United States Department of the Interior
U.S. GEOLOGICAL SURVEY
Western Ecological Research Center
San Diego Field Station
4165 Spruance Road, Suite 200
San Diego, California 92101

4/23/2020

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San Diego, CA 92101

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San Diego Management and Monitoring Program
4165 Spruance Road, Suite 200
San Diego, California 92101

Dear Ms. Smith and Dr. Preston,

This letter transmits the U.S. Geological Survey (USGS) Western Ecological Research Center's Draft Final: Aseasonal Flow and Associated Nonnative Species in San Diego. This work was completed under agreement number 5004597. We expect to publish these data in a paper in 2021 as part of a synthesis on urban threats and stressors.

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

USGS
science for a changing world

Draft Final: Aseasonal Flow and Associated Nonnative Species in San Diego

Data Summary

Draft Final: Aseasonal Flow and Associated Nonnative Species in San Diego

By: Chris Brown[1], Emily Perkins[1], Cynthia J. Hitchcock[2], Angelica Aguilar Duran[1], Omar Guerra Salcido[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,
San Diego Management and Monitoring Program,
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Scientific Collecting Permit (Entity) and MOU: SCP838

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Cover Photographs: Buena Vista Creek aseasonal flow study site, City of Vista (left; photo by C. Brown), nonnative crayfish (*Procambarus clarkii*) from Salt Creek aseasonal flow study site, (upper right, photo by A. Aguilar Duran), and California treefrog (*Pseudacris cadaverina*) from Lawson Canyon aseasonal flow study site in Sycuan Peak Ecological Reserve (lower right; photo by O. Guerra Salcido).

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Executive Summary

This document provides a summary of data collected for the purpose of understanding aseasonal flow in 14 watersheds in southern California. Aseasonal flow is an increased discharge of runoff during dry seasons resultant from land use changes. Visual surveys, Stream Temperature, Intermittency, and Conductivity loggers (STICs), and GIS analysis of land use and land cover were used to identify maximum hydroperiods for 56 sites in San Diego County. Visual surveys were conducted to record presence of native and nonnative aquatic species as well as physical characteristics of the stream morphology and surrounding vegetation. Data were collected between 2015 and 2016. This document is not meant to provide a comprehensive report and interpretation of the data but to simply present the data collected and how it was collected. This summary is one piece of a larger on-going project with San Diego Association of Governments (SANDAG) and San Diego Management and Monitoring Program (SDMMP), implemented to better understand the biological processes and anthropogenic affects driving local community dynamics of native species. Preliminary investigations of some of the relationships between species presence and upstream land use and cover are presented graphically for the reader's interpretation. Appendices include detailed site information and individual graphs and photographs depicting the stream conditions at each site.

Introduction

The presence of nonnative flora and fauna along with associated changes to ecological processes can jeopardize the persistence of native species via direct and indirect effects. The Management and Monitoring Strategic Plan (MSP; SDMMP and TNC 2017) of the San Diego Management and Monitoring Program (SDMMP) identifies potential threats to native species and presents goals and objectives associated with monitoring their effects. The impact of urban aseasonal flow (increased discharge during dry seasons resultant from land use changes) on local and regional stream systems is a primary conduit for potential threats because it allows nonnative species to persist in areas where they normally would not (Riley et al. 2005; White and Greer 2006; Cooper et al. 2013). Therefore, aseasonal flow is the focus for this study.

Runoff can have a range of effects including increased soil moisture levels, geomorphic changes in creeks, and perennial flows in xeric landscapes. USGS is working with SDMMP and their partners in the Management Strategic Plan Area (MSPA) to determine what GIS covariates of land cover/land use might correlate with field measurements of the hydrological cycle in small watersheds. This will help to identify where urban runoff is providing habitat for aquatic nonnative species in areas inhabited by native species, such as arroyo toads and western pond turtles, or entering areas with biologically important vernal pools.

Study Area

The focal area of this study consists of riparian habitat along the coastal streams of San Diego County outside of Marine Corps Base Camp Pendleton (MCBCP, Figure 1). There are 14 coastal watersheds which are included in this study area. These watersheds are, from north to south, the Santa Margarita River, San Luis Rey River, Buena Vista Creek, Agua Hedionda Creek, San

Marcos Creek, Escondido Creek, San Dieguito River, Los Penasquitos Creek, Mission Bay, San Diego River, Pueblo San Diego, Sweetwater River, Otay River, and Tijuana River (Figure 1, Table 1). We focused on conserved lands within these watersheds where upstream urbanization and impermeable surfaces may cause an increase in runoff to the location. Detailed descriptions, maps, photos, and STIC data for individual sites are organized by watershed and located in Appendix A (some sites do not have photographs).

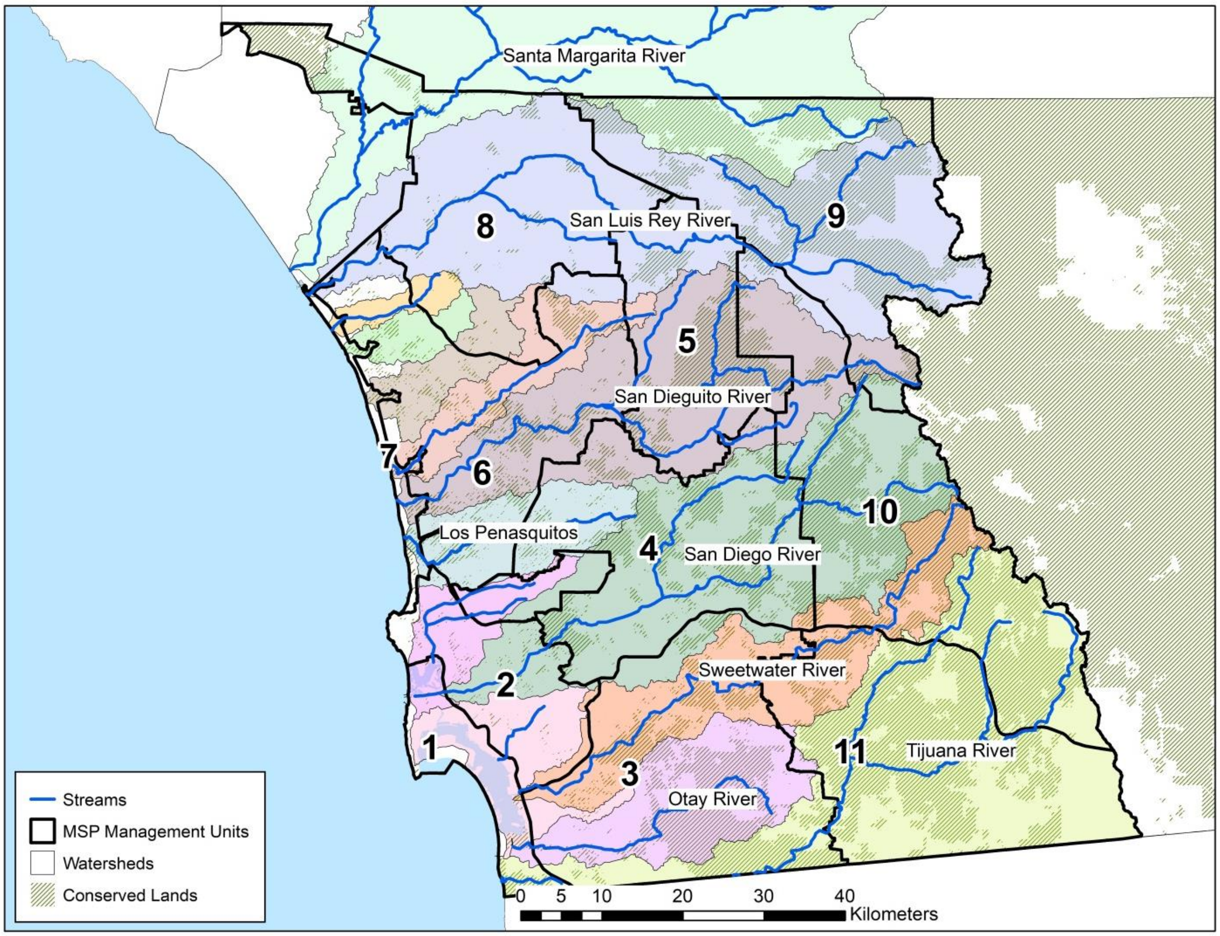

Figure 1. Study area overview, San Diego, CA. San Diego County is the southernmost county in California, bordering Orange and Riverside Counties to the north, Imperial County to the east, the Pacific Ocean to the west, and Baja California Norte, Mexico to the south. The study area includes 14 coastal watersheds and is divided into 11 management units within the MSPA (indicated by the numbers on the map; SDMMP and TNC, 2017).

Table 1. Watersheds from north to south with approximate area in hectares and percent conserved land for the 14 watersheds within the study area. Number of sites per watershed is included for 56 total surface water monitoring sites. Values for the Santa Margarita and Tijuana rivers are given first for the entire watershed, then for San Diego County only.

Watershed	Total Area (Ha)	Conserved Area (Ha)	Conserved (%)	Number of Sites
Santa Margarita River (in San Diego County)	191,918 (50,787)	-na- (19,679)	-na- (39%)	3
San Luis Rey	144,835	40,235	28%	5
Buena Vista Creek	5,642	323	6%	2
Agua Hedionda Creek	7,684	1,232	16%	1
San Marcos Creek	13,859	1,511	11%	1
Escondido Creek	21,952	4,450	20%	2
San Dieguito River	89,422	26,715	30%	5
Los Penasquitos Creek	24,384	5,807	24%	3
Mission Bay Watershed	16,013	1,078	7%	3
San Diego River	112,078	43,821	39%	1
Pueblo San Diego	23,709	1,270	5%	3
Sweetwater River	56,407	23,655	42%	11
Otay River	36,764	16,663	45%	14
Tijuana River (in California)	453,248 (120,998)	-na- (71,662)	-na- (59%)	2

Site Descriptions

The 56 aseasonal flow sites were selected to represent an expected gradient of urban runoff based on the amount and type of development (e.g., agricultural, residential, commercial) in the watershed above the selected location. Thus, they may exhibit an increased flow and volume during times of the year when they may otherwise be naturally dry or have little surface water. These sites represent a cross section of available watershed sizes and riparian habitat types found in coastal San Diego County. These sites together with 64 USGS arroyo toad monitoring study sites (Brown et al. 2019) and 41 stations used by the California Water Quality Control Board, San Diego Region (SDRWQCB unpublished data) comprised a useful network of surface water availability and temperature data from coastal San Diego to the foothills of the Cuyamaca, Laguna, Palomar, and Santa Margarita mountain ranges (Figure 2). This study utilized only the 56 aseasonal flow sites. Individual site maps, descriptions, and photographs are included in Appendix A.

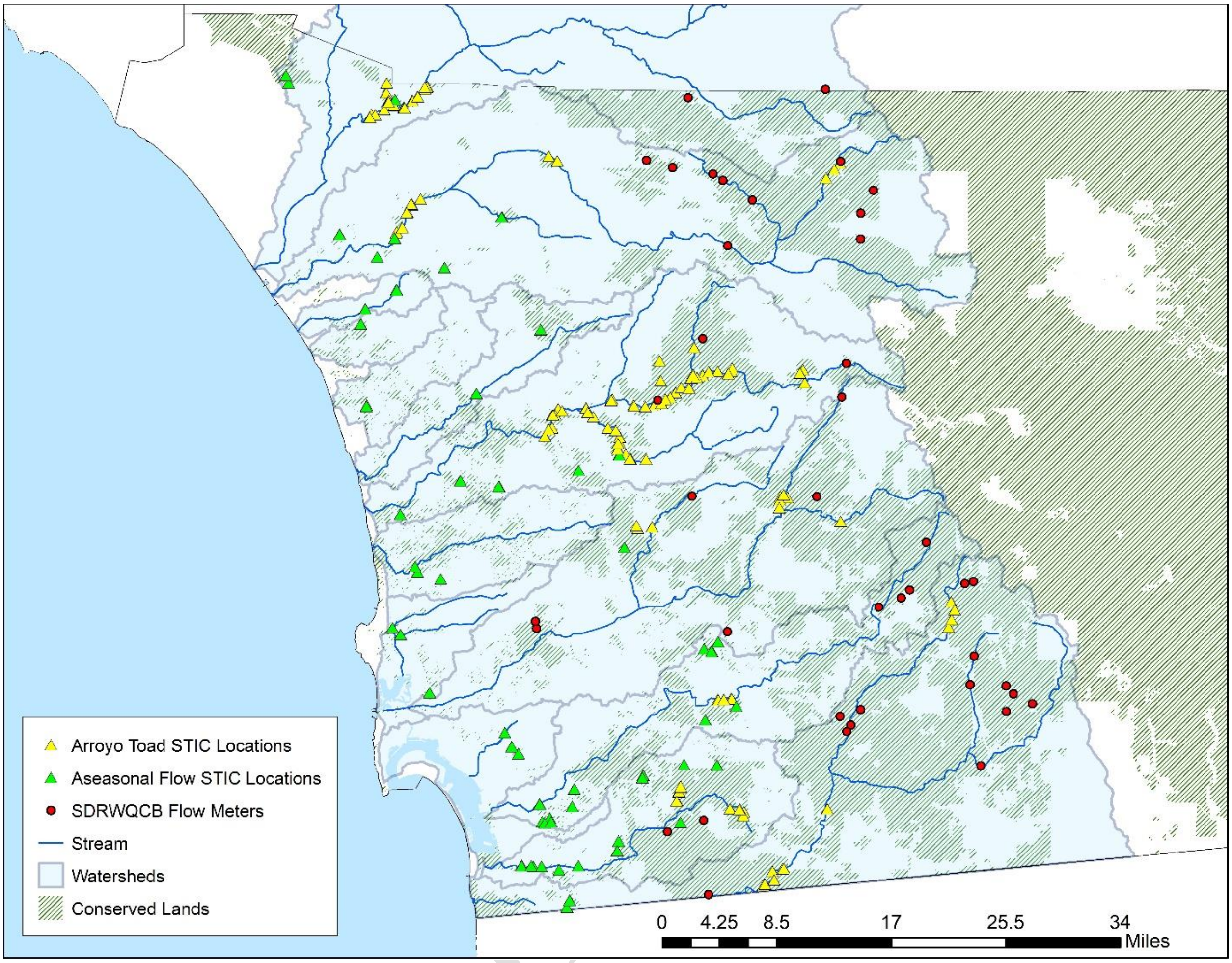

Figure 2. Stream surface water study sites, San Diego, CA. There are 56 aseasonal flow study sites throughout coastal San Diego County. The aseasonal flow monitoring sites were established in addition to 64 previously established USGS surface water monitoring stations for the arroyo toad. The 41 surface water flow meter stations used by California Water Quality Control Board, San Diego Region (SDRWQCB) are also included on the map.

Methods

Site Selection

The surface water monitoring locations were chosen in ArcGIS 10.3 using the SanGIS Conserved Lands database (downloaded February 2016), intersected with the National Hydrologic Dataset (NHD) flow line in San Diego County. These GIS datasets have layers delineating urban areas and impervious surfaces, indicating locations of probable urban runoff. Details of this process are described later in the text (GIS Analysis section). The specific sites were chosen manually from within these locations to get an equal representation of watershed sizes and percent of urban area covering each watershed. In cases where the streambed was altered or realigned, the site was moved to fall within the current stream channel.

Following the USGS aquatic species and habitat assessment protocols for the South Coast Region (USGS 2006a, 2006b), the selected monitoring locations were mapped and placed into the USGS Stream Survey Database as predefined sites.

Visual Surveys

The predefined sites, being our Aseasonal Flow (ASF) sites, were downloaded to handheld GPS units (Trimble Juno SB, Garmin eTrex 20, or Pro GPS for iPhone). We navigated to each coordinate using GPS, preferring 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 coordinate by GPS to use as the survey start point. Geotagged site photos were taken using either a Canon PowerShot D30 or Apple iPhone.

Visual surveys were conducted at all predefined (ASF) sites to determine presence of water and aquatic species (both native and nonnative) following USGS Stream Survey Protocols (USGS 2006a, 2006b). Data were also collected on stream morphology, riparian habitat, upland habitat, and water quality (when water was present). Field data, including actual survey and species coordinates, were collected into a Trimble Juno SB and uploaded to the USGS Stream Survey Database upon returning from the field.

Stream Temperature, Intermittency, and Conductivity loggers (STICs)

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, deployment, and data upload were conducted according to the USGS STIC Protocol (Attached as Appendix C).

STICs were launched in the lab and set to record data at 15-minute intervals. The data collected included temperature and a relative measure of conductivity. The data loggers were originally made to record light and temperature but were converted to record conductivity (instead of light); therefore, the recorded unit for conductance is in lumens per square foot ranging from 0 to

30,000. The value 0 represents no conductivity (no water) and high values (20,000 and higher) represent high conductivity (clear presence of water). Values in between the two extremes appear as the STICs become exposed to air but are still moist or have water on the contacts. Thus, STICs were used as a surrogate for water presence, and therefore, maximum hyrdoperiod could be estimated at our ASF sites according to the conductivity readings.

Prior to deployment, the STIC number and coordinate 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.

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 coordinate taken. Two STICs were deployed when uncharacteristic stream features were present, such as large bedrock or artificially dammed pools within a typically sandy wash. This allowed for collection of surface water data characteristic of the stream system and testing for the presence of permanent pooling water, which could facilitate persistence of nonnative aquatic species within the system.

STIC Data Reduction

Data from STICs were analyzed using an analysis workbook developed by Brown and Aguilar Duran in Microsoft Excel based on the analysis spreadsheet developed by Chapin et al. 2014. In most cases, water was presumed present when temperature corrected percent relative conductivity (%RC) was greater than 10%. Max hydroperiod was defined as the maximum number of days having consecutive data points where the percent relative conductivity was greater than 10% and was recorded as the max number of consecutive days that water was present. This was calculated using the excel analysis workbook which corrects and combines data across multiple STIC deployments for a total number of wet days across multiple survey time periods. The data for each site were checked manually against site photos for anomalies such as STIC burial in sediment, sediment movement elevating STIC above the pool surface, or a STIC being thrown up on the bank by animals or heavy current. Relative conductivities used to determine max hydroperiod were corrected for “ringing” (oscillations between the measured conductivity and a near-0% or near-100% value; Chapin et al. 2014) and anomalous inconsistencies. In these cases, site photos and changes in temperature variation were used along with the conductivity to determine the actual max hydroperiod.

Not all sites had complete data for the entirety of the survey period due to technical problems, lost STICs, and access restrictions. Technical problems included prematurely dead batteries, corroded electrodes or circuitry, and computer to STIC communication errors while reading or offloading data. Lost STICs occurred when heavy storm flows displaced enough sediment or rock to move the STIC and mounting hardware enough that it could not be found. Additionally, two instances of cable corrosion accounted for lost STICs, one of which was eventually recovered approximately 120 meters downstream from the initial deployment location. Access restrictions due to road conditions, recreation, and management activities resulted in late recovery and deployment dates in some instances. Because of this, data used for analysis were confined to data taken between January 4th, 2016, and September 19th, 2016. This date range was chosen to incorporate the breeding season of the threatened arroyo toad and to incorporate typical seasonal rain events where the highest rainfall months are January, February and March (NOAA 2004). Coincidentally, the first major rain of the season occurred on January 4, 2016. By September 19, 2016, (250 days later), the arroyo toad breeding season was complete and the 2016 cohort of toads, if present, should have metamorphosed and dispersed to the upland.

GIS Analysis

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 3). This DEM has a horizontal spatial resolution of 10m and was created in 2013.

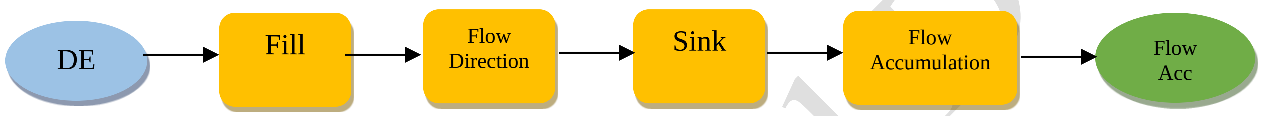

Figure 3. GIS flow accumulation model. ArcGIS was used to calculate stream flow accumulation. The tools used are in yellow boxes. The input and output are listed in ovals.

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 (USGS 2013). 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. 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 4). Finally, the percent of each vegetation category was calculated using the Fire Resource and Assessment Program (FRAP) vegetation layer (CDFW 2015). These vegetation data are a compilation of the most recent vegetation data available throughout the county. They include the AECOM 2014 vegetation map (AECOM 2014), preserve mapping where available, and CALVEG data (CDFW 2015) in the gaps. Unified vegetation classes were calculated and can be found in SDMMP’s MSP Volume 1 section 3 (SDMMP and TNC 2017).

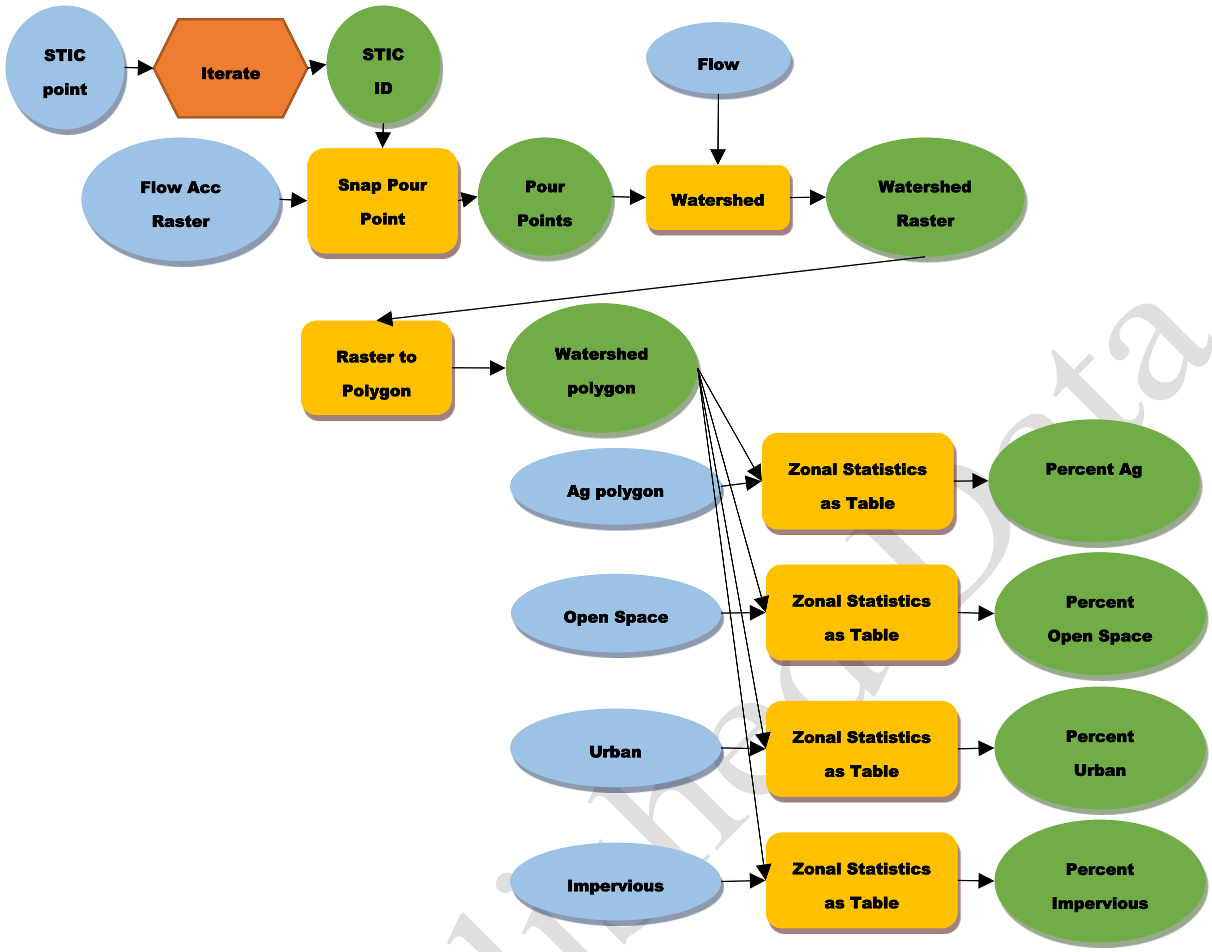

Figure 4. GIS land cover statistics model. Using ArcGIS to calculate watershed characteristics.

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

Site Selection

A total of 56 sites were chosen along streams. Areas (watersheds) draining to the sites ranged from 187 to 132,403 hectares. The majority of sites had watersheds from 1,000 to 5,000 hectares (Figure 5). Upstream land cover ranged from 0% impervious to 66.8% impervious cover. The majority of sites (29 out of 56) had between 0% and 20% impervious surface cover.

Watersheds also represented a range of land use types, including commercial, residential, agriculture, and open space. Total urban cover ranged from 0% to 88% with the sites falling fairly evenly among cover classes (Figure 6). Impervious surface correlated with urban land use, but the correlation varied with urban type (Figure 7). Rural residential areas had relatively low impervious surface while commercial parks had a very high impervious surface cover.

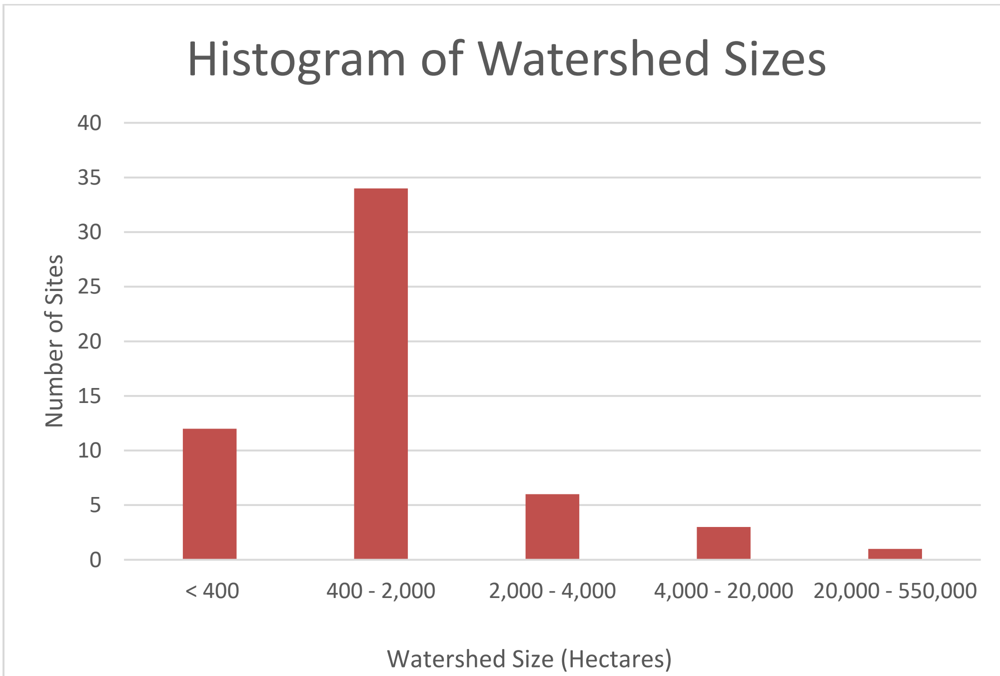

Figure 5. Histogram of watershed sizes associated with sites. Watershed sizes are the area of the watershed above the STIC at the study site.

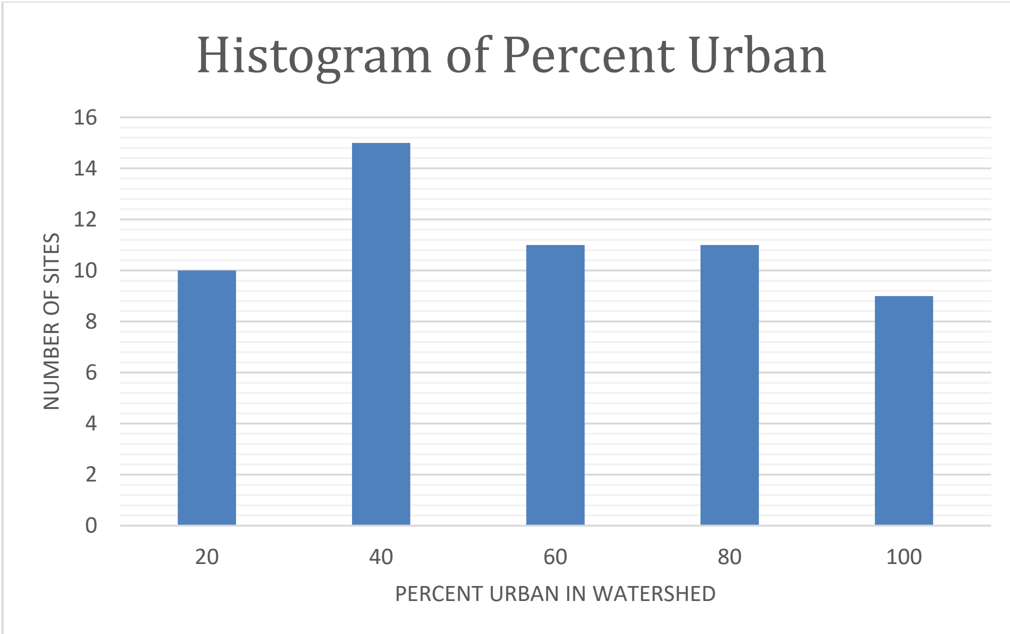

Figure 6. Histogram showing the percent of urban cover in watersheds associated with sites.

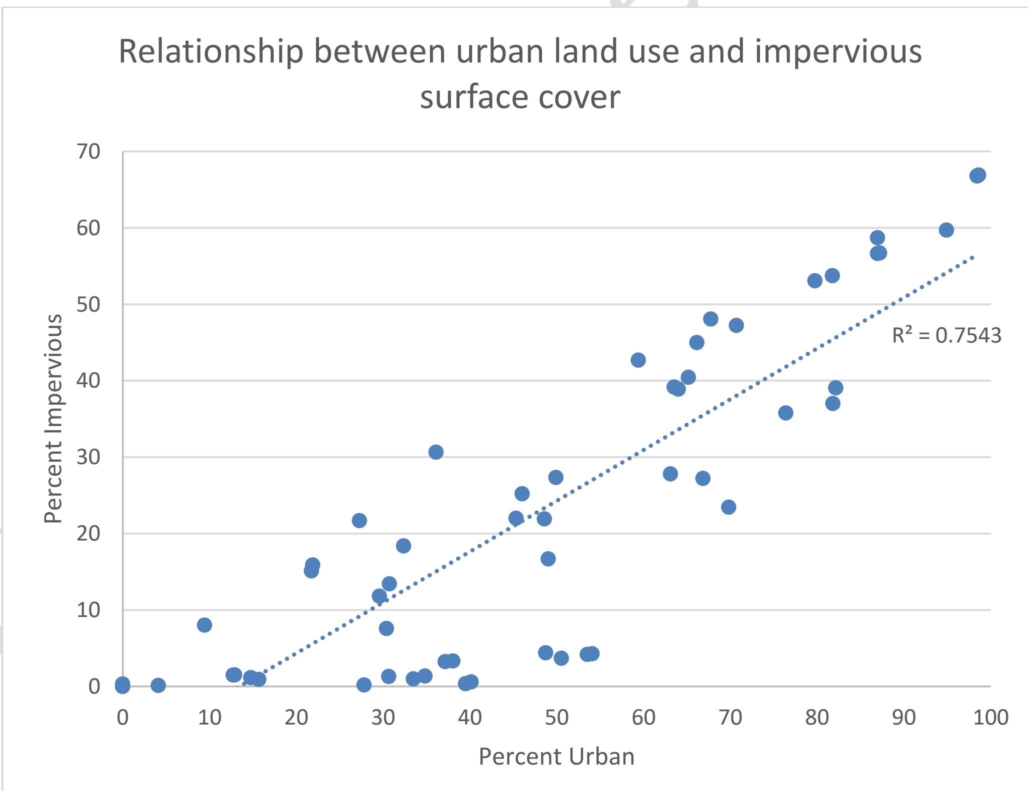

Figure 7. Scatterplot depicting the relationship between percent of urban and percent of impervious covers. While there is a positive relationship, several sites fall outside of the pattern with high urban percentage and low impervious surface percentage.

Visual Surveys

A total of 223 visual surveys were conducted at the 56 ASF sites during the fall and winter of 2015–2016 (Table 2). During our surveys, 37 sites had detectable surface water during at least one site visit and only 10 sites had detectable surface water on all visits (19 sites were dry on all visits). Two sites were visited only once due to access limitations.

Native aquatic species observed included Pacific treefrogs (*Pseudacris regilla*) and California treefrogs (*Pseudacris cadaverina*). In spite of low water levels, many nonnative aquatic species were also observed during visual surveys, including crayfish (*Procambarus* spp.), mosquitofish (*Gambusia affinis*), largemouth bass (*Micropterus salmoides*), and goldfish (*Carassius auratus*) (Table 3 and Figure 8).

Native aquatic species were observed at only five sites whereas nonnative aquatic species were observed at eight sites. Native and nonnative aquatic species were never observed at the same sites. No native aquatic species were observed at sites that were scored as having greater than 34% upstream urban development. No nonnative aquatic species were observed at sites that were scored as having less than 43% upstream urban development (Table 3).

Sites with more dry visits were more likely to have native species and less likely to have nonnative species (Figure 9). Sites with 3 or more dry visits had only one or fewer nonnative aquatic species. Sites with fewer dry days (more wet days observed) tended to have 2 or more nonnative aquatic species.

Stream morphology, substrate, and riparian vegetation were recorded at each site. Native plant communities recorded included mule fat scrub, coast live oak forests, cottonwood willows, and other sage scrubs. Invasive plant communities were present at 15 sites and included tamarisk scrub, arundo scrub/forest and cattails. Plant communities were assigned using the naming convention from the CDFW CALFIRE-FRAP vegetation dataset (CDFW 2015).

The entrenchment ratio calculated to characterize the stream morphology uses the ratio of average bank full width over the average flood prone width. High entrenchment ratios indicate a wide area prone to flood. Stream morphology is important for native species, like arroyo toads, which need shallow braided slow-moving water. Changes in stream morphology could contribute to the establishment of invasive aquatic species because habitat composition and structure, such as deeper water and a prolonged wet season, may be beneficial to nonnatives but unsuitable for natives that are often habitat specialists. Streams in this study had entrenchment ratios ranging from 0 to 10.

Table 2. Presence of water. Number of survey visits to each site when the site was wet (had surface water present) or dry (had no surface water present, as indicated by the blank fields).

Watershed	Site	Dry Visits	Wet Visits	Total Visits
Santa Margarita	ASF50-Santa Margarita River Trib	3		3
	ASF51-Roblar Creek 1	2		2
	ASF64-Roblar Creek 2		1	1
San Luis Rey	ASF28-Guajome Creek Trib	2	1	3
	ASF29-San Luis Rey Park	2		2
	ASF30-Pilgrim Creek	2	1	3
	ASF38-Keys Creek	3	1	4
	ASF53-Gopher Canyon Trib	1	3	4
Buena Vista	ASF52-Buena Vista Creek	1	2	3
	ASF54-Buena Vista Creek Trib	1	2	3
Agua Hedionda	ASF27-Upper Calavera Creek	1	2	3
San Marcos Creek	ASF25-Batiquitos Lagoon Trib	1	3	4
Escondido Creek	ASF31-Escondido Creek	1	2	3
	ASF33-Escondido Creek Trib	2	1	3
San Dieguito River	ASF22-Gonzales Canyon	4		4
	ASF23-Lusardi Creek 1	1	3	4
	ASF24-Lusardi Creek 2	1	4	5
	ASF39-Santa Maria Creek	3		3
	ASF40-Green Valley	3	2	5
Los Penasquitos Creek	ASF21-Los Penasquitos Creek Trib	4		4
	ASF37-Carroll Canyon	4		4
	ASF60-Los Penasquitos Creek	1	3	4
Mission Bay WMA	ASF19-San Clemente Canyon	1	2	3
	ASF20-Rose Creek		3	3
	ASF18-Tecolote Creek	1	3	4
San Diego River	ASF36-Foster Canyon	2	1	3
Pueblo San Diego	ASF15-Encanto Creek	4		4
	ASF16-South Chollas Creek	1	2	3
	ASF17-Chollas Creek	2	1	3
Sweetwater River	ASF03-Sweetwater County Park	1	3	4
	ASF04-Bonita Meadows	2	2	4
	ASF05-Rice Canyon	3	2	5
	ASF06-Rancho Del Rey	1	3	4
	ASF07-Terra Nova	5		5
	ASF08-Long Canyon	2	2	4
	ASF41-Harbison Canyon trib	5	1	6
	ASF42-Harbison Canyon	1	5	6
	ASF43-Galloway Valley	4	2	6
	ASF44-Beaver Hollow	3		3
	ASF47-Lawson Canyon		3	3
Otay River	ASF02-Dennery Canyon	5		5
	ASF09-Otay River Trib 2	6		6
	ASF10-Otay River Trib 3		3	3
	ASF11-Otay River Trib 1	2	1	3
	ASF13-Salt Creek 1		2	2
	ASF14-Salt Creek 2	1	4	5
	ASF45-Dulzura Creek Trib	1	2	3
	ASF48-Otay River	3	1	4
	ASF55-Jamul Creek Trib 15	2		2
	ASF57-Jamul Creek	5		5
	ASF58-Proctor Valley 1	1	6	7
	ASF61-Proctor Valley 2	3	2	5
	ASF62-Otay River Trib 2B	4	2	6
	ASF63-Otay River Trib 1B	5		5
Tijuana River	ASF01-Spring Canyon 2	10		10
	ASF59-Spring Canyon 1		5	5
	Grand Total	129	94	223

Table 3. Results of visual encounter surveys. Aquatic species observations (number of site visits where the species was detected) by watershed and site for the 23 sites where aquatic species were observed. This indicates presence at the site versus abundance. Watersheds are listed from north to south, species are listed as native or nonnative. Percent of upstream urban development is listed by site. The 33 sites where no native or nonnative species were observed are excluded from this table. Watershed characteristics for all sites are included in Appendix B.

Site (from north to south)	Aquatic Species Observations												Watershed Size (hectares)	Percent Urban	Max Hydroperiod (days)
	Native			Nonnative											
	California treefrog	Baja California treefrog	Two-striped gartersnake	Bullfrog	Red-eared slider	Largemouth bass	Green sunfish	Goldfish	Mosquitofish	Crayfish	Asian clam	Total Species Observed			
(ASF29) San Luis Rey Park		3										1	121.0	48%	1
(ASF30) Pilgrim Creek				1					1			2	7,926.9	20%	11
(ASF38) Keys Creek	1											1	476.8	34%	70
(ASF54) Buena Vista Creek trib								1	2	3		3	2,707.0	72%	385
(ASF52) Buena Vista Creek									1	2	1	3	7,291.0	87%	244
(ASF25) Batiquitos Lagoon trib										1		1	4,603.5	71%	366
(ASF33) Escondido Creek Tributary		1										1	1,819.1	6%	13
(ASF31) Escondido Creek						1			1			2	31,285.4	52%	316
(ASF40) Green Valley		1										1	2,261.3	30%	81
(ASF24) Lusardi Creek Black Mountain					1					1		2	4,765.6	41%	358
(ASF60) Los Penasquitos Creek						1			1	1		3	34,544.6	54%	183
(ASF20) Rose Creek							1		2	1		3	9,045.6	61%	222
(ASF19) San Clemente Canyon									2	1		2	11,774.2	43%	12
(ASF18) Tecolote Creek									2	1		2	5,689.8	84%	253
(ASF42) Harbison Canyon										1		1	1,902.8	41%	265
(ASF47) Lawson Canyon	2											1	7,512.0	28%	*
(ASF04) Bonita Meadows			1									1	1,314.4	48%	*
(ASF05) Rice Canyon				1								1	862.6	78%	260
(ASF 03) Sweetwater Co Park										1		1	132,506.9	33%	260
(ASF13) Salt Creek 1									2	1		2	2,975.5	54%	413
(ASF14) Salt Creek 2									2	3		2	3,229.9	50%	226
(ASF10) Otay River Trib 3									1			1	81,630.2	18%	406
(ASF62) Otay River Tributary 2B					1							1	877.1	97%	26
Total observations:	3	5	1	2	2	1	1	1	17	17	1	11			

*STIC data logger failed to record/download

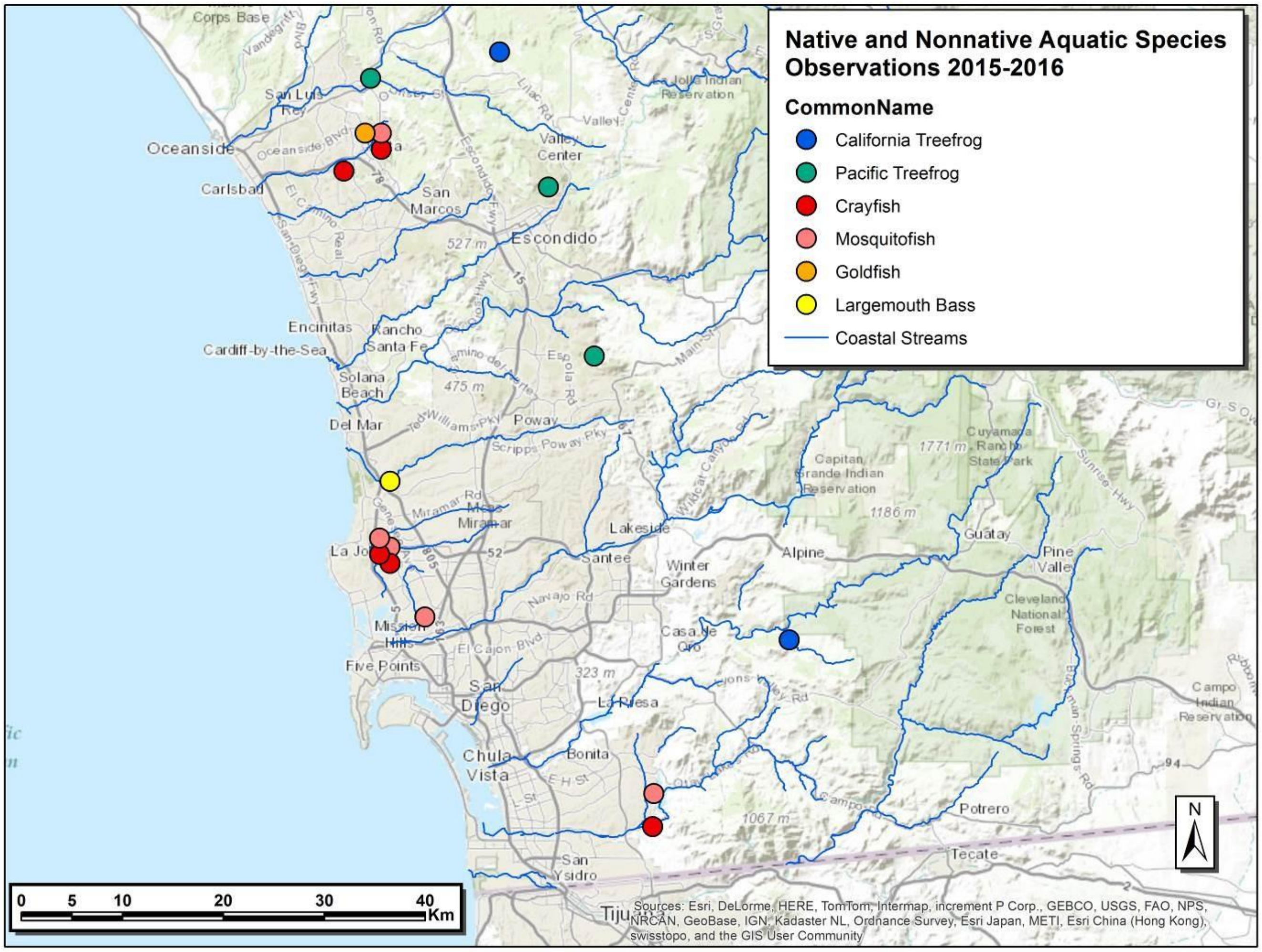

Figure 8. Map of native and nonnative aquatic species observations for 2015 and 2016.

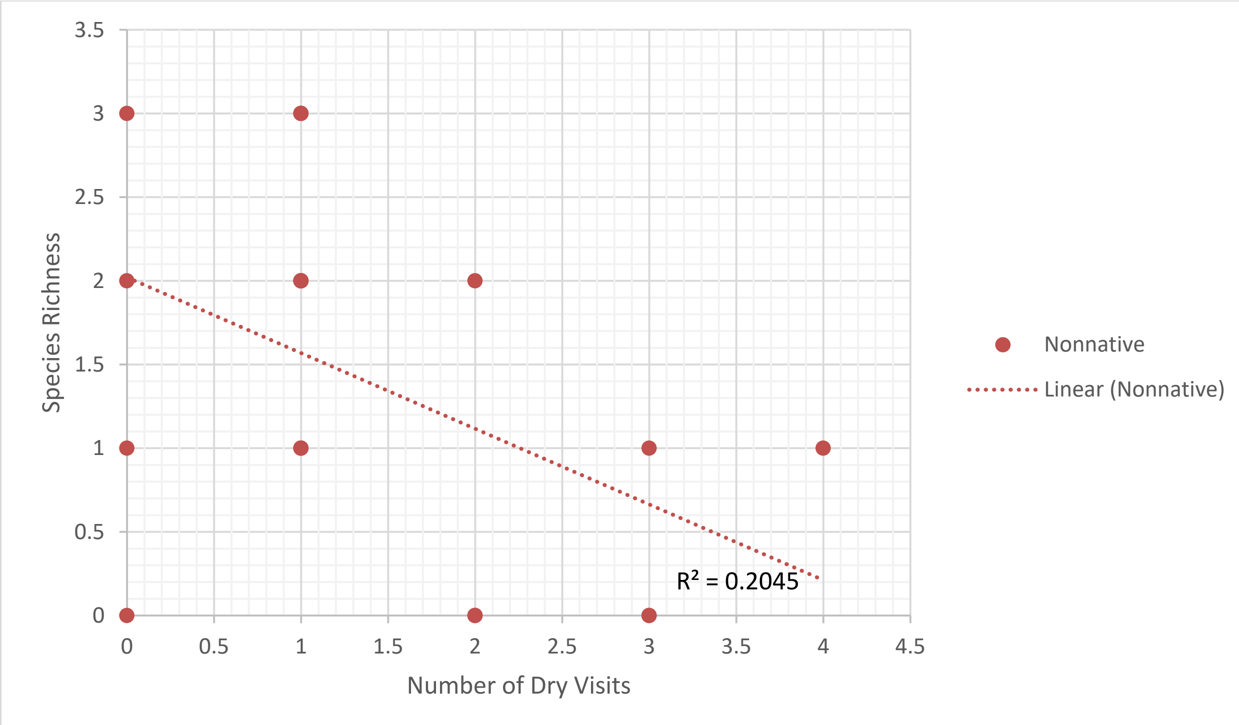

Figure 9. Scatterplot of the relationship between the number of dry visits to the site and the nonnative aquatic species richness that was recorded during a visual survey.

STIC Data Loggers

Site photos and preliminary STIC data are presented in Appendix A. Charts present relative conductivity and temperature over the duration of the data logger deployment. The STIC data loggers will continue to be monitored and hydroperiod calculations can continue to be made.

Corrected and standardized relative conductivities ranged from 0% to 100%. This surrogate for water presence was used to calculate number of days that water was present to determine percent of days with water present and maximum hydroperiod for each site. As such, we determined that hydroperiods ranged from 0 to 366 days (Appendix B) and percent of days with water present ranged from 0 to 100% for the timeperiod of 4 January to 19 September 2016 (hydroperiods over 259 days were scored as 100%). In cases where the STIC was buried by sediment, site photos and changes in temperature variation were used along with the conductivity to determine the maximum hydroperiod. Maximum hydroperiods varied by watershed size (Figure 11), percent urban (Figure 12), and percent impervious surface. Larger watersheds and sites with more urban cover tended to have longer maximum hydroperiods (Figures 10 and 11). Some watersheds with high urban cover still had relatively short hydroperiods.

Watershed Characteristics

Land use and cover were calculated for watersheds associated with all 56 sites. Upstream percent urban area use was positively correlated with invasive aquatic species detections and negatively correlated to native aquatic species detections (Figure 13). Sites with over 50% urban upstream did not have any native aquatic species detected. Sites with over 45% urban cover always had at least one nonnative aquatic species detected.

In particular, crayfish were more likely to be found at sites with a higher percent impervious cover (Figure 14). Watersheds with at least 60% impervious surface had as many as 17 crayfish detections (survey site visits where crayfish were observed). Watersheds with lower impervious surface percentages were less likely to have crayfish. While sites with higher impervious surface percentages were more likely to have crayfish; for many watersheds with high impervious surface percentages we did not detect crayfish. This relationship is affected by a number of other factors, including whether there are crayfish sources in the area and watershed size.

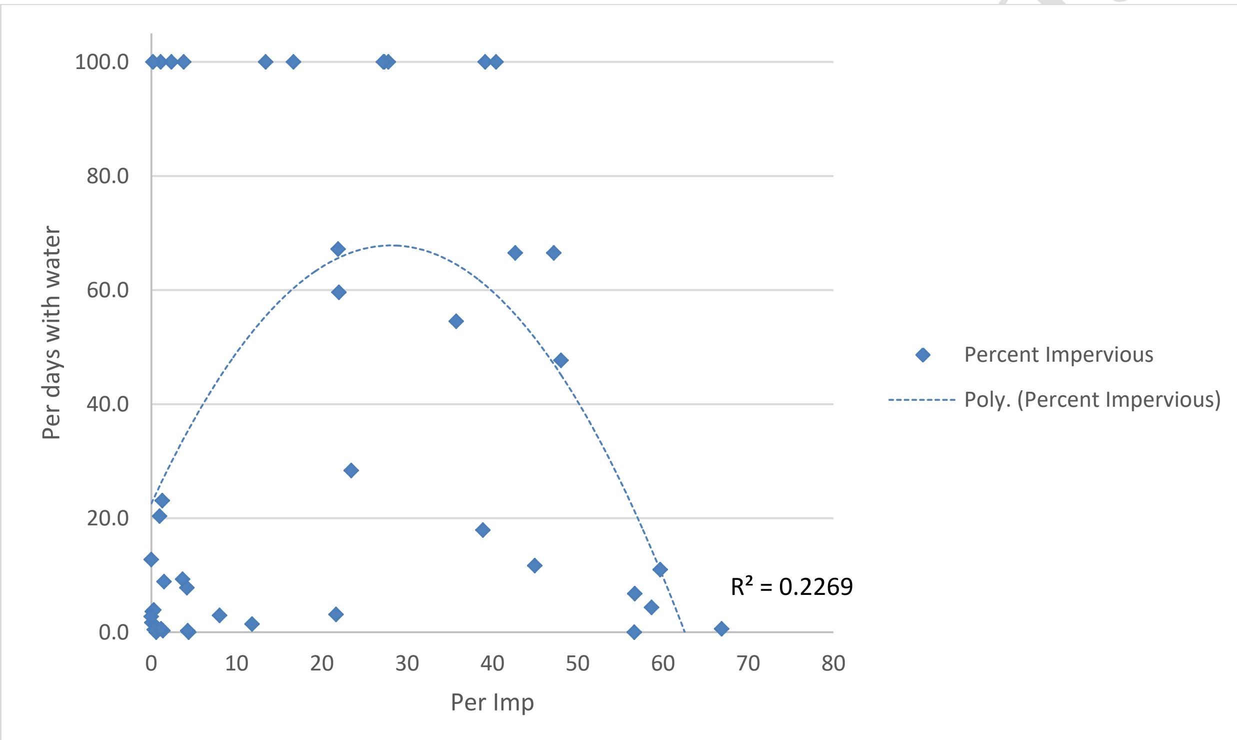

Figure 10. Scatterplot depicting the relationship between percent of days with water and percent impervious surfaces, 2015 to 2017.

