UPPER GUADALUPE RIVER
FLOOD RISK MANAGEMENT PROJECT
San José, California

Engineering and Design

Hydraulics, Hydrology and Climate Assessment

Appendix A1

DRAFT INTEGRATED
GENERAL REEVALUATION REPORT
& SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT

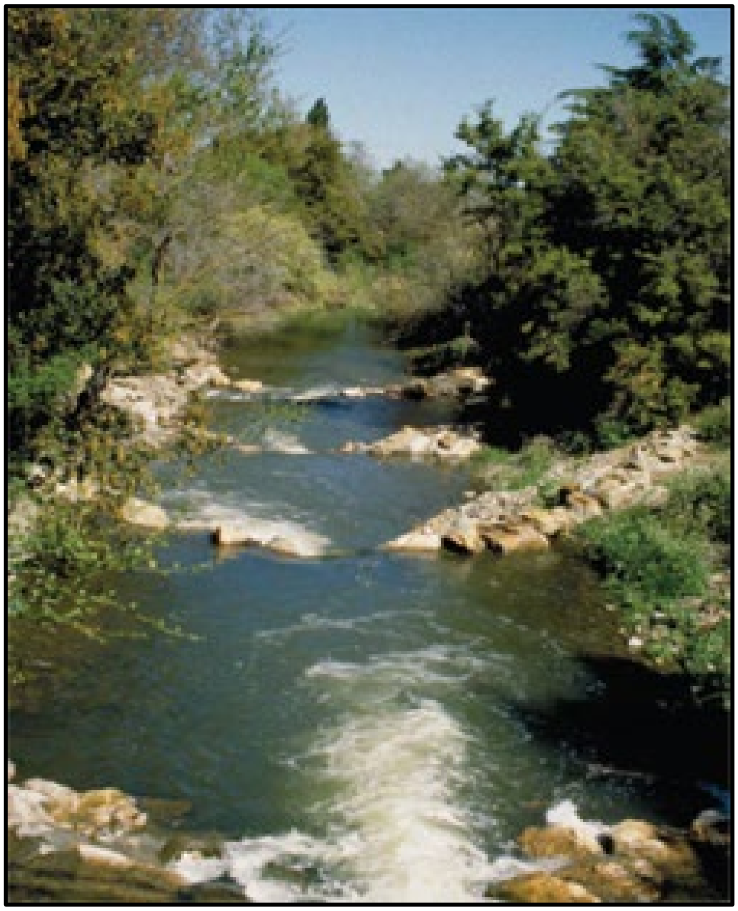
November 2022

US Army Corps
of Engineers®
San Francisco District

Valley Water

UPPER GUADALUPE RIVER FLOOD RISK MANAGEMENT PROJECT

GUADALUPE RIVER



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Acronyms / Abbreviations	Definition
1D	One Dimensional
2D	Two Dimensional
ACE	Annual Chance Exceedance
CFS	Cubic Feet per Second
DTM	Digital Terrain Model
DQC	District Quality Control
EC	Engineering Circular
ER	Engineering Regulation
FRM	Flood Risk Management
FWOP	Future Without Project
GRR	General Re-Evaluation Report
GIS	Geographic Information Systems
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center River Analysis System
LiDAR	Light Detection and Ranging
LPP	Locally Preferred Plan
LRR	Limited Re-Evaluation Report
NAVD	North American Vertical Datum
NLCD	National Land Cover Dataset
NED	National Economic Development
PDT	Project Delivery Team
R&U	Risk and Uncertainty
TSP	Tentatively Selected Plan
USACE	United States Army Corps of Engineers

1.0 STUDY DESCRIPTION

1.1 Purpose and Scope

The Upper Guadalupe River General Re-Evaluation Report (GRR) is reevaluating the previously studied, congressionally authorized, and partially constructed project along the Guadalupe River. A reformulation is assessing the feasibility of managing flood risks and identifying recreation improvement opportunities in the system to develop alternatives that can meet current and future needs within the policies and regulations of the United States Army Corps of Engineers (USACE). The local non-federal sponsor of the GRR is Valley Water (formerly known as Santa Clara Valley Water District and is shown as such in many legacy documents associated with the GRR study area). The purpose of this document is to summarize the hydraulic assumptions used for the hydraulic modeling.

This report will provide hydraulic assumptions, document modeling decisions for the hydraulic model which consists of one dimensional (1D) and two dimensional (2D) components. The report presents the floodplain maps for the existing condition and various with-project condition alternatives.

1.2 Study Area

The Guadalupe River is located within Santa Clara County in the city of San Jose, California, with its headwaters located in the Santa Cruz Mountains and its mouth located in San Francisco Bay. The GRR study area is focused on Reaches 7 through 12 of the Guadalupe River, known as "Upper Guadalupe". Water in the channel flows from south (Reach 12) to north (Reach 7). The upstream extent of Reach 12 is Blossom Hill Road, and the downstream extent of Reach 7 is the Caltrain railroad bridge, as shown in Figure 1. A table with complete reach delineation for the GRR study area is described in Table 1. The reaches downstream of Reach 7 were previously constructed and known as "Downtown Guadalupe", which was built by the Corps of Engineers and "Reach 6" and "Lower Guadalupe", which were built by Valley Water (Figure 2). Two significant tributaries, Ross and Canoas Creeks, empty into the Guadalupe River between Reach 7 and 12. The GRR study area is highly urbanized, containing mostly residential and commercial structures.

Table 1. Reach Delineation for GRR Study Area

Reach	Upstream Extent	Downstream Extent
7 (Downstream End of Study Area)	Caltrain Railroad Bridge	Abandoned Railroad Bridge
8	Abandoned Railroad Bridge	Willow Glen Way
9	Willow Glen Way	Curtner Avenue
10	Curtner Avenue	Capitol Expressway
11	Capitol Expressway	Branham Lane
12 (Upstream End of Study Area)	Branham Lane	Blossom Hill Road

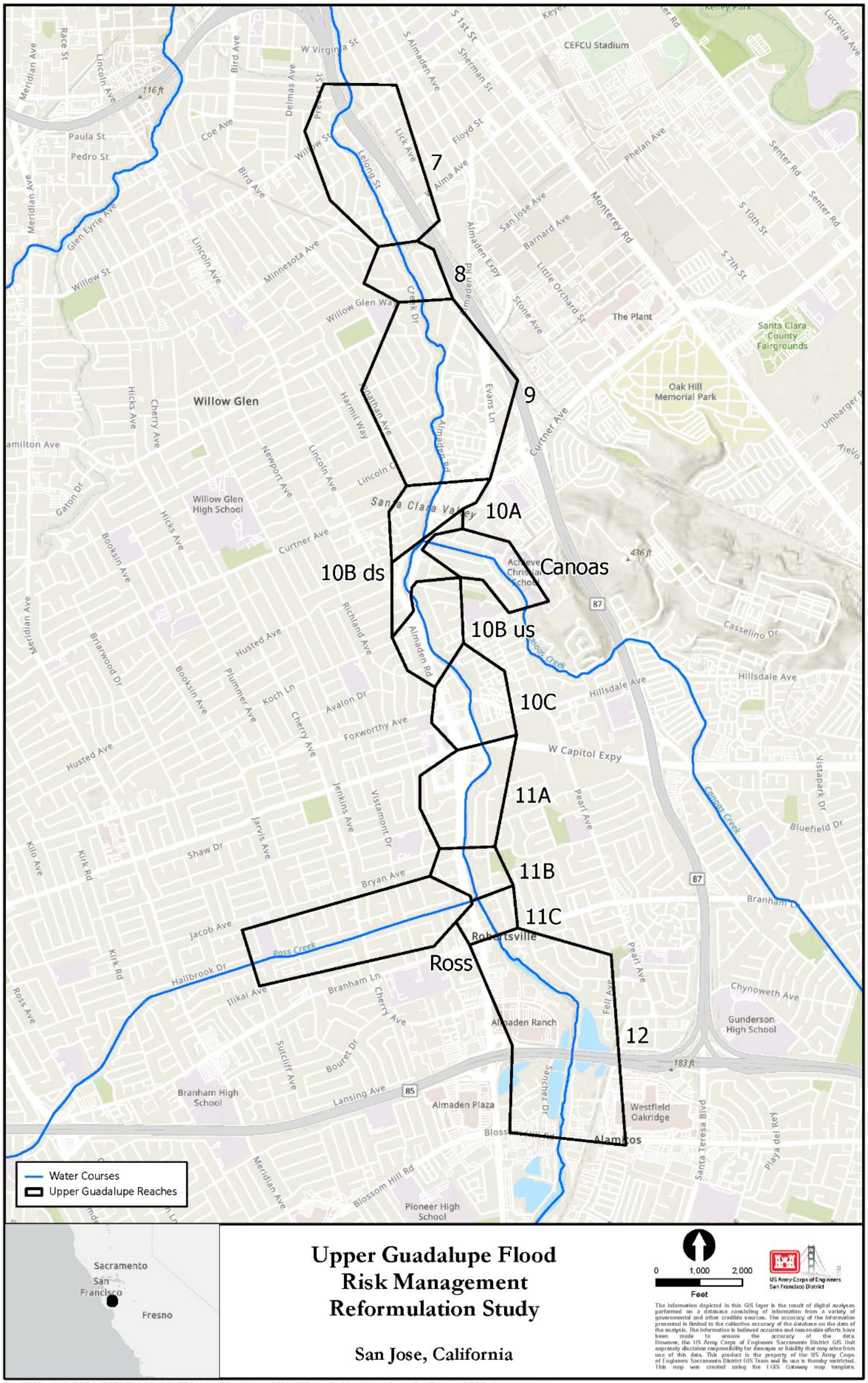

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Figure 1. Map of GRR Study Area

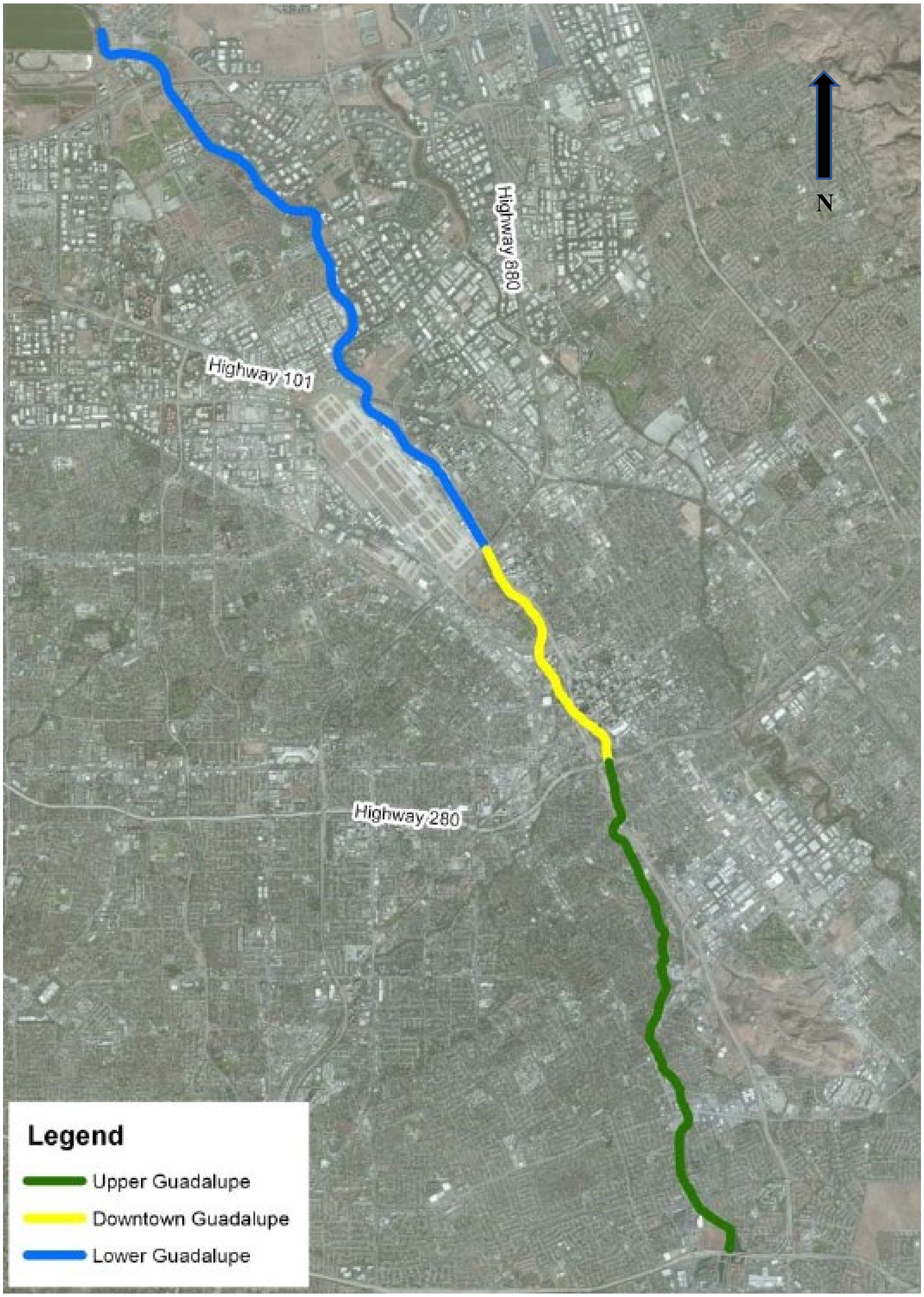

Figure 2. Map of the Entire Guadalupe River (USACE, 2013)

1.3 Flood History

Reports regarding out of channel flow events for the entire Santa Clara County were provided by Valley Water staff to Water Resources Section staff (Santa Clara Valley Water District, 1995 & Santa Clara Valley Water District, 2004). The reports indicate that the GRR study area last experienced significant flooding in both 1995 and 1998 (Table 2). It should be noted that areas outside of Reaches 7 through 12 of the Guadalupe River also experienced significant flooding in the same time period. Peak flows on the Guadalupe River, Ross Creek and Canoas Creek within the GRR study area for the 1995 and 1998 events were estimated by Valley Water from gage data and other methods and are presented in Table 3. Although there are some inconsistencies between the areas noted as flooded and the estimated peak flows in the reports from Valley Water, in general it can be inferred that both the 1995 and 1998 caused damages within the GRR study area.

Table 2. Summary of Observed Flooding within GRR Study Area in 1995 and 1998 (Santa Clara Valley Water District, 1995 & Santa Clara Valley Water District, 2004)

Date	Guadalupe River	Ross Creek	Canoas Creek
January 9-10, 1995	Flow overbanked at Alma Avenue in Reach 7	Flow overbanked at Cherry Avenue and Jarvis Avenue	Flow overbanked near Redbird Drive and Kingfisher Drive
March 10, 1995	Flow overbanked at Alma Avenue in Reach 7	None reported by Valley Water document	None reported by Valley Water document
February 2-7, 1998	Flow overbanked at Alma Avenue in Reach 7	Flow overbanked at Cherry Avenue	None reported by Valley Water document

Table 3. Summary of Estimated Peak Discharges within GRR Study Area in 1995 and 1998 (Santa Clara Valley Water District, 1995 & Santa Clara Valley Water District, 2004)

Date	Guadalupe River at Almaden Expressway (cfs)	Ross Creek at Cherry Avenue (cfs)	Canoas Creek at Almaden Expressway (cfs)
January 8-12, 1995	8,470	910	Not Reported
March 9-14, 1995	5,590	935	Not Reported
February 2-5, 1998	6,725	1,158	1,400
February 6-9, 1998	3,980	1,114	830

2.0 HYDROLOGY

2.1 Peak Discharges

USACE conducted a hydrologic analysis of the entire Guadalupe River watershed in 2009 via HEC-HMS (USACE, 2009). The analysis served as an update to the original 1977 analysis of the watershed and was reviewed and certified by South Pacific Division prior to the GRR. No updates to this analysis were made as part of the GRR.

The analysis had the watershed split up into 42 smaller sub-basins and the model was configured to estimate peak discharge values for the 50-, 20-, 10-, 4-, 2-, 1-, 0.5, and 0.2- annual percent chance exceedance (ACE) events with a storm centering over the Guadalupe Reservoir. The relevant peak discharge values within the GRR study area are shown in Table 4. The flow hydrographs from this analysis were used as input boundary conditions for the hydraulic analysis of future without-project conditions and the proposed final array of alternatives. The existing conditions is assumed to be the same as future without project conditions as there are no plans for future projects.

Table 4. Peak Flows on the Guadalupe River in the GRR Study Area from 2009 Hydrologic Analysis

Percent Exceedance	Guadalupe River Upstream of Ross Creek (cfs)	Guadalupe River Downstream of Ross Creek (cfs)	Guadalupe River Downstream of Canoas Creek (cfs)
50	1,382	1,841	2,521
20	3,141	3,910	4,859
10	4,095	5,149	6,267
4	6,629	7,562	8,865
2	8,990	10,181	11,691
1	11,165	12,564	14,366
0.5	13,298	15,077	16,996
0.2	15,676	17,893	19,909

2.2 Climate Change to Inland Hydrology

The Guadalupe River watershed is situated in the mid-latitudes between the 37th and 38th north parallels and has a Mediterranean climate. The most distinct feature of Mediterranean climates is a single rainy season each winter and drought each summer. The South Bay's variation of the Mediterranean climate includes cool (mild) summers and cool (mild) winters. A high-pressure system, the Pacific High, blocks storms from reaching the region in summer months. During winter months, the system moves south and allows storm systems to move in. Mid-latitude storms that impact the region generally originate either from extratropical cyclones along the northern polar front or narrow bands of subtropical moisture (atmospheric rivers). Flooding in the Bay Area can result from conditions associated with atmospheric rivers, extratropical cyclones, or combinations of the two event types.

Cumulative annual precipitation amounts vary widely by water year (Figure 3). This high interannual variability can be impacted by the El Niño Southern Oscillation (ENSO). Some of the water years with the highest precipitation totals (e.g., 1982–1983, 1997–1998) have coincided with warm (El Niño) episodes of ENSO. Annual precipitation totals are lowest along the coastline and increase as elevation increases. Elevations in the Guadalupe River watershed range from sea level to approximately 3,800 ft NAVD 88. The 2009 USACE hydrology study reported average annual basin rainfall totals ranging from 13 inches at the downtown San Jose station to 42 inches at the Lexington gage (USACE 2009).

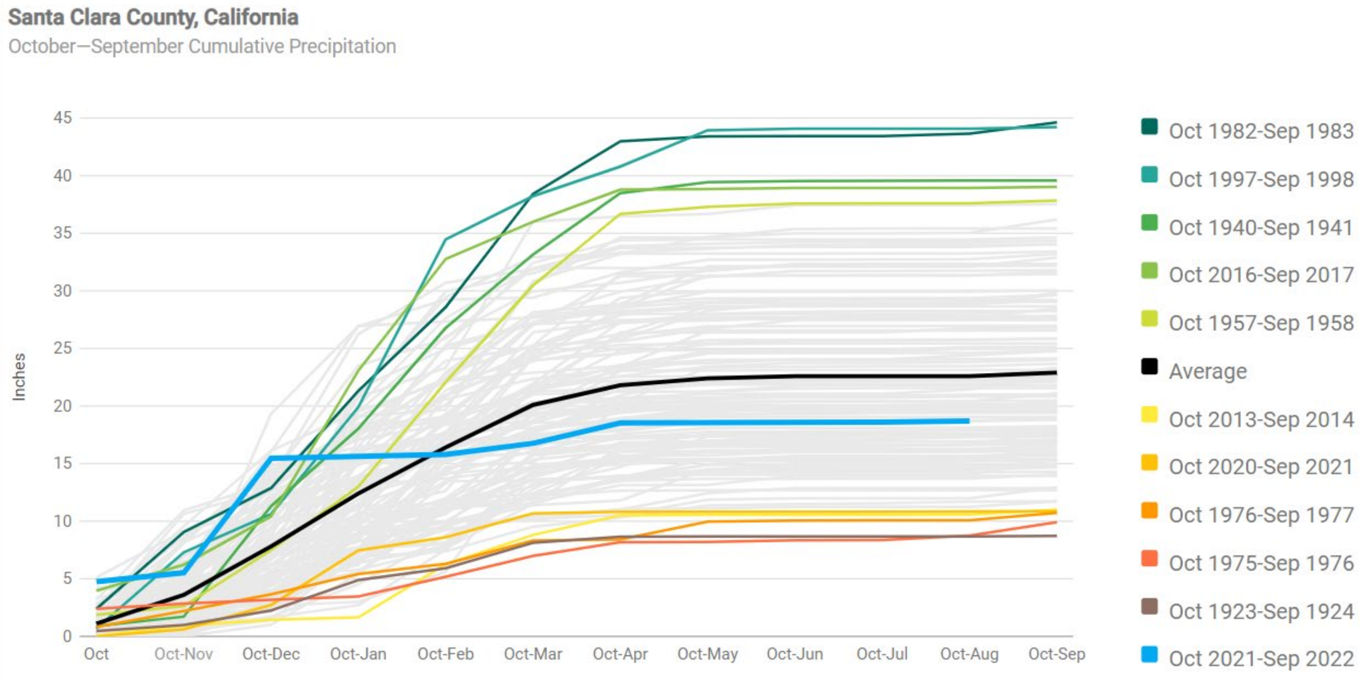

Figure 3. Cumulative precipitation totals by water year for the County of Santa Clara for the recent historical record (1895-present). The five highest (green), lowest (orange), and current year-to-date (blue) water year totals are highlighted. Haywood plot downloaded September 27, 2022. Source: https://www.ncei.noaa.gov.

2.3 Observed and Projected Trends

The 4th (most recent) National Climate Assessment (NCA) was used to investigate general temperature, precipitation, flooding, and drought trends for the United States and the Southwest region. The USACE Climate Hydrology Assessment Tool (CHAT) (Nguyen et al 2020)[1] was used to investigate trends in simulated historical and projected future precipitation, temperature, and streamflow for Hydrologic Unit Code (HUC) HUC 18050003. The Upper Guadalupe project is located in HUC 18050003 (San Francisco Bay - Coyote), which includes both Coyote Creek and Guadalupe River watersheds. CHAT results have been spatially aggregated to HUC-8 regions and provide projected future results for Representative Concentration Pathway (RCP) scenario 4.5 (low emissions) and RCP scenario 8.5 (high emissions). Results of the CHAT tool trends, and significance tests are summarized in Table 5.

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[1] CHAT version 2.2 (February 2022)

Table 5. Summary of Trends and Significance for Climate Parameters in HUC 18050003.

Parameter		Simulated Historical	Projected Future (4.5)	Projected Future (8.5)	Interpretation
		p-value (5% significance level)			
Daily Average Temperature	**Annual Average**	Significant (Increasing)	Significant (Increasing)	Significant (Increasing)	The directionality and magnitude of trends suggest that increases in temperature are already materializing in the region and can be anticipated to persist and accelerate into the future.
Daily Maximum Temperature	**Annual Maximum**	Significant (Increasing)	Significant (Increasing)	Significant (Increasing)	
Daily Accumulated Precipitation	**Annual Sum**	Not significant	Significant (Increasing)	Significant (Increasing)	There is not enough evidence to suggest a trend in the simulated historical precipitation data, but the statistically significant change in projected, future precipitation suggests changes in the future without project condition due to climate change.
Daily Accumulated Precipitation	**Annual Maximum of 3-day Sum**	Not Significant	Significant (Increasing)	Significant (Increasing)	
Number of Consecutive Dry Days	**Annual Maximum**	Significant (Increasing)	Not significant	Significant (Increasing)	The significance in the projected future scenarios depends on emissions scenario.
Average Monthly Streamflow	**Annual Maximum**	Not significant	Significant (Increasing) (Note: Streamflow trend analysis combines RCP 4.5 and 8.5 scenarios)		There is not enough evidence to suggest a trend in the simulated historical streamflow data, but the statistically significant change in projected future stream flows suggests changes in the future without project condition due to climate change.

2.4 Temperature

2.4.1 United States and Southwest Region

The annual average temperature of the contiguous United States has risen by approximately 1.2°F to 1.8°F since the start of the twentieth century (Vose et al. 2017). The Southwest National Climate Assessment region experienced an increase in annual average, annual average minimum, and annual average maximum temperatures of 1.61°F between the present-day measurement period (1986-2016) and the first half of the last century measurement period (1901-1960) (Vose et al. 2017). Figure 4 shows the spatial variation of temperature increases across the Southwest region. Higher air temperatures are associated with an increase in the intensity of extreme precipitation events (Easterling et al. 2017).

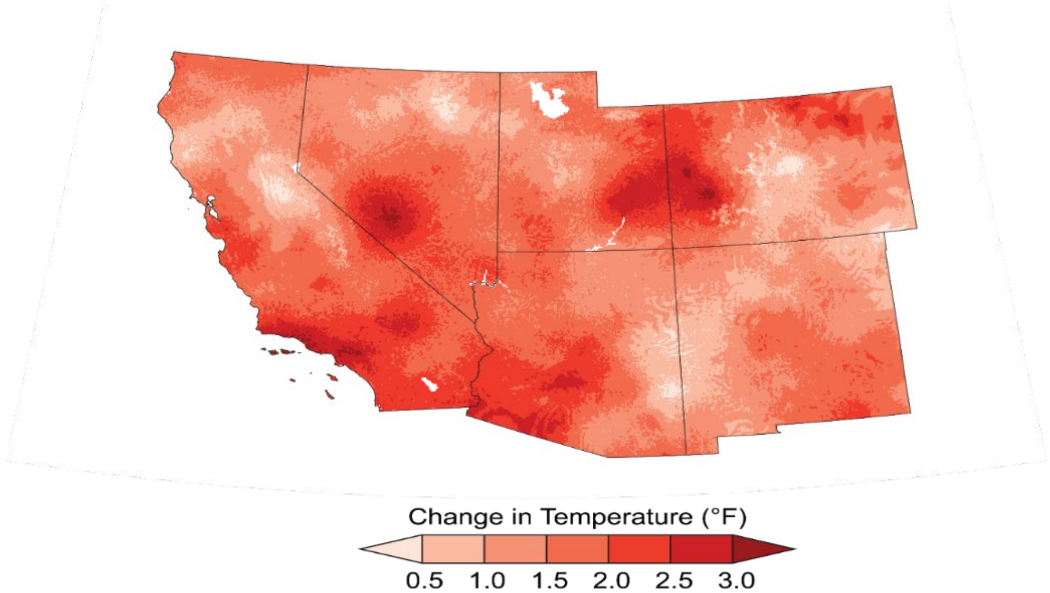


Figure 4. Difference between 1986–2016 average temperature and 1901–1960 average temperature for the Southwest Region (Gonzalez et al. 2018)

Temperatures are expected to increase throughout the United States under both the low and high emissions scenarios (Figure 5). In general, northern latitudes and inland areas will experience greater increases in temperatures than coastal areas. Daily extreme temperatures (e.g., coldest and warmest daily temperatures) are also expected to increase in most areas by mid-century (Vose et al. 2017).

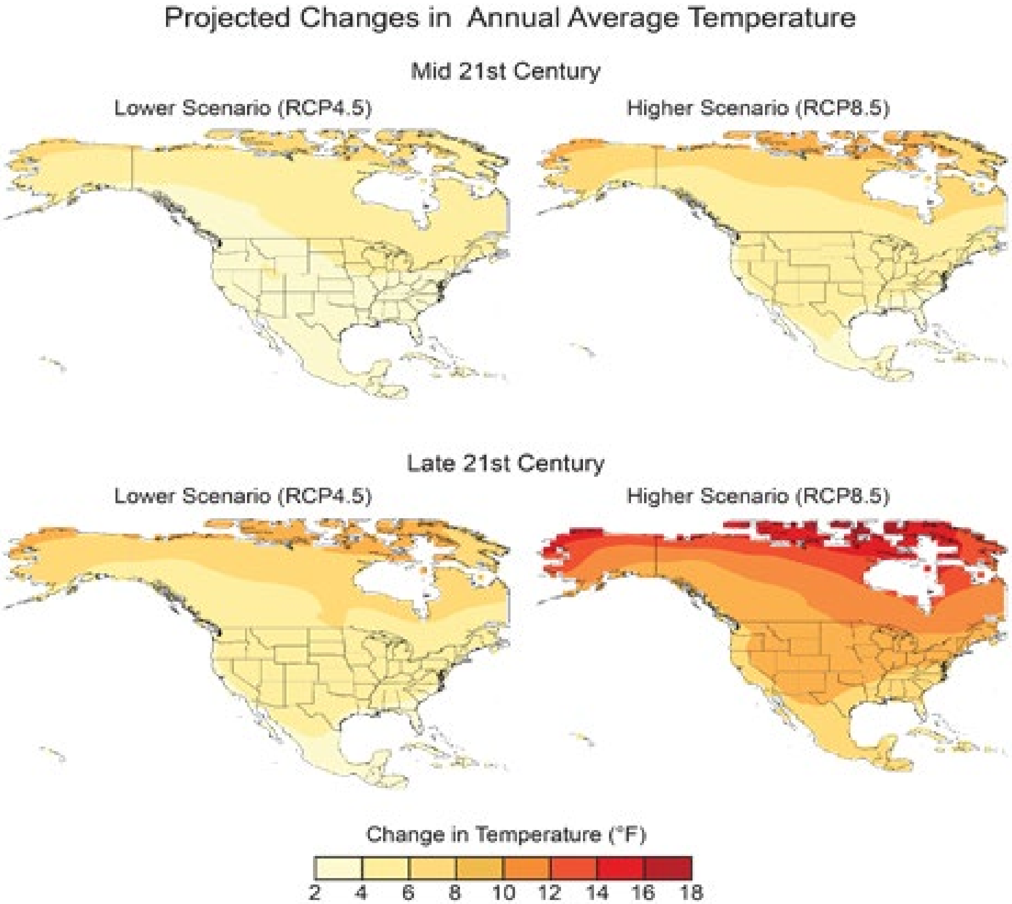


Figure 5. Projected changes in annual average temperatures (°F) for mid and late 21st century under low and high Representative Concentration Pathways (RCP) (emission) scenarios.

