

San Francisquito Creek Integrated Floodplain Model Update

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List of Acronyms

Acronym	Description
AMC	Antecedent Moisture Condition
ATR	Agency Technical Review
BCDC	Bay Conservation and Development Commission
CDEC	California Data Exchange Center
CFD	Computational fluid dynamics
CFS	Cubic feet per second
CN	Curve Number
CTP	Cooperating Technical Partners
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HEC-HMS	Hydrologic Engineering Center's Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center’s River Analysis System
HEC-SSP	Hydrologic Engineering Center's Statistical Software Package
HSG	Hydrologic Soil Group
ICM	Integrated Catchment Model
LiDAR	Light detection and ranging
MRLC	Multl-Resolution Land Characteristics Consortium
MRMS	Multi-Resolution, Multi-Sensor
NEXRAD	Next Generation Weather Radar
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources and Conservation Service
NYE22	New Year’s Eve 2022
PAFB	Palo Alto Flood Basin
QPE	Quantitative Precipitation Estimate
SAFER Bay	Strategy to Advance Flood Protection, Ecosystems Restoration and Recreation along San Francisco Bay
SD	Storm drain
SDMP	Storm Drain Master Plan
SFCJPA	San Francisquito Creek Joint Powers Authority (also “JPA”)
SSURGO	Soil Survey Geographic Database
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey

1. Introduction

Schaaf & Wheeler has undertaken a comprehensive update of the San Francisquito Creek integrated floodplain model, developed previously using Innovyze ICM software. This update builds on prior efforts to more accurately map interior drainage floodplain extents and calibrate the model to reproduce recent flooding during the New Year's Eve 2022 (NYE22) storm event. The calibrated model can then be used to simulate overbank flooding during a variety of design storm events and map the resulting floodplains.

Flooding on December 31, 2022 and January 1, 2023 (NYE22) prompted a re-evaluation of Valley Water's HEC-RAS model for San Francisquito Creek based on observations made during the event and high-water marks recorded in its aftermath. In the flood's aftermath, the Valley Water model was calibrated and improved to reproduce creek spills observed during the flood event with in-channel conditions adjusted based on an August 2023 walk inside the creek from Middlefield Road to Highway 101, using recorded high-water marks and time-stamped photographic and video documentation of flooding conditions at or near the banks of the creeks.

Based on an integrated catchment model (ICM), Schaaf & Wheeler concluded that observed flooding characteristics, notably high-water marks, are markedly affected by the function of local storm drain systems (inlets, pipe, and pump stations) during the storm. At the time of the 2023 work, the HEC-RAS model did not incorporate local storm drain system functions, so replicating flood observations and high-water marks using only HEC-RAS would lead to a false calibration of the HEC-RAS model by having certain model parameters such as channel roughness or overflow coefficients explain observed behavior that was actually explained by storm drain infrastructure located away from the creek banks. Additional photographs and video further from the banks of the Creek were used to verify that the ICM reasonably reproduced flooding – which primarily occurred at the Pope-Chaucer bridge.

Since that effort was completed, planning and design of flood control improvements have continued using the updated, calibrated HEC-RAS model as a foundation. The US Army Corps of Engineers (USACE) has also completed their review and revision to the HEC-RAS model, releasing the updated "Agency Technical Review" (ATR) model, noting the ATR does not incorporate local storm drain infrastructure.

The results of the ATR model renewed interest in the effect of storm drain systems on the floodplain for larger storm events than NYE22, prompting this update to the independent integrated catchment model.

1.1 Scope of This Model Update

This effort is focused on evaluating the existing suite of models developed since the 2023 ICM update, and integrating the latest information into a comprehensive integrated catchment model. The scope of work documented by this report includes the following tasks.

1.1.1 Unify and Ground-Truth San Francisquito Creek ICM

- Replace the Menlo Park portion of the ICM with the recently completed portion of Menlo Park's storm drain system in ICM, which was a Menlo SAFER Bay task.
- Incorporate the ICM for the East Palo Alto storm drain system prepared by Sherwood Design Engineers as part of East Palo Alto SAFER Bay.

- Modify Palo Alto systems as necessary to improve modeling in the expanded 2D area, adding a small number of inlets and laterals. Most of Palo Alto's systems in the model were not modified from prior versions.
- Using LiDAR, aerial photography, field reconnaissance, and information furnished by Caltrans regarding their facilities, update the unified ICM to appropriately reflect ground conditions within the creek corridor U.S. Highway 101 right-of-way. This includes median barriers, soundwalls, cross-freeway drainage, pumping facilities, and other infrastructure or ground features that could affect the conveyance of spilled San Francisquito Creek floodwaters. (Note that walls and other barriers are assumed not to fail due to the force of floodwater or for other reasons because the updated floodplain mapping described herein is not performed to FEMA's Guidelines and Specifications.)
- Based on the local rainfall data for the NYE22 storm event used in the previous ICM calibration, the updated unified ICM is run to better replicate the NYE22 flood event. This provides a final check on the reasonableness of the ICM to faithfully replicate a significant discharge event. It is acknowledged that the NYE22 event may not have been large enough in magnitude to test the updated model representation of the Highway 101 corridor.
- Provide a unified flood depth map of San Francisquito Creek and its overbanks based on the modeled NYE22 event to the JPA and its member agencies.
- Reconcile the ICM until it provides a faithful representation of previously observed flooding during the NYE22 event.

1.1.2 Evaluate Design Project Discharge

- The reconciled ICM is used to prepare an existing conditions flood hazard map for the design (7,200 cfs) discharge at the USGS gage location at Stanford and coincident local rainfall-runoff throughout the watershed. A joint (combined) runoff event equivalent to approximately the 70-year return period is shown.
- Discharge hydrograph volume is also important to accurately map flood hazards within natural storage areas, for example, south of the Bayshore Freeway. The precipitation pattern from the Christmas 1955 storm, which remains the local rainfall of record and has historically been used for work in the greater Bay Area, is used as a basis to statistically balance a design storm pattern to local, updated rainfall statistics.
- A unified flood depth map of San Francisquito Creek and its overbanks based on the design 70-year (7,200 cfs peak) discharge event and coincident local runoff is included with this report.

Although this ICM update is a standalone effort, the ATR model was obtained to further update and validate the ICM and ensure that results are not vastly different. While the ATR model is the primary tool for evaluating San Francisquito Creek flood remediation projects, the independent ICM serves a broader purpose – encompassing both San Francisquito and Matadero Creeks, plus 2-dimensional floodplain areas and interior drainage systems (pipe networks, culverts, and ditches) outside of the two creeks. For this effort, the ATR model is considered the most recent representation of conditions within the San Francisquito Creek banks.

1.2 Other Model Uses

Beyond the scope of this effort, the updated ICM can be used for evaluations of planning and design alternatives for San Francisquito Creek, and evaluations of storm drainage infrastructure capacity improvements to remediate or reduce flood risk hazards.

The JPA's permission has also been received to utilize this model update as the basis for the interior drainage studies needed to complete SAFER Bay, both in Menlo Park and East Palo Alto, including responses to questions from regulatory authorities such as BCDC.

2. Model Development History

Hydrologic and hydraulic models for the San Francisquito Creek watershed were first developed in the late 1970s to support the initial FEMA Flood Insurance Study (FIS), with a Flood Insurance Rate Map (FIRM) issued in 1980. Valley Water archives indicate that the foundational HEC-2 models were modified in the early 1990s.

Following the February 1998 flood of record, the San Francisquito Creek Joint Powers Authority was formed to coordinate flood studies and improvements. Detailed HEC-RAS hydraulic models were developed during the early to mid-2000s and formally documented in a 2009 model calibration and verification report. Those models were calibrated against historical floods that occurred in 1955, 1958, 1962, 1982, and 1998.[1]

Valley Water completed a watershed-wide hydrology report in 2006 and 2007 that applied their new methodology at the time to estimate 50-year discharges in San Francisquito Creek, which were presented as "recommended design flows."[2] The recommended design flow for San Francisquito Creek at the USGS stream gage at Stanford was 8,900 cfs. Since then, updated studies identified errors in Bulletin 17B 'k' coefficients, and a 2020 "Design Flood Flow Manual" cites a 50-year peak flow at the USGS stream gage of 6,710 cfs.[3]

2.1 FEMA CTP Study

In 2019 Wood Rodgers and Schaaf & Wheeler completed an ICM for the San Francisquito Creek, Matadero Creek, Barron Creek, and Adobe Creek watersheds as part of a comprehensive watershed flood study performed by Valley Water and sponsored through FEMA's Cooperating Technical Partner (CTP) program. The 2019 ICM is the basis for the work described herein. That study was performed to FEMA Guidelines and Specifications, but no regulatory mapping changes have resulted from study results to date. The effective date on the FIRM remains February 19, 2014.

