SMALL DAM REMOVAL EFFECTIVENESS MONITORING FOR STEELHEAD TROUT IN SOUTHERN CALIFORNIA UNDER EXTENDED DROUGHT CONDITIONS

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I. Executive Summary

The removal of dams has recently increased over historical levels due to aging infrastructure, changing societal needs, and modern safety standards rendering some dams obsolete (Duda et. al 2016). Removal of obsolete dams is an innovative way to ensure public safety, provide resiliency and ecosystem function through river restoration, all while creating jobs to support the communities these dams once served.

Dam removal in southern California is critically important for the recovery of the federally listed endangered southern steelhead but has the potential to provide larger multi-species ecological benefits both upstream and downstream. Dam removal allows for steelhead to access additional habitat upstream of the dam that may include more ideal spawning and rearing habitat than was previously available. Downstream benefits include gravel and sediment transport that can improve habitat quality and replenishes sediment starved beaches and estuaries.

The potential benefits of dam removal are not without risks, and there remains concern for both short and long-term impacts following dam removal of any size. Southern California has a significant number of both small and large dams. Small dams that litter the southern California landscape have the potential to yield a high level of benefit with removal for little fiscal investment. Dam removals need to be considered in the context of the unique drivers specific to the region, such as hydrology and geomorphology, and are vital in understanding the influence of this restoration technique. An important element of cost-effective small dam removal is the ability for restoration partners to obtain and meet permit requirements to undertake the removal process.

Streamlined and programmatic permits are powerful permit and design tools for restoration practitioners who can leverage them. Programmatic biological opinions (needed to meet the Endangered Species Act obligations) exist for the National Marine Fisheries Service (NMFS) for all anadromous waters in California. The NOAA Restoration Centers' Southern and South-Central California Salmonid Restoration Programmatic Biological Opinion (issued December 23, 2015) includes detailed requirements for small dam removal. Development of small dam removal limitations and requirements was hindered by the complete lack of published dam removal data for the region. This study aimed to explore the feasibility of applying the constraints and data requirements set forth in the NMFS southern California programmatic biological opinion (appendix II) to understand how sediment released by small dam removal influences streambed morphology under extended drought conditions in southern California.

This study provides region specific examples of effects of small dam removal (all dams under 10ft) on steelhead habitat under a range of regulatory and climatic conditions that covers projects inside and outside NMFS jurisdiction under drought, fire, and flood conditions. The study spans 3-4 years (2014-2017) in three priority steelhead watersheds in Ventura, Los Angeles, and Orange Counties. This study captured site conditions at the end of a drought (2011-2016) and El Nino/La Nina conditions in 2017. Three of the four study sites were subject to fires including the 2016 Holy Fire and December 2017-January 2018 Thomas Fire. The 2017 Thomas fire was the largest single wild fire in Californian modern history. During the compilation of this report another fire in the Holy Jim watershed ignited in August of 2018. The variability of southern California climatic conditions supports long term studies that better capture this year-to-year variability of climate and episodic events. Watershed inputs from fires, roads, and runoff events have a greater effect on the habitat structure than any of the small dam removals included in this study. The amount of sediment impounded by these small dams was indeed small and did not exceeded the 900-cubic yard of impounded sediment threshold set forth by the programmatic biological opinion. Therefore, future studies should aim to investigate dam removals that exceed this threshold. This study was able to employ cost effective monitoring strategies needed to meet permit monitoring requirements through collaboration with National Oceanic and Atmospheric Administration's Restoration Center, California Conservation Corps, California Department of Fish and Wildlife, University California Los Angeles and Santa Barbara, U.S. Forest Service, and Pacific States Marine Fisheries Commission to help to inform future dam removal efforts in southern California.

This study provides a foundation of support for the value of pre-dam removal data. Where pre-dam removal data was available this study showed a somewhat cyclical pattern of sedimentation and infilling under drought conditions (2014 and 2016). Without pre-dam removal data the assumption would be made that this sedimentation and subsequent infilling in later years could be the result of dam removal. Through the utilization of pre-dam removal data, this study was able to show that sediment quality improved immediately after dam removal with flushing of fines (even under drought conditions).

Variation in regulatory conditions provided an opportunity to share lessons learned and to highlight the value in biological opinions. Trabuco and Holy Jim Creek offer an example of a potential cost-effective strategy for high density small dam removal by taking advantage of its location in relation to NMFS jurisdiction. Without being subject to NMFS review, the range of methodologies by which dam removal can be implemented is greater and not subject to terms and conditions of an opinion. Thus, portions of the dam were left instream in Trabuco and subsequent years of flows and scour unearthed more of the structure requiring repeat demolition to ensure fish passage. Despite repeat treatments, the value of removing these small dams is still recognized in the cost savings of the removals (no requirement for high-level engineering to meet fish passage criteria at this time) that allows the habitat to be primed for and promote the removal of downstream legacy fish passage barriers like Interstate 5.

Dam removal is a complicated restoration strategy, but vital in restoring stream connectivity for anadromous species. This study fills a critical geographic gap in dam removal knowledge in a region with increasingly dynamic hydrologic variation, placing questionable doubt on the paradigm that hydrology and watershed setting are subordinate influences on initial geomorphic response to dam removal. This study also provides insight into dam removal response under a range of management strategies to help focus future small dam removal planners on key factors where monitoring is needed to best inform managers and agencies when making species specific recommendations. Finally, while no two dams are likely to respond identically, programmatic permitting gives an opportunity to create consistency in pre- and post-dam-removal monitoring requirements and should be viewed as an opportunity to understand dam removal on a regional scale for recovery of species most at risk.

Building of the works of Fejtek Smith 2017, this study is a continuation of monitoring efforts to document the effects of dam removal on habitat quality and streambed substrate within streams located in southern California that have experienced extended drought conditions.

II. Introduction

Southern California populations of steelhead trout, *Oncorhynchus mykiss,* have declined within this century to the point where their populations are believed to be less than one percent of their former historical population (Stoecker and Kelley 2005). These depletions are due in large part to the inability of species to migrate freely up and down watersheds to complete their life cycles (Whol 2012, Moyle et al. 2017). The National Marine Fisheries Service (NMFS) Southern California Steelhead Recovery Plan (NMFS 2012) identifies fish passage barrier removal as a critical recovery action to assist the highly endangered southern steelhead (*Oncorhynchus mykiss*). Sixty-eight percent of steelhead losses are associated with anthropogenic barriers to migration (e.g. dams, flood-control structures, culverts, etc.) (Boughton et al. 2006), yet a critical gap in dam removal understanding still exists in scientific literature. Of the 1,594 dams in California, less than 100 have been removed statewide and only four of those dams have one or more scientific publication associated with them (Bellmore et al. 2017). Dam removal monitoring that does exist is often short term (1-2yrs) and often includes little or no data prior to dam removal (Major et al. 2017). Due to changing societal needs including the environmental understanding in dam function and modern safety standards rendering some dams obsolete, dam removals have recently increased nationwide over historical levels (Duda et. al 2016). However, prior to this study the United States Geological Survey (USGS) Dam Removal Information Portal (DRIP) identified a complete gap in studies for the Southern California Bight (USGS 2018 https://www.sciencebase.gov/drip/).

Dam removal in southern California has the potential to provide both upstream and downstream benefits for steelhead recovery. Most importantly dam removal allows for access of additional habitat upstream of the dam that may include more ideal spawning and rearing habitat than was previously available. Downstream benefits include gravel transport that improves habitat quality. Monitoring of over 400 redds in the Ventura and Malibu watersheds identified preferred particle sizes of 10-140mm for spawning by southern steelhead (Per comm. R. Bush 2014). Logically this is the grain size that restoration practitioners hope to release and see transported downstream post dam removal. Understanding the impacts of dam removal in the context of unique drivers of the region such as hydrology and geomorphology are vital in understanding the influence of this restoration technique (Graf 2005). The potential benefits of releasing impounded preferred spawning gravel are not without risks, and there remains concern for both short- and long-term impacts following dam removal.

Sediment quantity and quality (“caliber,” or grain size) are concerns for small dam removal in steelhead-bearing streams. Importantly, these factors are influenced in part by the hydrology of the region (Graf 2005, Skalak et al. 2009, Major et al. 2017). Southern California hydrology can be highly variable and could be even more so under the extended drought conditions anticipated in climate change scenarios. This variability in hydrology has the potential for dam removal to result in sediment fouling (fine particles <6.4mm inundating areas of more optimal grain size) downstream of dam removal location. While some sediment fouling is anticipated with almost any instream restoration effort, there is concern that this sediment fouling has the potential to become a longer-term impact (1 to 2 years or longer under drought conditions like those as exhibited between 2011-2016 (NMFS 2015)) by slowly bleeding until a significant (>2-year event) rain event can flush the system. This type of sediment fouling/bleeding is likely to negatively impact steelhead habitat and fry emergence times (Bjorn and Reiser 1991). However, negative impacts from dam removal may be temporary and potentially outweighed by better quality upstream made accessible by dam removal. Of course, there are still major considerations when permitting such an activity (NMFS 2015). To make an informed decision, it is important to understand the quantity and quality of impounded sediment and the role that region-specific hydrology may play in permitting dam removal to ensure restoration activities yield net-positive benefits for target protected species.

Due to the potential risks, small dam removal is subject to environmental review despite the potential recovery benefits it may yield. The ESA Section 7 biological consultation process can be costly and time consuming, resulting in permitting delays or making restoration projects financially infeasible. Programmatic biological opinions (BOs) are one method that restoration projects can be prioritized by and the Section 7 process can be streamlined while still providing necessary protections to threatened and endangered resources. This reduces the time and cost involved in the formal Section 7 consultation process for the applicant, reviewing agency, and other permitting entities (Pagliuco and Samonte 2015). A review of consultations for restoration actions completed in Oregon in 2011 showed that the average time for restoration projects covered by a programmatic consultation was 6 days or less—as compared to 132 days or longer for restoration projects that required individual consultation (NMFS 2014). Programmatic biological opinions for all anadromous waters in California will be available in early 2019. Programmatic biological opinions currently exist for all coastal counties throughout California with limitations on dam removal varying by region. These programmatic documents are powerful permit and design tools for restoration practitioners who can leverage them.

The NOAA Restoration Centers' Southern and South-Central California Salmonid Restoration Programmatic Biological Opinion (issued December 23, 2015) includes dam removal with three exclusionary constraints. Three conditions preclude a small dam removal project from eligibility for coverage under the southern California BO: 1) sediments stored behind dam have a reasonable potential to contain environmental contaminants (dioxins, chlorinated pesticides, polychlorinated biphenyls, or mercury); 2) the risk of significant loss or degradation of downstream spawning or rearing areas by sediment deposition is considered to be such that the project requires more detailed analysis; or 3) impoundment of more than 900-cubic yards of sediment (regardless of quality/grain size). This study aims to explore the feasibility of applying the constraints and monitoring requirements set forth in the NMFS southern California programmatic biological opinion to understand how sediment released by small dam removal influences streambed morphology under extended drought conditions in southern California.

III. Methodology

During 2014, several small dams were removed throughout southern California (Table III-1.): 1) One small check dam structure from Lion Creek in the Sespe Wilderness, Los Padres National Forest. Project implementation began October 13 and was completed November 17 (Figure III-1); 2) One small check dam structure from Arroyo Sequit Creek. Project implementation began August 18 and was completed September 4 (Figure III-2); and 3) Four small dams (only dams 7, 10, and 11 impounded sediment) within Cleveland National Forest in Trabuco Creek were removed in December of 2014 (Figure III-3 a-d). Trabuco Creek is the only site in which multiple dams were removed simultaneously. Building upon lessons learned and the desire to expand dam removal knowledge, three small dams and one Arizona crossing on Holy Jim Creek, a tributary to Trabuco, were surveyed in 2017 to establish pre-dam removal data (Figure III-4 a-d). Removal of Holy Jim barriers were scheduled for the summer of 2018 but delayed in August 2018 due to the Holy Fire. Holy Jim Creek and Trabuco Creek are two of

Table III-1. Comparison of dam removal site characteristics (based on 2013 US Fish and Wildlife review). *Dam remnants did not impound sediment, but constricted flows.

Dam Site Name	Latitude	Longitude	Barrier Severity	Sediment Storage (Yrds^3)	Dam Height (ft)	Thick (ft)	Width (ft)	Valley Form	NMFS Biological Opinion	Road adjacent	Removal Method
Trabuco 7	33.67437	-117.52586	Total	631	6	5.5 base, 2.5 cap	31	Constrained	No	Yes	Excavator and pneumatics
Trabuco 9	33.67426	-117.52536	None	0	4.5 - 9 at thalweg	4.5	25	Constrained	No	Yes	Excavator and pneumatics
Trabuco 10	33.67432	-117.52521	Total	74	2.5	2.5	2.5	Constrained	No	Yes	Excavator and pneumatics
Trabuco 11	33.67436	-117.52507	Partial	281	6.5	2	40	Constrained	No	Yes	Excavator and pneumatics
Arroyo Sequit	34.05788	-118.93298	Partial	185	5	4	40	Constrained	Yes	No	Pneumatic hand tools
Lion Creek	34.54345	-119.16380	Partial	182	3.1	1.5	26.5	Constrained	Yes	No	Pneumatic hand tools

four streams included in the US Forest Service Trabuco District Dam Removal Project working to remove 78 small dams since 2014. In addition to the four dams removed from Trabuco Creek, as of December 2018, Holy Jim Creek has had thirty-one total manmade dams removed thus far with five removed in 2014, five removed in 2017, and an additional twenty-one dams removed in April 2018 (Donnell et al., 2018).

Figure III-1. Lion Creek check dam before removal, looking upstream from left bank at small (3.1 feet high). Lion Creek check dam was removed in October of 2014. Photo courtesy of CCC Camarillo.

Figure III-2. Arroyo Sequit check dam before removal. Upstream view of small (5 feet high) check dam that was demolished in August-September 2014. Photo courtesy of CCC Camarillo.

Figure III-3 a-d. Trabuco Creek Fish Dams (TCFD) prior to removal in 2014 a) TCFD7 (6 feet high), b) TCFD9 (4.5-9 feet high at thalweg), c) TCFD10 (2.5 feet high) and d) TCFD11 (6.5 feet high). Photos courtesy of Trabuco Ranger District, Cleveland National Forest.

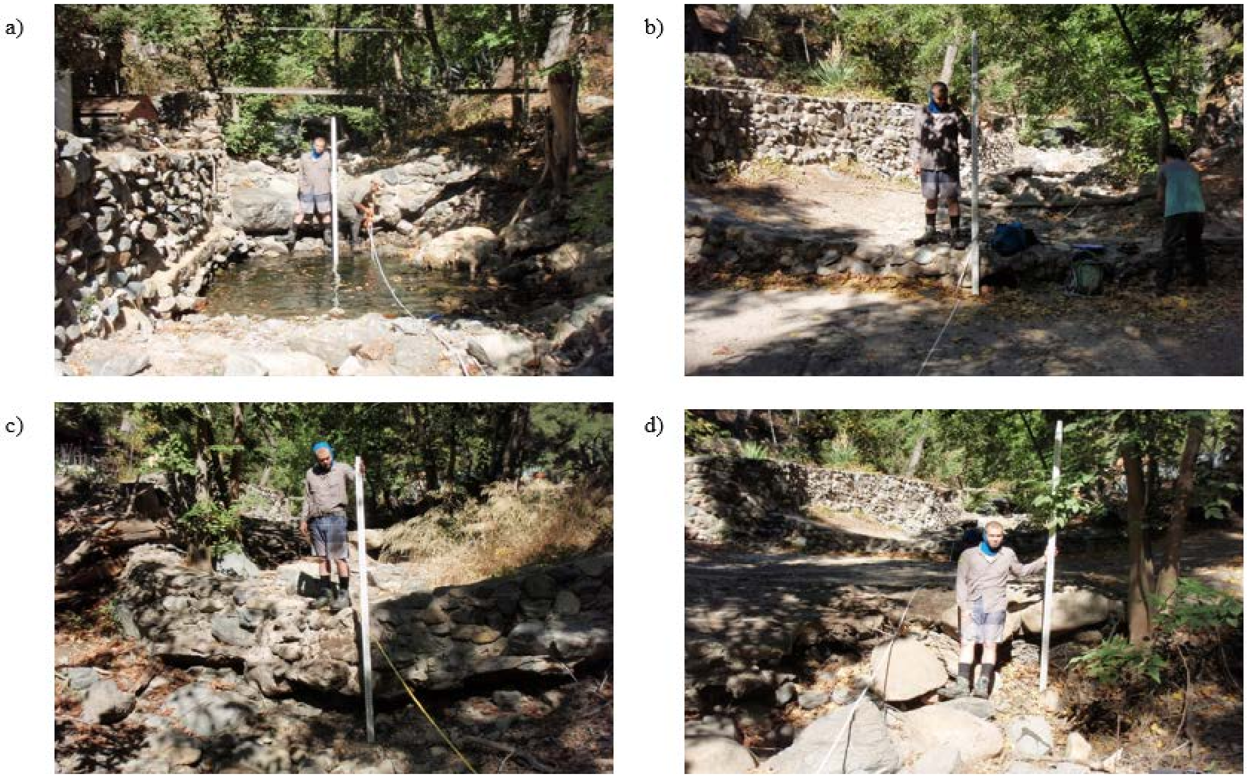


Figure III-4 a-d. Holy Jim Fish Dams (HJFD) during 2017 surveys; a) HJFD5 (6.3 feet high), b) HJFD4 (1.9 feet high), c) HJFD3 (4.2 feet high) and d) Holy Jim Canyon Road Arizona crossing (3.1 feet high).

These dams and barriers were selected for the study due to their high priority value for contribution to southern steelhead recovery and the timing of the removal. Arroyo Sequit Creek is one of three known watersheds to host southern steelhead currently in the Santa Monica Mountains (https://www.parks.ca.gov/?page_id=28350). The small check dam on Lion Creek that served as a partial barrier was ranked as one of the highest prioritized barriers to be removed within the tributaries to Sespe Creek (Stoecker and Kelley 2005). Trabuco and Holy Jim dams are above two high priority barrier removal projects that are underway, Interstate 5 and Metrolink Fish Barrier projects.

Figure III-5. shows locations of small dam removal projects overlaid on southern California steelhead DPS (adapted from NMFS 2012). Physical and land-use characteristics are compiled in Table III-2. to provide context of watershed characteristic relative to study sites

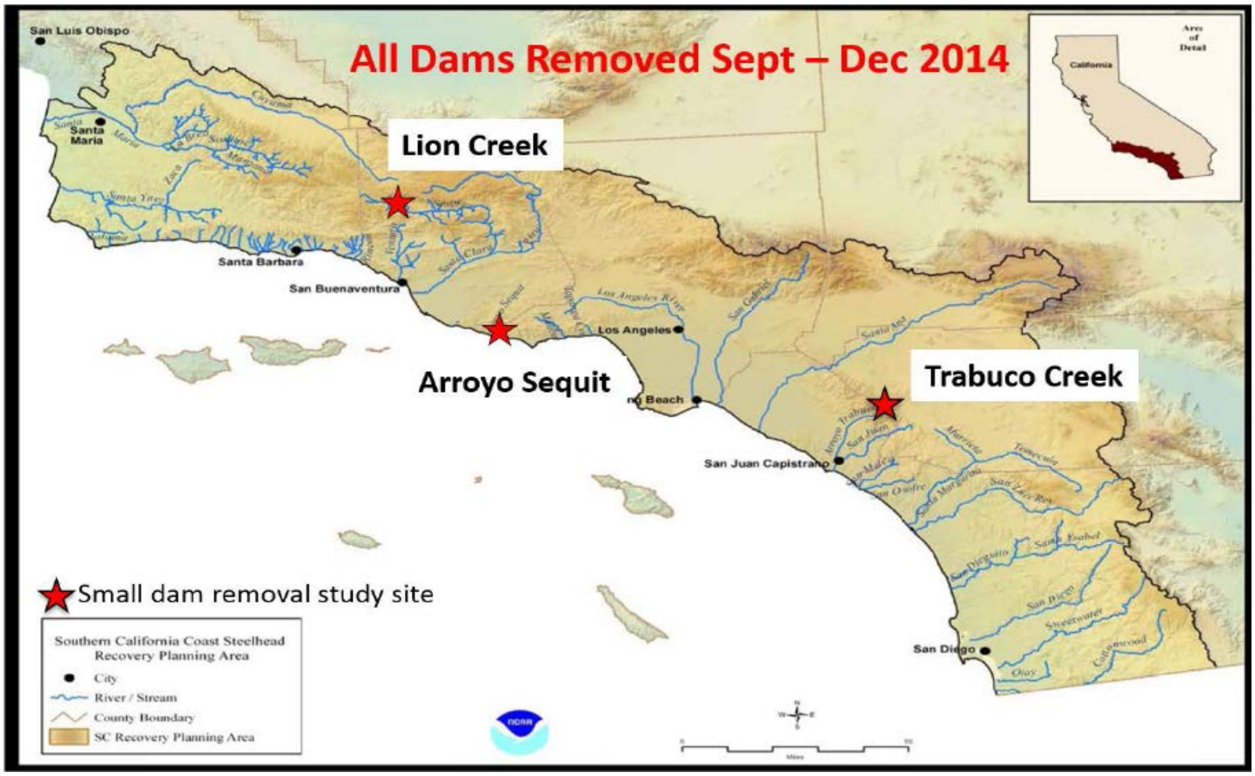


Figure III-5. Locations of dam study sites overlaid on southern California steelhead DPS (adapted from NMFS 2012).

Table III-2. Physical and land use characteristics for dam removal sites watersheds. Santa Clara River watershed includes Lion Creek dam removal site and San Juan Creek watershed includes both Trabuco and Holy Jim Creek dam removal study sites.

Physical Charactersitics						Land-Use			
Watersheds	**Area (acres)**	**Area (sq miles)**	**Stream Length (miles)**	**Ave. Annual Rainfall (inches)**	**Total Human Population**	**Public Ownership**	**Urban Area**	**Agricultural/ Barren**	**Open Space**
Santa Clara River	1,040,223	1625	2485	16.7	350,363	54%	6%	7%	87%
Arroyo Sequit	7,572	12	17	17.9	370	43%	3%	1%	96%
San Juan Creek	113,977	178	280	12.5	191,997	37%	23%	7%	70%

(adapted from NMFS 2012). None of these dams had reasonable potential to contain environmental contaminants; therefore, contamination was not examined in this study. The study sites share few similarities (Table III-1.) with the exception that all four survey reaches share a step-pool channel morphology and each stream is recognized as historic southern steelhead waters. Except for the Arizona crossing on Holy Jim, all the dams are obsolete and serve no current purpose but act as fish passage barriers. Arroyo Sequit, Trabuco Creek, and Holy Jim Creeks are ephemeral (containing dry segments reducing connectivity some portion of the year) while Lion Creek exhibits perennial flows. The four creeks currently have varying levels of protection due to position in watershed and ability for steelhead to access the sites. Lion Creek and Arroyo Sequit check dams were both accessible to steelhead under certain flow conditions while Trabuco and Holy Jim Creek have multiple total barriers (barriers that prevent fish passage under all flow conditions) in the watershed (notably Interstate 5 and Orange County Metrolink crossings). Thus, Trabuco Creek and Holy Jim Creek dam sites would only have resident rainbow trout (the landlocked life history form of steelhead), which do not receive protection under the Endangered Species Act, and therefore would not require a Section 7 consultation to engage in dam removal activities. Therefore, Trabuco Creek and Holy Jim Creek dams could be removed differently (not subject to a NMFS biological opinion) and under much fewer constraints than if done in areas accessible to steelhead.

A. Hydrology

To understand the hydrologic context southern California streams face under extended drought conditions, publicly available stream discharge data was reviewed (Figure III-6). Stream discharge data from the nearest USGS stream gauge was used for Lion Creek (USGS 11111500- Sespe Creek near Wheeler Springs, CA) and Trabuco Creek (USGS 11047300- Arroyo Trabuco at San Juan Capistrano, CA). No gauge data is available in Arroyo Sequit Creek; therefore, the nearest gauge data was reviewed (Topanga Creek – Los Angeles Department of Public Works No. F54C). It should be noted that Lion Creek and Trabuco gauges are further downstream (12

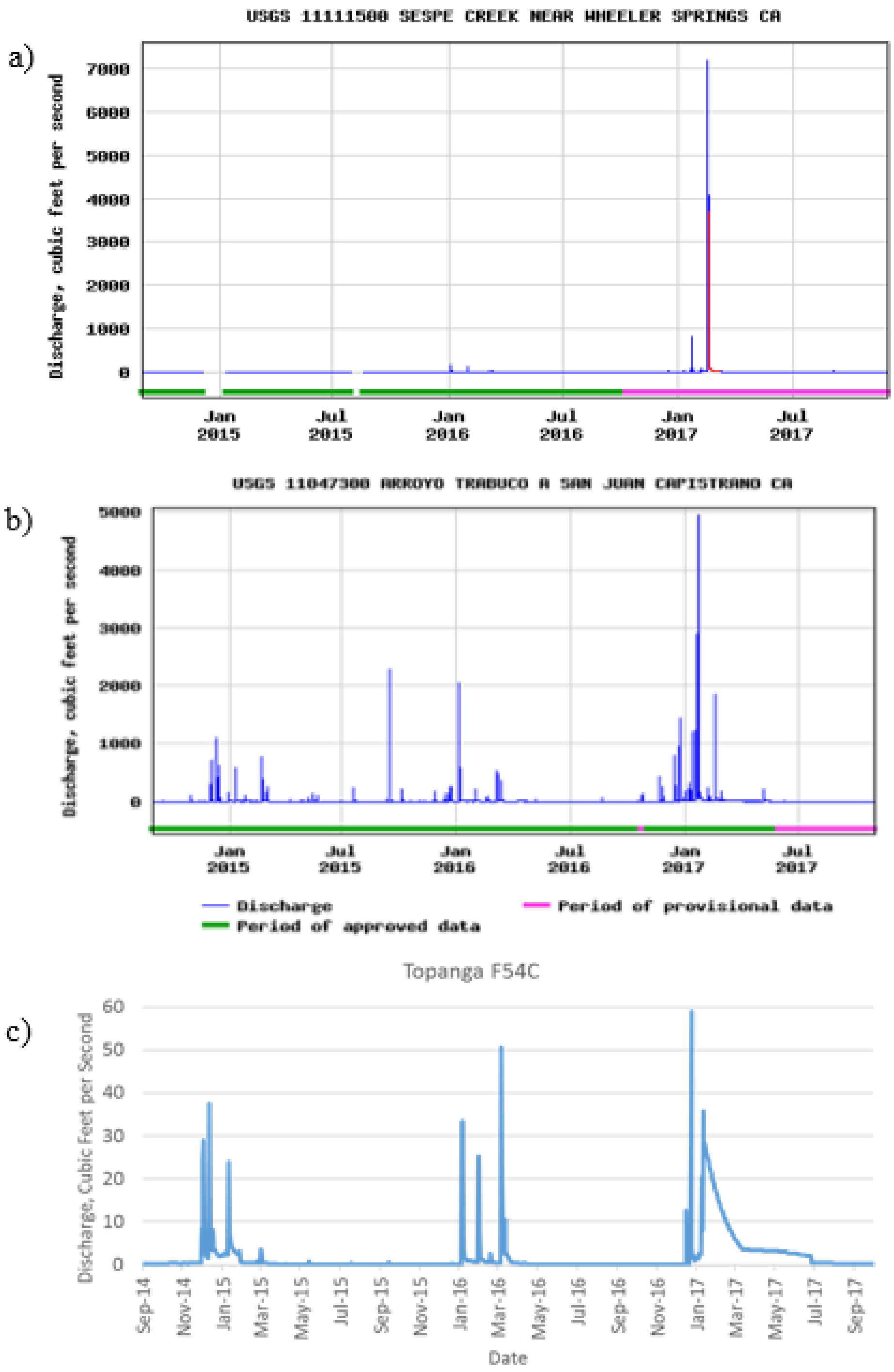
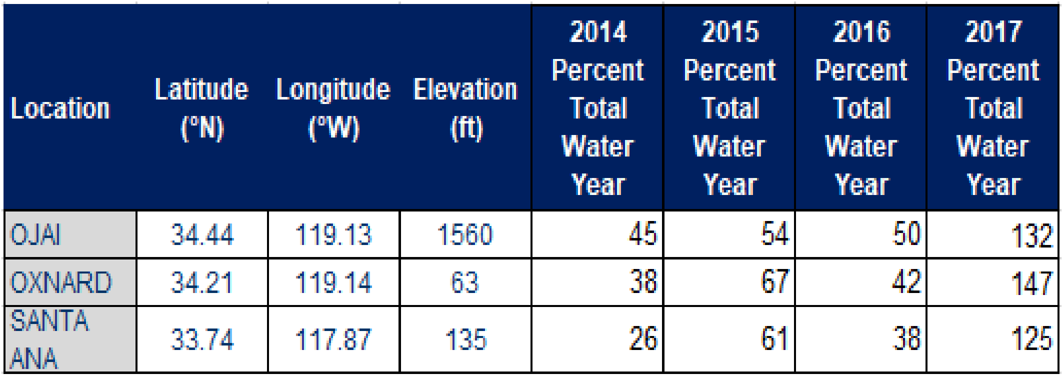


Figure III-6. Stream discharge data for dam removal study sites September 2014-Septemer 2017. Stream discharge data from the nearest a) USGS stream gauge was used for Lion Creek (USGS 11111500- Sespe Creek near Wheeler Springs, CA) and b) Trabuco Creek (USGS 11047300- Arroyo Trabuco at San Juan Capistrano, CA). No gauge data is available in Arroyo Sequit Creek; therefore, the nearest gauge data was reviewed c) Topanga Creek – Los Angeles Department of Public Works No. F54C).

and 23 miles respectively), where flows are likely to be greater due to increased runoff and convergence of flows from other tributaries. Gauge data was used to understand flows that each stream experienced following dam removal (September 2014) during the study period (September 2015-October 2017). Additionally, monthly precipitation summaries (NOAA California Nevada River Water Forecast Center 2017) were compiled for 2014-2017 to show range of variability in precipitation. The nearest stations available were used to create water year summaries: Ojai station was used as a proxy for Lion Creek (~15 miles away), Oxnard station for Arroyo Sequit (~20 miles away), and Santa Ana for Trabuco Creek (~28 miles away) (Table III-3).

