DELTA ADAPTS: CREATING A CLIMATE RESILIENT FUTURE

SACRAMENTO-SAN JOAQUIN RIVER DELTA CLIMATE CHANGE VULNERABILITY ASSESSMENT

DRAFT FLOOD HAZARD ASSESSMENT TECHNICAL MEMO

NOVEMBER 5, 2020

CONTENTS

APPENDICES

FIGURES

TABLES

ACRONYMS AND OTHER ABBREVIATIONS

ART	Adapting to Rising Tides
BDCP	Bay Delta Conservation Plan
CDEC	California Data Exchange Center
CDF	Cumulative Distribution Function
CFS	Cubic feet per second
CVFPP	Central Valley Flood Protection Plan
CVHS	Central Valley Hydrology Study
DEM	Digital Elevation Model
DSC	Delta Stewardship Council
DSM2	Delta Simulation Model II
DLIS	Delta Levee Investment Strategy
DRMS	Delta Risk Management Strategy
DWR	Department of Water Resources
ENSO	El Nino-Southern Oscillation
FEMA	Federal Emergency Management Agency
GCM	General Circulation Model (or Global Climate Model)
HEC	Hydrologic Engineering Center
LiDAR	Light Detection and Ranging
MHW	Mean High Water
MHHW	Mean Higher High Water
MLW	Mean Low Water
MLLW	Mean Lower Low Water
MSL	Mean Sea Level
MTL	Mean Tide Level
NOAA	National Oceanic and Atmospheric Administration
OPC	Ocean Protection Council
PDF	Probability Density Function
RCP	Representative Concentration Pathway
RMSE	Root Mean Square Error
SLR	Sea level rise
SSP	Statistical Software Package
TDI	Total Delta Inflow
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WSE	Water Surface Elevation

This page intentionally left blank

CHAPTER 1. INTRODUCTION

1.1 Background

A primary goal of the Delta Stewardship Council's (DSC) Delta Adapts: Creating a Climate Resilient Future project is to develop a better understanding of the effects of sea level rise and changing Delta inflows on local water levels within the Delta. Local water level variations in the Delta are driven by a number of factors, including astronomical tides, atmospheric effects (pressure and wind), fluvial inflow, Delta exports, and other flow and salinity control operations. Climate change will affect a number of these factors by increasing mean sea level at the Golden Gate, changing oceanic and coastal processes that influence the Bay and Delta, and changing the nature of freshwater inflows to the Delta (for example, timing and magnitude of inflow).

A number of previous studies such as the Delta Risk Management Strategy (DRMS 2008a, DRMS 2008b), Delta Levee Investment Strategy (DLIS) (http://deltacouncil.ca.gov/delta-levees-investment-strategy), and the Central Valley Flood Protection Plan (CVFPP) have conducted technical analyses of the dependence of Delta water levels on tides, inflows, and sea level rise. The West Sacramento Levee Improvement Study also evaluated the effect of sea level rise on flood levels in the Sacramento River. The Central Valley Hydrology Study (CVHS) (USACE 2015) also developed information on tributary streamflows which have informed the CVFPP. CVHS hydrology data is leveraged in the Delta Adapts project as well as part of the Flood Hazard Analysis task.

Considerable work has also been invested in developing spatial maps of tidal datum variability throughout the Delta – for example, analysis based on RMA2 model results (Dudas et al. 2016). The Delta Modeling Section within the Bay-Delta Office of the Department of Water Resources (DWR) evaluated sea level rise amounts of 6 and 18 inches using the Delta Simulation Model II (DSM2) as part of the Bay Delta Conservation Plan (BDCP 2016).

Recent modeling using the UnTRIM model (Anchor QEA and AECOM 2018) for BCDC's Adapting to Rising Tides (ART) Program in eastern Contra Costa County developed estimates of typical tidal datums and 100-year water surface elevations for a portion of the Delta for existing conditions and sea level rise scenarios of 12, 36, and 83 inches. In general, these studies have shown that Bay tides and ocean processes exert a strong influence on water levels in Suisun Marsh and the central Delta and that the influence of Bay processes decreases with distance into the Delta as riverine inflows become more dominant. This is particularly true during high discharge events in upstream areas of Delta tributaries where water level fluctuations can be entirely driven by discharge. Understanding the spatial patterns of influence of tides and inflow on water levels throughout the Delta and how local water levels respond to sea level rise and inflows is a key aspect of the Delta Adapts effort.

Key questions that drove the analysis approach included the following:

- How does sea level rise at the Golden Gate translate to increases in typical water levels (i.e., tidal datums) throughout the Delta?
- How does sea level rise at the Golden Gate coupled with storm and meteorological events (i.e., extreme tides, winds, and low atmospheric pressure) translate to increases in peak water levels throughout the Delta?
- How do projected changes in oceanic and coastal processes (such as atmospheric pressure, wind, and El Niño events) due to climate change affect water levels in the Delta?
- How does fluvial inflow, and projected changes in inflow due to climate change, translate to changes in water levels in the Delta?
- How do changes in all of the above listed processes interact to affect water levels and flood risk throughout the Delta and how can we plan for these conditions in a risk management framework?

This technical memorandum documents the analysis conducted as part of the Flood Hazard Analysis task for the Delta Adapts project.

1.2 Purpose

The purpose of the Flood Hazard Analysis task is to develop spatially variable estimates of future tidal datums and peak water levels throughout the Delta. These are two separate analyses that are independent from one another except for the fact that they rely on a common set of hydraulic model runs completed in support of the project. Both analyses are discussed in this technical memorandum:

- Tidal Datums Analysis. The tidal datums analysis (Chapter 2) evaluates the effect of sea level rise on future daily water level fluctuations throughout the Delta and the results were used as inputs to the assessment of intertidal habitats as part of the Ecosystem assessment (see Ecosystem Technical Memorandum). The outputs of the tidal datums analysis are GIS shapefiles containing the future tidal datum estimates at over 400 points throughout Suisun Marsh and the Delta for each sea level rise scenario (0 through 10 feet).
- Peak Water Levels Analysis. The peak water level analysis (Chapter 3) evaluates the effects of sea level rise and changes in the timing, magnitude, and distribution of peak inflows to the Delta. The results of the peak water level analysis were used in the flood hazard mapping to inform the flooding and economic exposure assessment. The outputs of the peak water level analysis are tables containing stage-recurrence curves at over 400 points throughout Suisun Marsh and the Delta corresponding to eight flood hazard scenarios (Section 4.1) that span a range of sea level rise conditions and future hydrologic conditions. The flood maps consider both deterministic (i.e., considered a specified amount of sea level rise at a given planning

horizon) and probabilistic scenarios (i.e., considered a sea level rise distribution at a given planning horizon).

The peak water level analysis also provides an informative contrast to existing flood risk products, such as the Federal Emergency Management Agency's Flood Insurance Rate Map (FIRM). In general, very few levees within the Delta meet the requirements for FEMA accreditation (per 44 CFR 65.10) so many Delta islands are mapped within Special Flood Hazard Areas (SFHAs), denoting a 1% or greater annual chance of flooding, even where levee elevations exceed projected flood levels within adjacent channels. While the Delta Adapts flood analysis and mapping does not consider all aspects of levee integrity (e.g., freeboard, embankment protection, stability, settlement, and interior drainage), it does provide increased granularity with respect to the levee overtopping aspect of flood protection and evaluation of the increase in flood exposure throughout the Delta with climate change. With the exception of urban areas, much of the Delta is currently mapped within the SFHA (Figure 1-1).

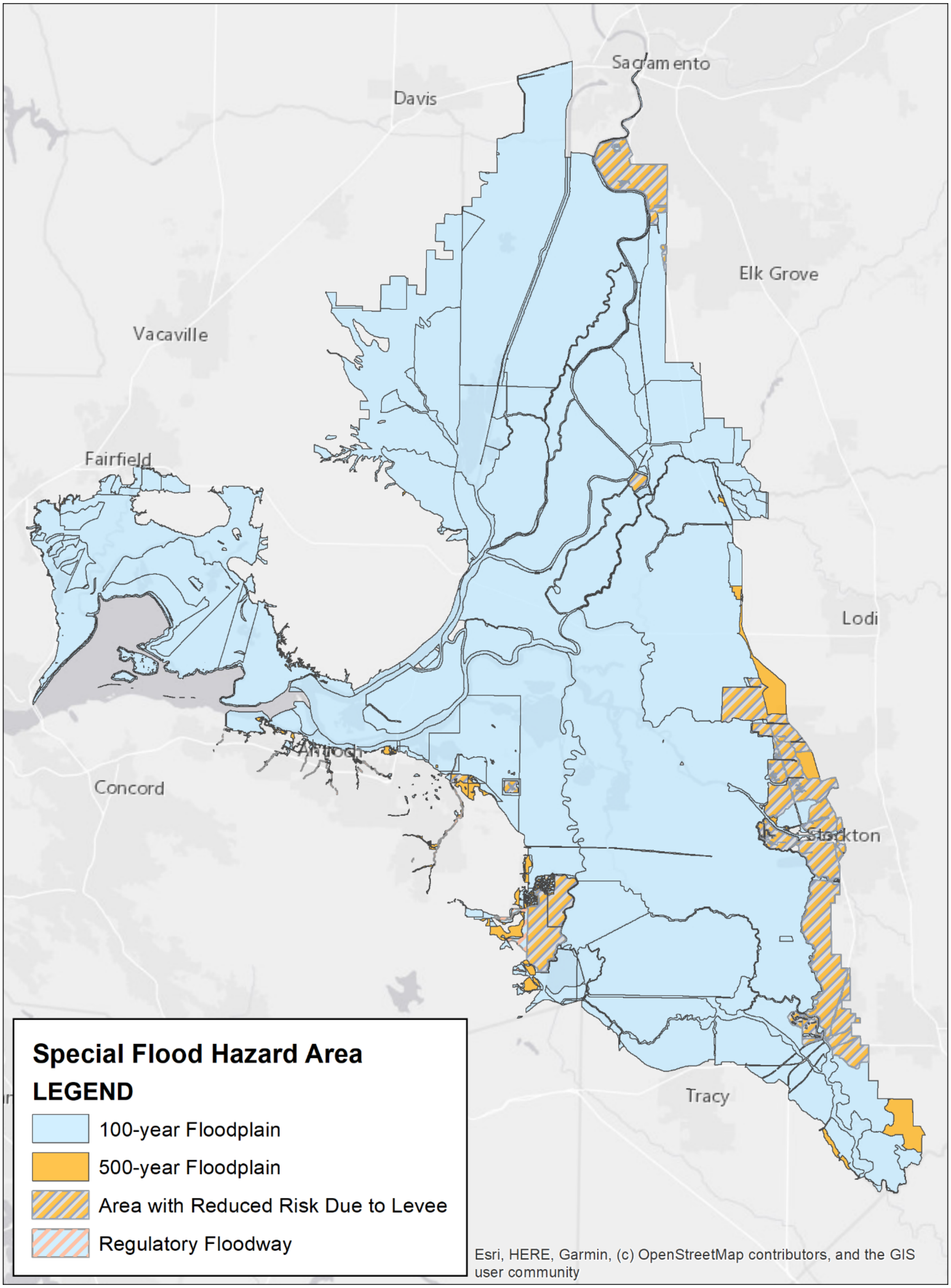


Figure 1-1. Delta areas mapped within the FEMA floodplain for existing conditions

1.3 Open Science and Key Assumptions

A basic objective of the Delta Adapts project is to develop technical information that is accessible, transparent, and replicable – characteristics that support the scientific process in the Bay-Delta research and planning community going forward in a region where best available science and policy-making is constantly changing. Therefore, the project is using open source software to the extent possible as a way to support community sharing of enhancements and derivative works (Morin et al. 2012). In addition, the following methods and assumptions are clearly documented in this technical memorandum so that the results of this work are transparent and replicable.

The key assumptions made in this task include the following:

- **Infinite levees**: The tidal datums and peak water level analysis described in this memorandum assume "infinite levees" and do not include entirely plausible major changes to the Delta landscape from isolated or widespread levee failure. The island interiors behind the levees, and the levees themselves, will likely continue to subside and increase the likelihood of levee failure in the future (Mount & Twiss, 2005, Bates and Lund 2013, Deverel et al 2016). These changes could result in a future condition where multiple Delta islands are flooded due to levee overtopping or breaches with no recovery. Such a change would dramatically alter the landscape of the Delta; the tidal prism would change and result in altered tidal datums, influence of Bay tides, and changes in salinity regime. Peak water levels would likely change as well as a result of increased flooded areas and changes in flow distribution. At the same time, significant investments have been made to reinforce and improve Delta levees, and these investments are likely to continue thus offsetting some or most of the subsidence and deterioration of levees. This project does not attempt to predict or simulate failure scenarios. Instead this analysis characterizes the potential for flooding from levee overtopping as a way to estimate potential flood exposure in Suisun Marsh and the Delta to inform potential policy measures.
- **Consistent Management**: This analysis simulates continued consistent operational goals, strategies, and infrastructure in the future. This means hydrodynamic modeling incorporated historical operations in the Delta and contributing watersheds. For example, reservoir operations and transforms from unregulated to regulated flows reflect the assumptions built into the CVHS and CVFPP and in Delta operations are consistent with the assumptions built into the DSM2 model.
- **Sea Level Rise:** A range of sea level conditions including 0, 1, 2, 3, 4, 5, 6, 7 and 10 ft of sea level rise were considered in the analysis.
- **Existing Inflows:** This analysis evaluates existing inflows to the Delta using a metric referred to as Total Delta Inflow (TDI), which is the sum of daily inflow from the primary tributaries (Yolo Bypass, Sacramento, Cosumnes, Mokelumne, Calaveras, and San Joaquin

Rivers). Existing inflow data was leveraged from work completed by Department of Water Resources (DWR) and others for the CVHS and CVFPP.

- **Future Inflows**: This analysis considers future projections of inflows across 10 General Circulation Models (GCM) based on analysis of data products developed by the U.S. Geological Survey (USGS) for the CASCaDE project (https://cascade.wr.usgs.gov/). These results were adapted and incorporated into the Flood Hazard Analysis by developing adjustment factors for future conditions hydrology that were applied to the existing TDI hydrology from the CVHS. Since these future projections by USGS were not developed specifically for the purposes of the Delta Adapts project, the methods and assumptions related to water supply management and operations are different than those assumed in the development of existing conditions hydrology by CVHS.

1.4 Overview of Approach

The flow chart in Figure 1-1 shows the approach to develop future conditions tidal datums estimates and stage-recurrence curves for peak water levels throughout the Delta. Future conditions tidal datums were derived using existing conditions tidal datum estimates from the RMA2 model combined with analysis of new sea level rise modeling results using the DSM2 model (described in Chapter 2). Peak water level stage-recurrence curves were derived using a regression equation and Monte Carlo analysis approach (described in Chapter 3), accounting for projected future changes in tide levels and TDI due to climate change.

Both the tidal datums and peak water level analysis relied on hydraulic modeling conducted using the DSM2 model. Simulations were performed using a 26-year historical time period; however, the tidal boundary condition at Martinez was adjusted to account for sea level rise in both analyses and the inflow boundary conditions were adjusted to capture a range of future inflow conditions representative of future hydrologic conditions in the development of the regression equations used in the peak water level analysis. For both analyses, sea level rise amounts of 0, 12, 24, 36, 48, 60, 72, 84, and 120 inches were evaluated.

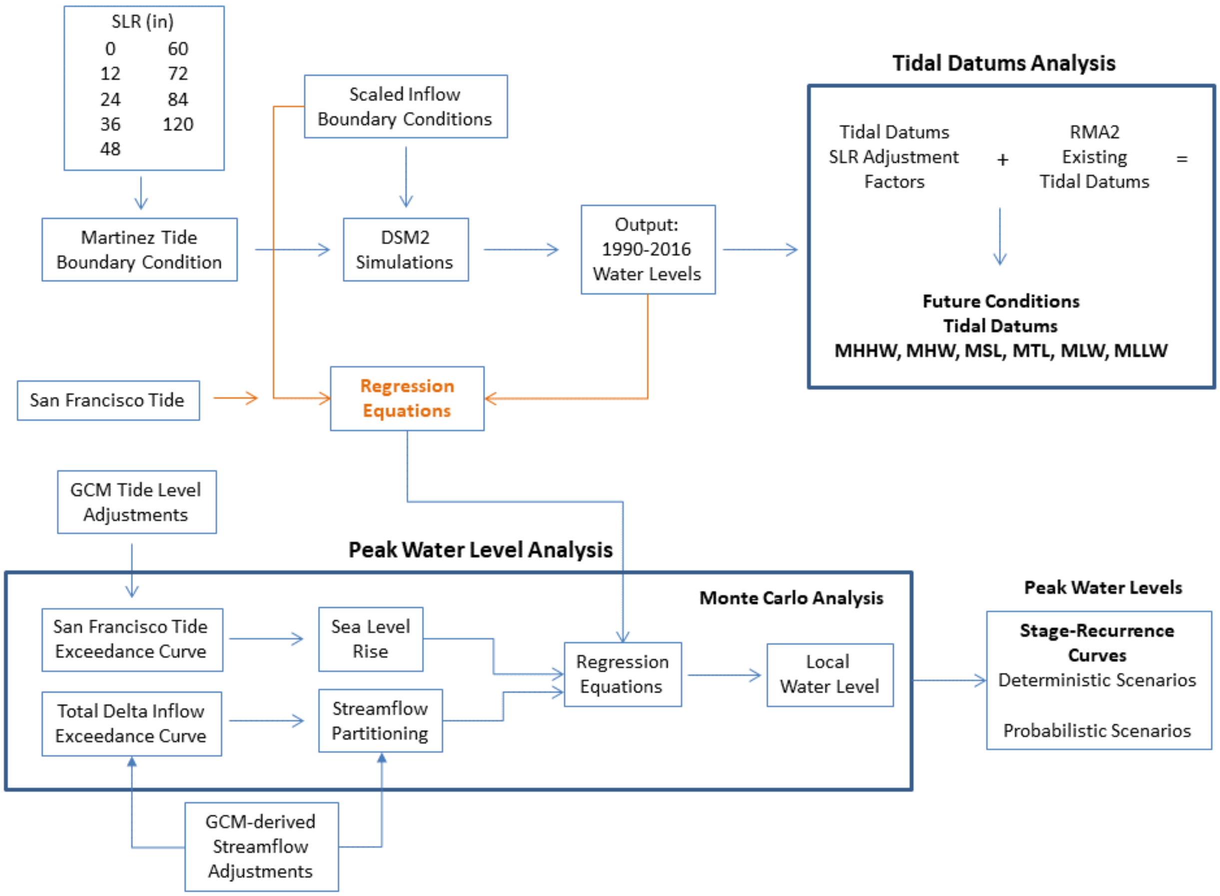


Figure 1-2. Overview of flood hazard analysis approach

The sections that follow present a more detailed discussion of the approach for future conditions tidal datums and peak water level stage-recurrence curves.

CHAPTER 2. TIDAL DATUMS ANALYSIS

Understanding how sea level rise affects tidal datums throughout the Delta is important for evaluating impacts to Delta and Suisun Marsh habitats. As sea level rises, existing intertidal habitat may convert to subtidal open water habitat. Upland transition areas will become more frequently exposed to inundation. Tidal datums – such as mean sea level and mean high water, etc. – are useful metrics to evaluate typical water levels with respect to land elevations.

A number of resources are available to characterize existing tidal datums in Suisun Marsh and the Delta, including water level measurements collected or published by the National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and California Data Exchange Center (CDEC). A key challenge in using water level observations to compute tidal datums in the Delta is that water level records are relatively sparse in space and time and often have poor or inconsistent vertical control to allow for comparisons among different gages.

Re-establishing or reanalyzing historical water level record datasets is beyond the scope of Delta Adapts and would not provide the spatial resolution needed for the assessment. Instead, the project leveraged the existing tidal datums dataset produced by Dudas et al. (2016), which applied the RMA2 model for the historical time period of 2000-2004 to develop baseline estimates of tidal datums representative of existing conditions. The approach applied for Delta Adapts is to use sea level rise simulations conducted with DWR's DSM2 model to estimate tidal datum adjustment factors that could be applied to the RMA2-based tidal datums to estimate future conditions tidal datums with sea level rise.

The sections below describe the methods to estimate future conditions tidal datums throughout Suisun Marsh and the Delta.

2.1 DSM2 Model Runs

The project team applied the DSM2 Version 8.1.2 to simulate local water levels in the project area. DSM2 is a one-dimensional hydraulic model that calculates stages, flows, and velocities at points throughout the Delta and Suisun Marsh. The model and associated documentation and calibration reports, etc. can be accessed from the DWR website (https://water.ca.gov/Library/Modeling-and-Analysis/Bay-Delta-Region-models-and-tools/Delta-Simulation-Model-II). DSM2 was selected for application because it is freely available and open source, fairly straightforward and efficient to apply, has undergone extensive calibration and validation, and is consistent with other State sponsored projects. In addition, DWR staff assisted with technical support and conducted a number of the model runs. The model uses an unsteady tidal boundary condition at Martinez and inflow boundary conditions for the Delta tributaries. The model was applied using a historical time period from 1990-2016, with adjustments to the tidal boundary conditions to account for future sea level rise.

The tidal boundary condition in the DSM2 model was detrended to account for historical sea level rise with a centerpoint around the year 2009, assuming a constant rate of sea level rise of 1.387 millimeters per year. This resulted in an upwards adjustment of the tidal boundary condition prior to December 31, 2008 and a downward adjustment after January 1, 2009. This was done to create a stationary tidal boundary condition consistent with prior modeling simulations such as FEMA's MIKE21 modeling in San Francisco Bay and the UnTRIM sea level rise modeling and mapping conducted by Anchor QEA and AECOM for the Adapting to Rising Tides program in Eastern Contra Costa County. It also provided a constant baseline upon which future sea level rise could be added. Sea level rise scenarios of 0, 12, 24, 36, 48, 60, 72, 84, and 120 inches were simulated using the DSM2 model, which provided water level time series output at over 400 model nodes throughout Suisun Marsh and the Delta (Figure 2-1).

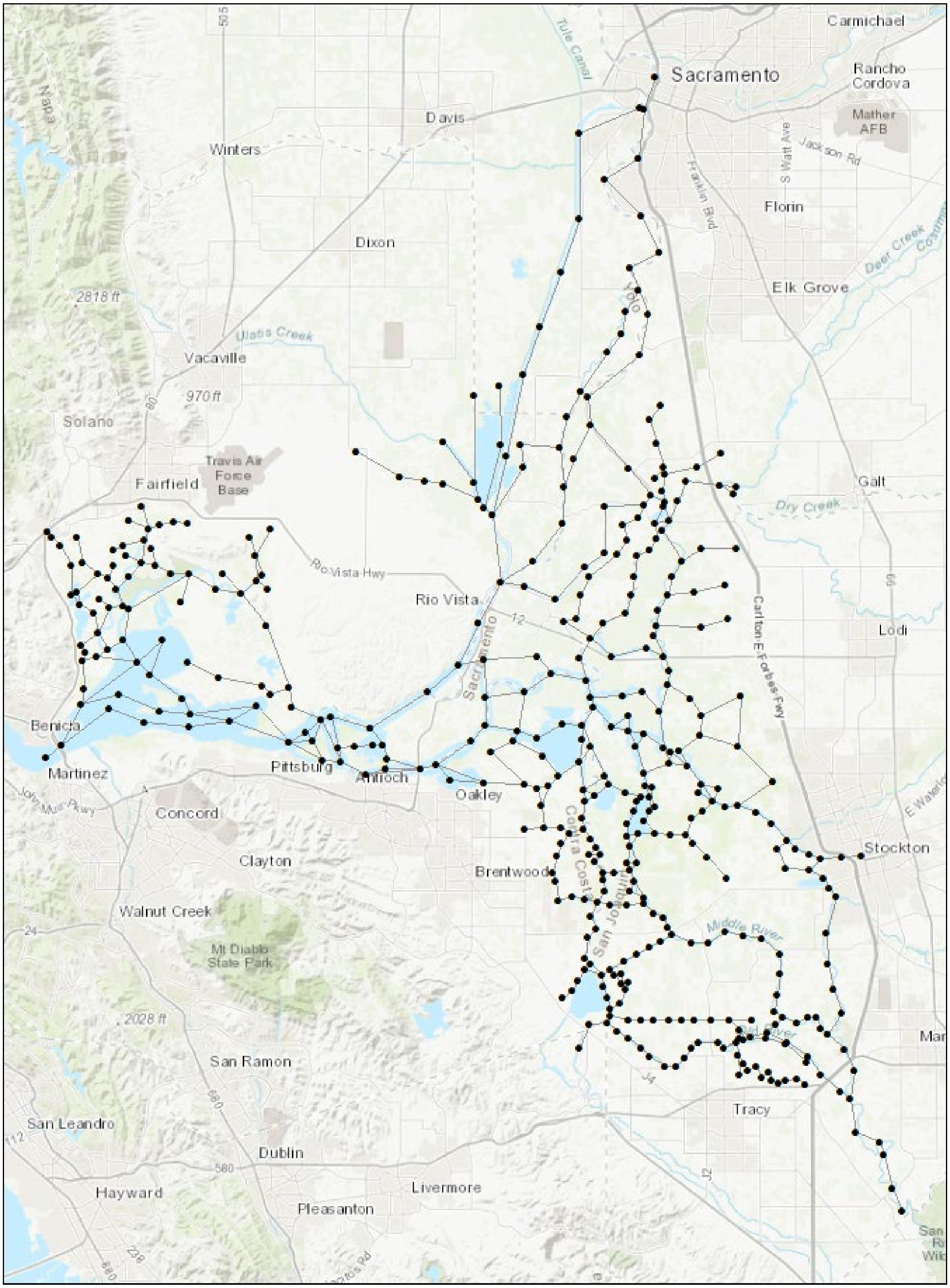


Figure 2-1. DSM2 model output locations

2.2 Methods

The water level time series from the DSM2 model runs were analyzed to estimate tidal datums at each model node. This was done by first calculating tidal datums for the baseline simulation (existing conditions) for the period of January 1, 2000 to December 31, 2005, to correspond to the time period of the RMA2 simulations. The following tidal datums were estimated:

- Mean higher high water (MHHW)
- Mean high water (MHW)
- Mean sea level (MSL)
- Mean tide level (MTL)
- Mean low water (MLW)
- Mean lower low water (MLLW)

Tidal datums were calculated using the method developed as part of the DWR Tidal Analysis Package (Tom 2004). The tidal datums procedure fits a moving polynomial to the water level time series to facilitate the identification of local minima and maxima. The local minima and maxima are then paired sequentially in higher high/lower high and lower low/higher low pairs, from which the tidal datums are calculated according to standard NOAA definitions.

The tidal datum calculations were then repeated for the sea level rise scenarios for the same time period and the differences in each tidal datum relative to the baseline simulation were calculated at each DSM2 model node.

Baseline tidal datums were assigned to each DSM2 model node in GIS by searching for the closest RMA2 model node. An additional manual quality control check was performed to remove and reassign nodes that were on adjacent channels. The tidal datum adjustment factors (from DSM2 simulations) were then added to the baseline tidal datum for each sea level rise scenario. The RMA2 results for the “All Data” case were used as the baseline.

A sample calculation for the 1 foot sea level rise scenario is shown in Table 2-1 for representative model points in Stockton, Sacramento, Suisun, and the central Delta. Future tidal datums were calculated as follows:

Future Datum = Existing Datum (from RMA2 model analysis) + Adjustment (from DSM2 sea level rise simulations)

In the table, the “Existing” tidal datum values were taken from the RMA2-based tidal datums and the adjustment factors were estimated from the DSM2 simulation for 1 foot of sea level rise. The adjustment factors were added to the baseline values to estimate the future tidal datum values.

Table 2-1. Sample Tidal Datum Calculations for the 1 foot Sea Level Rise Scenario

Location	Existing MHHW (from RMA2)	Existing MSL (from RMA2)	Existing MLLW (from RMA2)	MHHW Adj. (from DSM2)	MSL Adj. (from DSM2)	MLLW Adj. (from DSM2)	Future MHHW	Future MSL	Future MLLW
Stockton	5.60	3.61	1.56	1.07	0.99	0.90	6.67	4.60	2.46
Sacramento	9.08	8.78	7.53	0.73	0.58	0.49	9.81	9.36	8.02
Suisun Bay	6.18	3.78	1.15	1.01	0.99	0.97	7.19	4.78	2.12
Franks Tract	5.57	3.91	2.16	1.07	0.99	0.91	6.64	4.90	3.06

Note: Elevations reported in feet relative to NAVD88.

2.3 Results

The results of the tidal datums analysis are archived in an ArcMap geodatabase included as a digital attachment to this technical memo. The geodatabase includes the DSM2 channel and node numbers, the RMA2 point that was paired with each DSM2 node, the baseline RMA2-based tidal datums (existing conditions), the DSM2-derived tidal datum adjustment factors for each sea level rise scenario, and the calculated future tidal datums for each sea level rise scenario.