2.2 ICM and HEC-RAS Models Updated in 2023

In 2023 Schaaf & Wheeler updated the Valley Water HEC-RAS and the 2019 CTP ICM to reproduce spills from San Francisquito Creek that occurred during the New Years Eve 2022 storm event. At that time, cross sections in the HEC-RAS model were updated with survey data acquired by Valley Water staff, and roughness values were mapped based on observations

[1] Noble Consultants, "San Francisquito Creek Development and Calibration/Verification of Hydraulic Model," USACE San Francisco District, May 26, 2009.
[2] Santa Clara Valley Water District, "San Francisquito Creek Hydrology Report," April 2006, Revised December 2007.
[3] Santa Clara Valley Water District, "Design Flood Flow Manual for All District Watersheds," December 2020.

during a dry-season walk through the Creek from Alma Street to Highway 101. Roughness values were then calibrated to reproduce high water marks observed during the event at various locations, and video and photographic records of spills from the Creek into surrounding communities.

The updated HEC-RAS inputs were then transferred to the ICM, which included Palo Alto's storm drain networks and pump stations. That integrated model allows spill from San Francisquito Creek to interact with storm drain systems and was used as a basis for evaluating model performance based on photos and video of flooding further from the creek banks. The models were then updated iteratively to develop a better calibrated pair of models.

Each model serves a different purpose. The HEC-RAS model is most useful in the development of flood control projects, while the ICM allows for a more refined evaluation of overbank flood risks posed by spill from San Francisquito Creek.

The 2023 model updates were done as part of a third-party peer review of Valley Water's models and documented in a report titled "San Francisquito Creek HEC-RAS Model Third-Party Peer Review" (Schaaf & Wheeler, 2023).

2.3 Updated Agency Technical Review (ATR) Model

Since that 2023 effort was completed, WRA has begun work on flood control project design, and the US Army Corps of Engineers (USACE) has used the product of Schaaf & Wheeler's calibration work to create an expanded 100- and 500-year ATR model.

Schaaf & Wheeler obtained an updated San Francisquito Creek HEC-RAS Agency Technical Review (ATR) model in April 2026. Some differences in the updated ATR model, as noted in the HEC-RAS model description and in the provided USACE Memorandum ("Post-ATR Updates to the Existing Conditions Model for San Francisquito Creek CAP 205 Study"), are:

- Additional cross sections near Highway 101, using LiDAR topography.
- Greatly expanded 2D areas to cover additional 100- and 500-year flooding extents not reached by the NYE22 event.
- With expansion of the mesh area, USACE also included highway barriers as modifications to the terrain with finer mesh elements in their immediate vicinity.
- The updated ATR models appear to use the "High n" geometry, with channel roughness values increased. This may produce water levels at the high end of expectations.

2.4 SAFER Bay and East Palo Alto Models

Also, since the completion of NYE22 model calibrations, other projects have driven the development of interior drainage models covering Menlo Park and East Palo Alto.

In East Palo Alto, storm drain master plan (SDMP) models developed in MIKE URBAN software were recently imported to MIKE+ in support of the Ravenswood Four Corners Specific Plan. That modeling effort focused on the area surrounding Bay Road and updated model inputs for several improved systems and as-builts.

SAFER Bay is a regional initiative spearheaded by SFCJPA focused on protecting communities and critical infrastructure along the San Francisco Bay shoreline from rising sea levels and tidal flooding. ICMs were prepared including drainage areas, pipe systems, and pump stations tributary to the Ravenswood Slough and O'Conner Pump Station. Spills from San Francisquito Creek accumulate at Highway 101. Characteristics of the floodplain are defined by the spill rate, volume, and the capacity of East Palo Alto's and Menlo Park's storm drain systems in this area.

Updated ICM data from these recent efforts were included in this effort to improve the integrated San Francisquito Creek ICM. This effort does not explore the post-project conditions for SAFER Bay or the Ravenswood Precise Plan, as these projects are not expected to impact the fluvial San Francisquito Creek floodplains in any significant way. (Further details about direct tidal influence on flooding are provided herein.)

3. Hydrology and Boundary Conditions

The updated ICM evaluates hydrology and boundary conditions for three storm events:

- New Year's Eve 2022 (NYE22) for verification of model performance.
- A design storm event with a peak discharge at the Stanford USGS gage of approximately 7,200 cfs (70-year storm) at the direction of SFCJPA.
- A 100-year design storm event, which while not part of this scope, is important informationally to the SAFER Bay effort.

3.1 New Year's Eve 2022

No changes are made to precipitation inputs for the NYE22 event from prior work. Extensive data collection efforts informed the previously derived rainfall inputs to the model in low-lying urban areas. Those precipitation time series are shown in Figure 3-1, taken directly from Schaaf & Wheeler's report on third-party peer review efforts in 2024.

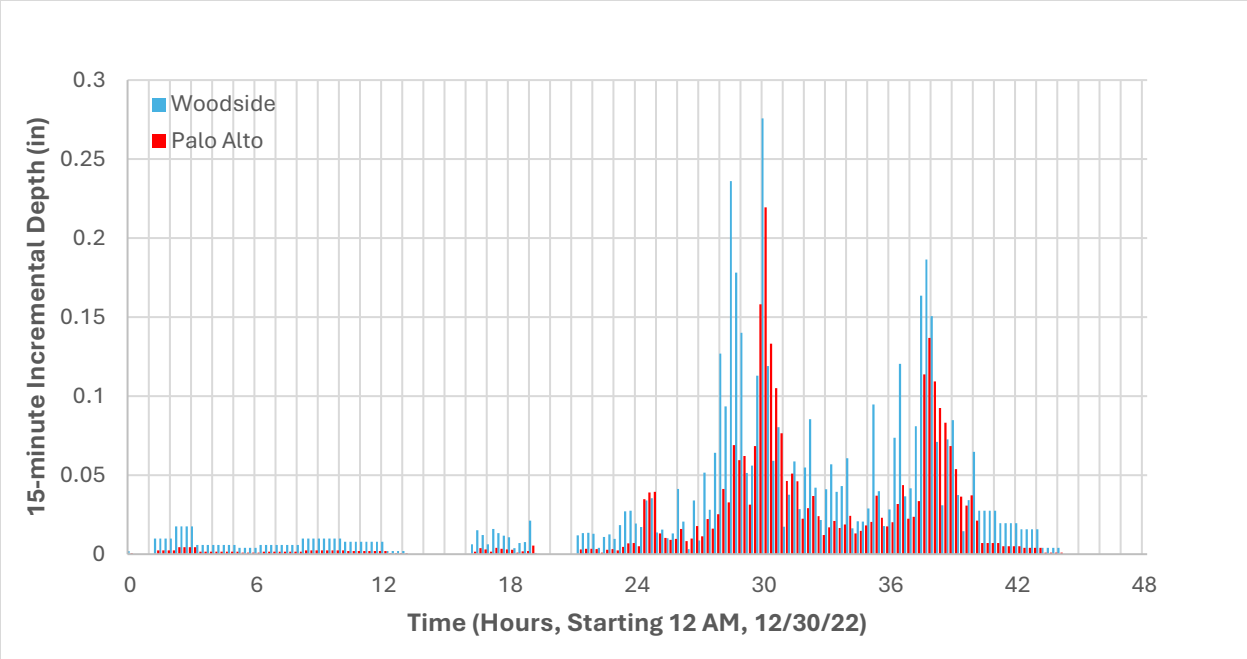


Figure 3-1: NYE22 Rainfall Timeseries Used in the ICM

3.2 Design Storm Events

Events added to the ICM for this effort are primarily characterized as “design storm” events – statistically balanced storms that represent a single return period for all durations used to balance the storm (e.g. 15-minute, 30-minute, 1-hour, 2-hour, etc). MetStat completed an analysis of precipitation gage data in multiple counties in the Bay Area, including San Mateo County and Santa Clara County. The gridded precipitation statistics layers from that analysis have finer spatial resolution and use additional gage data compared to the widely used NOAA ATLAS 14 precipitation-frequency estimates. The MetStat precipitation-frequency grids are used as the basis for developing balanced storms with a 15-minute interval for this study.