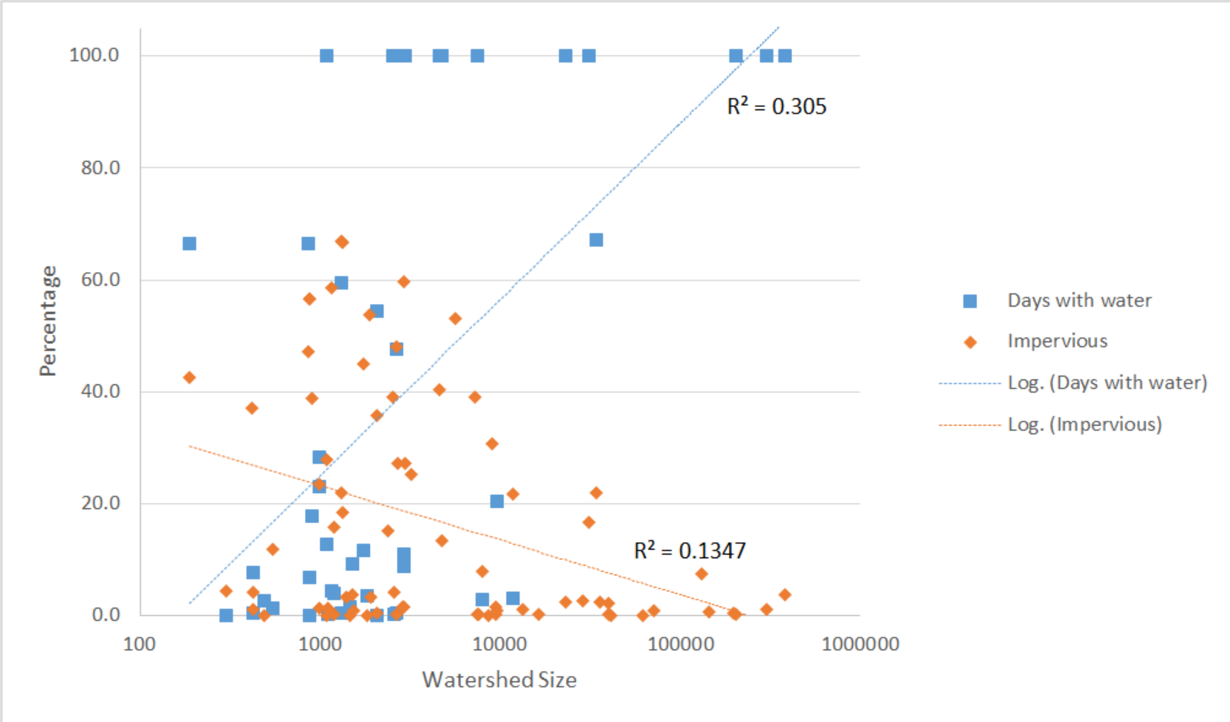

Figure 11. Scatterplot depicting the relationship between percent of days with water and percent impervious surfaces with watershed size, 2015 to 2017.

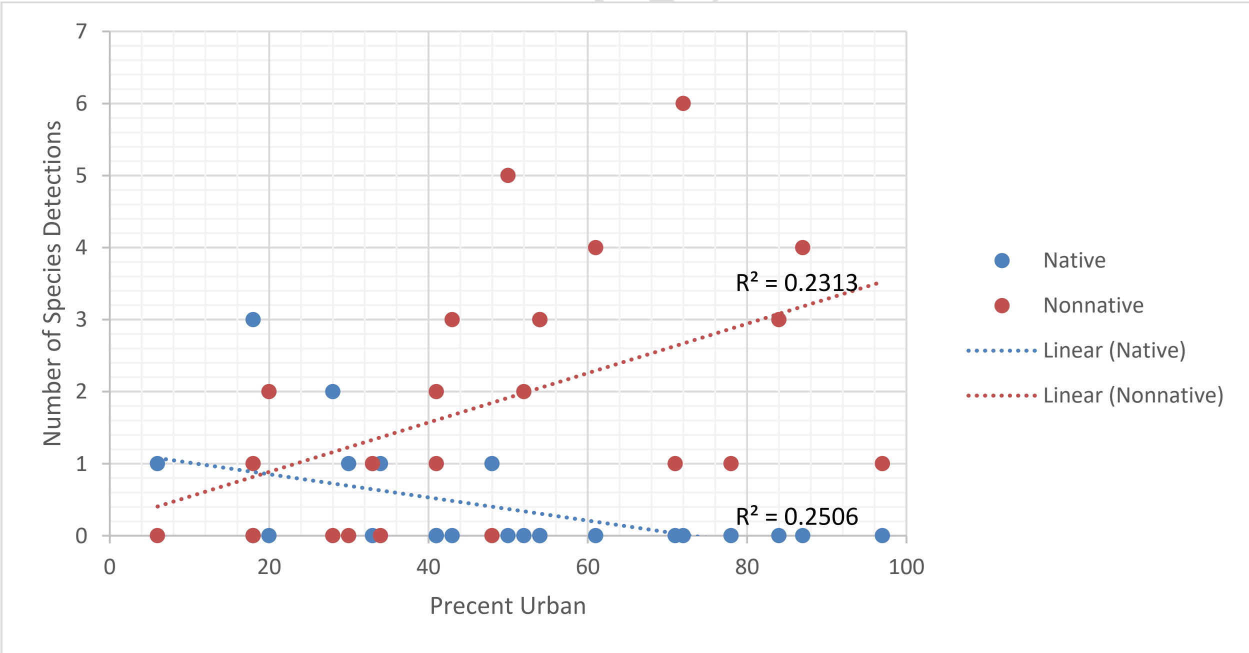

Figure 12. Scatterplot depicting the relationships between percent urban cover and the number of species detection for native and nonnative aquatic species.

Discussion

The urban ASF study sites were surveyed a minimum of four times, with the exception of two sites that were visited only once due to access limitations. We were able to make observations of water presence at several of these sites during one of the driest years in recent record, and we documented nonnative aquatic species at many of those locations. We found that nonnative aquatic species were observed only at sites with high upstream urban development (45% or greater) as scored by our GIS model. Likewise, as more of the upstream habitat was urban and impervious surface increased, observations of native species dropped off. Our study implied that there could be a threshold for native species presence in terms of how much upland was urban. At >50% urban, native species were no longer found.

Most notable was our finding that as percent impervious surface cover and percent urban cover increased in the upland, the maximum hydroperiod at each site increased, with the exception of a few very highly developed sites (Figure 10). With surface water present for more continuous days of the year (longer hydroperiod), this aseasonal flow provides habitat for nonnative species (such as the many crayfish we recorded) even during drought years. Absent higher percentages of impervious and urban cover, these areas would dry each year; native species are typically able to survive such drying events, and nonnatives are not. Since these areas have been altered by aseasonal flows from urban runoff, they now tend to harbor nonnatives and exclude natives. This altered surface water presence/absence pattern also promotes changes in the stream morphology which favor nonnative species, such as red-eared sliders over the native pond turtle.

Furthermore, we observed that sites with high urban development also had dramatic flow events. ASF 37 in Carroll Canyon is a sand and cobble wash that has an upstream urban development score of 90%. Both surveys at this site found it to be dry. However, during the single rain event between the two surveys, the stream bed changed so dramatically that the STIC has yet to be recovered, even with use of a metal detector (see Appendix A Figure 19c). These small to medium watersheds with very high percentages of impervious surface have extremely altered hydrology though they have nearly no days with surface water present during the course of the year (Figure 10). In these cases, no aquatic species are present (native or nonnative). These sites need to be taken into account when examining the relationship between nonnative species and the percent of impervious surfaces.

Complex relationships exist between the presence of native and nonnative species and upstream characteristics, including urban land use and impervious surface cover. The shape and size of the channel can also contribute to the local ecology. Preliminary investigations of these relationships are presented here, but further analysis is needed. The data collected can be combined with data from arroyo toad surveys (Brown et al. 2009; Clark et al. 2010) and the existing SDRWQCB water monitoring sites (SDRWQCB unpublished data) to evaluate these relationships in more detail in the future.

Acknowledgements

Site Access

Many thanks to the California Department of Fish and Wildlife, Center for Natural Lands Management, County of San Diego, Escondido Creek Conservancy, and the cities of Carlsbad, Escondido, Oceanside, and San Diego. These entities have provided and coordinated access to the reserves.

Fieldwork, Equipment, and Study Design

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APPENDIX A

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

Note: *Relative conductivity (RC) readings of zero on graphs imply times when water is not present. Thus, when RC is zero, temperatures recorded reflect air temperatures at the ground rather than water.

Santa Margarita River Watershed

The Santa Margarita River Watershed occupies the northernmost region of our study area with approximately 73% of the watershed being in Riverside County. The watershed area within San Diego County consists of approximately 50,787 hectares. The upper reaches of the watershed in San Diego County are on U.S. Forest Service (USFS) lands. The middle reaches within San Diego County are surrounded by low density urban and rural development. The lower reaches of the watershed are on Marine Corps Base Camp Pendleton (MCBCP). The watershed consists of approximately 19,679 hectares of conserved lands within San Diego County. Previously established arroyo toad monitoring sites include three surface water monitoring sites in Sandia Canyon and seven monitoring sites in Santa Margarita River between MCBCP and Riverside County (Brown et al. 2019). This study adds two surface water monitoring sites in upper Roblar Creek and one site in a tributary to Santa Margarita River. The open space land managers within the watershed are Fallbrook Public Utilities District (FPUD), County of San Diego, USFS, and Fallbrook Land Conservancy.

Roblar Creek 1 and 2 (ASF 51 & 64).–The upper portion of Roblar Creek is a remote section of ephemeral stream running approximately 3.5 kilometers upstream from the MCBCP border. The stream channel consists largely of mixed reaches of boulder/bedrock and sandy wash. The upland habitat consists primarily of rugged chaparral. ASF 51 and 64 were located in the Margarita Peak Reserve on land owned and managed by the Fallbrook Land Conservancy.

Santa Margarita River Tributary (ASF 50).–This small tributary to the Santa Margarita River is dominated by oak woodland/riparian. Land use includes low density rural development and light agriculture. ASF 50 was located in Santa Margarita River Park on land owned and managed by the FPUD.

Santa Margarita River Watershed (three ASF sites):

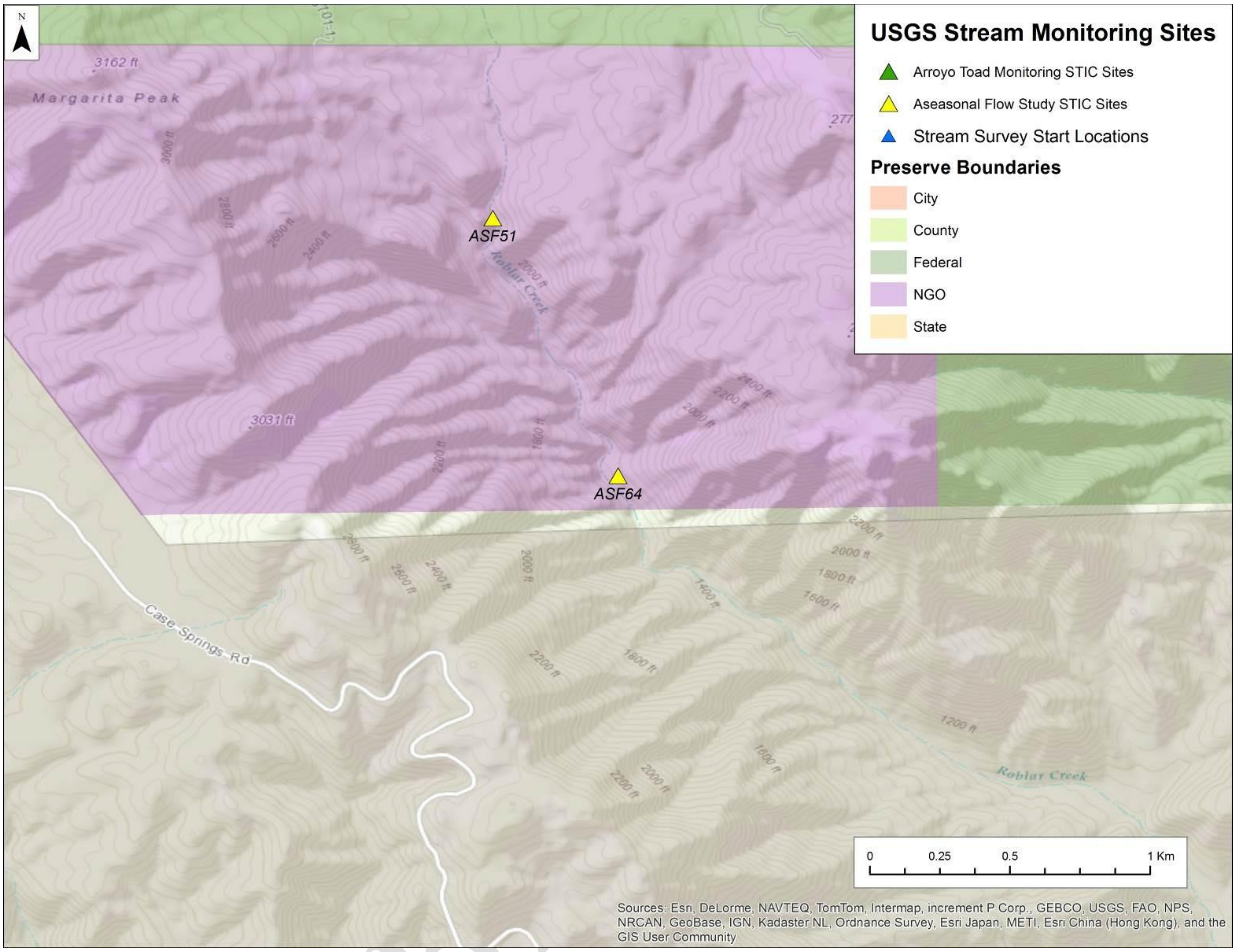

Figure A1a. ASF 51 and ASF 64. Roblar Creek within the Margarita Peak Reserve owned and managed by Fallbrook Land Conservancy.

Roblar Creek 1 (ASF 51)

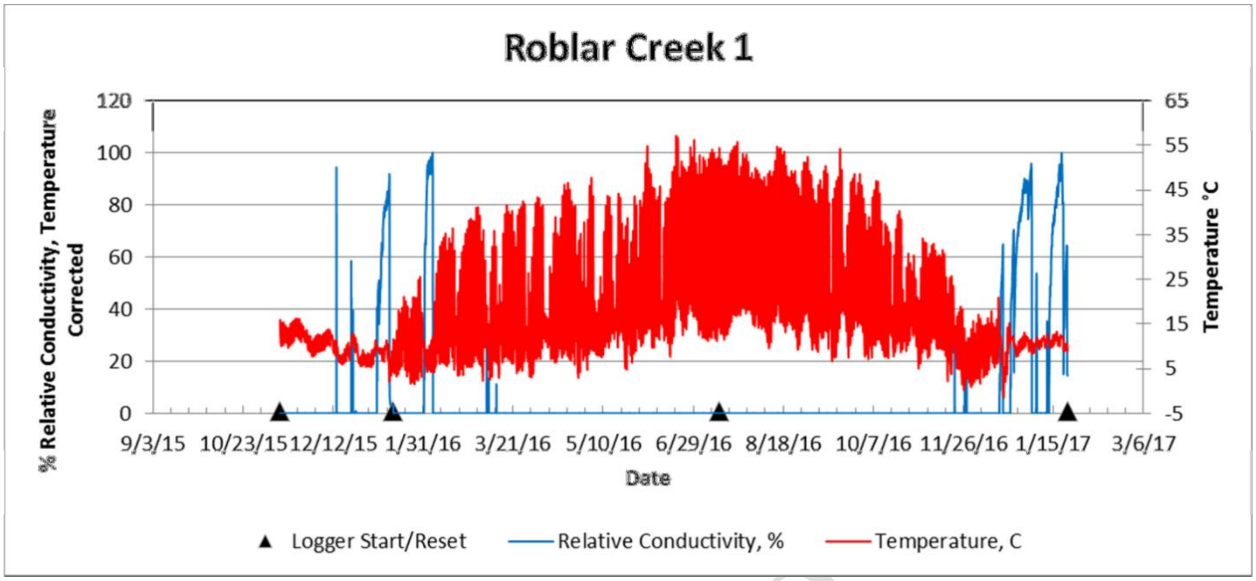

Figure A1b. Relative conductivity and temperature graph of Roblar Creek 1 (ASF 51)*.

Figure A1c. Habitat at Roblar Creek 1 (ASF 51) on 13 July 2016.

Roblar Creek 2 (ASF 64)

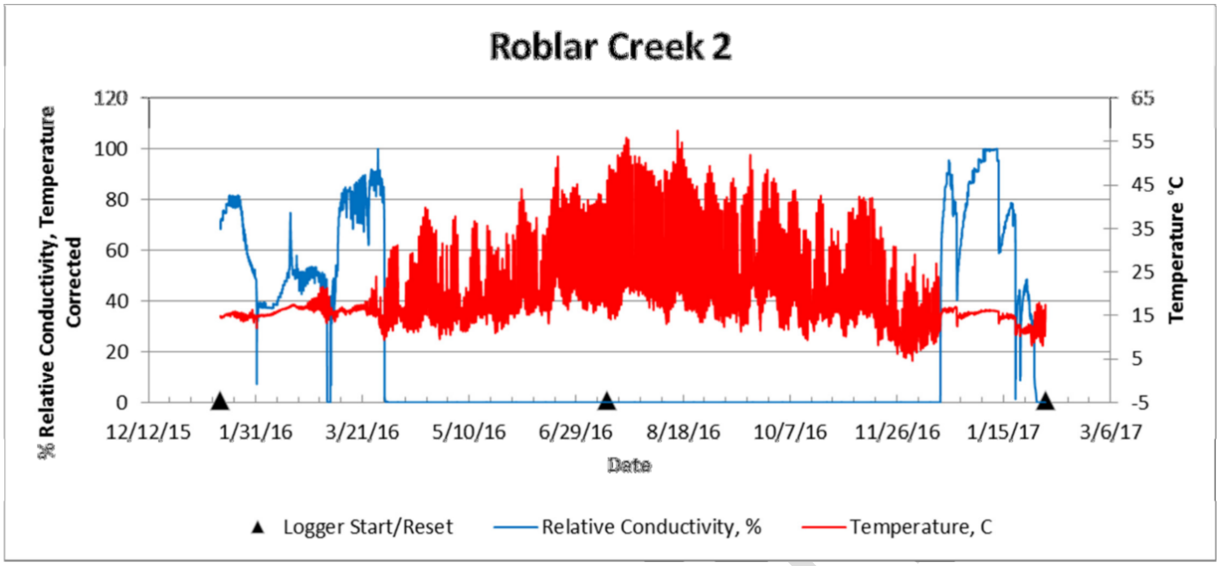

Figure A1d. Relative conductivity and temperature graph of Roblar Creek 2 (ASF 64)*.

Figure A1e. Habitat Roblar Creek 2 (ASF 64) on 14 January 2016 (left) and on 03 February 2017 (right).

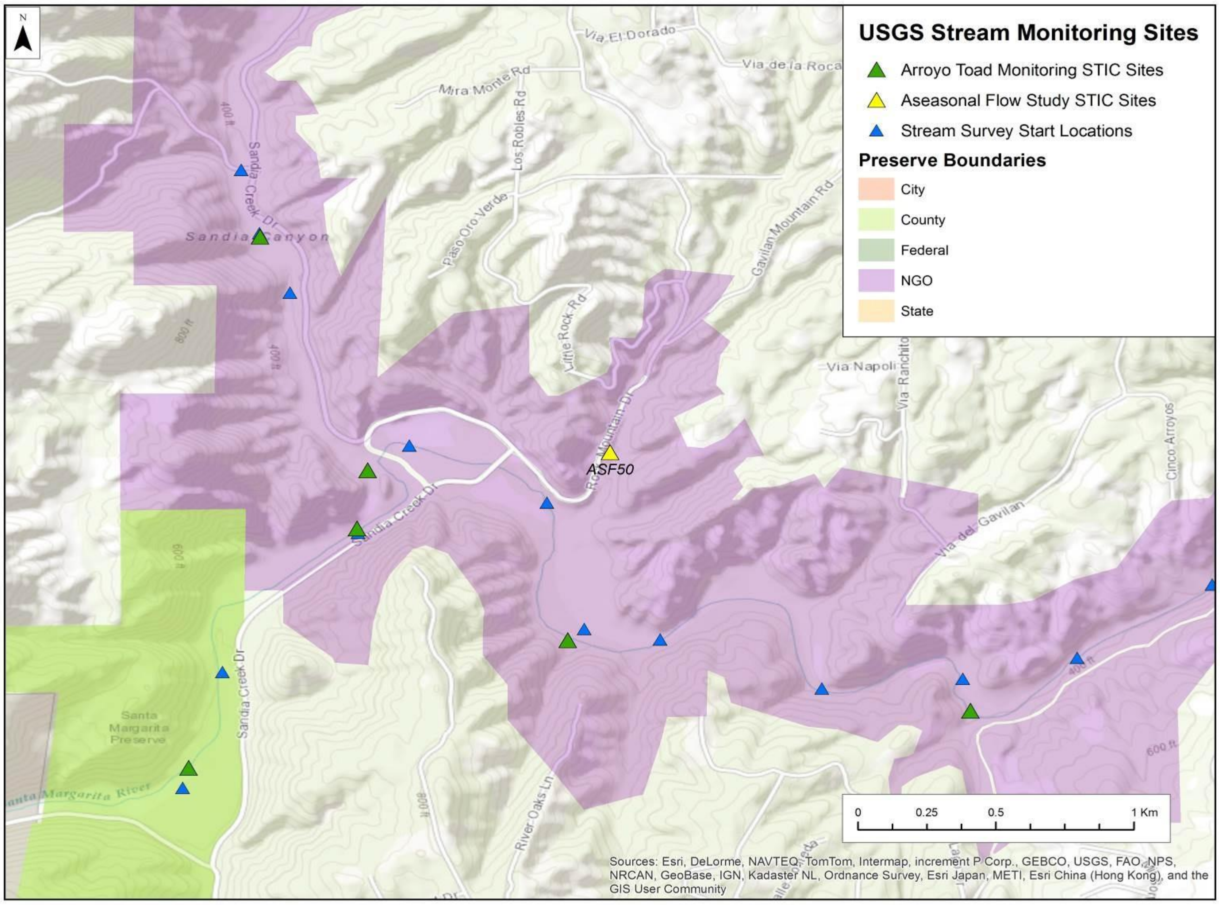

Figure A2a. ASF 50. Santa Margarita River tributary in Santa Margarita River Park owned and managed by Fallbrook Public Utilities District.

Santa Margarita River Tributary (ASF 50)

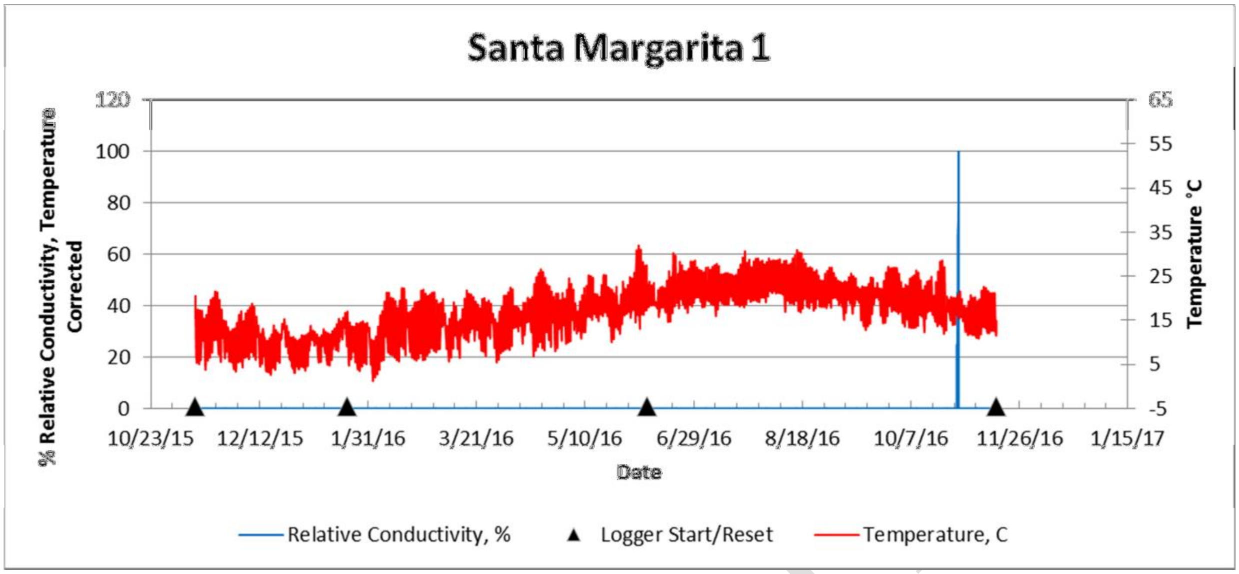

Figure A2b. Relative conductivity and temperature graph of Santa Margarita (ASF 50)*.

Figure A2c. Habitat at Santa Margarita (ASF 50) on 07 June 2016 (left) and on 15 November 2016 (right).

San Luis Rey River Watershed

The San Luis Rey River winds through northern San Diego County south of the 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. Previously established arroyo toad monitoring sites include five surface water monitoring sites along the San Luis Rey River (Brown et al. 2019). This study adds a total of five surface water monitoring sites in the main stem of the San Luis Rey River, Pilgrim Creek, and Guajome Creek. The open space land managers within the watershed are California Department of Fish and Wildlife (CDFW), California Department of Transportation (Caltrans), Center for Natural Lands Management (CNLM), City of Oceanside, County of San Diego, and Fallbrook Land Conservancy.

San Luis Rey River (ASF 29).– ASF 29 was located in San Luis Rey River Park. The 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.

Pilgrim Creek (ASF 30).– ASF 30 was located in Pilgrim Creek Ecological Reserve, which is owned and managed by CDFW. Much of this tributary to the San Luis Rey River is within MCBCP, this site being approximately 900 meters downstream from MCBCP's Horseshoe Reservoir. Recreation is limited to hiking on trails along the southwestern side of Pilgrim Creek.

Mission Meadows (ASF 28).–ASF 28 was located in a small tributary to Guajome Creek in Mission Meadows, which is owned and managed by City of Oceanside. Land use in the area around the tributary is largely urban and agriculture; some land is being restored. Recreation at this site is limited to hiking.

Keys Creek (ASF 38).–ASF 38 was located on Keys Creek at Lilac Ranch, which is currently owned and managed by Caltrans. The site is in a live oak riparian section of Keys Creek adjacent to disturbed grassland and agriculture surrounded by dense chaparral and a low-density rural community. Recreation at this site is limited to hiking.

Gopher Canyon Tributary (ASF 53).–ASF 53 was located along a tributary to South Fork Gopher Canyon in an open space reserve owned and managed by the City of Oceanside. This small tributary is surrounded by coastal sage scrub and chaparral. Recreation at this site is limited to hiking.

San Luis Rey River Watershed (five ASF sites):

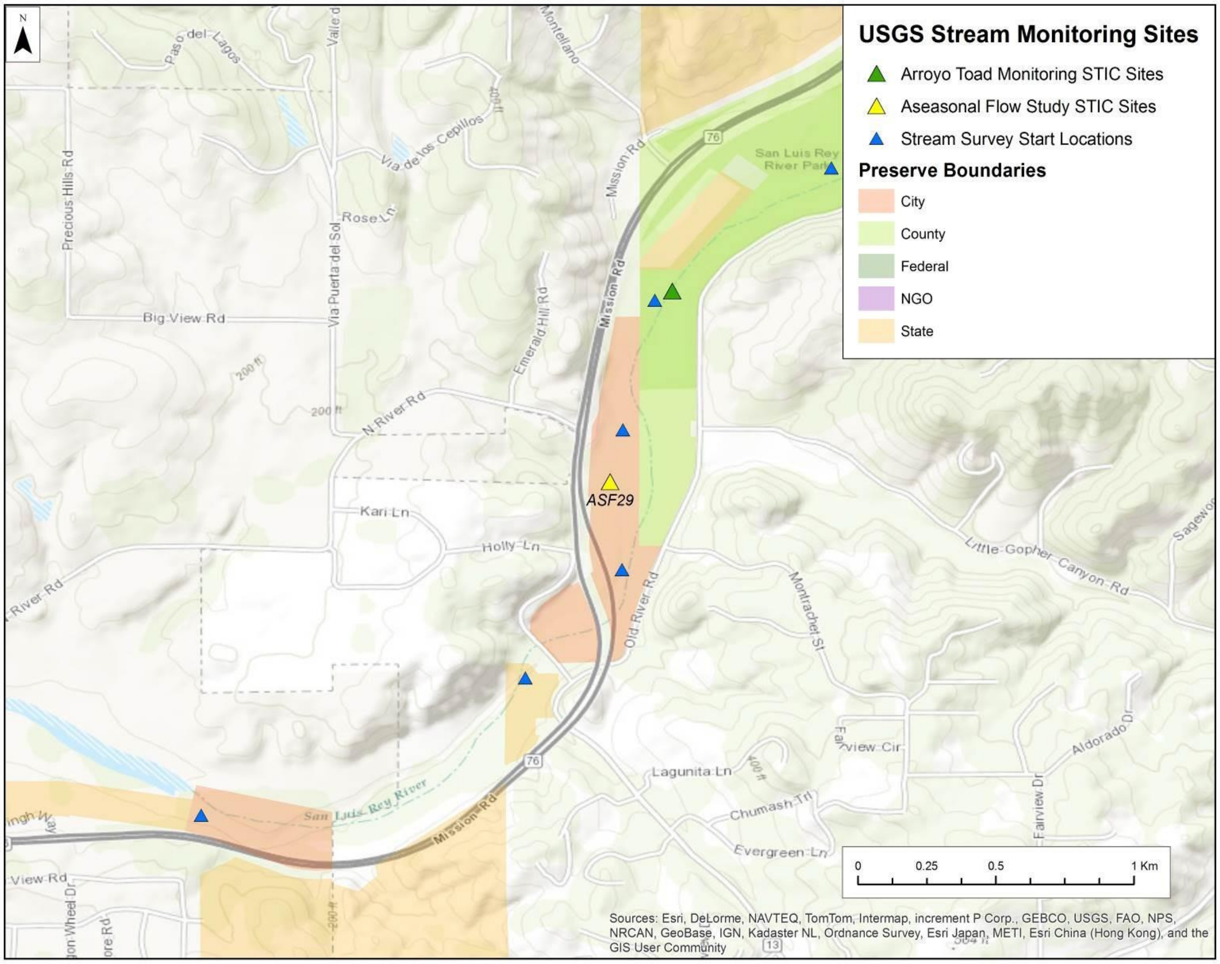

Figure A3a. ASF 29. San Luis Rey River in the San Luis Rey River Park owned and managed by City of Oceanside.

San Luis Rey Park (ASF 29)

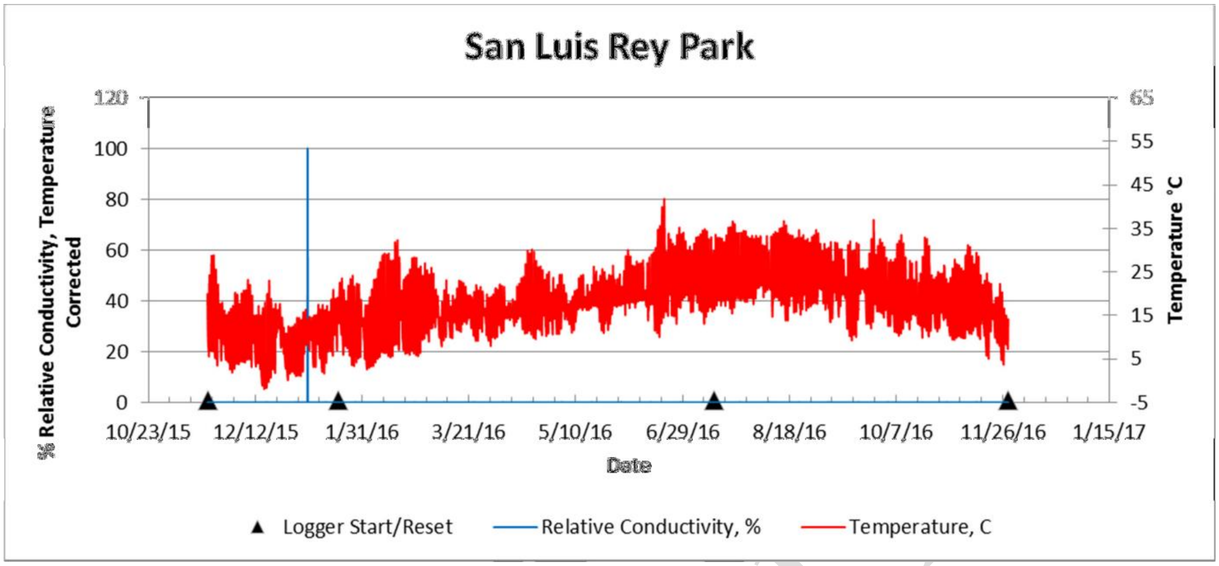

Figure A3b. Relative conductivity and temperature graph of San Luis Rey Park (ASF 29)*.

Figure A3c. Habitat at San Luis Rey Park (ASF 29) on 19 January 2016 (left) and on 20 November 2016 (right).

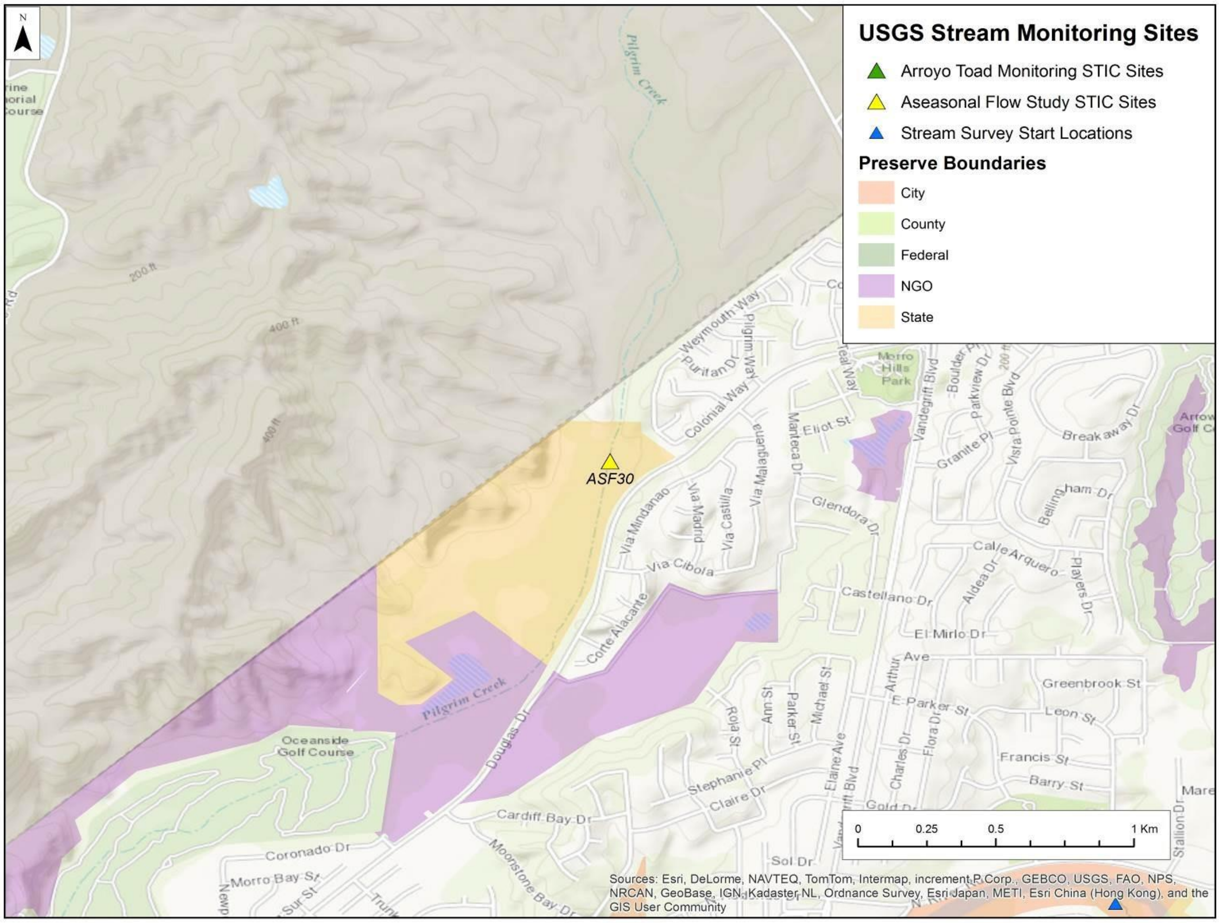

Figure A4a. ASF 30. Pilgrim Creek in the Pilgrim Creek Ecological Reserve owned and managed by California Department of Fish and Wildlife.

Pilgrim Creek (ASF 30)

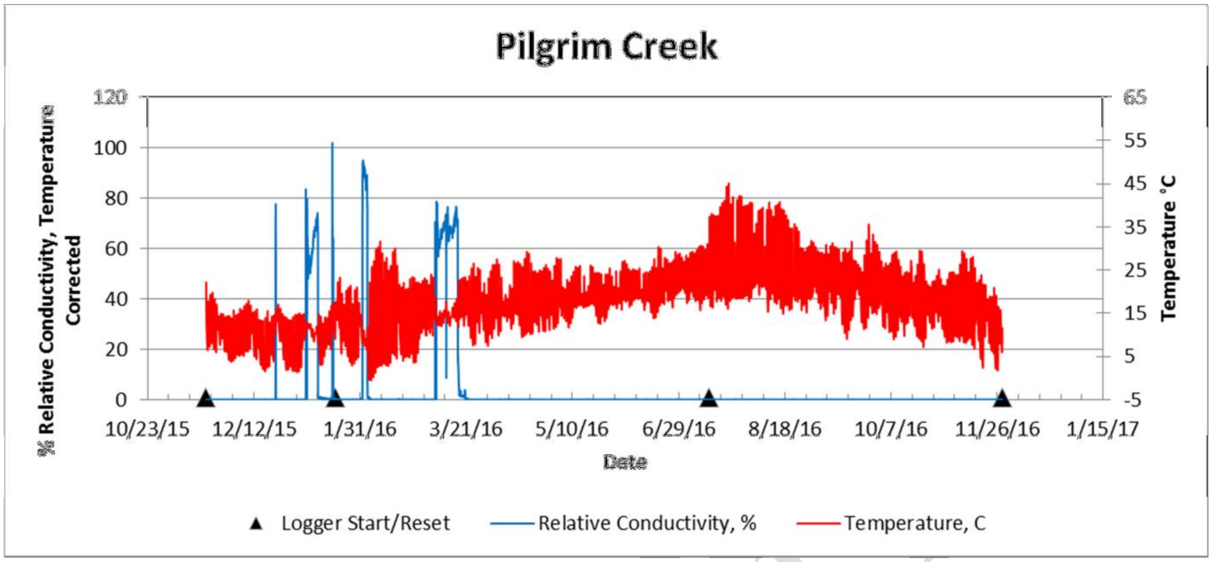

Figure A4b. Relative conductivity and temperature graph of Pilgrim Creek (ASF 30)*.

Figure A4c. Habitat at Pilgrim Creek (ASF 30) on 19 January 2016 (left) and on 28 November 2016 (right).

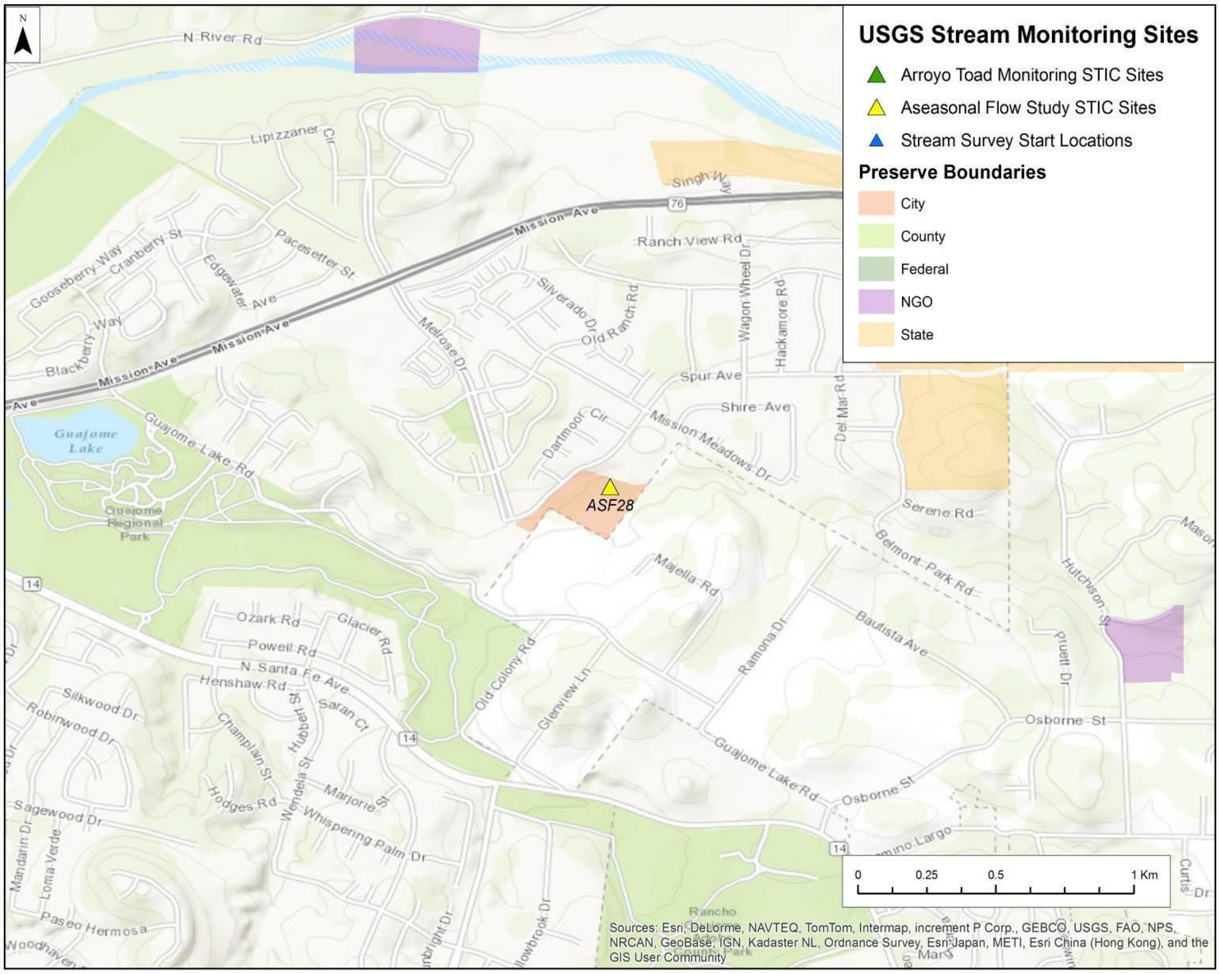

Figure A5a. ASF 28. Guajome Creek tributary in Mission Meadows, the open space owned and managed by City of Oceanside near Mission Meadows.

Guajome Creek tributary (ASF 28)

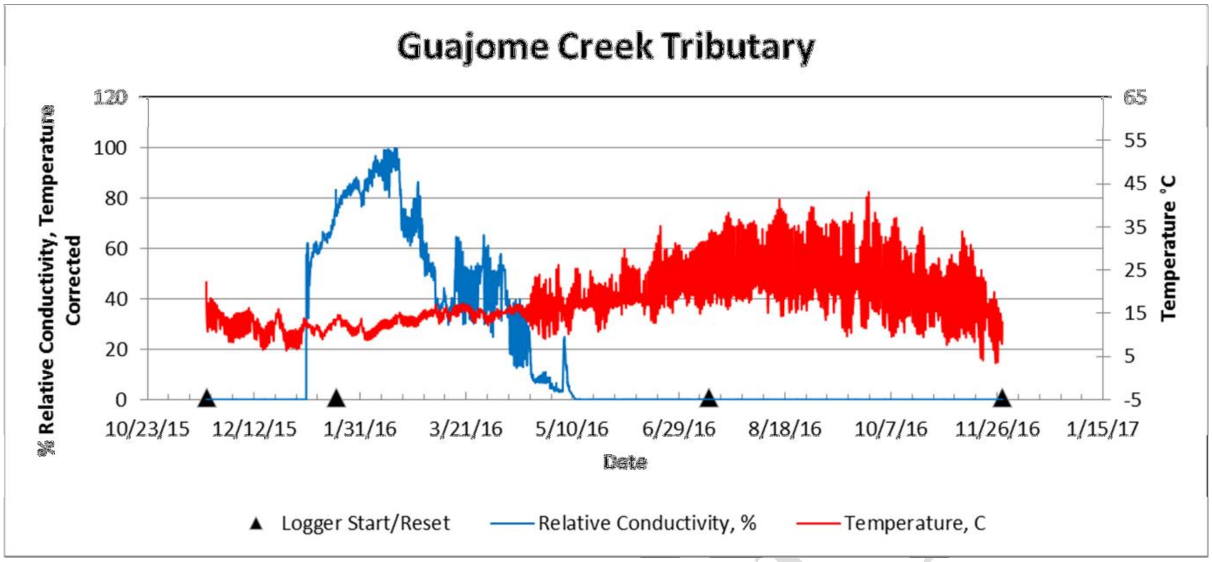

Figure A5b. Relative conductivity and temperature graph of Guajome Creek tributary of Mission Meadows (ASF 28)*.

Figure A5c. Habitat at Guajome Creek tributary of Mission Meadows (ASF 28) on 19 January 2016 (left) and on 28 November 2016 (right).

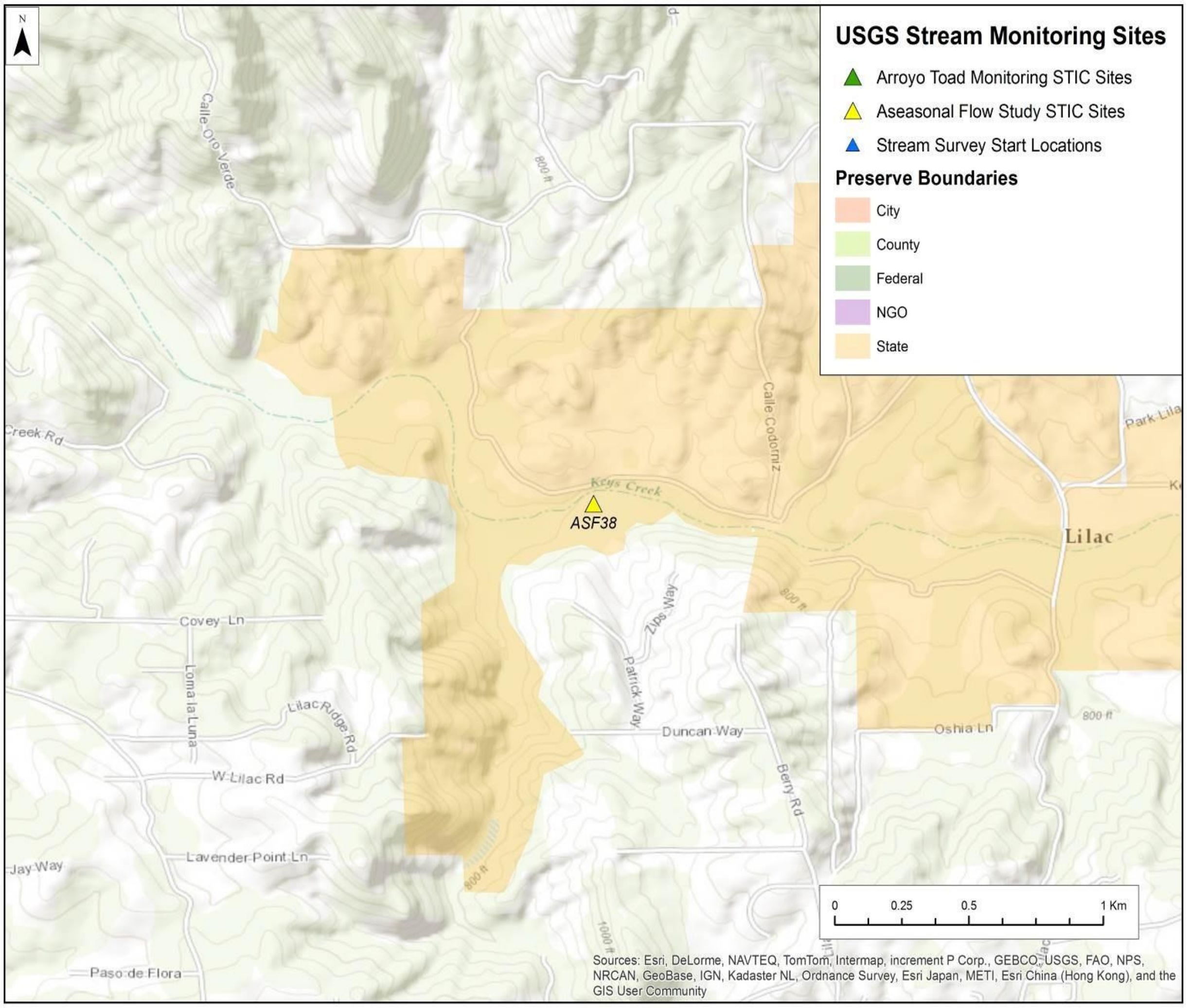

Figure A6a. ASF 38. Keys Creek in Lilac Ranch owned and managed by State of California, Caltrans.