One finding of the analysis that is observed in some parts of the study area is that the high tide datums (MHHW and MHW) appear to increase at a faster rate than MSL or the low tide datums (MLLW and MLW) in response to sea level rise. As a result, the modeling and analysis suggests that the tide range in the Delta may also increase as a result of sea level rise. This can be seen in Table 2-1 for points where the MHHW adjustment factor is larger than the MLLW adjustment factor. Based on a review of the results for the 1 foot sea level rise scenario, this effect is least pronounced in strongly tidally influenced areas such as Suisun Bay, Rio Vista, and lower Yolo Bypass (i.e., tide range increases less than 2%), moderately pronounced in the central Delta (i.e., tide range increases by approximately 5%), and strongly pronounced in the north Delta (i.e., tide range increases by approximately 10 to 15%), and very strongly pronounced in the south Delta (i.e., tide range increases by greater than 20% in some areas). For higher sea level rise scenarios, this trend increases and the tide range is even further amplified. For example, the average tide range increase in the project area for 1 foot of sea level rise was 6% and increases to 20% at 3 feet of sea level rise. A preliminary review of the UnTRIM model results and tidal datums analysis completed by Anchor QEA and AECOM in support of the Adapting to Rising Tides project supported this finding.

CHAPTER 3. PEAK WATER LEVEL ANALYSIS

The peak water level analysis applied and improved upon the regression equation and Monte Carlo analysis approach developed initially for the DRMS and DLIS studies to estimate stage-recurrence curves in the Delta and Suisun Marsh. This approach provides a method to estimate local peak water levels at any location within the Delta as a function of tide and TDI, where TDI is the sum of the inflows of the primary tributaries to the Delta, including Sacramento, Yolo Bypass, San Joaquin, Calaveras, Cosumnes, and Mokelumne. The approach applied for the Flood Hazard analysis was to use the results of DSM2 sea level rise simulations to derive regression equations to predict local water levels at each DSM2 model node location. Since there are over 400 DSM2 nodes throughout the Delta and Suisun Marsh, this approach improves upon the DRMS and DLIS approaches, which were based on local water level observations at just a handful of sparsely distributed gaging stations. In addition, the density of DSM2 nodes eliminated the need to interpolate/extrapolate the results, which was a limitation of the DRMS and DLIS approach.

3.1 Regression Equation Development

This section describes the application of the DSM2 hydraulic model to simulate water levels throughout the Delta to develop a dataset to derive regression equations for use in the peak water level analysis.

The following sections describe the DSM2 model runs (Section 3.1.1), the development of the regression equations to predict local water levels (Section 3.1.2), and the validation results comparing the predicted water levels from the regression equations to the DSM2 model output (Section 3.1.3).

3.1.1 DSM2 Model Runs

As previously discussed, the project team applied DSM2 Version 8.1.2 to simulate local water levels in the project area. See in Section 2.1 for additional discussion of the model. The same simulations that were conducted for the tidal datums analysis were also used in the peak water level analysis.

3.1.1.1 Sea Level Rise Boundary Condition

The tidal boundary condition in the DSM2 model was detrended to account for historical sea level rise with a centerpoint around the year 2009, assuming a constant rate of sea level rise of 1.387 millimeters per year. This resulted in an upwards adjustment of the tidal boundary condition prior to December 31, 2008 and a downward adjustment after January 1, 2009. This was done to create a stationary tidal boundary condition consistent with prior modeling simulations such as FEMA's MIKE21 modeling in San Francisco Bay and the UnTRIM sea level rise modeling and mapping conducted by Anchor QEA and AECOM for the Adapting to Rising Tides program in Eastern Contra Costa County. It also provided a constant baseline upon which future sea level rise could be added. Sea level rise scenarios of 0, 12, 24, 36, 48, 60, 72, 84, and 120 inches were evaluated using the DSM2 model.

3.1.1.2 Tributary Inflow Boundary Conditions

A goal of the regression equation development was to develop simple equations that would perform well over the full range of potential inflow conditions that might be expected over the coming century. Since the historical DSM2 hindcast period only extended from 1990 to 2016, it represents a relatively short period of record and one that is not representative of the full range of potential historical or future conditions. For example, the peak TDI event in the 26-year DSM2 simulation was approximately 600,000 cfs; however, analysis of future hydrologic conditions conducted as part of this assessment (see Section 3.2.3.2) may approach 1,000,000 cfs.

Therefore, an additional set of DSM2 runs were performed where the primary tributary inflows were scaled by linear factors to create a broader range of inflow conditions from which to derive the regression equations. Two scaling factors were applied to adjust the inflows. The first scaling factor was calculated by comparing the peak inflow on each tributary in the 1990 to 2016 hindcast period to the peak inflow in the 1956 to 2005 Dayflow data (which was readily available from data compiled as part of the DRMS effort). This scaling factor acted to adjust the flows to be more representative of peak flow events in the historical record. The second scaling factor was taken from the 2017 Central Valley Flood Protection Project Climate Change Technical Memo (DWR 2017), which calculated climate change factors for peak flows for various tributaries that feed into the Central Valley. The flow factors for the end-of-century 100-year 3-Day inflows were used and combined with the first scaling factor described above to create a combined scaling factor as shown in Table 3-1.

Table 3-1. Tributary Inflow Scaling Factors Applied to DSM2 Inflow Boundary Conditions

Tributary	DSM2 Peak Inflow (1990-2016) (cfs)	Dayflow Peak Inflow (1956-2005) (cfs)	Ratio of Peak Dayflow to DSM2 Inflow	CVFPP Climate Change Factor (2070-2099)	Combined Scaling Factor
Yolo Bypass	401,211	499,301	1.24	1.24	1.54
Sacramento	112,811	115,000	1.02	1.28	1.30
San Joaquin	53,073	54,300	1.02	1.76	1.80
Cosumnes	46,958	53,600	1.14	1.25	1.43
Mokelumne	5,020	14,200	2.83	1.61	4.55
Calaveras	9,385	30,532	3.25	1.26	4.10

Note: Climate change factor of 1.24 applied for Yolo Bypass was calculated as the average of the reported factors from Sacramento River at Shasta, Feather River at Oroville, and Yuba River at Smartville values from Table 2-1 of DWR 2017.

The DSM2 model was then run for each sea level rise scenario using the baseline and scaled inflows for the 26-year simulation period and water level time series were extracted at each of the 429 model nodes shown in Figure 2-1.

3.1.2 Regression Equations

3.1.2.1 Selection of TDI Events

The purpose of the regression equations is to predict peak water level events during high inflow conditions in the Delta. As such, the inflow time series from the DSM2 model runs were screened to identify large TDI events from which to develop the regression equations. Based on prior work completed for DRMS and sensitivity testing completed as part of the Delta Adapts project, a daily TDI threshold of 200,000 cfs was selected to identify high inflow conditions during the simulation period. The 200,000 cfs threshold corresponded to approximately a 3-year return period TDI based on prior DRMS analysis and represented a balance of filtering out low flow conditions while still retaining a sufficient number of events to develop the regression equations. Using this threshold, daily inflow events from the baseline and scaled model runs with daily TDI greater than 200,000 cfs were identified and used as input to the regression equation development. Using this threshold, 161 daily TDI events were identified in the baseline and scaled inflow model runs. From this population of extreme TDI events, 89 were chosen to develop the regression equations and 76 were retained for use as a validation dataset to test the performance of the regression equations in reproducing the simulated water levels from the DSM2 model (Table 3-2). Due to the small number of simulated events with TDI greater than 600,000 cfs, the four TDI events that exceeded 600,000 cfs were used in both the regression and validation datasets.

Table 3-2. Number of TDI Events Used to Develop Regression Equations and Perform Validation

TDI Range (cfs)	Events for Regression	Events for Validation
200,000 to 300,000	30	30
300,000 to 400,000	30	30
400,000 to 500,000	15	6
500,000 to 600,000	10	6
600,000 to 700,000	1	1

TDI Range (cfs)	Events for Regression	Events for Validation
700,000 to 800,000	2	2
800,000 to 900,000	1	1
Total	89	76

3.1.2.2 Regression Equation Development

A regression analysis was performed at each DSM2 model output node to derive equations to enable estimation of local water levels as a function of tide at the San Francisco tide station, sea level rise, and tributary inflows. Regression coefficients were estimated independently for each sea level rise scenario from 0 to 10 feet, resulting in nine sets of coefficients (one set for each sea level rise amount). The regression analysis was performed in Python. In order to accommodate a constrained multi-variable regression, the Sequential Least Squares Programming (SLSQP) minimization algorithm was selected from the SciPy optimization library.

Preliminary analysis attempted to develop a single set of regression equations for each model node that combined the output from all of the sea level rise simulations to simplify the analysis and application of the regression equations; however, testing and validation of the predicted water levels showed that considerably better results were obtained using nine sets of coefficients in which the coefficients are specifically calibrated for the level of sea level rise. The form of the regression equation is a modified Manning's equation as follows:

$$WSE = aT + b(SLR) + c(Q_{Sac})^{0.67} + d(Q_{Yolo})^{0.67} + e(Q_{SJ})^{0.67} + f(Q_{Cos})^{0.67} + g(Q_{Mok})^{0.67} + h(Q_{Cal})^{0.67}$$

where:

a, b, c, d, e, f, g, and h = regression coefficients

WSE = local water surface elevation at DSM2 node

T = tide at Golden Gate

SLR = sea level rise at Golden Gate

Q_{Sac} = Sacramento River inflow at Freeport

Q_{Yolo} = Yolo Bypass inflow at Woodland

Q_{SJ} = San Joaquin River inflow at Vernalis

Q_{Cos} = Cosumnes River inflow at Michigan Bar

Q_{Mok} = Mokelumne River inflow at Woodbridge

Q_{Cal} = Calaveras River inflow at Jenny Lind

The primary output of the regression analysis is the coefficients a through h as shown above. A table of regression coefficients for each model node and sea level rise scenario is included in Appendix D. When applying the regression equations for sea level rise amounts in between the values simulated in the DSM2 runs, the value of each coefficient was interpolated as a function of sea level rise.

3.1.3 Regression Equation Validation

The regression equations were evaluated by comparing the predicted local water levels at each node with the modeled water surface elevations in the DSM2 simulations. Comparison were made using both the regression equations dataset and the validation dataset.

Table 3-3 shows regression equation error statistics for the validation equation dataset for a select number of sea level rise scenarios. These statistics were computed by comparing the DSM2-modeled water surface elevations to the regression equation-predicted water surface elevations. The values shown correspond to the 95^{th} percentile value of the statistics across all model nodes. For example, 95 percent of the model nodes had mean absolute errors, max errors, and root mean square errors (RMSE) less than the value shown and R-squared values greater than the value shown. In general, the regression equations performed quite well throughout the Delta with the exception of a handful of nodes that extend upstream to the Cosumnes-Mokelumne confluence region. Figure 3-1 shows the spatial variability in root mean square error and Figure 3-2 shows the spatial variability of max error. In general, regression errors relative to modeled results were within about 1 foot for peak events. While predicted peak water surface elevations for individual events could differ from the DSM2 model by up to approximately 3 feet in some locations, on average the regression equations showed no bias to over- or under-predict. The average bias for the regression equations across all model nodes for the baseline scenario ranged from +0.2 ft to -0.2 ft for individual nodes, with an average of -0.04 ft for all nodes (Table 3-3). The table shows the 5^{th} and 95^{th} percentile range for the bias calculations across all nodes.

Table 3-3. Error Statistics for Validation Dataset (95^{th} Percentile Values of All Model Nodes)

SLR Scenario (ft)	Mean Absolute Error (ft)	Max Error (ft)	RMSE (ft)	R-squared	Average Bias (all nodes) (ft)	Range of Bias (ft)
0	0.57	3.58	0.79	0.88	-0.04	-0.1 to 0.0
1	0.55	3.55	0.77	0.88	N/A	N/A
2	0.53	3.47	0.74	0.88	N/A	N/A
3	0.51	3.35	0.70	0.87	-0.04	-0.2 to 0.0
6	0.48	2.63	0.62	0.84	0.04	0.0 to 0.1
10	0.48	2.02	0.62	0.82	N/A	N/A

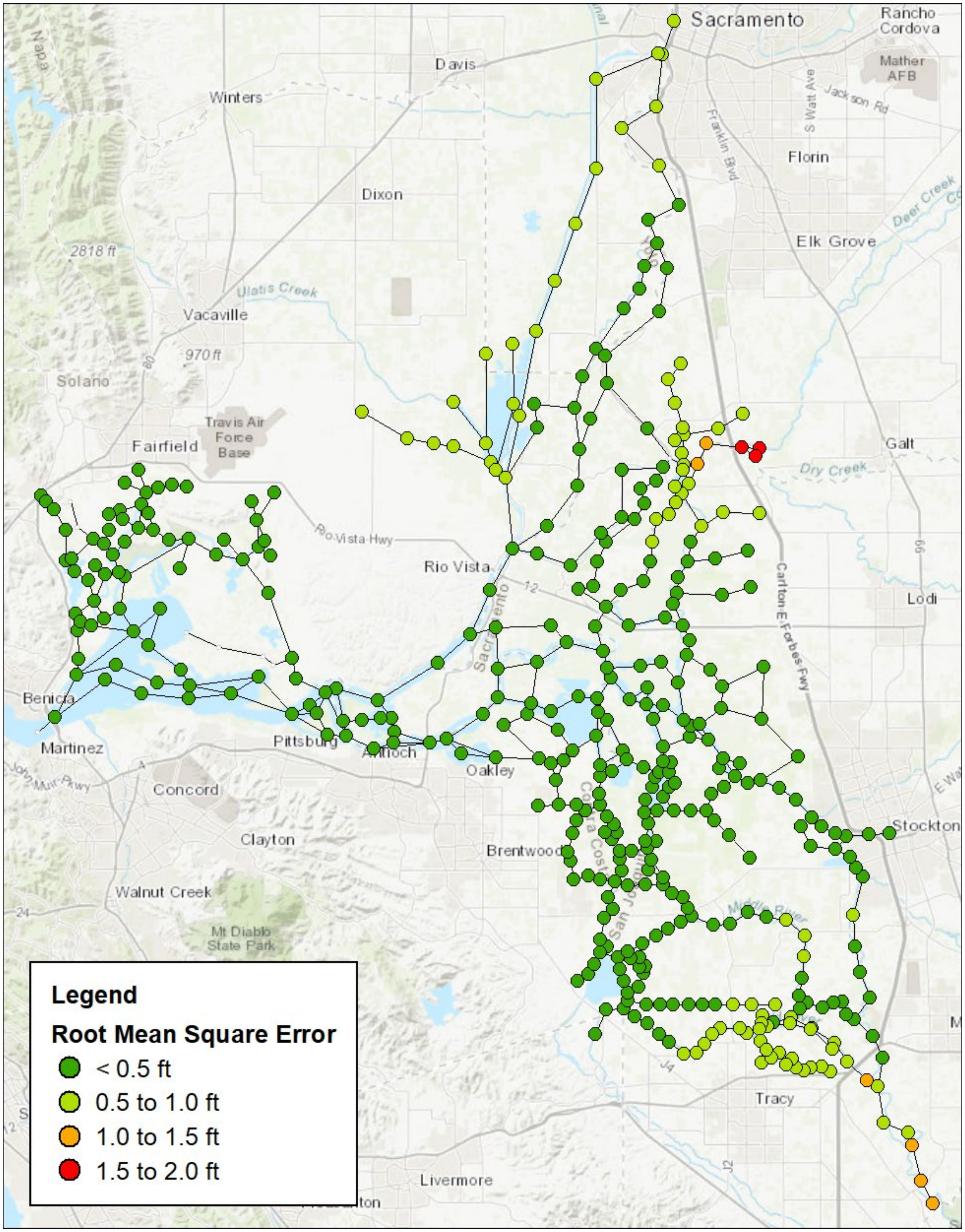


Figure 3--1. Root mean square error at each model output point for validation dataset

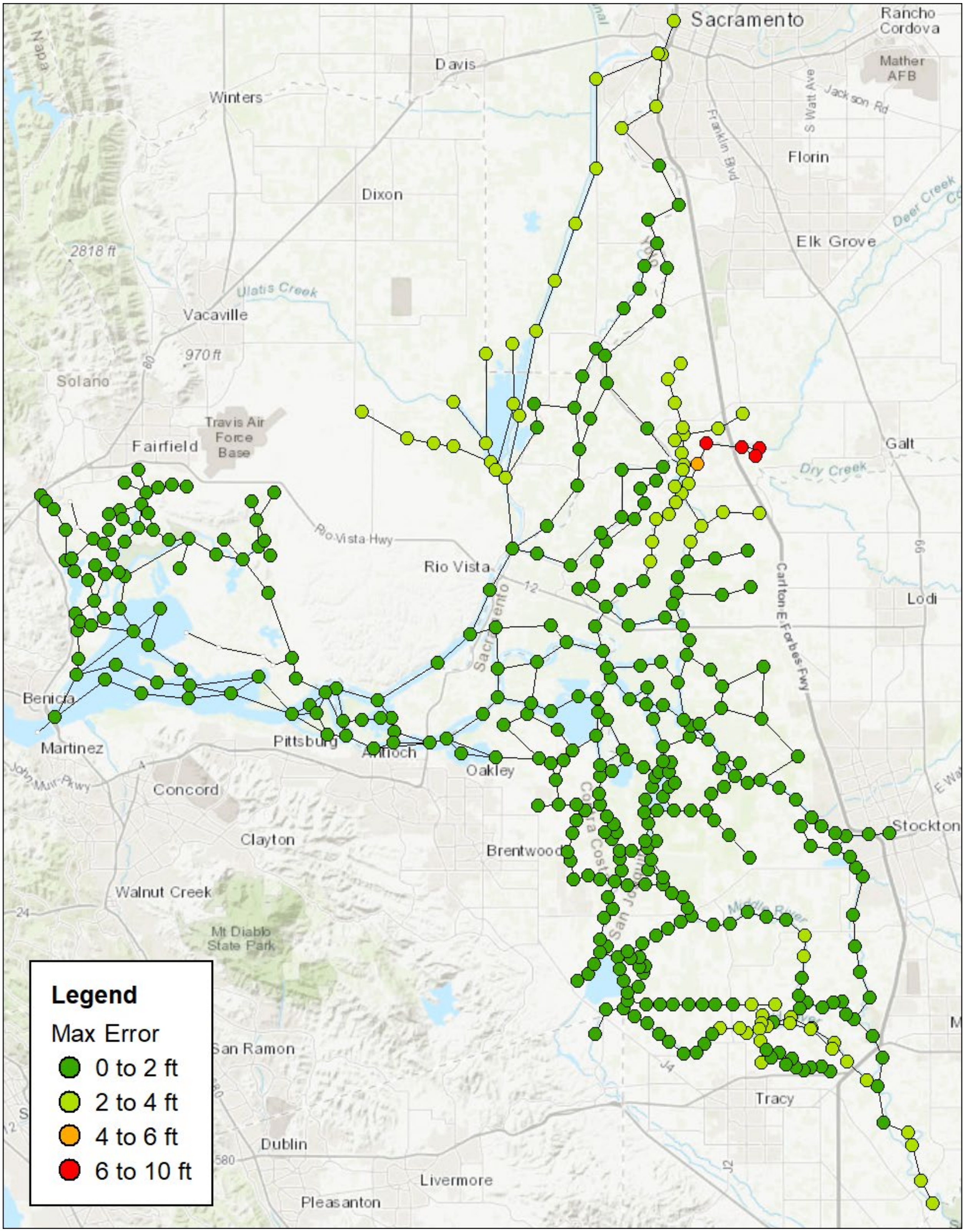


Figure 3--2. Max error at each model output point for validation dataset

3.2 Stage-Recurrence Curve Development

3.2.1 Overview of Approach

As shown in Figure 1-1, the development of the stage-recurrence curves relies on a Monte Carlo analysis framework, where distributions of tide, sea level rise, and TDI are sampled many times to evaluate the many different possible combinations of these variables that may occur to produce elevated water levels within the Delta. The sections that follow step through each of the components of the Monte Carlo analysis and discuss the source data and analysis conducted to develop the existing and future conditions distributions for each input to the Monte Carlo analysis.

3.2.2 Tide Distribution

The DRMS analysis calculated a binned distribution of daily high tides for the winter months of December through April, based on observed data at the San Francisco tide station from 1956 to 2006. The December to April period was selected to correspond to the typical timing of historical peak annual TDI events in the Delta. Since warmer future climate conditions may lead to a concentration of peak TDI events within the core winter months (D. Cayan, pers. comm., February 2020), the project team evaluated the monthly occurrence of peak TDI events in the future relative to historical conditions. These large TDI events are of particular interest when they co-occur with king tides (which typically occur in December, January, and February), so a concentration of peak TDI events in the winter months could increase the likelihood of high TDI events coinciding with higher than normal tides, which could exacerbate flooding in the Delta.

Projected daily maximum TDI values for ten different global climate models (ACCESS1-0, CESM1-BGC, CCSM4, CanESM2, CMCC-CMS, CNRM-CM5, GFDL-CM3, HadGEM2-CC, HadGEM2-ES, MIROC5) under two different Representative Concentration Pathway (RCP) scenarios (4.5 and 8.5) covering years 1980-2099 were obtained from USGS modeling output (Knowles et al. 2018) for this analysis. The projected flows take upstream management and regulation into account, which includes the influence of reservoirs, diversions, groundwater extraction, and other human activities throughout the contributing watersheds.

TDI was composed of streamflows from Cosumnes at Michigan Bar, Mokelumne at Woodbridge, American River at Nimbus, San Joaquin River near Vernalis, Sacramento River near Verona, and Yolo Bypass near Woodland. These streamflow values were combined to create a daily TDI time series for each model. The TDI data were organized into water years (October 1 through September 30) and divided into three 30-year time periods:

- Historical: 1981 to 2010
- 2050: 2035 to 2064
- 2085: 2070 to 2099

The timing of peak TDI events was evaluated for daily maxima (top ten TDI events in each year) and for annual maxima from each model and RCP scenario. The data were tallied to count the number of TDI occurrences in each month for the planning horizons listed above.

Based on this analysis, it was found that future peak TDI events are projected to become increasingly concentrated in the winter months – particularly January and February (when king tides typically occur). This concentration of TDI events in the core winter months increases the likelihood that a large TDI event would co-occur during a higher than normal astronomical tide. The percentage of annual maximum TDI events occurring in each month is shown in Table 3-4 for historical, mid-century, and end-of-century planning horizons. For the RCP 8.5 scenario, in particular, there is a concentration of peak annual TDI occurrence in the months of January and February – increasing from 43% of annual TDI peaks occurring in January or February in the historical period to 56% by mid-century and 65% by end-of-century.

Table 3-4. Percentage of Annual Maximum TDI Events Occurring in Each Month

Month	Historical	2050 RCP 8.5	2085 RCP 8.5
October	0.3%	0.0%	0.3%
November	1.5%	2.7%	2.3%
December	8.2%	8.7%	7.7%
January	17.8%	27.3%	30.0%
February	25.3%	28.3%	34.7%
March	24.2%	22.7%	19.0%
April	12.5%	8.0%	5.0%
May	7.5%	2.0%	0.0%
June	2.2%	0.3%	0.0%
July	0.0%	0.0%	0.3%
August	0.2%	0.0%	0.3%
September	0.3%	0.0%	0.3%

Based on these findings, the historical San Francisco tide data were reanalyzed to develop binned daily high tide distributions by month and the Monte Carlo analysis was revised to include a sampling of the month of occurrence of each peak TDI event to capture this shift in the timing of peak TDI events in the future. Including this effect means that future TDI events are more likely to be assigned a monthly tide distribution corresponding to January or February. Since these months have a higher likelihood of elevated tide conditions (due to astronomical and storm surge events), it is more likely that combinations of elevated Bay water levels and high inflow events would be sampled in the Monte Carlo analysis. The TDI monthly occurrence distributions and monthly tide distributions are shown in Appendix B.

3.2.3 TDI Distributions

3.2.3.1 Existing Inflow Conditions

The DRMS analysis calculated a binned daily TDI distribution from a flow-frequency analysis of 50 years of Dayflow data from 1956 to 2005 (https://data.cnra.ca.gov/dataset/dayflow). The TDI distribution represents the annual likelihood of exceeding a given daily TDI value. After discussions with staff from DSC, DWR, and staff working on the CVFPP update, it was decided not to use the DRMS historical TDI distribution and instead adopt a TDI distribution that was consistent with analysis conducted for the CVHS (USACE 2015) and CVFPP. The project team coordinated with DWR staff to obtain the CVHS TDI distribution in a format that could be incorporated into the Monte Carlo analysis. Because the Mokelumne River was not included in the CVHS TDI distribution, an adjustment factor was applied to pro-rate the CVHS TDI values to include the Mokelumne's contribution to the TDI. The adjustment factor was estimated by reviewing the DRMS 50-year Dayflow dataset and calculating the average contribution of the Mokelumne to Delta TDI. Based on this analysis, it was estimated that on average the Mokelumne contributes approximately 0.7% of the TDI during high inflow events. This factor was used to pro-rate the TDI distribution at each percentile to account for the contribution of the Mokelumne and create an adjusted TDI distribution representative of existing conditions that included all the primary tributaries that are included as inputs to the DSM2 simulations and are variables in the regression equations.

3.2.3.2 Future Inflow Conditions

A goal of the Delta Adapts flooding analysis was to explore a wide range of potential future climate conditions and at the same time retain information about the relative likelihood of uncertain future conditions (as informed by an ensemble of global climate model projections). To achieve this, the project team relied on modeling of managed future Delta inflows developed by the USGS (Knowles et al., 2018). Similar to the analysis conducted to assess the monthly occurrence of TDI events, projected daily maximum TDI values from ten different global climate models (ACCESS1-0, CESM1-BGC, CCSM4, CanESM2, CMCC-CMS, CNRM-CM5, GFDL-CM3, HadGEM2-CC, HadGEM2-ES, MIROC5) for the RCP 8.5 scenario covering years 1980-2099 were obtained from USGS modeling output. The project team used these data to develop adjustment factors that could be applied to the existing conditions CVHS TDI distribution to produce future TDI distributions that reflect the changes to flows projected by Knowles et al. (2018).

Daily TDI from the USGS dataset was composed of streamflows from the Cosumnes River at Michigan Bar, Mokelumne River at Woodbridge, American River at Nimbus, San Joaquin River near Vernalis, Sacramento River near Verona, and Yolo Bypass near Woodland and combined to create a daily TDI time series. The TDI data were organized into water years (October 1 through September 30) and divided into three 30-year time periods:

- Historical: 1981 to 2010
- 2050: 2035 to 2064
- 2085: 2070 to 2099

For the historical time period, data from both the RCP 4.5 and 8.5 simulations were used totaling 600 annual max TDI events (30 years times 10 models times two RCP scenarios). For the future time periods, 300 annual max TDI events were extracted (30 years times 10 models times one RCP scenario (the RCP 8.5 scenario)).

For each planning horizon (historical, 2050, and 2085), the annual max TDI data were input to the U.S. Army Corps of Engineers Hydrologic Engineering Center's (HEC) Statistical Software

Package (HEC-SSP) to perform a flow-frequency analysis using the Bulletin 17C methods. Flow frequency curves were developed for the historical, 2050, and 2085 planning horizons. TDI values at each percentile were compared to calculate a percent change in TDI relative to the historical baseline distribution. These adjustment factors were then applied to the CVHS existing conditions TDI distribution to calculate the future conditions TDI distributions at 2050 and 2085 for use in the Monte Carlo analysis. Table 3-5 shows the historical and future TDI values at select return periods and the adjustment factors applied for 2050 and 2085. The existing and future conditions TDI distribution curves are shown in Figure 3-3.