Table III-3. Monthly precipitation summaries (adapted from NOAA California Nevada River Water Forecast Center 2017) were compiled for 2014-2017 to show range of variability in precipitation.



Location	Latitude (°N)	Longitude (°W)	Elevation (ft)	2014 Percent Total Water Year	2015 Percent Total Water Year	2016 Percent Total Water Year	2017 Percent Total Water Year
OJAI	34.44	119.13	1560	45	54	50	132
OXNARD	34.21	119.14	63	38	67	42	147
SANTA ANA	33.74	117.87	135	26	61	38	125

B. Topographic Surveys

Longitudinal profiles were conducted for each year after dam removal to assess any changes to stream elevation and habitat quality with focus on changes in pool habitat that may be a direct response to dam removals. The longitudinal profiles followed standard protocols described in the California Department of Fish and Wildlife Salmonid Restoration Manual (Flosi et al. 1998) and the US Forest Service Field Technique Guide (Harrelson et al. 1994). These monitoring assessments took place on 10/14/15, 6/29/16 and 10/13/17 for Arroyo Sequit, on 10/2/15, 5/17/16, and 10/19/17 for Lion Creek, and 10/16/15, 5/26/16, and 10/24/17 for Trabuco Creek. Pre-dam removal longitudinal profiles were only available for Lion Creek and were conducted on 9/15/14 (U.S. Forest Service, Los Padres unpublished data). Pre-dam removal longitudinal profile and seven cross-sections were conducted on 10/25 and 10/26/2017 on a survey reach on Holy Jim Creek in which three dams and one Arizona crossing were scheduled for removal in late summer of 2018 but delayed due to August 2018 Holy Fire.

C. Streambed Substrate

To assess any resulting changes to streambed surface substrate influenced by dam removal, Wolman pebble counts were conducted on focal areas of interest for each stream assessed. These substrate assessments followed standard protocols described in the US Forest Service Field Technique Guide (Harrelson et al. 1994). Grain size analysis followed particle size classes presented by Bevenger et al. 1995. Using standardized methodologies meant that size categories within the gravel class (8-11.3mm,11.3-16mm) and cobble class (90-128mm, 128-180mm) did not precisely match the ideal spawning gravel sizes identified by NMFS surveys (10-140mm) and therefore this study used a grain size of 8-128mm to represent preferred grain size for spawning in our analysis and discussion. Since the size range of fine gravel used in this assessment was 4-8mm, fines for this study were classified as particles within the size range <.62-8mm instead of the size range <.62-6.4mm which is more commonly used. Analysis of grain size followed Bevenger et al. 1995 and used Potyondy and Bunte 2002 publicly free software. Limitations of the software exclude more than two years of data analysis and therefore Microsoft excel was used to create graphs for further analysis. Cumulative particle size distribution graphs were created and used to compare coarseness of streambed material using pebble count data among all sampled years. When comparing surveyed years, interest was focused on comparing the 50th percent grain diameter (D50) and the 84th percent grain diameter (D84). Particle size histograms were created and used to compare changes in the frequency of fine sediment as well as the percentage of preferred particles for spawning among surveyed years.

There was no pre-dam removal data documenting the amount of sediment stored behind any of the dams studied; therefore, sediment storage capacity was estimated using dam height, dam width, and estimates of length of impounded sediment from pre-removal photographs (Table III-1). The only stream reach where cross-sections and substrate assessments were completed on impounded sediment was Holy Jim Creek because all the other dams were removed prior to the initiation of the study.

IV. Results and Analysis

A. Arroyo Sequit

1. Survey Results

a. Discharge

When summary monthly precipitation water year records were compared to the 30-year average, Arroyo Sequit Creek (Oxnard proxy station) ranged from a low of 38% in 2014 and a high of 147% in 2017 (Table IV-1). Topanga Stream gauge (Arroyo Sequit nearest gauge) exhibited intermittent flows with only eight events over 20cfs in all three sampling years and two events exceeding 50cfs from early 2016 to early 2017 (Figure IV-1). The highest total monthly discharge for the entire survey period occurred in January 2017 at 532.29cfs. Although the Topanga gauge is in a different watershed than where dam removal occurred (23 miles down coast), it is likely to represent flows near the study site because of the gauge’s location in the watershed. The Topanga gauge is in a similar location of dam removal within the watershed (dam removal and gauge are less than one mile from the ocean).

Table IV-1. Summary of monthly percent total water year records when compared to the 30-year average for the Oxnard proxy station for Arroyo Sequit Creek.

Location	Latitude (°N)	Longitude (°W)	Elevation (ft)	2014 Percent Total Water Year	2015 Percent Total Water Year	2016 Percent Total Water Year	2017 Percent Total Water Year
OXNARD	34.21	119.14	63	38	67	42	147

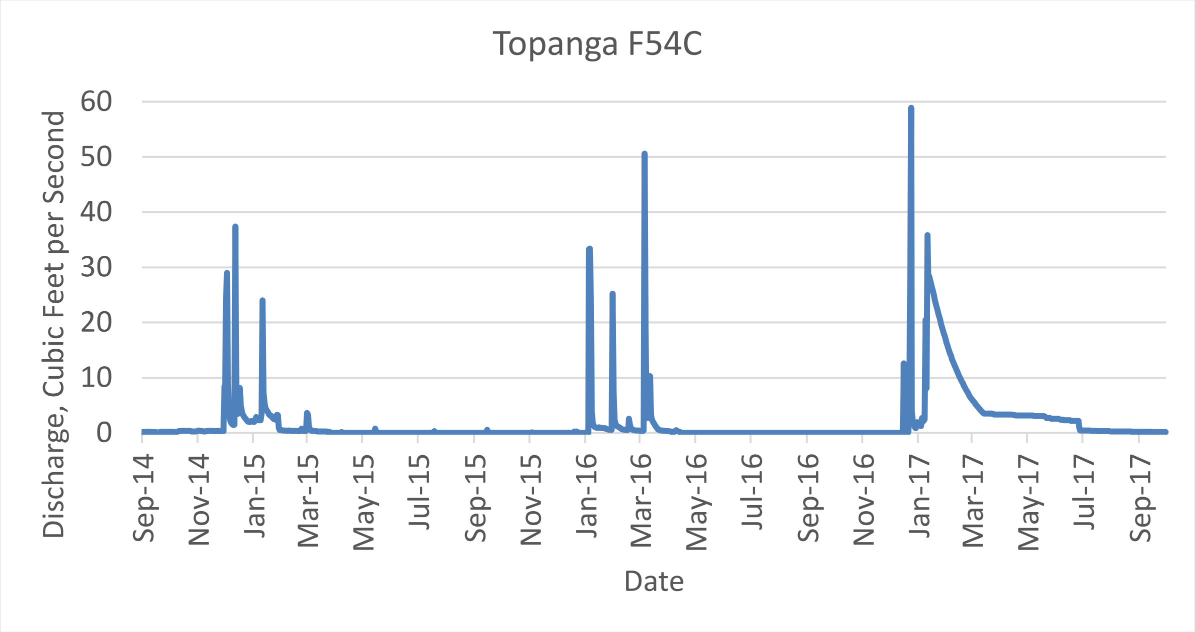


Figure IV-1. Discharge data from Topanga Creek Stream Gauge (Los Angeles Department of Public Works No. F54C).

b. Topographic and Geomorphic Survey Results

The Project's longitudinal surveys (Figure IV-2) extended 331.4 feet from a perennial pool to a survey monument established by the Bay Foundation in conjunction with the larger

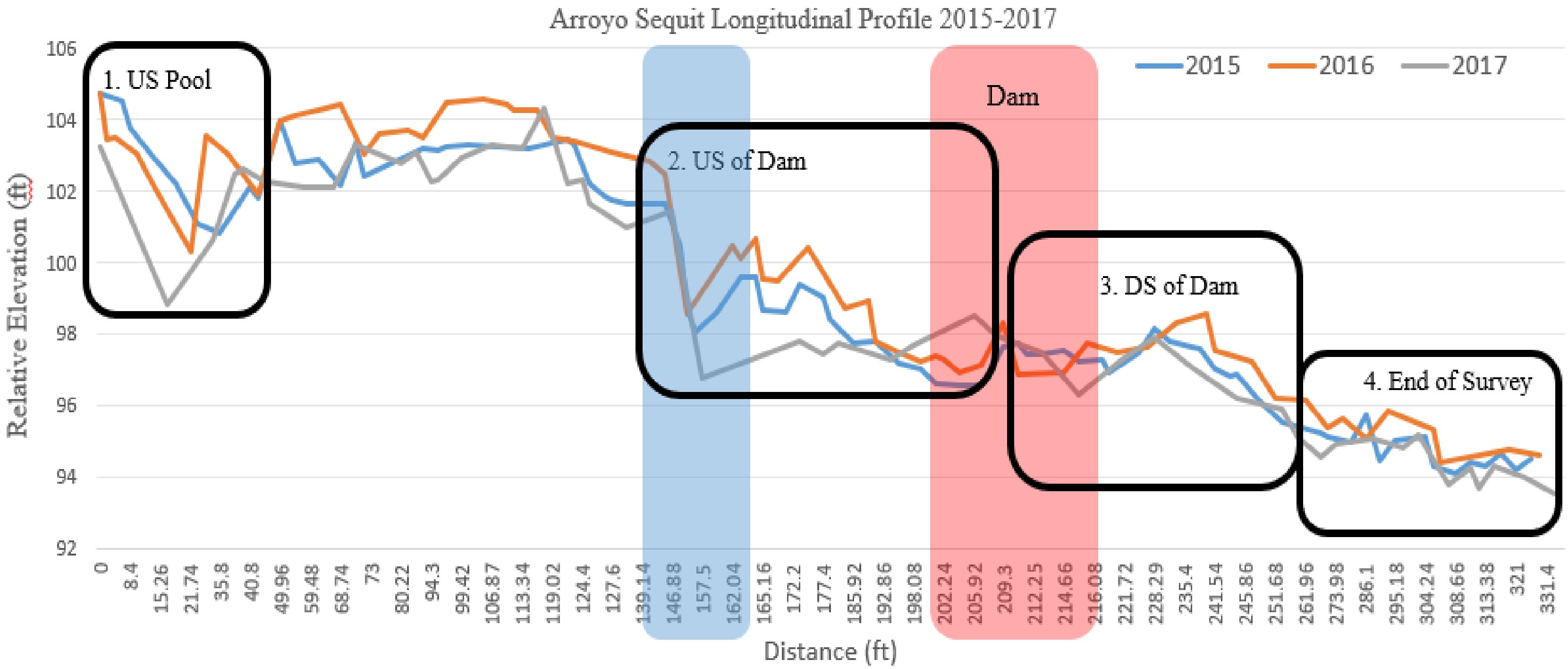


Figure IV-2. Longitudinal profile for Arroyo Sequit small dam removal study. Red shaded area represents area of dam influence where dam and reservoir once existed. Blue shaded area represents a boulder forced plunge which reached its greatest depth in 2017. Black boxes represent the four areas where pebble counts were conducted; 1) Upstream (US) pool 2) Upstream (US) of dam 3) Downstream (DS) of dam 4) End of survey.

survey of the Arroyo Sequit Fish Passage Projects which included removal of the small dam and two downstream Arizona crossings (Figure IV-3). Site photos for all surveyed years are included in appendix I.

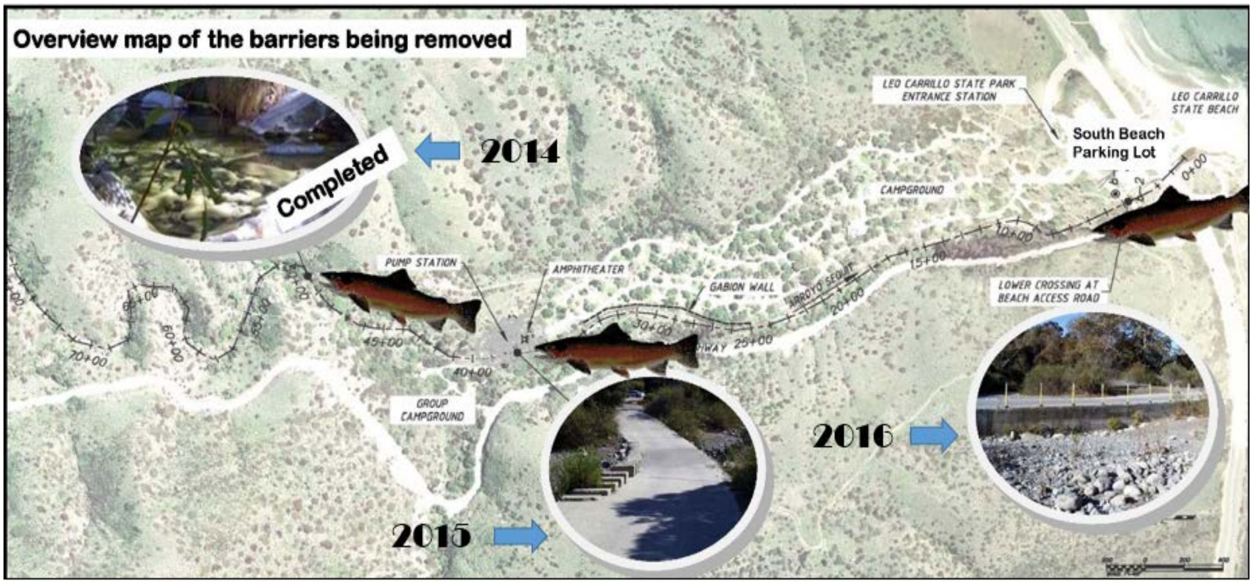


Figure IV-3. Map of larger Arroyo Sequit barrier removal project that included the small dam removal completed in 2014, and two downstream Arizona crossings completed in 2015 and 2016 (adapted from outreach materials developed by the Bay Foundation and CA state parks).

Survey results are discussed in relation to the location of the pebble count locations which were grouped into four separate reaches: 1) upstream pool, 2) the area directly upstream of dam (extent of former reservoir), 3) the area located directly downstream of dam removal, and 4) downstream to the end of survey.

i. Upstream Pool

The maximum thalweg elevation of the pool decreased (increased in depth) continuously across all survey years (Figure IV-2 US Pool). The pool tail varied in depth across the survey years decreasing in depth from 2015 to 2016 and then increasing in depth in 2017 surveys.

Figure IV-4. 2017 “upstream pool” above Arroyo Sequit dam removal site. Looking upstream at the “upstream pool” from the dam removal showing pool with Santa Monica Mountain Resource Conservation District conducting snorkel surveys. This perennial pool exhibits good overhead coverage/shading provided by terrestrial vegetation, trees, and bedrock cliff.

There was a 1.48ft difference in the deepest thalweg measurement within the pool from 2016 to 2017. In 2017, the pool had a max depth of 4.88ft and had good overhead coverage/shading provided by terrestrial vegetation, trees, and bedrock cliff (Figure IV-4). This pool remained wetted throughout the duration of the survey period despite drought conditions. The sediment frequency distribution within the upstream pool (Figure IV-5) exhibited a significant increase in silt (grain size <.062) from 2015 to 2016 which then significantly decreased in 2017 surveys. Silt comprised 28% of the stream channel particles sampled in 2016 and only 4% in 2017 and was not reported in 2015. There was more coarse sand (1-2mm) and very fine gravel (2-4mm) encountered in 2017 than in 2015 or 2016. Fine sediment had a frequency of 48% in 2017, 28%

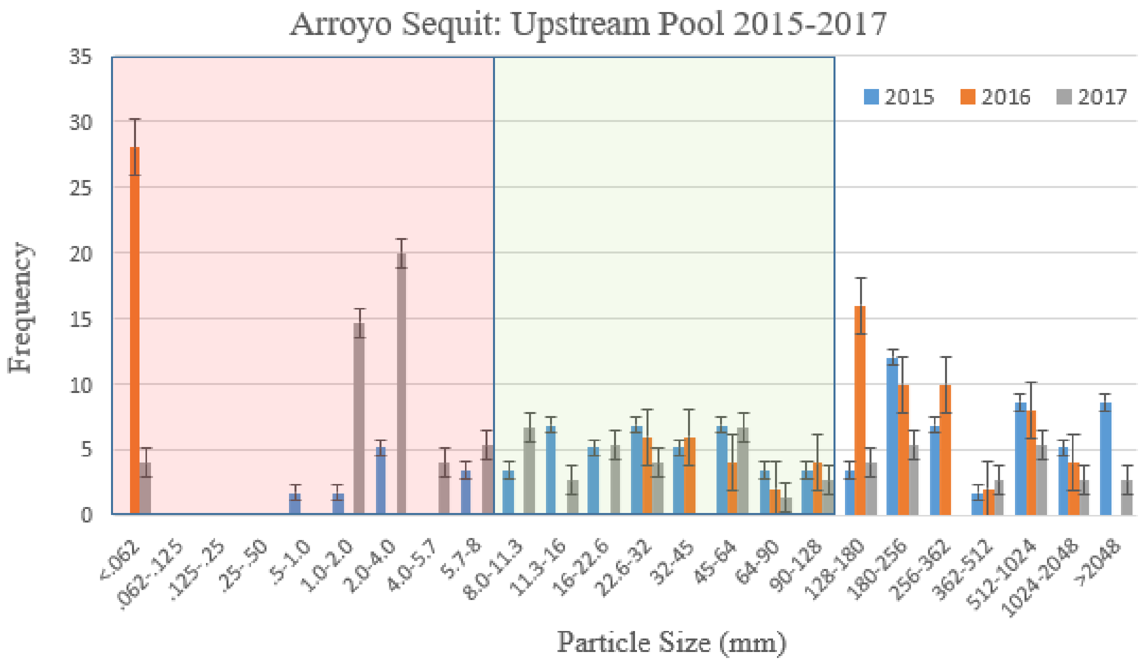


Figure IV-5. Particle size frequency distribution with standard error for upstream pool above Arroyo Sequit dam removal. Percentage of preferred spawning particle sizes (green shaded area), both 2015 (drought year) and 2017 (wet year) had a higher percentage at 41% and 29% than 2016 (drought year) at 22%.

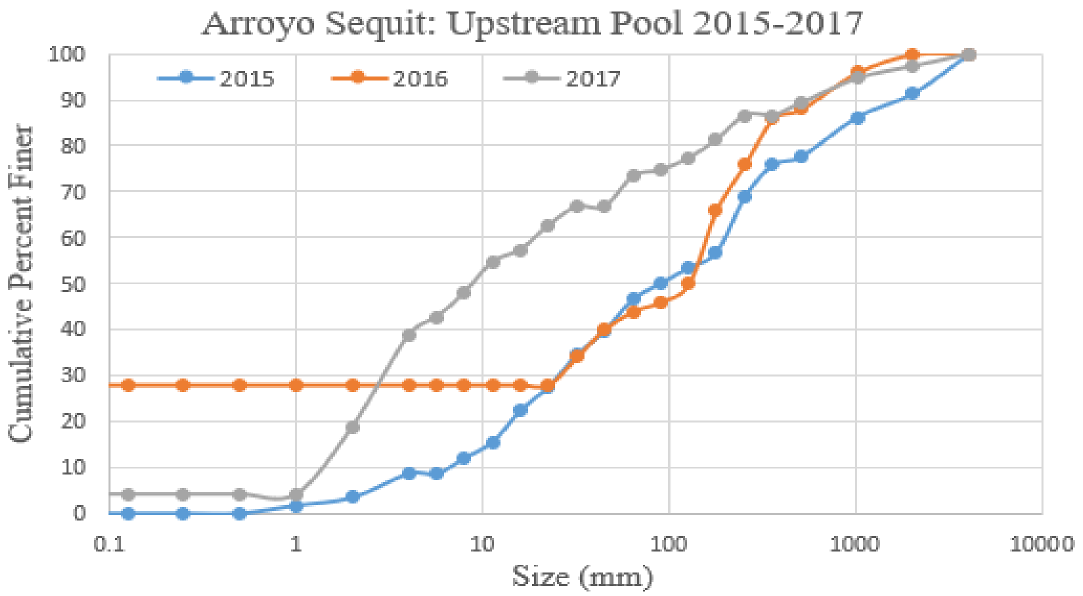


Figure IV-6. Cumulative particle size distribution curve for pool located upstream of the Arroyo Sequit check dam removal. D50 and D84 values were the lowest in 2017 at 9mm and 219mm respectively.

in 2016, and 12% in 2015. D50 and D84 values were the smallest in 2017 at 9mm (medium gravel) and 219mm (large cobble) respectively (Figure IV-6).

Impacts from dam removal likely had little to do with infilling of this pool and are more likely attributed to upstream watershed inputs. Despite the extended drought from 2011-2016 (NMFS 2016), there were storm events in January through March 2016 (Figure IV-1) in which pulse storm events deposited upstream sediment to create the infilling observed in the 2016 survey, two years post dam removal. Higher flows associated with winter rains in late 2016 and early 2017 scoured out the pool. The streambed substrate in 2015 and 2016 had a coarser grain size (Figure IV-5) where large cobble and boulder frequencies were higher (Figure IV-6). When comparing years in terms of percentage of sampled particles who fall in the range of preferred particle size for spawning, both 2015 (drought year) and 2017 (rain) had a higher percentage at 41% and 29% respectively than in 2016 (drought year) at 22%. This variation in percentage of preferred gravel habitat was higher immediately after dam removal.

ii. Upstream of Dam

Step-pool formations encountered in 2015 and 2016 located above dam removal area transitioned into one pool in 2017 (~146.88-165.16ft in Figure IV-2 US of Dam). A small boulder forced plunge feeding into a pool reached its highest plunge height in 2017 where there was a 2.66ft difference between the top of the small fall and the water surface of the corresponding pool (Figure IV-7). The max depth of the corresponding pool in 2017 was 2ft. This plunge doesn’t appear to be large enough to impede steelhead movement under high flows but may potentially be a barrier during periods of low flow. The twelve feet stretch of shallow

Figure IV-7. 2017 Arroyo Sequit, small boulder forced plunge pool above dame removal site. In 2017, there was a 2.66ft difference between the top of the small fall and the water surface of the corresponding pool.

pool-like habitat directly above dam site saw noticeable infilling in 2017 (~193-to-205.92ft in Figure IV-2 US of Dam). The amount of silt was highest in 2016 at 21% and the amount of fine gravel (2-4mm) was the highest in 2017 at 17% (Figure IV-8). Fine sediment had a frequency of 42% in 2017, 40% in 2015, and 26% in 2016. Despite the high frequency of silt (grain size <.062) in 2016, the streambed substrate was most coarse in 2016 (Figure IV-9) with D50 and D84 values of 91mm (small cobble) and 1290mm (large boulder) respectively. This is a result of a higher frequency of large boulders in 2016 for this reach at 16%. The percentage of preferred spawning particles sampled was 36% in 2015, 31% in 2017, and 30% in 2016.

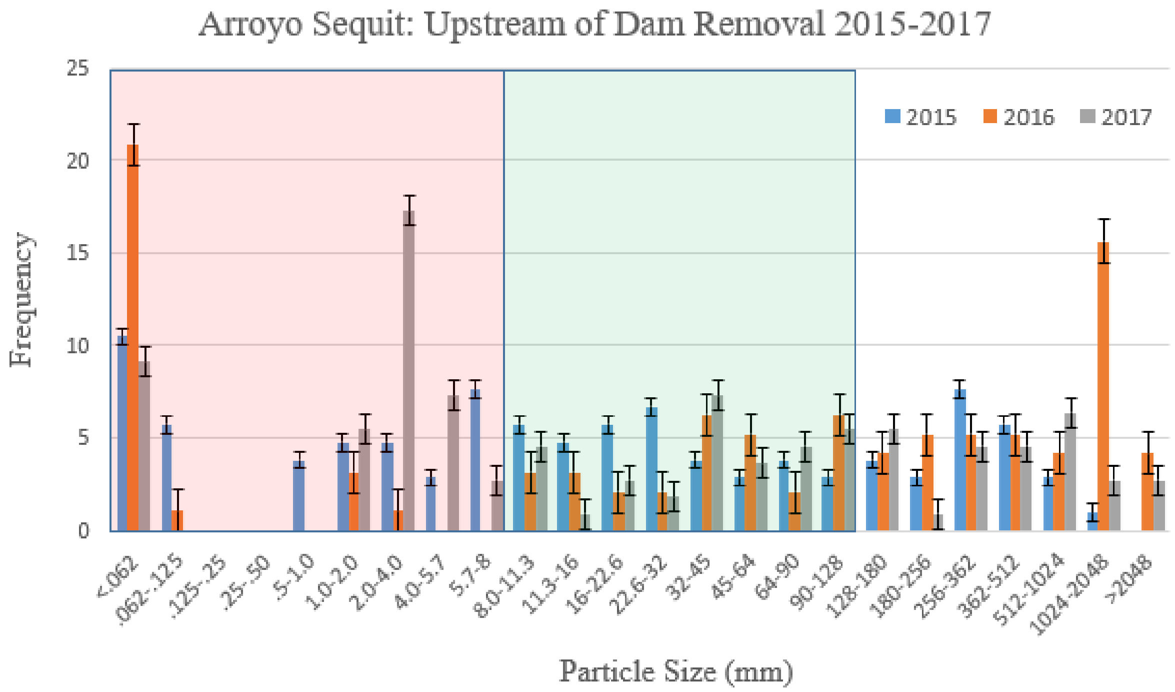


Figure IV-8. Particle size frequency distribution with standard error for area directly upstream from dam removal. The percentage of preferred spawning particles sampled (green shaded area) was similar among the three years surveyed (31-36%).

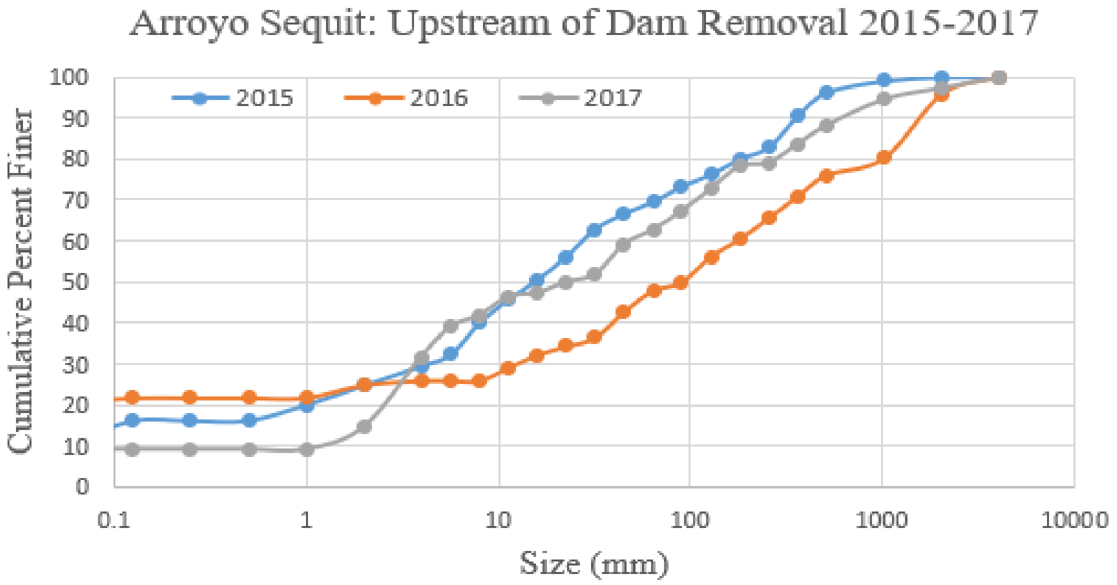


Figure IV-9. Cumulative particle size distribution curve for the area directly upstream of dam removal. D50 and D84 values were highest in 2016 at 91mm and 1290mm respectively.

iii. Immediately Below Dam

The area immediately downstream of dam removal saw an increase in thalweg elevation from 2015 to 2016 and a decrease in 2017 (Figure IV-2 DS of Dam). Silt (grain size <.062) had the highest frequency in 2016 comprising 23% of the sampled substrate (Figure IV-10). Coarse sand (.5-1mm) had a frequency of 14% in 2015 while very coarse sand (1-2mm) had a frequency of 16% in 2016. In 2017, there was a significant increase in very fine (2-4mm) and fine (4-8mm) gravel that was accounted for in pebble counts compared to previous years. Fine sediment had a frequency of 43% in 2017, 39% in 2016 and 20% in 2015.

