United States Department of the Interior
U.S. GEOLOGICAL SURVEY
Western Ecological Research Center
San Diego Field Station
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Dear Ms. Kim Smith and Dr. Preston,

This letter transmits the U.S. Geological Survey (USGS) Western Ecological Research Center's Draft Final: San Diego Streams Hydroperiod and Aquatic Species Study 2022-2024. This work was completed under agreement number 548642.

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.

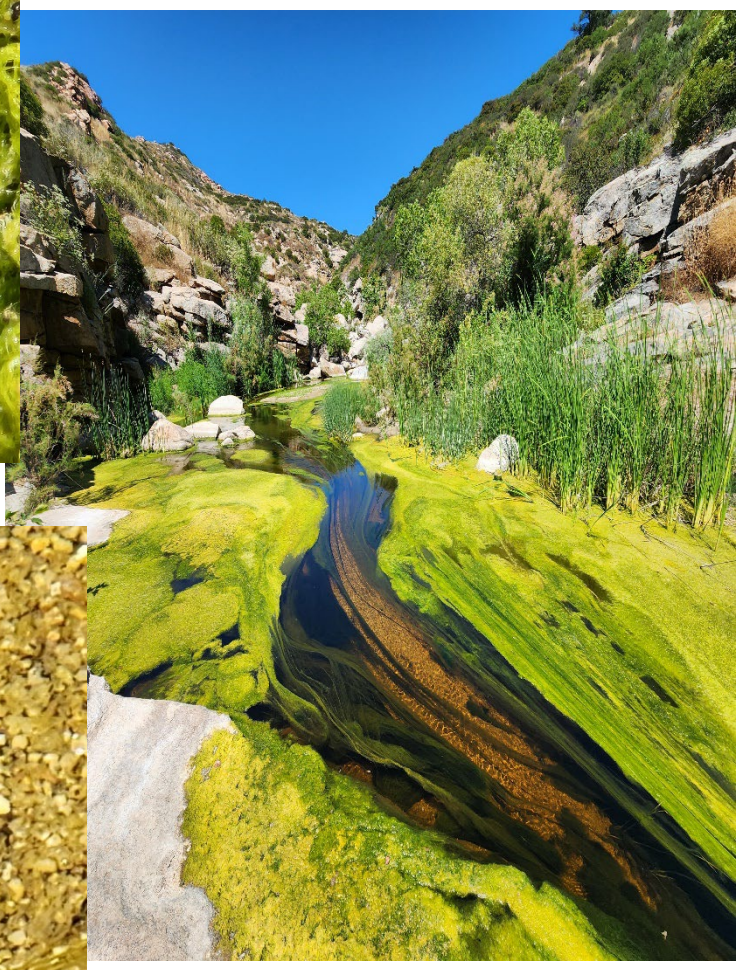
Please direct any questions to me at (619) 206-5686.

Sincerely,

ROBERT FISHER Digitally signed by ROBERT FISHER Date: 2025.01.28 13:43:34 -08'00'

Principal Investigator

San Diego Streams Hydroperiod and Aquatic Species Study 2022-2024



San Diego Streams Hydroperiod and Aquatic Species Study 2022-2024

By: Dhafir Williams, Chris Brown, and Robert N. Fisher

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WESTERN ECOLOGICAL RESEARCH CENTER

Data Summary

Prepared for:

San Diego Association of Governments (SANDAG)
and
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10(a)1(A) Recovery Permit TE-045994-19
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Cover photographs: Pacific Chorus Frog (Santa Maria Creek; Top), Santa Maria Creek (Center Right), Arroyo Toad Tadpole (Santa Maria Creek; Bottom) by Dhafir Williams

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INTRODUCTION

Natural stream hydrology in San Diego County includes both runoff and groundwater inputs. This historically provided for a mixture of perennial and seasonal streams with a wide range of riparian habitats and stream morphologies (Taniguchi and Biggs 2015). Native aquatic species in this region make use of the varied stream habitats with some species requiring permanent or semi-permanent water, such as the southwestern pond turtle (*Actinemys pallida*, hereafter pond turtle; Rhodin et al. 2021), while others make use of seasonal streams with warmer, shallow, slow-flowing water, such as the arroyo toad (*Anaxyrus californicus*; Preston et al. 2022). Natural and anthropogenic alterations to streamflow can impact stream morphology and hydroperiods (amount of time surface water is present during the year), which can cause changes to species composition. For example, water diversions and prolonged drought can decrease hydroperiods in permanent streams. Increased runoff from urbanization can increase hydroperiods in seasonal streams (Hawley et al. 2012; Booth and Fischenich 2015).

These hydroperiod alterations with associated changes in stream morphology can cause changes in aquatic species compositions with longer hydroperiods facilitating the spread of nonnative aquatic species (White and Greer 2006). The persistence of nonnative aquatic species in previously seasonal streams can have deleterious impacts on native aquatic species, including the arroyo toad (Miller et al. 2012). USGS began to study these relationships between hydroperiod and native aquatic species in San Diego in 2015 by deploying a network of Stream Temperature, Intermittency, and Conductivity data loggers (STICs) on conserved lands throughout the county (Brown et al. 2020b; Brown et al. 2020c). This report presents the results of our stream surveys associated with this network of STIC sites in San Diego County from 2022 to 2024.

Study Area

This study is focused on 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 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.

Site Descriptions

The individual STIC sites are listed in Table 2 and were selected for three different purposes. Two sets of STIC sites were selected based on the presence or potential presence of the Federally endangered arroyo toad or the southwestern pond turtle which has been proposed for listing under the Endangered Species Act (Brown et al. 2020a; Brown et al. 2020b; USFWS 2023). Sites in potential arroyo toad habitat are listed as ARTO in Table 2 and sites in southwestern pond turtle habitat are listed as SWPT in Table 2. These sites were established to determine if hydroperiods were appropriate for these two species without facilitating the spread of invasive aquatic species.

The remaining STIC sites listed in Table 2 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 (Brown et al. 2020c). 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 are listed as ASF (Aseasonal Flow) in Table 2.

These sites all together 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 report covers data collected from surveys at 130 surface water monitoring sites between 29 December 2022 and 02 March 2024. Detailed descriptions, maps, and photos for individual sites can be found in previous USGS reports for SANDAG on arroyo toads, pond turtles, and altered hydrology (Brown et al. 2020a; Brown et al. 2020b; Brown et al. 2020c).

METHODS

Stream Temperature, Intermittency, and Conductivity loggers (STICs)

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 which can be found in Brown et al. (2020a). STICs were launched in the lab and set to record data at 30-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 reflect relative conductivity in water (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 detection of water presence, and therefore, maximum hydroperiod could be estimated at our ASF sites according to the conductivity readings.

STIC loggers were deployed and replaced in designated reaches for temperature, conductance, and hydroperiod monitoring throughout the duration of the study (see STIC section above). Prior to deployment, the STIC number and coordinates were recorded in the Trimble TDC600 for upload to the USGS Stream Survey database. A photo of the STIC number, logger serial number, and current GPS coordinate was also taken at the time of deployment to use as a reference for future site visits. STIC loggers were placed at the start of the predefined reaches and ASF sites or as close as possible to the start (see predefining specs next section). 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 was 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 the collection of surface water data characteristic of the stream system and testing for the presence of permanent pooling water, which could facilitate the persistence of nonnative aquatic species within the system.

