Appendix E. Roman Creek Hydrology and Hydraulics Memorandum

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Roman Creek Hydrology and Hydraulics – Proposed and Existing Conditions

City of Vista: Roman Creek (CIP 8188)

Vista, CA
May 27, 2020

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1 Background

The City of Vista (City) is proposing the Roman Creek Mitigation and Habitat Restoration Project (Project), which is a combined hydromodification and habitat restoration improvement project within the limits of Buena Vista Park (Park), located in the City of Vista, California. Buena Vista Park is owned by the City and managed by the City's Parks Maintenance Division, Public Works. According to the City's General Plan (2030), Buena Vista Park contains both active use areas and areas intended for the permanent conservation of natural resources. In conjunction with the City's 2030 General Plan Update, the City adopted a Biological Preserve Overlay (BPO) with the primary purpose of conserving the City's biological resources. The BPO was adopted to restrict land uses to only limited passive recreational uses where protection of those resources is ensured, or those uses are required to protect public health and safety.

Since the preparation of the Agua Hedionda Watershed Management Plan (WMP) in 2008 (Tetra Tech 2008), the City has contemplated the implementation of the Project so as to provide multiple benefits in terms of mitigating existing hydromodification within the watershed and supporting the compensatory mitigation needs for individual City sewer projects. In 2012, the City prepared a preliminary mitigation concept for an off-channel basin in the southwest corner of Buena Vista Park. At the time, the goal of the mitigation concept was to provide a source of potential wetland and riparian habitat mitigation credits for impacts contemplated under the City's 2012 Sewer Master Plan. Following agency feedback, the initial concept was abandoned.

In 2018, the City decided to expand the mitigation concepts in the Sewer Mitigation Program (SMP) to include additional portions of Buena Vista Park to consider other habitat establishment (or creation), rehabilitation, and enhancement opportunities. The contemplated mitigation opportunities for the Roman Creek Mitigation Site (or project) include proposed in-channel mitigation concept designed to address strategies identified in the Carlsbad Watershed Management Area Water Quality Improvement Plan (May 2018), specifically, improvements to hydromodification and improvement of channel habitat structure and function.

The purpose of this technical memorandum is to document the hydrologic and hydraulic analyses for existing conditions in Roman Creek, present results for the proposed condition, and provide initial conclusions to support regulatory permitting and the design process.

2 Previous Studies

The following represents a brief summary of previous mitigation and/or hydrologic and hydraulic studies that have been completed for Roman Creek.

- Agua Hedionda Watershed Management Plan (WMP - 2008), Tetra Tech – Signs of degradation (i.e. channel modification due to watershed development, erosion, incising, etc.) and loss of natural habitat have been observed within the Agua Hedionda watershed. In order to address such concerns, the WMP was developed to "preserve, restore, and enhance the watershed's natural functions and features". The WMP provides recommended actions to address priority issues identified in the watershed conditions and trends assessment.

- Drainage Master Plan Update (2009), Dudek – This report inventories the City of Vista's drainage facilities, analyzes hydrologic and hydraulic characteristics, evaluates the condition of drainage conveyance system, and performs capacity analysis, and identifies recommended actions, projects and costs estimates.

- Erosion Susceptibility Analysis of Roman Creek for 1525 Buena Vista Drive, Vista CA (2017) Tory R. Walker Engineering – This study evaluated Roman Creek's susceptibility to erosion for the upper portion of the Roman Creek watershed.

3 Project Mitigation Concept

The City is currently evaluating habitat mitigation concepts for the Project with the goal of obtaining regulatory approval from the Regional Water Quality Control Board (RWQCB), U.S. Army Corps of Engineers (USACE), and the California Department of Fish and Wildlife (CDFW). Following the completion of habitat mapping within western portions of Buena Vista Park, multiple riparian, streambed, and upland habitat mitigation opportunities exist that could provide a source of offsite compensatory mitigation for the City's sewer improvement projects.

For any habitat mitigation opportunity to be successful, a basic understanding of the site hydrology, channel hydraulics, and geomorphic context is required. In addition, the probable conditions for agency approval must be identified to facilitate implementation. In this context, the current mitigation strategy at Roman Creek emphasizes in-channel opportunities that would be phased under a long-term, adaptive management strategy. The ultimate goal is to avoid and minimize further degradation of the existing aquatic and riparian habitat along Roman Creek.

From a phasing perspective, existing hydromodification conditions and resulting flow velocities must be addressed to support any habitat revegetation strategy. Opportunities for channel widening, increased surface roughness, or inclusion of drop structures will be investigated using the results of this analysis to attenuate existing peak flows, provide variation in channel morphology and flow velocity, and a substrate suitable for plant growth. This may include the provision of additional flow paths (or channels) to decrease flow velocities at steeper sections of the channel profile while maintaining base flows within the existing channel.

Additional alternatives analysis may be conducted following selection of one or more habitat concept alternatives by the City for presentation and feedback by regulatory agencies.

4 Roman Creek Hydrology

The Roman Creek watershed is a tributary to Agua Hedionda Creek, which flows in a westerly direction and ultimately discharges into the Pacific Ocean via the Agua Hedionda Lagoon. The upper reaches of Roman Creek do not lie in a designated FEMA floodplain. For a distance of approximately 250 feet, the lower reach of Roman Creek is designated as a Zone A, where base flood elevations have not been determined. This area represents backwater from Agua Hedionda Creek. The FEMA flood designation of Agua Hedionda Creek varies by location. Upstream of Roman Creek, Agua Hedionda Creek is designated as a Zone AE floodplain, where base flood elevations have been determined. In the vicinity of the confluence with Roman Creek, Agua Hedionda Creek has a Zone A designation without base flood elevations. Refer to Figure 1 for a graphical illustration of the floodplain designations in the vicinity of the project.

Roman Creek generally flows in a southerly direction, and has a total drainage area of approximately 1.1 square miles to an outlet location near the project site. The Roman Creek watershed includes a relatively steep terrain and consists primarily of urban developed communities, in addition to a high school, an 18-hole golf course, and Buena Vista Park. The Roman Creek watershed is a densely urbanized and highly geomorphologically controlled creek for the majority of the upper-two thirds of the watershed, receiving stormwater runoff from residential and commercial areas (Tory Walker, 2017). The creek is conveyed via both hardened and unlined channels and passes through multiple grade controls at culverts before draining into the Buena Vista Park open space area (Tory Walker, 2017). Roman Creek exhibits a vegetated natural channel through Buena Vista Park, before discharging into Agua Hedionda Creek.

At the north end of Buena Vista Park, flows enter an engineered wet pond and with an outlet structure, commonly referred to as the duck pond (see Figure 1). Below the outlet structure, Roman Creek exhibits a vegetated natural channel through Buena Vista Park, before discharging into Agua Hedionda Creek. Two crossings intersect Roman Creek below the duck pond and include an existing pedestrian bridge and an access roadway that follows a water main owned by the San Diego County Water Authority (SDCWA).

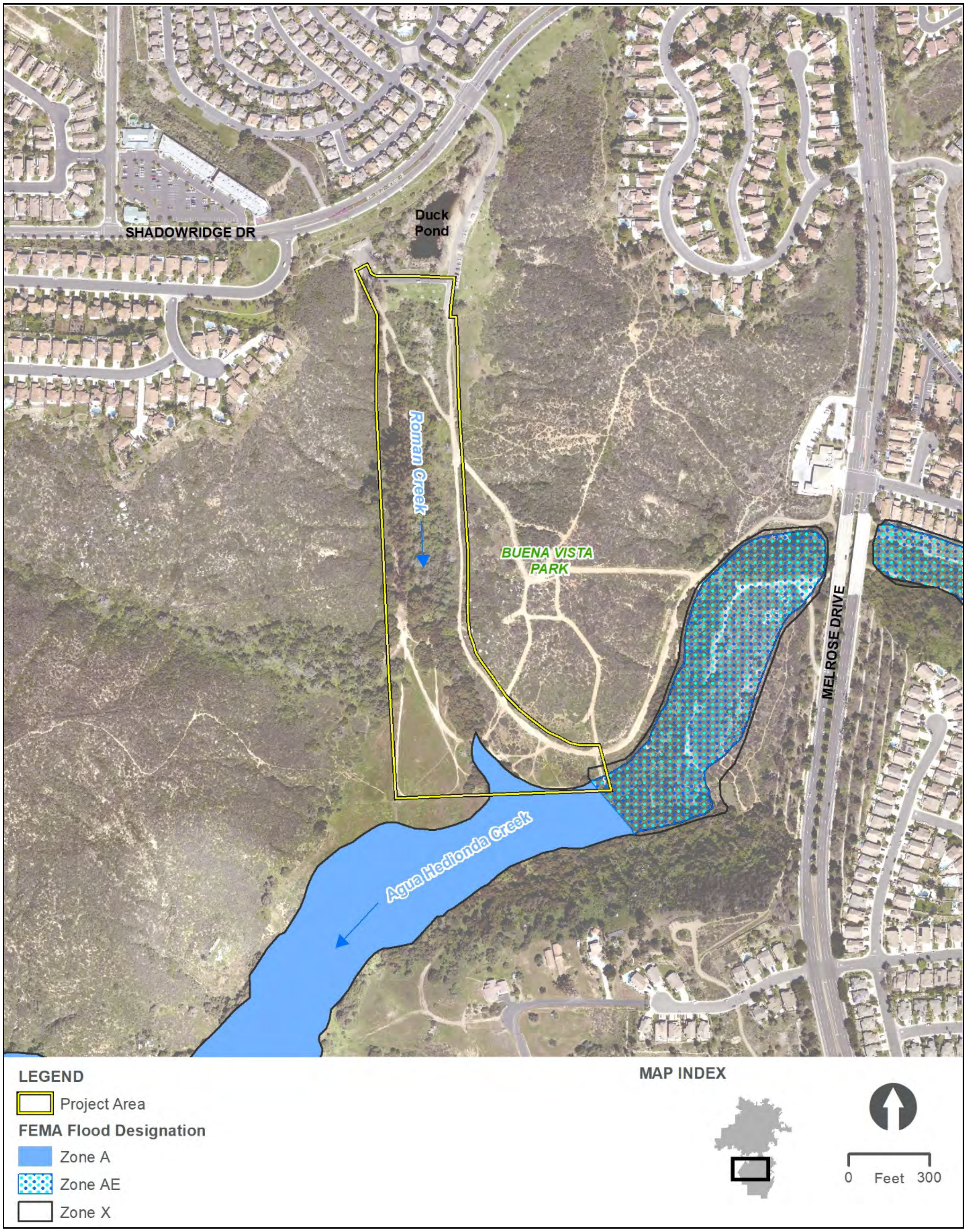


Figure 1. Effective FEMA Mapping

The hydrologic analysis for Roman Creek was generally performed in accordance with the 2003 San Diego County Hydrology Manual (SDCHM) procedures and guidelines. Per the SDCHM, the Soil Conservation Service (SCS) hydrologic method, now called the Natural Resources Conservation

Service (NRCS) hydrologic method, shall be used for watershed areas greater than one square mile. Hydrologic analysis for the Roman Creek watershed was prepared using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS) for the 2-, 5-, 10-, 25-, 50-, and 100-year storm events.

The watershed delineation was developed using United States Geological Survey (USGS) Light Detection and Ranging (LiDAR) data, published in 2017. Stormwater network linework provided from the City also helped inform the watershed delineations. The outer watershed boundary was further delineated into subwatersheds to provide reasonably representative subwatersheds based on slope, conveyance type, and general drainage characteristics. The watershed was subdivided into a total of seven subwatersheds for modeling purposes. Refer to Figure 2 for a graphical depiction of the subwatershed boundaries.

The SCS curve number method was used for the precipitation loss method per the SDCHM. The input requirements for the SCS curve number method include runoff curve number, impervious percentage, and initial abstraction. Input parameters were computed in accordance with the SDCHM and are summarized in Table 1. Land use data for the watershed was obtained from San Diego Geographic Information Source (SANGIS) and was adjusted as needed to represent current conditions.

The SCS Unit Hydrograph method was used for the transform method. Subwatershed lag time was computed using the Corps lag equation, per the SDCHM. Lag times are summarized in Table 1.

Table 1. Subwatershed Hydrologic Inputs

Subwatershed ID	Drainage Area (sq mi)	Initial Abstraction (in)		Curve Number		Lag Time (min)
		< 35-yr storm	> 35-yr storm	< 35-yr storm	> 35-yr storm	
A	0.286	0.28	0.19	87.8	91.5	8.9
B	0.155	0.14	0.09	93.3	95.5	7.5
C	0.163	0.19	0.13	91.3	94.0	7.2
D	0.122	0.20	0.13	90.9	94.0	5.3
E	0.262	0.23	0.15	89.5	93.0	6.3
F	0.075	0.44	0.30	81.8	87.0	5.1
G	0.052	0.62	0.42	76.3	82.5	4.3

The rainfall distribution adopted for the SDCHM is a nested storm pattern with a 2/3, 1/3 distribution, resulting in a peak of the storm at hour 16 of the 24-hour storm. The nested storm pattern as shown in the SDCHM is generally considered overly conservative. As a result, a balanced rainfall distribution pattern (1/2, 1/2) with the peak at hour 12 of the 24-hour storm was also evaluated in conjunction with the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation depths. The NOAA Atlas 14 precipitation depths are slightly lower (1-10%) than the depths provided in the SDCHM. Both rainfall distributions were evaluated as part of this project.

Routing between subwatersheds was evaluated using the Kinematic Wave routing method. Routing parameters, including flow path length, slope, roughness coefficient, channel dimensions (shape, bottom width, side slope), and pipe parameters (shape, diameter) were determined from aerial imagery, 2017 LiDAR data, and stormwater GIS linework provided from the City. The routing parameters for each routing reach are summarized in Table 2 and depicted in Figure 3.

Table 2. Routing Reach Inputs

Routing Reach ID	Description	Length (ft)	Slope (ft/ft)	Manning's n	Shape	Width (ft)	Sideslope H:V)	Diameter (ft)
1	60" RCP	806	0.011	0.013	Circular	-	-	5
2	48", 60", 72" RCP	1016	0.008	0.013	Circular	-	-	5
3	Open Channel	638	0.005	0.05	Trapezoidal	25	3	-
4	72" RCP	583	0.021	0.013	Circular	-	-	6
5	Open Channel	1482	0.012	0.06	Trapezoidal	10	5	-

An existing duck pond is situated at the upstream end of Buena Vista Park, which provides storage and flow reduction benefits. The duck pond is located downstream of Shadowridge Drive at the downstream end of subwatershed E. The duck pond was evaluated in the HEC-HMS model with an outflow curve, and the storage method was entered as elevation-storage-discharge. The elevation and storage information was based on the 2017 LiDAR data as storage information was not available on as-built drawings. An outflow storage curve was developed based on as-built drawings. The outflow structure consists of a 24" RCP low flow pipe, a 12-foot wide low flow notch, and a 64-foot wide overflow weir. Flow from the outflow structure discharges into an 8-foot x 7-foot RCB beneath the roadway and south into Roman Creek. The pond sustains a permanent pool, and as a result the starting elevation of the pond was based on the elevation collected during the time the LiDAR data was collected and the low flow 24" RCP within SDCWA's access roadway was assumed to be blocked. Outflow from the pond overtops the access roadway during large rainfall events. The resulting outflow curve is depicted in Figure 4. Based on the elevation in the pond at the time the LiDAR data was collected, the storage volume available in the pond is approximately 10 ac-ft before it overtops the downstream access roadway. The rating curve between elevations 341 and 344 is limited by pressure flow through the 8-foot x 7-foot RCB. Discharge increases once flow overtops the roadway above elevation 344.