The design storm events for this modeling effort use the December 1955 storm event as a basis for constructing a realistic temporal distribution of statistical rainfall depths. This storm caused widespread flooding and is commonly used as a basis for design storm distributions in hydrologic studies across the region. To illustrate the process of developing a balanced design storm, the December 1955 storm event is shown in Figure 3-2 (data acquired from NOAA Climate Data Online system for Santa Clara County), along with a re-balanced hourly pattern matching local precipitation-frequency statistics.

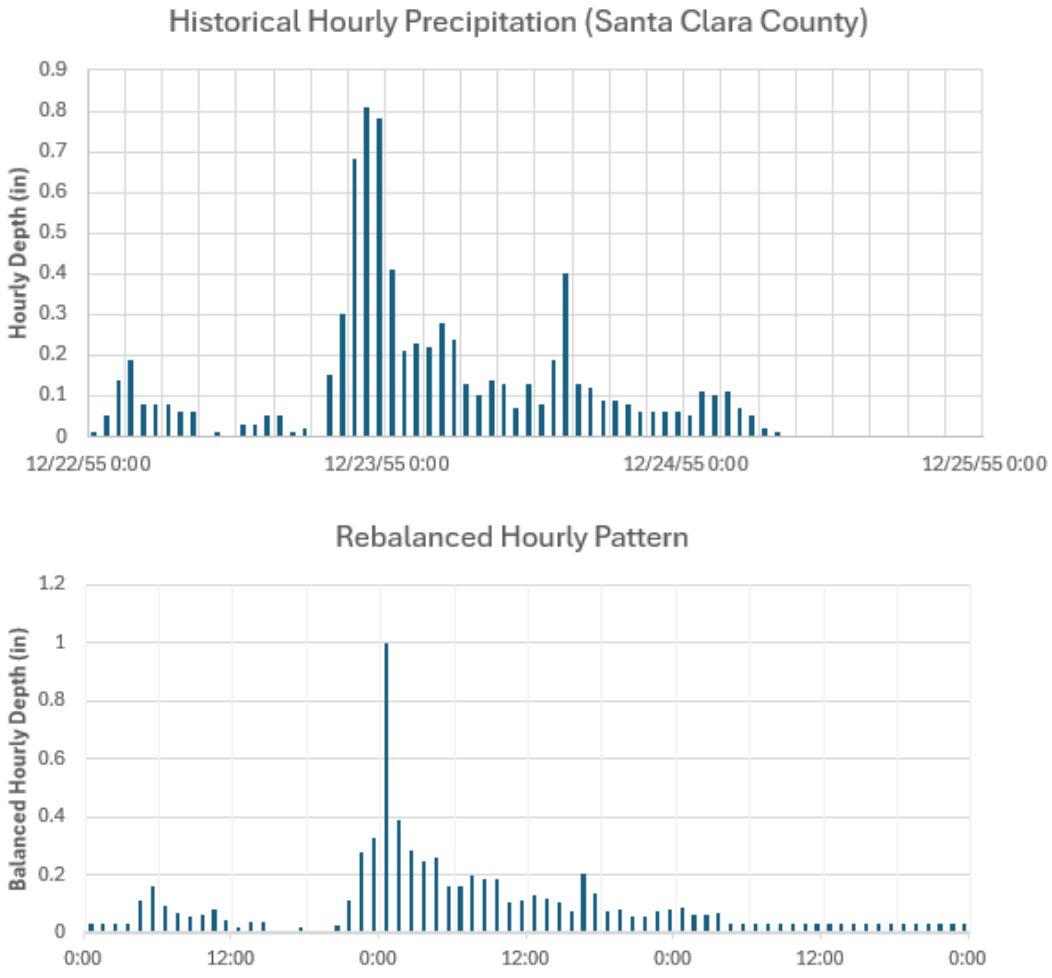


Figure 3-2: December 1955 Precipitation (Top) Rebalanced with Local Statistics (Bottom)

Further modifying the 1955 storm event with a 15-minute interval captures extreme short-duration rainfall intensities that can be a source of flooding in urban systems. An example of the design storm pattern for a 100-year event is shown in Figure 3-2, in this case from the Bear Creek subbasin.

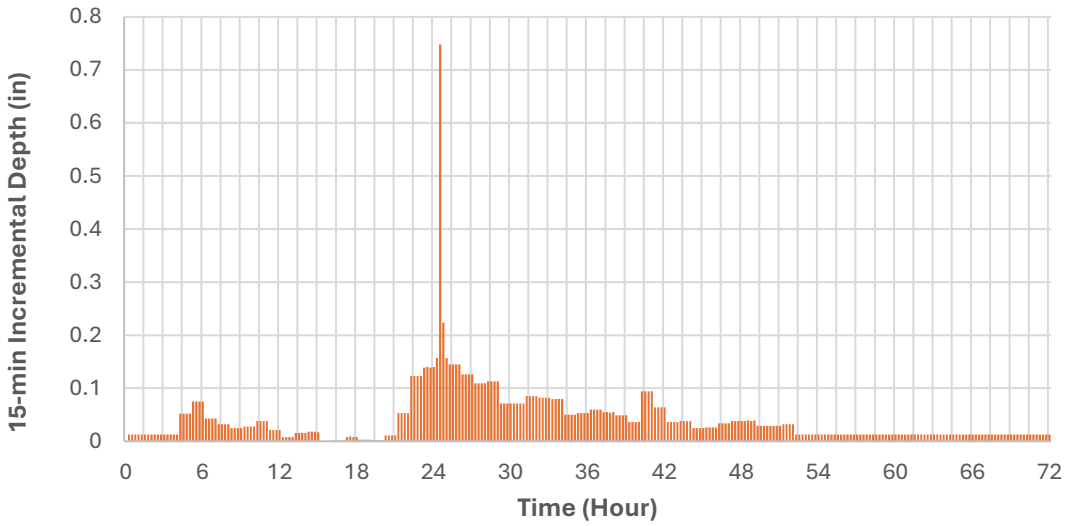


Figure 3-3: 100-year Design Storm Hyetograph for Bear Creek

SFCJPA is interested in evaluating a design storm with a peak discharge matching the 1998 flood of record (7,200 cfs) recorded by the USGS streamflow gage at Stanford. This requires an approximation of the return period associated with that event to construct balanced design storm events for combined hydrologic model input throughout the watershed.

The San Francisquito Creek stream gage (USGS Gage 11164500) has a drainage area of approximately 32 square miles. Gage data spanning the period between October 1930 and October 2023 were evaluated with Bulletin 17B methodology in HEC-SSP (Figure 3-3) as part of the 2023 model update. The Bulletin 17C methodology was evaluated then as well. However, the 17C method identified an excessive number of non-zero low outliers for the San Francisquito Creek gage: 41 low outliers with a threshold of 1,560 cfs.