Data from STIC loggers were exported to a Microsoft Excel® spreadsheet for reduction via analysis workbooks developed by Chris Brown and Aguilar Duran, based on the analysis spreadsheet developed by Chapin et al. (2014). In 2020 USGS began to collaborate with the Southern California Coastal Water Research Project (SCCWRP) to utilize STIC data to examine hydrologic vulnerability of the arroyo toad. Based on the Brown and Aguilar Duran data reduction code, Jessica Weidenfeld and Kris Taniguchi-Quan from SCCWRP developed a data automation package in R to return summary stats of hydroperiod (consecutive wet) with graphics of temperature and relative conductivity (Figure 3). This code was finished in January 2014, and we will update and utilize this code for current hydroperiod and temperature data reduction. Loggers will continue to be monitored and hydroperiod calculations can continue to be made as more data are recovered.

Visual Surveys

Sites for STIC loggers were pre-selected 1) according to the history of presence or potential for supporting arroyo toads or pond turtles, and 2) looking at a subset of sites that would represent a gradient of urban runoff (Brown et al. 2020c). The selected sites were pre-defined by categorizing each as arroyo toad sites (ARTO), southwestern pond turtle sites (SWPT), or aseasonal flow sites (ASF). Each site was divided into 250-meter (m) reaches with a start and end point along the streambed on a digital map. Coordinates for the predefined STIC sites were downloaded to handheld GPS units (Trimble TDC600, Garmin eTrex 20, or Pro GPS for iPhone). Survey data was collected while navigating between the start and end coordinates of each 250-meter reach using GPS, preferring to get as close to the coordinates as possible. If the selected coordinate was outside the channel (due to an estimate of position error or an imprecise record), we moved to the closest adjacent point inside the channel and collected an "actual" coordinate to be used for data collection in the Trimble TDC600. Geotagged site photos were taken using Apple iPhone, Canon PowerShot D30, and Samsung Galaxy cameras.

Visual surveys were conducted at predefined (ARTO, SWPT, and ASF) sites to determine the 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, weather, and water quality (when water was present). Field data, including survey and species coordinates, were collected into a Trimble TDC600 and uploaded to the USGS Stream Survey Database upon returning from the field. Surveys were conducted by two biologists walking upstream while examining the water, stream bottom, and shoreline for aquatic and semi-aquatic species along each 250-meter reach. Care was taken to examine underneath overhangs and floating material for hiding animals. All stream-associated amphibians, invertebrates, fish, mammals, reptiles, and nonnative species were recorded. Representative site and species photos were uploaded to our centralized repository and labeled by survey. Representative site and species photos are presented in Appendices A and B.

Stream morphology, substrate, water quality, and riparian vegetation were recorded at each site. Both native and invasive plant communities were recorded. 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 the average bank full width over the average flood-prone width.

Beginning 08 December 2023, the visual survey component of the STIC surveys was paused until late March 2024. We resumed visual surveys on 25 March 2024, to collect these data and search for aquatic and semi-aquatic wildlife.

Early Season Precipitation

Early season rain precipitation data was accessed from California Data Exchange Center (CDEC 2024). We used the station at San Miguel Mountain (station ID SMG) and plotted accumulated precipitation for the rain year prior to March 15th (October 1 to March 15). March 15th is considered an average start to the breeding season for arroyo toads (USFWS 1994). San Miguel Mountain is 2,567 feet tall and located in the lower center of the Sweetwater watershed. The station at San Miguel Mountain has been collecting hourly precipitation data from 08 April 2002 to present and is presented in real-time through CDEC. Rainfall varies substantially throughout the county, but we use San Miguel Mountain to represent relative year to year variations in rainfall for the study area (watersheds of San Diego County) at the beginning of the field season. The real-time access to a long-term hourly precipitation data provides for reasonable expectations of stream conditions prior to survey visits.

RESULTS

A total of 148 surveys were conducted at 129 STIC sites between 29 December 2022 and 02 March 2024 (Table 2). 55 ASF sites were surveyed, 54 ASF sites had detectable surface water during at least one site visit. Only 14 sites had water present on both visits. ASF 07 was the only site surveyed twice with no detectable water. ASF 43 and ASF47 were not surveyed at all during the reported period. A total 74 ARTO and SWPT sites were surveyed and found to have surface water during at least one visit, 4 ARTO and SWPT sites had water present during both visits. Two sites located in Boulder Creek and Santa Margarita River were not surveyed during this reported period. Not all sites were surveyed more than once.

Early season precipitation (October 1 through March 14) increased more in 2023 and 2024 compared to recent years (Figure 4). Rainfall sampled from San Miguel Mountain shows that precipitation increased over 100% from 2022 to 2023. Precipitation increased again in 2024.

Native semi-aquatic species observed include arroyo toads (*Anaxyrus californicus*), Baja California treefrogs (*Pseudacris hypochondriaca*), California treefrogs (*Pseudacris cadaverina*), the two-striped gartersnake (*Thamnophis hammondii*) and western toads *(Anaxyrus borea*s). During periods of decreased water levels, many nonnative aquatic and semi-aquatic species were observed during visual surveys, including American bullfrogs (*Lithobates catesbeinaus*), crayfish (*Procambarus spp.*), green sunfish (*Lepomis cyanellus*) and mosquitofish (*Gambusia affinis*) (Table 3). Native species were observed at 2 of 55 ASF sites (3.64%) and 18 of 74 ARTO/SWPT sites (24.32%). Nonnative species were observed at 3 of 55 ASF sites (5.45%) and 8 of 74 ARTO/SWPT sites (10.81%).

STIC sites had varying stream morphology, water quality, substrates, riparian vegetation and upland communities. Native plant communities recorded included mule fat scrub, coast live oak forests, cottonwood willows, and other sage scrubs. Invasive plant communities were also

present at sites and included tamarisk scrub, arundo scrub/forest, and cattails.

DISCUSSION

The visual survey component of the STIC project was paused from December of 2023 until late March 2024. Due to a lack of funding, the focus of the STIC surveys shifted towards retrieving and replacing as many STIC loggers as possible. A decrease in wildlife activity was also expected due to the colder, wetter winter season.

The total number of animals detected in 2024 was significantly lower than in 2023 because of this hiatus. Conducting fewer visual surveys this reported period has led to a smaller sample size of wildlife detections compared to previous reports. This will not be an issue for analyses. There have been multiple visits to all sites since 2016 and the presence of native and nonnative species is the target metric for this part of the study.

We returned to visited sites that had not been visually surveyed beginning 25 March 2024. Visual surveys continued to be conducted in the Spring of 2024 as we expected wildlife detections to increase. The decrease in rainfall from winter storms made it easier to survey the streams after the water depth and speed dropped. The calmer flow of water increased detectability of aquatic and semi-aquatic wildlife as well.

Flooding made it more difficult to recover STIC loggers and walk in the streams to survey for wildlife. Many loggers were washed out by strong flow in the waterway, buried in substrates, or submerged in water too deep to retrieve. When we were unable to locate a STIC logger, new loggers were deployed close by. Adjustments were made when deploying the new STIC to prevent it from being lost in a similar manner as the previous logger. We plan on revisiting loggers that can't be retrieved when the water is too high.

Omitting the 250m survey portion of the protocol allowed for us to visit more study sites in 2024 than in 2023. Collecting more STIC loggers in a shorter time frame has allowed USGS to compile a more robust archive of data about watersheds in San Diego for 2023-2024.

San Diego County saw increased levels of rainfall this reported period compared to the previous reported period (Figure 4). ASF sites showed similar water presence with 44 wet sites (75.8%) and the ARTO/SWPT sites showed increased water presence increasing from 45 detections of water at 69 sites in the previous report period compared to 58 wet sites (77.3%) this period (Table 2). Only 4 study sites have not been surveyed during the reported period between December 2022 and March 2024. Not all sites were surveyed twice.

The ASF study sites were more susceptible to urban development and runoff throughout the year. The ARTO and SWPT sites are protected habitats and further away from urbanization. These sites present a greater frequency of native species than the ASF sites (Table 3).