Table 3-5. Future Conditions TDI Adjustments at Select Return Periods

Return Period (yrs)	Historical TDI from CVHS (cfs)	2050 Adjustment Derived from USGS models and Bulletin 17C Analysis	2050 TDI (cfs)	2085 Adjustment Derived from USGS models and Bulletin 17C Analysis	2085 TDI (cfs)
2	193,400	+48.2%	286,621	+77.5%	343,221
5	309,607	+26.4%	391,222	+64.8%	510,326
10	403,777	+25.4%	506,372	+64.9%	665,844
20	504,466	+29.0%	650,893	+67.6%	845,388
25	529,859	+30.7%	692,604	+68.7%	894,111
50	590,876	+37.0%	809,575	+72.8%	1,020,811
100	631,973	+44.4%	912,704	+77.1%	1,119,115
200	678,857	+52.7%	1,036,411	+81.6%	1,232,514
500	794,682	+64.2%	1,304,589	+87.2%	1,487,638

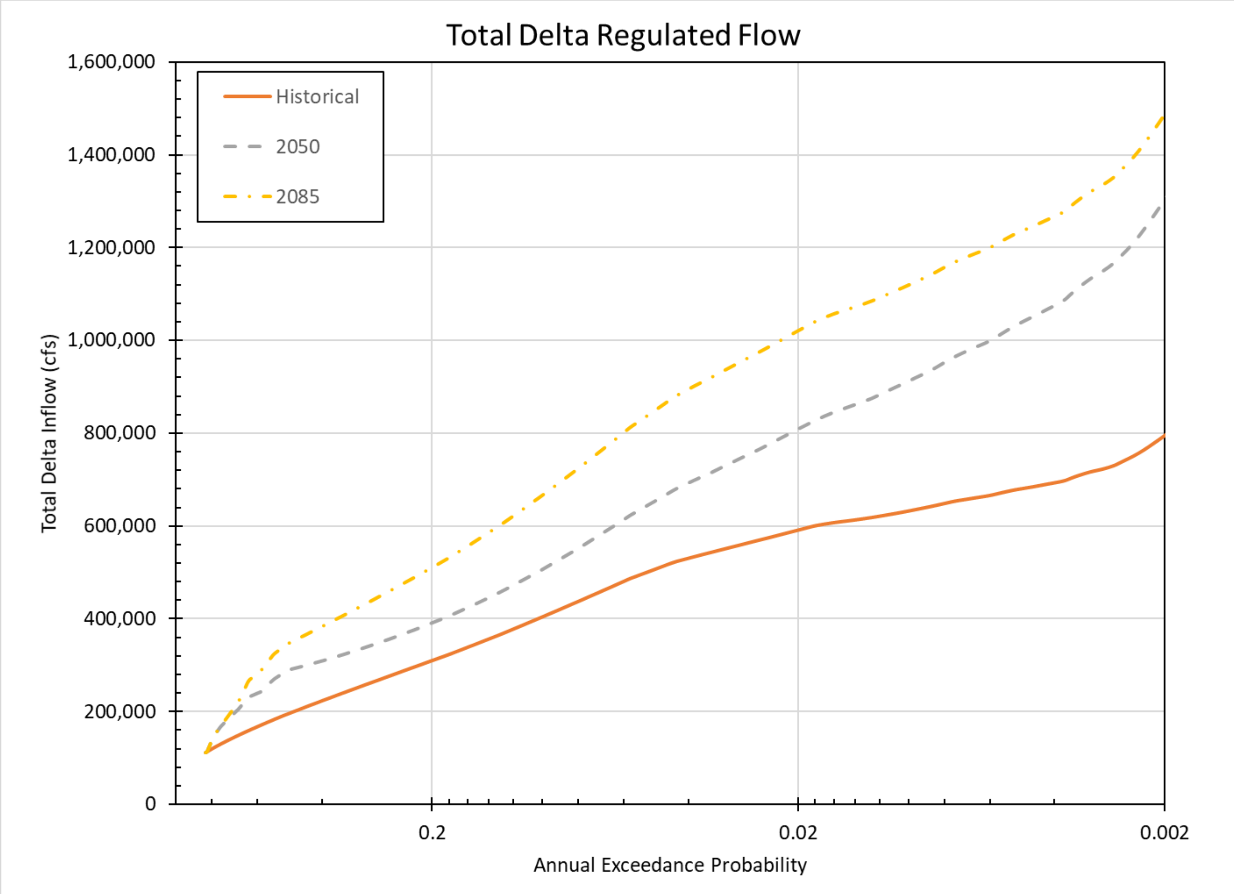


Figure 3-3. TDI distributions for Existing Conditions and Future Conditions at 2050 and 2085

3.2.4 Streamflow Partitioning Adjustments

Once a TDI value is sampled from the existing or future conditions TDI distribution, the inflow is partitioned among the primary Delta tributaries. This partitioning step occurs for each iteration of the Monte Carlo analysis. This is a key step in the Monte Carlo analysis because it allows for evaluation of many different combinations of streamflow distributed across the Delta tributaries and allows for the partitioning to change in the future as a result of climate change. The streamflow partitioning process is described in the DRMS Flood Hazard Technical Memorandum (DRMS 2008) and was originally developed based on analysis of tributary flow distributions in the historical Dayflow dataset from 1956 to 2005. The DRMS analysis developed regression equations that characterized the average distribution of flows across the tributaries and the variability around that average distribution as a function of TDI. The process distributes flow for a given TDI sequentially to the Yolo/Sacramento, San Joaquin, Calaveras, Cosumnes, and Mokelumne Rivers. Because of the standard error term for each tributary's partitioning, the partitioning among the tributaries will be different for each Monte Carlo iteration, even given the same TDI.

The sections that follow describe the adjustments that were made to the DRMS partitioning equations to better match the historical flow-frequency distributions derived by the CVFPP and to account for future climate change.

3.2.4.1 Existing Conditions Adjustments

The project team rederived the partitioning coefficients for application to the Delta Adapts Monte Carlo simulations for a number of reasons. First, the project team wanted to incorporate the additional 15 years of streamflow data that had been collected since the DRMS analysis was completed in the mid-2000s. Instead of deriving the partitioning coefficients from Dayflow data (as was done for DRMS), the partitioning analysis was conducted using a 1950 to 2020 streamflow dataset compiled as part of the DSC's DLIS project. One advantage of using streamflow data instead of Dayflow data is that the Calaveras River was independently considered instead of being grouped into "Miscellaneous" streams as it is in Dayflow. This was an important modification for Delta Adapts since the DSM2 simulations treated the Calaveras River as its own inflow boundary condition and water surface elevation regression equations consider it as its own variable. Second, comparisons of flow-frequency estimates derived using the CVHS TDI distribution coupled and the original DRMS partitioning with available flow-frequency data from CVFPP for the Sacramento, San Joaquin, and Calaveras Rivers indicated that the DRMS-based partitioning did not produce flows that were in agreement with CVFPP values. Notably, estimates of extreme flows on the San Joaquin River were underestimated when using the DRMS partitioning coefficients relative to the CVFPP values (e.g., 67,000 cfs for the 100-year inflow using DRMS partitioning vs. 81,000 for CVFPP). Therefore, the project team rederived the partitioning coefficients using the updated streamflow dataset and applied manual adjustments to the partitioning coefficients so that the estimated flow-frequency distributions matched the CVFPP values (pers. comm., R. Maendly, DWR) across a range of return periods.

3.2.4.2 Future Conditions Adjustments

Based on review of preliminary results of the CVFPP 2022 Update climate change analysis, it was noted that future inflows in the San Joaquin basin are predicted to increase at a faster rate than inflows from the Sacramento basin. Analysis of the distribution of inflow across Delta tributaries in the USGS managed flow projections also confirmed that, in the future, the San Joaquin River contribution to TDI during extreme events will increase relative to historical conditions (Table 3-6). As shown in the table, the average fraction of TDI in the San Joaquin River for high TDI events (greater than 150,000 cfs) is projected to increase from 7.2% historically to 9.4% by mid-century and 12.1% by end-of-century. This is due to a number of factors but is primarily related to the differences in elevation between the two basins and how runoff patterns will change in response to climate change. The San Joaquin watershed extends to much higher elevations that will be more sensitive to a warming climate as rain falls higher in the watershed, contributing to larger runoff and peak inflows to the Delta.

Table 3-6. Average Streamflow Partitioning for Daily TDI Events Greater Than 150,000 cfs

Tributary	Historical Average Partitioning	2050 Average Partitioning	2085 Average Partitioning
Yolo Bypass	45.9%	44.8%	43.0%
Sacramento	43.9%	42.7%	41.6%
San Joaquin	7.2%	9.4%	12.1%
Cosumnes	1.9%	1.9%	2.0%
Mokelumne	1.1%	1.2%	1.3%

Table 3-6 demonstrates the increased average partitioning of flows from the Sacramento River to San Joaquin River for future conditions. To reflect these changing inflow conditions, the slope and intercept coefficients for the Sacramento/Yolo and San Joaquin Rivers partitioning equations were manually adjusted so that the average partitioning in the Sacramento/Yolo matched the average partitioning from the future USGS runoff projections shown in the table above and so that the average flow remaining for the Calaveras, Cosumnes, and Mokelumne after allocating the Sacramento/Yolo and San Joaquin remained the same. The result of these adjustments is that for a given TDI, less flow is allocated to the Sacramento/Yolo and more to the San Joaquin. By constraining the remaining flow after the San Joaquin is partitioned to be the same, there are no changes in partitioning to the subsequent tributaries. This was an assumption made for the Delta Adapts analysis (i.e., that flow partitioning only changed between the Sacramento/Yolo and San Joaquin not the other tributaries). This is a topic that could be evaluated further in future studies; however, based on the changes in the mean partitioning shown in Table 3-6 this appears to be a reasonable assumption.

3.2.4.3 Streamflow Partitioning

The results of the streamflow partitioning analysis are shown in Table 3-7. Coefficient "a" is the slope term and coefficient "b" is the intercept term for each tributary (see DRMS 2008). For each tributary, as slope increases and intercept increases (i.e., becomes less negative), a larger fraction of the flow is partitioned to that tributary for a given TDI. These trends can be seen in the values of the coefficients for the San Joaquin River, indicating that a larger fraction of the flow is partitioned to this tributary in future conditions relative to historical conditions. The standard error term was held constant for historical and future conditions.

Table 3-7. Streamflow Partitioning Coefficients for Historical and Future Conditions

Tributary	a Historical	a 2050	a 2085	b Historical	b 2050	b 2085	Standard Error
Sacramento + Yolo	0.37	0.36	0.355	-2.47	-2.587	-2.777	0.703
San Joaquin	0.34	0.351	0.355	-2.6	-2.496	-2.34	0.629
Calaveras	0.43	0.43	0.43	-4.9	-4.9	-4.9	0.513
Cosumnes	1.1	1.1	1.1	-7.0	-7.0	-7.0	1.1

3.2.4.4 Validation of Partitioning

Table 3-8, Table 3-9, and Table 3-11 show the calculated flow-frequency distributions for each tributary for existing, 2050, and 2085 conditions, as derived using the Delta Adapts TDI distributions and partitioning coefficients. For comparison purposes, the 100-year regulated inflows to the Delta for the CVFPP are shown for the Sacramento, Yolo Bypass, San Joaquin, and Calaveras. These were the flows that were used to tune the partitioning coefficients by matching the derived flow-frequency distributions with CVFPP values. Table 3-10 and Table 3-12 show the percent change in streamflow for each tributary relative to historical conditions at 2050 and 2085, respectively.

Table 3-8. Estimated Tributary Inflows Using Partitioning Coefficients Derived for Existing Conditions and Comparison to CVFPP

Tributary	500-year Inflow (cfs)	200-year Inflow (cfs)	100-year Inflow (cfs)	100-year Inflow CVFPP (cfs)	50-year Inflow (cfs)	20-year Inflow (cfs)	10-year Inflow (cfs)
Sacramento + Yolo	729,210	629,910	586,400	596,330	540,460	456,120	364,480
Yolo	614,730	520,990	479,930	489,300	436,570	356,960	270,460
Sacramento	114,490	108,910	106,470	107,030	103,900	99,170	94,020
San Joaquin	116,400	94,890	80,150	81,630	66,370	49,810	38,380
Calaveras	19,180	15,170	12,280	13,400	9,810	6,990	5,120

Tributary	500-year Inflow (cfs)	200-year Inflow (cfs)	100-year Inflow (cfs)	100-year Inflow CVFPP (cfs)	50-year Inflow (cfs)	20-year Inflow (cfs)	10-year Inflow (cfs)
Cosumnes	38,070	30,640	25,510	-	20,890	15,450	11,760
Mokelumne	8,780	6,660	5,250	-	3,980	2,600	1,760

Table 3-9. Estimated Tributary Inflows Using Partitioning Coefficients Derived for 2050 Conditions

Tributary	500-year Inflow (cfs)	200-year Inflow (cfs)	100-year Inflow (cfs)	50-year Inflow (cfs)	20-year Inflow (cfs)	10-year Inflow (cfs)
Sacramento + Yolo	1,187,160	956,522	838,380	731,740	581,870	449,670
Yolo	1,046,980	829,290	717,770	617,110	475,650	350,890
Sacramento	140,780	127,240	120,610	114,630	106,220	98,802
San Joaquin	185,600	152,460	127,990	105,940	80,050	62,180
Calaveras	23,300	18,230	14,960	12,010	8,480	6,190
Cosumnes	44,420	35,930	30,040	24,580	18,120	13,710
Mokelumne	9,490	7,050	5,530	4,210	2,720	1,820

Table 3-10. Estimated Percent Change in Tributary Inflows Relative to Historical for 2050 Conditions

Tributary	500-year Inflow (cfs)	200-year Inflow (cfs)	100-year Inflow (cfs)	50-year Inflow (cfs)	20-year Inflow (cfs)	10-year Inflow (cfs)
Sacramento + Yolo	+63%	+52%	+43%	+35%	+28%	+23%
Yolo	+70%	+59%	+50%	+41%	+33%	+30%
Sacramento	+23%	+17%	+13%	+10%	+7%	+5%

Tributary	500-year Inflow (cfs)	200-year Inflow (cfs)	100-year Inflow (cfs)	50-year Inflow (cfs)	20-year Inflow (cfs)	10-year Inflow (cfs)
San Joaquin	+59%	+61%	+60%	+60%	+61%	+62%
Calaveras	+21%	+20%	+22%	+22%	+21%	+21%
Cosumnes	+17%	+17%	+18%	+18%	+17%	+17%
Mokelumne	+8%	+6%	+5%	+6%	+5%	+3%

Table 3-11. Estimated Tributary Inflows Using Partitioning Coefficients Derived for 2085 Conditions

Tributary	500-year Inflow (cfs)	200-year Inflow (cfs)	100-year Inflow (cfs)	50-year Inflow (cfs)	20-year Inflow (cfs)	10-year Inflow (cfs)
Sacramento + Yolo	1,326,220	1,115,650	1,013,470	906,660	741,860	580,750
Yolo	1,178,250	979,480	883,040	782,220	626,660	474,600
Sacramento	147,980	136,160	130,430	124,440	115,190	106,160
San Joaquin	276,070	228,260	193,150	161,240	122,770	95,210
Calaveras	28,190	22,090	18,000	14,120	9,880	7,150
Cosumnes	52,010	41,600	34,420	27,900	20,430	15,260
Mokelumne	9,850	7,280	5,690	4,280	2,780	1,850

Table 3-12. Estimated Percent Change in Tributary Inflows Relative to Historical for 2085 Conditions

Tributary	500-year Inflow (cfs)	200-year Inflow (cfs)	100-year Inflow (cfs)	50-year Inflow (cfs)	20-year Inflow (cfs)	10-year Inflow (cfs)
Sacramento + Yolo	+82%	+77%	+73%	+68%	+63%	+59%

Tributary	500-year Inflow (cfs)	200-year Inflow (cfs)	100-year Inflow (cfs)	50-year Inflow (cfs)	20-year Inflow (cfs)	10-year Inflow (cfs)
Yolo	+92%	+88%	+84%	+79%	+76%	+75%
Sacramento	+29%	+25%	+23%	+20%	+16%	+13%
San Joaquin	+137%	+141%	+141%	+143%	+146%	+148%
Calaveras	+47%	+46%	+47%	+44%	+41%	+40%
Cosumnes	+37%	+36%	+35%	+34%	+32%	+30%
Mokelumne	+12%	+9%	+8%	+8%	+7%	+5%

3.2.5 Sea Level Rise Distributions

Sea level rise distributions were extracted using Matlab routines obtained from Professor Bob Kopp through the LocalizeSL Matlab package (https://github.com/bobkopp/LocalizeSL). Projections were developed using the Kopp et al. (2014) framework; however, the Kopp et al. (2017) core data files were used with slight modifications. Sea level rise projections were extracted for the RCP 8.5 scenario at the San Francisco tide station. Projections were extracted for the 2030, 2050, and 2085 planning horizons (2085 values were estimated by linearly interpolating results for 2080 and 2090). Maximum sea level rise projections (i.e., zero percent chance of exceedance) for the distributions were set equal to the H++ projections provided in the California State Sea Level Rise Guidance document (OPC 2018).

Sea level rise distributions for 2030, 2050, and 2085 are provided in Appendix C.

3.2.6 Storm Surge Analysis

A commonly discussed potential impact of climate change is an increase in the frequency and/or intensity of storm events. An increase in the frequency or intensity of coastal storm events and the associated atmospheric and meteorological conditions that accompany those events, could have an influence on future regional coastal water levels that influence local water levels within the Delta. The project team conducted an analysis to assess whether climate change driven amplification of storm surge should be included in the flood hazard analysis. If climate change was found to alter the amplitude or frequency of storm surge events in San Francisco Bay, then this affect would need to be captured in the tide distributions as part of the Monte Carlo analysis.

The project team obtained sea level projections from eight GCMs for two RCP scenarios developed for California's Fourth Climate Assessment (Pierce et al. 2018). The sea level data were obtained directly from Scripps Institution of Oceanography (D. Cayan, pers. comm., January

2020) and were analyzed to evaluate whether there was a detectable difference in storm surge characteristics between historical and future time periods.

The sea level height due to all meteorological and climate influences was analyzed, which included the contributions from sea level pressure, local sea surface temperature, El Nino-Southern Oscillation (ENSO), and local wind. These four components combined (excluding astronomical tide and sea level rise) is commonly referred to as storm surge. The analysis examined both daily and annual maxima storm surge data from the eight models and two RCP scenarios by constructing cumulative distribution functions (CDF) for the historical (1980-2010), 2030 (2015-2045), 2050 (2035-2065), and 2085 (2070-2099) planning horizons.

Based on comparisons between the historical and future storm surge CDFs, it was concluded that there does not appear to be a meaningful difference in the storm surge component of water level at the Golden Gate (Figure 3-4). As a result, no adjustments to the historical San Francisco tide distributions (Sections 3.2.2) were made.

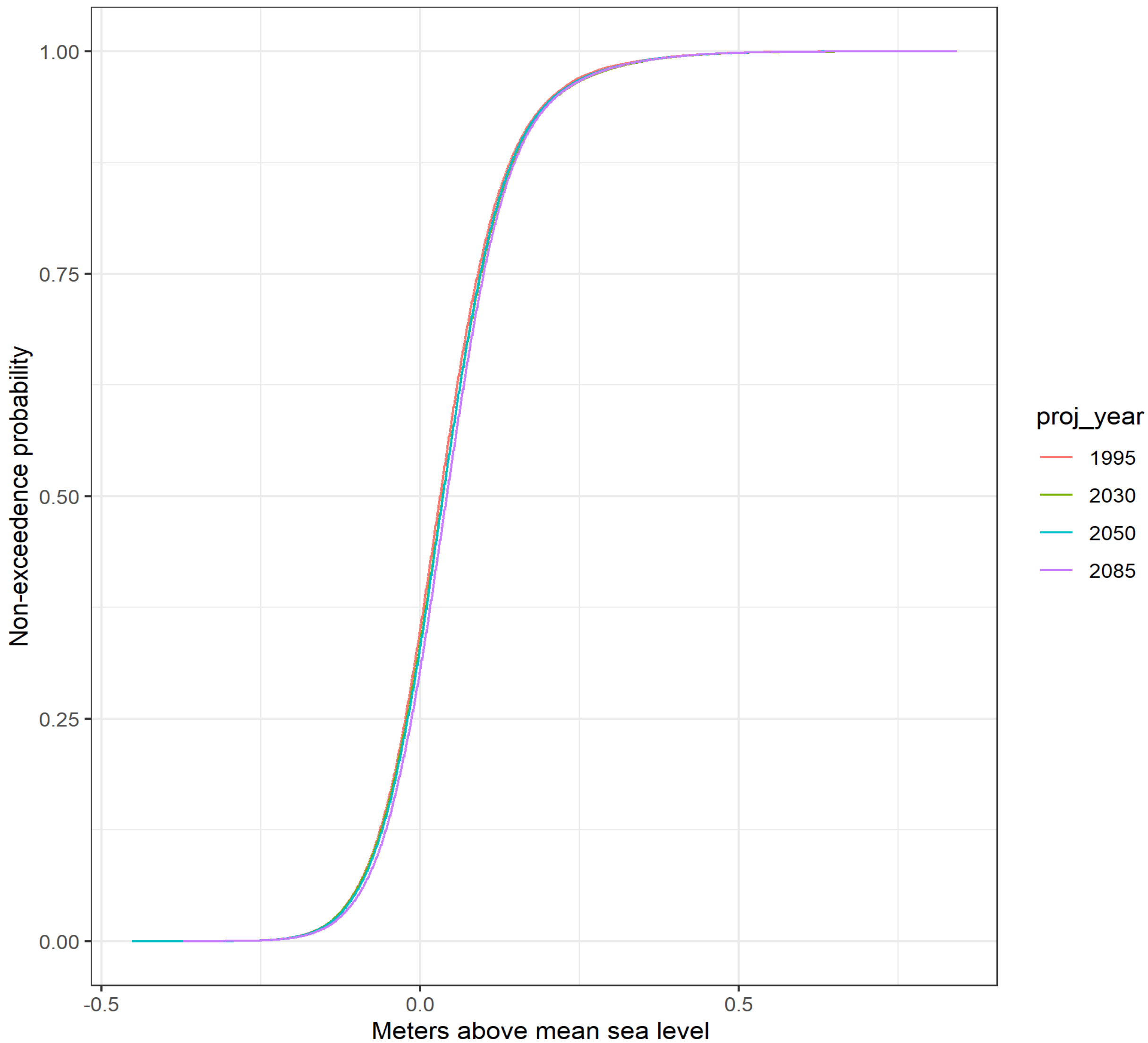


Figure 3-4. CDF of daily water level exceedance for historical, 2030, 2050, and 2085 planning horizons

3.2.7 Monte Carlo Analysis

Once all the input variables were defined, the Monte Carlo analysis was performed to sample the distributions to provide input values to the regression equations to make predictions of local water levels at each DSM2 model output point. The Monte Carlo analysis computed either three hundred thousand or two million iterations depending on the mapping scenario being analyzed (see Section 4.1). CDFs of local water levels were computed from the output at each model node and used to produce stage-recurrence curves that provided input to the flood mapping task.

CHAPTER 4. FLOOD HAZARD MAPPING

4.1 Mapping Scenarios

4.1.1 Overview

This section outlines the scenarios analyzed for the peak water level analysis and mapping tasks of the Delta Adapts project and documents assumptions related to these scenarios. The project team evaluated seven flood hazard scenarios. Four are *deterministic* scenarios that map potential areas of inundation resulting from a 100-year storm event with 6, 12, 24, and 42 inches of sea level rise. Three are *probabilistic* scenarios that identify areas based on their likelihood of flooding at three future planning horizons (2030, 2050, 2085). The peak water level analysis considers the combined climate change effects of sea level rise and changes in watershed hydrology that influence runoff into the Delta, as well as astronomical tides and storm surge.

Scenarios 1-4 are referred to as *deterministic* scenarios and may be more intuitively understandable by the general public as they are more closely tied to specific sea level rise amounts and a commonly used storm event (the 100-year or 1% annual chance water level) that have been pre-selected by the project team to be representative of conditions at specific planning horizons. Water levels for the deterministic scenarios were estimated using Monte Carlo simulations with 300,000 iterations.

Scenarios 5-7 are *probabilistic* scenarios that combine potential conditions across a range of possible climate outcomes, providing planners and managers with information that more readily fits into a risk-based decision-making framework. The probabilistic scenarios show flooding impacts that have a “low”, “medium”, “high”, or “very high” probability of occurring at each planning horizon. Water levels for the probabilistic scenarios were estimated using Monte Carlo simulations with 2,000,000 iterations. The reason so many iterations are required for the probabilistic scenarios is due to the addition of a probability distribution for sea level rise at each planning horizon as opposed to a constant sea level rise value. As a result, many more iterations are required to examine the full range of potential sea level rise and inflow conditions.

4.1.2 Deterministic Scenarios

The deterministic scenarios require a selection of planning horizon, sea level rise amount, watershed hydrology, and storm return period to develop the water surface conditions for mapping. Table 4-1 presents a summary of the four deterministic scenarios evaluated for the Delta Adapts project.

Table 4-1. Summary of Deterministic Scenarios for Flood Hazard Analysis and Mapping

Mapping Scenario	Planning Horizon	Sea Level Rise	Watershed Hydrology	Storm Event
0	Existing	0”	Historical	100-year water level
1	2030	6”	Historical	100-year water level
2	2050	12”	Mid-century (2035-2064) RCP 8.5	100-year water level
3	2050	24”	Mid-century (2035-2064) RCP 8.5	100-year water level
4	2050+	42”	End-of-century (2070-2099) RCP 8.5	100-year water level

The rationale for selection of specific planning horizons, amounts of sea level rise, watershed hydrology, and storm event are given below.

Planning Horizon. Planning horizons of 2030, 2050, and “2050+” were selected for the deterministic mapping scenarios. Beyond 2050, with higher levels of sea level rise, there may be substantial flooding of some Delta islands that would change the hydrodynamics in a way that is not captured by applying a model that represents the existing configuration of Delta islands. As a result, producing flood maps or analysis for those future scenarios without considering potential levee breaches and island flooding would not provide accurate water level results for planning purposes. In addition, critical thresholds for overtopping of existing levees are likely to occur for lower amounts of sea level rise up to about 3 feet and these are the thresholds that are important to identify for the Adaptation Strategy phase of the project. Therefore, the 2030 and 2050 planning horizons were selected for primary focus and a single post-2050 planning horizon (“2050+”) was selected to illustrate the nature of flood hazards that may occur later in the century under a no-action scenario. This approach was selected given the uncertainties in sea level rise and climate change projections, future land use, levee upgrades, and other adaptation actions that may occur in the coming decades.

Sea Level Rise. The selection of sea level rise amounts for specific planning horizons was informed by the Ocean Protection Council’s Sea Level Rise Guidance document (2018). Sea level rise projections for the San Francisco tide station are provided in Table 4-2.

Table 4-2. Sea Level Rise Projections at San Francisco Tide Station from OPC (2018)

RCP 8.5	Median	Likely Range	Upper Range
2030	5 in	4 to 7 in	10 in

RCP 8.5	Median	Likely Range	Upper Range
2050	10 in	7 to 14 in	23 in
2070	17 in	12 to 23 in	42 in
2100	30 in	20 to 41 in	83 in

Sea level rise amounts of 6, 12, 24, and 42 inches were selected for mapping as these amounts align closely with the OPC projections, as follows:

- 6 inches is nearly equal to the median projection for 2030 and was selected to be representative of plausible 2030 conditions
- 12 inches is roughly equal to the median projection for 2050 and was selected to be representative of plausible 2050 conditions (or extreme 2030 conditions)
- 24 inches is nearly equal to the upper range projection for 2050 and was selected to be representative of extreme 2050 conditions (or plausible 2070 conditions)
- 42 inches may occur before 2100 and could occur as early as 2070 and was selected to be representative of post-2050 conditions. In addition, 3.5 feet (42 inches) is recommended for planning by the state's recently adopted *Principles for Aligned State Action* (CNRA 20202) and Ocean Protection Council's Strategic Plan (OPC 2020).

Watershed Hydrology. Both the RCP 4.5 and 8.5 scenarios were considered for use in the flood hazard analysis; however, it was decided to use future hydrologic conditions modeled under the RCP 8.5 scenario since the majority of the flood hazard scenarios correspond to planning horizons of 2050 or earlier and RCP 8.5 is more representative of the current emissions trajectory.

Event Recurrence. A 100-year return period (i.e., 1-percent annual chance) water level was selected as the storm event of interest for the deterministic scenarios. There is considerable precedence in selecting the 100-year event for flood hazard mapping purposes (for example, FEMA's Flood Insurance Rate Maps depict flood hazards associated with the 100-year flood event). The 100-year water level at each future planning horizon (2030, 2050, and 2050+) was estimated from the stage-recurrence curves developed from the Monte Carlo analysis described in Section 3.2. While the 100-year water level was selected for mapping, the full stage-recurrence curves were archived for each point within the study area.

4.1.3 Probabilistic Scenarios

For the probabilistic scenarios, the intent was to evaluate the likelihood that different areas of the Delta and Suisun Marsh may be exposed to flooding at each planning horizon (2030, 2050, and 2085). Water levels were estimated at each DSM2 output point using the Monte Carlo analysis by sampling the TDI, tide, and sea level rise distributions – where the TDI distributions were adjusted to account for future conditions watershed hydrology and tide distributions have been selected to align with changing timing of peak Delta inflows (see Sections 3.2.2 and 3.2.3). Table 4-3 shows the probabilistic scenarios for the three planning horizons with their respective SLR distribution and watershed hydrology adjustments. Table 4-4 lists sea level rise and Total Delta Inflow values for representative percentiles to show the range of values included in the distributions for each parameter sampled for each probabilistic mapping scenario.