2.4.2 HUC 18050003 (San Francisco Bay – Coyote)

CHAT results for daily average temperature (annual average) and daily maximum temperature (annual maximum) are shown in Figure 6 - Figure 7.

For daily average temperature, the linear trend equates to an increase of 3.7 degrees F (6.2%) over the 93-year projection period (low emissions scenario) and an increase of 7.7 degrees F (13.2%) over the 93-year projection period (high emissions scenario).

For daily maximum temperature, the linear trend equates to an increase of 4.0 degrees F (4.1%) over the 93-year projection period (low emissions scenario) and an increase of 7.7 degrees F (7.8%) over the 93-year projection period (high emissions scenario).

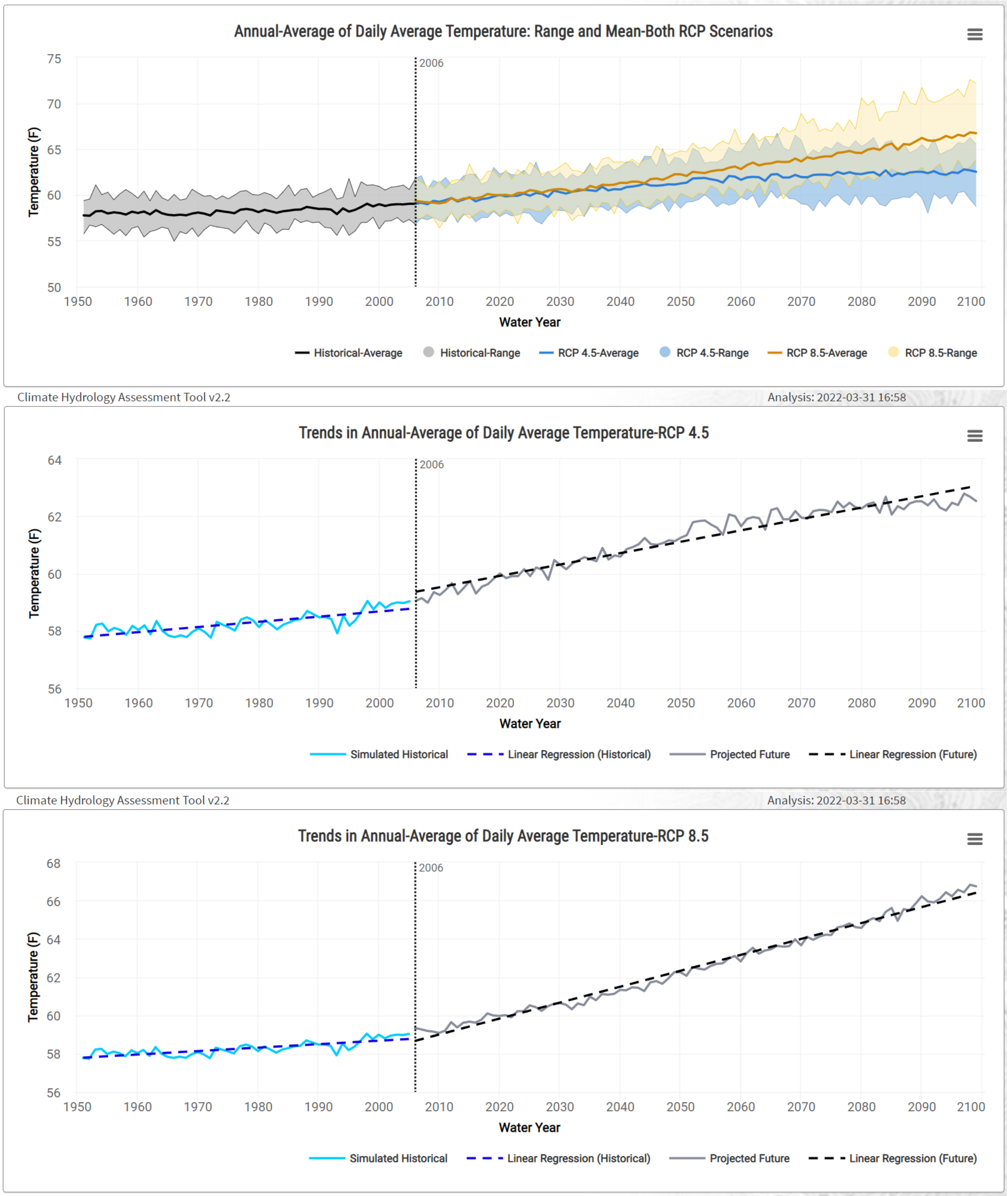


Figure 6. Annual Average of Daily Average Temperature. Range and mean (top), trend for RCP Scenario 4.5 (middle), trend for RCP Scenario 8.5 (bottom). Statistically significant trends were detected for simulated historical and projected future temperatures under both scenarios.

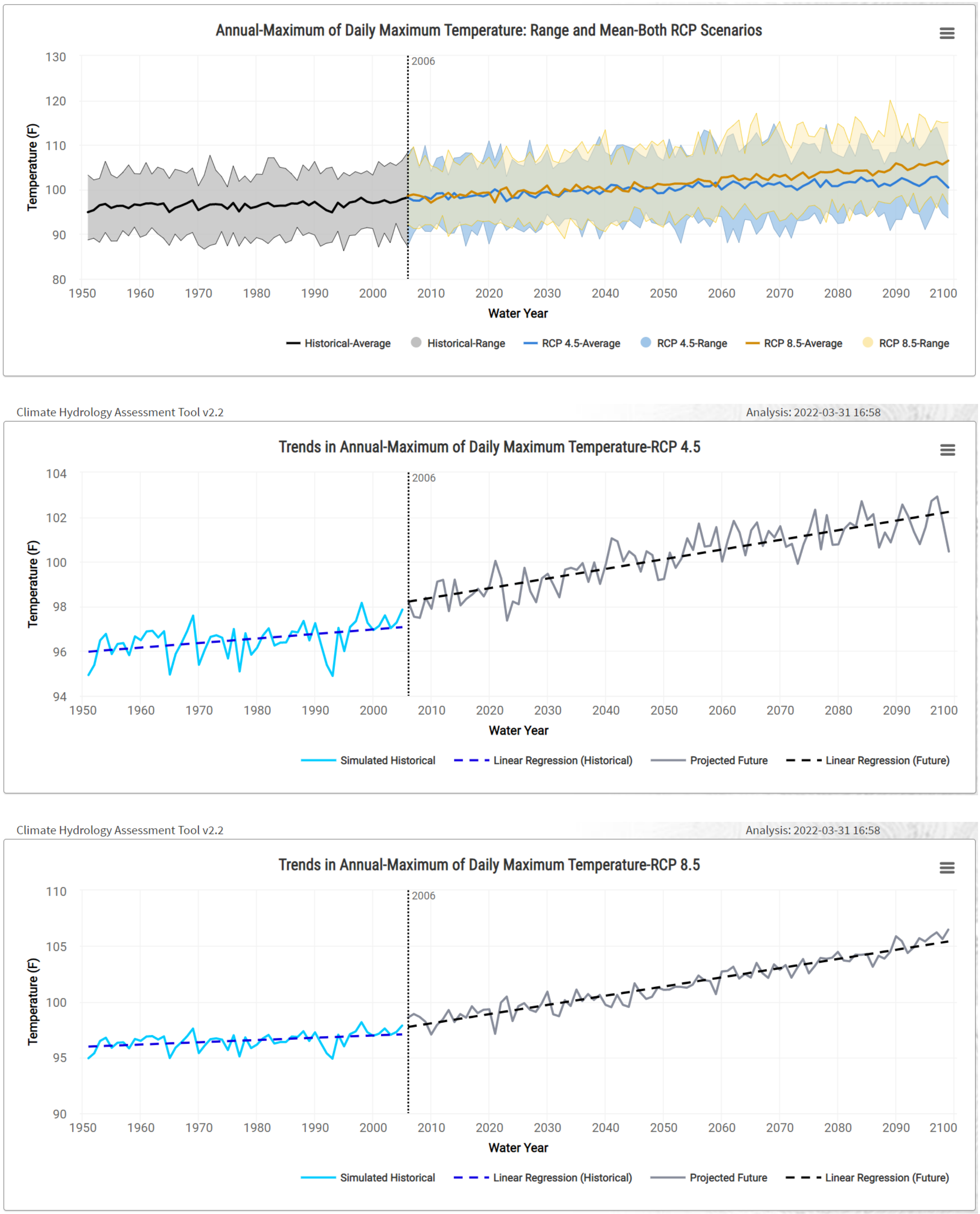


Figure 7. Annual Maximum of Daily Maximum Temperature. Range and mean (top), trend for RCP Scenario 4.5 (middle), trend for RCP Scenario 8.5 (bottom). Statistically significant trends were detected for simulated historical and projected future temperatures under both RCP scenarios.

2.5 Precipitation

2.5.1 United States and Southwest Region

Annual and seasonal precipitation have changed throughout the United States from the first half of the last century (1901-1960) to the present (1986-2015). Average annual precipitation for the entire country has increased by approximately 4%, but the observed changes in magnitude vary by season and by region (Easterling et al 2017; Figure 8).

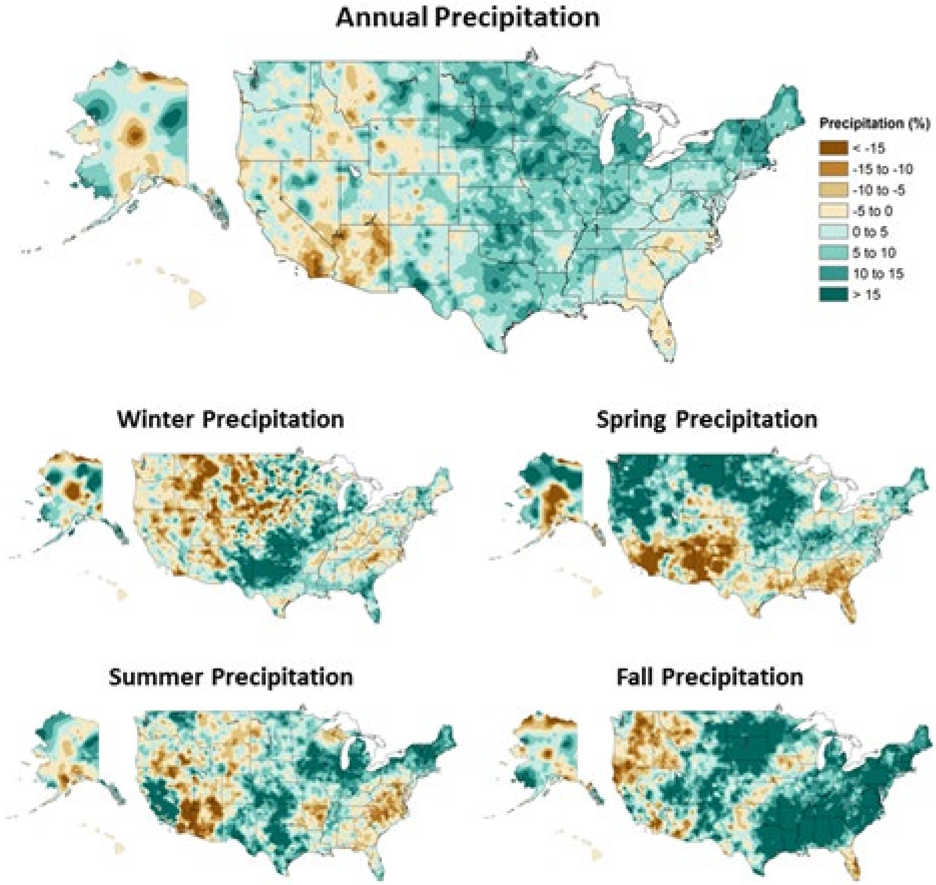


Figure 8. Annual and seasonal changes in average precipitation in the United States. Changes are the average for present-day (1986–2015) minus the average for the first half of the last century (1901–1960 for the contiguous United States, 1925–1960 for Alaska and Hawai'i) divided by the average for the first half of the century. (Easterling et al 2017)

Extreme precipitation indices have also shown increases (Easterling et al 2017). Figure 9 shows a general increasing trend for most of the country in daily 20-year return level precipitation by season over the period 1948-2015.

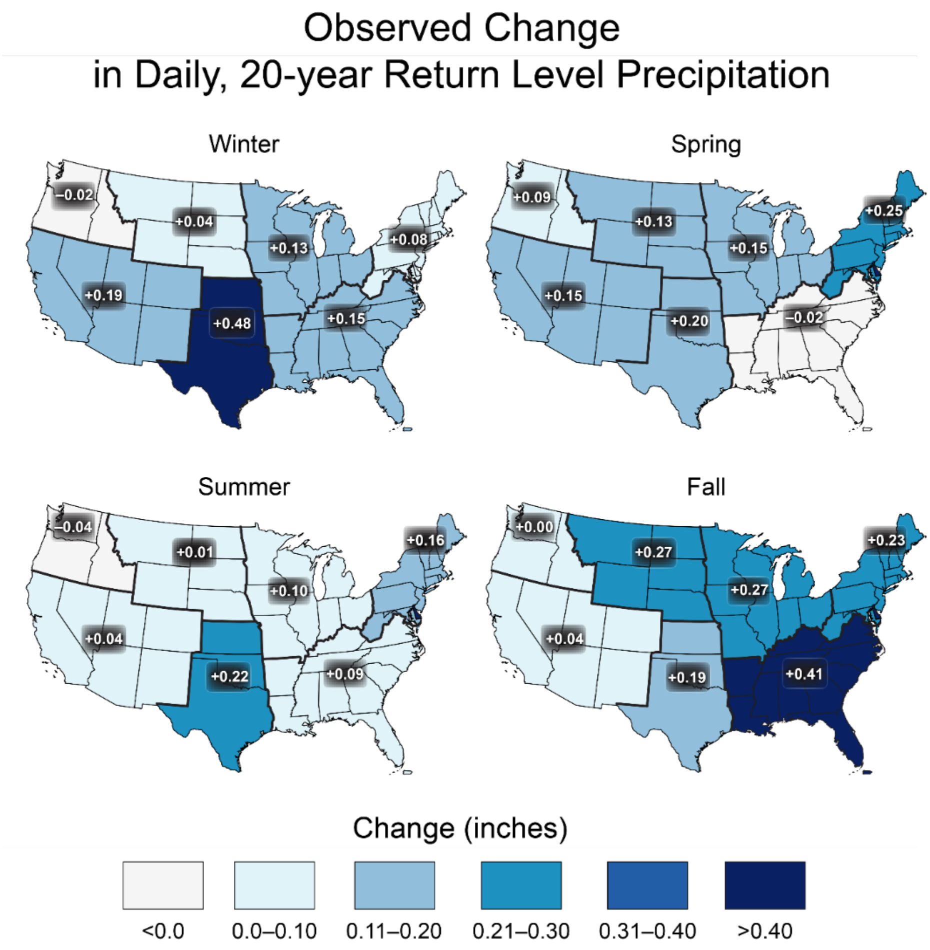


Figure 9. Observed change in the 20-year return value of the seasonal daily precipitation totals over the period 1948 to 2015 (Easterling et al 2017)

Changes in seasonal mean precipitation is projected to vary by region across the country (Easterling 2017). Extreme precipitation is expected to increase throughout all NCA regions (Easterling 2017; Figure 10). The increases in extreme precipitation tend to increase with return level, such that increases for the 1% ACE return level are about 30% by the end of the century under a higher (RCP8.5) scenario (Easterling 2017).

Along the West Coast, atmospheric rivers are responsible for a significant portion of annual precipitation and have historically been connected to flood events (Kossin et al 2017). Climate projections indicate a greater frequency of atmospheric rivers in the future (Wehner et al 2017) and an increase in atmospheric river water vapor transport by the end of the 21st century (Easterling 2017).

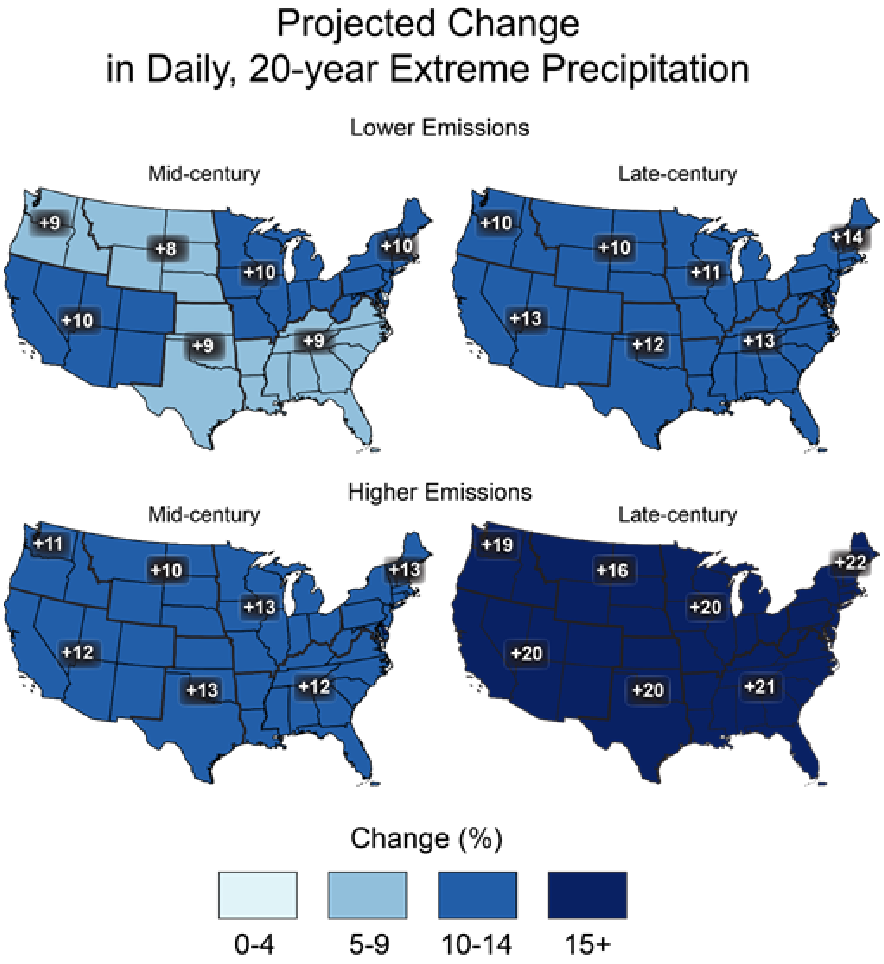


Figure 10. Projected change in the 20-year return period amount for daily precipitation for mid- (left) and late- (right) 21st century. Results are shown for a lower scenario (top; RCP 4.5) and for a higher scenario (bottom; RCP 8.5) (Easterling et al 2017).

HUC 18050003

CHAT results for daily accumulated precipitation (annual sum) and 3-day sum of accumulated precipitation (annual maximum) are shown in Figure 11 - Figure 12.

For annual sum of daily accumulated precipitation, the linear trend equates to an increase of 1.3 inches (5.9%) over the 93-year projection period (low emissions scenario) and an increase of 1.7 inches (7.8%) over the 93-year projection period (high emissions scenario).

For the 3-day sum of accumulated precipitation, the linear trend equates to an increase of 0.4 inches (11.5%) over the 93-year projection period (low emissions scenario) and an increase of 0.6 inches (18.5%) over the 93-year projection period (high emissions scenario).

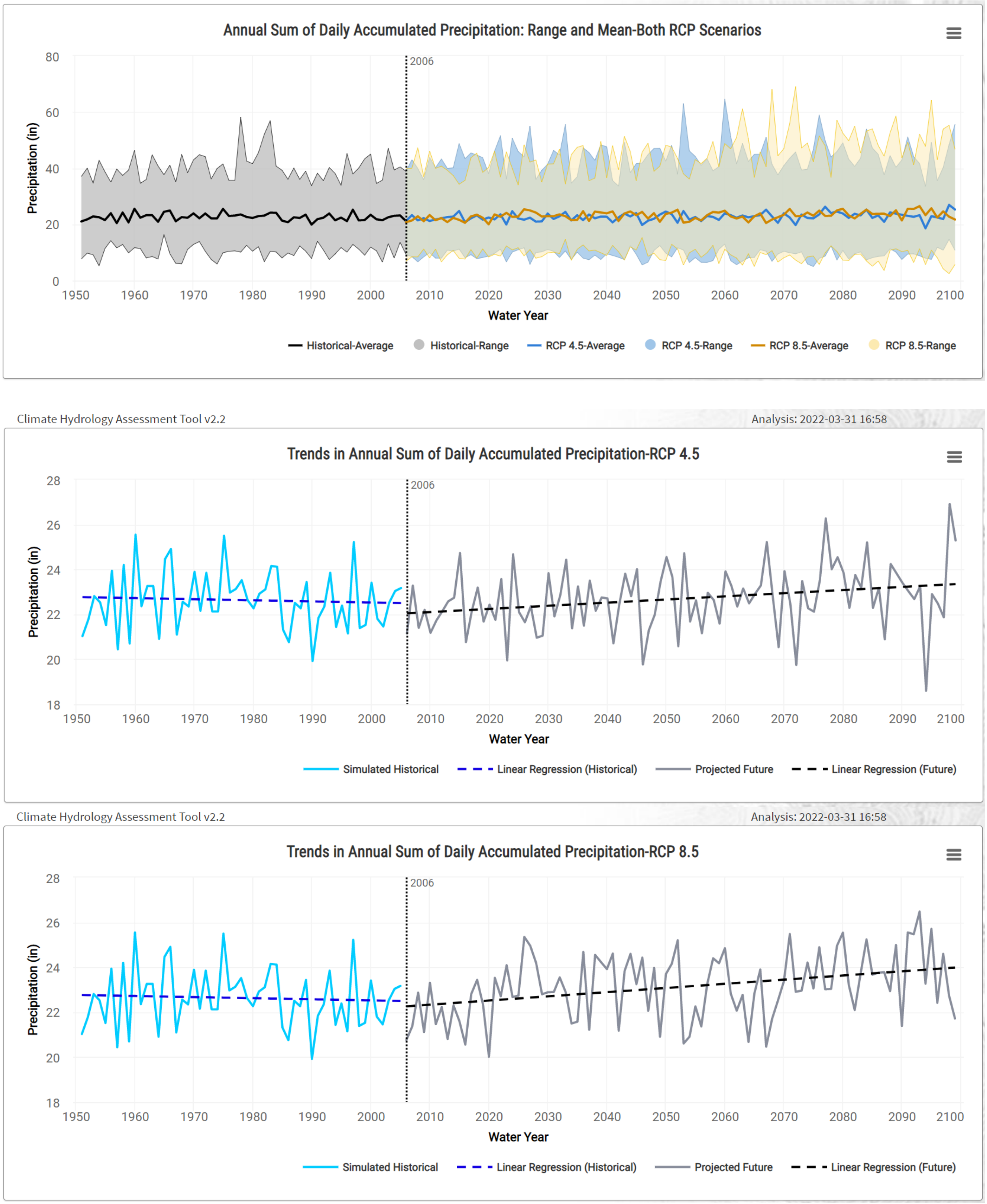
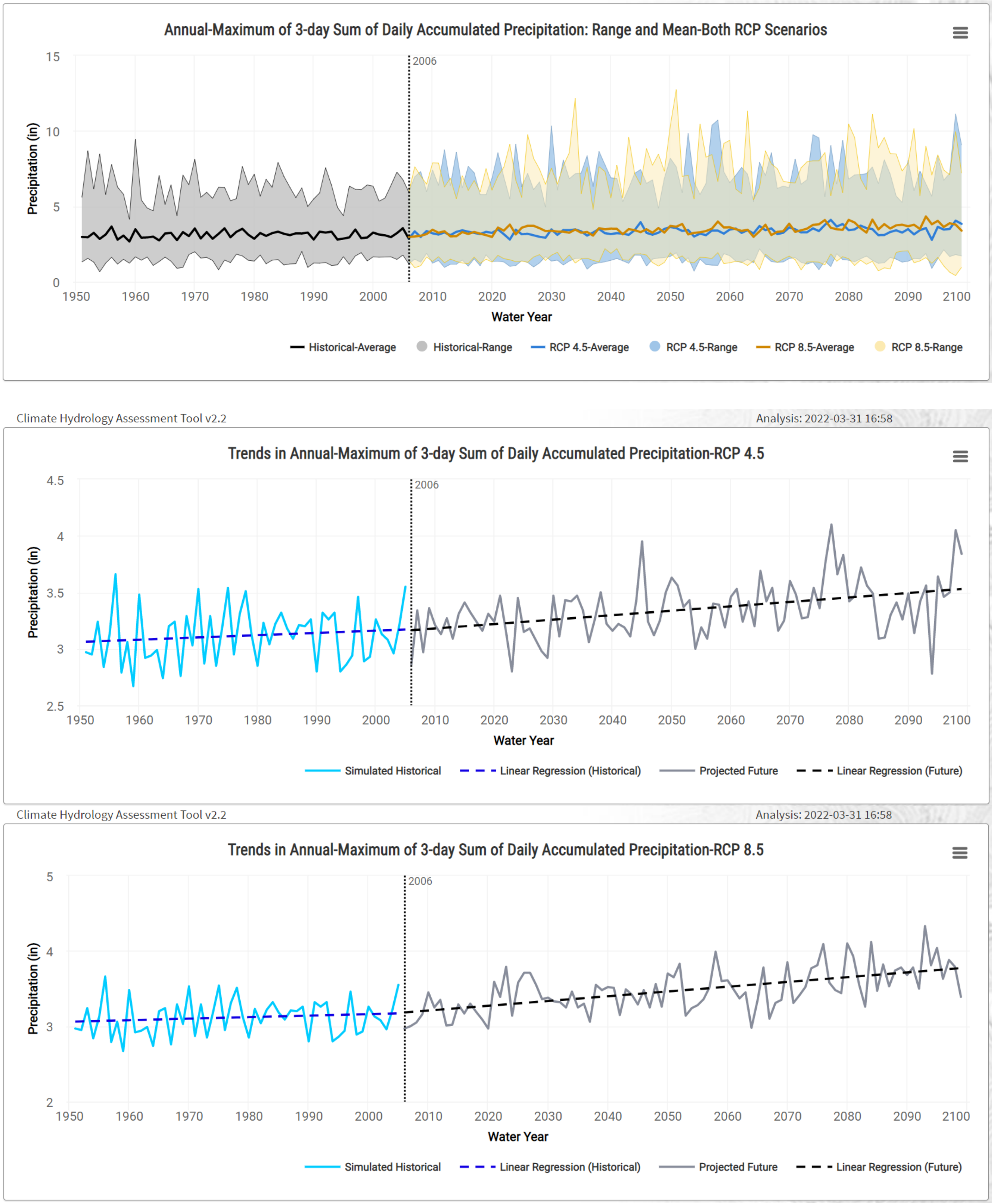


Figure 11. Annual Sum of Daily Accumulated Precipitation. Range and mean (top), trend for RCP Scenario 4.5 (middle), trend for RCP Scenario 8.5 (bottom). Statistically significant trends were detected for projected future precipitation under both scenarios. Statistically significant trend was not detected for simulated historical precipitation.


Annual-Maximum of 3-day Sum of Daily Accumulated Precipitation: Range and Mean-Both RCP Scenarios

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Trends in Annual-Maximum of 3-day Sum of Daily Accumulated Precipitation-RCP 4.5

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Trends in Annual-Maximum of 3-day Sum of Daily Accumulated Precipitation-RCP 8.5

Figure 12. Annual Maximum of 3-day Sum of Daily Accumulated Precipitation. Range and mean (top), trend for RCP Scenario 4.5 (middle), trend for RCP Scenario 8.5 (bottom). Statistically significant trends were detected for projected future precipitation under both scenarios. Statistically significant trend was not detected for simulated historical precipitation.

2.6 Streamflow

2.6.1 Climate Hydrology Assessment Tool

The CHAT can be used to assess projected, future changes to streamflow in the watershed. Projections are at the spatial scale of a HUC-8 watershed, with flows generated using the U.S. Bureau of Reclamation (USBR) Variable Infiltration Capacity (VIC) model from temperature and precipitation data downscaled from GCMs. The USBR VIC model is setup to simulate unregulated basin conditions. Figure 13 shows the range of output presented in the CHAT using 64 combinations of GCMs and representative concentration pathways (RCPs) applied to generate climate-changed hydrology using the USBR VIC model. The range of data is indicative of the uncertainty associated with projected, climate-changed hydrology. Simulated streamflow values represent only the single largest stream in the HUC-8 basin.