Figure 2. Roman Creek Drainage Area Map

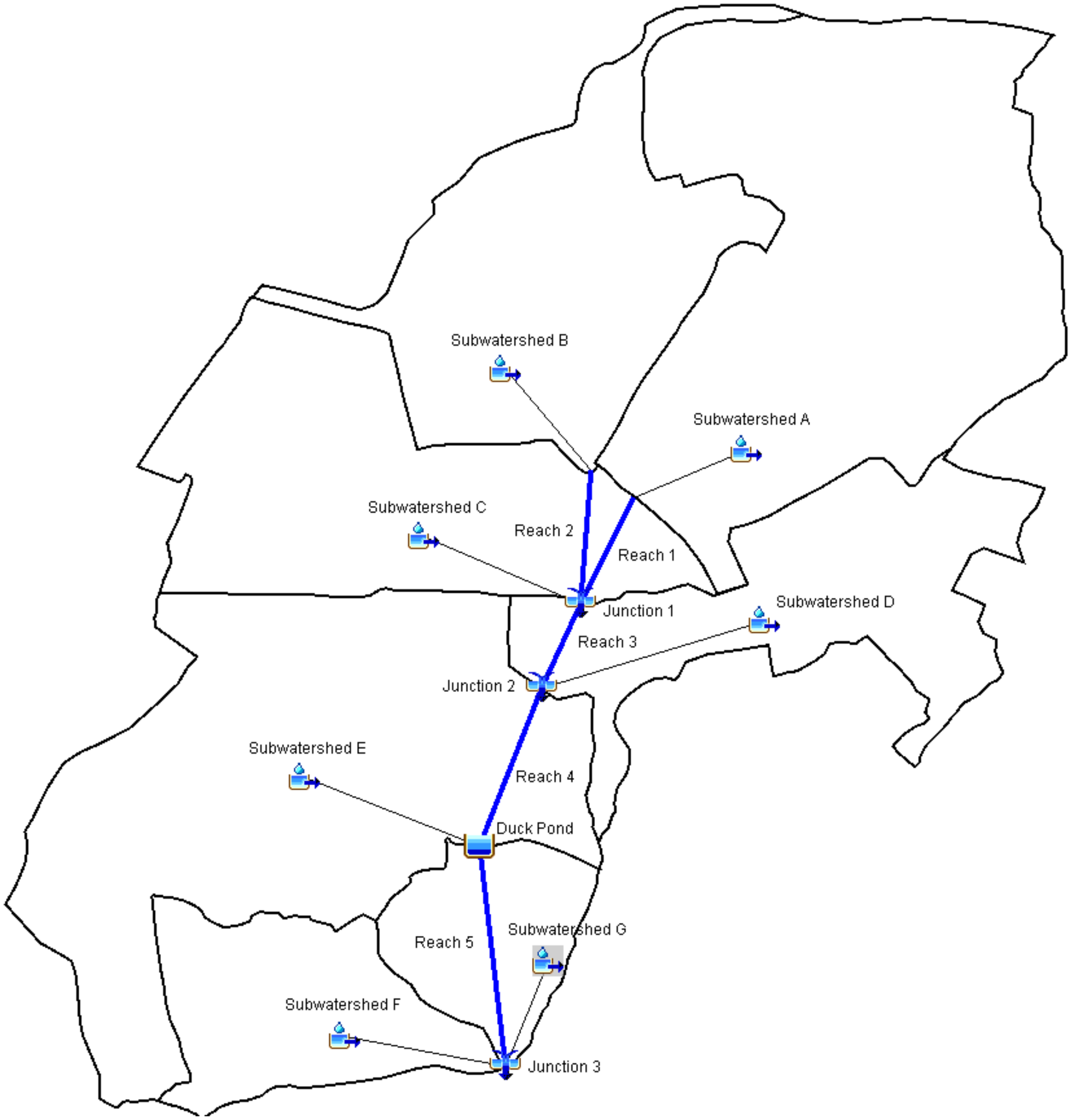


Figure 3. Roman Creek Existing Conditions HEC-HMS Schematic

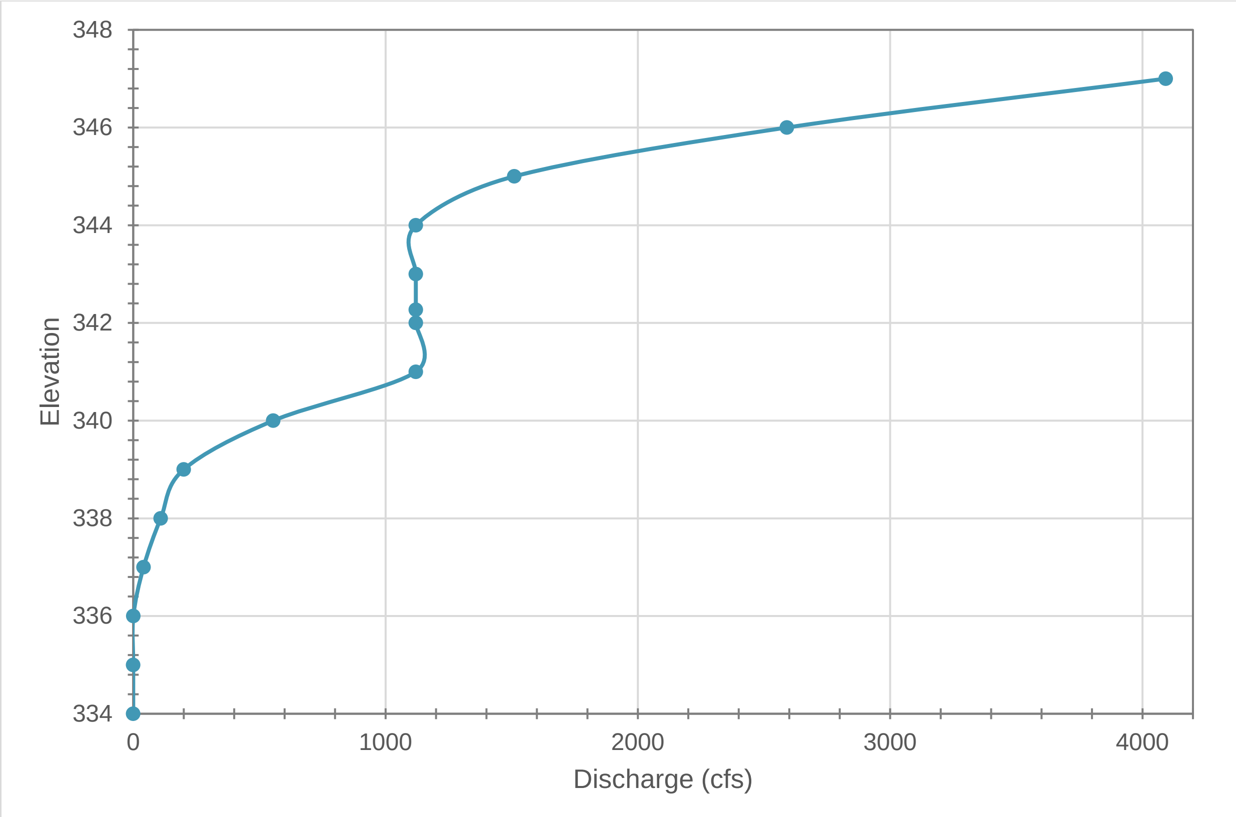


Figure 4. Duck Pond Outflow Rating Curve

Existing conditions modeling results indicate a substantial difference in peak discharge for the two modeled storm distributions. The peak discharge was approximated using the Rational Method to provide a comparison of results. The peak discharge based on the Rational Method was more comparable to the balanced storm distribution results, with a 10- and 100-yr peak discharge of 924 and 1386 cfs, respectively. The nested storm distribution per the SDCHM is generally considered conservative and it was decided to move forward with the results from the balanced storm distribution in conjunction with the NOAA Atlas 14 rainfall precipitation depths. These results align more closely with the results from the Rational Method as well as other previous studies completed in the San Diego area. Existing conditions modeling results are summarized in Table 3.

Table 3. Existing HEC-HMS Model Results (Junction 3*)

Storm Event	SDCHM (Nested Storm 2/3, 1/3 Distribution)		Balanced Storm Distribution 1/2,1/2 w/ NOAA Atlas 14	
	Peak Outflow (cfs)	Storage Volume (ac-ft)	Peak Outflow (cfs)	Storage Volume (ac-ft)
2-year	947	85	455	70
5-year	1182	112	686	101
10-year	1207	134	881	128
25-year	1422	173	1159	166
50-year	2023	234	1239	217
100-year	2415	268	1304	251

* See Figure 3 for the location of Junction 3.

5 Existing Conditions Hydraulic Model Development

The hydraulic analyses for the Roman Creek channel was performed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) version 5.0.6. The project analysis and results are georeferenced to the California State Plane coordinate system, Zone VI and the North American Datum of 1983. Vertical data is referenced to the North American Vertical Datum of 1988 (NAVD 88).

A two-dimensional (2D) hydraulic analysis was performed for Roman Creek to more accurately capture the overbank flow and split flow conditions within the project reach that would not be suitable for a one-dimensional analysis.

HEC-RAS 2D utilizes unsteady-state hydrograph inputs for hydraulic simulation. The simulation requires input hydrographs to be routed into and through a gridded computational 2D flow area. HEC-RAS 2D uses a finite volume approach to flow routing, meaning the volume introduced into the model is completely accounted for until it exits the system.

HEC-RAS 2D requires a flow hydrograph input at the boundary of the computational mesh. For purposes of this project, the inflow hydrograph is introduced at the upstream end of the modeled reach and is based on hydrographs from the HEC-HMS model developed as part of this study. The hydrograph from the downstream end of the hydrologic analysis (Junction 3) was used as the inflow hydrograph at the outlet of the duck pond, which is a conservative measure because runoff from Subwatersheds F and G collects further downstream from the duck pond. Figure 5 provides a graphical illustration of the input flow hydrographs for the 2-, 5-, 10-, 25-, 50-, and 100-year rainfall simulations.

Flows were introduced into the model by establishing a boundary element along the upstream edge of the computational flow area. The boundary element is oriented perpendicular to flow, and is extracted from the model terrain, and act in the same manner as a one-dimensional cross section. An energy grade slope is associated with boundary elements and the model determines normal depth hydraulics as a starting point for flow introduction. An approximate channel slope of 0.005 feet/feet was input for the upstream boundary condition.

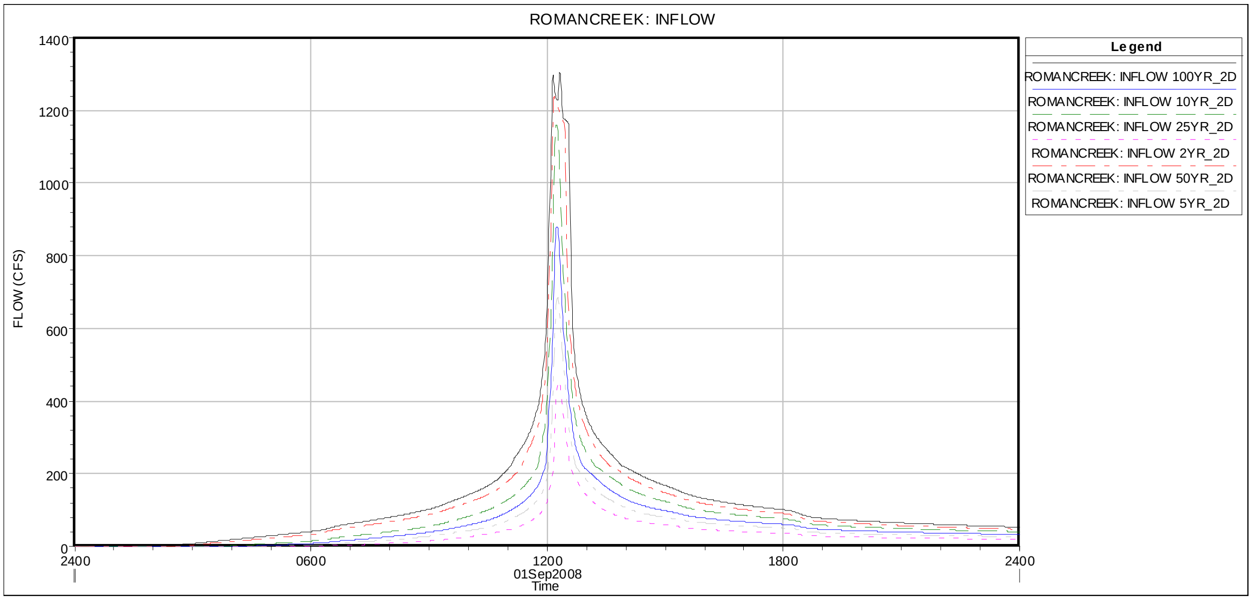


Figure 5. Inflow Hydrographs

Similarly, a downstream boundary element must be established to allow flows to exit the computational flow area to avoid artificial ponding within the modeling area. The downstream boundary element is based on normal depth hydraulics and an approximate channel slope of 0.015 feet/feet was entered into the model. The hydraulic analysis for Roman Creek does not consider backwater from Agua Hedionda Creek in order to compute velocity conditions under free flowing conditions.

The 2D gridded flow area developed in HEC-RAS uses a series of regular and irregular grid cells and the shallow water Saint Venant equations to route flow through the project area. During pre-processing of the model, hydraulic tables or rating curves are developed for each grid cell face. These hydraulic properties are then used as “lookup” tables for a particular flow rate through the cell. Each of these grid cell faces derives its cross sectional geometry from the underlying associated terrain dataset.

The terrain is processed in HEC-RAS as a floating point file, which creates a gridded representation of a surface. The resolution of the gridded point file determines the definition of features in the terrain data set. The terrain in a 2D HEC-RAS model is the foundation for the entire model; therefore the quality and accuracy of the terrain is critical. The terrain for hydraulic modeling was based on 2019 field survey data (by San Dieguito Engineering) collected as part of this study.

The 2D computational flow area used a base cell size of 20 feet. The grid cells were reduced to a cell size of approximately ten feet within the channel to provide an increased level of detail. The model simulations were performed at a computational time step of 1 second to provide numerical stability.

Refer to Figure 6 for an illustration of the 2D model layout.