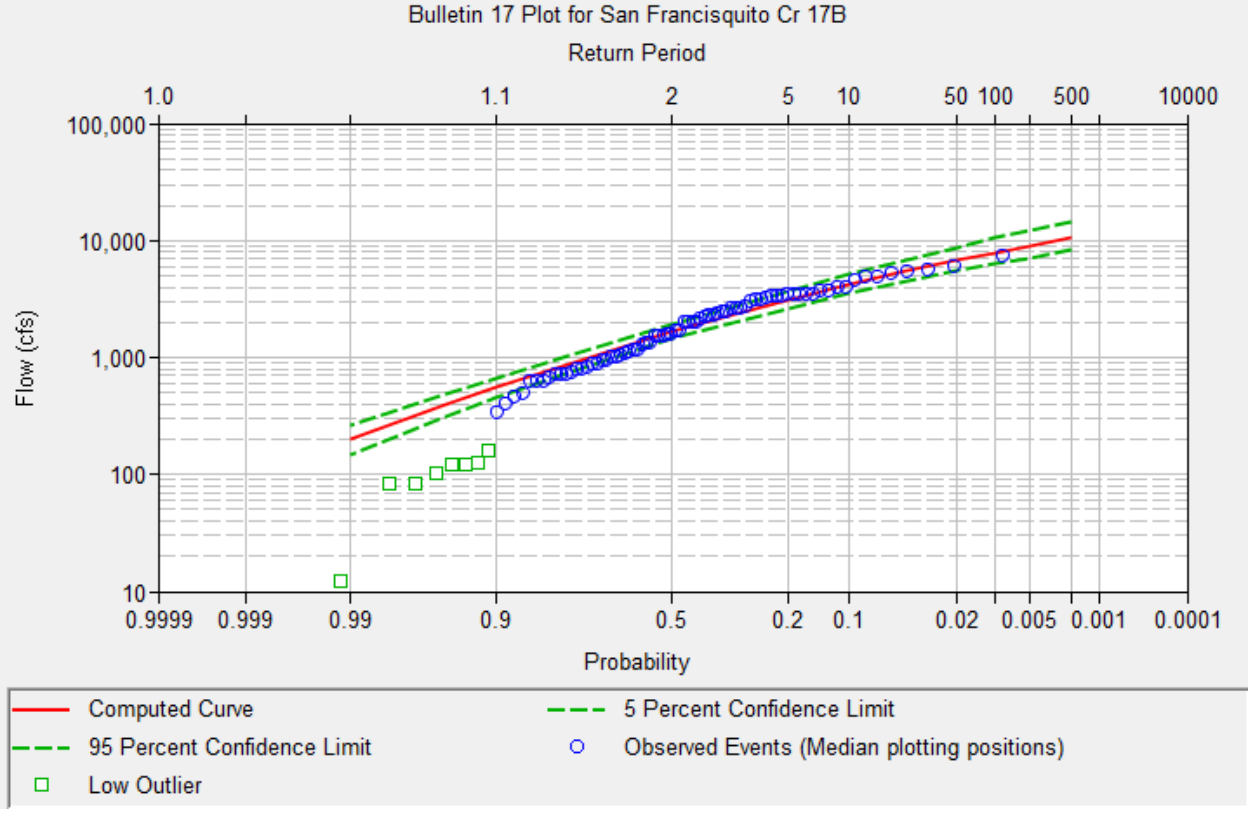


Figure 3-4: San Francisquito Creek Flood-Frequency Analysis

Based on the frequency curve generated in HEC-SSP, a 7,200 cfs peak discharge represents a 70-year event. The 100-year design storm hyetographs used in the model are re-balanced with 70-year precipitation depths interpolated from MetStat grids for durations from 15 minutes through 72 hours. The resulting 70-year storm hyetograph and 72-hour depths for each subbasin are used as input into the hydrologic models to produce a discharge hydrograph with the desired peak flow rate of approximately 7,200 cfs, taken from the flood-frequency analysis of streamflow records.

The 100-year discharge at Stanford is 7,900 cfs, based on updated Bulletin 17B analysis of gage data including the 2023 water year. The 2020 “Design Flood Flows Manual” cited a peak 100-year discharge of 7,640 cfs at the USGS gage and 8,410 cfs at US 101; however, those estimates were based on gage data through 2016, not inclusive of the major NYE22 storm event.

3.3 ICM Inflow Hydrographs

Drainage areas to urban pipe systems in the ICM are included as subbasin elements, with hydrologic inputs and precipitation applied to generate runoff hydrographs. However, inflow hydrographs are used at points in the model in lieu of full ICM hydrologic calculations.

3.3.1 New Year’s Eve 2022 Storm Event

For the NYE22 event, the gaged flow hydrograph shown in Figure 3-4 is used as input to the upstream end of the San Francisquito Creek 1D river model in ICM. This is the same upstream boundary condition that was used in prior modeling efforts.

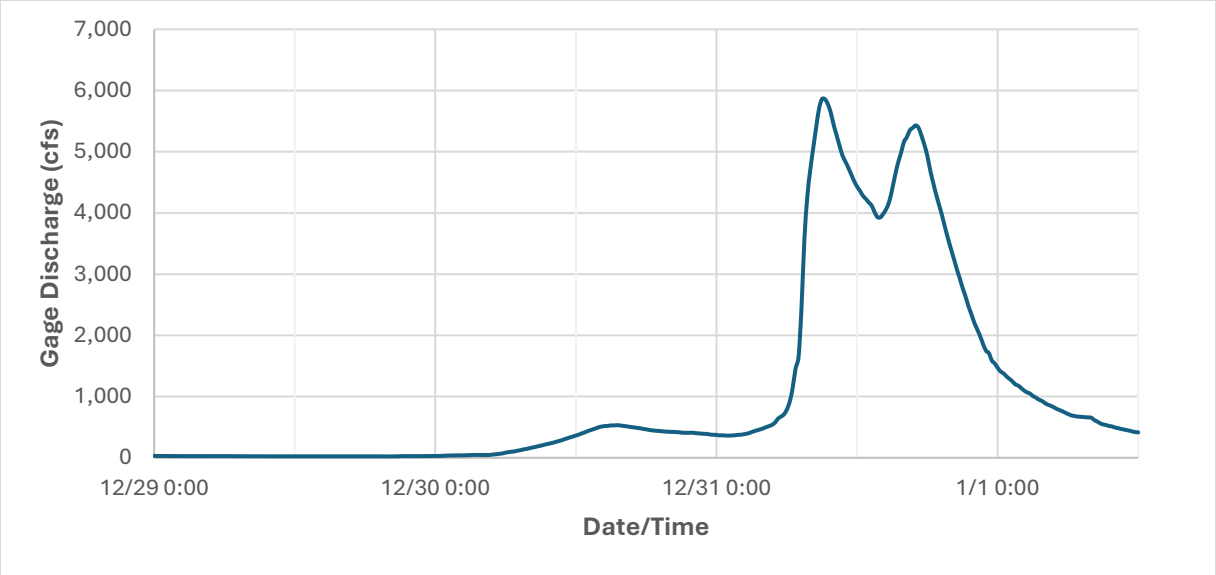


Figure 3-5: Stanford Gage Hydrograph for NYE22

3.3.2 Design Storm HEC-HMS Model

Rather than include the drainage area to the USGS San Francisquito Creek gage in the ICM, a previously well-calibrated HEC-HMS model is used to develop runoff hydrograph inputs for the 70-year and 100-year design storm events.

Previous HEC-HMS model calibration efforts focused on four gages in the region (Saratoga Creek, San Francisquito Creek, Coyote Creek above Coyote Reservoir, and Arroyo Hondo) using the Curve Number loss methodology. Calibration modeling produced 100-year discharge results at the gage within approximately 5-10% of calculated 1% peak discharges at each gage based on flood-frequency analyses.

Hydrologic properties including Curve Numbers and basin lag times are estimated for the 32 square mile drainage area to the USGS gage at Stanford. Four subbasins in the model are shown in Figure 3-5. Estimated hydrologic parameters are summarized in Table 3-1. Like the local storm drainage system catchments, this evaluation uses the SSURGO soils database. However, instead of zoning polygons, the 2023 National Land Cover Database (NLCD) is used to estimate the basin's composite Curve Number and percentage of impervious land cover. Over a large, less developed area, this satellite-derived data set is better suited to characterizing vegetated cover.

Based on the NLCD dataset, the drainage area is approximately 58% forested lands (a mixture of Evergreen and Deciduous), 22% open space, 11% grassland/shrubs, 7% developed (roads and rural properties), and 2% other cover types. The soils in the basin are classified as 9% Type A and B HSG, 73% Type C HSG, 4% Type D HSG, and 15% unclassified (considered Type D HSG for hydrologic purposes).