For HUC 18050003, there is no statistically significant trend in average monthly streamflow for the hindcast/historic (pre-2006) period. There is a statistically significant positive trend in the projection period with a linear trend equating to an increase of 213 cfs (24.4%) over the 93-year projection period. Projected future streamflow reflects the combined RCP 4.5 and 8.5 scenarios. (Figure 13)

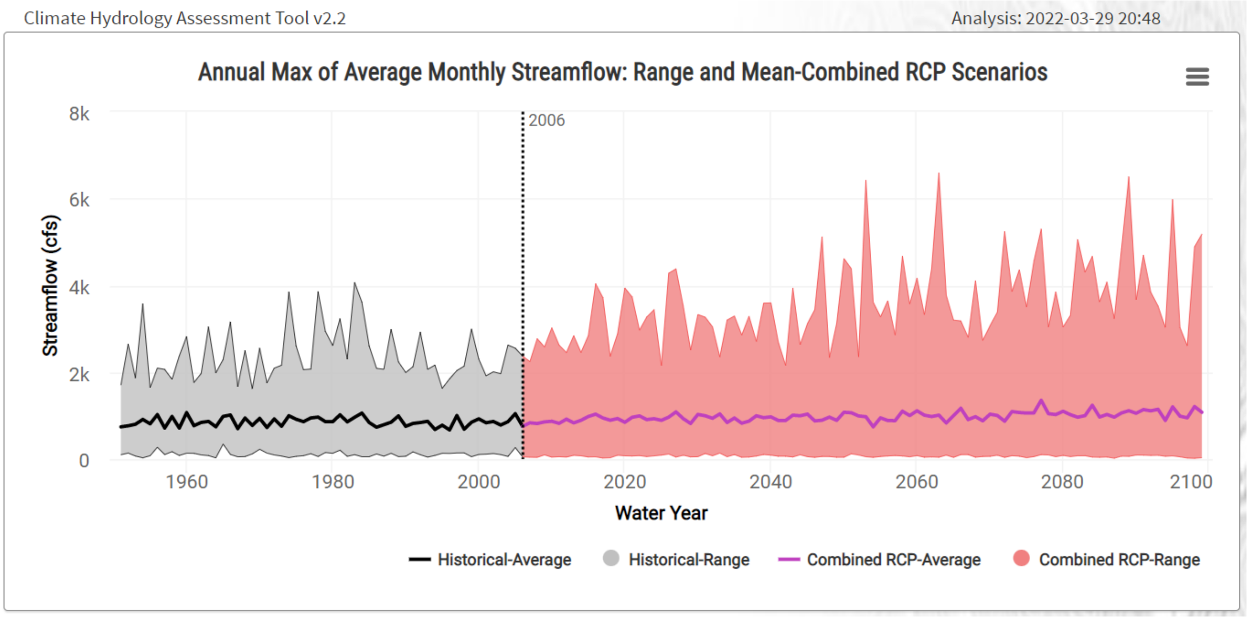

Figure 13. Range and mean of Annual Maximum of Average Monthly Streamflow for HUC 18050003. Spatially downscaled, hydrologically-simulated and routed, and statistically-aggregated CMIP5 GCM output for the stream segment with the largest flow in the HUC 8 region. Streamflow is representative of cumulative flow from all upstream segments as well as the local runoff contributions to the aligned stream segment. Simulated flows are unregulated.

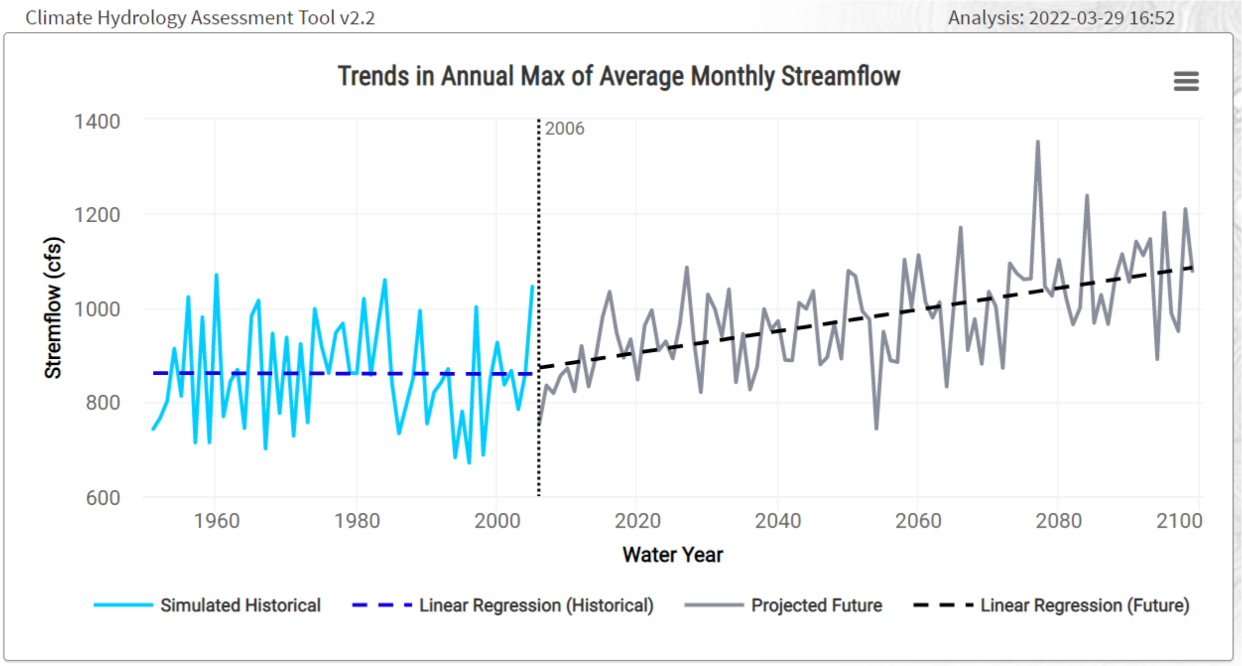

Figure 14. Trend in Annual Maximum of Average Monthly Streamflow. A statistically significant trend was detected for projected streamflow. A statistically significant trend was not detected for simulated historical streamflow.

2.6.2 Nonstationary Detection Tool

For this project, the USACE Non-stationarity Detection tool (Friedman et al 2018)[2] was applied using annual peak streamflow data from the three USGS gages in HUC 18050003 that have the longest continuous records, excluding the Coyote Creek gages (where large reservoirs have impacted flow trends) (Table 6).

Table 6. Gage records evaluated using the Non-Stationarity Detection Tool

Gage ID	Gage Name	Drainage Area	Continuous Period of Record (Annual Peaks)	Notes
11169000	GUADALUPE R A SAN JOSE CA	146 mi^2	WYR 1930-2003	
11164500	SAN FRANCISQUITO C A STANFORD UNIVERSITY	37.4 mi^2	WYR 1931-1941 WYR 1951-2020	Flows slightly regulated by Searsville Lake (capacity 952 ac-ft)
11169500	SARATOGA C A SARATOGA	9.22 mi^2	WYR 1934-2021	Water is diverted for municipal use 0.7 miles upstream

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[2] NSD tool version as of February 1, 2022

As shown in Figure 15 - Figure 16, no strong non-stationarities were detected for the three gages. This is consistent with the non-significant trend detected in the simulated historical results from the CHAT streamflow tool. For the Guadalupe River gage, the Lombard Mood test identified a change in variance (1960), the Energy Divisive Method detected a change in distribution (1967), and the Lombard Wilcoxon test detected a change in mean (1976). For the San Francisquito Creek gage, the Energy Divisive Method detected a change in distribution (1973). However, without consensus or robustness from other tests, there is insufficient evidence to reject the null hypothesis of statistical stationarity at either of these sites. There was no non-stationarity detected at the Saratoga Creek gage.

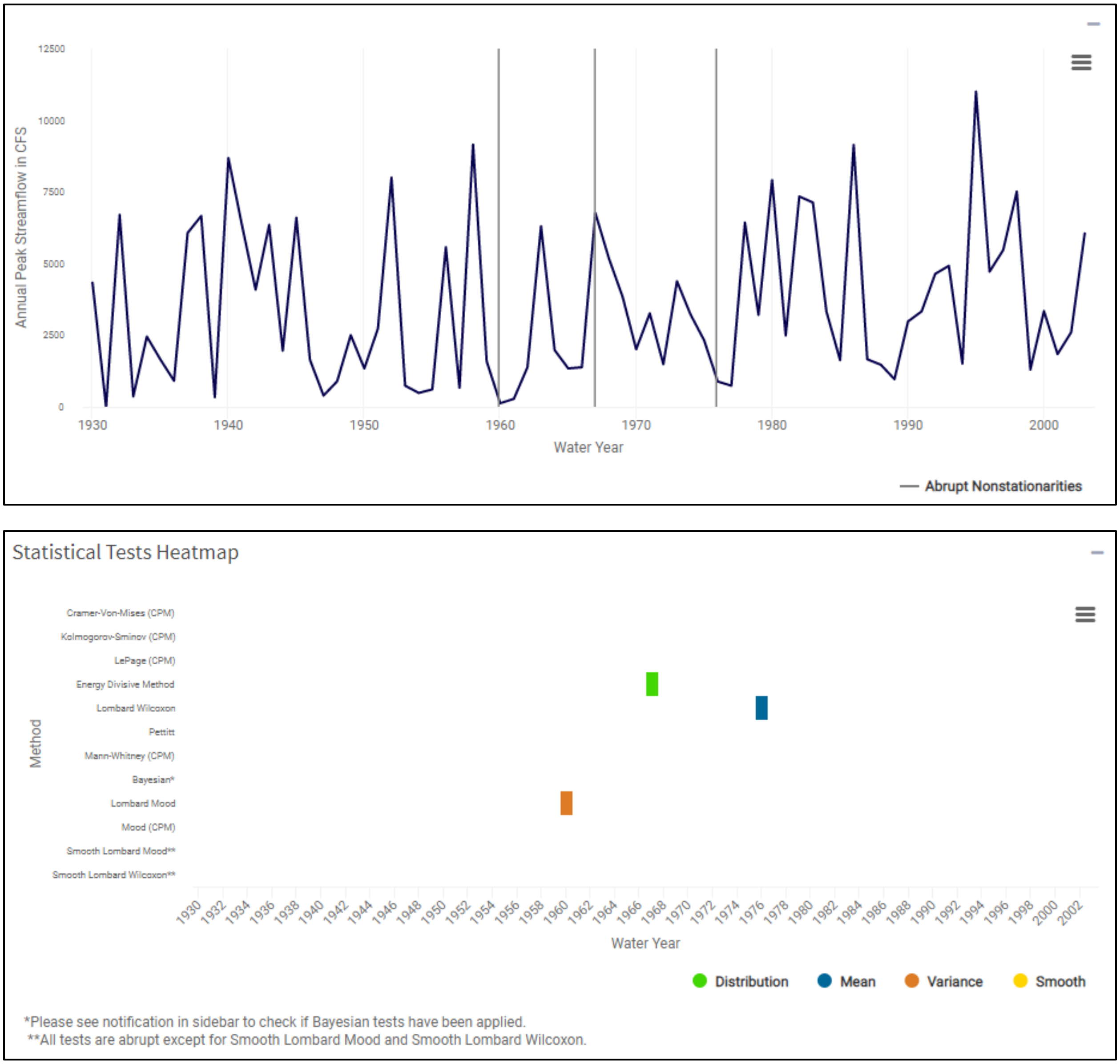
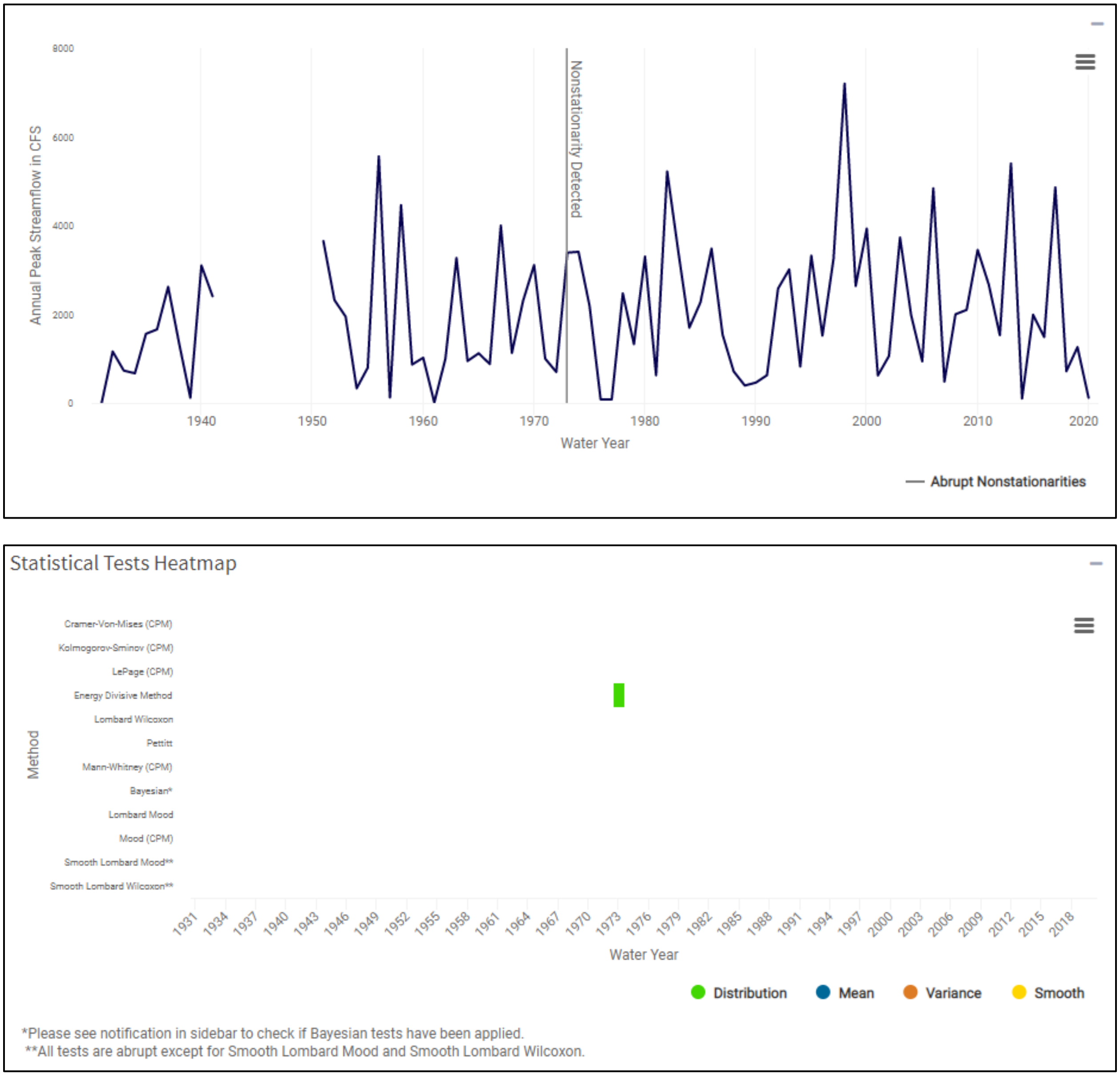


Figure 15. Non-stationarity detection results for GUADALUPE R A SAN JOSE CA (11169000). Non-stationarities were detected in 1960 (in variance), 1967 (in distribution), and 1976 (in mean). No consensus or robustness were detected for these non-stationarities.



*Please see notification in sidebar to check if Bayesian tests have been applied.
**All tests are abrupt except for Smooth Lombard Mood and Smooth Lombard Wilcoxon.

Figure 16. Non-stationarity detection results for SAN FRANCISQUITO C A STANFORD UNIVERSITY (11164500). One non-stationarity was detected in 1973 (in distribution). No consensus or robustness were detected for this non-stationarity.

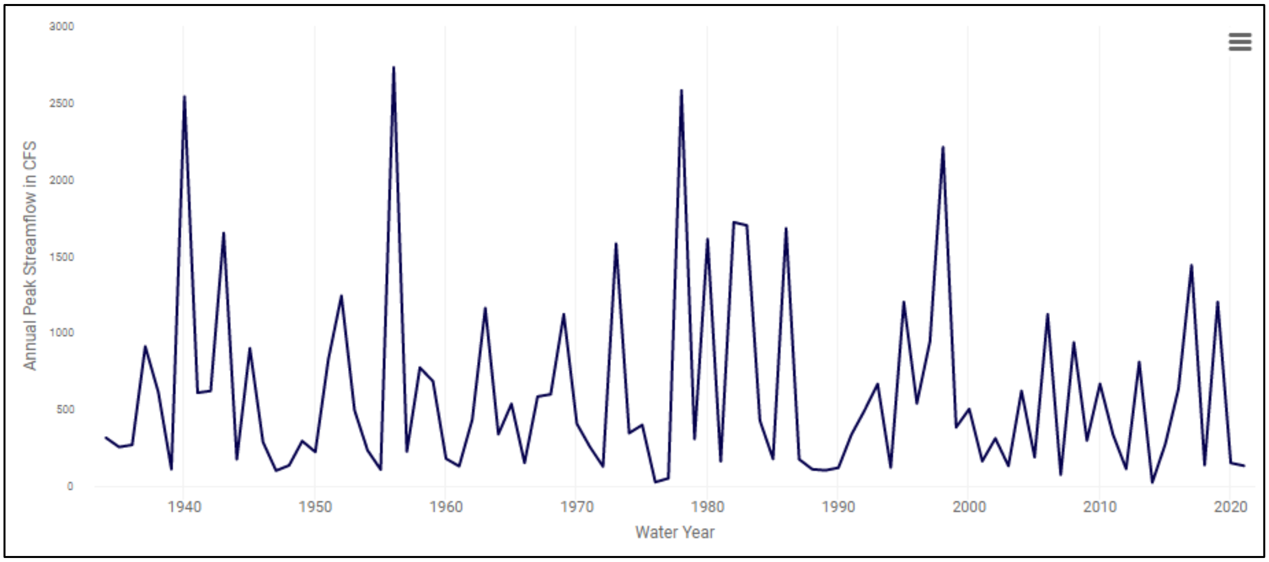
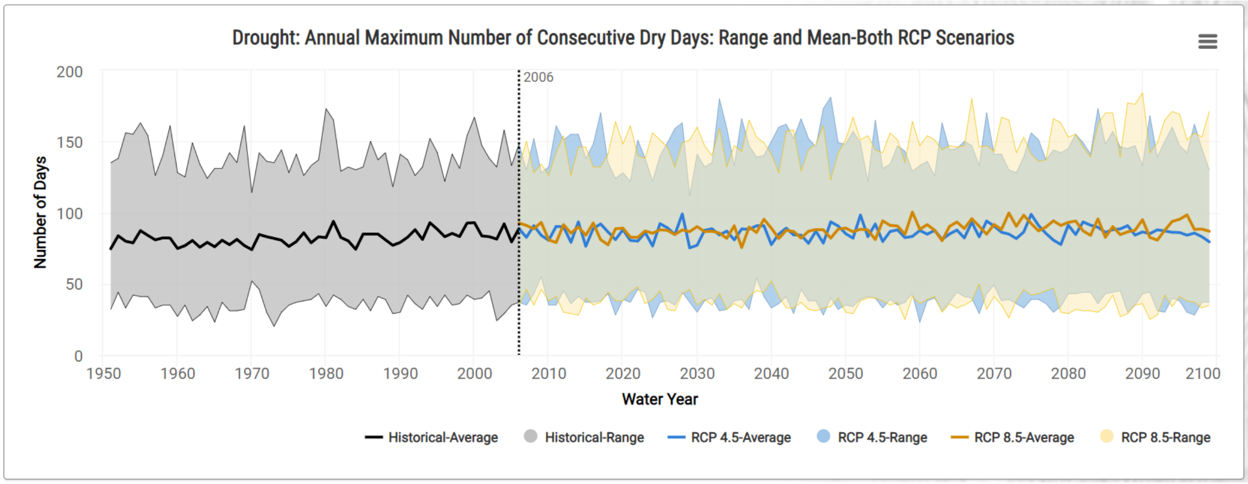


Figure 17. Non-stationarity detection results for SARATOGA C A SARATOGA (11169500). No non-stationarities were detected.

2.7 Drought

Climate Hydrology Assessment Tool (CHAT) results for number of consecutive dry days (annual maximum) are shown in Figure 18.

Under the RCP 8.5 scenario (the scenario for which trend is significant), the linear trend equates to an increase of 4.6 days per water year (5.4%) over the 93-year projection period



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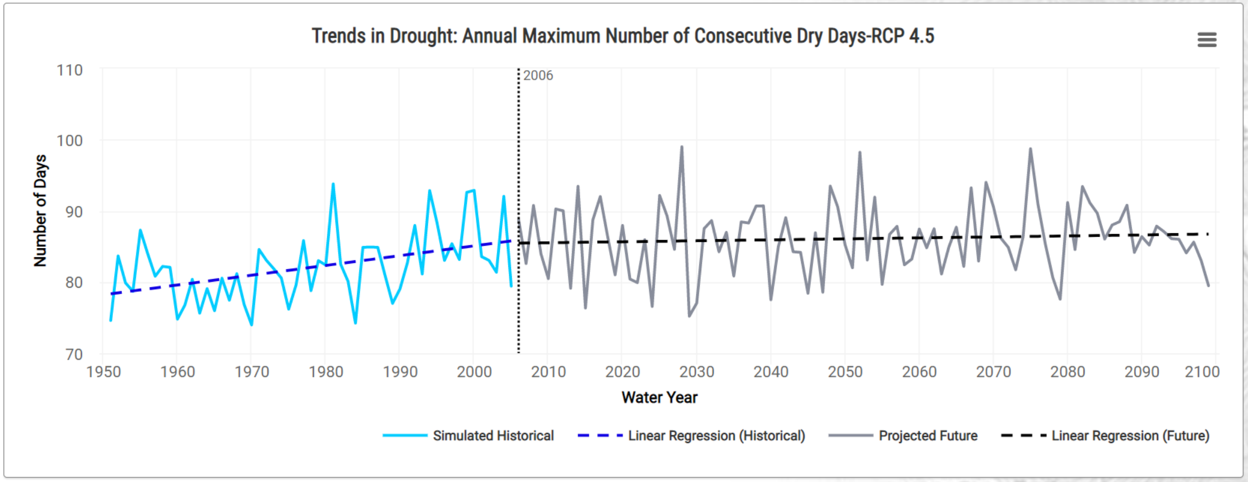

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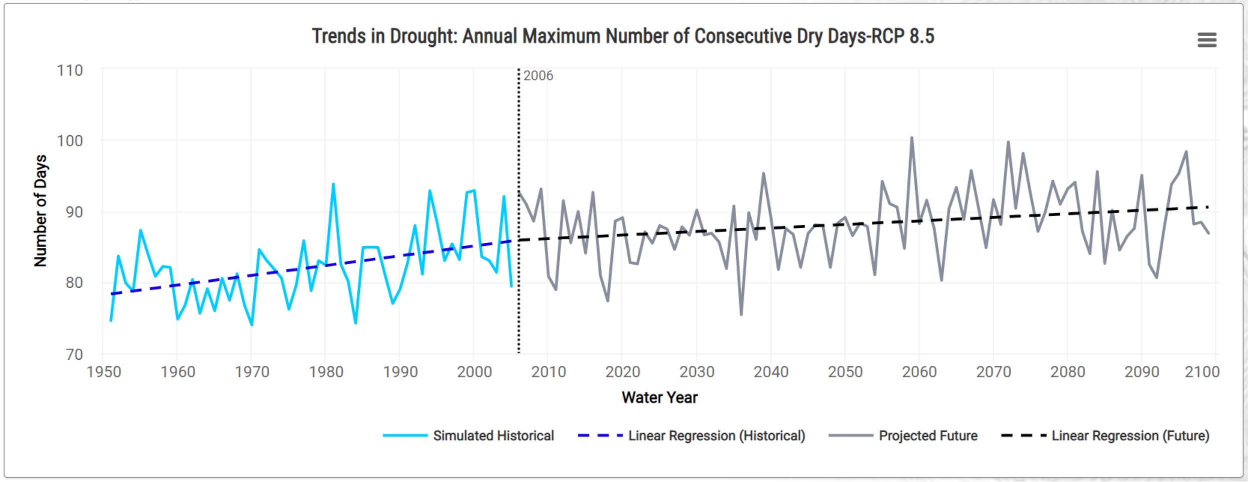


Figure 18. Annual Maximum of Number of Consecutive Dry Days. Range and mean (top), trend for RCP Scenario 4.5 (middle), trend for RCP Scenario 8.5 (bottom). Statistically significant trends were detected for simulated historical precipitation and projected future precipitation under the RCP 8.5 scenarios. A statistically significant trend was not detected for the RCP 4.5 scenario.

3.0 HYDRAULIC MODELING

Hydraulic modeling was performed for the GRR study area. Boundary condition inputs were generated by the HEC-HMS model that was described in section 0 of this report and used in the form of Hydrologic Engineering Center Data Storage System (HEC-DSS) files. Riverine Modeling was performed for the 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, 0.2% - ACE (Annual Chance Exceedance) for existing conditions and with-project conditions. The existing conditions is assumed to be the same as future without project conditions as there are no plans for future projects. Maximum water surface elevation results and maximum velocity results for each frequency were extracted and provided to the Project Delivery Team (PDT) for use in economic, environmental, and engineering analyses.

Final Array of Alternatives includes the Valley View Plan, Bypass Plan, the Lower Scope Plan (LS), and a Combination Plan (Combo), for a total of four alternatives. The Upper Guadalupe project features are all above 100 ft NAVD 88 and are not subject to tidal influence, nor are they expected to be impacted by sea level rise due to the distance from the San Francisco Bay, therefore, an alternative including seal level rise impacts was not considered.

3.1 Model from Local Sponsor

The HEC-RAS model developed for this GRR study began from a calibrated model that was provided by Valley Water. The model domain includes the Guadalupe River, Ross Creek, and Canoas Creek. The model includes 1-Dimensional (1D) cross sections in the channels and 2-Dimensional (2D) mesh for floodplains. The horizontal projection for the model is in North American Datum of 1983 (NAD83) California State Plane. Computation of water surface elevations for the hydraulic analysis are relative to the North American Vertical Datum of 1988 (NAVD88).

The model included a terrain dataset for the FWOP/existing conditions that consisted of multiple raster layers. It also included a spatially varied Manning's roughness coefficient, n value, map. USACE did not alter the terrain or Manning's n values for the FWOP/existing conditions model. As mentioned previously the model received from Valley Water was calibrated. However, USACE does not have access to the calibration files.

The manning's values used for all hydraulic simulations were provided to USACE by Valley Water. After a full review, USACE agrees with the Manning's values provided and used those values, in the form of Layers in the hydraulic model, for all FWOP and Alternatives. The original manning's values also came from a Valley Water model. USACE performed a sensitivity analysis, but has not yet updated the original manning's value for all the project model runs.

3.1.1 Model Terrain

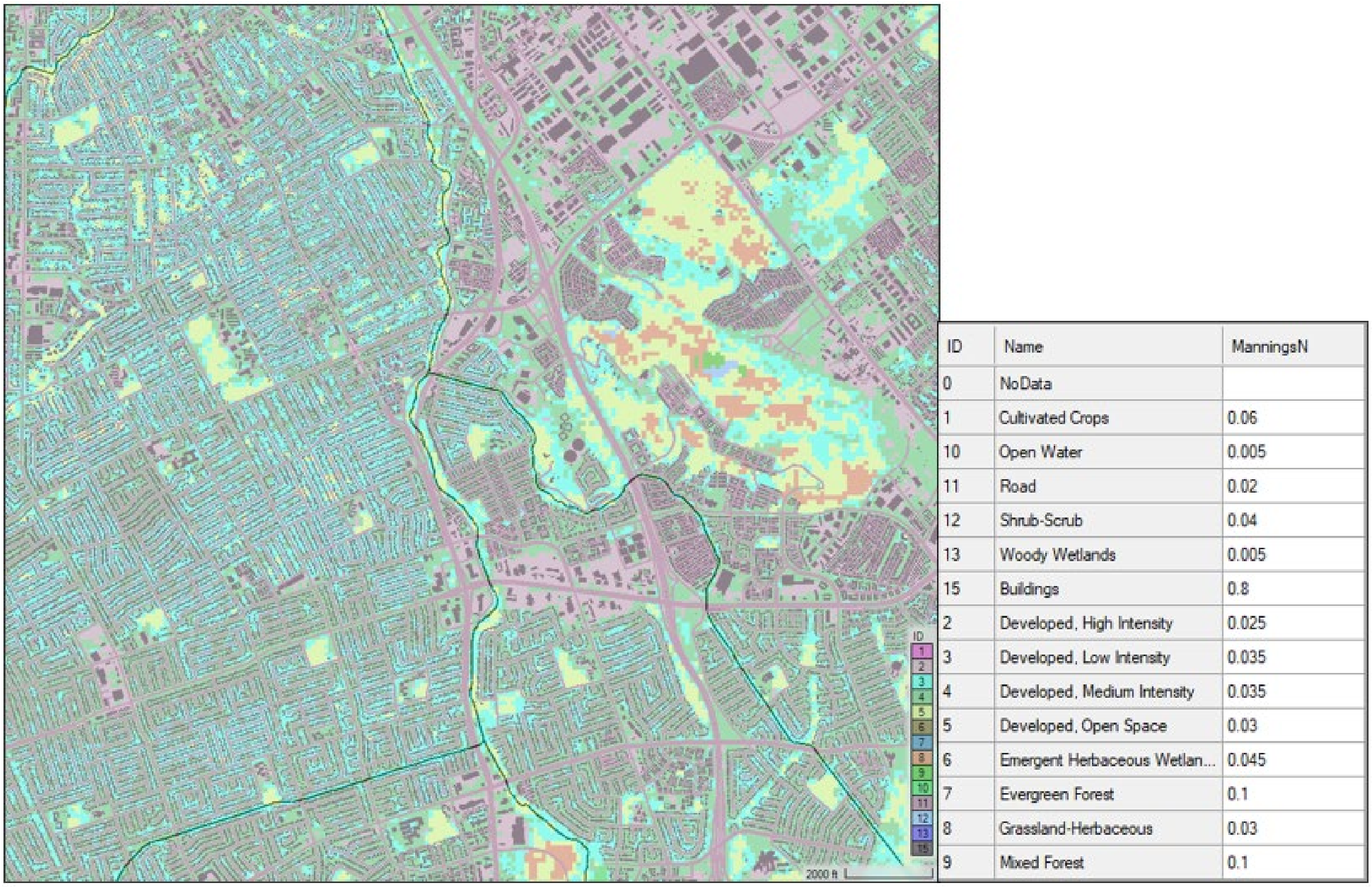
Elevation data is used by 2D flow areas to calculate storage within and flow between 2D cells from detailed Digital Elevation Model (DEM) data. It is also used by both the 1D and 2D flow areas to map inundation boundaries and water depth. The Raster file name, cell size and layer order can be found in Table 7. The layer order used for the terrain is numbered as one being the top-most layer and each subsequent number being a layer below.