Table 4-3. Summary of Probabilistic Scenarios for Flood Hazard Mapping

Mapping Scenario	Planning Horizon	Sea Level Rise Distribution	Watershed Hydrology (TDI Distribution)
5	2030	RCP 8.5 2030	Historical
6	2050	RCP 8.5 2050	Mid-Century (2035-2064) RCP 8.5
7	2085	RCP 8.5 2085	End-of-Century (2070-2099) RCP 8.5

Table 4-4. Representative Sea Level Rise (SLR) and Total Delta Inflow (TDI) Percentile Values for Probabilistic Mapping Scenarios

Mapping Scenario	SLR 1st (ft)	SLR 50th (ft)	SLR 99th (ft)	SLR Max (ft)	TDI 10th	TDI 50th	TDI 99th
5	0.16	0.43	0.72	1.0	193,400	403,777	631,973
6	0.30	0.85	1.74	2.7	286,621	506,372	912,704
7	0.96	1.90	5.0	7.5	343,221	665,844	1,119,115

The distinguishing feature of these mapping scenarios (compared to the deterministic mapping scenarios) is that different areas are color-coded (or symbolized) based on their probability of flooding at each planning horizon, as opposed to showing flood extents for a pre-selected combination of SLR, climate change, and storm event. These areas were designated using qualitative descriptors – “very high”, “high”, “medium”, or “low” – that correspond to specified probability thresholds. Water levels corresponding to the thresholds were established from the Monte Carlo results of the peak water level analysis at each DSM2 output point to come up with probabilistic water level exceedance curves for each planning horizon. Water level thresholds were then compared to adjacent levee crest elevations to identify areas with high, medium, low, or very low likelihood of flooding in the mapping task (see Section 4.2). Table 4-4 shows the framework for establishing the low/medium/high/very high probability of flooding designations.

Table 4-5. Qualitative and Quantitative Probability of Flooding Thresholds for Probabilistic Scenarios

	Quantitative Probability of Flooding based on Stage-Recurrence Curves from Monte Carlo Analysis		
Qualitative Probability of Flooding	Stage-Recurrence Curve Threshold	Equivalent Annual Probability of Exceedance	Equivalent Return Period
Low (Levee crest elevation is between the Medium and Low water level thresholds)	0.99 to 0.995	0.5% to 1%	100-year to 200-year
Medium (Levee crest elevation is between the High and Medium water level thresholds)	0.98 to 0.99	1% to 2%	50-year to 100-year
High (Levee crest elevation is between the Very High and High water level threshold)	0.90 to 0.98	2% to 10%	2-year to 10-year
Very High (Levee crest elevation is below the Very High water level threshold)	0.90	10%	10-year

4.2 Mapping Methods

Flood mapping was conducted using two procedures, both of which compare elevations of levees to the water surface elevations (WSE) from the nearest model output point to determine if a levee could experience overtopping. The first procedure is used to map the deterministic hydrology scenarios, where a single 100-year water surface elevation was selected (described in in Section 4.1.2). The second procedure, used for probabilistic scenarios, includes a series of probability thresholds for water surface elevations (described in Section 4.1.3). Under both procedures, the extent of flooding is mapped based on the water surface elevation for a model output point near the region.

4.2.1 Levee Centerline Data

To create an updated levee centerline dataset for the Legal Delta and Suisun Marsh, Council staff evaluated existing levee and shoreline shapefiles to identify source data layers that most closely tracked levees in the USGS/DWR 2017 LiDAR DEM (released 2019). After the best base shapefile was selected, heads-up digitizing was used to adjust the shapefiles to more accurately track the most up-to-date levee centerlines on the 2017 DEM. Waterway and island information tags were added to the levee centerlines using polygons that had been previously defined for other Council projects and DWR datasets.

Staff included external levees, prominent internal ad-hoc flood protection (e.g., a train track through Suisun Marsh), and developed areas of shoreline without levees (e.g., Antioch, Stockton, and Discovery Bay) near DSM2 nodes and channels. Levees that are antiquated and no longer maintained are included; breached levees are only included in Suisun Marsh for levees that still may yet be repaired. Surface information (elevation statistics) was derived from the 2017 USGS/DWR 2017 LiDAR DEM.

The dataset was reviewed in multiple stages by engineers who maintain most of the levees in the Delta system. In the first stage of the review, the accuracy of the levee lines and elevations were tested against survey data used by levee engineers. In the second stage of review, the validity of low points identified by a flood analysis across the system were confirmed by engineers with on-the-ground experience managing Delta levees. These reviews resulted in improvements in the dataset by identifying areas to revise the heads-up digitization or remove misidentified features.

Reviews for major urban areas (Stockton and West Sacramento) were conducted by engineers responsible for designing, maintaining, and/or evaluating flood control systems in those areas. These reviews resulted in using the as-built engineering blueprint from the Southport Levee Improvement Project which improved 5.8 miles of levee on the west bank of the Sacramento River along the City of West Sacramento. The project was not in the DEM on which the levee digitization was based because the LiDAR flight occurred before the project was completed. In Stockton, the dataset was adjusted to more accurately represent the high ground near the Port of Stockton.

Figure 4-1 shows the location of the levee data that were included in this flood analysis as well as the model output points along the channels that were used to estimate local water surfaces.

See Appendix E For further details on the development of the Levee data.

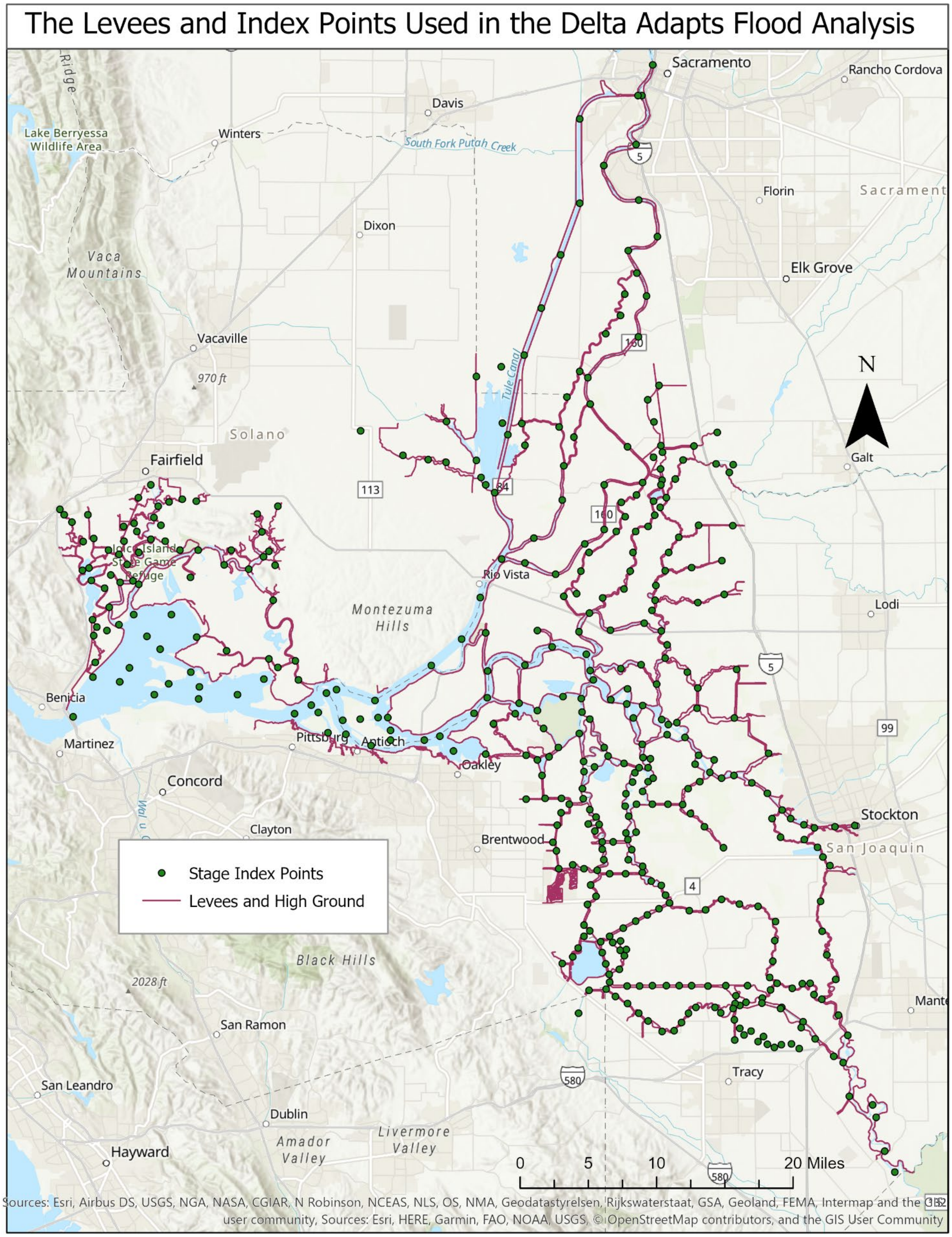


Figure 4-1. Levees and Model Output Points

4.2.2 DSM2 Node Location Updates

Six DSM2 nodes that had been relocated in the 2009 calibration were not reflected in DSM2 model output point geographic datasets. Bay-Delta DWR staff did not have the exact coordinates of the relocated nodes and corresponding grid channels but are remediating their datasets for a new release in 2020-2021.

The moved nodes are 333 to 338, and the corresponding grid changes are channel numbers 412 to 418. The image below (Figure 4-2) is copied from the 2009 calibration documentation, but the image of the grid is for the 2002 grid and does not reflect the new locations of the adjusted nodes.

The locations of the index point nodes were adjusted in the dataset to reflect the available description in DSM2 documentation (Figure 4-2). Those changes are depicted in Figure 4-3.

TABLE 2-1
Comparison of Existing and Modified Channel Lengths

DSM2 Channel #	DSM2 Node at d/s of the Channel	DSM2 Existing Channel Lengths (ft)	DSM2 Modified Channel Lengths (ft)
411	332	18,620	18,620
412	333	14,386	17,340
413	334	14,323	11,828
414	335	17,612	24,177
415	336	12,285	6,300
416	337	17,389	25,418
417	338	12,716	6,133
418	339	16,047	13,562

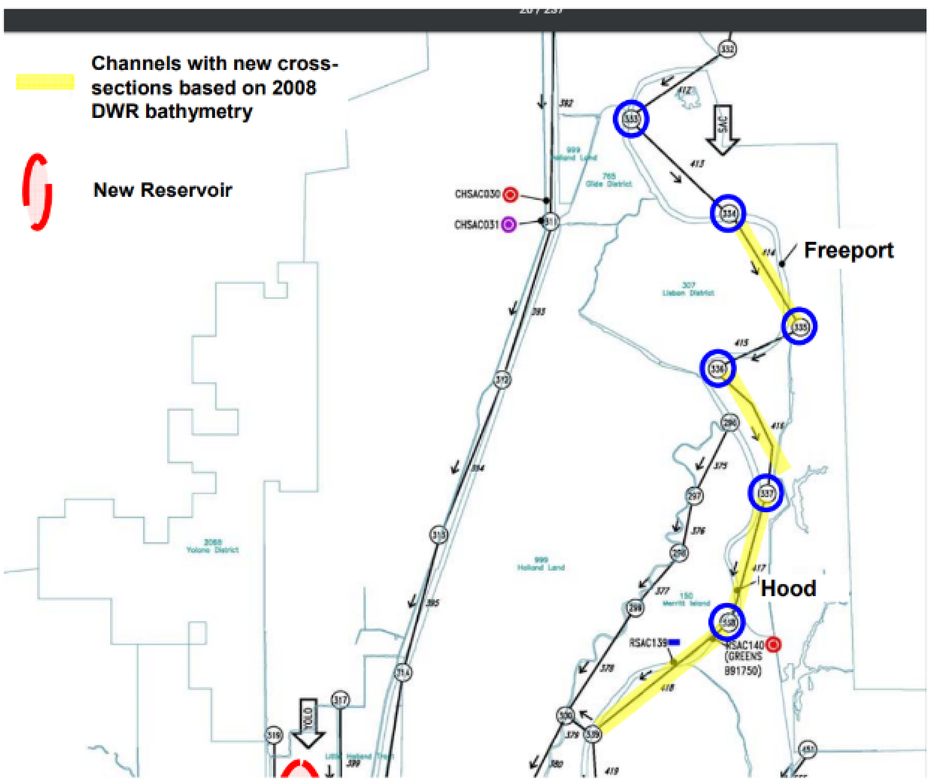


Figure 4-2. 2009 DSM2 calibration documentation

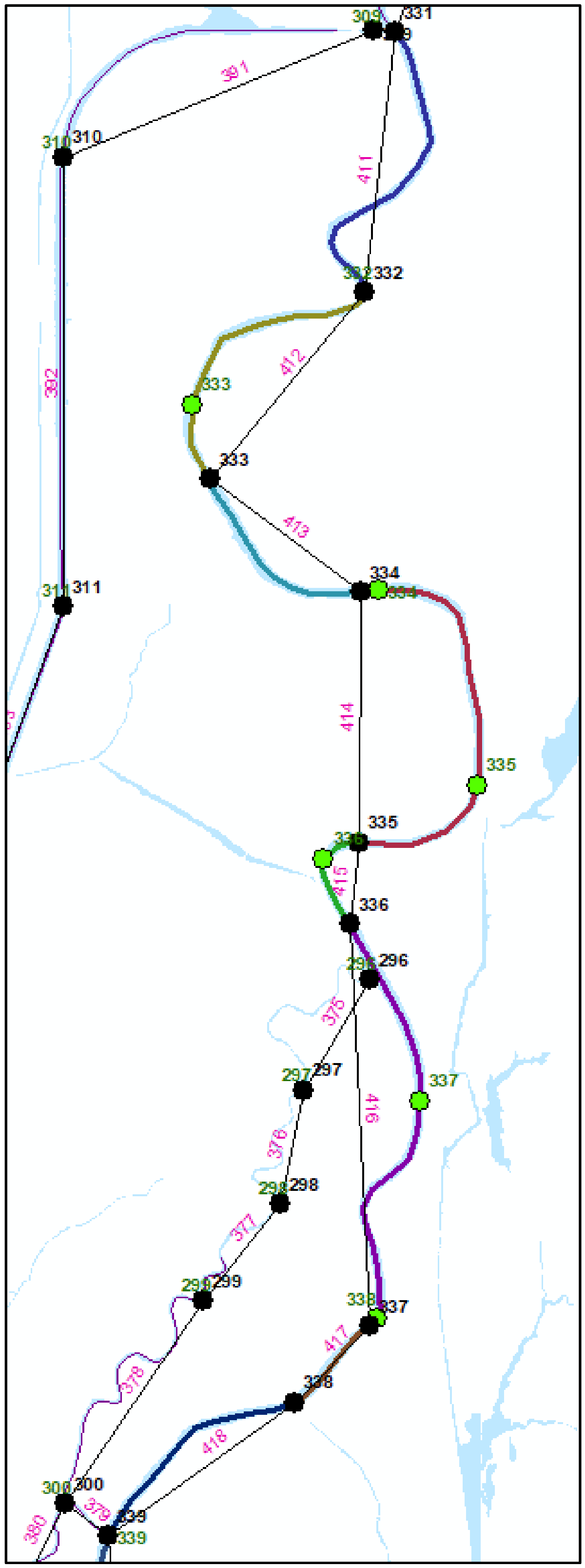


Figure 4-3. Relocated nodes and grid (black), old node locations (green), and updated channels form DWR (various colors) that were used to adjust the relocated nodes

4.2.3 Levee Overtopping

In order to identify levee overtopping conditions, a simple geometric nearest neighbor analysis was conducted to find the nearest model output point to each levee segment in the levee dataset. After each nearest neighbor was identified, manual improvements were conducted that included removing levee segments without a point near them and adjusting point identification where complicated stream geometry misidentified the nearest point in an adjacent channel. Water levels were then compared to the mean elevation of each levee segment using one of two procedures for the deterministic and probabilistic scenarios, respectively.

4.2.3.1 Deterministic Scenarios

Overtopping in the deterministic scenarios was evaluated by comparing the mean elevation of a levee segment to the nearest appropriate water surface elevation for the 100-year WSE for each scenario (described in Section 4.1.2). Three outcomes were possible for each levee segment: (1) no overtopping, (2) overtopping by less than 6 inches, which was assumed to be mitigatable with flood fighting, or (3) overtopping greater than 6 inches. Six inches was selected as a threshold for overtopping in consultation with engineers experienced in flood fighting in the Delta. However, actual flood fighting capacities may be affected by local conditions (e.g., access, availability of flood fighting materials such as sandbags and equipment, and weather), the duration of high waters, wind wave action, the extent of the levee that is at risk, and other situationally specific factors. For the deterministic scenarios, the following rules were applied:

Elevation Comparison	Result
WSE < Levee elevation	The Levee does not overtop
Levee elevation < WSE < Levee elevation + 6 inches	Overtopping assumed to be mitigatable with flood fighting
Levee elevation + 6 inches < WSE	The levee overtops

4.2.3.2 Probabilistic scenarios

Overtopping in the probabilistic scenarios was evaluated by comparing the mean elevation of a levee segment to the nearest appropriate water surface elevation for a series of WSEs for each planning horizon (described in Section 4.1.3). For each levee segment the analysis was run for four annual exceedance water elevations.

Annual Exceedance	Elevation Comparison	Result
10%	WSE < Levee elevation	Levee does not overtop
10%	WSE > Levee elevation	Levee overtops
2%	WSE < Levee elevation	Levee does not overtop
2%	WSE > Levee elevation	Levee overtops
1%	WSE < Levee elevation	Levee does not overtop
1%	WSE > Levee elevation	Levee overtops
0.5%	WSE < Levee elevation	Levee does not overtop
0.5%	WSE > Levee elevation	Levee overtops

4.2.4 Flood Regions

To connect levee overtopping to inundated areas a dataset of "regions" was created. Regions for this purpose are areas in the Delta protected by contiguous levee feature or whose overtopping risk is, to a reasonable extent, independent from the overtopping risk experienced by another region. The regions are used to identify which areas experience inundation risk in the case that a levee overtops. The regions were based on the regions developed for DLIS, and expanded to cover the entire legal Delta (Figure 4-4). Most regions in the Delta are surrounded by ring levees. In the outer Delta where there are no ring levees, the regions were selected to represent, to the extent reasonable, contiguous hydrologically connected areas. Areas already hydrologically connected to the tidal or river systems were excluded (e.g., tidal/muted marsh, un-leveed floodplain in the Cosumnes River Preserve area, Clifton Court Forebay, etc.).

Based on the regional dataset, a new dataset was created that shows potential inundation levels based on water surface elevations within a region for each new foot of water. That dataset was produced by polygonising the DEM raster dataset based on a chosen elevation. That polygon was then used to clip regions. Appendix F contains the details of this procedure. This process was used to produce potential inundation extents from 1 ft to 300 ft elevation for every region. Figure 4-5 illustrates a few of the clipped regions for the 5 ft, 15 ft, and 25 ft inundation extents. This was done so that the process can look at inundation areas within a region based on water surface elevations. This is especially important for areas in the Delta that are not subsided below normal water elevations. For example, if WSEs are 5 ft for the polygon containing Antioch the area inundates a smaller area than if WSEs are 15 ft. This dataset allows us to identify inundated areas based on the elevation within a given region. Section 4.2.5 describes how this dataset is used.

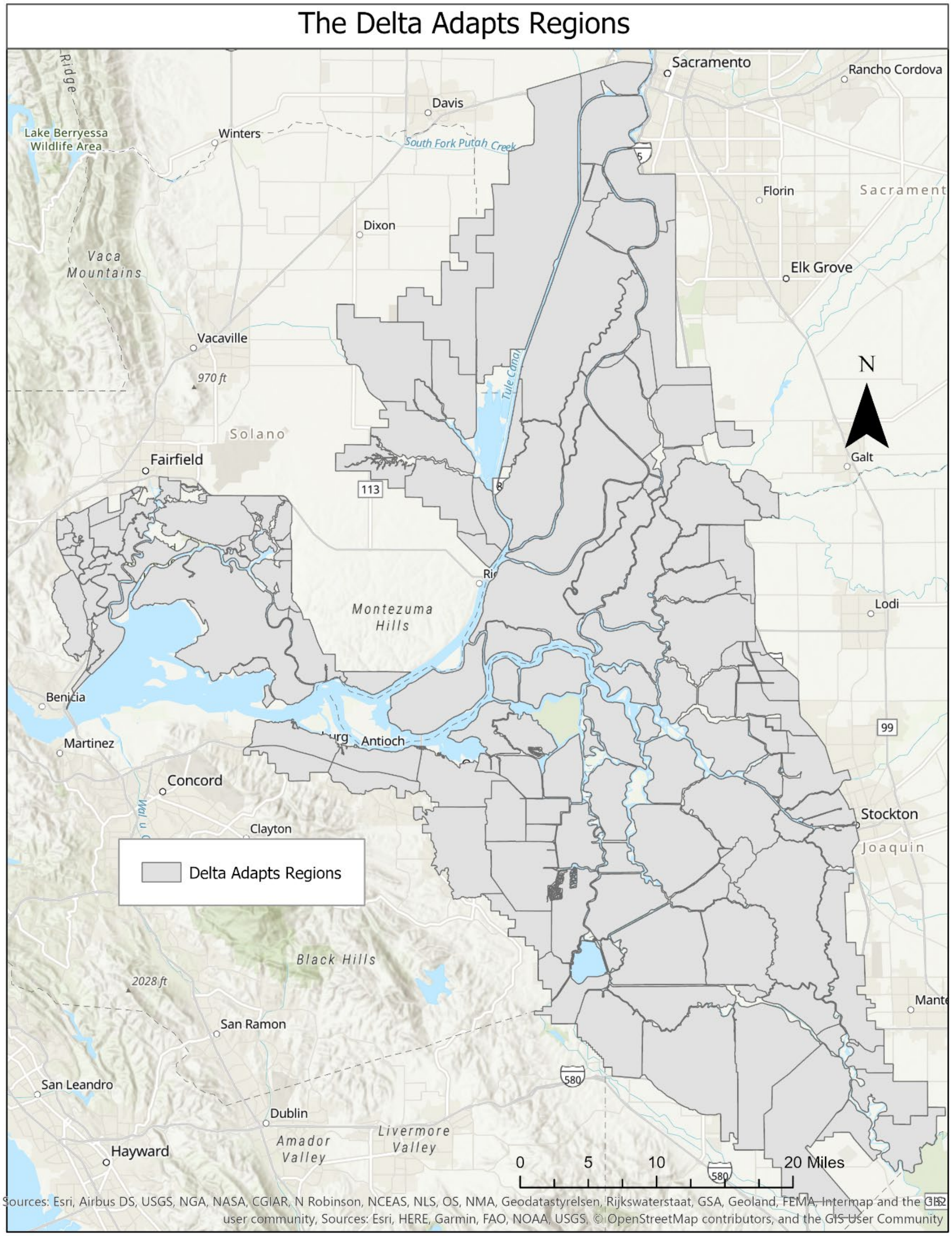


Figure 4-4. Flood regions used in Delta Adapts Flood Analysis

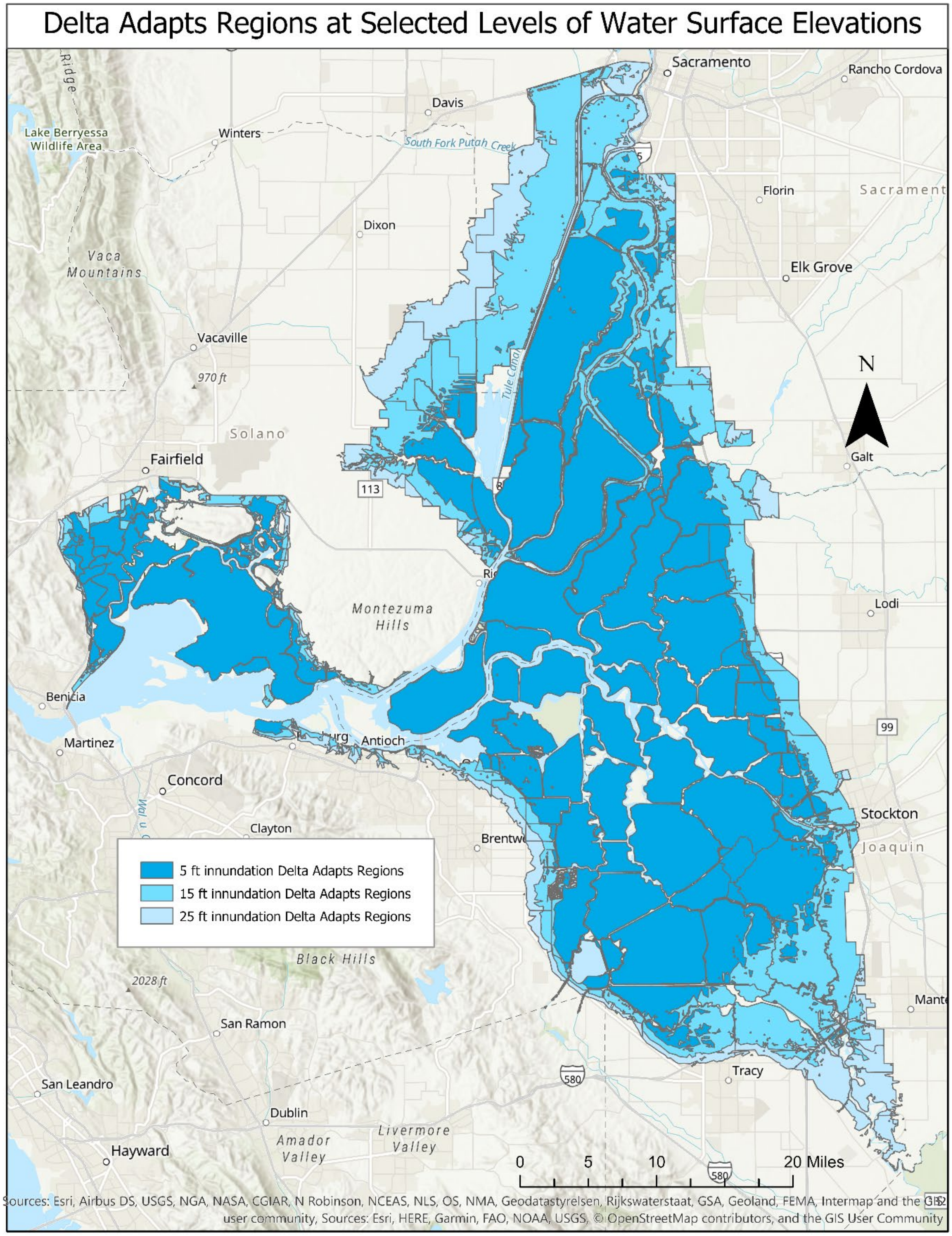


Figure 4-5. Delta Adapts regions at selected levels of water surface elevations

4.2.5 Generating Flood Maps

Each levee segment is tagged with the region it protects. The analysis uses an R script that looks at the levees for each region and summarizes instances where the analysis results in a levee overtopping or overtopping in a manner that might be mitigatable through flood fighting. The process then identifies the maximum WSE (rounded to the nearest foot) at an overtopping levee segment. Lastly, the process selects the polygon for that region that represents that elevation of inundation.

For example, imagine a result in which Sherman Island had 3 levee segments that overtopped. One overtopped with local WSE at 13.1 ft, and two sections overtopped with local WSEs at 12.7 ft. The process would use the maximum WSE at a section where a levee overtopped. In this case, 13.1 ft. The process would round the maximum WSE to the nearest whole number, in this case 13 ft. Then, it would select the polygon for Sherman Island from the regional dataset for 13 ft of inundation. The procedure would do this for all remaining overtopping regions and stitch those together.

Once those polygons were stitched together, they were mapped using ESRI's ArcPro software. The maps developed for each deterministic and probabilistic scenario are presented in Section 4.3.

4.2.6 Delta Inflow Assumptions and Flood Mapping

The Delta Adapts flood mapping analysis takes Delta inflows on each of the six major Delta tributaries (Sacramento River, Yolo Bypass, Calaveras River, Mokelumne River, Cosumnes River, and San Joaquin River) as boundary conditions for the assessment of water surface elevations throughout the Delta (as described above). The Monte Carlo sampling, streamflow partitioning, and climate change scaling factors individually and in combination allow for the simulation of very high inflow conditions at each of boundary. This is a feature of the model, providing important information about the potential likelihood and effects of extreme inflow events on the Delta. These possibilities are based on several assumptions:

1. Flows entering the Delta assume that no actions are taken upstream that would change the operation of the flood management system. These actions could increase flows in the system by, for example, increasing the height or stability of upstream levees making upstream failures less likely, or decrease flows by improving reservoir management.
2. Delta Adapts assumes that all flow entering the Delta at latitude arrives at the Delta in the channel. In practice, this means that water that has been modeled to overtop the levee system upstream, but flows down through the system and arrives at the Delta through overland flow is added to the in channel flow at the Delta boundary.

Some stakeholders have expressed concern about these assumptions, stating that assuming no actions are taken upstream overstates the risk to the Delta and that in any case, existing channel capacity cannot carry the amount of flow simulated in the Delta Adapts modeling.

In order to address these concerns additional sensitivity analyses were conducted to evaluate the degree to which allowing such large inflows to enter the system results in flooding of Delta islands or whether other factors such as sea level rise are driving flooding under future climate conditions.

Sensitivity analysis of the system was conducted by defining a maximum channel capacity for each major Delta tributary and re-modeling the system with a cap on flows applied. For the purposes of this sensitivity analysis, the maximum channel capacity was set at the 200-year flow level under historical conditions except as specifically noted below. Table 4-5 shows the flow caps applied to each tributary. After running the modeling scenarios with each of the caps applied, we compared the flooded area under the uncapped scenarios with the respective flooded areas for the capped inflow scenarios. In cases where the flow capping resulted in a reduction of the water surface elevation in a channel of 12" or more, and that reduction in water surface elevation resulted in changing the modeled determination of flooded versus non-flooded, the island was notated with hatching in the maps noting that the flooding shown is "highly sensitive to inflow assumptions".

