Two-Dimensional Modeling of the Ventura River

This fact sheet summarizes several unique challenges for 2D modeling in the Ventura River's Intermittent Reach, and describes California Department of Fish and Wildlife (CDFW) approaches to addressing those challenges.

The CDFW Instream Flow Program (IFP) employs two-dimensional (2D) hydraulic habitat models to assess relationships between instream flows and fish habitat needs (see our 2D modeling fact sheet: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=209086&inline). The IFP has developed 2D models to estimate water depths and widths needed for salmonid passage through depth-sensitive areas of the Big Sur River in Monterey County (Holmes et al. 2015) and Butte Creek in Butte County (Cowan et al. 2016). 2D modeling is advantageous for determining passage flows through complex low-gradient critical riffles because it can explicitly handle complex hydraulics, including transverse flows, across-channel variation in water surface elevations, and flow contractions and expansions (Ghanem et al. 1996; Crowder and Diplas 2000; Pasternack et al. 2004).

2D models were also used to assess flows expected to enhance passage conditions for Southern California steelhead in the Ventura River, in response to the California Water Action Plan (CNRA et al. 2014). The Intermittent Reach of the Ventura River is an important migration route for steelhead that migrate to tributaries in the upper watershed to seek cooler, perennial flows (Figure 1). The Intermittent Reach is dry most of the year; hydrology consists of intense, short duration rainstorms that produce what are commonly referred to as flashy storm events.

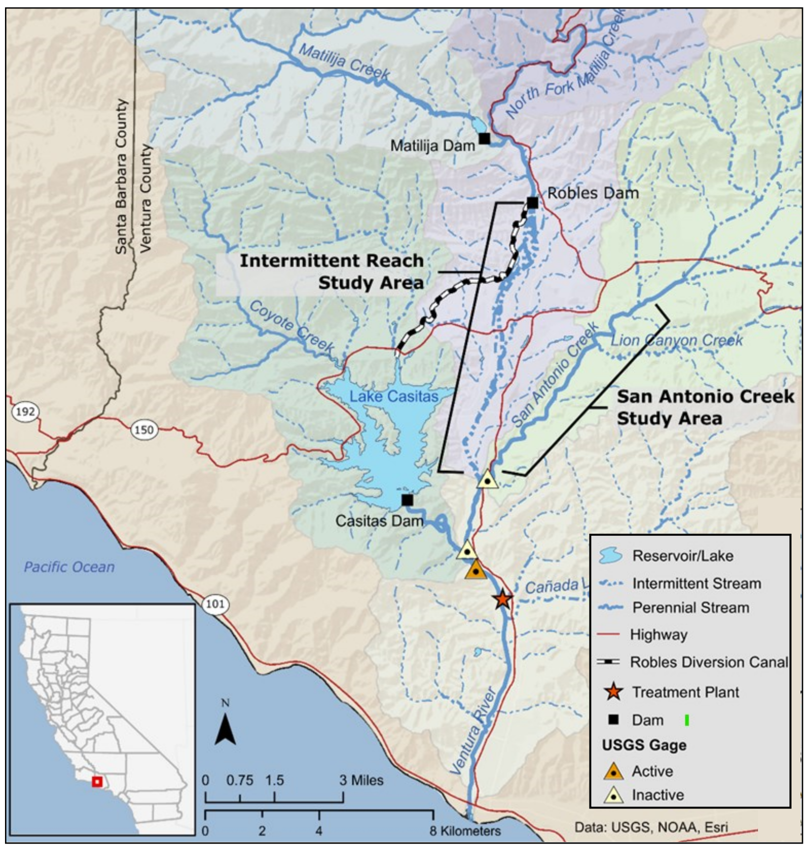

Figure 1. Ventura River watershed map. The study area is marked by the dashed blue line indicating an intermittent stream reach.

Challenge #1: Data Collection

The Intermittent Reach of the Ventura River is not only an important migration route for steelhead, but is also a very challenging section of river for developing 2D models. The development of predictive 2D hydraulic models requires that flow (i.e., discharge) and water level data be collected over a range of predetermined target flows. High intensity, short duration storm events can make data collection difficult.