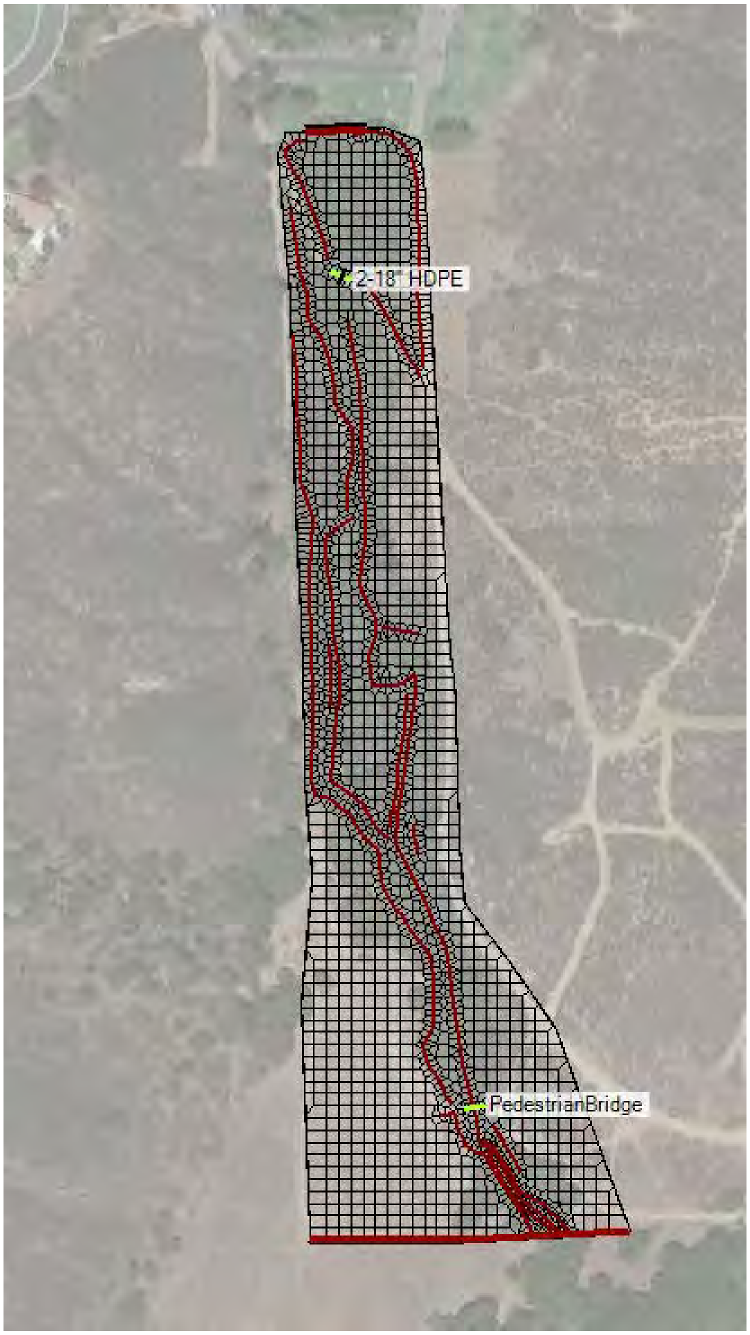


Figure 6. Existing Model Layout

HEC-RAS allows the user to select the set of equations for hydraulic computation, the Diffusion Wave equation or the Full Momentum Saint Venant Equation. The Diffusion Wave equation is typically adequate for most large, low velocity floodplain applications without contractions or expansions of flow and is more stable and computationally faster than the Full Momentum equation. However, in locations of rapidly varied flow (expansion and contraction) through rapid flow direction changes or around structures, the Full Momentum equation provides more accurate results in support of hydraulic design as it utilizes inertial terms (excluded with the Diffusion Wave solution) to solve correctly. While the Full Momentum solution is less stable than the Diffusion Wave solution, the 2D hydraulic model was run using the Full Momentum equation as it yields a more accurate solution for the study reach due to the high flow velocities and contractions/expansions. Using this approach yielded a volume continuity error less than 0.01% for all rainfall simulations.

The computational mesh was refined with the inclusion of breaklines along key terrain features. Due to the nature of the HEC-RAS 2D computational methodology, which calculates hydraulics based upon the grid cell faces, it is important that flow confining features are properly accounted for in the computation mesh. Breaklines force revisions in the mesh, allowing for grid cell faces to align along the drawn breakline. This aids considerably in reducing incorrect flow conveyance over hydraulic features such as roads and channel berms.

It is important for hydraulic modeling to accurately represent roadway crossings and account for impacts to flow paths and inundation limits. HEC-RAS 2D models bridges and culverts in the same manner by using a culvert routine to explicitly compute the hydraulics from an upstream grid cell to a downstream grid cell. This approach is ideal for detailed hydraulic analysis of culverts that pressurize and can cause significant upstream ponding and flow redirection. Bridges that become pressurized currently cannot be modeled in HEC-RAS 2D. Two existing crossings were identified within the modeled reach. The first crossing is a low water crossing located toward the upstream end of the project, which includes two 18" high density polyethylene (HDPE) pipes. The second crossing is the pedestrian bridge at the downstream end of the modeled reach. The pedestrian bridge was represented in the model geometry using the culvert feature with a 2D area connection and the box culvert size was approximated based on the open flow area of the bridge geometry.

A Manning's roughness coefficient of 0.05 was used as the default value in the 2D computational mesh to represent a heavily vegetated condition. Areas of lower roughness (0.035) were applied in the model within the channel banks to override the default value and represent a flow path with less vegetation undergrowth. Similarly, Manning's roughness in areas of proposed channel improvement were revised (lowered) to 0.035 to better represent the new vegetated condition,

6 Existing Conditions Model Results

Within the project limits, the Roman Creek channel represents a relatively natural channel with heavily vegetated overbanks areas below the point of discharge from the duck pond grading to less understory vegetation downstream. The channel is relatively steep with an average slope of 0.012 feet/feet. The channel includes multiple constrictions and expansions, split flow conditions, and natural drop structures throughout the reach. The approximate channel elevation profile is shown in Figure 7 which extends from the outlet of the duck pond to approximately 350 feet upstream of the Agua Hedionda Creek. The HEC-RAS 2D hydraulic model served as an effective tool to represent this complex system, including flow within the overbank areas and split flow areas.

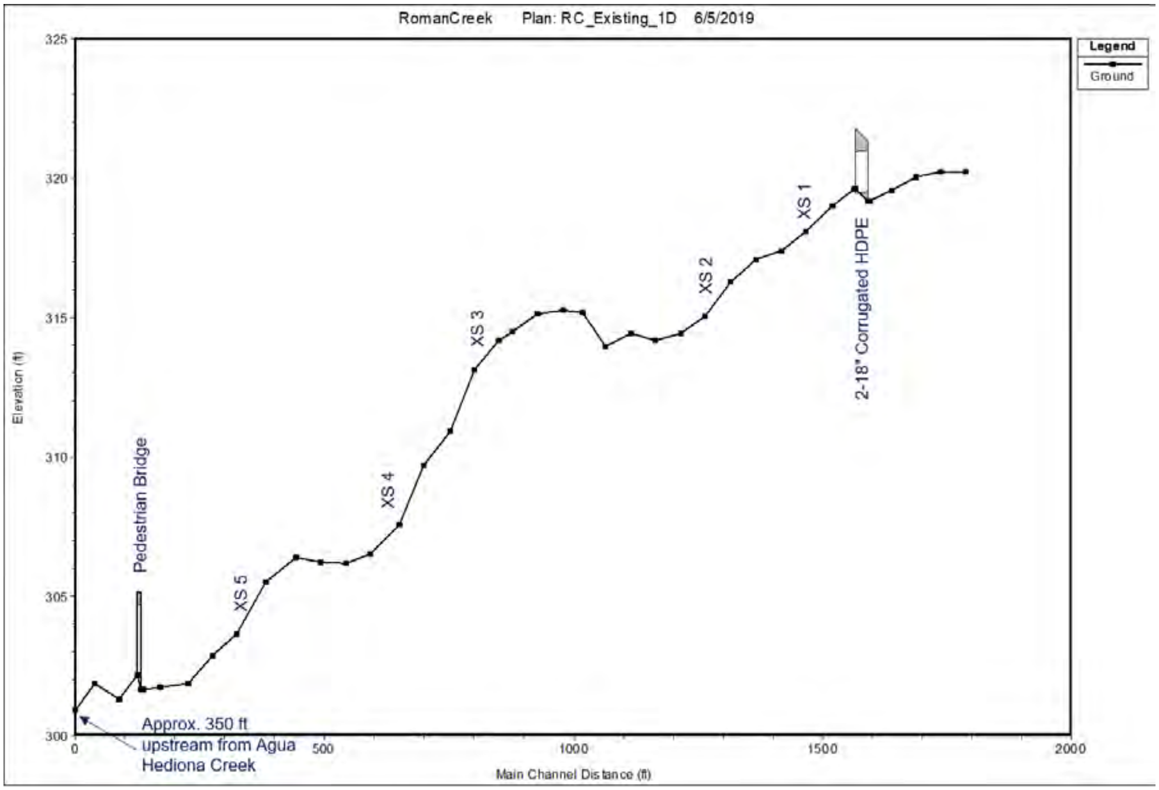


Figure 7. Existing Channel Profile

Hydraulic modeling results for existing conditions are depicted below. Figure 8 and Figure 9 show resulting water depth and flow velocity within the modeled reach for the 2-year storm event. The 2-year storm event is especially pertinent to the project purposes of improving conditions for targeted habitat re-vegetation. Additionally, the 2-year storm event is the channel forming flow, which is the flow that performs the most "work" on the channel system. As such, 2-year hydraulic results from existing and proposed conditions provide an appropriate comparison of change and impact. During the 2-year storm event, water depths average 2.5 to 5 feet in the main channel, with minimal flow in the overbank areas (Figure 8). Model results indicate typical channel velocities between 2.5 and 7 feet per second (fps) and can exceed 7.5 fps in the narrower, more constricted channel reaches (Figure 9). Depths and velocities are higher for the less frequent storm events. Model results, including channel depth, maximum velocity, top width, and slope within the Roman Creek project area are summarized in Table 4 for the 2-, 10- and 100-year storm events.

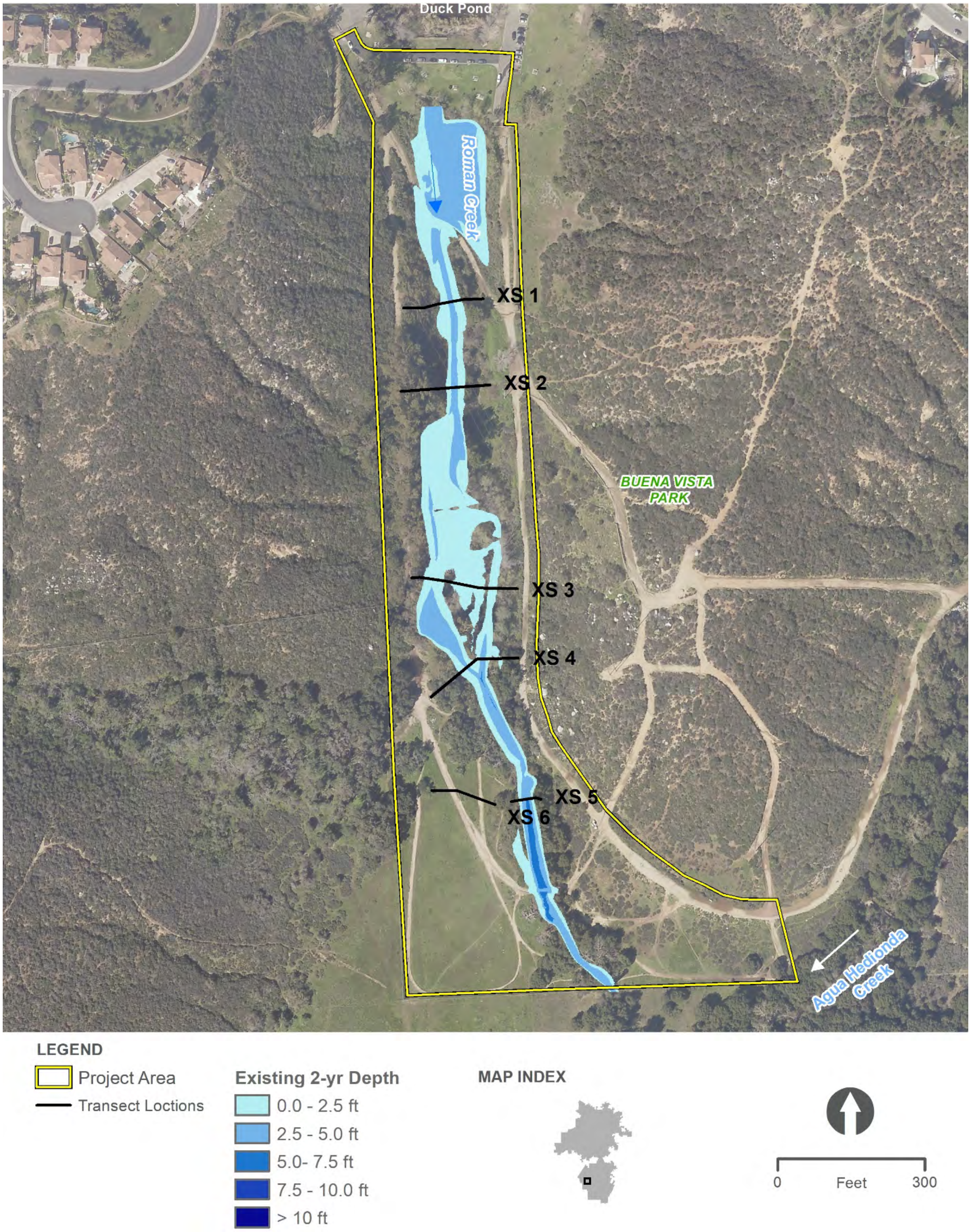


Figure 8. Existing 2-year Water Depths

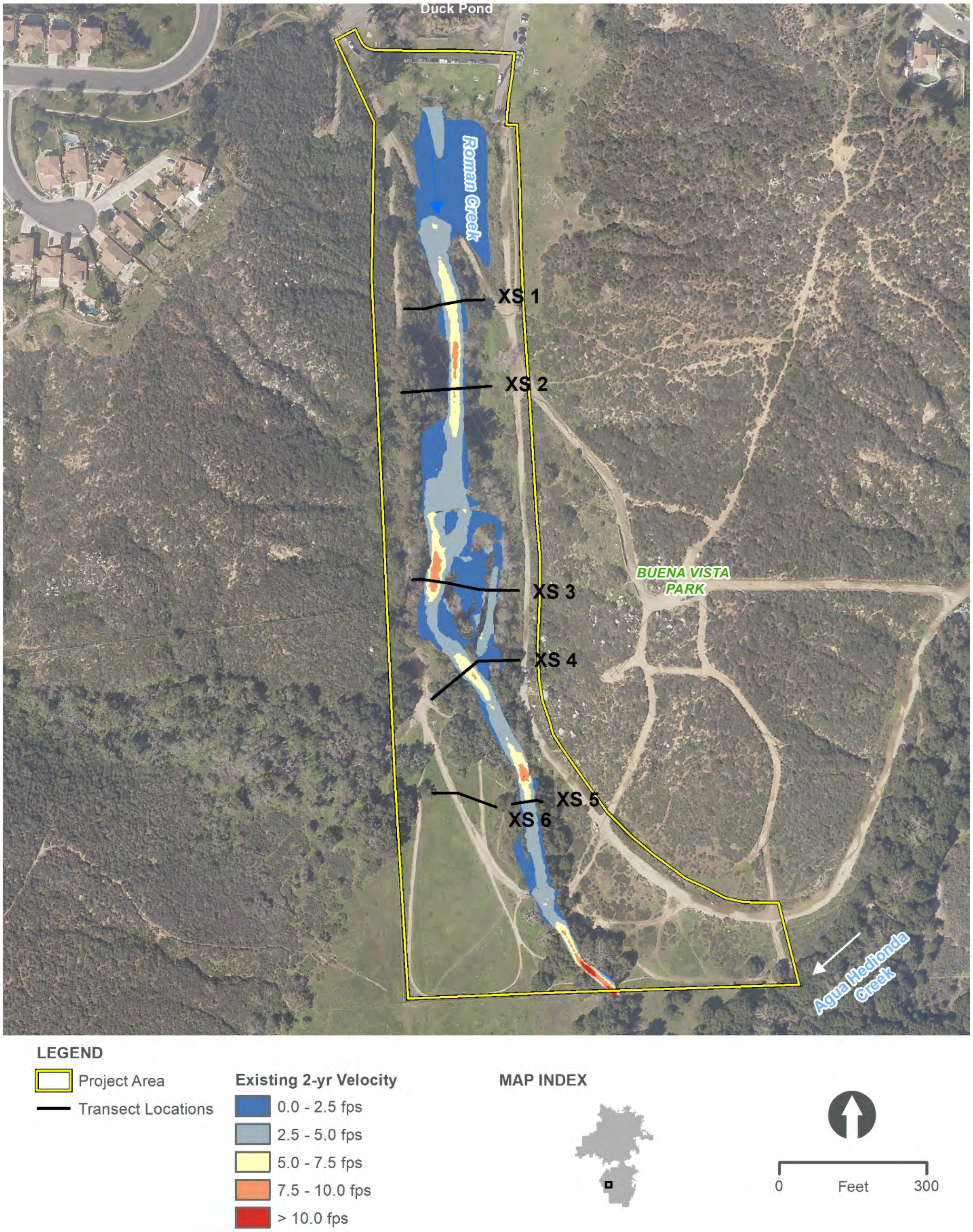


Figure 9. Existing 2-year Flow Velocities

Table 4. Existing Hydraulic Results

XS ID	Max. Depth (ft)			Max. Velocity (fps)			Top Width (ft)			Approx. Channel Slope (ft/ft)
	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr	
XS1	4.1	5.0	5.7	8.6	9.8	10.6	43	54	66	0.012
XS2	4.1	5.2	6.0	9.5	11.2	12.2	39	53	66	0.018
XS3	2.3	3.0	3.6	9.7	11.1	11.7	148	163	169	0.025
XS4	4.4	5.9	7.3	7.7	8.3	8.2	71	102	114	0.037
XS5	4.5	6.2	6.8	8.2	9.7	11.7	29	37	42	0.02

Five transects were cut in the existing model terrain to graphically represent the channel cross-section looking downstream and approximate water surface elevation at various storm events. The transect locations are shown in Figure 8 and Figure 9, and include upstream, within, and downstream of the split flow area. Water surface elevations for the 2-, 10-, and 100-year storm events are shown in Figures 10 to 14. The hydraulic depth for each is summarized in Table 4.

