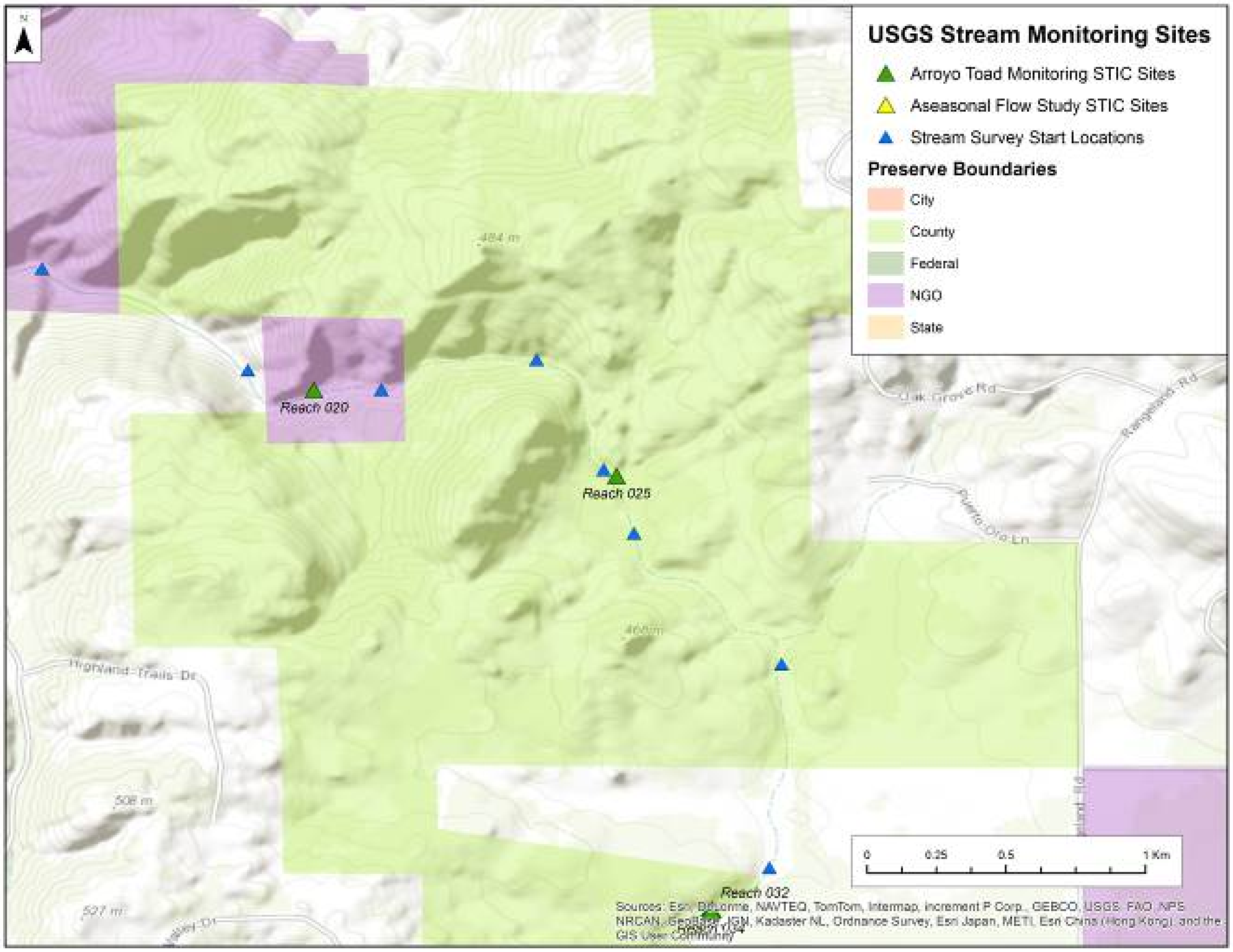

Figure B113. Santa Maria Creek 2. Santa Maria Creek Reaches 20 through 25.

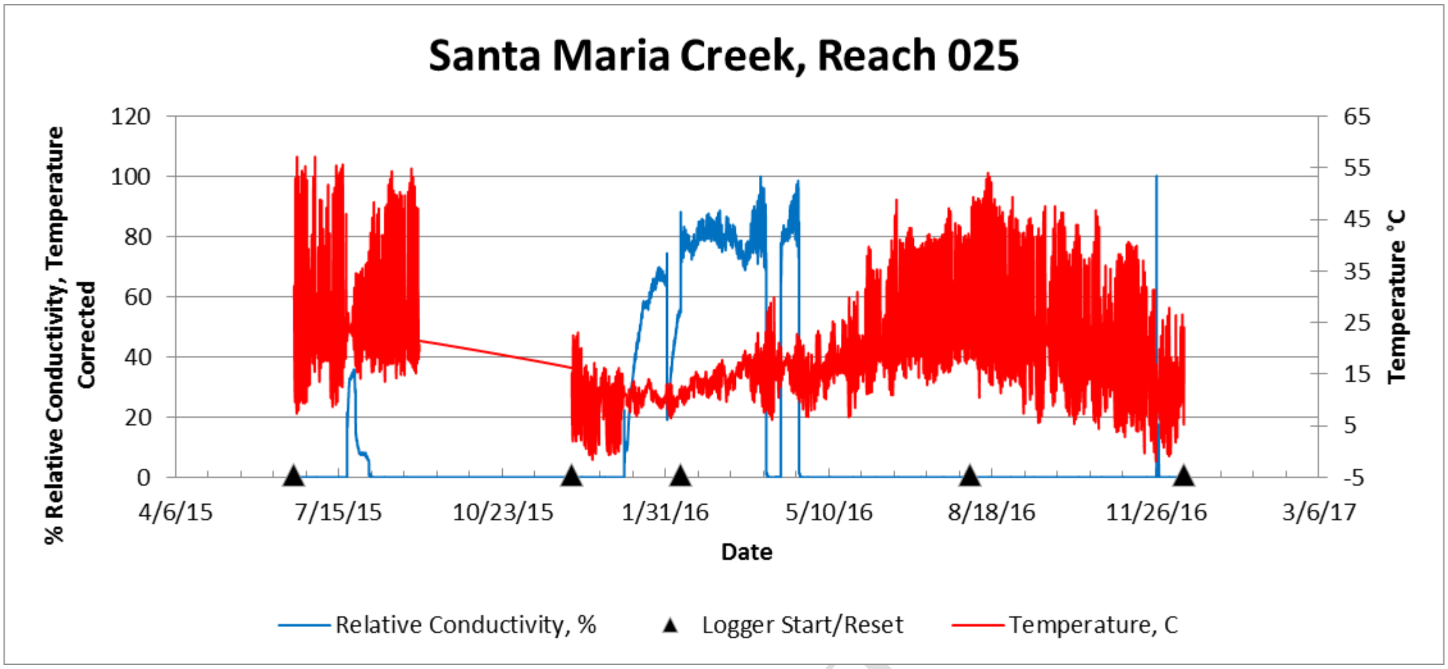

Figure B114. Relative conductivity and temperature graph of Santa Maria Creek Reach 025.

Figure B115. Habitat at Santa Maria Creek Reach 025 on 02 September 2015 (left) and on 09 February 2016 (right).

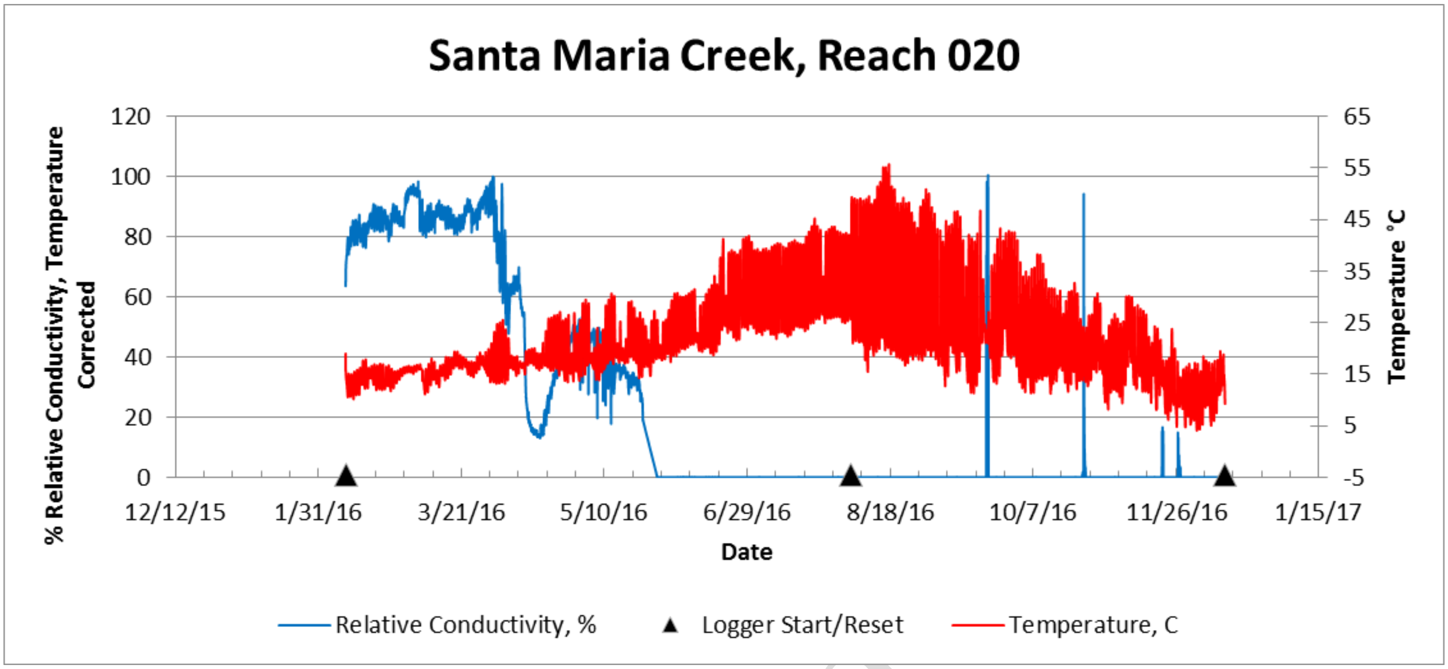

Figure B116. Relative conductivity and temperature graph of Santa Maria Creek Reach 020.

Figure B117. Habitat at Santa Maria Creek Reach 020 on 17 December 2015 (left) and on 09 Feb 2016 (right).

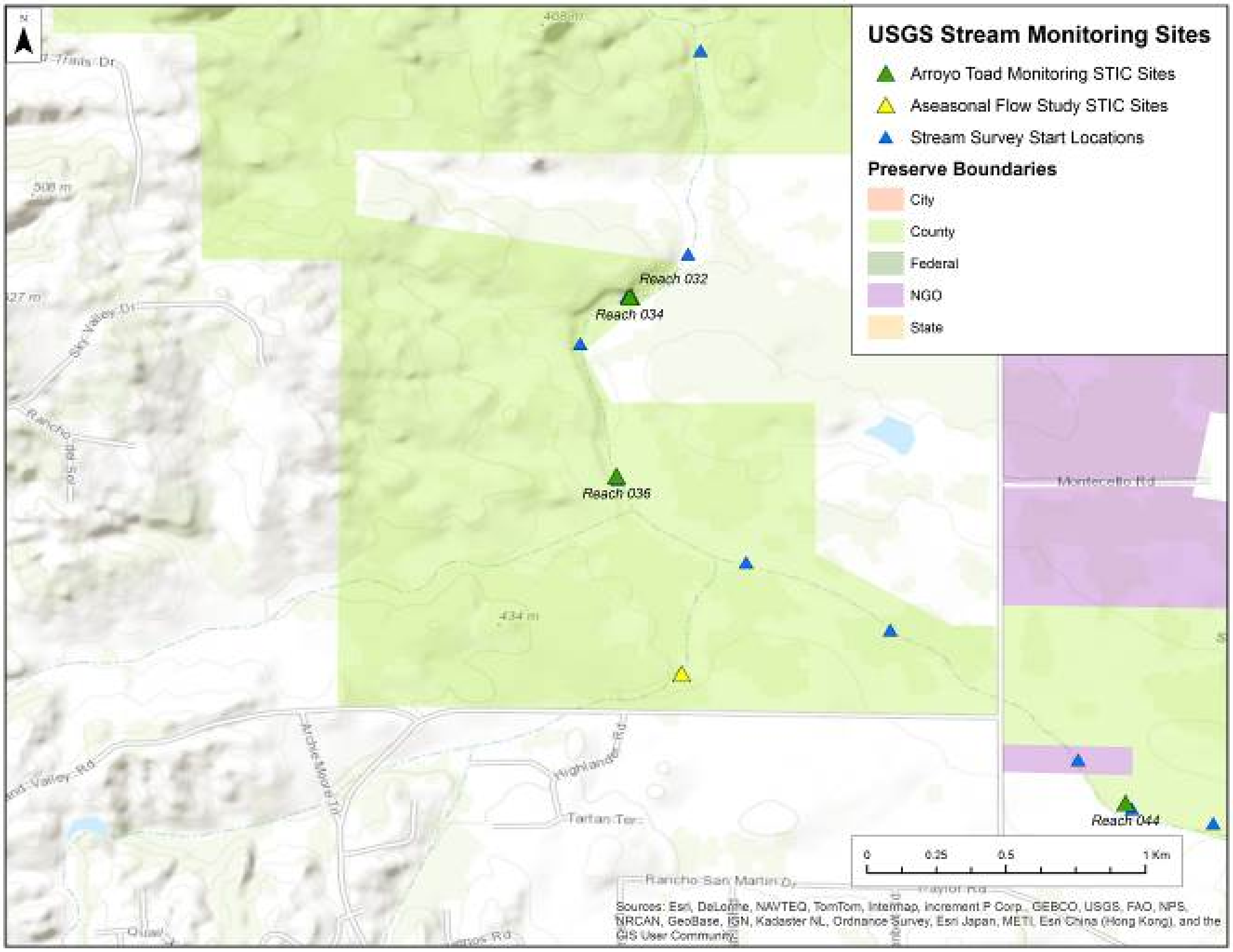

Figure B118. Santa Maria Creek 3. Santa Maria Creek Reaches 32 through 44.

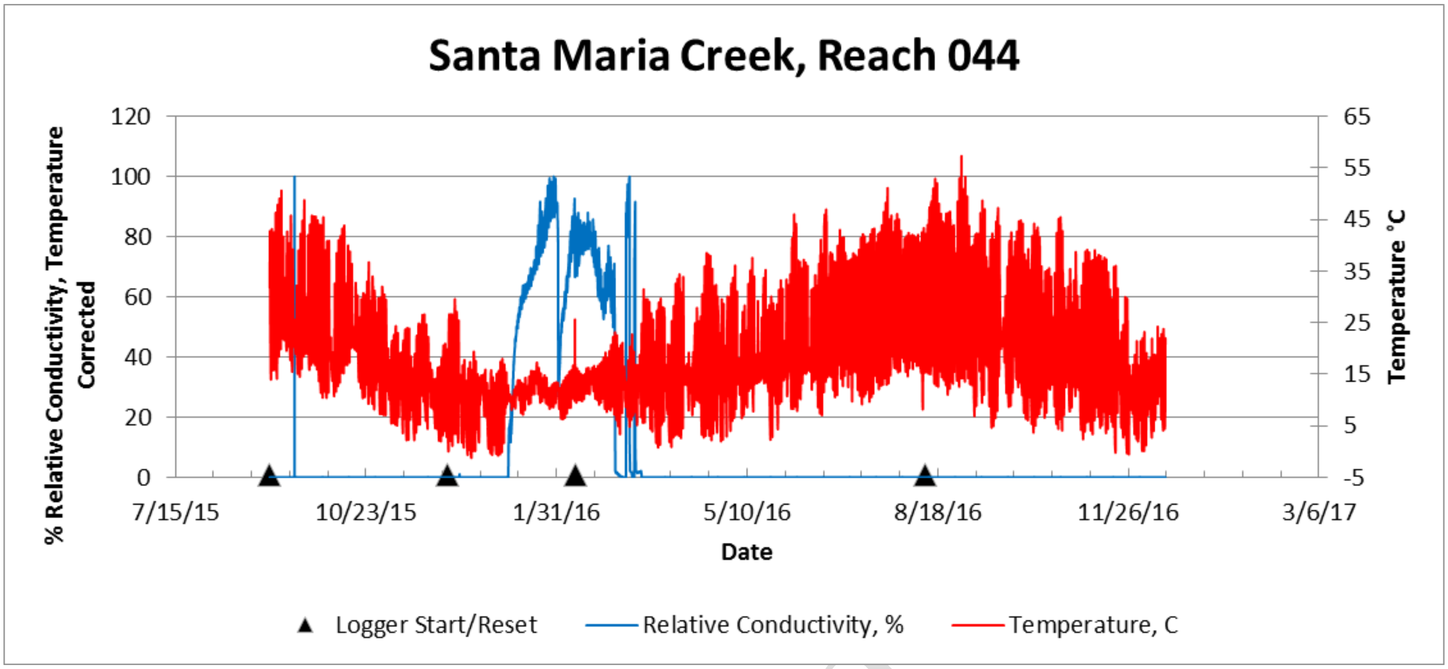

Figure B119. Relative conductivity and temperature graph of Santa Maria Creek Reach 044.

Figure B120. Habitat at Santa Maria Creek Reach 044 on 9 February 2016 (left) and on 11 August 2016 (right).

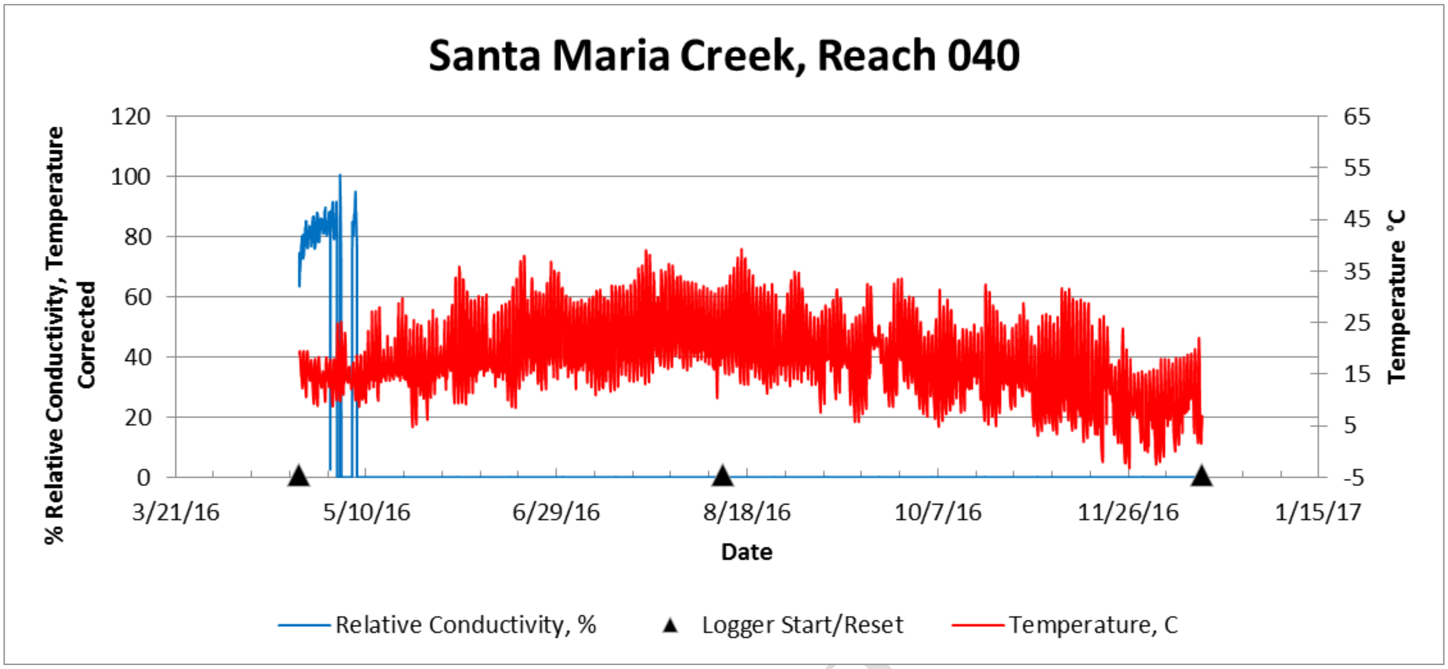

Figure B121. Relative conductivity and temperature graph of Santa Maria Creek Reach 040.

Figure B122. Habitat at Santa Maria Creek Reach 040 on 11 August 2016 (left) and on 15 December 2016 (right).

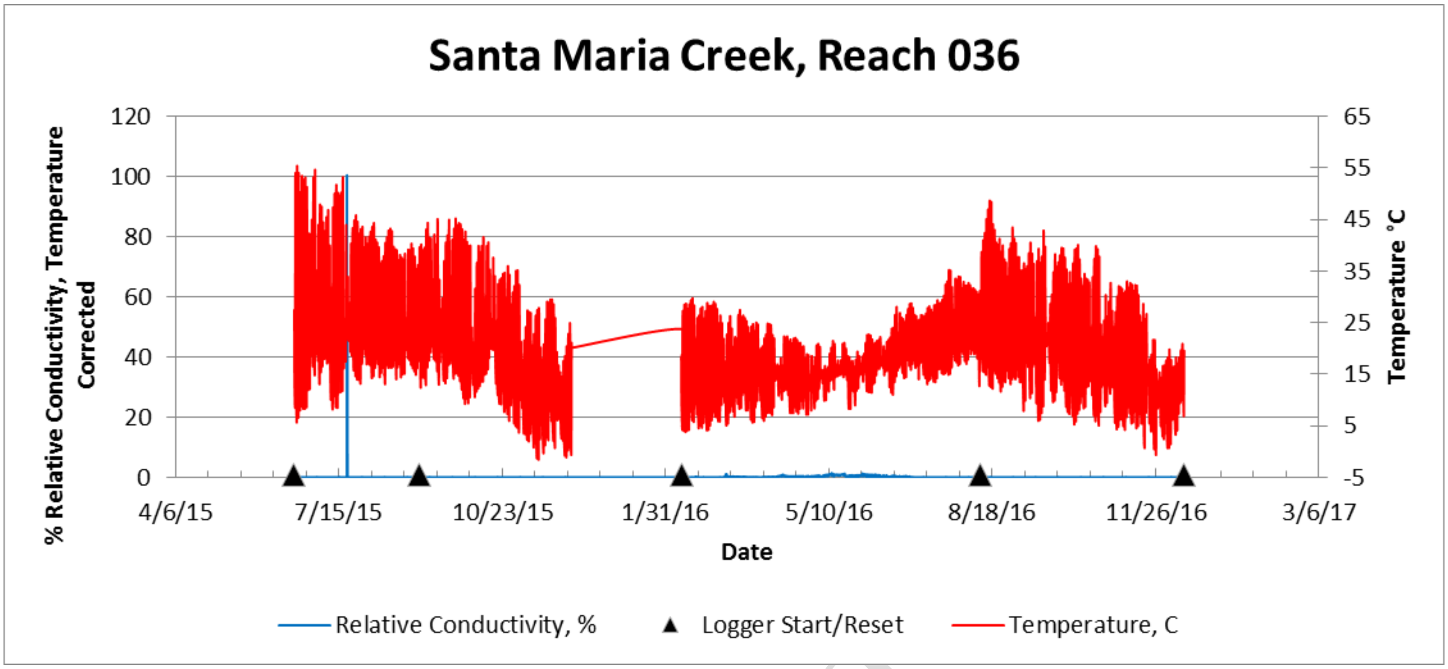

Figure B123. Relative conductivity and temperature graph of Santa Maria Creek Reach 036.

Figure B124. Habitat at Santa Maria Creek Reach 036 on 02 September 2015 (left) and on 11 August 2016 (right).