Keys Creek (ASF 38)

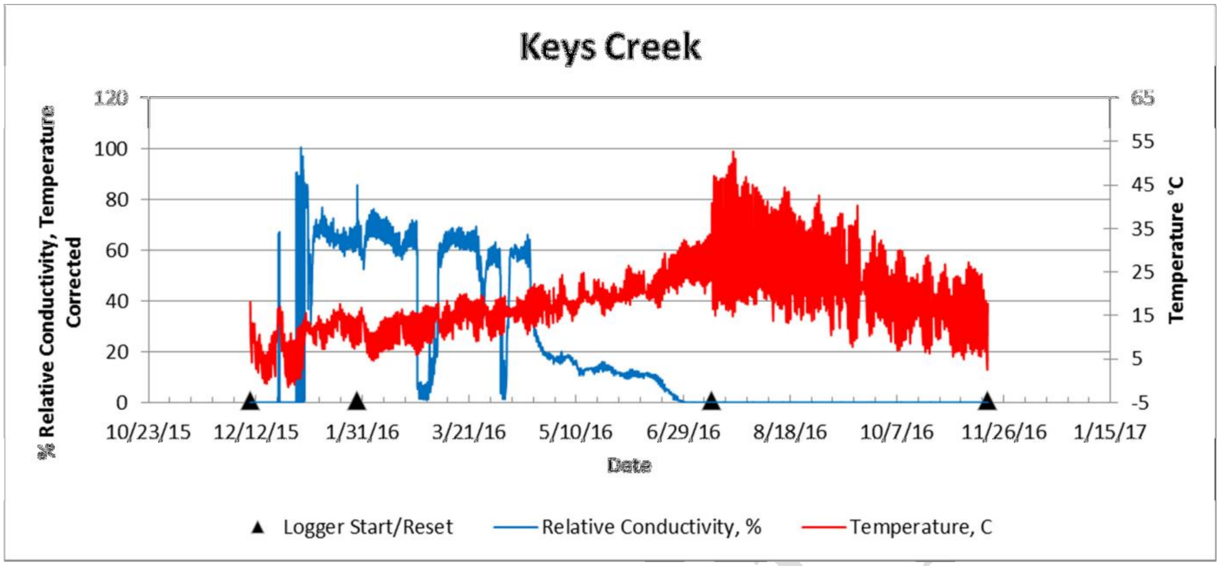

Figure A6b. Relative conductivity and temperature graph of Keys Creek (ASF 38)*.

Figure A6c. Habitat at Keys Creek (ASF 38) on 28 January 2016 (left) and on 12 July 2016 (right).

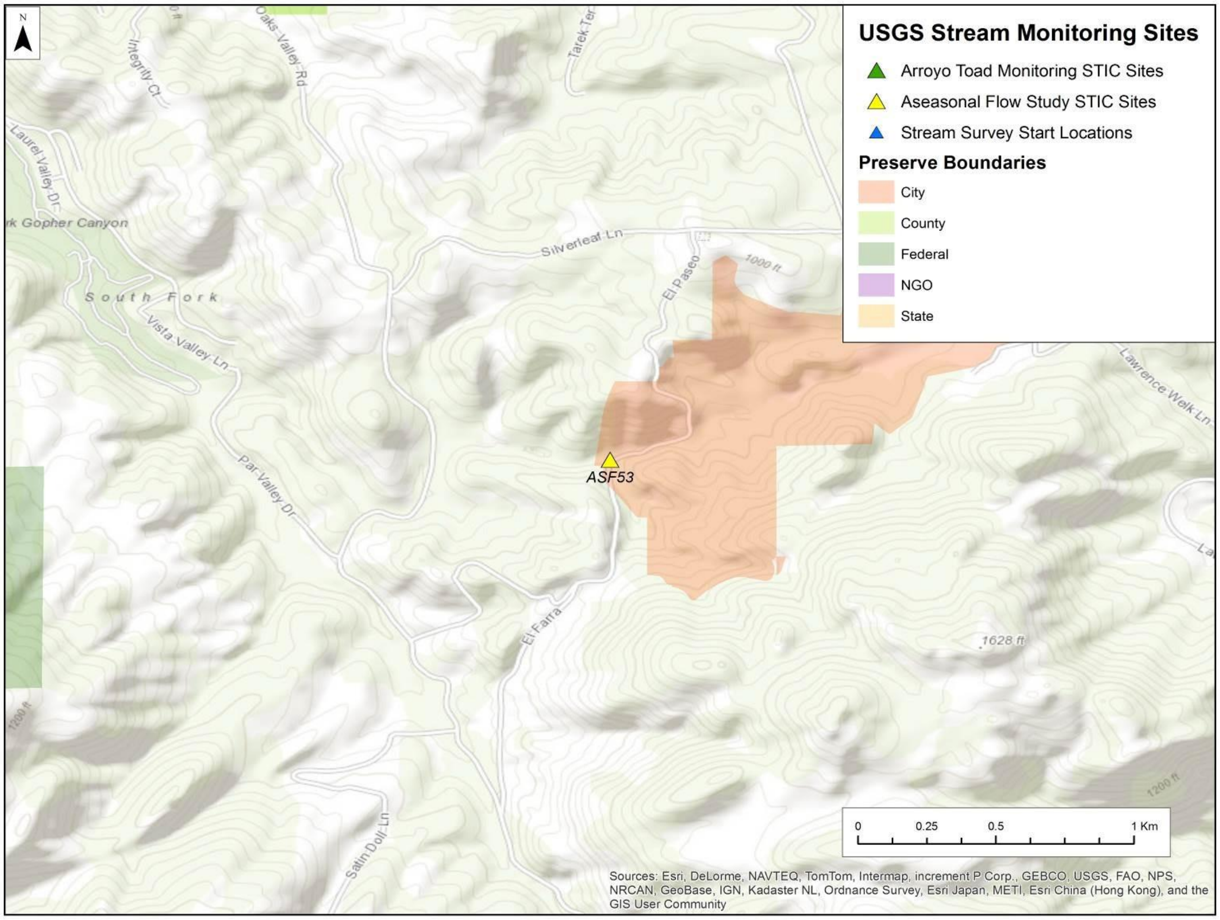

Figure A7a. ASF 53. Gopher Canyon tributary in Gopher Canyon Open Space owned and managed by City of Oceanside.

Gopher Canyon Tributary (ASF 53)

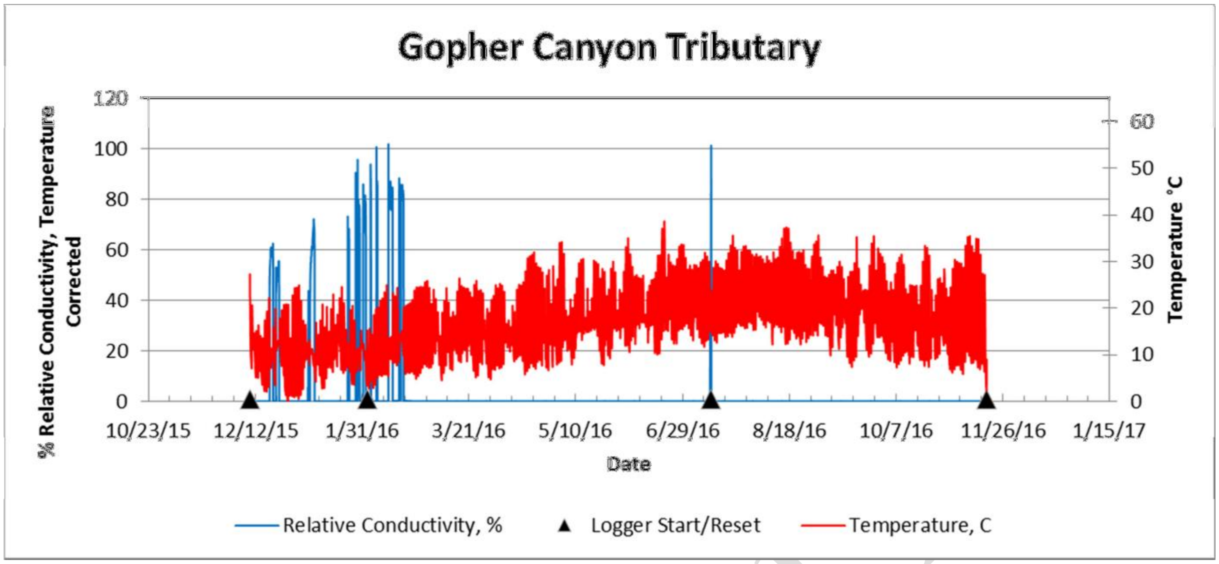

Figure A7b. Relative conductivity and temperature graph of Gopher Canyon Tributary (ASF 53)*.

Figure A7c. Habitat at Gopher Canyon Tributary (ASF 53) on 02 February 2016 (left) and on 12 July 2016 (right).

Buena Vista Creek Watershed

The mouth of the Buena Vista Creek Watershed is an open and recently restored estuary/lagoon, and the creek stretches upstream through urban development to water district and county open space lands. The watershed is approximately 5,642 hectares with approximately 323 hectares of conserved lands. We surveyed two sites along the main stem of this drainage. Most of the conserved riparian habitat in this watershed is owned by CDFW and the City of Vista with private conserved lands making up approximately 10 hectares. Much of the upper portion of the creek has been modified, including lined and fully encased channels. The creek receives large inputs from urban and agricultural runoff and heavy sediment and nutrient loads (Carlsbad Watershed Network 2002). Due to streambed alterations, increased runoff, and increased sediment associated with the large amount of urbanization, the main creek channel largely consisted of shallow stream with constant flow.

Buena Vista Creek Tributary (ASF 54).–ASF 54 was located in a small park along a tributary of Buena Vista Creek owned by the Vista Conservancy. The creek channel is surrounded by urbanization with high flow and sediment from urban runoff. Heavy recreation at this site includes hiking, picnicking, and bathing.

Buena Vista Creek (ASF 52).–ASF 52 was located on a section of Buena Vista Creek within the City of Vista's Buena Vista Creek Ecological Reserve. This small section of riparian habitat is surrounded by urban development and bordered by Highway 78 on the northwest side. Recreation is limited to hiking, but site use is heavy.

Buena Vista Creek Watershed (two ASF sites):

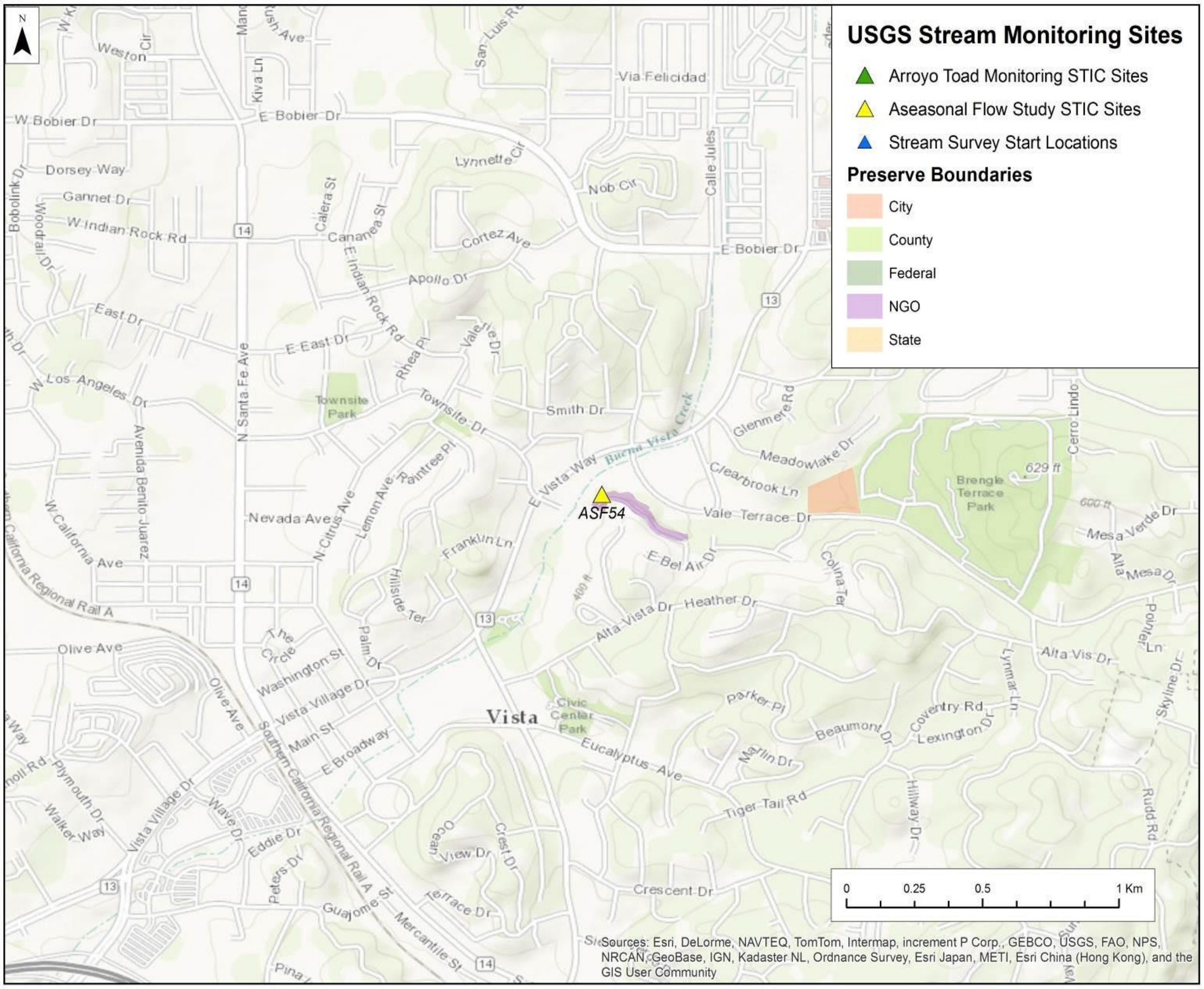

Figure A8a. ASF 54. Buena Vista Creek tributary in Buena Vista Creek Ecological Reserve owned and managed by Vista Conservancy.

Buena Vista Creek tributary (ASF 54)

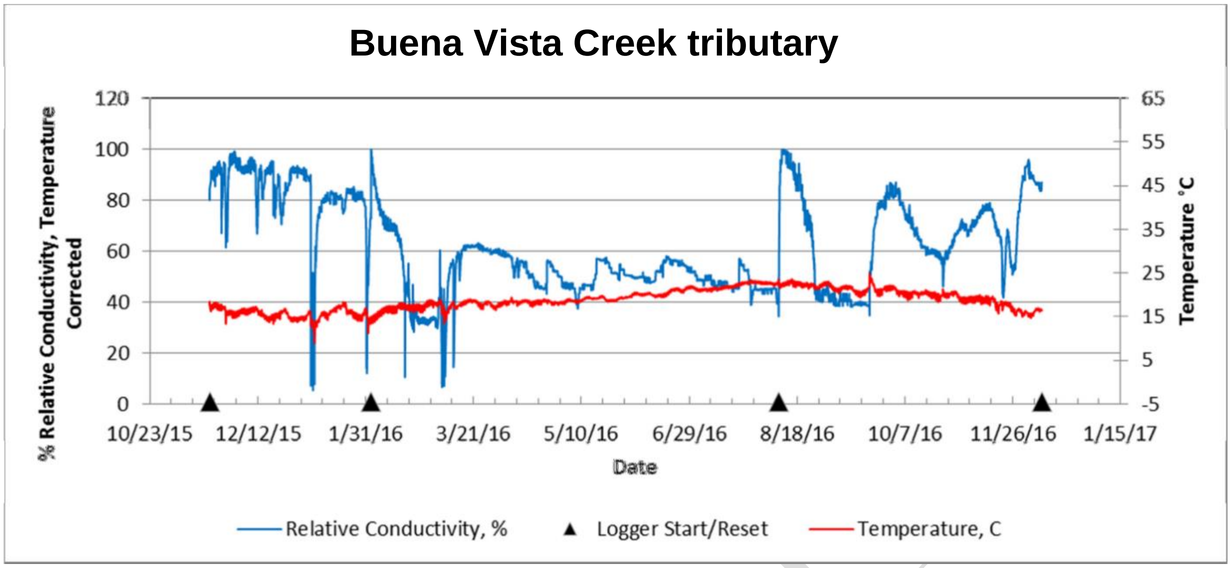

Figure A8b. Relative conductivity and temperature graph of Buena Vista Creek tributary (ASF 54).

Figure A8c. Habitat at Buena Vista Creek tributary (ASF 54) on 02 February 2016 (left) and on 09 December 2016 (right).

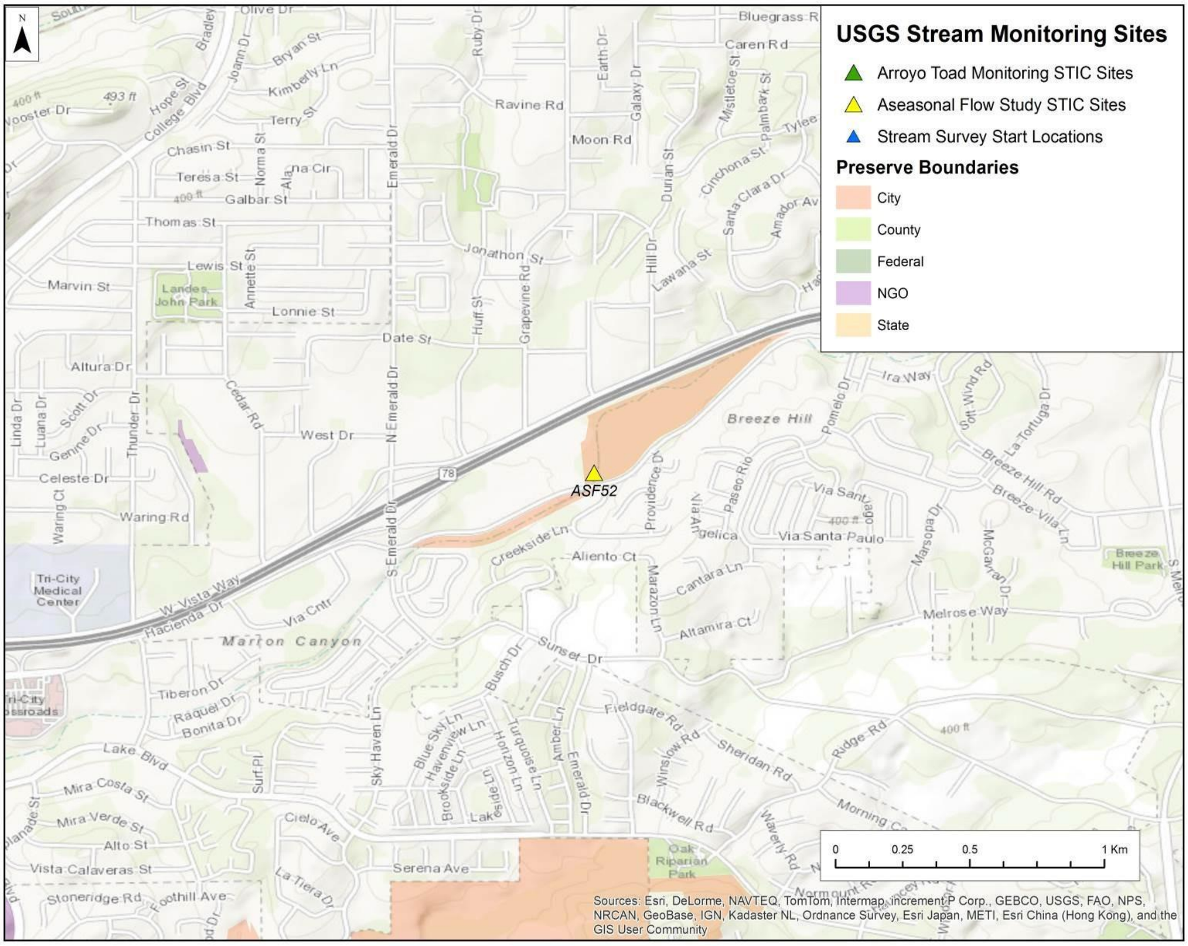

Figure A9a. ASF 52. Buena Vista Creek in Buena Vista Creek Ecological Reserve owned and managed by City of Vista.

Buena Vista Creek (ASF 52)

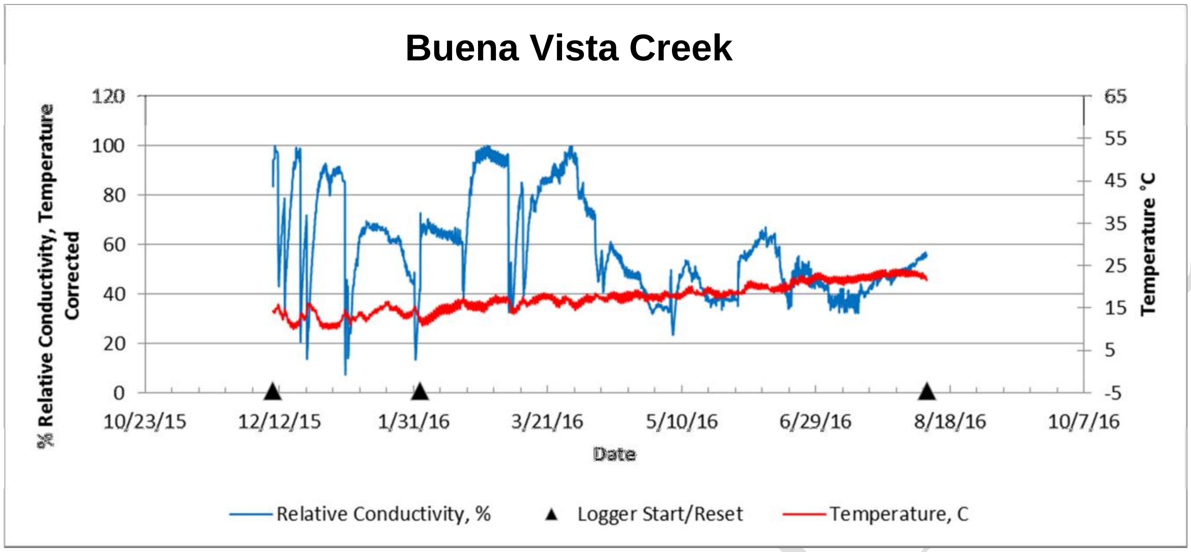

Figure A9b. Relative conductivity and temperature graph of Buena Vista Creek (ASF 52).

Figure A9c. Habitat at Buena Vista Creek (ASF 52) on 02 February 2016 (left) and on 09 August 2016 (right).

Agua Hedionda Creek Watershed

The Agua Hedionda Creek watershed within our study area encompasses approximately 7,684 hectares. The mouth of Agua Hedionda Creek is an open estuary/lagoon similar to Buena Vista Creek, and the creek stretches upstream through urban areas, then water district and county open space, with approximately 1,232 hectares of conserved lands. Within this watershed, we surveyed one site along Calavera Creek. Open space land managers of this watershed are University of California San Diego, San Diego County, CNLM, CDFW, and the cities of Carlsbad, San Marcos, and Escondido. Most of the conserved land is managed by these entities in combination with the public works or municipal water departments.

Upper Calavera Creek (ASF 27).–ASF 27 was located on Upper Calavera Creek. This site, located in the cities of Carlsbad and Oceanside, consists of approximately 1.3 kilometers of Calavera Creek riparian habitat upstream from Lake Calavera. The site is conserved riparian owned by City of Carlsbad and managed by CNLM. Calavera Creek meanders through nearly 75 hectares of conserved riparian with urban residential development on three sides, then drains into a marsh at the northeast end of the lake. While habitat restoration at the site is ongoing, recreation includes hiking, biking, and fishing, and public access is high.

Agua Hedionda Creek Watershed (one ASF site):

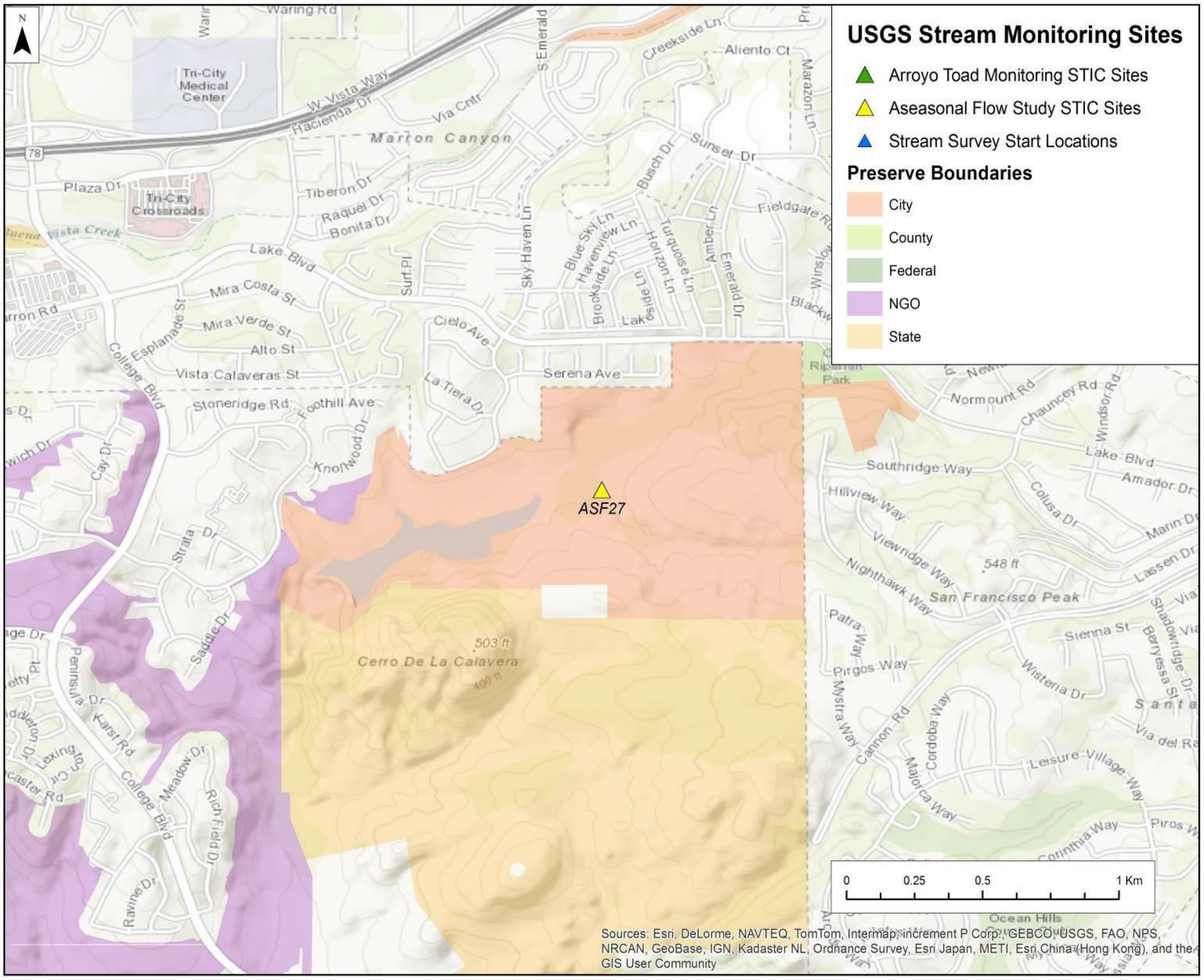

Figure A10a. ASF 27. Upper Calavera Creek is on land owned by City of Carlsbad and managed by Center for Natural Lands Management. It is covered in the Carlsbad Habitat Management Plan (1999).

Upper Calavera Creek (ASF 27)

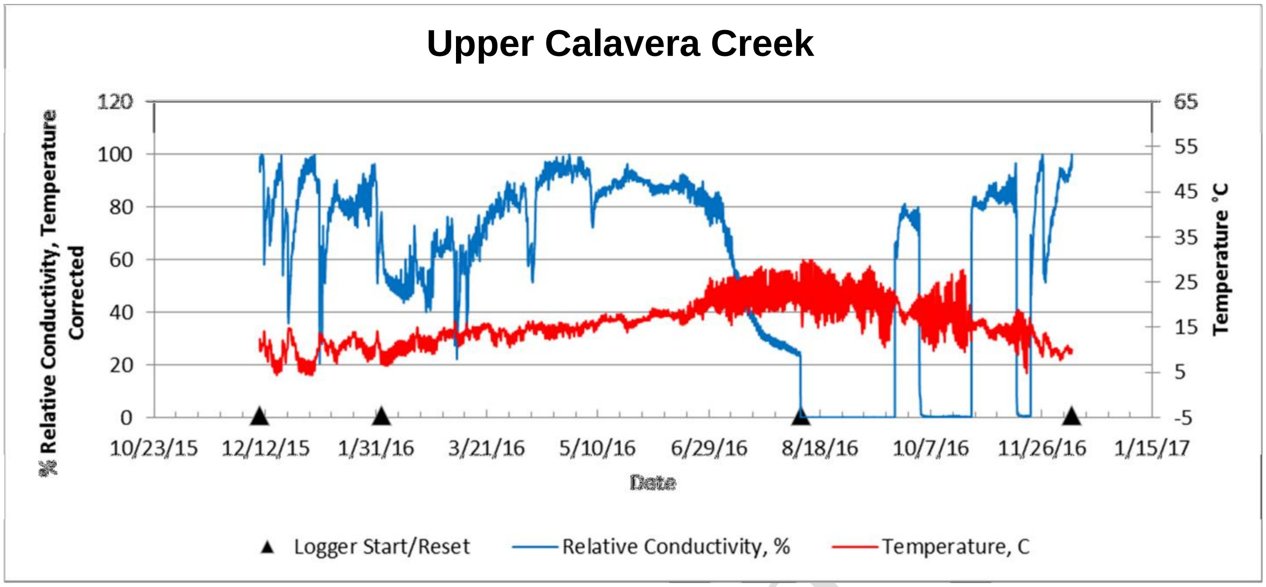

Figure A10b. Relative conductivity and temperature graph of Upper Calavera Creek (ASF 27).

Figure A10c. Habitat at Upper Calavera Creek (ASF 27) on 9 December 2015 (left) and on 09 August 2016 (right).

San Marcos Creek Watershed

The San Marcos Creek Watershed encompasses approximately 13,859 hectares, with approximately 1,511 hectares conserved along the main stem and flowing tributaries. We surveyed one site along a tributary to San Marcos Creek at the most upstream portion of Batiquitos Lagoon Ecological Reserve. The principal open space land managers within this watershed include CNLM, CDFW, and the City of San Marcos. Lake San Marcos is a private, recreational lake near the middle of the watershed. Above the lake, upper San Marcos Creek has very little associated conserved land (less than 50 hectares along the stream). Below the lake, CNLM manages over 5 kilometers of stream with lush riparian, large boulder strewn pools, and restricted access before the creek enters the La Costa Resort and Spa. The creek then enters Batiquitos Lagoon with over 50 hectares of mixed freshwater and brackish marsh.

Batiquitos Lagoon tributary (ASF 25).–ASF 25 was located on a tributary at the southwestern most section of the Batiquitos Lagoon Ecological Reserve in dense riparian habitat downstream from large urban developments. The relatively small watershed for this tributary contains over 80% urban land cover. The Batiquitos Lagoon Ecological Reserve, owned and managed by CDFW, has controlled access, limiting recreation to hiking and birdwatching along a few well maintained trails.

San Marcos Creek Watershed (one ASF sites):

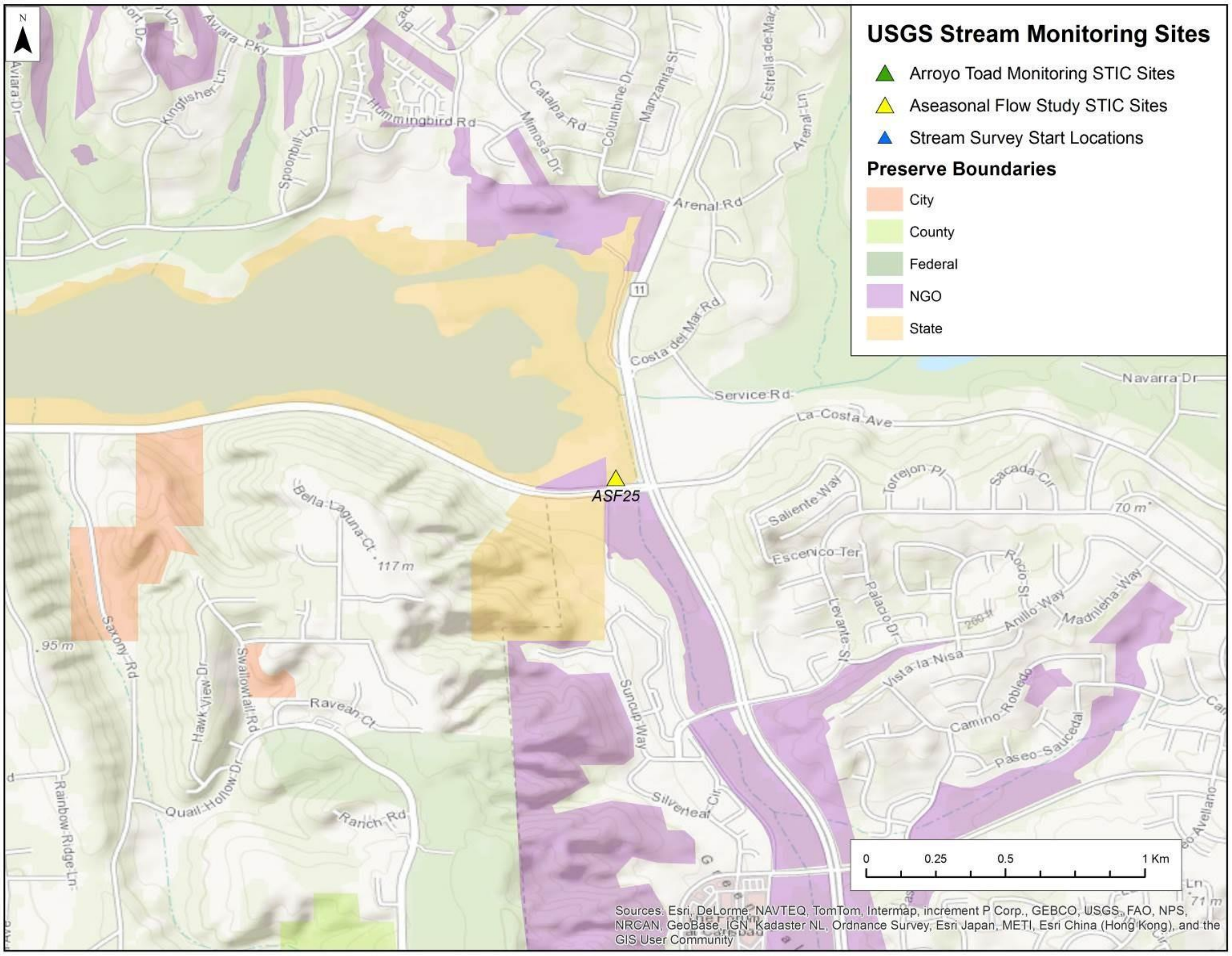

Figure A11a. ASF 25. Batiquitos Lagoon tributary in Batiquitos Lagoon Ecological Reserve owned and managed by CDFW.

San Marcos Creek Watershed

Batiquitos Lagoon tributary (ASF 25)

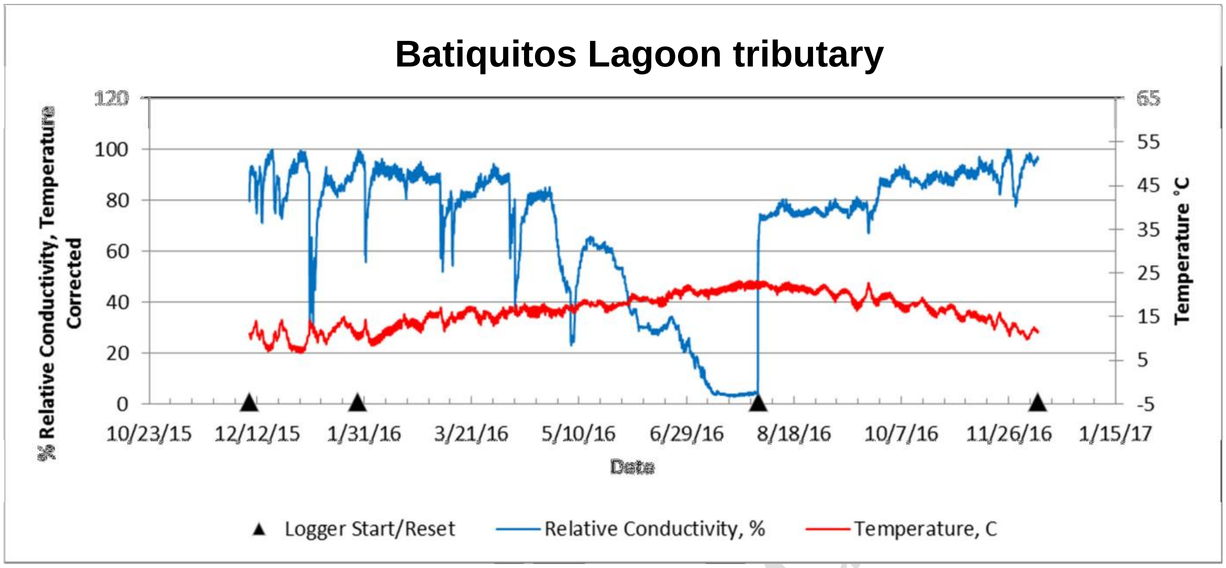

Figure A11b. Relative conductivity and temperature graph of Batiquitos Lagoon tributary (ASF 25).

Figure A11c. Habitat at Batiquitos Lagoon tributary (ASF 25) on 28 January 2016 (left) and on 09 December 2016 (right).

<u>Escondido Creek Watershed</u>

Escondido Creek Watershed is the second largest watershed in the study area and the largest in the Carlsbad Hydrologic Unit. The watershed is approximately 21,952 hectares with approximately 4,450 hectares of conserved lands. We surveyed two sites along Escondido Creek. Open space land managers include Olivenhain Municipal Water District, San Diego County, CNLM, Escondido Creek Conservancy (ECC), CDFW, and the cities of San Diego and Escondido.

Escondido Creek tributary (ASF 33).–ASF 33 was located upstream from Dixon Lake, at a site in the Daley Ranch Open Space Preserve owned and managed by the City of Escondido. This small watershed consists of primarily coastal sage scrub and chaparral with some agriculture and urban land cover. Recreation is limited to hiking and biking on few well maintained trails.

Escondido Creek (ASF 31).–ASF 31 was located on a section of Escondido Creek in the community of Harmony Grove in the City of Escondido, owned and managed by Escondido Creek Conservancy (ECC). This section of low gradient, wide, boulder lined stream has a relatively closed canopy of sycamore. Even though the creek parallels the adjacent community's main road, under current management by ECC, recreation appears to be limited to hiking and picnicking on established trails.

Escondido Creek Watershed (two ASF sites):

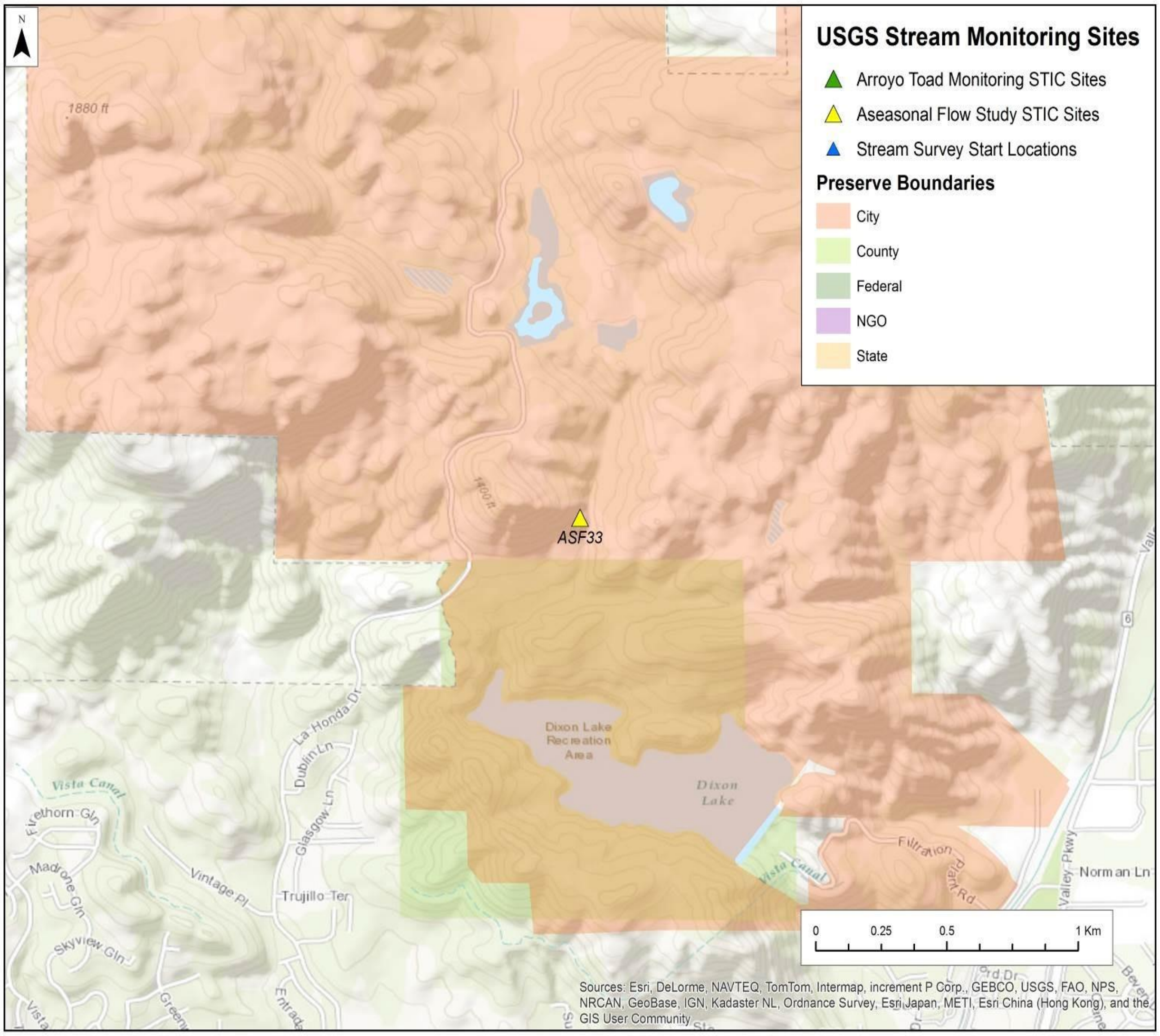

Figure 12a. AASF 33. Escondido Creek tributary in Daley Ranch Open Space Preserve owned and managed by City of Escondido.

Escondido Creek Tributary (ASF 33)

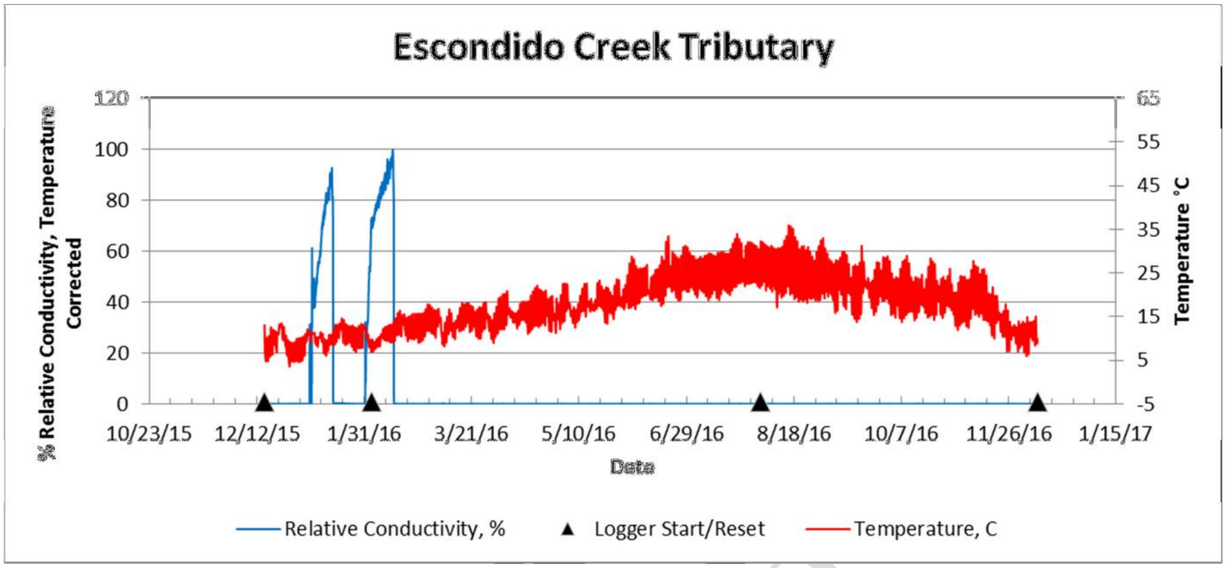

Figure A12b. Relative conductivity and temperature graph of Escondido Creek Tributary (ASF 33)*.

Figure A12c. Habitat at Escondido Creek Tributary (ASF 33) on 15 December 2015 (left) and on 09 December 2016 (right).

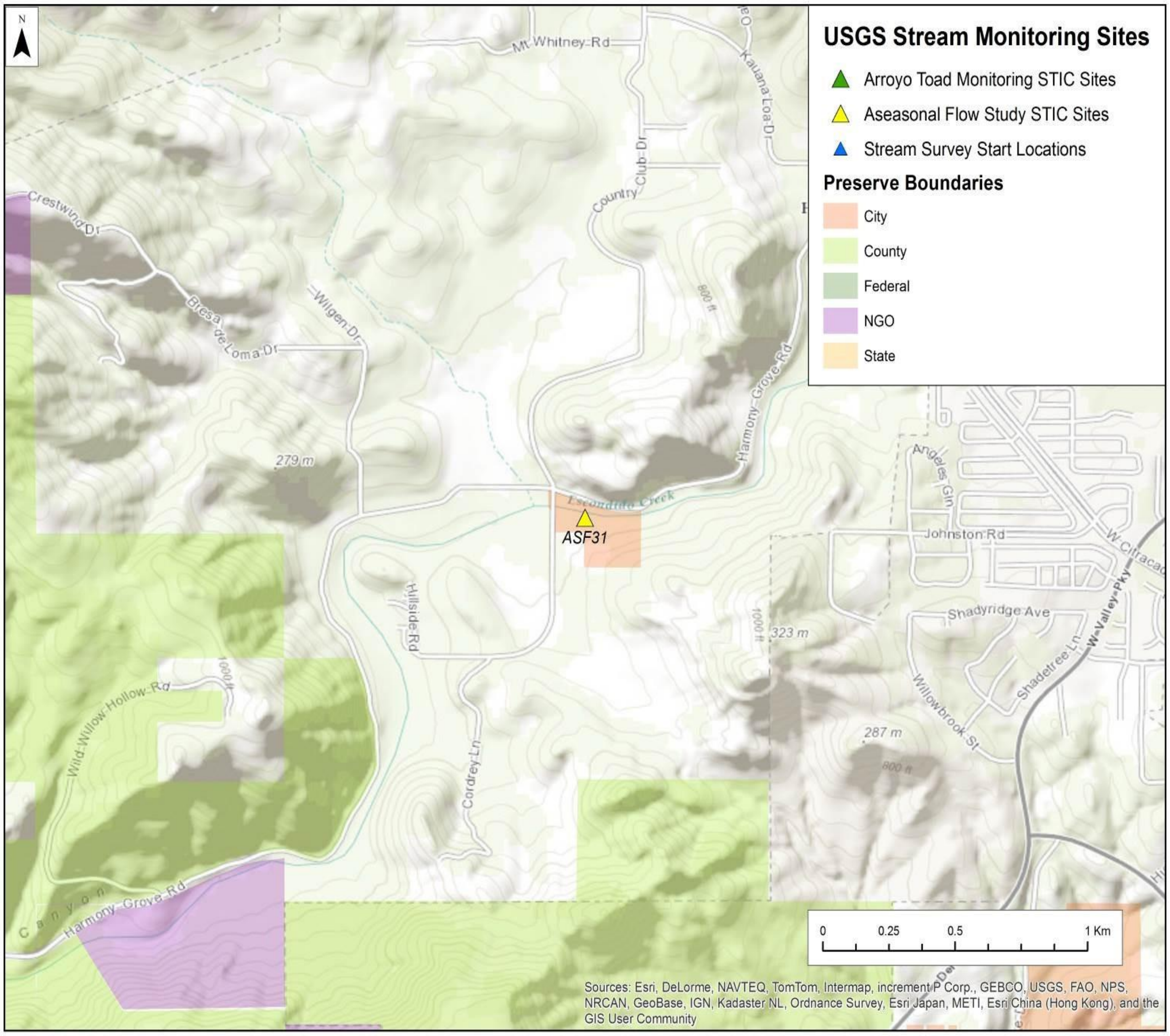

Figure A13a. ASF 31. Escondido Creek in Escondido Creek Preserve owned and managed by City of San Diego and Escondido Creek Conservancy.

Escondido Creek (ASF 31)

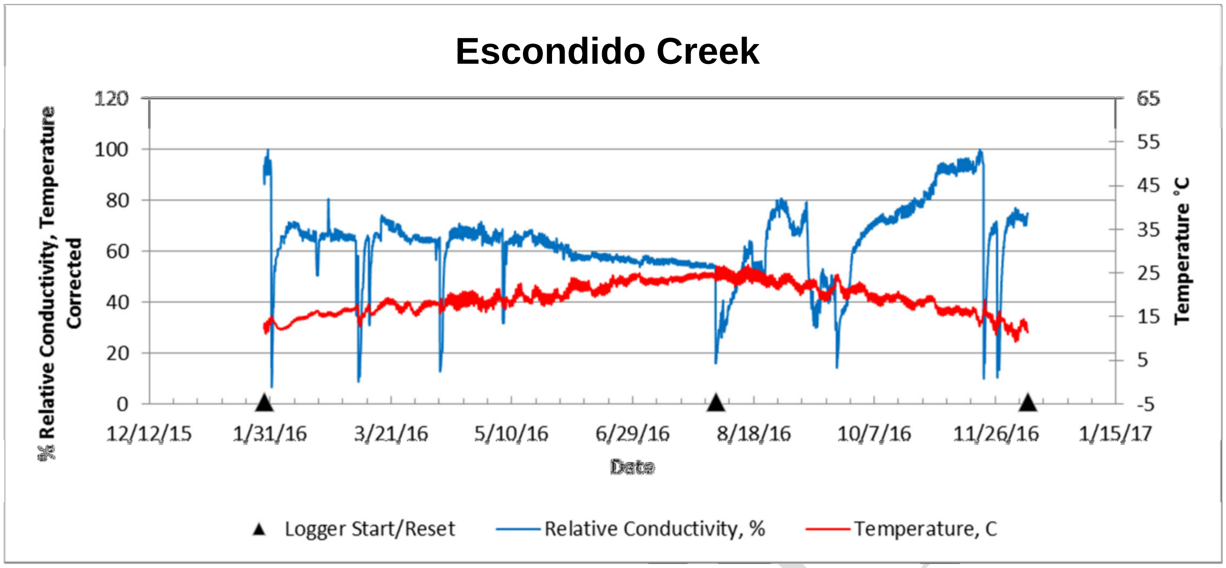

Figure A13b. Relative conductivity and temperature graph of Escondido Creek (ASF 31).

Figure A13c. Habitat at Escondido Creek (ASF 31) on 28 January 2016 (left) and on 09 December 2016 (right).

San Dieguito River Watershed

San Dieguito River Watershed encompasses approximately 89,422 hectares with approximately 26,715 hectares of conserved lands. The San Diego River flows 88 kilometers from Volcan Mountain near Julian to the Pacific Ocean. Habitat within the watershed includes mixed conifer, oak woodland, chaparral, coastal sage scrub, and grasslands as well as riparian. Previously established arroyo toad monitoring sites include 15 surface water monitoring sites along Santa Ysabel Creek and associated tributaries (Brown et al. 2019). This study adds a total of five surface water monitoring sites along tributaries to Santa Ysabel Creek and San Dieguito River. The conserved lands in this area are primarily owned by the City of San Diego, County of San Diego, USFS, San Dieguito River Conservancy, and local homeowner's associations.