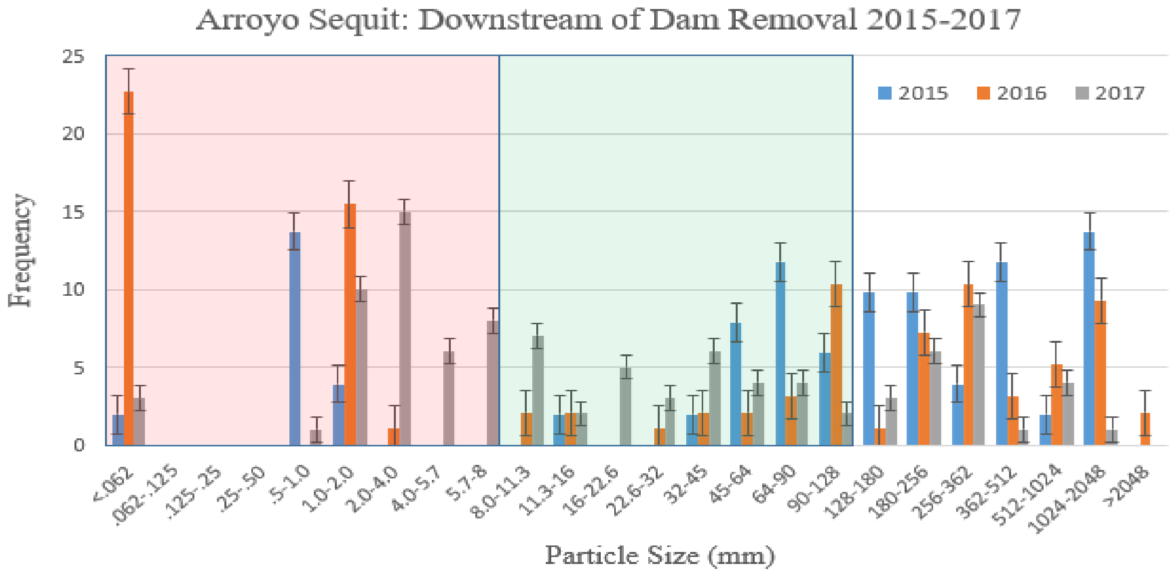


Figure IV-10. Particle size frequency distribution with standard error for area located directly downstream of dam removal. The percentage of preferred particle size for spawning (green shaded area) was lowest in 2016 (23%) and highest in 2017 (33%).

Like what was observed with the upstream pool reach, the increase in elevation observed from 2015 to 2016 was likely a result of flows from pulse storm events (Figure IV-1) that transported and deposited sediments from fluvial sources. This influx of sediment (mostly silt) was transported downstream beyond the extent of the surveys by the late 2016 and early 2017

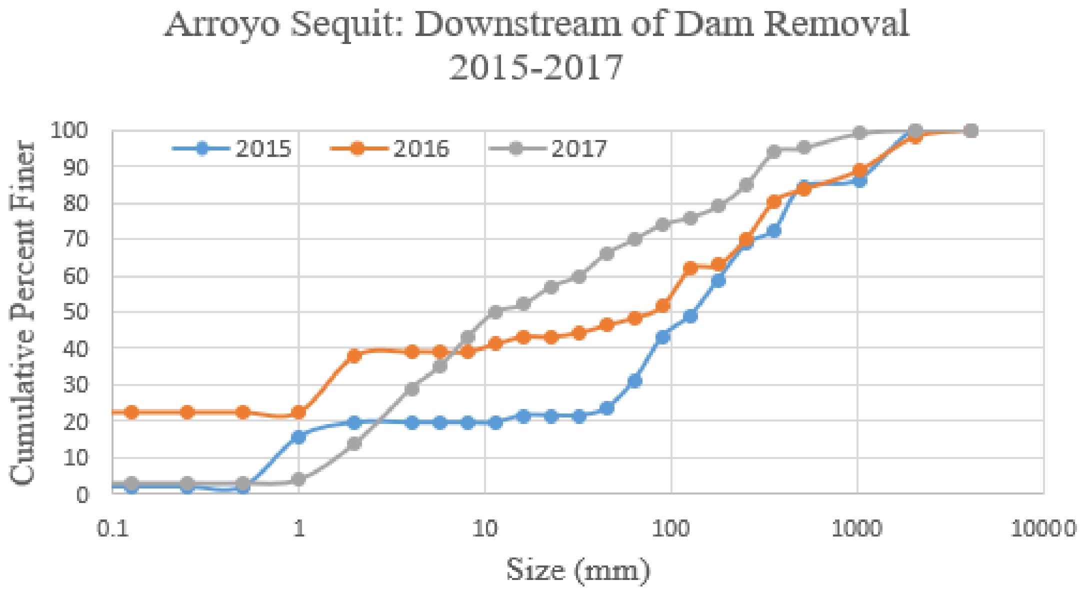


Figure IV-11. Cumulative particle size distribution curve for the area located directly downstream of dam removal. D50 value was highest in 2015 at 134mm while the highest D84 value was in 2016 at 563mm.

storm system when assessed in 2017. The streambed material was coarser in 2015 and 2016 where there was a higher frequency of cobble and boulder (Figure IV-10 and IV-11). D50 value was highest in 2015 at 134mm (large cobble) while the highest D84 value was in 2016 at 563mm (medium boulder) (Figure IV-11). The percentage of preferred particle size for spawning within pebble counts was lowest (23%) in 2016 (two years post dam removal) and highest (33%) in 2017 (three years post dam removal). Intermediate levels of all metrics were observed immediately after dam removal in 2015.

iv. End of Survey

Similar to trends observed with the upstream reaches, the end of survey reach experienced sediment deposition in 2016 and subsequent sediment removal in 2017. An increase in thalweg elevation was observed in 2016 with a decrease in 2017 (Figure IV-2 End of Survey).

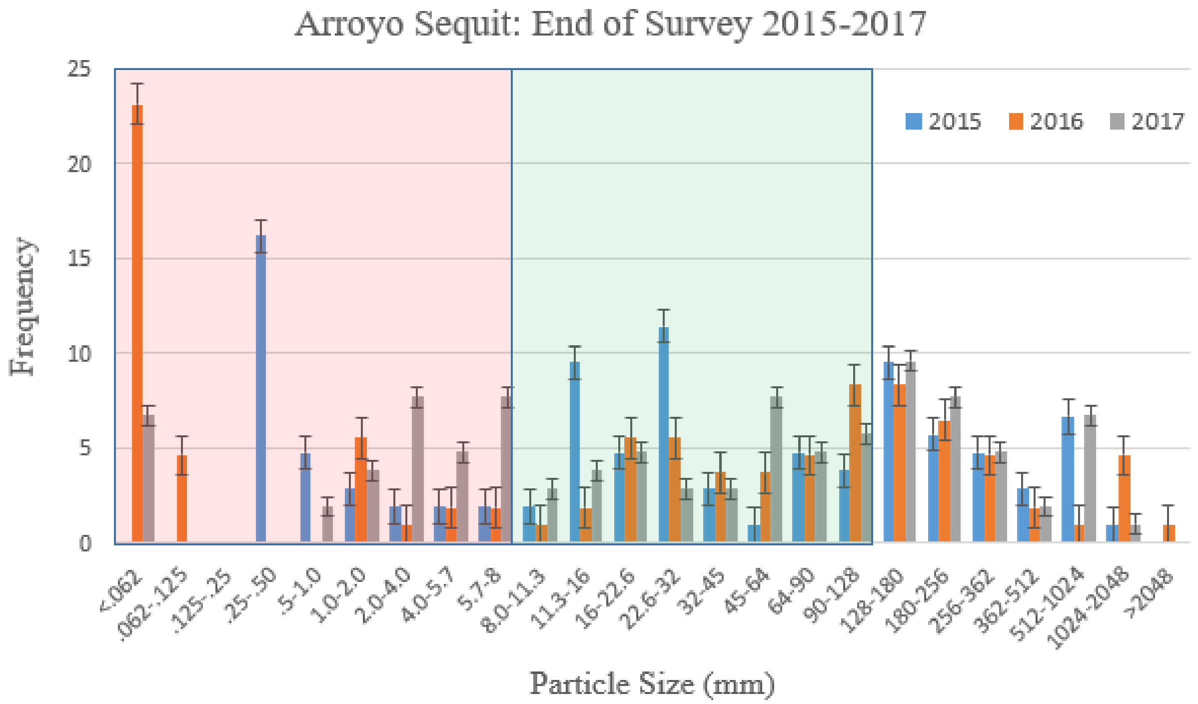


Figure IV-12. Particle size frequency distribution with standard error for the end of survey reach. The percentage of preferred particles for spawning (green shaded area) had its highest frequency in 2015 at 40% followed by 34% in 2016 and 36% in 2017.

Silt (grain size <.062) once again had its highest frequency in 2016 at 23% while particles in sand size class (.062-2mm) were highest in 2015 at 24% (Figure IV-12). In 2017, there was a significant increase in the amount of very fine (2-4mm) and fine (4-8mm) gravel with a total frequency of 20%. Fine sediment had a frequency of 38% in 2016, 33% in 2017, and 30% in 2015. Because of the high frequency of silt and sand occurring in 2015 and 2016, the highest D50 value was in 2017 at 45mm which is in the very coarse gravel size class (Figure IV-13). All three years had similar D84 values (222-247mm) where measurements fell into large cobble size classes. The percentage of preferred particles for spawning had its highest frequency in 2015 at 40% followed by 36% in 2017 and 34% in 2016.

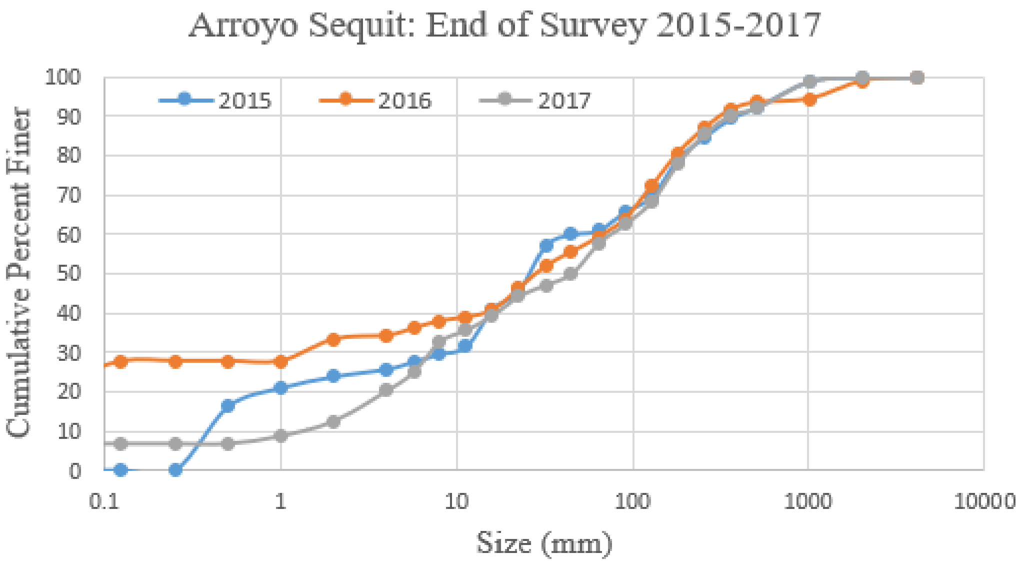


Figure IV-13. Cumulative particle size distribution curve for end of survey reach. The highest D50 value was in 2017 at 45mm and all three years had similar D84 values (222-247mm).

c. Arroyo Sequit Discussion

The longitudinal profile and pebble count analysis revealed that there was a significant increase in silt in 2016 more than any other survey year. As a result, the two main pools of interest (both above dam removal site) experienced infilling and riffle areas experienced increased sedimentation. Infilling of pools is mostly due to increased flows with limited transport capacity due to minor storm events in late 2015 that deposited silt from fluvial sources rather than the effects from dam removal. The pattern of sediment transport reflects upstream watershed inputs (road or bank erosion) rather than impacts from dam removal. Despite drought conditions, 2014/2015 storm events were sufficient at transporting what reservoir sediment may have remained (that was not removed by construction contractors) as noted by the lower levels of silt in 2015 than all areas except immediately upstream of dam. The locations upstream of dam showed no significant difference in silt between 2015 and 2017, but still indicated a clear spike in 2016. The higher flows associated with the larger storms in late 2016 and early 2017 scoured out silt, transported some large grain size particles, and led to a natural dispersion of gravel throughout the surveyed reach.

B. Lion Creek

1. Survey Results

a. Discharge

When summary monthly precipitation water year records were compared to the 30-year average, Lion Creek (Ojai proxy station) ranged from 45% in 2014 to 132% in 2017 (Table IV-2). Sespe Creek near Wheeler Springs gauge (12 miles downstream of the Lion Creek dam removal site) indicated a few storm events exceeding 100 CFS with a large storm event in early 2017 with discharges exceeding 7000 CFS (Figure IV-14).

Table IV-2. Summary of monthly percent total water year records when compared to the 30-year average for the Ojai proxy station (Lion Creek).

Location	Latitude (°N)	Longitude (°W)	Elevation (ft)	2014 Percent Total Water Year	2015 Percent Total Water Year	2016 Percent Total Water Year	2017 Percent Total Water Year
OJAI	34.44	119.13	1560	45	54	50	132

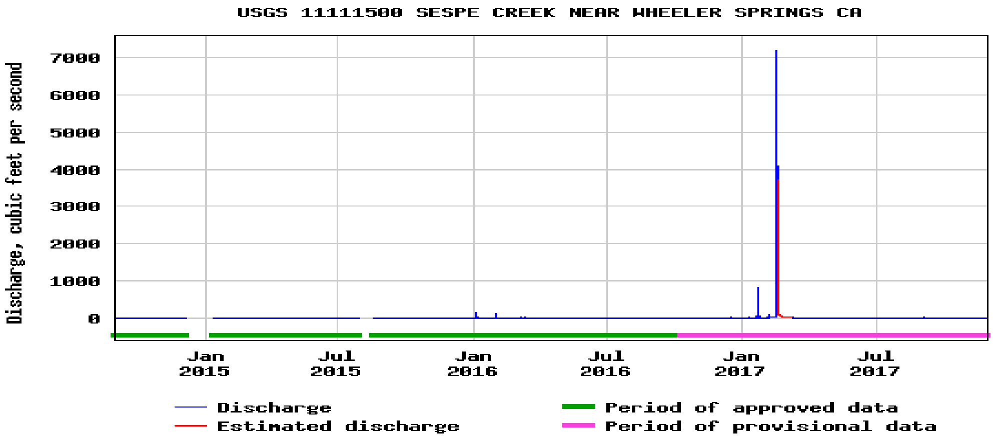


Figure IV-14. Stream discharge data at the nearest stream gauge for the Lion Creek dam removal site.

b. Topographic and Geomorphic Survey Results

The Project's longitudinal surveys (Figure IV-15) extended 240 feet from an existing survey monument established by the US Forest Service (USFS), Los Padres National Forest. Lion Creek is the only creek surveyed with available pre-dam removal data (U.S. Forest Service, Los Padres unpublished data). Site photos are included for survey years 2016 and 2017 (appendix I).

Survey results are discussed based on the location of the pebble counts which were grouped into two reaches: a monumented pre-dam removal cross-section upstream of the dam removal site and a monumented pre-dam removal cross-section directly downstream of the dam removal site. Cross-sections were not included in this study analysis, but rather used as established landmarks.

i. Upstream of Dam Removal

There was an increased thalweg elevation observed for portions of this reach in 2016 when compared to 2014 and 2015 (Figure IV-15 US of Dam). This is most likely due to sediment transportation and deposition from flows associated with minor storm events in early 2016 despite extreme drought conditions. The stream experienced much higher discharge rates in early 2017 due to more impactful storms which contributed to the scour that was represented when comparing the longitudinal profile results from 2016 and 2017. Within the upstream area, there was a transition over time from one long pool to more of a step pool habitat from 2014-2015 to 2016-2017 respectively. These step pools gained in depth from 2016 when surveyed in 2017.

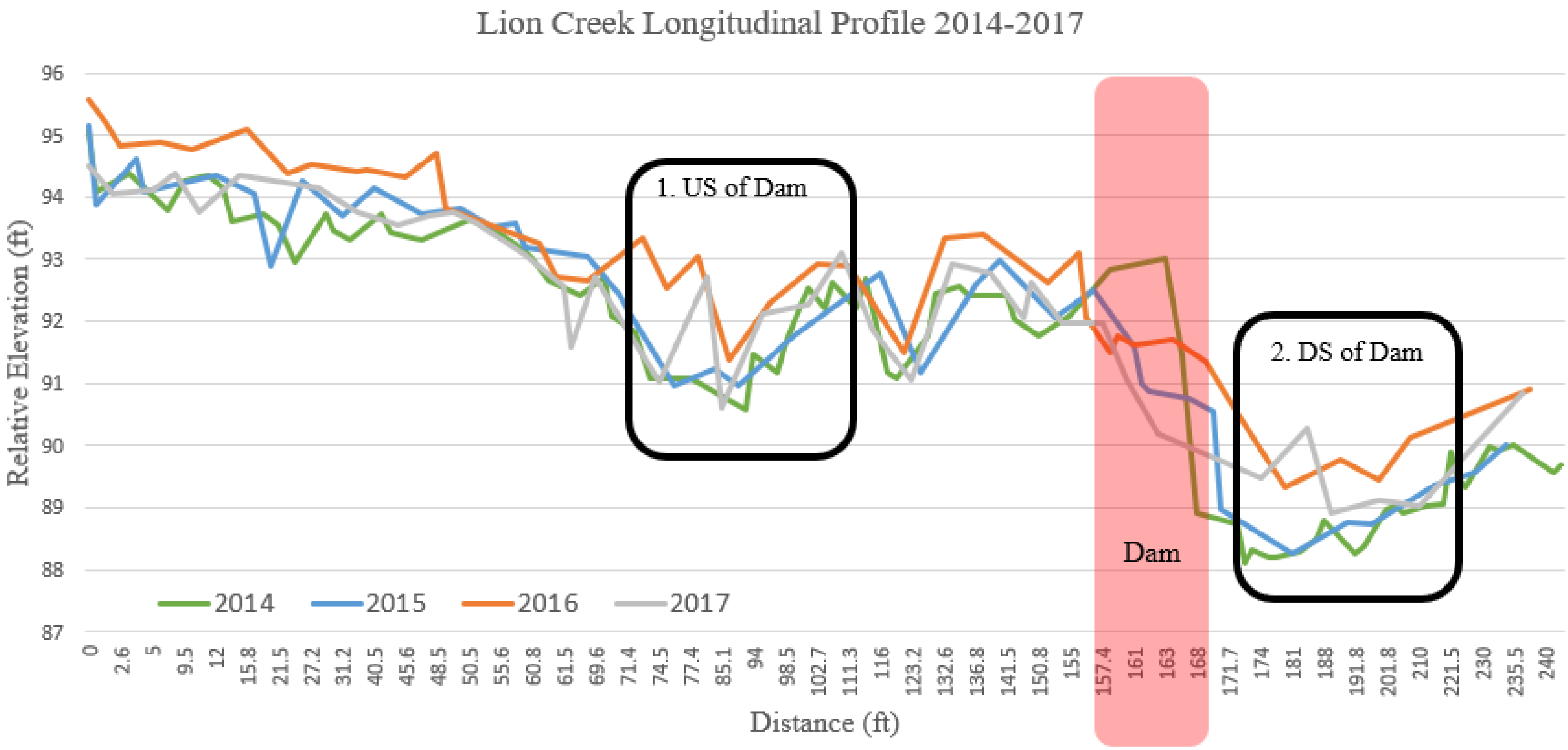


Figure IV-15. Longitudinal profile for Lion Creek small dam removal study. Red shaded area represents area of dam influence where dam and reservoir once existed. Black boxes represent two areas where pebble counts were conducted; 1) Upstream (US) of dam 2) Downstream (DS) of dam.

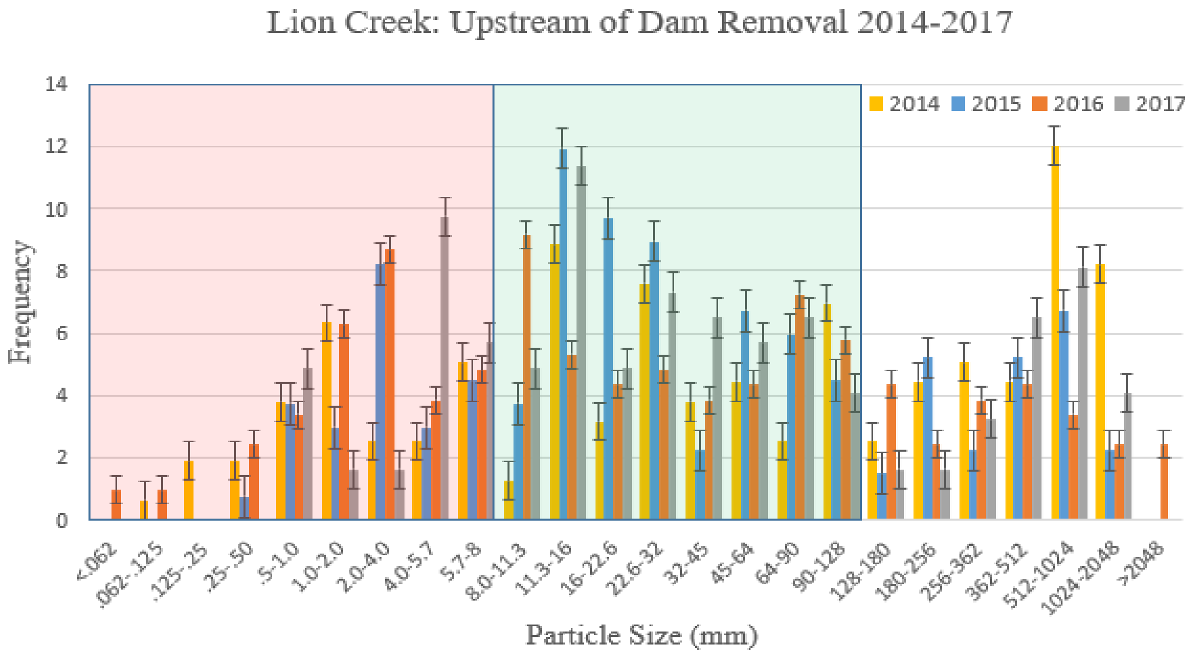


Figure IV-16. Particle size frequency distribution with standard error for area upstream of dam removal. All three years surveyed post dam removal had a higher percentage of preferred particles for spawning (green shaded area) sampled than in 2014 (54%, 45%, 51% versus 39%).

Very fine gravel (2-4mm) had the highest frequency in 2015 and 2016 where the percentage of particles of this grain size sampled were nearly identical (8-9%). Fine gravel (4-5.7mm) had its highest frequency in 2017 at 10%. Fine sediment had a frequency of 32% in 2016, 25% in 2014, 24% in 2017, and 23% in 2015. Pebble count comparisons reveal that medium gravel (11.3-16mm) had a significant increase in both 2015 and 2017 while coarse gravel (16-22.6mm) had its highest frequency in 2015 (Figure IV-16). All three years surveyed post dam removal had a higher percentage of ideal spawning gravel sampled than in 2014 (54%, 45%, 51% versus 39%). The streambed substrate was coarser in 2014 than any of the post-dam removal years according to pebble counts (Figure IV-17). Pebble count data shows that there were more medium and large boulders (512-2048mm) encountered in this reach in 2014 than any of the years' post-dam removal. Subsequently, D50 and D84 values were highest in 2014 at

49mm (very coarse gravel) and 745mm (medium boulder) respectively. D50 and D84 values for 2015-2017 were in the coarse gravel and small boulder size classes.

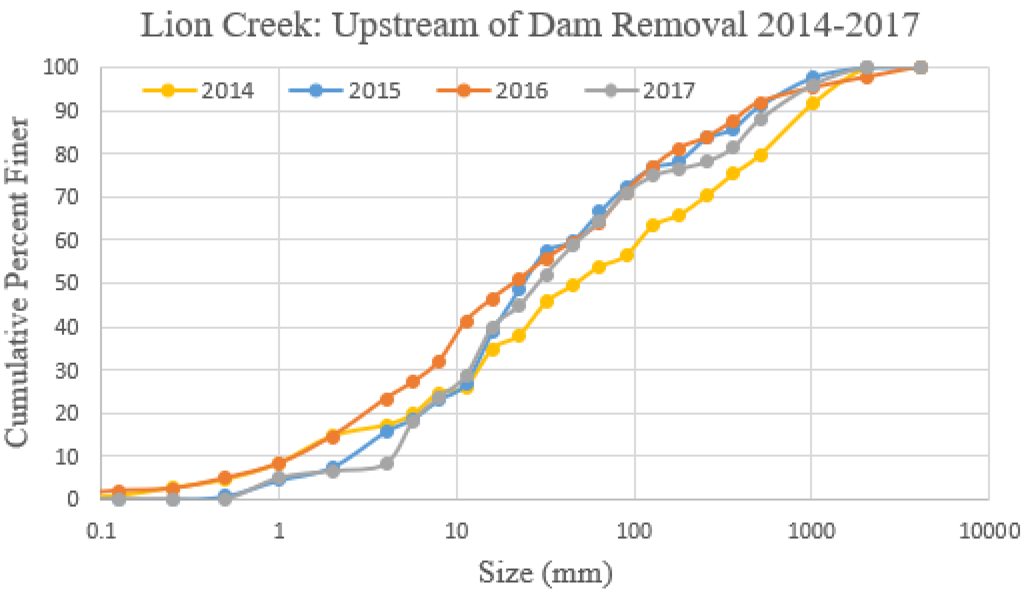


Figure IV-17. Cumulative particle size distribution curve for the area upstream of the dam removal. D50 and D84 values were highest in 2014 (pre-dam removal) at 49mm and 745mm respectively.

ii. Downstream of Dam Removal

Longitudinal profile comparison showed that the thalweg elevation in 2014 (pre-dam removal) was comparable to that of 2015 (immediately after dam removal) but infilled in 2016 and then scoured out again in 2017 (Figure IV-15 DS of Dam). Similar infill and scour pattern was observed in the upstream area. In 2017, this pool gained in both size (total distance of pool habitat) and depth. Frequency of very coarse sand (1-2mm) was highest in 2016 and which most likely contributed to some pool infilling (Figure IV-18). Frequency of very fine gravel (2-4mm) was highest in 2014 and 2016. Fine sediment had a frequency of 35% in 2016, 26% in both 2014 and 2017, and 19% in 2015. The percentage of preferred particles for spawning were

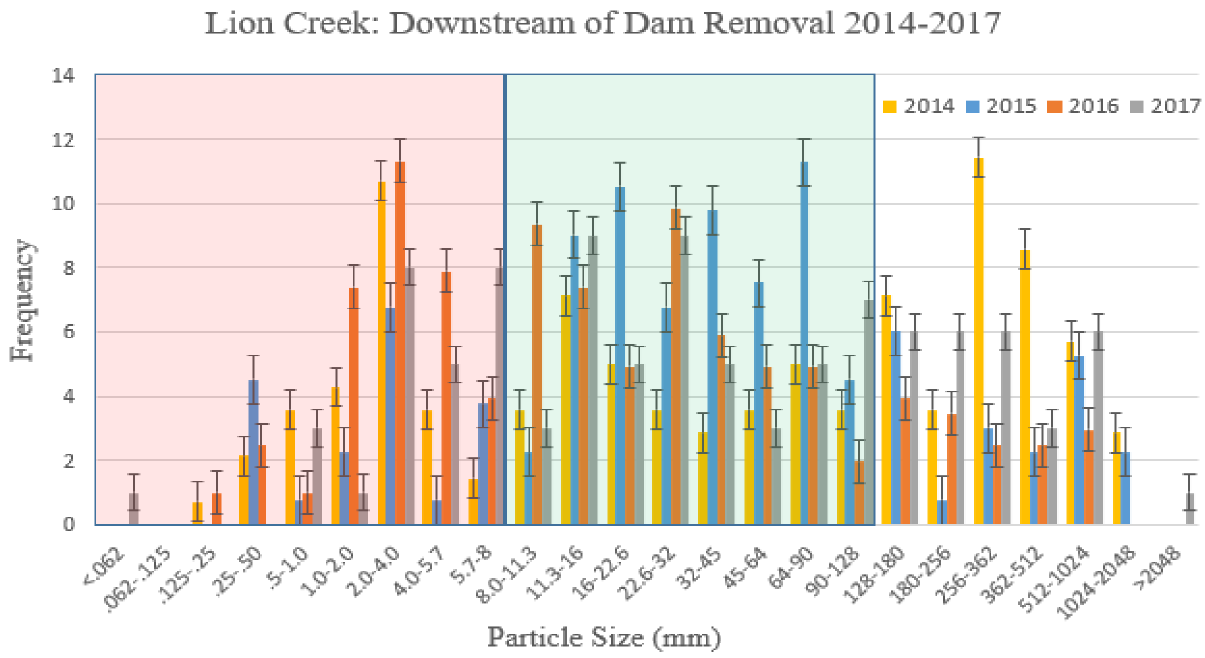


Figure IV-18. Particle size frequency distribution with standard error for the area within the area downstream of dam removal. The percentage of preferred particles for spawning (green shaded area) were higher in post-dam removal years than in 2014 (46-62% versus 34%).