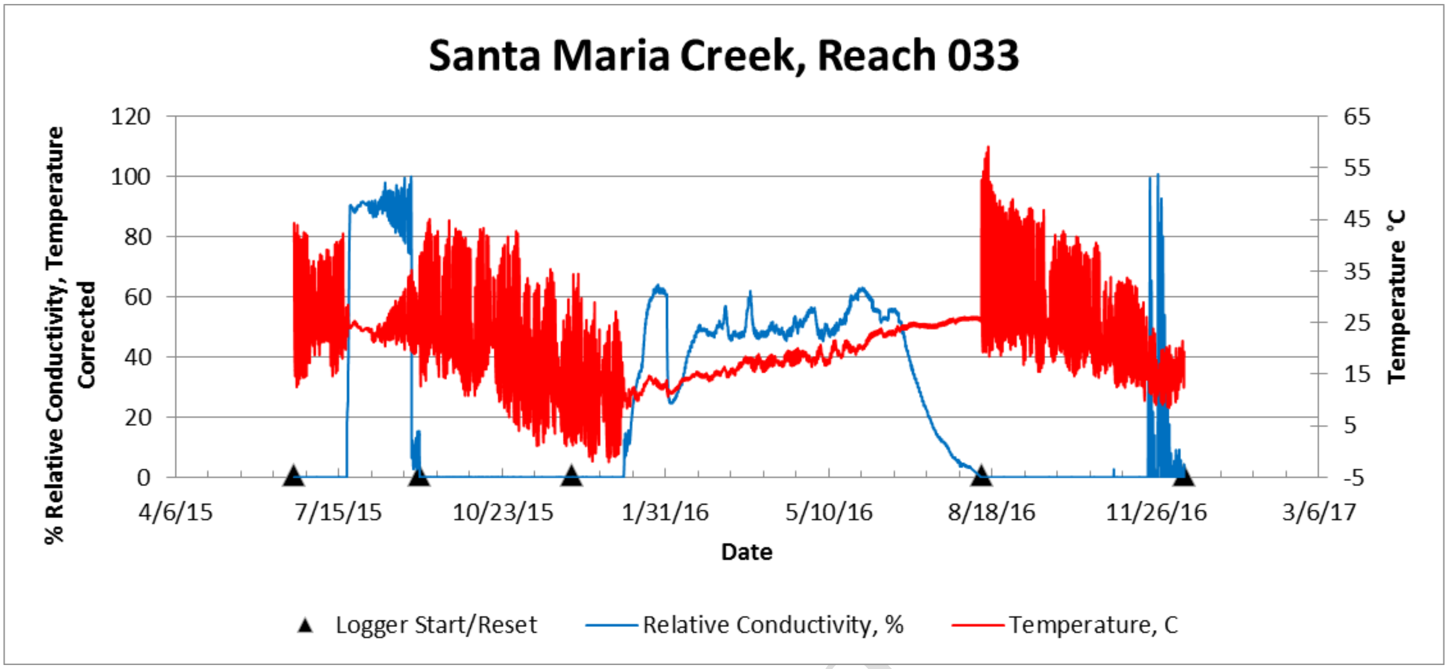

Figure B125. Relative conductivity and temperature graph of Santa Maria Creek Reach 033.

Figure B126. Habitat at Santa Maria Creek Reach 032 on 09 February 2016 (left) and on 11 August 2016 (right).Santa Maria Creek 052.

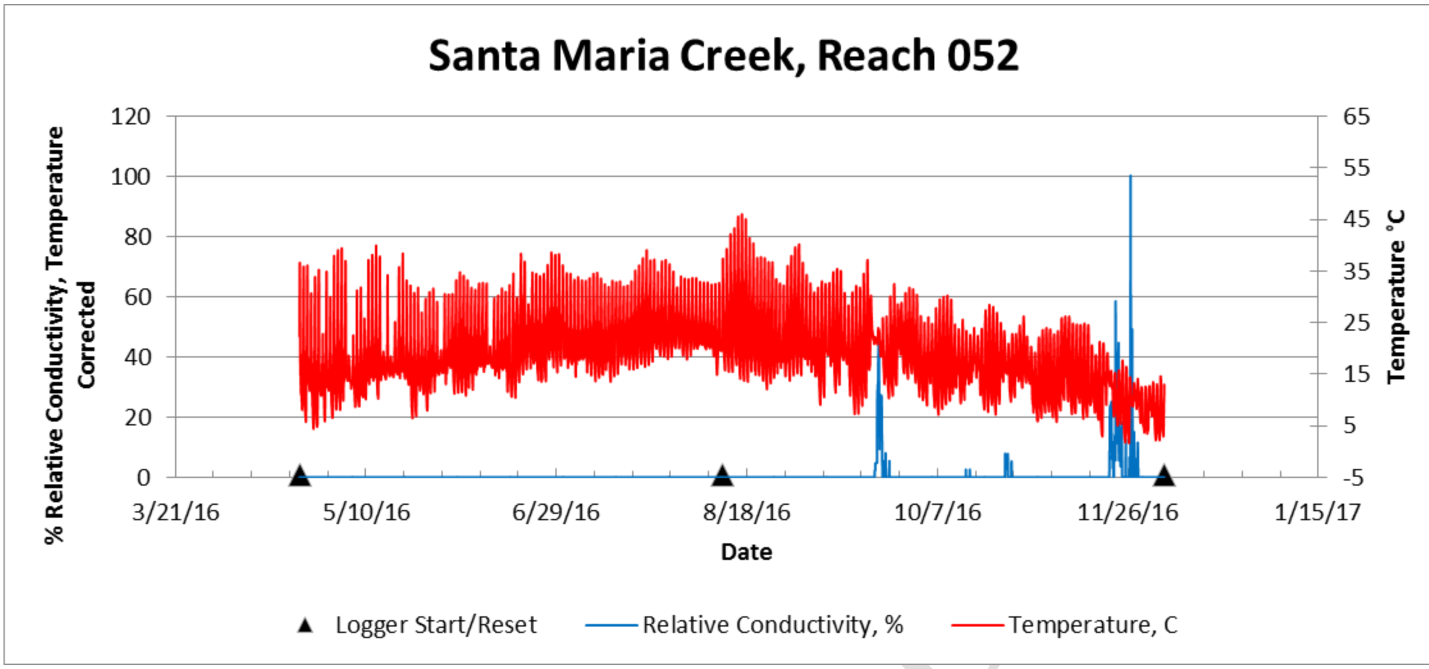

Figure B127. Relative conductivity and temperature graph of Santa Maria Creek Reach 052.

Figure B128. Habitat at Santa Maria Creek Reach 052 on 11 August 2016 (left) and on 15 December 2016 (right).

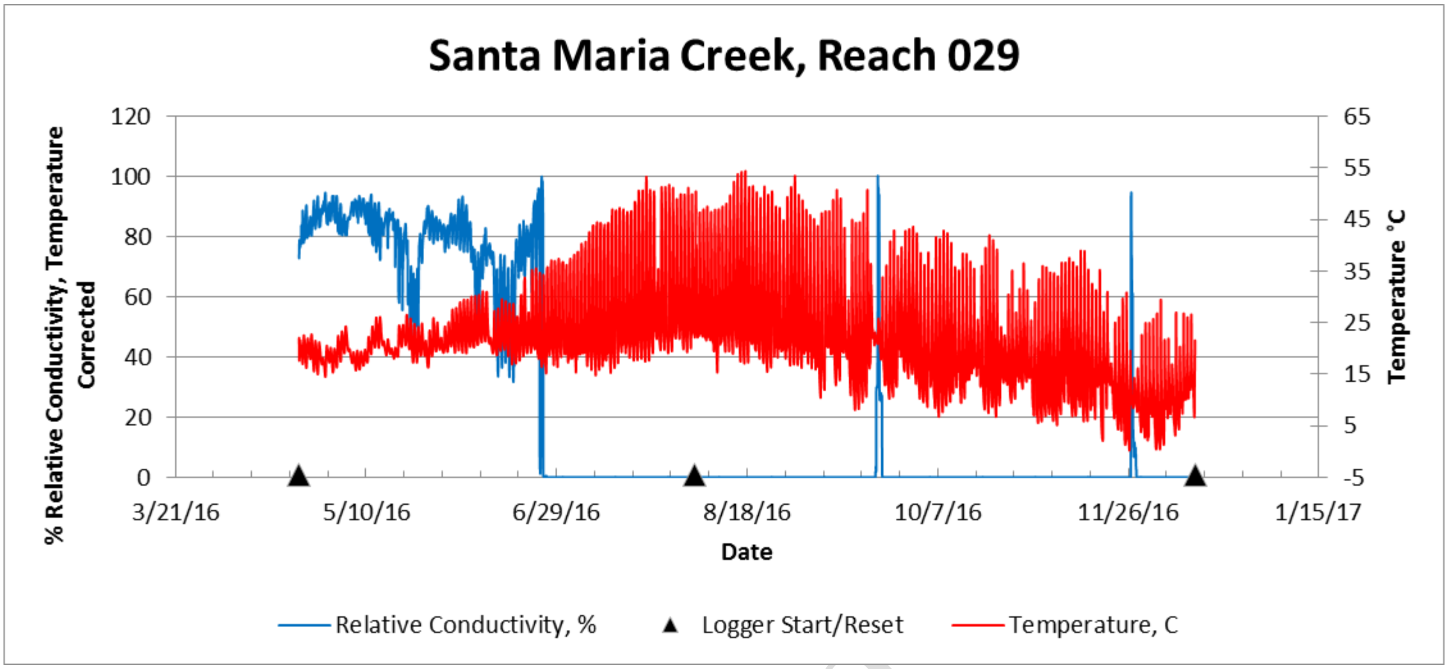

Figure B129. Relative conductivity and temperature graph of Santa Maria Creek Reach 029.

Figure B130. Habitat at Santa Maria Creek Reach 029 on 22 April 2016 (left) and on 13 December 2016 (right).

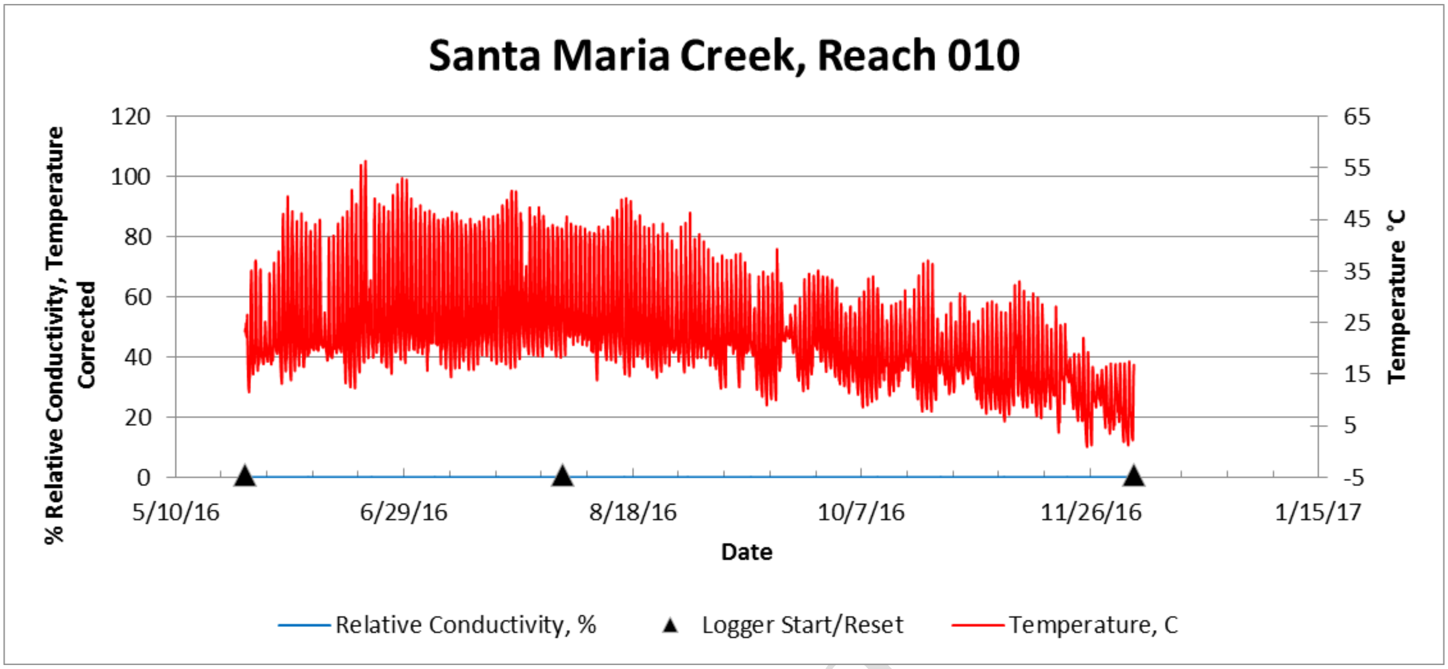

Figure B131. Relative conductivity and temperature graph of Santa Maria Creek Reach 010.

Figure B132. Habitat at Santa Maria Creek Reach 010 on 25 May 2016 (left) and on 02 August 2016 (right).

San Diego River Watershed

The San Diego River watershed is the third largest coastal watershed in the county and the largest coastal watershed completely within the county. It encompasses 112,078 hectares from sea level to nearly 2,000 meters. The previously known arroyo toad populations are divided between San Vicente Creek above San Vicente Reservoir and San Diego River above El Capitan Reservoir (including small portions of Cedar and Boulder creeks). The San Diego River below El Capitan Reservoir in El Monte Valley was included in the USFWS critical habitat designation for the arroyo toad (USFWS 2011). There is an unconfirmed recent record of an adult below El Monte Valley (R. Fisher pers. comm. 2017). There are approximately 43,821 hectares of conserved lands within this watershed managed largely by USFS, CDFW, City of San Diego, County of San Diego, and Endangered Habitats Conservancy.

Kimball Valley

This section of San Vicente Creek upstream from the San Vicente Reservoir has historically supported a large population of arroyo toads (USFWS 2015) and consists of a mixture of open sandy wash and thick willow riparian punctuated by occasional boulder lined deep pools. USGS detected recruitment at this site as recently as 2010 (USFWS 2015). The riparian habitat is surrounded by thick chaparral and coastal sage scrub with no urban development and is within designated critical habitat (USFWS 2011). This site is owned and managed by City of San Diego and is currently being monitored for arroyo toads.

Upper San Diego River

This site includes the main stem of the San Diego River above El Capitan Reservoir and the Capitan Grande Reservation to approximately one kilometer upstream from Penin Canyon. This site is owned and managed by USFS. Arroyo toads were previously known from this site (USFWS 2015), most of which is included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

San Diego Watershed (no map available)

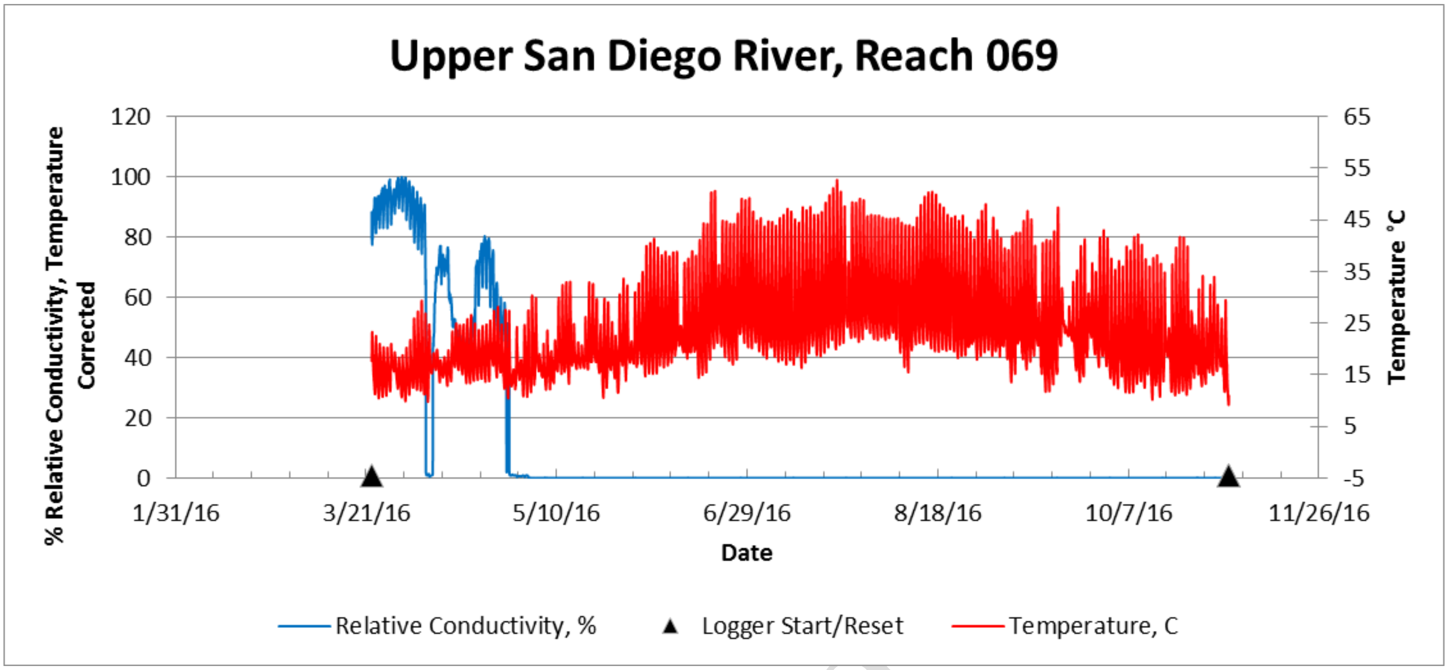

Figure B133. Relative conductivity and temperature graph of Upper San Diego River Reach 069.

Figure B134. Habitat at Upper San Diego River Reach 069 on 22 March 2016.

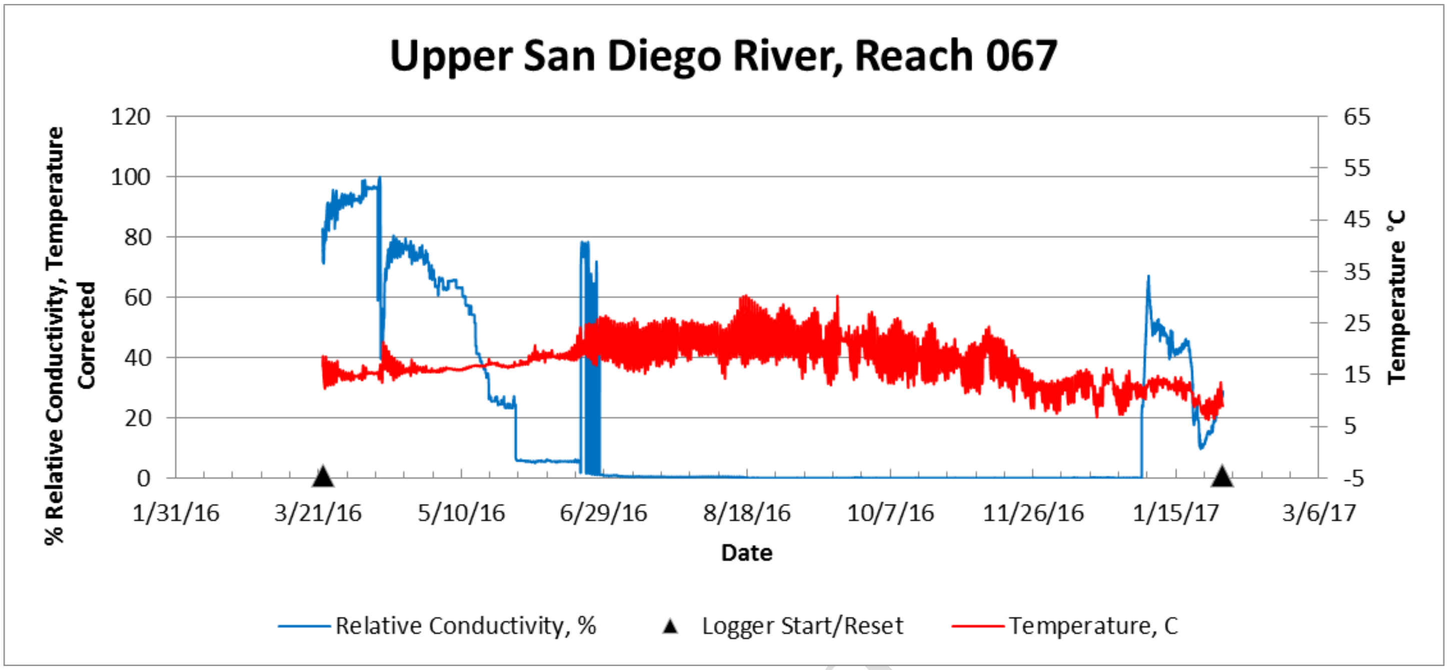

Figure B135. Relative conductivity and temperature graph of Upper San Diego River Reach 067.

Figure B136. Habitat at Upper San Diego River Reach 067 on 22 March 2016 (left) and on 31 January 2017 (right).

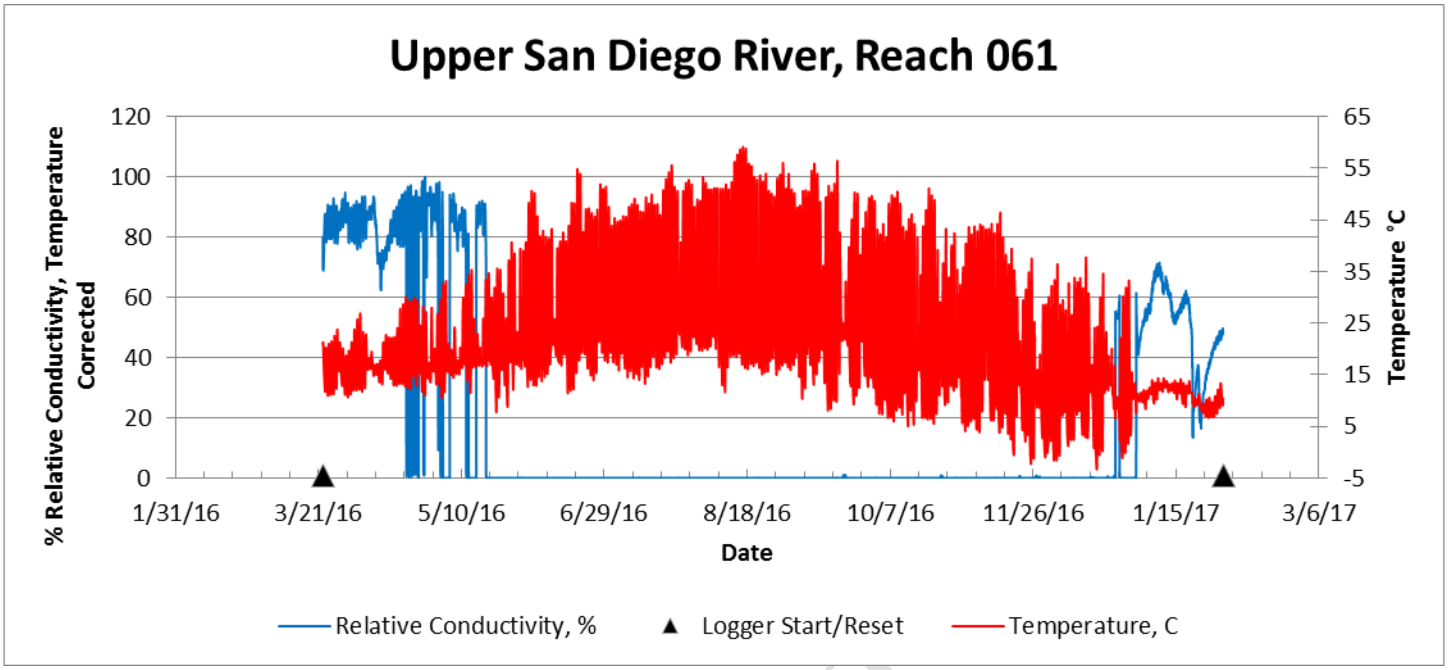

Figure B137. Relative conductivity and temperature graph of Upper San Diego River Reach 061.

Figure B138. Habitat at Upper San Diego River Reach 061 on 22 March 2016 (left) and on 31 January 2017 (right).