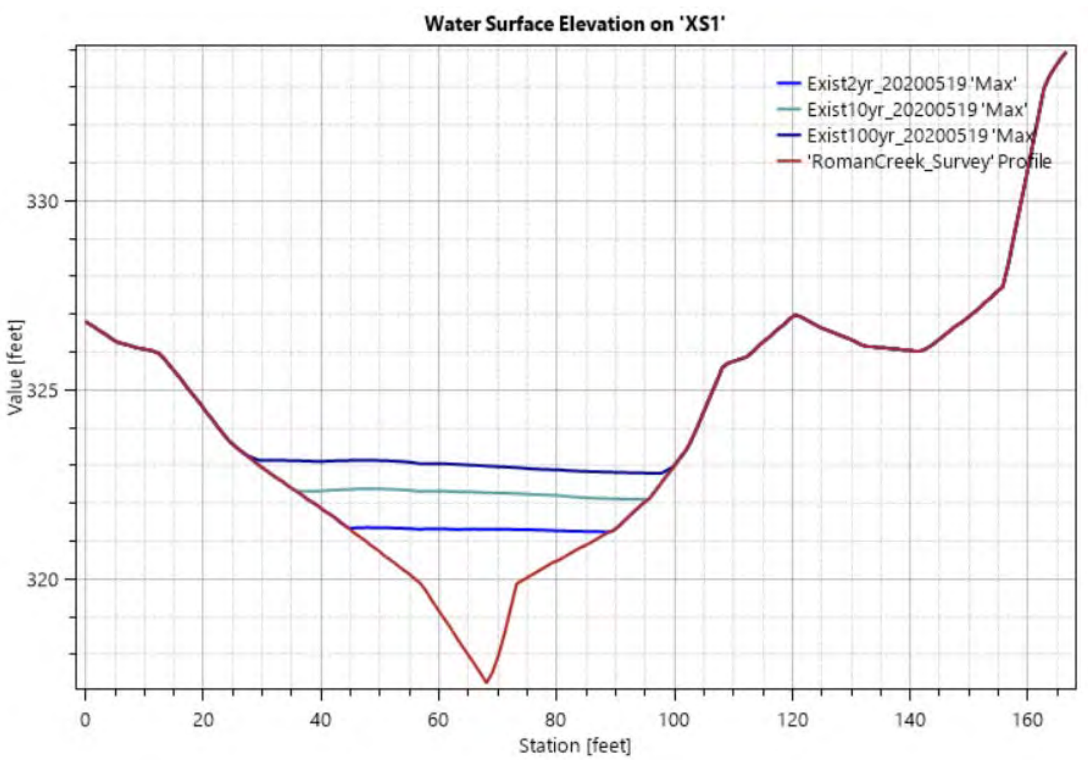


Figure 10. XS1 Water Surface Elevation Plot

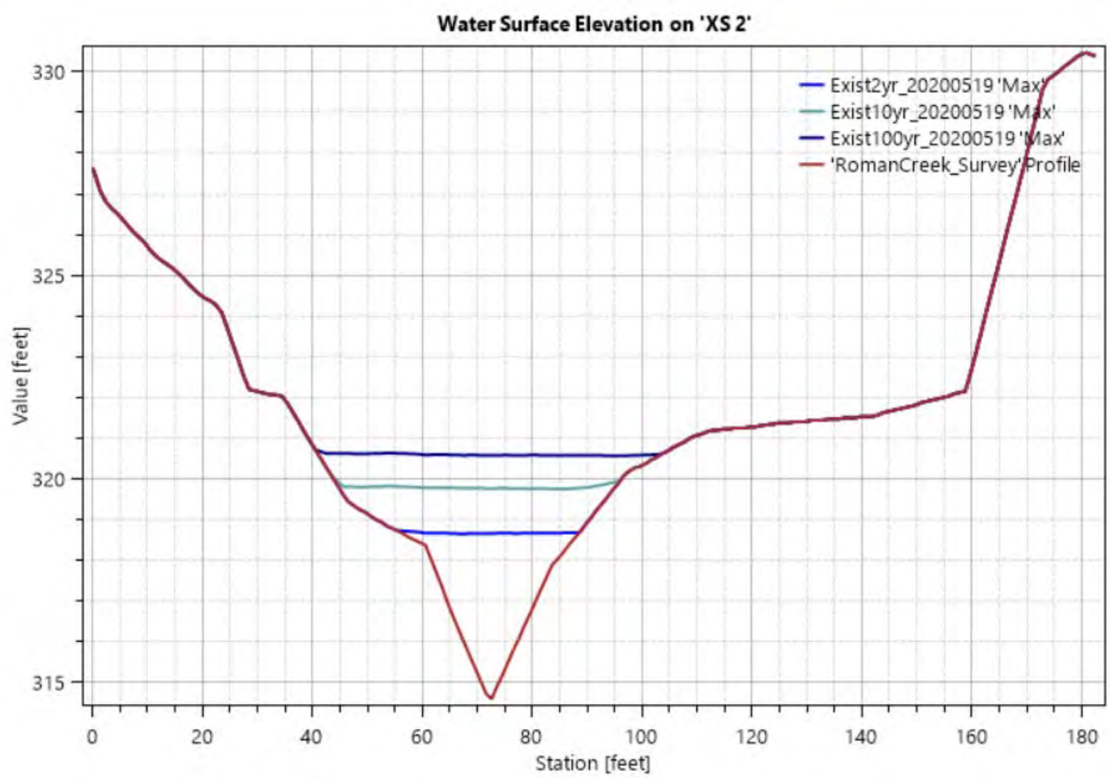
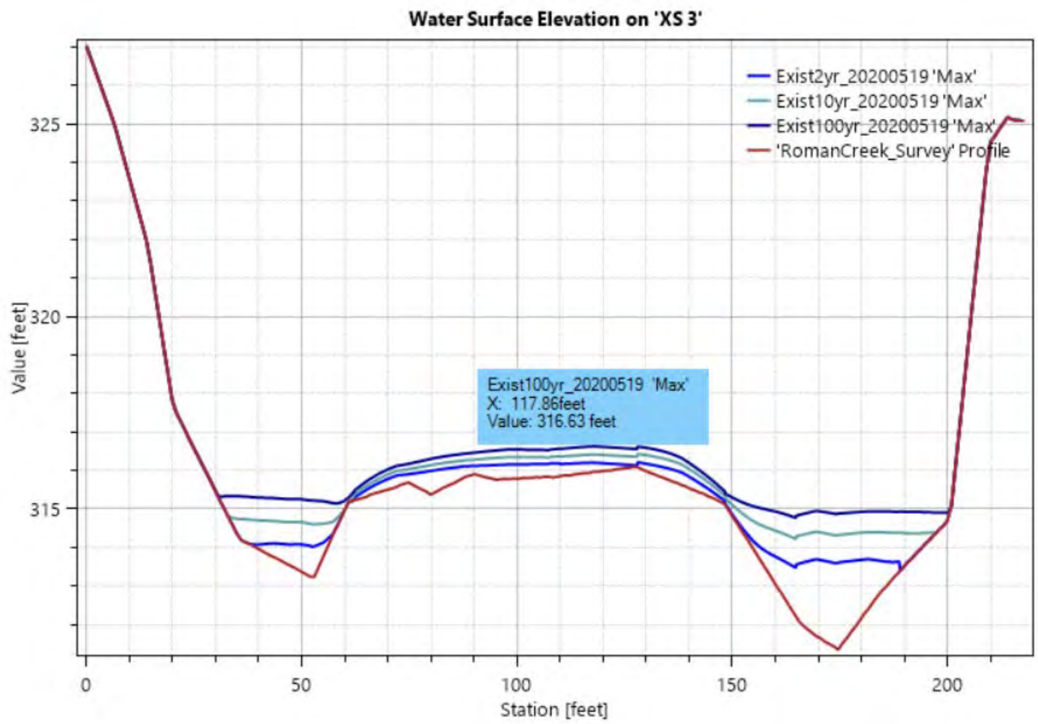


Figure 11. XS2 Water Surface Elevation Plot



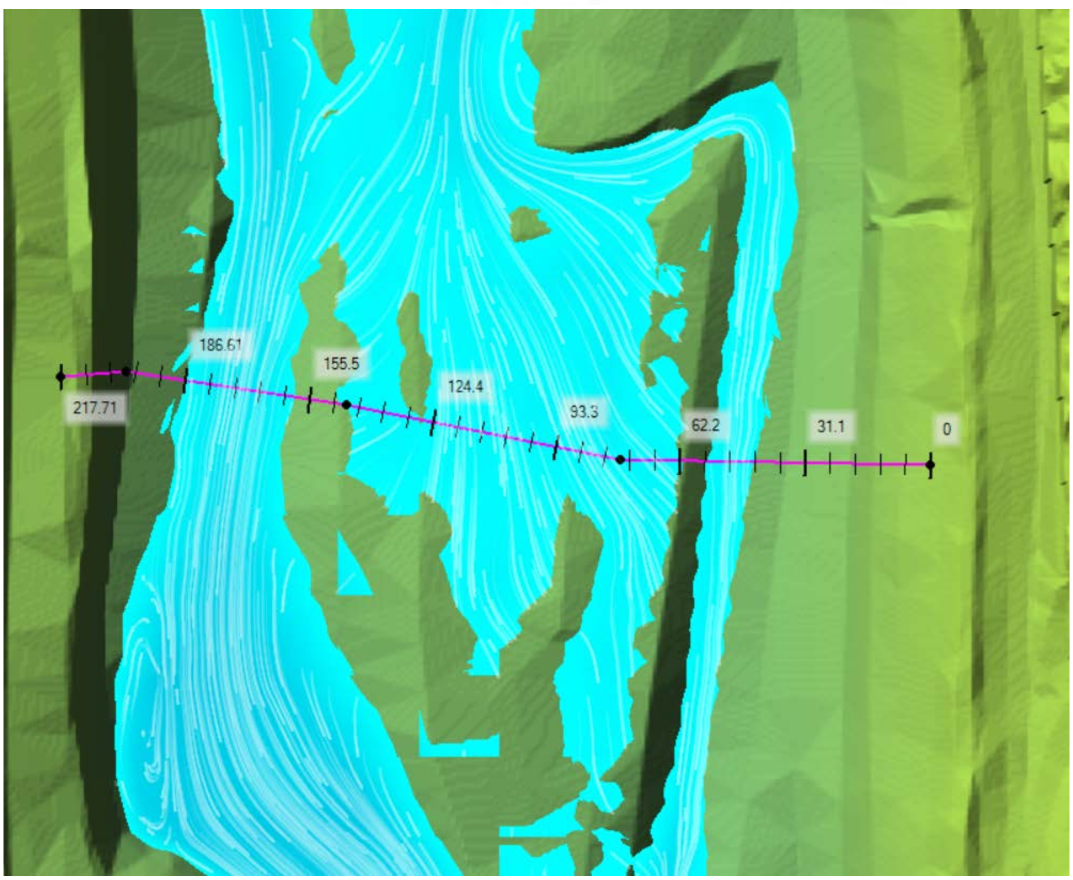


Figure 12. XS3 Water Surface Elevation Plot (Top) and XS3 Split Flows under 100-year Storm Event (Bottom)