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. Urban

aseasonal flow (increased discharge during dry seasons resultant from land use changes) in local and regional stream systems is a primary conduit for nonnative species influx and persistence in areas where they normally would be excluded due to seasonal dry down (Riley et al. 2005; White and Greer 2006; Cooper et al. 2013). Therefore, aseasonal flow was the focus of this study. Runoff can have a range of effects including increased soil moisture levels, geomorphic changes in creeks, and perennial flows in xeric landscapes (Litwin et al. 2022; Singh et al. 2021). 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.

Relationships between native, nonnative species and upstream characteristics, including urban land use and impervious surface cover, are complex. The size and shape of the watershed and surface water features within the watershed also contribute to the local ecology (Singh et al. 2021). Preliminary data that can assist in describing some of these relationships are presented here, but further analysis is needed. The data collected can be combined with other data efforts from arroyo toad surveys (Brown et al. 2009; Brown et al. 2020b; Clark et al. 2010) and the existing San Diego Regional Water Quality Control Board water monitoring sites (SDRWQCB unpublished data) to evaluate and better understand these relationships in more detail.

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Site Access
Many thanks to the California Department of Fish and Wildlife, Center for Natural Lands Management, County of San Diego, Daley Preserve, Escondido Creek Conservancy, The Wildlands Conservancy, United States Forest Service and the cities of Carlsbad, Chula Vista, Escondido, Poway, Oceanside, and San Diego. These entities have provided and coordinated access to the reserves.

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We would like to thank the following people for their assistance with field surveys, data analysis, and building STIC loggers: Adam Backlin, Bradley Wineholt, Carlton Rochester, Cayden Hershey, Darren Chon, Denise Clark, Elizabeth Gallegos, Jeremy Sebes, Jordyn Ochoa, Jorge Ayon, Sarah Villar, and Thomas Fies.

LITERATURE CITED

Booth, D.B. and C.J. Fishcenich. 2015. A channel evolution model to guide sustainable urban stream restoration. Area, 47: 408-421, doi:10.1111/area.12180.

Brown, C., D. Clark, C. Hitchcock, and R.N. Fisher. 2020a. Western Pond Turtle Response to translocation and nonnative aquatic species removal. U.S. Geological Survey data report prepared for San Diego Association of Governments and U.S. Fish and Wildlife Service Conservation Partnerships Program. 41 pp.

Brown, C., E. Perkins, C. Hitchcock, A. Aguilar-Duran, L. Grolle, E. Watson, and R.N. Fisher. 2020b. Associations between arroyo toads, nonnative species, drought, and impervious surfaces in San Diego County. U.S. Geological Survey data report prepared for San Diego Association of Governments. 178 pp.

Brown, C., E. Perkins, C. Hitchcock, A. Aguilar-Duran, O. Guerro-Salcido, E. Watson, and R.N. Fisher. 2020c. Draft Final: Aseasonal flow and associated nonnative species in San Diego. U.S. Geological Survey data report prepared for SANDAG, SDMMP, and USFWS. 158 pp.

California Data Exchange Center (CDEC). 2024. Online realtime precipitation. Accessed 08 April 2024. https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=SMGCalifornia Department of Fish and Wildlife (CDFW). 2015. Vegetation (fveg) – CALFIRE FRAP [ds1327]. Publication date 01/01/2015, source: http://www.dfg.ca.gov/biogeodata/vegcamp/

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.

Cooper, S.D., Lake, P.S., Sabater, S., Melack, J.M., & Sabo, J., 2013. The effects of land use changes on streams and rivers in mediterranean climates. Hydrobiologia, 719(1):383–425. https://doi.org/10.1007/s10750-012-1333-4

Hawley, R.J., B.P. Bledsoe, E.D. Stein, and B.E. Haines. 2012. Channel evolution model of semiarid stream response to urban-induced hydromodification. Journal of the American Water Resources Association (JAWRA) 48(4): 722-744. DOI: 10.1111/j.1752–1688.2012.00645.

Lee, M.B., and J.T. Rotenberry. 2015. Effects of land use on riparian birds in a semiarid region. Journal of Arid Environments, 119:61–69.

Litwin, D. G., Tucker, G. E., Barnhart, K. R., & Harman, C. J. (2022). Groundwater affects the geomorphic and hydrologic properties of coevolved landscapes. Journal of Geophysical Research: Earth Surface, 127, e2021JF006239. https://doi.org/10.1029/2021JF006239

Miller, D.A., C.S. Brehme, J.E. Hines, J.D. Nichols, and R.N. Fisher. 2012. Joint estimation of habitat dynamics and species interactions: disturbance reduces co-occurrence of nonnative predators with an endangered toad. Journal of Animal Ecology, 81(6):1288–1297.

Preston, K., E. Perkins, C. Brown, S. McCutcheon, A. Bernabe, E. Luciani, B. Kus, and S. Wynn. 2022. State of the Regional Preserve System in western San Diego County, USGS cooperator report prepared for San Diego Association of Governments Environmental Mitigation Program, Agreements 5004597 and 548642.

Rhodin, A.G.J, J.B. Iverson, P.P. van Dijk, C.B. Stanford, E.V. Goode, K.A. Buhlmann, and R.A. Mittermeier, (Eds.). 2021. Conservation biology of freshwater turtles and tortoises:

A compilation project of the IUCN/SSC tortoise and freshwater turtle specialist group. Chelonian Research Monographs, 8:1–472. Doi:10.2854/crm.8.checklist.atlas.v.9.
San Diego Management and Monitoring Program (SDMMP) and The Nature Conservancy (TNC). 2017. Management and monitoring strategic plan for conserved lands in western San Diego County, Draft unpublished data: A strategic habitat conservation roadmap. 3 Volumes. Prepared for the San Diego Association of Governments. San Diego.
San Diego Management and Monitoring Program (SDMMP). 2023. Conserved Lands. Created December 28, 2023. San Diego Geographic Information Source - JPA. Downloaded December 28, 2023. http://www.sangis.org/download/index.html.
Singh, N.K., Emmanual, R.E., McGlynn, B.L., Miniat, C.F. 2021. Soil moisture responses to rainfall: implications for runoff generation. Water Resources Research, 57, e2020WR028827. https://doi.org/10.1029/2020WR028827
Taniguchi, K.T. and T. Biggs. 2015. Regional impacts of urbanization on stream channel geometry: A case study in semiarid Southern California. Geomorphology, 248:228–236. DOI:10.1016/j.geomorph.2015.07.038.
U.S. Fish and Wildlife Service (USFWS). 1994. Endangered and threatened wildlife and plants; determination of endangered status for the arroyo southwestern toad. Federal Register 59: 64859–64866.
USFWS. 2023. Endangered and threatened wildlife and plants; threatened species status with section 4(d) rule for the northwestern pond turtle and southwestern pond turtle. Federal Register 88(190):68370–68399.
U.S. Geological Survey. 2006a. USGS aquatic species and habitat assessment protocol for south coast ecoregion rivers, streams, and creeks. U.S. Geological Survey protocol. San Diego, CA. 48 pp.
U.S. Geological Survey. 2006b. USGS protocol for nocturnal aquatic species of south coast ecoregion rivers, streams, and creeks. U.S. Geological Survey protocol. San Diego, CA. 14 pp.
U.S. Geological Survey. 2019. National Hydrography Dataset Plus High Resolution beta Vectors. https://apps.nationalmap.gov/downloader/#/. Accessed 12/14/2021.
White, M.D. and Greer, K.A. 2006, The effects of watershed urbanization on the stream hydrology and riparian vegetation of Los Peñasquitos Creek, California. Landscape and Urban Planning, v.74, no.2, p.125-138.