Santa Maria Creek (ASF 39).–This site in Ramona Grasslands Open Space Preserve along a tributary to Santa Maria Creek adds to a network of seven additional arroyo toad monitoring locations along the main stem of Santa Maria Creek. The preserve is owned and maintained by County of San Diego and recreation is limited to hiking and biking.

Green Valley (ASF 40).–This site between Lake Ramona and Lake Poway is in Green Valley, a tributary to the San Dieguito River, and is surrounded predominately by coastal sage scrub, recreational park lands, agriculture, and low density rural community. This portion of the reserve is owned and maintained by the County of San Diego and has limited access though the adjacent recreation area that has one well maintained and traveled trail.

Lusardi Creek 1 (ASF 23).–This site in Lusardi Creek above the reservoir is the highest section of Lusardi Creek in conserved lands. The land is owned and managed by the 4-S Ranch Masters Association and County of San Diego. The habitat downstream is dominated by riparian, coastal sage scrub, and chaparral, but the upper reaches of Lusardi Creek are surrounded by medium-density urban development.

Lusardi Creek 2 (ASF 24).–This site on Lower Lusardi Creek is below both 4S-Ranch reservoirs and is in City of San Diego's Black Mountain Open Space Preserve. Upland habitat is dominated by grasses, coastal sage scrub, and chaparral, and recreation is restricted to hiking and biking.

Gonzales Canyon (ASF 22).–This site in Gonzales Canyon is at the most downstream reach of the stream within the City of San Diego's Del Mar Heights Preserve. The dominant land cover for this watershed includes chaparral, coastal sage scrub, historic agriculture, and urban.

San Dieguito River Watershed (five ASF sites):

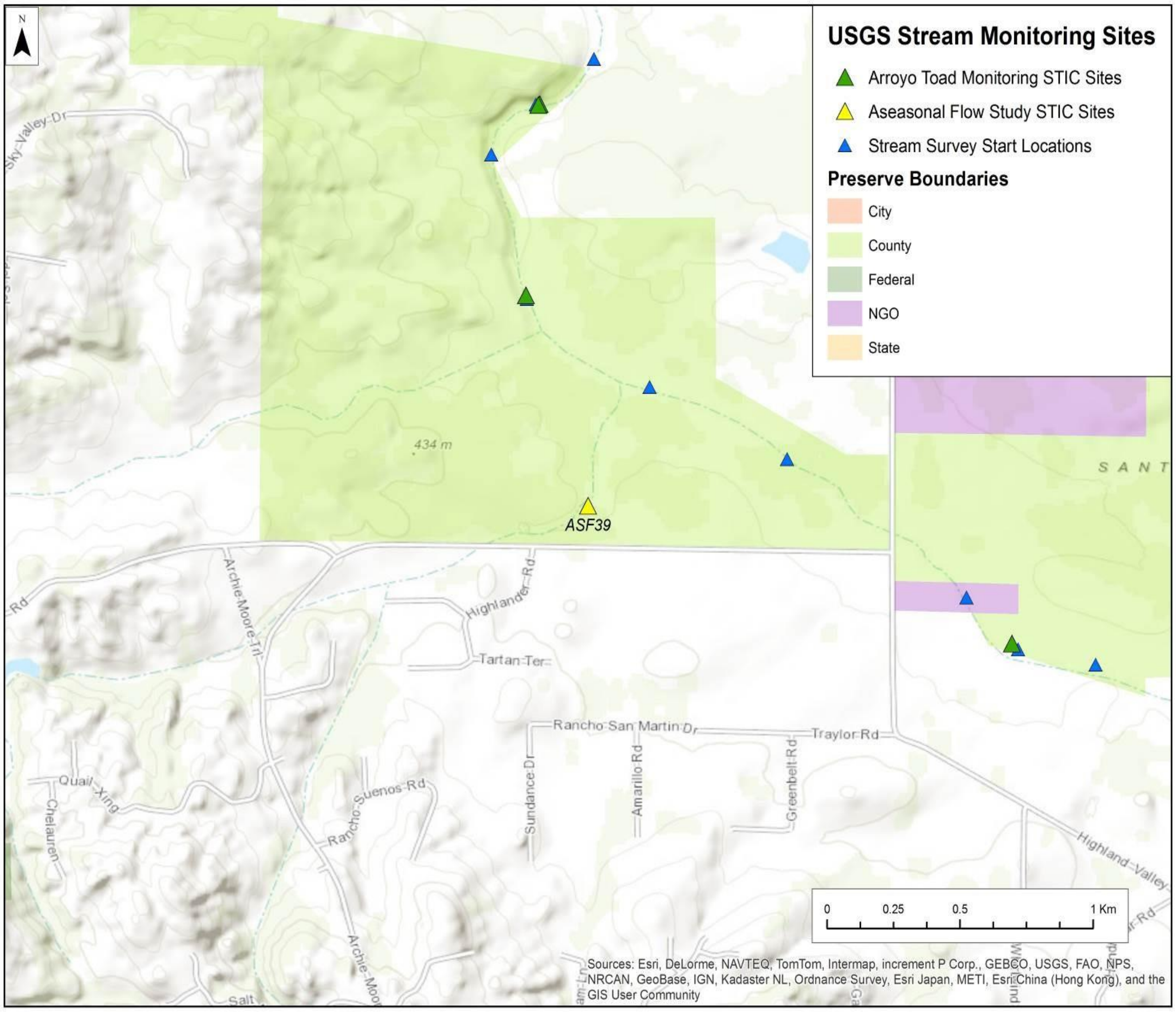

Figure A14a. ASF 39. Santa Maria Creek tributary in Ramona Grasslands Preserve owned and managed by County of San Diego.

San Dieguito River Watershed

Santa Maria Creek (ASF 39)

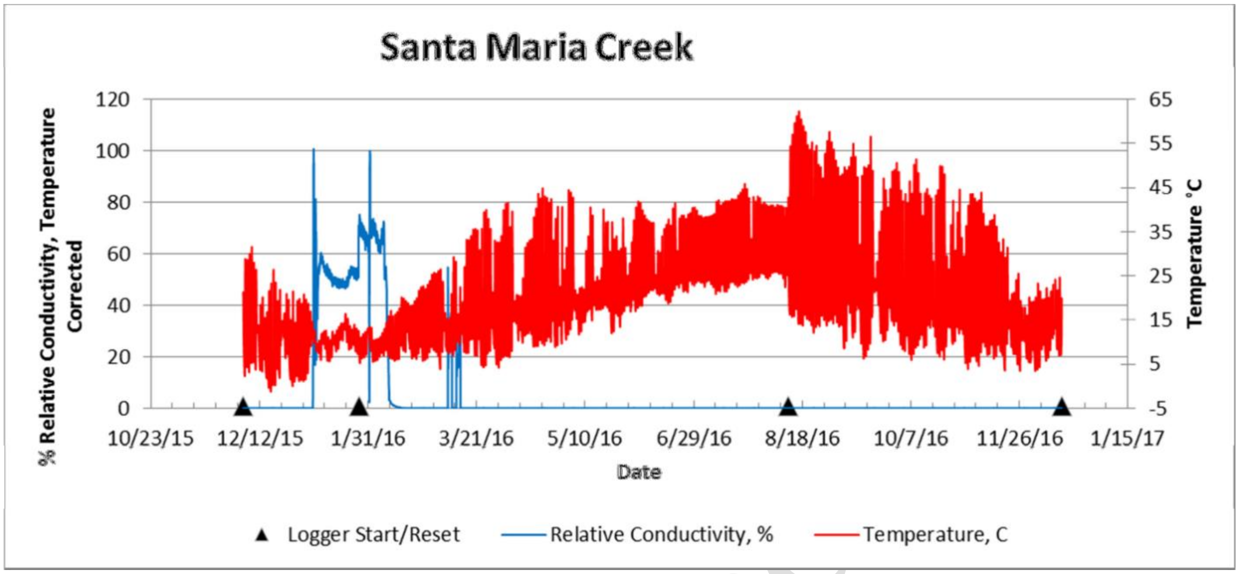

Figure A14b. Relative conductivity and temperature graph of Santa Maria Creek (ASF 39)*.

Figure A14c. Habitat at Santa Maria Creek (ASF 39) on 26 January 2016 (left) and on 15 December 2016 (right).

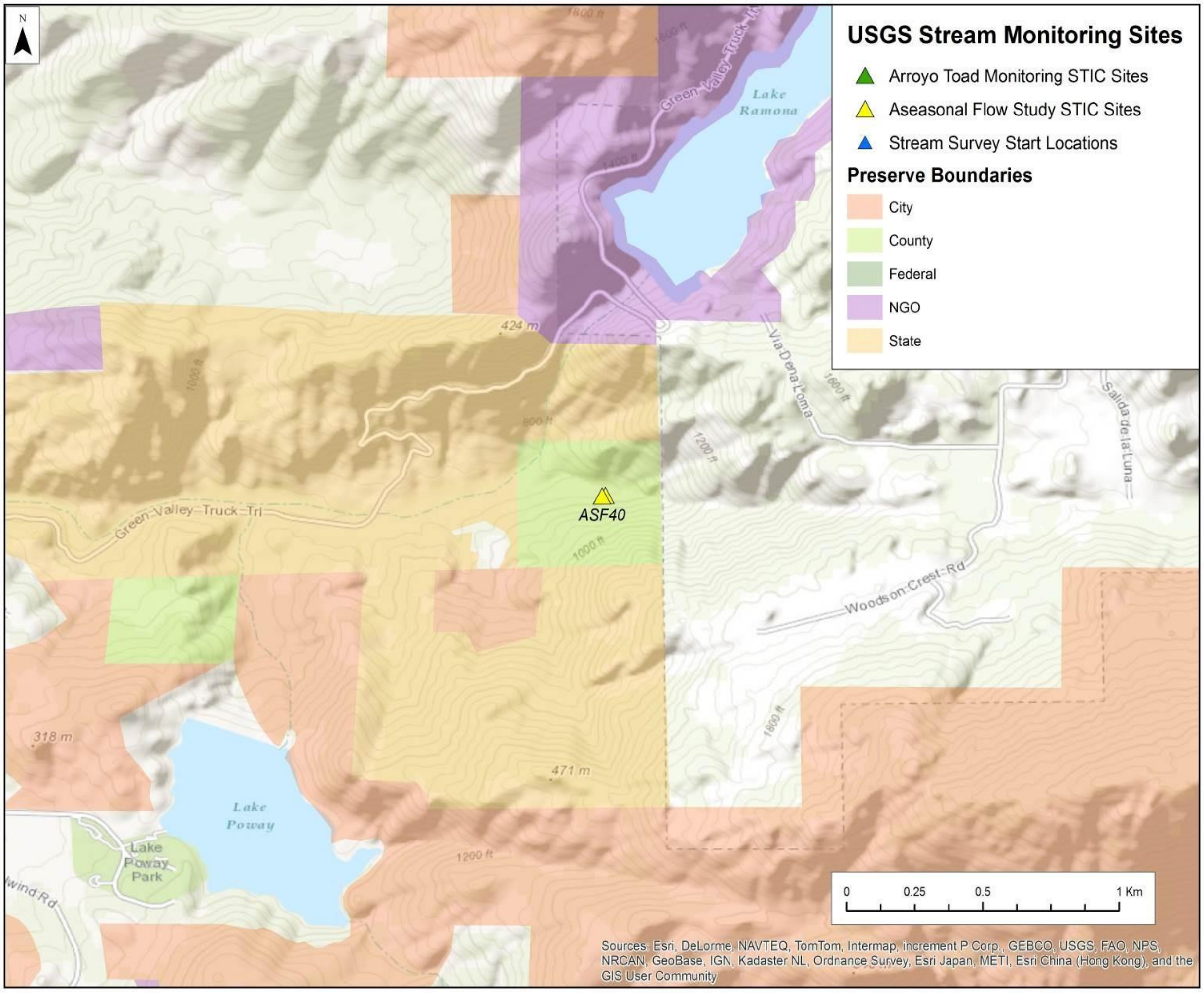

Figure A15a. ASF 40. Green Valley in Blue Sky Ecological Reserve owned and managed by County of San Diego.

Green Valley (ASF 40)

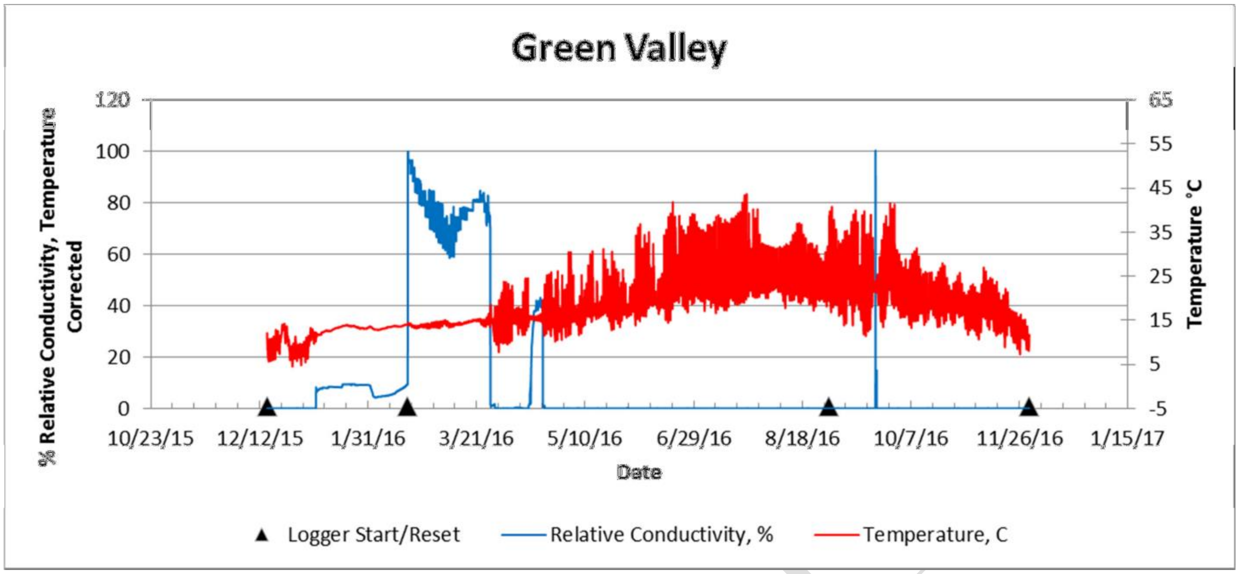

Figure A15b. Relative conductivity and temperature graph of Green Valley (ASF 40)*.

Figure A15c. Habitat at Green Valley (ASF 40) on 18 February 2016 (left) and on 30 August 2016 (right).

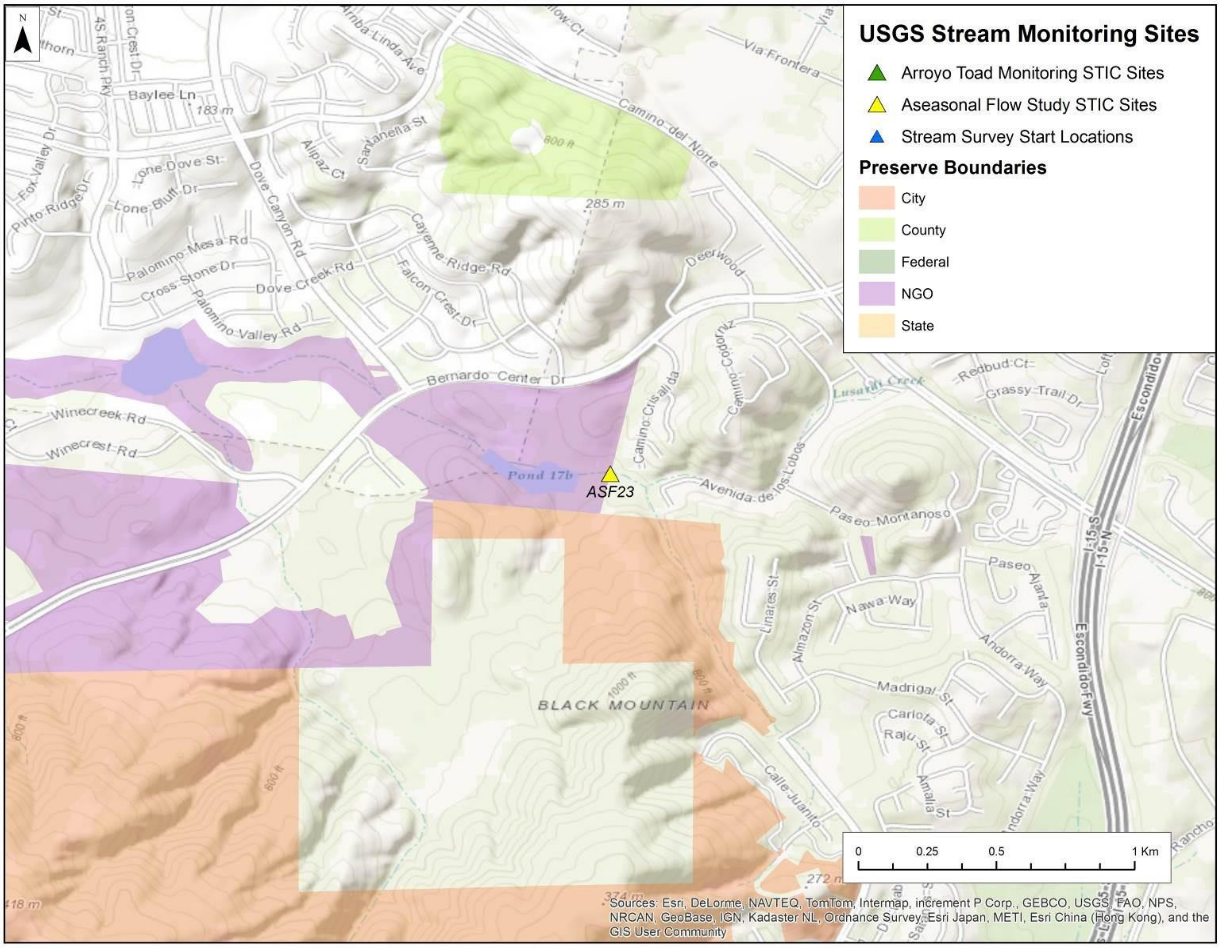

Figure A16a. ASF 23. Lusardi Creek 1 in 4-S Ranch HOA owned and managed by 4-S Ranch Masters Association and County of San Diego.

Lusardi Creek 1 (ASF 23)

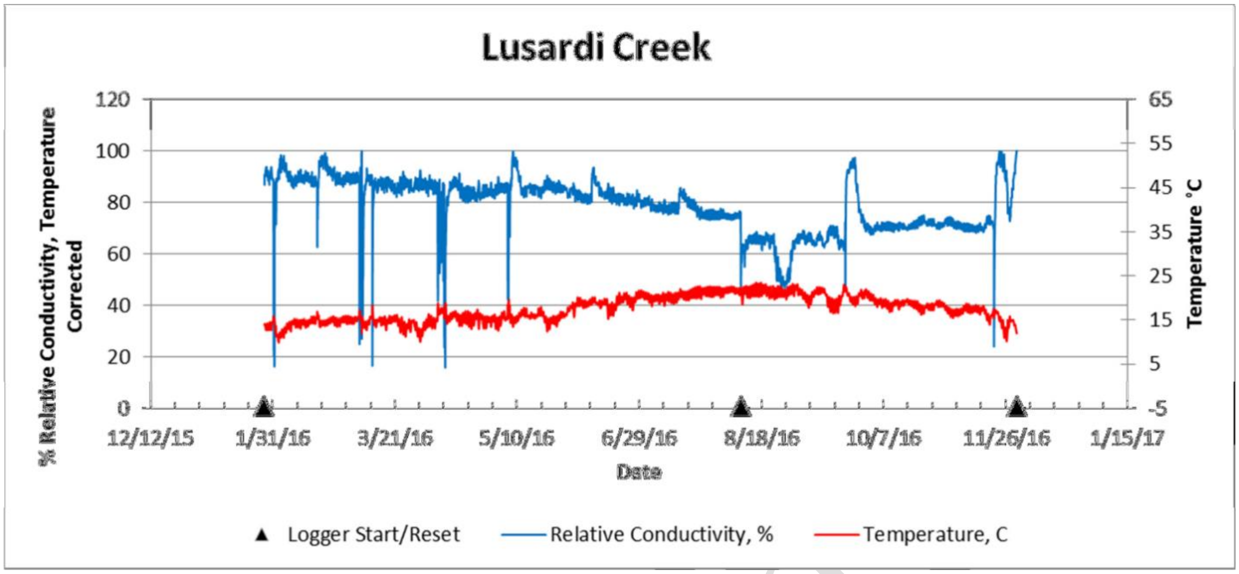

Figure A16b. Relative conductivity and temperature graph of Lusardi Creek 1 (ASF 23).

Figure A16c. Habitat Lusardi Creek 1 (ASF 23) on 27 January 2016 (left) and on 09 August 2016 (right).

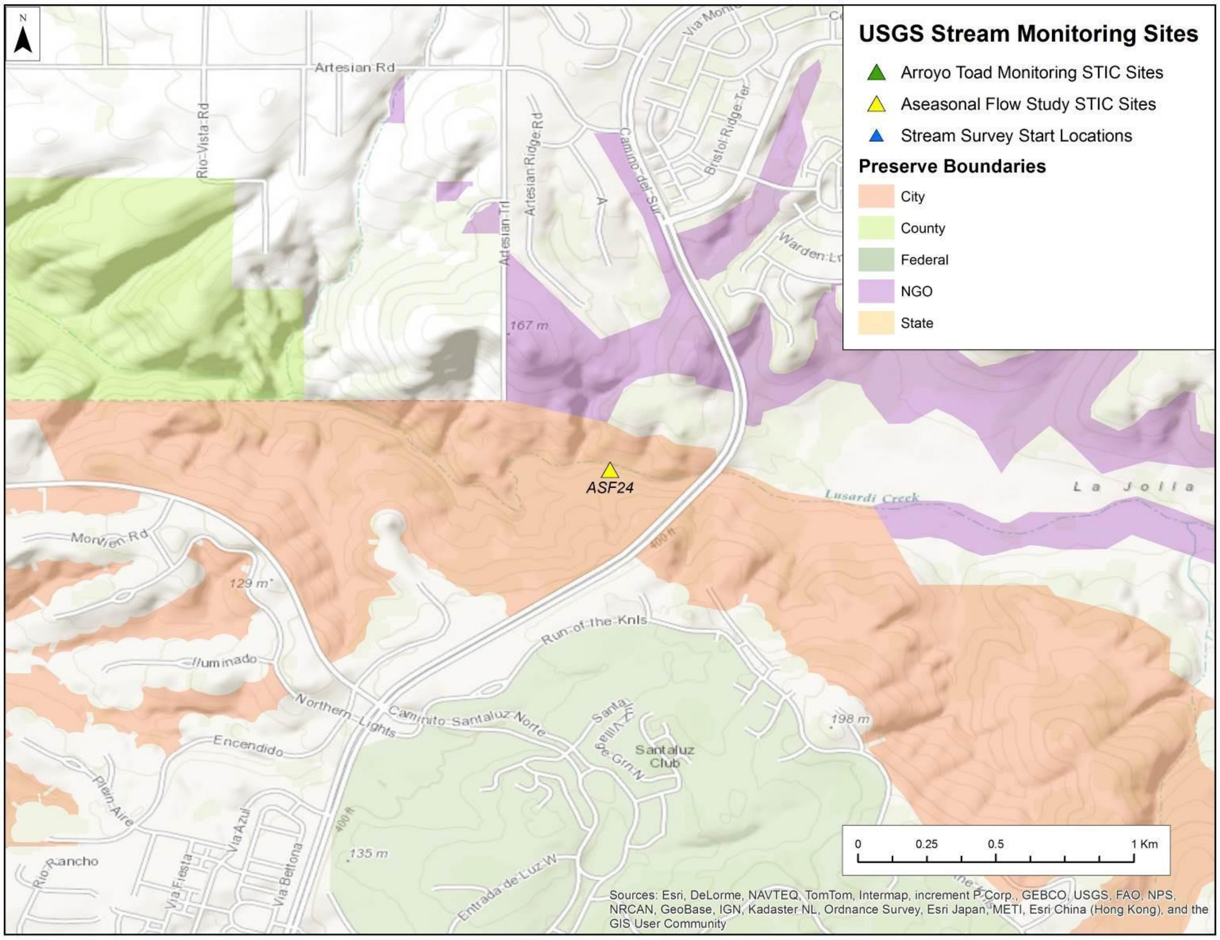

Figure A17a. ASF 24. Lusardi Creek 2 in Black Mountain Open Space Preserve owned and managed by City of San Diego.

Lusardi Creek 2 (ASF 24)

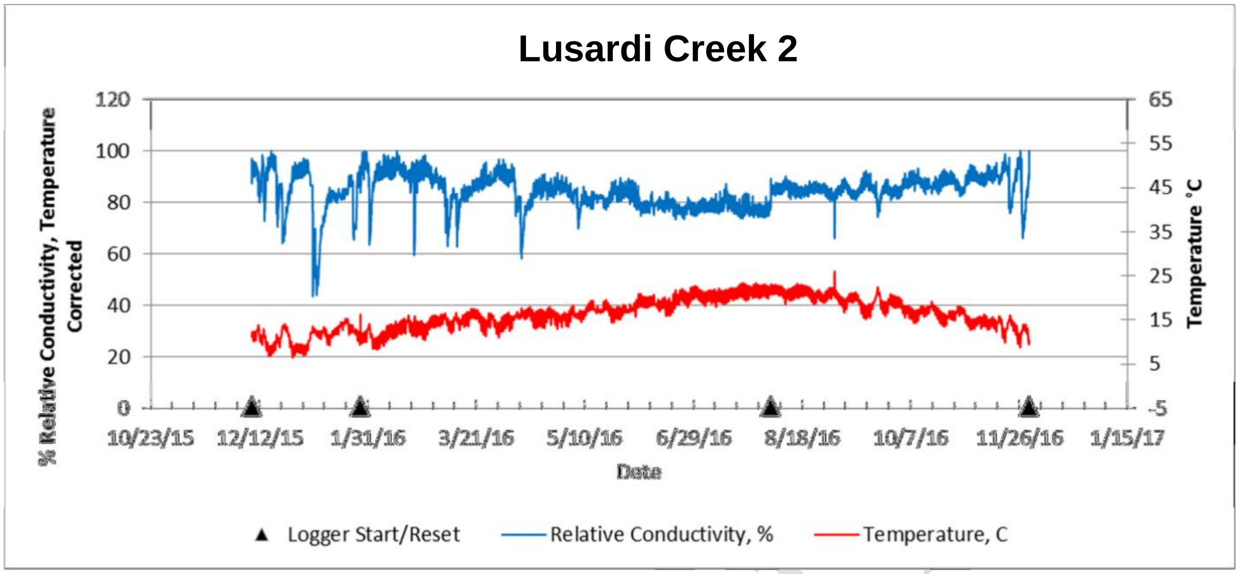

Figure A17b. Relative conductivity and temperature graph of Lusardi Creek 2 (ASF 24).

Figure A17c. Habitat at Lusardi Creek 2 (ASF 24) on 27 January 2016 (left) and on 30 November 2016 (right).

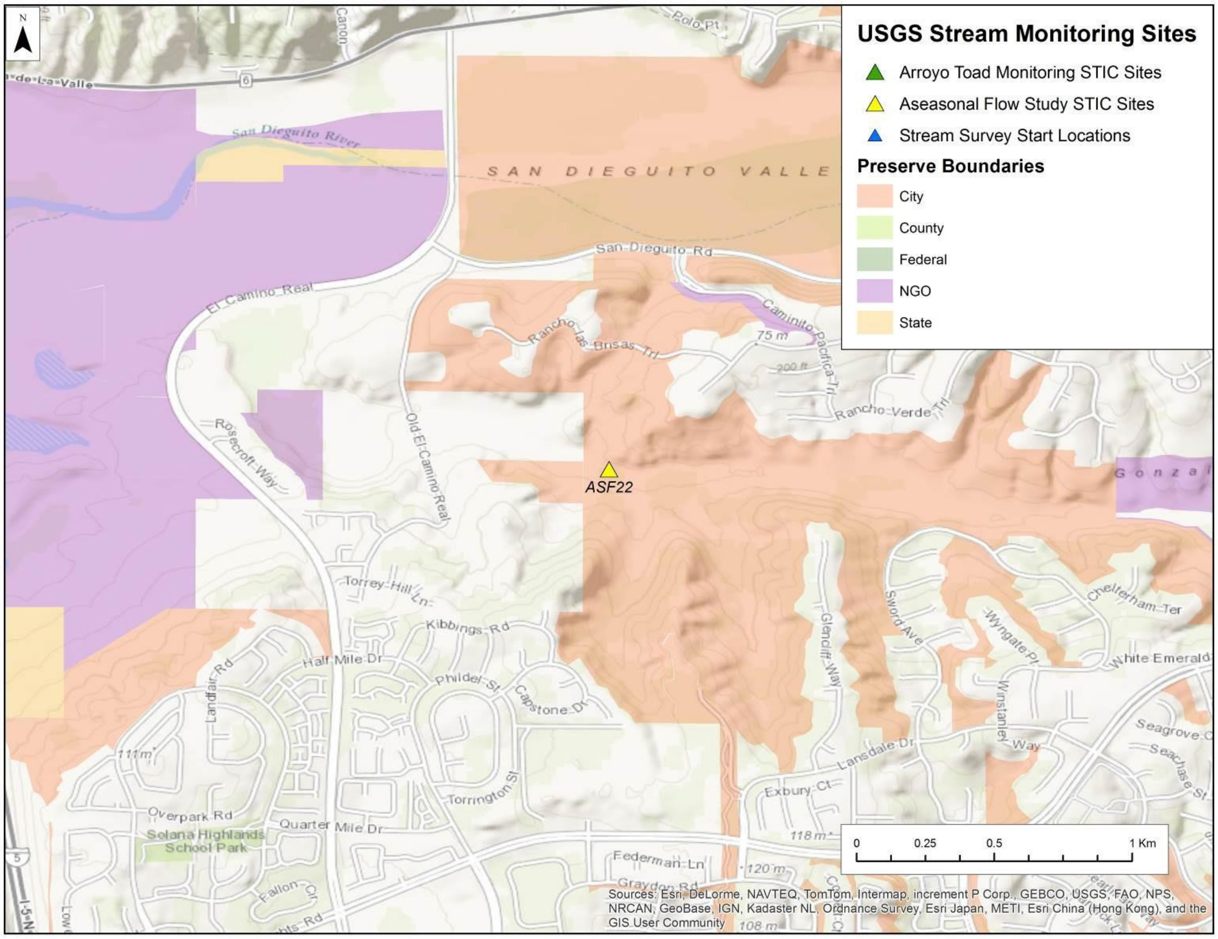

Figure A18a. ASF 22. Gonzales Canyon in Del Mar Heights Preserve owned and managed by City of San Diego.

Gonzales Canyon (ASF 22)

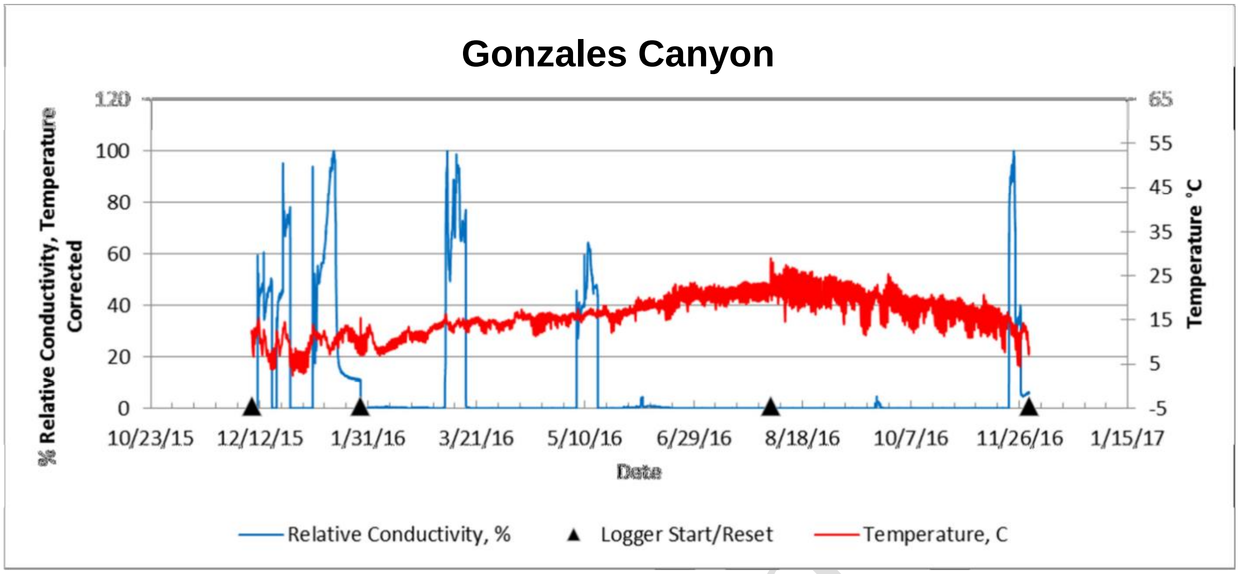

Figure A18b. Relative conductivity and temperature graph of Gonzales Canyon (ASF 22)*.

Figure A18c. Habitat at Gonzales Canyon (ASF 22) on 08 December 2015 (left) and on 27 January 2016 (right).

Los Penasquitos Creek Watershed

The Los Penasquitos Creek Watershed encompasses nearly 24,384 hectares of highly urbanized coastal San Diego County, with approximately 5,807 hectares of conserved lands. The watershed drains out through Los Penasquitos Lagoon in Torrey Pines State Park. We surveyed three sites along Los Penasquitos Creek and associated tributaries. Open space land mangers include the Cities of San Diego and Poway and County of San Diego.

Carroll Canyon (ASF 37).–This sand and cobble wash through chaparral and coastal sage scrub in the City of San Diego's Carroll Canyon Preserve is surrounded by urban development which makes up approximately 90% of the watershed's land cover. The urban development is a mix of medium to high density residential and office park with larger amounts of open, paved parking lot.

Los Penasquitos Preserve (ASF 21 and ASF 60).–ASF 21 in Sorrento Valley and ASF 60 in Los Penasquitos Creek are both within the City of San Diego's Los Penasquitos Canyon Preserve. The open space reserve provides recreation for hiking and mountain biking on well maintained and traveled trails. The large preserve contains riparian, chaparral, and coastal sage scrub, with much of the surroundings being urban land cover.

Los Penasquitos Creek Watershed (three ASF sites):

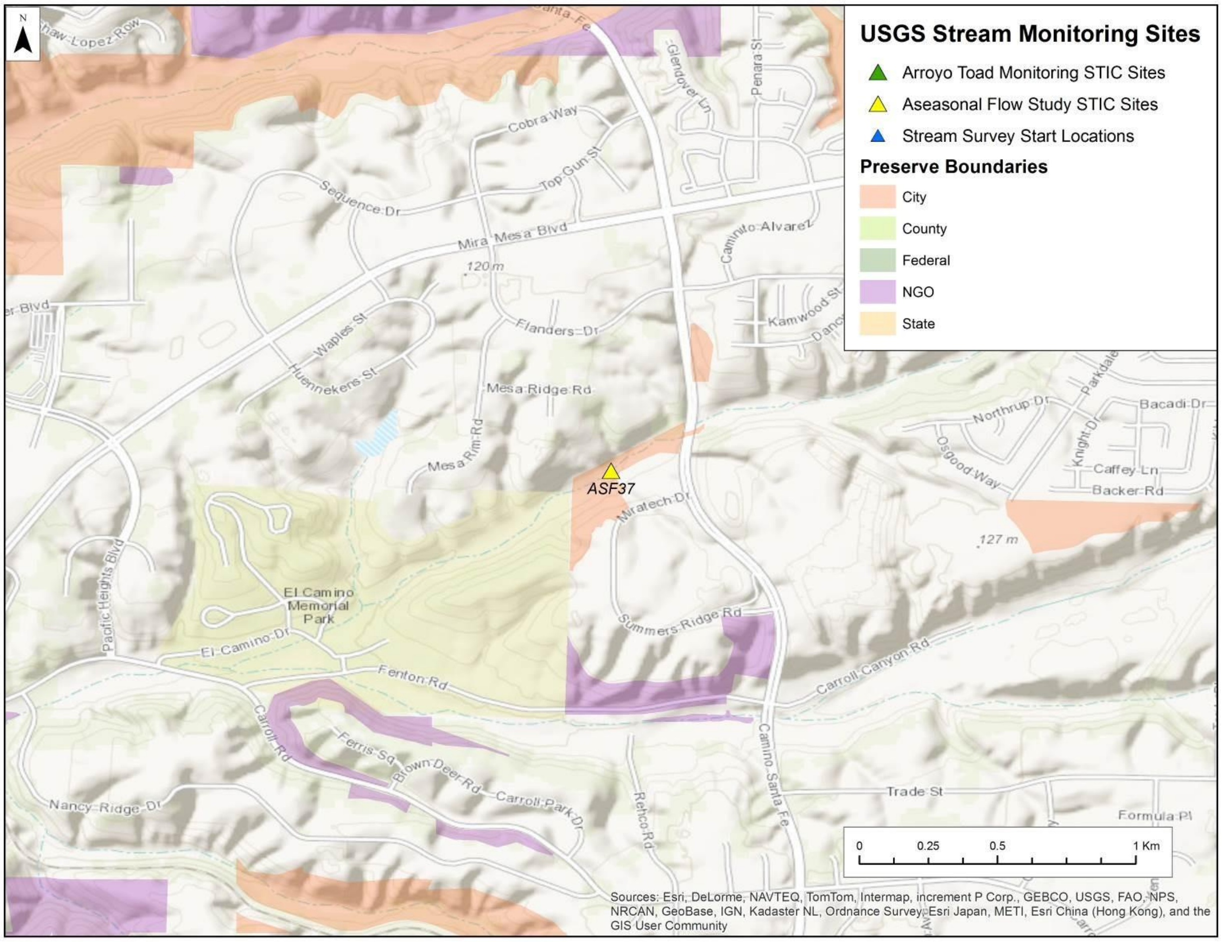

Figure A19a. ASF 37. Carroll Canyon in Carroll Canyon Preserve owned and managed by City of San Diego.

Los Penasquitos Creek Watershed

Carroll Canyon (ASF 37)

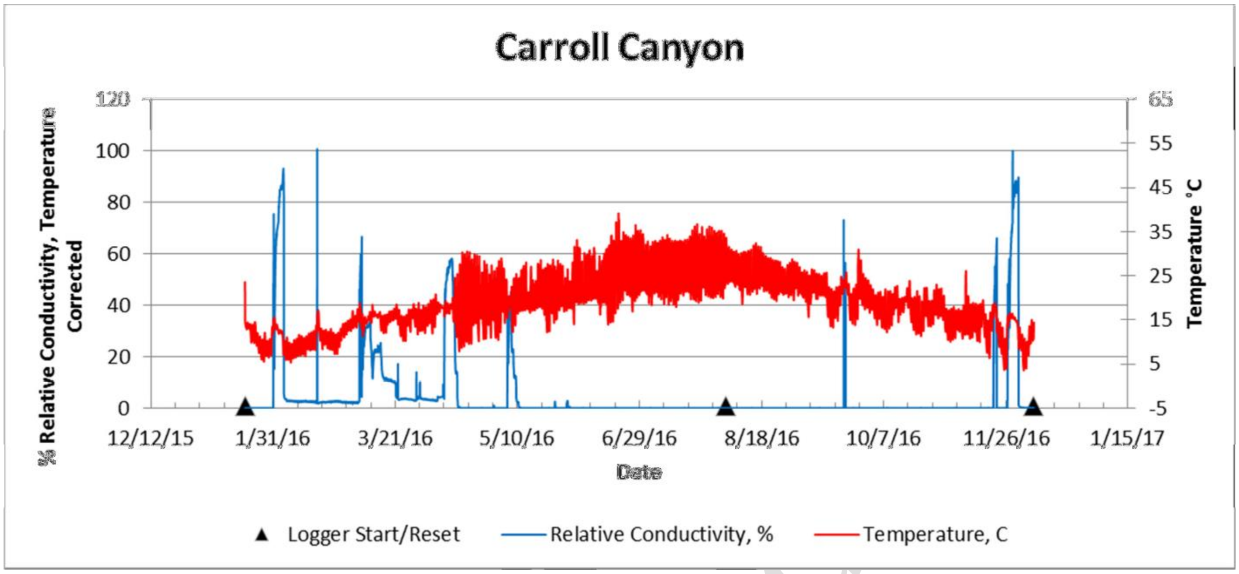

Figure A19b. Relative conductivity and temperature graph of Carroll Canyon (ASF 37)*.

Figure A19c. Habitat at Carroll Canyon (ASF 37) on 19 January 2016 (left) and on 07 December 2016 (right).

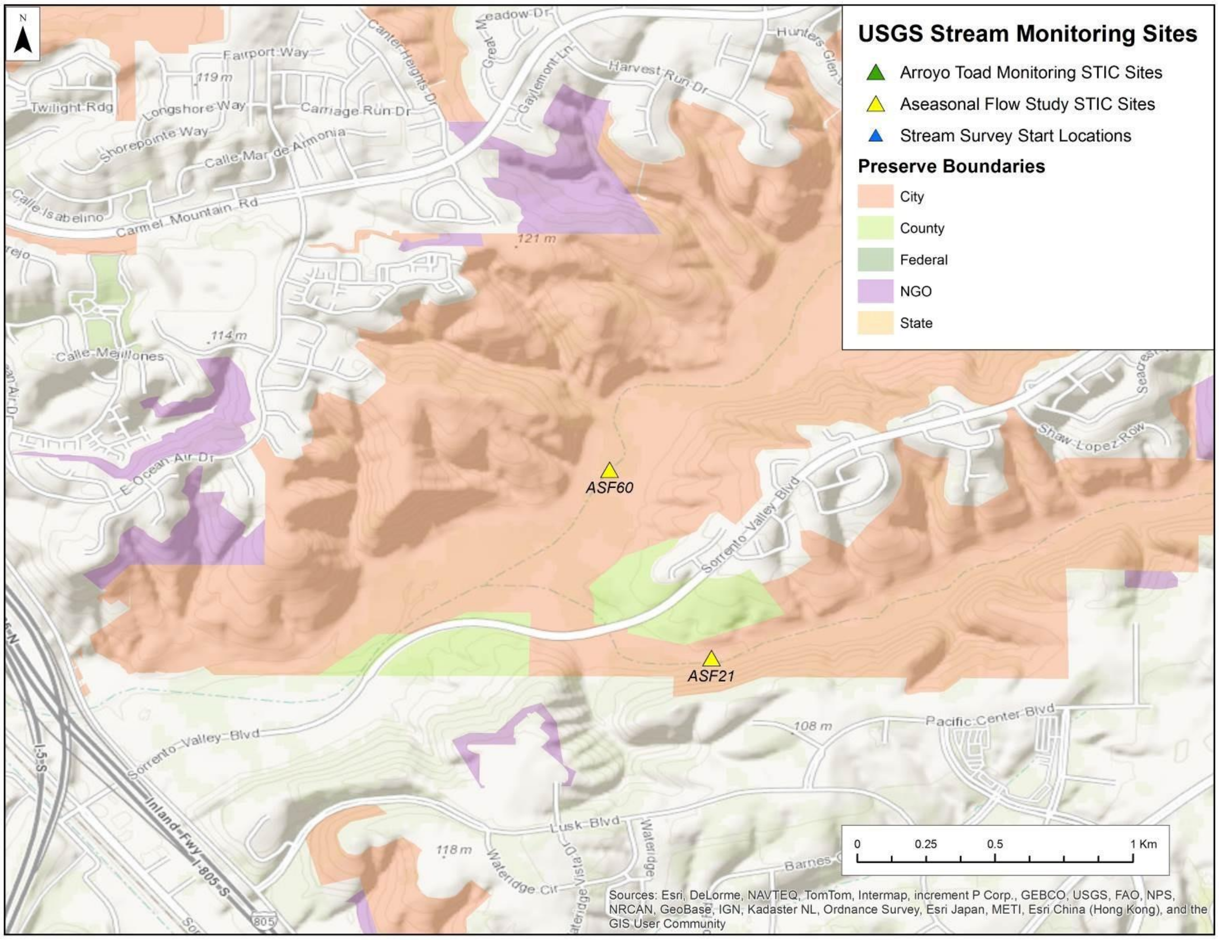

Figure A20a. ASF 21 and 60. Sorrento Valley and Los Penasquitos Creek in Los Penasquitos Canyon Preserve owned and managed by City of San Diego.

Sorrento Valley (ASF 21)

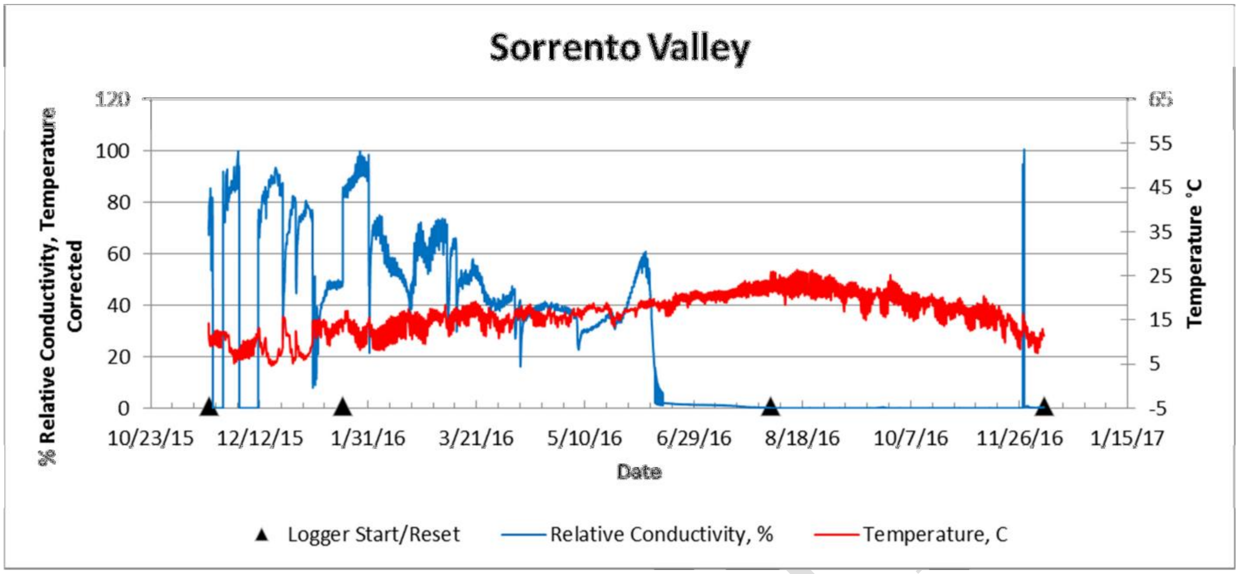

Figure A20b. Relative conductivity and temperature graph of Sorrento Valley (ASF 21)*.

Figure A20c. Habitat at Sorrento Valley (ASF 21) on 19 January 2016 (left) and on 03 August (right).

Los Peñasquitos Creek (ASF 60)

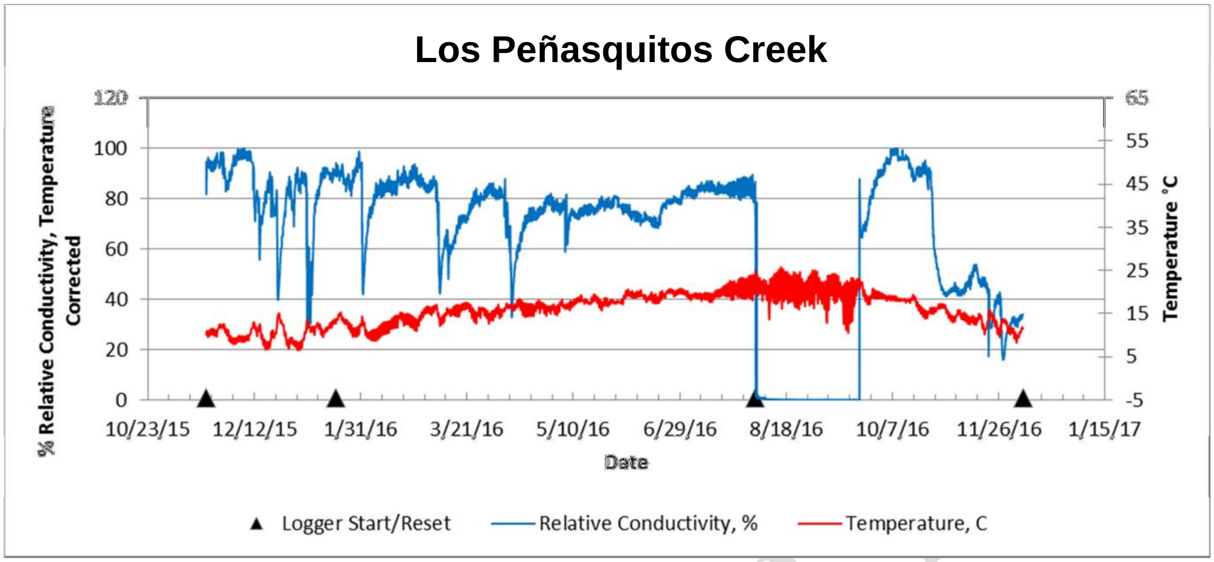

Figure A20d. Relative conductivity and temperature graph of Los Peñasquitos Creek (ASF 60)*.


Figure A20e. Habitat at Los Peñasquitos Creek (ASF 60) on 15 November 2015 (left) on 03 August 2016 (right).

Mission Bay Watershed Management Area

The Mission Bay Watershed contains Rose Creek, San Clemente Canyon, and Tecolote Creek, encompassing nearly 16,013 hectares with approximately 1,078 hectares of conserved lands. We surveyed three sites in this watershed, two in the Rose Creek drainage and one in the Tecolote Creek drainage. Conserved lands within this watershed are predominately City of San Diego parkland and preserves.

Historically this watershed was intermittently connected to the San Diego River. Dredging began in 1946 to open up the bay to recreation and shipping. By 1952, the San Diego River had been completely separated from Mission Bay and a seawall had been built keeping the San Diego River mouth from shifting during normal rainfall years. These three streams were designated as part of the Mission Bay Watershed Management Area by the San Diego Regional Water Quality Control Board in 1994 (SDRWQCB 1994).

Rose Canyon Open Space (ASF 20).–This preserve consists of thick riparian surrounded by coastal sage scrub and urban development and is owned and managed by the City of San Diego Park and Recreation Department. Recreation at this site consists of heavy hiking and bicycle traffic. The creek downstream becomes channelized before entering Mission Bay.

Marian Bear Natural Park (ASF 19).–San Clemente Canyon is a tributary to Rose Creek with coastal sage scrub and chaparral upland. This site is owned and managed by City of San Diego Park and Recreation Department and recreation is limited to day use picnicking, hiking, and biking.

Tecolote Canyon Natural Park (ASF 18).–Owned and managed by City of San Diego Park and Recreation Department. The monitoring station is located in thick riparian surrounded by maintained recreational park lands and urban development, downstream from the regional golf course. Well maintained trails with park benches follow the stream course through the canyon.