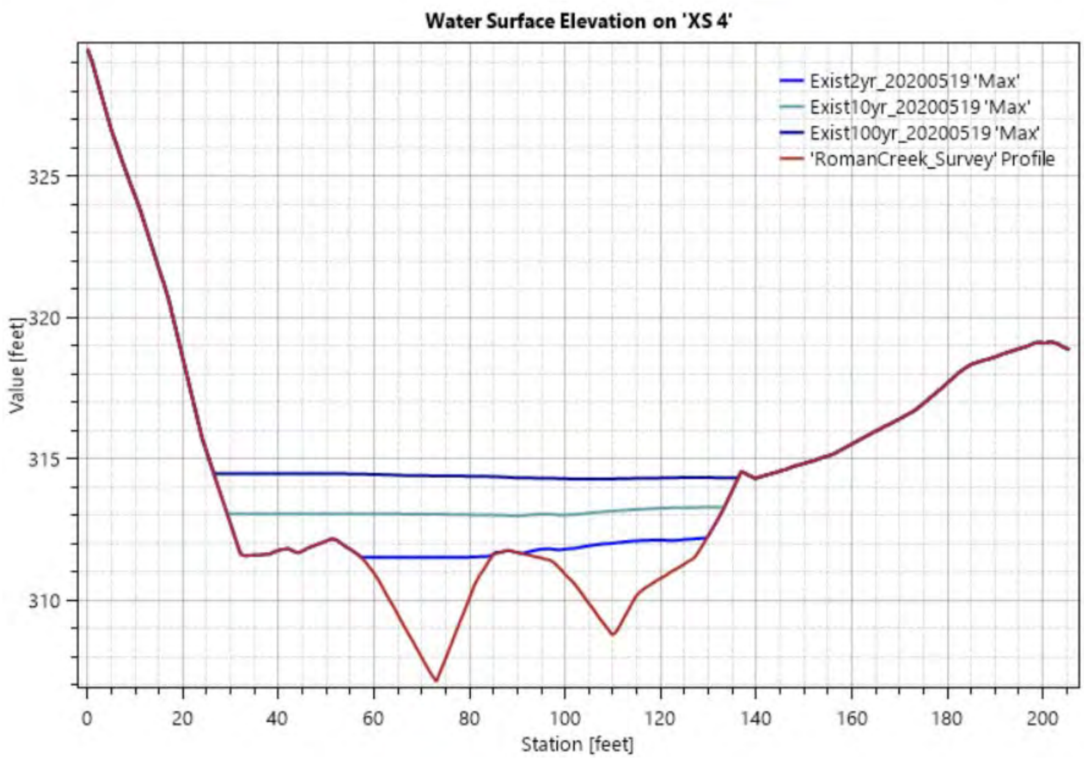


Figure 13. XS4 Water Surface Elevation Plot

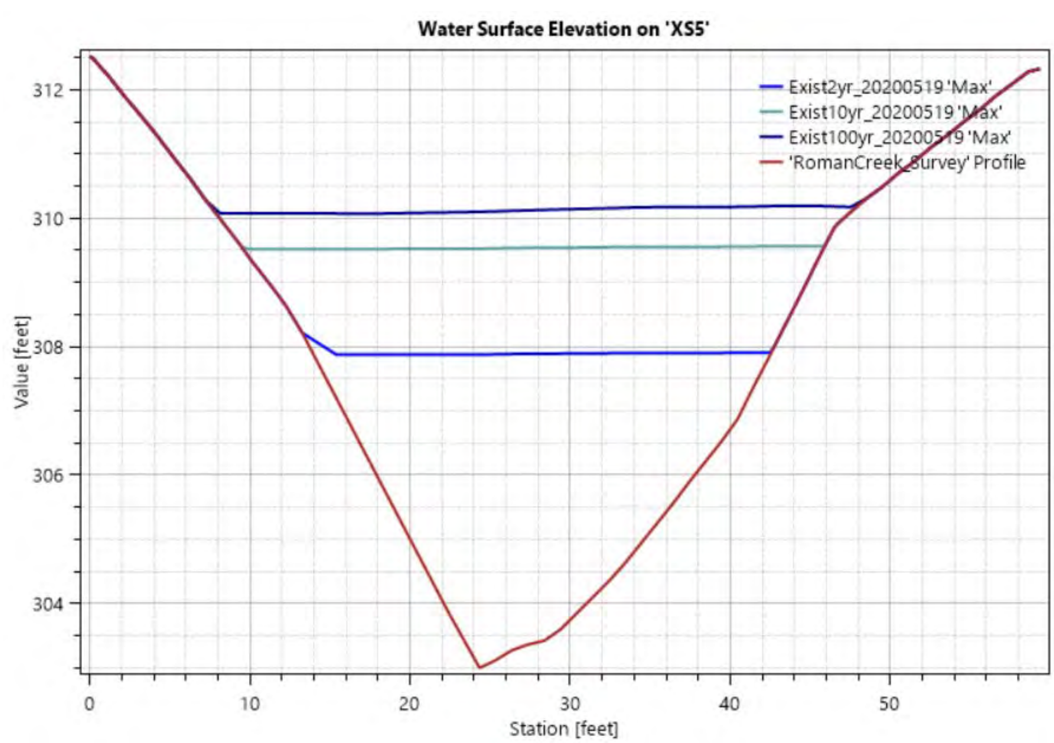


Figure 14. XS5 Water Surface Elevation Plot

7 Proposed Conditions Model Results

Proposed modifications to two reaches of Roman Creek within the project limits were developed. Using the existing condition hydraulic results to inform siting of graded improvements, a proposed grading concept was developed with the goal of expanding the inundation extent of the 2-yr storm event. Figure 15 depicts approximate areas of grading for the conceptual grading for two locations along Roman Creek. The upstream location includes a proposed side terrace that would provide for additional inundation west of the Roman Creek Channel, in the vicinity of XS 1 and XS 2. The downstream location is a secondary channel, which accepts flow from Roman Creek at XS 4 and temporarily provides for a split flow condition before rejoining the existing channel upstream of the Agua Hedionda confluence. An additional 1D HEC-RAS model was created to provide hydraulics results at the Proposed Roman Creek Bridge (see Section 9).

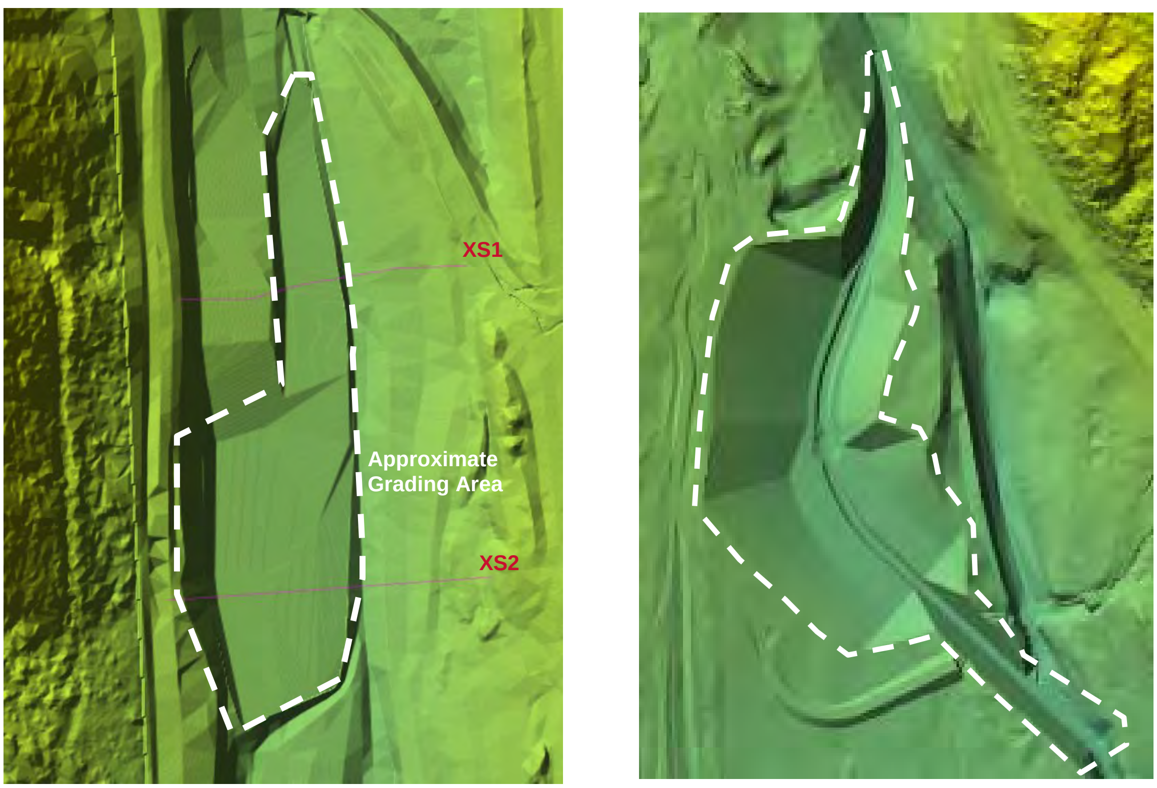


Figure 15. Proposed Terrace (left) and Secondary Channel (right)

Hydraulic modeling results for proposed conditions are depicted below. The results for these conceptual designs demonstrate increased areas of inundation during the 2-year storm event. Additionally, the secondary channel provides for a rough division of flow between the proposed channel and the existing Roman Creek Channel. Figure 16 and Figure 17 provide sectional views at XS 2 and XS 6 to provide an additional representation of the grading and a comparison of the existing and proposed 2-year flow depths.

Figure 16 depicts the proposed excavation in comparison with the existing ground surface. The water surface is lowered under the proposed condition and the inundation area is increased. Figure 17 depicts the proposed secondary channel and provides a comparison of the existing and proposed ground surface. At this location, flow does not reach this area during the 2-yr storm event under existing condition.

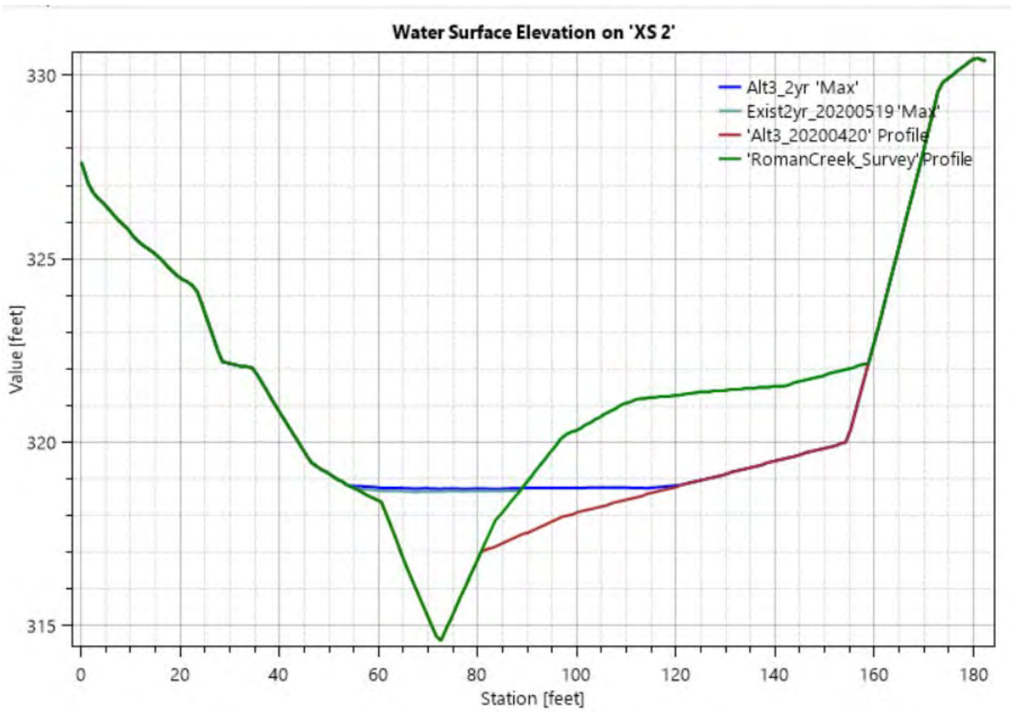


Figure 16. XS2 Existing vs Proposed 2-year Water Surface Elevation Plot

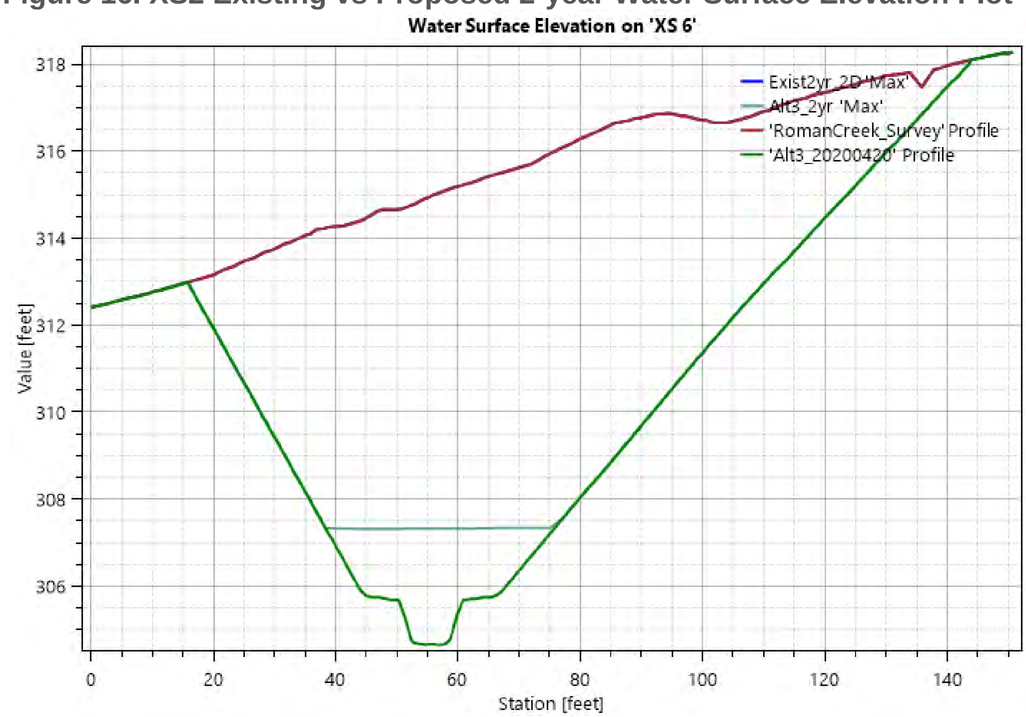


Figure 17. XS6 Proposed 2-year Water Surface Elevation Plot (purple line represents existing surface)

Figure 18 and Figure 19 show resulting water depth, flow velocity, and inundation extent within the modeled reach for the 2-year storm event.