Table 1. Study Area Watersheds. 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, totaling 130 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%)	7
San Luis Rey	144,835	40,235	28%	11
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%	46
Los Penasquitos Creek	24,384	5,807	24%	3
Mission Bay Watershed (Rose Creek)	16,013	1,078	7%	2
San Diego River	112,078	43,821	39%	10
Pueblo San Diego (Chollas Creek)	23,709	1,270	5%	3
Sweetwater River	56,407	23,655	42%	15
Otay River	36,764	16,663	45%	15
Tijuana River (in San Diego County)	453,248 (120,998)	-na- (71,662)	-na- (59%)	12

Table 2. Survey Summary. Survey dates with count of wet and dry visits for each site by watershed.

Watershed	Stream	Reach	Study	2022 Survey Date	Wet (Y/N)	2023 Survey Date	Wet (Y/N)	2024 Survey Date	Wet (Y/N)	Total Visits
Santa Margarita	Roblar Creek	ASF51	ASF	Not Surveyed		Not Surveyed		31-Jan-24	N	1
		ASF64	ASF	Not Surveyed		Not Surveyed		31-Jan-24	Y	1
Santa Margarita River	Sandia Canyon	1	ARTO	Not Surveyed		15-Jun-23	Y	30-Jan-24	Y	2
		5	ARTO	Not Surveyed		15-Jun-23	Y	30-Jan-24	Y	2
		10	ARTO	Not Surveyed		15-Jun-23	Y	30-Jan-24	Y	2
	Santa Margarita River	133	ARTO	Not Surveyed		Not Surveyed		30-Jan-24	Y	1
	Santa Margarita River Tributary	ASF50	ASF	Not Surveyed		Not Surveyed		30-Jan-24	Y	1
	Block0935	16A	ARTO	Not Surveyed		Not Surveyed		Not Surveyed		0
San Luis Rey River	Gopher Canyon Tributary	ASF53	ASF	Not Surveyed		Not Surveyed		24-Jan-24	N	1
	Keys Creek	ASF38	ASF	Not Surveyed		Not Surveyed		25-Jan-24	Y	1
	Pilgrim Creek	ASF30	ASF	Not Surveyed		Not Surveyed		25-Jan-24	Y	1
	Guajome Creek Tributary	ASF28	ASF	Not Surveyed		Not Surveyed		26-Jan-24	Y	1
	San Luis Rey River	ASF29	ASF	Not Surveyed		Not Surveyed		25-Jan-24	N	1
	Middle San Luis Rey River	55	ARTO	Not Surveyed		1-Jan-00	N	Not Surveyed		1
		60	ARTO	Not Surveyed		29-Jun-23	N	Not Surveyed		1
	Lower San Luis Rey	82	ARTO	Not Surveyed		29-Jun-23	Y	Not Surveyed		1
		86	ARTO	Not Surveyed		29-Jun-23	Y	Not Surveyed		1
		98	ARTO	Not Surveyed		15-Jun-23	Y	Not Surveyed		1
		104	ARTO	Not Surveyed		15-Jun-23	Y	Not Surveyed		1
Buena Vista	Buena Vista Creek	ASF52	ASF	Not Surveyed		Not Surveyed		24-Jan-24	Y	1
	Buena Vista Creek Trib	ASF54	ASF	Not Surveyed		Not Surveyed		24-Jan-24	Y	1
Agua Hedionda	Upper Calavera Creek	ASF27	ASF	Not Surveyed		Not Surveyed		24-Jan-24	Y	1
San Marcos Creek	Batiquitos Lagoon Tributary	ASF25	ASF	Not Surveyed		Not Surveyed		8-Feb-24	Y	1
Escondido Creek	Escondido Creek	ASF31	ASF	Not Surveyed		Not Surveyed		8-Feb-24	Y	1
	Escondido Creek Tributary	ASF33	ASF	Not Surveyed		Not Surveyed		8-Feb-24	Y	1
San Dieguito River	Temescal Creek (Santa Ysabel)	1	ARTO	Not Surveyed		Not Surveyed		10-Jan-24	Y	1
		16	ARTO	Not Surveyed		Not Surveyed		10-Jan-24	N	1
	Upper Santa Ysabel Creek Trib11A	3	ARTO	Not Surveyed		8-Dec-23	Y	Not Surveyed		1
		6	ARTO	Not Surveyed		8-Dec-23	N	Not Surveyed		1
	Upper Santa Ysabel Creek	40	ARTO	Not Surveyed		8-Dec-23	Y	Not Surveyed		1
	Black Canyon	3	ARTO	Not Surveyed		Not Surveyed		29-Jan-24	Y	1
	Boden Canyon	13	SWPT	Not Surveyed		Not Surveyed		15-Feb-24	Y	1
		23	SWPT	Not Surveyed		Not Surveyed		15-Feb-24	Y	1
	Lower Santa Ysabel Creek	1	ARTO	29-Dec-22	N	Not Surveyed		Not Surveyed		1
		15	ARTO	29-Dec-22	N	Not Surveyed		Not Surveyed		1
		28	ARTO	Not Surveyed		24-Jan-23	N	Not Surveyed		1
		40	ARTO	Not Surveyed		24-Jan-23	Y	Not Surveyed		1
		47	ARTO	Not Surveyed		24-Jan-23	Y	Not Surveyed		1
		53	ARTO	Not Surveyed		13-Dec-23	Y	Not Surveyed		1
		59	ARTO	Not Surveyed		13-Dec-23	N	Not Surveyed		1
		62	ARTO	Not Surveyed		13-Dec-23	Y	Not Surveyed		1
		65	ARTO	Not Surveyed		13-Dec-23	Y	Not Surveyed		1
		69	ARTO	Not Surveyed		18-Dec-23	Y	Not Surveyed		1

ARTO = arroyo toad, SWPT = southwestern pond turtle, ASF = sites with aseasonal flow.

Table 2 cont. Survey dates with count of wet and dry visits for each site by watershed.