Cedar and Boulder Creeks

Cedar and Boulder creeks are tributaries to San Diego River above El Capitan Reservoir with the lower reaches having open sandy wash with mixed willow and coast live oak riparian. These sites are owned and managed by USFS. Arroyo toads were previously known from this site (USFWS 2015), which was included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

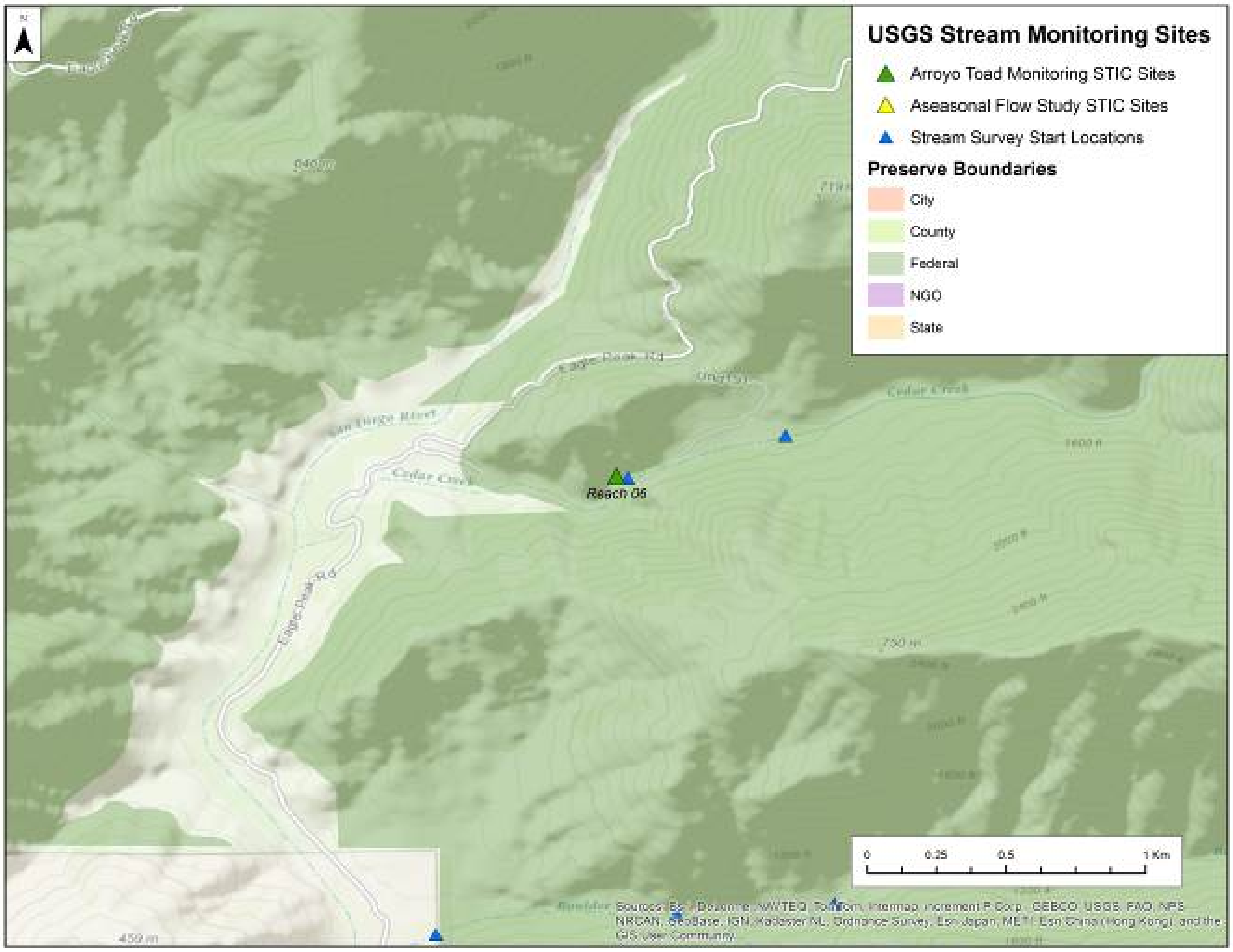

Figure B139. Cedar Creek Reach 6.

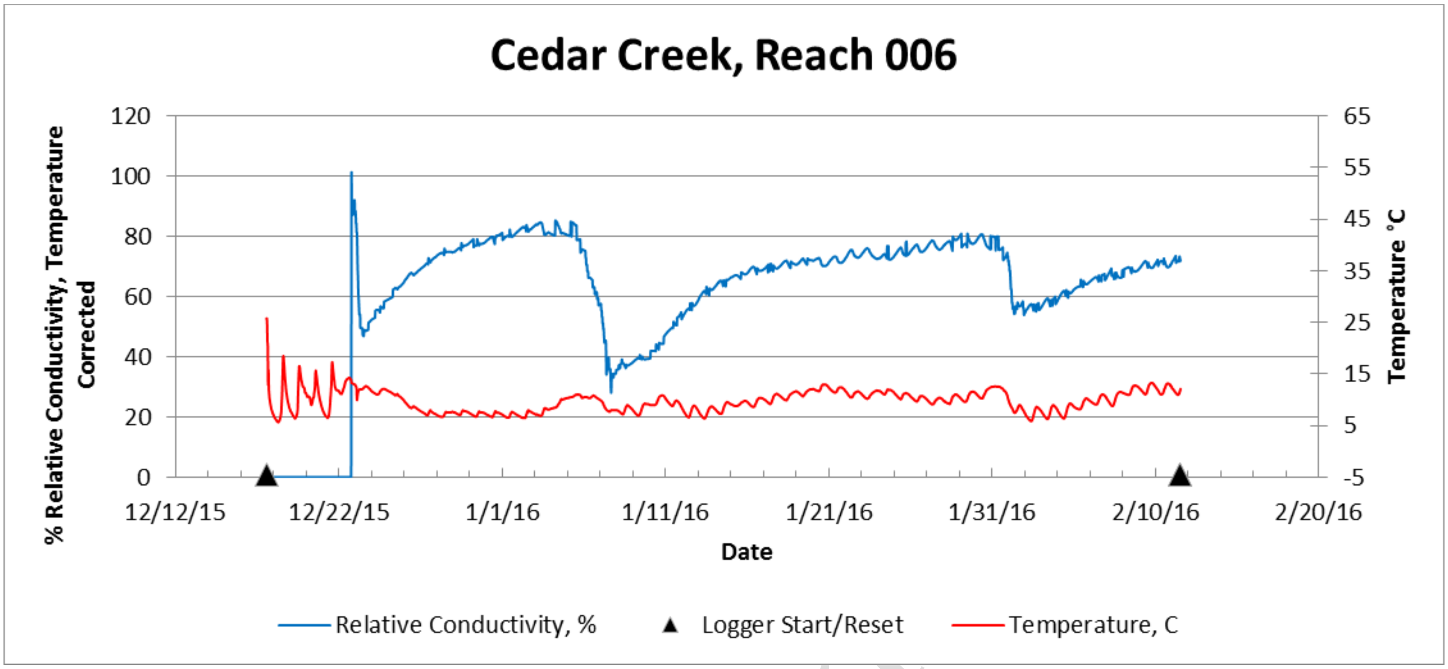

Figure B140. Relative conductivity and temperature graph of Cedar Creek Reach 006.

Figure B141. Habitat at Cedar Creek Reach 006 on 17 December 2015.

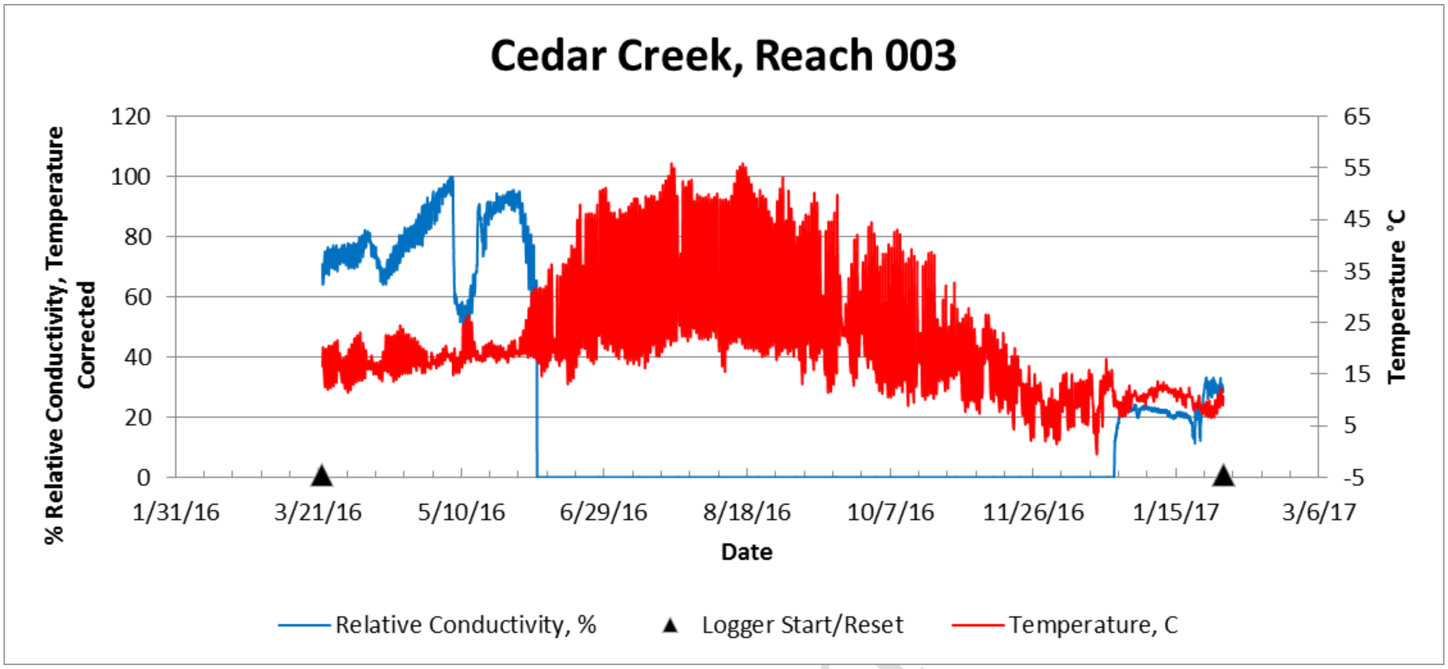

Figure B142. Relative conductivity and temperature graph of Cedar Creek Reach 003.

Figure B143. Habitat at Cedar Creek Reach 003 on 22 March 2016 (left) and on 31 January 2017 (right).

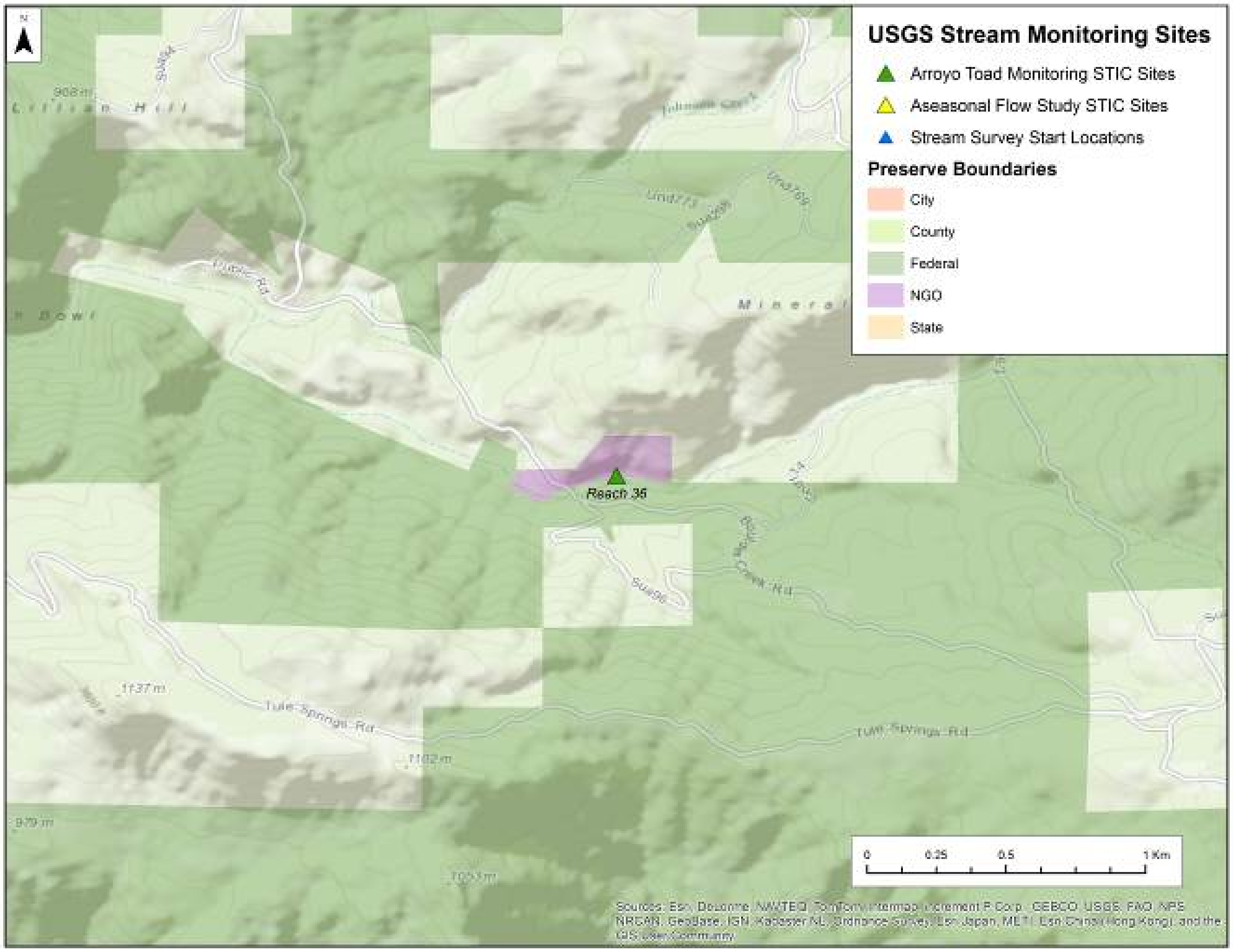

Figure B144. Boulder Creek Reach 36.

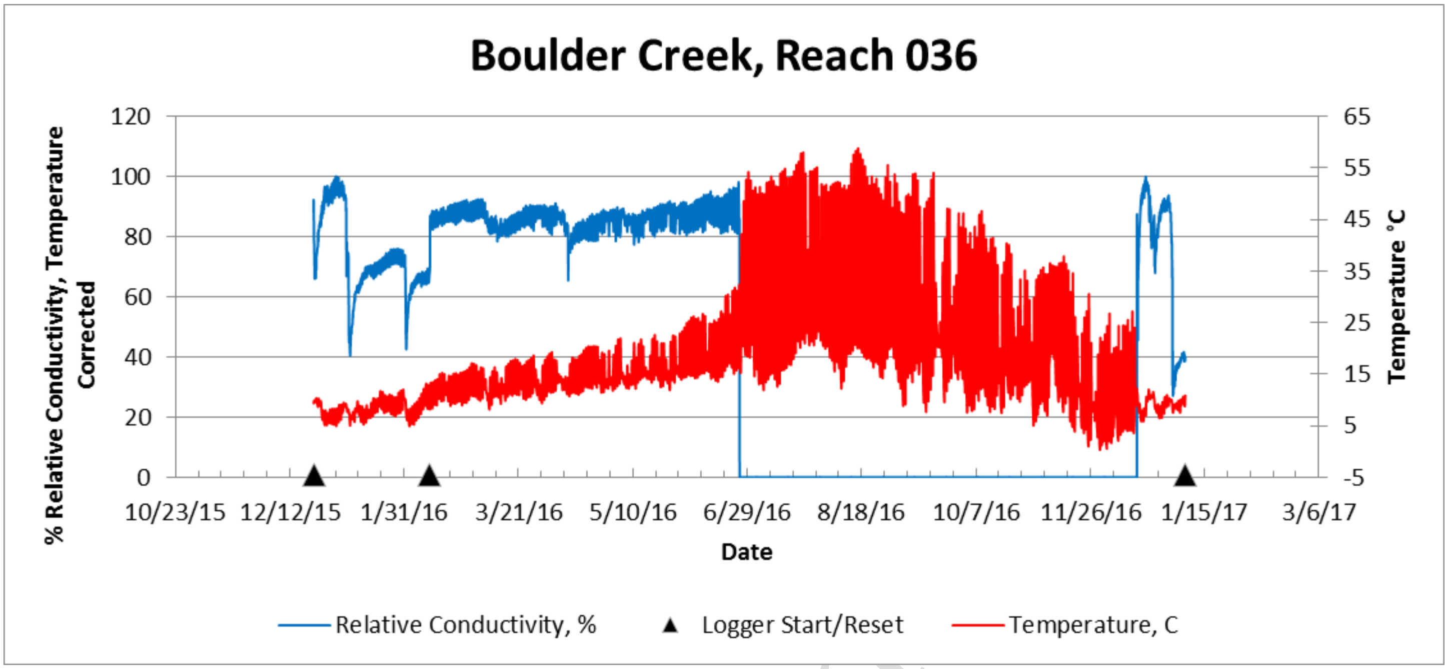

Figure B145. Relative conductivity and temperature graph of Boulder Creek Reach 036.

Figure B146. Habitat at Boulder Creek Reach 036 on 11 February 2016 (left) and on 06 January 2017 (right).

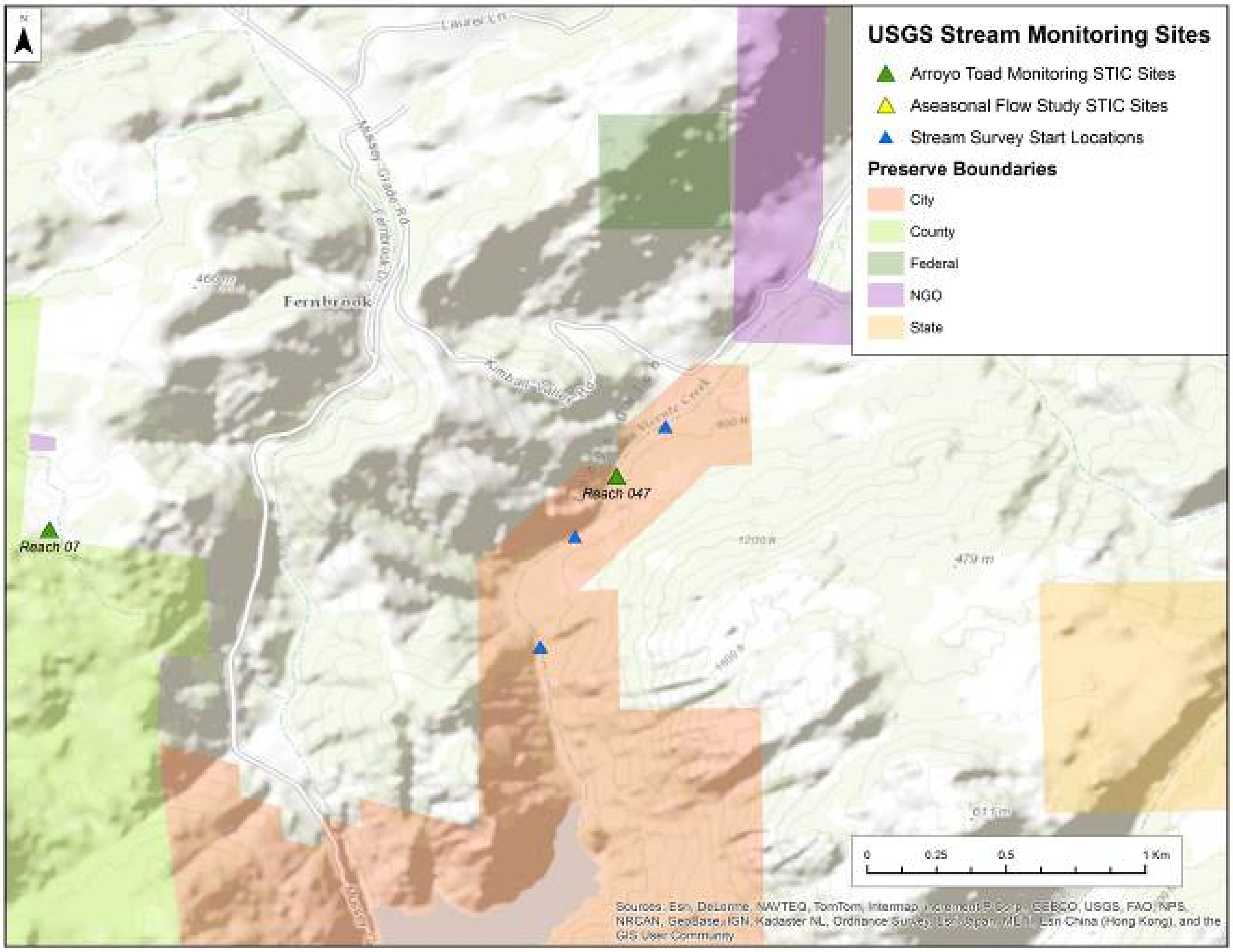

Figure B147. San Vicente Creek Reach 047.

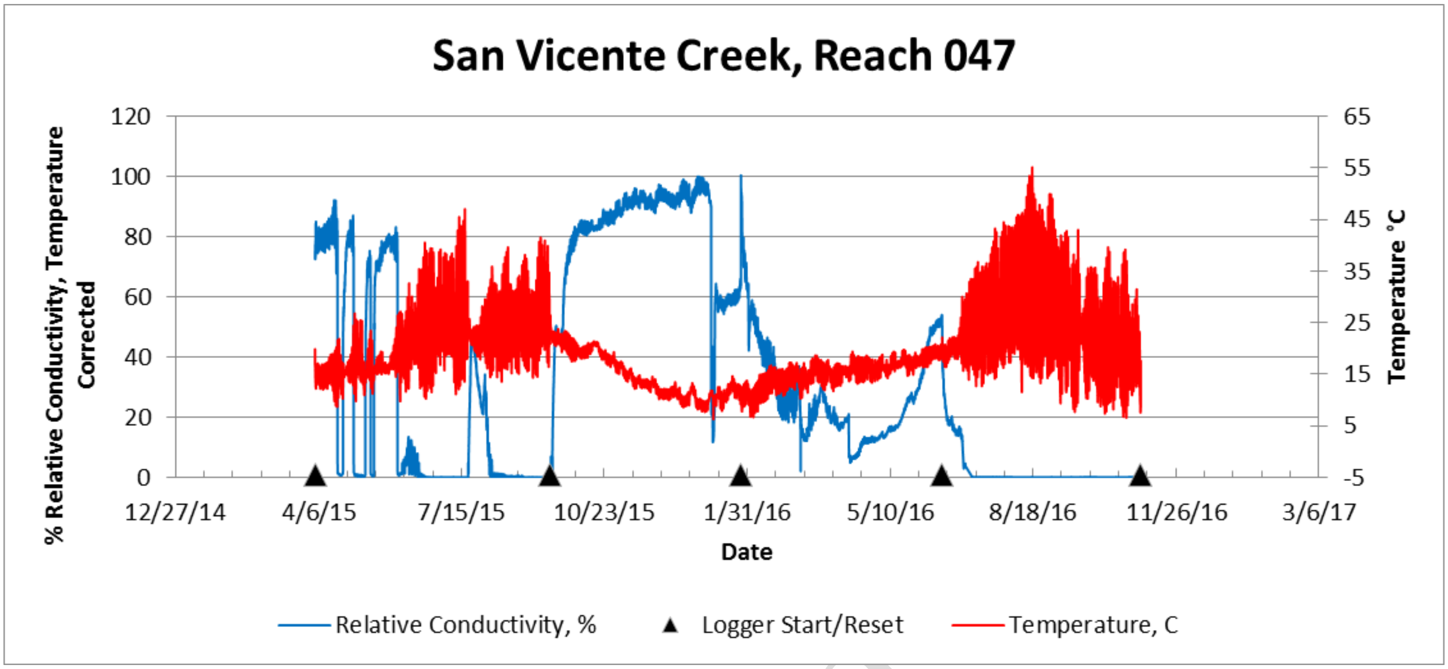

Figure B148. Relative conductivity and temperature graph of San Vicente Creek Reach 047.