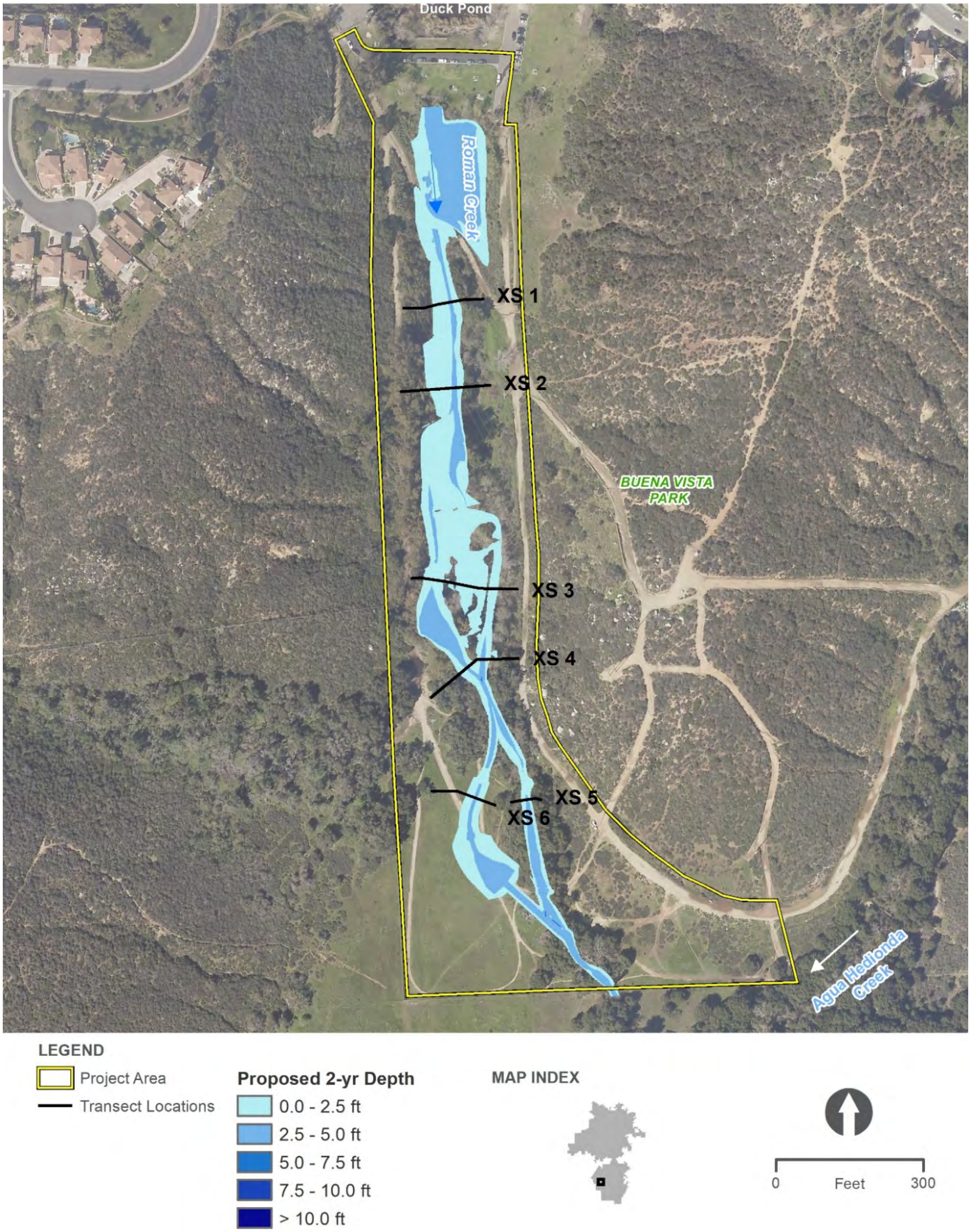


Figure 18. Proposed 2-year Water Depths

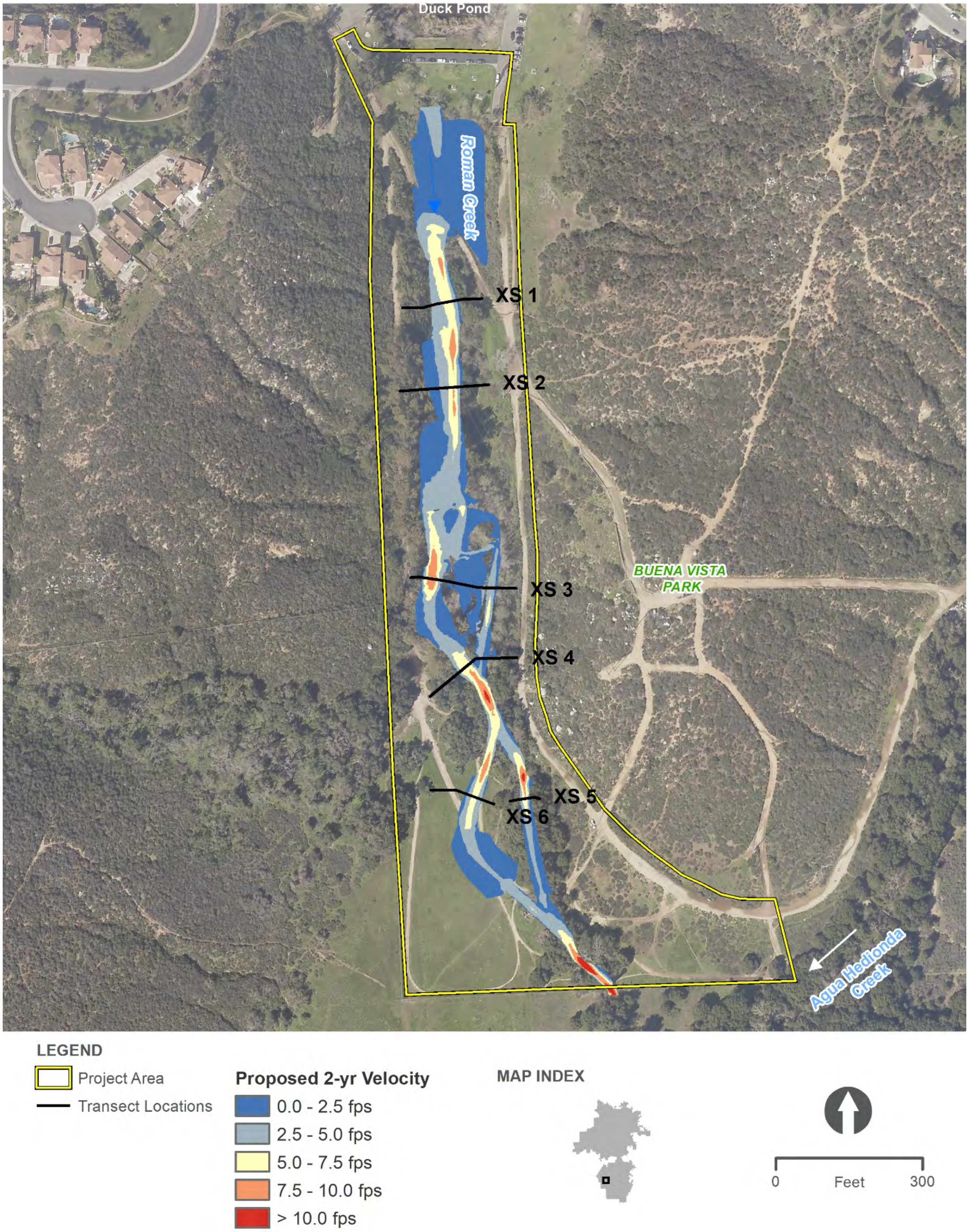


Figure 19. Proposed 2-year Flow Velocities

Table 5. Proposed Hydraulic Results

XS ID	Max. Depth (ft)			Max. Velocity (fps)			Top Width (ft)			Approx. Channel Slope (ft/ft)
	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr	
XS1	3.6	4.3	4.9	7.0	8.8	10.1	55	64	69	0.012
XS2	4.1	5.1	5.7	7.4	8.3	9.1	67	105	113	0.018
XS3	2.4	3.2	3.7	9.5	10.7	11.3	150	165	168	0.025
XS4	4.3	5.7	6.9	7.2	7.7	7.7	72	103	107	0.034
XS5	2.9	5.2	6.4	7.3	7.8	8.0	21	30	36	0.02
XS6	2.7	4.1	5.2	6.6	7.5	8.3	35	51	63	0.008

General hydraulic parameters for proposed conditions are summarized in Table 5. The major hydraulic changes are evident in the reaches of proposed channel changes. The transect locations (XS 2 and XS 6) shown in Figure 20 and Figure 21, depict proposed condition depths for the 2-, 10-, and 100-year storm events.

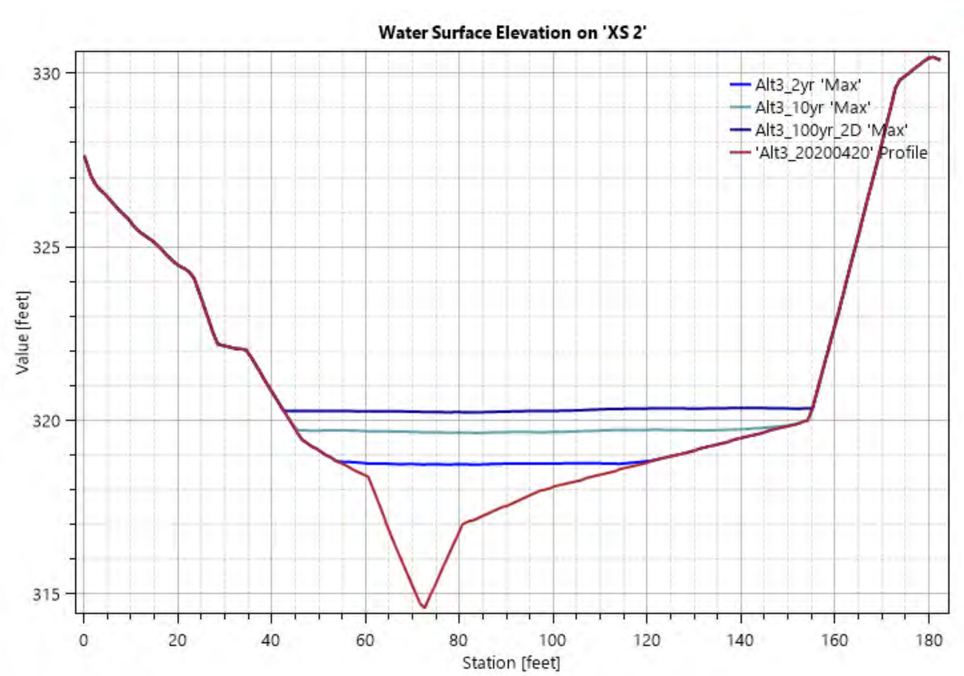


Figure 20. XS2 Proposed Water Surface Elevation Plot

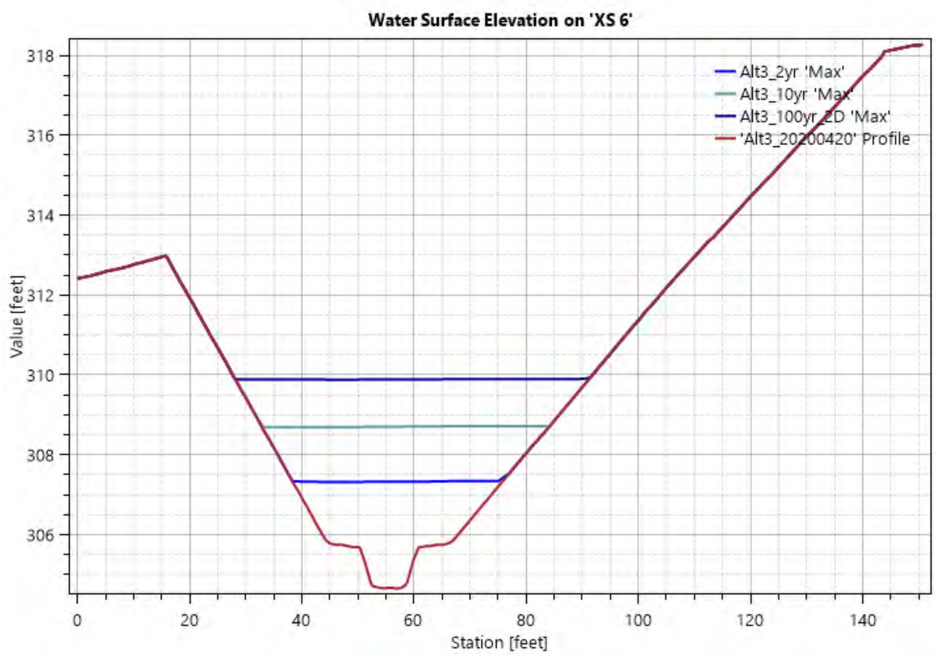


Figure 21. XS6 Proposed Water Surface Elevation Plot

8 Comparison of Results

Table 6 depicts changes in the 2-year hydraulic parameters from existing to proposed conditions. In general, proposed conditions result in lower depths and lower velocities due to the additional available flow area. The additional flow area also provides for a general increase in flow top width in the modified areas.

Table 6. Existing and Proposed Results Comparison

XS ID	Max. Depth (ft)			Max. Velocity (fps)			Top Width (ft)		
	Existing 2-yr	Proposed 2-yr	Δ	Existing 2-yr	Proposed 2-yr	Δ	Existing 2-yr	Proposed 2-yr	Δ
XS1	4.1	3.6	-0.5	8.6	7.0	-1.6	43	55	12
XS2	4.1	4.1	0.1	9.5	7.4	-2.0	39	67	28
XS3	2.3	2.4	0.1	9.7	9.5	-0.2	148	150	2
XS4	4.4	4.3	-0.1	7.7	7.2	-0.6	71	72	1
XS5	4.5	2.9	-1.6	8.2	7.3	-0.8	29	21	-8
XS6	N/A	2.7	N/A	N/A	6.6	N/A	N/A	35	N/A

Figure 22 shows the 2-year hydrograph at XS 5 for the existing and proposed conditions. It depicts an existing conditions peak flow of 436 cfs and a proposed conditions peak flow of 182 cfs. This represents a 58% reduction of flow within the original Roman Creek channel due to the secondary channel split flow. Therefore, the proposed grading results in a 40/60 spilt between the original and secondary channels for the 2-yr storm event.

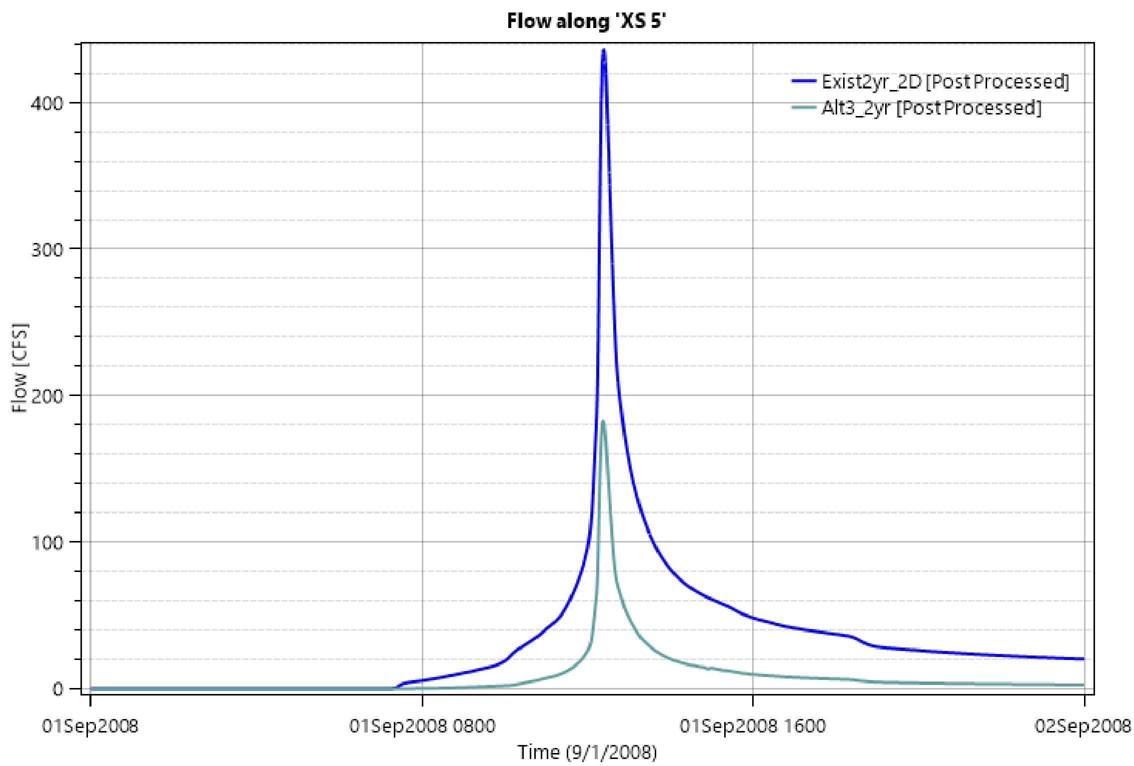


Figure 22. XS5 Discharge – Existing vs Proposed Conditions

There is a change in velocity at approximately 70 feet downstream of XS 4 (Figure 23). The existing velocity is approximately 5.0 feet per second, whereas the proposed velocity is approximately 10.5 feet per second. This change is due to the introduction of the secondary channel since the existing adverse slope downstream of XS 4 acts as a tailwater control. Under proposed conditions, the secondary channel creates a new flow path, and as a result, the velocities upstream are impacted.