Mission Bay Watershed (three ASF sites):

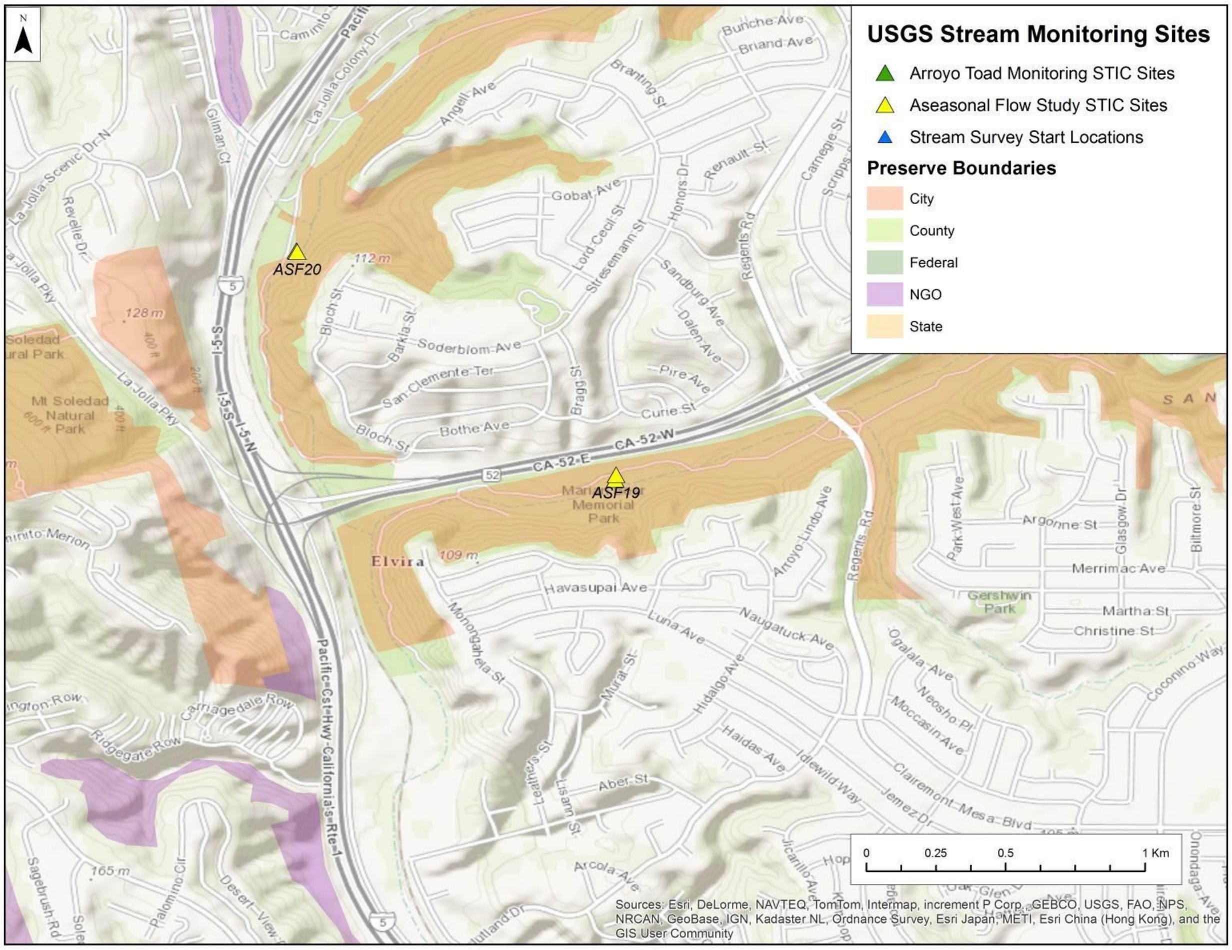

Figure A21a. ASF 19 and 20. San Clemente Canyon and Rose Creek in Marian Bear Natural Park and Rose Canyon Open Space owned and managed by City of San Diego Parks and Recreation Department

Mission Bay Watershed

Rose Creek (ASF 20)

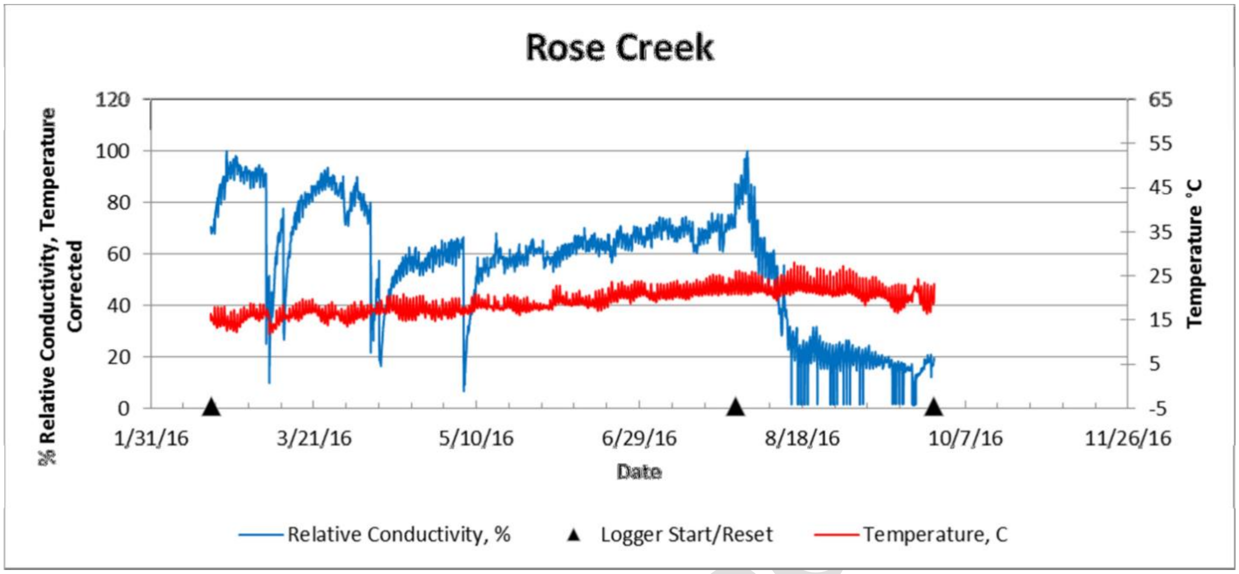

Figure A21b. Relative conductivity and temperature graph of Rose Creek (ASF 20).

 

Figure A21c. Habitat at Rose Creek (ASF 20) on 28 July 2016 (left) and on 07 December 2016 (right).

San Clemente Canyon (ASF 19)

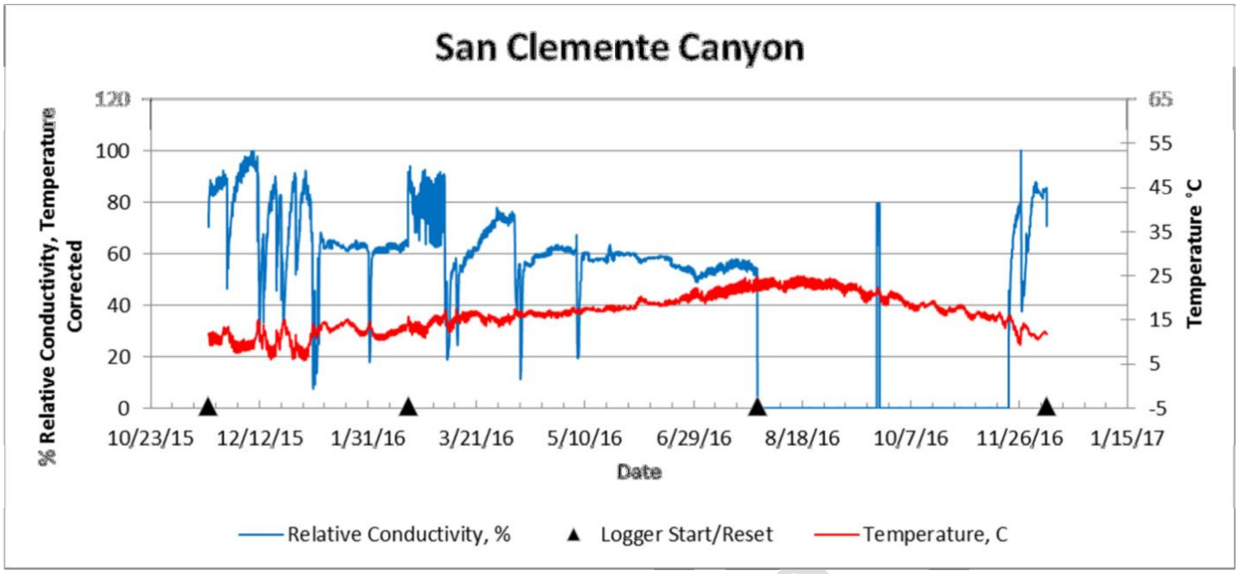

Figure A21d. Relative conductivity and temperature graph of San Clemente Canyon (ASF 19)*.

Figure A21e. Habitat San Clemente Canyon (ASF 19) on 18 November 2015 (left) and on 28 July 2016 (right).

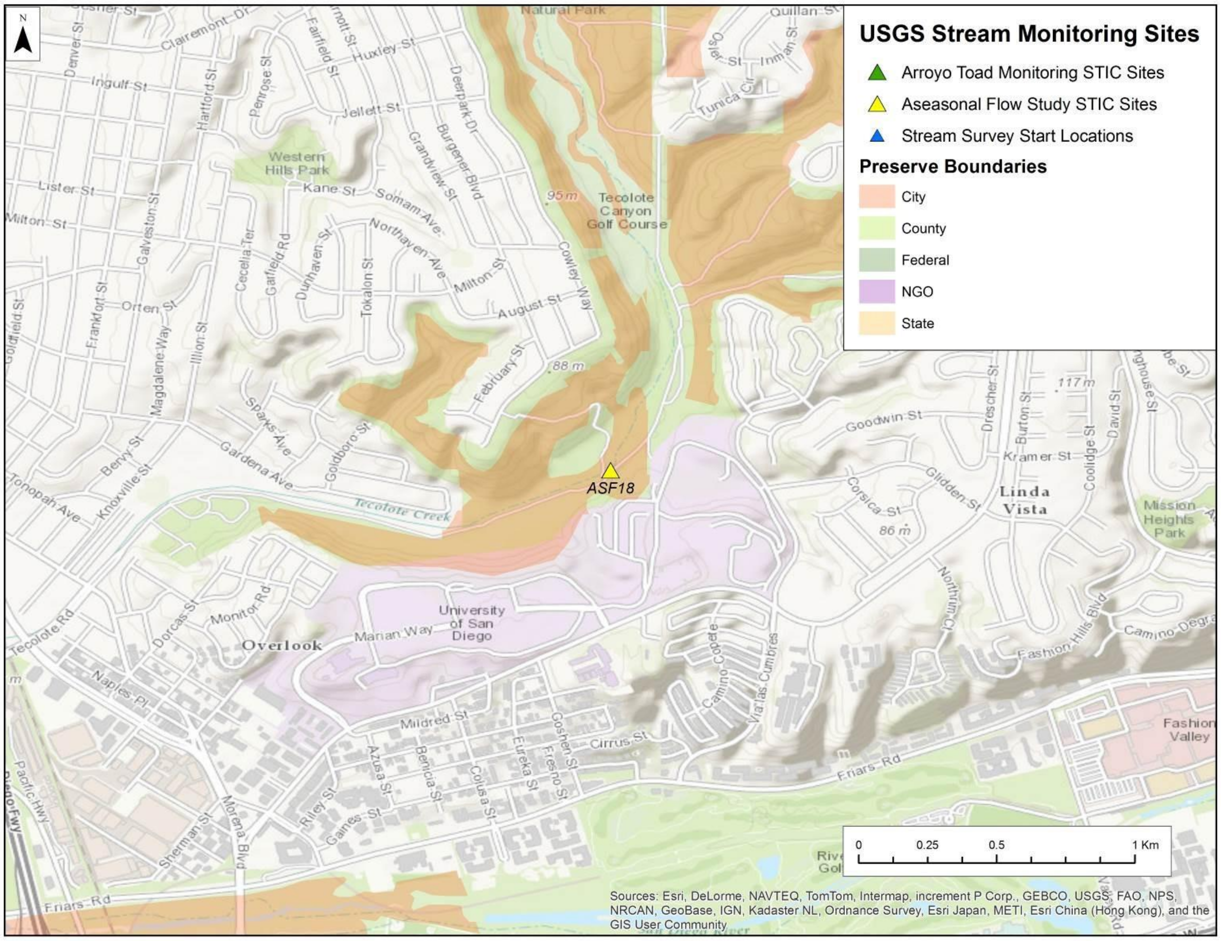

Figure A22a. ASF 18. Tecolote Creek in Tecolote Canyon Natural Park owned and managed by City of San Diego Park and Recreation Department.

Tecolote Creek (ASF 18)

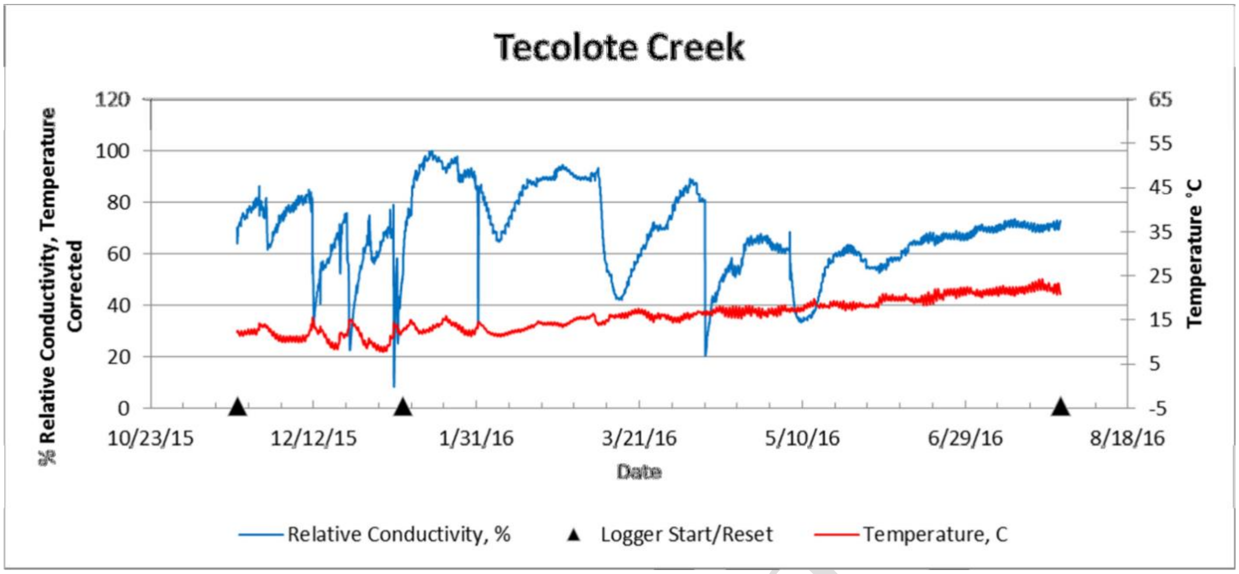

Figure A22b. Relative conductivity and temperature graph of Tecolote Creek (ASF 18).


Figure A22c. Habitat at Tecolote Creek (ASF 18) on 18 November 2015 (left) and on 28 July 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. The watershed encompasses 112,078 hectares from sea level to nearly 2,000 meters with approximately 43,821 hectares of conserved lands. Previously established arroyo toad monitoring sites include nine surface water monitoring sites along the San Diego River, Cedar Creek, and San Vicente Creek (Brown et al. 2019). This study adds one additional site in a tributary to San Vicente Creek. The large open space land mangers within the watershed are USFS, City of San Diego, CDFW, and County of San Diego.

Foster Canyon in San Vicente Cornerstone Preserve (ASF 36).–This small creek is a tributary to San Vicente Creek that flows into San Vicente Reservoir. The riparian habitat is surrounded by thick chaparral and coastal sage scrub with no urban development. This site is owned and managed by City of San Diego Public Utilities Department.

San Diego River Watershed (one ASF sites):

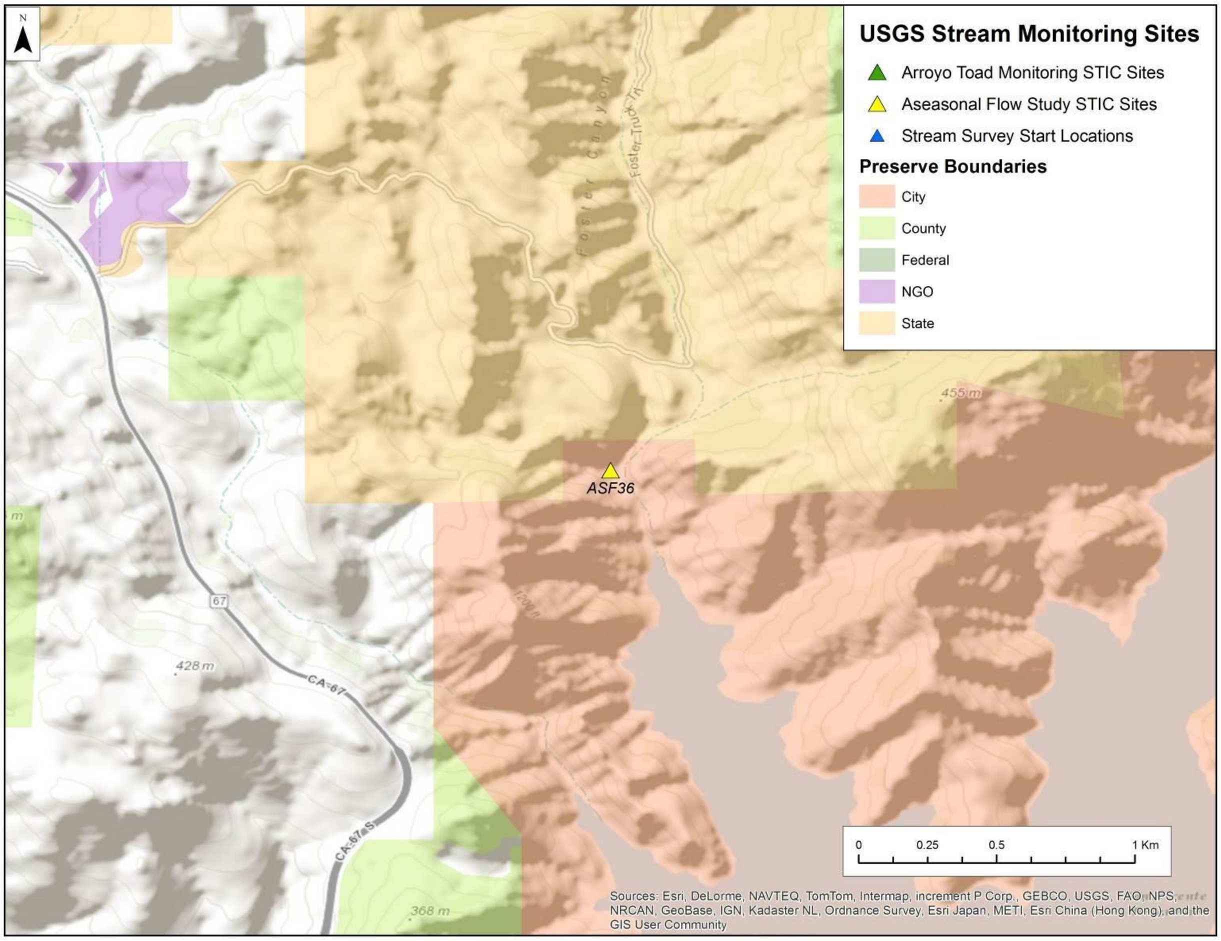

Figure A23a. ASF 36. Foster Canyon in San Vicente Reservoir Cornerstone Lands owned and managed by City of San Diego Public Utilities Department.

San Diego River Watershed

Foster Canyon (ASF 36)

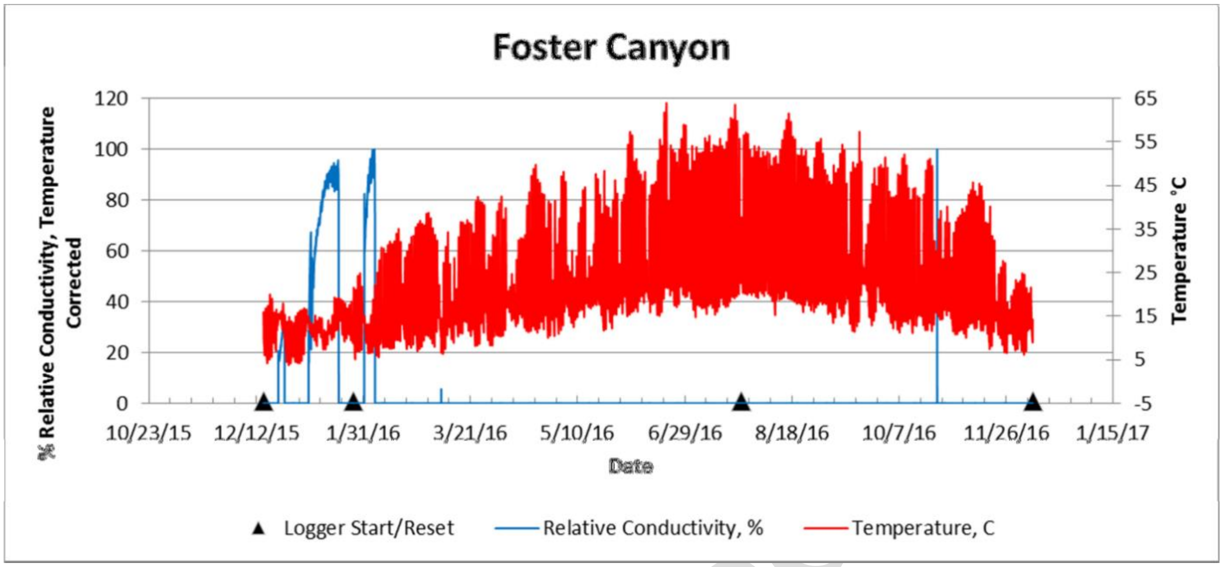

Figure A23b. Relative conductivity and temperature graph of Foster Canyon (ASF 36)*.

Figure A23c. Habitat at Foster Canyon (ASF 36) on 26 January 2016 (left) and on 08 December 2016 (right).

Pueblo San Diego Watershed

This 15,540 hectare watershed includes the Chollas and Paleta creeks which drain into San Diego Bay. Highly urbanized, approximately 75% of the watershed is developed. We surveyed 3 sites in Chollas Creek and associated tributaries. The conserved lands are predominately City of San Diego preserves.

Chollas Preserve (ASF 17).–Owned and managed by City of San Diego Park and Recreation Department, this nature park is surrounded by high density residential housing. The Chollas Creek Watershed above this site is approximately 98% urban with the remainder being largely coastal sage scrub and riparian. Recreation is restricted to hiking and biking.

Rancho Mission Preserve (ASF 16 and ASF 15).–Owned and managed by City of San Diego Park and Recreation Department, the Rancho Mission Preserve includes ASF 16 in South Chollas Creek and ASF 15 in Encanto Creek. Similar to Chollas Creek, these sites are both over 90% urban with the remainder being mostly coastal sage scrub. Recreation is restricted to hiking at both locations.

Pueblo San Diego Watershed (three ASF sites):

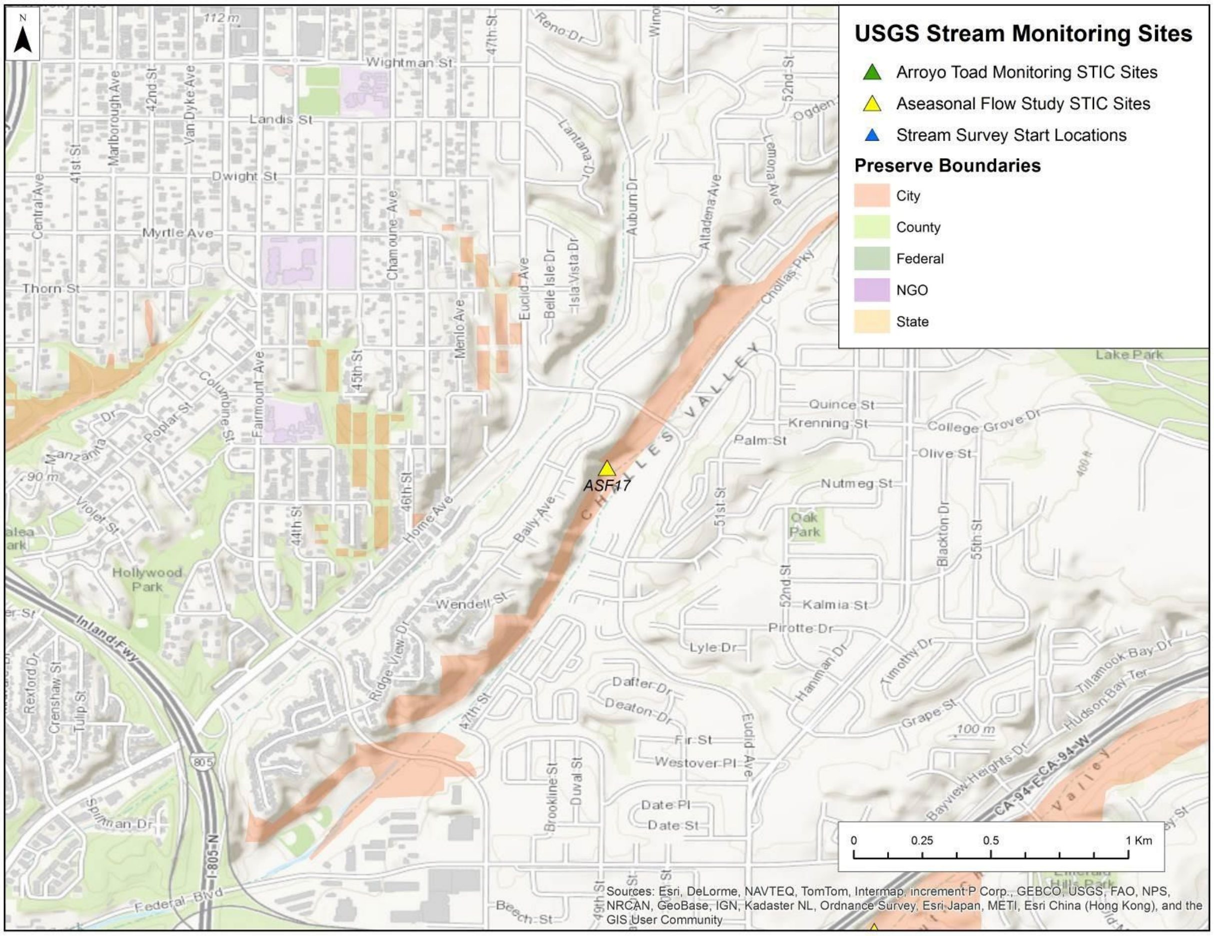

Figure A24a. ASF 17. Chollas Creek in Chollas Preserve owned and managed by City of San Diego Park and Recreation Department.

Pueblo San Diego Watershed

Chollas Creek (ASF 17)

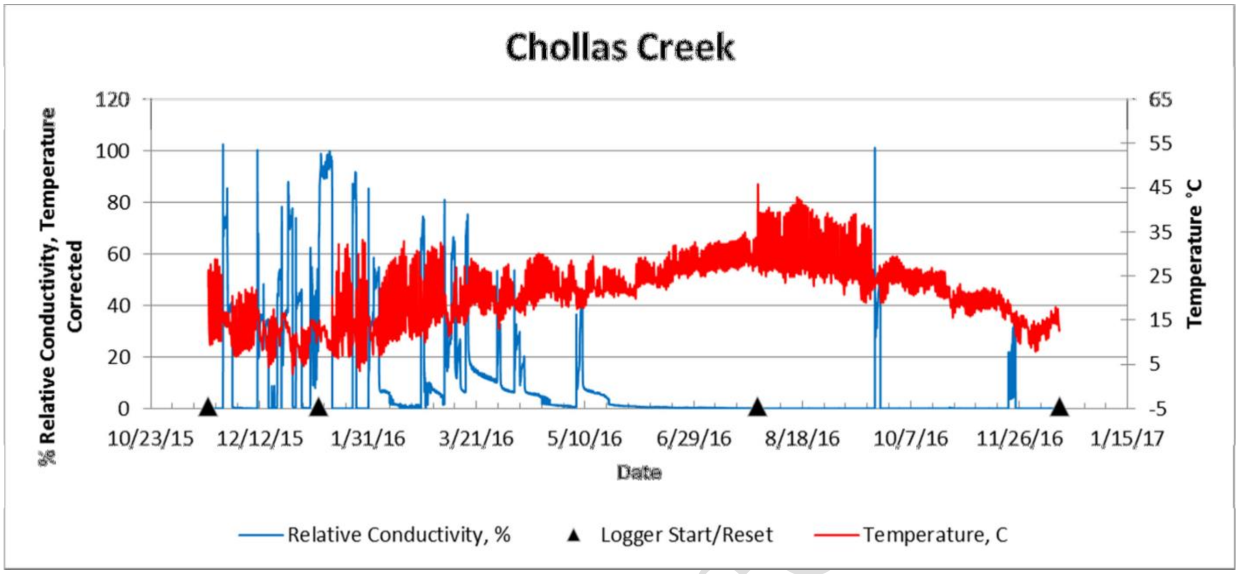

Figure A24b. Relative conductivity and temperature graph of Chollas Creek (ASF 17)*.

Figure A24c. Habitat at Chollas Creek (ASF 17) on 08 January 2016 (left) and on 28 July 2016 (right).

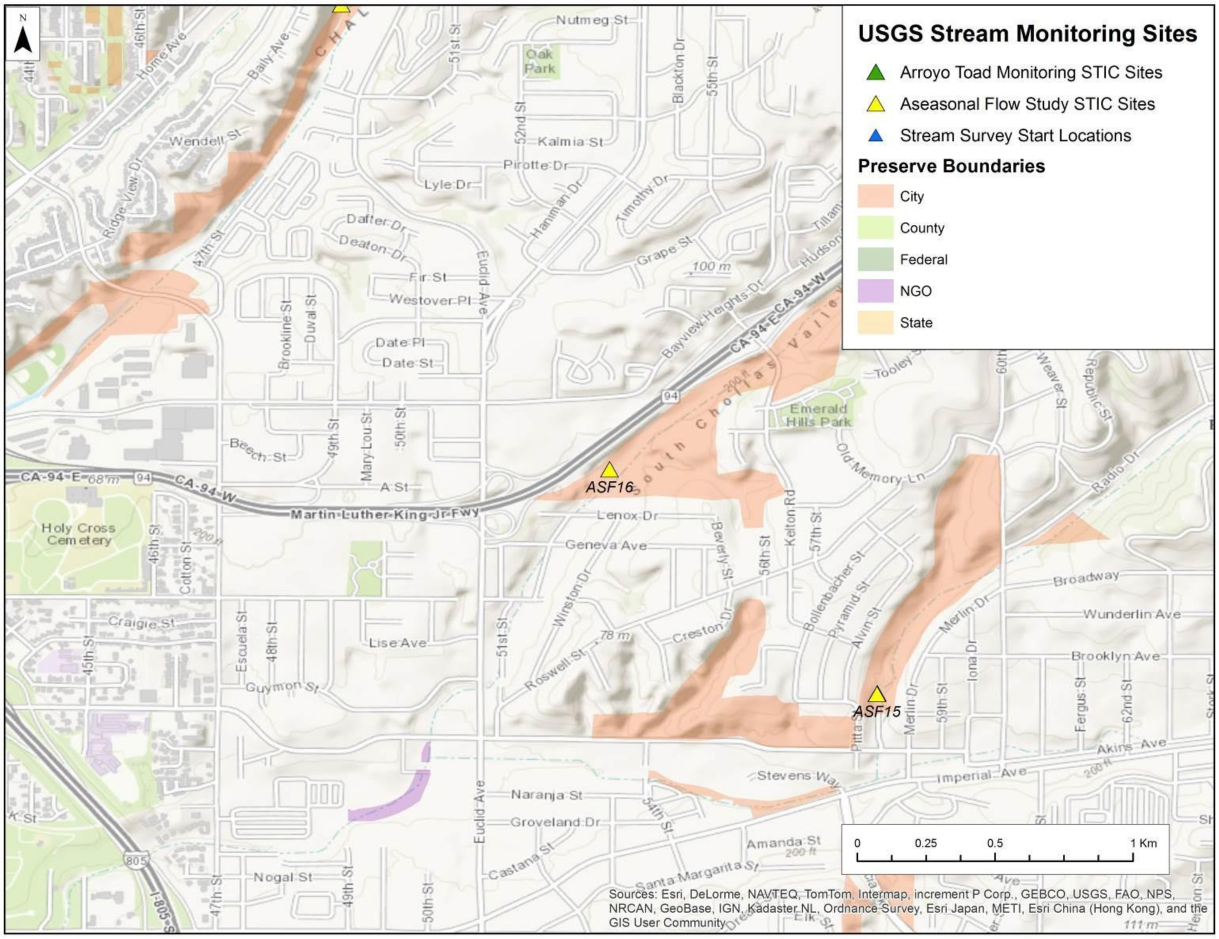

Figure A25a. ASF 16 and 15. South Chollas Creek and Encanto Creek in Rancho Mission Preserve owned and managed by City of San Diego Park and Recreation Department.

South Chollas Creek (ASF 16)

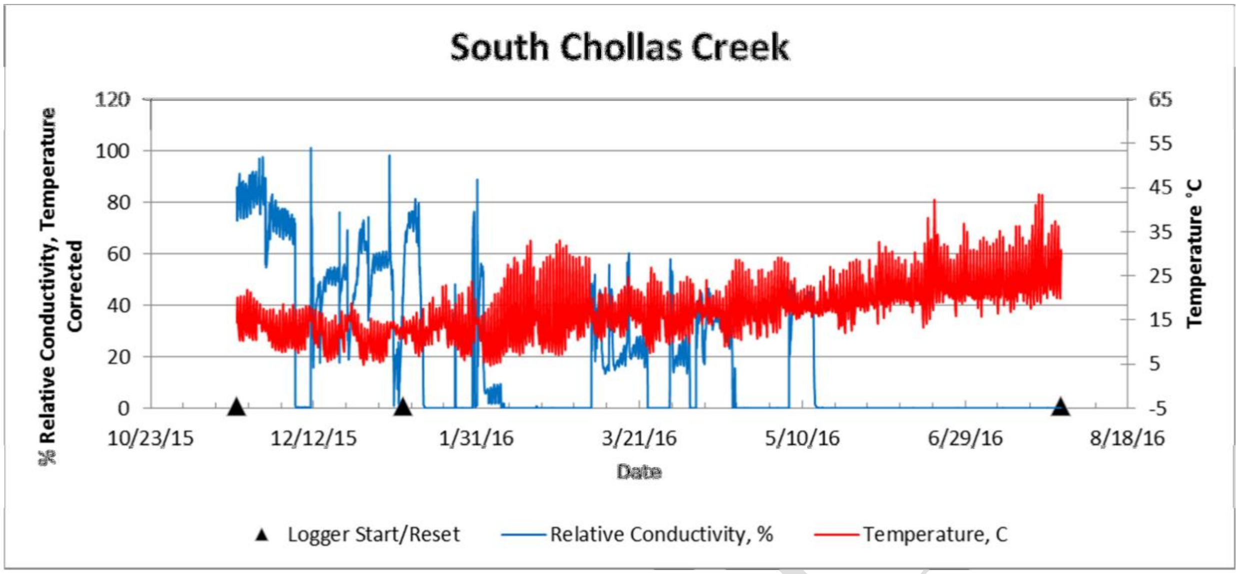

Figure A25b. Relative conductivity and temperature graph of South Chollas Creek (ASF 16)*.

Figure A25c. Habitat at South Chollas Creek (ASF 16), on 08 January 2016 (left) and on 28 July 2016 (right).

Encanto Creek (ASF 15)

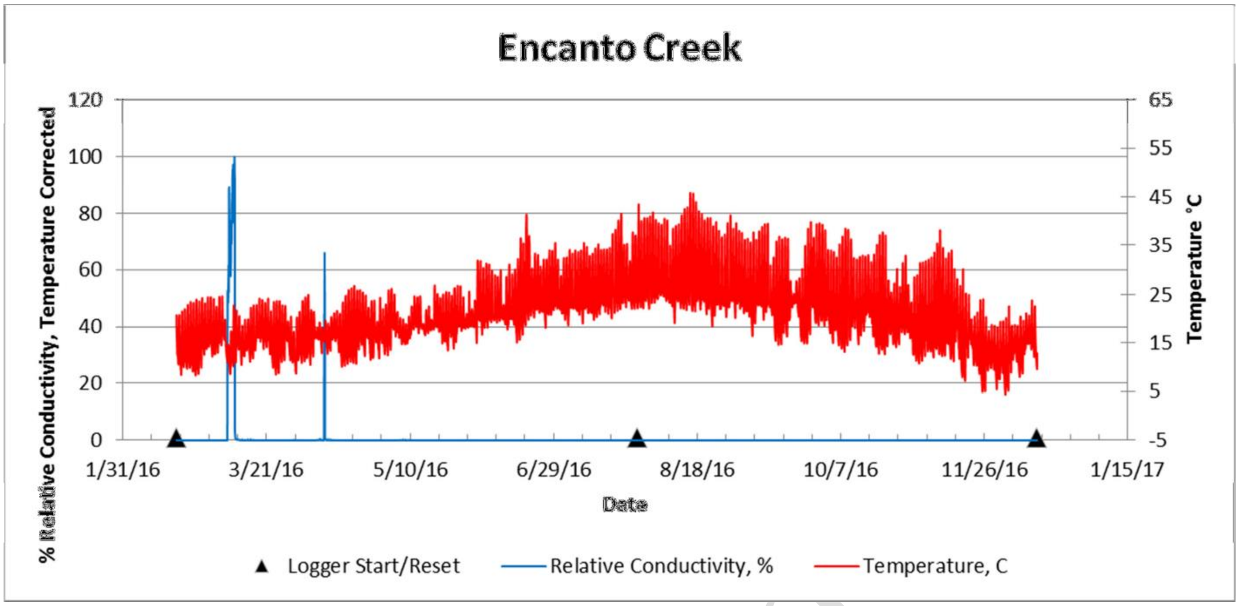

Figure A25d. Relative conductivity and temperature graph of Encanto Creek (ASF 15)*.

Figure A25e. Habitat at Encanto Creek (ASF 15) on 08 January 2016 (left) and on 14 December 2016 (right).

Sweetwater River Watershed

The Sweetwater River Watershed encompasses 56,407 hectares from the coast to the Cuyamaca and Laguna mountains with approximately 23,655 hectares of conserved lands. In addition to riparian habitats, this long, narrow watershed contains oak and pine woodlands, grasslands, chaparral, and coastal sage scrub. Previously established arroyo toad monitoring sites include three surface water monitoring sites along Sweetwater River (Brown et al. 2019). This study adds a total of 11 surface water monitoring sites in the main stem of the Sweetwater River and associated tributaries (Appendix A). The open space land managers within the watershed are California State Parks, USFS, CDFW, City of San Diego, Caltrans, and County of San Diego.

Harbison Canyon (ASF 41, ASF 42, and ASF 43).–Owned and managed by County of San Diego Park and Recreation Department, and Endangered Habitats Conservancy, these nature parks are surrounded by a low-to medium-density rural community. Predominately riparian and chaparral, these small creeks Harbison Canyon tributary (AFS 41), Harbison Canyon (ASF 42), and Galloway Valley (ASF 43), range from 40 to 60% developed. Recreation is limited to hiking at these sites.

Sycuan Peak Ecological Reserve (ASF 47 and ASF 44).–Lawson Canyon (ASF 47) and Beaver Hollow (ASF 44) are tributaries to the Sweetwater River, joining the river in Sloane Canyon. The two sites are in the Sycuan Peak Ecological Reserve, owned and managed by CDFW. Both streams have large amounts of chaparral upland, and access for recreation is limited only to public roads.

Bonita Meadows (ASF 04).–This tributary to the Sweetwater River flows through the Bonita Meadows preserve owned and managed by Caltrans. The uplands are mostly coastal sage scrub and grassland, the watershed having 48% urban land cover. Recreation is relatively low with one trail that parallels the riparian but remains in the upland.

Chula Vista Central Preserve (ASF 05, ASF 06, ASF 07, ASF 08).–Owned by City of Chula Vista in Long Canyon (ASF 08), Rice Canyon (ASF 05), Rancho Del Rey (ASF 06), and Terra Nova (ASF 07), this series of urban canyons are all nearly 75% urban with most of the remainder being coastal sage scrub. With mixed use, recreation is limited to hiking, biking, and equestrian use on well-maintained trails with ongoing restoration off trail.

Sweetwater County Park (ASF 03).–This site is along the main stem of the Sweetwater River in Sweetwater County Park. Upland habitat is predominately chaparral and coastal sage scrub with approximately 33% of the watershed being urban land cover. Owned and managed by the San Diego County Parks and Recreation Department, this site experiences heavy recreation from hiking, horseback riding, and biking. The area is also subject to unpermitted camping and bathing.

Sweetwater River Watershed (eleven ASF sites):

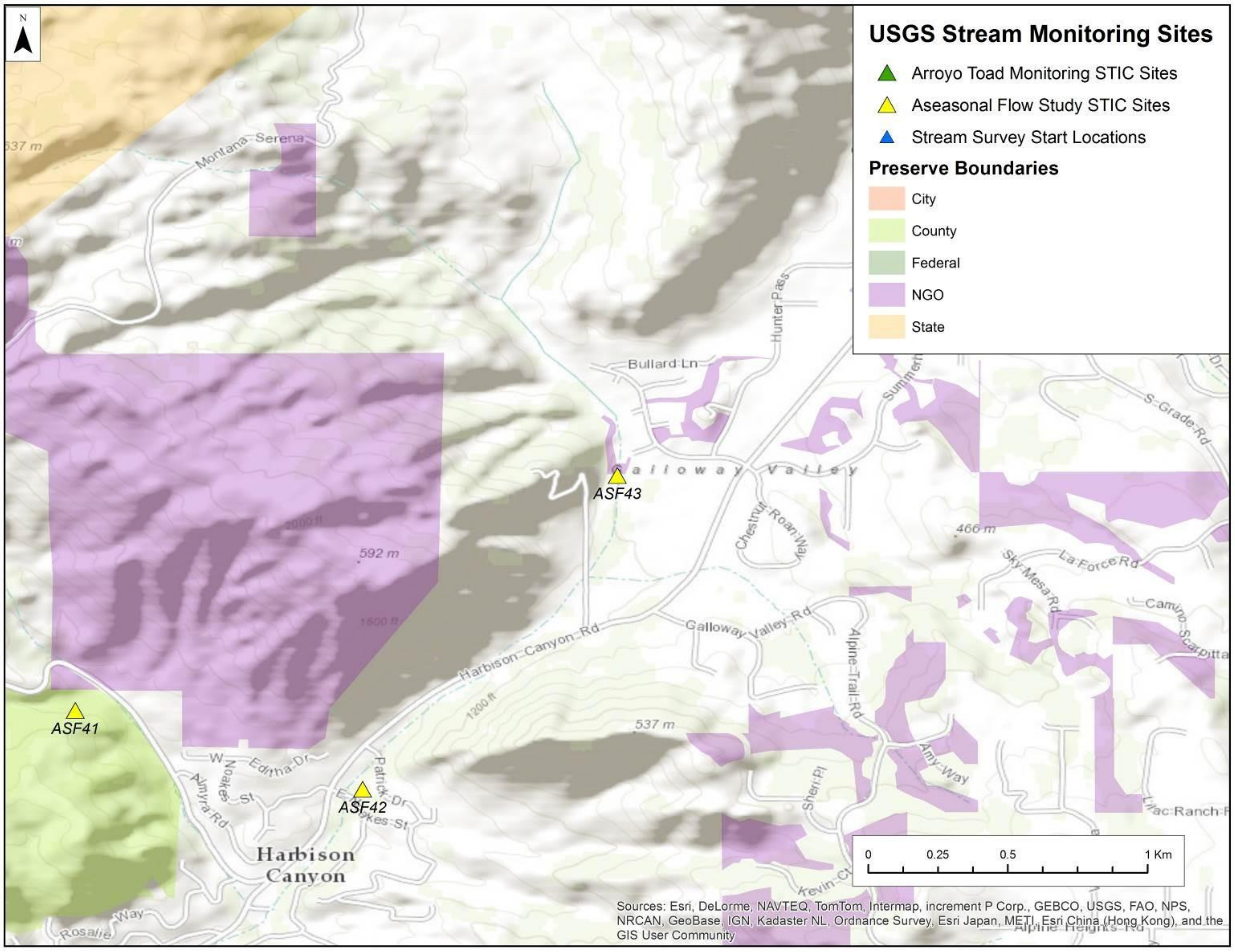

Figure A26a. ASF 41, 42, and 43. Harbison Canyon tributary, Harbison Canyon, and Galloway Valley in Harbison Canyon owned and managed by County of San Diego Department of Parks and Recreation, Endangered Habitats Conservancy.

Sweetwater River Watershed

Harbison Canyon Tributary (ASF 41)

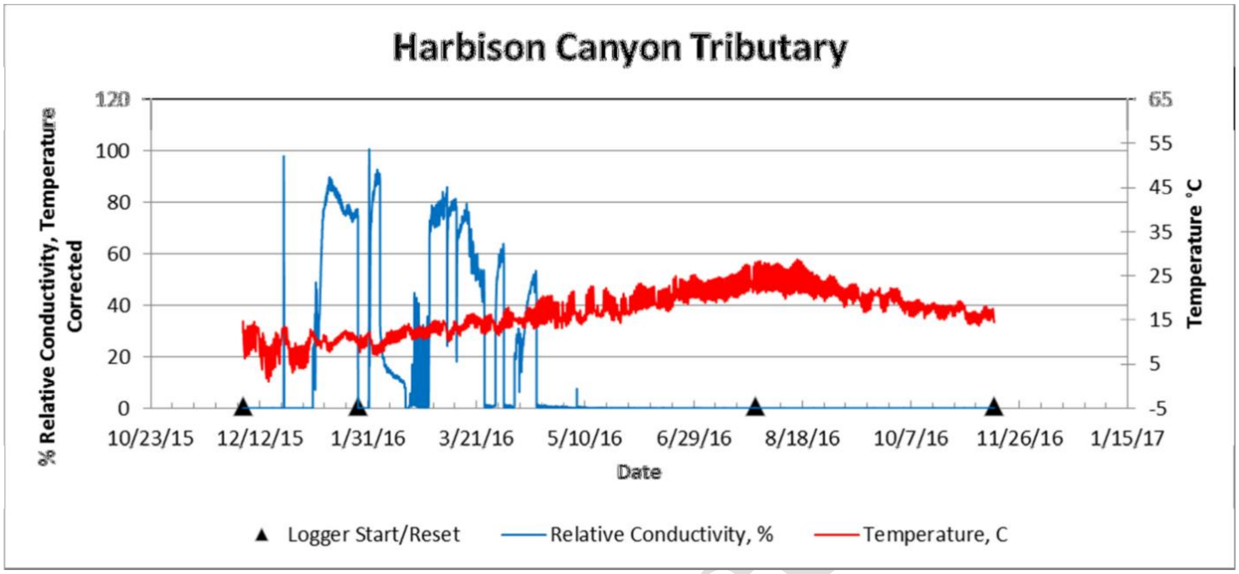

Figure A26b. Relative conductivity and temperature graph of Harbison Canyon Tributary (ASF 41)*.

Figure A26c. Habitat at Harbison Canyon Tributary (ASF 41) on 26 January 2016 (left) and on 27 July 2016 (right).

Harbison Canyon (ASF 42)

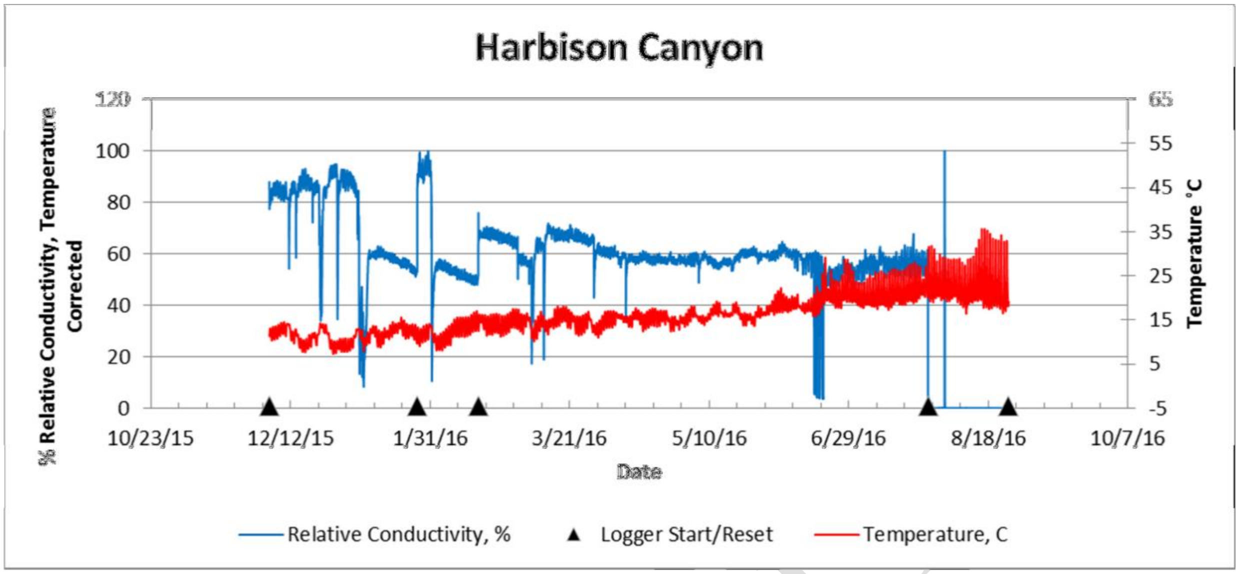

Figure A26d. Relative conductivity and temperature graph of Harbison Canyon (ASF 42).

Figure A26e. Habitat at Harbison Canyon (ASF 42) on 27 July 2016 (left) and on 25 August 2016 (right).

Galloway Valley (ASF 43)

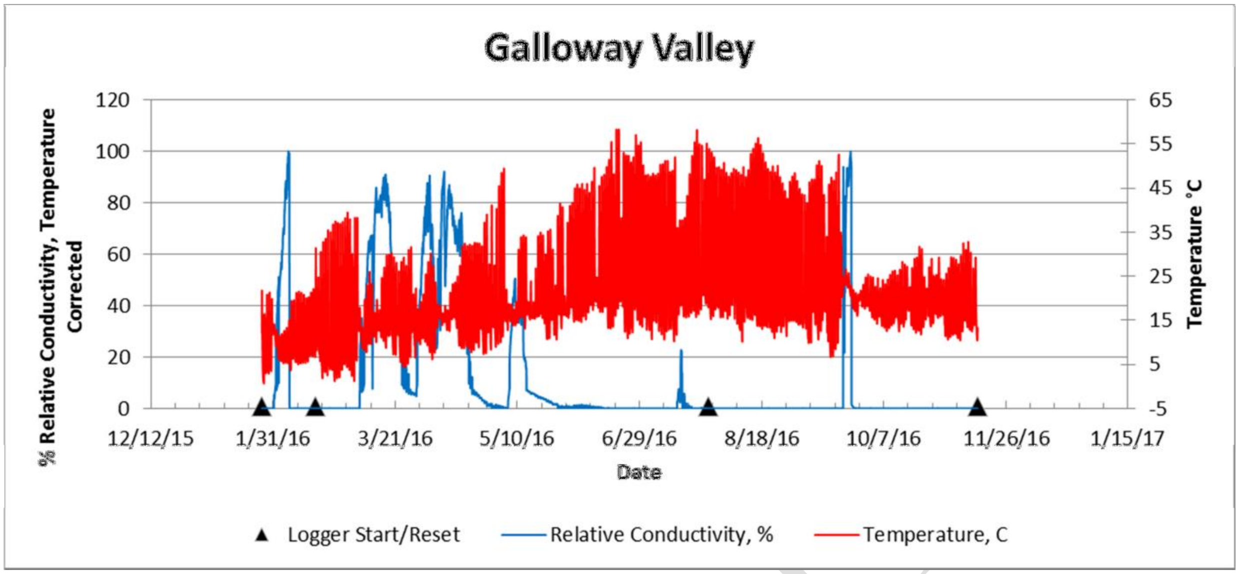

Figure A26f. Relative conductivity and temperature graph of Galloway Valley (ASF 43)*.