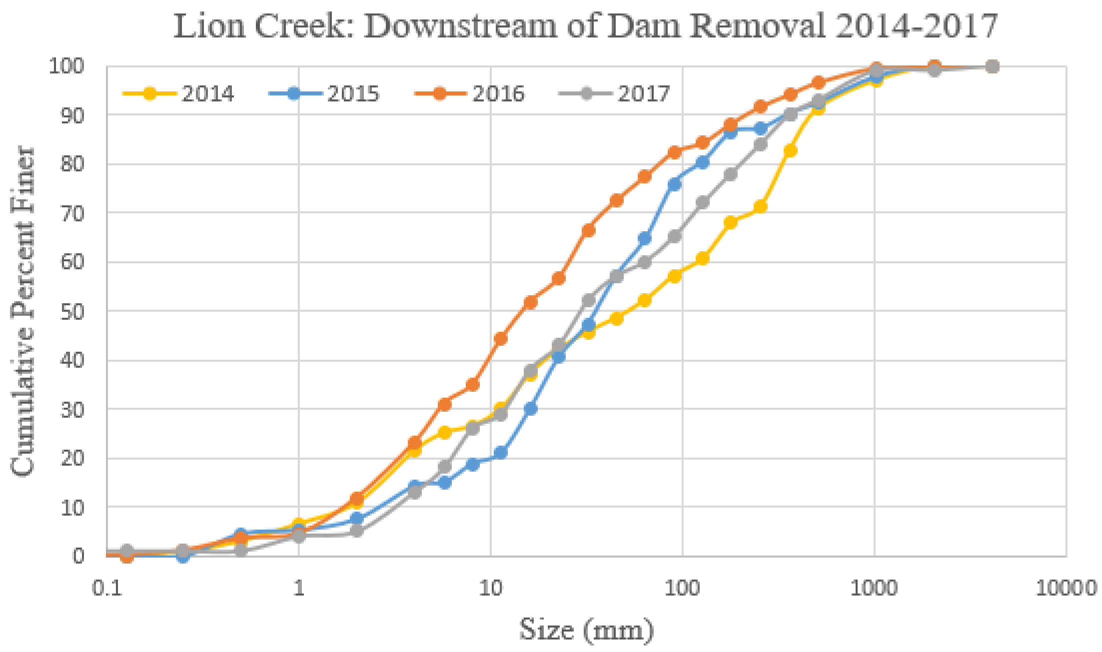


Figure IV-19. Cumulative particle size distribution curve for area downstream of dam removal. D50 and D84 values were highest in 2014 (pre-dam removal) at 53mm and 383mm respectively.

higher in post-dam removal years than in 2014 (46-62% versus 34%). The highest percentage of preferred particles for spawning sampled was in 2015 (62%) and this is in part due to a higher frequency of coarse gravel (16-22.6mm, 32-64mm) and fine cobble (64-90mm). The cumulative particle size distribution curve showed that 2014 had the coarsest streambed material with D50 and D84 values of 53mm (very coarse gravel) and 383mm (small boulder) due to more small and medium boulder (180-512mm) sampled in pebble counts (Figure IV-19). Also, the D84 value for 2017 was 256mm (large cobble) while 2015 and 2016 had nearly identical D84 values that fell within the small cobble size category.

c. Lion Creek Discussion

Lion Creek provides a foundation of support for the value of pre-dam removal data. Having pre-dam removal data showed a somewhat cyclical pattern of sedimentation and infilling under drought conditions (2014 and 2016). Without pre-dam removal data the assumption would be made that this sedimentation and subsequent infilling could be the result of dam removal. The check dam was estimated to impound 182 cu yds of sediment (although much of this was removed as part of the project) and 2015 longitudinal profile showed little in terms of increased thalweg elevation below dam removal. When comparing 2014 and 2015 pebble counts of cross-section 2 (below dam) 2014 had a higher frequency of fines at 26% than the 19% sampled in 2015. Therefore, fine grain sizes prior to dam removal were flushed out even under drought conditions. The increased thalweg elevations and increase in fine grain sizes in 2016 is more likely due to upstream watershed inputs rather than dam removal.

This stretch of surveyed creek provides suitable habitat for steelhead in terms of pool habitat as well as abundant spawning gravel. In 2016, a presence/absence snorkel survey was conducted for *O. mykiss* for this reach. 23 *O. mykiss* were observed in the pool located above dam removal area and 16 were observed in the pool located directly below the dam removal. When conducting the stream monitoring surveys on 10/19/17, *O. mykiss* were observed once again in both the pools above and below the dam removal area and estimates were similar to fish observed in 2016.

During December 2017 the Thomas Fire, California's largest wildfire in history, burned directly through the Lion Creek study site. Much of the watershed was left burned and denuded and storm events in January 2018 are likely to have altered the site to a level that is unrecognizable from these surveys. Understanding the impacts of dam removal would have been completely lost if not for pre, post, and multiple years of monitoring. It is not uncommon for projects to wait for a 2 year plus storm event to resurvey project sites, but in a region that faces droughts, fires, and flashfloods, monitoring on in a pre, post, and multiple year design can provide insight into the value and effects of these types of restoration projects with emphasis on the benefits to southern steelhead. Because of these devastating occurrences, further monitoring will be needed to assess the impacts of the fire on not only the habitat and substrate quality, but on Lion Creek's *O. mykiss* populations as well.

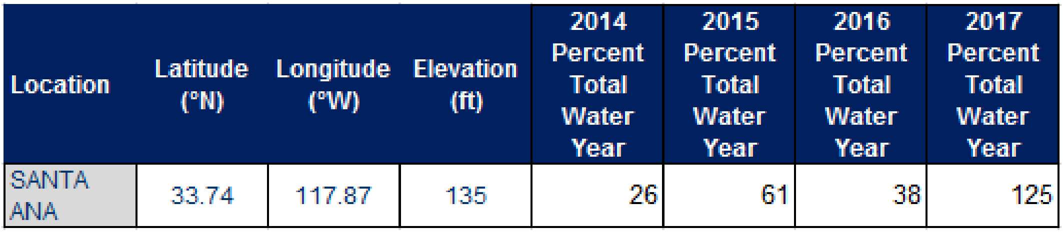
C. Trabuco Creek

1. Survey Results

a. Discharge

When monthly precipitation water year records were compared to the 30-year average, Trabuco Creek (Santa Ana proxy station) ranged from 26% in 2014 to 125% in 2017 (Table IV-3). Due to its position in the watershed (23 miles downstream from dam removal site), the Trabuco Creek stream gauge is subject to increased flow from water releases from upstream

Table IV-3. Summary of monthly percent total water year records when compared to the 30-year average for the Santa Ana proxy station (Trabuco Creek).



Location	Latitude (°N)	Longitude (°W)	Elevation (ft)	2014 Percent Total Water Year	2015 Percent Total Water Year	2016 Percent Total Water Year	2017 Percent Total Water Year
SANTA ANA	33.74	117.87	135	26	61	38	125

sources (e.g., private golf course pond and reservoir) and occurs in the most developed of watersheds in the study. Trabuco Creek stream gauge (USGS 11047300 Arroyo Trabuco A San Juan Capistrano) experienced the highest flows among the surveyed creeks for the survey period exceeding 100 CFS on more than 30 occasions and even neared 5000 CFS in early 2017 (Figure IV-20). Trabuco Creek stream gauge exhibited flows over 100 CFS during July 2015 which exemplifies the role urban discharge may be playing in summer flows.

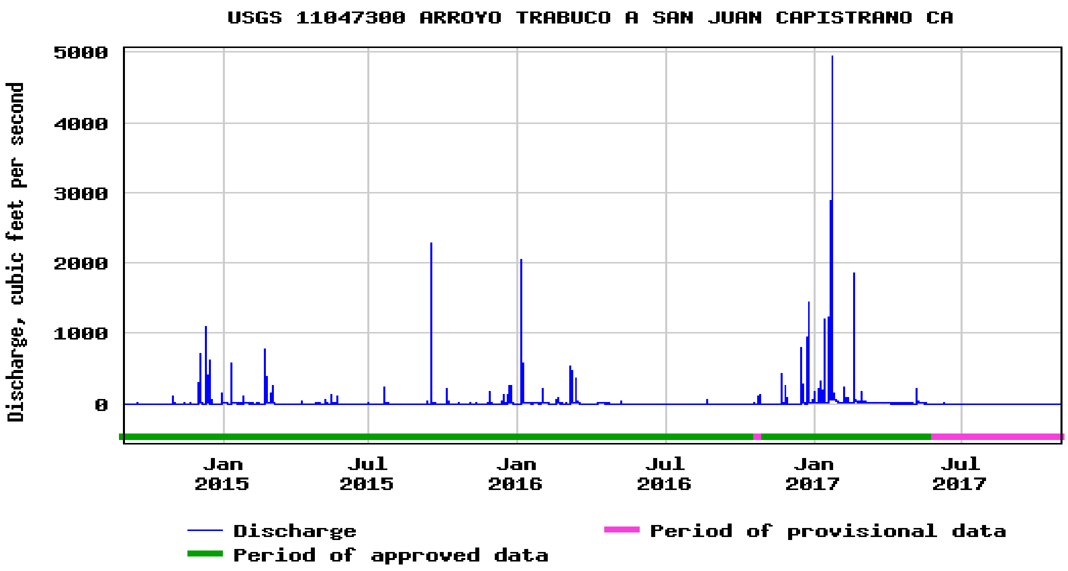


Figure IV-20. Stream discharge data at nearest functional stream gauge to Trabuco Creek dam removal site.

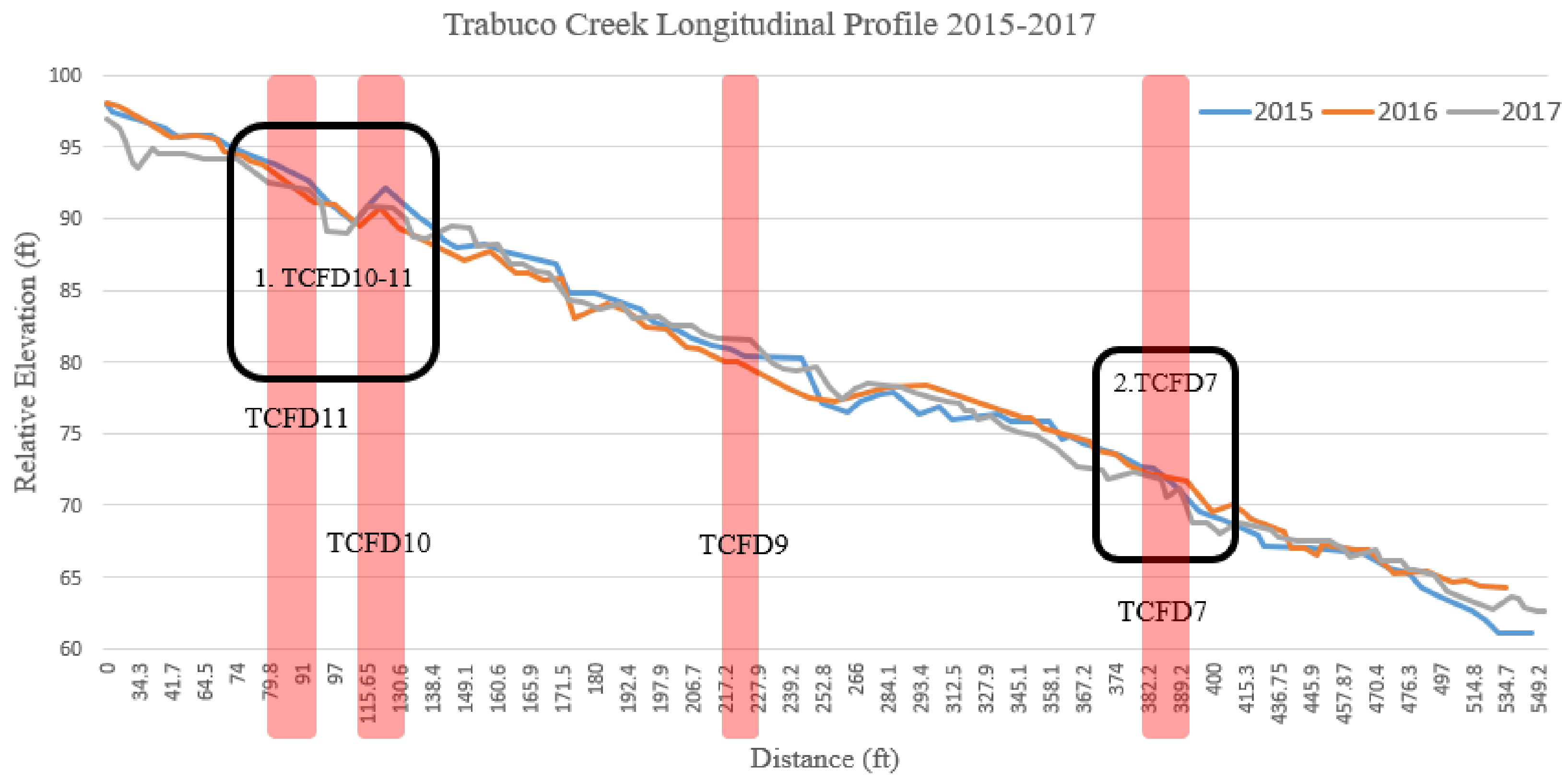


Figure IV-21. Longitudinal Profile for Trabuco Creek small dam removal study. Red shaded area represents area of dam influence where dams and reservoirs once existed. Black boxes represent two areas where pebble counts were conducted; 1) TCFD10-11 2) TCFD7.

b. Topographic and Geomorphic Survey Results

The project's longitudinal profile reach extended 549 feet that encompasses a survey reach where four small dams were removed (Figure IV-21). The Trabuco Ranger District of the Cleveland National Forest's surveys of streams where dam removal is completed or scheduled for removal followed the California State Water Resources Control Board's SWAMP (Surface Water Ambient Monitoring Program) protocols and while informative are not directly comparable to data collected through this project.

In the upper portion of the profile, the thalweg elevation decreased between 2015 and 2016 survey years while downstream the lower section of the profile experienced increased thalweg elevations from 2015-2016. Shortly after 2016 surveys, in late August 2016, a fire erupted upstream in the Holy Jim area. Substantial amounts of sediment (enough to cover the road in 4+ feet of mud) moved down the watershed after the 2016 Holy Fire, but astonishingly significant streambed scour was still observed throughout most of the survey reach in 2017 (Figure IV-22,23). The top of a new dam structure became partially exposed in 2017 (not observed in any other year) directly adjacent to the start of the survey benchmark.

Additional survey results will be discussed in relation to the location of the pebble count assessments which were grouped into two areas: 1) an area that encompasses both Trabuco Creek Fish Dam (TCFD) 10 and 11 removal sites and 2) the area where TCFD7 was removed. Pebble counts were not conducted immediately adjacent to TCFD9 because the dam remnants were not retaining sediment and the area was composed of large bedrock. Due to the proximity of TCFD10 and TCFD11, pebble counts were combined for both dams. Site photos for all survey years are included in appendix I.

Figure IV-22. Comparison of 2016 vs. 2017 TCFD11 dam removal site . High levels of scour and large boulder movement was observed when conducting monitoring activities in 2017.

Figure IV-23. Comparison of 2016 vs. 2017 TCFD7 dam removal site in which nearly 2ft of scour was observed in 2017 when compared to 2016.

i. TCFD 10 and 11

The longitudinal profile (Figure IV-21) shows that the pool below TCFD11 experienced scouring in 2016 and 2017. The pool habitat directly below TCFD11 had its highest thalweg elevation (shallowest pool depth) in 2015. With no prior pre-dam removal data, it's hard to infer the amount of infilling that was attributed to released sediment stored by the dam and the dam remnants that were left in the stream. Significant scour was observed in 2017 which exposed a lower remnant section of TCFD11 creating a small plunge to the pool below (Figure IV-24). Riffle area below pool where TCFD10 was removed had the highest thalweg elevation in 2015 and then subsequently scoured out in 2016 (Figure IV-21). Figure IV-25 shows the particle size frequency distribution for TCFD10 and 11. Silt (<.62mm) accounted for 6% of sampled particles in 2015 and 8% in 2017. Fines (<.062-8mm) observed in 2016 were comprised of very fine sand (.62-.125mm) at 9% and fine gravel (5-8mm) at 12%. Fine sediment had a frequency of 38% in 2017, 21% in 2015, and 20% in 2016. The percentage of particles of ideal spawning size sampled was highest in 2015 at 56% and lowest in 2017 at 37%. The highest combined percent total of sand (.062-2mm) and very fine gravel (2-4mm) occurred in 2017 (26%) which contributed to the low percent total of ideal spawning gravel. Streambed substrate was most coarse in 2016 according to pebble counts with D50 value of 53mm (very coarse gravel) and D84 value of 270mm (small boulder) (Figure IV-26). When comparing the pebble counts of the surveyed years, 2016 had the highest frequency of large cobble (180-256mm) and small boulder (256-512mm). Although D50 in 2017 was lower than 2015, D84 values were higher in 2017 at 199mm than in 2015 at 165mm (both of large cobble class size) because of the presence of exposed bedrock (>2048mm).

Figure IV-24. TCFD11 in 2017. Significant scour observed in 2017 exposing lower remnant section of TCFD11 creating a small plunge to lower pool with additional scour.

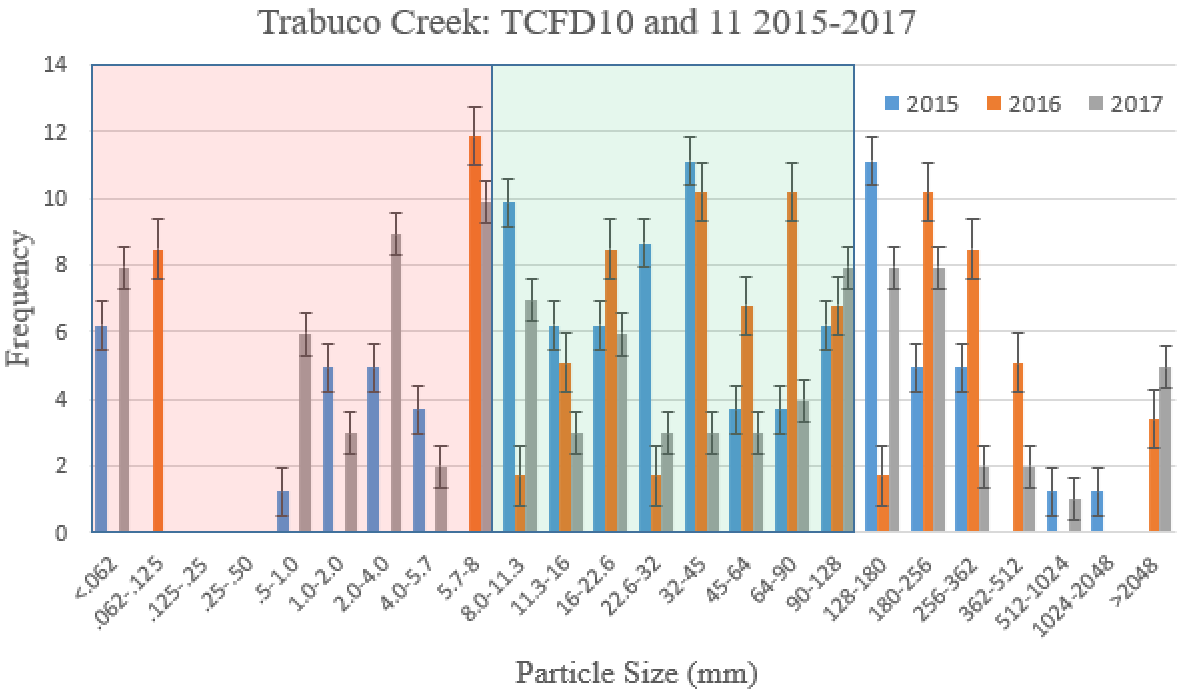


Figure IV-25. Particle size frequency distribution with standard error for the reach that encompasses the area where both TCFD10 and 11 once existed. The percentage of particles of ideal spawning size sampled (green shaded area) was highest in 2015 at 56% and lowest in 2017 at 37%.

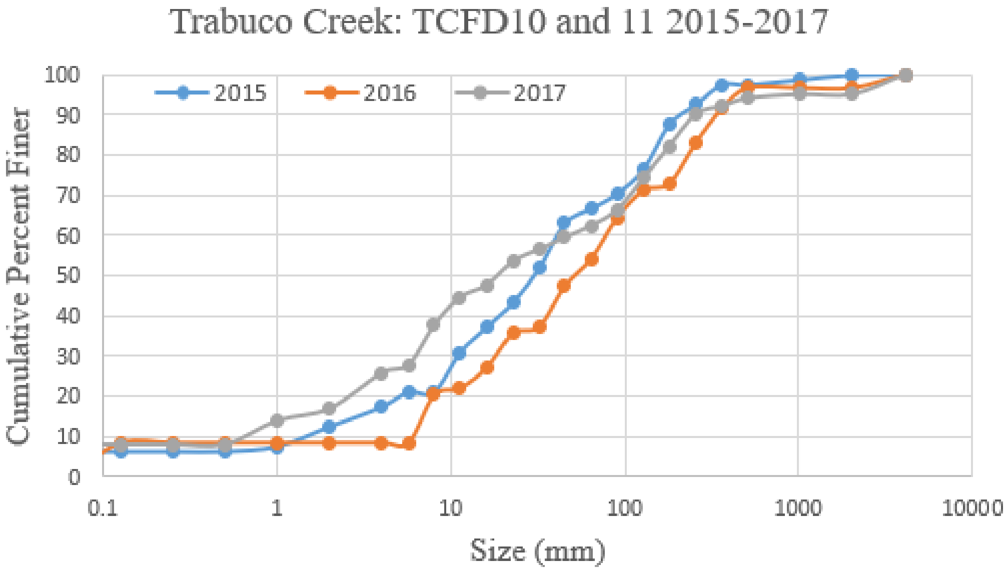


Figure IV-26. Cumulative particle size distribution curve for area that encompasses both the area where TCFD10 and 11 once existed. This sections streambed material was most coarse in 2016 according to pebble count data.

ii. TCFD 7

As seen with the survey reach for TCFD10 and 11, the area directly above and below TCFD7 experienced significant scour in 2017 from storm events (Figure IV-21 TCFD7). In 2017, 1-2ft of scour could be seen at the TCFD7 removal location (Figure IV-23). Despite the significant scour, there was significantly more coarse sand and very fine gravel (.5-5.7mm) than previous years (Figure IV-27). There was considerably more exposed bedrock for this reach in 2017 than in previous sample years. Silt had its highest frequency for this reach at 11% in 2016. Fine sediment had a frequency of 30% in 2017, 20% in 2016, and 16% in 2015. In 2015, the amount of coarse gravel (22.6-32mm) and very coarse gravel (45-64mm) had a frequency of 15% and 13% respectively which was the highest percentages of a certain size class (notably within the preferred spawning gravel range) for this reach between all the surveyed years. Pebble count analysis reveals that the highest frequency of preferred particles for spawning sampled was in 2015 at 65% while the lowest frequency occurred in 2017 at 42%. The cumulative particle size distribution curve shows that while all three years had similar D50 values, 2017 had the highest D84 value of 274mm (small boulder) while 2015 and 2016 values fell within the large cobble size class (Figure IV-28). The higher D84 value in 2017 can be attributed to newly exposed bedrock resulting from the scour. This increase in fine particles, reduction of spawning gravel, and exposure of bedrock is a likely combination of sediment input from the Holy Fire and scour from 2017 storms.

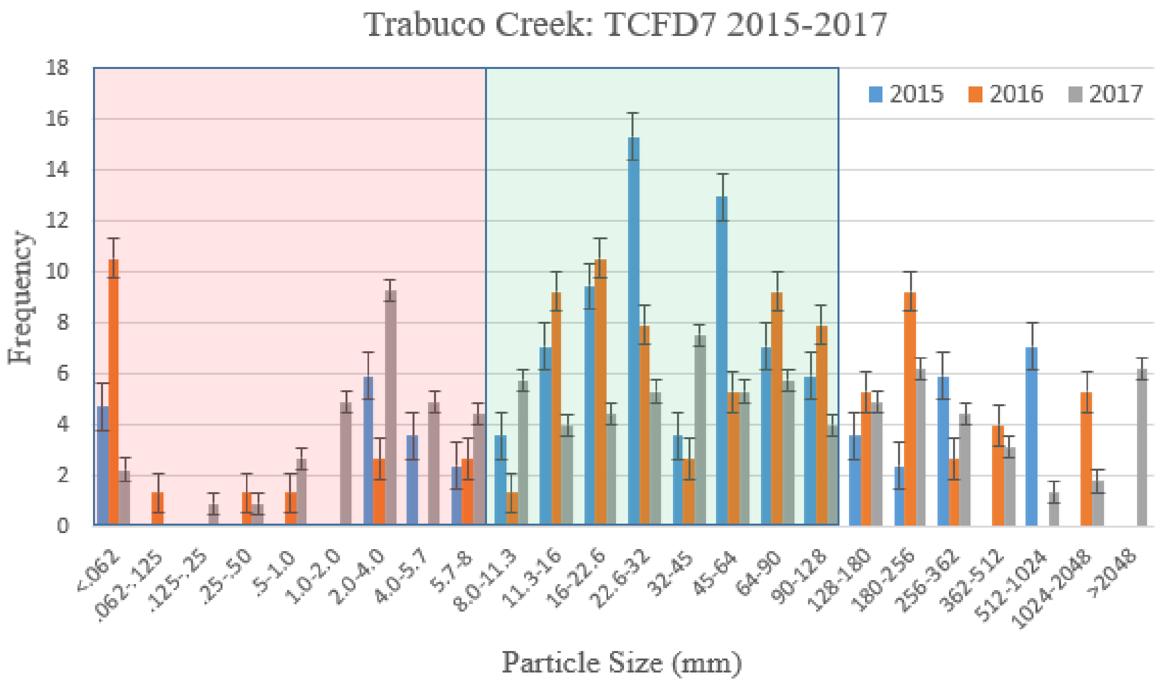


Figure IV-27. Particle size frequency distribution with standard error for site of TCFD7 removal and area directly upstream and downstream of where the dam once existed. 2017 had the lowest frequency of preferred particles for spawning (green shaded area) for this reach at 42% while 65% was encountered in 2015 and 54% in 2016.

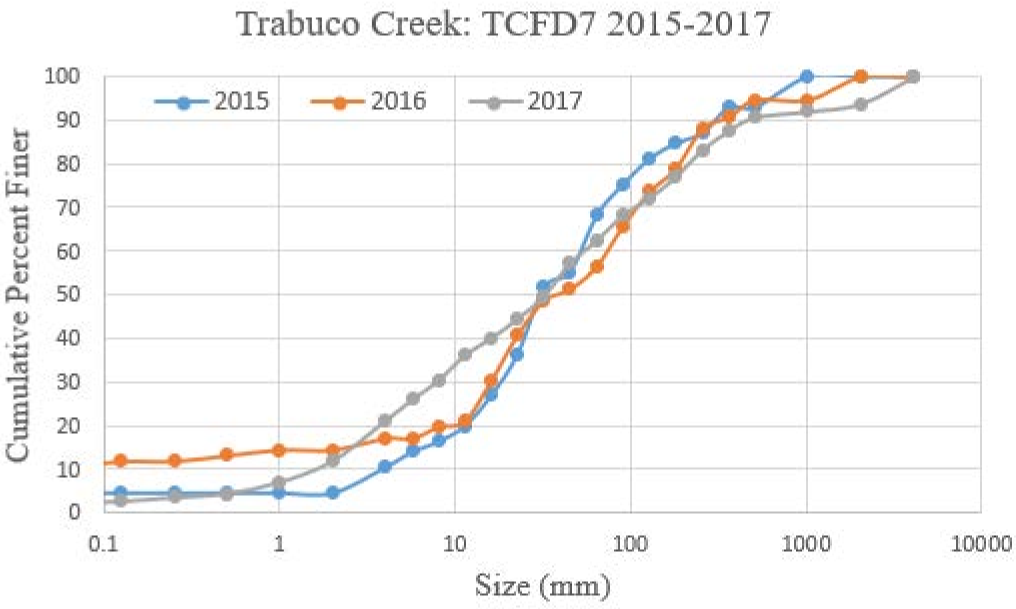


Figure IV-28. Cumulative particle size distribution curve for site of TCFD7 removal and area directly upstream and downstream of where the dam once existed. Newly exposed bedrock attributed to D84 value in 2017 being highest among the sampled years.

c. Trabuco Creek Discussion

Trabuco Creek TCFD7 and 11 impounded 631 and 281 square yards of sediment respectively. These two dams' reservoirs impounded more sediment than the check dams on Arroyo Sequit Creek and Lion Creek. While the pool directly below TCFD11 had the highest thalweg elevation (shallowest max depth) in the year following the dam's removal (2015), without pre-dam removal data it is difficult to determine the removals role in these findings. In 2016, TCFD11 downstream pool had scoured out and most fines had been flushed out except for very fine sand. The area surrounding TCFD7 experienced the opposite in which most notably the pool directly below the removal experienced infilling from 2015 to 2016. However, significant scour was observed in 2017 despite significant sediment flows from the 2016 Holy Fire in all the pool habitats directly adjacent to dam removal. The scour that resulted was significant enough to warrant additional dam removal actions and, in April 2018, instream dam remnants of TCFD11 were removed with the use of power and hand tools. Pools below both TCFD11 and 7 had significant scour (1-2ft) and a lot of the survey reach displayed both evidence of coarse particle distribution and exposed bedrock. It is likely that the 2016 Holy Fire may have contributed to the fines sampled in 2017.