Discharge is estimated by measuring the average water column velocity across a transect in a portion of the river where flow is perpendicular to the general downstream direction and not over-turbulent (CDFW 2020). Discharge measurements are made by staff members wading into the stream. It was difficult for staff to plan discharge data collection events in the Ventura River because target flows were only present for brief time periods. Staff also found flows over approximately 100 cfs were too swift and posed a wading hazard when trying to collect discharge measurements.

Challenge #2: Channel-Forming Flow Event

Water level was measured continuously by installing pressure transducers (PTs) in protective plastic vaults along boundary condition transects (Figure 2).

Figure 2. Pressure transducer installed in the stream bed to monitor water level.

During data collection in February 2017, a channel-forming flow event with a peak flow of approximately 18,000 cfs (Figure 3) ripped through the Intermittent Reach. The channel-forming flow event buried or dislodged the PTs that were installed at the upstream and downstream boundary transects of the site (Figure 4). Staff worked tirelessly to recover as many of the probes as possible.

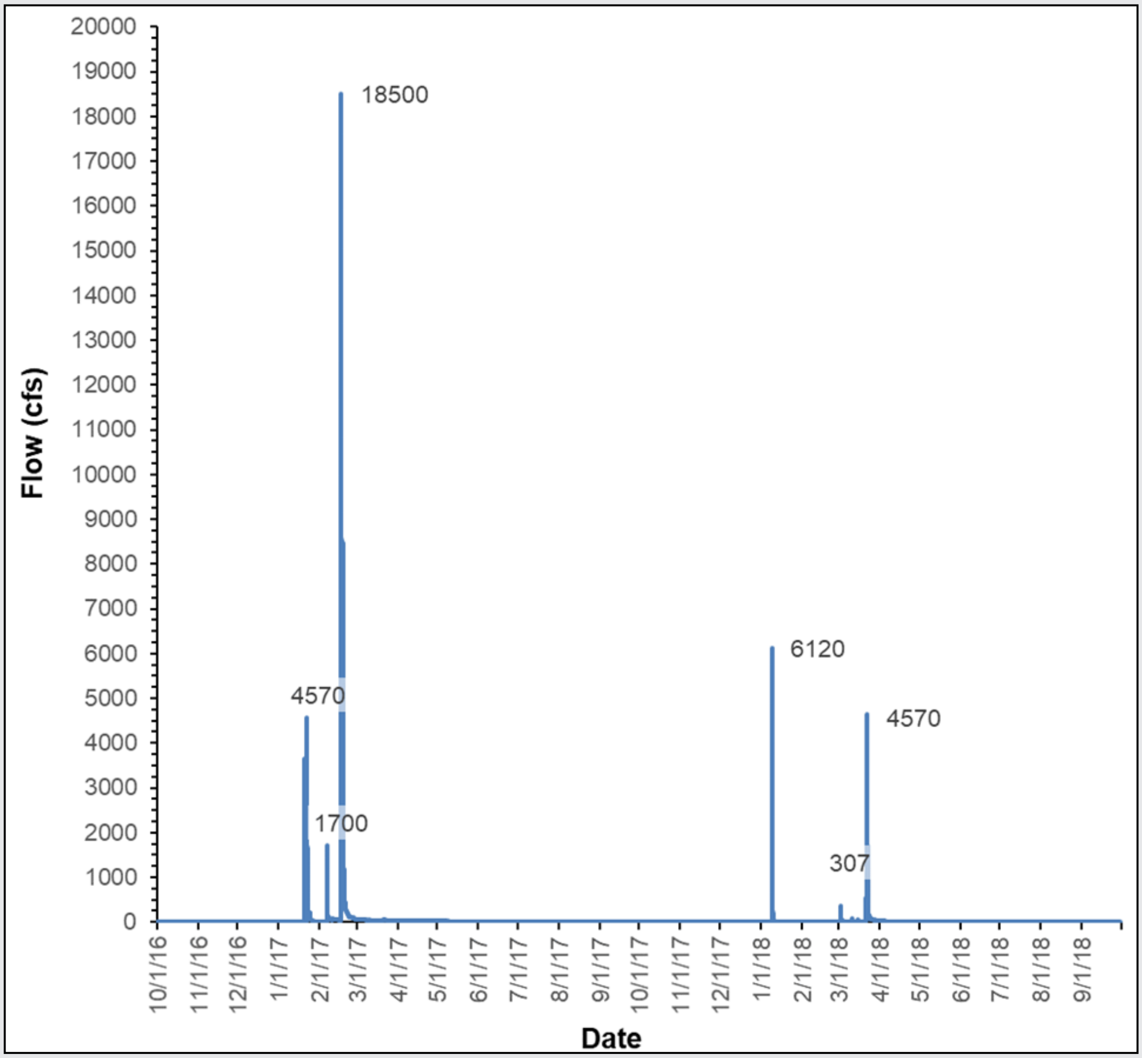

Figure 3. Flows recorded in the Ventura River at Foster Park (USGS 11118500) during water years 2017-2018.