Table 7. Raster resolution size and Layer Order for Existing Conditions Terrain

Raster File Name	Resolution Cell Size (pixel)	Layer Order: Top (1) to Bottom (5)	Description
Terrain10_additional terrain data.From San Fran.tif	1	1	Covers the Guadalupe River Channel within Reaches 7&8 as shown in Figure 1.
Terrain10_additional terrain data.From Valley Water Model.tif	1	2	Covers the Guadalupe River Channel downstream of reaches 7&8.
Terrain10_additional terrain data.Terrain10.Terrain4.2018-110Contours.tif	1	3	Covers the railroad crossing near river station 78071.
Terrain10_additional terrain data.Terrain10.Terrain6.280Underpass.tif	1	4	Includes terrain data for under the Sinclair Freeway within the 2D Flow Area.
Terrain10_additional terrain data.Terrain10.Terrain9.TerrainMerge.tif	5	5	Covers the rest of the 2D Flow Area and upstream Guadalupe River as well as Ross Creek and Canoas Creek.

3.1.2 Manning's n Regions

Land cover data is used to spatially vary the Manning's n roughness coefficients throughout the 2D flow areas. Manning's roughness coefficients are used in the calculation of flow between 2D cells. Land cover data came from the National Landcover Database (NLCD) which provides nationwide data on land cover at a 30- meter resolution. The NLCD assigns all land cover into one of 13 categories (for this project area); therefore, it is less precise than digitizing terrains manually, but sufficiently accounts for variation in the terrain. The 2D hydraulic model uses a spatially varied Manning's n value layer based on gridded land cover data. Given the size of the project area, the relative consistency of the terrain throughout the watershed, and the model type used, the NLCD data was used as the base layer for the land cover dataset in the project reach.



ID	Name	ManningsN
0	NoData	
1	Cultivated Crops	0.06
10	Open Water	0.005
11	Road	0.02
12	Shrub-Scrub	0.04
13	Woody Wetlands	0.005
15	Buildings	0.8
2	Developed, High Intensity	0.025
3	Developed, Low Intensity	0.035
4	Developed, Medium Intensity	0.035
5	Developed, Open Space	0.03
6	Emergent Herbaceous Wetlan...	0.045
7	Evergreen Forest	0.1
8	Grassland-Herbaceous	0.03
9	Mixed Forest	0.1

Figure 19. Manning's n Roughness ID Map

3.2 Existing Conditions Model Setup and Results

The hydraulic model described in the following paragraphs was developed using HEC-RAS version 6.1. The model provided by Valley Water was mostly unchanged to represent FWOP/existing conditions, except for the addition of a missing bridge pier at Foxworthy Avenue. The 2D mesh in the model is broken into 3 sections. Section 1 is the area South of Ross Creek and West of the Guadalupe River called 'RossS' in the model. Section 2 is the area directly South of Canoas Creek and East of the Guadalupe River called 'CanS' in the model. Section 3 is the area North of both Ross Creek and Canoas Creek as well as both sides of the Guadalupe River called 'RossN+CanN' in the model.

The model domain and 2D mesh locations are shown in Figure 20.

Information pertaining to specific inputs for the geometry, flow and plan files are described in the following subsections.

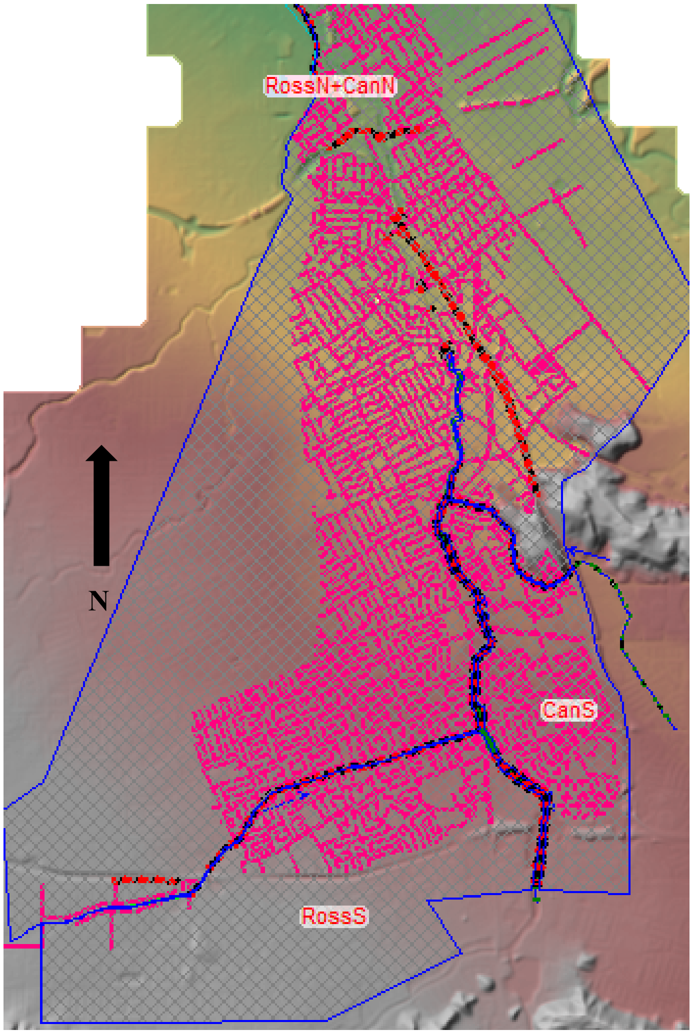


Figure 20. Existing Conditions Model Domain

3.2.1 Computational Settings

The model used a simulation time of three full days. The initial timestep is set to 10 seconds and can cut to 5 seconds or doubled twice up to 40 seconds given the maximum courant of 2.0 and minimum Courant of 0.45. For the simulation to meet the Courant conditions the grid cell size divided by the velocity be approximately 1.0. In other words, water passing over a grid cell in the 2D mesh shall not be able to travel from one grid cell face across the cell and out another grid cell face before the simulation can complete one time step.

For model stability the 1D mixed flow regime was used. The mixed flow regime is especially helpful in areas that move from subcritical to supercritical flow and supercritical to subcritical flow (hydraulic jump).

The 2D flow modeling algorithm in HEC-RAS can solve either the Full Momentum Equations or the Diffusion Wave Equations. The equation set used for the 2D flow area are the Diffusion Wave Equations which is the default setting. This equation set was chosen for model stability and a more efficient run-time. Modeling four different alternatives including the FWOP model requires 40 different simulations runs. Optimizing stability and an efficient run-time is important in this case. A primary reason to utilize the Full Momentum Equations would be for highly dynamic flows like dam breach, waterfall, levee overtop, etc. This equation set would also require much greater model refinement which would impose complications with the PDT scheduling.

All other computation settings are also set to within HEC-RAS default parameters.

The 2D solution algorithm requires the following parameters to run:

- 3.2.2 2D Computational Mesh, refer to Section 3.2.2 2D Computational Mesh
- 3.1.1 Model Terrain, refer to Section 3.1.1 Model Terrain
- 3.1.2 Manning's n Regions , refer to Section 3.1.2 Manning's n Regions
- 3.2.8 Flow Hydrographs and Lateral Inflow Hydrographs refer to Section 3.2.8 Flow Hydrographs and Lateral Inflow Hydrographs
- 3.2.9 Downstream Boundary Conditions refer to Section 3.2.9 Downstream Boundary Conditions

3.2.2 2D Computational Mesh

A computational mesh (2D mesh) in HEC-RAS is required to route hydrodynamic flow as the 2D mesh preprocesses hydraulic property tables from the underlying terrain. This retains the detail of the terrain instead of averaging the terrain into one data point per cell. The 2D flow area pre-processor computes an elevation-volume relationship, based on the detailed terrain data within each cell. A cell can be partially wet with the correct water volume for the given water surface elevation based on the terrain data. Each computational cell face is evaluated like a cross-section and is pre-processed into detailed hydraulic property tables (elevation versus – wetted perimeter, area, roughness, etc.). The flow moving across the face (between cells) is based on this detailed DEM data. This allows for the use of larger computational cells, whilst retaining details of the underlying terrain that govern the movement of the flow (Hydrologic Engineering Center, 2017).

Selecting the grid cell size for a 2D flow area is an iterative process that depends on the underlying terrain, velocity of flow, and the overall size of the model. The 2D computation grid cell size was set at 10 feet in the upper portion of the model and 20 feet in the project reach. Smaller grid cell sizes were used along the various channels, high ground, and embankments to provide finer mesh resolution as necessary.

3.2.3 Reaches

Model reaches are split into 5 sections: Ross Creek, Canoas Creek, Guadalupe Upper, Guadalupe Middle, and Guadalupe Lower. Reach locations are shown in Figure 21.

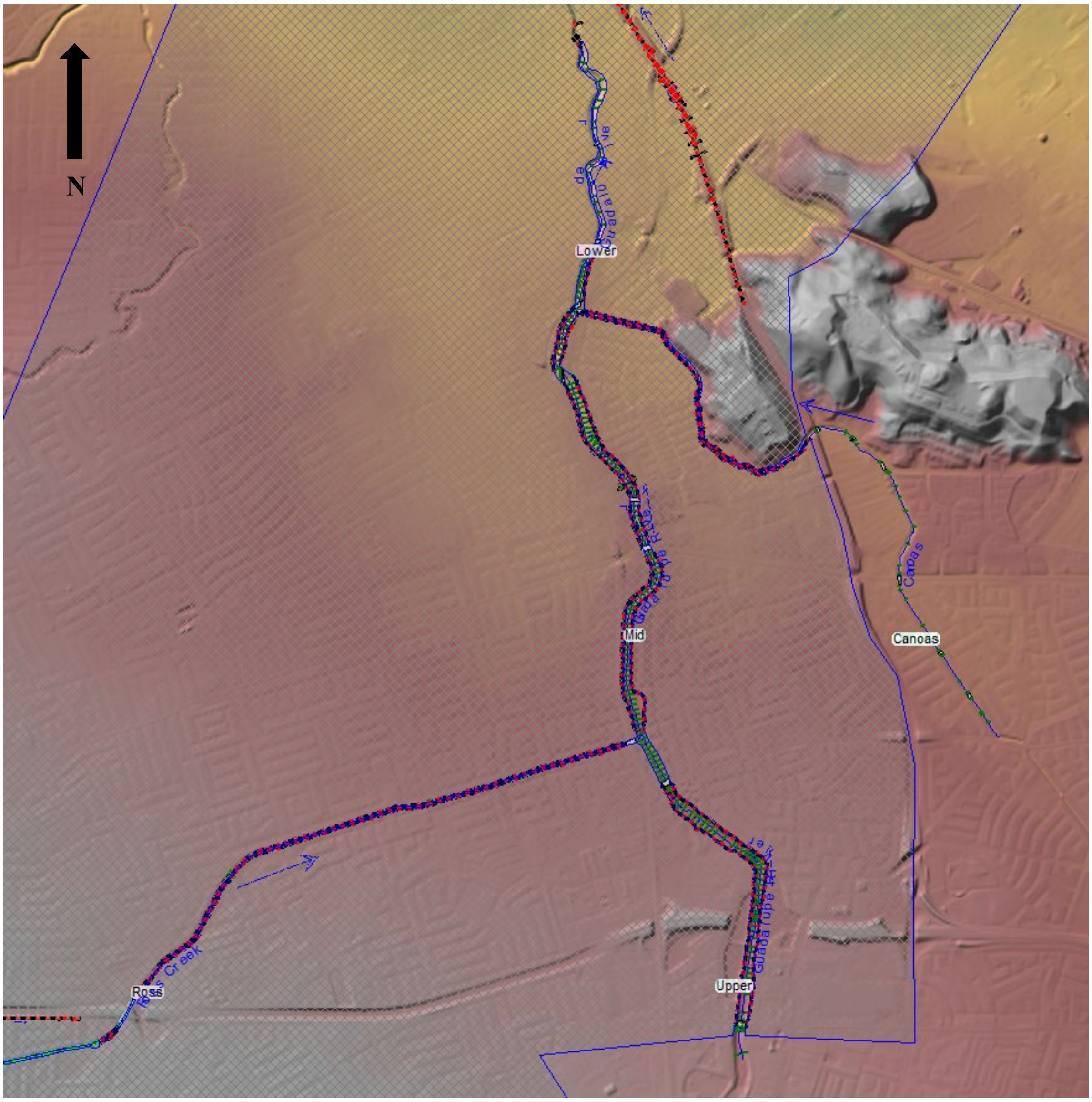


Figure 21. Existing Conditions Cross Section Layout

3.2.4 Cross Sections

Surveyed cross sections are used at the five reaches and include horizontally varied Manning's n roughness coefficients. These cross sections from Valley Water were kept as received and unchanged for this project.

Typical model cross section is shown in Figure 22.

The red dots are bank stations and are typically set at locations where one would see water levels on average throughout the year. Bank stations are also the location for the horizontally varied Manning's roughness coefficient show the overbank and the main channel can be evaluated with different values. Figure 6 shows a Manning's n roughness coefficient of 0.04 in the overbanks and 0.05 in the main channel. The "Current Terrain" line in Figure 22 shows LiDAR data against the "Ground" line which is the surveyed cross section.

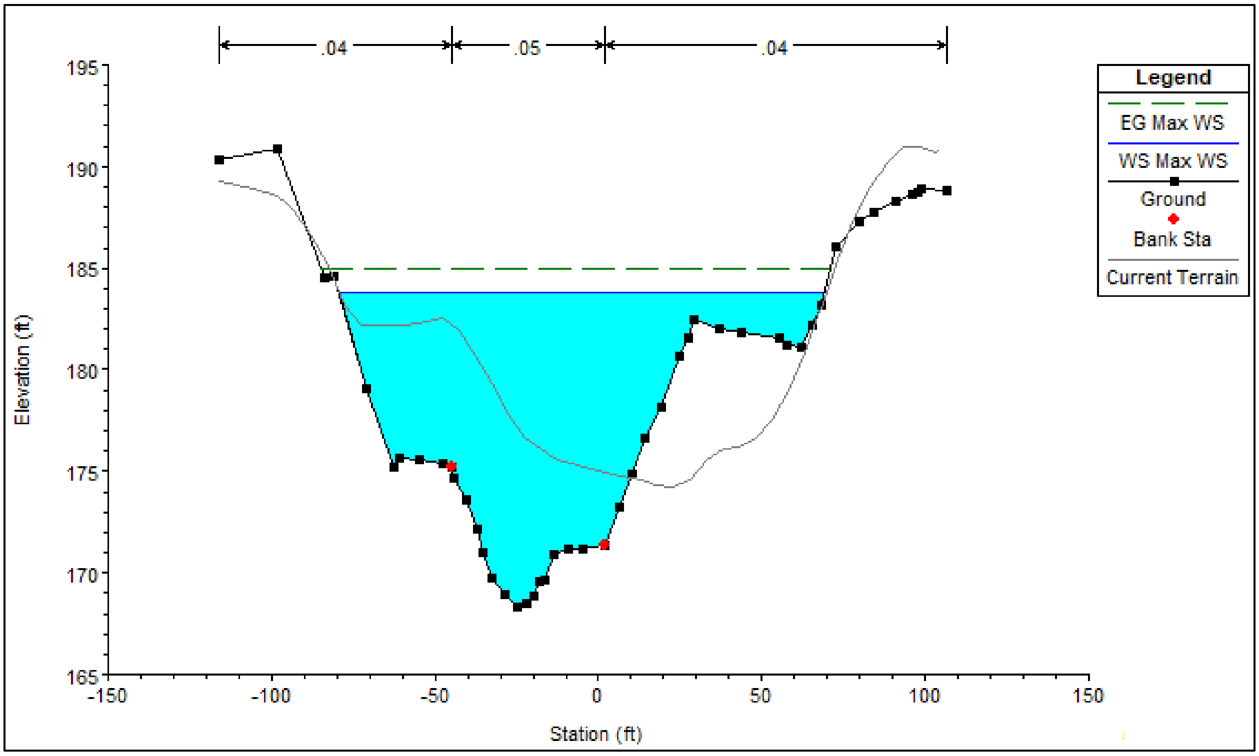
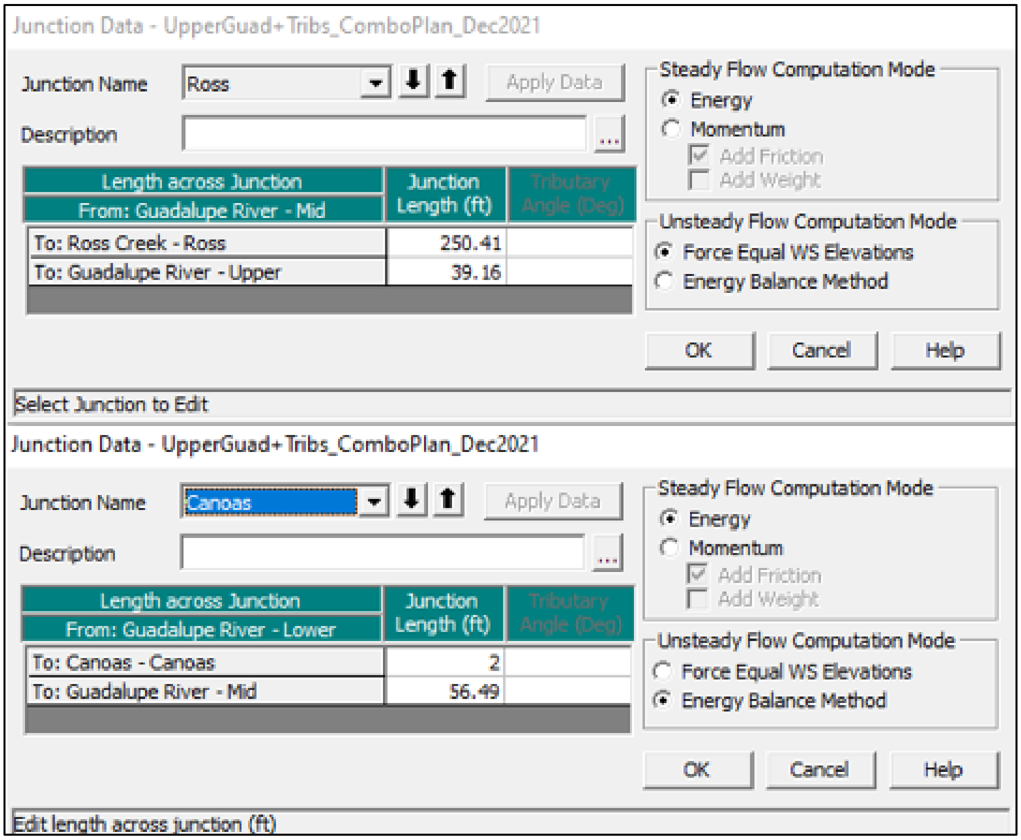


Figure 22. Typical Model Cross Section

3.2.5 Junctions

The model includes two junctions: one at the Ross Creek and Guadalupe River confluence, and the other at the Canoas Creek and Guadalupe River confluence. Both model junctions use the calculation option for the Energy Balance Method which allows the water surface to be computed across the entire junction, rather than force a singular water surface elevation for the length of the junction. The junction length is the length of the junction to the upstream confluence. HEC-RAS requires the junction length to be inputted. The junction length will override any downstream cross section length associated with cross section data. Like the cross sections, the junctions were kept as received. The input for both junctions is shown in Figure 23.



Junction Data - UpperGuad+Tribs_ComboPlan_Dec2021

Junction Name: Ross

Description:

Length across Junction From: Guadalupe River - Mid	Junction Length (ft)	Tributary Angle (Deg)
To: Ross Creek - Ross	250.41	
To: Guadalupe River - Upper	39.16	

Steady Flow Computation Mode
● Energy
○ Momentum
☑ Add Friction
☐ Add Weight

Unsteady Flow Computation Mode
● Force Equal WS Elevations
○ Energy Balance Method

Select Junction to Edit

Junction Data - UpperGuad+Tribs_ComboPlan_Dec2021

Junction Name: Canoas

Description:

Length across Junction From: Guadalupe River - Lower	Junction Length (ft)	Tributary Angle (Deg)
To: Canoas - Canoas	2	
To: Guadalupe River - Mid	56.49	

Steady Flow Computation Mode
● Energy
○ Momentum
☑ Add Friction
☐ Add Weight

Unsteady Flow Computation Mode
○ Force Equal WS Elevations
● Energy Balance Method

Edit length across junction (ft)

Figure 23. HEC-RAS Junction Input

3.2.6 Culverts/Bridges

There are a total of 24 culverts/bridges in the FWOP/existing conditions model. 10 are located along Canoas Creek, 6 on Ross Creek, and 8 along the Guadalupe River.

Culverts and bridges are coded into the model for both the 1D and 2D portions of the model. These include surveys of the high and low chord of the structure as well as the immediate upstream and downstream cross section of the structure. This gives essentially four calculation points for each bridge. Two points are the upstream and downstream edge of the bridge and the other two are the upstream and downstream cross sections (typically within 50 feet). With this information the model only needs a user defined approach to calculations.

In frequency events where the water remains lower than the low chord of the bridge, low flow calculation methods are utilized. Low flow methods for calculation in the model include the Energy Method and the Momentum Method. If a crossing included piers or was modeled as a culvert both methods were calculated, and the highest answer between Energy Method and Momentum Method was used. If the bridge did not include piers and/or is not a culvert the Energy Method was used.

The Energy Method computations are based on friction losses, contraction losses, and expansion losses. These three items are calculated using the Manning's n values, contraction coefficient, and expansion coefficient from the bounding cross sections for the bridge.

The Momentum Method is based on performing momentum balance across the bounding cross sections of each bridge. Drag coefficients are used to estimate the water force and water surface elevation as water moves around piers. The coefficients are derived from experimental data and provided through the HEC-RAS user manual.

In events where water touches the low chord of the bridge crossing, the user can continue with the Energy Method or chose to calculate based on the Pressure and Weir Flow Method. The model provided by Valley Water included the Pressure and Weir Flow Method for all bridges and culverts in high flow scenarios. Once water contacts the low chord, backwater occurs, and orifice flow takes over. Orifice flow includes two separate equations for the situation where water touches the upstream low chord but not the downstream side and when the bridge flow is completely full. Weir flow computations are used for flow that overtops the bridge or culvert. Default drag coefficients were kept for all bridges in the model as they relate to contraction at the inlet and drag over the weir (bridge deck).

3.2.7 Lateral Structures

Lateral structures are used to connect a river reach with a 2D flow area mesh. Lateral structures use the standard weir equation to calculate flow over the top of them. The weir equation requires a weir coefficient. The coefficient is based on the lateral structure height above natural ground. If the lateral structure is to mimic natural ground, then a 0.5 coefficient should be selected. If the later structure is simulating a levee, road, or anything 1-3 feet above natural ground a coefficient of approximately 2.0 should be used. The model provided by Valley Water included lateral structures near known river reach breakout locations and were not altered for the existing conditions evaluation. Figure 24 shows the locations of all the lateral structures along the overbank in bright green. All of Ross Creek and Canoas Creek include lateral structures where the 1D reach interfaces with the 2D mesh. Lower Guadalupe and select portions of Mid-Guadalupe include lateral structures where the 1D reach interfaces with the 2D mesh.

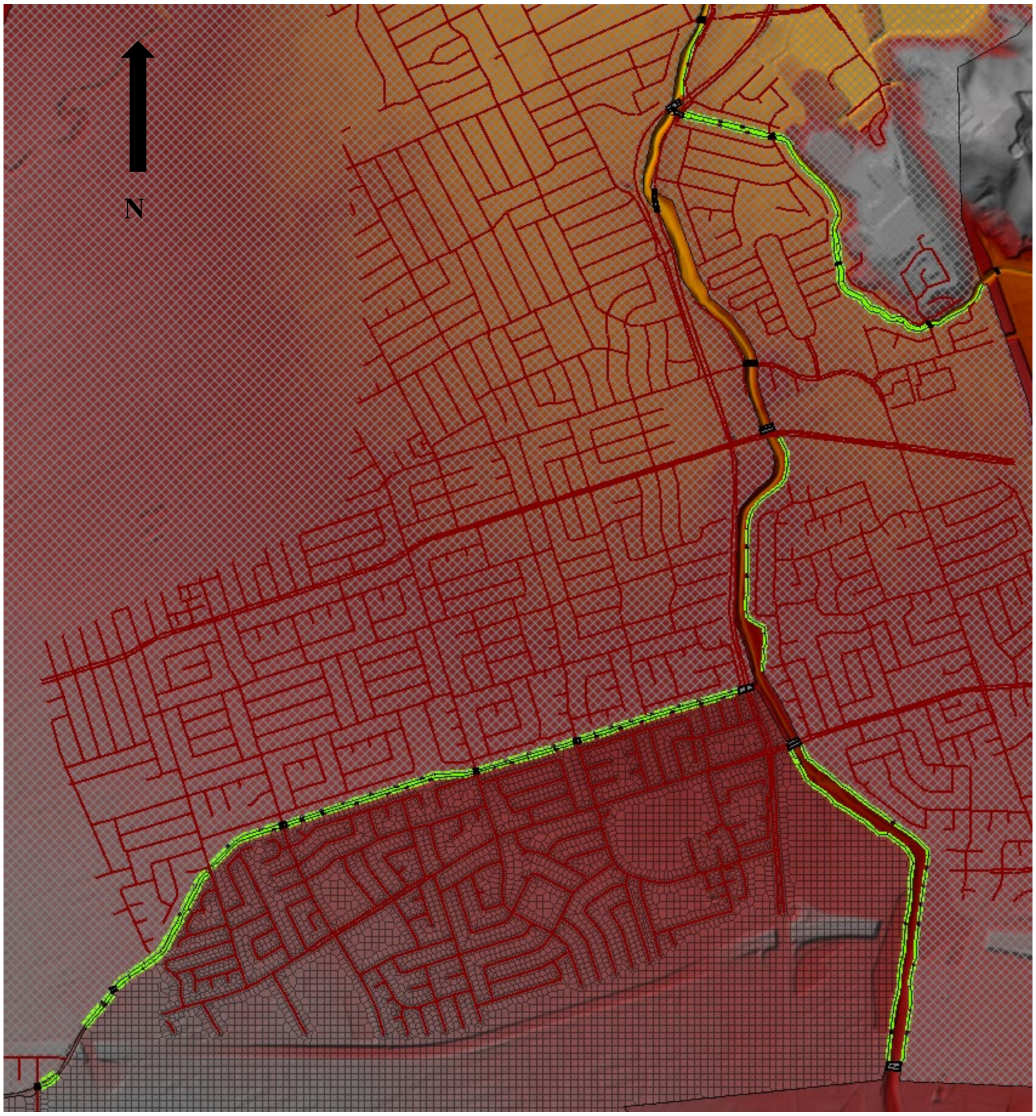
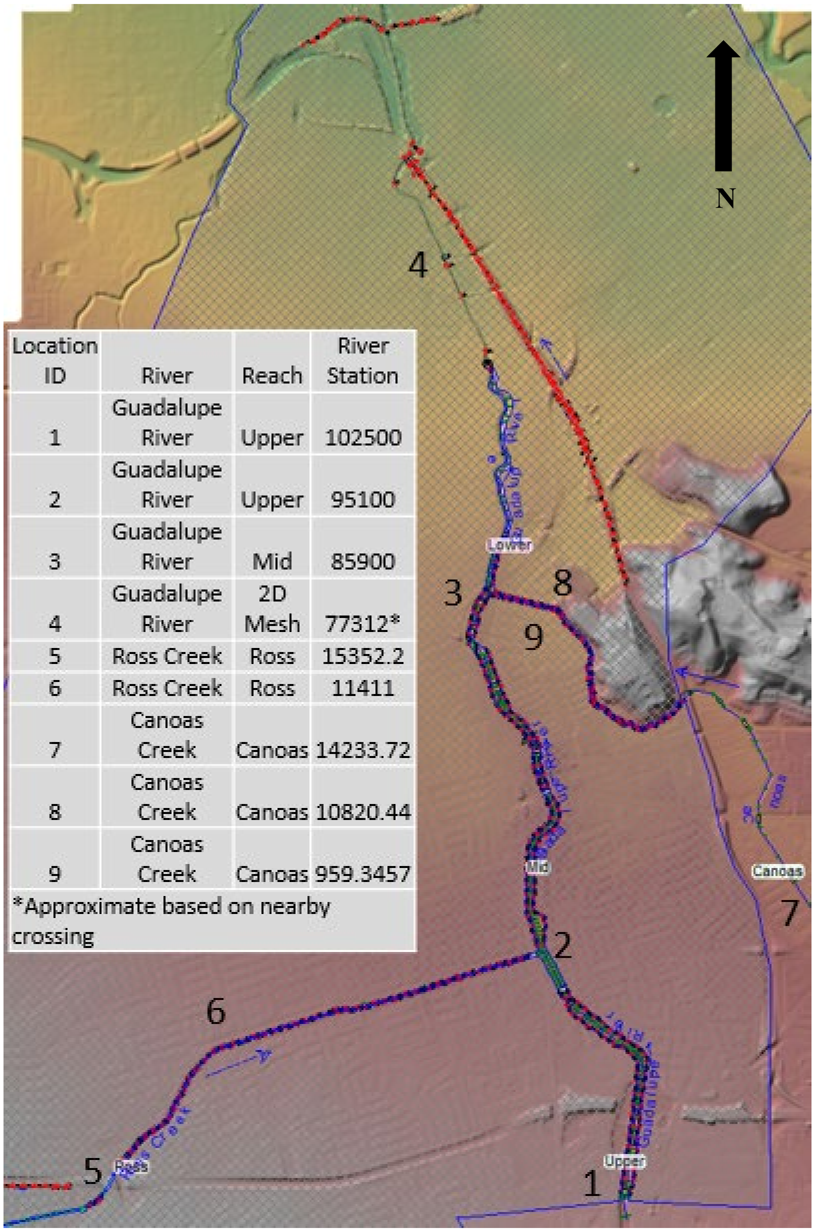


Figure 24. Lateral Structure Locations on FWOP Model

3.2.8 Flow Hydrographs and Lateral Inflow Hydrographs

Flow Hydrographs in the hydraulic model were obtained from the analysis described in the 2009 USACE report on the Guadalupe watershed and were applied to 1D and 2D portions of the model. There are eight flow or lateral inflow hydrographs used in the 1D portion of the model and one flow hydrograph in the 2D portion. The approximate location of each hydrograph is shown in Figure 25.