Figure A26g. Habitat at Galloway Valley (ASF 43) on 26 January 2016 (left) and on 14 November 2016 (right).

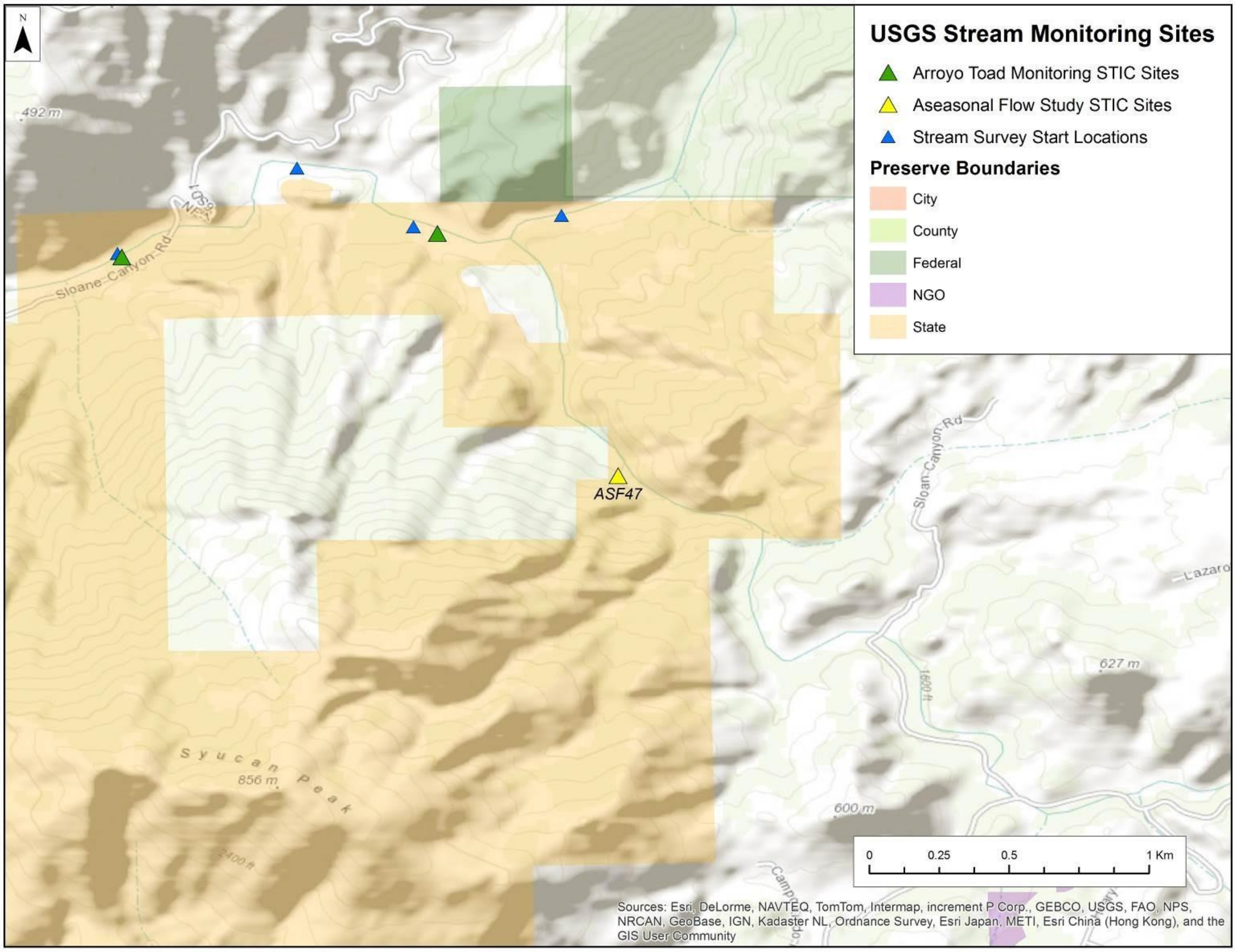

Figure A27a. ASF 47. Lawson Canyon in Sycuan Peak Ecological Reserve owned and managed by CDFW.

Lawson Canyon (ASF 47)

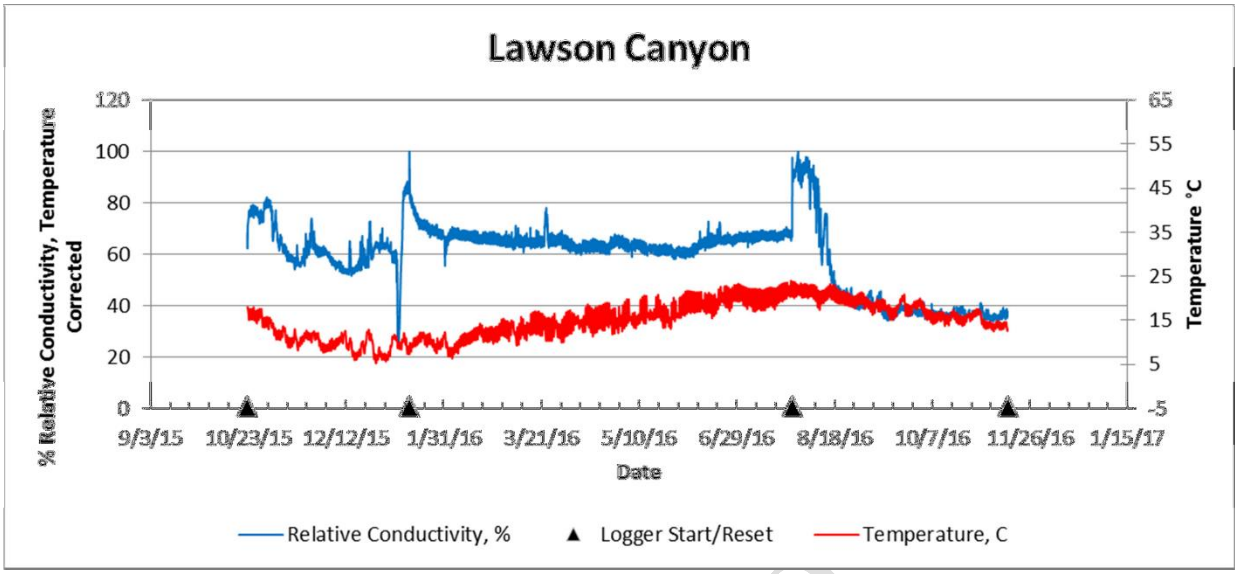

Figure A27b. Relative conductivity and temperature graph of Lawson Canyon (ASF 47).

Figure A27c. Habitat at Lawson Canyon (ASF 47) on 13 January 2016 (left) and on 14 November 2016 (right).

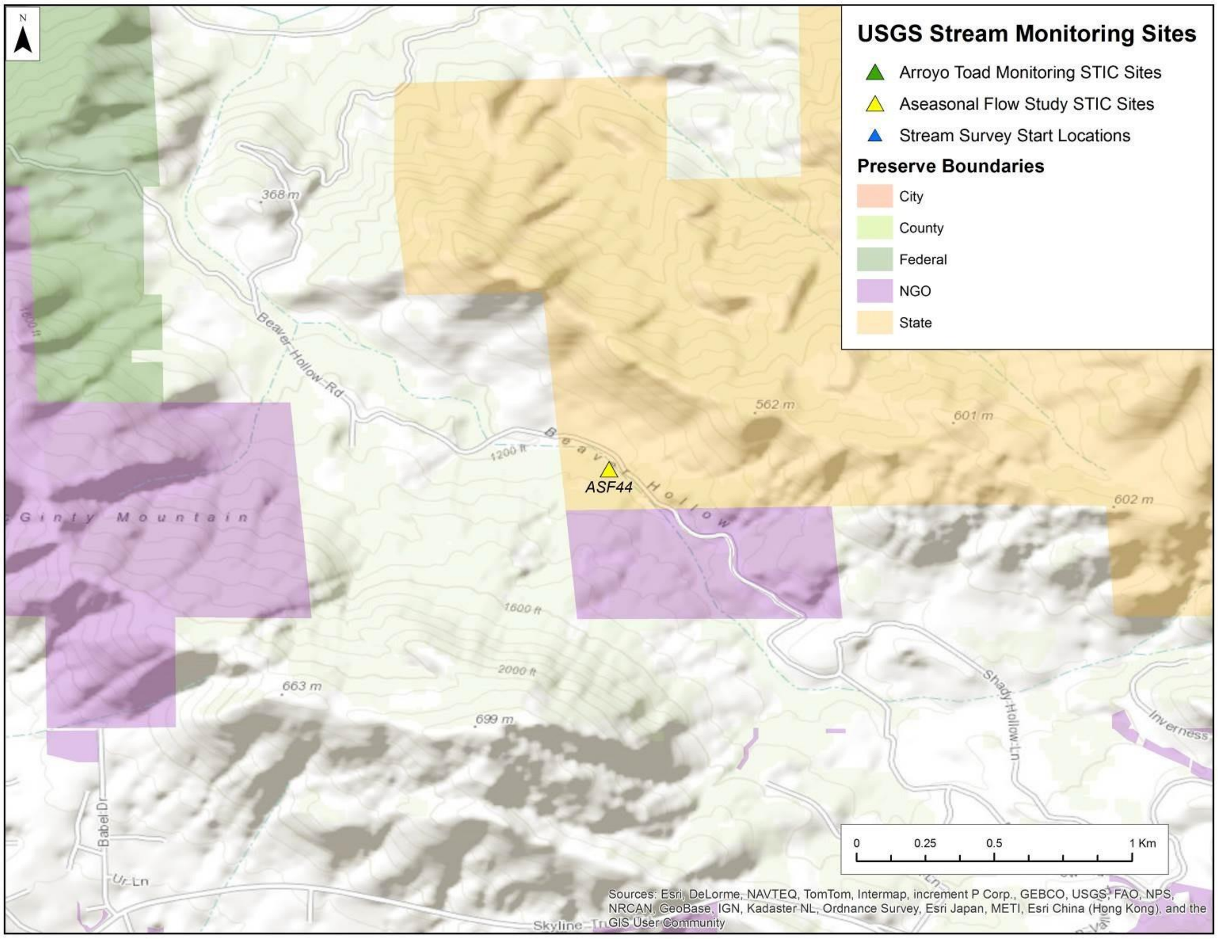

Figure A28a. ASF 44. Beaver Hollow in Sycuan Peak Ecological Reserve, owned and managed by CDFW.

Beaver Hollow (ASF 44)

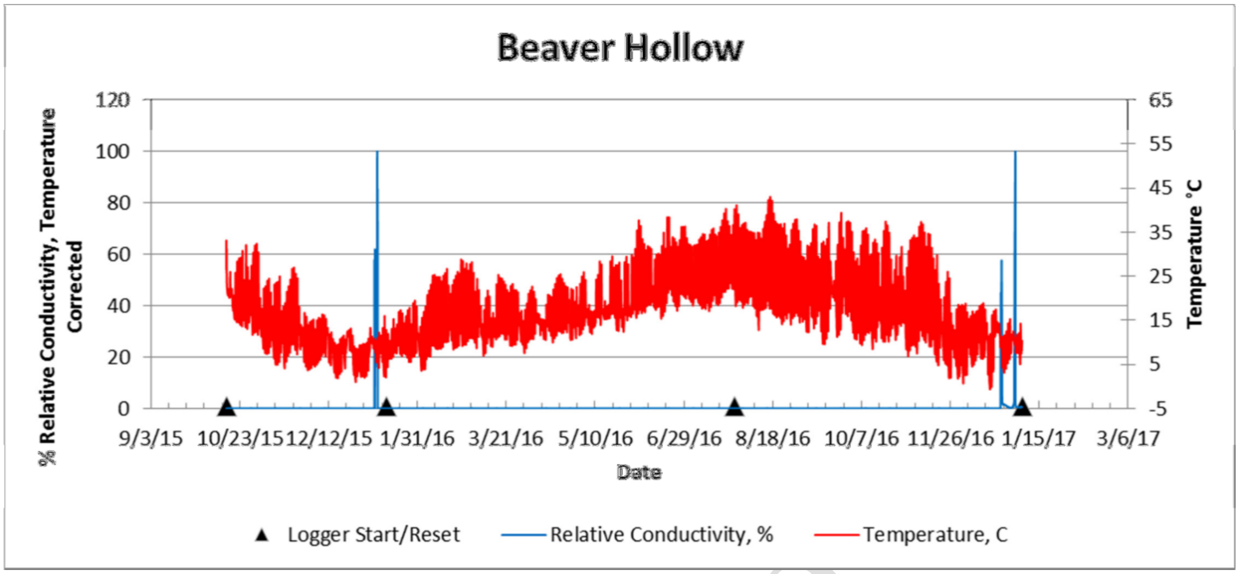

Figure A28b. Relative conductivity and temperature graph of Beaver Hollow (ASF 44)*.

Figure A28c. Habitat at Beaver Hollow (ASF 44) on 15 October 2015 (left) and on 27 July 2016 (right).

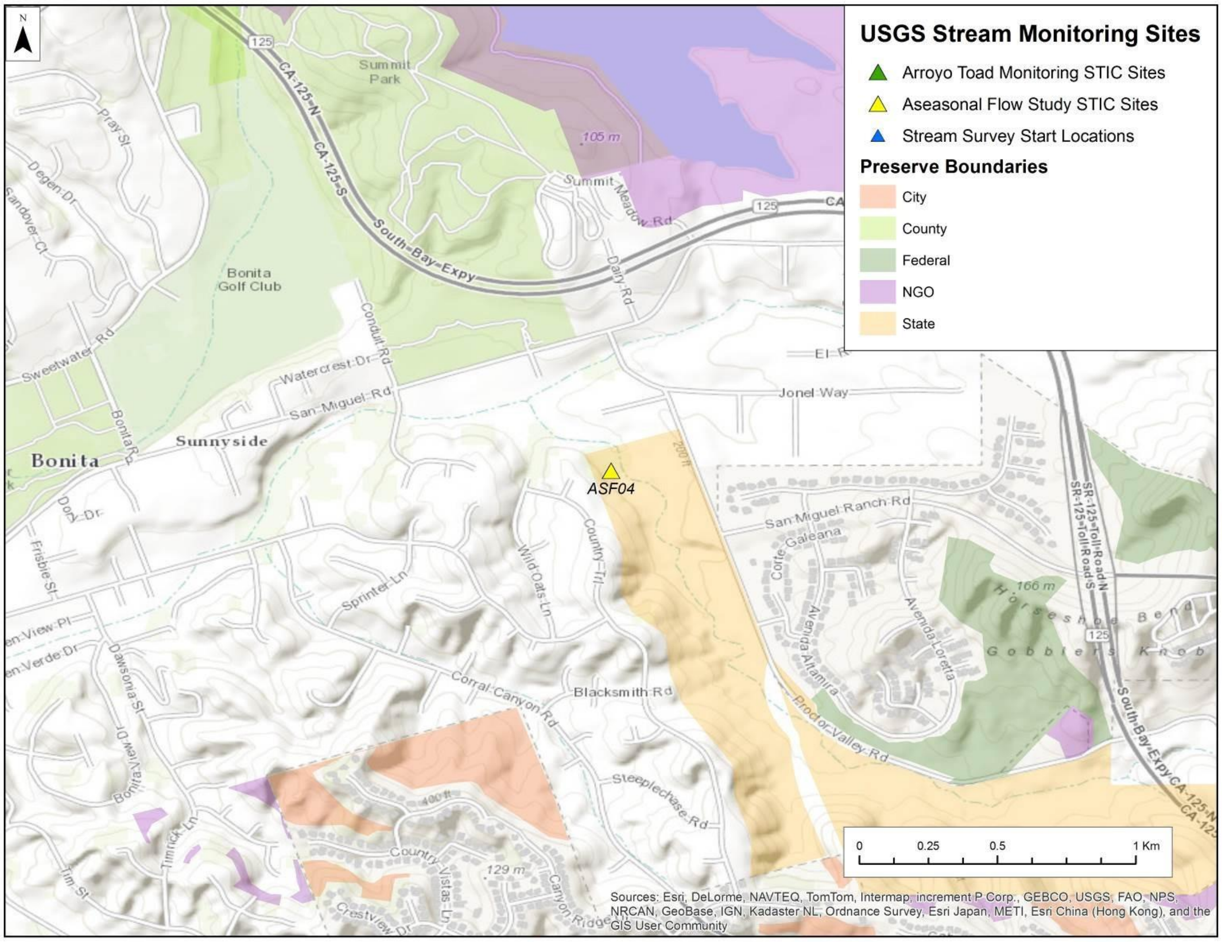

Figure A29a. ASF 04. Sweetwater River tributary in Bonita Meadows owned and managed by Caltrans.

Bonita Meadows (ASF 04)

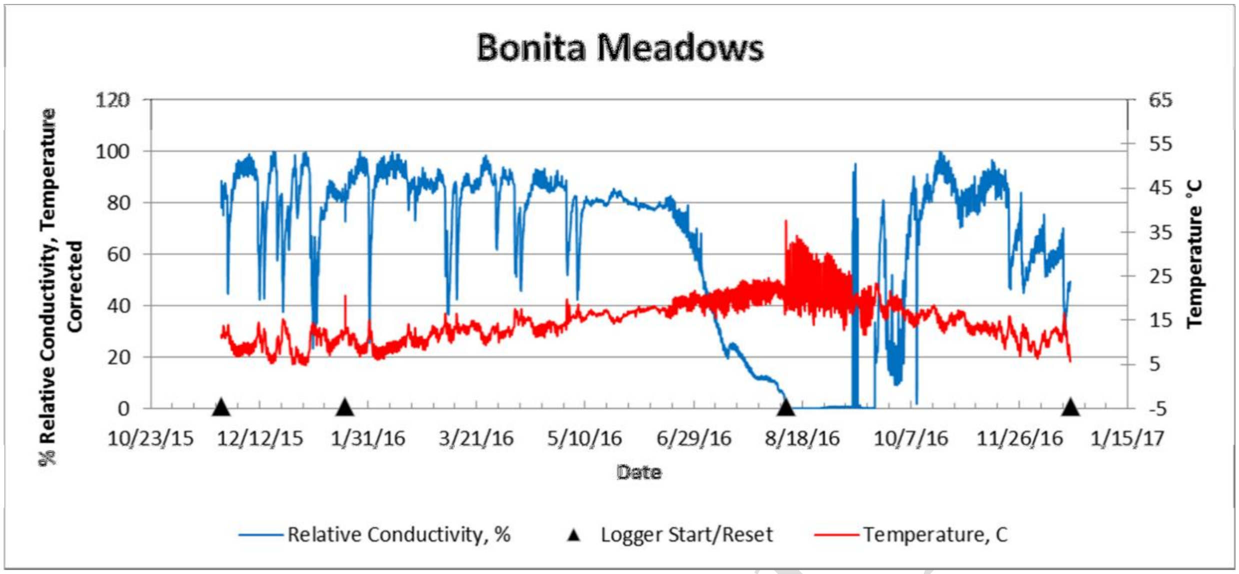

Figure A29b. Relative conductivity and temperature graph of Bonita Meadows (ASF 04).

Figure A29c. Habitat at Bonita Meadows (ASF 04) on 24 November 2015 (left) and on 19 December 2016 (right).

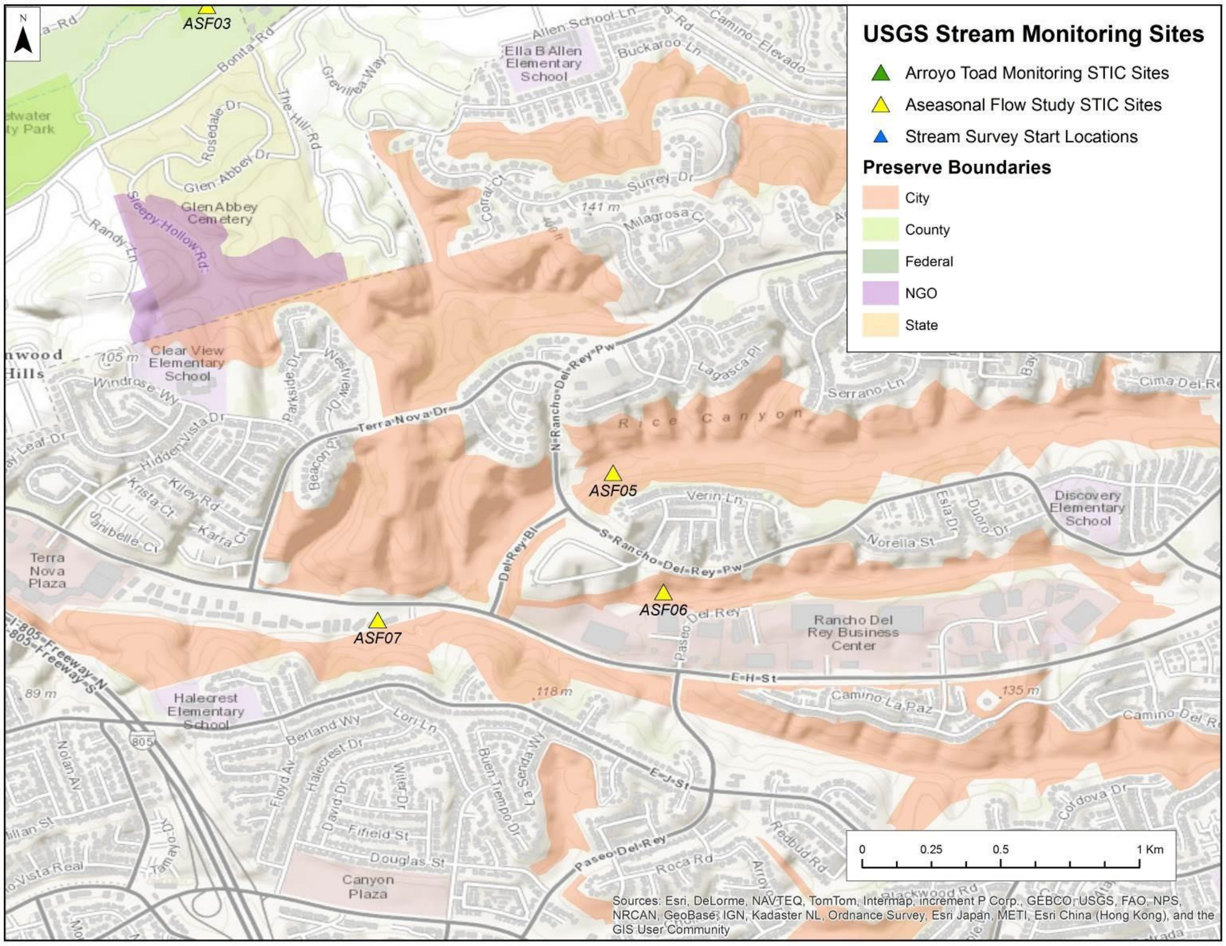

Figure A30a. ASF 05, 06, and 07. Rice Canyon, Rancho Del Rey, and Terra Nova in Chula Vista Central Preserve owned and managed by City of Chula Vista.

Rice Canyon (ASF 05)

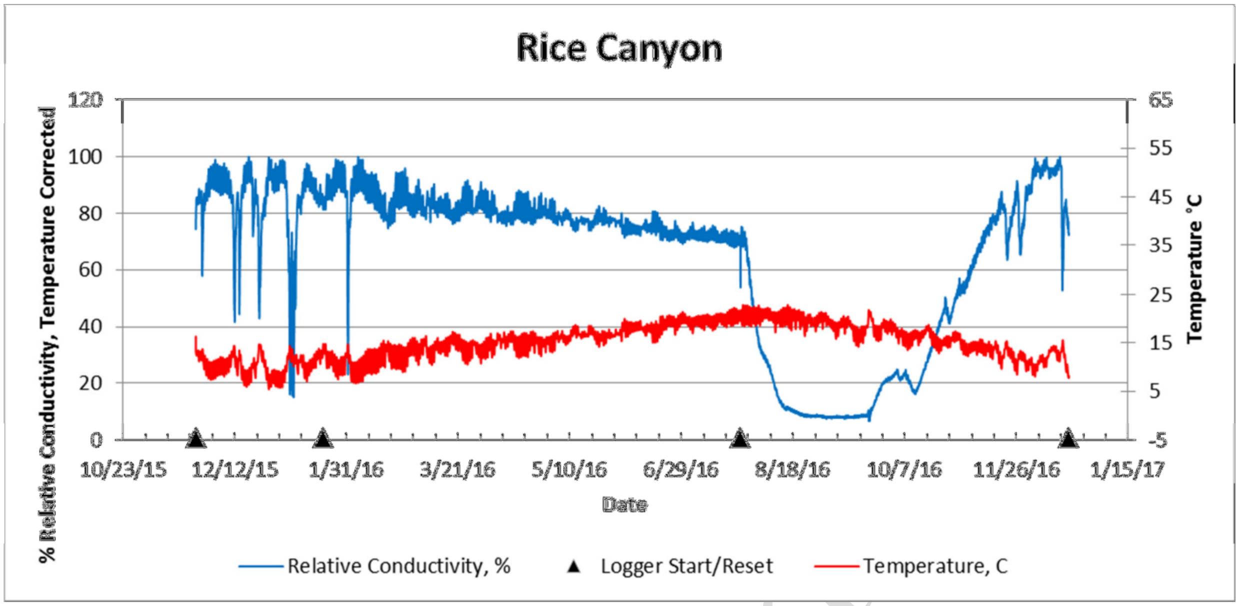

Figure A30b. Relative conductivity and temperature graph of Rice Canyon (ASF 05).

Figure A30c. Habitat at Rice Canyon (ASF 05) on 25 July 2016 (left) and on 19 December 2016 (right).

Rancho Del Rey (ASF 06)

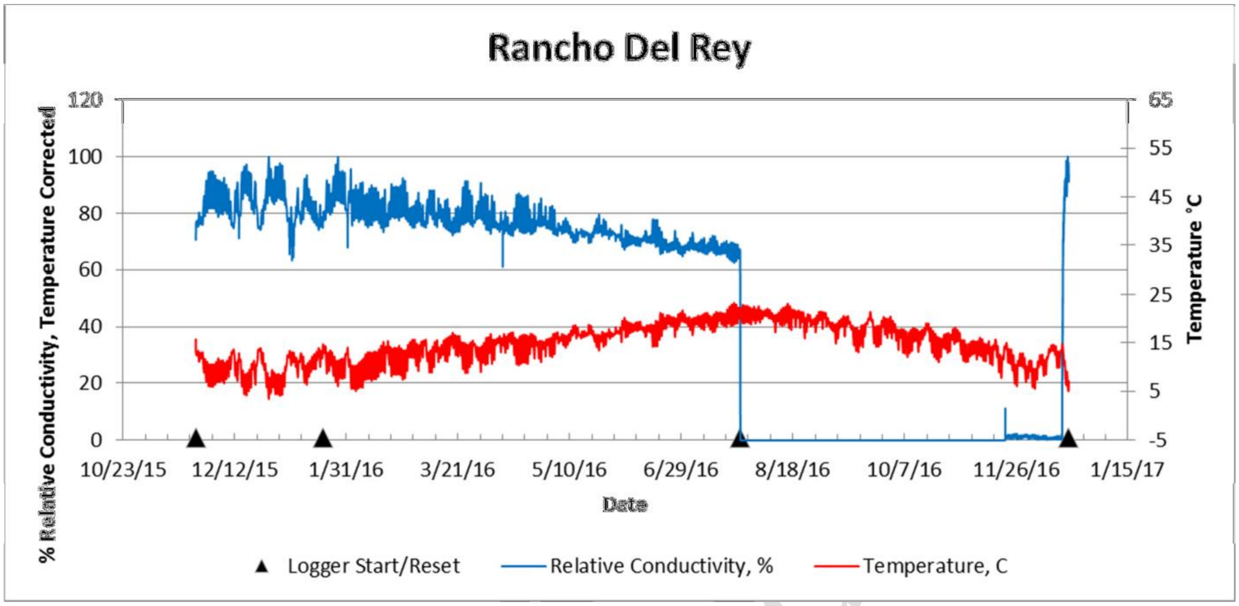

Figure A30d. Relative conductivity and temperature graph of Rancho Del Rey (ASF 06)*.


Figure A30e. Habitat at Rancho Del Rey (ASF 06) on 24 November 2015 (left) and 25 July 2016 (right).

Terra Nova (ASF 07)

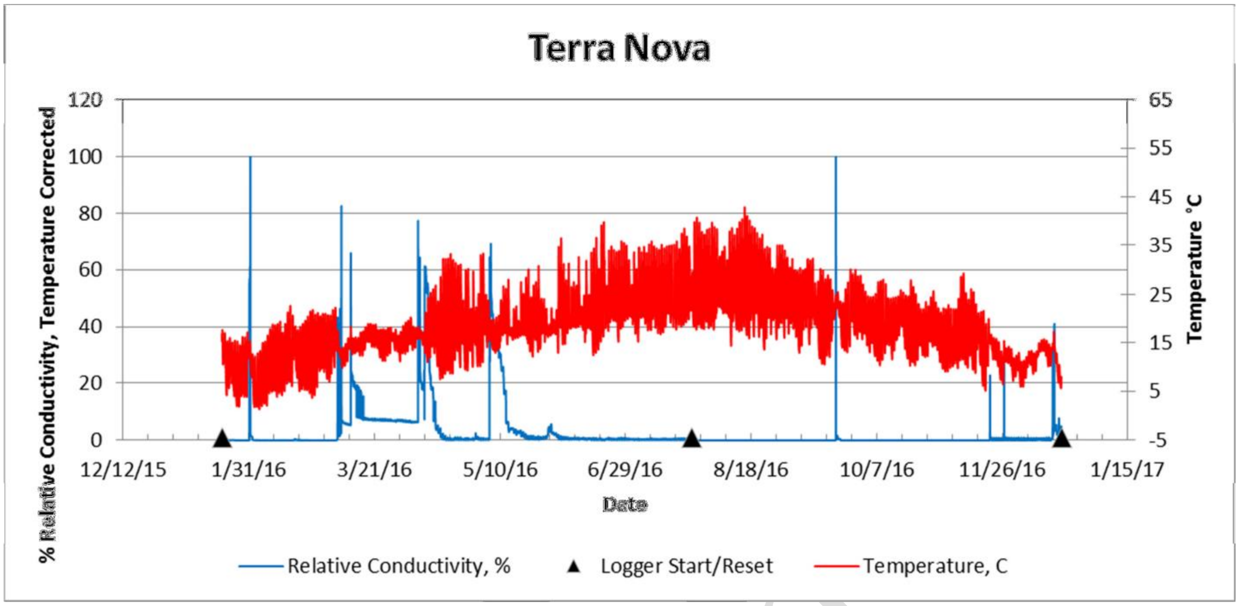

Figure A30f. Relative conductivity and temperature graph of Terra Nova (ASF 07)*.

Figure A30g. Habitat at Terra Nova (ASF 07) on 2 December 2015 (left) and on 25 July 2016 (right).

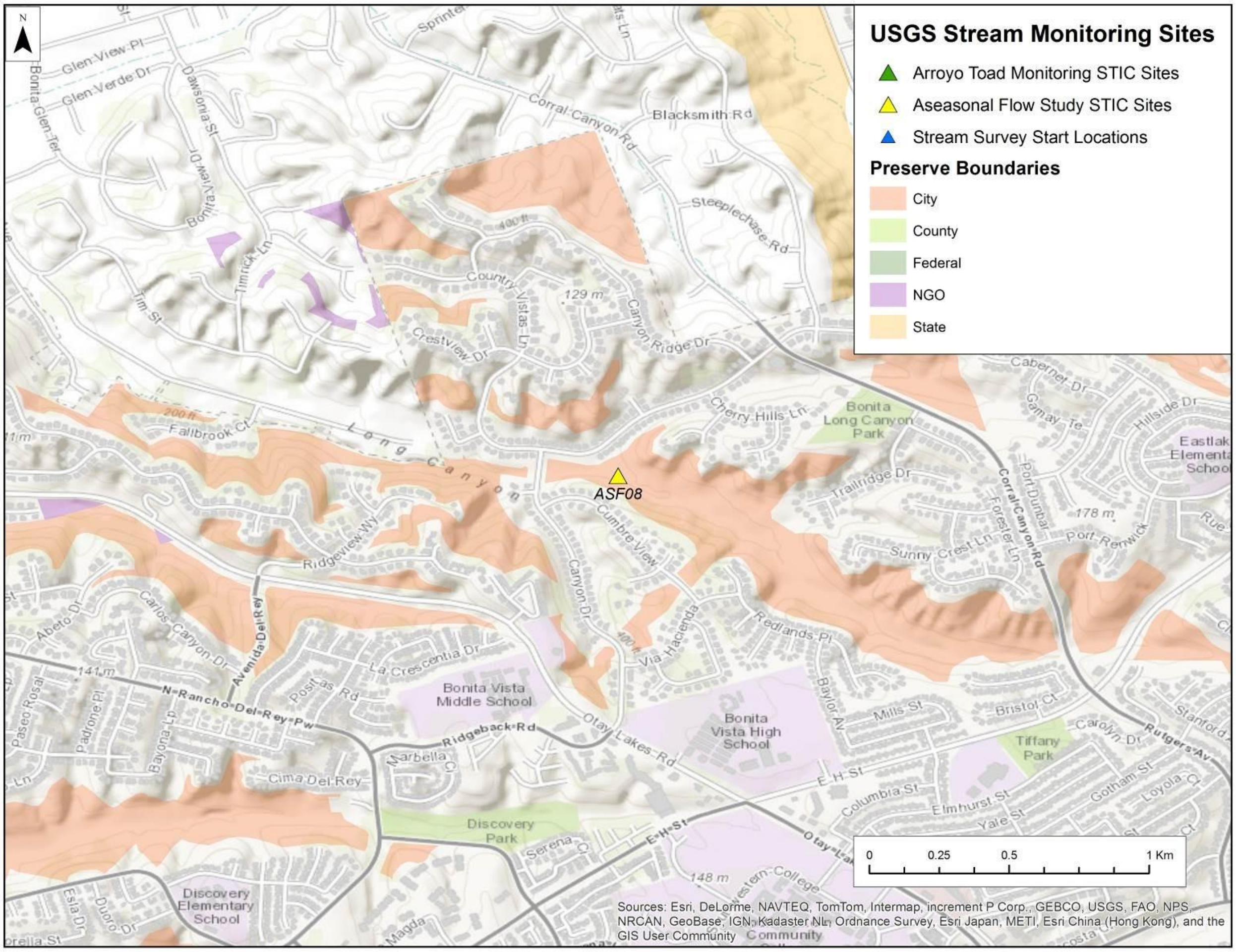

Figure A31a. ASF 08. Long Canyon in Chula Vista Central City Preserve owned and managed by City of Chula Vista.

Long Canyon (ASF 08)

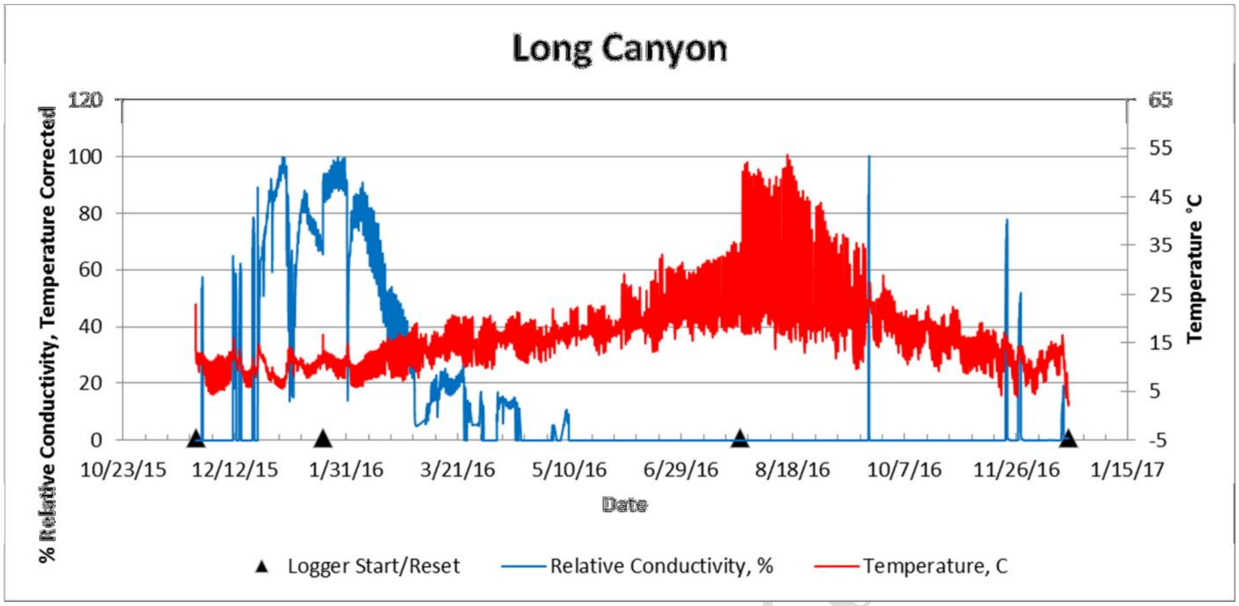

Figure A31b. Relative conductivity and temperature graph of Long Canyon (ASF 08)*.

Figure A31c. Habitat at Long Canyon (ASF 08) on 24 November 2015 (left) and on 25 July 2016 (right).

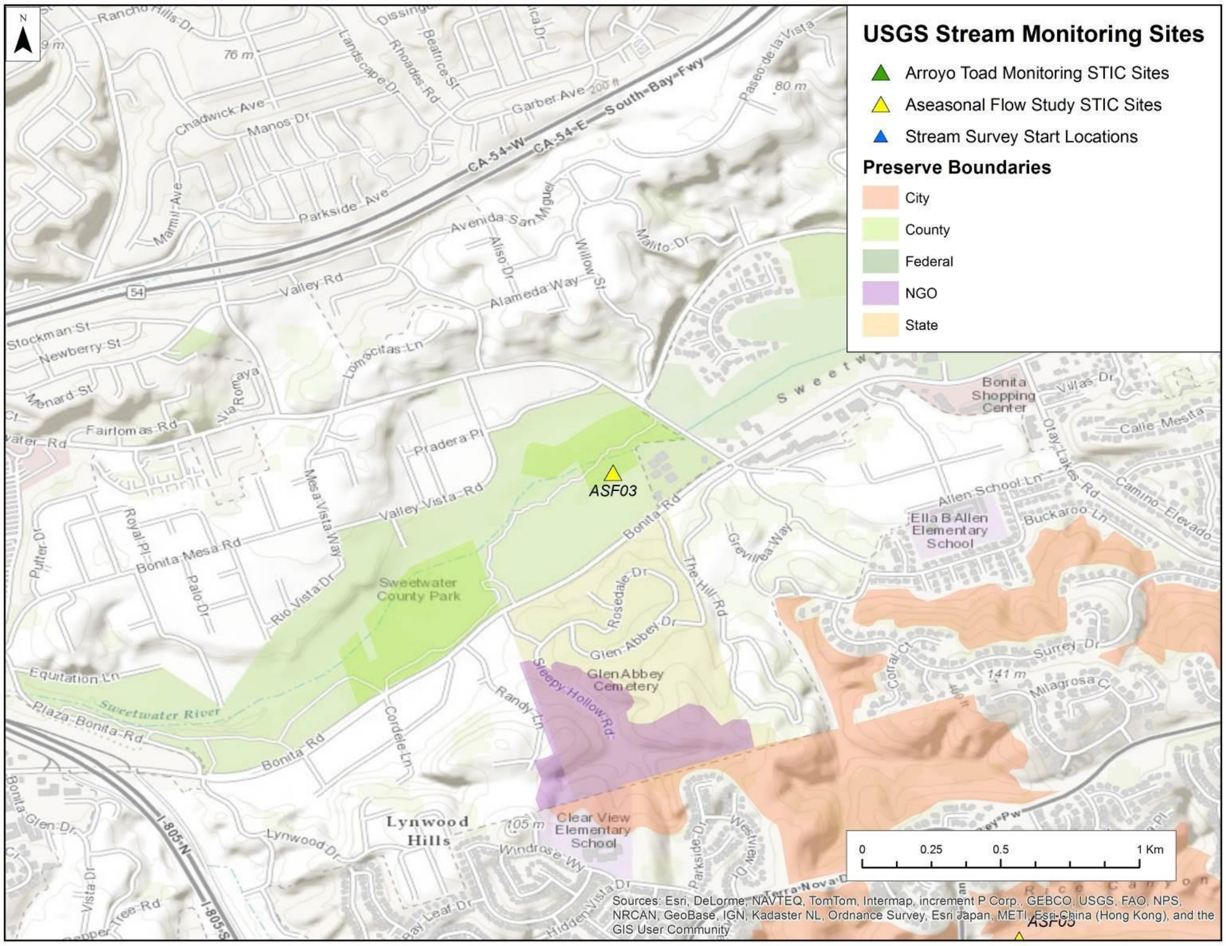

Figure A32a. ASF 03. Sweetwater County Park owned and managed by County of San Diego Parks and Recreation Department.

Sweetwater County Park (ASF 03)

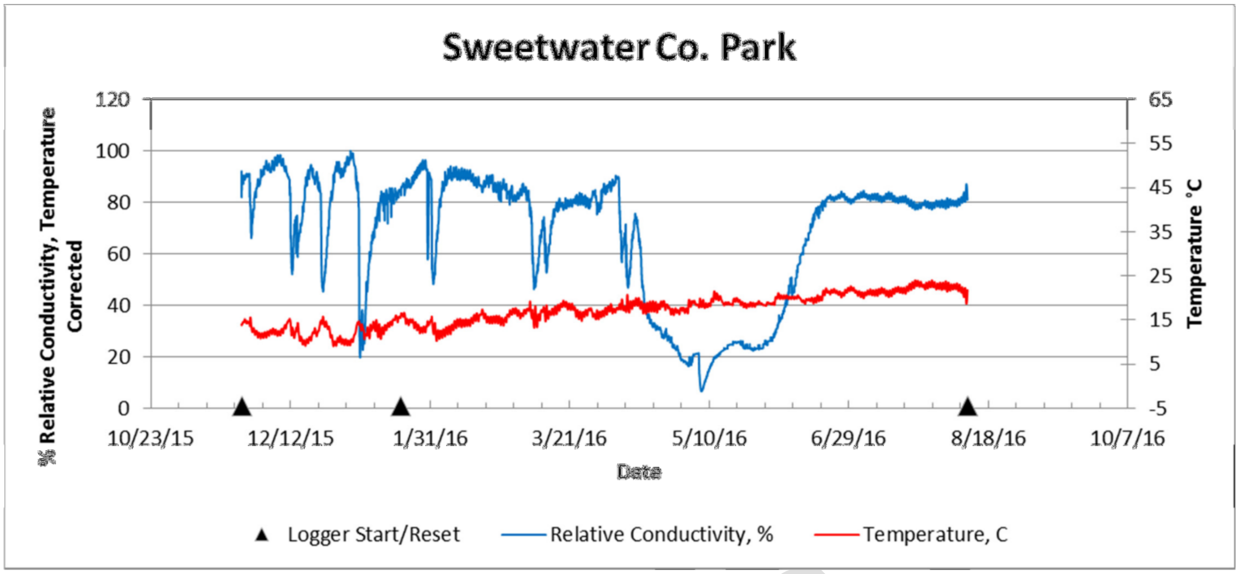

Figure A32b. Relative conductivity and temperature graph of Sweetwater County Park (ASF 03).


Figure A32c. Habitat at Sweetwater County Park (ASF 03) on 24 November 2015 (left) and on 25 July 2017 (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 with approximately 16,663 hectares of conserved lands. This watershed is heavily urbanized in the mid and lower regions with rural, agriculture, and open space in the upper portion. Previously established arroyo toad monitoring sites include seven surface water monitoring sites along tributaries to Otay River (Brown et al. 2019). This study adds a total of 14 surface water monitoring sites in the main stem of the Otay River and associated tributaries. The open space land managers within the watershed are CDFW, Bureau of Land Management (BLM), City of San Diego, City of Chula Vista, and County of San Diego.

Hollenbeck Canyon (ASF 57 and ASF55).–These sites along Jamul Creek (ASF 57) and its tributary (ASF 55) have uplands consisting predominately of chaparral, coastal sage scrub, and grasslands. Jamul Creek joins with Dulzura Creek before flowing into Lower Otay Reservoir. Owned and managed by CDFW, these sites have 40 to 55% urban land cover which consists of mostly low to medium density rural community.

Proctor Valley (ASF 58 and ASF61).–The creek through this section of Proctor Valley drains the east slope of San Miguel Mountain and is primarily coastal sage scrub and chaparral. Having approximately 13% urban, this reach, owned and managed by CDFW, is part of a multi-agency preserve.

Dulzura Creek Tributary (ASF 45).–This small tributary in Otay Ranch Preserve is primarily chaparral, Tecate Cypress (*Cupressus forbesii*) woodland, and coastal sage scrub. Owned and managed by County of San Diego, there is no upstream urban development.

Salt Creek Preserve (ASF 13 and ASF 14).–Salt Creek is a tributary to Otay River with chaparral and coastal sage scrub upland. This section of Salt Creek is owned and managed by City of Chula Vista and has approximately 50% upstream urban development.

Otay Valley Preserve (ASF 02 and ASF 48).–Dennery Canyon (ASF 02) and Otay River in Wolf Canyon (ASF 48) are small, lightly developed tributaries to Otay River. Consisting primarily of coastal sage scrub and chaparral, they are owned and managed by the City of Chula Vista and have approximately 30% upstream urban development.

Otay Ranch Regional Park (ASF 09, ASF 10, ASF 11, ASF 62, and ASF 63).–These sites are a series of small, highly developed tributaries to Otay River. The reserves are surrounded by urban development and are owned and managed by the City of San Diego.

Otay River Watershed (fourteen ASF sites):

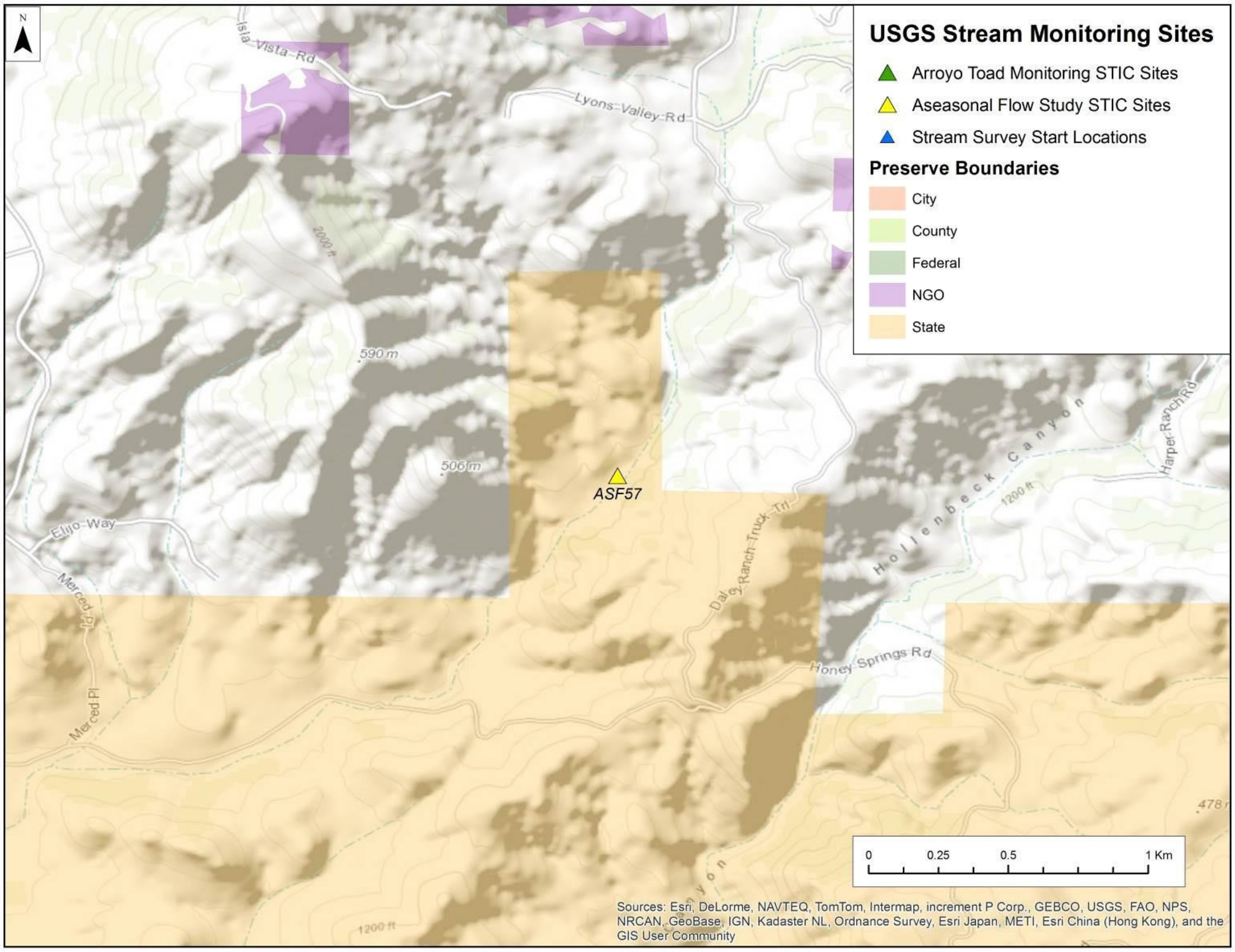

Figure A33a. ASF 57. Jamul Creek in Hollenbeck Canyon Wildlife Area owned and managed by CDFW.