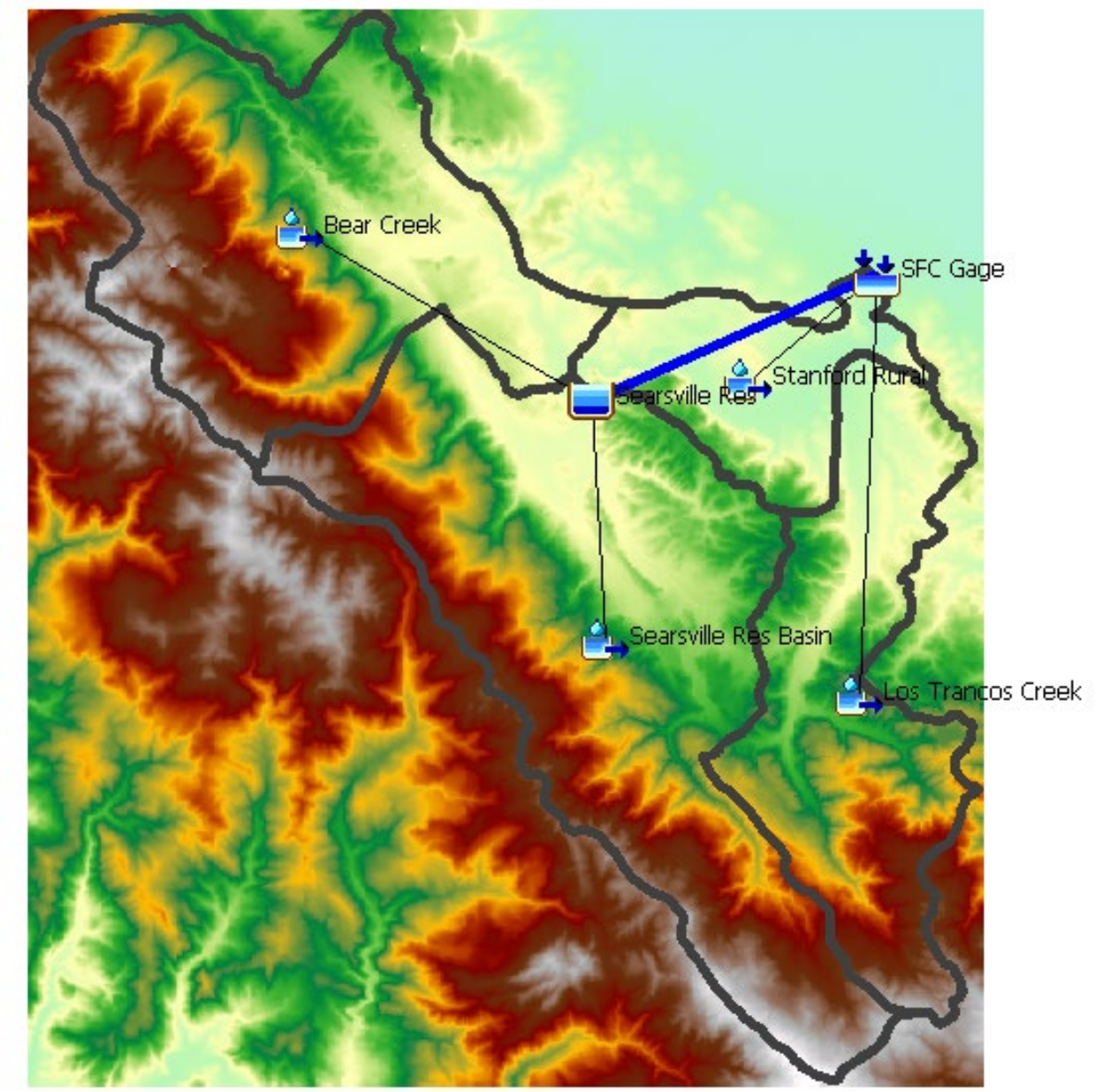


Figure 3-6: HEC-HMS Calibration at Stanford Gage Location

Table 3-1: San Francisquito Creek at Stanford Watershed Parameters

Subbasin	Area (sq mi)	Percent Impervious	Lag Time (min)	100-yr Rainfall Depth (in)	AMC II Pervious CN
Bear Creek	11.7	3%	136	12.29	72.2
Los Trancos Creek	7.5	4%	128	9.88	72.3
Searsville Reservoir	14.7	3%	151	10.68	69.4
Stanford Rural	3.5	13%	127	8.66	76.2

Four events are evaluated in HEC-HMS with the estimated AMC II CN (the calculated curve number value from GIS analysis of the drainage area). Multiple factors are considered as adjustments to the model to calibrate hydrologic model inputs, including:

1. Soil moisture: Adjusting the curve number values in the model due to AMC that deviates from “average” conditions nationally can affect peak magnitude and volume.

2. Baseflow: Depending upon the characteristics of the storm, baseflow can influence the peak flow produced in even small storm events.

3. Drainage area: Large areas are not necessarily subject to the same precipitation return period across their entire surface. Variability in precipitation intensity during a storm can be accounted for by applying depth-area reduction factors.

Schaaf & Wheeler performed extensive modeling on the New Years Eve 2022 event, which provides a basis for evaluating calculated lag times and curve numbers, as well as estimating appropriate baseflow model inputs. Baseflow and area reduction factors are generally expected to have lesser impact on the modeled peak flows than modification to the curve number, so adjustments were first made to the AMC based on prior modeling efforts. The results of that analysis are summarized in Table 3-2.

Table 3-2: AMC Sensitivity Evaluation

Return Period (Exceedance Prob.)	HEC-SSP Predicted	HEC-SSP Confidence Limits	HEC-HMS (AMC II)	HEC-HMS (AMC I-3/4)
100-year (1%)	7,890	6,280-10,460	9,600	8,100
25-year (4%)	5,600	4,590-7,140	7,670	6,750
10-year (10%)	4,150	3,680-5,100	5,900	5,020
2-year (50%)	1,640	1,420-1,890	2,840	2,215

The recorded New Year’s Eve 2022 event provides a recent creek discharge event with an approximately 30-year peak discharge of 5,880 cfs to use in establishing reasonable baseflow parameters. An HEC-HMS model developed for the San Francisquito Creek drainage area uses multiple precipitation gages, plus a radar-derived bias grid to improve the representation of spatial variability during the storm. The selected baseflow method is “linear reservoir,” which preserves volume loss from the surface and routes it through subsurface layers based on a time coefficient and a fraction of groundwater storage occurring in each defined layer.

Additional streamflow gages upstream of the Stanford gage are used to evaluate reasonable baseflow inputs for each subbasin in the model. Antecedent moisture conditions across the drainage area were highly variable during this storm, which was centered north of the gage nearer to San Carlos and San Mateo. The calibration model accounts for that variability as closely as possible by varying curve numbers to better reproduce peaks at each gaged point. Model results are shown in Figure 3-6.