Location ID	River	Reach	River Station
1	Guadalupe River	Upper	102500
2	Guadalupe River	Upper	95100
3	Guadalupe River	Mid	85900
4	Guadalupe River	2D Mesh	77312*
5	Ross Creek	Ross	15352.2
6	Ross Creek	Ross	11411
7	Canoas Creek	Canoas	14233.72
8	Canoas Creek	Canoas	10820.44
9	Canoas Creek	Canoas	959.3457

*Approximate based on nearby crossing

Figure 25. Approximate Location of Input Flow Hydrographs and Lateral Inflow Hydrographs

3.2.9 Downstream Boundary Conditions

There are four downstream boundary conditions in the model. All four boundaries use the normal depth option which requires the friction slope for input. The friction slope is the slope of the energy grade line and can be estimated by calculating the slope of the bed at the downstream end of the reach. With the friction slope, the flow, and a Manning’s n value, the model uses the Manning’s Equation to back calculate the water surface elevation starting from the downstream end and working upstream.

The general location of each downstream boundary condition is shown on the map in Figure 26. The first downstream boundary condition is the interface between the 1D reach and the 2D Flow Area (Green Oval). This uses a friction slope of 0.002 and allows flow to enter the 2D mesh from the 1D cross sections. As you move downstream in the model you enter the area that is entirely 2D. The other three downstream boundary conditions are on the West end of the model at a point far enough downstream as to not influence the project area. These boundary conditions take flow and remove it from the model system. The main channel for Guadalupe River has a friction slope of 0.006. The left and right overbank for the Guadalupe River is the other two boundary conditions that use a friction slope of 0.005. All three of these boundary conditions are within the area of the yellow oval.

Figure 26. Downstream Boundary Conditions General Locations

3.3 FWOP Results

The model performed the eight different annual exceedance probability events prefaced in section 0. Raster files for maximum depth and maximum velocity were provided to economics for cost-benefit analysis.

Six main breakout locations were identified for the 4% event. Using Figure 27 and Table 8 you can identify the breakout locations.

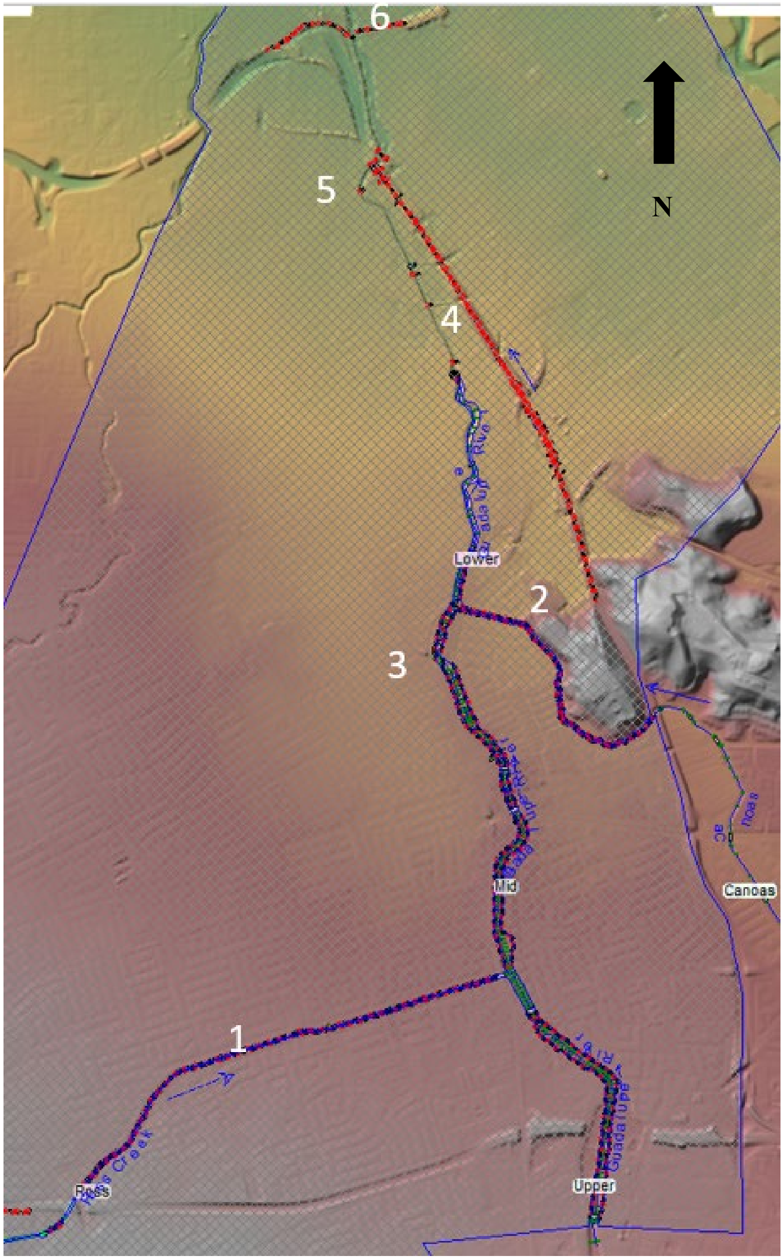


Figure 27. Map showing breakout Locations Described in Table 10

Table 8. Table of Existing Conditions Breakout Locations

Breakout Point	River Reach	Location Description
1	Ross Creek	Breakout occurs approximately at Jarvis Ave. and travels North to merge with breakout water from point #3.
2	Canoas Creek	Breakout occurs approximately at Nightingale Ave. on both the North and South side of the Creek.

Breakout Point	River Reach	Location Description
		Breakout on the North bank continues North overland. The South bank breakout ponds immediately in the vicinity of Canoas Creek.
3	Guad - Reach 10	Breakout occurs upstream of the confluence between the Guadalupe River and Canoas Creek and travels North eventually combining with flow from point #1 and point #5.
4	Guad - Reach 8	Breakout occurs on the East bank of Guadalupe River within Reach 8 as defined in Figure 1. Flow Travels North overland
5	Guad - Reach 7	Breakout occurs on the West bank of Guadalupe River within Reach 7 as defined in Figure 1. Flow travels North overland combining with points #1 and #3.
6	Guad - Lower	Breakout occurs on the East Bank of Guadalupe River, downstream of Reach 7 as defined in Figure 1. Flow travels North overland.

Table 9 presents the approximate existing flow capacity for the project if no action was taken. Flows are taken from the 4% ACE. The model was investigated at each primary reach identified in Figure 1. Map of GRR Study Area. If it was observed that a breakout occurred within the reach, then the flow at the time of breakout at the location was recorded. If no breakout was observed the maximum flow within the reach for the 4% ACE was recorded.

Table 9. Approximate Existing Flow Capacity (If no breakout was observed the maximum flow within the reach for the 4% ACE was recorded.)

Reach	Approximate length (ft)	Capacity (cfs)
Canoas Creek	6,530	640
Ross Creek	18,250	960
Reach 7	4,360	4,400
Reach 8	2,165	3,400
Reach 9	4,820	7,550
Reach 10	5,800	6,400
Reach 11	4,800	7,900
Reach 12	5,700	8,000

3.3.1 Levee Breaching (Canoas Creek)

During a site visit with the PDT and USACE River Engineering Committee in August 2021, it was noted by participating site visit members that the potential failure of levee that exists on Canoas Creek, spanning from Nightingale Drive (on the upstream end) to the confluence with the Guadalupe River (on the downstream end), could impact the computation of project benefits and cost. Subsequently, it was suggested that levee failure should be evaluated.

A separate analysis specific to levee breaching for existing conditions on Canoas Creek was conducted and completed in HEC-RAS with assistance and input from the Geosciences and Economics PDT members, and a Modeling, Mapping and Consequences Center (MMC) staff member. The analysis was conducted consistent with guidelines provided by the MMC for breaching analyses conducted in other parts of the country. A soil sample of the levee was taken to determine the erodibility parameter to compute widening and downcutting rates to include in the breaching routine of HEC-RAS. The model runs showed that levee breaching for Canoas Creek would lead to a few tenths increase of inundation in the floodplain when compared to a scenario with no levee breaching. Potential levee breaching was found to not have a significant impact on the computed damages and benefits for the GRR study area (USACE, 2022). An example inundation map from this analysis that shows the difference in inundation for existing conditions with and without a potential levee failure for the 1% event is shown below in Figure 28

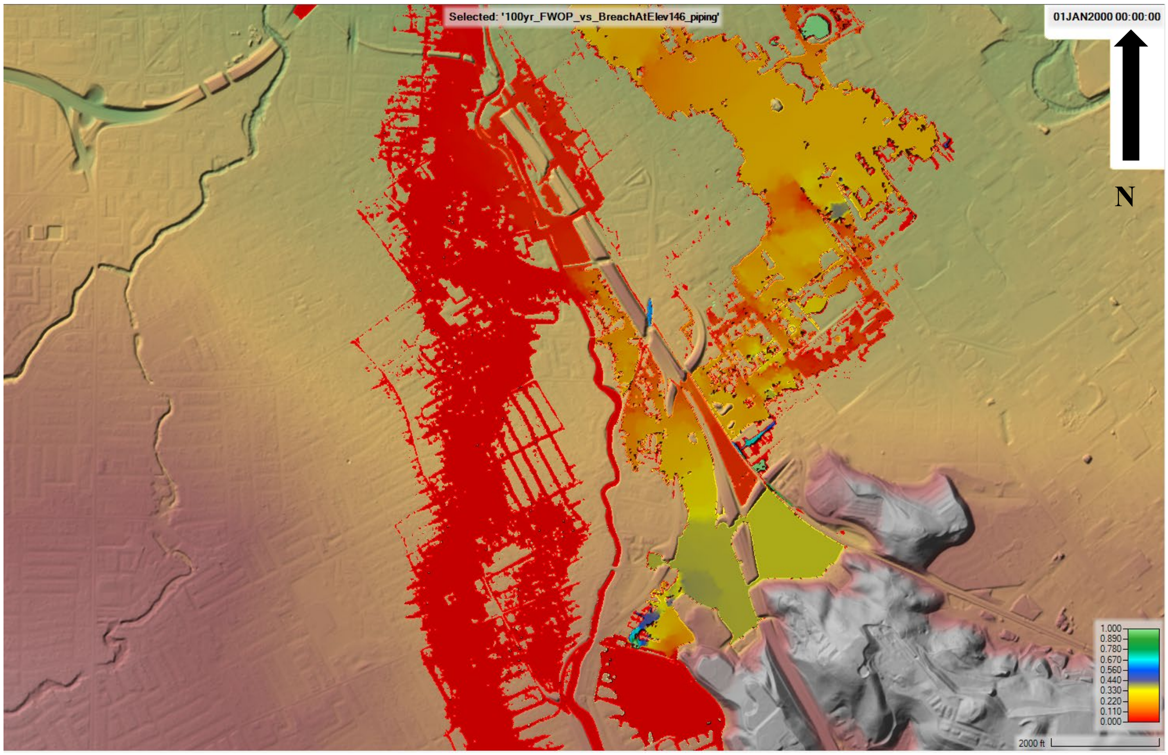


Figure 28. Analysis of Potential Levee Failure on Canoas Creek

4.0 WITH-PROJECT MODEL SETUP AND RESULTS

For with-project, the model domain was converted from a 1D/2D model to a fully 2D model. This change was to help with model run-time and provide more accurate results for each alternative. The surveyed cross sections for each reach were mosaicked into the terrain at locations that did not have a feature such as widening and benching that was implemented with raster files provided by the PDT. Bridges and culverts were coded in the model as 2D structures.

Ross Creek was converted from a 1D reach into a 2D reach. This included converting the inflow hydrograph and a lateral inflow hydrograph. The upstream flow hydrograph was converted to a 2D inflow hydrograph and remained in the same location on the model. The River Station for the existing model is located on Ross Creek at station "15352.2" and becomes and internal boundary condition flow hydrograph called "Ross – Upper Ross." The lateral inflow hydrograph located at River Station "11411.0" in the model was converted to the internal boundary condition flow hydrograph called "Ross

W1270." The internal boundary inflow hydrograph was drawn to face and enter the channel on the same side as the existing conditions lateral flow hydrograph. Figure 29 shows the Ross Creek inflow locations for both the existing conditions model (green cross sections) and the 2D model (pink boundary condition lines).

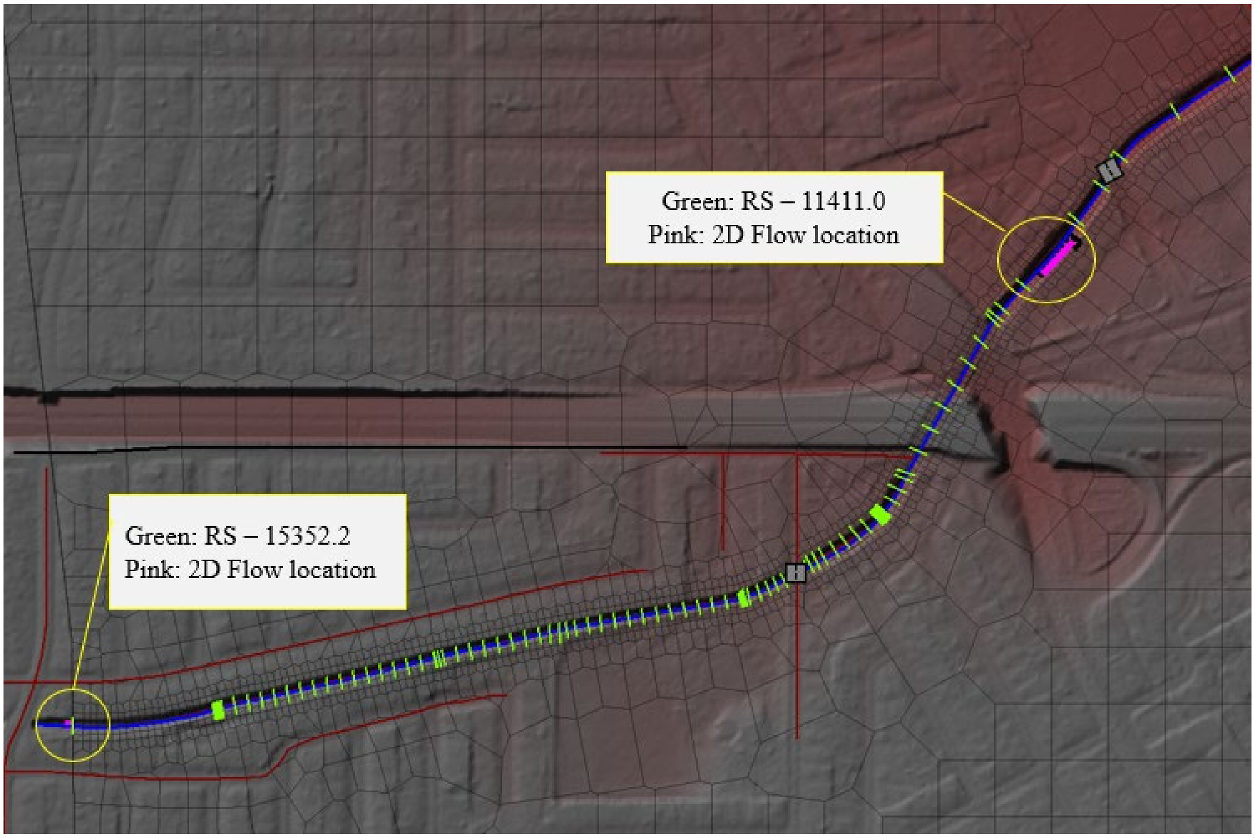


Figure 29. Location of Ross Creek Flow Inputs

Canoas Creek was converted from a 1D reach to 2D as well. The reach was cut down to fit the existing 2D mesh extents. Figure 30 shows Canoas Creek. The yellow arrow shows where the 1D flow hydrograph was moved for the fully 2D model. The upstream hydrograph was pulled from the existing conditions model at this location to ensure any losses that occurred upstream of where the 2D extents stopped were captured. The other two lateral inflow hydrographs were converted to internal boundary conditions and placed near their respective river station.

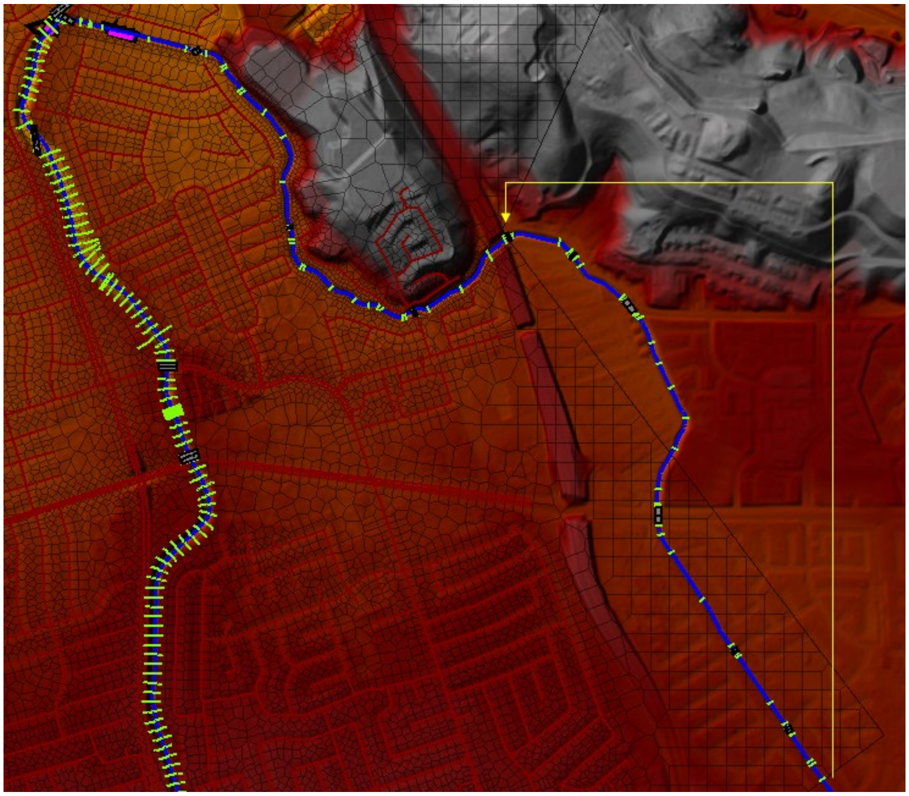


Figure 30. Upstream Flow Hydrograph Movement

4.1 Alternative Measures

The alternative plans all feature a range of features. This section discusses how the features were incorporated into the modeling for hydraulic analyses.

4.1.1 Detention Basins on Ross Creek

The FWOP model was updated by the Los Angeles District (SPL) Hydrology and Hydraulics team to include four detention basins along Ross Creek. Detention basins, originally part of the combo plan was analyzed as a stand-along features for the purposes of identifying their individual hydraulic impact. Basins were proposed at Challenger School, Stratford School, Branham Park, and Reed Elementary School. Raster files were created for each basin and burned into the FWOP terrain. -Lateral structures to function as a weir and allow flow to enter the detention basin from the channel were built. Results from the modeling showed a negligible difference in water inundation around Ross Creek and downstream. Due to the high cost of construction and maintenance for detention basins coupled with none and/or negligible hydraulic impact this feature was screened out from further consideration. For more information on the detention basin model development refer to the MFR: HEC-RAS MODELING OF DETENTION BASISN ON ROSS CREEK, (USACE, 2021).

4.1.2 Bypass Channel

The Valley View Plan and Bypass Plan utilizes a bypass channel within portions of the Guadalupe River. Raster files were provided by the Civil Design Section T to be burned into the FWOP terrain at locations where the bypass channel is being analyzed. Refer to Section 4.5 Alternative Plan Terrains for a list of the raster files used in development of each alternative plan's terrain.

A terrain comparison of the Reach 7 cross section is shown on Figure 31. The red line is the existing conditions terrain. The black line is the Valley View Plan and Bypass Plan terrain. The green line is the Lower Scope and Combo plan terrain. The bypass would be approximately 100-feet wide at the channel invert for the Valley View Plan and Bypass Plan. Bypass extents start in Reach 7 and continue upstream through Reach 11 for the Bypass Plan. The bypass channel is used in the Bypass Plan from Reach 7 to Reach 9 before converting to a widened channel with a bench.

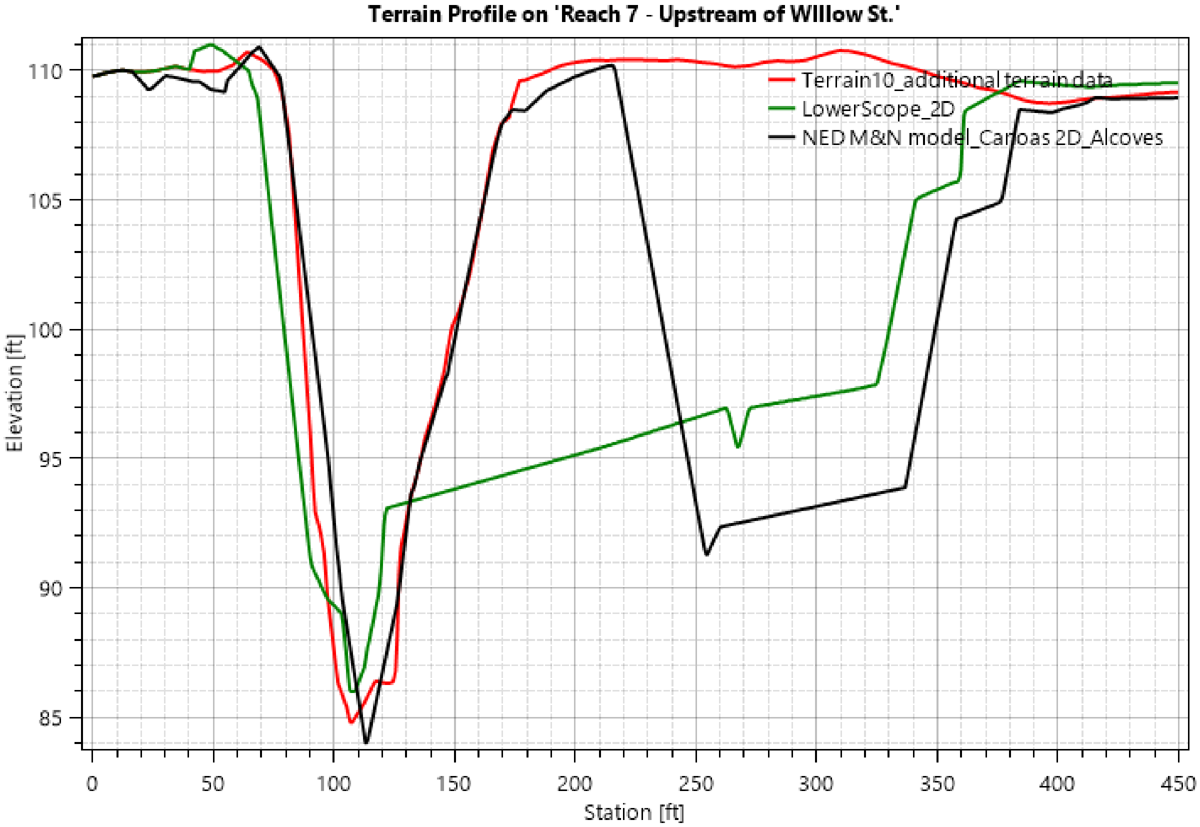


Figure 31.Terrain Comparison of the Alternative Features at Reach 7

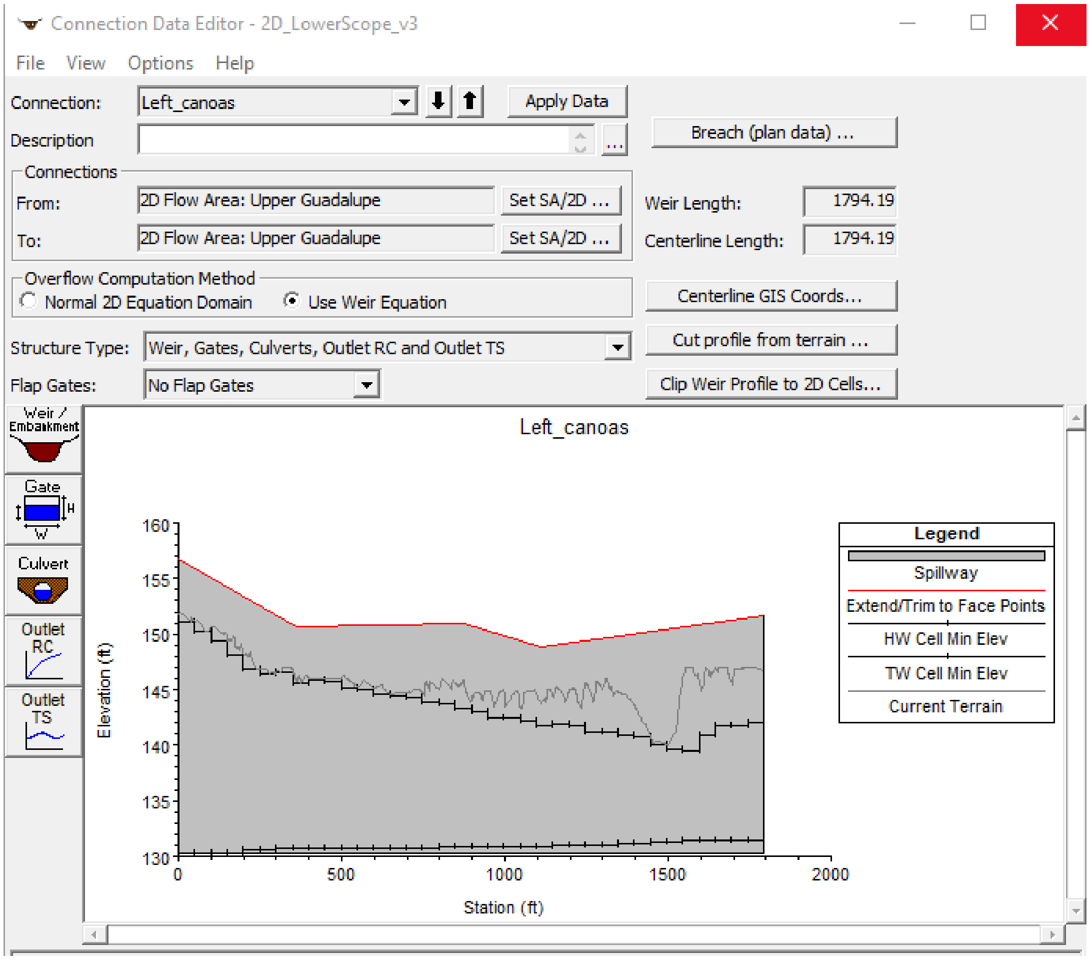
4.1.3 Widening and Benching

The Lower Scope, Combo Plan, and Bypass Plan include the widening and benching feature. Like the bypass channel, the PDT provided a raster file to be mosaicked onto the FWOP terrain. As shown in Figure 31 the channel is widened approximately 200-feet. The bench invert is approximately 5-feet above what the bypass channels invert would be in Reach 7.

The Combo Plan and Lower Scope include widening and benching within Reaches 7 and 8. As discussed in Section Study Description 4.1.2 Bypass Channel the Bypass Plan includes a bypass Channel from Reach 7 through Reach 8 to Reach 9. Reach 9, 10, and 11 utilizes the channel widening feature.

4.1.4 Floodwalls

Floodwalls were coded into the model for the Lower Scope as 2D structures. They were placed near the top of bank and extended as one continuous 2D structure. The underlying terrain was extracted and coded into the weir/embankment editor as station and elevation points. Five feet was added to the elevation points to project the top of the floodwall. 5 feet was chosen as a starting point to calculate impacts. Final heights will be calculated during optimization. The station/elevations points were then filtered to smooth the top of the floodwall for model stability. Figure 32 shows the floodwall top (red line) and the underlying terrain (light grey line). The floodwall is approximately 1800 feet in the model tying into high ground on either side.



Connection: Left_canoas

Description:

Connections

From: 2D Flow Area: Upper Guadalupe

To: 2D Flow Area: Upper Guadalupe

Weir Length: 1794.19

Centerline Length: 1794.19

Overflow Computation Method

○ Normal 2D Equation Domain ● Use Weir Equation

Structure Type: Weir, Gates, Culverts, Outlet RC and Outlet TS

Flap Gates: No Flap Gates

Figure 32. 2D Structure Editor for Canoas Floodwall

The Combo Plan is like the Lower Scope Alternative. The Lower Scope model was used and then optimized for the Combo Plan. This includes burning the floodwall into the terrain instead of using the 2D structure editor. Figure 33 shows a cross section on Canoas Creek where floodwalls are proposed for the Combo Plan. This method of coding the floodwalls in makes the model run more efficient in stability and accuracy.