It is worth noting that the only areas where flooding is highly sensitive to inflow assumptions is on the lower San Joaquin River south of Stockton (Figure 4-6). No other area of the Delta showed a high sensitivity to capping of in-channel inflows. This indicates that in most of the Delta, where flooding occurs, it is driven primarily by sea level rise.

In locations noted as highly sensitive to inflow assumptions, we recommend that the outputs from Delta Adapts be used in conjunction with the results of other 2 and 3-dimensional flooding models that can dynamically simulate floodplain processes and consider a range of potential upstream flood management scenarios.

Table 4-6. Maximum channel capacities applied for inflow sensitivity analysis

Tributary	Capacity (cfs)
Sacramento River Yolo Basin	109,000 No cap
Cosumnes River	30,500
Mokelumne River	6,600
Calaveras River	15,000
San Joaquin River	110,000 (source CVFPP 2017)

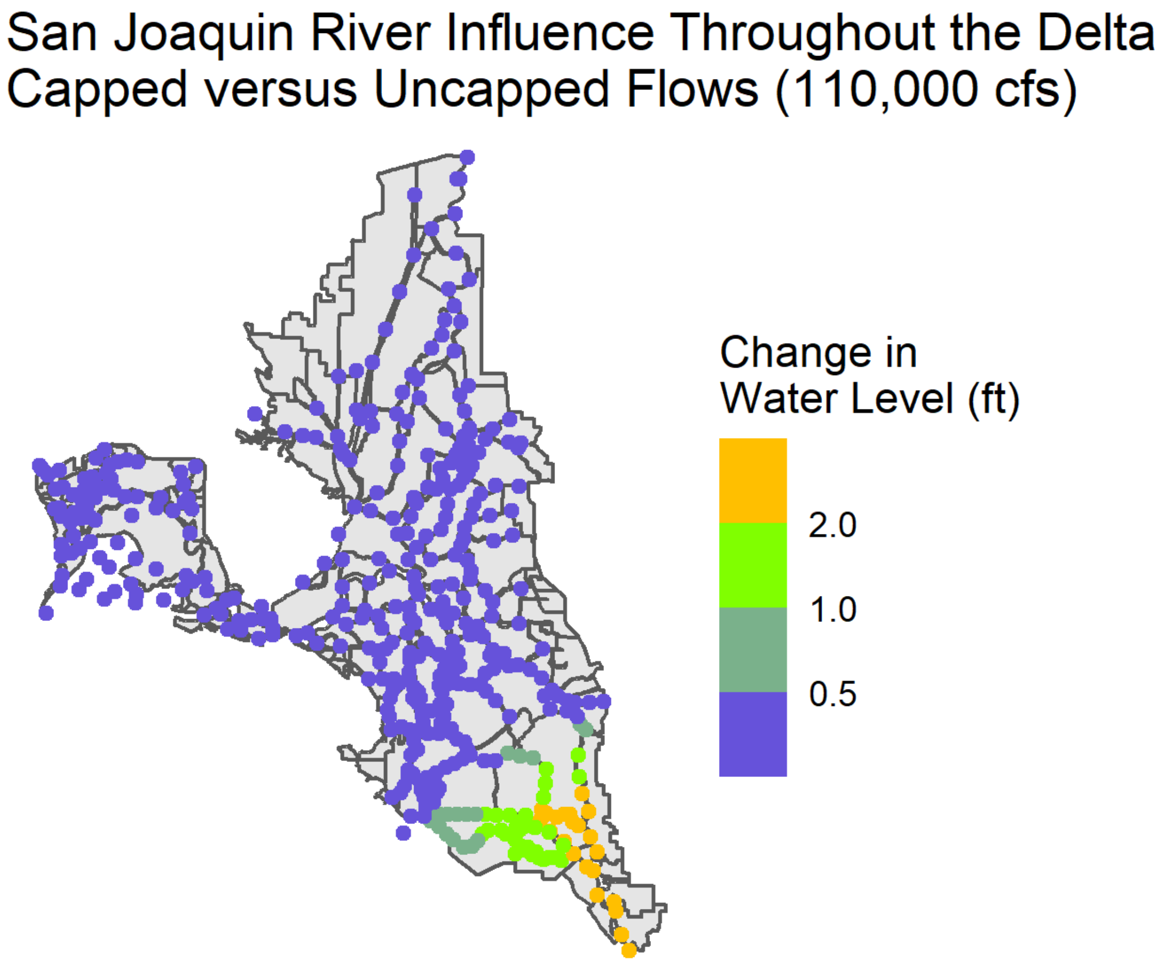


Figure 4-6. Influence of channel inflow capping on peak water surface elevations in the Delta

4.3 Flood Hazard Maps

This section presents the Flood Hazard Maps produced in support of the Delta Adapts project.

The flood hazard maps identify islands and tracts that are exposed to flooding by overtopping of levees for each future planning horizon. Other modes of levee failure such as seepage and stability are not evaluated; thus, the likelihood of flooding shown in these maps may under-estimate the likelihood of levee failure across all failure modes. Changes to local water levels and flood risk caused by un-reclaimed island flooding are also not considered in these maps. Un-reclaimed islands could lower water levels in adjacent channels by providing additional storage but could also increase flood risk by creating open water conditions that increase wind wave and other erosive processes. The flood hazard modeling also does not account for overbank flows and floodplain storage that may be especially important along the San Joaquin River as it enters the Delta.

4.3.1 Deterministic Scenarios

Figure 4-7 through Figure 4-11 present the flood hazard maps for the deterministic scenarios.

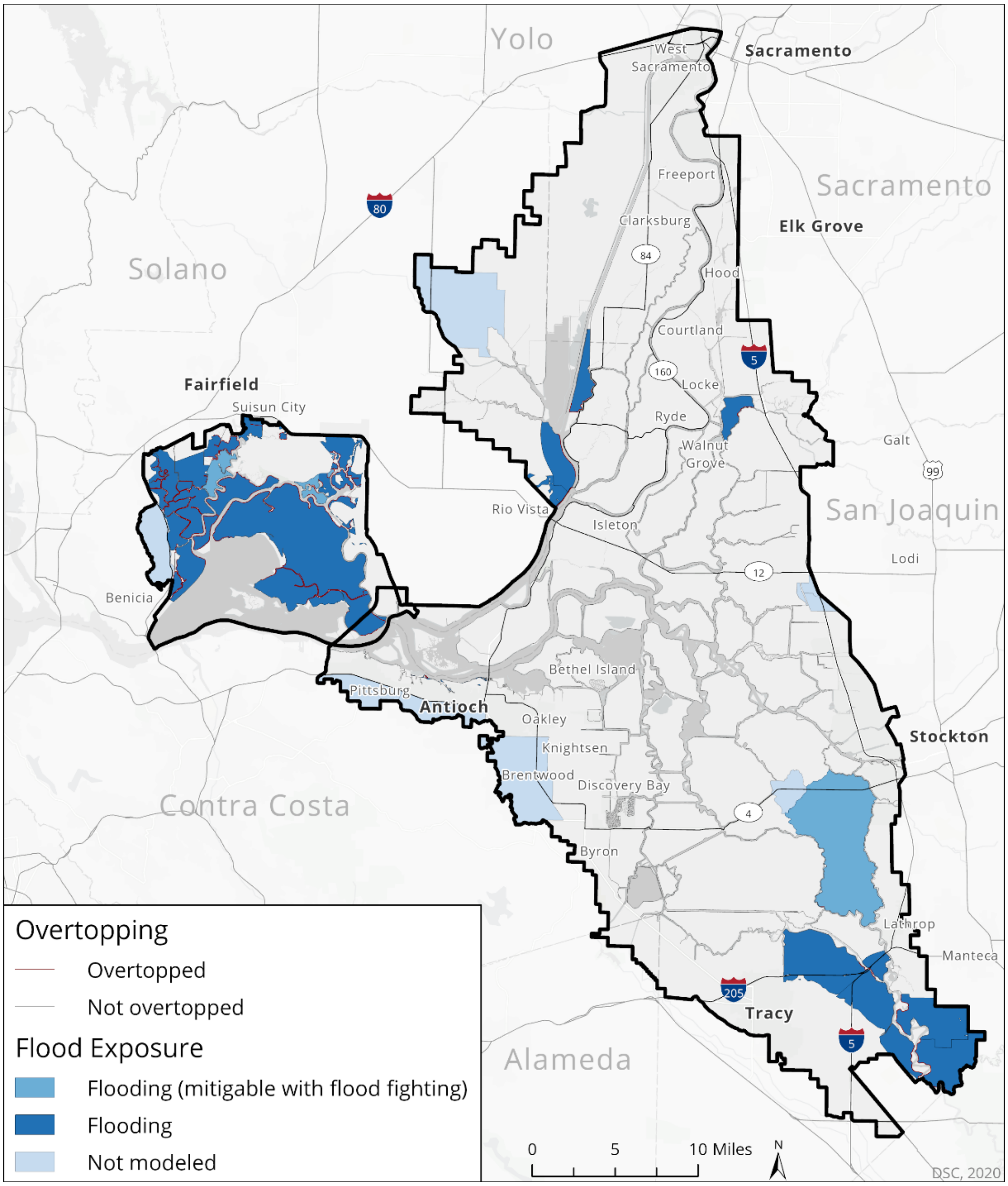


Figure 4-7. Flood hazard map for Deterministic Scenario M-0 (Existing Conditions)

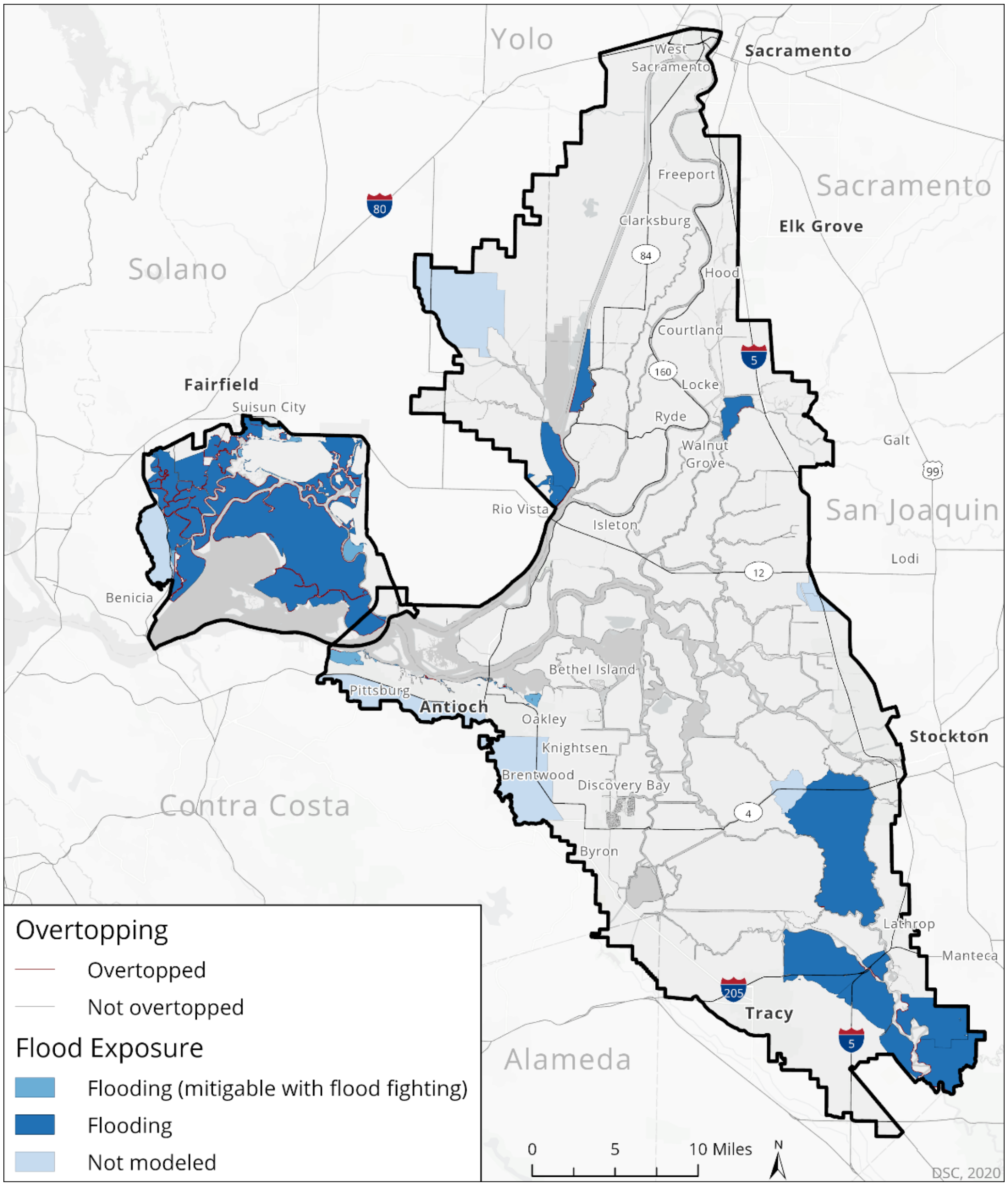


Figure 4-8. Flood hazard map for Deterministic Scenario M-1 (2030 Conditions)

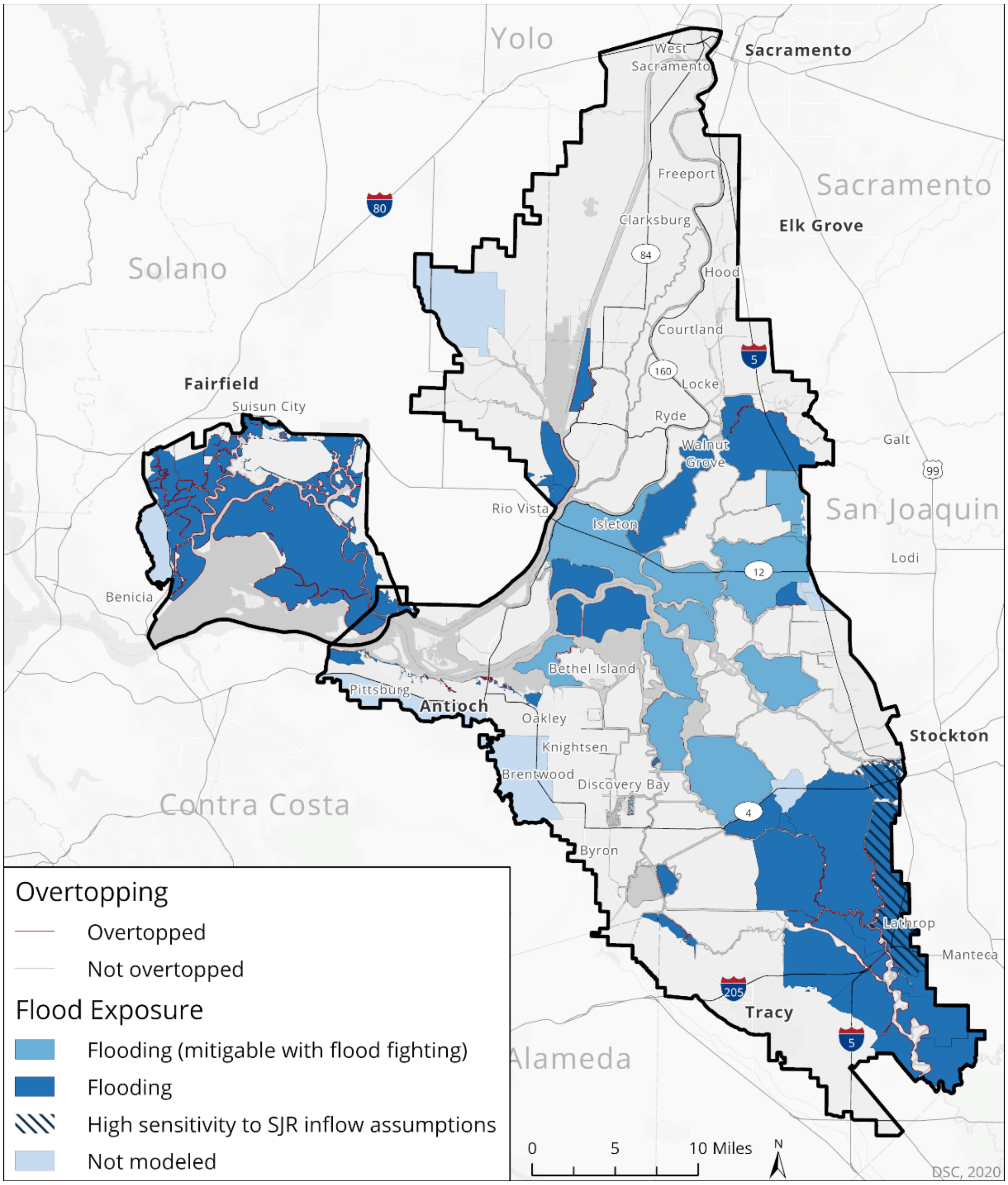


Figure 4-9. Flood hazard map for Deterministic Scenario M-2 (2050 Conditions)

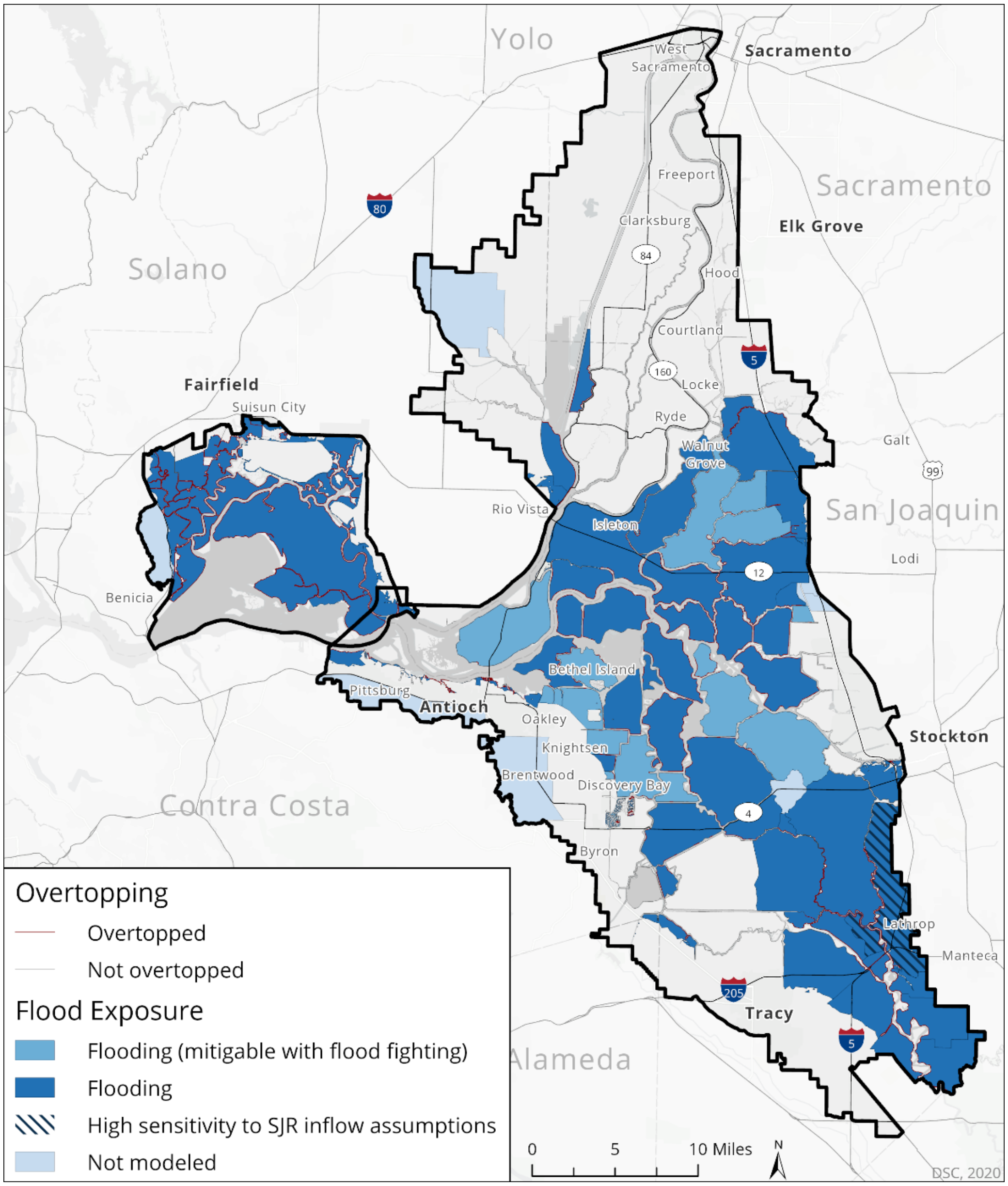


Figure 4-10. Flood hazard map for Deterministic Scenario M-3 (2050 Conditions)

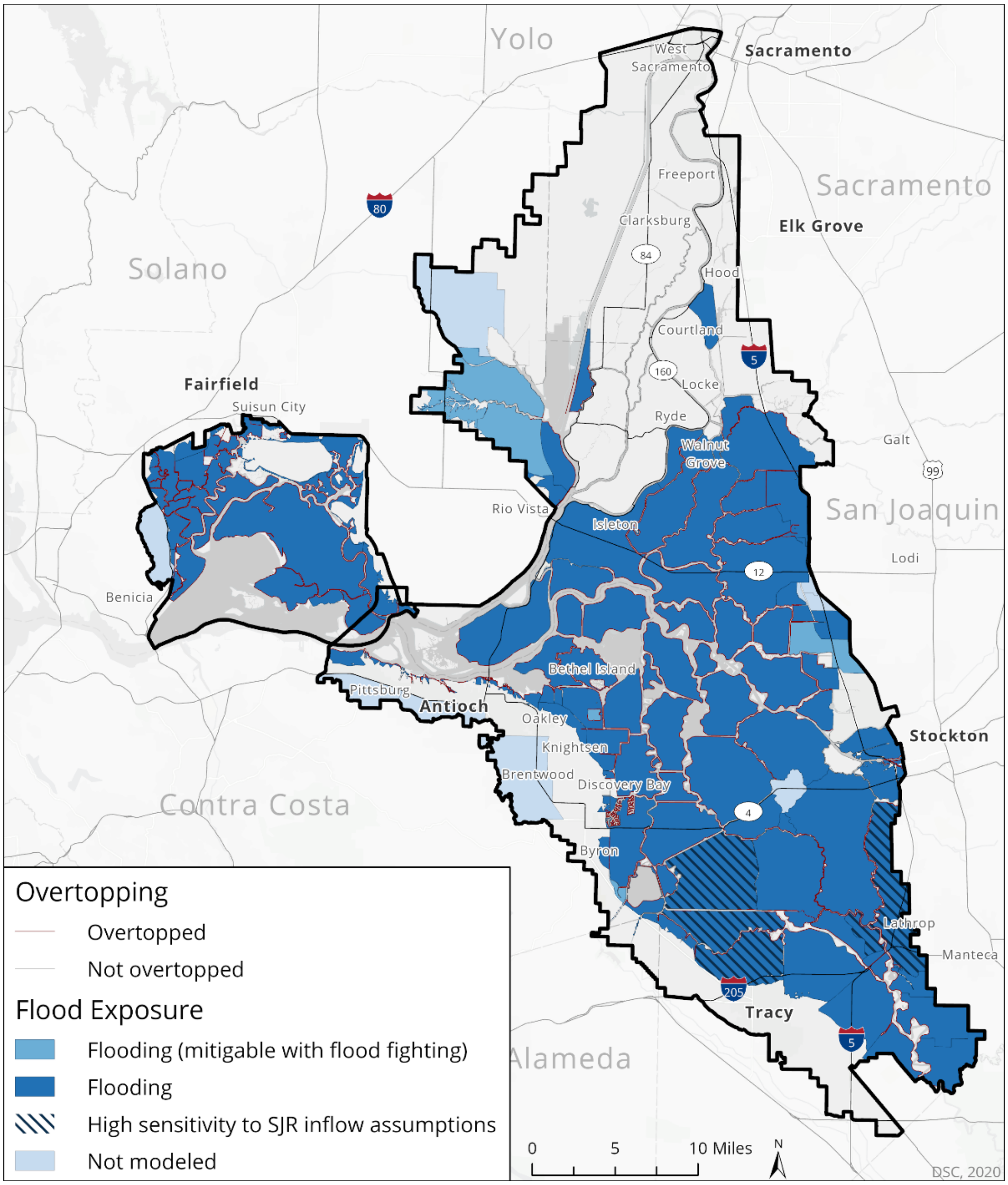


Figure 4-11. Flood hazard map for Deterministic Scenario M-4 (2050+ Conditions)

4.3.2 Probabilistic Scenarios

Figure 4-12 through Figure 4-15 present the flood hazard maps for the probabilistic scenarios.