Figure 4. Channel-forming flow event on February 17, 2017.

Challenge #3: Spatial Scale

Another complicating factor in developing the 2D model was the spatial scale of the required study site. The Intermittent Reach contains many depth-sensitive critical riffles that pose challenges for fish passage, as flows are spread throughout a triple-braided portion of the river channel (Figure 5).

A requirement of a 2D model is that the upstream and downstream boundaries (where flows enter and exit the model) be single-thread channels. A study site length of approximately 1.3 miles was required (Figure 6) to maintain a single-thread channel at the entry and exit of the 2D model and capture the portion of the Intermittent Reach where critical riffles were previously identified. The minimum site length for a 2D model to be considered representative is 4% of the study reach length (USFWS 2011). The resulting study site was 22% of the total length of the Intermittent Reach.

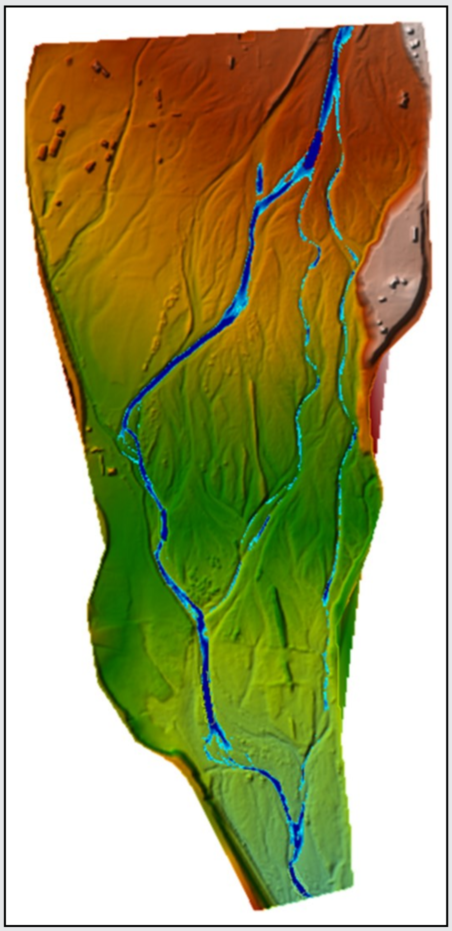

Figure 5. A digital representation of the depth-sensitive area of the Intermittent Reach displaying the three main distributaries.