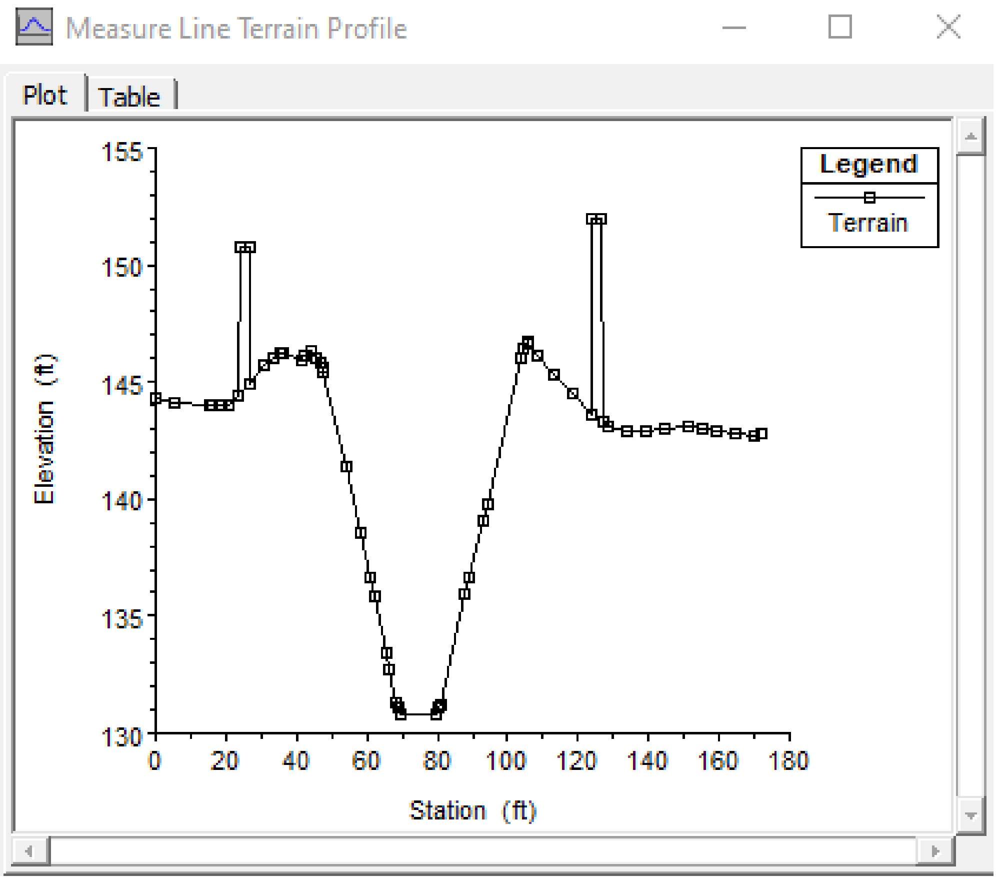
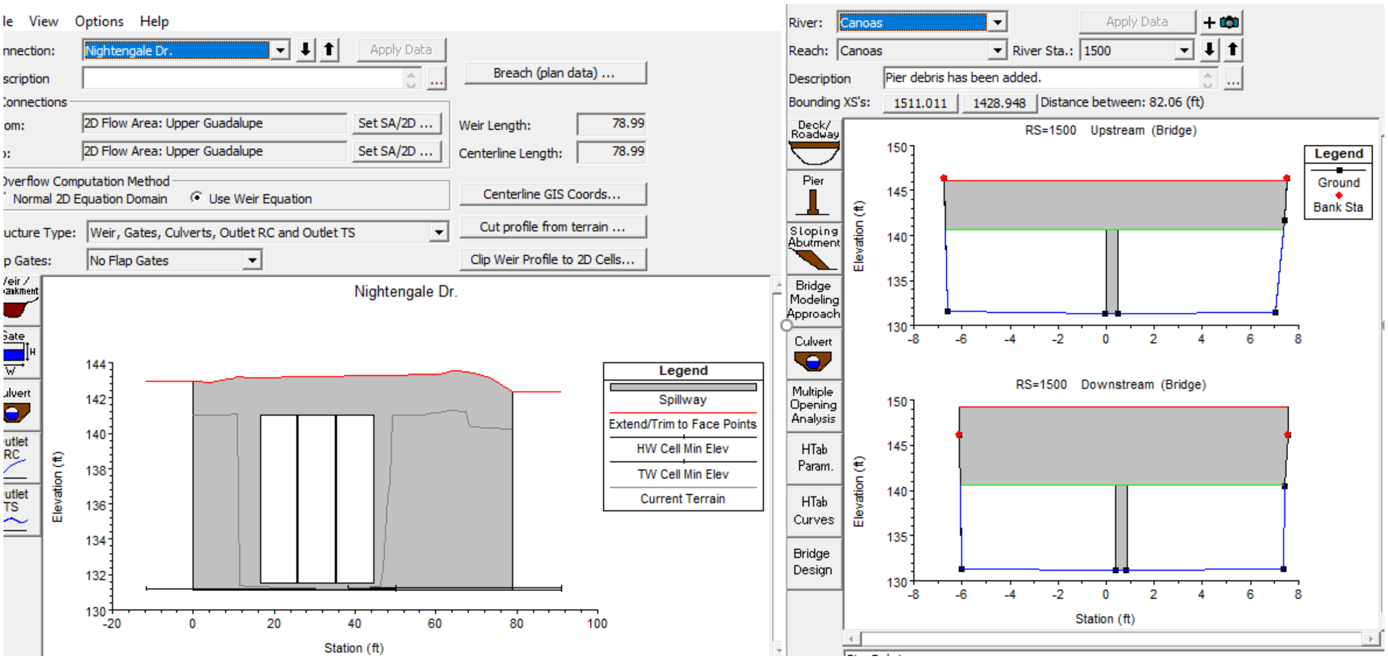


Figure 33.Cross section on Canoas Creek Downstream of Nightingale Dr. for the Combo Plan

4.1.5 Bridge Replacements/Upgrades

All the alternatives include bridge/culvert replacements and/or upgrades. HEC-RAS version 6.1 has a new ability to model bridges within the 2D mesh. The functionality is the same for coding in a 2D bridge and a 1D bridge as discussed in Section 3.2.6 Culverts/Bridges. For example, Nightingale Drive located on Canoas Creek is going from 2 culvert openings to 3 for the Lower Scope. Figure 34 shows the Lower Scope proposed structure on the left and the FWOP/existing conditions on the right. The proposal includes 3 box culverts that span 9-feet by 9.5 feet tall.



nnection: Nightengale Dr.
om: 2D Flow Area: Upper Guadalupe
: 2D Flow Area: Upper Guadalupe
Weir Length: 78.99
Centerline Length: 78.99
Overflow Computation Method: ○ Normal 2D Equation Domain ● Use Weir Equation
ucture Type: Weir, Gates, Culverts, Outlet RC and Outlet TS
p Gates: No Flap Gates

River: Canoas
Reach: Canoas
River Sta.: 1500
Description: Pier debris has been added.
Bounding XS's: 1511.011 1428.948 Distance between: 82.06 (ft)

Figure 34. Nightingale Drive on Canoas Creek

4.2 Alternative Descriptions

The following sections provide a description for each of the alternatives.

4.2.1 Existing and Future Without-Project (No Action)

Section 0 provides an overview of the hydraulic model development, model parameters, boundary conditions, and assumptions.

4.2.2 Valley View Plan (Previously Identified NED) Alternative

Reach 7

SPRR Bridge to Union Pacific Railroad (UPRR) Bridge (Sta. 741 + 00 to 781 + 00)

Utilizing the 1998 Valley View plan, which proposed that the east bank to be widened, creating a bench roughly 75 feet wide. Riparian forest restoration would occur along the toe of the bench to partially mitigate habitat losses due to channel widening. The plan was modified in 2004 to replace the river widening and benching with a bypass channel. The 3,845 feet bypass channel in Reach 7 would be constructed using stepped gabions. After further consideration in 2021, all gabion stepped walls are to be removed and replaced by crib walls in the bypass channel of the modified Valley View plan._ A maintenance-access road would be constructed in the bypass channel. The plan design for this reach allows a tie-in to the Reach 6 bypass channel that is expected to be constructed independently by the SCVWD. Bridges at Willow Street and Alma Avenue will be replaced. A levee would be constructed near Route 87/Light Rail. A floodwall would be constructed within the Elks Lodge parking lot, extending from West Alma Avenue south to the SPRR tracks at the boundary of Reach 8. Revegetation area is proposed on the east bank of the bypass near between Caltrain/UPRR and Willow Street Bridge. Existing ruderal, herbaceous, and otherwise degraded habitat would be replanted to provide an expanded area of riparian forest.

Reach 8

UPRR Bridge to Willow Glen Way (Sta. 781+00 to 795+00)

In Reach 8, crib walls for the 1,325 feet bypass channel would be constructed similar to Reach 7. A levee would be constructed near UPRR Bridge. A weir abutment with a channel lining would be constructed at the end of Reach 8 (795+00).

Reach 9

Willow Glen Way to Curtner Avenue (Sta. 795+00 to 845+00) – Bridge Replacement

From the 1998 Valley View plan, the Willow Glen Way Bridge will be replaced with a new 120-foot-long structure. The existing railroad bridge will be removed and salvaged for the city. A mitigation area is proposed at station 829+00. In 2004, the plan was modified by adding a short bypass channel to be constructed using stepped gabions in the reach. After further consideration in 2021, all stepped gabions are replaced with crib walls in the channel widening (3,430 feet) of the modified Valley View plan, where applicable.

Reach 10A

Curtner Avenue to Canoas Creek (Sta. 845 + 00 to 857 + 00) - Widened Earth Channel with Bench

From the 1998 Valley View plan, the east bank would be widened for 1,330 feet, creating a bench 10 to 40 feet wide. Riparian forest would be planted on the toe of the bench where space allows, whereas the new top of the bank would be along the shoulder of Almaden Road. In 2004, the plan was modified by widening and benching to heights of 6 to 8 feet on the east bank for a 2% event. After further consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening of the modified Valley View plan.

Reach 10B

Canoas Creek to Berkshire Drive (Sta. 857+00 to 888+00)- No Improvements.

No flood control modifications are proposed along this reach. Construction of a rock lined low-flow channel is proposed in 1,360 feet of the river. To mitigate construction impacts, riparian forest would be created and/or enhanced within the 50- to 80-foot-wide channel bottom area from the northbound Almaden Expressway bridge southward to the upstream end of the reach. The plantings along the toe of the west bank would extend northward from the Almaden Expressway bridge to the downstream end of the reach. No modification was made in 2004 and 2021 for this section of the reach.

Reach 10C

Berkshire Drive to Capitol Expressway (Sta. 888 + 00 to 913 +50) - Widened Earth Channel with Bench.

From the 1998 Valley View plan, at the downstream end of this reach, the east bank would be widened out into adjoining agricultural land for a length of about 400 feet. Upstream, channel widening would shift to the west bank, continuing as far as Hillsdale Avenue. Both banks would be widened from Hillsdale Avenue to Capitol Expressway, and the Hillsdale Avenue Bridge would be replaced. Riparian forest would be restored on the toes of the benches. An additional mitigation area is proposed along the terrace of the west bank in ruderal herbaceous habitat. In 2004, the plan was modified by widening and benching to heights of 6 to 8 feet on the east bank for a 2% event. After further consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening (1,795 feet in this reach) of the modified Valley View plan, where applicable.

Reach 11

Capitol Expressway to Branham Lane (Sta. 913 +50 to 961 + 00) - Widened Earth Channel with Bench.

From the 1998 Valley View plan, no flood control modifications are proposed for the first 2,100 feet of the reach until the vicinity of Sta 934+00. At this point, widening of the east bank is proposed for 450 to 500 feet, with the top of the cut slope extending into an existing SCVWD easement that abuts the adjacent residential area. One water well on the east bank would be relocated. In the vicinity of a concrete apron, channel widening would shift to the west bank for 200 to 400 feet then shift back to the east bank, continuing upstream along the SCVWD's easement to Branham Lane. The toes of the benches would be revegetated to partially mitigate riparian forest losses. Within the downstream portion of this reach, riparian forest creation or enhancement is proposed in five discrete areas of predominantly ruderal herbaceous habitat along the upper part of the west bank adjacent to Orchard Drive and Almaden Expressway. Large oak trees along the roadside would be avoided. In 2004, some channel widenings were moved to the west bank. After further consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening (4,750 feet in this reach) of the modified Valley View plan, where applicable.

Canoas Creek (50-year, 3000 cfs)

Almaden Expressway to 1,400 feet Upstream of Nightingale Drive- Floodwalls.

From the 1998 Valley View plan, culverts beneath Almaden Expressway and Nightingale Drive are to be widened, low floodwalls approximately 1 to 3 feet high and 2,800 feet long would be constructed on both creek banks. No changes were made in 2004 and 2021.

Ross Creek (50-year, 1950 cfs)

Valley View plan, Almaden Expressway to 750 feet Upstream of Jarvis A venue - Floodwalls.

In 1998 Valley View plan, low floodwalls 1 to 3 feet high and 5,200 feet long would be constructed on both creek banks. The creek channel would be widened to a 27-foot-wide trapezoidal design from the main river channel to 750 feet upstream of Jarvis Avenue. New culverts would be constructed under Almaden Expressway and Jarvis Avenue.

4.2.3 Bypass Plan Alternative

Reach 7 & 8

This is a bypass channel approximately 1-mile-long ranging from 80 to 120 feet wide from top of bank to top of bank. The demolition for this area will consist mostly of concrete foundations ranging from 4 to 8 feet deep which will need to be exported from the project site. During construction a 6 ft high fence with 9 gage wire woven 1inch diamond mesh with vinyl coating will be needed. No barbed wire is necessary. The gates will be 6 ft high with 1.9-inch outer diameter poles and similar fence fabric. Approximate 270,000 CYs will be excavated and approximately 90% will need to be transported to a disposal site. There are existing bridges (approximately 100ft wide) which will require tunneling underneath with allowable clearance of about 15 feet after excavation. Riprap is proposed to be place under the two bridges with about 5ft of overhead clearance between the bridge soffit and the highest proposed grade. There are two ramps (747 and 752) to the active river that are aligned to avoid impacting existing trees in proximity. Gravel augmentation will be placed in the channel to provide protection from erosion. At these areas, it is suggested that a conveyor belt system is used to place rock in the active river for Gravel Augmentation Placement (GAP) Site 778 and GAP Site 784. The river will likely need to be diverted for the bypass inlet for approximately 200 feet.

Reach 9

*Willow Glen Way to Curtner Avenue (Sta. 795+00 to 845+00) – Widened Gabion/Cribwall***.**

From the 1998 Bypass plan, the east bank of the river will be widened up to 60 feet, creating a bench 20 to 70 feet wide and between 5 to 12 feet above the river bottom. A maintenance road will be placed along the bench. Two short bypasses will be constructed east of the river to avoid areas of high-quality riparian forest, to reduce ecological impacts. One 500-foot-long bypass between Willow Glen Way and Pine. A proposed venue to have a bottom width of 40 feet with stepped gabions on 1: 1 side slopes. The second bypass upstream of Malone Road will be located on currently vacant land east of the river with a bottom width of 40 feet. The east bank will have a proposed crib wall built at a 1:6 slope. Within the bypass, the maintenance road will be located on the bypass channel bottom. Portions of excavated bench areas would be revegetated.

Six homes, two partial backyard areas, and two businesses would be impacted. Existing water wells and facilities operated by the San Jose Water Company would be relocated. The Willow Glen Way bridge would be replaced. Two eroded sections of the west bank, totaling 500 feet in length, would be stabilized using boulders, root wads, soil, live cuttings, or other methods consistent with SCVWD's approved flood control program. In 2004 Bypass plan, gabions were replaced by crib walls in the lower part of the reach. After further consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening of the modified Bypass plan, where applicable.

Reach 10A
Curtner Avenue to Canoas Creek (Sta. 845+00 to 857+00)- Widened Cribwall Channel.
From the 1998 Bypass plan, east bank widening would continue, creating a bench from 18 to 40 feet. Wide, with an elevation about 5 feet above the present channel bottom, and a crib wall on 1:6 slopes (Parsons Engineering Science 1997). The maintenance road would be placed along the bench. Riparian vegetation along the east bank would be removed. The Curtner A venue bridge would be replaced. Portions of excavated bench areas would be revegetated. After further consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening of the modified Bypass plan.

Reach 10B
Canoas Creek to Berkshire Drive (Sta. 857 + 00 to 888 + 00) – Levee and Revegetation.
From the 1998 Bypass plan, a proposed 4 feet high levee with a top width of 15-18 feet and 2:1 side slope to be constructed on the west bank between the northbound and southbound Almaden Expressway. A proposed 4-foot-high floodwall to be built at the Lincoln Avenue overpass for 300 feet, and a rock-lined low-flow channel would be made by reconfiguring rocks. A maintenance road would be built on the existing east bench upstream of northbound Almaden Expressway, with access to the road provided by a ramp upstream of Almaden Expressway. A Pearl A venue bridge would be constructed in coordination with the City of San Jose, replacing the Hillsdale Avenue bridge, which would be removed in Reach 10C. Riparian Forest would be created or enhanced from the northbound Almaden Expressway bridge southward to the upstream end of the reach. The plantings along the toe of the west bank would extend northward from the Almaden Expressway bridge to the downstream end of the reach. After further consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening of the modified Bypass plan.

Reach 10C
Berkshire Drive to Capitol Expressway (Sta. 888 + 00 to 911 + 75) – Widened Gabion Channel.
From the 1998 Bypass plan, the east bank would be excavated creating a bench between 20 and 58 feet wide, 8 feet above the present channel bottom. A maintenance road would be placed along the bench. For most of this reach, gabions would be used above the bench, and the slope from the bench down to the channel bottom would be left natural. Between Hillsdale and Capitol Expressway bridges, above the maintenance road the bank would be lined with crib walls at a 1 :6 slope, while the bank below would be lined with stepped gabions. A portion of the depressed bench would be revegetated. A portion of the Valley View Packing Plant would be removed. In 2004, gabions were replaced with crib walls to reduce costs. After further consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening of the modified Bypass plan.

Reach 11A

Capitol Expressway to Bryan Avenue (Sta. 911 + 75 to 937 + 60) – Widened Gabion Channel.

From the 1998 Bypass plan, the east bank would be widened from Capitol Expressway south for approximately 300 feet, where a 700-foot-long bypass channel with a bottom width of 50 feet and 2:1 unlined slope would begin. Bypass channel slopes would be revegetated. After this point, the east bank would again be widened, where a maintenance road would be placed. Gabions would line the 1:1 slope above the bench. Existing concrete rubble within the river channel would be removed to enhance fish passage. After consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening of the modified Bypass plan.

Reach 11B

Bryan Avenue to Ross Creek (Sta. 937+60 to 947+90)- West Bank Widening with Crib_walls.

In 1998 Bypass plan, the west bank would be widened, creating an earth bench 40 feet wide and 5 feet above the channel bottom. The 1:6 side slope above the bench would be lined with crib_walls, and the 1:1 slope below lined with stepped gabions. Maintenance roads would be placed on the widened bench and on top of the east bank. After consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening of the modified Bypass plan.

Reach 11C

Ross Creek to Bryan Avenue (Sta. 947+90 to 960+00)- West Bank Widening with Crib_walls.

From the 1998 Bypass plan, the west bank would be widened to create a bench up to 60 feet wide with a 1:6 side slope lined with crib_wall approximately 6 feet above the channel bottom. A maintenance road would be placed on the bench and along the top of the east bank. Vegetation on the east bank would be avoided. After consideration in 2021, all stepped gabions are being replaced by crib walls in the channel widening of the modified Bypass plan.

Reach 12

Branham Lane to Blossom Hill Road (Sta. 961 + 00 to 1017 + 35) – Widened Earth Channel with Bench.

From the 1998 Bypass plan, the west bank would be widened 25 feet between the seasonal percolation ponds and Blossom Hill Road to create a vegetation bench. Levees would be constructed and raised 6 feet on both banks between Chynoweth A venue and Route 85, with maintenance roads placed on top of both the east and west banks. Large areas of riparian, wetland, and open-water habitat would be planted in the reach area. Reduction in percolation pond areas would be offset by construction of 4.5 acres of pond off stream. Ruderal vegetation would be removed.

Canoas Creek (1% event, 3300 cfs)

Almaden Expressway to 1,400 feet Upstream of Nightingale Drive- Floodwalls.

From the 1998 Bypass plan, culverts beneath Almaden Expressway and Nightingale Drive would be widened, and low floodwalls 1 to 3 feet high and 2,800 feet long would be constructed on both creek banks. No changes were made in 2004 and 2021.

Ross Creek (1% event, 2350 cfs)

From the 1998 Bypass plan, the creek channel would be widened to a 35-foot-wide trapezoidal design from the main river channel to 750 feet upstream of Jarvis Avenue. Both banks would be lined with articulated concrete mats at a 1:1 slope. New culverts would be constructed under Almaden Expressway and Jarvis A venue. The Ross Creek culvert entering the Guadalupe River in Reach 11 C would be extended 80 feet, with a concrete apron. The existing sanitary sewer pipe under Almaden Expressway would be relocated in coordination with the city. Mitigation for fisheries impacts along Ross Creek would include stepped fish pools, a low-flow channel to enhance fish passage, and weirs. No changes were made in 2004 and 2021.

4.2.4 Lower Scope Plan

Reach 7 & 8

The lower scope plan for Reach 7 and 8 provides a natural approach to increasing the capacity by widening the river channel. The channel cross sections would follow a floodplain bench configuration on the east bank of the river with a 2% slope toward the existing channel. Existing native riparian habitat on the east bank will be left untouched to allow the design utilizes the natural mitigation areas within the channels. The natural separation helps alleviate high velocity flow and prevents erosion. Additionally, gravel augmentation will be incorporated along the channel to help further reduce velocity and reduce scouring along the toe of the channel.

At Willow Street and Alma Avenue crossing, the channels will be widened with a trapezoidal channel adjacent to the existing channel. The new channel at Willow Street crossing will feature an 85-ft wide trapezoidal channel will include a pilot channel and 18-ft maintenance road channel which can be accessed from the 18-ft ramp. The new channel crossing at Alma Avenue will feature a 60-ft wide concrete lined channel with an 18-ft wide maintenance road which will allow for a steeper 1:1 side slope while providing erosion protection. At both locations, a new bridge will be built across the span of the new extended channel. The UPPR bridge will be extended to help maximize the flow capacity through this crossing. A proposed ramp along the west bank of the river at this intersection to provide access for maintenance.

There are 3 permanent placement sites within Reach 7 and 8: Willow Street & Lelong Street, W Alma Avenue (Elks Lodge) and along Mackey Avenue. These 3 sites will act as temporary staging and lay-down areas during construction and will help reduce the truck trips during construction. This will help with reduce the environmental impact of transporting all the earthwork.

A culvert replacement is being discussed instead of the original bridge extension in the at the downstream of Reach 7 due to Caltrain project.

Canoas Creek

The culverts at Almaden Expressway and Nightingale Drive would be widened to allow more efficient flow which will reduce bottlenecking. Additionally, 4 to 6-ft floodwalls will be place along both creeks' banks (approximately 2800-ft) to increase the capacity of the channel. The top of wall elevation across the floodwalls will be at 152-ft. The additions of these structures will significantly reduce flooding to the surrounding area.

Ross Creek

The culverts at Almaden Expressway, Cherry Ave, and Jarvis Avenue are being widened to help with the flooding along Ross Creek. Upon further investigation additional culverts at Meridian Avenue and Kirk Road are also being updated with widened culverts. Floodwalls are proposed to be constructed along where the existing top of levee have previously breached to contain any future flood events. The top of wall elevation across the floodwalls will be approximately at 175-ft.

4.2.5 Combo Plan

Reach 7 & 8
The combination plan for Reach 7 and 8 will exhibits a more natural river channel than the authorized plan by using channel widening to increase capacity rather than a bypass trapezoidal channel. The channel cross sections would follow a floodplain bench configuration on the east bank of the river with a 2% slope toward the existing channel. Existing native riparian habitat on the east bank would be avoided during excavation resulting in so-called mitigation islands between the river and the toe of the floodplain bench. The design would optimize cut and fill balance and create a mound where space is available.
The Alma Avenue Bridge would use 1:1 channel slope with concrete lining to reduce the roughness coefficient and the design flow water surface elevation. The ramp would be on the west bank of the river. The design of Willow Street Bridge does not provide a ramp under the existing bridge in order to avoid impacts to existing riparian forest habitat.

Gravel augmentation would be incorporated into the plan where needed to reduce scouring along the toe of the channel. Proposed permanent placement sites have been established to reduce environmental impacts, such as, truck trips to disposal sites.

Canoas Creek
The culverts at Almaden Expressway and Nightingale Drive would be widened to allow more efficient flow to reduce the bottlenecking. Floodwalls are place along both creek banks (approximately 2800-ft) to increase the channel height where the existing elevation are not at 152'. The additions of these structures will significantly reduce flooding to the surrounding area.

Ross Creek
Culverts at Almaden Expressway, Cherry Ave, and Jarvis Avenue are being widened to help with the flooding along Ross Creek. Upon further investigation additional culverts at Meridian Avenue and Kirk Road are also being updated with widened culverts. Floodwalls are proposed to be constructed along where the existing top of channel have been breached to contain any future flood events. The top of wall elevation across the floodwalls will be approximately at 175-ft.

4.3 Feature Locations

For simplicity the alternatives will be discussed as they relate to their location within the project area working downstream to upstream.

Table 10. Reach 7 Alternative Features

Reach 7		
Alternative	**Plan**	**Notes**
Valley View Plan	Bypass Channel	Willow St. and Alma St. Bridge Modifications
Bypass Plan	Bypass Channel	Willow St. and Alma St. Bridge Modifications
Lower Scope	Widening and Benching	Caltrain Bridge Update with Culverts
Combo Plan	Widening and Benching	Willow St. and Alma St. Bridge Updates. Caltrain Bridge Extension (No Culverts)

Reach 7 features are the same for the Valley View and Bypass plans except for alcoves placed along the Bypass plan. Alcoves make a negligible difference hydraulically but provide some environmental benefit for fish spawning. Reach 7 features are the same for the Lower Scope and Combo Plan. The Willow St. and Alma St. Bridges were not modified in the Lower Scope model but were updated in the Combo Plan model.

Table 11. Reach 8 Alternative Features

Reach 8		
Alternative	**Plan**	**Notes**
Valley View Plan	Bypass Channel	No Bridge Modifications
Bypass Plan	Bypass Channel and Floodwalls	No Bridge Modifications
Lower Scope	Widening and Benching	No Bridge Modifications
Combo Plan	Widening and Benching	No Bridge Modifications

Table 12. Reach 9 Alternative Features

Reach 9		
Alternative	**Plan**	**Notes**
Valley View Plan	Bypass Channel	Modification of Malone Rd. Bridge and replacement of Willow Glen Way and Curtner Ave. Bridges
Bypass Plan	Short Bypass Channel	Replace Willow Glenn Way Bridge
Lower Scope	Nothing	
Combo Plan	Nothing	

Table 13. Reach 10 Alternative Features

Reach 10		
Alternative	**Plan**	**Notes**
Valley View Plan	Bypass Channel	Modify Capitol Expressway Bridge
Bypass Plan	Widening and Benching	
Lower Scope	Bridge Update	Modify Capitol Expressway Bridge
Combo Plan	Bridge Update	Modify Capitol Expressway Bridge

Table 14. Reach 11 Alternative Features

Reach 11		
Alternative	**Plan**	**Notes**
Valley View Plan	Bypass Channel	No Bridge Modficiations
Bypass Plan	Widening and Benching	No Bridge Modifications
Lower Scope	Nothing	
Combo Plan	Nothing	

Table 15. Reach 12 Alternative Features

Reach 12		
Alternative	**Plan**	**Notes**

Valley View Plan	Widening and Reconstruct Levees	No Bridge Modifications
Bypass Plan	Nothing	
Lower Scope	Nothing	
Combo Plan	Nothing	

Table 16. Ross Creek Alternative Features

Ross Creek		
Alternative	**Plan**	**Notes**
Valley View Plan	Channel Widening and Floodwalls	New Culverts for Almaden and Jarvis Ave.
Bypass Plan	Floodwalls and New Culverts	
Lower Scope	Floodwalls	New Culverts for Almaden and Jarvis Ave.
Combo Plan	Small Floodwall	Floodwall only on left bank

Floodwalls for the Lower Scope plan are on both the left and right bank of the channel and extend from the Guadalupe River and Ross Creek Confluence upstream to a point just past Jarvis Ave. The Combo Plan only includes a floodwall on the left back in the vicinity of Jarvis Ave. This is shown in Figure 35 where the orange lines show the floodwalls on the Lower Scope plan and the pink line shows the floodwall on the Combo Plan.