Figure B149. Habitat at San Vicente Creek Reach 047 on 03 April 2015 (left) and on 26 January 2016 (right).

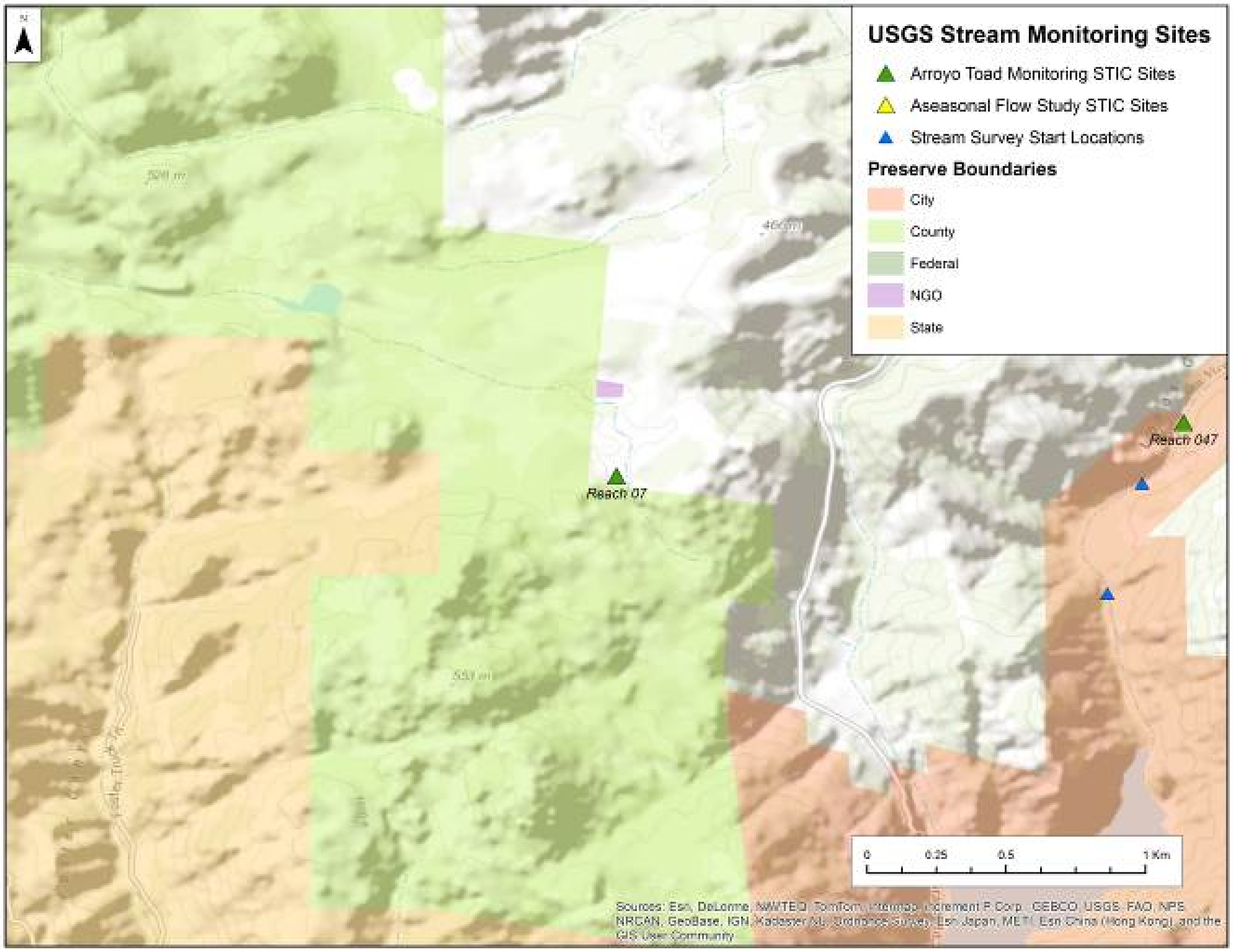

Figure B150. West Branch San Vicente Creek Tributary 1 Reach 7.

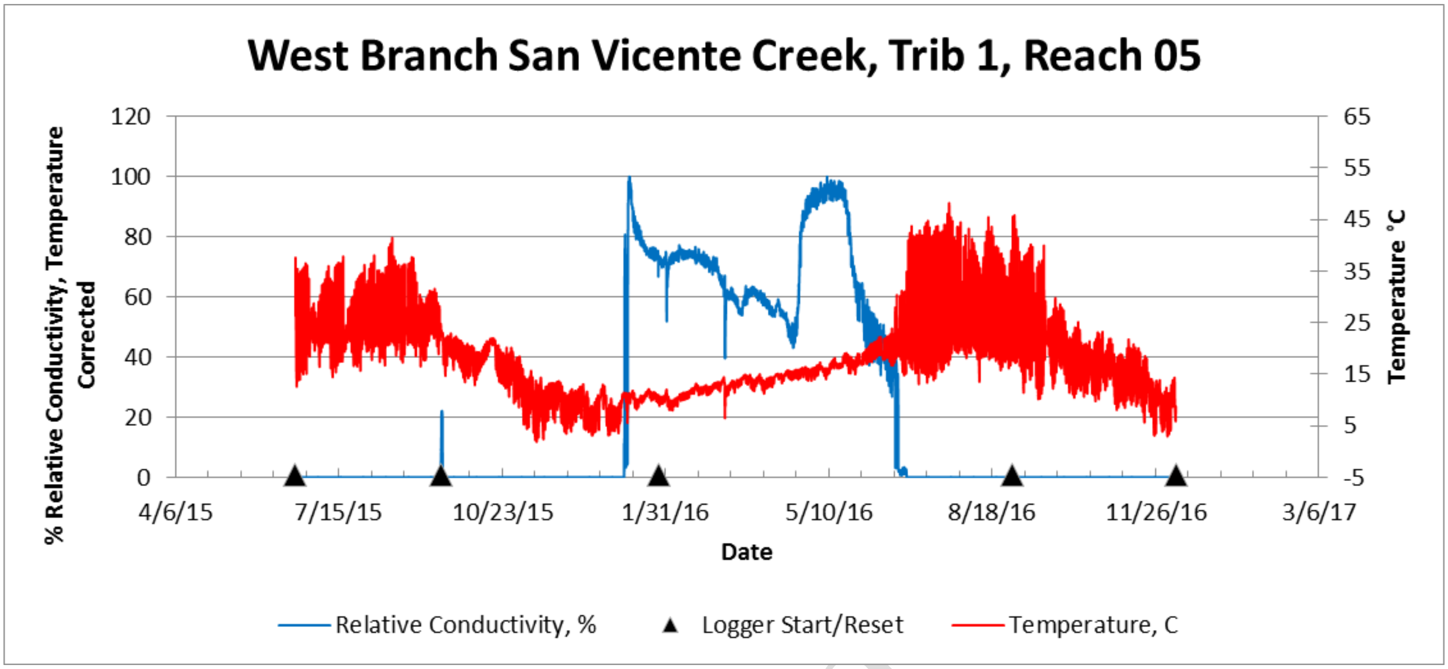

Figure B151. Relative conductivity and temperature graph of San Vicente Creek Tributary 1 Reach 007.

Figure B152. Habitat at West Branch San Vicente Creek Tributary 1 Reach 007 on 26 January 2016 (left) and on 08 December 2016 (right).

Sweetwater River Watershed

The Sweetwater River watershed encompasses 56,407 hectares from the coast to the Cuyamaca and Laguna mountains. In addition to riparian habitats, this long, narrow watershed contains oak and pine woodlands, grasslands, chaparral, and coastal sage scrub. There are approximately 23,655 hectares of conserved lands within this watershed, managed in large part by California State Department of Parks and Recreation, USFS, CDFW, USFWS, Sweetwater Authority, Sycuan Band of Kumeyaay Indians, Caltrans, and County of San Diego.

Upper Sweetwater River

Upper Sweetwater River within Cuyamaca Rancho State Park consists of nearly 14 kilometers of riparian ranging from low gradient open sandy wash to steep reaches lined with boulder and bedrock. Recreation at this site is limited to hiking, biking, equestrian use, and fishing. Arroyo toads were previously known from this site (USFWS 2015), which was included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

Middle Sweetwater River

Sweetwater River in and downstream from the Sycuan Peak Ecological Reserve owned and managed by CDFW. Arroyo toads had been observed here historically (USFWS 2015), and the site was included in USFWS' critical habitat designation for the arroyo toad (USFWS 2011).

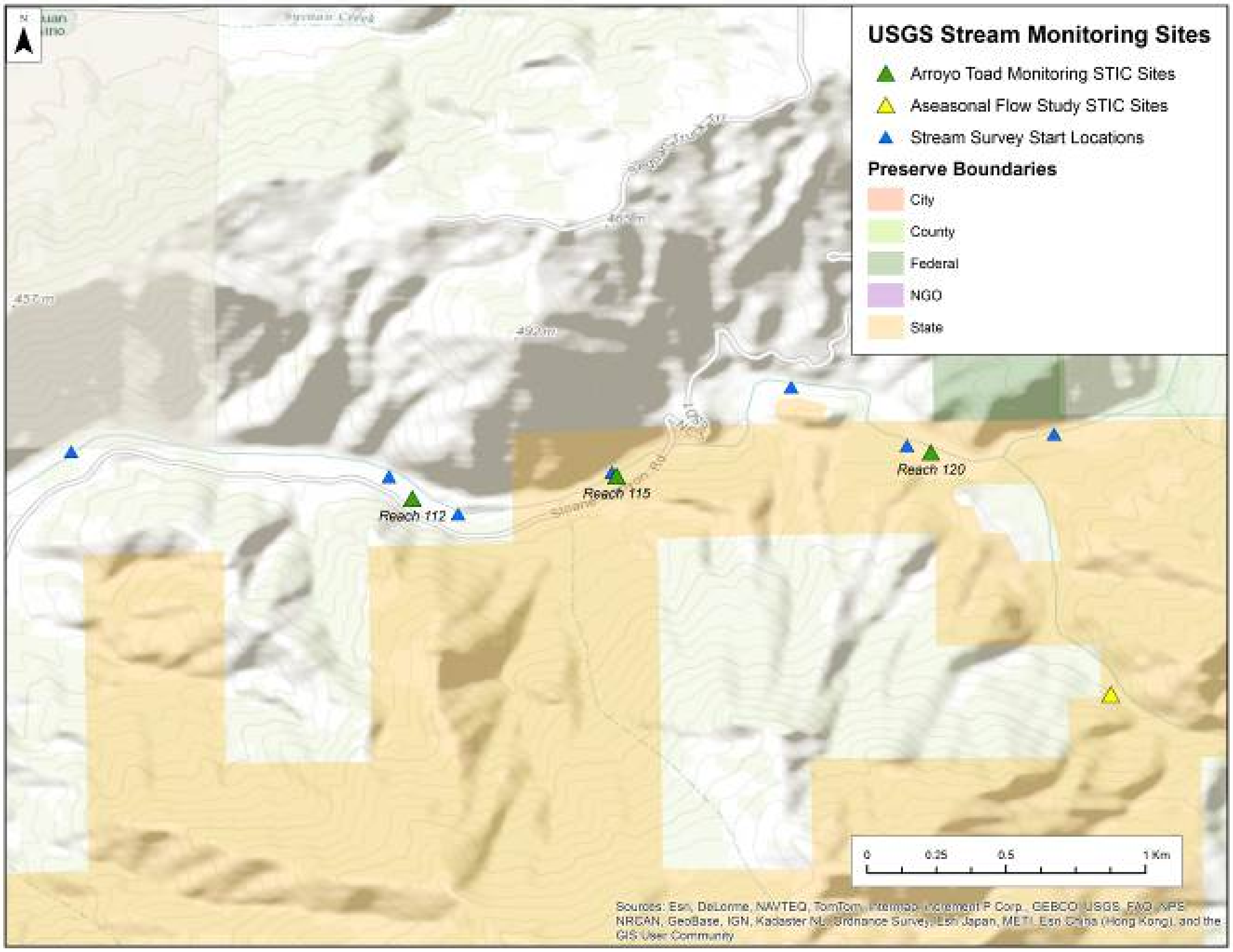

Figure B153. Middle Sweetwater River Reaches 112 through 120.

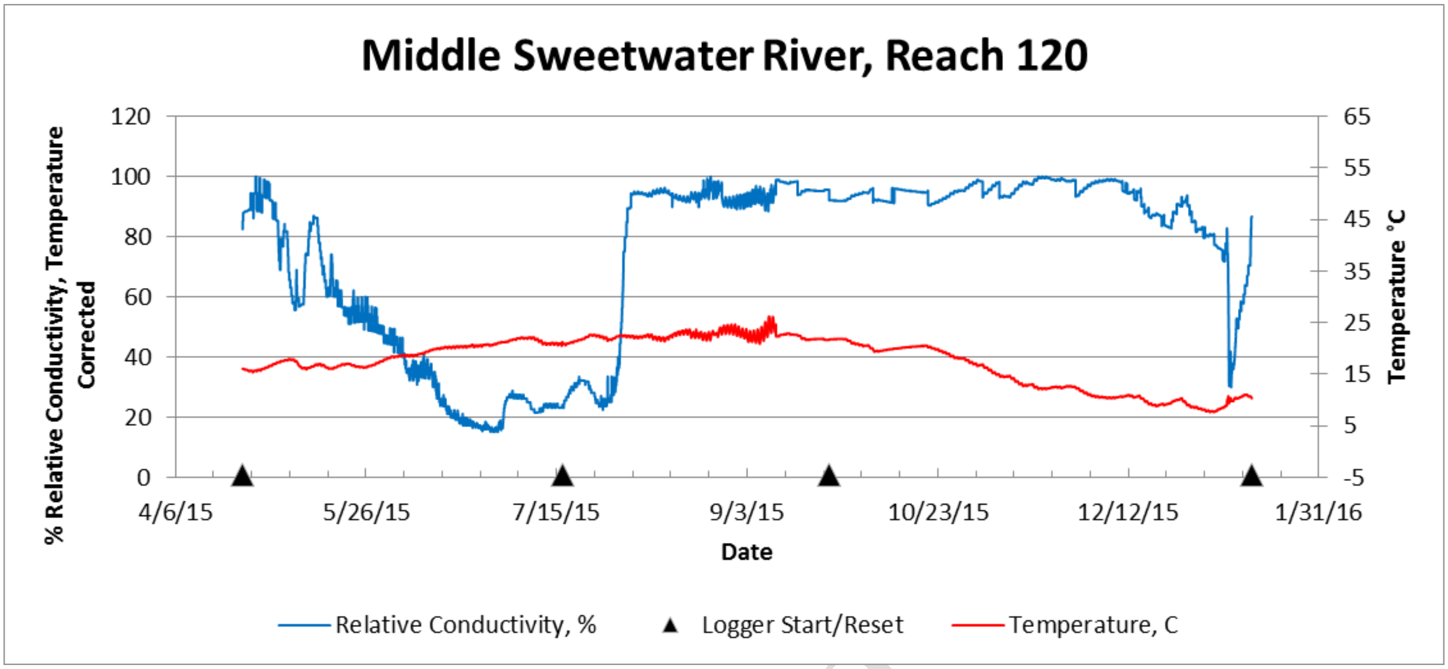

Figure B154. Relative conductivity and temperature graph of Middle Sweetwater River Reach 120.

Figure B155. Habitat at Middle Sweetwater River Reach 120 on 14 August 2015 (left) and on 10 September 2015 (right).

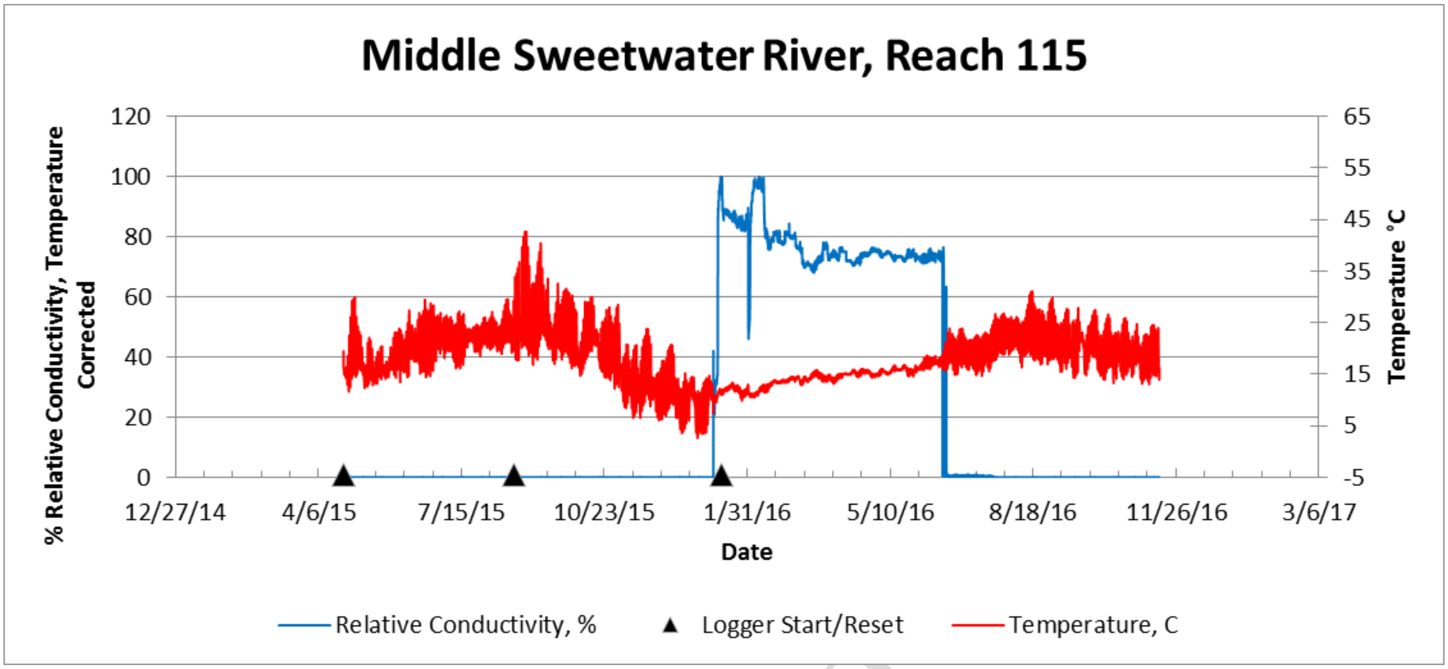

Figure B156. Relative conductivity and temperature graph of Middle Sweetwater River Reach 115.

Figure B157. Habitat at Middle Sweetwater River Reach 115 on 13 January 2016 (left) and on 14 November 2016 (right).

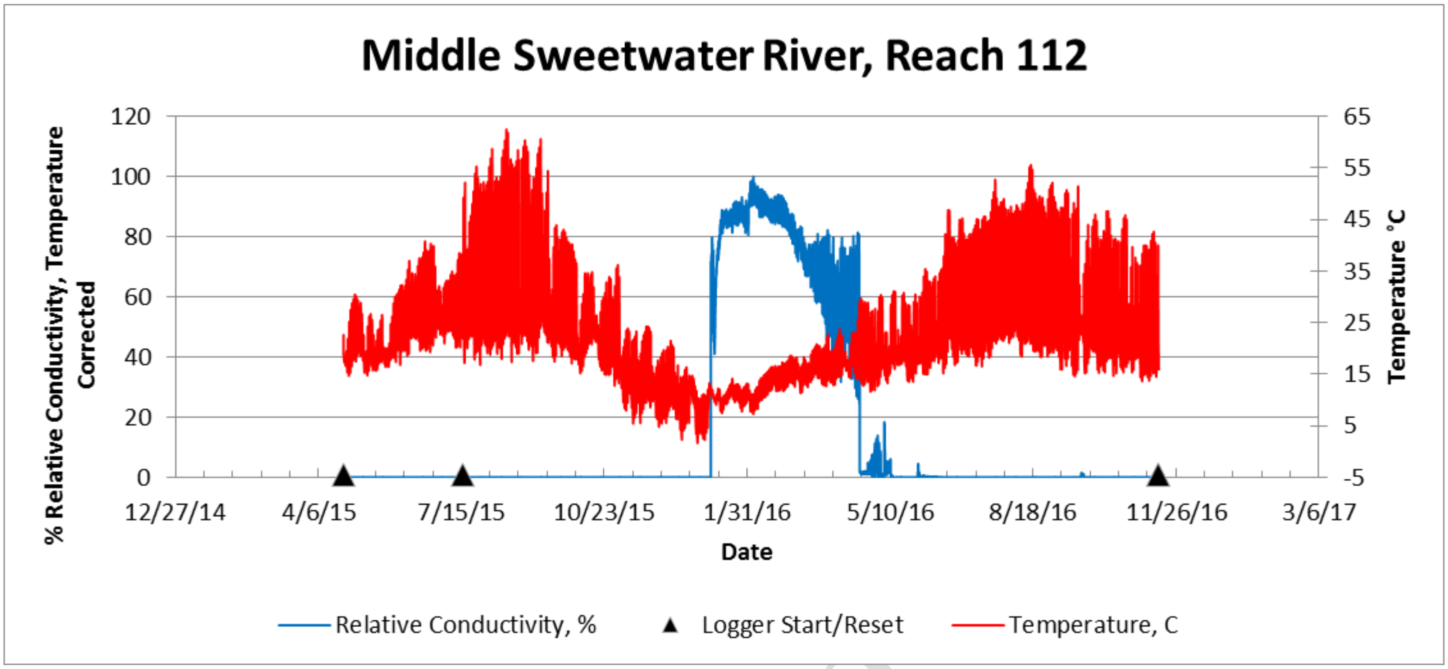

Figure B158. Relative conductivity and temperature graph of Middle Sweetwater River Reach 112.

Figure B159. Habitat at Middle Sweet Water River Reach 112 on 16 July 2015 (left) and on 15 November 2016 (right).

Otay River Watershed

The Otay River watershed is approximately 36,764 hectares and drains into San Diego Bay along with the Sweetwater River and Pueblo San Diego watersheds. This watershed is heavily urbanized in the mid and lower regions with rural, agriculture, and open space in the upper portion. While there are no known populations of arroyo toads in the Otay River Watershed (USFWS 2015), portions of Jamul and Dulzura Creeks which are being restored may be suitable for reintroduction of the arroyo toad. There are approximately 16,663 hectares of conserved land in this watershed managed in large part by CDFW, USFWS, County of San Diego, and City of Chula Vista.

Jamul Creek

Jamul Creek within the Rancho Jamul Ecological Reserve contains approximately 10 kilometers of low gradient stream with sandy substrates and mixed willow and coast live oak riparian surrounded by coastal sage scrub and grassland. Jamul Creek joins with Dulzura Creek before flowing into Lower Otay Reservoir. Currently owned and managed by CDFW, this site is currently undergoing restoration, including several riparian restoration projects.