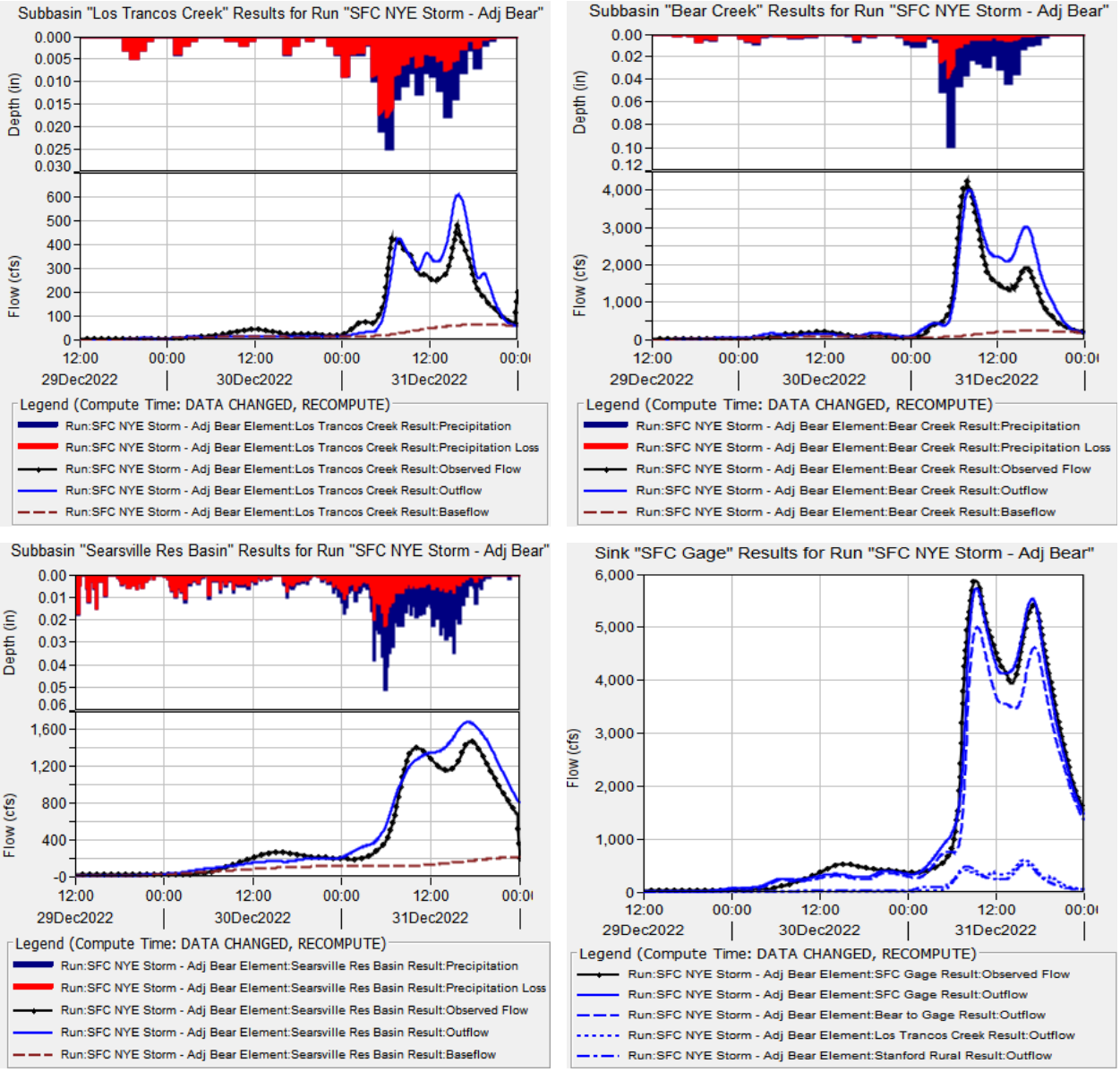
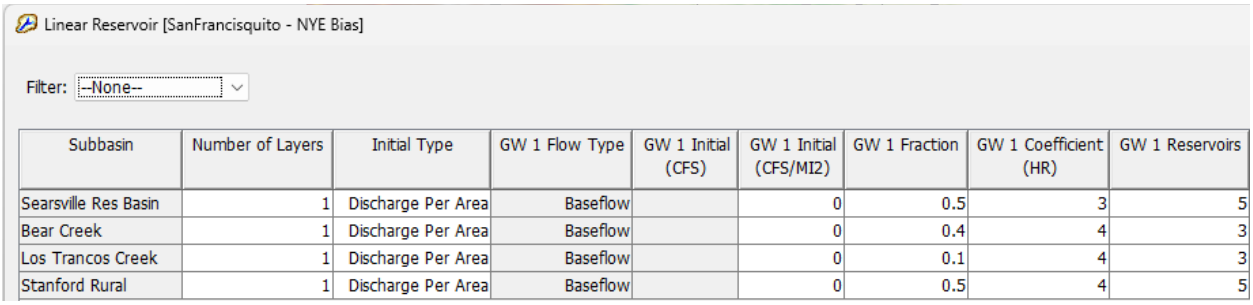


Figure 3-7: Baseflow Calibration Results

A single baseflow reservoir layer is used to represent the more highly responsive soil layers that contribute the most to increasing peak flow. Deeper groundwater layers that respond to rainfall loss on a longer timescale were ignored. Input parameters for the NYE22 linear reservoirs are shown in Figure 3-7.



Subbasin	Number of Layers	Initial Type	GW 1 Flow Type	GW 1 Initial (CFS)	GW 1 Initial (CFS/MI2)	GW 1 Fraction	GW 1 Coefficient (HR)	GW 1 Reservoirs
Searsville Res Basin	1	Discharge Per Area	Baseflow		0	0.5	3	5
Bear Creek	1	Discharge Per Area	Baseflow		0	0.4	4	3
Los Trancos Creek	1	Discharge Per Area	Baseflow		0	0.1	4	3
Stanford Rural	1	Discharge Per Area	Baseflow		0	0.5	4	5

Figure 3-8: Linear Reservoir Inputs for NYE22

Spatial variability in the NYE22 model is accounted for by using different precipitation gages and radar rainfall data. That event serves as an excellent example of the impacts of storm centering on areas greater than 30 square miles, as the Bear Creek subbasin saw significantly greater precipitation depths than Los Trancos to the south.

For the design event models, the input precipitation grids represent statistically balanced rainfall occurring across the entire surface of the drainage area. This is idealized and may overestimate design event runoff at the gage point. To account for the size of the calibration basin, HEC-HMS built-in area reduction is applied based on NOAA Technical Paper 40 (TP40). Reduction factors for the subbasins estimated by HEC-HMS are small, at roughly 97.5 percent. However, precipitation reduction and baseflow bring the HEC-HMS modeled peak flows for 10-year, 25-year, and 100-year events very close to the HEC-SSP predicted peaks. Results are summarized in Table 3-3.

Table 3-3: Hydrologic Calibration Results

Return Period (Annual Exceedance)	HEC-SSP Predicted	HEC-SSP Confidence Limits	HEC-HMS (AMC I-3/4) w/Baseflow and Depth-Area Reduction	% Difference from Predicted
100-year (1%)	7,890	6,280-10,460	8,380	+6.2%
25-year (4%)	5,600	4,590-7,140	5,600	0.0%
10-year (10%)	4,150	3,680-5,100	4,170	+0.5%
2-year (50%)	1,640	1,420-1,890	2,220	+35%

Ultimately, AMC I-3/4 is deemed an appropriate condition for modeling design storm events based on the Christmas 1955 pattern that are more extreme than a 2-year return period. If models of lesser return periods are of interest, the AMC should be decreased to AMC 1-1/4, which produces a peak 2-year flow in the calibrated hydrology model of 1,875 cfs that is within one standard deviation of the predicted peak based on flood frequency analysis.

Given the proximity of local drainage areas to the San Francisquito Creek gage watershed, and the similar regional climate patterns, it is assumed that the selection of AMC I-3/4 is also appropriate for the local storm drain system catchments. It is emphasized that this AMC calibration to a flood-frequency analysis of streamflow gage records is for the Christmas 1955 storm pattern. Using another design storm pattern would require recalibration.

Hydrographs produced at the USGS gage for the 65- and 100-year storm events are shown in Figure 3-8. The 70-year MetStat storm produces a peak discharge of approximately 7,160 cfs. This is scaled slightly to 7,200 cfs to produce a hydrograph with the target peak design flow rate to be analyzed.