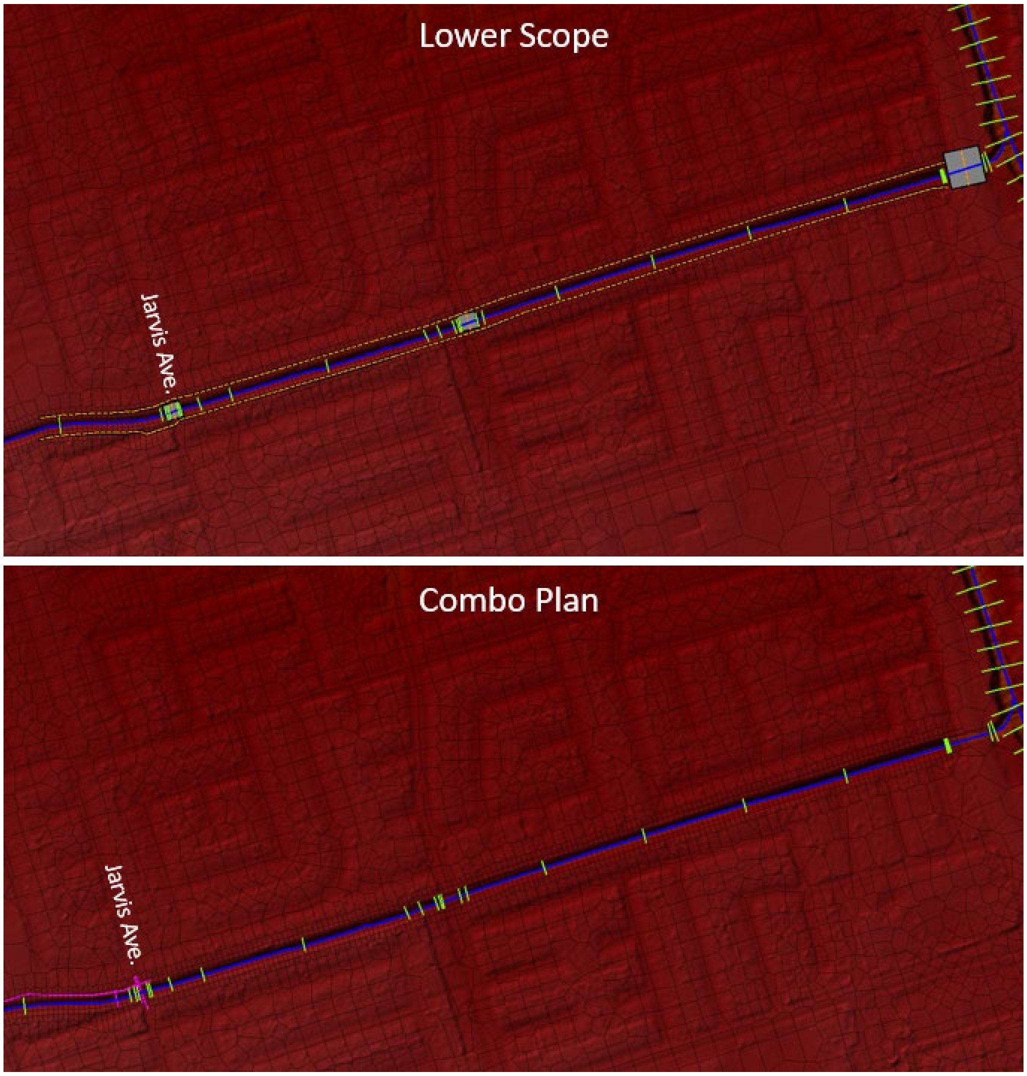


Figure 35. Lower Scope and Combo Plan Floodwall Positions on Ross Creek

Table 17. Canoas Creek Alternative Features

Canoas Creek		
Alternative	**Plan**	**Notes**
Valley View Plan	Floodwalls	New Culverts for Almaden and Nightingale Ave.
Bypass Plan	Floodwalls and New Culverts	
Lower Scope	Floodwalls	
Combo Plan	Floodwalls	

Figure 36 shows the Lower Scope and Combo plan floodwalls. They are the same position except the Combo Plan left bank is extended upstream, by approximately 500-feet. The orange lines show the floodwalls on the Lower Scope plan and the pink line shows the floodwall on the Combo Plan.

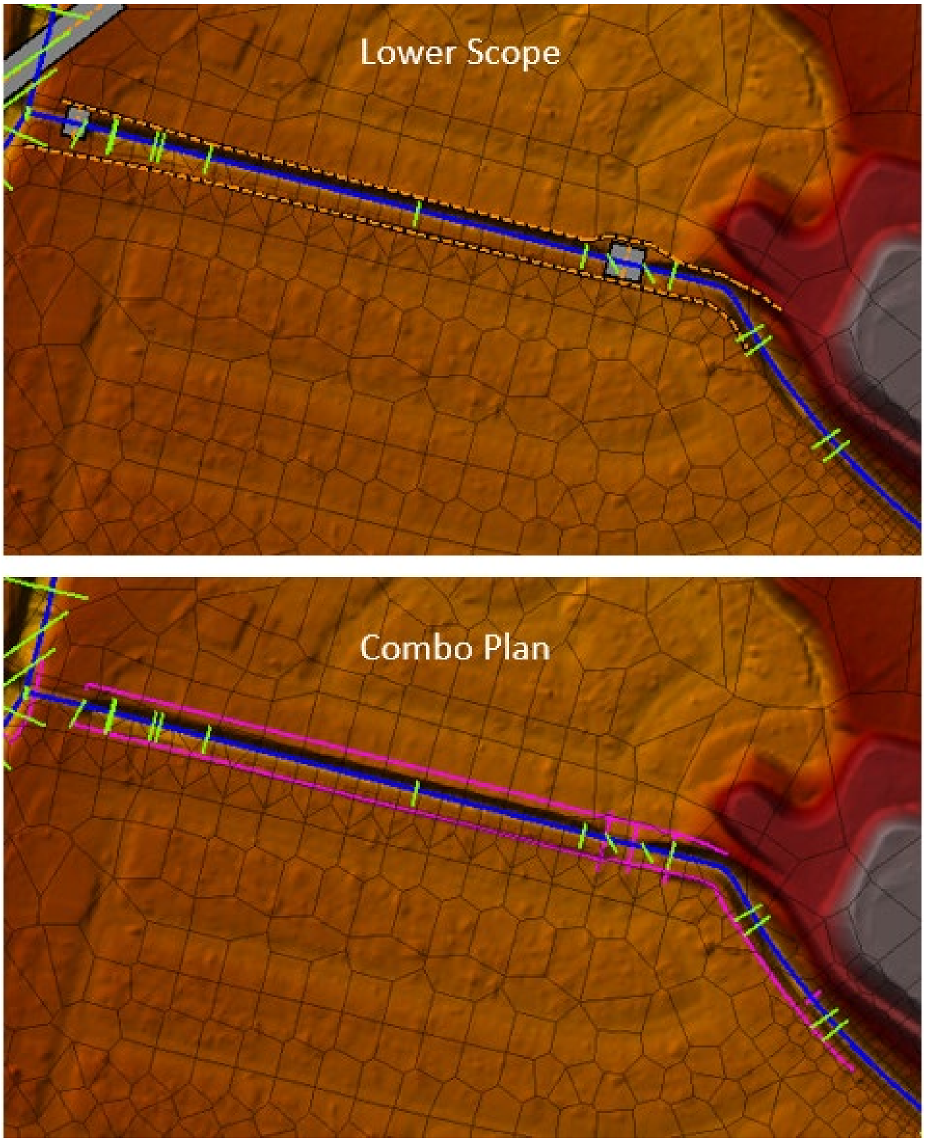


Figure 36. Lower Scope and Combo Plan Floodwall Positions on Canoas Creek

4.4 Alternative Plan Terrains

The alternative plans were modeled to all use the same 2D mesh and inflow hydrographs. The differences in their respective model terrain account for most of the features in each plan. The following tables include a raster ID, cell size, and description for the four alternative plans terrain data sets.

4.4.1 Valley View Plan Alternative Raster Layers

Table 18. Raster resolution size and Layer Order for the Valley View Plan

Raster File Name	**Resolution Cell Size (pixel)**	**Layer Order: Top (1) to Bottom (7)**	**Description**
NED M&N model_Canoas 2D_Alcoves.M&N_2002 culverts_2D Canoas.tif	1	1	Covers the Canoas Creek Channel
NED M&N model_Canoas 2D_Alcoves.NED Model M& N_Rev2.tif	1	2	Covers the Guadalupe River Channel from Reach 9 to Reach 12
NED M&N model_Canoas 2D_Alcoves.Rch 7&8.tif	1	3	Covers the Guadalupe River Channel from Reach 7 to Reach 8
NED M&N model_Canoas 2D_Alcoves.Reaches 5 and 6.Reaches 5 and 6.tif	1	4	Covers the Guadalupe River Channel from Reach 5 to Reach 6
NED M&N model_Canoas 2D_Alcoves.Terrain10.Terrain4.2018-110Contours.tif	1	5	Covers the railroad crossing near river station 78071.
NED M&N model_Canoas 2D_Alcoves.Terrain10.Terrain6.280Underpass.tif	1	6	Includes terrain data for under the Sinclair Freeway within the 2D Flow Area.
NED M&N model_Canoas 2D_Alcoves.Terrain10.Terrain9.TerrainMerge.tif	5	7	Covers the rest of the 2D Flow Area and upstream Guadalupe River as well as Ross Creek and Canoas Creek.

4.4.2 Bypass Plan Alternative Raster Layers

Table 19. Raster resolution size and Layer Order for the Bypass Plan

Raster File Name	**Resolution Cell Size (pixel)**	**Layer Order: Top (1) to Bottom (8)**	**Description**
M& N LPP_Canoas_Feas Ross_Bypass Alcoves.M&N_2002 culverts_2D Canoas.tif	1	1	Covers the Canoas Creek Channel
M& N LPP_Canoas_Feas Ross_Bypass Alcoves.LPP TIFF2.tif	2	2	Covers the Guadalupe River Channel from Reach 9 to Reach 12
M& N LPP_Canoas_Feas Ross_Bypass Alcoves.From	1	3	Covers the Guadalupe River

Raster File Name	Resolution Cell Size (pixel)	Layer Order: Top (1) to Bottom (8)	Description
Valley Water Model.tif			Channel Downstream of Reach 5 to the model downstream boundary condition
M& N LPP_Canoas_Feas Ross_Bypass Alcoves.UpperGuadWithAlcoves20170503.tif	0.99	4	Covers the Guadalupe River Channel from Reach 7 to Reach 8
M& N LPP_Canoas_Feas Ross_Bypass Alcoves.From San Fran.tif	1	5	Covers the Guadalupe River Channel from Reach 5 to Reach 6
M& N LPP_Canoas_Feas Ross_Bypass Alcoves.NED M&N Terrain.Terrain10.Terrain4.2018-110Contours.tif	1	6	Covers the railroad crossing near river station 78071.
M& N LPP_Canoas_Feas Ross_Bypass Alcoves.NED M&N Terrain.Terrain10.Terrain6.280Underpass.tif	1	7	Includes terrain data for under the Sinclair Freeway within the 2D Flow Area.
M& N LPP_Canoas_Feas Ross_Bypass Alcoves.NED M&N Terrain.Terrain10.Terrain9.TerrainMerge.tif	5	8	Covers the rest of the 2D Flow Area and upstream Guadalupe River as well as Ross Creek

4.4.3 Lower Scope Alternative Raster Layers

Table 20. Raster resolution size and Layer Order for the Lower Scope

Raster File Name	Resolution Cell Size (pixel)	Layer Order: Top (1) to Bottom (9)	Description
LowerScope_2D.Lower Scope 2D.Ross Creek.tif	2	1	Covers the Ross Creek Channel
LowerScope_2D.Lower Scope 2D.Canoas Existing.tif	2	2	Covers the Canoas Creek Channel
LowerScope_2D.Lower Scope 2D.Guadalupe Existing.tif	2	3	Covers the Guadalupe River Channel from Reach 9 to Reach 12
LowerScope_2D.Upper Guadalupe FG Lower Scope.tif	0.99	4	Covers the Guadalupe River Channel from Reach 7 to Reach 8
LowerScope_2D.Lower Scope 2D.R5andR6_Rev1.Rch5 and 6 Rev 1.tif	0.5	5	Covers the Guadalupe River Channel from Reach 5 to Reach 6
LowerScope_2D.Lower Scope 2D.Terrain10.Underpass.tif	1	6	Road Underpass data for Reaches 5 and 6
LowerScope_2D.Lower Scope 2D.Terrain10.Terrain4.2018-110Contours.tif	1	7	Covers the railroad crossing near river station 78071.

Raster File Name	Resolution Cell Size (pixel)	Layer Order: Top (1) to Bottom (9)	Description
LowerScope_2D.Lower Scope 2D.Terrain10.Terrain6.280Underpass.tif	1	7	Includes terrain data for under the Sinclair Freeway within the 2D Flow Area.
LowerScope_2D.Lower Scope 2D.Terrain10.Terrain9.TerrainMerge.tif	5	9	Covers the rest of the 2D Flow Area

4.4.4 Combo Plan Alternative Raster Layers

Table 21. Raster resolution size and Layer Order for the Combo Plan

Raster File Name	Resolution Cell Size (pixel)	Layer Order: Top (1) to Bottom (7)	Description
LS_Rch6_Canoas_Ross.M& N_2002 culverts_2D Canoas.tif	1	1	Covers the Canoas Creek Channel
LS_Rch6_Canoas_Ross.Ross Creek.tif	2	2	Covers the Ross Creek Channel
LS_Rch6_Canoas_Ross.exist Guad_LS_Rch6.tif	1	3	Covers the Guadalupe River Channel
LS_Rch6_Canoas_Ross.Terrain10.Terrain4.2018-110Contours.tif	1	4	Covers the railroad crossing near river station 78071.
LS_Rch6_Canoas_Ross.Terrain10.Underpass.tif	1	5	Road Underpass data for Reaches 5 and 6
LS_Rch6_Canoas_Ross.Terrain10.Terrain6.280Underpass.tif	1	6	Includes terrain data for under the Sinclair Freeway within the 2D Flow Area.
LS_Rch6_Canoas_Ross.Terrain10.Terrain9.TerrainMerge.tif	5	7	Covers the rest of the 2D Flow Area

5.0 RESULTS

Riverine Modeling was performed for the 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, 0.2% - ACE events for FWOP/existing conditions and With-Project conditions. Economics was provided water surface elevation (WSE) raster files for all the alternative plans including the FWOP plans for analysis. Model and plan optimization has not yet been conducted.

5.1 Combo Plan

Figure 37 shows the inundation mapping for the FWOP plan and the Combo Plan. The figure includes 3 shapes to help highlight the inundation differences. Within the circle is breakout flow from Ross Creek. The Combo plan reduces but does not eliminate this flow. The triangle helps to highlight the differences around Canoas Creek. The FWOP simulation shows breakouts on the North and South side of Canoas

Creek at Nightingale Dr. that are eliminated with the combo plan. Additionally, a breakout at the confluence of Canoas Creek and the Upper Guadalupe River is eliminated in the combo plan. The rectangle includes breakouts along the Guadalupe River and deep-water depths below and around the overpass highway system. This is greatly reduced in the combo plan as shown.

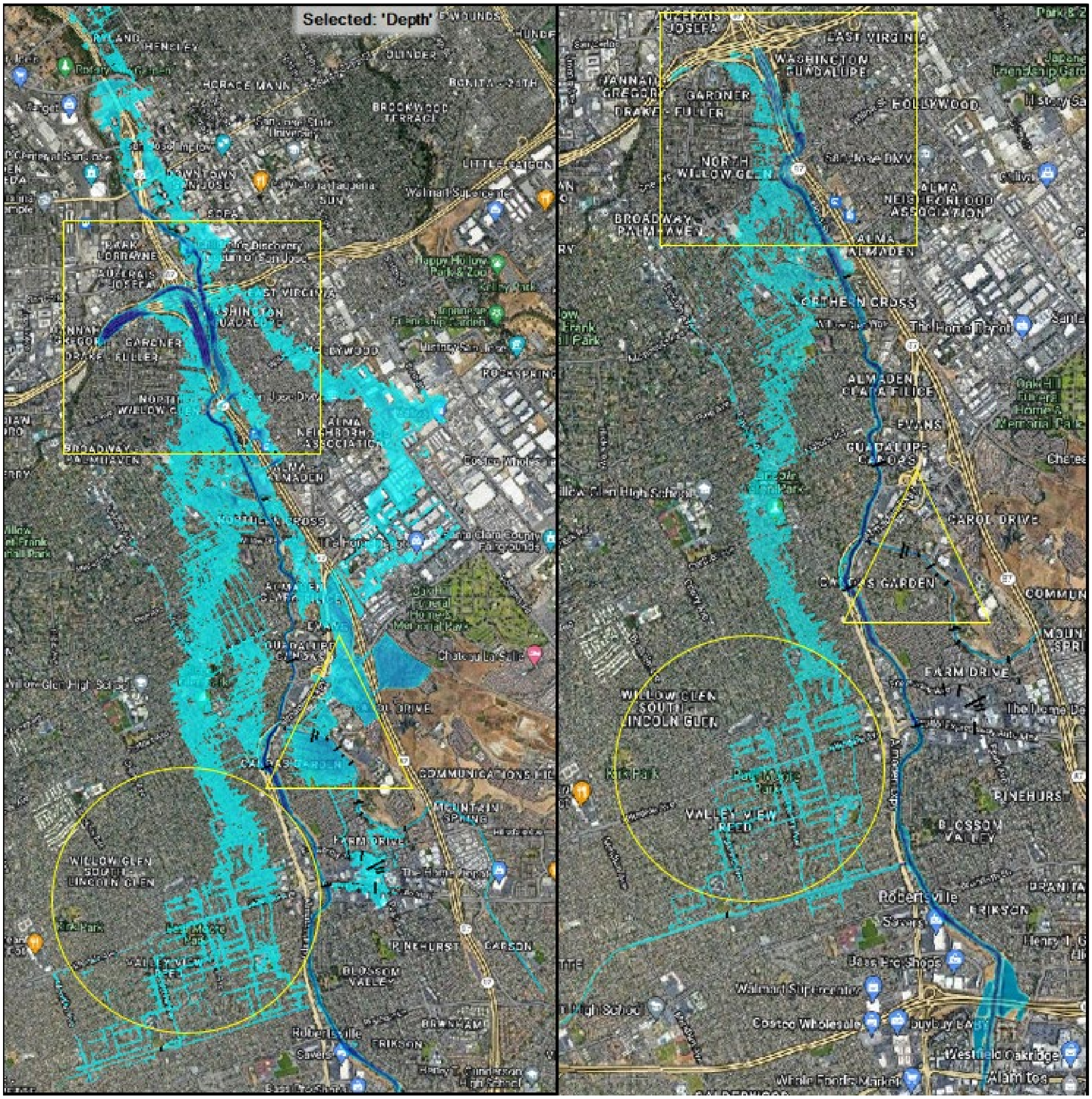


Figure 37. 2% Event Inundation Map Comparison of FWOP (left) and Combo Plan (right)

Figure 38 shows the 1% event comparison. WSE levels are reduced throughout the system and eliminated North of Canoas Creek.

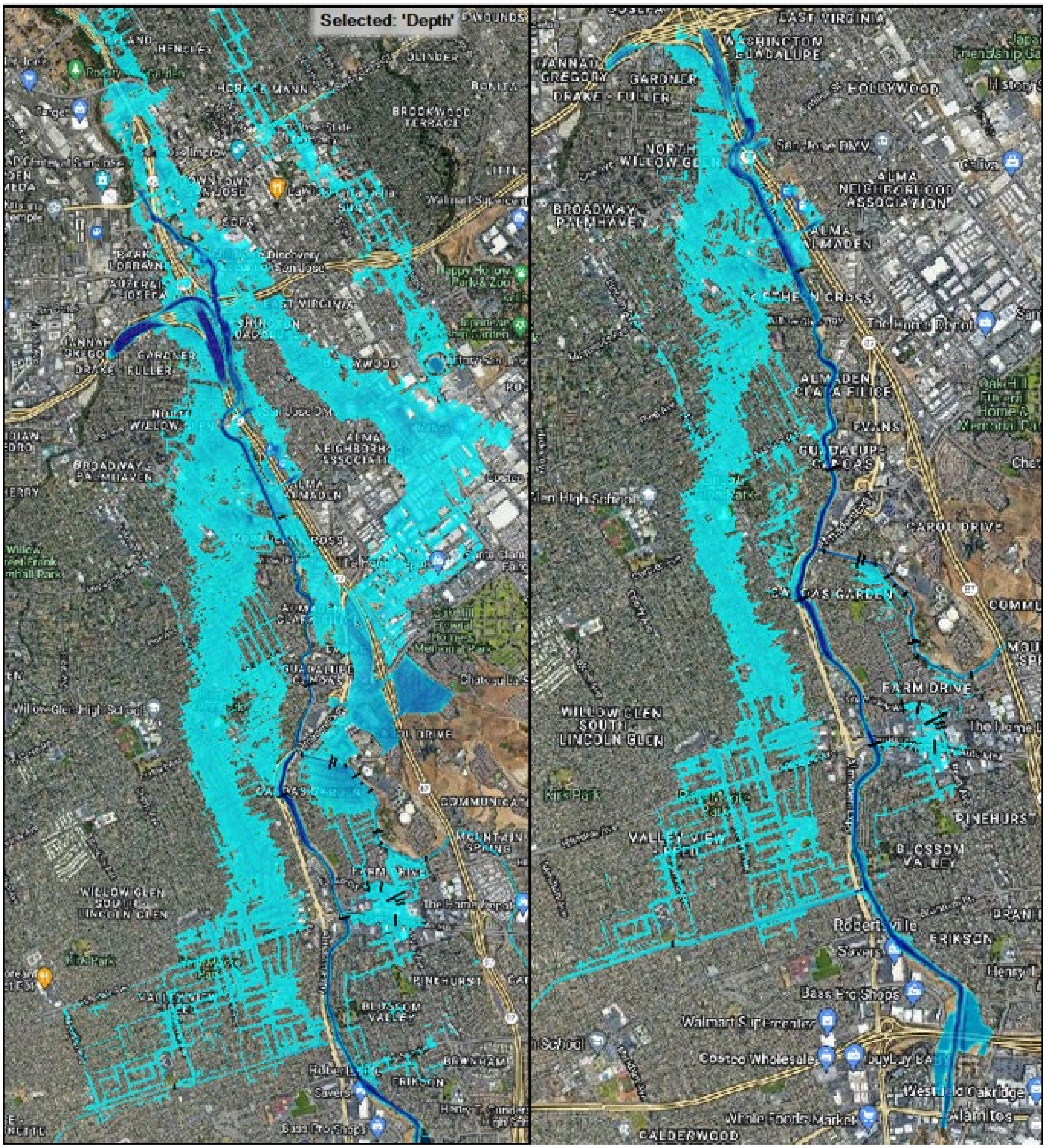


Figure 38. 1% Event Inundation Map Comparison of FWOP (left) and Combo Plan (right)

5.2 Additional Analysis Needed

The TSP has not gone through optimization. The purpose of the optimization is to select the alternative and design frequency that provides the maximum benefit with consideration of the non-Federal sponsor preference.

Risk and Uncertainty (R&U) analysis has not been conducted for the TSP. A R&U will be conducted to optimize the resiliency of the recommended plan. The analysis will follow the procedures from EM

1100-2-1619, *Risk-Based Analysis for Flood Damage Reduction Studies* (USACE, 1976) and ER 1105-2-101, Risk Analysis for Flood Damage Reduction Studies (USACE, 2006).

The flood walls have not undergone a risk assessment. Thorough analysis of the velocity and flow will be required to properly size and construct the floodwalls and to assist with developing of R&U analysis.

6.0 EROSION ANALYSIS-REACHES 7 & 8

There was consideration for a detailed sediment transport model to measure and track gravel movement. The District engaged the USACE Committee on River Engineering (CRE). The Committee reviewed the project files and conducted a site visit and met with the PDT in August 2022. The Committee made the following statement regarding development of a sediment transport model: "This is an incised channel, and the Committee feels that a detailed sediment transport model would not provide any significant value in accomplishing the Flood Risk Management objectives of the project. The Committee also feels there is minimal risk with respect to other considerations such as environmental issue, etc." H&H agrees with this recommendation.

6.1 With-Project Analysis:

Part of the analysis process was determining whether hydraulic reaches 7 & 8 would experience high velocities with the improved condition of adding a bench to the right descending bank of the existing channel. Because of the addition of a newly constructed channel, Valley Water is concerned about the maintenance and how often they would need to maintain the bench.

The analysis includes taking the Combo Plan grid and terrain and modifying it to be able to perform a more detailed analysis. The Civil Design Section of the San Francisco District provide a detailed with project terrain that included reaches 7 & 8. That terrain was cut several hundred feel upstream of the Willow Glenn Way bridge downstream to where Valley Water has finished their work on reach 6.

The grid for the limits of the terrain was constructed using a cell size of 25'x25'. That size was selected to be able to determine the local depth averaged velocities within the existing channel and the new bench. Those velocities will determine the type of erosion control measures, if any are needed. According to the Valley Water, the in-situ material is primarily made up of clay to sandy clays. During design phase, a detailed boring plan will need to be developed for the areas of reaches 7 & 8 to determine the actual material types.

Valley Water requested that we look at the 4% event for the velocity analysis. The NFS uses that event to design all their channel protection. We also looked at the 1% event as a second event to see how much of an increase there would be in the depth averaged velocities. The plots below show examples of the velocities for each of the modeled events.

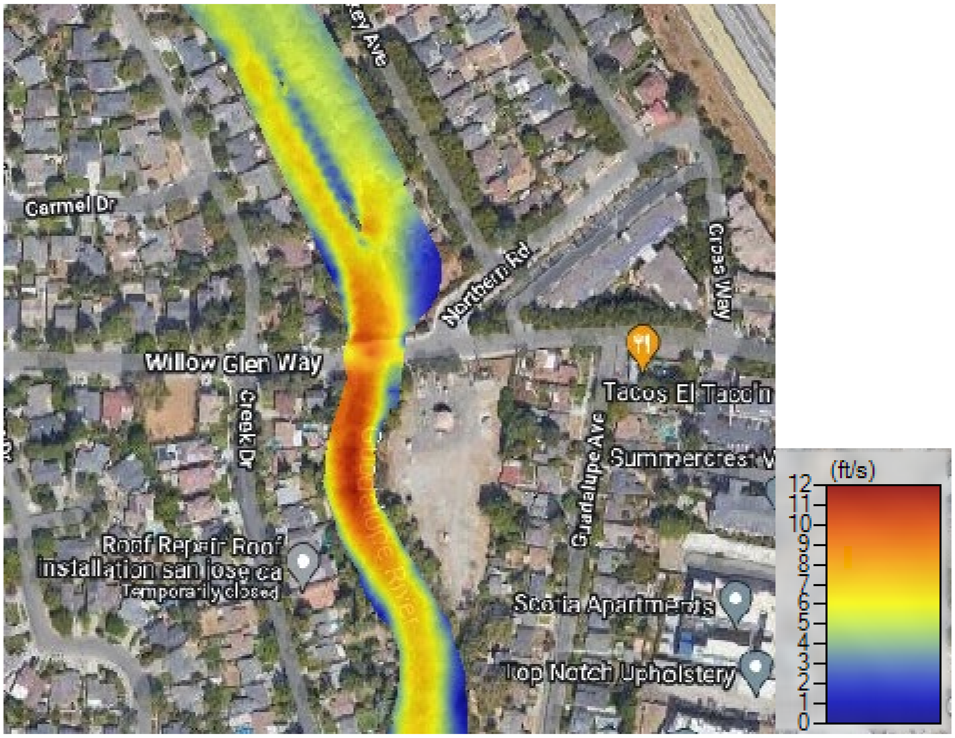


Figure 39. 4% Event velocity map

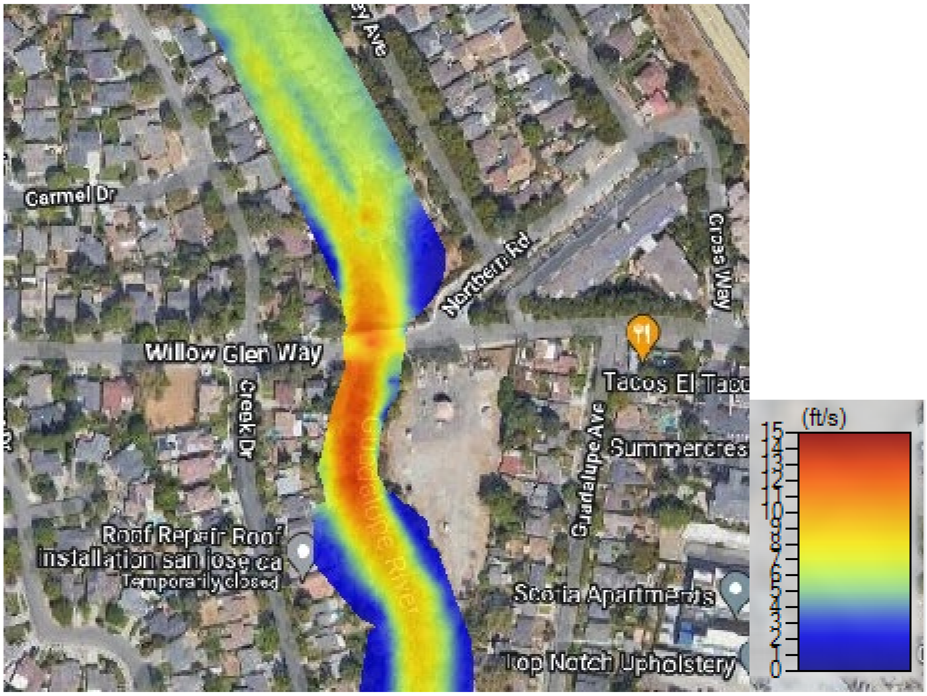


Figure 40. 1% Event velocity map

The maximum velocities for the 4% event are approximately 11 to 12 fps where the maximum velocities for the 1% event is nearly 15 fps. If rock protection is used for the channel to prevent erosion, the size would most likely be very similar for both cases.

To complete the analysis, a similar simulation would need to be done for the future without project existing channel to determine t the existing velocities -

7.0 SUMMARY OF CLIMATE RISK

7.1 Climate Risk Table

A summary of climate risk to the Tentatively Selected Plan is presented in Table 22. The results of the CHAT tool indicate that HEC-RAS model sensitivity runs may be helpful. Climate model output shows a 24% increase in projected annual maximum monthly streamflow over the 93-year projection period (s-). The sensitivity runs can be used to assess whether the TSP is sensitive to changes in flows.