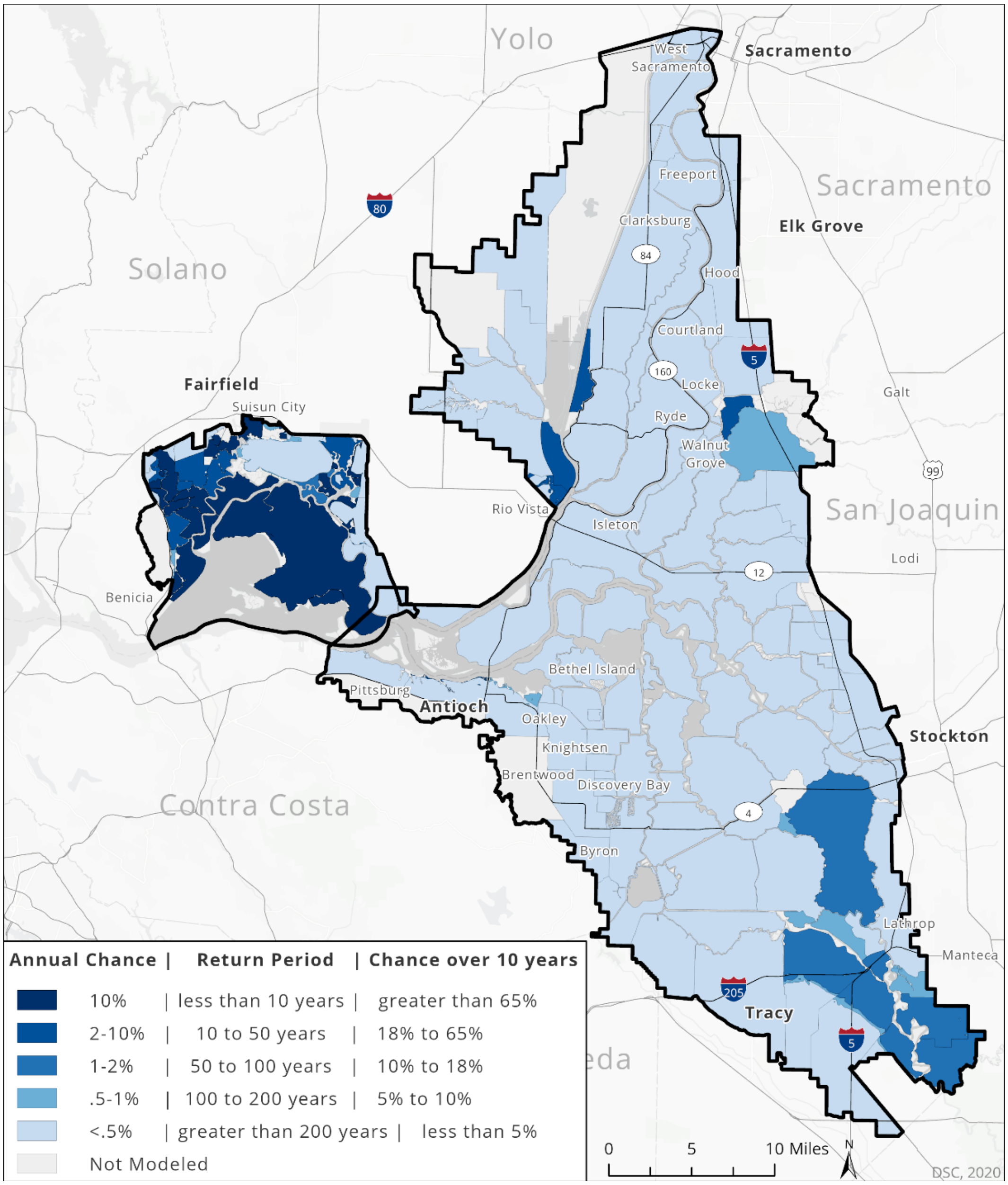


Figure 4-12. Flood hazard map for Probabilistic Scenario M-0 (Existing Conditions)

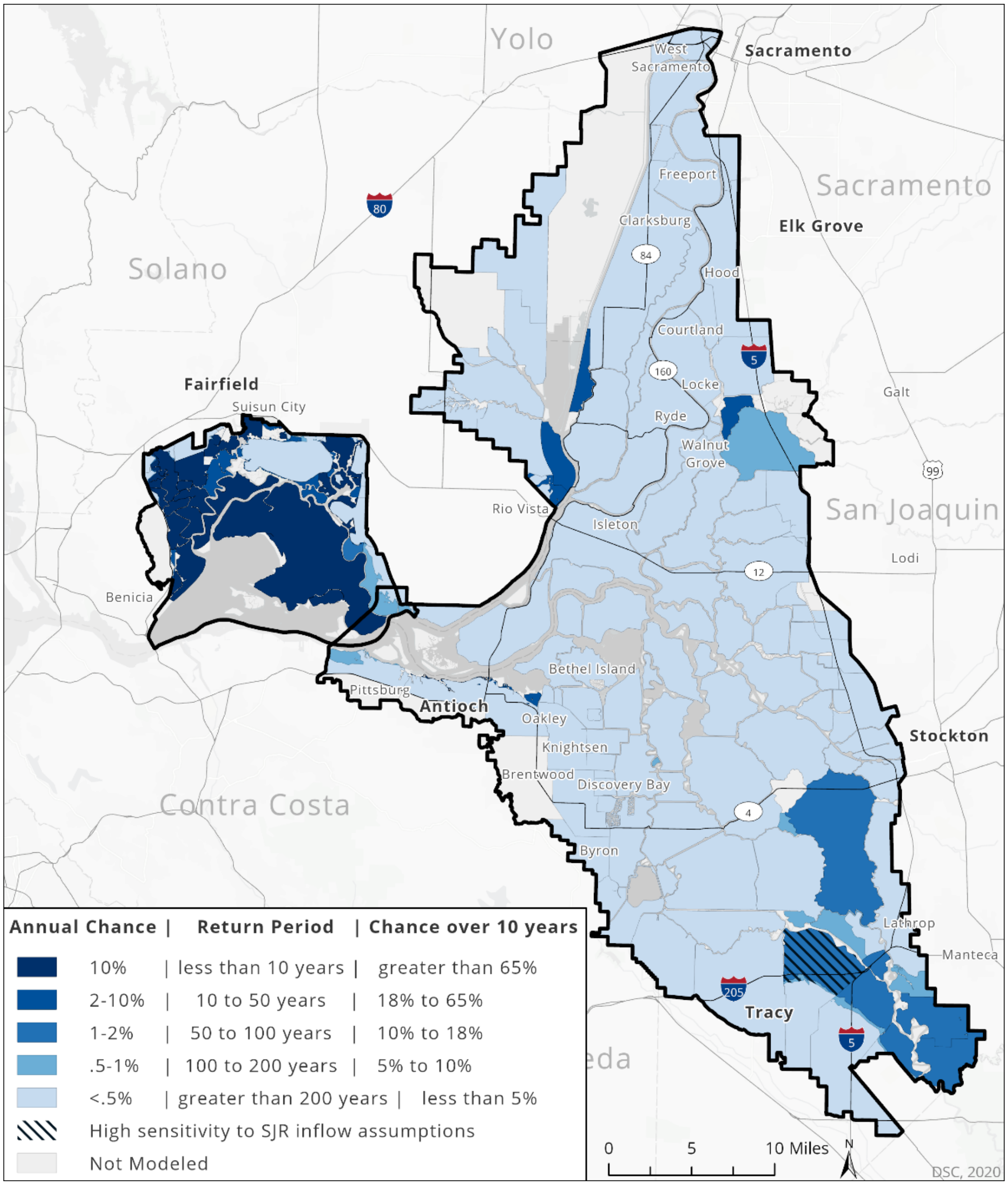


Figure 4-13. Flood hazard map for Probabilistic Scenario M-5 (2030 Conditions)

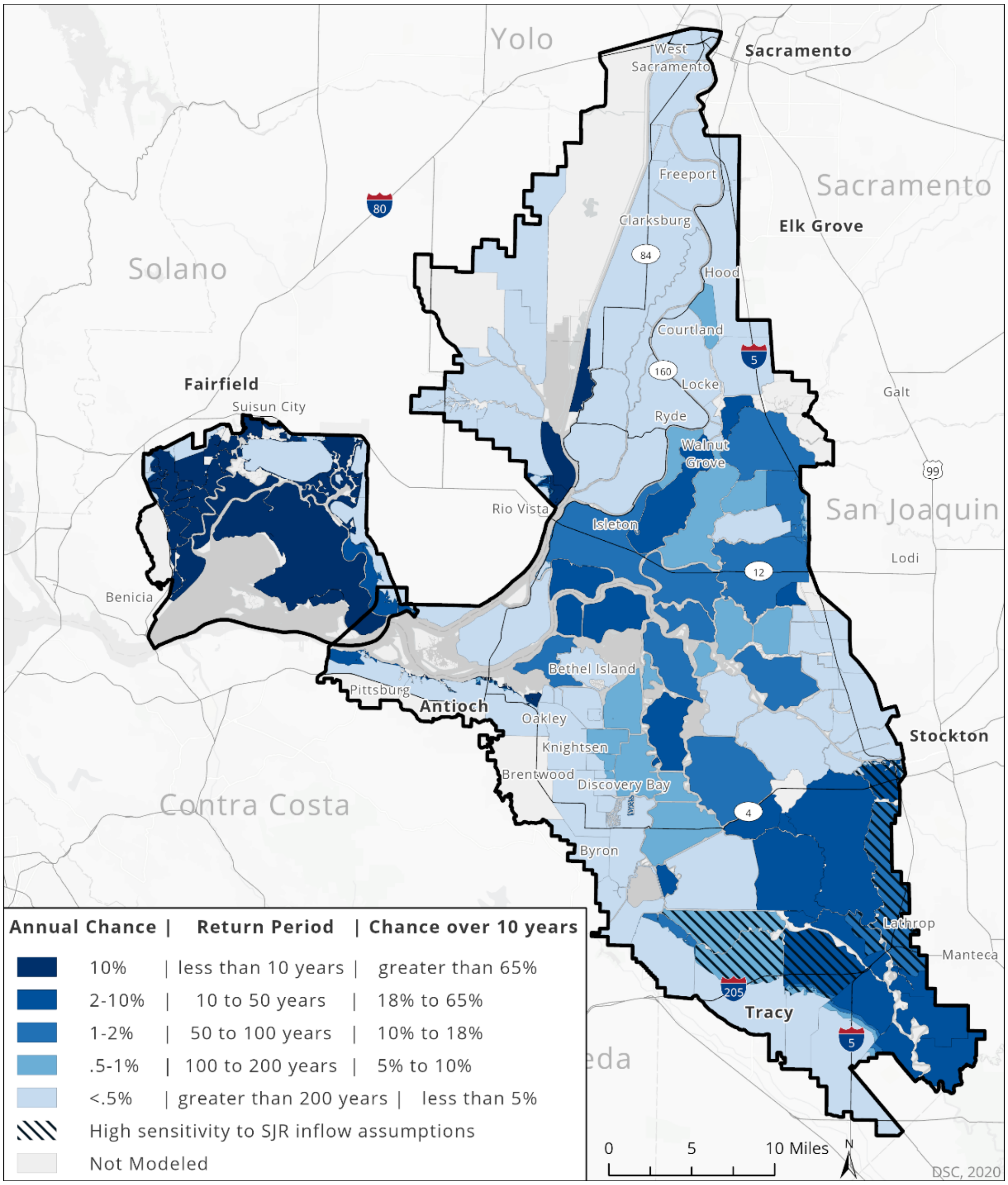


Figure 4-14. Flood hazard map for Probabilistic Scenario M-6 (2050 Conditions)

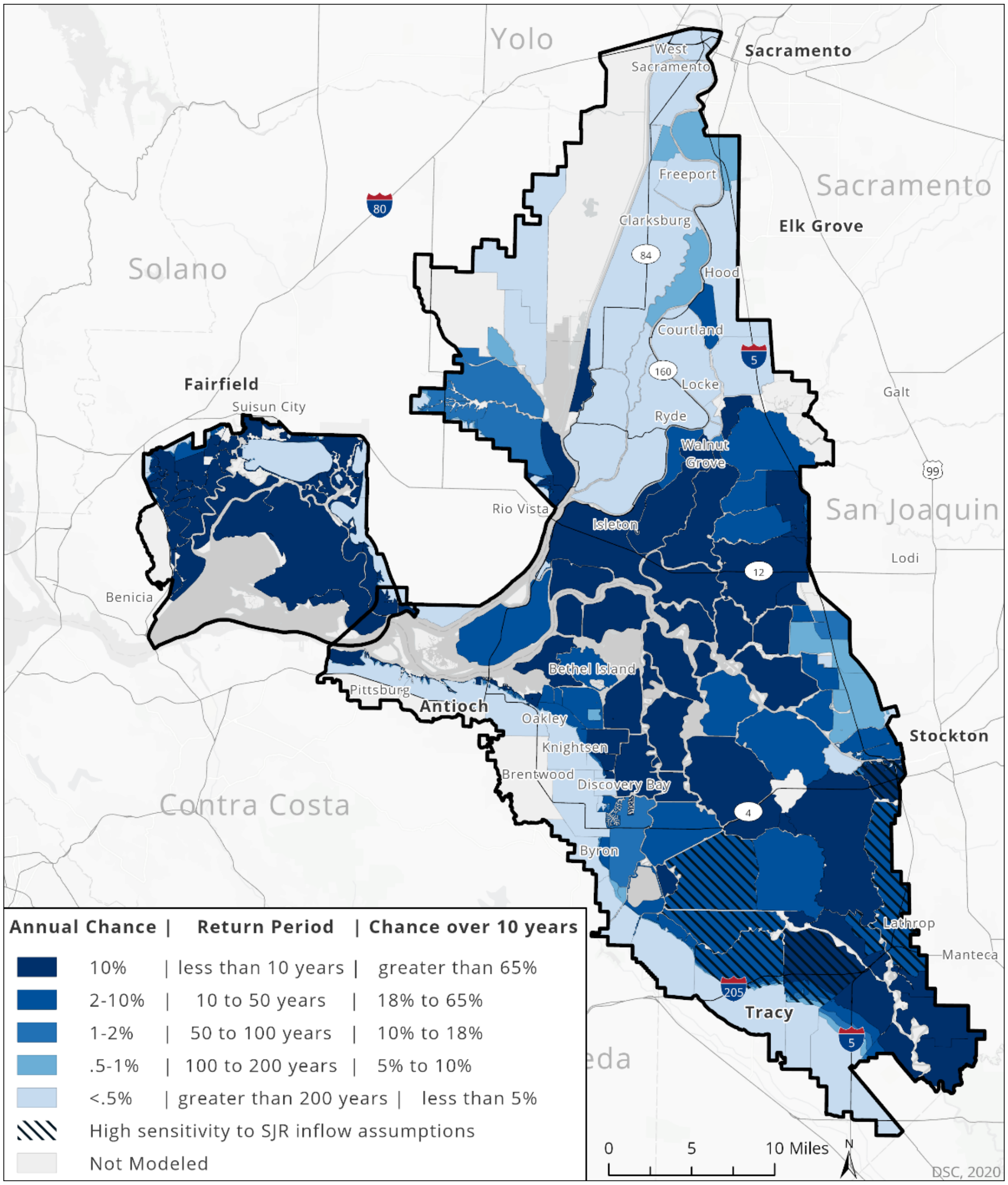


Figure 4-15. Flood hazard map for Probabilistic Scenario M-7 (2085 Conditions)

CHAPTER 5. OVERALL SYSTEM FINDINGS

The Delta Adapts flood risk analysis and mapping framework was also used to investigate which climate change influences (sea level rise, changes in riverine flow, or both) were driving flood risk throughout the Delta. In this analysis, the modeling framework described above was used to run the model holding sea level at current conditions and only changing riverine inflows as a consequence of climate change and subsequently running the model with riverine inflows held consistent and increasing only sea level rise as a consequence of climate change. These simulations were then used to identify areas of the Delta where water level changes were driven by changes in riverine flows versus locations where water level changes were driven by sea level changes.

Figure 5-1 below shows the strongest climate change influence throughout the Delta. Areas annotated as "Riverine" influenced indicate that shifting from historical riverine inflows to projected 2050 inflow conditions raises water levels in these locations by at least one foot across events of the same recurrence interval (e.g., 50-year, 100-year, 200-year). Areas annotated as "SLR" influence indicate that in these areas an increase in sea level rise at Golden Gate Bridge of one foot results in at least nine inch increase in water surface elevation across events of the same recurrence interval. Areas annotated as "Transition" influenced indicate that water levels in these areas meet the criteria for both "Riverine" influence and "SLR" influence, which means these areas will be strongly effected by both ocean conditions and changes in riverine flows.

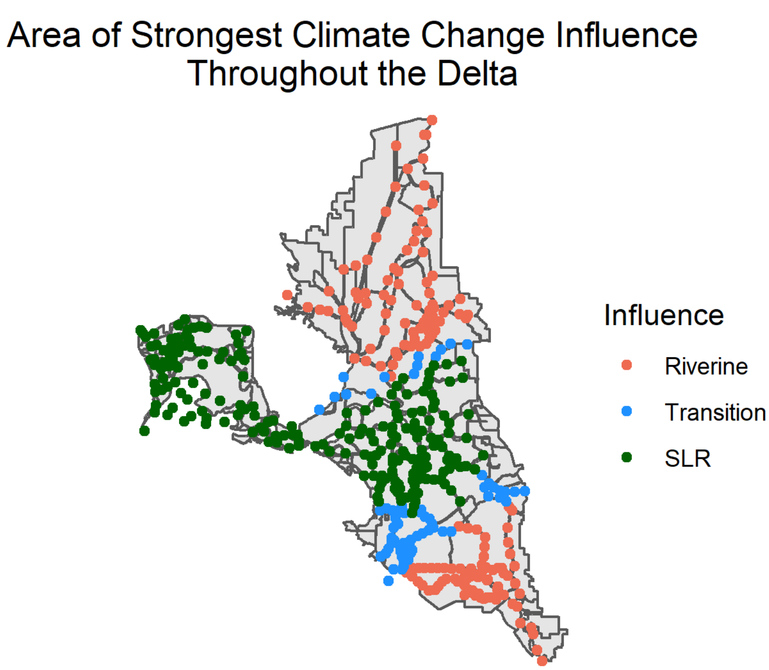


Figure 5-1. Area of Strongest Climate Change Influence Throughout the Delta.

Understanding the climate change stressors that will drive flooding and climate change vulnerability is important for adaptation planning. This insight shows that areas annotated as "Riverine" influenced may realize reduced flooding exposure and vulnerability if investments and adaptations are made in the watersheds flowing into the Delta, if these investments and adaptations result in reduced Delta inflows. Those watershed investments and adaptations will do little for the areas annotated as "SLR" influenced. In these areas, adaptation to rising sea levels must be the focus of exposure reduction. In areas annotated as "Transition" influenced, adaptation and consideration of both sea level rise and riverine inflows will be important.

CHAPTER 6. REFERENCES

DRMS 2008a. Flood Hazard Technical Memorandum. Delta Risk Management Strategy (DRMS) Phase 1. Prepared by: URS Corporation/Jack R. Benjamin & Associates, Inc. Prepared for: California Department of Water Resources. January 25, 2008.

DRMS 2008b. Climate Change Technical Memorandum. Delta Risk Management Strategy (DRMS) Phase 1. Prepared by: URS Corporation/Jack R. Benjamin & Associates, Inc. Prepared for: California Department of Water Resources. March 8, 2008.

DLIS 2017. Delta Levees Investment Strategy. Final Report. Prepared by: Arcadis et al. Prepared for: Delta Stewardship Council. July 2017.

DWR 2017. 2017 CVFPP Update- Climate Change Analysis Draft Technical Memorandum. Prepared by: CH2M. Prepared for: California Department of Water Resources. March 2017.

Dudas et al. 2016. Tidal Datum and 100-year Water Level Estimates in the Delta.

Knowles, N., C. Cronkite-Ratcliff, D.W. Pierce, D.R. Cayan (2018). Responses of Unimpaired Flows, Storage, and Managed Flows to Scenarios of Climate Change in the San Francisco Bay-Delta Watershed. Water Resources Research 54(10): 7631-7650. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018WR022852

Kopp, R. M. Horton, C. M. Little, J. X. Mitrovica, M. Oppenheimer, D. J. Rasmussen, B. H. Strauss, and C. Tebaldi. 2014. Probabilistic 21st and 22nd century sea-level projections at a global network of tide gauge sites. Earth's Future 2: 287–306, doi:10.1002/2014EF000239.

Kopp, R. M. DeConto, D. A. Bader, R. M. Horton, C. C. Hay, S. Kulp, M. Oppenheimer, D. Pollard, and B. H. Strauss. 2017. Implications of Antarctic ice-cliff collapse and ice-shelf hydrofracturing mechanisms for sea-level projections. Earth's Future 5, 1217-1233. doi: 10.1002/2017EF000663.

Ocean Protection Council. 2020. Strategic Plan to Protect California's Coast and Ocean 2020–2025.

Tom, B. 2004. Chapter 10: Development of Tidal Analysis Routines. In: Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 25th Annual Progress Report. October 2004.

U.S. Army Corps of Engineers. 2015. Central Valley Hydrology Study. Prepared for: California Department of Water Resources. Prepared by: U.S. Army Corps of Engineers Sacramento District and David Ford Consulting Engineers, Inc. November 29, 2015.

CHAPTER 7. SUPPORTING APPENDICES

This page intentionally left blank

Appendix A. Total Delta Inflow Distribution

Tables of Total Delta Inflow for existing and future conditions are included in an Excel file as supporting data to this technical memo.

Appendix B. Tide Distributions

Table B-1. Historical Distribution of Monthly Occurrence of Annual Max TDI Events

Month	Percent of Annual Max TDI events in each month
1	17.8%
2	25.3%
3	24.2%
4	12.5%
5	7.5%
6	2.2%
7	0.0%
8	0.2%
9	0.3%
10	0.3%
11	1.5%
12	8.2%

Table B-2. Future Distribution of Monthly Occurrence of Annual Max TDI Events (2035-2064)

Month	Percent of Annual Max TDI events in each month
1	27.3%
2	28.3%
3	22.7%
4	8.0%
5	2.0%
6	0.3%
7	0.0%
8	0.0%
9	0.0%
10	0.0%
11	2.7%
12	8.7%

Table B-2. Future Distribution of Monthly Occurrence of Annual Max TDI Events (2070-2099)

Month	Percent of Annual Max TDI events in each month
1	30.0%
2	34.7%
3	19.0%
4	5.0%
5	0.0%
6	0.0%
7	0.3%
8	0.3%
9	0.3%
10	0.3%
11	2.3%
12	7.7%

Table B-4. Binned Tide Distributions by Month (Probability of Exceedance)

Bin Center (ft NAVD88)	10	11	12	1	2	3	4	5	6	7	8	9
3.875	1.0000	1.0000	1.0000	1.0000	1.0000	0.9994	0.9987	1.0000	1.0000	1.0000	1.0000	1.0000
4.125	1.0000	1.0000	1.0000	1.0000	1.0000	0.9975	0.9876	0.9975	1.0000	1.0000	1.0000	1.0000
4.375	1.0000	0.9973	0.9955	0.9993	1.0000	0.9943	0.9529	0.9772	0.9947	1.0000	1.0000	1.0000
4.625	0.9845	0.9788	0.9755	0.9954	0.9943	0.9605	0.8791	0.9317	0.9793	1.0000	1.0000	1.0000
4.875	0.9310	0.9235	0.9419	0.9661	0.9795	0.8936	0.7641	0.8419	0.9333	0.9916	0.9981	0.9973
5.125	0.8187	0.8210	0.8703	0.9145	0.9144	0.7559	0.6229	0.7306	0.8427	0.9351	0.9741	0.9637
5.375	0.6697	0.7165	0.7923	0.8193	0.8117	0.5908	0.4497	0.5882	0.7267	0.8365	0.8885	0.8345
5.625	0.4742	0.6004	0.6916	0.6954	0.6348	0.4079	0.2876	0.4415	0.5913	0.7067	0.7140	0.6272
5.875	0.2974	0.4488	0.5742	0.5747	0.4565	0.2562	0.1856	0.3055	0.4400	0.5574	0.5272	0.3991
6.125	0.1800	0.3115	0.4277	0.4214	0.3043	0.1294	0.1118	0.1986	0.3080	0.3744	0.3048	0.1952
6.375	0.0923	0.2070	0.3103	0.2890	0.1791	0.0523	0.0510	0.1025	0.1947	0.2291	0.1485	0.0646
6.625	0.0426	0.1257	0.2052	0.1748	0.1040	0.0191	0.0190	0.0481	0.1067	0.1265	0.0551	0.0175
6.875	0.0129	0.0587	0.1219	0.0985	0.0502	0.0076	0.0039	0.0158	0.0387	0.0519	0.0188	0.0040
7.125	0.0019	0.0171	0.0510	0.0502	0.0269	0.0025	0.0007	0.0025	0.0093	0.0110	0.0045	0.0020
7.375	0.0000	0.0075	0.0200	0.0267	0.0134	0.0019	0.0000	0.0006	0.0000	0.0013	0.0013	0.0007
7.625	0.0000	0.0014	0.0039	0.0157	0.0071	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7.875	0.0000	0.0007	0.0013	0.0072	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8.125	0.0000	0.0000	0.0006	0.0026	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8.375	0.0000	0.0000	0.0006	0.0013	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8.625	0.0000	0.0000	0.0006	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8.875	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9.125	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix C. Sea Level Rise Distributions

Table C-1. Sea Level Rise Distributions for Probabilistic Scenarios

Probability of Non-Exceedance	Probability of Exceedance	2030 RCP 8.5 SLR (ft)	2050 RCP 8.5 SLR (ft)	2085 RCP 8.5 SLR (ft)
0.000	1.000	0.03	-0.03	-0.07
0.001	0.999	0.10	0.13	0.28
0.010	0.990	0.16	0.30	0.62
0.050	0.950	0.26	0.46	0.97
0.100	0.900	0.30	0.52	1.16
0.150	0.850	0.33	0.59	1.30
0.200	0.800	0.33	0.66	1.39
0.250	0.750	0.36	0.69	1.51
0.300	0.700	0.36	0.72	1.61
0.350	0.650	0.39	0.75	1.67
0.400	0.600	0.39	0.79	1.76
0.450	0.550	0.39	0.82	1.84
0.500	0.500	0.43	0.85	1.92
0.550	0.450	0.43	0.89	2.00
0.600	0.400	0.46	0.92	2.08
0.650	0.350	0.46	0.98	2.17
0.700	0.300	0.49	1.02	2.28
0.750	0.250	0.49	1.05	2.38
0.800	0.200	0.52	1.12	2.51
0.850	0.150	0.56	1.15	2.69
0.900	0.100	0.56	1.25	2.90
0.950	0.050	0.62	1.38	3.28
0.960	0.040	0.62	1.41	3.43
0.970	0.030	0.66	1.48	3.59
0.980	0.020	0.69	1.57	3.87
0.990	0.010	0.72	1.74	4.41
0.995	0.005	0.79	1.94	5.02
0.999	0.001	0.95	2.46	6.94
1.0	0.0	1.0	2.7	7.45

Note: Upper limit of sea level rise distribution (probability of exceedance=0) was set equal to the H++ projection corresponding to each planning horizon – 2030, 2050, and 2085, respectively.

Appendix D. Regression Coefficients

Tables of regression coefficients for each sea level rise scenario and model node are included in an Excel file as supporting data to this technical memo.

Appendix E. Levee Dataset Metadata

Methods: Legal Delta and Suisun Marsh Levee Centerline Dataset (2020)

To create an updated levee centerline dataset for the Legal Delta and Suisun Marsh, Council staff evaluated existing levee and shoreline shapefiles to identify source data layers that most closely tracked levees in the USGS/DWR 2017 LiDAR DEM (released 2019). After the best base shapefile was selected, heads-up digitizing was used to adjust the shapefiles to more accurately track the most up-to-date levee centerlines on the 2017 DEM. Waterway and island information tags were added to the levee centerlines using a DLIS polygon and DWR datasets.

Staff included external levees, prominent internal ad-hoc flood protection (e.g. a train track through Suisun Marsh), and developed areas of shoreline without levees (e.g. Antioch, Stockton, and Discovery Bay) near DSM2 nodes and channels. Levees that are antiquated and no longer maintained may be included; breached levees are only included in Suisun Marsh for levees that still may yet be repaired. Surface information (elevation statistics) was derived from the 2017 USGS/DWR 2017 LiDAR DEM.

In project-specific sub-datasets generated after October 2019, staff then added, modified, or removed features following feedback from local experts and/or to accommodate pairing with DSM2 nodes.

E.1 Products

'Full' datasets: 2020

- 20200226 Levee datasets

  2019 overall 'complete' DSC tracing of the 2017 LiDAR DEM for the Delta. Heads-up digitizing was used to adjust the 2012 DWR levee centerlines dataset to track the most up-to-date levee centerlines on the 2017 DEM and other high shoreline points. Staff focused on external levees and prominent internal levees (e.g. the train track throughout Suisun Marsh) near DSM2 nodes and channels, and did not digitize natural areas of higher elevation in this dataset. Breached levees are only included in Suisun Marsh for levees that may still be repaired (Flooded 0 = not breached, Flooded 1 = breached).

  10/01/2019: Elevations were recalculated to account for Suisun changes. 08/20/2019: Edits were made to Suisun Marsh with input from Stuart Siegel and Dan Gillenwater. 07/24/19: Islands/waterways/DLIS numbers were named for each segment. 02/2020: Splash berms on four central Delta islands were added. (see peer review section).

- An alternate version of this dataset *omitting* splash berms was retained for potential future DLIS analyses.

Project-specific sub-datasets

- 20200526 DeltaAdapts

Working from the above 02/2020 'full' dataset WITH splash berms, staff added an attribute for the nearest logical DSM2 node in 04/2020. Segments too far from a DSM2 node for an accurate water surface elevation were removed. Other segments were removed following feedback from external peer review. 04/2020: West Sac. Southport Setback levee elevation was corrected, Stockton high ground area was adjusted, (see peer review section below), Tom Payne slough was removed due to water levels being controlled by a gate, and high ground on the interior of Smith's Canal in Stockton were removed due to Smith's Canal flood gate project.

E.1.1 Attributes

LMA: local maintaining agency: usually the tract or island name (from DWR dataset)

DLIS_Is: the DLIS name of an island or tract, used to match to polygon dataset

Reach: Waterway that the levee is on

LMA number: From a past DWR dataset- the RD no.

Z min, max, average: elevation in meters

Z min_ft, Zmax_ft, Z_mean_ft: elevation in feet

DataSrc: Indicating that the line has been checked for the 2019 linework tracing 2017 LiDAR DEM, or later adjusted based on feedback from peer review

Flooded: Applies to a few levee segments in Suisun Marsh that have been flooded after 2017 and may yet be repaired

SplashBr: Indicates if the levee segment is part of an earthen splash berm.

DSMNode: Closest logical DSM2 Node.

Comments: Misc. comments.

StrngNd: Closest logical DSM2 Node in string data structure

E.2 LiDAR DEM background

LiDAR data were gathered over two flights in December 2017 and January 2018 through a USGS-DWR contract with Woolpert. The data were developed based on a horizontal datum/projection of NAD83 (NSRS2007) UTM Zone 10 (EPSG 3717) meters, and a vertical datum of NAVD88 (GEOID12B), US survey feet.

Please see LiDAR documentation for complete information (LiDAR factsheet_FINAL_June2019.pdf and CA_Sacramento_Lidar_2017_B16_Lidar_Project_Report.pdf in the "Documentation" Folder). LiDAR DEM data are available from https://data.cnra.ca.gov/dataset/delta-lidar-2017

E.3 Heads-up digitizing to adjust levee centerlines

Information on source layers can be found at the final section of this document. Council staff determined that "i17_Delta_Levee_Centerline_Classifications_2012": Levee Centerline Class 2012 (DWR) was the best base set of lines to edit according to the new DEM. The 2012 levee centerlines were projected (from WGS_1984_Web_Mercator_Auxiliary_Sphere) to NAD_1983_2011_UTM_Zone_10N.

Lines were reshaped (vertices moved) in some areas to align to the center of the levee as identified with elevation symbology. Most adjustments were minor. Some line segments were moved to connect unconnected lines. NAIP 2016/2018 imagery helped verify features. Roads such as Interstate 5 were not included, but high elevation areas were added in many areas (and may have been later removed for sub-datasets for specific projects).

Staff then added island names, waterways/reach information, and DLIS number to all line segments.

E.4 Elevation attributes

Lines were made into polylines (added elevation information) with the
3D analyst>Functional Surface>Add Surface Information tool in ArcMap and/or ArcGIS Pro.

Input: new levee centerline dataset

Input Surface: 2017 LiDAR DEM;

Output Property: Added z min/max avg and slope min/max/average. Other parameters were left on default (e.g. method: bilinear)

E.5 QAQC: External peer review

E.5.1 Legal Delta

Overall:

Joel Dudas from DWR informally provided comments via email in 09/2019.