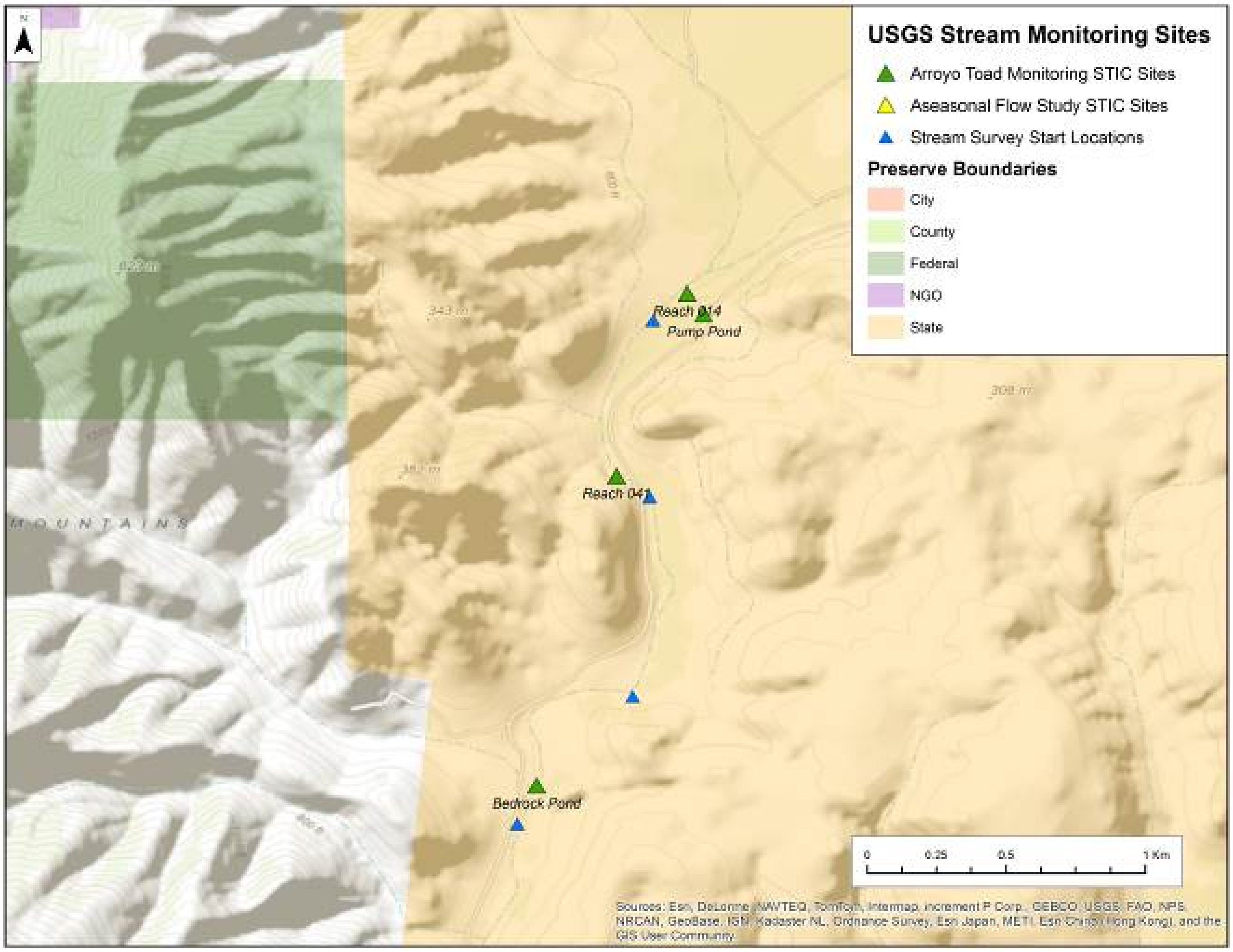

Figure B160. Pump Pond Jamul Creek Reach 041 and Bedrock Pond.

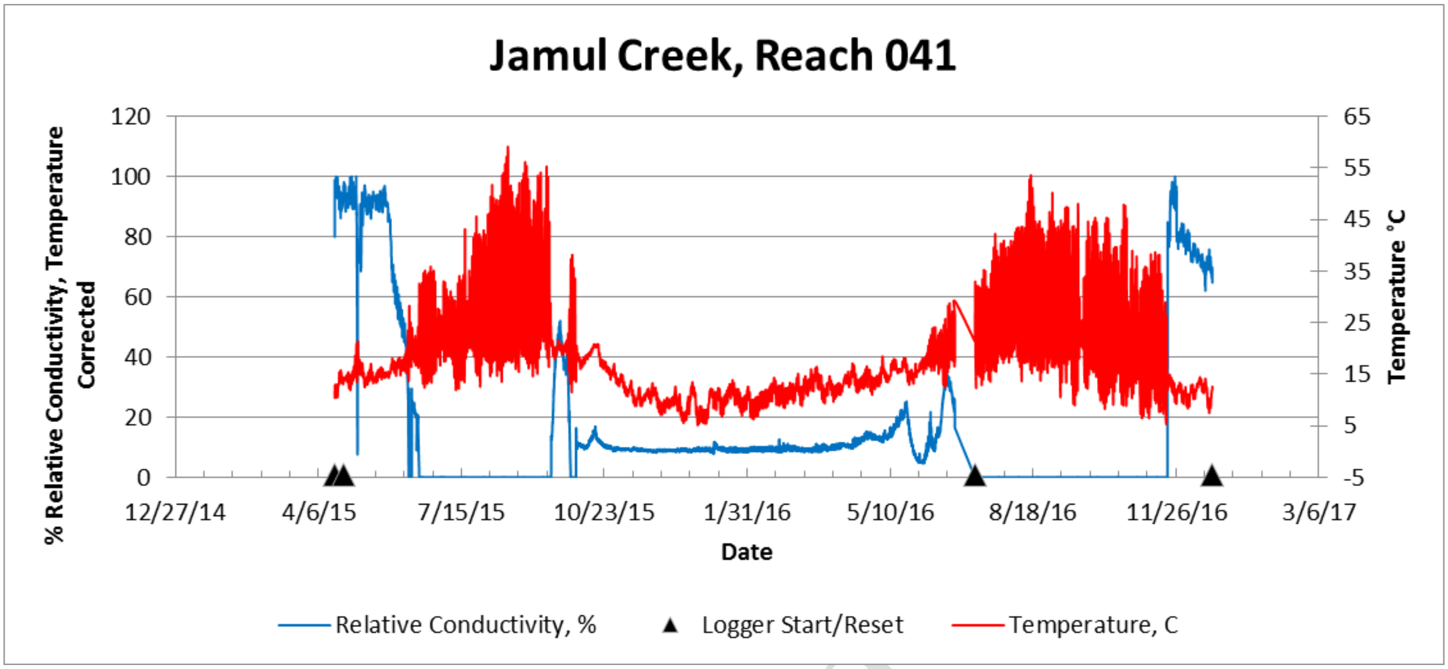

Figure B161. Relative conductivity and temperature graph of Jamul Creek Reach 041.

Figure B162. Habitat at Jamul Creek Reach 041 on 10 September 2015 (left) and on 16 July 2016 (right).

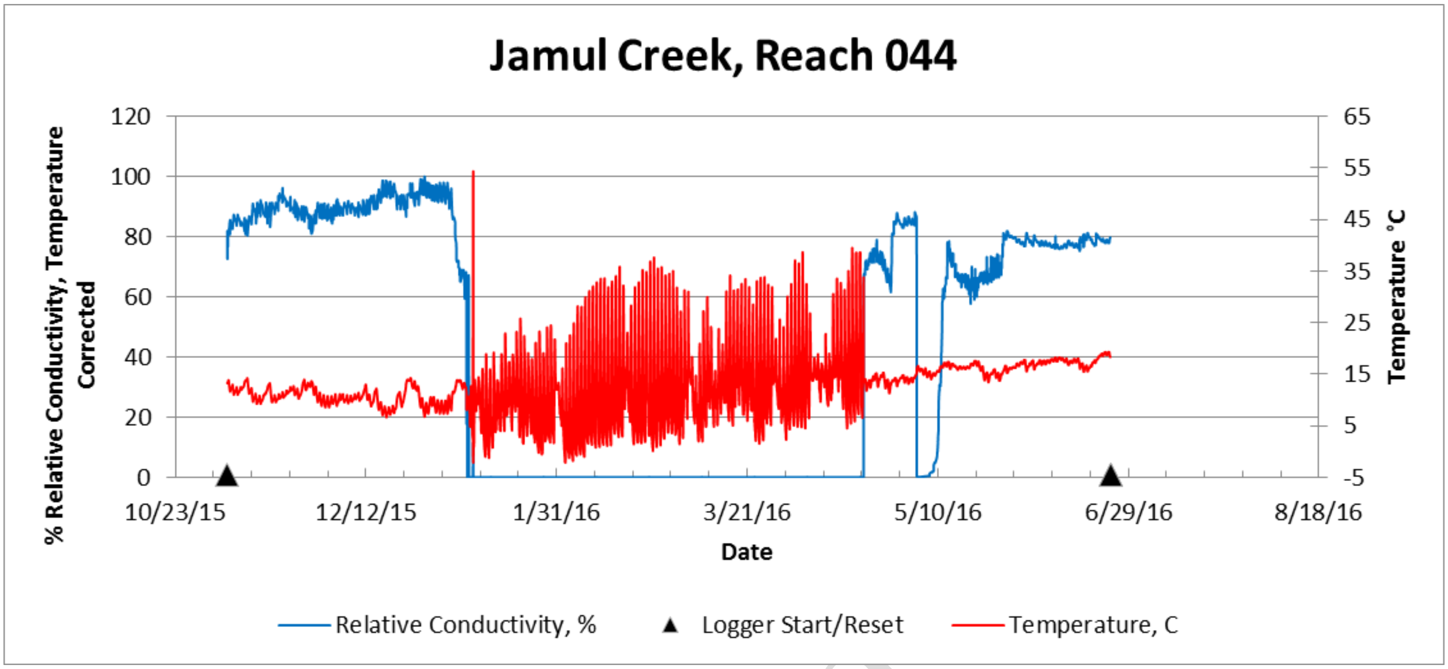

Figure B163. Relative conductivity and temperature graph of Jamul Creek Reach 044.

Figure B164. Habitat at Jamul Creek Reach 044 on 21 December 2016 (left) and on 10 March 2016 (right).

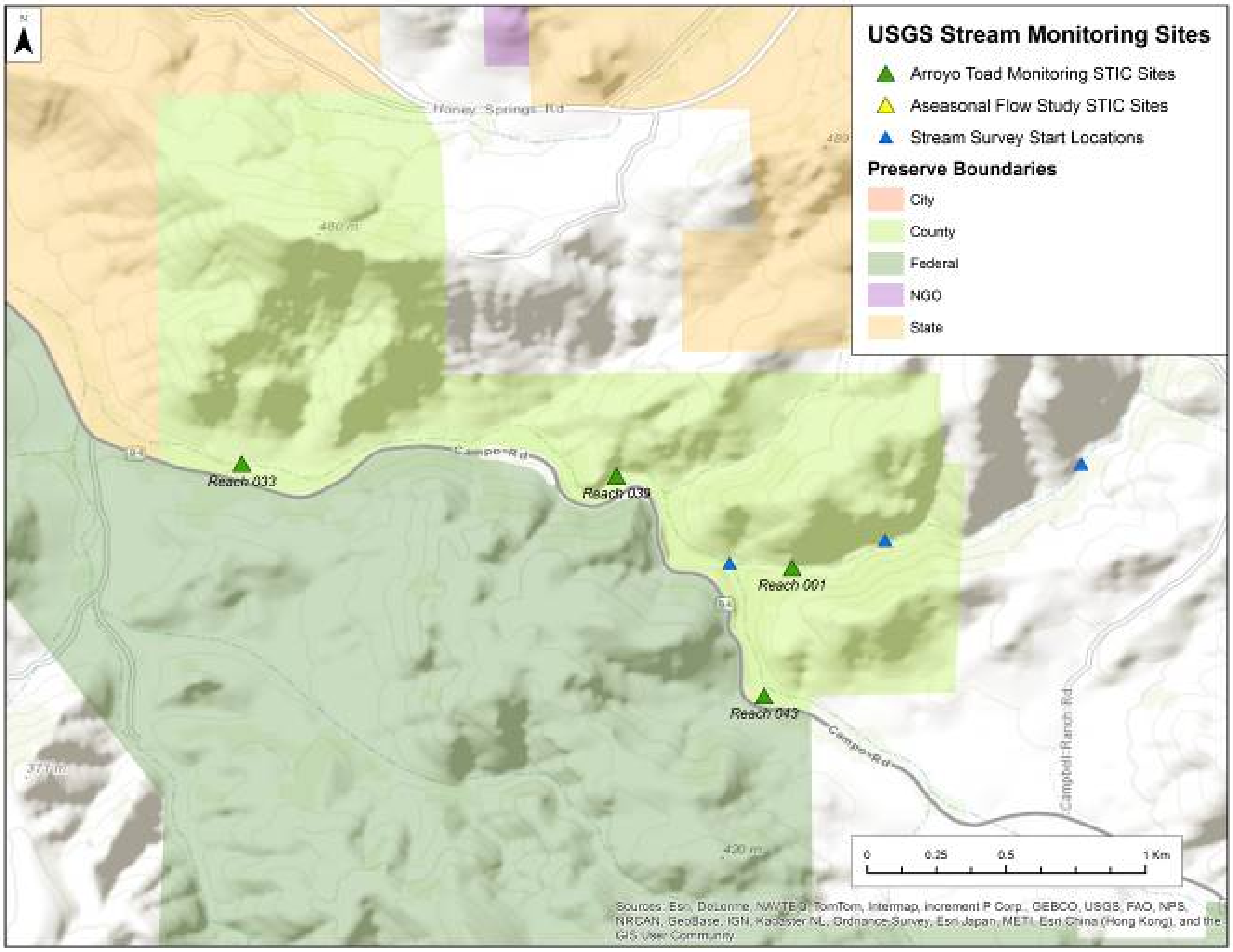

Figure B165. Pringle Canyon Reach 1 and Dulzura Creek Reaches 33 through 43.

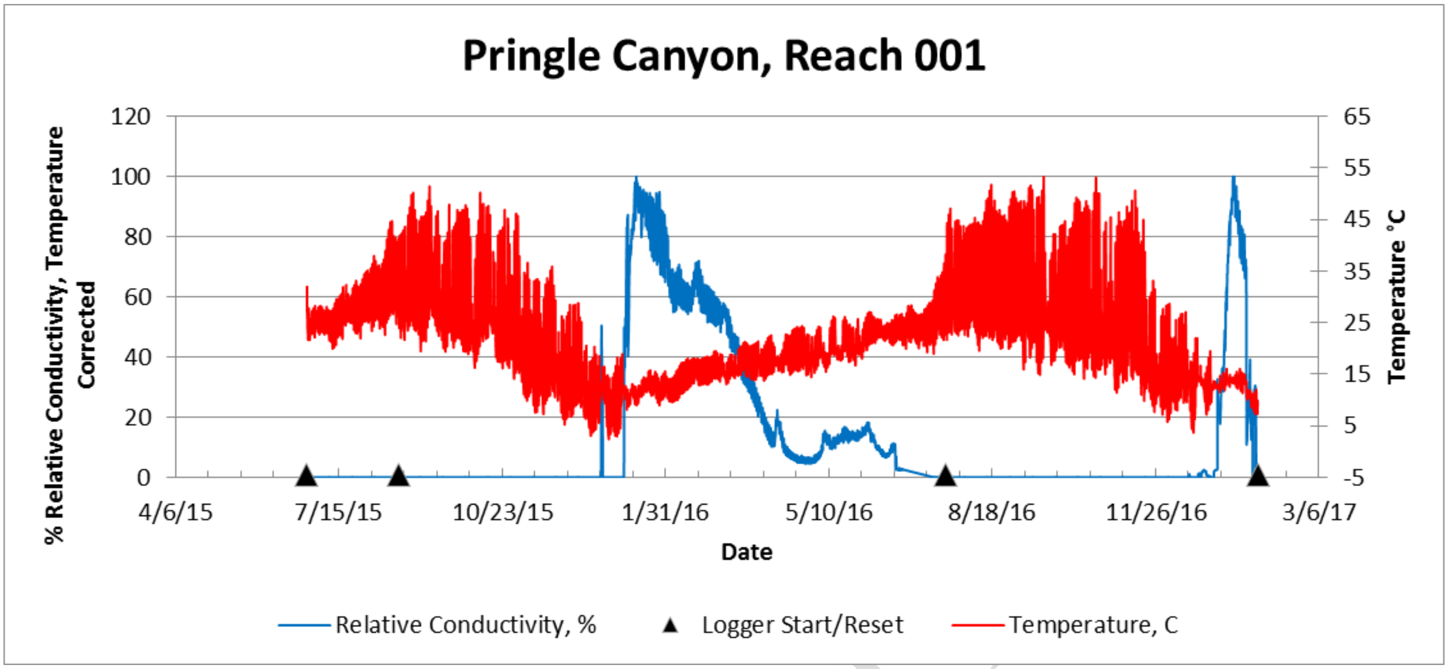

Figure B166. Relative conductivity and temperature graph of Pringle Canyon Reach 001.

Figure B167. Habitat at Pringle Canyon Reach 001 on 25 June 2015 (left) and on 27 January 2017 (right).

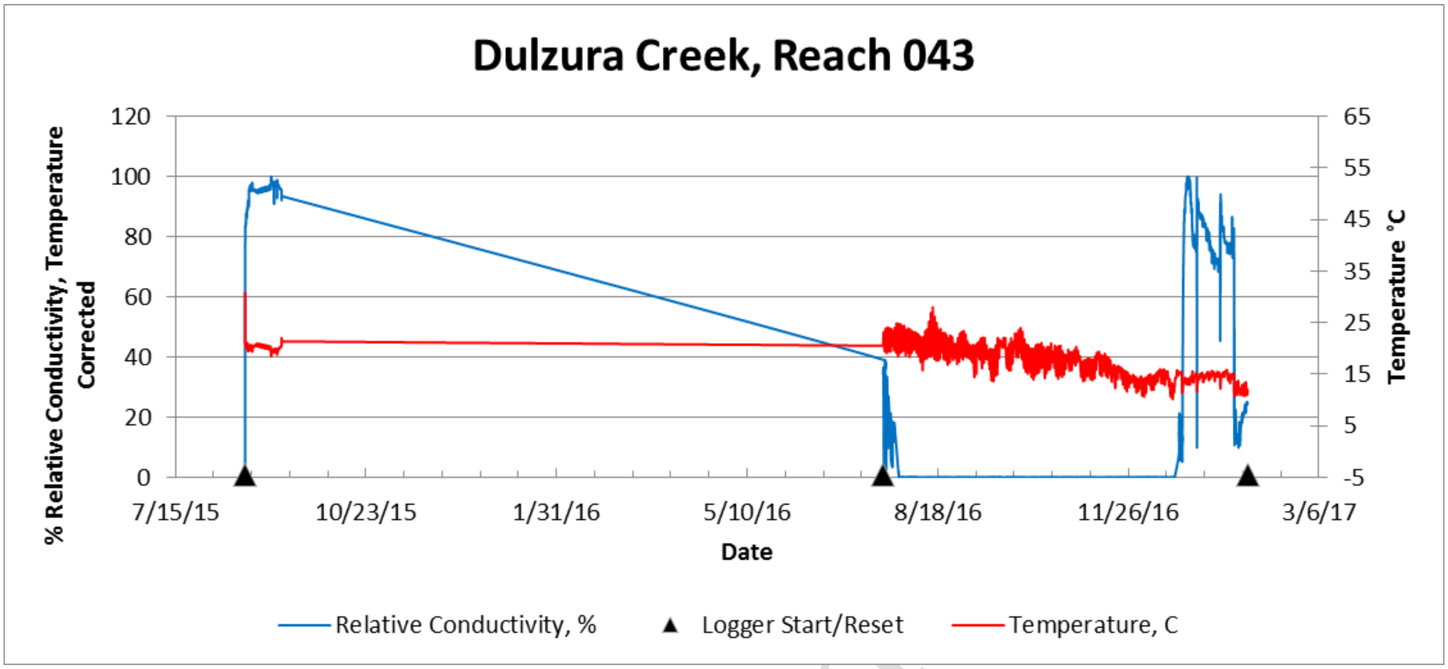

Figure B168. Relative conductivity and temperature graph of Dulzura Creek Reach 043.

Figure B169. Habitat at Dulzura Creek Reach 043 on 20 July 2016 (left) and 2on 7 January 2017 (right).

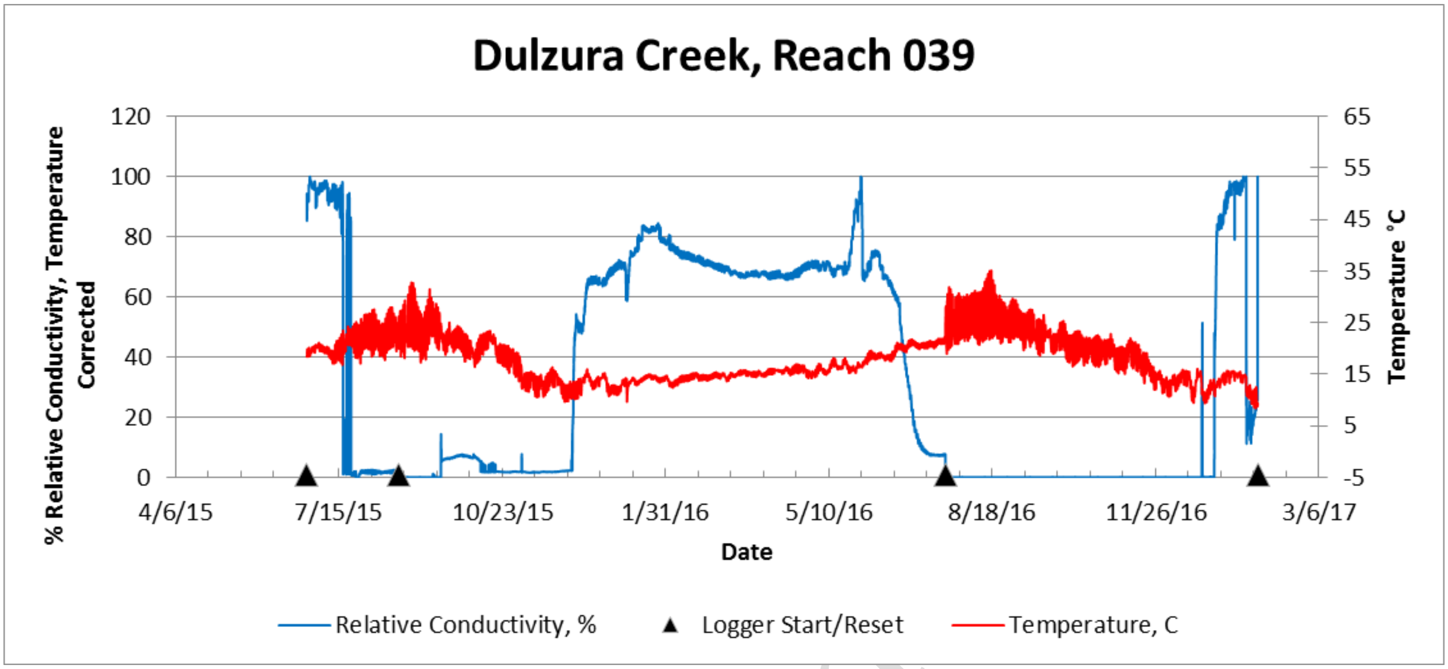

Figure B170. Relative conductivity and temperature graph of Dulzura Creek Reach 039.

Figure B171. Habitat at Dulzura Creek Reach 039 on 20 July 2016 (left) and on 27 January 2017 (right).