Watershed	Stream	Reach	Study	2022 Survey Date	Wet (Y/N)	2023 Survey Date	Wet (Y/N)	2024 Survey Date	Wet (Y/N)	Total Visits
San Dieguito River	Lower Santa Ysabel Creek	73	ARTO	Not Surveyed		18-Dec-23	Y	Not Surveyed		1
		77	ARTO	Not Surveyed		18-Dec-23	N	Not Surveyed		1
		83	ARTO	Not Surveyed		Not Surveyed		10-Jan-24	Y	1
		86	ARTO	Not Surveyed		Not Surveyed		10-Jan-24	Y	1
		89	ARTO	Not Surveyed		Not Surveyed		25-Jan-24	Y	1
		92	ARTO	Not Surveyed		Not Surveyed		25-Jan-24	Y	1
		97	ARTO	Not Surveyed		Not Surveyed		25-Jan-24	Y	1
		104	ARTO	Not Surveyed		Not Surveyed		29-Jan-24	Y	1
		107	ARTO	Not Surveyed		Not Surveyed		29-Jan-24	Y	1
	Gonzales Creek	ASF22	ASF	Not Surveyed		Not Surveyed		26-Jan-24	Y	1
	Lusardi Creek	ASF23	ASF	Not Surveyed		18-Jan-23	Y	26-Jan-24	Y	2
		ASF24	ASF	Not Surveyed		18-Jan-23	Y	26-Jan-24	Y	2
	Green Valley	ASF40	ASF	Not Surveyed		18-Jan-23	Y	26-Jan-24	N	2
	Santa Maria Creek Tributary	ASF39	ASF	Not Surveyed		18-Jan-23	Y	26-Jan-24	Y	2
	Santa Maria Creek	7	ARTO	29-Dec-22		Not Surveyed		Not Surveyed		1
		10	ARTO	29-Dec-22		Not Surveyed		Not Surveyed		1
		20	ARTO	Not Surveyed		21-Jun-23	Y	Not Surveyed		1
		25	ARTO	Not Surveyed		28-Jun-23	Y	Not Surveyed		1
		29	ARTO	Not Surveyed		28-Jun-23	Y	Not Surveyed		1
		33	ARTO	Not Surveyed		23-Jun-23	Y	Not Surveyed		1
		36	ARTO	Not Surveyed		23-Jun-23	N	Not Surveyed		1
		40	ARTO	Not Surveyed		8-Dec-23	Y	Not Surveyed		1
		44	ARTO	Not Surveyed		8-Dec-23	N	Not Surveyed		1
		52	ARTO	Not Surveyed		23-Jun-23	Y	Not Surveyed		1
	Upper San Dieguito River	52	ARTO	Not Surveyed		Not Surveyed		15-Feb-24	N	1
		60	ARTO	Not Surveyed		Not Surveyed		15-Feb-24	N	1
	Upper San Dieguito River B	9	ARTO	Not Surveyed		Not Surveyed		15-Feb-24	Y	1
	Upper San Dieguito River Trib 4	2	ARTO	Not Surveyed		14-Jun-23	Y	15-Feb-24	N	2
Los Penasquitos Creek	Los Penasquitos Creek	ASF21	ASF	Not Surveyed		Not Surveyed		11-Jan-24	Y	1
	Los Penasquitos Canyon	ASF60	ASF	Not Surveyed		Not Surveyed		11-Jan-24	Y	1
	Carrol Canyon	ASF37	ASF	Not Surveyed		Not Surveyed		11-Jan-24	N	1
Mission Bay WMA	Tecolote Creek	ASF18	ASF	Not Surveyed		Not Surveyed		24-Jan-24	Y	1
	San Clemente Canyon	ASF19	ASF	Not Surveyed		Not Surveyed		11-Jan-24	Y	1
	Rose Creek	ASF20	ASF	Not Surveyed		Not Surveyed		11-Jan-24	Y	1
San Diego River	Upper San Diego River	61	ARTO	Not Surveyed		Not Surveyed		17-Jan-24	Y	1
		65	ARTO	Not Surveyed		Not Surveyed		17-Jan-24	Y	1
		67	ARTO	Not Surveyed		Not Surveyed		17-Jan-24	Y	1
		69	ARTO	Not Surveyed		Not Surveyed		18-Jan-24	Y	1
	Cedar Creek	3	ARTO	Not Surveyed		Not Surveyed		18-Jan-24	Y	1
		6	ARTO	Not Surveyed		Not Surveyed		18-Jan-24	Y	1
	San Vicente Creek	47	ARTO	Not Surveyed		Not Surveyed		9-Jan-24	Y	1
	West Branch San Vicente Creek Trib	5	ARTO	Not Surveyed		Not Surveyed		9-Jan-24	N	1
	San Vicente Creek Tributary	ASF36	ASF	Not Surveyed		Not Surveyed		10-Jan-24	N	1
	Boulder Creek	36	ARTO	Not Surveyed		Not Surveyed		Not Surveyed		0

ARTO = arroyo toad, SWPT = southwestern pond turtle, ASF = sites with aseasonal flow.

Table 2 cont. Survey dates with count of wet and dry visits for each site by watershed.

Watershed	Stream	Reach	Study	2022 Survey Date	Wet (Y/N)	2023 Survey Date	Wet (Y/N)	2024 Survey Date	Wet (Y/N)	Total Visits
Pueblo San Diego	Encanto Creek	ASF15	ASF	Not Surveyed		Not Surveyed		24-Jan-24	Y	1
	South Chollas Creek	ASF16	ASF	Not Surveyed		Not Surveyed		24-Jan-24	Y	1
	Chollas Creek	ASF17	ASF	Not Surveyed		Not Surveyed		24-Jan-24	Y	1
Sweetwater River	Middle Sweetwater River	112	ARTO	Not Surveyed		30-Jun-23	Y	Not Surveyed		1
		115	ARTO	Not Surveyed		30-Jun-23	Y	Not Surveyed		1
		120	SWPT	Not Surveyed		30-Jun-23	Y	Not Surveyed		1
	Lawson Creek	ASF47	ASF	Not Surveyed		Not Surveyed		Not Surveyed		0
	Steele Canyon	23	SWPT	Not Surveyed		21-Dec-23	Y	Not Surveyed		1
	Sweetwater River	ASF03	ASF	Not Surveyed		8-Dec-23	Y	Not Surveyed		1
	Bonita Meadows	ASF04	ASF	Not Surveyed		17-Jan-23	Y	22-Feb-24	Y	2
	Rice Canyon	ASF05	ASF	Not Surveyed		17-Jan-23	Y	29-Jan-24	Y	2
	Rancho Del Rey	ASF06	ASF	Not Surveyed		17-Jan-23	Y	29-Jan-24	Y	2
	Terra Nova	ASF07	ASF	Not Surveyed		17-Jan-23	N	29-Jan-24	N	2
	Long Canyon	ASF08	ASF	Not Surveyed		17-Jan-23	Y	22-Feb-24	Y	2
	Harbison Canyon	ASF41	ASF	Not Surveyed		8-Dec-23	Y	Not Surveyed		1
	Harbison Canyon	ASF42	ASF	Not Surveyed		8-Dec-23	Y	Not Surveyed		1
	Harbison Canyon	ASF43	ASF	Not Surveyed		Not Surveyed		Not Surveyed		0
	Beaver Hollow	ASF44	ASF	Not Surveyed		21-Dec-23	Y	Not Surveyed		1
Otay River	Dulzura Creek	ASF45	ASF	Not Surveyed		Not Surveyed		19-Jan-24	N	1
	Jamul Creek Tributary	ASF55	ASF	Not Surveyed		Not Surveyed		30-Jan-24	N	1
	Jamul Creek	41	SWPT	Not Surveyed		Not Surveyed		19-Jan-24	Y	1
		44	SWPT	Not Surveyed		Not Surveyed		19-Jan-24	Y	1
		ASF57	ASF	Not Surveyed		Not Surveyed		30-Jan-24	Y	1
		Pump Pond	SWPT	Not Surveyed		Not Surveyed		19-Jan-24	Y	1
		Bedrock Pond	SWPT	Not Surveyed		Not Surveyed		19-Jan-24	Y	1
	Proctor Valley	ASF58	ASF	Not Surveyed		7-Feb-23	Y	30-Jan-24	Y	2
		ASF61	ASF	Not Surveyed		7-Feb-23	Y	30-Jan-24	Y	2
	Salt Creek	ASF13	ASF	Not Surveyed		Not Surveyed		12-Jan-24	Y	1
		ASF14	ASF	Not Surveyed		Not Surveyed		12-Jan-24	Y	1
	Otay River	ASF02	ASF	Not Surveyed		Not Surveyed		12-Jan-24	N	1
		ASF48	ASF	Not Surveyed		Not Surveyed		12-Jan-24	Y	1
	Lower Otay Tributaries	ASF09	ASF	Not Surveyed		14-Feb-23	Y	22-Feb-24	Y	2
		ASF10	ASF	Not Surveyed		14-Feb-23	Y	22-Feb-24	Y	2
		ASF11	ASF	Not Surveyed		14-Feb-23	Y	22-Feb-24	Y	2
		ASF62	ASF	Not Surveyed		14-Feb-23	Y	Not Surveyed		1
		ASF63	ASF	Not Surveyed		14-Feb-23	N	Not Surveyed		1
Tijuana River	Pine Valley Creek	124	ARTO	Not Surveyed		14-Jun-23	Y	Not Surveyed		1
		128	ARTO	Not Surveyed		14-Jun-23	Y	Not Surveyed		1
		134	ARTO	Not Surveyed		14-Jun-23	Y	Not Surveyed		1
		139	ARTO	Not Surveyed		14-Jun-23	Y	Not Surveyed		1
	Lower Cottonwood Creek	5	ARTO	Not Surveyed		13-Jun-23	Y	Not Surveyed		1
		10	ARTO	Not Surveyed		13-Jun-23	Y	Not Surveyed		1
		15	ARTO	Not Surveyed		13-Jun-23	Y	Not Surveyed		1
		20	ARTO	Not Surveyed		13-Jun-23	Y	Not Surveyed		1
		66	ARTO	Not Surveyed		21-Dec-23	Y	Not Surveyed		1
	Spring Canyon	ASF01	ASF	Not Surveyed		Not Surveyed		29-Jan-24	N	1
		ASF59	ASF	Not Surveyed		Not Surveyed		29-Jan-24	Y	1
		Grand Total		**4**	**0**	**64**	**54**	**80**	**64**	**148**

ARTO = arroyo toad, SWPT = southwestern pond turtle, ASF = sites with aseasonal flow.