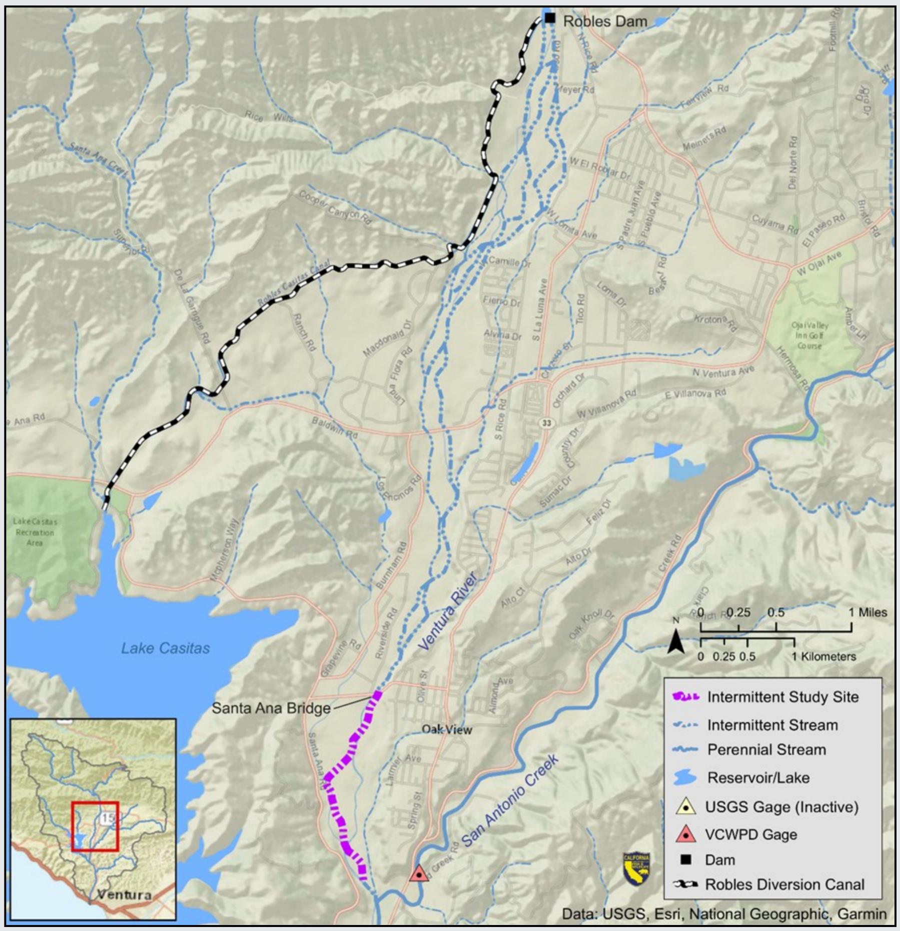

Figure 6. Location of the Ventura River Intermittent Reach study site.

Challenge #4: Critical Riffle Survey

The performance of a 2D model to predict water depth and width is dependent upon the resolution of the stream bed topography entered into the model. A higher frequency of points must be collected in complex portions of the streambed. The streambed of the Intermittent Reach is dominated by cobble and boulder substrates (Figure 7).

Figure 7. Intermittent Reach cobble- and boulder-sized substrates.

A critical riffle survey was conducted in April 2017 under low-flow conditions to assess which stream braid would be the most viable for fish passage. The west side of the river was found to remain hydraulically connected from the top to the bottom of the site as flows receded. Staff walked upstream through the west side channel and surveyed the shallowest course from bank to bank of each riffle encountered using a real-time kinematic global positioning system (RTK-GPS) device (Figure 8).

Figure 8. Ventura River Intermittent Reach critical riffle survey.

A total of 22 critical riffles were surveyed for 2D model analysis (Figure 9).