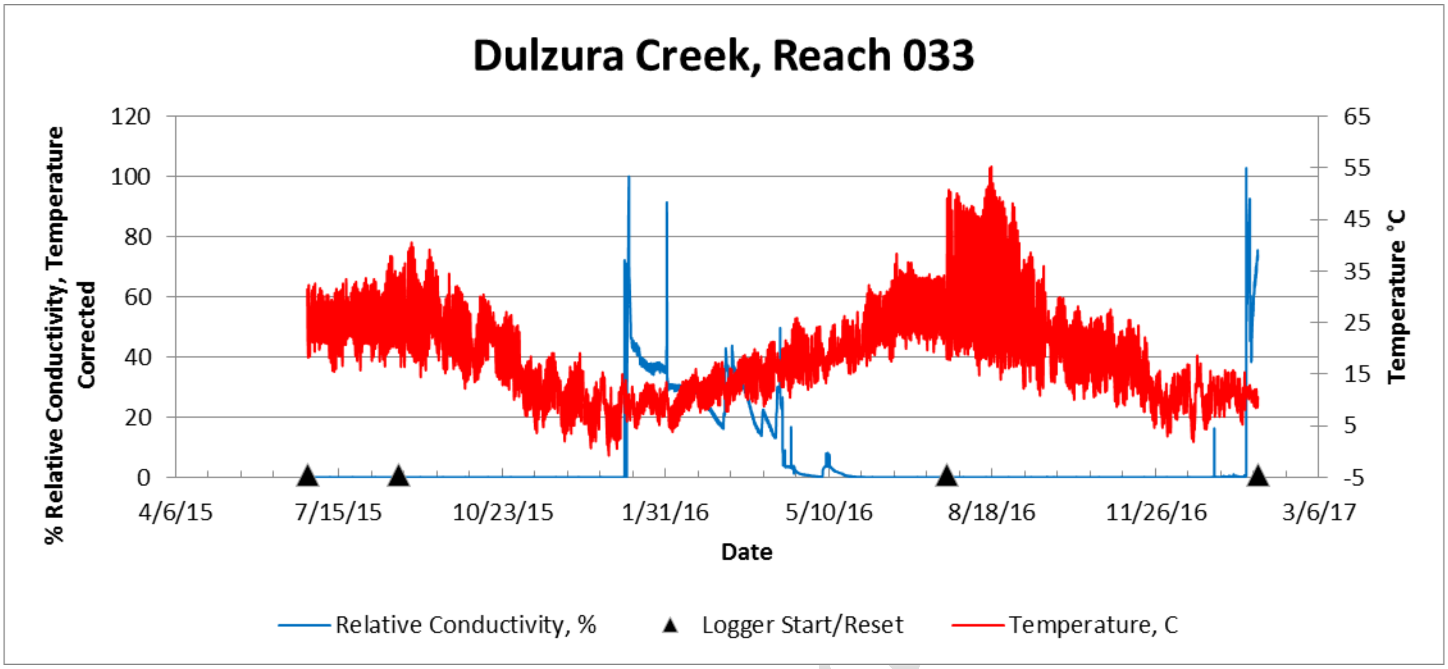

Figure B172. Relative conductivity and temperature graph of Dulzura Creek Reach 033.

Figure B173. Habitat at Dulzura Creek Reach 033 on 25 June 2015 (left) and on 27 January 2017 (right).

Tijuana River Watershed

The Tijuana River watershed is the largest watershed in our study area at 453,248 hectares, over twice the size of the second largest Santa Margarita River watershed. However, nearly 75% of the watershed is in Mexico, leaving 120,998 hectares in San Diego County. There are approximately 71,662 hectares of conserved land within the watershed, managed in large part by USFS, BLM, City of San Diego, County of San Diego, and Back Country Land Trust. Within the watershed, we have two arroyo toad study sites.

Cottonwood Creek

All of Cottonwood Creek below Barrett Reservoir and upstream from Tecate Creek is within USFWS' critical habitat designation for the arroyo toad (USFWS 2011). The lower six kilometers of Cottonwood Creek are within a preserve adjacent to the U.S./Mexico Border owned and managed by City of San Diego. Arroyo toads were known from this site (USFWS 2015), which is recovering from the 2003 and 2007 wildfires.

Pine Valley Creek

Most of Pine Valley Creek upstream from Barrett Reservoir falls within USFWS' critical habitat designation for the arroyo toad (USFWS 2011). Much of the creek is within the Pine Creek Wilderness Area managed by USFS. The most upstream portion of the creek is on USFS property but outside of the wilderness area designation. Arroyo toads are well documented from (USFWS 2015) and currently occupy this site.

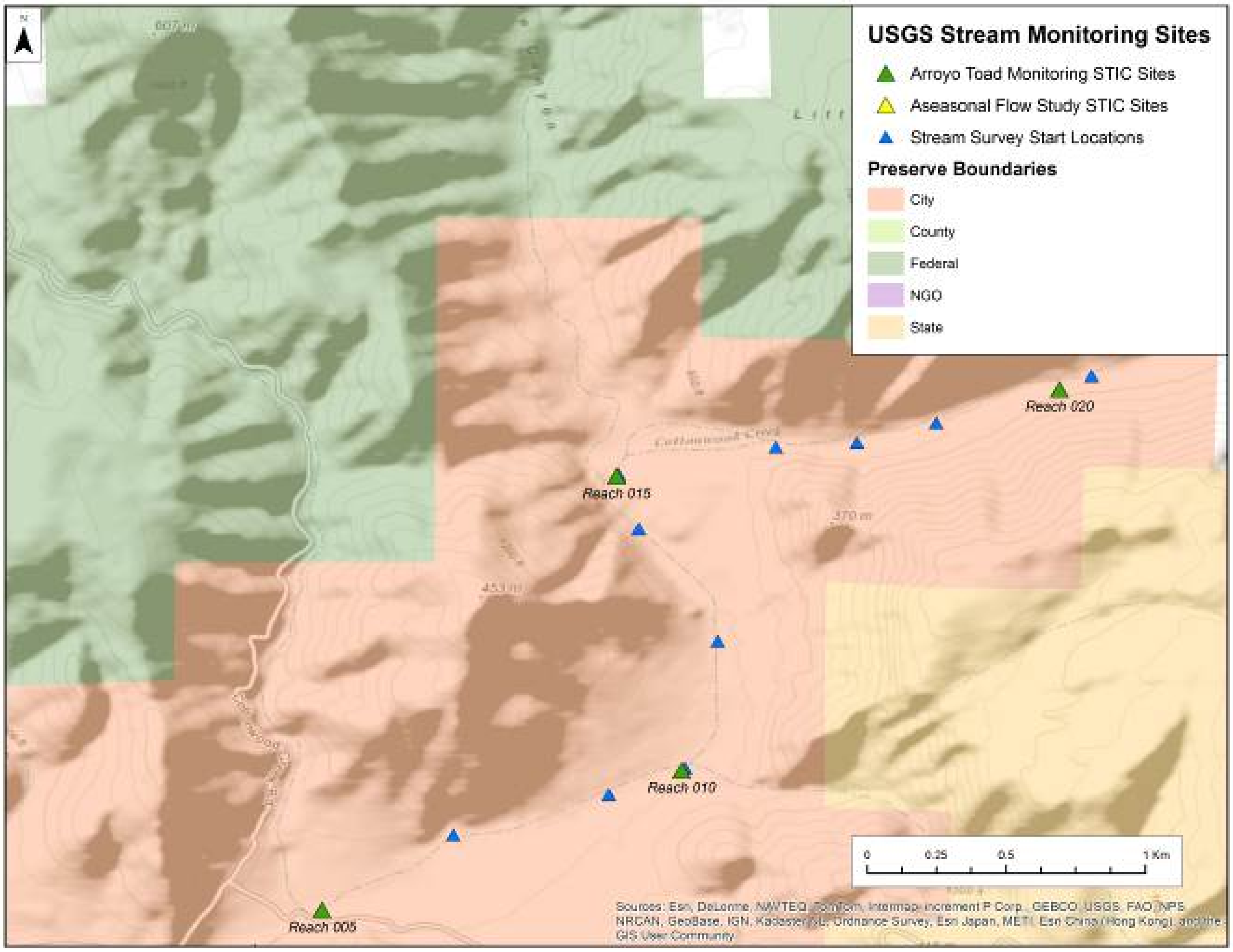

Figure B174. Lower Cottonwood Creek Reaches 5 through 20.

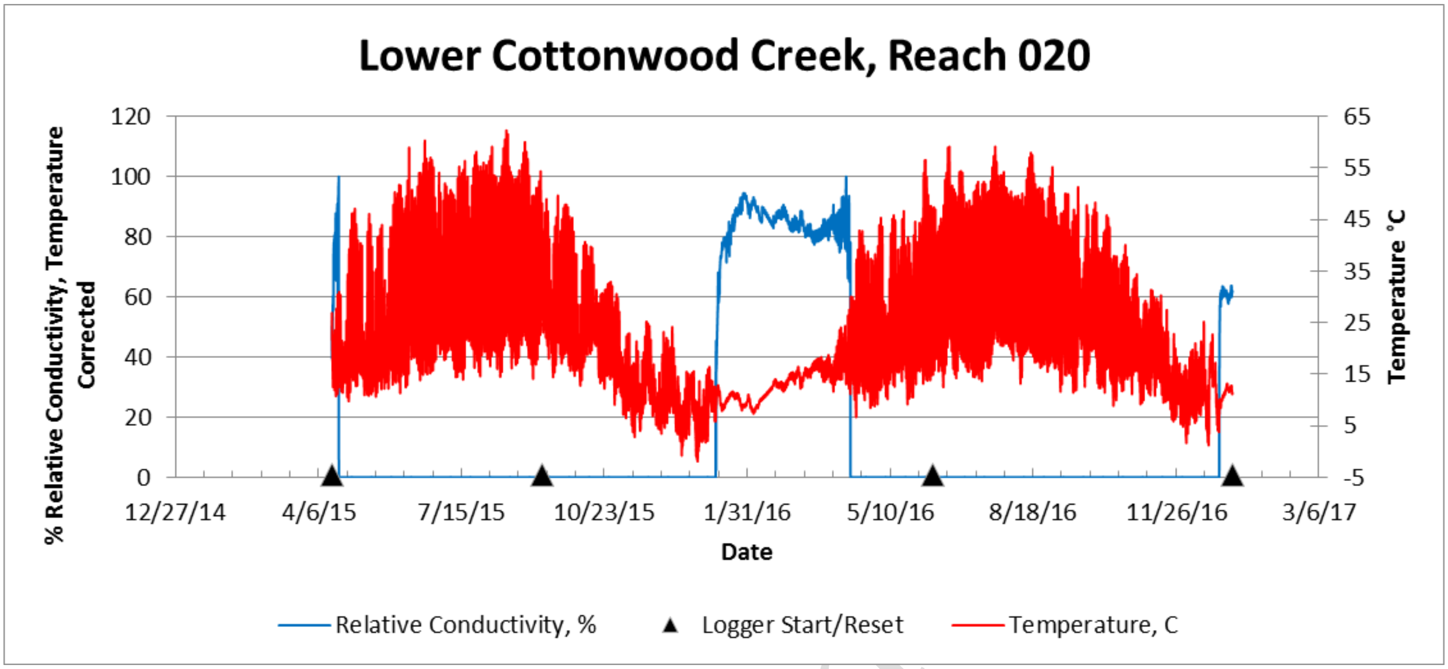

Figure B175. Relative conductivity and temperature graph of Lower Cottonwood Creek Reach 020.

Figure B176. Habitat at Cottonwood Creek Reach 020 on 9 September 2015 (left) and on 04 January 2017 (right).

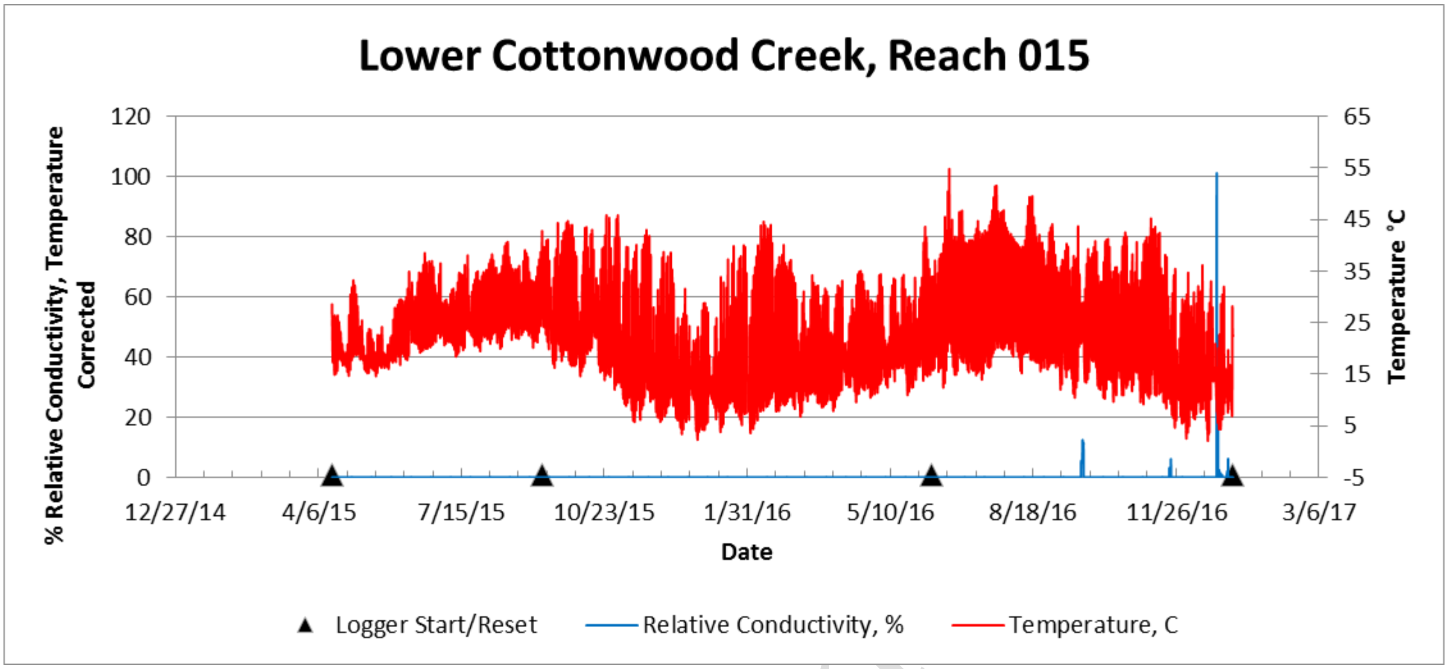

Figure B177. Relative conductivity and temperature graph of Lower Cottonwood Creek Reach 015.

Figure B178. Habitat at Cottonwood Creek Reach 015 on 9 September 2015 (left) and on 04 January 2017 (right).

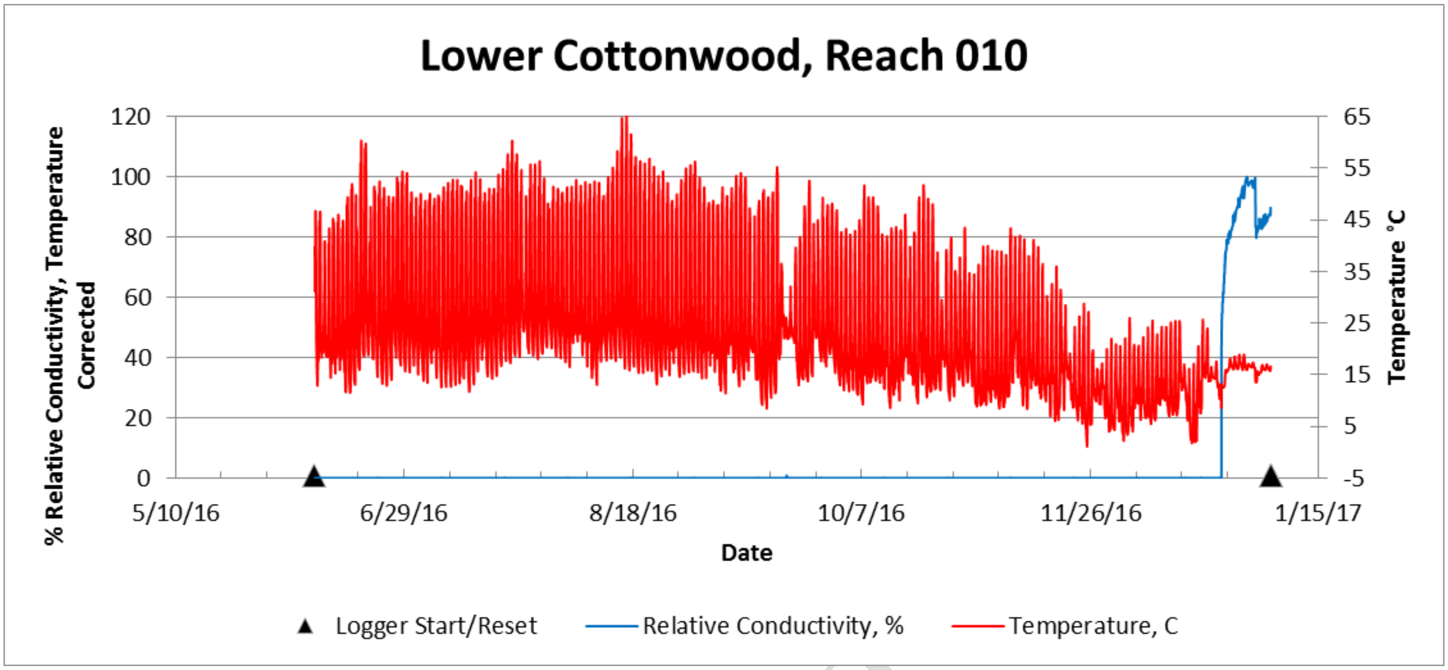

Figure B179. Relative conductivity and temperature graph of Lower Cottonwood Creek Reach 010.

Figure B180. Habitat at Cottonwood Creek Reach 010 on 09 September 2015 (left) and on 04 January 2017 (right).

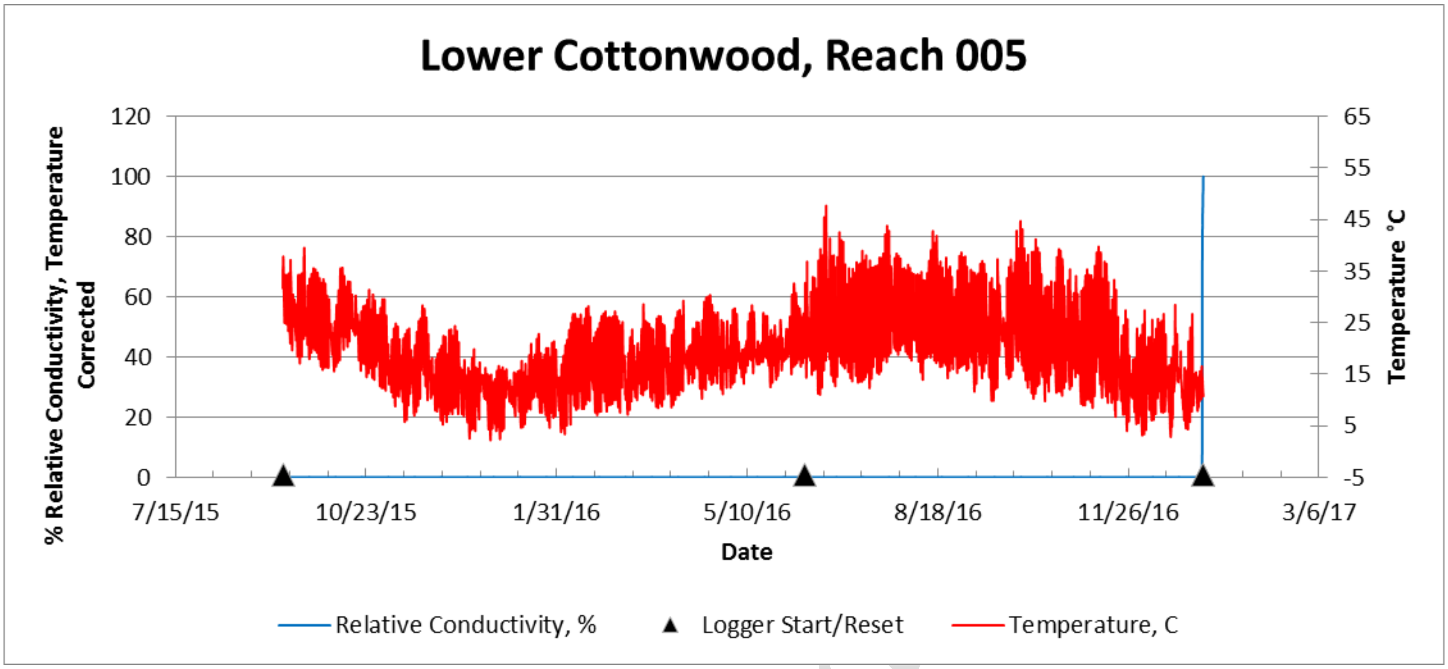

Figure B181. Relative conductivity and temperature graph of Lower Cottonwood Creek Reach 005.

Figure B182. Habitat at Lower Cottonwood Creek Reach 005 on 09 September 2015 (left) and on 04 January 2017 (right).

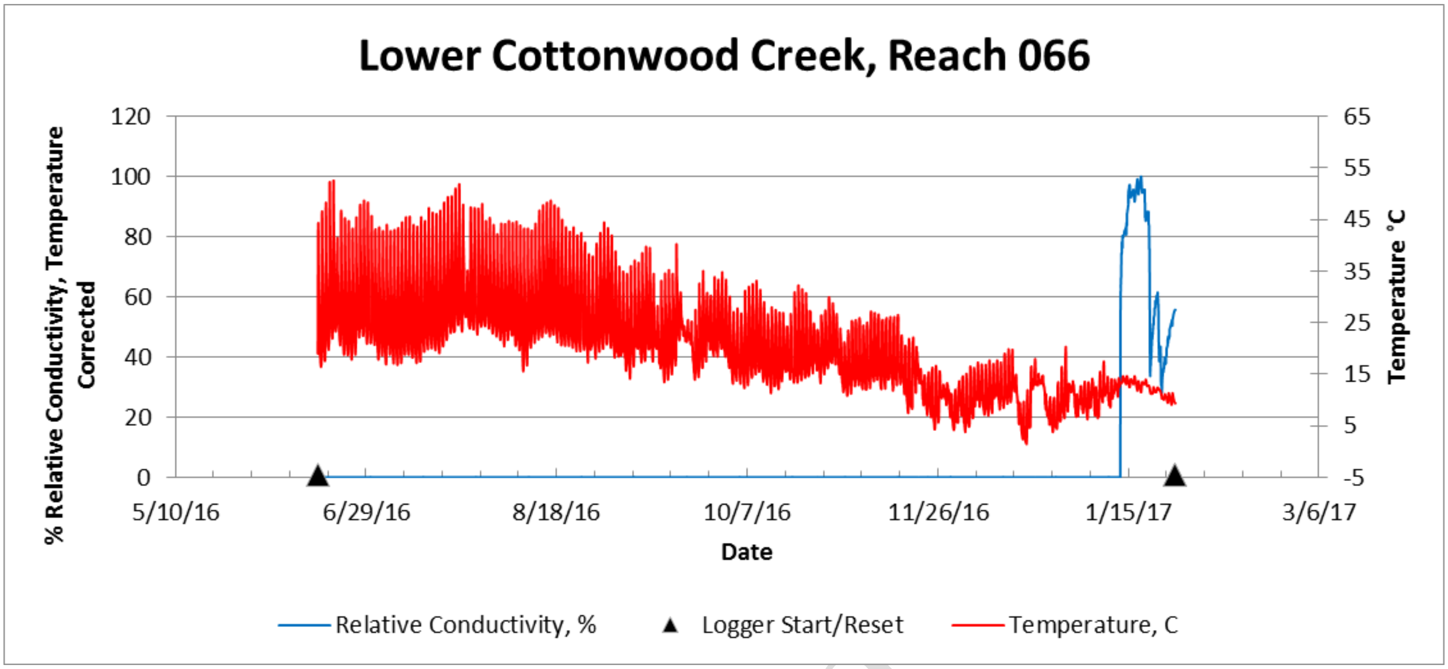

Figure B183. Relative conductivity and temperature graph of Lower Cottonwood Creek Reach 066.

Figure B184. Habitat at Cottonwood Creek Reach 066 on 16 June 2016 (left) and on 27 January 2017 (right).