D. Holy Jim Creek

1. Survey Results

a. Discharge

Due to limited gauge data availability, the same gauge data and precipitation water records were used for both Trabuco and Holy Jim surveys. See Table IV-3, Figure IV-20, and section C-1.a for narrative on Trabuco Creek discharge.

b. Topographic and Geomorphic Survey Results

This study was able to obtain pre-dam removal data on a stretch of Holy Jim Creek that includes three manmade dams and one Arizona crossing that were scheduled to be removed in the summer of 2018 but have been delayed by the 2018 Holy Fire (Table IV-4). The origin of the longitudinal profile is at the location where Holy Jim Fish Dam (HJFD) 6 was removed in 2014 and extends 329ft downstream (Figure IV-29). There is a stretch of cabins throughout this reach which have developed infrastructure to maintain the local access road and to provide water to the cabins. Within the surveyed area, Holy Jim Canyon Road borders the stream’s left bank for about half the reach and then crosses. One of the cabins that was built in proximity to the survey reach has a retaining wall that serves as the streams right bank from HJFD4 to HJFD5. HJFD5 is the largest of the three dams in this cluster and has a height of 6.3ft. When surveyed,

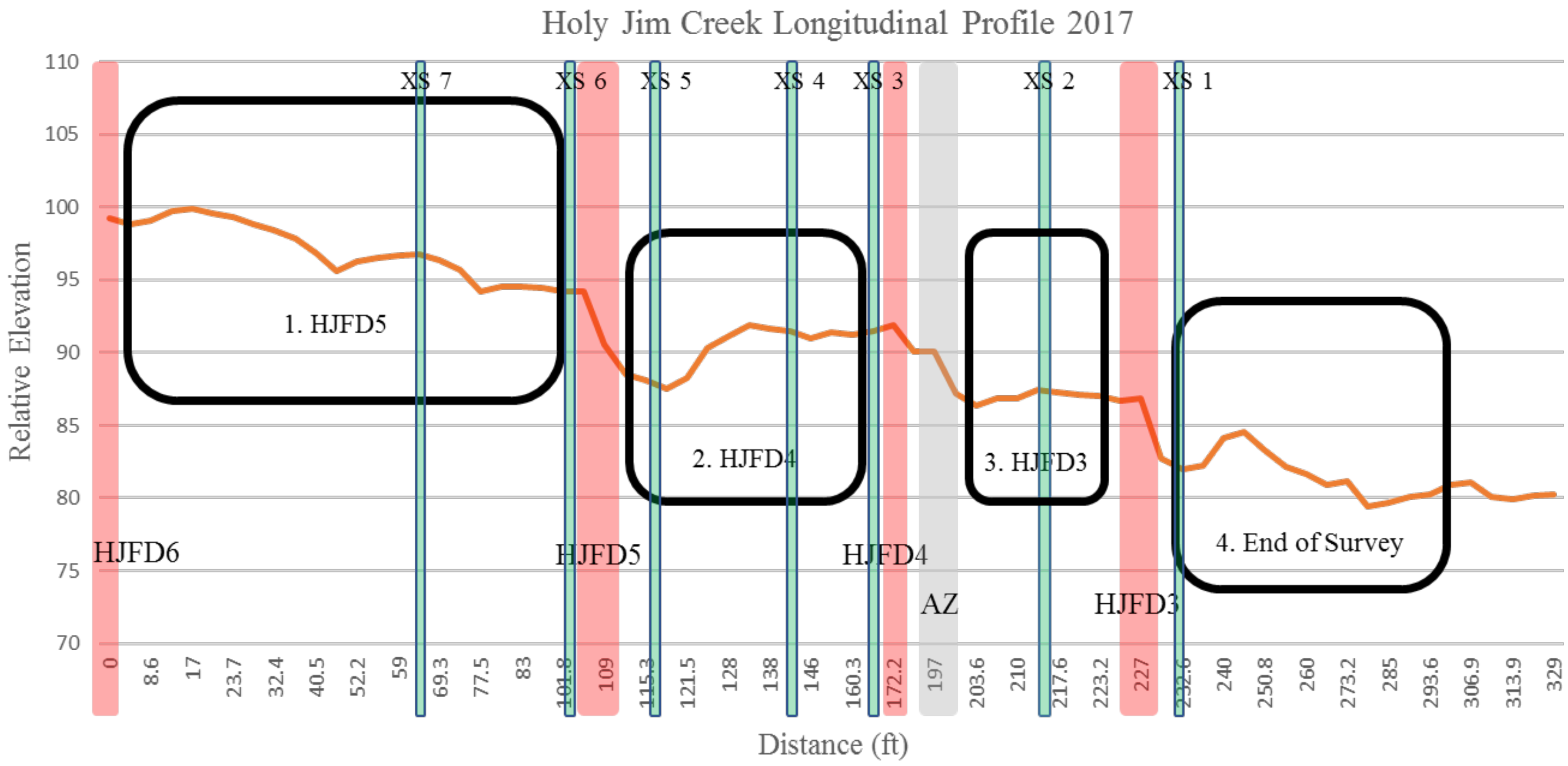
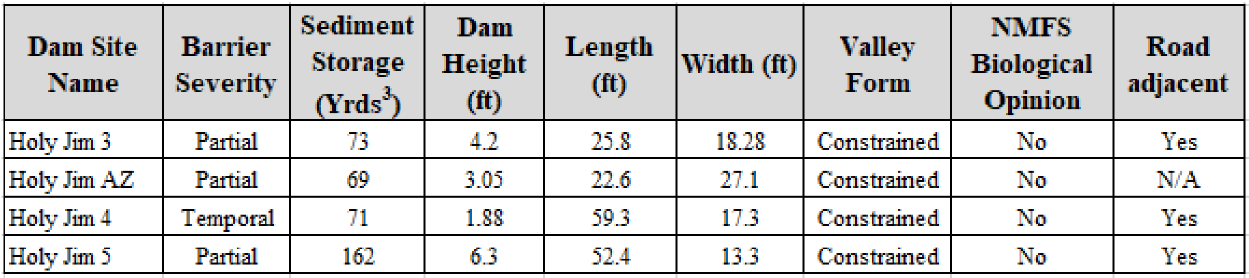


Figure IV-29. Longitudinal profile for Holy Jim Creek small dam removal study. Red shaded area represents three areas of dam influence where the dams were scheduled to be removed in the summer of 2018 but have been delayed by the 2018 Holy Fire (HJFD6 was demolished in 2014). Gray shaded area represents the concrete Arizona crossing of Holy Jim Canyon Road. Black boxes represent four areas where pebble counts were conducted; 1) HJFD5 2) HJFD4 3) HJFD3 4) End of survey. Green shaded area represents locations where a cross-section was conducted.

Table IV-4. Comparison of Holy Jim Creek dam removal site characteristics.



Dam Site Name	Barrier Severity	Sediment Storage (Yrds^3)	Dam Height (ft)	Length (ft)	Width (ft)	Valley Form	NMFS Biological Opinion	Road adjacent
Holy Jim 3	Partial	73	4.2	25.8	18.28	Constrained	No	Yes
Holy Jim AZ	Partial	69	3.05	22.6	27.1	Constrained	No	N/A
Holy Jim 4	Temporal	71	1.88	59.3	17.3	Constrained	No	Yes
Holy Jim 5	Partial	162	6.3	52.4	13.3	Constrained	No	Yes

the wetted pool directly below HJFD5 had a max depth of 2.77ft. HJFD3 is 4.2ft high and a dry scour pool was located directly below. Pre-dam removal data will be discussed based on locations of four pebble counts: 1) upstream of HJFD5 (reservoir), 2) upstream of HJFD4 (reservoir), 3) upstream of HJFD3 (reservoir), and 4) downstream of HJFD3 to the end of survey. Pre-dam removal site photos for 2017 are included in appendix I.

The upstream of HJFD5 pebble count encompasses the reservoir of the dam upstream to where HJFD6 was once located prior to being demolished in 2014. This area is comprised mostly of riffle habitat (Figure IV-29 HJFD5). Cross-sections were conducted at HJFD5 reservoir and slightly upstream of the base of the dam (Figures IV-30 and IV-31). Silt had a very low frequency for this stretch at 2% (Figure IV-32). Very fine gravel (2-4mm) had the highest frequency at 11%. The percentage of preferred particles for spawning for this reach was 40%. D50 value was 48mm (very coarse gravel) while the D84 value was 327mm (small boulder) (Figure IV-33). This reach had over 4% exposed bedrock and over 4% medium boulders which elevated the D84 value.

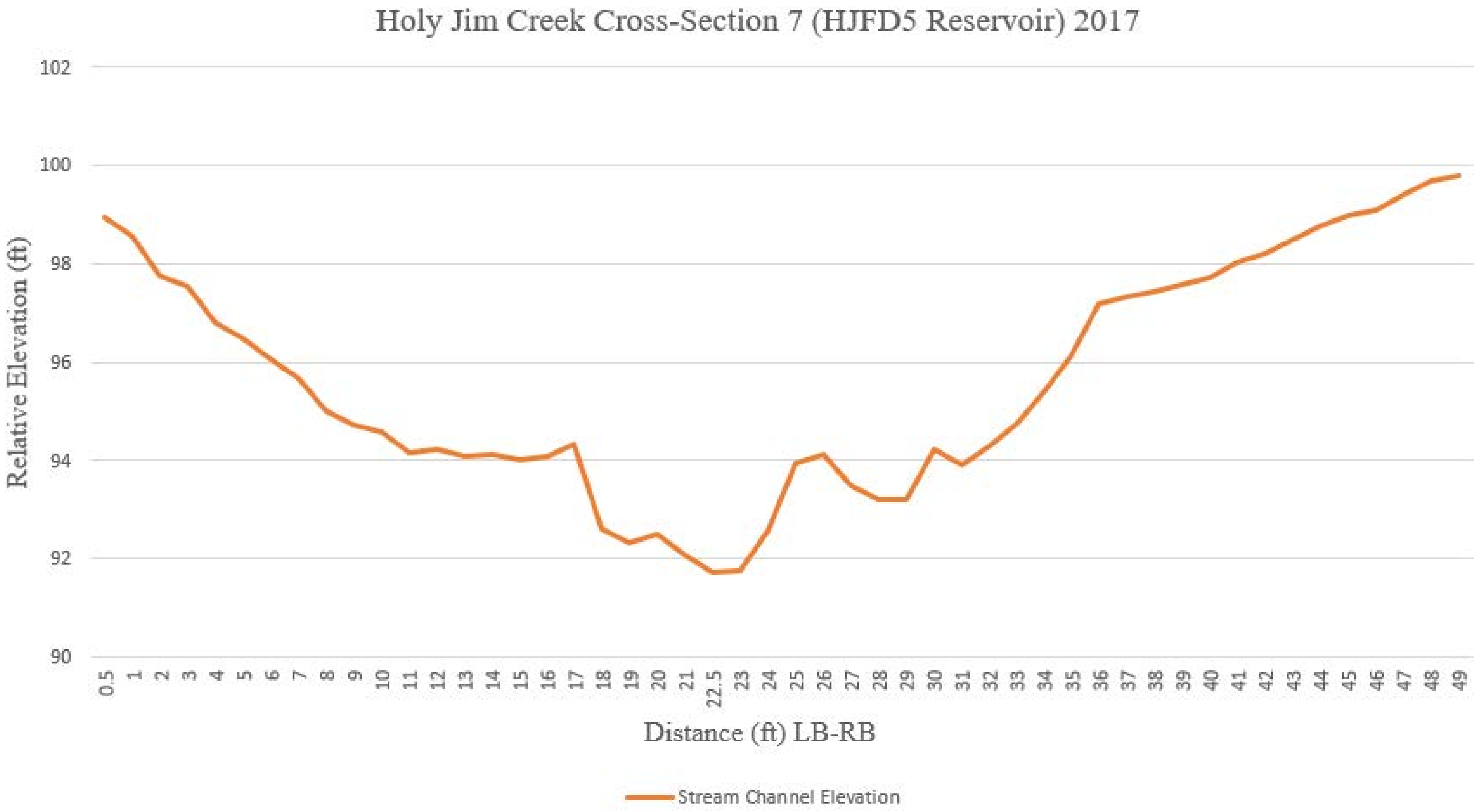


Figure IV-30. Cross-section of stream channel conducted at HJFD5 reservoir.

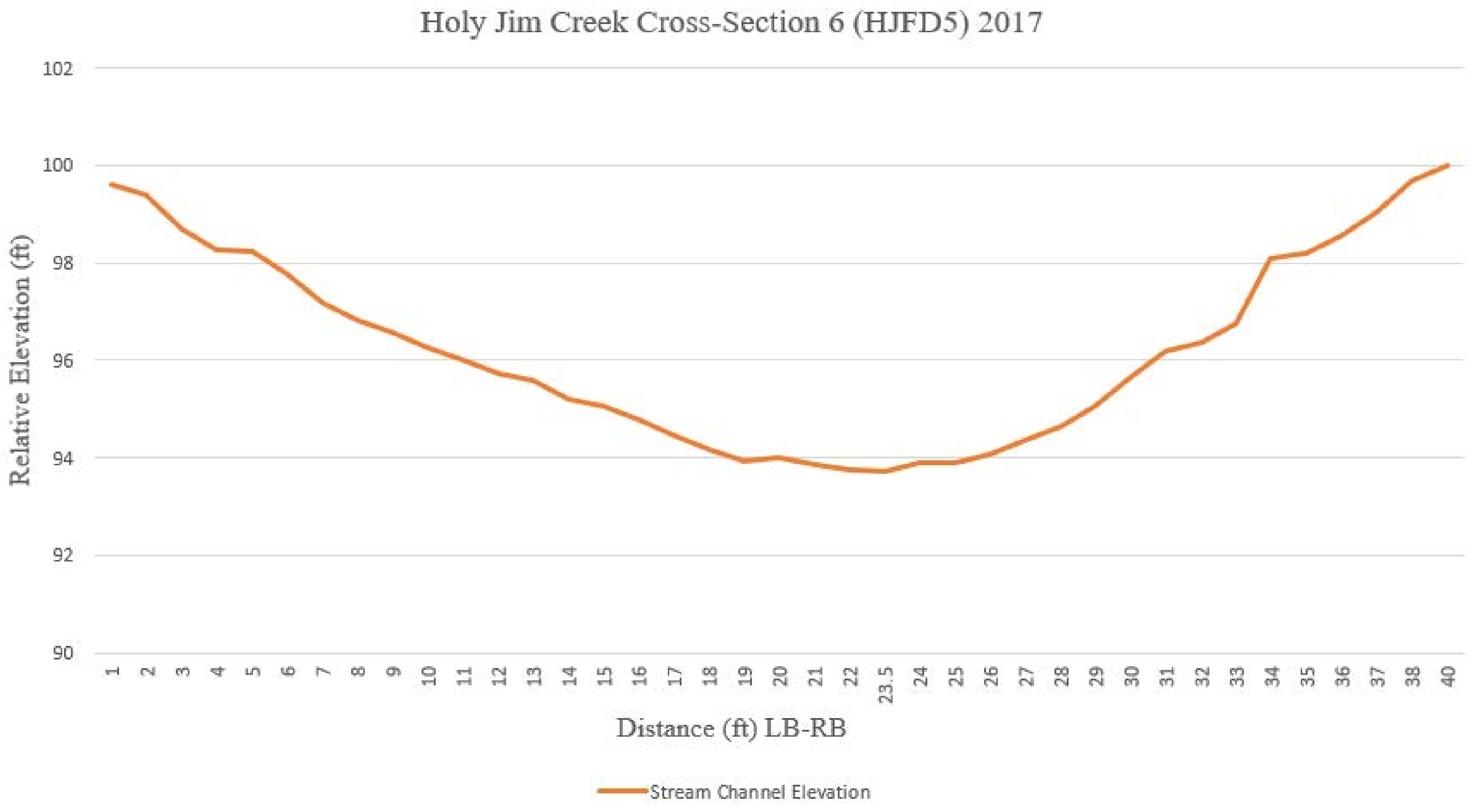


Figure IV-31. Cross-section of stream channel conducted slightly upstream of the base of HJFD5.

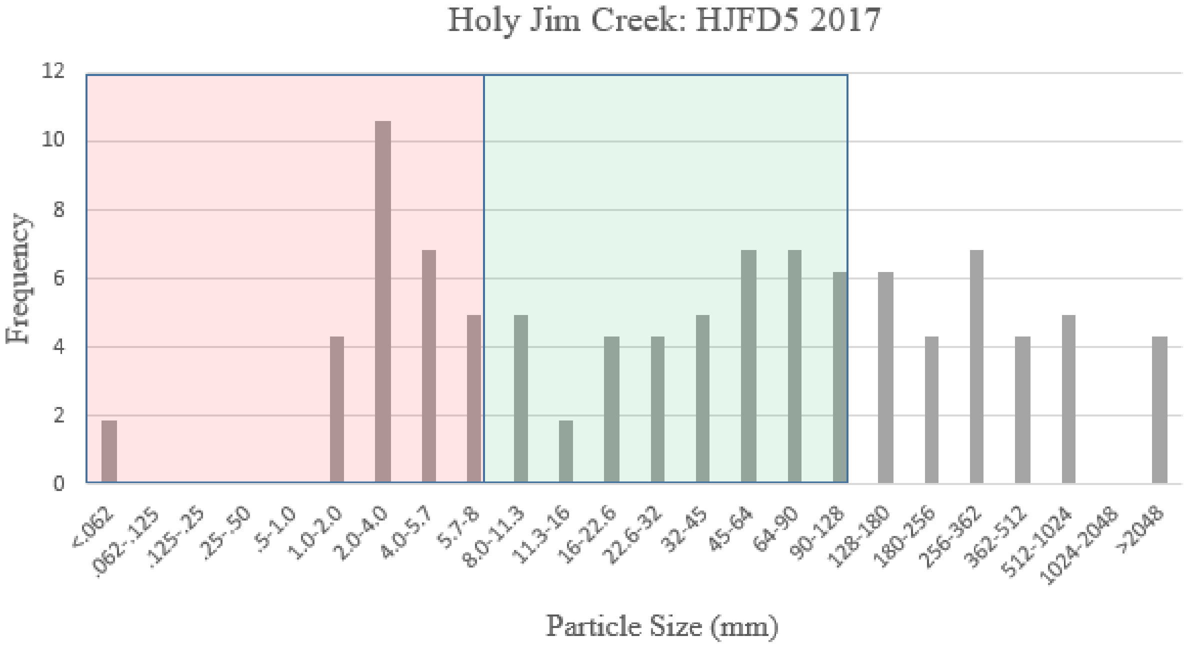


Figure IV-32. Particle size frequency distribution for the area from HJFD5 to where HJFD6 once existed. The percentage of preferred particles for spawning (green shaded area) sampled within the pebble count for this reach was 40%.

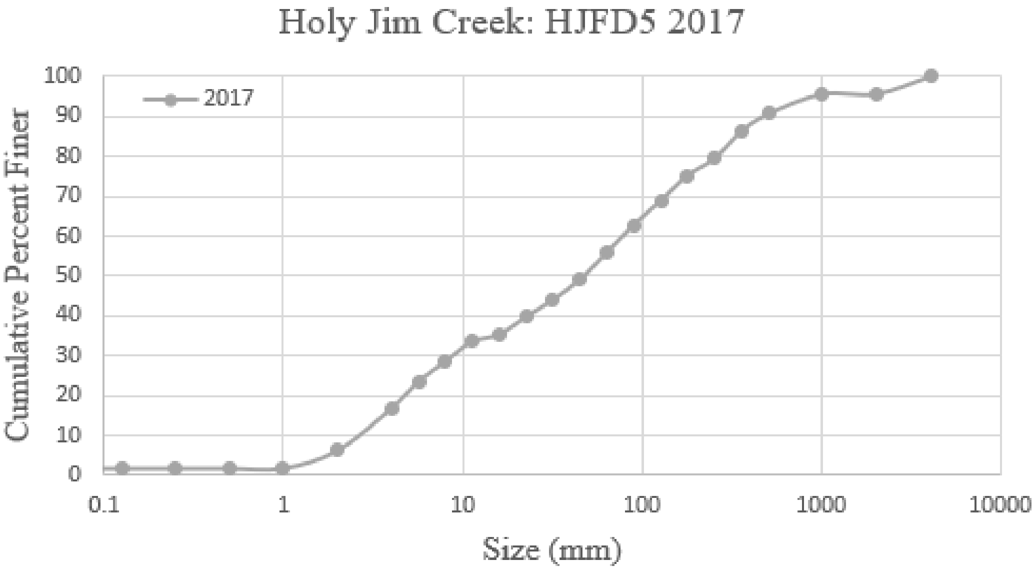


Figure IV-33. Cumulative particle size distribution curve for the area from HJFD5 to where HJFD6 had previously existed. D50 value was 48mm while D84 was 327mm.

The upstream of HJFD4 pebble count includes the reservoir of this dam up to the pool directly below HJFD5. The height of HJFD4 is 1.88ft from the top of the dam to the upstream base of Holy Jim Canyon Road. The pool at the end of this survey reach (below HJFD5) was the only wetted section of the entire survey. This pool is most susceptible to effects directly linked to dam removal due to HJFD5 impounded sediment and the retaining wall constructed on its right bank. Cross-sections were conducted at the pool directly below HJFD5, the reservoir of HJFD4, and slightly upstream from the base of HJFD4 (Figures IV-35, IV-36, and IV-37). The grain size class that had the highest frequency for this reach was very fine gravel (2-4mm) at 10% and silt (<.062mm) at 9% (Figure IV-34). This reach had a finer streambed substrate due to a higher frequency of fines than the upper reach above HJFD5 with a D50 and D84 value of 14mm (medium gravel) and 145mm (large cobble) respectively (Figure IV-38). The frequency of preferred particles for spawning for this reach was 40%.

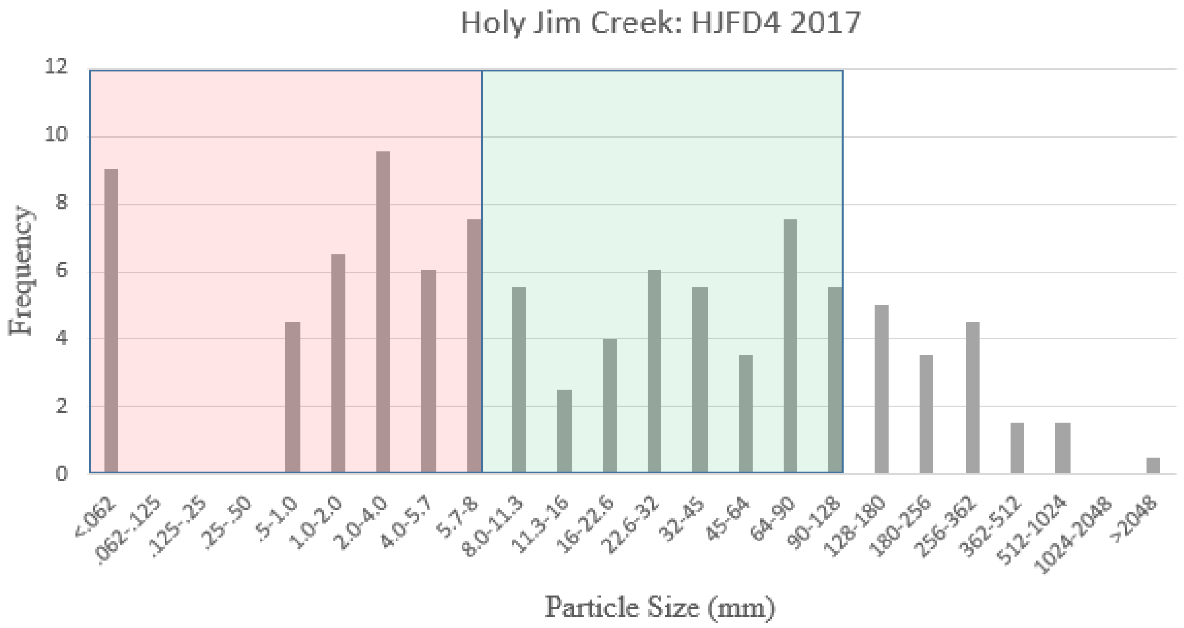


Figure IV-34. Particle size frequency distribution for the area beginning at HJFD4 up to the wetted pool directly below HJFD5. The percentage of preferred particles for spawning (green shaded area) sampled for this reach in the pebble count was 40%.

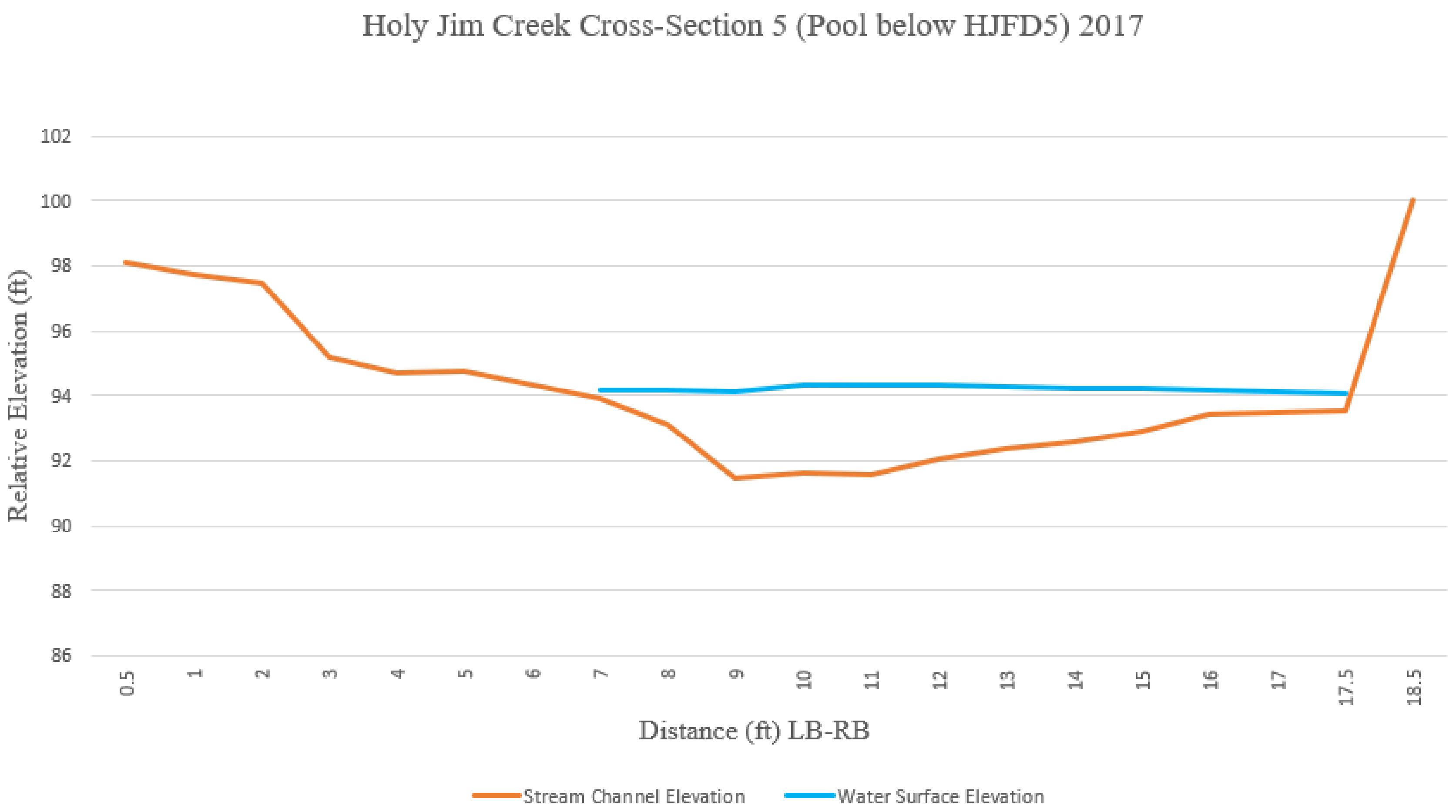


Figure IV-35. Cross-section of stream channel conducted at the wetted pool located directly below HJFD5.

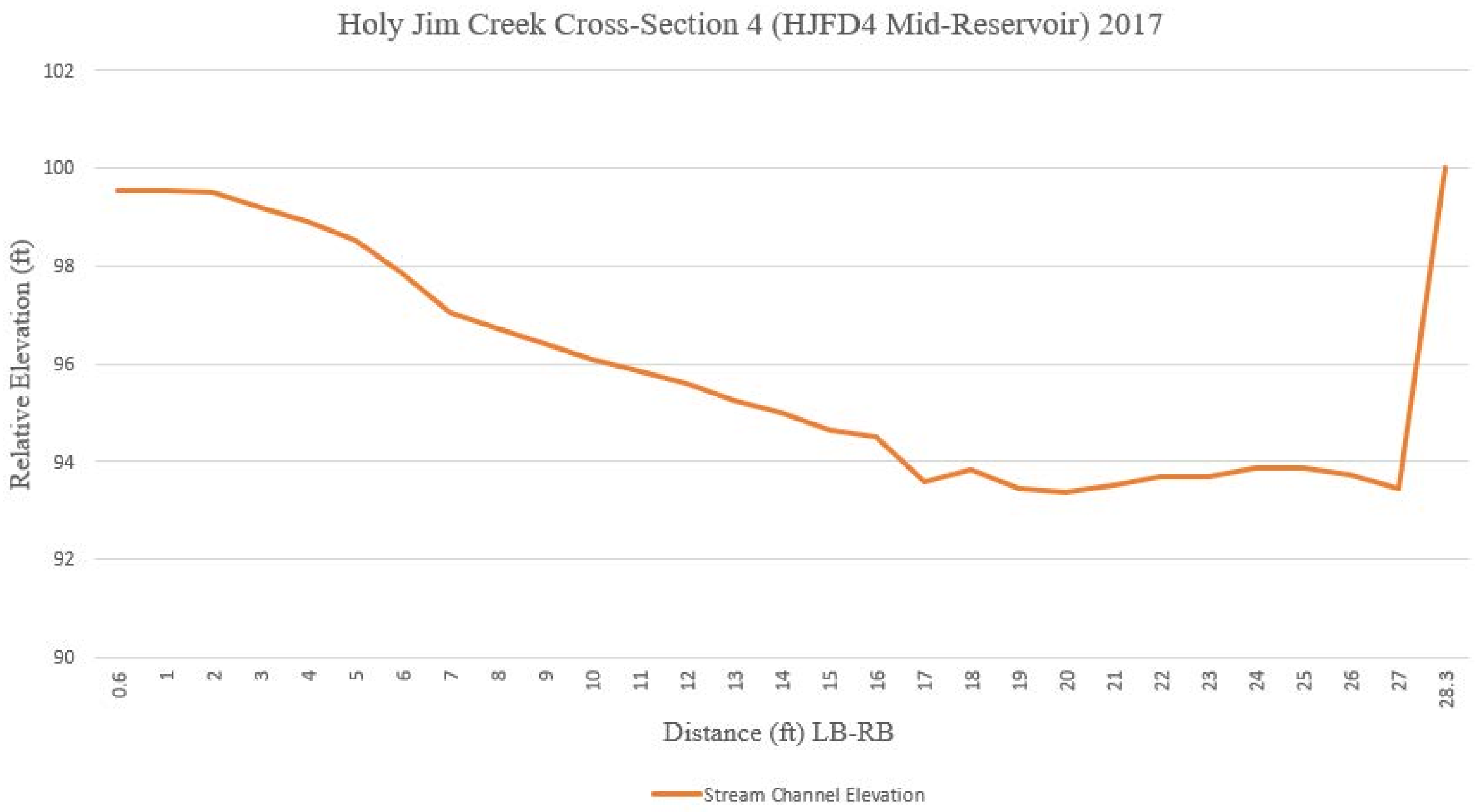


Figure IV-36. Cross-section of stream channel conducted in the middle of the reservoir of HJFD4.