MBK Engineers: provided feedback in 02/2020, they reviewed the veracity of the levee heights against their surveys. Given overtopping maps they identified incorrect identification of high ground in Stockton.

Atlas Tract, Shima Tract, DLIS-14

Removed (b/c of node proximity), then re-added levees to include it in the overtopping analysis. 09/2020

Discovery Bay, Byron Tract, DLIS- 64:

The centerlines in these regions were revised to align with RD 800 shapefiles and documentation provided by KSN and to more appropriately align with high ground/ higher levees set back on the western side of this region that protect homes. Added back in the internal levee along Byron Tract. Revised 09/2020.

Goodyear Slough

Removed levees that were behind the slough because there was no polygon here to indicate flooding. 09/2020.

New Hope Tract:

At the advice of Gilbert Cosio at MBK, realigned the northern centerline to cover an area of slightly higher elevation, a suspected splash berm along the Mokelumne River. 09/2020.

Pittsburg and Antioch

Digitized shoreline to allow for overtopping analysis, revised through 09/2020.

River Islands Development and Stewart Tract

At the direction of Councilmembers, staff split the built portion of River Islands off of Stewart Tract and digitized a portion of its internal levee and removing a portion of the outer Project levee on Old River. 09/2020.

Manually entered levee heights surrounding Stewart Tract, the future location of River Islands Phase II. 11/2020

Sherman Island:

Staff manually replaced elevations on Sherman Island with tabular data from December 2019 provided by Martin Berber on 9/24/20.

Method:

1. Enter points into the GIS (state plane coordinate system to UTM Zone 10 NAD83) using *XY Table To Point*
2. Use *Point to Raster*, Input= Sherman Island Points , Value= heights, Cellsize=36 (auto)
3. *Add Surface Information* to the Sherman Island Lines (in feet), copy to Z_Min_ft and Z_Mean_ft
4. Convert the feet values in the meters fields (Z_Min, Z_Max, Z_Mean) to meters (!field! * 0.3048) using the *Calculate Field* tool.

Data: G:\Projects\CCVA_Flood\DeltaAdapts_Mapping_KG\DeltaAdapts_Levee_Adjustments\Reference Levee Documents\ShermanIsland

Smith Canal:

Excluded 05/2020.

Stockton area:

Council staff were advised on modifying two line segments in the south portion of the Port of Stockton waterfront to more accurately capture an area of high ground that may serve as an area of defense in a high water event. These changes were made 04/2020. KSN provided further suggestions on shoreline alignment in South Central Stockton that prompted some changes in 09/2020

Summer Lake

The Oakley community of Summer Lake, with over 500 homes already built, was added to the dataset even though the levees that surround the community may be considered 'interior levees'. Revised 09/2020.

Terminous Marina:

Manually entered heights around the marina from data provided by Dominick Gulli on 9/17/20. Covered structures prevented LiDAR from correctly depict the splash wall / heights.

Tyler Island, Jersey Island (RD 830), Webb Tract (RD 2026), Holland Tract:

Engineers from KSN, Inc. advised on the existence of splash berms in 04/2020.

Tom Paine Slough:

Staff were advised of a gate on Tom Paine Slough and recommended its removal for the analysis by MBK Engineers and KSN, Inc. because the water levels are managed in the slough. Excluded from dataset 04/2020.

West Sacramento:

Southport Levee - As advised by City of West Sacramento staff, staff updated the elevations and segments in 04/2020 using as-built engineering documents. The LiDAR did not capture the elevation improvements, as they had not been built at the time of the survey.

SDWSC North – One levee segment was set back to correctly align with levee documents for the region 09/2020.

Uncentered / misaligned levees:

These areas were examined based off of looking at the deterministic layers and spot-checking sections that had only one to ~few segments overtopped.

Corrected DLIS-50, Fay Island (south), Mandeville Island (north), Bacon Island (NW), Lower Jones Tract (W), Venice Island (SE, E) Sherman Island (S), Terminous Island (S), Pico-Naglee (W), Veale Tract (N), Lower Roberts (N), Upper/Middle Roberts (S), Mossdale Island, Shifted some RD-17 lines probably inconsequential. 09/2020.

E.5.2 Suisun Marsh

Stuart Siegel and Dan Gillenwater reviewed the centerline dataset within the boundaries of Suisun Marsh in August 2019. Comments were submitted via email and discussed on a phone call.

Full comments and how they were addressed can be viewed here:
G:\Projects\Levee_Heights\Methods_Source_Info\ Siegel_SM_levee_comments_20190815

E.6 Assumptions and Limitations

This document and dataset has assumptions and limitations. The dataset does not include all Project and Non-Project levees, and includes some areas of high ground or de-facto levees (e.g. Suisun Marsh train track, in part). The dataset contains centerline elevation, but not other characteristics of levee geometry. Centerlines may not be true centers of the levee crown. Because of the timeframe of the analysis, the centerlines from the 2012 DWR dataset were retained in most cases, and adjusted using heads-up digitizing when necessary.

This dataset is intended to be used for general planning purposes and overtopping analysis for the Delta Adapts Climate Change Vulnerability Assessment. It should not be used for site-specific design or assessment purposes. Elevation data can change over time via levee settling or deforming, or through routine maintenance work or rehabilitation projects.

Please consult the LiDAR survey documentation regarding accuracy of the elevation data.

E.7 Selection of source data layers:

When available, source documents were copied into the Project Methods/Source Info folder. Source data layers can be found in G:\GIS_Data\Hydrology\Levee_centerline_2019\SourceData
Working archive can be found here: G:\Projects\Levee_Heights\Base_layers

E.7.1 Legal Delta

For the Legal Delta, the following shapefiles were evaluated in order to select and integrate which ones most closely aligned with levees and covered the study area.

- "Delta_Levee_Centerline_2012_NAD83_DWR": **DWR Levee Centerline Class 2012, from 2007-8 acquisition**

  Use: Base levee lines that most adjustments were made from (projected to NAD83 by Council staff)

  Developed by: California Department of Water Resources

  Date: 2007-8 imagery; 2012 dataset

  Metadata: This line feature class represents levee centerlines for 93 Levee Maintenance Agencies/Reclamation Districts in the Sacramento-San Joaquin Delta. The centerline features contain levee geometry classification that indicates whether a levee segment meets the FEMA's Hazard Mitigation Plan (HMP) or USACE's Public Law 84-99 (PL8499) Delta levee standards.

  DWR conducted an entire-Delta analysis of the Delta levee system's achievement of design geometry using the **2007-08 LIDAR dataset**. That analysis was conducted at 50 foot intervals. The values for this field represent the LIDAR-based analysis result sub-sampled at the appropriate 1000-foot cross section used for this consolidated analysis. Final classification may be derived from DWR/LIDAR-based analysis or LMA engineer-supplied surveys.

  There are four categories used in the classification of the centerlines: HMP, Below HMP, Minimally Below HMP, and PL84-99. The classification and other data associated with these centerlines (such as Minimum Freeboard, Maximum Freeboard, Average Freeboard, Minimum Crown Elevation, Maximum Crown Elevation, and Average Crown Elevation) were produced as results of the Levee Geometry Assessment analysis performed by the California Department of Water Resources Delta Levees and Environmental Engineering Branch in 2012. The centerlines used in this analysis are part of the dataset produced from the Delta Levee Anatomy Mapping Project in 2011 through a contract between DWR and the Geographic Information Center at California State University, Chico.

  Source: Transmittal Document: Analysis of Delta Levees Compliance of HMP and PL84-99 Design Geometry. 2012. G:\Projects\Levee_Heights\Methods_Source_Info\

DWR_2012_levees_Transmittal_Document.pdf;
Compliance maps in G:\Projects\Levee_Heights\Methods_Source_Info\

G:\Projects\Levee_Heights\Methods_Source_Info\ DWR_2012_levees_Assumptions

https://www.arcgis.com/home/item.html?id=df57b2bdb7954cad8c89210738cfa658#overview

- "BCDCART_CCC_shoreline": **AECOM tracing of the Contra Costa County Shoreline**

  Use: This delineation was used for overtopping assessment and represents shoreline and/or levees.

  Developed by: AECOM and the San Francisco Bay Conservation and Development Commission

  Date: 2002-8 imagery; 2018 dataset

  Metadata: This line feature class represents the Contra Costa shoreline in the Legal Delta that was developed for the East Contra Costa County BCDC Adapting to Rising Tides Project in 2018.

  The topographic data used for this analysis relied on a 2017 seamless digital elevation model (DEM) developed by the California Department of Water Resources (DWR). The terrain dataset relies on multiple sources of topographic data, including 2007-2008 Delta lidar, 2002 U.S. Geological Survey lidar,

  2008 Solano County lidar, and 2005 Suisun Marsh/Yolo Bypass lidar. AECOM delineated a continuous shoreline within the study area that traces high ground and levee crests. A levee centerline file provided by the Delta Stewardship Council was used as a guide in the delineation where available. Due to the extensive levee network and shoreline complexities in the study area, the shoreline and levee crest delineation is not perfect and could benefit from further review and refinement in future efforts.

  Source: G:\Projects\Levee_Heights\Methods_Source_Info\
  AECOM_2019_ECC_Shoreline_Methods ;

  http://www.adaptingtorisingtides.org/wp-content/uploads/2019/05/Eastern20CC20and20SOL20SLR20Mapping20Methods20and20Data20Sources2020190228.pdf

- "NLD_DeltaSystems_projected": **United States Army Corps of Engineers National Levee Database Sacramento-San Joaquin Delta, California 94571, USA**

  Use: This delineation was used for comparison to the DWR Levee Centerline dataset.

  Developed by: U.S. Army Corps of Engineers (USACE)

  Metadata: This line feature class represents levee centerlines for USACE and non-USACE levee systems in the USACE National Levee Database.

Source: The version of this dataset used was located using the advanced search “Sacramento District”; downloaded 06/24/2019 from https://levees.sec.usace.army.mil/

- “RevisedIslands_160912_AllIslands”: **DLIS Islands and Tracts for the Legal Delta and Suisun Marsh**

  Use: This polygon dataset was used to add waterway and island information to the levee centerline dataset.

  Developed by: Arcadis and the Delta Stewardship Council

  Date: 2017 dataset

  Metadata: This feature class represents all of the islands and tracts identified for the Delta Levee Investment Strategy (DLIS). Islands and Tracts of the Sacramento, San Joaquin Delta & Suisun Marsh developed as part of the Delta Levees Investment Strategy for the Delta Stewardship Council. The regional divisions were developed by the Arcadis team with input from other agencies and stakeholders in the Delta and Suisun Marsh.Key:Cateogry0: Leveed1: Unleveed2: Floodway Delta Zone 0: Suisun Marsh1: Primary Delta2: Secondary DeltaSuisun0: Island is not in Suisun Marsh1: Island is in Suisun Marsh

E.7.2 Suisun Marsh

For Suisun Marsh, the following shapefiles were evaluated in order to select and integrate which ones most closely aligned with levees and covered the study area.

- “SRCD_Properties”: **Suisun Marsh Property Boundary Outlines**

  Use: This polygon dataset was used to add waterway and island information to the levee centerline dataset.

  Developed by: Suisun Marsh Resource Conservation District (SRCD)

  Metadata: This feature class represents property boundary outlines for the duck clubs in Suisun Marsh and was shared by Christina Tortosa from the Suisun Resource Conservation District. This dataset does not delineate levees but was used to help identify interior vs. external levees.

- “RevisedIslands_160912_AllIslands”: **DLIS Islands and Tracts for the Legal Delta and Suisun Marsh**

  Use: This polygon dataset was used to add waterway and island information to the levee centerline dataset and help identify interior vs. external levees.

  Developed by: Arcadis and the Delta Stewardship Council

  Date: 2017 dataset

  Metadata: This feature class represents all of the islands and tracts identified for the Delta Levee Investment Strategy (DLIS). Islands and Tracts of the Sacramento, San Joaquin Delta & Suisun Marsh developed as part of the Delta Levees Investment Strategy for the Delta Stewardship Council. The regional divisions were developed by the Arcadis team with input from other agencies and stakeholders in the Delta and Suisun Marsh. Key: Category 0: Leveed 1: Unleveed 2: Floodway Delta Zone0: Suisun Marsh1: Primary Delta2: Secondary DeltaSuisun0: Island is not in Suisun Marsh1: Island is in Suisun Marsh

- "NAIP 2016": NAIP 2016

  Use: This polygon dataset was used to identify flooded tidal marsh areas not surrounded by intact levees. It also helped classify 'Suisun Islands polygons' as tidal marsh, flooded marsh (areas with breached levees that may be repaired), managed marsh, or muted marsh.

  Developed by: U.S. Department of Agriculture

  Date: 2016 imagery; 2017 dataset

  Metadata: Natural color representation of NAIP 2016 aerial imagery. Band1=R, Band2=G, Band3=B.

- "current_modern_baylands": SFEI/WWR 2014

  Use: This polygon dataset was used to identify flooded tidal marsh areas not surrounded by intact levees. It also helped classify 'Suisun Islands polygons' as tidal marsh, flooded marsh (areas with breached levees that may be repaired), managed marsh, or muted marsh.

  Developed by: San Francisco Estuary Institute and Wetlands and Water Resources

  Date: 2014 dataset

  Metadata: This is an updated version of the SFEI 1998 EcoAtlas. Updated with the following steps: Note: Original file was "current_modern_baylands", updated by WWR, by Leigh Etheridge, 6/15/2010 2) Using 2010 orthorectified NAIP, all tidal sloughs and channels were digitized at scale 1:6000, producing the polygon shapefile, "suisun_tidal_channels_jan2011". The EcoAtlas "deep" and "shallow" channel distinctions were maintained within the updated channel extents following digitizing completion. 3) Channels were merged with the EcoAtlas, replacing EcoAtlas classification at overlap. 4) Remaining (obsolete) EcoAtlas classified tidal channel polygons remained outside the extent of channel digitization. Most of these obsolete polygons rested over developing tidal marsh. The boundary between tidal marsh and diked marsh polygons was determined using the dissolved JSA-SMP levees shapefile (levee_segments). All polygons extending into both classified areas were split along the levees shapefiles and marsh fragments were reclassified based on visual verification over the 2010 NAIP. 6) Riparian communities from the DFG 2006 vegetation data were corrected to EcoAtlas channels and bays extents, then merged with EcoAtlas, replacing EcoAtlas classifications at overlap. 7) All tidal features (Legend: tidal brackish marsh, managed marsh, and tidal open water) from Vegetation_SAIC_Suisun_Final (from AECOM) outside the EcoAtlas extent, were clipped and merged with the EcoAtlas, broadening baylands extent, mostly toward the northern Suisun border. EcoAtlas now encompasses both historic bayland extent, as well as increased modern bayland extent due to this addition from SIAC data. 8) Original EcoAtlas digitizing errors (holes with no polygon features within the baylands extent) were discovered during SAIC-EcoAtlas data comparisons. EcoAtlas was erased from Vegetation_SAIC_Suisun_final. All subsequent polygons that had tidal features, and as such should be classified as baylands and covered by the EcoAtlas, were selected and added back into the EcoAtlas in order to fill polygon "holes." All holes were <0.01ac and were reclassified to match appropriate Level 4 EcoAtlas classifications. 9) WWR staff also discovered that EcoAtlas original file had overlapping polygons, roughly 7 acres of overlapping coverage. As of 02/02/2011, this issue has not been resolved but the data is considered complete for our current purposes. 10) The EcoAtlas extended beyond the historic bayland margin to the east, unnecessarily including a pheasant club as baylands. This polygon was clipped to the historic baylands margin, and divided between uplands and baylands. Then the uplands portion was erased and replaced with all of the overlapping polygons from the SAIC vegetation data. All polygons outside the historic baylands margin in the pheasant club were described at level 2: uplands and level 4: Pheasant club. Level 3 was classified the same as the SAIC vegetation data with "grasslands", "vernal pool complex", or "alkali seasonal wetland complex", as appropriate. March 24, 2011 WWR Update: Club 910, in South south-east corner of SMPP boundary, converted description from Low/Mid Elevation Marsh to Muted Tidal Marsh under appropriate terminologies under Levels 3 and 4, short description, and updaed WWR_update fields. **05/13/2011 WWR update**: Converted portion of Goodyear slough unit from managed marsh to High elevation tidal marsh and included in SHORT-DEF, restored by DFG 2006. **9/13/2011 WWR update**: Reassigned Tule Red Club (Club 539) from muted tidal marsh to diked marsh and updated all corresponding fields. **Modified by WWR Nov 2013**. Tidal Marsh Status field added to indicate current condition of tidal marsh. Field designations are 'Historic Tidal Marsh', 'Naturally Formed Tidal Marsh', 'Restored Tidal Marsh', and 'Restored Tidal Marsh, Muted'. To provide detail to areas designated as 'Restored Tidal Marsh' the field 'Restoration Year' was added and populated. Modified again in **February and April 2014**, checking tidal marsh Status designations using google earth (current and historic imagery) and editing these designations. Also added polygons from current_modern_baylands that were not tidal marsh (Diked lands or other), but have since been restored to tidal action and populated the field TM_Status for these known tidal and muted tidal restoration sites. Some tidal marsh polygons in the South Bay are not in this shapefile and can be found within the current_modern_baylands shapefile.In **June 2014** - Added additional baylands polygons from original SFEI modern baylands shapefile. Added four polygons that used to be diked lands, but are now muted tidal marsh or tidal marsh on the northern edge along Honker Bay.**09/25/2014 WWR** performed spatial join between (1) current_modern_baylands_June2014_tidalmarsh_only, (2) modern_baylands_SMPP2011_updated 2014, and (3) modern_baylands_to_display_tidal_waters to incorporate added fields and edits to tidal marsh only dataset into a comprehensive bay and suisun current modern baylands dataset. The three files were joined in this order as the tidal marsh only file had the most recent updates, followed by the clipped area of the Suisun Marsh Protection Plan Boundary, and finally the older version of the modern baylands. Use this file for the most up to date current modern baylands file and clip future areas from this data set. The June 2014 tidal marsh only dataset is also up to date.

Appendix F. Delta Adapts Inundation Polygon Identification Method

Inundation polygons

Goal: Create .shp file with separate polygons for Delta regions within elevation ranges based on new aggregate LIDAR data.

- 25-30 overlapping bands: <1ft, 1-2ft, 1-3ft, 1-4ft, … , >25 ft.
- Only the <1ft and >25ft bands are NOT overlapping with any other polygons.
- Still need to clip data to islands once we figure out which are "true" islands, etc.

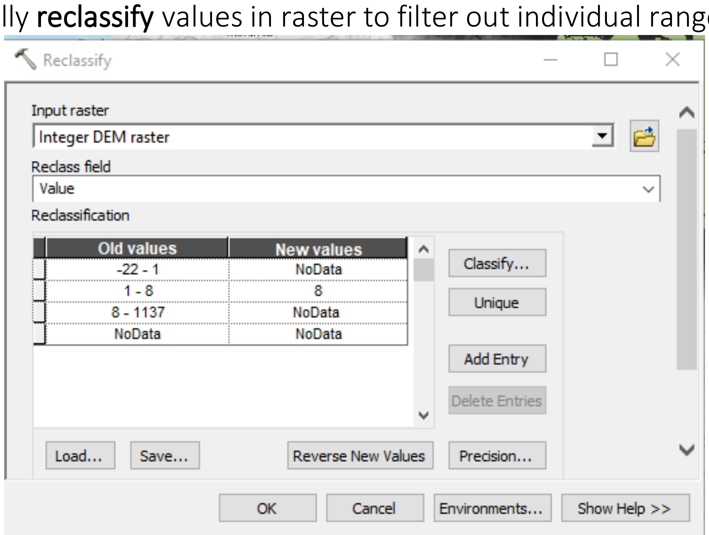
20-21 Feb 2020

Creating separate rasters from elevation raster for the data, then converting into polygons.

1. First go to Customize > Extensions and check 3D analyst and Spatial Analyst (otherwise tools/functions won't work)
2. Use **Int** function to convert data in 100ftDEM.tif to integers (otherwise data cannot be reclassified)

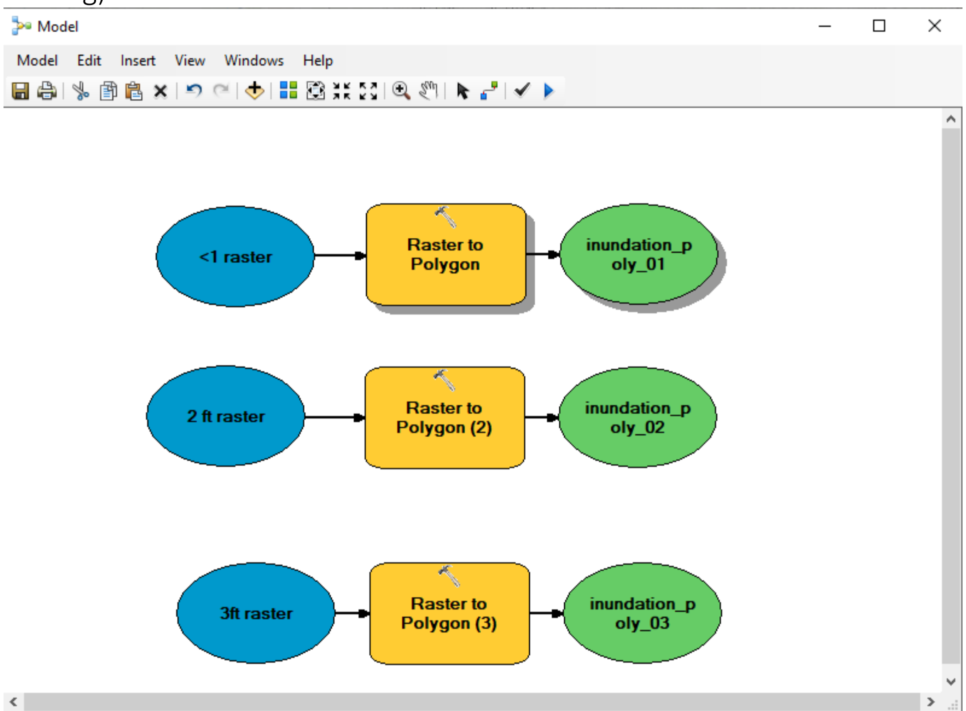
Use ModelBuilder for steps 3-5:

3. Manually **reclassify** values in raster to filter out individual ranges one at a time:

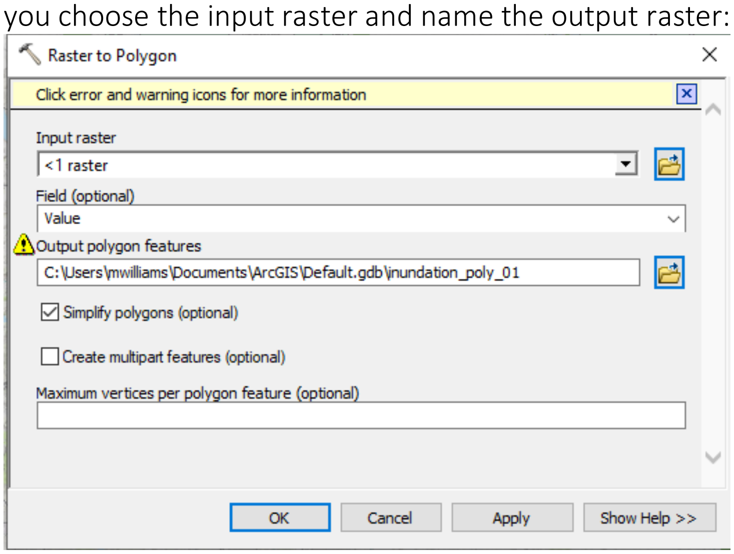


Assign "NoData" to all data you don't want featured in the polygon. Here we only want elevation values between 1 and 8, which are assigned to a constant value of 8 to indicate the elevation band category.

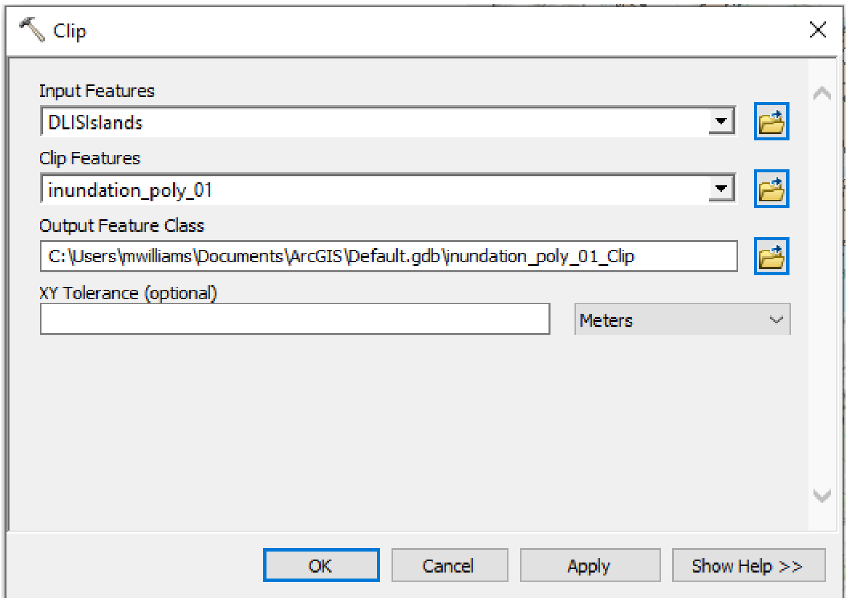
4. Convert **rasters to polygons** (used Model Builder to simplify process and minimize clicking):



Double-clicking the yellow raster to polygon box yields the following dialog box where you choose the input raster and name the output raster:

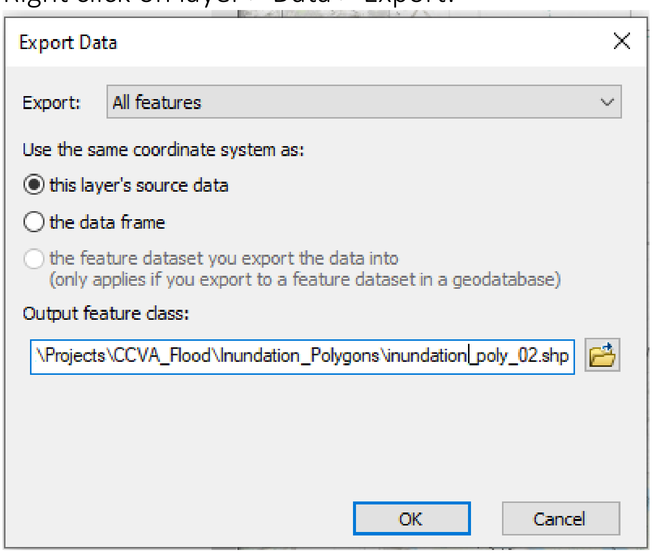


5. **Clip** island layers using DLISIslands.shp file
    a. Use "Clip" tool to clip each elevation polygon to island polygons and preserve data:



Note: applying this function also cut out all of the waterways from the polygons.

6. **Export/save** individual clipped .shp files for each band
   a. Right click on layer > Data > Export:



Currently saved under G:\Projects\CCVA_Flood\Inundation_Polygons

- Naming convention: inundation_poly_01 = polygon for all areas <1ft elevation, inundation_poly_02 = polygon for all areas between 1-2ft elevation, etc.
- Island_clipped_elevation_polygons: folder containing all of the clipped polygons up to 130 ft.
- Inundation_polygons.mxd map file contains models used to create shape files. Within the toolbox_inundation_polys.tbx file there are three models:
  - Model: polygons <1 - 50 ft

- Model1: polygons 51-90ft
- Model2: polygons 91- >130ft

To export multiple files in the geodatabase at once:

a. *Catalog > right click on default geodatabase > export > to shapefile…*
b. *Select files to export as shapefiles*

Appendix G. Flood Exposure by Tract

Table G-1. Flood Exposure by Tract ; Probabilistic Scenarios

*Asterisks note Tracts sensitive to San Joaquin River inflow assumptions at a given scenario. These tracts would be less likely to flood if San Joaquin inflows are reduced by upstream channel capacity limitations. See Section 4.3 of the Flood Exposure Technical Memo for additional details.