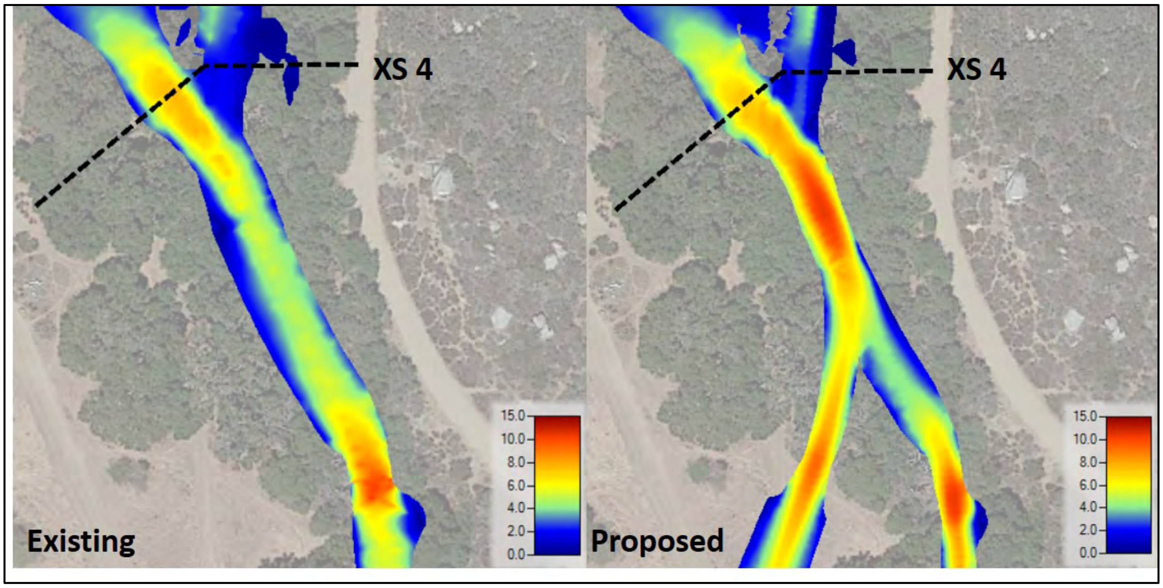


Figure 23. Comparison of Velocties at XS 4 under 2-year Flows

9 Proposed Roman Creek Bridge

HEC-RAS 2D cannot adaquetly model the characteristics of Proposed Roman Creek Bridge (proposed bridge). HEC-RAS 1D, however, allows accurate representation of the terrain and computes various bridge hydraulics conditions (i.e. pressurized vs unpressurized) using different sets of equations. Therefore, a HEC-RAS 1D model was created to provide hydraulics results of the proposed bridge. The proposed bridge is located approximately 200 feet downstream of the propsoed 2D XS5. Appendix-1 displays the conceptual design of the proposed bridge.

The model extent begins approximately 150 feet upstream of the proposed bridge and ends about 200 feet downstream of the bridge (Figure 24). The proposed bridge has a length of 100 feet and a width of 6 feet. The bridge was assumed to be 2-feet thick, with a bottom and top of bridge elevations of 309 feet and 311 feet, respectively. Figure 25 depicts the water surface elevations for various storm events. The proposed bridge remains unpressurized at flows less than a 10-year storm events, meaning that the water surface elevation does not reach the bottom of the bridge. Flows less than 10-year storm events are contained within the secondary channel and the existing channel downstream of the proposed bridge. For flows that are greater than 10-year storm event, the right bank of the secondary channel is overtopped at River Station 240 and 214 (Figure 24). Flows inundate the proposed trail embankment but do not overtop it. Downstream of the proposed bridge, flows break out of the channel and inundates the right overbank area. Table 7 sumarizes the hydraulics results at proposed bridge.

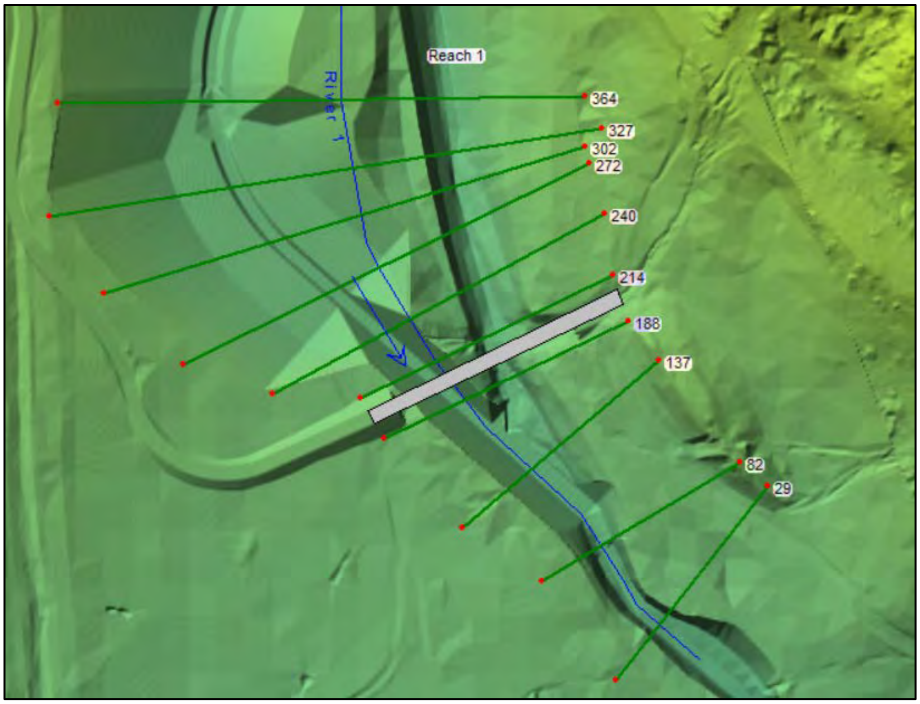


Figure 24. Proposed Roman Creek Bridge HEC-RAS 1D Layout

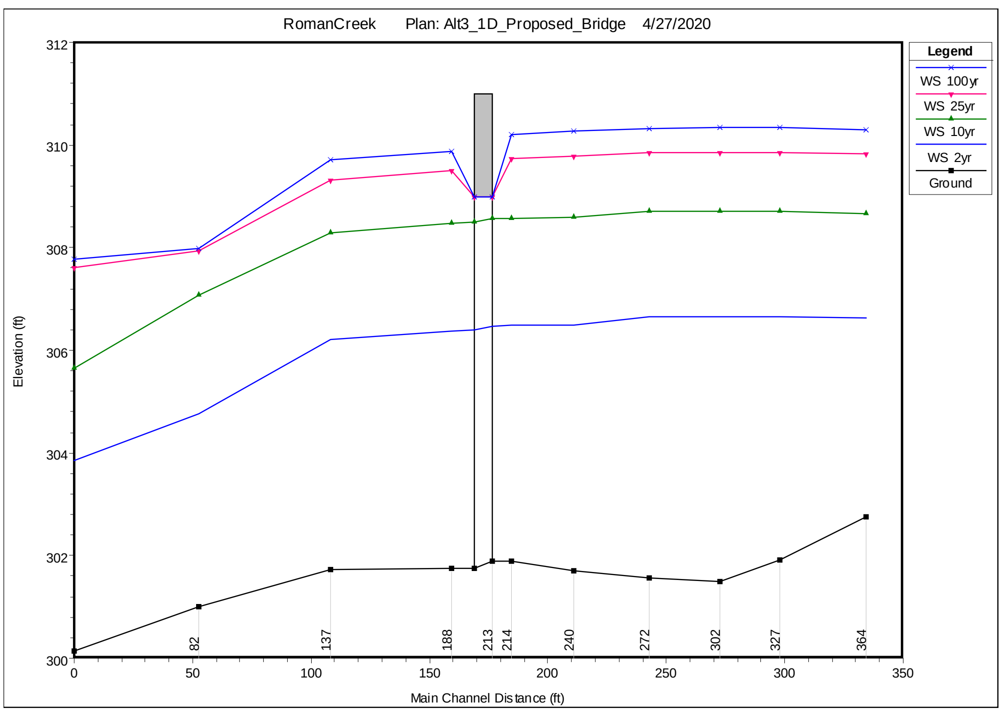


Figure 25. Water Surface Profiles for 2-yr, 10-yr, 25-yr, and 100-yr Storm Events

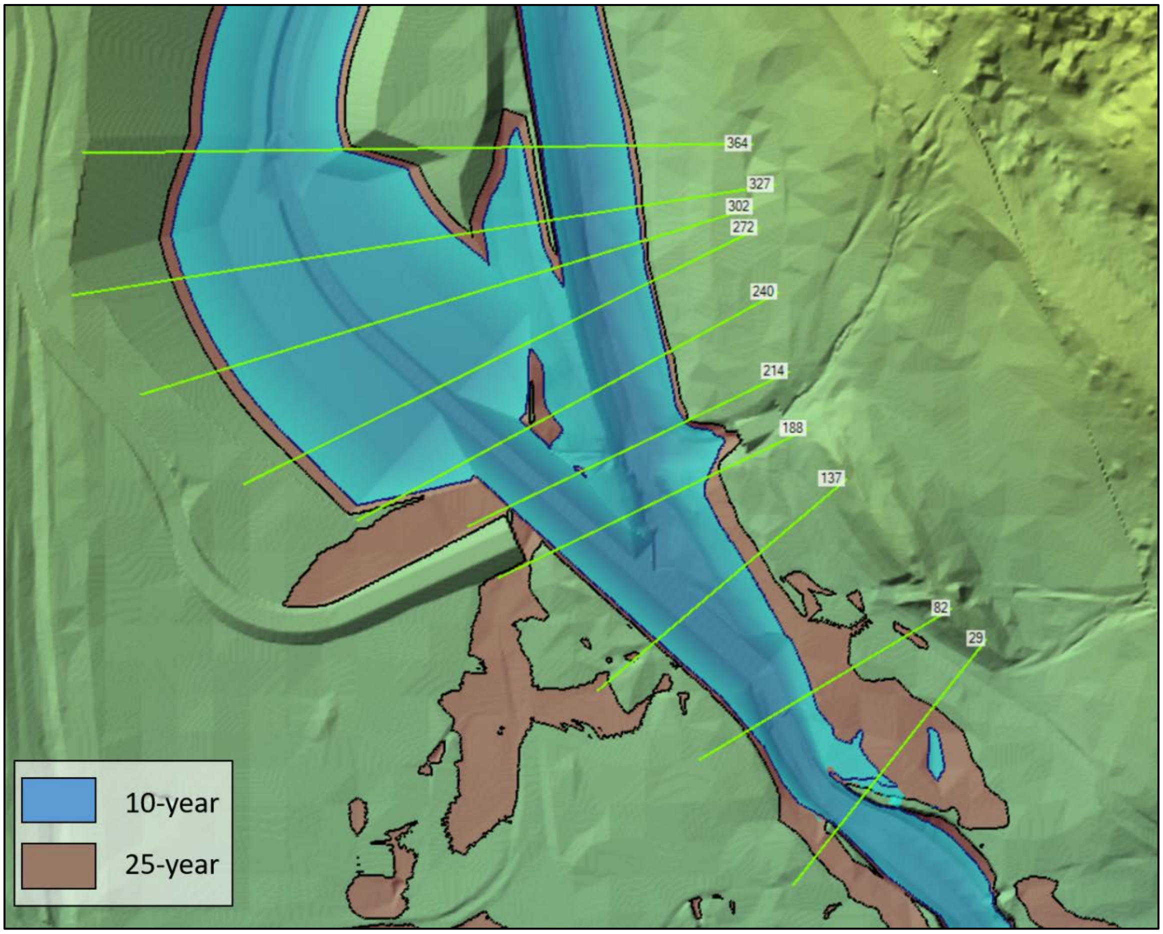


Figure 26. Inundation Boundary for 10-yr and 20-yr Storm Events at Proposed Bridge

Table 7. Proposed Roman Creek Bridge Hydraulics Results

	Velocity [fps]	Water Surface Elevation [ft]	Freeboard
2-yr	3.0	306.6	-2.4
10-yr	3.1	308.7	-0.3
100-yr	4.0	310.3	+1.3

Scour countermeasure protection is recommended to protect the proposed bridge abutments and approaches from potential scouring effects of high flows and channel instability, to include lateral migration or vertical incision. An appropriately sized riprap revetment or other armoring means at areas that are susceptible to scour would be required.

10 Existing Channel Headcut

Approximately 900 feet of the the lower reach of Roman Creek within the project area exhibits signs of incision vertical channel banks and exposed tree roots (Figure 27). Channel incision is typically a sign of stream instability resulting from a change to the flow conditions (hydromodification), or sediment supply. Incision can occur simultaneously through a vulnerable reach or can progress from downstream to upstream in the form of a headcut.

Figure 27. Channel Incision, Looking Upstream from Pedestrian Bridge

Within the project reach the lower section is incised due to a migrating headcut. During site visits, a headcut was located approximately 600 ft upstream of the pedestrian bridge (See Figure 28). This headcut has a current depth of three feet, meaning that the channel invert downstream of the cut is three feet lower than immediately upstream. Figure 29 depicts the headcut at the time of photo (November 2019)

Figure 28. Existing Headcut Location

Figure 29. Existing Headcut

The Roman Creek channel upstream of the headcut location does not exhibit the same incision as the lower reach, suggesting that headcutting is likely responsible for the downstream changes. Headcuts form downstream and migrate upstream, as the vertical face of the cut is eroded. Anedoctal evidence suggests that Agua Hedionda has experienced incision in the vicinity of the Roman Creek confluence and it is plausible that the current Roman Creek headcut originated in Agua Hedionda Creek.

As stated previously, channel incision is a natural response to changed conditions. The stream is attempting to find a new balance. Upon reaching a new vertical equilibrium, the channel often begins to move horizontally to redefine an equilibrium channel width and shape. Often, these processes have undesirable effects and mitigation measures are put in place. There are three potential consequences of note for the project. First, channel lowering could alter anticipated water surface elevations from those used for design, resulting in disconnected overbank areas. This specifically could impact the success of the proposed terrace. Second, channel incision could result in lower ground water elevations, also impacting existing and proposed vegetation of importance. Third, channel incision has already resulted in the root exposure and collapse of coast live oak trees through the lower reach. Further propagation of the headcut is likely to yield similar results upstream.

It is recommended that a grade control structure is constructed to prevent further channel incision upstream through the project reach. Specifically, placing the grade control structure at the existing headcut located just upstream of the proposed secondary channel. This will likely consist of sized riprap, buried at grade, and keyed into the banks.

11 Conclusions and Next Steps

The hydraulic analyses documented here include existing conditions and one proposed concept that considered two in-channel modifications. Proposed results provide initial validation that the grading concept will facilitate the goal of increasing inundation areas during the 2-year event to support habitat enhancement. In general, the proposed conditions provide for a reduction in flow velocity, both in the graded areas and beyond. Additionally, initial hydraulic results indicate that the current conceptual bridge design freely passes the 10-year flow through the bridge opening. The 25-year and 100-year flow events pressurize the bridge superstructure, but do not overtop. Finally, a grade control feature designed to mitigate further upstream migration of the identified headcut is recommended.

The following next steps are recommended to support further development of the design and permitting:

- Upon approval of the proposed bridge configuration, conduct riprap sizing analysis and conceptual placement to estimate construction costs.
- Re-visit the identified headcut and Identify the most suitable location for the proposed grade control. Site selection will significantly impact the size, type, and configuration of the feature.
- Conduct focused hydraulic analysis at the feature to support material sizing and toe down requirements.

12 References

Carlsbad Watershed Management Area Responsible Agencies, 2018 (Updated). Carlsbad Watershed Management Area Water Quality Improvement Plan.