Otay River Watershed

Jamul Creek (ASF 57)

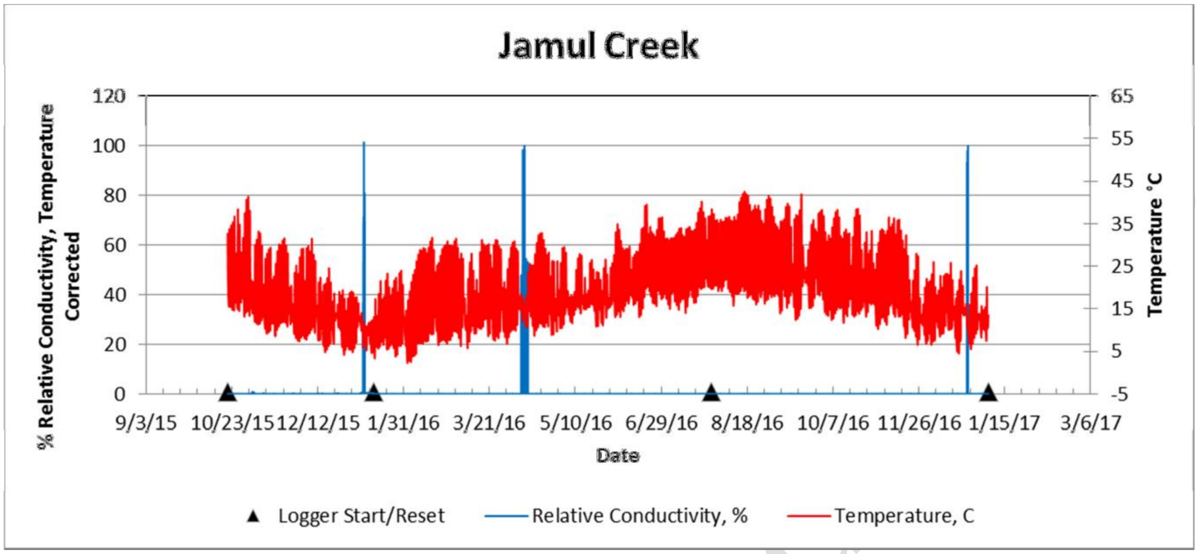

Figure A33b. Relative conductivity and temperature graph of Jamul Creek (ASF 57)*.

Figure A33c. Habitat at Jamul Creek (ASF 57) on 13 January 2016 (left) and on 20 October 2016 (right).

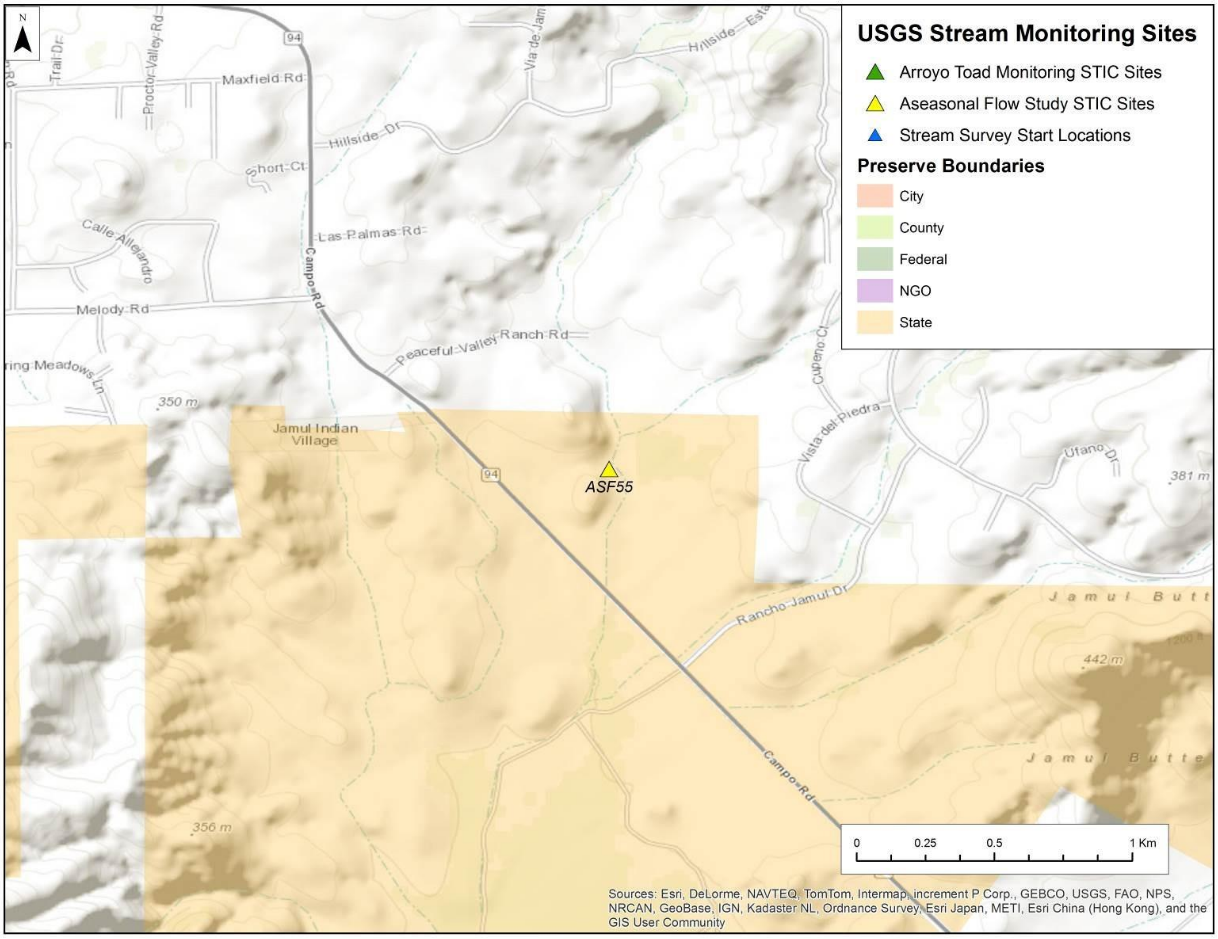

Figure A34a. ASF 55. Jamul Creek tributary in Rancho Jamul Ecological Reserve owned and managed by CDFW.

Jamul Creek Tributary 15 (ASF 55)

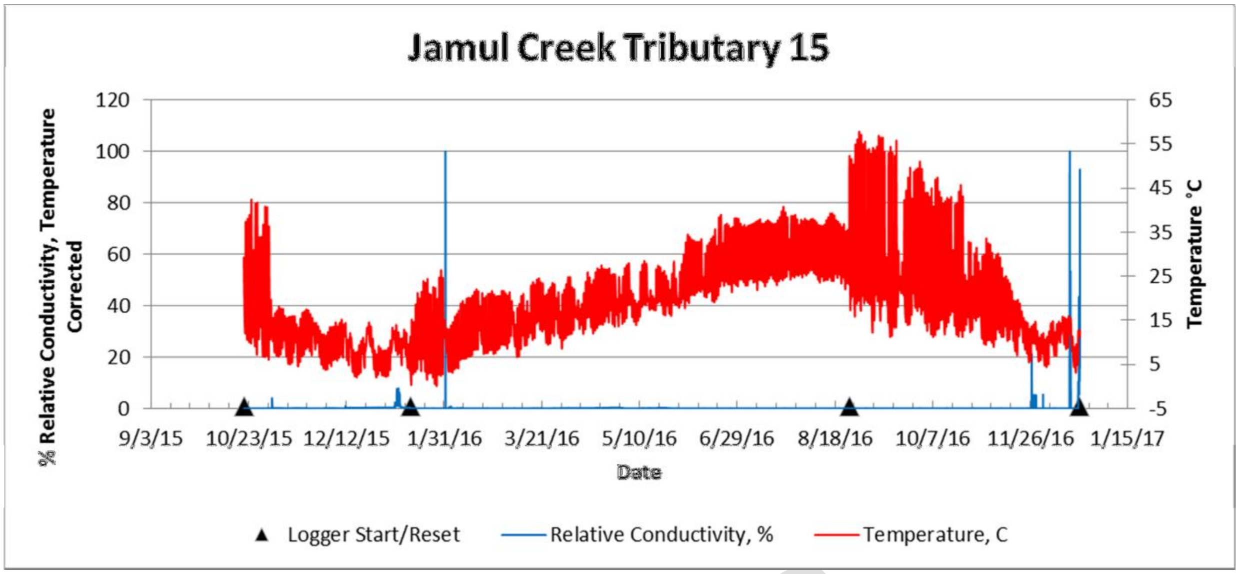

Figure A34b. Relative conductivity and temperature graph of Jamul Creek Tributary 15 (ASF 55)*.

Figure A34c. Habitat at Jamul Creek Tributary 15 (ASF 55) on 13 January 2016 (left) and on 21 December 2016 (right).

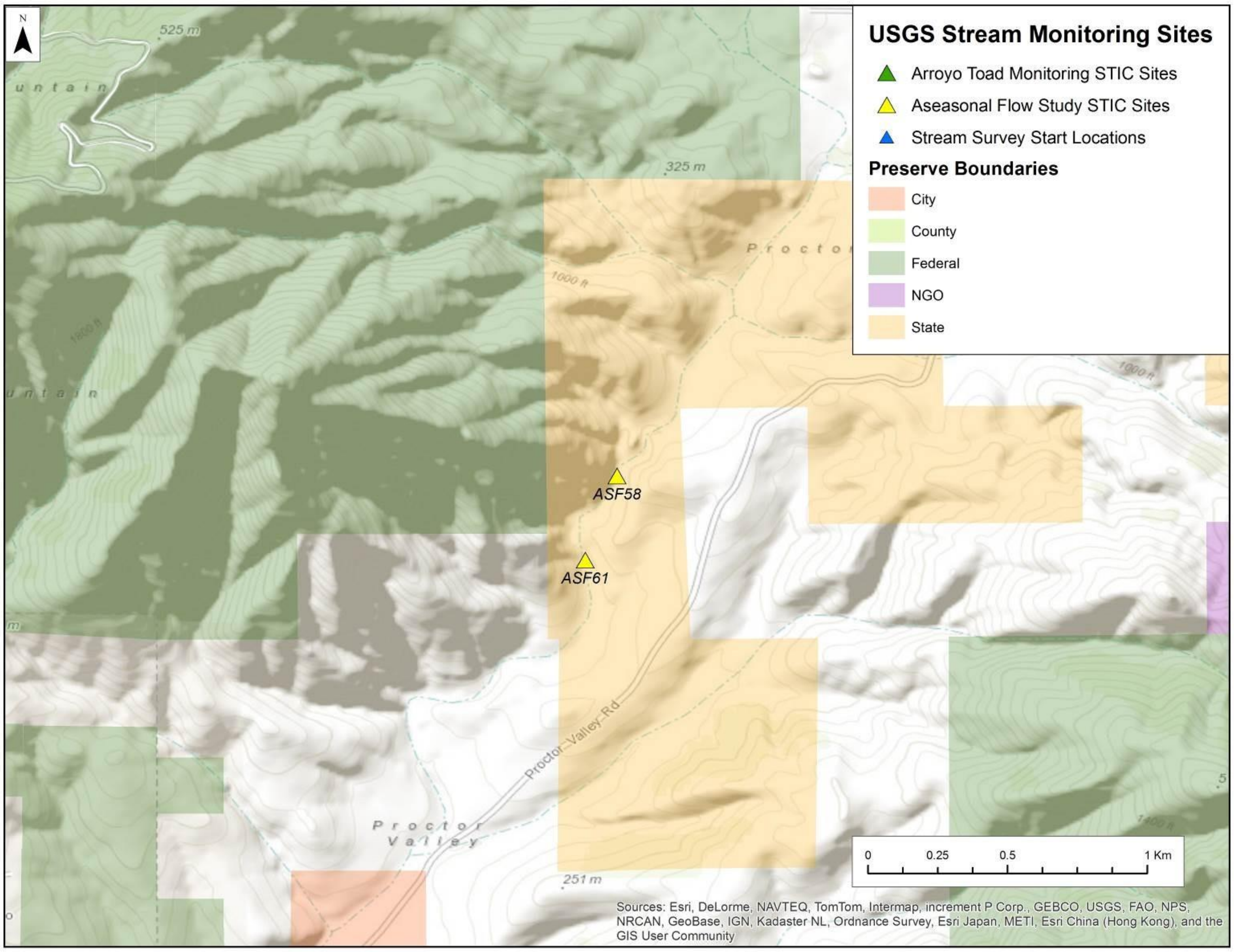

Figure A35a. ASF 58 and 61. Proctor Valley owned and managed by CDFW.

Proctor Valley 1 (ASF 58)

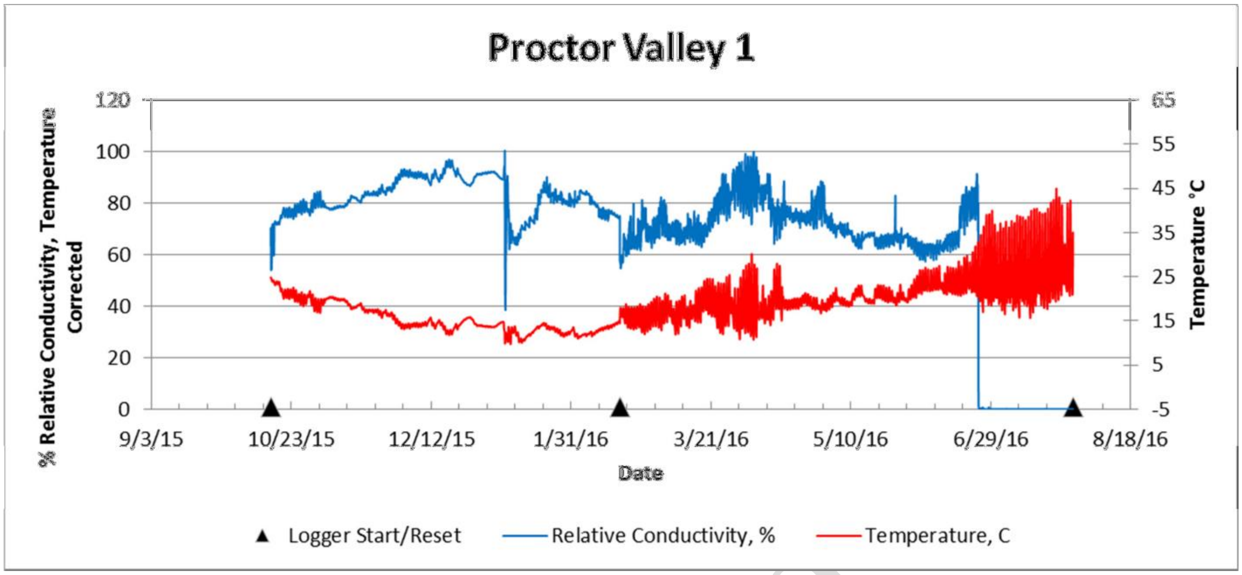

Figure A35b. Relative conductivity and temperature graph of Proctor Valley 1 (ASF 58).

Figure A35c. Habitat at Proctor Valley 1 (ASF 58) on 17 February 2016 (left) and on 28 July 2016 (right).

Proctor Valley 2 (ASF 61)

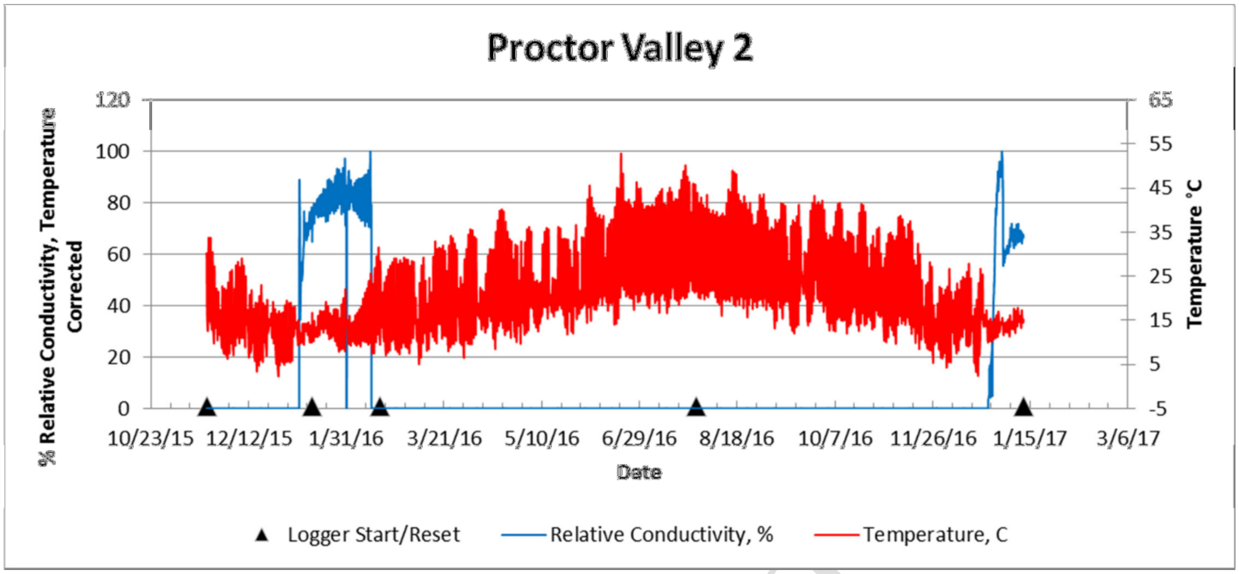

Figure A35d. Relative conductivity and temperature graph of Proctor Valley 2 (ASF 61)*.

Figure A35e. Habitat at Proctor Valley 2 (ASF61) on 17 February 2016 (left) and on 28 July 2016 (right).

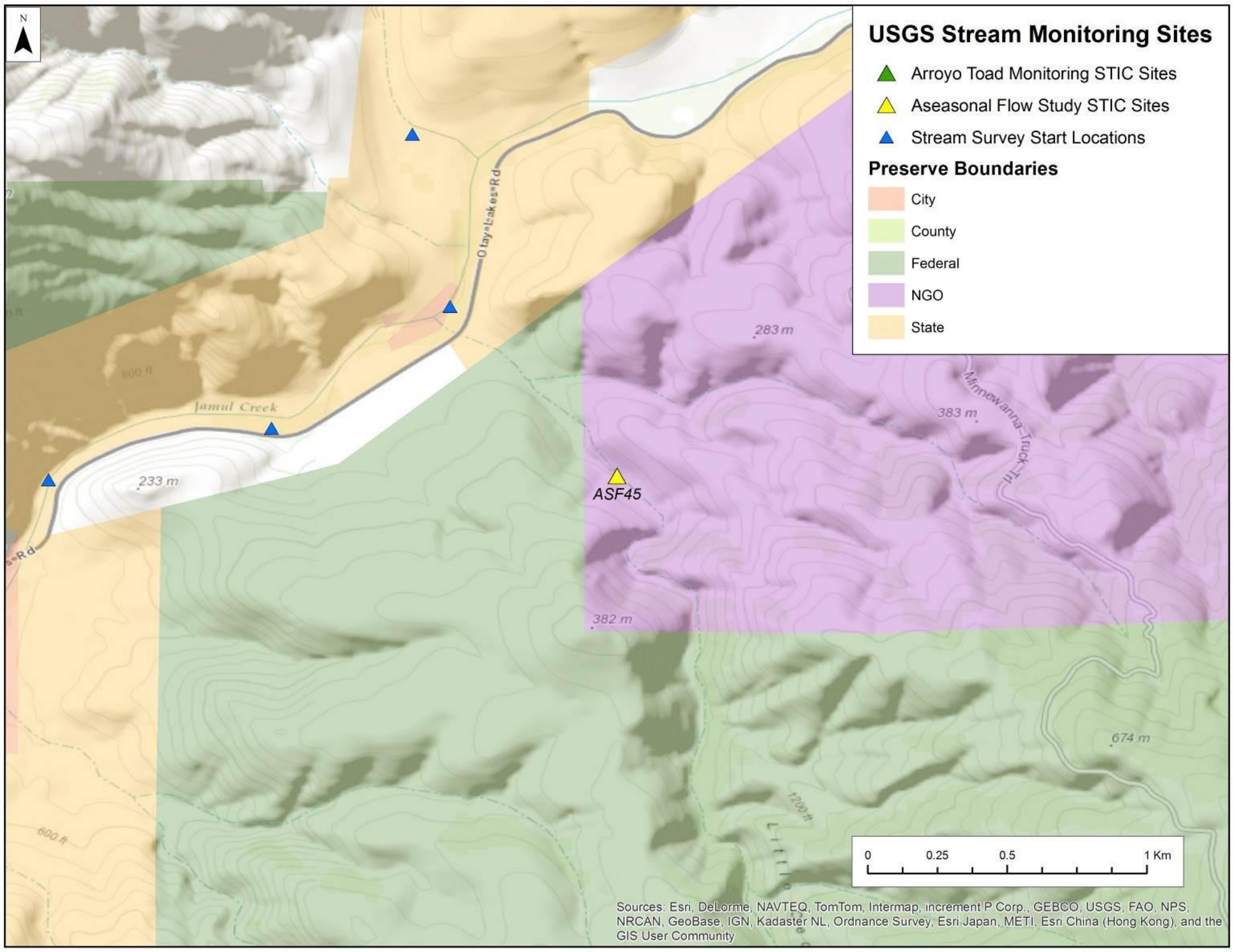

Figure A36a. ASF45. Dulzura Creek Tributary in Otay Ranch Preserve owned and managed by Otay POM.

Dulzura Creek Tributary (ASF 45)

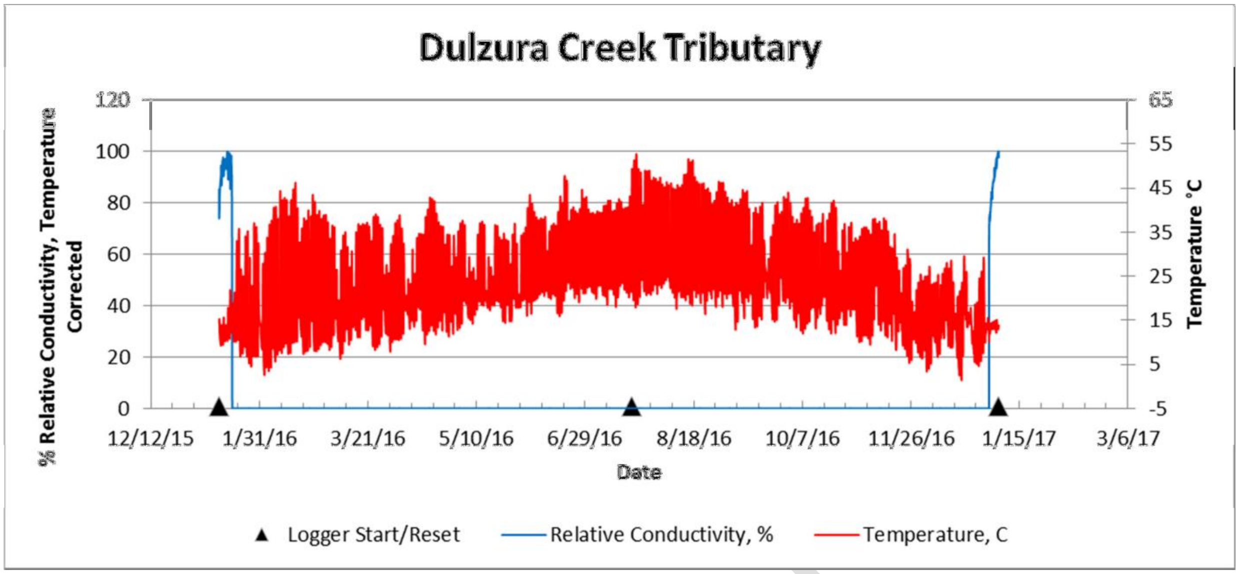

Figure A36b. Relative conductivity and temperature graph of Dulzura Creek Tributary (ASF 45)*.

Figure A36c. Habitat at Dulzura Creek Tributary (ASF 45) on 12 January 2016 (left) and on 20 July 2016 (right).

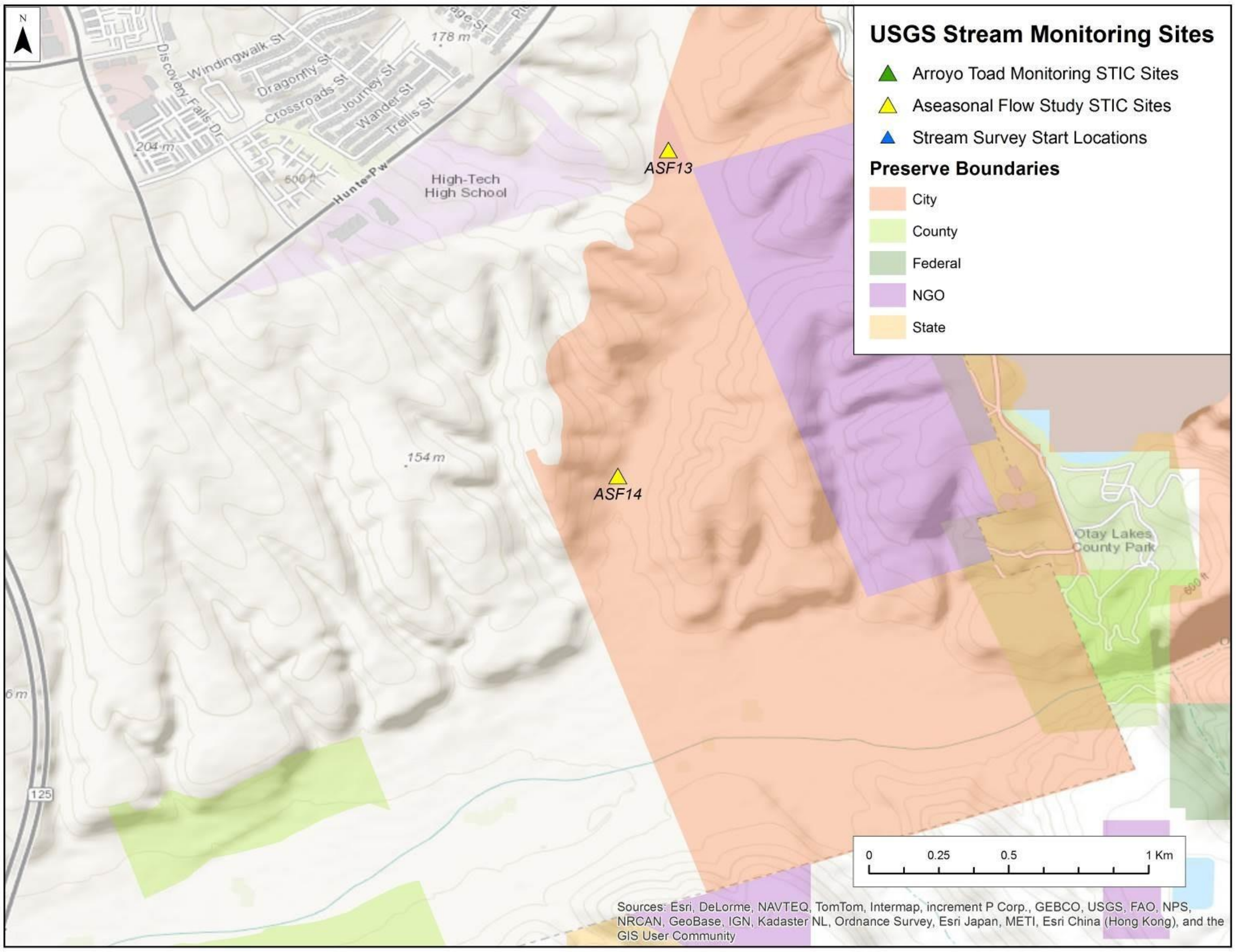

Figure A37a. ASF 13 and 14. Salt Creek in Salt Creek Preserve owned and managed by City of Chula Vista.

Salt Creek 1 (ASF 13)

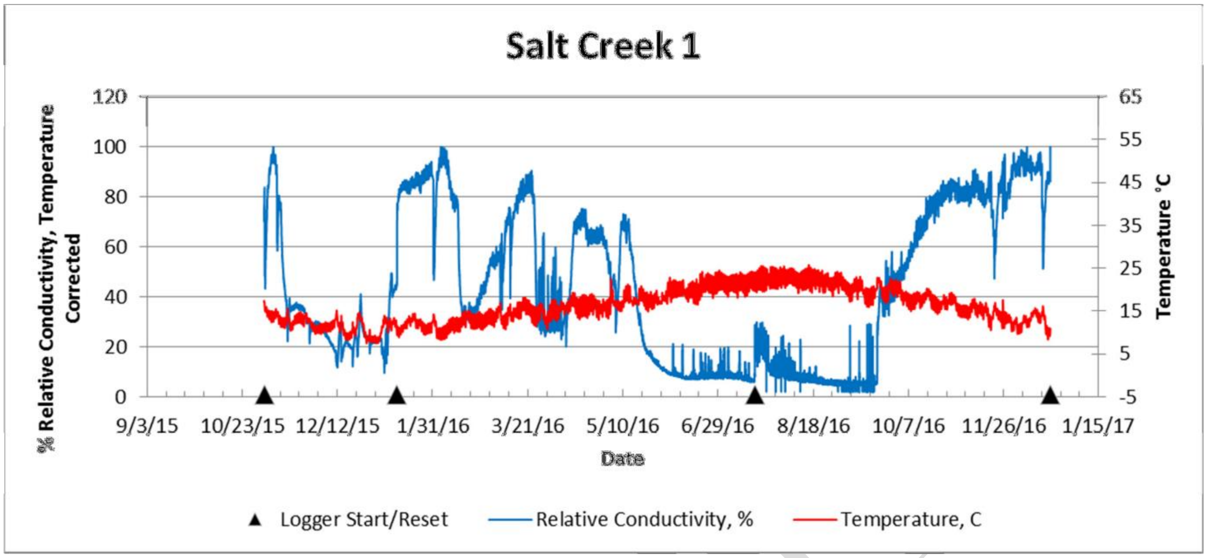

Figure A37b. Relative conductivity and temperature graph of Salt Creek 1 (ASF 13).

Figure A37c. Habitat at Salt Creek 1 (ASF 13) on 12 January 2016 (left) and on 18 July 2016 (right).

Salt Creek 2 (ASF 14)

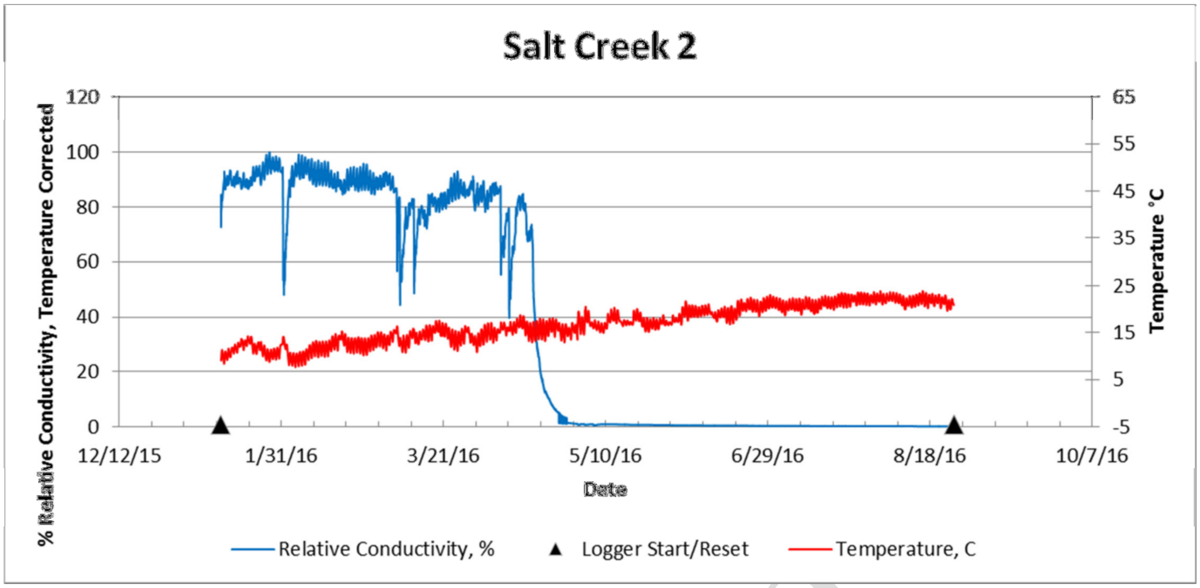

Figure A37d. Relative conductivity and temperature graph of Salt Creek 2 (ASF 14)*.

Figure A37e. Habitat at Salt Creek 2 (ASF 14) on 12 January 2016 (left) and on 25 August 2016 (right).

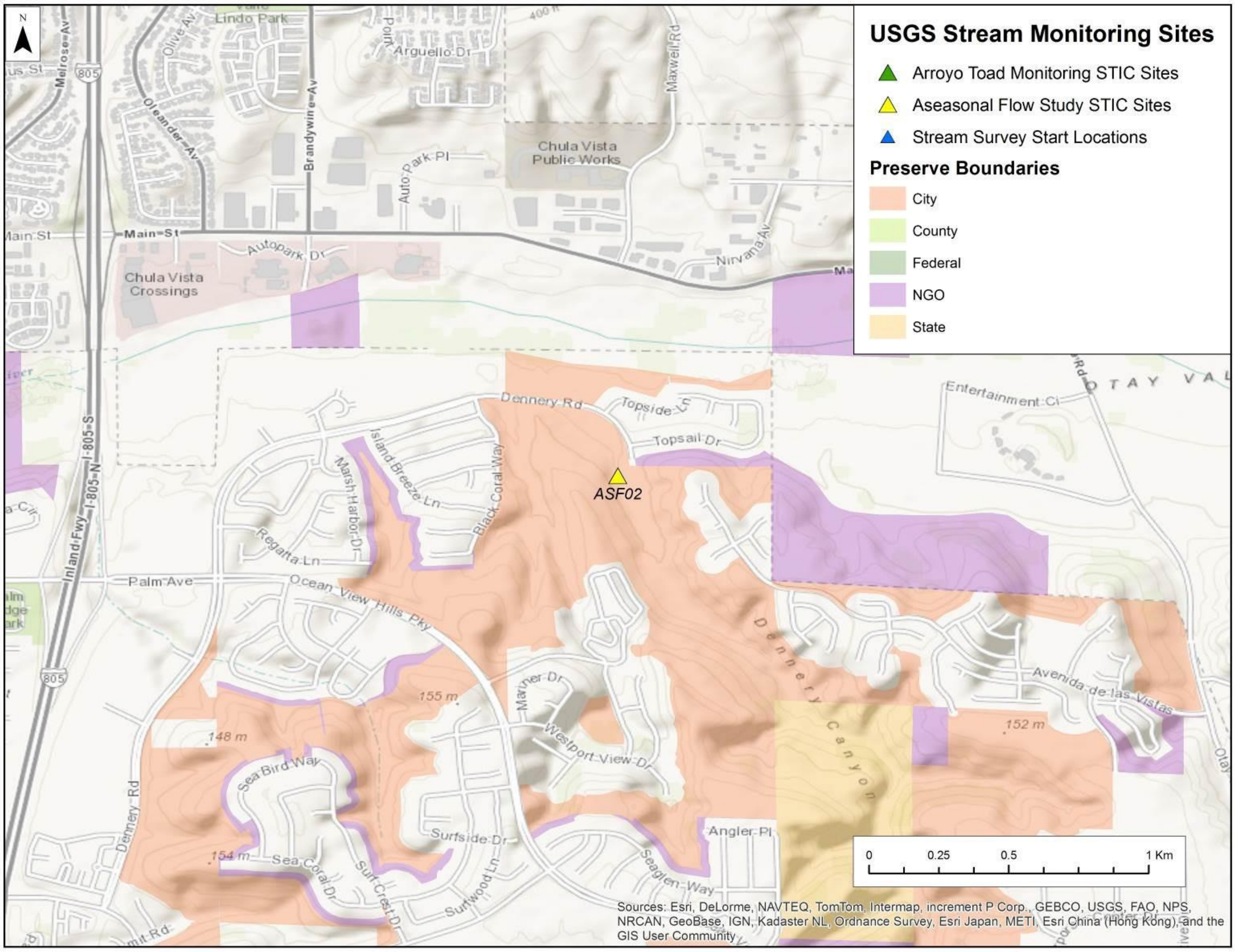

Figure A38a. ASF 02. Dennery Canyon in Otay Valley Preserve owned and managed by City of Chula Vista.

Dennery Canyon (ASF 02)

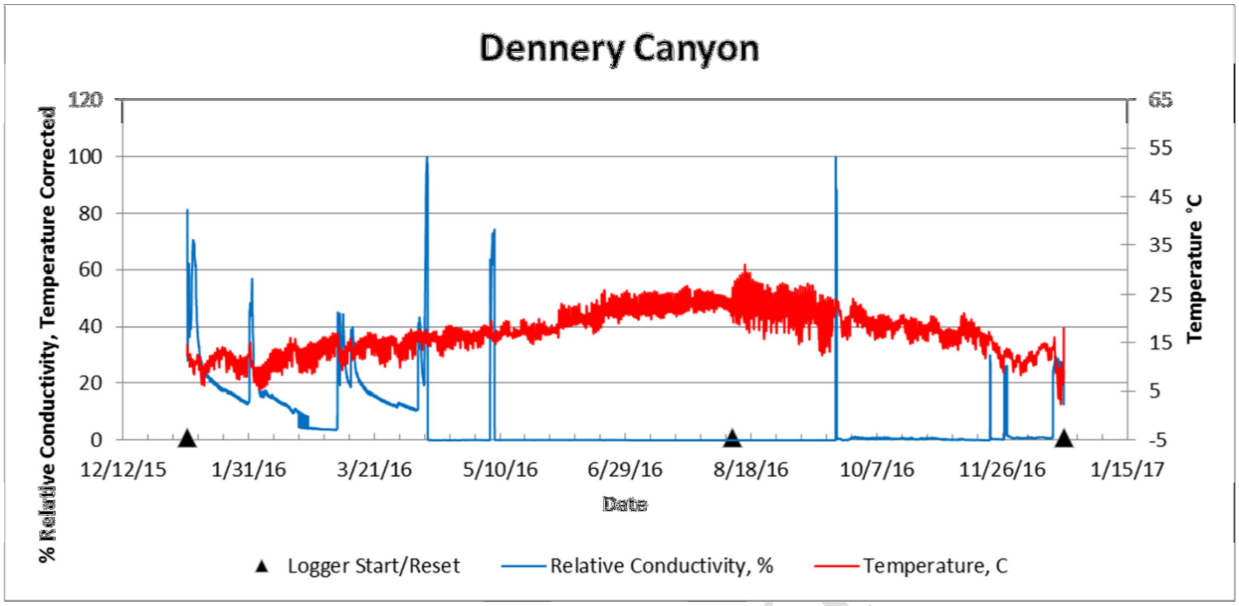

Figure A38b. Relative conductivity and temperature graph of Dennery Canyon (ASF 02)*.

Figure A38c. Habitat at Dennery Canyon (ASF 02) on 06 January 2016 (left) and on 20 December 2016 (right).

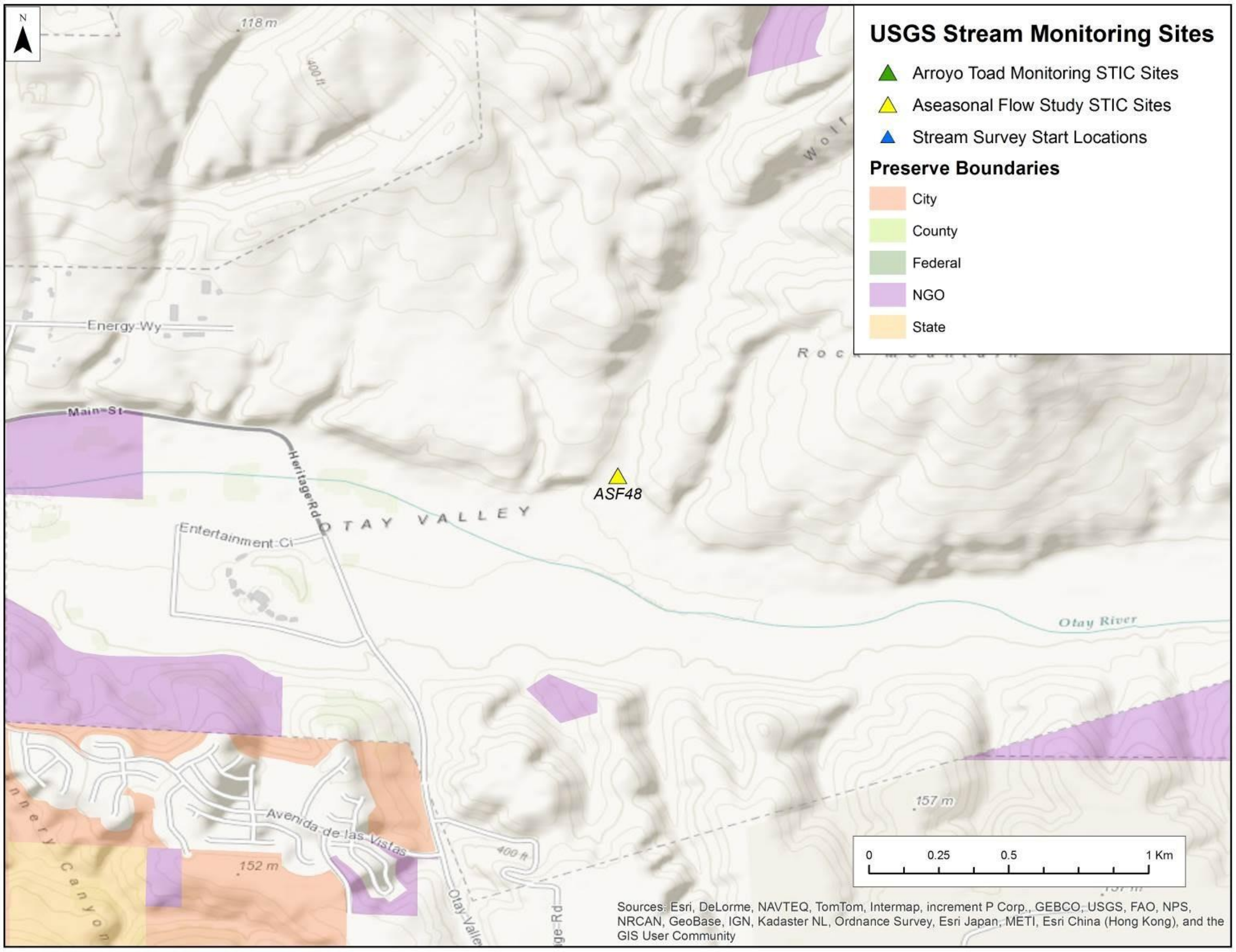

Figure A39a. ASF 48. Wolf Canyon in Otay Valley Preserve owned and managed by City of Chula Vista.

Otay River (ASF 48)

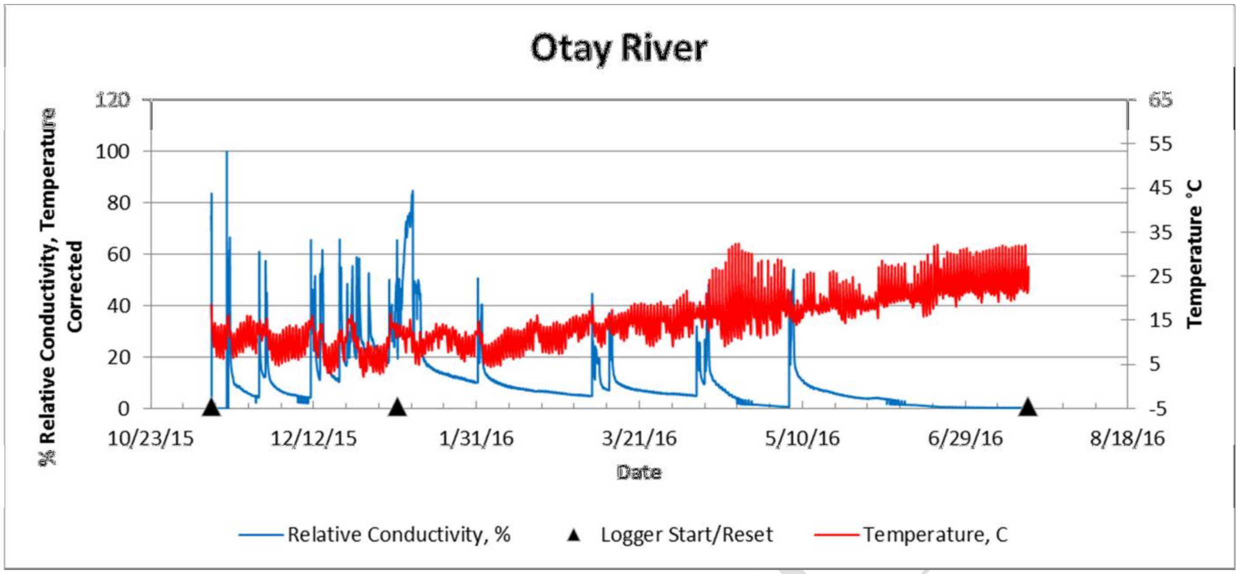

Figure A39b. Relative conductivity and temperature graph of Otay River (ASF 48).

Figure A39c. Habitat at Otay River (ASF 48) on 18 July 2016 (left) and on 20 December 2016 (right).

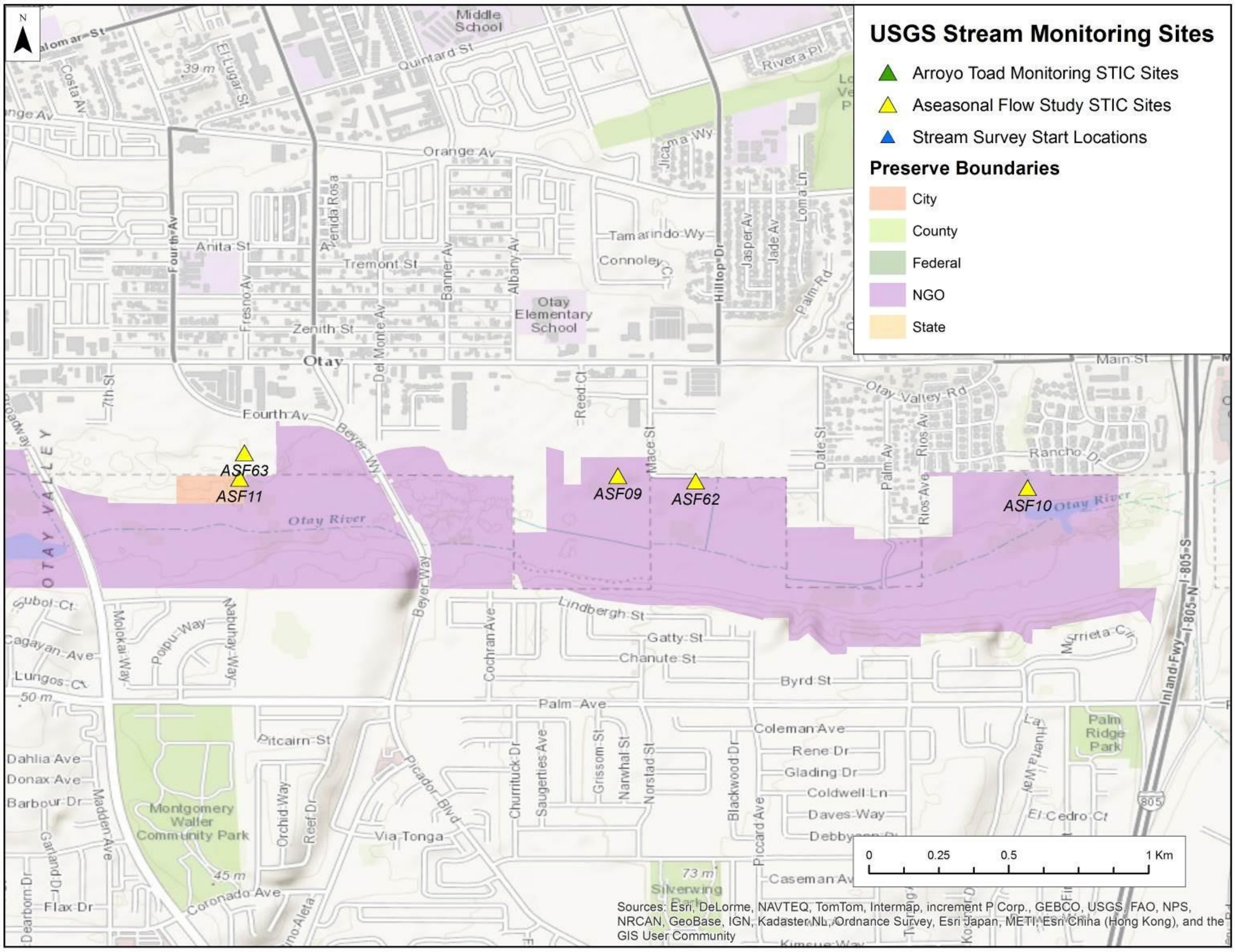

Figure A40a. ASF 09, 10, 11, 62, and 63. Otay River Tributaries in Otay River Park owned and managed by City of San Diego.

Otay River Tributary 2 (ASF 09)

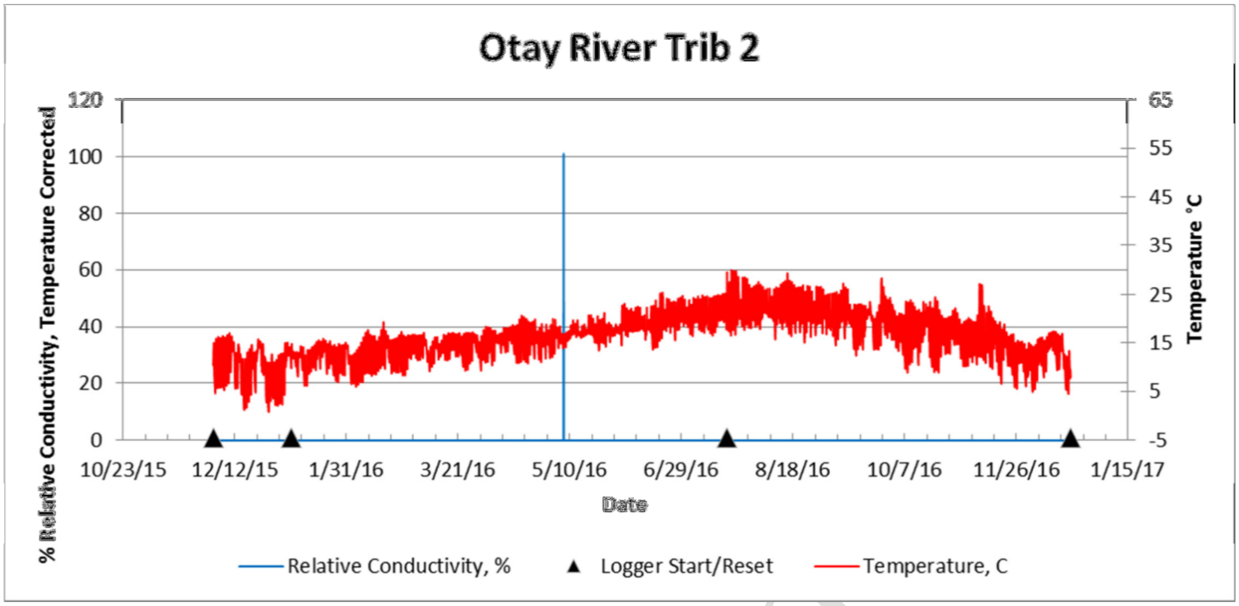

Figure A40b. Relative conductivity and temperature graph of Otay River Tributary 2 (ASF 09)*.

Figure A40c. Habitat at Otay River Tributary 2 (ASF 09) on 06 January 2016 (left) and on 20 December 2016 (right).