Table 3. Species Detected. Species detections by site.

			Native					Nonnative					
Watershed	Stream	Reach/Site	California Treefrog	Pacific Chorus Frog	Arroyo Toad	Western Toad	Two-Striped Garter Snake	Bullfrog	African Clawed Frog	Green Sunfish	Mosquitofish	Crayfish	Total Species Observed
Santa Margarita River	Roblar Creek	ASF51											0
		ASF64											0
	Sandia Canyon	1		1							1		2
		5	1	1									2
		10		1									1
	Santa Margarita River	133											0
	Santa Margarita River Tributary	ASF50											0
	Block0935	16A											NS*
San Luis Rey River	Gopher Canyon Tributary	ASF53											0
	Keys Creek	ASF38											0
	Pilgrim Creek	ASF30											0
	Guajome Creek Tributary	ASF28											0
	San Luis Rey River	ASF29											0
	Middle San Luis Rey River	55											0
		60											0
	Lower San Luis Rey	82										1	1
		86											0
		98											0
		104											0
Buena Vista	Buena Vista Creek	ASF52											0
	Buena Vista Creek Trib	ASF54											0
Agua Hedionda	Upper Calavera Creek	ASF27											0
San Marcos Creek	Batiquitos Lagoon Tributary	ASF25											0
Escondido Creek	Escondido Creek	ASF31											0
	Escondido Creek Tributary	ASF33		1									1
San Dieguito River	Temescal Creek (Santa Ysabel)	1											0
		16											0
	Upper Santa Ysabel Creek Trib11A	3											0
		6											0
	Upper Santa Ysabel Creek	40											0
	Black Canyon	3											0
	Boden Canyon	13											0
		23											0
	Lower Santa Ysabel Creek	1											0
		15											0
		28											0
		40											0
		47											0
		53											0
		59											0
		62											0
		65											0

ASF = sites identified for the aseasonal flow study, NS*=Not Surveyed

Table 3 cont. Species detections by site.

			Native					Nonnative					
Watershed	Stream	Reach/Site	California Treefrog	Pacific Chorus Frog	Arroyo Toad	Western Toad	Two-Striped Garter Snake	Bullfrog	African Clawed Frog	Green Sunfish	Mosquitofish	Crayfish	Total Species Observed
San Dieguito River	Lower Santa Ysabel Creek	69											0
		73											0
		77											0
		83											0
		86											0
		89											0
		92						11					11
		97											0
		104											0
		107											0
San Dieguito River	Gonzales Creek	ASF22											0
	Lusardi Creek	ASF23											0
		ASF24											0
	Green Valley	ASF40											0
	Santa Maria Creek Tributary	ASF39											0
	Santa Maria Creek	7											0
		10		1									1
		20	1	1	20	10							32
		25		55	200								255
		29			1						1		2
		33		20	11	100					1		132
		36				1							1
San Dieguito River	Santa Maria Creek	40											0
		44											0
		52				1							1
	Upper San Dieguito River	52											0
		60											0
	Upper San Dieguito River B	9											0
	Upper San Dieguito River Trib 4	2											0
Los Penasquitos Creek	Los Penasquitos Creek	ASF21											0
	Los Penasquitos Canyon	ASF60											0
	Carrol Canyon	ASF37											0
Mission Bay WMA	Tecolote Creek	ASF18											0
	San Clemente Canyon	ASF19											0
	Rose Creek	ASF20											0
San Diego River	Upper San Diego River	61											0
		65											0
		67											0
		69											0
	Cedar Creek	3											0
		6											0
	San Vicente Creek	47											0
San Diego River	West Branch San Vicente Creek Trib 1	5											0
	San Vicente Creek Tributary	ASF36											0
	Boulder Creek	36											NS*
Pueblo San Diego	Encanto Creek	ASF15											0
	South Chollas Creek	ASF16											0
	Chollas Creek	ASF17											0

ASF = sites identified for the aseasonal flow study, NS*=Not Surveyed

Table 3 cont. Species detections by site.

			Native					Nonnative					
Watershed	Stream	Reach/Site	California Treefrog	Pacific Chorus Frog	Arroyo Toad	Western Toad	Two-Striped Garter Snake	Bullfrog	African Clawed Frog	Green Sunfish	Mosquitofish	Crayfish	Total Species Observed
Sweetwater River	Middle Sweetwater River	112	1			1							2
		115											0
		120											0
	Lawson Creek	ASF47											0
	Steele Canyon	23											0
	Sweetwater River	ASF03											0
	Bonita Meadows	ASF04											0
	Rice Canyon	ASF05											0
	Rancho Del Rey	ASF06											0
	Terra Nova	ASF07											0
	Long Canyon	ASF08											0
	Harbison Canyon	ASF41											0
	Harbison Canyon	ASF42											0
	Harbison Canyon	ASF43											0
	Beaver Hollow	ASF44											0
Otay River	Dulzura Creek	ASF45											0
	Jamul Creek Tributary	ASF55											0
	Jamul Creek	41											0
		44											0
		ASF57											0
		Pump Pond											0
		Bedrock Pond											0
	Proctor Valley	ASF58											0
		ASF61											0
	Salt Creek	ASF13										1	1
		ASF14										1	1
	Otay River	ASF02											0
		ASF48											0
	Lower Otay Tributaries	ASF09											0
		ASF10									3		3
		ASF11											0
		ASF62											0
		ASF63											0
Tijuana River	Pine Valley Creek	124		100		20							120
		128			250	100							350
		134			300								300
		139			25		2						27
Tijuana River	Lower Cottonwood Creek	5			6				1		3	5	15
		10									5		5
		15			1								1
		20								1			1
		66											0
	Spring Canyon	ASF01											0
		ASF59											0