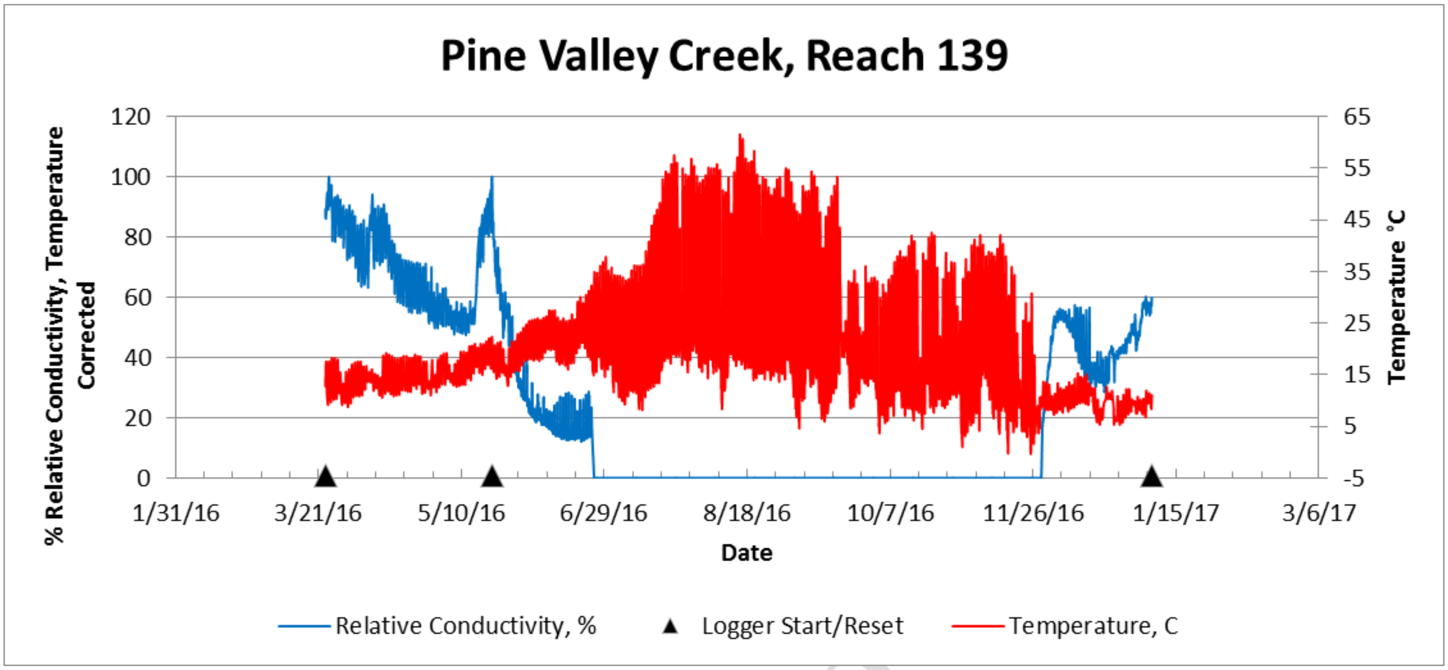

Figure B185. Relative conductivity and temperature graph of Pine Valley Creek Reach 139.

Figure B186. Habitat at Pine Valley Creek Reach 139 on 23 March 2016 (left) and on 06 January 2017 (right).

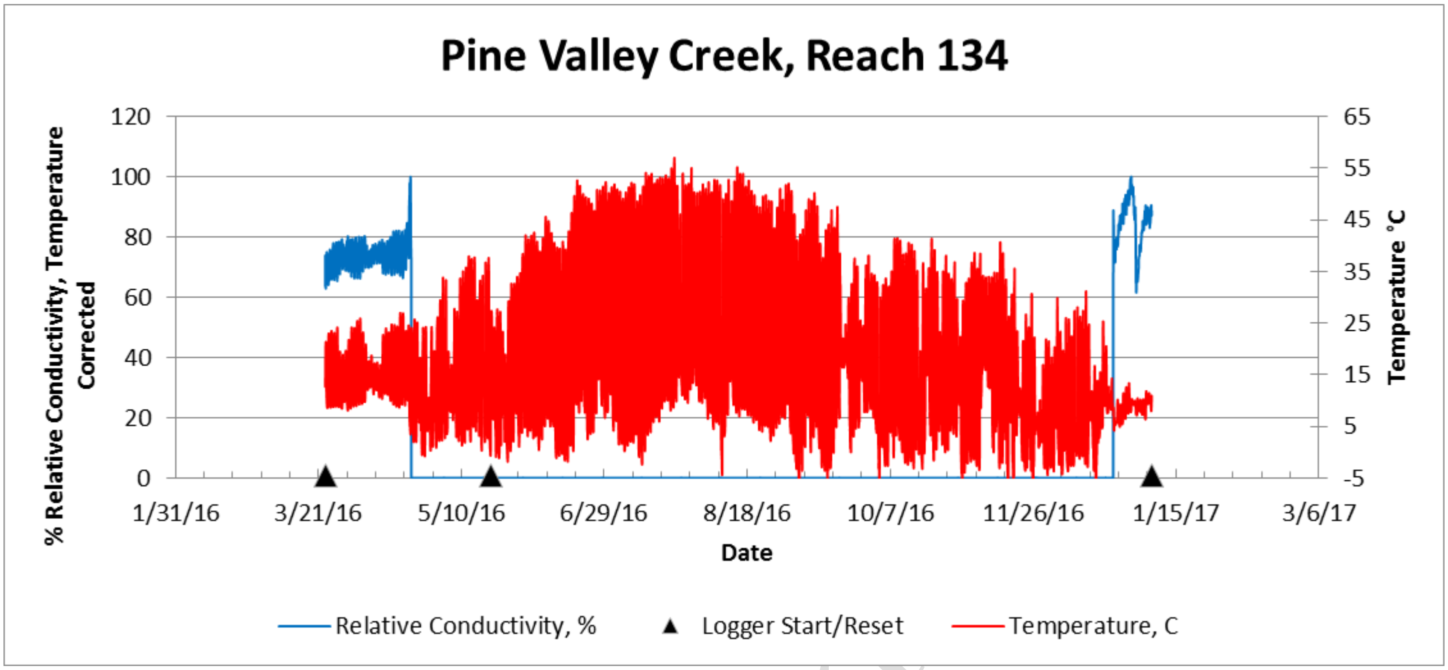

Figure B187. Relative conductivity and temperature graph of Pine Valley Creek Reach 134.

Figure B188. Habitat at Pine Valley Creek Reach 134 on 20 May 2016 (left) and on 06 January 2017 (right).

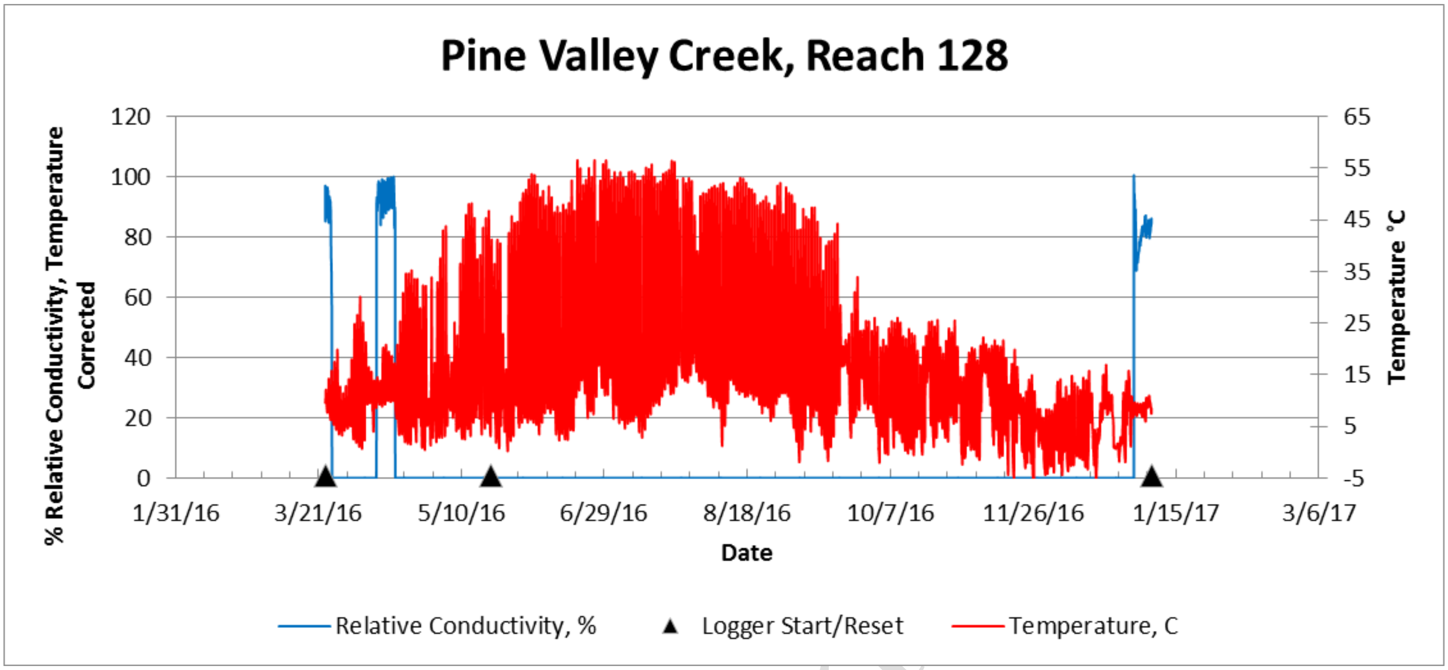

Figure B189. Relative conductivity and temperature graph of Pine Valley Creek Reach 128.

Figure B190. Habitat at Pine Valley Creek Reach 128 on 23 March 2016 (left) and on 20 May 2016 (right).

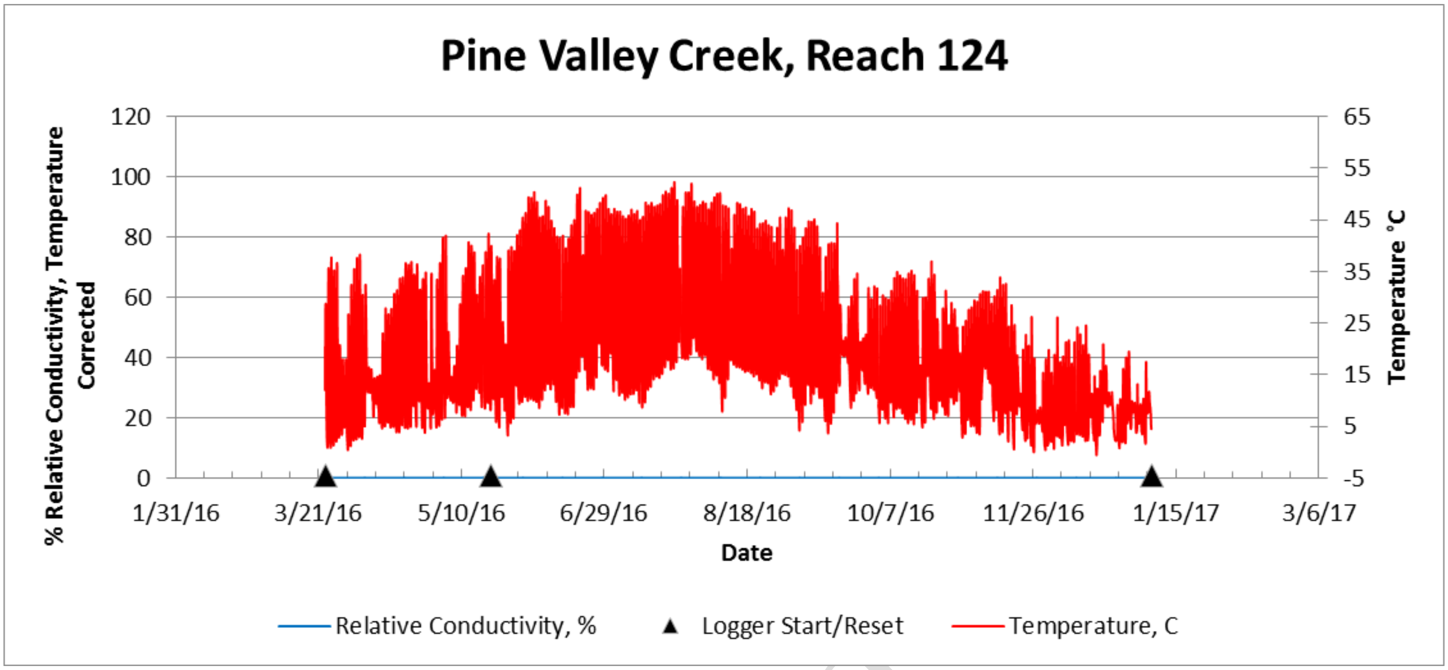

Figure B191. Relative conductivity and temperature graph of Pine Valley Creek Reach 124.

Figure B192. Habitat at Pine Valley Creek Reach 124 on 23 March 2016 (left) and on 06 January 2017 (right).

Literature Cited for Appendix B

U.S. Fish and Wildlife Service (USFWS). 2011. Endangered and threatened wildlife and plants; revised critical habitat for the arroyo toad. Federal Register 76: 7246–7467.

U.S. Fish and Wildlife Service (USFWS). 2015. Occurrence Information for Multiple Species within Jurisdiction of the Carlsbad Fish and Wildlife Office (CFWO). Version 10/21/2015 (https://www.fws.gov/carlsbad/GIS/CFWOGIS.html), accessed April 2016.

APPENDIX C

STIC (Stream Temperature, Intermittency, and Conductivity data logger) Protocol.
By
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STIC (Stream Temperature, Intermittency, and Conductivity logger) Construction:

Stream Temperature, Intermittency, and Conductivity loggers (STICs) are Onset Hobo Pendant temperature and light data loggers (Model UA-002-64) that have been modified to collect relative conductivity when submerged (Chapin et al. 2014). The modification, launch, construction of deployment hardware, and data upload are described here.

Data Logger Modification:

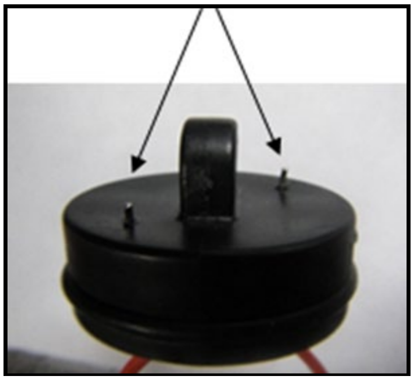
Equipment:

1. Onset Hobo Pendant waterproof temperature and light data logger (Model UA-002-64)
2. 100mm 24 gauge male-male jumper wires with chrome plated brass machine pin heads (Digikey #438-1074-ND)
3. Marine epoxy (slow set)
4. Silicon grease
5. Electrical tape
6. Piece of rubber (ex. cut piece of bicycle inter tube)
7. Solder
8. Jeweler's Philips screwdriver
9. Jeweler's flat tip screwdriver
10. Drill
11. 0.65mm drill bit
12. Soldering iron with small tip
13. Alligator clip
14. Small pliers
15. Vise

Modification Procedures:

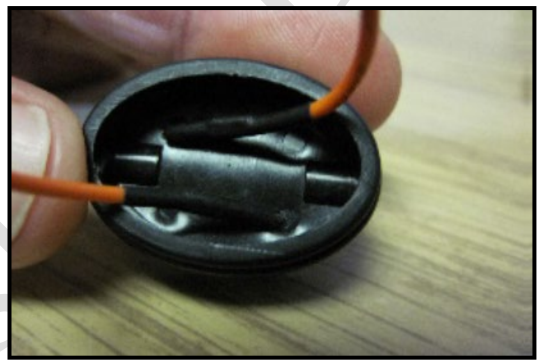
1. Remove cap from data logger by removing the two screws (save for reassembly).

2. Drill two 0.65 mm holes through cap. Place the holes on opposite sides and as far apart as possible. (Note hole location)

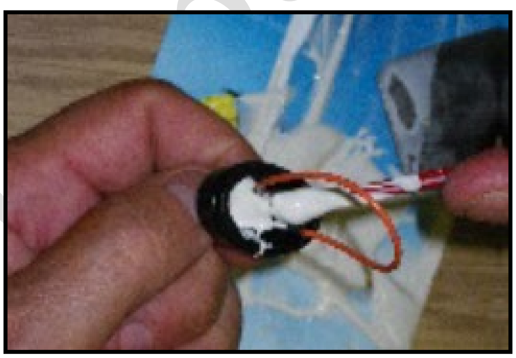
3. Insert the 24 gauge male-male jumper wires into the holes so that the tips are completely inserted and protruding on the outside of the cap. Pliers may be needed.

4. Carefully bend the wires (bending them too quickly can break them off).

5. Move the wires to one side of the cap.

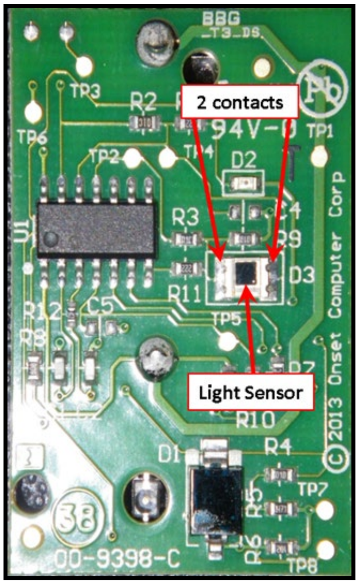
6. Apply marine epoxy inside the cap, just enough to seal the holes and create a water tight fit. Do not fill epoxy to top of cap. (Note how the wires have been moved to the top half of the cap). Allow to dry overnight.

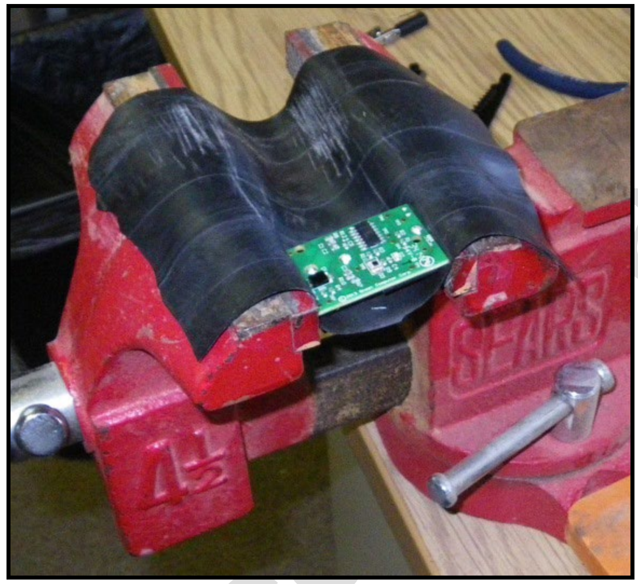
 

7. Remove the circuit board from the plastic housing. Remove the desiccant bags and save for reassembly.

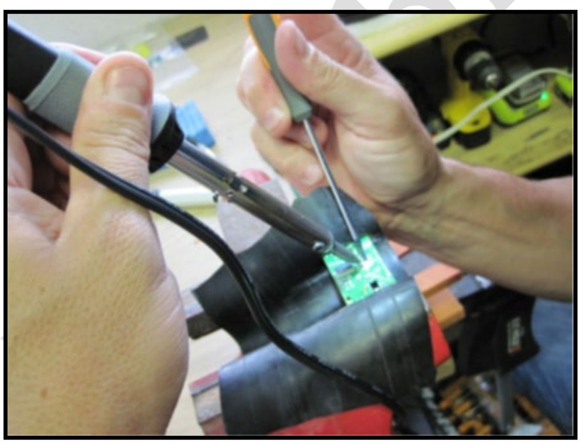
8. Using a popsicle stick, or other nonconductive stick, remove the battery from the circuit board. (Use caution not to touch the top of the battery)

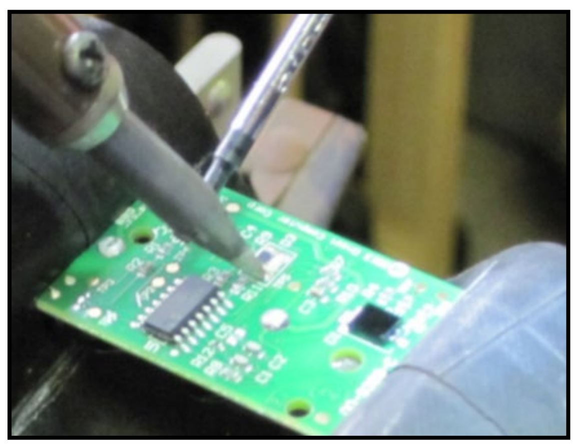
9. Plug in soldering iron. Place the circuit board gently in the vise with the light sensor facing up, using the rubber strip as padding.





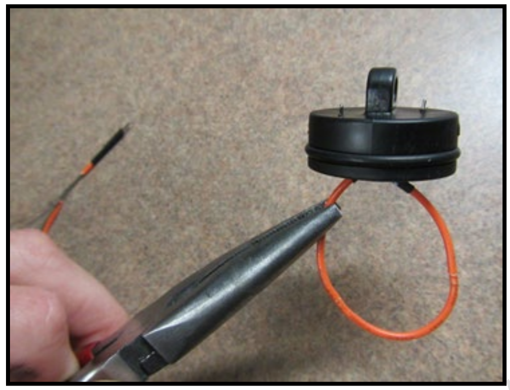
10. Once the soldering iron is hot, place the iron in one hand and the jeweler's flat tip screw driver in the other. Place the tip of the iron on one side of the light sensor for about 2-4 seconds. Then use the screw driver to pry up the sensor once the solder begins to melt. This will take some practice. Don't let the iron burn the board by leaving it in contact for more than 20-30 seconds. Make sure that the entire sensor is removed not just the top layer peeled off. Once the sensor is properly removed, you should see two metal contacts that were connecting the light sensor to the board.



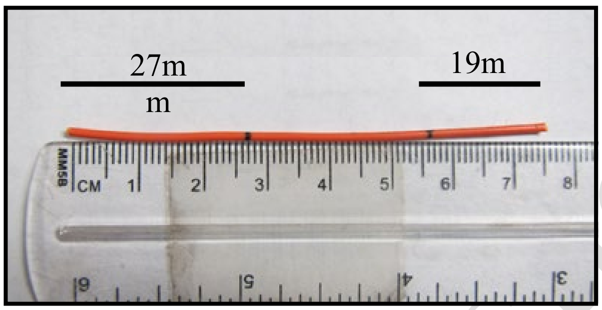


11. With the marine epoxy dry, cut the wire loop into two separate wires. Then you will need to cut each wire to the appropriate length so that, when the logger is put together, the wires are long enough to reach over the board but not so long that they impede the cap from sealing properly.

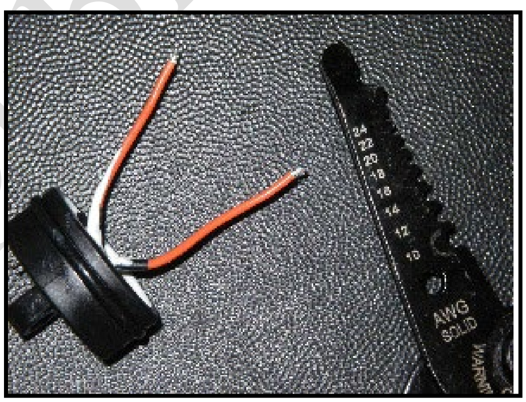
a) Orient the cap so that the side closest to the wires is facing towards you.



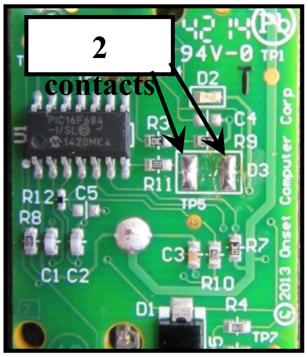
b) Measuring from the end of the black tape on the wire, cut the left wire to 27 mm long. Cut the right wire to 19 mm long. It may be easier to make a template with these lengths first and then use the template to measure out where you need to cut the wires.

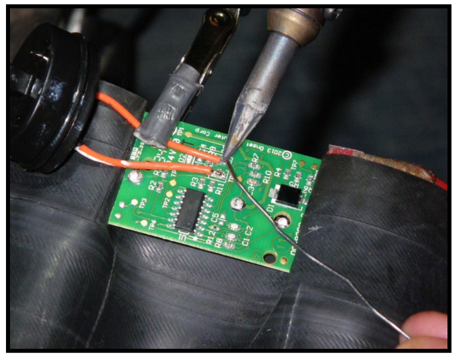


12. Once the wires are cut to the correct length, splice approximately 2 mm of the insulation off. A 24 gauge wire splicer works well.