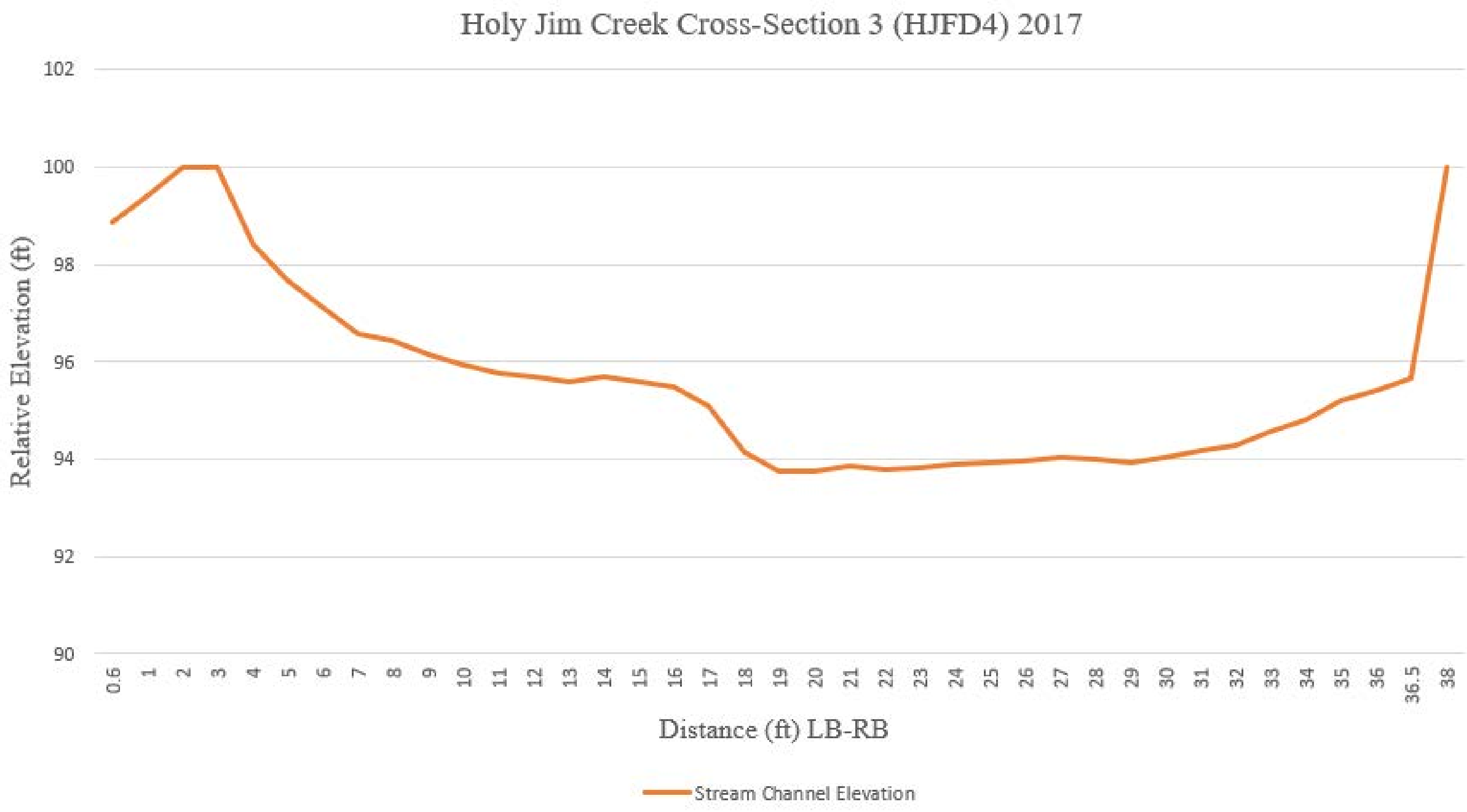


Figure IV-37. Cross-section of stream channel conducted slightly upstream from the base of HJFD4.

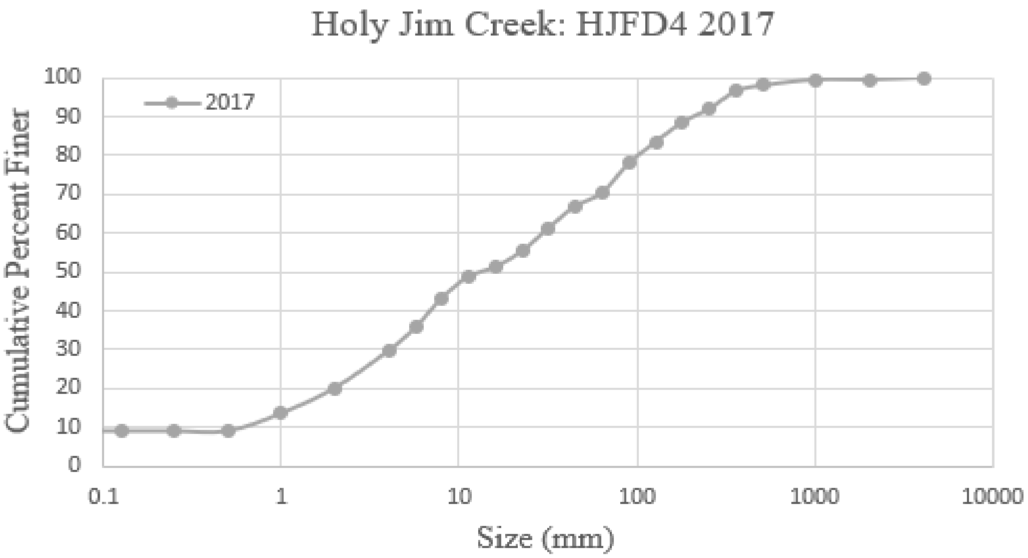


Figure IV-38. Cumulative particle size distribution curve for the area from HJFD4 to the wetted pool directly below HJFD5. This reach had finer streambed material with a D50 value of 14mm and D84 value of 145mm.

The upstream of HJFD3 survey reach includes stream distance from base of HJFD3 to the bottom of the plunge below the Arizona crossing of Holy Jim Canyon Road. The Arizona crossing of Holy Jim Canyon Road is a concrete road crossing and has a length of 22.6ft and a width of 27.1ft within the stream channel. The plunge from the surface of Holy Jim Canyon road crossing to base of dry scour pool below was 3.05ft. A cross-section was conducted at the reservoir of HJFD3 (Figure IV-39). There was a high frequency of silt (<.062mm) for this reach at 18% (Figure IV-40). Frequency of preferred particles for spawning was 30% for this area. D50 value was 25mm (coarse gravel) and D84 was 276mm (small boulder) (Figure IV-41).

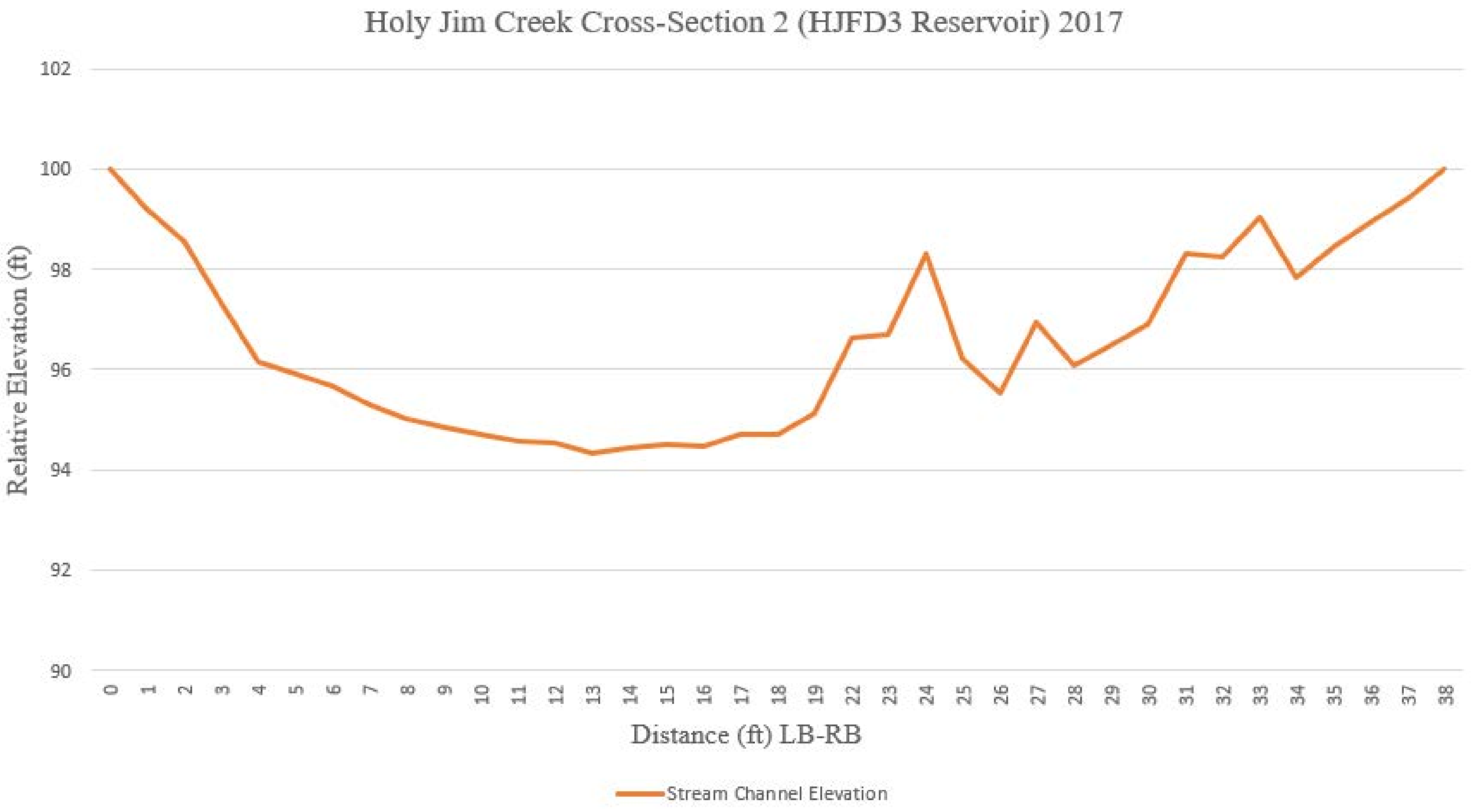


Figure IV-39. Cross-section of stream channel conducted in the reservoir of HJFD3.

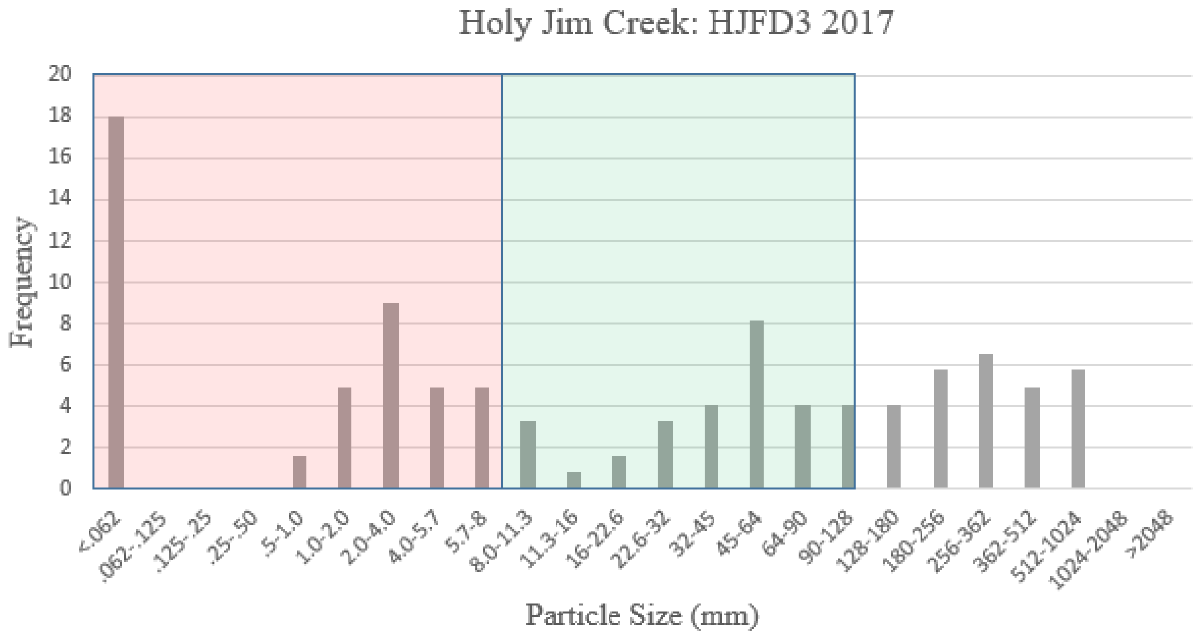


Figure IV-40. Particle size frequency distribution for the area of stream channel from the base of HJFD3 to the plunge below the concrete Arizona crossing of Holy Jim Canyon Road. Percentage of preferred particles for spawning (green shaded area) sampled in this reach was 30%.

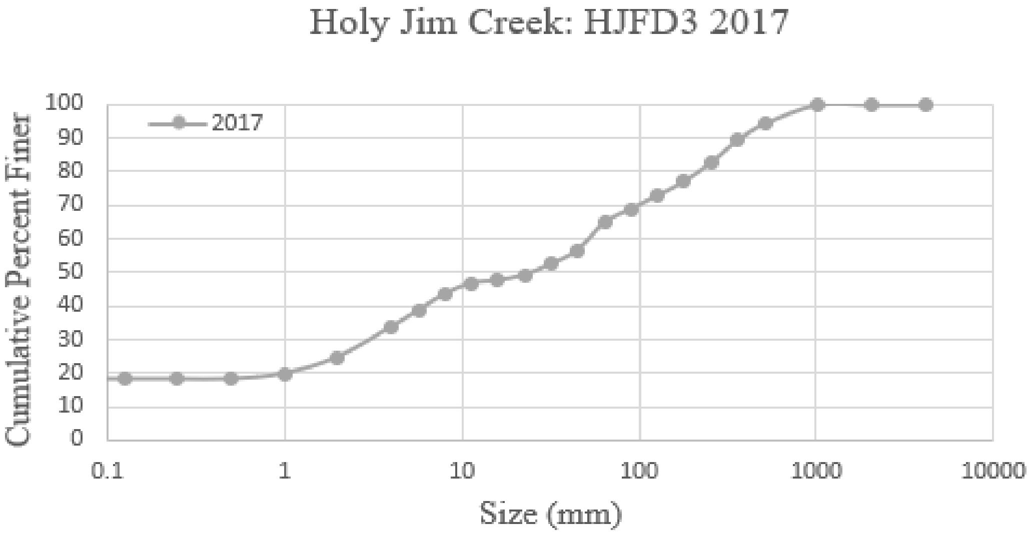


Figure IV-41. Cumulative particle size distribution curve for the area from the base of HJFD3 to the plunge below the concrete Arizona crossing of Holy Jim Canyon Road. D50 value for this reach was 25mm and D84 value was 276mm.

The end of survey reach (DS of HJFD3) is comprised mostly of high-gradient riffle and step-pool habitat and a cross-section was conducted at the dry scour pool directly below HJFD3 (Figure IV-43). There was a high frequency of silt for this reach at 11% (Figure IV-42). Medium sized boulders (512-1024mm) had the highest frequency of all grain size classes at 13%. This reach had the coarsest streambed substrate according to pebble counts with D50 value of 112mm (small cobble) and D84 value of 527mm (medium boulder) (Figure IV-44). The frequency of preferred particles for spawning for this reach was 35%.

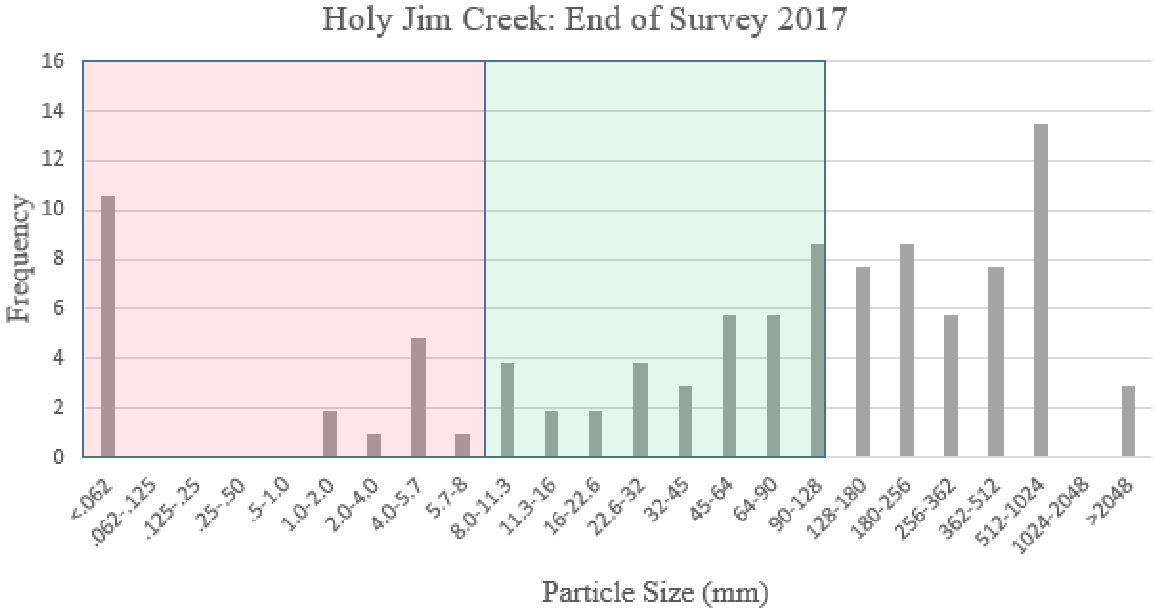


Figure IV-42. Particle size frequency distribution for stream channel from bottom of HJFD3 to the end of the survey. Percentage of preferred particles for spawning (green shaded area) sampled for this reach was 35%.

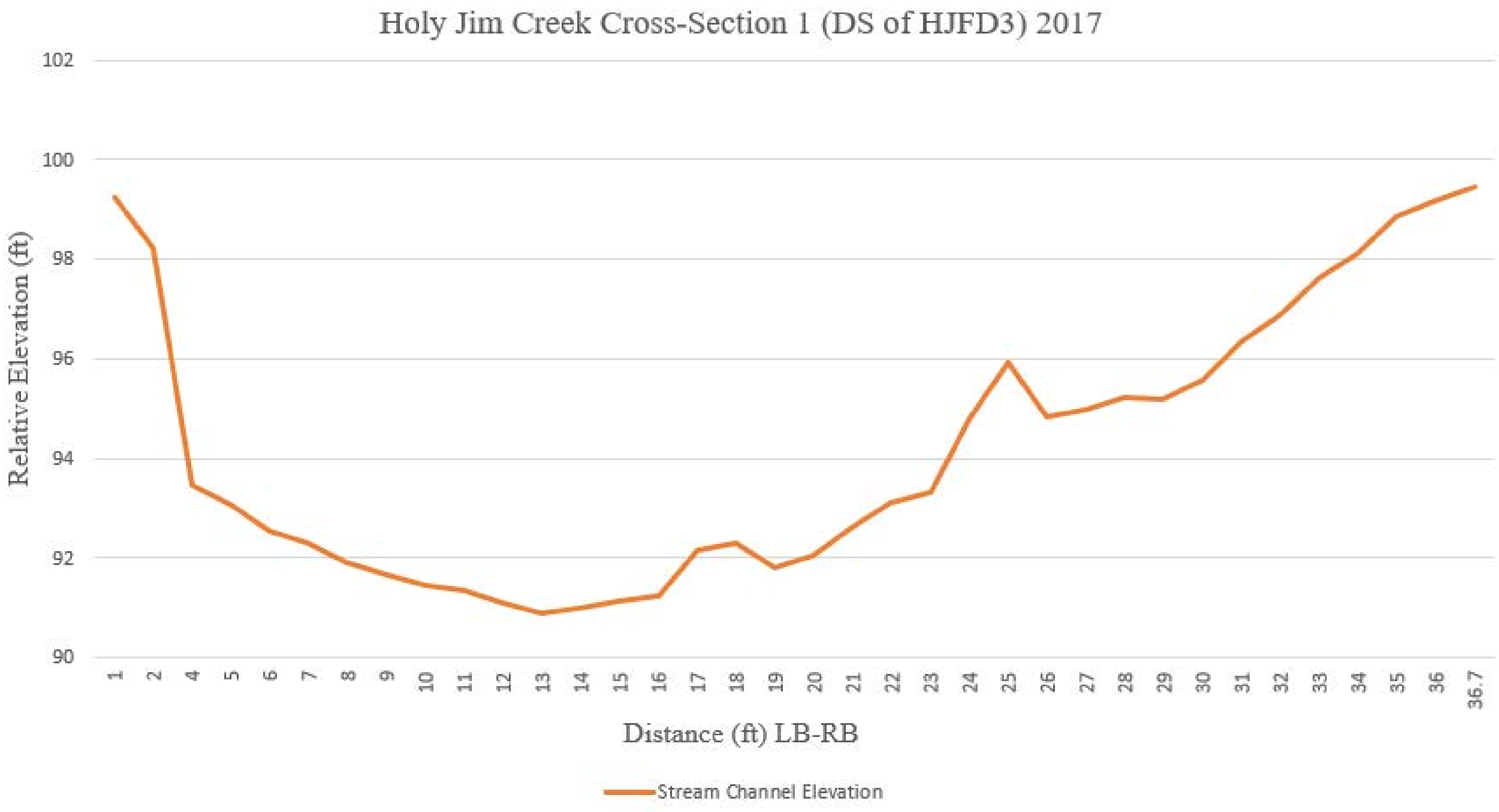


Figure IV-43. Cross-section of stream channel conducted slightly downstream of the base of HJFD3.

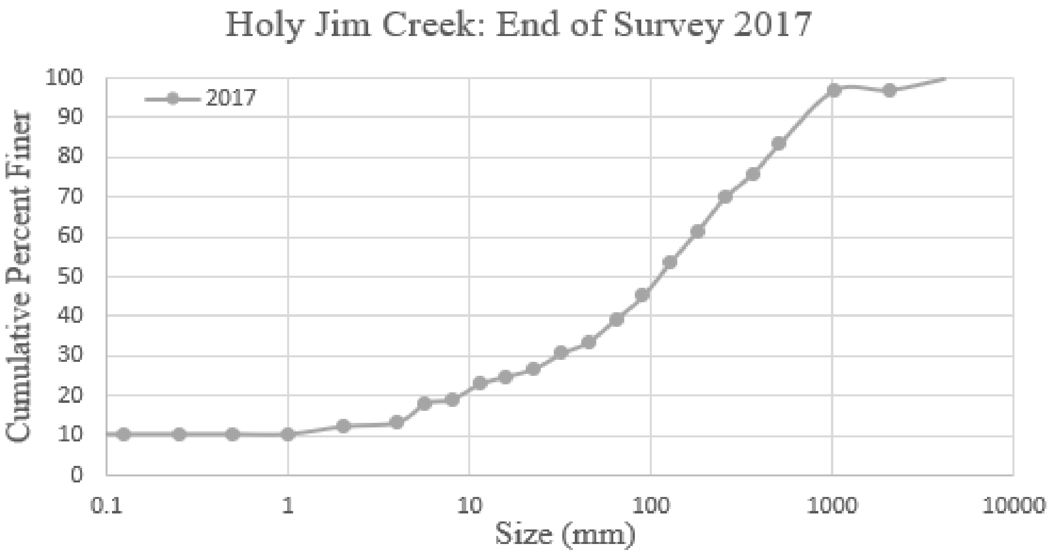


Figure IV-44. Cumulative particle size distribution curve for the stream channel from below HJFD3 to the end of survey. This reach had the coarsest streambed substrate according to pebble counts with D50 value of 112mm and D84 value of 527mm.

V. Project Discussion and Conclusion

Even under extended drought conditions, flows were sufficient to transport most of the sediment stored by the small dams included in this study within a year of removal (if not sooner). This supports other finding in which flows below a 2-year storm event were adequate to mobilize most of the sediment previously stored behind dams (Pearson et al. 2011, Major et al. 2012, Wilcox et al. 2014, Major et al. 2017). Southern California, like much of the arid southwest is subject to flashy storm events that, even under drought conditions, appear sufficient to prevent sediment bleeding scenarios that would create prolonged impacts to stream water quality (Graf 2005). Future studies could further investigate this specific factor by quantifying sediment caliber prior to dam removal and then directly tracking turbidity following removal along with other biologically relevant characteristics (e.g. dissolved oxygen) to provide greater insight on potential impacts of dam removals occurring in ephemeral and low-flow streams.

Numerous studies identify reservoir sediment quantity and caliber as critical pieces of information to inform dam removal decisions (Doyle et al. 2003, Sawaske and Freyburg 2012, O'Connor et al. 2015, Major et al. 2017). Sediment storage capacity was not directly measured by this study although volume of stored sediment was roughly estimated to provide insight into the scale of potential dam removal impacts in the future. None of the dams included in this study impounded more than the threshold of 900 cubic yards identified by the programmatic biological opinion, therefore it is still uncertain if 900 cubic yards is indeed a reasonable threshold for southern California or if there is opportunity for larger scale projects to be eligible for coverage under the programmatic permit to further enable this critical recovery action to be undertaken. This study echoes Bellmore et al.'s assertion that inadequate pre-dam-removal data is a critical gap in dam removal science and emphasizes the importance of capturing a better understanding of reservoir sediment quantity and caliber prior to dam removal.

While the sediment quality impounded by these dams was unknown, there was variability in what remained instream after removal based on regulatory ability. Lion Creek and Arroyo Sequit were subject to terms and conditions under their own individual biological opinions requiring that all concrete be removed from the stream because they are part of the southern steelhead DPS. Roughly 20 tons of concrete and sediment were removed by hand from Arroyo Sequit during the 11-day process (The Bay Foundation 2014). Trabuco Creek, however, was not subject to a NMFS biological opinion because of downstream barriers which exclude it from NMFS jurisdiction. The Trabuco dam removals left most of the dam debris (locally sourced rock and mortar) instream and experienced both infilling and scour between 2015-2017. Without pre-dam removal data and complicated by multiple sequential dams, adjacent road, and fire inputs in Trabuco, it is difficult to say with certainty that the dam removal technique was the cause of infilling and increased fines. However, this study did indicate that full removal of instream structures can prevent the need to repeat effort to remove structures revealed through scour post dam removal.

Increased fines and subsequent increased thalweg elevations in 2016 at both Arroyo Sequit and Lion Creek survey reaches highlights the importance of the watershed's background sediment flux (which was not accounted for in this study or required under the programmatic opinion). Sediment input from land-use practices and watershed inputs (fires, roads, erosion from unseasonal urban freshwater inputs) and natural annual sediment flux may be more important influences on stream morphology and habitat quality under drought conditions than dam removal itself in these southern California systems. Calculating a sediment budget for a watershed is a complex undertaking and would likely be cost-prohibitive for small dams such as these. However, it is not uncommon for small dams to be located in systems with larger projects in which case sediment budgets may already exist and have the potential to add considerable insight to projects throughout the watershed. The ability to track these large-scale watershed inputs is limited but should not be underestimated even in these seemingly remote and less-impacted streams.