ASF= sites identified for the aseasonal flow study, NS*=Not Surveyed

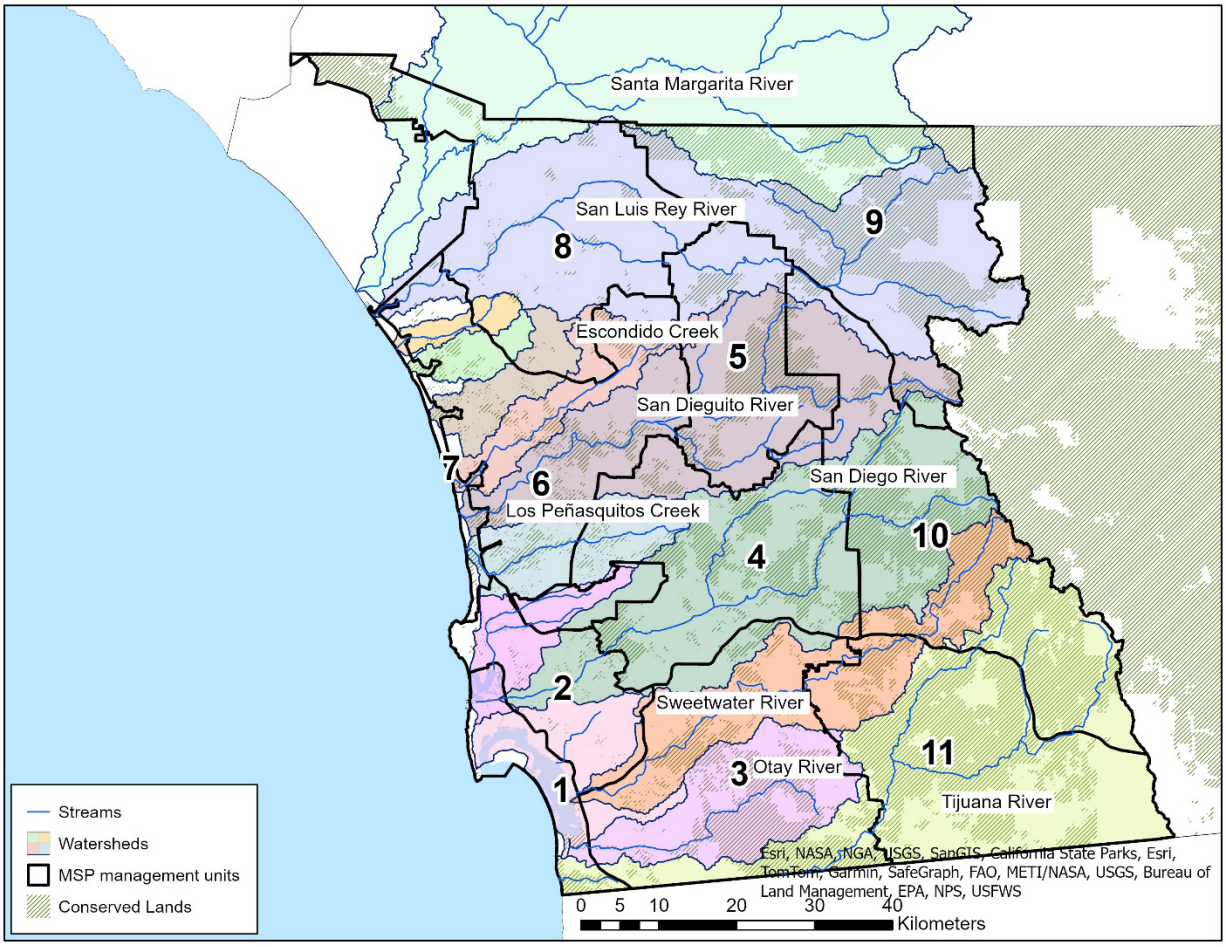


Figure 1. Study Area. Overview of study area with watersheds, conserved lands, and MSP management units. (SDMMP and TNC 2017; USGS 2019.)

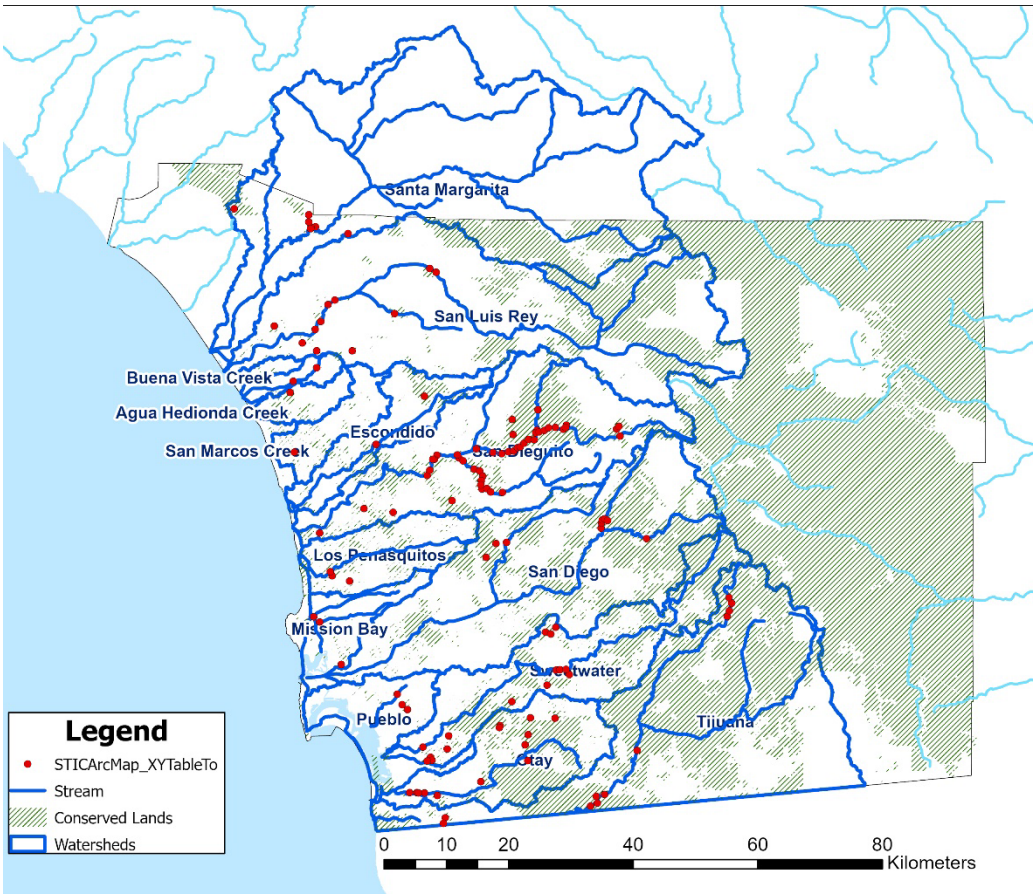


Figure 2. Study Sites. Stream surface water study sites, San Diego, CA. There were 134 sites in 14 watersheds throughout coastal San Diego County. (SDMMP 2023.) Service layer credits not available, base maps were not used.