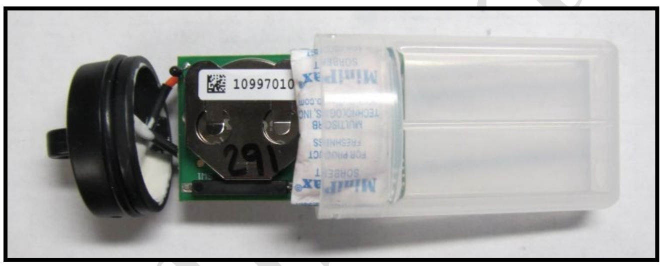
13. Using an alligator clip that has been insulated with electrical tape, hold one of the wires in place on one of the contacts. Place the alligator clip as far away from the contact as possible. If the clip is close, the heat from the soldering iron will melt the wire insulation. Place the hot soldering iron so that it is in contact with both the wire and the contact. It will take a few seconds to heat to the correct temperature that will allow the solder to be melted onto the connection. You should only use about a 3 mm of solder for each connection. Solder both wires to the separate contacts.



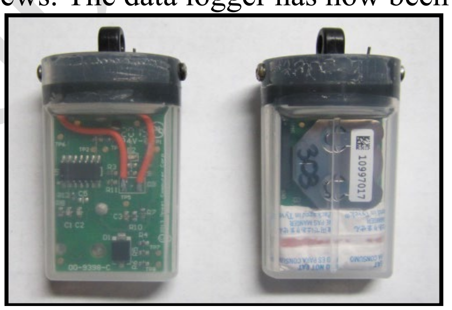


14. On the housing for the battery, with a Sharpie ®, label the STIC with a unique ID number. (Contact your project lead before assigning a number to the STIC to make sure there are no two STICs with the same ID number.)

15. The data logger is now ready to be reassembled. Replace the battery. Flatten out the desiccant bag and place onto the circuit board just below the battery slot. Slide the circuit board into the plastic housing. Notice, the circuit board only fits in one way. It will be a snug fit, but you will not have to force it into the casing.



16. Apply a thin layer of silicon grease to the rubber O-ring on the cap. Firmly press the cap into the plastic housing and replace the two set screws. The data logger has now been transformed into a STIC.



Deployment Hardware Construction:

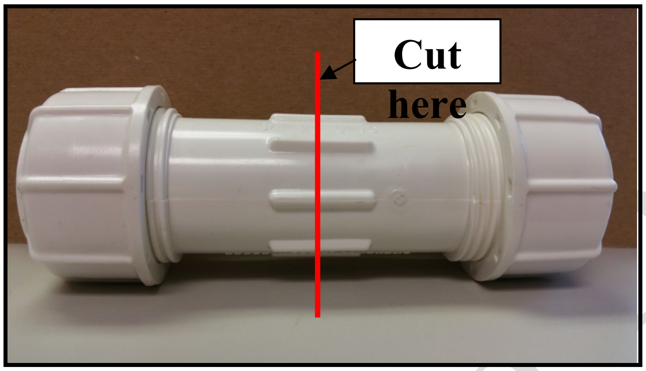
Equipment:

1. 3/4" PVC pipe coupler
2. Copper cable (green coat vinyl 1/16")
3. Crimper tool and crimps (ferrule 3/32")
4. Metal stakes with holes (length and type is habitat specific)
5. Fiberglass window screen (cut into 3" x 3" squares)
6. Cable cutters
7. Saw (band saw works well)

8. Drill
9. Drill bit

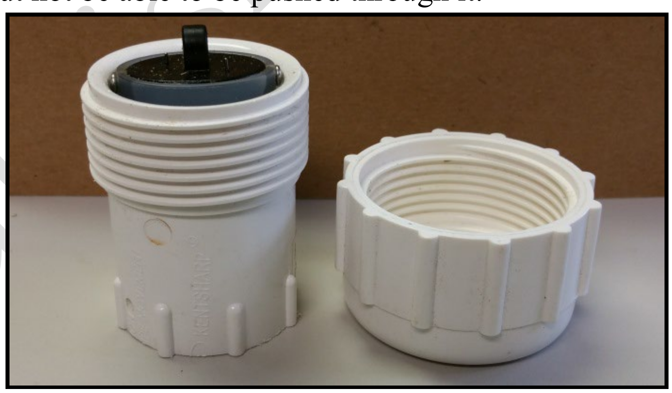
Construction and Assembly Procedures:

1. Take the PVC pipe coupler and remove the rubber gaskets under each threaded cap.
2. Cross cut the PVC union in half.



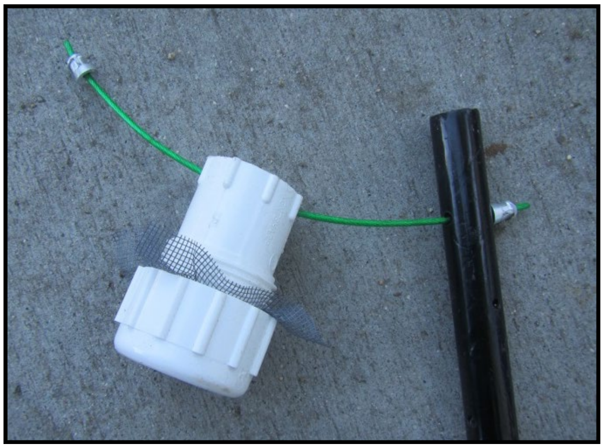
3. Drill a hole slightly larger than the cable that will be used to mount the STIC, through both sides of the PVC. The hole should be drilled on the opposite side of the threaded cap approximately ¼" from the end. A drill press works great for this.

4. The STIC should fit inside the PVC but not be able to be pushed through it.



5. Cut the green cable to the desired length, thread it through the holes drilled in the PVC pipe and crimp it to the metal stake. (Note: There are several ways to attach the PVC casing to stake.)

6. Screw on the PVC threaded cap over the screen. (This will keep the cap on during transport to the site.)



Launching a STIC (at the office)

1. Open HOBOware Pro software.
2. Connect the shuttle to the host computer.
3. Insert the STIC into the coupler attached to the shuttle.
4. Momentarily push down the coupler lever and release. The yellow light will blink momentarily, then the green light should illuminate, indicating that the logger is ready to communicate with HOBOware. (If the red light blinks, then the logger was not found. Make sure the logger is clean and that the logger and coupler are properly aligned.)

5. Click Device > Status.

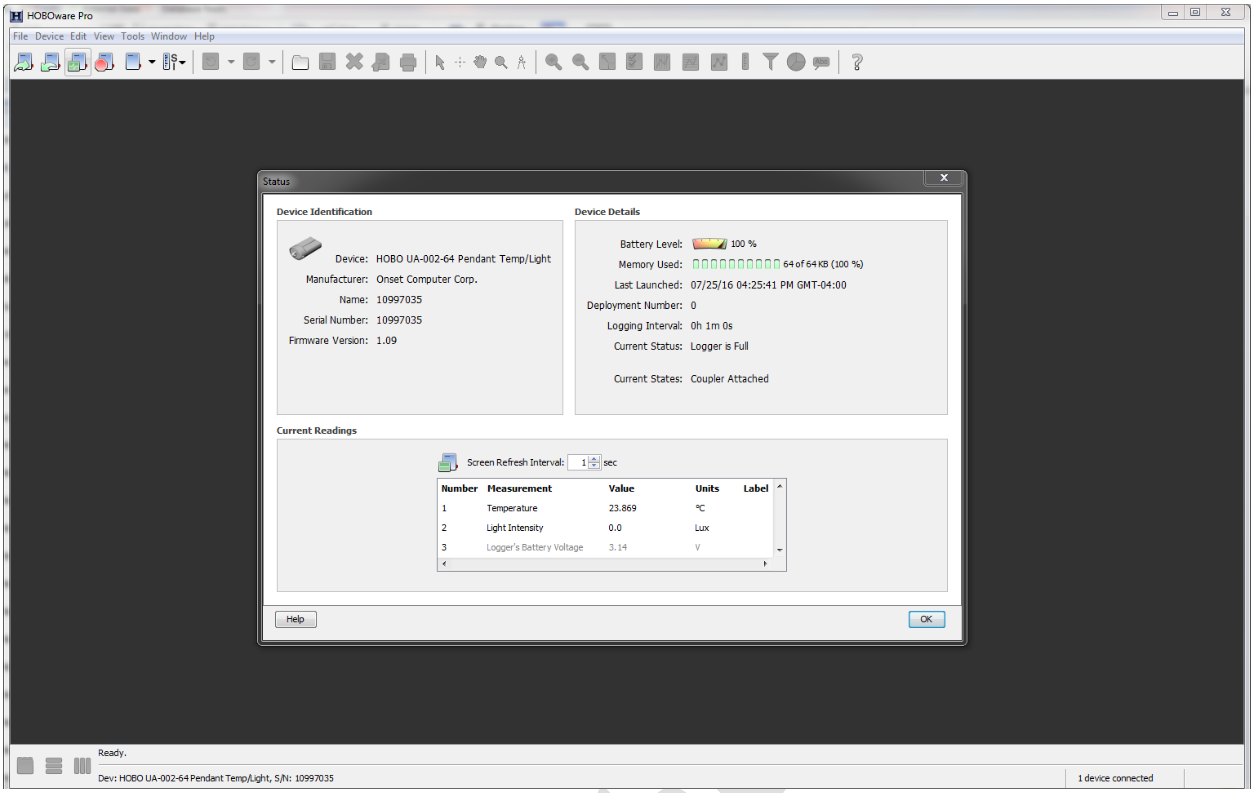


Figure #. HOBOware Pro when a new STIC is first connected to the computer. Note the battery level, Memory Used, and Deployment Number.

6. Check to see if the STIC is running properly.
   a) The Battery Level should be at 100%.
   b) The Memory Used should be at 100%.
   c) The Deployment Number should be 0.
   d) Look at the Current Readings section at the bottom. Make sure the temperature is showing a reasonable reading and that the Light Intensity value is relatively stable. (If not, there could be something wrong with the STIC.)
7. If everything is working correctly, select Device > Launch.
   At this point, you may get a warning message saying that the logger's power has been reset. This is normal if the battery was just replaced. Press "OK".

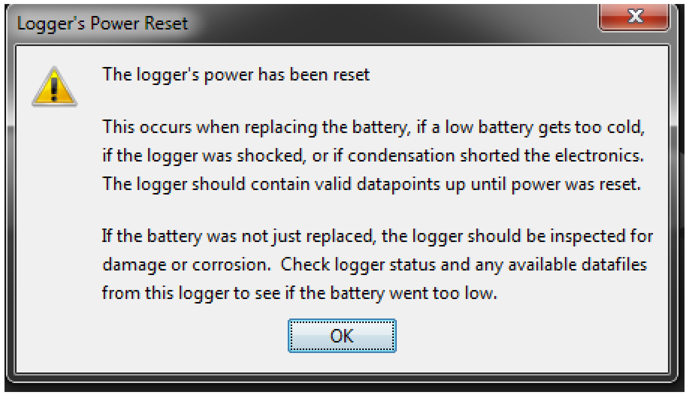


Figure #. "Logger Power Reset" warning.

This will open up the "Logger Launch" window.

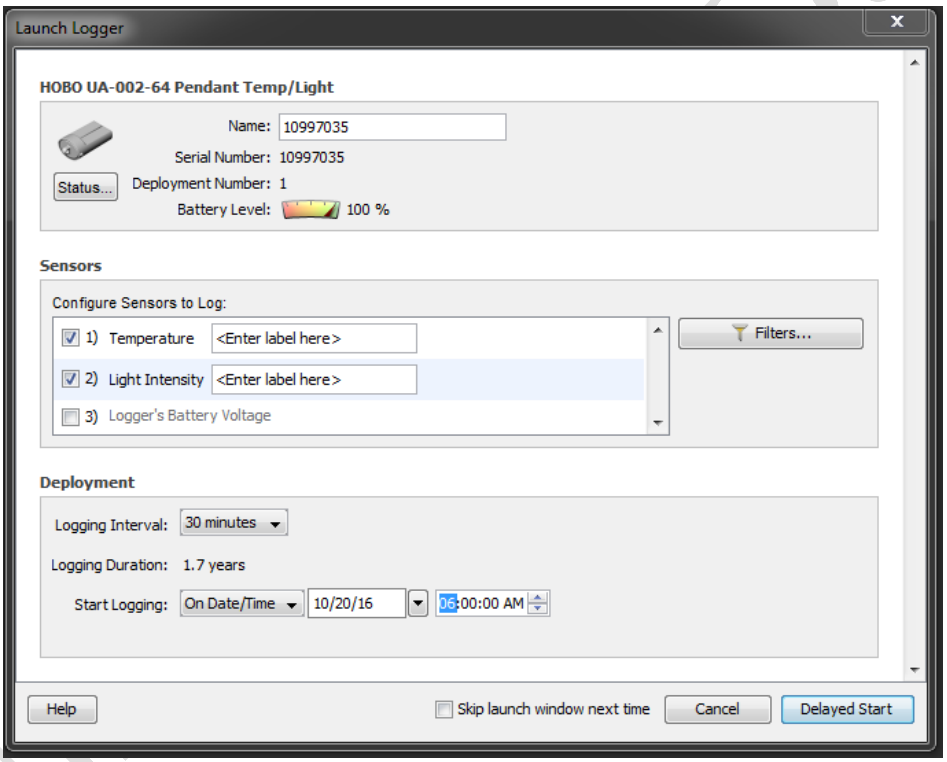


Figure #. "Logger Launch" window.

8. Make sure the logger name is the same as the serial number (found immediately below the name field).
9. Set the "Logging Interval" to 30 minutes.
10. Select "Start Logging (a) Now or (b) on Date/Time" and select date and time. If you selected "Start Logging on Date/Time", make sure that it is set to start logging before the STIC is deployed.
11. Press "Start/Delayed Start". The STIC has now been launched or set to launch.
12. Remove the STIC from the coupler.

Installing the STIC

Equipment:

STIC's - Hobo Pendant Temp/Light, 64K – retrofitted and launched
HOBO waterproof shuttle with COUPLER2-A
STIC anchors (preassembled)
extra fiberglass window screen (precut into squares)
extra copper cable (green coat vinyl 1/16")
extra crimps (ferrule 3/32")

Tools:

crimper tool
wire cutters
mallet / sledge hammer
shovel
metal detector
gloves

Determining Specific STIC Location Placement in Field

Navigate to the predefined STIC location. Since the predefined coordinates are typically figured using a topographical mapping program (TOPO!®), you can expect there to be some positioning error and you may need to adjust your position accordingly. If the selected coordinate is off channel, move to the channel or water body.

When determining the specific location in which to place the STIC, find the deepest part of the stream channel or pond that is closest to the predefined STIC location. Do not choose a shallower location simply for the ease of setting the STIC and retrieving the data. If the STIC is not in the deepest part of the channel, the data will not accurately represent the hydroperiod of the stream. Placing the STIC at the deepest spot will allow for the collection of surface water data characteristics of the water body and also test for the presence of permanent pooling water. Permanent water could facilitate persistence of non-native aquatic species within the system.

If this protocol is being used in conjunction with other survey protocols and the surveyors are walking the full reach of the stream, multiple STICs may be deployed when uncharacteristic stream features are present, such as large bedrock pools within a typically sandy wash or pools holding water within a dry stream system.

STIC Profile Picture

Take a GPS point of the actual STIC location. Before closing out of the waypoint form, name the waypoint as the site name (usually stream name and reach number) and enter in the date in the notes section. On the threaded cap of the modified PVC pipe coupler use a Sharpie® to write the site name.

Take a profile picture of the STIC. This picture and specific format will be important later to double check your data in the analysis process. The profile picture includes the GPS waypoint screen, STIC, and PVC cap showing the name of the site, the date, STIC ID number, and STIC serial number. Set up the picture in the following way:

Figure 1. STIC profile picture set-up.

Installing the STIC

After you take the profile picture, you can install the STIC.

1. Place in thalweg – below larger boulder if one is present.

2. Hammer in stake until only the top hole is left out of ground. Try to keep the hole pointing upstream.
   a) If stream bed is sandy use 3 foot rectangular stake.
   b) If stream bed is rocky try the 2 foot rectangular stake.
   c) If stream bed is really rocky use round 2 foot stake.
   d) If stream bed is not stable, wrap cable around a tree or other solid object. Make cable long enough to place STIC in thalweg.
   e) If no trees are present, place stake on bank and thread in cable long enough to reach thalweg.

3. Put the cable through the holes in the PVC.

4. Insert the STIC into the PVC with the screen on the top.

5. Screw on the PVC cap with screen over the top of the STIC.

6. Run cable through the hole in stake.

7. Use crimp to attach both sides of cable fairly tightly to stake. Make sure that the STIC is on the downstream side of the stake.

8. Secure crimp with crimper tool.

9. Flag/mark the location: Depending on the location of the STIC, you may want to place flagging in conspicuous areas and/or spray paint the stake so you can find the STIC later to retrieve data. If the STIC is in an area of high foot traffic and accessible to the public, you may want to hide the STIC by covering it with a few rocks. This will not affect the data and will hide it from anyone who may want to tamper with the setup.

10. Take photos of the STIC location: Once the flagging has been put up or the STIC has been hidden, take photos of the habitat and STIC location. Take habitat photos looking upstream and downstream and to the left and right of the STIC. Also take several photos that you can use later for locating the STIC. If you hid the STIC, take a few pictures with something pointing to the hidden STIC.



Figure 3. Showing various STIC locations, anchoring techniques, and visibility. (From top to bottom, left to right) 1. Anchored with spray-painted rectangular stake, 2. Visible in sandy stream channel, flagged, 3. and 4. Hidden under large rock, 5. Underwater, and 6. Anchored to tree with a cable.

STIC Field Data Download

If a STIC has already been placed at a site, you just need to retrieve data from the STIC. To download the data in the field, follow these steps.

1. Clean off the STIC casing.

2. Insert the STIC into the coupler attached to the HOBO waterproof shuttle.

3. Momentarily push down the coupler lever and release. The yellow "Transfer" light should begin to flash. The shuttle will begin reading the data from the STIC immediately. A blinking yellow light indicates that the readout and relaunch are in progress. Do not remove the STIC while the yellow light is blinking. Once the data transfer is complete the green "OK" light will illuminate. You can now remove the STIC from the coupler.

   If there was a problem with the STIC or the data transfer, the red light will come on. If this happens, you will need to place a new STIC in the field and bring the old one back to the office.

4. Take a STIC profile picture following the steps outlined above.

5. Record the location and STIC number as well as any notes. In the comments section, make sure to write down any relevant information about placement. Indicate if the STIC was replaced and record the STIC number of the old STIC.

Record the STIC location and STIC number.

Record the STIC location and STIC number each time you install, check, or replace a STIC. Data fields are presented in the digital PDA forms format under "Loggers". If using paper data forms, you will be manually recording these data fields.

1. Record the Logger Type as STIC.

2. Record the logger number (this is the number written in Sharpie® on the STIC).

3. Lat / Long: Perform a GPS grab at the STIC location (if using a PDA and have a GPS attached), or write in the GPS location including elevation, EPE, and datum in the PDA fields provided or on your paper data sheet.

4. Enter date and time you installed the STIC (if using a PDA, this will be automatically filled in for you).

5. Comments: Write down any relevant information about placement to make it easier to find (e.g., which side of the stream the STIC was placed, a major landmark, etc.). Also write down if the STIC was replaced and the STIC number of the old STIC.

Retrieving the Data off of a STIC in the Office

If you brought the loggers back from the field instead of using the shuttle to collect the data, you can offload the data directly off of the STIC.

1. Open HOBOware.

2. Connect the shuttle to the computer.

3. Insert the STIC.

4. Momentarily push down the coupler lever and release. The yellow light will blink momentarily, then the green light should illuminate, indicating that the logger is ready to communicate with HOBOware. (If the red light blinks, then the logger was not found. Make sure the logger is clean and that the logger and coupler are properly aligned.)

5. Click "Readout Device" and then "Ok". A Stop Logger? window will appear. Click "Stop".

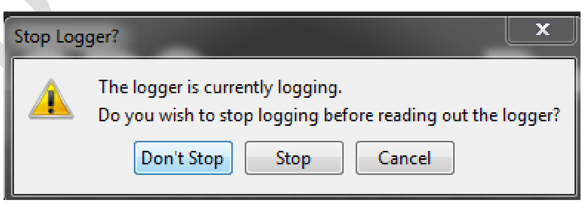


Figure 4. "Stop Logger?" popup window. Note: If "Don't Stop" is selected the data will still be downloaded, but the STIC will continue to record data.

6. A "Save As" window will appear. Save the file to the appropriate folder. Once saved, the Plot Setup window will appear. Press "Plot".

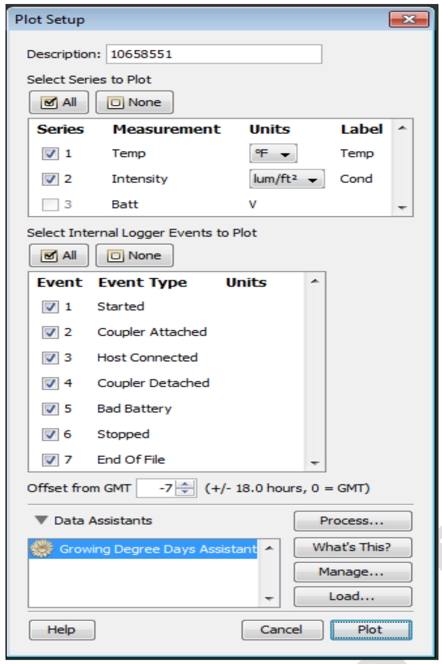


Figure 5. Plot Setup window. Make sure the appropriate boxes are checked and press "Plot".

7. Look at the graph and make note of any potential problems.

8. Save an Excel file of the data. Click "Export Table Data…"

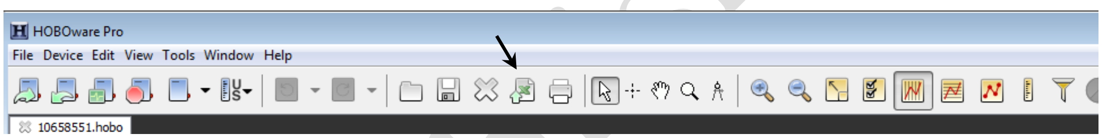


Figure 6. Showing which button to push to save an Excel file of the data.

9. The Export window will appear. Press "Export…"

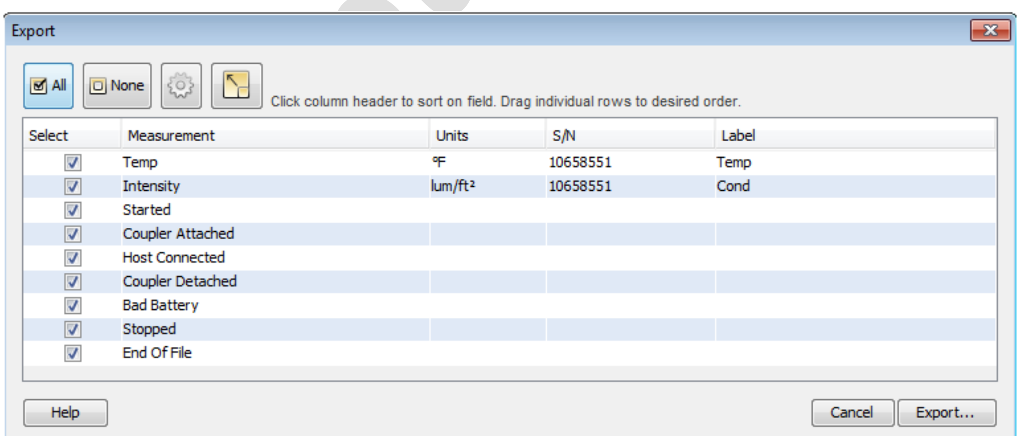


Figure 7. Export window.

10. Save the data file in the appropriate file location.

References Cited:

Chapin, T.P., A.S. Todd, and M.P. Zeigler (2014), Robust, low-cost data loggers for stream temperature, flow intermittency, and relative conductivity monitoring, Water Resour. Res., 50, 6542–6548, doi:10.1002/2013WR015158.