Cycles of sedimentation and subsequent scouring observed throughout survey years was a result of upstream watershed inputs and storm influenced winter flows. Both study reaches in Arroyo Sequit and Lion Creek experienced elevated thalweg elevations in 2016. These findings point to a greater influence of upstream watershed inputs rather than effects directly related to the removal of the small dams. Pools located below dams in both Lion Creek and Trabuco Creek were maintained throughout the survey years. Percentage of preferred particles for spawning fluctuated throughout the years but all three sites had high frequencies of preferred spawning gravel in 2015 despite being one-year post-dam removal. In fact, all three post-dam removal years in Lion Creek had a higher frequency of preferred particles for spawning than in the year prior to dam removal. In the case of Trabuco, preferred particles for spawning was lowest in 2017 but this can be likely attributed to the extensive scour observed along with the increased sedimentation due to the Holy Fire and will likely be subject to a greater extent in coming years after the 2018 Holy Fire. Fluctuations in coarseness of streambed material observed for some of the survey reaches also seems to be a result of watershed inputs and flow rates rather than resulting from the dam removal itself. In fact, the results of this study revealed no long-term negative instream impacts due to dam removal especially in streams where removal is within NMFS jurisdiction. It appears that none of these dams impounded enough sediment where resulting sediment pulses from removal threatened habitat quality and streambed substrate composition. These streams seem to experience more changes and adjustments due to upstream watershed inputs, flow rates, and fires than as a result of the removal of these small obsolete dams.

Trabuco and Holy Jim Creek offer an example of a potential cost-effective strategy for high density small dam removal by taking advantage of its location in relation to NMFS jurisdiction. Without being subject to NMFS review, the range of methodologies by which dam removal can be implemented are greater. This is key for the removal of over 80 small dams (many only a few feet away from each other) with a budget that might be insufficient to design and remove even a single barrier lower in the watershed. The value of removing these small dams is not only recognized in the cost savings of the removals but provides additional momentum to address downstream legacy fish passage barriers like Interstate 5, priming the upstream habitat for potentially when the downstream barriers (most notable is the Interstate 5 spillway and concrete apron) are remedied.

Dam removal is a complicated restoration strategy, but vital in restoring stream connectivity for anadromous species. This study fills a critical geographic gap in dam removal knowledge in a region with increasingly dynamic hydrologic variation, placing questionable doubt on the paradigm that hydrology and watershed setting are subordinate influences on initial geomorphic response to dam removal. This study also provides insight into dam removal response under a range of management strategies to help focus future small dam removal planners on key factors where monitoring is needed to best inform managers and agencies when making species specific recommendations. Finally, while no two dams are likely to respond identically, programmatic permitting gives an opportunity to create consistency in pre- and post-dam removal monitoring requirements and should be viewed as an opportunity to understand dam removal on a regional scale for recovery of species most at risk.

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Appendix I

Site Photos

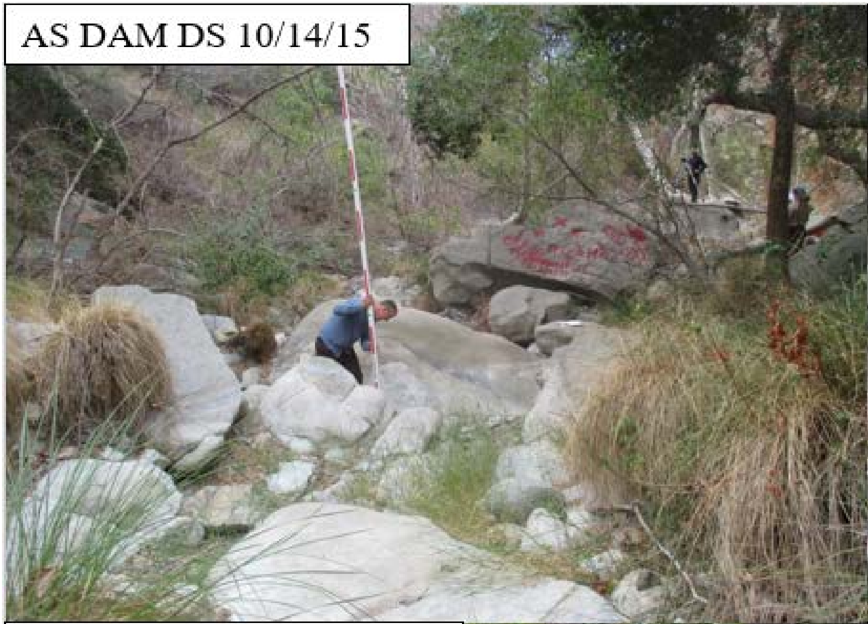
(Arroyo Sequit (AS), Lion (LC), Trabuco (TC), and Holy Jim Creek (HJ))


AS BM#1 RB above 10/14/15


AS BM#1 RB-LB 10/14/15


AS BM#2 RB 10/14/15


AS BM#2 RB-LB 10/14/15


AS DAM DS 10/14/15

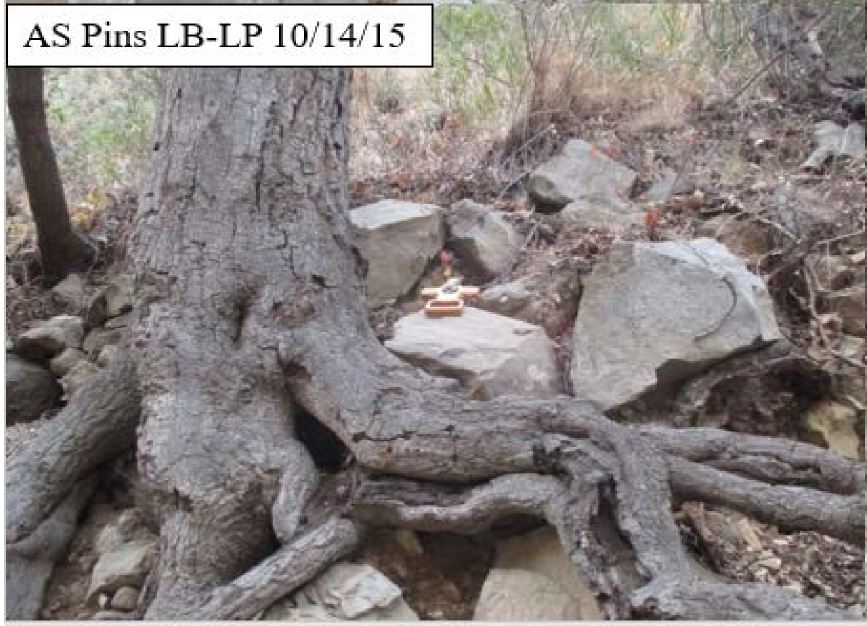

AS DAM US 10/14/15

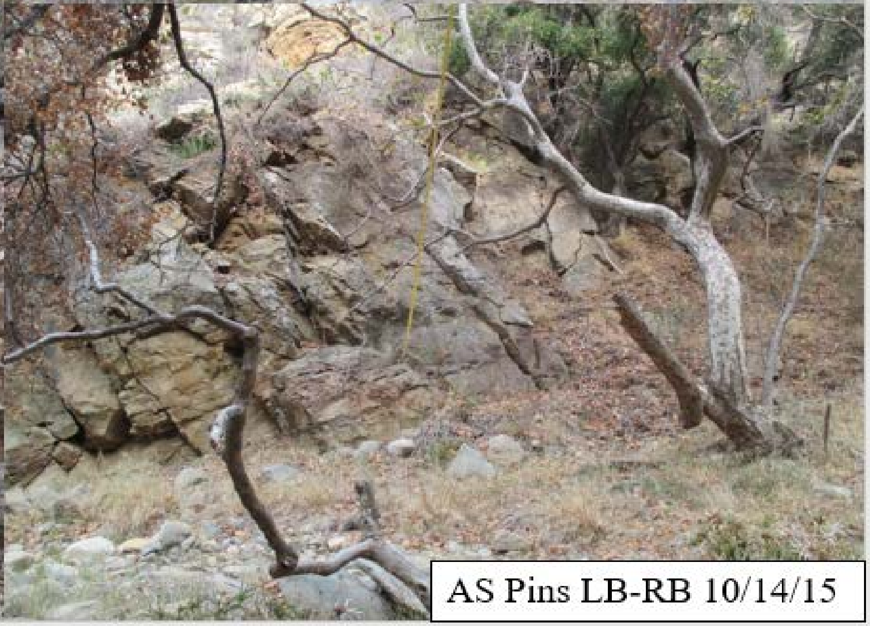

AS DAM LB-RB 10/14/15


AS DAM RB-LB 10/14/15


AS Pins DS 10/14/15


AS Pins US 10/14/15


AS Pins LB-LP 10/14/15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AS Pins RB-RP 10/14/15

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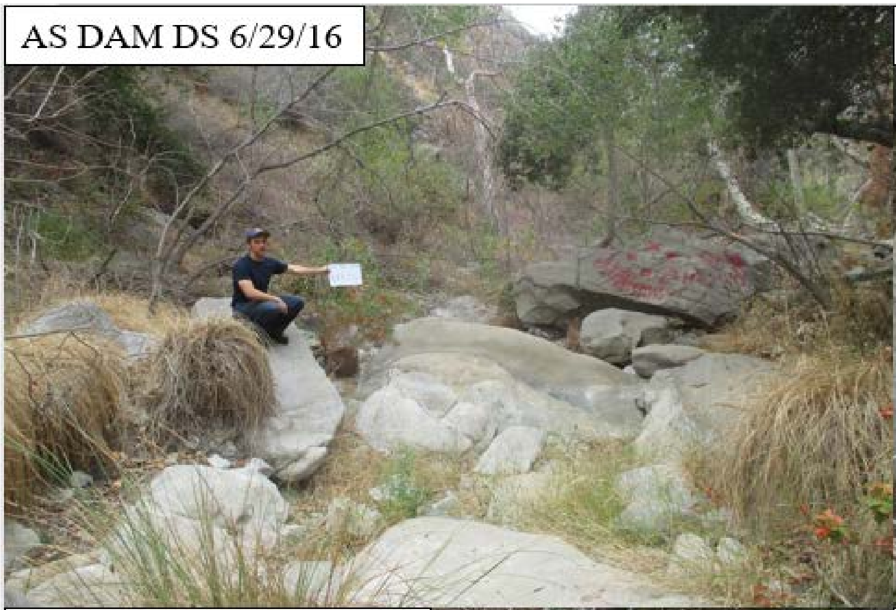
AS BM#1 RB-LB 6/29/16

AS BM#2 RB 6/29/16

AS BM#2 RB-LB 6/29/16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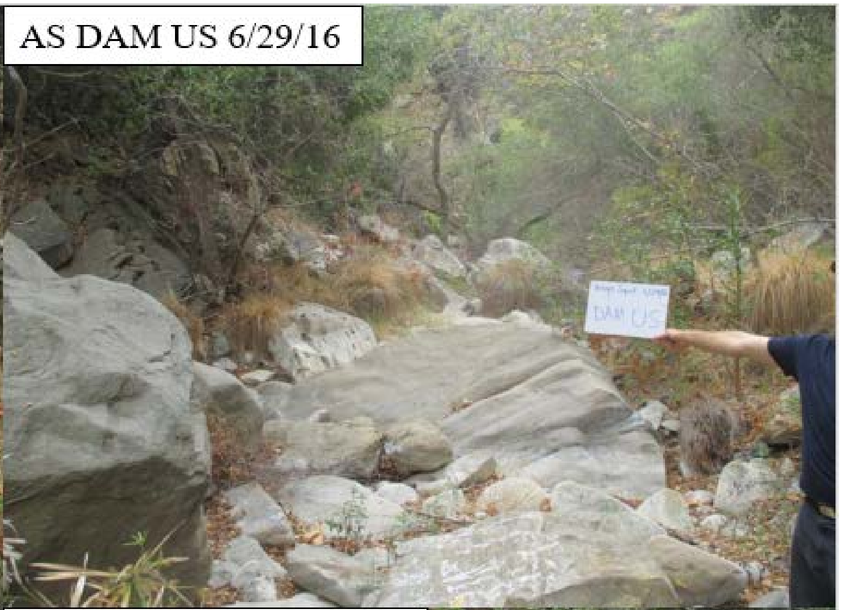
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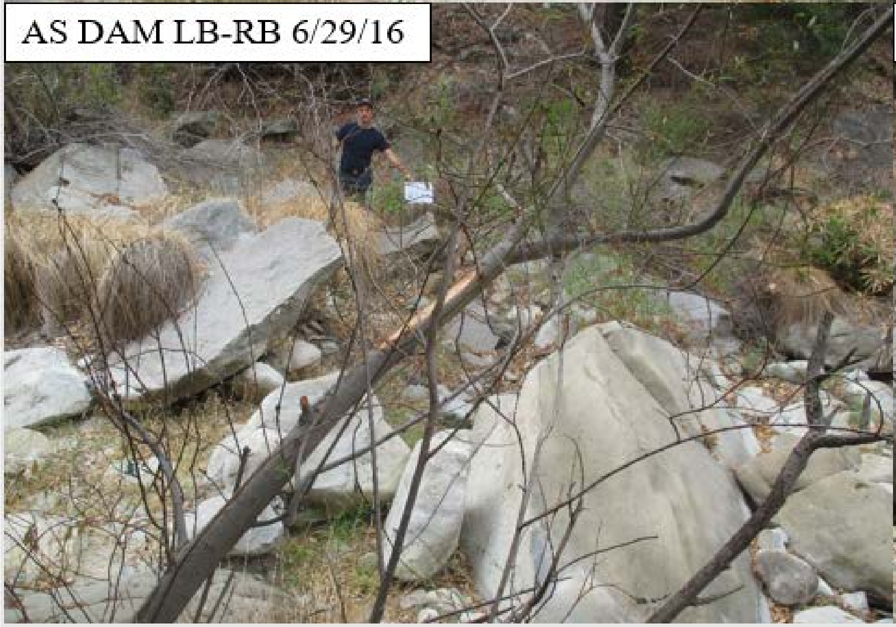
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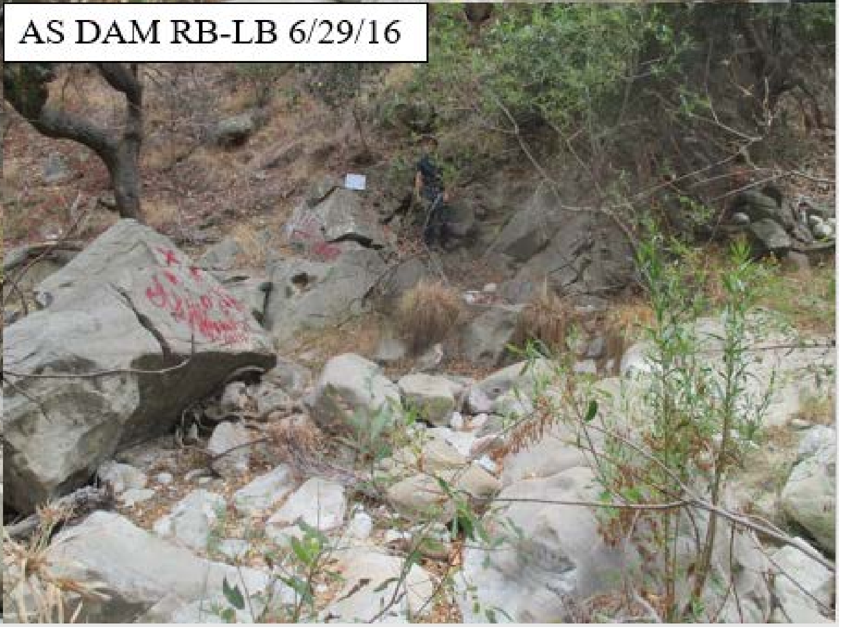
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AS Pins DS 6/29/16


AS Pins US 6/29/16


AS Pins LB-LP 6/29/16


AS Pins LB-RB 6/29/16

AS Pins RB-LB 6/29/16

AS Pins RB-RP 6/29/16

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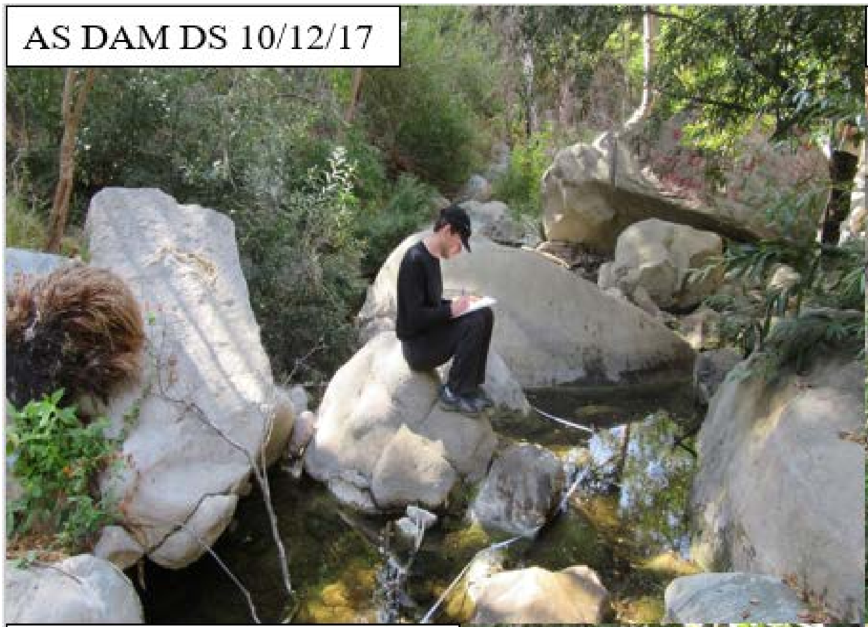
AS BM#1 RB-LB 10/12/17

AS BM#2 RB 10/12/17

AS BM#2 RB-LB 10/12/17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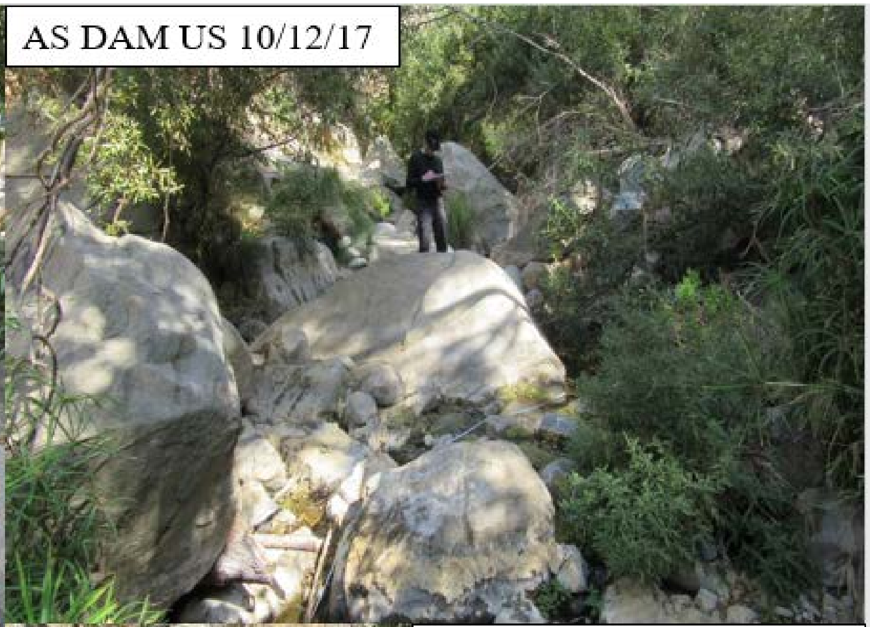
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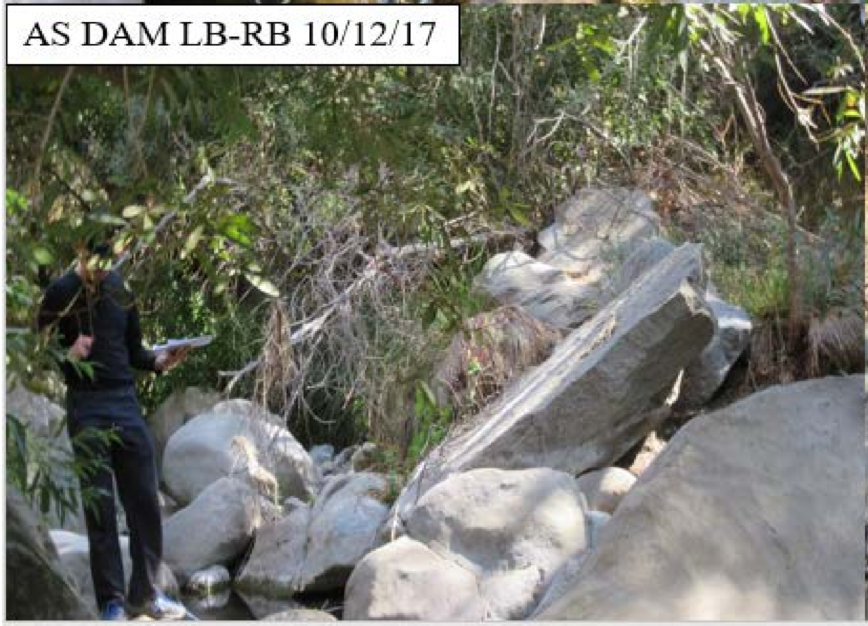
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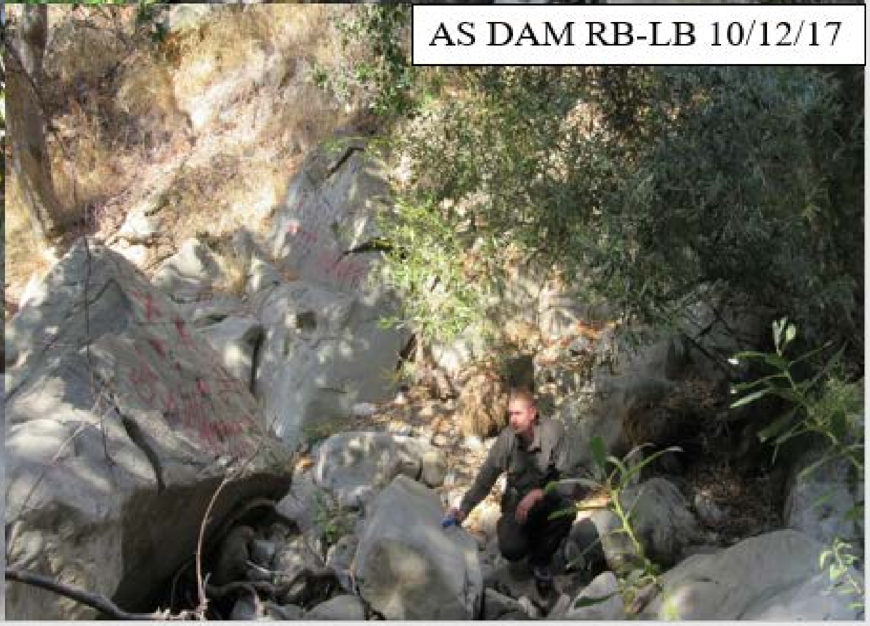
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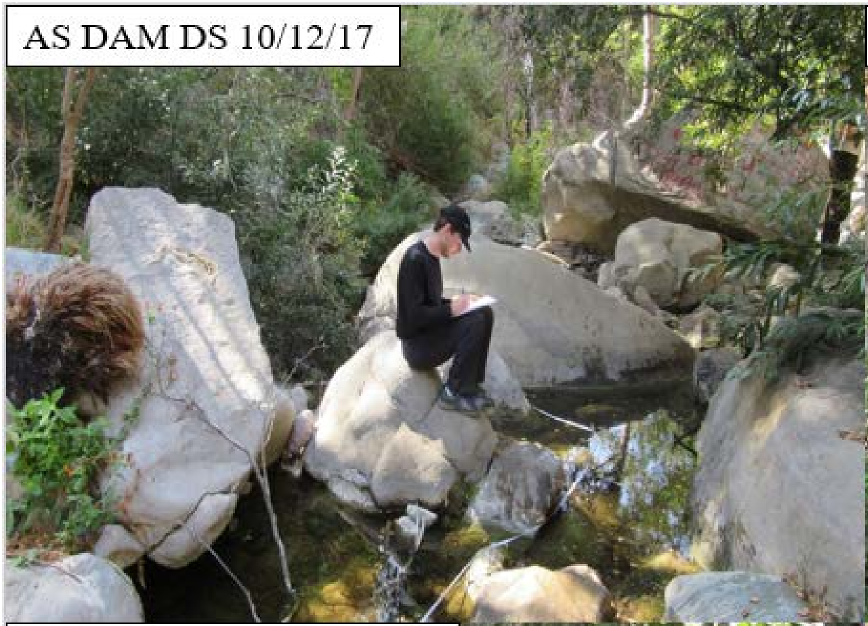
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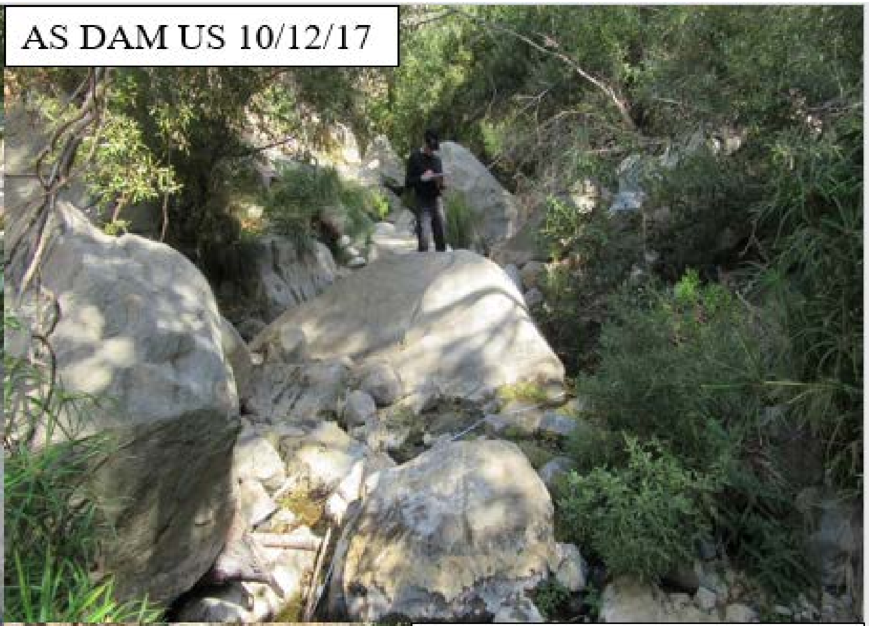
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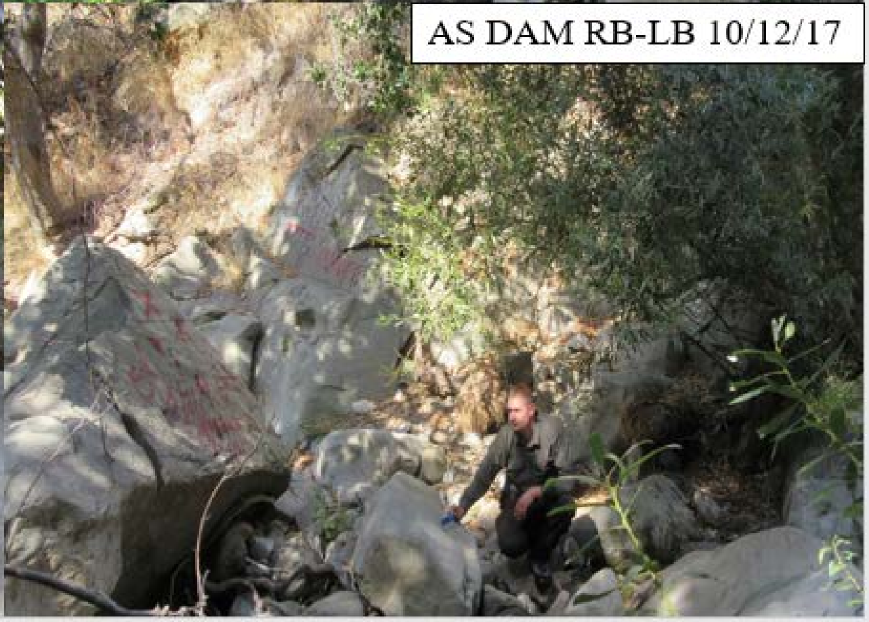
AS DAM LB-RB 10/12/17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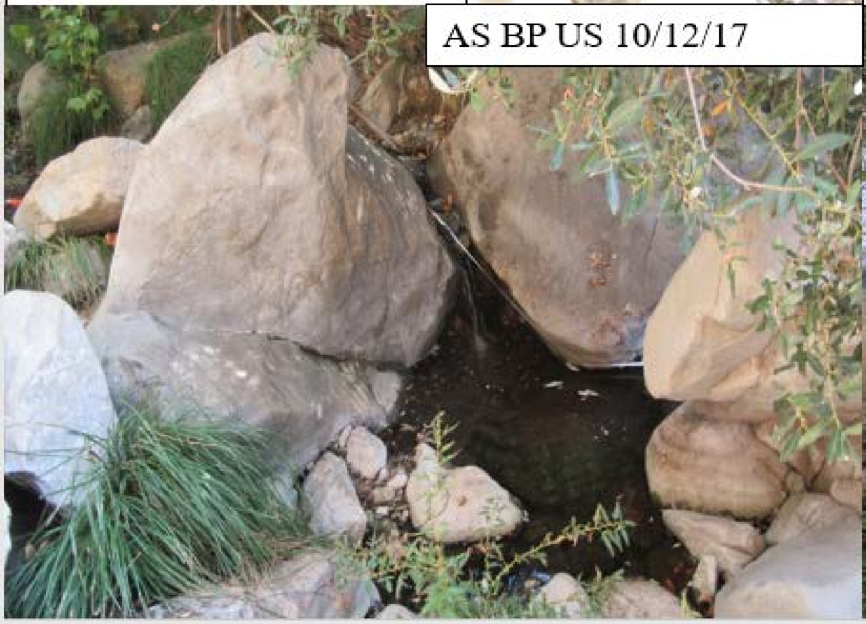