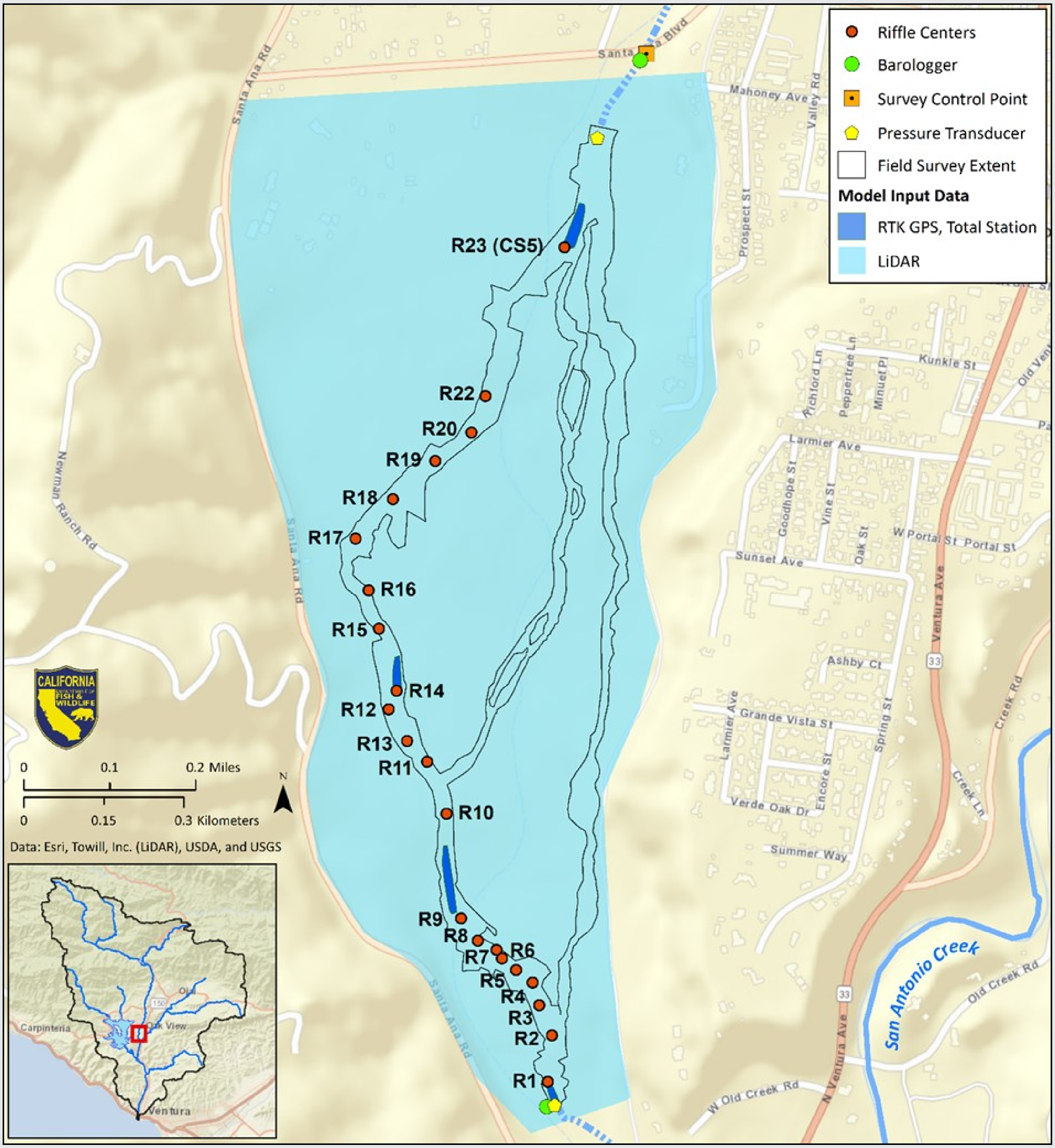

Figure 9. Ventura River Intermittent Reach fish passage study site.

Success #1: Pre-Storm and Post-Storm Models

Two elements of the 2D model data collection had not been completed prior to the channel-forming flow event in February 2017: the critical riffle location survey and the measurement of randomly located depths to validate the model. The decision was made to complete a second, Post-storm topographic survey to account for the changes in the stream bed structure and that would be directly applicable to the timing of critical riffle and model validation data collection. Surveying the Post-storm study site started in November 2017. Five separate trips to the study site were needed to survey the Post-storm site, and concluded in June 2018.

Figure 10. Ventura River Intermittent Reach Post-storm topographic survey.

The resulting topographic survey point density was one point per 6.2 m^2 (0.2 points/m^2). To save time, staff only surveyed the instream channel of the three main braids. An existing 3-m resolution light detection and ranging (LIDAR) study from 2005 (Airborne 1 2005) was used to represent the over-bank areas. Ideally, the 2D model data collection would go as follows:

1. The flow/WSEL rating relationship would be developed from the receding limb of a routine storm.

2. The streambed topography would be captured immediately as a super high-resolution snapshot before any other storm events passed through that could possibly alter the streambed structure.

Over the course of the topographic survey, several storm events moved through the study site (Figure 3). The only storm events in the 2017-2018 water year occurred in January 2018 with a peak of approximately 6,000 cfs and March 2018 with a peak of approximately 4,000 cfs. The storm events occurred in the middle of when the Post-storm topographic survey was conducted. While those events did not meet the flow magnitude threshold to be considered channel-forming, the flows may have caused some of the bed load to be mobilized and lead to some minor rearranging of the bed structure within the site while the topographic survey data collection was occurring.

Success #2: High-Resolution LIDAR

The California Department of General Services contracted with Towill, Inc. to complete an airborne LIDAR flight of the Ventura River watershed to help account for the impacts of the December 2017 Thomas Fire and Montecito Debris Flow events. The airborne LIDAR data collection occurred from January 30 to February 3, 2018 (Figure 3).

The LIDAR data were collected at a very high resolution of 0.25-m^2 cells and a very high-quality level (referred to as QL-1 or quality level one; Towill Inc. 2018). Once the raster-based dataset was made available on the Ventura County Watershed Protection District's public maps data webpage (i.e., https://vcwatershed.net/publicMaps/data), IFP staff downloaded the study site portions for use in developing the 2D digital terrain model (DTM). The difference in streambed resolution between the DTM generated from the QL-1 LIDAR data and the field based topographic survey data was appreciable (Figure 11).