Table 22. Climate Residual Risks Table

Project Feature of Measure	Trigger (Climate Variable)	Impact or Hazard	Harm	Qualitative Likelihood	Justification for Rating
Benching and mitigation islands	Increased average and maximum temperatures. Increased precipitation and flow from more frequent high intensity storms.	Increase in flood magnitude and/or frequency Erosion/ sedimentation Changes in outflows and/or operations of three small upstream water supply reservoirs	Decreased level of project performance Increased O&M costs	Low/ Moderate	CHAT tool indicates changes in the future without project condition due to climate change.
Widening	Increased average and maximum temperatures. Increased precipitation and flow from more frequent high intensity storms.	Increase in flood magnitude and/or frequency Erosion/ sedimentation Changes in outflows and/or operations of three small upstream water supply reservoirs	Decreased level of project performance Increased O&M costs	Low/ Moderate	CHAT tool indicates changes in the future without project condition due to climate change.
Floodwalls	Increased average and maximum temperatures. Increased precipitation and flow from more frequent high intensity storms.	Increase in flood magnitude and/or frequency Increase in maximum air temperature	Decreased level of project performance Increased O&M costs Reduced lifecycle performance of	Low/ Moderate	CHAT tool indicates changes in the future without project condition due to climate change.

Project Feature of Measure	Trigger (Climate Variable)	Impact or Hazard	Harm	Qualitative Likelihood	Justification for Rating
		Erosion/ sedimentation Changes in outflows and/or operations of three small upstream water supply reservoirs	construction materials		
Culverts	Increased average and maximum temperatures. Increased precipitation and flow from more frequent high intensity storms.	Increase in flood magnitude and/or frequency Increase in maximum air temperature Increase in maximum air temperature Erosion/ sedimentation Changes in outflows and/or operations of three small upstream water supply reservoirs	Decreased level of project performance Increased O&M costs Reduced lifecycle performance of construction materials	Low/ Moderate	CHAT tool indicates changes in the future without project condition due to climate change.
Bridge Updates, **Modifications, Replacements, and Extension (Caltrain)** -Willow St -Alma St -Caltrain (with culverts) -Capitol Expressway	Increased average and maximum temperatures. Increased precipitation and flow from more frequent high intensity storms.	Increase in flood magnitude and/or frequency Increase in maximum air temperature Increase in maximum air temperature Erosion/ sedimentation Changes in outflows and/or operations of three small upstream water supply reservoirs	Decreased level of project and materials performance Channel incision, scour at bridge piers Increased O&M costs Reduced lifecycle performance of construction materials	Low/ Moderate	CHAT tool indicates changes in the future without project condition due to climate change.

Project Feature of Measure	Trigger (Climate Variable)	Impact or Hazard	Harm	Qualitative Likelihood	Justification for Rating
Gravel Augmentation and Erosion Protection Measures	Increased precipitation and flow from more frequent high intensity storms.	Increase in flood magnitude and/or frequency Increase in maximum air temperature Erosion/ sedimentation Changes in outflows and/or operations of three small upstream water supply reservoirs	Decreased level of project and materials performance Channel incision, scour at bridge piers Increased O&M costs Reduced lifecycle performance of construction materials	Low/ Moderate	CHAT tool indicates changes in the future without project condition due to climate change.

7.2 Guidance

The content of this climate assessment was prepared in accordance with USACE guidance relevant to inland hydrology and sea level change climate assessments (Table 23).

Table 23. USACE guidance relevant to climate assessments

Guidance Document	Description	Date
ECB 2018-14	*Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies*	10 Sep 2020 (Rev 1)
ER 1100-2-8162	*Incorporating Sea Level Change in Civil Works Programs*	31 December 2013
EP 1100-2-1	*Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation*	30 June 2019

According to ECB 2018-14 (Rev 1), sea level change analysis consistent with ER 1100-2-8162 must be conducted prior to the TSP milestone if the elevation of the project area is ≤ 50 ft NAVD 88 and sea level change is likely to affect the project hydrology. For project areas at elevations less than or equal to 50 ft NAVD88, a determination should be made as to whether sea level rise will affect the river stage by increasing (or decreasing) water surface elevation downstream of the project area.

Elevations in the Guadalupe River watershed range from sea level to approximately 3,800 ft NAVD 88. Elevations in the Upper Guadalupe project area range from approximately 85 to 200 ft NAVD 88.

7.3 Vulnerability Assessment

The USACE Watershed Climate Vulnerability Assessment (VA) Tool facilitates a screening-level, comparative assessment of the vulnerability of a given business line and HUC-4 watershed to the impacts of climate change, relative to the other HUC-4 watersheds within the continental United States (CONUS). It uses the Coupled Model Intercomparison Project (CMIP5) dataset to define projected hydrometeorological inputs, combined with other data types, to define a series of indicator variables to define a vulnerability score.

Vulnerabilities are represented by a weighted-order, weighted-average (WOWA) score generated for two subsets of simulations (wet—top 50% of cumulative runoff projections; and dry—bottom 50% cumulative runoff projections). Data are available for three epochs. The epochs include the current time period ("Base") and two 30-year, future epochs (centered on 2050 and 2085). The Base epoch is not based on projections and so it is not split into different scenarios. For this application, the tool was applied using its default, National Standards Settings. In the context of the VA Tool, there is some uncertainty in all of the inputs to the vulnerability assessments. Some of this uncertainty is already accounted for in that the tool presents separate results for each of the scenario-epoch combinations rather than presenting a single aggregate result. Under the National Standard settings, the vulnerability threshold for each business line is typically 20% (i.e., 20% of HUC-4 watersheds throughout the country are classified as vulnerable).

The Upper Guadalupe project is in HUC 1805 (San Francisco Bay) and classified under the Flood Risk Management business line. Potential Upper Guadalupe project alternatives have features that can also be classified under Recreation or Ecosystem Restoration business lines. Table 24shows that all three of these business lines in HUC 1805 are vulnerable to climate change under nearly all scenario/epoch combinations.

Table 25 shows the three indicators exhibiting the highest contribution to climate change vulnerability for each scenario/epoch combination. Figure 41 - Figure 43 show the relative vulnerability of watersheds throughout the country and summarize the vulnerability assessment results for HUC 1805.

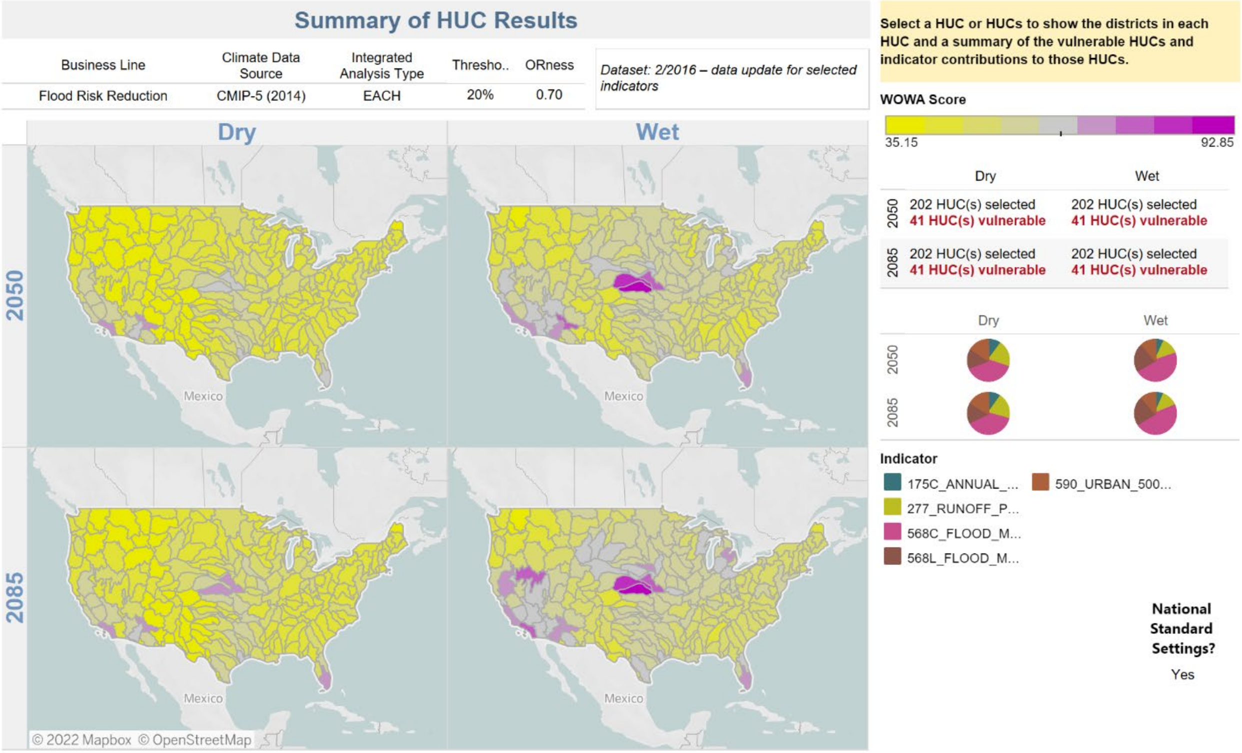
Table 24. HUC-1805 Climate Vulnerability by Epoch/Scenario Combination

Business Line	Epoch	Dry Subset of Scenarios	Wet Subset of Scenarios
Flood Risk Management	2050	Most Vulnerable	Most Vulnerable
	2085	Less vulnerable	Most Vulnerable
Recreation	2050	Most Vulnerable	Most Vulnerable
	2085	Most Vulnerable	Most Vulnerable
Ecosystem Restoration	2050	Most Vulnerable	Most Vulnerable
	2085	Most Vulnerable	Most Vulnerable

Table 25. Top three indicators exhibiting the highest contribution to climate change vulnerability for each epoch/scenario

<table>
<tr><th>Business Line</th><th>Epoch</th><th>Dry Subset of Scenarios</th><th>Wet Subset of Scenarios</th></tr>
<tr><td rowspan="2">**Flood Risk Management**</td><td>2050</td><td>(1) Acres of urban area within the 500-yr floodplain (590)
(2) Long-term variability in hydrology (175C)
(3) Flood magnification - cumulative runoff (568C)</td><td rowspan="2">(1) Flood magnification – cumulative runoff (568C)
(2) Flood magnification – local runoff (568L)
(3) Acres of urban area within the 500-yr floodplain (590)</td></tr>
<tr><td>2085</td><td>(1) Acres of urban area within the 500-yr floodplain (590)
(2) Flood magnification – cumulative runoff (568C)
(3) Long-term variability in hydrology (175C)</td></tr>
<tr><td>**Recreation**</td><td>2050/2085</td><td colspan="2">(1) Low runoff (monthly runoff exceeded 90% of the time) (570L)
(2) Short-term variability in the region’s hydrology (221C)
(3) Low flow reduction (change in low runoff) (700C)</td></tr>
<tr><td>**Ecosystem Restoration**</td><td>2050/2085</td><td colspan="2">(1) Percentage of wetland and riparian plan communities that are at risk of extinction, based on remaining number and condition, remaining acreage, threat severity, etc. (8)
(2) Short-term variability in the region’s hydrology (221C)
(3) Percent change in runoff divided by percent change in precipitation (elasticity between precipitation and streamflow) (277)</td></tr>
</table>

Note: The flood magnification indicators represent change in flood runoff (monthly runoff exceeded 10% of the time) from the base period.



Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Thresho..	ORness
Flood Risk Reduction	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selected indicators

Select a HUC or HUCs to show the districts in each HUC and a summary of the vulnerable HUCs and indicator contributions to those HUCs.

WOWA Score

35.15 92.85

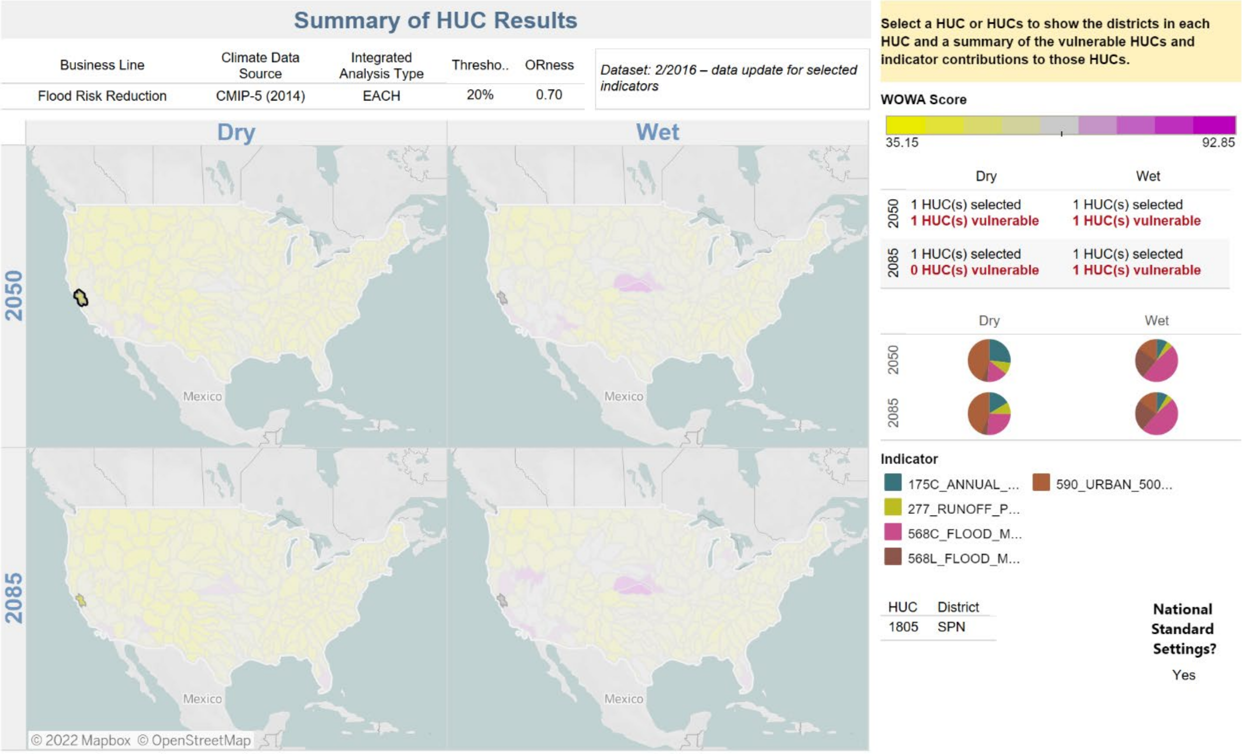
	Dry	Wet
2050	202 HUC(s) selected **41 HUC(s) vulnerable**	202 HUC(s) selected **41 HUC(s) vulnerable**
2085	202 HUC(s) selected **41 HUC(s) vulnerable**	202 HUC(s) selected **41 HUC(s) vulnerable**

Indicator

- ■ 175C_ANNUAL_...
- ■ 277_RUNOFF_P...
- ■ 568C_FLOOD_M...
- ■ 568L_FLOOD_M...
- ■ 590_URBAN_500...

National Standard Settings?

Yes



Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Thresho..	ORness
Flood Risk Reduction	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selected indicators

Select a HUC or HUCs to show the districts in each HUC and a summary of the vulnerable HUCs and indicator contributions to those HUCs.

WOWA Score

35.15 92.85

	Dry	Wet
2050	1 HUC(s) selected **1 HUC(s) vulnerable**	1 HUC(s) selected **1 HUC(s) vulnerable**
2085	1 HUC(s) selected **0 HUC(s) vulnerable**	1 HUC(s) selected **1 HUC(s) vulnerable**

Indicator

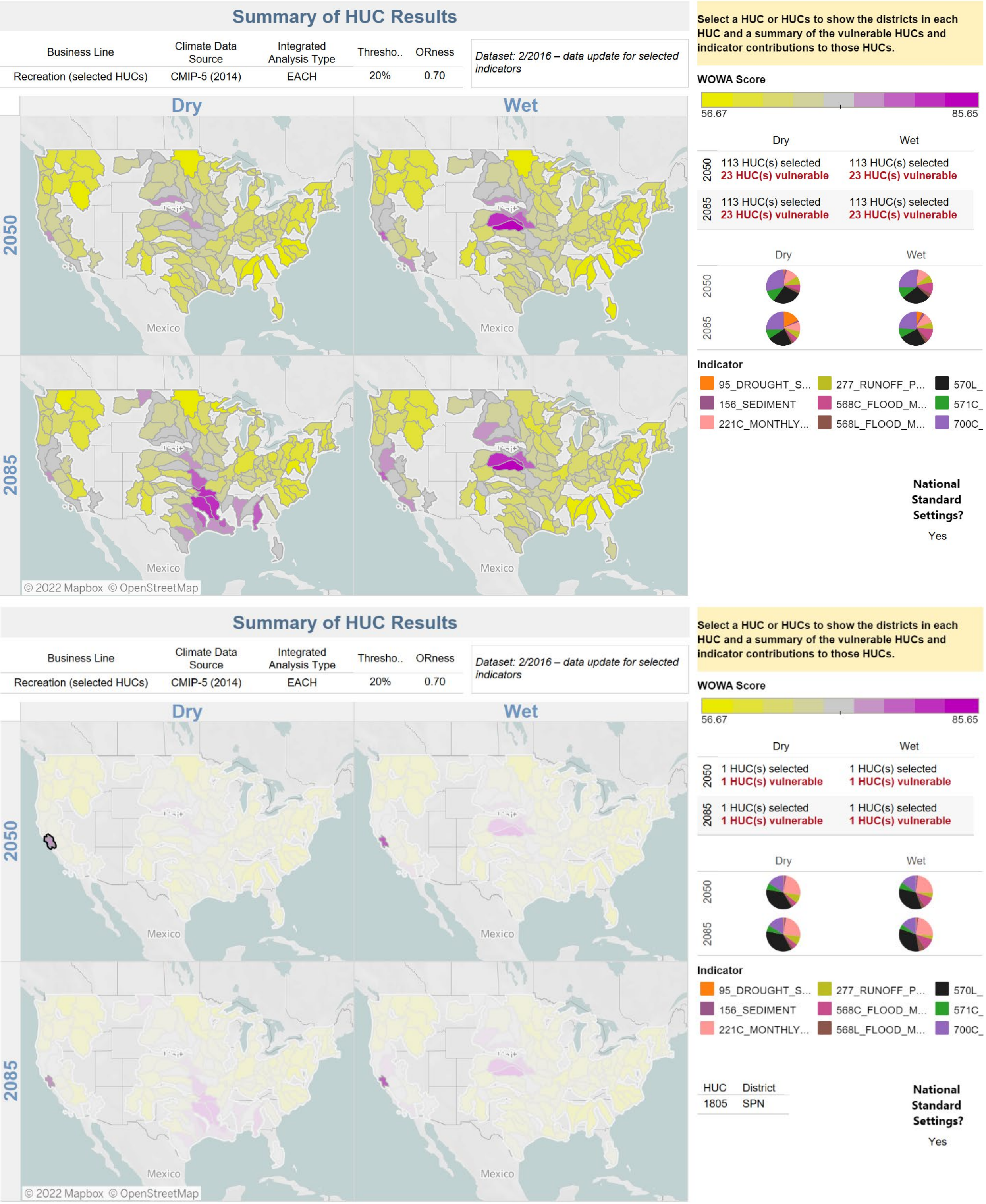
- ■ 175C_ANNUAL_...
- ■ 277_RUNOFF_P...
- ■ 568C_FLOOD_M...
- ■ 568L_FLOOD_M...
- ■ 590_URBAN_500...

HUC	District
1805	SPN

National Standard Settings?

Yes

Figure 41. Top: For the Flood Risk Reduction Line of Business, approximately 20% of included HUC-4 watersheds are considered vulnerable nationwide. Bottom: HUC 1805 (San Francisco Bay) is considered vulnerable under three epoch/scenario combinations (2050 dry, 2050 wet, and 2080 wet).



Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Thresho..	ORness
Recreation (selected HUCs)	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selected indicators

Select a HUC or HUCs to show the districts in each HUC and a summary of the vulnerable HUCs and indicator contributions to those HUCs.

WOWA Score

56.67 85.65

	Dry	Wet
2050	113 HUC(s) selected **23 HUC(s) vulnerable**	113 HUC(s) selected **23 HUC(s) vulnerable**
2085	113 HUC(s) selected **23 HUC(s) vulnerable**	113 HUC(s) selected **23 HUC(s) vulnerable**

Indicator

- 🟧 95_DROUGHT_S...
- 🟪 156_SEDIMENT
- 🟥 221C_MONTHLY...
- 🟨 277_RUNOFF_P...
- 🟥 568C_FLOOD_M...
- 🟫 568L_FLOOD_M...
- ⬛ 570L_
- 🟩 571C_
- 🟪 700C_

National Standard Settings?

Yes

Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Thresho..	ORness
Recreation (selected HUCs)	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selected indicators

Select a HUC or HUCs to show the districts in each HUC and a summary of the vulnerable HUCs and indicator contributions to those HUCs.

WOWA Score

56.67 85.65

	Dry	Wet
2050	1 HUC(s) selected **1 HUC(s) vulnerable**	1 HUC(s) selected **1 HUC(s) vulnerable**
2085	1 HUC(s) selected **1 HUC(s) vulnerable**	1 HUC(s) selected **1 HUC(s) vulnerable**

Indicator

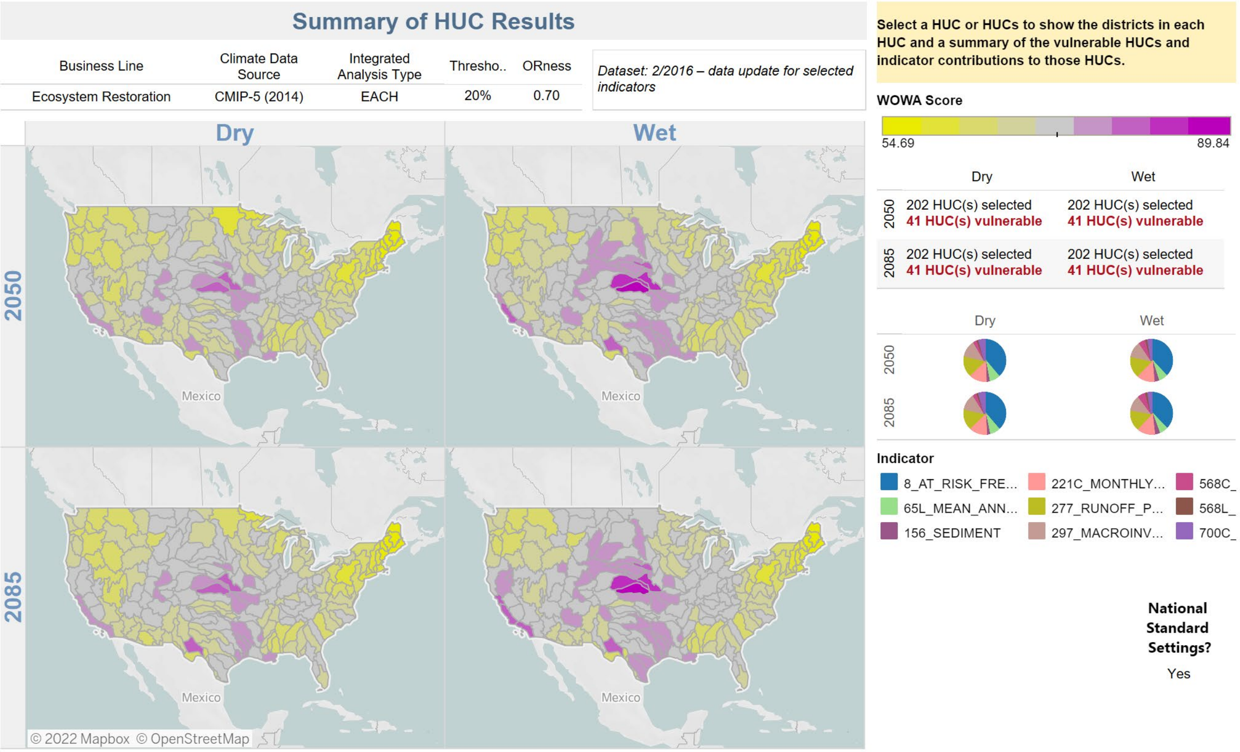
- 🟧 95_DROUGHT_S...
- 🟪 156_SEDIMENT
- 🟥 221C_MONTHLY...
- 🟨 277_RUNOFF_P...
- 🟥 568C_FLOOD_M...
- 🟫 568L_FLOOD_M...
- ⬛ 570L_
- 🟩 571C_
- 🟪 700C_

HUC	District
1805	SPN

National Standard Settings?

Yes

Figure 42. Top: For the Recreation Line of Business, approximately 20% of included HUC-4 watersheds are considered vulnerable nationwide. Bottom: HUC 1805 (San Francisco Bay) is considered vulnerable under all epoch/scenario combinations.



Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Thresho..	ORness
Ecosystem Restoration	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selected indicators

Select a HUC or HUCs to show the districts in each HUC and a summary of the vulnerable HUCs and indicator contributions to those HUCs.

WOWA Score

54.69 89.84

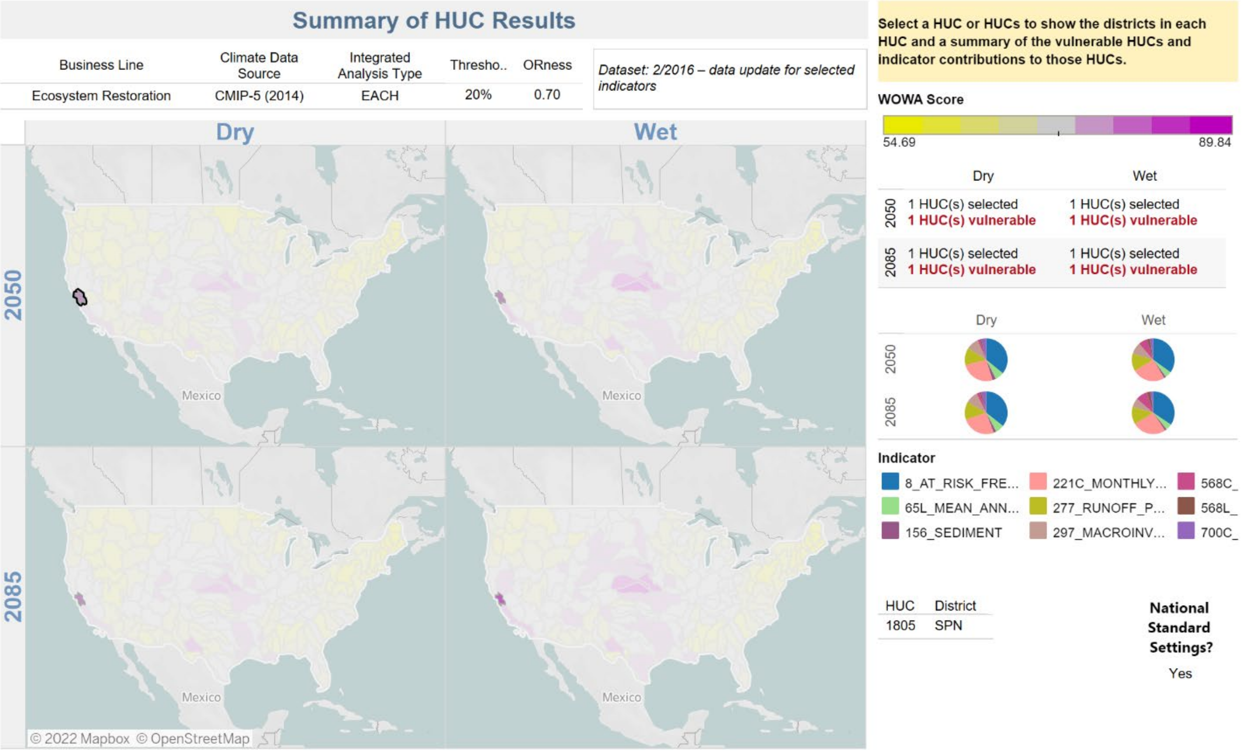
	Dry	Wet
2050	202 HUC(s) selected **41 HUC(s) vulnerable**	202 HUC(s) selected **41 HUC(s) vulnerable**
2085	202 HUC(s) selected **41 HUC(s) vulnerable**	202 HUC(s) selected **41 HUC(s) vulnerable**

Indicator

8_AT_RISK_FRE...	221C_MONTHLY...	568C_
65L_MEAN_ANN...	277_RUNOFF_P...	568L_
156_SEDIMENT	297_MACROINV...	700C_

National Standard Settings?

Yes



Summary of HUC Results

Business Line	Climate Data Source	Integrated Analysis Type	Thresho..	ORness
Ecosystem Restoration	CMIP-5 (2014)	EACH	20%	0.70

Dataset: 2/2016 – data update for selected indicators

Select a HUC or HUCs to show the districts in each HUC and a summary of the vulnerable HUCs and indicator contributions to those HUCs.

WOWA Score

54.69 89.84

	Dry	Wet
2050	1 HUC(s) selected **1 HUC(s) vulnerable**	1 HUC(s) selected **1 HUC(s) vulnerable**
2085	1 HUC(s) selected **1 HUC(s) vulnerable**	1 HUC(s) selected **1 HUC(s) vulnerable**

Indicator

8_AT_RISK_FRE...	221C_MONTHLY...	568C_
65L_MEAN_ANN...	277_RUNOFF_P...	568L_
156_SEDIMENT	297_MACROINV...	700C_

HUC	District
1805	SPN

National Standard Settings?

Yes

Figure 43. Top: For the Ecosystem Restoration Line of Business, approximately 20% of included HUC-4 watersheds are considered vulnerable nationwide. Bottom: HUC 1805 (San Francisco Bay) is considered vulnerable under all epoch/scenario combinations.

8.0 REFERENCES

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