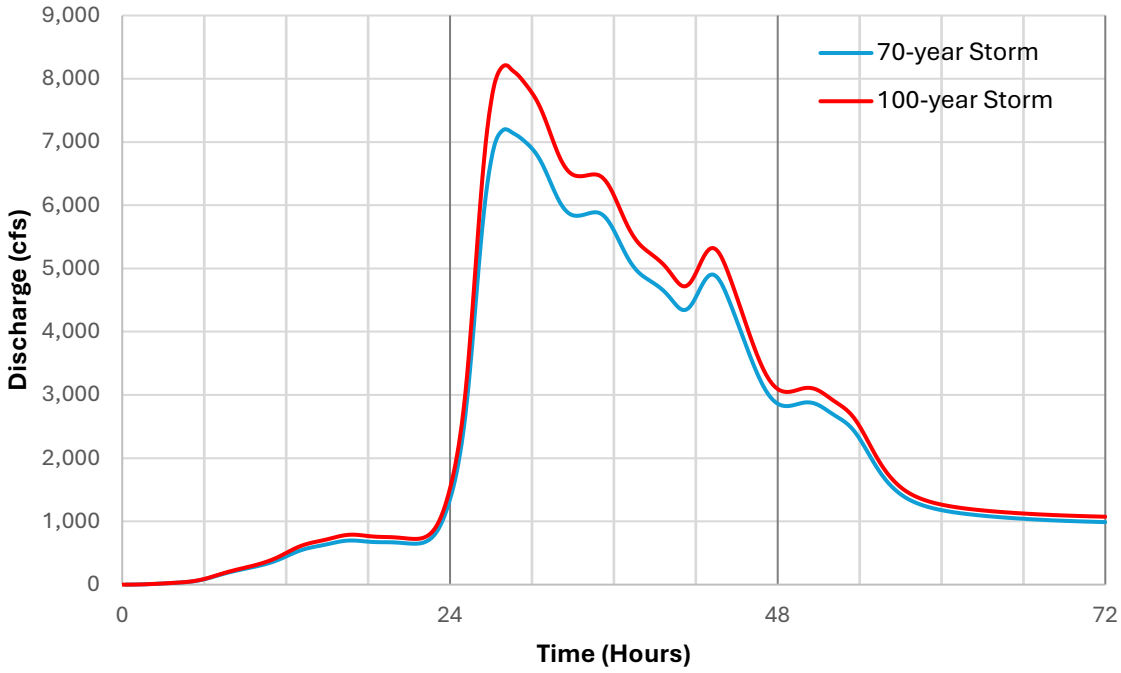


Figure 3-9: Design Storm Discharge Hydrographs at Stanford Gage

3.3.3 Adobe-Barron Creek Drainage Area

The updated ICM excludes Adobe and Barron Creeks and their drainage areas, creating a more focused and efficient model of San Francisquito Creek and its overbank floodplains. Flooding from San Francisquito Creek overbank spill impacts interior drainage systems that discharge to Matadero Creek, so Matadero Creek and its drainage areas remain in the model, along with the Palo Alto Flood Basin (PAFB).

Because the Flood Basin remains in the model, runoff from Adobe and Barron Creeks' drainage areas is included in the updated modeling as an inflow hydrograph boundary condition inserted directly into PAFB. This ensures that the volume stored in the PAFB and tailwater conditions in Matadero Creek remain consistent with modeled storm events.

The Adobe-Barron drainage area was extracted from USGS StreamStats. There is a small amount of overlap between ICM catchments and the StreamStats basin, amounting to roughly 2% of the 8,400-acre drainage area (Figure 3-9). The overlap balances closely with the area of gaps between the ICM catchments and the Adobe-Barron drainage catchment, so adjustments have not been made to the drainage area boundaries from StreamStats.

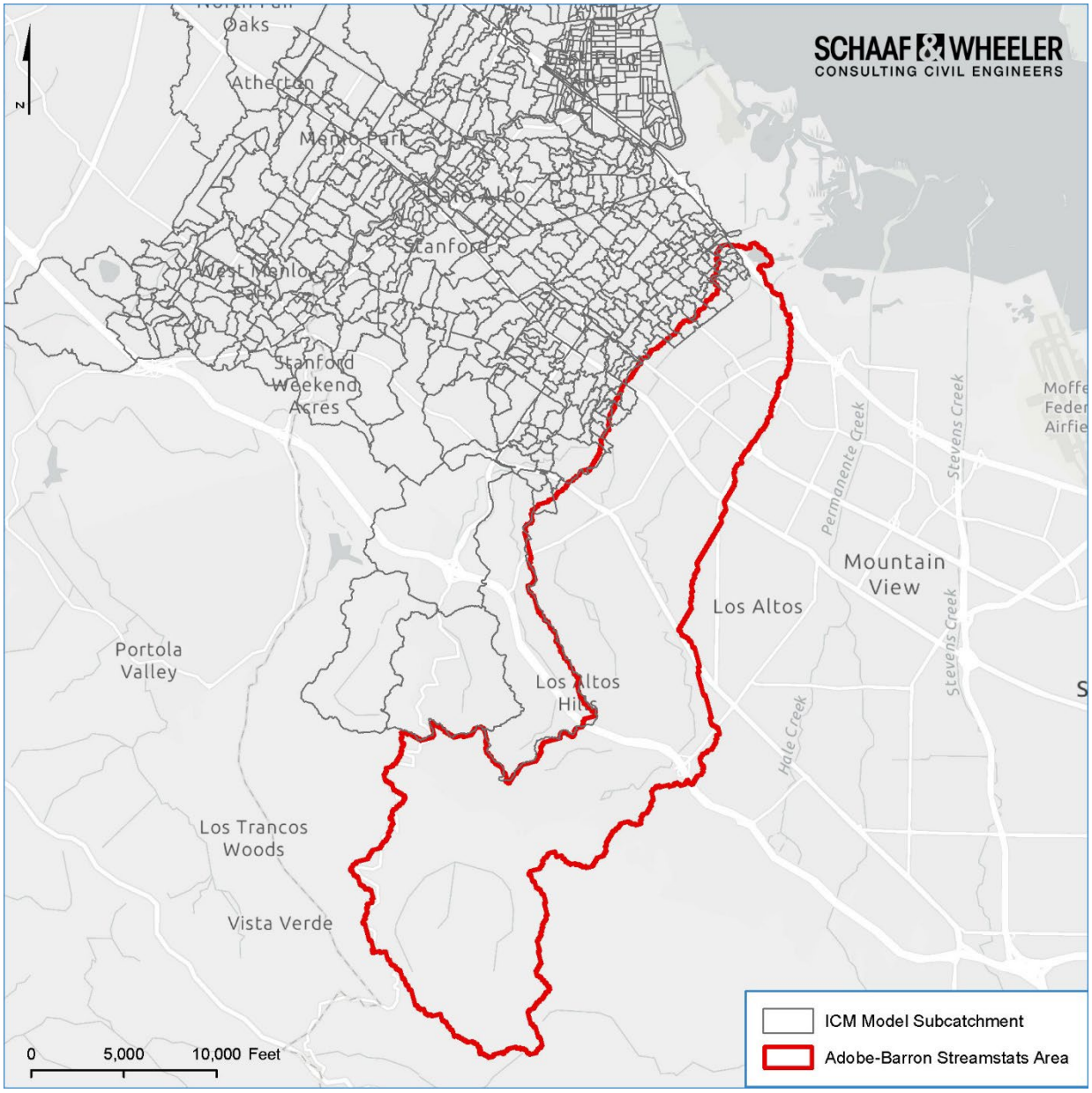


Figure 3-10: Adobe-Barron Watershed Definition

Curve Number values within the Adobe and Barron Creek watershed are estimated based on adjacent San Francisquito Creek drainage area characteristics, StreamStats estimates of percent impervious land cover, and basin lag times calculated using StreamStats basin characteristics. Hydrologic model inputs are summarized by Table 3-4.

Table 3-4: Adobe-Barron Hydrologic Model Inputs

Parameter	Value	Units
Curve Number	63	--
Longest Path (ft)	12.2	mi
Slope	0.0437	ft/ft
Lag Time	114	minutes

Runoff hydrographs into the Palo Alto Flood Basin (PAFB) from the combined Adobe and Barron Creeks are used as boundary condition inputs to ICM and shown in Figure 3-10.