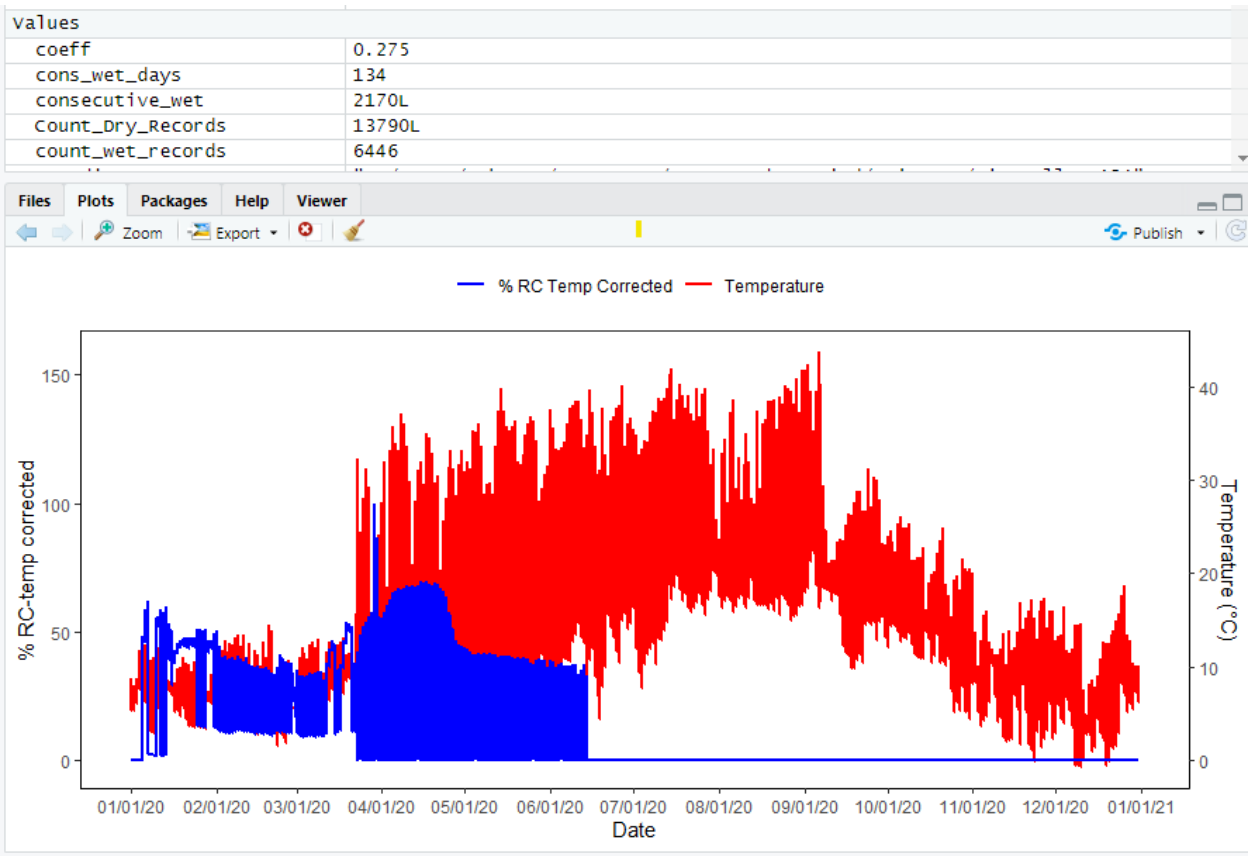


Figure 3. Hydroperiod Data Automation. Example of the data automation R program developed by Jessica Weidenfeld and Kris Taniguchi-Quan from SCCWRP based off of the Brown and Aguilar Duran data reduction code. Example shows relative conductivity in blue indicating when water was present and temperature in red. Summary stats provide information on consecutive wet days (hydroperiod) and record counts.

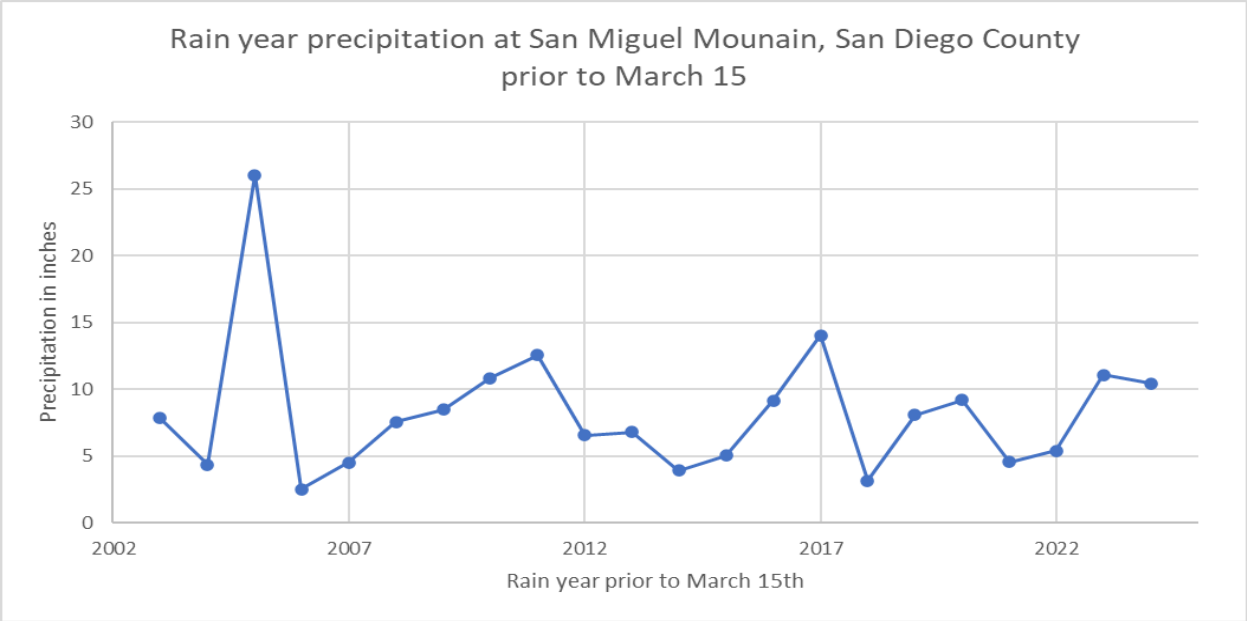


Figure 4. San Miguel Mountain Annual Precipitation. Data from the California Data Exchange Center estimating amount of rainfall precipitated at San Miguel Mountain before 15 March 2024. San Miguel Mountain is located in the Sweetwater River watershed. San Miguel's precipitation data is used to represent increased rainfall in San Diego County.

Appendix 1. Representative photos of watersheds surveyed 2022–2024.

(Santa Margarita River) Sandia Canyon Reach 001: 15 June 2023 by Dhafir Williams

Middle San Luis Rey Reach 60: 29 Jun 2023 by Dhafir Williams

(San Dieguito River) Lower Santa Ysabel Creek Reach 053: 11 Dec 2023 by Jenna Levy

Los Penasquitos ASF60, by Darren Chon

(San Diego River) San Vicente Creek Reach 047, by Sarah Villar

Middle Sweetwater River Reach 112, by Dhafir Williams

Pueblo San Diego ASF17, by Sarah Villar

Otay River ASF14, by Sarah Villar

(Tijuana River) Pine Valley Creek Reach 134, by Jorge Ayon

Appendix 2. Representative photos of species detected during surveys.

Arroyo Toad (*Anaxyrus californicus*), by Dhafir Williams

California Treefrog (*Pseudacris cadaverina*), by Dhafir Williams

Pacific Chorus frog (*Pseudacris regilla*), by Dhafir Williams

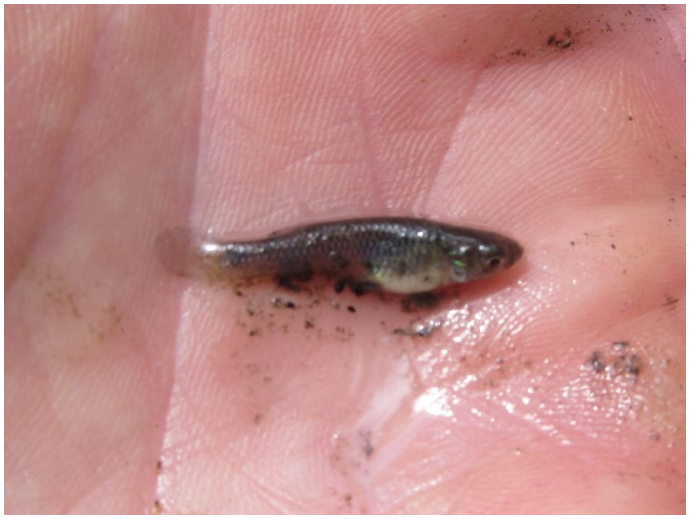
Western Toad (*Anaxyrus boreas*), by Dhafir Williams

Greater Roadrunner (*Geococcyx californianus*), by Dhafir Williams

Two-Striped Gartersnake (*Thamnophis hammondii*), by USGS

Red Swamp Crayfish (*Procambrus clarkii),* by USGS

American Bullfrog (*Lithobates catesbeianus*), by Dhafir Williams



Western Mosquitofish (*Gambusia affinis*), by USGS