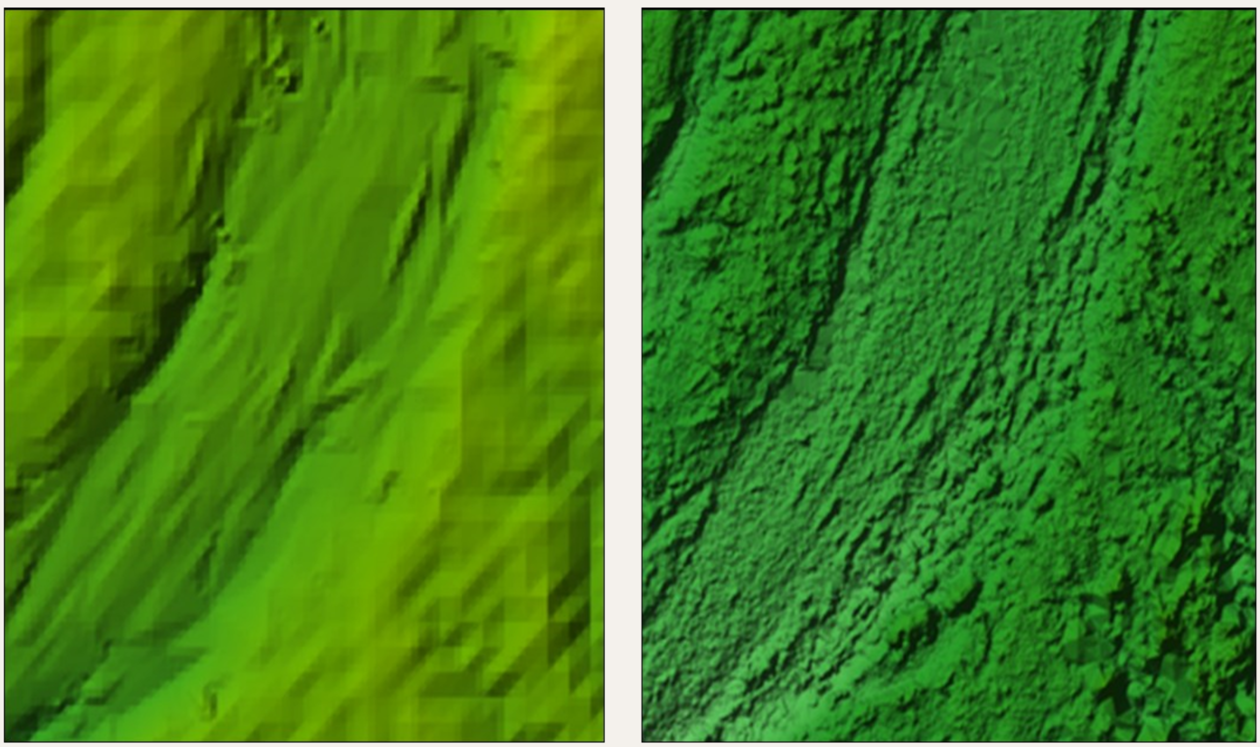

Figure 11. DTM generated from field survey points and 2005 3-m LIDAR (left) compared to 2018 0.25-m QL1 LIDAR (right).

The final DTM used to assess passage in the Intermittent Reach was a composite composed primarily of the LIDAR data with localized patches of topographic survey data grafted into pool areas where the topographic survey resolution was superior. Figure 9 indicates where the LIDAR (light blue) and patches of topographic survey data (dark blue) were used.

Success #3: Identifying Steelhead Passage Flows

2D models provided a valuable tool to identify passage flows for Southern California steelhead in the complex and braided Intermittent Reach of the Ventura River. As expected, the Pre-storm and Post-storm DTMs produced differing 2D flow simulation results largely due to the higher-resolution LIDAR data used in the Post-storm model. The Post-storm model revealed more avenues between the large cobble- and boulder-sized substrates for fish passage than the Pre-storm model could detect.