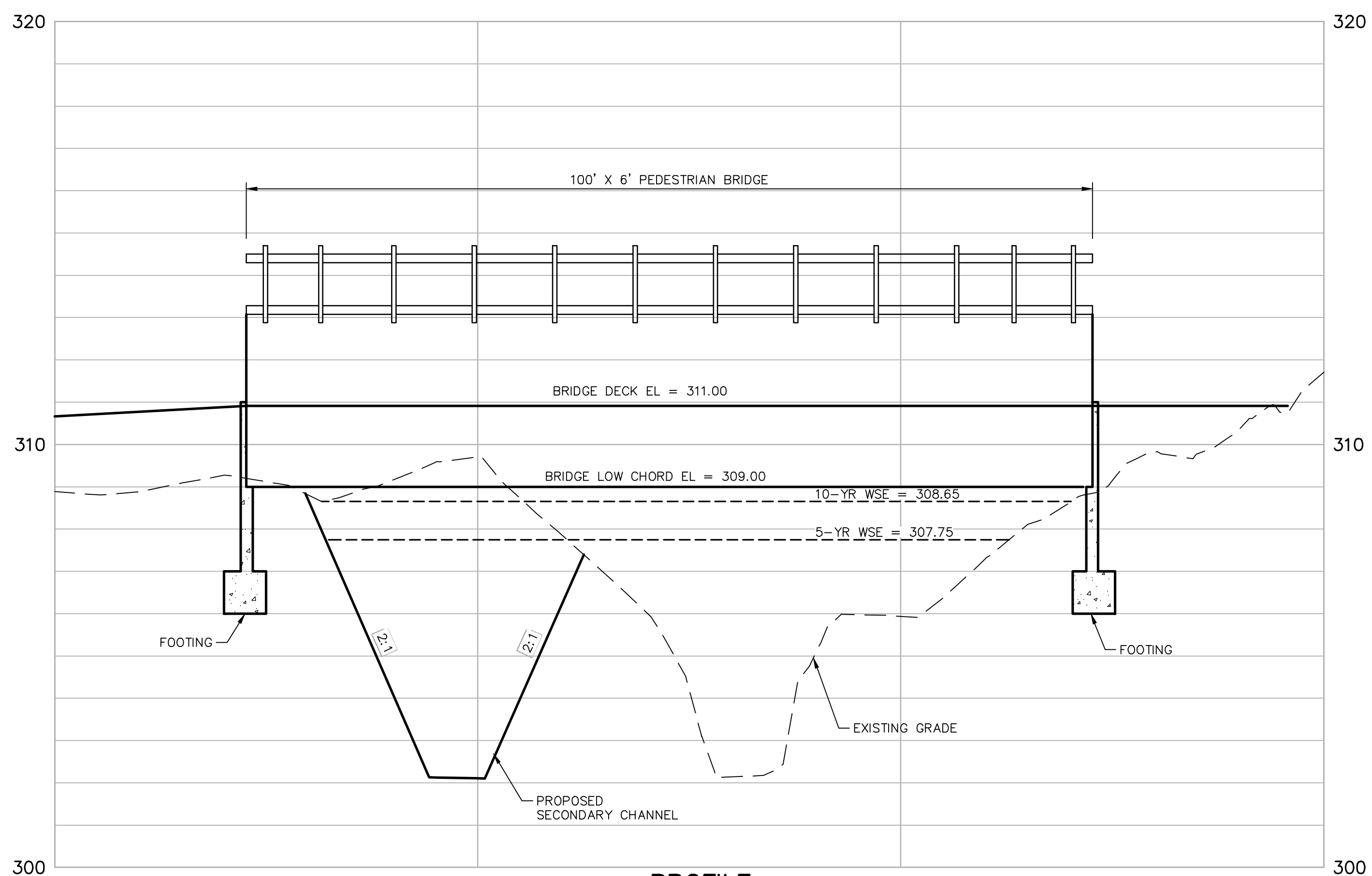
Tetra Tech, 2008. Agua Hedionda Watershed Management Plan – Final.

Tory R. Walker Engineering, 2017. Technical Memorandum: Erosion Susceptibility Analysis of Roman Creek for: 1525 Buena Vista Drive, Vista, CA.

USACE Hydrologic Engineering Center, 2016. HEC-RAS River Analysis System – User's Manual. Version 5.0.

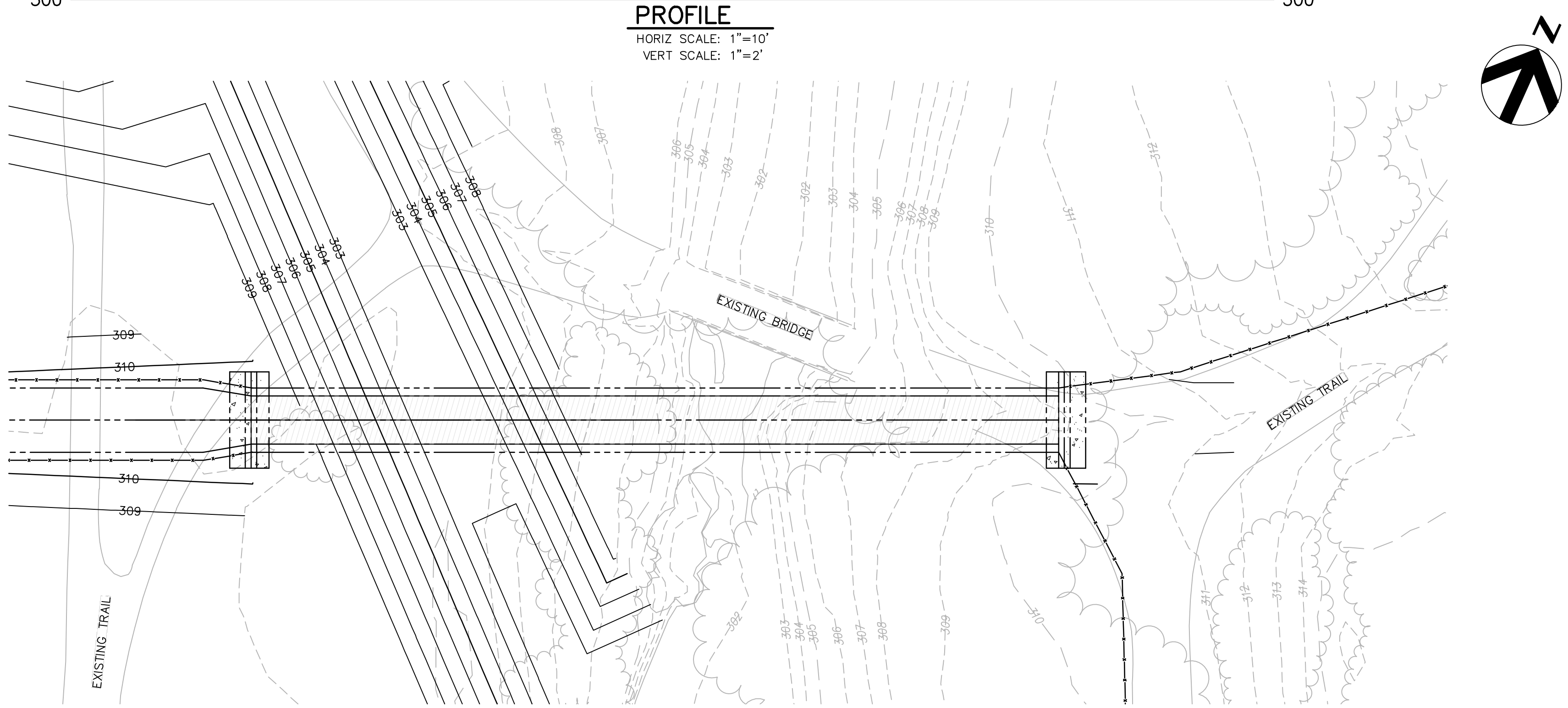
USACE Hydrologic Engineering Center, 2016. Hydrologic Modeling System HEC-HMS – User's Manual. Version 4.2.

Appendix



PROFILE

HORIZ SCALE: 1"=10'
VERT SCALE: 1"=2'



ROMAN CREEK BRIDGE PLAN

SCALE: 1"= 10'

HDR

NO.	DESCRIPTION	CITY	DATE	VID	DATE
	APPROVED CHANGES				

ENGINEER OF WORK | RCE | EXP.LIC.DATE | DATE

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SCALE IN FEET

C-00

CITY of VISTA

IMPROVEMENT PLANS FOR:
ROMAN CREEK MITIGATION AND HABITAT RESTORATION PROJECT
ROMAN CREEK BRIDGE PLAN AND PROFILE
(C.I.P. NO. XXXX)

APPROVED

CITY ENGINEER | P.E. | EXPIRES | DATE

SHEET X OF XX

DWG-XXXX

PREPARED BY: DATE:

XX% SUBMITTAL

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LDXX-XXX CIP NO. XXXX

Proposed Roman Creek Bridge HEC-RAS Results

HEC-RAS Plan: Alt3_1D River: River 1 Reach: Reach 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	364	2yr	455.20	302.75	306.63		306.81	0.002727	3.46	131.40	68.69	0.44
Reach 1	364	5yr	685.80	302.75	307.77		307.92	0.001546	3.13	219.36	84.95	0.34
Reach 1	364	10yr	881.00	302.75	308.67		308.80	0.001080	2.91	303.09	105.14	0.30
Reach 1	364	25yr	1159.40	302.75	309.82		309.93	0.000765	2.61	443.72	139.16	0.26
Reach 1	364	50yr	1238.90	302.75	310.08		310.18	0.000718	2.58	479.81	146.44	0.25
Reach 1	364	100yr	1304.30	302.75	310.31		310.41	0.000666	2.54	514.19	152.29	0.24
Reach 1	327	2yr	455.20	301.92	306.66		306.72	0.000875	2.01	226.48	114.41	0.25
Reach 1	327	5yr	685.80	301.92	307.81		307.86	0.000498	1.83	375.55	150.57	0.20
Reach 1	327	10yr	881.00	301.92	308.71		308.75	0.000351	1.69	520.77	173.89	0.17
Reach 1	327	25yr	1159.40	301.92	309.86		309.89	0.000237	1.57	737.33	200.88	0.14
Reach 1	327	50yr	1238.90	301.92	310.11		310.15	0.000223	1.57	788.24	203.45	0.14
Reach 1	327	100yr	1304.30	301.92	310.34		310.37	0.000209	1.56	835.05	205.57	0.14
Reach 1	302	2yr	455.20	301.50	306.66		306.70	0.000560	1.69	269.38	123.92	0.20
Reach 1	302	5yr	685.80	301.50	307.81		307.85	0.000343	1.60	428.07	157.05	0.17
Reach 1	302	10yr	881.00	301.50	308.71		308.74	0.000248	1.52	579.48	176.58	0.15
Reach 1	302	25yr	1159.40	301.50	309.85		309.89	0.000179	1.47	790.83	189.49	0.13
Reach 1	302	50yr	1238.90	301.50	310.11		310.14	0.000172	1.48	838.79	191.76	0.12
Reach 1	302	100yr	1304.30	301.50	310.33		310.37	0.000164	1.48	882.89	193.65	0.12
Reach 1	272	2yr	455.20	301.56	306.64		306.68	0.000432	1.60	284.82	116.14	0.18
Reach 1	272	5yr	685.80	301.56	307.80		307.84	0.000298	1.58	435.14	148.03	0.16
Reach 1	272	10yr	881.00	301.56	308.70		308.73	0.000228	1.53	574.62	160.47	0.14
Reach 1	272	25yr	1159.40	301.56	309.85		309.88	0.000174	1.52	764.42	170.01	0.13
Reach 1	272	50yr	1238.90	301.56	310.10		310.13	0.000169	1.53	807.42	172.04	0.12
Reach 1	272	100yr	1304.30	301.56	310.33		310.36	0.000163	1.54	847.00	173.88	0.12
Reach 1	240	2yr	455.20	301.71	306.50	304.74	306.65	0.001666	3.12	145.77	59.27	0.35
Reach 1	240	5yr	685.80	301.71	307.68	305.34	307.81	0.001293	2.95	232.54	93.23	0.33
Reach 1	240	10yr	881.00	301.71	308.60	305.74	308.71	0.000880	2.69	328.07	113.45	0.28
Reach 1	240	25yr	1159.40	301.71	309.78	306.26	309.87	0.000615	2.42	479.25	151.78	0.24
Reach 1	240	50yr	1238.90	301.71	310.03	306.40	310.12	0.000562	2.39	518.20	153.57	0.23
Reach 1	240	100yr	1304.30	301.71	310.26	306.51	310.35	0.000514	2.35	554.09	154.91	0.22
Reach 1	214	2yr	455.20	301.88	306.49	304.31	306.60	0.001205	2.70	168.44	59.55	0.28
Reach 1	214	5yr	685.80	301.88	307.66	304.87	307.78	0.001043	2.80	244.82	71.15	0.27
Reach 1	214	10yr	881.00	301.88	308.57	305.27	308.69	0.000916	2.81	314.01	80.57	0.25
Reach 1	214	25yr	1159.40	301.88	309.72	305.78	309.85	0.000712	2.83	410.41	104.71	0.23
Reach 1	214	50yr	1238.90	301.88	309.97	305.89	310.10	0.000726	2.86	432.48	109.62	0.23
Reach 1	214	100yr	1304.30	301.88	310.20	306.02	310.33	0.000737	2.87	454.02	114.29	0.23
Reach 1	213		Bridge									
Reach 1	188	2yr	455.20	301.74	306.37	304.55	306.54	0.001827	3.38	134.87	50.91	0.37
Reach 1	188	5yr	685.80	301.74	307.55	305.19	307.73	0.001292	3.39	202.34	62.13	0.33
Reach 1	188	10yr	881.00	301.74	308.48	305.62	308.65	0.001027	3.35	263.33	70.68	0.31
Reach 1	188	25yr	1159.40	301.74	309.49	306.20	309.66	0.001079	3.31	349.88	98.53	0.31
Reach 1	188	50yr	1238.90	301.74	309.69	306.34	309.87	0.001075	3.35	370.08	101.64	0.31
Reach 1	188	100yr	1304.30	301.74	309.88	306.47	310.05	0.001055	3.35	389.31	105.43	0.31
Reach 1	187		Lat Struct									
Reach 1	137	2yr	455.20	301.72	306.22		306.44	0.001791	3.74	121.65	38.64	0.37
Reach 1	137	5yr	685.80	301.72	307.38		307.63	0.001611	4.04	169.76	44.21	0.36
Reach 1	137	10yr	881.00	301.72	308.29		308.56	0.001700	4.11	214.24	56.44	0.37
Reach 1	137	25yr	1159.40	301.72	309.31		309.56	0.002044	4.02	288.05	90.24	0.40
Reach 1	137	50yr	1238.90	301.72	309.52		309.77	0.001951	4.04	306.89	92.31	0.39
Reach 1	137	100yr	1304.30	301.72	309.71		309.96	0.002001	4.01	325.40	101.06	0.39
Reach 1	82	2yr	455.20	301.00	304.76	304.76	306.10	0.015203	9.30	48.96	18.51	1.01
Reach 1	82	5yr	685.80	301.00	305.81	305.70	307.31	0.012984	9.82	69.84	21.26	0.96
Reach 1	82	10yr	881.00	301.00	307.08	306.40	308.28	0.008899	8.79	100.18	27.32	0.81
Reach 1	82	25yr	1159.40	301.00	307.94	307.29	309.25	0.009203	9.18	126.34	33.61	0.83
Reach 1	82	50yr	1238.90	301.00	307.95	307.50	309.44	0.010406	9.76	126.91	33.75	0.89
Reach 1	82	100yr	1304.30	301.00	307.98	307.72	309.60	0.011384	10.22	127.67	33.93	0.93
Reach 1	29	2yr	455.20	300.15	303.84	303.66	305.19	0.014009	9.31	48.88	15.43	0.92
Reach 1	29	5yr	685.80	300.15	304.88	304.66	306.59	0.014003	10.50	65.32	16.30	0.92
Reach 1	29	10yr	881.00	300.15	305.66	305.39	307.62	0.014003	11.26	78.27	17.01	0.92
Reach 1	29	25yr	1159.40	300.15	307.61	306.27	308.55	0.014002	7.78	148.93	92.99	1.08
Reach 1	29	50yr	1238.90	300.15	307.75	307.75	308.65	0.012975	7.63	162.29	94.34	1.03
Reach 1	29	100yr	1304.30	300.15	307.78	307.78	308.75	0.013699	7.88	165.51	94.61	1.05