Island or Tract Name	M0	M5	M6	M7
ATLAS TRACT	<0.5%	<0.5%	<0.5%	<0.5%
BACON ISLAND	<0.5%	<0.5%	2-10%	10%
BETHEL ISLAND	<0.5%	<0.5%	<0.5%	2-10%
BISHOP TRACT/DLIS-14	<0.5%	<0.5%	<0.5%	0.5-1%
BIXLER TRACT	<0.5%	<0.5%	0.5-1%	10%
BOULDIN ISLAND	<0.5%	<0.5%	1-2%	10%
BRACK TRACT	<0.5%	<0.5%	<0.5%	2-10%
BRADFORD ISLAND	<0.5%	<0.5%	2-10%	10%
BRANNAN-ANDRUS	<0.5%	<0.5%	1-2%	10%
BRENTWOOD AREA	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
BYRON TRACT	<0.5%	<0.5%	<0.5%	1-2%
CACHE HAAS AREA	<0.5%	<0.5%	<0.5%	<0.5%
CANAL RANCH TRACT	<0.5%	<0.5%	0.5-1%	2-10%
CENTRAL STOCKTON NORTH	<0.5%	<0.5%	<0.5%	2-10%
CENTRAL STOCKTON SOUTH	<0.5%	<0.5%	2-10%*	10%*
CLIFTON COURT FOREBAY	<0.5%	<0.5%	<0.5%	2-10%
CONEY ISLAND	<0.5%	<0.5%	2-10%	10%
DEAD HORSE ISLAND	<0.5%	<0.5%	<0.5%	1-2%
DISCOVERY BAY	<0.5%	<0.5%	<0.5%	2-10%
DISCOVERY BAY AREA NORTH	<0.5%	<0.5%	<0.5%	<0.5%

Island or Tract Name	M0	M5	M6	M7
DISCOVERY BAY AREA SOUTH	<0.5%	<0.5%	<0.5%	2-10%
DLIS-01 (PITTSBURG AREA) NORTH	<0.5%	0.5-1%	2-10%	10%
DLIS-01 (PITTSBURG AREA) SOUTH	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-02 (ANTIOCH AREA) NORTH	2-10%	10%	10%	10%
DLIS-02 (ANTIOCH AREA) SOUTH	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-06 (OAKLEY AREA)	0.5-1%	2-10%	10%	10%
DLIS-07 (KNIGHTSEN AREA)	<0.5%	<0.5%	<0.5%	2-10%
DLIS-08 (DISCOVERY BAY AREA)	<0.5%	<0.5%	<0.5%	<0.5%
DLIS-09 (BYRON AREA)	<0.5%	<0.5%	<0.5%	2-10%
DLIS-10	<0.5%	<0.5%	<0.5%	0.5-1%
DLIS-15	<0.5%	<0.5%	<0.5%	1-2%
DLIS-16 (LODI)	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-17	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-18	<0.5%	<0.5%	1-2%	10%
DLIS-21	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-22 (RIO VISTA)	2-10%	2-10%	10%	10%
DLIS-25	2-10%	10%	10%	10%
DLIS-26 (MORROW ISLAND)	2-10%	10%	10%	10%
DLIS-27	0.5-1%	2-10%	10%	10%
DLIS-28	2-10%	10%	10%	10%
DLIS-29	2-10%	10%	10%	10%
DLIS-30	10%	10%	10%	10%
DLIS-31 (GARABALDI UNIT)	10%	10%	10%	10%
DLIS-32	10%	10%	10%	10%
DLIS-33	10%	10%	10%	10%
DLIS-34	2-10%	10%	10%	10%
DLIS-35	2-10%	10%	10%	10%
DLIS-36	10%	10%	10%	10%
DLIS-37 (CHADBOURNE AREA)	2-10%	10%	10%	10%

Island or Tract Name	M0	M5	M6	M7
DLIS-38	<0.5%	<0.5%	<0.5%	2-10%
DLIS-39	10%	10%	10%	10%
DLIS-40	2-10%	2-10%	10%	10%
DLIS-41 (JOICE ISLAND AREA)	10%	10%	10%	10%
DLIS-42 (PEYTONIA ECO PRSRV)	1-2%	2-10%	10%	10%
DLIS-43 (POTRERO HILLS AREA)	0.5-1%	2-10%	10%	10%
DLIS-44 (HILL SLOUGH UNIT)	10%	10%	10%	10%
DLIS-45	10%	10%	10%	10%
DLIS-46	1-2%	2-10%	10%	10%
DLIS-47	1-2%	2-10%	10%	10%
DLIS-48	10%	10%	10%	10%
DLIS-49	1-2%	2-10%	10%	10%
DLIS-50	10%	10%	10%	10%
DLIS-51	2-10%	2-10%	10%	10%
DLIS-52	2-10%	10%	10%	10%
DLIS-53	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-54	10%	10%	10%	10%
DLIS-55	2-10%	10%	10%	10%
DLIS-56	10%	10%	10%	10%
DLIS-57	0.5-1%	2-10%	10%	10%
DLIS-59	10%	10%	10%	10%
DLIS-62	<0.5%	0.5-1%	2-10%	10%
DLIS-63 (GRIZZLY ISLAND AREA)	10%	10%	10%	10%
DLIS-64	<0.5%	<0.5%	1-2%	10%
DREXLER POCKET	0.5-1%	0.5-1%	2-10%	10%
DREXLER TRACT	<0.5%	<0.5%	2-10%	10%
DUTCH SLOUGH	<0.5%	<0.5%	<0.5%	2-10%
EGBERT TRACT	<0.5%	<0.5%	<0.5%	1-2%
EHRHEARDT CLUB	<0.5%	<0.5%	0.5-1%	2-10%
EMPIRE TRACT	<0.5%	<0.5%	0.5-1%	10%
FABIAN TRACT	<0.5%	<0.5%	0.5-1%*	2-10%*
FAY ISLAND	<0.5%	0.5-1%	2-10%	10%
GLANVILLE	<0.5%	<0.5%	<0.5%	<0.5%
GLIDE DISTRICT	<0.5%	<0.5%	<0.5%	0.5-1%

Island or Tract Name	M0	M5	M6	M7
GRAND ISLAND	<0.5%	<0.5%	<0.5%	<0.5%
HASTINGS TRACT	<0.5%	<0.5%	<0.5%	1-2%
HOLLAND TRACT	<0.5%	<0.5%	0.5-1%	10%
HOLT STATION	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
HONKER BAY	10%	10%	10%	10%
HONKER LAKE TRACT	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
HOTCHKISS TRACT	<0.5%	<0.5%	<0.5%	2-10%
JERSEY ISLAND	<0.5%	<0.5%	1-2%	10%
JONES TRACT (LOWER AND UPPER)	<0.5%	<0.5%	1-2%	10%
KASSON DISTRICT	1-2%	1-2%	2-10%	10%
KING ISLAND	<0.5%	<0.5%	0.5-1%	10%
LIBBY MCNEIL	<0.5%	<0.5%	<0.5%	<0.5%
LISBON DISTRICT	<0.5%	<0.5%	<0.5%	<0.5%
LITTLE EGBERT TRACT	2-10%	2-10%	10%	10%
LOWER ROBERTS ISLAND	<0.5%	<0.5%	<0.5%	1-2%
MAINTENANCE AREA 9 NORTH	<0.5%	<0.5%	<0.5%	0.5-1%
MAINTENANCE AREA 9 SOUTH	<0.5%	<0.5%	<0.5%	<0.5%
MANDEVILLE ISLAND	<0.5%	<0.5%	1-2%	10%
MCCORMACK-WILLIAMSON TRACT	2-10%	2-10%	2-10%	10%
MCDONALD ISLAND	<0.5%	<0.5%	<0.5%	2-10%
MCMULLIN RANCH	1-2%	1-2%	2-10%	10%
MEDFORD ISLAND	<0.5%	<0.5%	0.5-1%	10%
MEIN'S LANDING	<0.5%	1-2%	2-10%	10%
MERRITT ISLAND	<0.5%	<0.5%	<0.5%	0.5-1%
MIDDLE & UPPER ROBERTS ISLAND	1-2%	1-2%	2-10%	10%
MONTEZUMA HILLS	<0.5%	<0.5%	<0.5%	<0.5%
MOSSDALE ISLAND	1-2%	1-2%	2-10%	10%
MOUNTAIN HOUSE	<0.5%	<0.5%	1-2%	2-10%
NETHERLANDS	<0.5%	<0.5%	<0.5%	<0.5%
NEW HOPE TRACT	0.5-1%	0.5-1%	1-2%	2-10%

Island or Tract Name	M0	M5	M6	M7
NORTH STOCKTON	<0.5%	<0.5%	<0.5%	0.5-1%
PALM-ORWOOD	<0.5%	<0.5%	0.5-1%	10%
PARADISE JUNCTION	1-2%	1-2%	2-10%	10%
PEARSON DISTRICT	<0.5%	<0.5%	<0.5%	<0.5%
PESCADERO DISTRICT	1-2%	1-2%*	2-10%*	10%*
PETERS POCKET	<0.5%	<0.5%	<0.5%	0.5-1%
PICO-NAGLEE	<0.5%	<0.5%	0.5-1%*	2-10%*
PROSPECT ISLAND	2-10%	2-10%	10%	10%
QUIMBY ISLAND	<0.5%	<0.5%	0.5-1%	10%
RANDALL ISLAND	<0.5%	<0.5%	<0.5%	<0.5%
RECLAMATION DISTRICT 17	<0.5%	<0.5%	1-2%*	2-10%*
RINDGE TRACT	<0.5%	<0.5%	1-2%	10%
RIO BLANCO TRACT	<0.5%	<0.5%	<0.5%	2-10%
RIVER ISLANDS	<0.5%	<0.5%	1-2%*	2-10%*
RIVER JUNCTION	1-2%	1-2%	2-10%	10%
ROUGH AND READY ISLAND	<0.5%	<0.5%	<0.5%	<0.5%
RYER ISLAND	<0.5%	<0.5%	<0.5%	<0.5%
SHERMAN ISLAND	<0.5%	<0.5%	<0.5%	2-10%
SHIMA TRACT	<0.5%	<0.5%	<0.5%	2-10%
SHIN KEE TRACT	<0.5%	<0.5%	2-10%	10%
STARK TRACT	0.5-1%	0.5-1%	2-10%	10%
STATEN ISLAND	<0.5%	<0.5%	0.5-1%	10%
STEWART TRACT	0.5-1%	0.5-1%	2-10%	10%
SUISUN WEST HILLS	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
SUMMER LAKE	<0.5%	<0.5%	<0.5%	0.5-1%
SUNRISE CLUB	2-10%	10%	10%	10%
SUTTER ISLAND	<0.5%	<0.5%	<0.5%	<0.5%
TERMINOUS TRACT	<0.5%	<0.5%	1-2%	10%
TWITCHELL ISLAND	<0.5%	<0.5%	2-10%	10%
TYLER ISLAND	<0.5%	<0.5%	2-10%	10%
UNION ISLAND EAST	<0.5%	<0.5%	2-10%	2-10%
UNION ISLAND WEST	<0.5%	<0.5%	<0.5%	2-10%*
UPPER ANDRUS ISLAND	<0.5%	<0.5%	0.5-1%	2-10%
VEALE TRACT	<0.5%	<0.5%	0.5-1%	10%

Island or Tract Name	M0	M5	M6	M7
VENICE ISLAND	<0.5%	<0.5%	1-2%	10%
VICTORIA ISLAND	<0.5%	<0.5%	0.5-1%	2-10%
WALNUT GROVE	<0.5%	<0.5%	<0.5%	<0.5%
WALTHALL	0.5-1%	0.5-1%	2-10%	10%
WEBB TRACT	<0.5%	<0.5%	2-10%	10%
WERNER	<0.5%	<0.5%	0.5-1%	10%
WEST SACRAMENTO NORTH	<0.5%	<0.5%	<0.5%	<0.5%
WEST SACRAMENTO SOUTH	<0.5%	<0.5%	<0.5%	<0.5%
WETHERBEE LAKE	0.5-1%	0.5-1%	2-10%	10%
WOODWARD ISLAND	<0.5%	<0.5%	0.5-1%	10%
WRIGHT-ELMWOOD TRACT	<0.5%	<0.5%	<0.5%	2-10%
YOLANO	<0.5%	<0.5%	<0.5%	<0.5%

Table G-2. Flood Exposure by Tract; Deterministic Scenarios
*Asterisks note Tracts sensitive to San Joaquin River inflow assumptions at a given scenario. These tracts would be less likely to flood if San Joaquin inflows are reduced by upstream channel capacity limitations. See Section 4.3 of the Flood Exposure Technical Memo for additional details.

Island or Tract Name	M0	M1	M2	M3	M4
ATLAS TRACT	No flooding	No flooding	No flooding	No flooding	No flooding
BACON ISLAND	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
BETHEL ISLAND	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
BISHOP TRACT/DLIS-14	No flooding	No flooding	No flooding	No flooding	Flooding Mitigable
BIXLER TRACT	No flooding	No flooding	No flooding	Flooding	Flooding
BOULDIN ISLAND	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
BRACK TRACT	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
BRADFORD ISLAND	No flooding	No flooding	Flooding	Flooding	Flooding

Island or Tract Name	M0	M1	M2	M3	M4
BRANNAN-ANDRUS	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
BRENTWOOD AREA	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
BYRON TRACT	No flooding	No flooding	No flooding	No flooding	Flooding
CACHE HAAS AREA	No flooding	No flooding	No flooding	No flooding	No flooding
CANAL RANCH TRACT	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
CENTRAL STOCKTON NORTH	No flooding	No flooding	No flooding	No flooding	Flooding
CENTRAL STOCKTON SOUTH	No flooding	No flooding	Flooding*	Flooding	Flooding
CLIFTON COURT FOREBAY	No flooding	No flooding	No flooding	No flooding	Flooding
CONEY ISLAND	No flooding	No flooding	Flooding	Flooding	Flooding
DEAD HORSE ISLAND	No flooding	No flooding	No flooding	No flooding	Flooding
DISCOVERY BAY	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
DISCOVERY BAY AREA NORTH	No flooding	No flooding	No flooding	No flooding	No flooding
DISCOVERY BAY AREA SOUTH	No flooding	No flooding	No flooding	No flooding	Flooding
DLIS-01 (PITTSBURG AREA) NORTH	No flooding	Flooding Mitigable	Flooding	Flooding	Flooding
DLIS-01 (PITTSBURG AREA) SOUTH	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*

Island or Tract Name	M0	M1	M2	M3	M4
DLIS-02 (ANTIOCH AREA) NORTH	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-02 (ANTIOCH AREA) SOUTH	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-06 (OAKLEY AREA)	No flooding	Flooding Mitigable	Flooding	Flooding	Flooding
DLIS-07 (KNIGHTSEN AREA)	No flooding	No flooding	No flooding	No flooding	Flooding
DLIS-08 (DISCOVERY BAY AREA)	No flooding	No flooding	No flooding	No flooding	No flooding
DLIS-09 (BYRON AREA)	No flooding	No flooding	No flooding	No flooding	Flooding
DLIS-10	No flooding	No flooding	No flooding	No flooding	Flooding Mitigable
DLIS-15	No flooding	No flooding	No flooding	No flooding	Flooding
DLIS-16 (LODI)	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-17	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-18	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
DLIS-21	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-22 (RIO VISTA)	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-25	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-26 (MORROW ISLAND)	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-27	No flooding	Flooding Mitigable	Flooding	Flooding	Flooding
DLIS-28	Flooding	Flooding	Flooding	Flooding	Flooding

Island or Tract Name	M0	M1	M2	M3	M4
DLIS-29	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-30	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-31 (GARABALDI UNIT)	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-32	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-33	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-34	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-35	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-36	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-37 (CHADBOURNE AREA)	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-38	No flooding	No flooding	No flooding	No flooding	Flooding
DLIS-39	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-40	Flooding Mitigable	Flooding	Flooding	Flooding	Flooding
DLIS-41 (JOICE ISLAND AREA)	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-42 (PEYTONIA ECO PRSRV)	Flooding Mitigable	Flooding	Flooding	Flooding	Flooding
DLIS-43 (POTRERO HILLS AREA)	No flooding	Flooding Mitigable	Flooding	Flooding	Flooding
DLIS-44 (HILL SLOUGH UNIT)	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-45	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-46	Flooding Mitigable	Flooding	Flooding	Flooding	Flooding
DLIS-47	Flooding Mitigable	Flooding	Flooding	Flooding	Flooding
DLIS-48	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-49	Flooding Mitigable	Flooding	Flooding	Flooding	Flooding
DLIS-50	Flooding	Flooding	Flooding	Flooding	Flooding

Island or Tract Name	M0	M1	M2	M3	M4
DLIS-51	Flooding Mitigable	Flooding	Flooding	Flooding	Flooding
DLIS-52	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-53	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
DLIS-54	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-55	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-56	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-57	No flooding	Flooding Mitigable	Flooding	Flooding	Flooding
DLIS-59	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-62	No flooding	No flooding	Flooding	Flooding	Flooding
DLIS-63 (GRIZZLY ISLAND AREA)	Flooding	Flooding	Flooding	Flooding	Flooding
DLIS-64	No flooding	No flooding	Flooding	Flooding	Flooding
DREXLER POCKET	No flooding	No flooding	Flooding	Flooding	Flooding
DREXLER TRACT	No flooding	No flooding	Flooding	Flooding	Flooding
DUTCH SLOUGH	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
EGBERT TRACT	No flooding	No flooding	No flooding	No flooding	Flooding Mitigable
EHRHEARDT CLUB	No flooding	No flooding	No flooding	No flooding	Flooding
EMPIRE TRACT	No flooding	No flooding	No flooding	Flooding	Flooding
FABIAN TRACT	No flooding	No flooding	No flooding	No flooding	Flooding*
FAY ISLAND	No flooding	No flooding	Flooding	Flooding	Flooding
GLANVILLE	No flooding	No flooding	No flooding	No flooding	No flooding
GLIDE DISTRICT	No flooding	No flooding	No flooding	No flooding	No flooding
GRAND ISLAND	No flooding	No flooding	No flooding	No flooding	No flooding

Island or Tract Name	M0	M1	M2	M3	M4
HASTINGS TRACT	No flooding	No flooding	No flooding	No flooding	Flooding Mitigable
HOLLAND TRACT	No flooding	No flooding	No flooding	Flooding	Flooding
HOLT STATION	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
HONKER BAY	Flooding	Flooding	Flooding	Flooding	Flooding
HONKER LAKE TRACT	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
HOTCHKISS TRACT	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
JERSEY ISLAND	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
JONES TRACT (LOWER AND UPPER)	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
KASSON DISTRICT	Flooding	Flooding	Flooding	Flooding	Flooding
KING ISLAND	No flooding	No flooding	No flooding	Flooding	Flooding
LIBBY MCNEIL	No flooding	No flooding	No flooding	No flooding	No flooding
LISBON DISTRICT	No flooding	No flooding	No flooding	No flooding	No flooding
LITTLE EGBERT TRACT	Flooding	Flooding	Flooding	Flooding	Flooding
LOWER ROBERTS ISLAND	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
MAINTENANCE AREA 9 NORTH	No flooding	No flooding	No flooding	No flooding	No flooding
MAINTENANCE AREA 9 SOUTH	No flooding	No flooding	No flooding	No flooding	No flooding
MANDEVILLE ISLAND	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
MCCORMACK-WILLIAMSON TRACT	Flooding	Flooding	Flooding	Flooding	Flooding

Island or Tract Name	M0	M1	M2	M3	M4
MCDONALD ISLAND	No flooding	No flooding	No flooding	Flooding	Flooding
MCMULLIN RANCH	Flooding	Flooding	Flooding	Flooding	Flooding
MEDFORD ISLAND	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
MEIN'S LANDING	No flooding	Flooding Mitigable	Flooding	Flooding	Flooding
MERRITT ISLAND	No flooding	No flooding	No flooding	No flooding	No flooding
MIDDLE & UPPER ROBERTS ISLAND	Flooding Mitigable	Flooding	Flooding	Flooding	Flooding
MONTEZUMA HILLS	No flooding	No flooding	No flooding	No flooding	No flooding
MOSSDALE ISLAND	Flooding	Flooding	Flooding	Flooding	Flooding
MOUNTAIN HOUSE	No flooding	No flooding	Flooding	Flooding	Flooding
NETHERLANDS	No flooding	No flooding	No flooding	No flooding	No flooding
NEW HOPE TRACT	No flooding	No flooding	Flooding	Flooding	Flooding
NORTH STOCKTON	No flooding	No flooding	No flooding	No flooding	No flooding
PALM-ORWOOD	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
PARADISE JUNCTION	Flooding	Flooding	Flooding	Flooding	Flooding
PEARSON DISTRICT	No flooding	No flooding	No flooding	No flooding	No flooding
PESCADERO DISTRICT	Flooding	Flooding	Flooding	Flooding	Flooding
PETERS POCKET	No flooding	No flooding	No flooding	No flooding	No flooding
PICO-NAGLEE	No flooding	No flooding	No flooding	No flooding	Flooding*

Island or Tract Name	M0	M1	M2	M3	M4
PROSPECT ISLAND	Flooding	Flooding	Flooding	Flooding	Flooding
QUIMBY ISLAND	No flooding	No flooding	No flooding	Flooding	Flooding
RANDALL ISLAND	No flooding	No flooding	No flooding	No flooding	No flooding
RECLAMATION DISTRICT 17	No flooding	No flooding	Flooding*	Flooding*	Flooding*
RINDGE TRACT	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
RIO BLANCO TRACT	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
RIVER ISLANDS	No flooding	No flooding	Flooding	Flooding*	Flooding*
RIVER JUNCTION	Flooding	Flooding	Flooding	Flooding	Flooding
ROUGH AND READY ISLAND	No flooding	No flooding	No flooding	No flooding	No flooding
RYER ISLAND	No flooding	No flooding	No flooding	No flooding	No flooding
SHERMAN ISLAND	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
SHIMA TRACT	No flooding	No flooding	No flooding	No flooding	Flooding
SHIN KEE TRACT	No flooding	No flooding	Flooding	Flooding	Flooding
STARK TRACT	No flooding	No flooding	Flooding	Flooding	Flooding
STATEN ISLAND	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
STEWART TRACT	No flooding	No flooding	Flooding	Flooding	Flooding
SUISUN WEST HILLS	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*	*Not modeled*
SUMMER LAKE	No flooding	No flooding	No flooding	No flooding	Flooding Mitigable
SUNRISE CLUB	Flooding	Flooding	Flooding	Flooding	Flooding
SUTTER ISLAND	No flooding	No flooding	No flooding	No flooding	No flooding

Island or Tract Name	M0	M1	M2	M3	M4
TERMINOUS TRACT	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
TWITCHELL ISLAND	No flooding	No flooding	Flooding	Flooding	Flooding
TYLER ISLAND	No flooding	No flooding	Flooding	Flooding	Flooding
UNION ISLAND EAST	No flooding	No flooding	Flooding	Flooding	Flooding
UNION ISLAND WEST	No flooding	No flooding	No flooding	No flooding	Flooding*
UPPER ANDRUS ISLAND	No flooding	No flooding	No flooding	No flooding	Flooding
VEALE TRACT	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
VENICE ISLAND	No flooding	No flooding	Flooding Mitigable	Flooding	Flooding
VICTORIA ISLAND	No flooding	No flooding	No flooding	Flooding	Flooding
WALNUT GROVE	No flooding	No flooding	No flooding	No flooding	No flooding
WALTHALL	No flooding	No flooding	Flooding	Flooding	Flooding
WEBB TRACT	No flooding	No flooding	Flooding	Flooding	Flooding
WERNER	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding
WEST SACRAMENTO NORTH	No flooding	No flooding	No flooding	No flooding	No flooding
WEST SACRAMENTO SOUTH	No flooding	No flooding	No flooding	No flooding	No flooding
WETHERBEE LAKE	No flooding	No flooding	Flooding	Flooding	Flooding
WOODWARD ISLAND	No flooding	No flooding	No flooding	Flooding Mitigable	Flooding

Island or Tract Name	M0	M1	M2	M3	M4
WRIGHT-ELMWOOD TRACT	No flooding	No flooding	No flooding	No flooding	Flooding
YOLANO	No flooding	No flooding	No flooding	No flooding	No flooding

Table G-3. List of all Islands or Tracts considered for flood modeling

Island or Tract Name	Caveat
ATLAS TRACT	
BACON ISLAND	
BETHEL ISLAND	
BISHOP TRACT/DLIS-14	
BIXLER TRACT	
BOULDIN ISLAND	
BRACK TRACT	
BRADFORD ISLAND	
BRANNAN-ANDRUS	
BRENTWOOD AREA	*Not Modeled*
BYRON TRACT	
CACHE HAAS AREA	
CANAL RANCH TRACT	
CENTRAL STOCKTON NORTH	
CENTRAL STOCKTON SOUTH	Sensitive to SJR inflow assumptions at M2, M6, M7
CLIFTON COURT FOREBAY	

CONEY ISLAND	
DEAD HORSE ISLAND	
DISCOVERY BAY	
DISCOVERY BAY AREA NORTH	
DISCOVERY BAY AREA SOUTH	
DLIS-01 (PITTSBURG AREA) NORTH	
DLIS-01 (PITTSBURG AREA) SOUTH	*Not Modeled*
DLIS-02 (ANTIOCH AREA) NORTH	
DLIS-02 (ANTIOCH AREA) SOUTH	*Not Modeled*
DLIS-06 (OAKLEY AREA)	
DLIS-07 (KNIGHTSEN AREA)	
DLIS-08 (DISCOVERY BAY AREA)	
DLIS-09 (BYRON AREA)	
DLIS-10	
DLIS-15	
DLIS-16 (LODI)	*Not Modeled*
DLIS-17	*Not Modeled*
DLIS-18	
DLIS-21	*Not Modeled*
DLIS-22 (RIO VISTA)	
DLIS-25	
DLIS-26 (MORROW ISLAND)	
DLIS-27	
DLIS-28	
DLIS-29	
DLIS-30	
DLIS-31 (GARABALDI UNIT)	
DLIS-32	
DLIS-33	
DLIS-34	
DLIS-35	
DLIS-36	
DLIS-37 (CHADBOURNE AREA)	

DLIS-38	
DLIS-39	
DLIS-40	
DLIS-41 (JOICE ISLAND AREA)	
DLIS-42 (PEYTONIA ECO PRSRV)	
DLIS-43 (POTRERO HILLS AREA)	
DLIS-44 (HILL SLOUGH UNIT)	
DLIS-45	
DLIS-46	
DLIS-47	
DLIS-48	
DLIS-49	
DLIS-50	
DLIS-51	
DLIS-52	
DLIS-53	*Not Modeled*
DLIS-54	
DLIS-55	
DLIS-56	
DLIS-57	
DLIS-59	
DLIS-62	
DLIS-63 (GRIZZLY ISLAND AREA)	
DLIS-64	
DREXLER POCKET	
DREXLER TRACT	
DUTCH SLOUGH	
EGBERT TRACT	
EHRHEARDT CLUB	
EMPIRE TRACT	
FABIAN TRACT	Sensitive to SJR inflow assumptions at M4, M6, M7
FAY ISLAND	
GLANVILLE	
GLIDE DISTRICT	
GRAND ISLAND	
HASTINGS TRACT	

HOLLAND TRACT	
HOLT STATION	*Not Modeled*
HONKER BAY	
HONKER LAKE TRACT	*Not Modeled*
HOTCHKISS TRACT	
JERSEY ISLAND	
JONES TRACT (LOWER AND UPPER)	
KASSON DISTRICT	
KING ISLAND	
LIBBY MCNEIL	
LISBON DISTRICT	
LITTLE EGBERT TRACT	
LOWER ROBERTS ISLAND	
MAINTENANCE AREA 9 NORTH	
MAINTENANCE AREA 9 SOUTH	
MANDEVILLE ISLAND	
MCCORMACK-WILLIAMSON TRACT	
MCDONALD ISLAND	
MCMULLIN RANCH	
MEDFORD ISLAND	
MEIN'S LANDING	
MERRITT ISLAND	
MIDDLE & UPPER ROBERTS ISLAND	
MONTEZUMA HILLS	
MOSSDALE ISLAND	
MOUNTAIN HOUSE	
NETHERLANDS	
NEW HOPE TRACT	
NORTH STOCKTON	
PALM-ORWOOD	
PARADISE JUNCTION	
PEARSON DISTRICT	
PESCADERO DISTRICT	Sensitive to SJR inflow assumptions at M5, M6, M7

PETERS POCKET	
PICO-NAGLEE	Sensitive to SJR inflow assumptions at M4, M6, M7
PROSPECT ISLAND	
QUIMBY ISLAND	
RANDALL ISLAND	
RECLAMATION DISTRICT 17	Sensitive to SJR inflow assumptions at M2, M3, M4, M6, M7
RINDGE TRACT	
RIO BLANCO TRACT	
RIVER ISLANDS	Sensitive to SJR inflow assumptions at M3, M4, M6, M7
RIVER JUNCTION	
ROUGH AND READY ISLAND	
RYER ISLAND	
SHERMAN ISLAND	
SHIMA TRACT	
SHIN KEE TRACT	
STARK TRACT	
STATEN ISLAND	
STEWART TRACT	
SUISUN WEST HILLS	*Not Modeled*
SUMMER LAKE	
SUNRISE CLUB	
SUTTER ISLAND	
TERMINOUS TRACT	
TWITCHELL ISLAND	
TYLER ISLAND	
UNION ISLAND EAST	
UNION ISLAND WEST	Sensitive to SJR inflow assumptions at M4, M7
UPPER ANDRUS ISLAND	
VEALE TRACT	
VENICE ISLAND	
VICTORIA ISLAND	
WALNUT GROVE	
WALTHALL	
WEBB TRACT	

WERNER	
WEST SACRAMENTO NORTH	
WEST SACRAMENTO SOUTH	
WETHERBEE LAKE	
WOODWARD ISLAND	
WRIGHT-ELMWOOD TRACT	
YOLANO	