Otay River Tributary 3 (ASF 10)

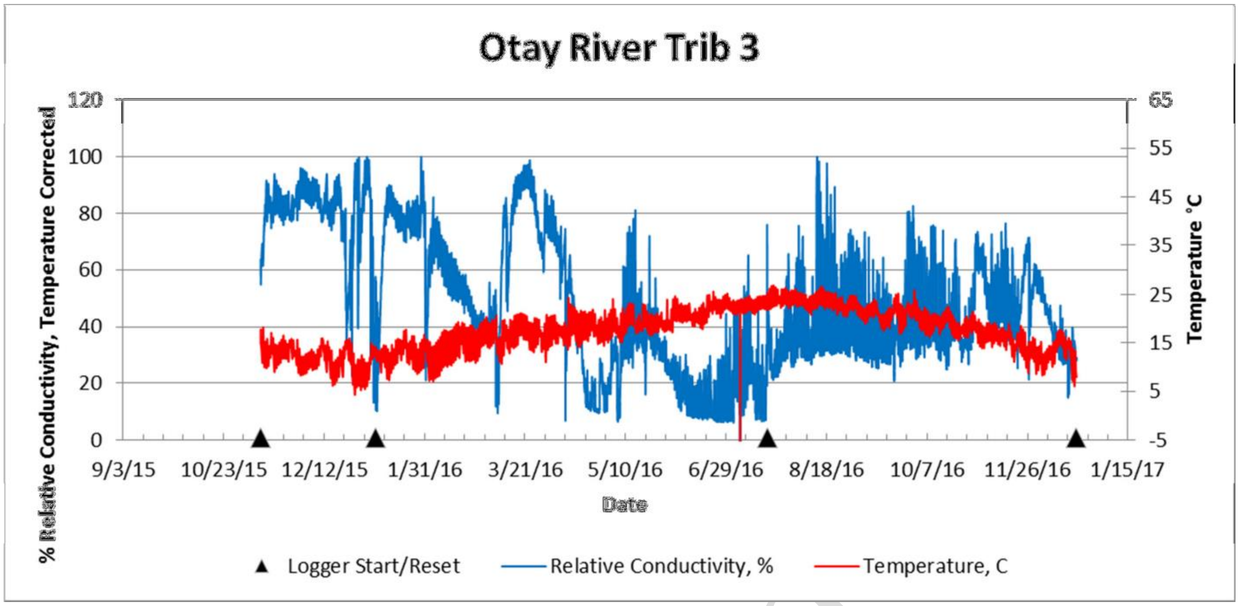

Figure A40d. Relative conductivity and temperature graph of Otay River Tributary 3 (ASF 10).

Figure A40e. Habitat at Otay River Tributary 3 (ASF 10) on 19 July 2016 (left) and on 20 December 2016 (right).

Otay River Tributary 1 (ASF 11)

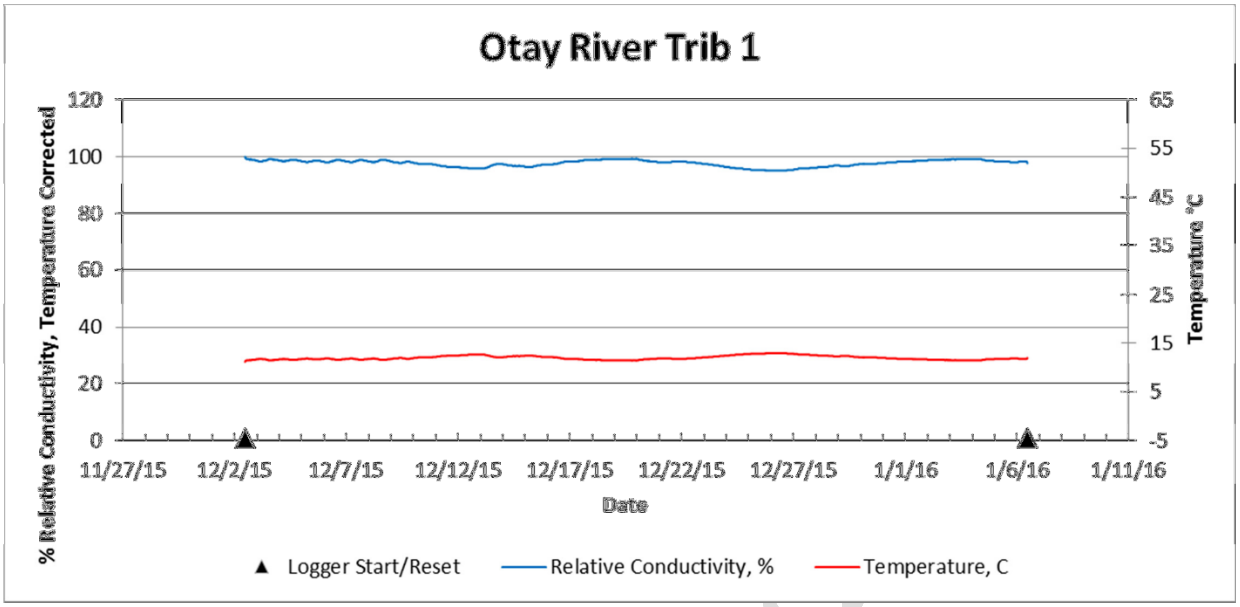

Figure A40f. Relative conductivity and temperature graph of Otay River Tributary 1 (ASF 11).

Figure A40g. Habitat at Otay River Tributary 1 (ASF 11) on 06 January 2016.

Otay River Tributary 2B (ASF 62)

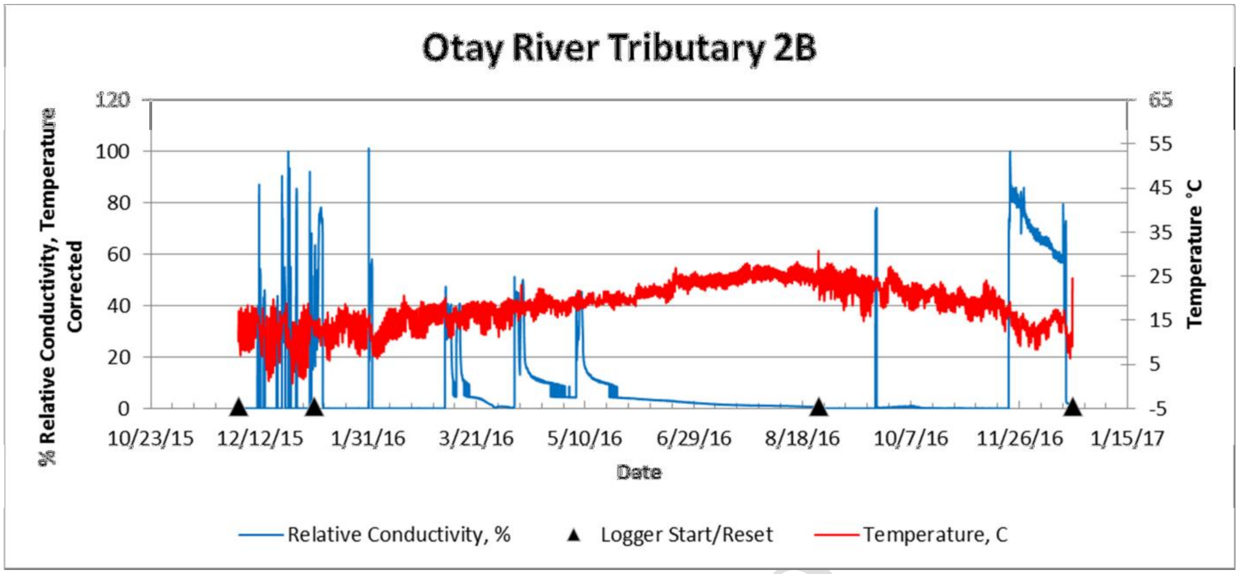

Figure A40h. Relative conductivity and temperature graph of Otay River Tributary 2B (ASF 62)*.


Figure A40i. Habitat at Otay River Tributary 2B (ASF 62) on 02 December 2015 (left) and on 20 December 2016 (right).

Otay River Tributary 1B (ASF 63)

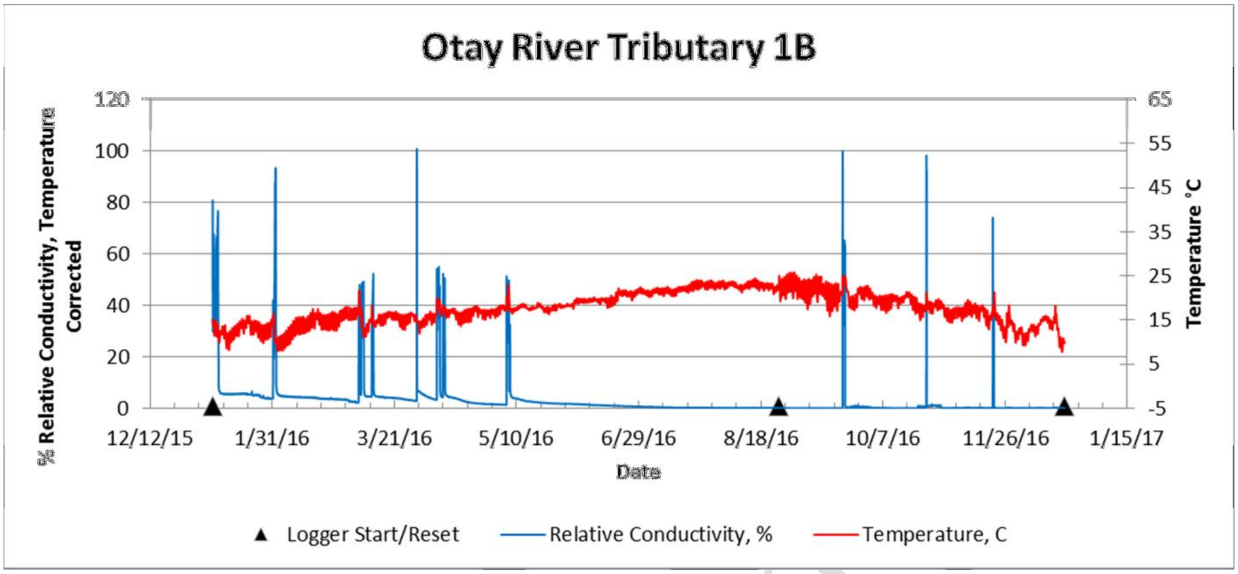

Figure A40j. Relative conductivity and temperature graph of Otay River Tributary 1B (ASF 63)*.

Figure A40k. Otay River Tributary 1B (ASF 63) on 02 December 2015 (left) and on 19 July 2016 (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. The watershed contains approximately 71,662 hectares of conserved lands within San Diego County. Previously established arroyo toad monitoring sites include eight surface water monitoring sites in Cottonwood Creek and Pine Valley Creek (Brown et al. 2019). This study adds two surface water monitoring sites in the Spring Canyon Open Space preserve (Appendix A). The open space land managers within the watershed are USFS, City of San Diego, Back Country Land Trust, County of San Diego, and BLM.

Spring Canyon (ASF 01 and ASF59).–The Spring Canyon Open space preserve is primarily coastal sage scrub and grassland with approximately 25% upstream urban development. The preserve adjacent to the U.S./Mexico Border is owned and managed by City of San Diego with recreation limited to hiking and biking.

Tijuana River Watershed (two ASF sites):

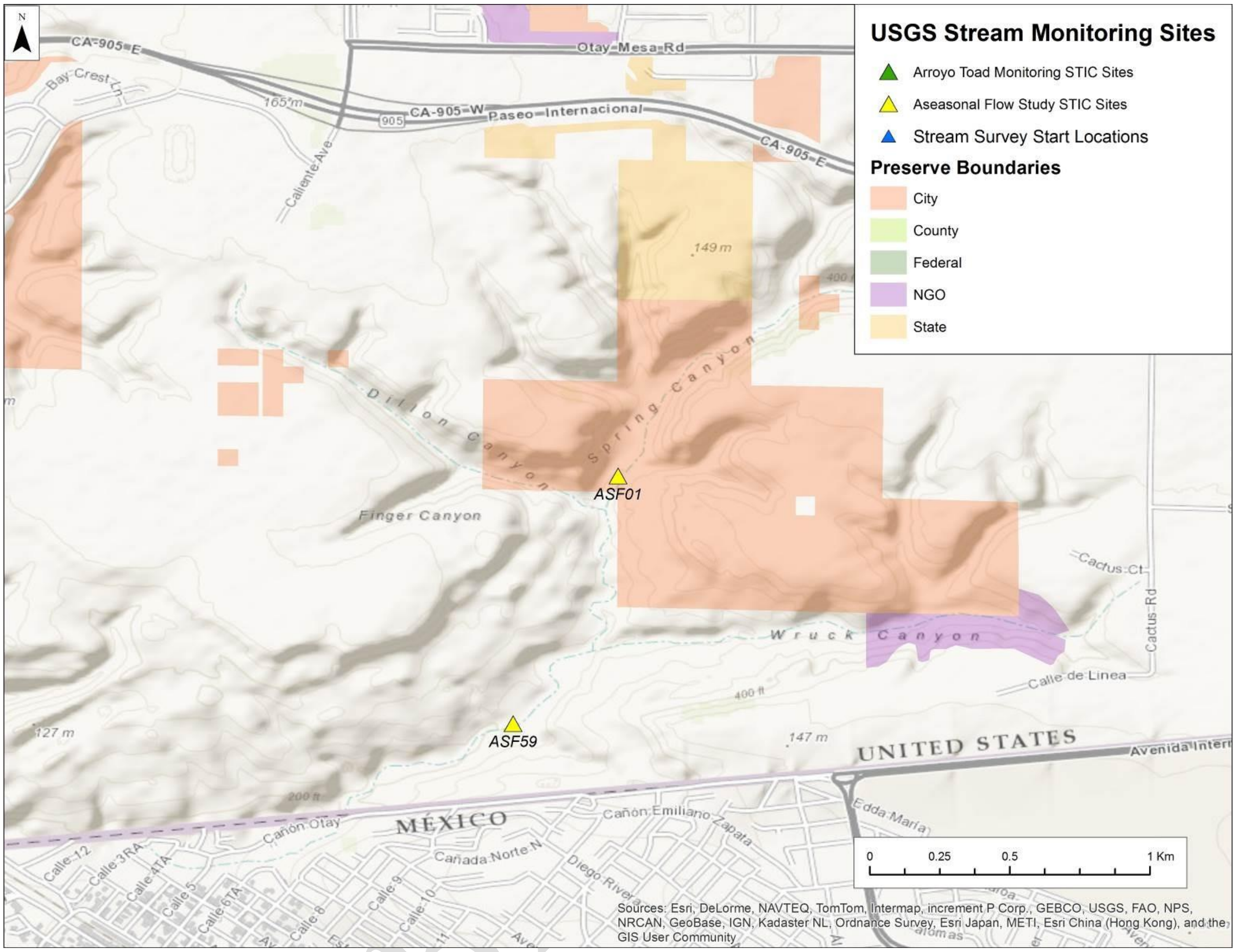

Figure A41a. ASF 01 and 59 in Spring Canyon Preserve owned and managed by City of San Diego.

Tijuana River Watershed

Spring Canyon 2 (ASF 01)

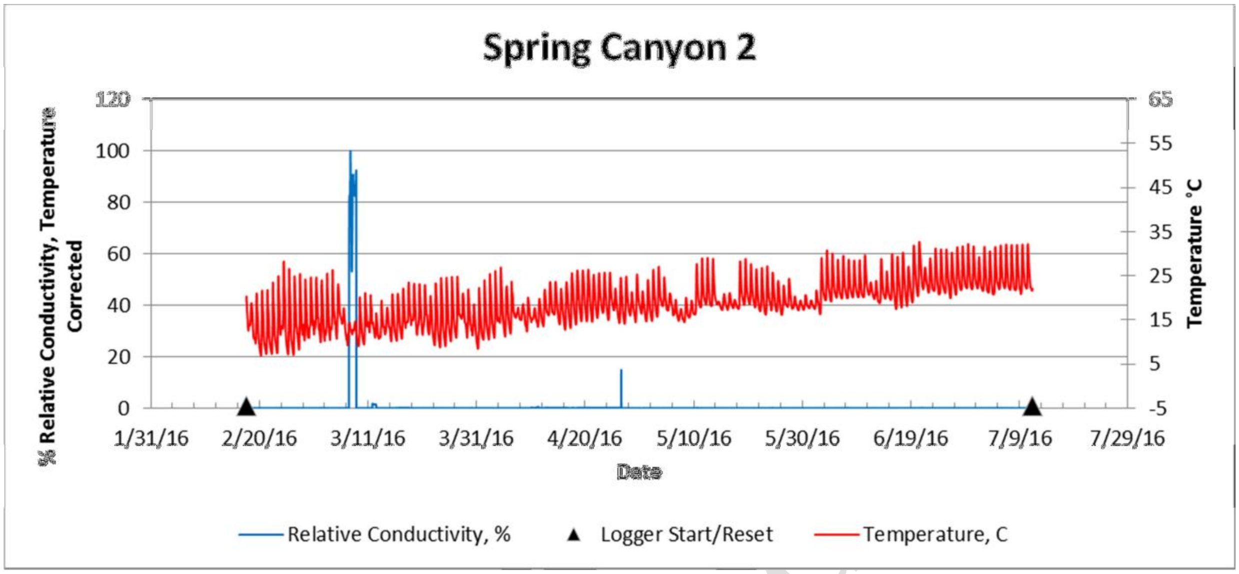

Figure A41b. Relative conductivity and temperature graph of Spring Canyon 2 (ASF 01)*.

Figure A41c. Habitat at Spring Canyon 2 (ASF 01) on 12 January 2016 (left) and on 11 July 2016 (right).

Spring Canyon 1 (ASF 59)

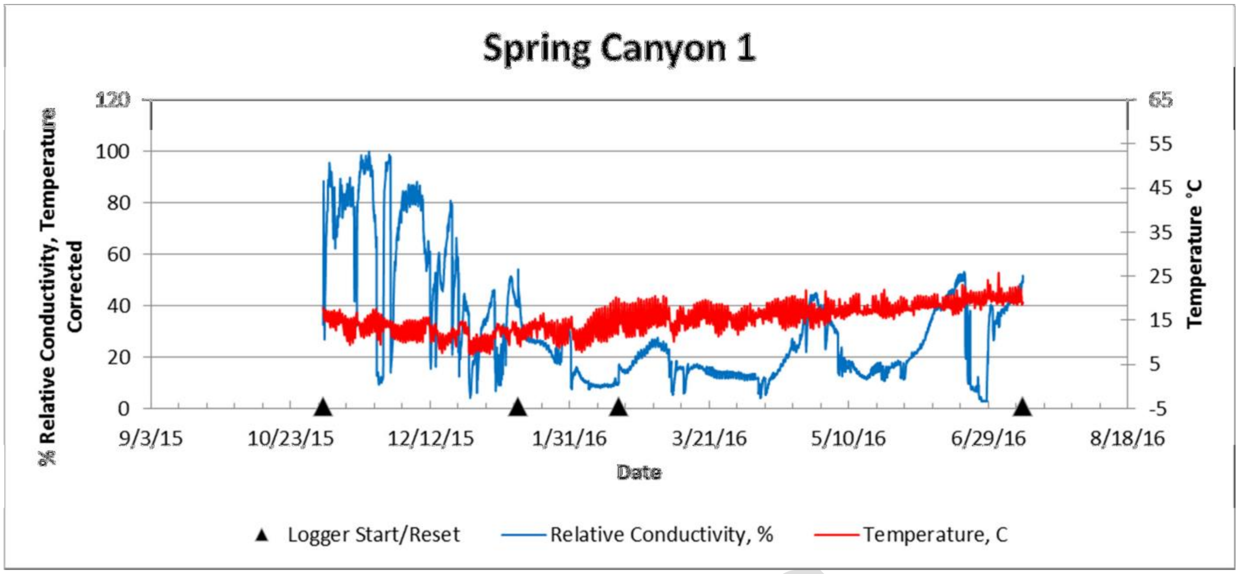

Figure A41d. Relative conductivity and temperature graph of Spring Canyon 1 (ASF 59).


Figure A41e. Habitat at Spring Canyon 1 (ASF 59) on 03 November 2015 (left) and on 11 July 2016 (right).

Literature Cited

Brown, C., E. Perkins, A. N. Aguilar Duran, O. Guerra Salcido, E. Watson, and R. N. Fisher. 2019. USGS 2015 Arroyo Toad Monitoring and Management. U.S. Geological Survey data summary prepared for SANDAG, San Diego, CA.

Carlsbad Habitat Management Plan (HMP). 1999. Habitat Management Plan for Natural Communities in the City of Carlsbad. 284pp.

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APPENDIX B

Land cover and watershed
characteristics for ASF sites.

Land cover per watershed for each of the Urban Aseasonal Flow study sites with percent urban cover and total watershed size.

			Acres of Land Coverage for Watershed											
Site	Latitude	Longitude	RIPARIAN	CHAPARRAL	CSS	GRASS	CONIFER	MONT_HW	OAK	Other	AG	URBAN	PercUrban	Grand Total
ASF01	32.70071783330	-117.06692900000				1.60						122.68	99%	124.28
ASF02	32.58712166670	-117.01943833300		68.28	230.77	79.40				6.41		164.00	30%	548.87
ASF03	32.65768450000	-117.04455050000	1,564.50	54,573.12	15,135.36	4,419.87	1,893.09	2,597.38	3,463.26	2,622.57	2,904.26	43,333.47	33%	132,506.89
ASF04	32.67409000000	-117.00071550000	4.94	5.57	339.25	287.83				8.24	41.88	626.71	48%	1,314.42
ASF05	32.64253250000	-117.03137350000		0.60	180.78	11.47						669.77	78%	862.62
ASF06	32.63866500000	-117.02973500000		0.60	164.39	0.00				8.55		515.21	75%	688.75
ASF07	32.63775000000	-117.03901100000	0.00	1.37	455.50	11.47				8.55		1,271.57	73%	1,748.46
ASF08	32.65525000000	-117.00304050000	2.73	0.48	222.39	15.10				11.57		646.71	72%	898.99
ASF09	32.59109000000	-117.05475000000	957.99	24,800.20	22,478.19	11,194.76	2,828.21		1,036.77	1,515.81	3,601.59	16,690.05	20%	85,103.56
ASF10	32.59070450000	-117.04156550000	895.20	24,744.19	22,252.65	10,930.15	2,828.21		1,036.77	1,471.44	3,154.57	14,317.02	18%	81,630.19
ASF11	32.59100500000	-117.06692200000	1,001.99	24,810.15	22,507.78	11,194.82	2,828.37		1,037.18	1,545.85	3,602.36	19,313.01	22%	87,841.51
ASF13	32.61848500000	-116.94392350000	15.42	158.47	491.44	140.17				11.99	557.97	1,603.06	54%	2,978.51
ASF14	32.60798100000	-116.94555133300	21.70	159.02	726.25	150.02				12.49	557.63	1,602.83	50%	3,229.94
ASF15	32.71190800000	-117.07208800000			13.51	0.57				1.14	0.36	3,127.58	100%	3,143.16
ASF16	32.71925100000	-117.08081450000			103.16	17.64				15.67		1,753.19	93%	1,889.66
ASF17	32.73445000000	-117.08956900000	7.72	0.42	49.91	8.49				0.21		2,839.28	98%	2,906.03
ASF18	32.77647500000	-117.18585266700	79.70	151.45	502.68	50.09			70.73	66.36		4,768.78	84%	5,689.79
ASF19	32.83910500000	-117.22371800000	252.74	3,795.85	1,628.87	762.62			124.80	109.82		5,099.50	43%	11,774.19
ASF20	32.84631700000	-117.23401200000	90.42	1,252.67	1,379.02	684.57			6.48	80.74		5,551.73	61%	9,045.63
ASF21	32.90616750000	-117.20263150000	83.15	274.75	239.77	150.02				36.56		1,883.48	71%	2,667.74
ASF22	32.96829650000	-117.22526250000	36.96	429.23	59.21	24.02			2.44	10.50	314.25	461.29	34%	1,337.89
ASF23	32.99927733330	-117.09929833300	3.59	33.30	198.09	7.11				5.13		841.83	77%	1,089.06
ASF24	33.00503500000	-117.14900433300	66.55	574.79	698.43	1,122.70				49.69	291.16	1,962.25	41%	4,765.57
ASF25	33.08567600000	-117.26967600000	206.27	444.38	388.21	225.88	0.61		0.03	34.21	30.68	3,273.27	71%	4,603.52
ASF27	33.17256650000	-117.27756900000	39.93	94.59	24.00	48.78			1.44	0.61	125.50	1,741.08	84%	2,075.91
ASF28	33.24519050000	-117.25795250000	17.66		27.60	29.69			6.98		176.25	730.69	74%	988.86
ASF29	33.26560650000	-117.23595050000	5,358.54	115,109.72	22,406.73	22,126.58	1,861.59	23,403.71	14,657.62	11,152.39	54,542.60	60,971.51	18%	331,590.99
ASF30	33.26937600000	-117.30651150000	338.20		4,131.18	411.15			45.70	1,021.69	383.75	1,595.26	20%	7,926.93
ASF31	33.09890000000	-117.12938350000	131.09	7,659.19	1,041.18	286.06			1,928.65	783.78	3,158.23	16,297.25	52%	31,285.43
ASF33	33.16826150000	-117.04802850000	34.38	890.82	50.36	103.36			399.50	67.13	160.11	113.42	6%	1,819.08
ASF36	32.93460750000	-116.93892500000		693.38	475.66	2.63			8.11	18.52	1.49		0%	1,199.79
ASF37	32.89912400000	-117.17314850000	21.82	47.95	15.49	0.45				26.93		1,048.60	90%	1,161.24
ASF38	33.28922650000	-117.09912500000	189.99	404.46	576.61	337.37			12.91	15.61	4,851.45	3,254.56	34%	9,642.96
ASF39	33.03433800000	-116.94638550000	1.14	391.86		72.31			6.61	96.60	89.06	853.14	56%	1,510.73
ASF40	33.01714700000	-116.99836200000	8.27	458.83	188.22				66.54	257.40	596.25	685.81	30%	2,261.33
ASF41	32.82595966670	-116.83584066700	0.38	155.68	43.10	0.83			5.81			270.96	57%	476.77
ASF42	32.82342100000	-116.82658933300	21.24	907.90	136.99	17.94			28.00	3.83	12.33	774.57	41%	1,902.80
ASF43	32.83353750000	-116.81838325000	10.09	767.83	52.51	17.94			8.84	3.83		537.22	38%	1,398.26
ASF44	32.74925350000	-116.83435600000		1,057.54	3.84	49.24			92.84	378.63	12.04	1,066.24	40%	2,660.35
ASF45	32.63896466670	-116.86526000000		862.51	278.04	33.10	289.94		0.48				0%	1,464.06
ASF47	32.76453000000	-116.79506950000	56.28	4,030.92	464.17	37.79			245.12	436.08	115.53	2,126.16	28%	7,512.04
ASF48	32.59167800000	-116.99478250000	1.26	41.82	220.63	646.24					350.05	283.30	18%	1,543.30
ASF50	33.41463266670	-117.23728566700	4,994.23	161,669.04	56,828.88	21,731.29	482.49	5,183.60	9,597.78	17,689.56	29,309.36	78,394.93	20%	385,881.16
ASF51	33.43979750000	-117.37772600000		334.54					10.30	149.09			0%	493.93
ASF52	33.18903900000	-117.27276400000	54.36	540.62	8.30	117.88			25.68	18.45	174.11	6,351.55	87%	7,290.95
ASF53	33.23441250000	-117.17181650000	5.28	168.29	139.66						47.49	64.70	15%	425.42
ASF54	33.20961500000	-117.23298500000	10.09	528.62	5.62	48.11			24.92	18.46	120.03	1,951.12	72%	2,706.97
ASF55	32.70148500000	-116.86128800000	14.94	719.59	185.65	43.93			7.21		183.96	1,408.40	55%	2,563.67
ASF57	32.70144750000	-116.81873850000	11.81	725.54	357.84	13.07			47.38	16.50	45.55	849.87	41%	2,067.55
ASF58	32.68955300000	-116.91302125000	10.54	697.09	1,467.91	275.71			3.42	40.14	1.34	387.46	13%	2,883.62
ASF59	32.54660066670	-117.00894833300		154.89	527.27	595.28					338.04	537.53	25%	2,153.01
ASF60	32.91231750000	-117.20595750000	608.73	4,886.34	6,541.79	1,417.76			25.57	2,048.18	422.50	18,593.78	54%	34,544.64
ASF61	32.68684200000	-116.91404600000	10.54	697.30	1,501.82	280.60			3.40	40.14	1.34	388.12	13%	2,923.28
ASF62	32.59091400000	-117.05224400000			17.02	0.46				7.93		851.65	97%	877.06
ASF63	32.59183400000	-117.06676150000	1,001.99	24,810.15	22,507.78	11,194.82	2,828.37		1,037.18	1,545.85	3,602.36	19,313.01	22%	87,841.51

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:

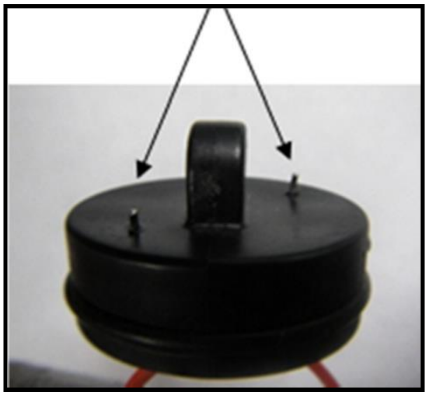
Equipment:

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

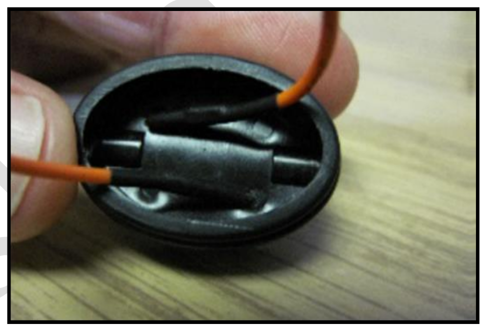
Modification Procedures:

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

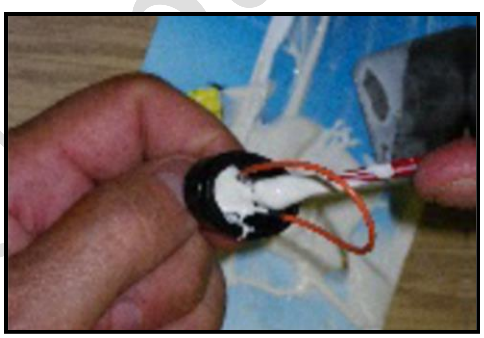
2. Drill two 0.65 mm holes through cap. Place the holes on opposite sides and as far apart as possible. (Note hole location).




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).

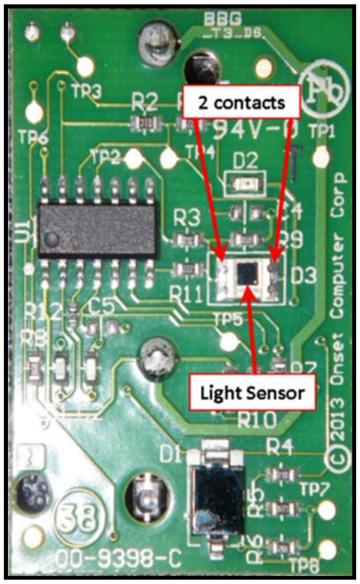



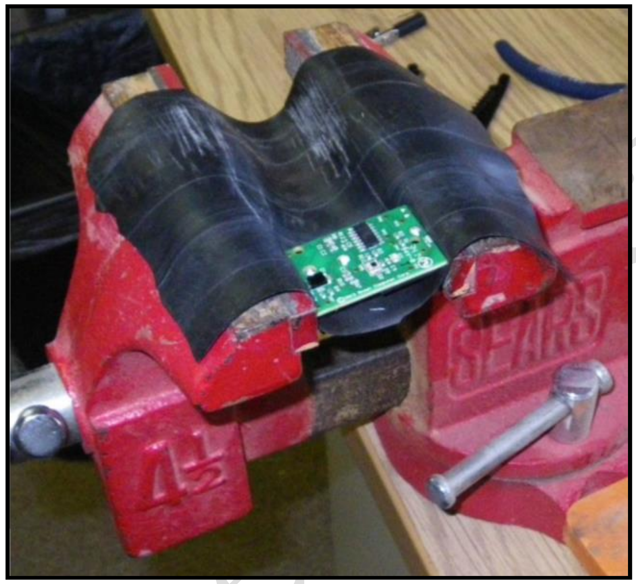
5. Move the wires to one side of the cap.
6. Apply marine epoxy inside the cap, just enough to seal the holes and create a water tight fit. Do not fill epoxy to top of cap. (Note how the wires have been moved to the top half of the cap). Allow to dry overnight.



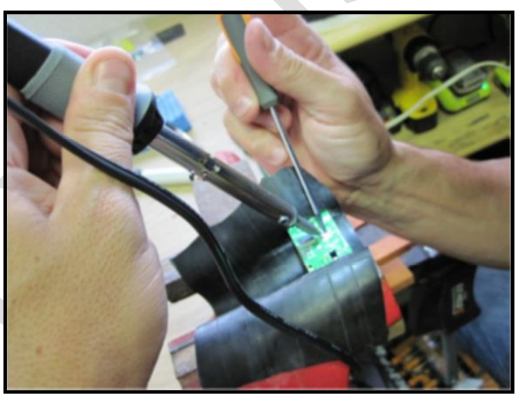
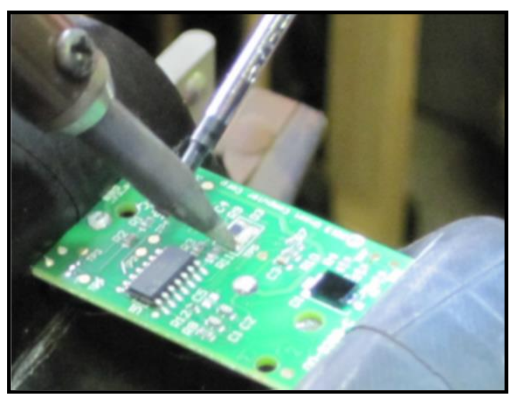

7. Remove the circuit board from the plastic housing. Remove the desiccant bags and save for reassembly.

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.



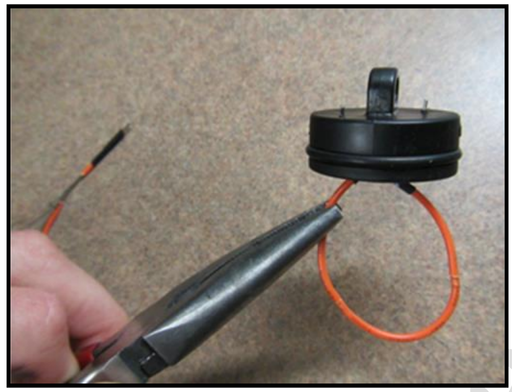


10. Once the soldering iron is hot, place the iron in one hand and the jeweler’s flat tip screwdriver in the other. Place the tip of the iron on one side of the light sensor for about 2-4 seconds. Then use the screwdriver to pry up the sensor once the solder begins to melt. This will take some practice. 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.

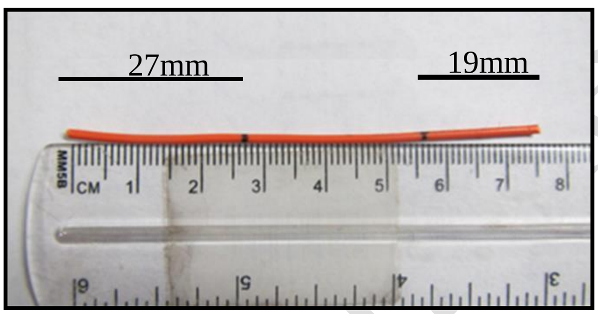



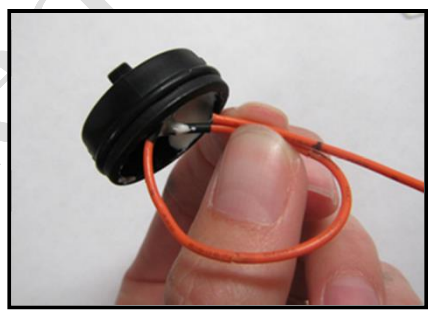
11. With the marine epoxy dry, cut the wire loop into two separate wires. Then you will need to cut each wire to the appropriate length so that when the logger is put together, the wires are long enough to reach over the board but not so long that they impede the cap from sealing properly.

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

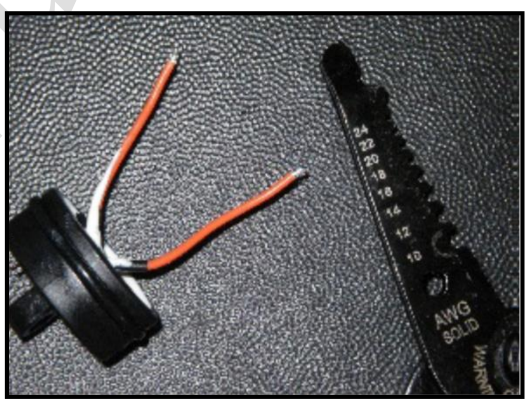


13. Measuring from the end of the black tape on the wire, cut the left wire to 27 mm long. Cut the right wire to 19 mm long. It may be easier to make a template with these lengths first and then use the template to measure out where you need to cut the wires.



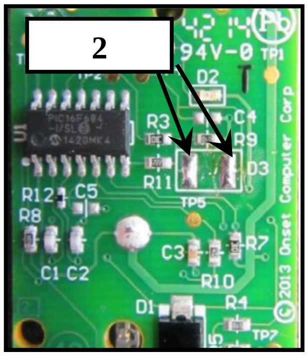


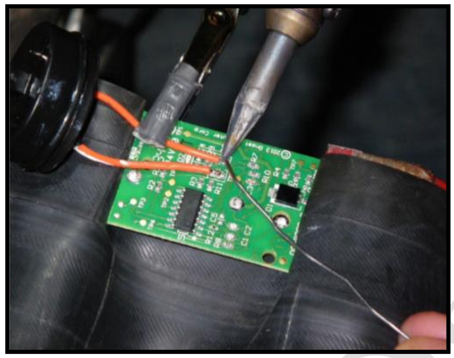
14. Once the wires are cut to the correct length, splice approximately 2 mm of the insulation off. A 24 gauge wire splicer works well



15. 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.





16. 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).
17. 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.

18. 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.

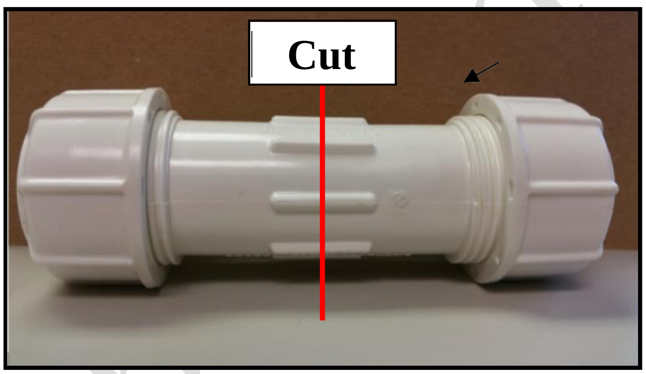
Deployment Hardware Construction:

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 are 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

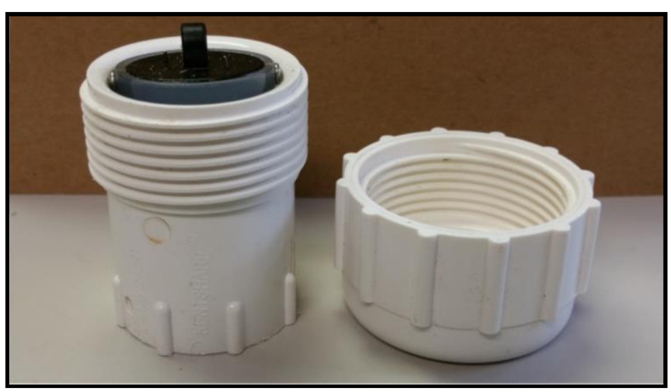
Construction and Assembly Procedures:

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



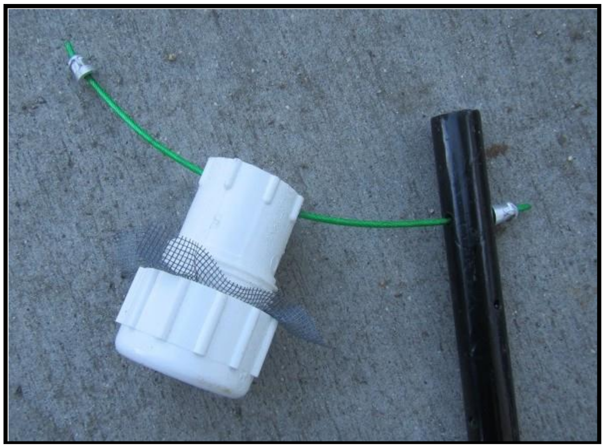
3. Drill a hole slightly larger than the cable that will be used to mount the STIC, through both sides of the PVC. The hole should be drilled on the opposite side of the threaded cap approximately ¼" from the end. A drill press works great for this.

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.

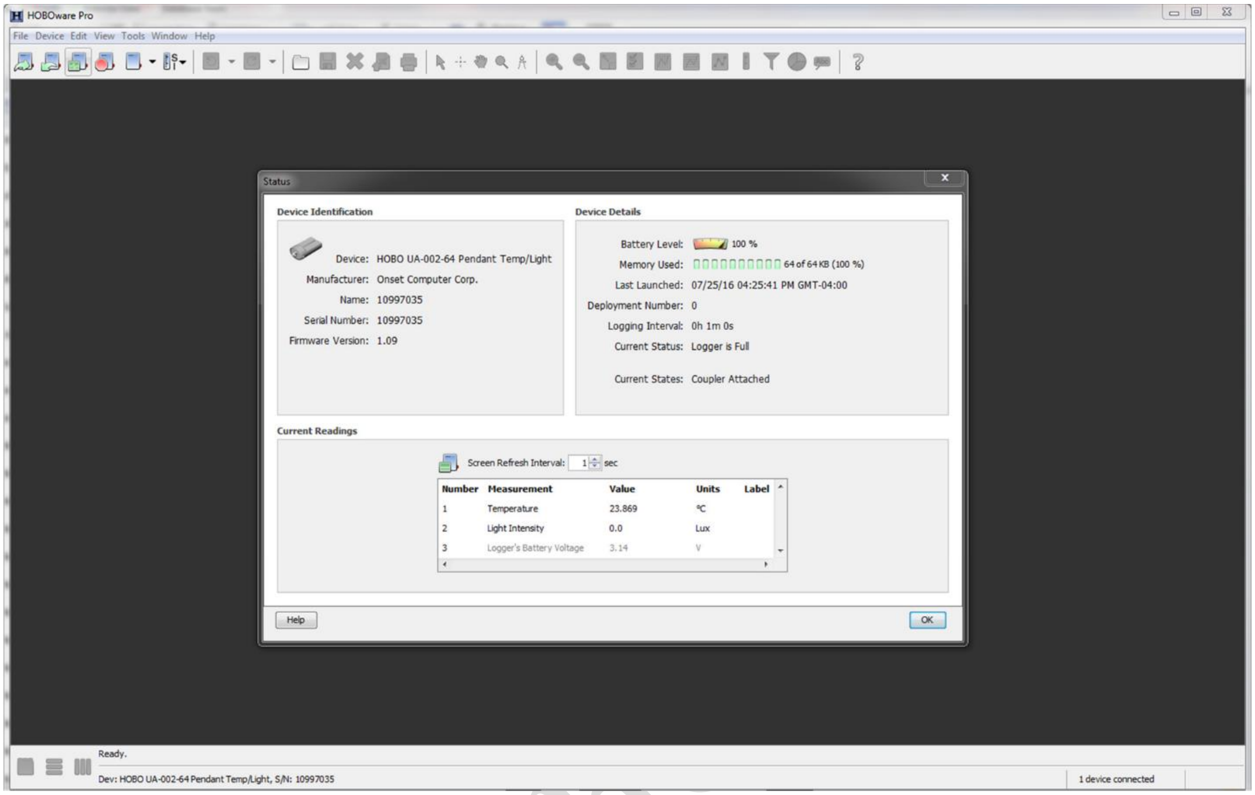


Figure C1. HOBOware Pro when a new STIC is first connected to the computer. Note the battery level, Memory Used, and Deployment Number.

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.

Note: 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".

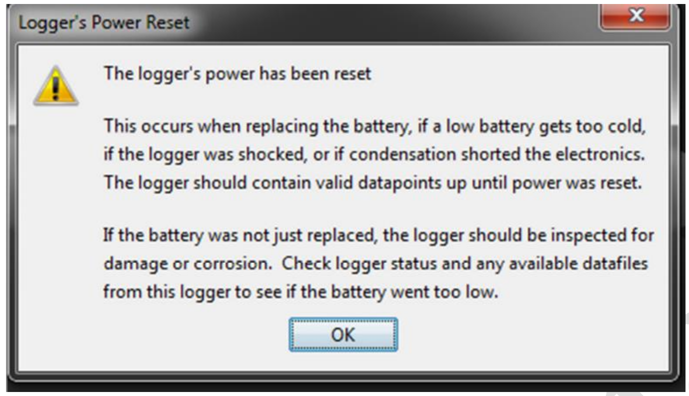


Figure C2. "Logger Power Reset" warning.

This will open up the "Logger Launch" window.

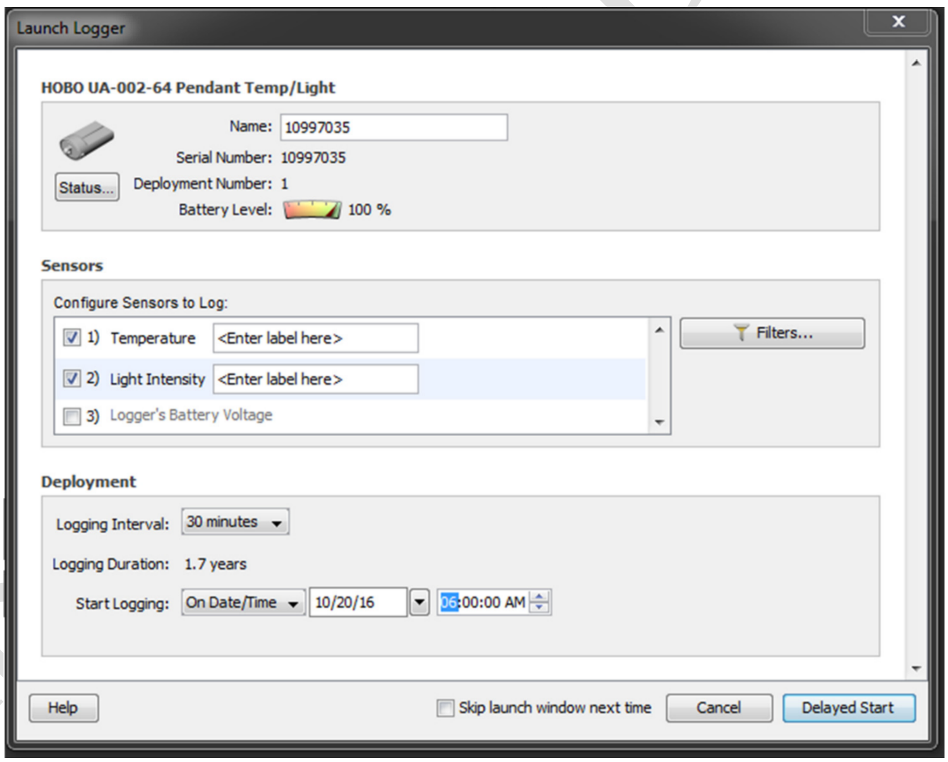


Figure C3. "Logger Launch" window.

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/Delated Start". The STIC has now been launched or set to launch.

12. Remove the STIC from the coupler.

Installing the STIC

Equipment:

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

Tools:

1. crimper tool wire cutters
2. mallet / sledge hammer shovel
3. 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. These data could facilitate persistence of nonnative 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 a 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 C4. 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 C5. 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.

Note: 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.

Record the Logger Type as STIC.

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

2. 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.

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

4. 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." "Ok." A Stop Logger? window will appear. Click "Stop."

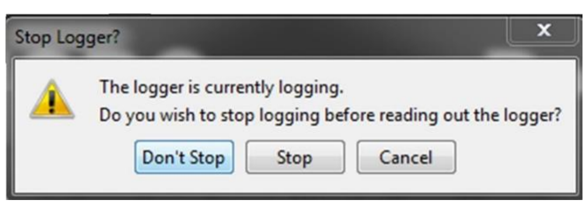


Figure C6. "Stop Logger?" popup window. Note: If "Don't Stop" is selected, the data will still be downloaded, but the STIC will continue to record data.

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

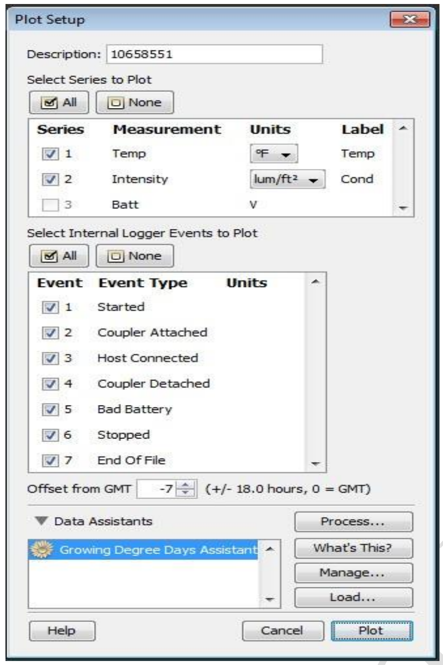


Figure C7. Plot Setup window. Make sure the appropriate boxes are checked and press "Plot."

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

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

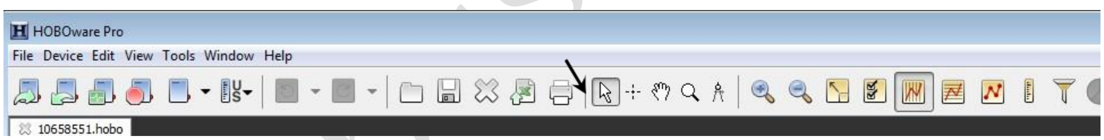


Figure C8. Showing which button to push to save an Excel file of the data.

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

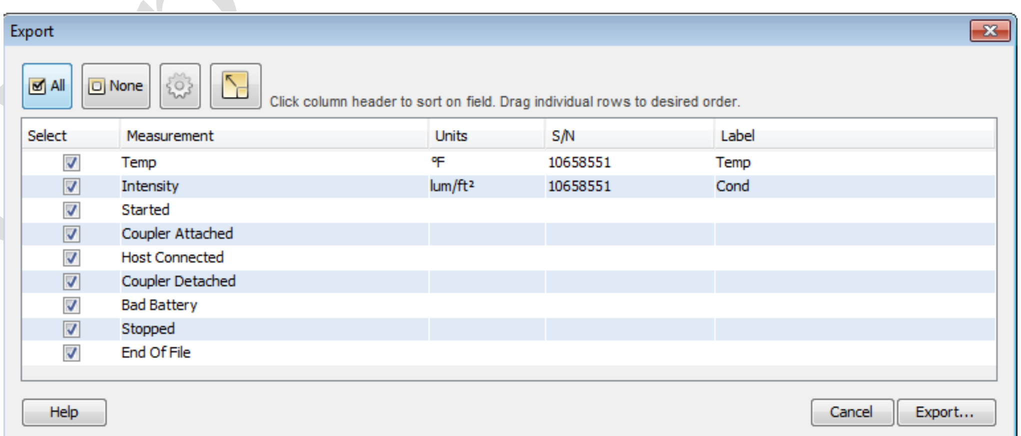


Figure C9. Export window.

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 Resources Research 50:6542-6548, doi:10.1002/2013WR015158.