The IFP used the results of the 2D hydraulic modeling and the critical riffle surveys to identify flow magnitudes required to meet passage depth and width criteria expected to enhance steelhead passage through the most depth-sensitive critical riffles in the Intermittent Reach. The relationship between the modeled results of discharge and width meeting the depth criteria for adult steelhead passage were plotted in Figure 12. For more details on the background, methods, and results of the passage study, please see *Instream flow evaluation: Southern California steelhead passage through the intermittent reach of the Ventura River, Ventura County* (CDFW 2021; https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=195755&inline and https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=195756&inline).

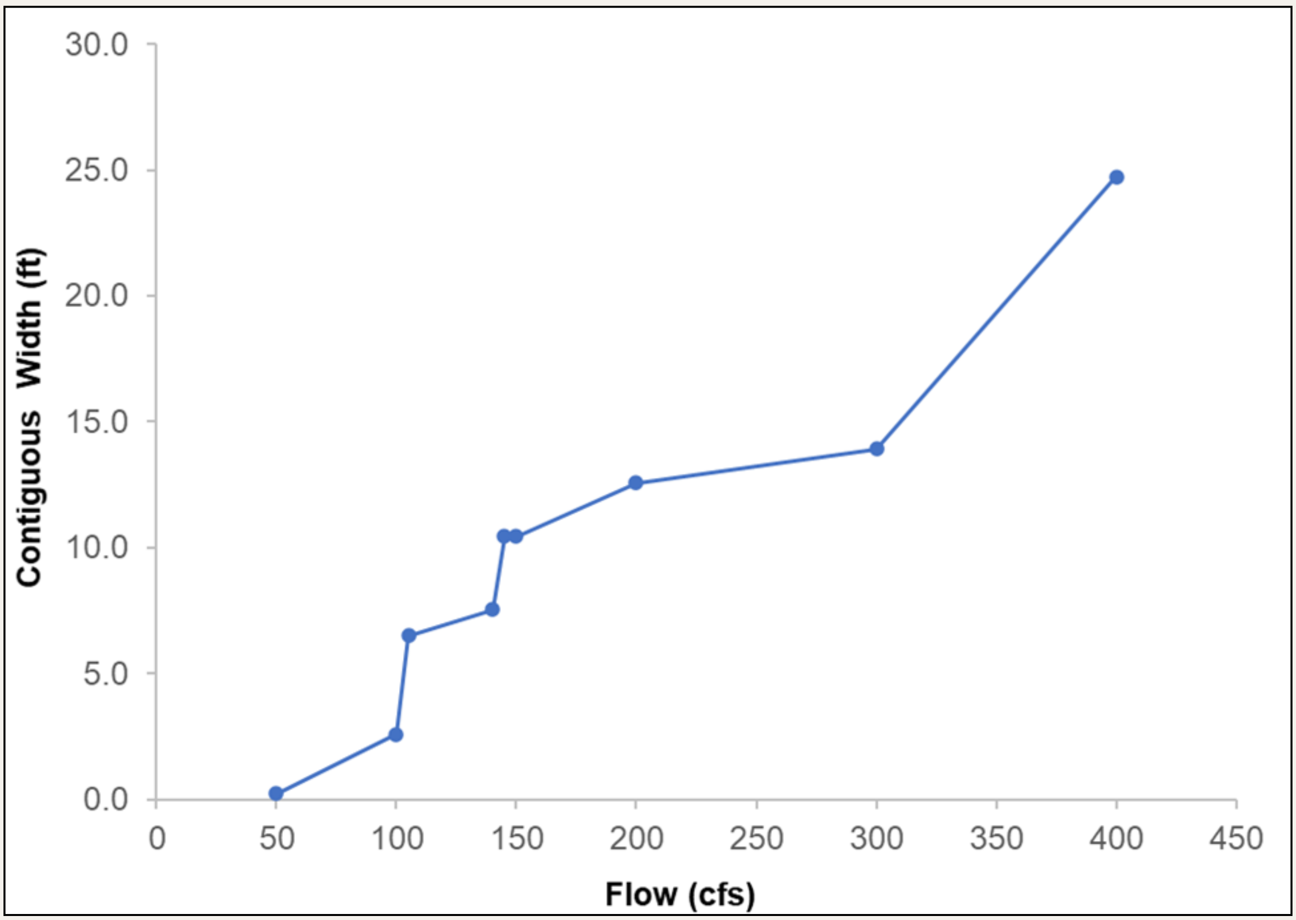

Figure 12. Flow versus contiguous width at the most depth-sensitive portion of the Ventura River study site.

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