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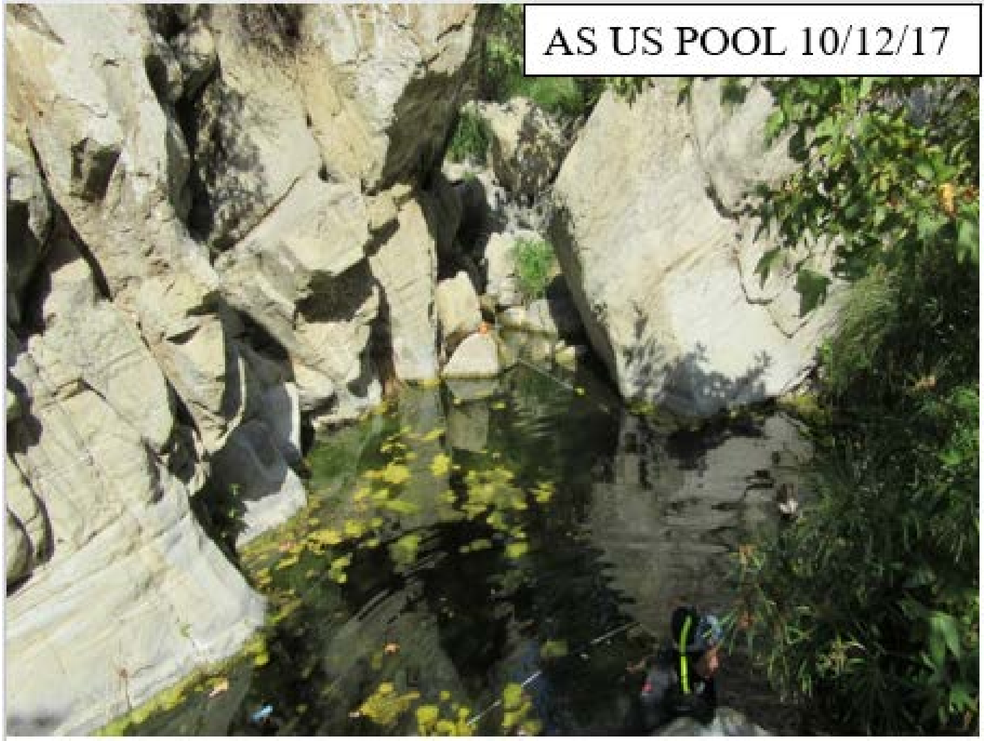
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LC XS#1 RB 05/17/16

LC XS#1 US 05/17/16

LC XS#1 DS 05/17/16


LC XS#2 LB 5/17/16


LC XS#2 RB 5/17/16


LC XS#2 US 5/17/16


LC XS#2 DS 5/17/16

LC XS#1 DS 10/19/17

LC XS#1 US 10/19/17

LC XS#1 LB-RB 10/19/17

LC BM#1 10/19/17

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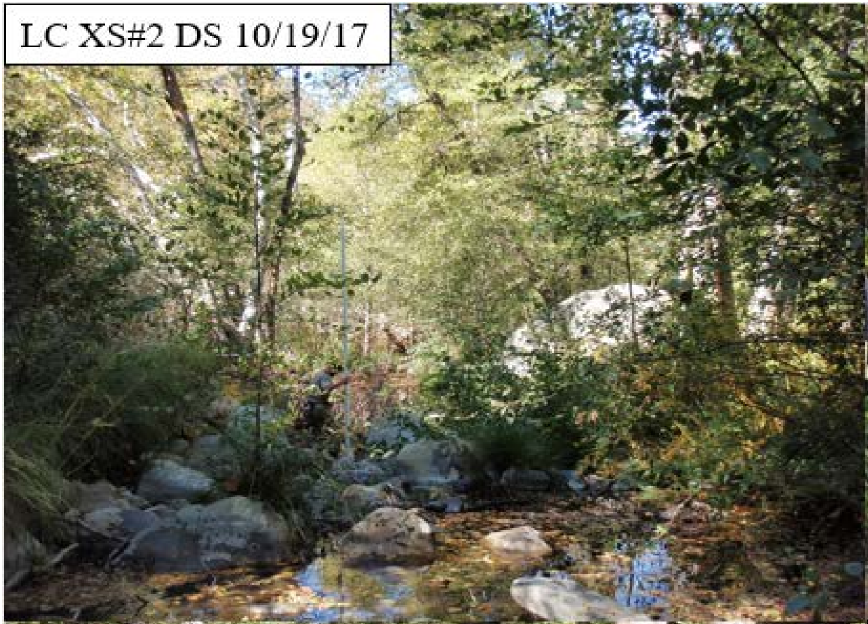
LC XS#1 RB-RP 10/19/17



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LC XS#2 RB-LB 10/19/17

LC XS#2 LB-LP 10/19/17

LC XS#2 RB-RP 10/19/17

LC XS#2 LP 10/19/17

LC XS#2 RP 10/19/17

TCFD#7 US 10/7/15

TCFD#7 DS 10/7/15

TCFD#7 RB 10/7/15

TCFD#7 LB 10/7/15

TCFD#9 US 10/7/15

TCFD#9 DS 10/7/15

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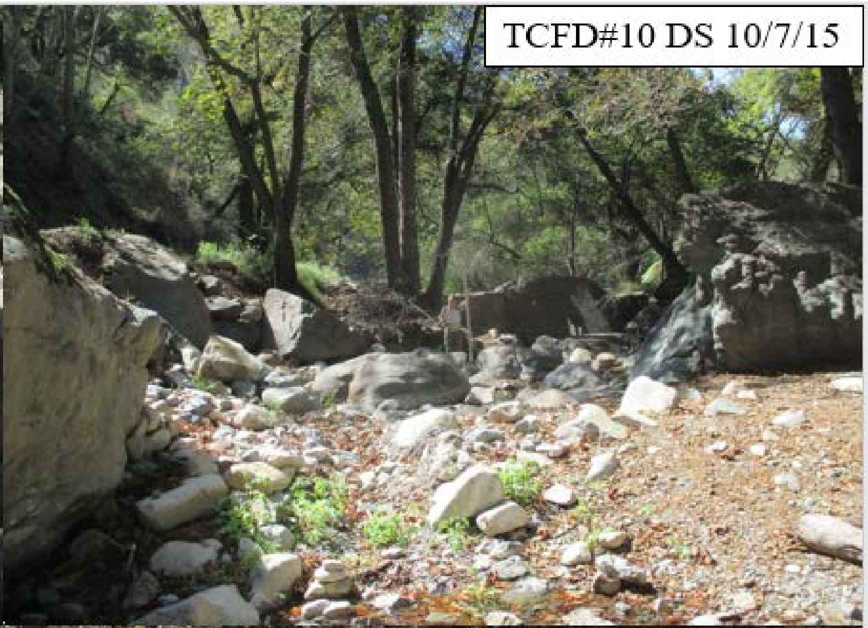
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TCFD#10 LB 10/7/15


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TCFD#11 DS 10/7/15


TCFD#11 LB 10/7/15


TCFD#11 RB 10/7/15

TCFD BM #1 US 10/16/15

TCFD BM #1 DS 10/16/15

TCFD BM #1 Above 10/16/15

TCFD BM #1 from road 10/16/15

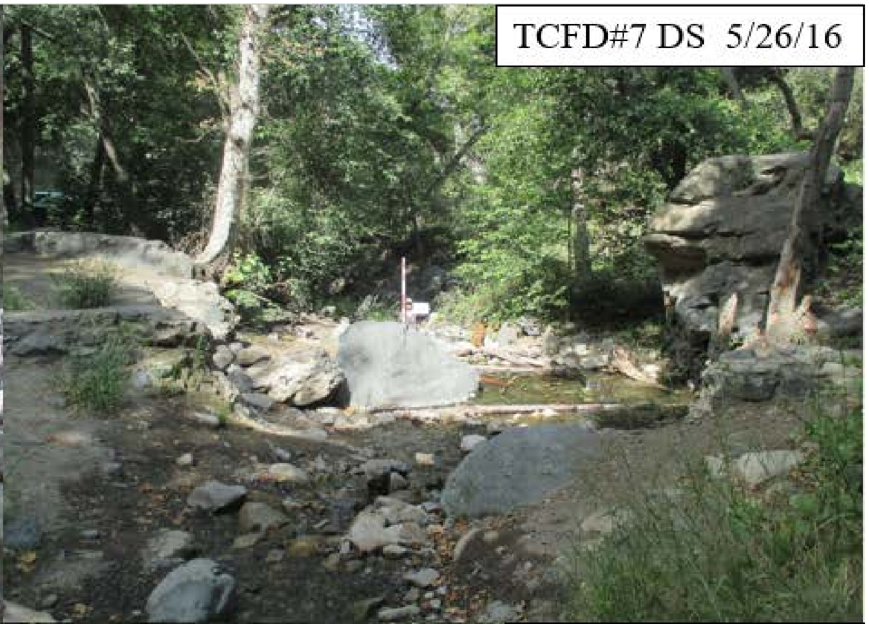
TCFD BM #2 US 10/16/15

TCFD BM #2 DS 10/16/15

TCFD BM #2 Above 10/16/15

TCFD BM #2 from road 10/16/15

TCFD#7 US 5/26/16



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TCFD#7 RB 5/26/16

TCFD#7 LB 5/26/16

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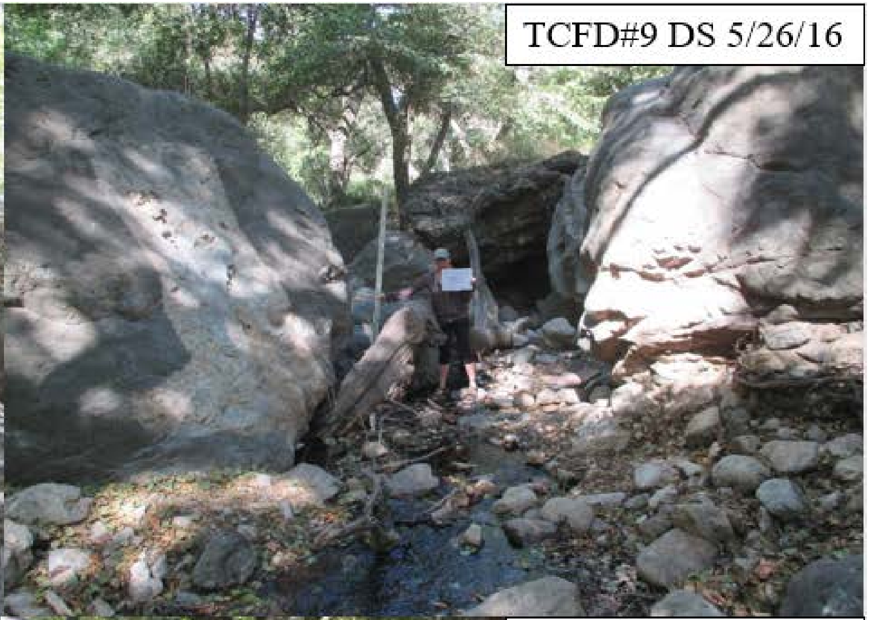

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TCFD#9 RB 5/26/16

TCFD#9 LB 5/26/16


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TCFD#10 DS 5/26/16


TCFD#10 RB 5/26/16


TCFD#10 LB 5/26/16


TCFD#11 US 5/26/16


TCFD#11 DS 5/26/16


TCFD#11 RB 5/26/16


TCFD#11 LB 5/26/16


TCFD#7 US 10/24/17


TCFD#7 DS 10/24/17


TCFD#7 RB 10/24/17


TCFD#7 LB 10/24/17


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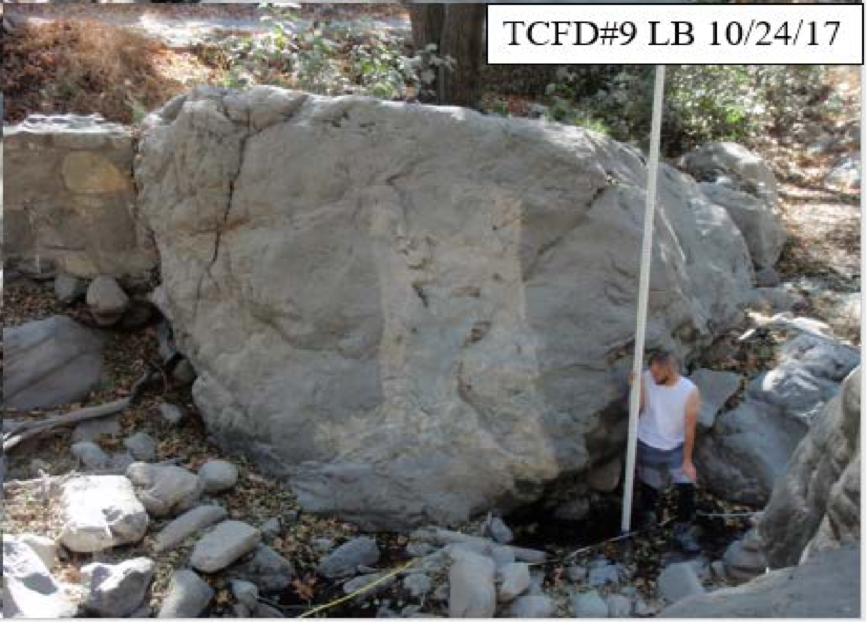
TCFD#9 RB 10/24/17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TCFD#11 US 10/24/17


TCFD#11 DS 10/24/17


TCFD#11 RB 10/24/17


TCFD#11 LB 10/24/17


TCFD BM#1 US 10/24/17


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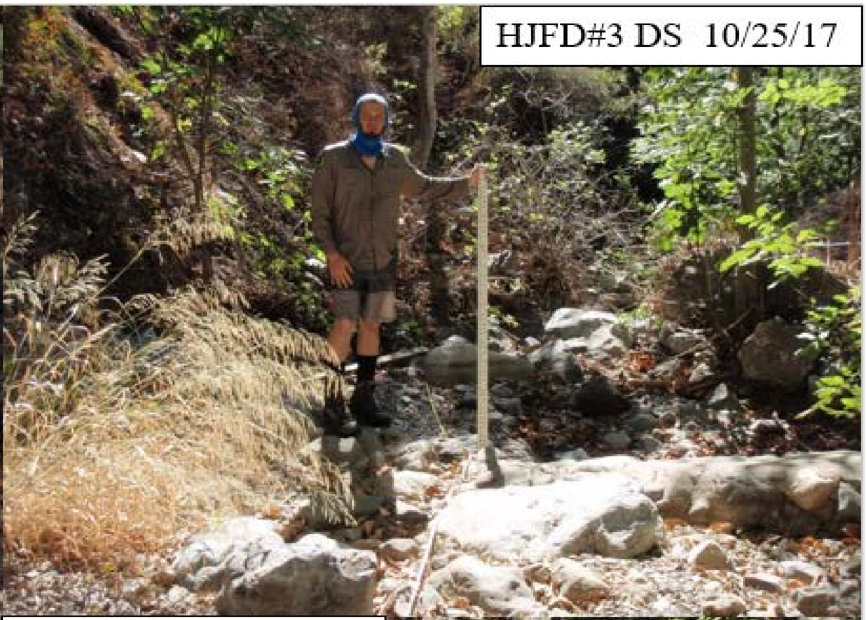
TCFD BM#1 RB 10/24/17


HJFD#3 US 10/25/17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HJFD#3 RB 10/25/17

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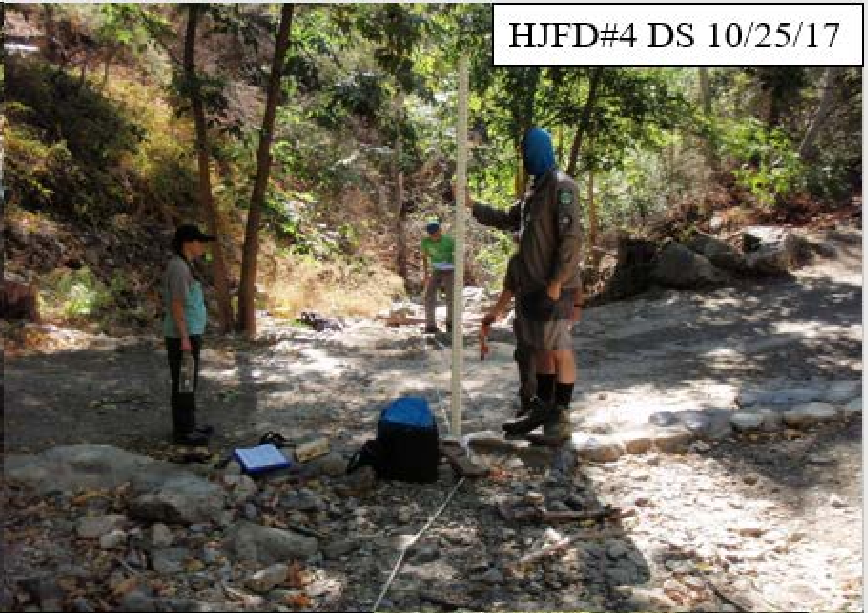
HJC AZ#2 LB 10/25/17

HJC AZ#2 RB 10/25/17


HJFD#4 US 10/25/17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HJFD#5 DS 10/25/17

HJFD#5 LB 10/25/17

HJFD#5 RB 10/25/17


HJFD#6 US 10/25/17


HJFD#6 DS 10/25/17


HJFD#6 LB 10/25/17


HJFD#6 RB 10/25/17

HJC BM#1 LB-RB 10/25/17

HJC BM#1 10/25/17

HJC BM#1 10/25/17

HJC BM#2 10/25/17


HJC BM#2 DS 10/25/17


HJC XS#1 US 10/26/17


HJC XS#1 DS 10/26/17


HJC XS#1 RP-LB 10/26/17


HJC XS#1 LP 10/26/17


HJC XS#2 US 10/26/17


HJC XS#2 DS 10/26/17


HJC XS#2 RP-LP 10/26/17

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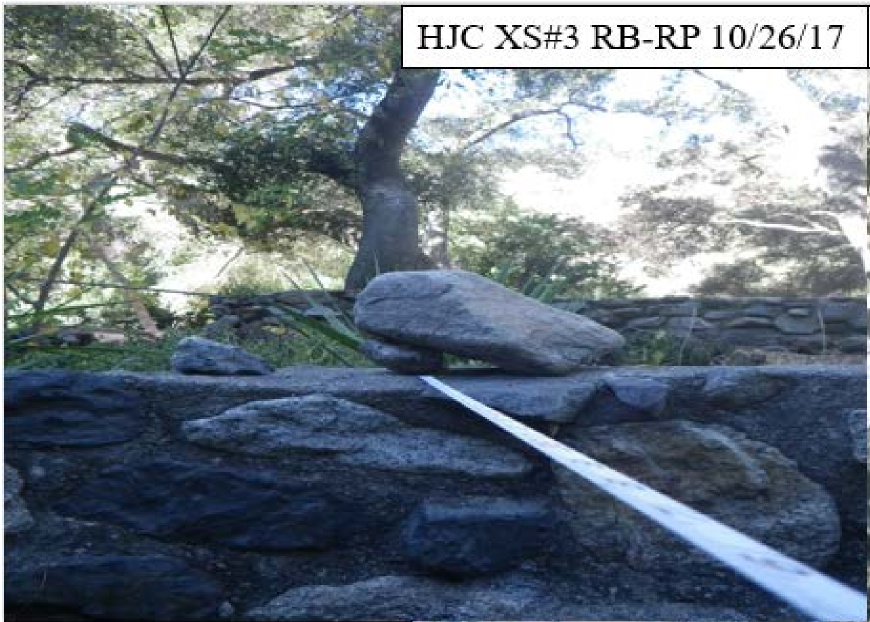
HJC XS#3 DS 10/26/17

HJC XS#3 LP-RB 10/26/17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HJC XS#4 US 10/26/17


HJC XS#4 DS 10/26/17


HJC XS#4 LB-RB 10/26/17

HJC XS#4 Road-LP 10/26/17

HJC XS#5 US 10/26/17

HJC XS#5 DS 10/26/17

HJC XS#5 RB-LP 10/26/17


HJC XS#5 LP-RB 10/26/17


HJC XS#6 US 10/26/17


HJC XS#6 DS 10/26/17


HJC XS#6 LP-RP 10/26/17


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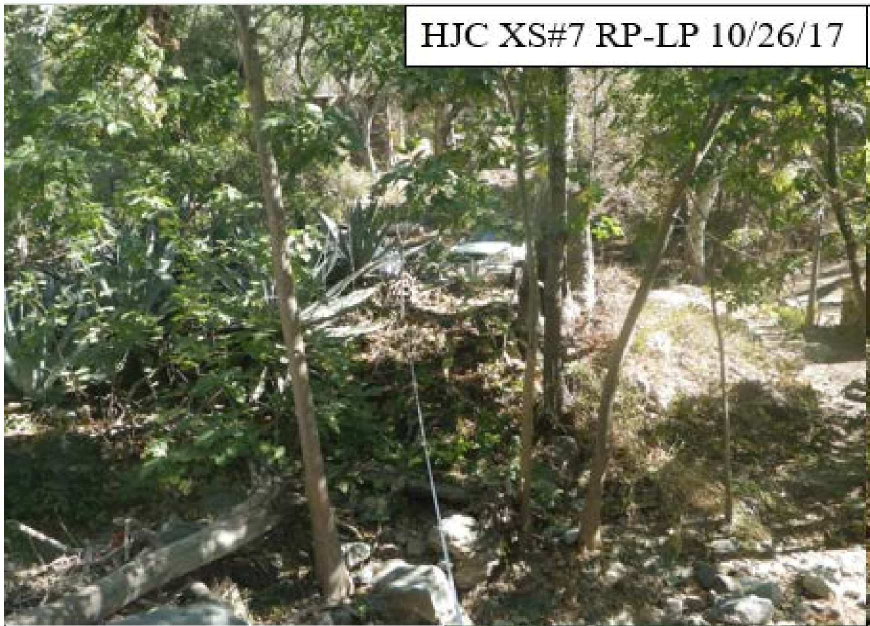

HJC XS#7 RP-LP 10/26/17

HJC XS#5-6 DS 10/26/17

HJC XS#5-6 US 10/26/17

HJC AZ#2 US 10/26/17

Appendix II

Data Requirements for Small Dam Removal Projects under NMFS Southern California Programmatic Biological Opinion.

1.3.4 Data Requirements

This section describes the data and required analyses that project applicants must provide to the RC and the Corps to evaluate if the proposed restoration project is a covered Program activity. These data requirements were taken directly from the BA (Suscon 2015).

Small Dam Removal Data Needs. —Listed below are the minimal and potential data needs for conducting any small dam removal project. However, site specific conditions may require additional information beyond what is identified here to adequately evaluate a small dam removal project. Similarly, unanticipated complications in a project such as the need to use a roughened channel and/or other fish passage techniques to pass fish over buried infrastructure (e.g., gas, water, and sewer lines) will require additional data. The minimal data needed to conduct a small dam removal project, along with the potential data needs for a more complex project, are listed below.

A. Minimal Data Requirements

1) A clear statement of the steelhead passage objectives of the project. Objectives shall be explicitly stated for any small dam removal project (e.g., to improve steelhead passage, improve sediment continuity and downstream spawning habitat, and/or to provide passage meeting specific steelhead passage guidelines).
2) A clear statement and justification for the project's method of restoring the channel along with a sediment-management plan.
3) The proposed time-frame for dam and sediment removal along with the time expected for channel equilibrium to occur at the project site. Include anticipated and actual start and end dates of project.

4) The distance and location of nearest upstream grade-control feature (natural or anthropogenic).

5) An estimate of depth, volume and grain size distribution of sediment stored above the dam. Evidence that the amount of sediment to be released above the dam is relatively small and unlikely to significantly affect downstream spawning, rearing, and/or over-summering habitats. The estimate should be determined with a minimum of five cross-sections - one downstream of the structure, three through the reservoir area upstream of the structure, and one upstream of the reservoir area outside of the influence of the structure - to characterize the channel morphology, quantify sediment grain size distribution and quantify the stored sediment. Wolman pebble counts (Harrelson et al 1994 and Kondolf 1997) should be used to characterize the sediment quality (i.e., grain size distribution) above and below the dam along the same five cross-sections used to quantify the stored sediment.

6) Detailed information on project/reference reach including:

- Location of project/reference reach.
- Channel width (baseline and target range in feet): Should be determined by taking three measurements of active channel at the dam and immediately upstream and downstream of the dam.
- Any existing geomorphic features present and that will be incorporated into the channel (e.g. pools, riffles, runs, step-pools, etc.).
- Overall channel slope (% baseline and target): determined by taking a longitudinal profile throughout the project reach upstream and downstream to the extent of dam influence on the channel slope.

- Maximum channel slope: determined through the site before and after the project using pre-project and as-built (post-project) longitudinal profiles
- Photographs of pre and post project conditions, illustrating implementation of the dam removal, upstream sediment deposit/reservoir, and channel morphology upstream and downstream of the proposed project reach.
- Maximum jump height (baseline and target range in inches): using the pre-project and/or as built longitudinal profile to determine the maximum height a fish would have to jump to migrate through the site.

7) A longitudinal profile of the stream channel thalweg for at least 20 channel widths upstream and downstream (pre and post project) of the structure or of a sufficient distance to establish the natural channel grade, whichever is greater, shall be used to determine the potential for channel degradation (as described in the CDFW Restoration Manual).
8) Post construction monitoring results: based on a post-implementation survey, the applicant should provide as-built conditions of channel width, channel slope, and maximum jump height.
9) The number of stream miles blocked by each small dam project should be estimated before removal and verified as steelhead accessible after project completion. The following sources may be used to verify the number of upstream miles made accessible as a result of the project: exiting aerial photos and maps of the project watershed, local or regional barrier databases, existing staff or local expert knowledge of project watershed, and/or field verification (in cases where there is permission to access the stream).

10) Operation and maintenance costs: Determine the expected operation, maintenance and/or liability costs over the next 5 years of the dam's operation if the dam were to remain in place. Periodic or less frequent costs that may occur during this period (e.g. structural upgrades to meet safety or regulatory requirements may be incorporated into this estimate). Determine the expected operation, maintenance and/or liability costs over the next 5 years if the dam is removed. Provide a comparison of these two estimates.
11) A survey of any downstream spawning areas that may be affected by sediment released by removal of the dam.
12) Surveys to assess presence of steelhead. The surveys will be stratified according to pre-implementation and post-implementation for a particular habitat-improvement activity, as described more fully below.

Pre-implementation: Under the proposed action, one of the following survey techniques, defined in California Coastal Salmonid Population Monitoring: Strategy, Design, and Methods (Adams et al. 2011), will be used to identify and report presence/absence for either adults or juveniles upstream of the project site. Describe the survey techniques used to determine presence/absence status of steelhead. If a pre-implementation survey is not possible, report whether the barrier is a known full barrier or partial barrier for steelhead. Describe any pre-project data that is available. If no recent, biological information is available, include surrogate information (e.g. most recent observation of species above barrier, description of "completeness" of barrier, etc.)

Post-implementation: If the pre-implementation status was determined to be "absent," use one of the survey techniques to identify and report presence/absence following implementation. If pre-project upstream status was determined to be “present” (e.g. partial barriers), report any change in presence/absence following implementation. In this case, the post-implementation result may be “continued presence." Describe the methodology used to determine presence/absence for the target fish species. Frequency /duration of sampling: The timing and frequency should correlate with the life history of the target fish species. At a minimum, this parameter should be monitored one time following implementation, and if funding allows, would preferably be monitored on an annual or seasonal basis. Monitoring for this measure is likely to yield meaningful results in the first 3 years after project implementation, although in some situations it may be valuable to monitor for the first 5 years. Once target fish presence is detected upstream of the project site post-implementation, monitoring for this measure is complete. Optional monitoring: for partial barriers or projects where the pre-implementation fish presence/absence status was identified as "present," the proportional change in the number of adults or juveniles due to project implementation may be measured.

B. <u>Potential Data Needs for Complex Small Dam Removal Projects</u>

1) Hydraulic modeling immediately upstream and downstream of the project site, and throughout the project reach.
2) Sediment modeling immediately upstream and downstream of the project site, and throughout the reach of the stream in which the project is located, including: Sediment grain size distribution within the dam depositional area and the sediment grain size distributions of the channel bed material within the equilibrium reaches upstream and

downstream of the dam; recurrence interval of the discharge needed to mobilize the sediment particles and any established vegetation within the sediment deposit upstream of the dam that is to be removed; And bed and bank grain size distributions.

3) A detailed geomorphic assessment of the watershed and/or stream reach.
4) A detailed hydrologic analysis of the watershed and how it will drive the geomorphic conditions within the watershed before and after dam removal.
5) A detailed assessment of the habitat conditions within the watershed and/or upstream and downstream of the reach of the stream in which the project is located.

1.3.4.1 More Complex Project Types Requiring Additional Oversight and Engineering Review

More complex project types covered by this programmatic consultation will require a greater level of oversight (e.g., engineering review) and review by the NOAA RC and Corps, which will consult with NMFS biologists and NMFS or CDFW engineers when appropriate. These project types involve (1) fish passage at stream crossings, (2) permanent removal of flashboard-dam abutments and sills, (3) removal of small dams involve special or complex conditions such as those in high risk areas (e.g. urbanized streams), dams in the lower portions of watersheds (where head cuts could be sent up multiple tributaries), and dams located in heavily incised channels, (4) debris basin removal, and (5) creation and/or connection of off-channel habitat features.