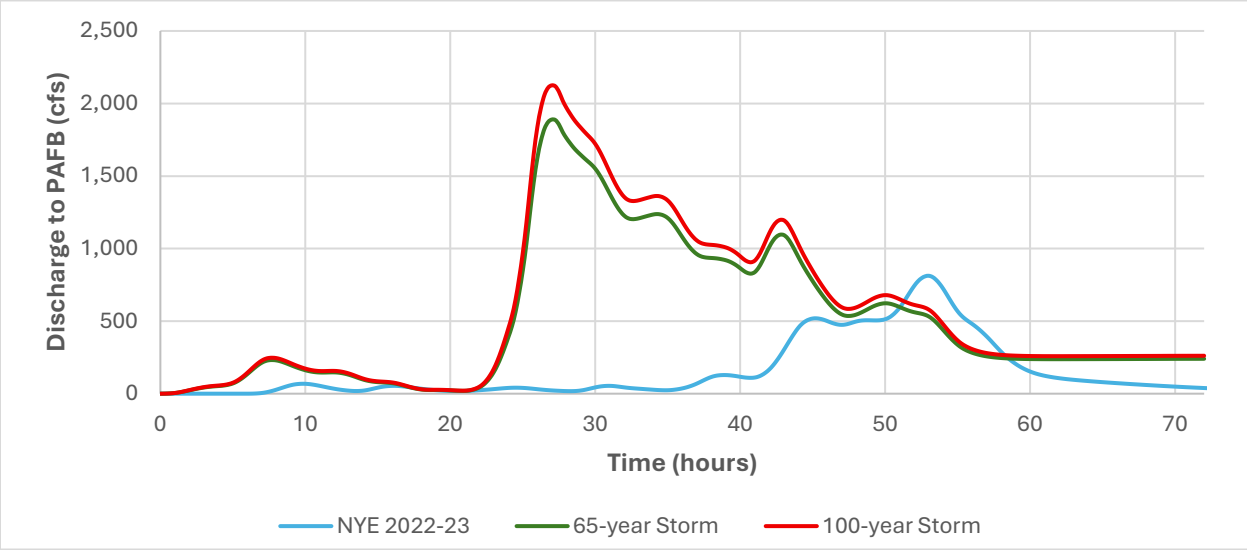


Figure 3-11: Adobe-Barron Design Hydrographs

For the NYE22 event, the calibrated HEC-HMS model of San Francisquito Creek drainage area uses multiple precipitation time series gage points to characterize the storm in each of its four subbasins. Discharges from the subbasins are evaluated against Valley Water stream gages to confirm that the hyetographs used in the model reasonably replicate the event (Figure 3-6).

Based on available data, the NYE22 event was most intense over the Bear Creek subbasin, at the northwest limits of the San Francisquito Creek drainage area. Raw, base-level radar reflectivity (taken from NOAA NEXRAD systems) and NOAA Multi-Resolution, Multi-Sensor (MRMS) qualitative precipitation estimates show that intensity decreased significantly in the southeastern subbasin areas of Searsville and Los Trancos. Reflectivity data are mapped around the first high intensity rainfall burst (at approximately 6 a.m.) in Figure 3-11.

Because the Adobe-Barron watershed lies east of the San Francisquito Creek drainage area, the hydrologic model uses the Los Trancos subbasin precipitation gage. That time series is developed by adjusting point precipitation gage data at Searsville Dam and radar-derived precipitation timeseries in Woodside based on NOAA's MRMS gridded precipitation dataset. Based purely on reflectivity during the storm, this may still represent some degree of conservatism.

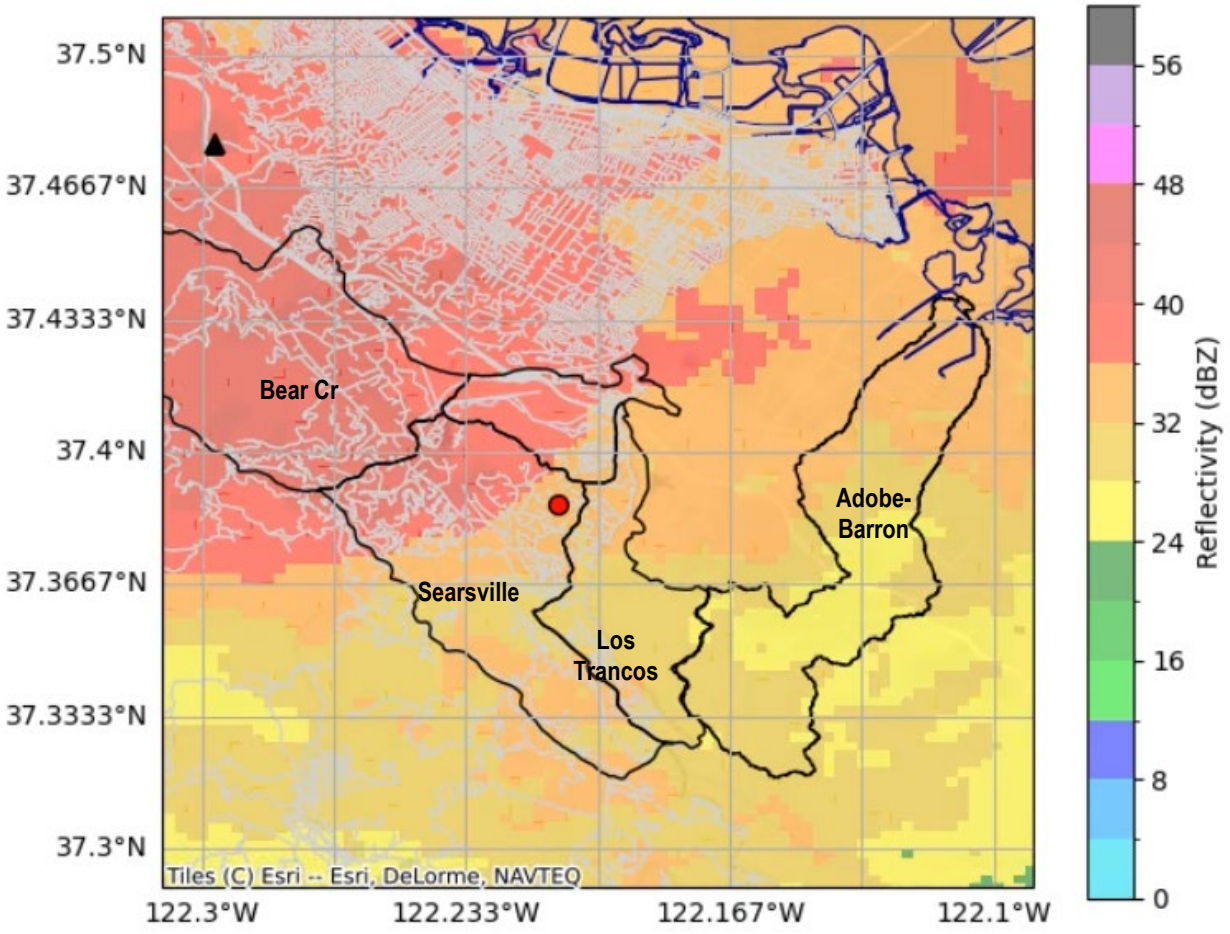


Figure 3-12: NEXRAD Reflectivity During NYE22

Design storm events assume conservatively that no depth-area reduction factor is applied to the Adobe and Barron Creeks drainage area. A storm centered on San Francisquito Creek drainage area would likely produce runoff of a lesser return period in adjacent watersheds or in low-lying areas, which is basically what occurred during the NYE22 event.

While contributions from the Adobe and Barron Creeks drainage area are likely inconsequential to mapping the San Francisquito Creek floodplain, the inclusion of these hydrographs as boundary conditions ensures that the model remains as true-to-life as possible.

3.4 Tidal Boundary Conditions

Tidal boundaries are applied to concentrated portions of the ICM 2D mesh boundary, as well as to 1D outfall points to evaluate a variety of scenarios, as summarized by Table 3-5.

Table 3-5: Tide and Storm Combinations Evaluated in ICM

Storm Event	NOAA Record	Mean Tide Cycle	10-year Tide Cycle
NYE22	X		
70-year Storm		X	X
100-year Storm		X	X

Tidal statistics used to generate these boundary conditions are extracted from the 2014 FEMA San Francisco Bay Tidal Datums interactive map, at a point near San Francisquito Creek (Figure 3-12). Mean low and lower low water values are not listed in the map for any nearshore point in the vicinity of San Francisquito Creek, so values are taken from near Dumbarton Bridge, as these values are of lesser importance in determining floodplain extents than mean high and higher high water.

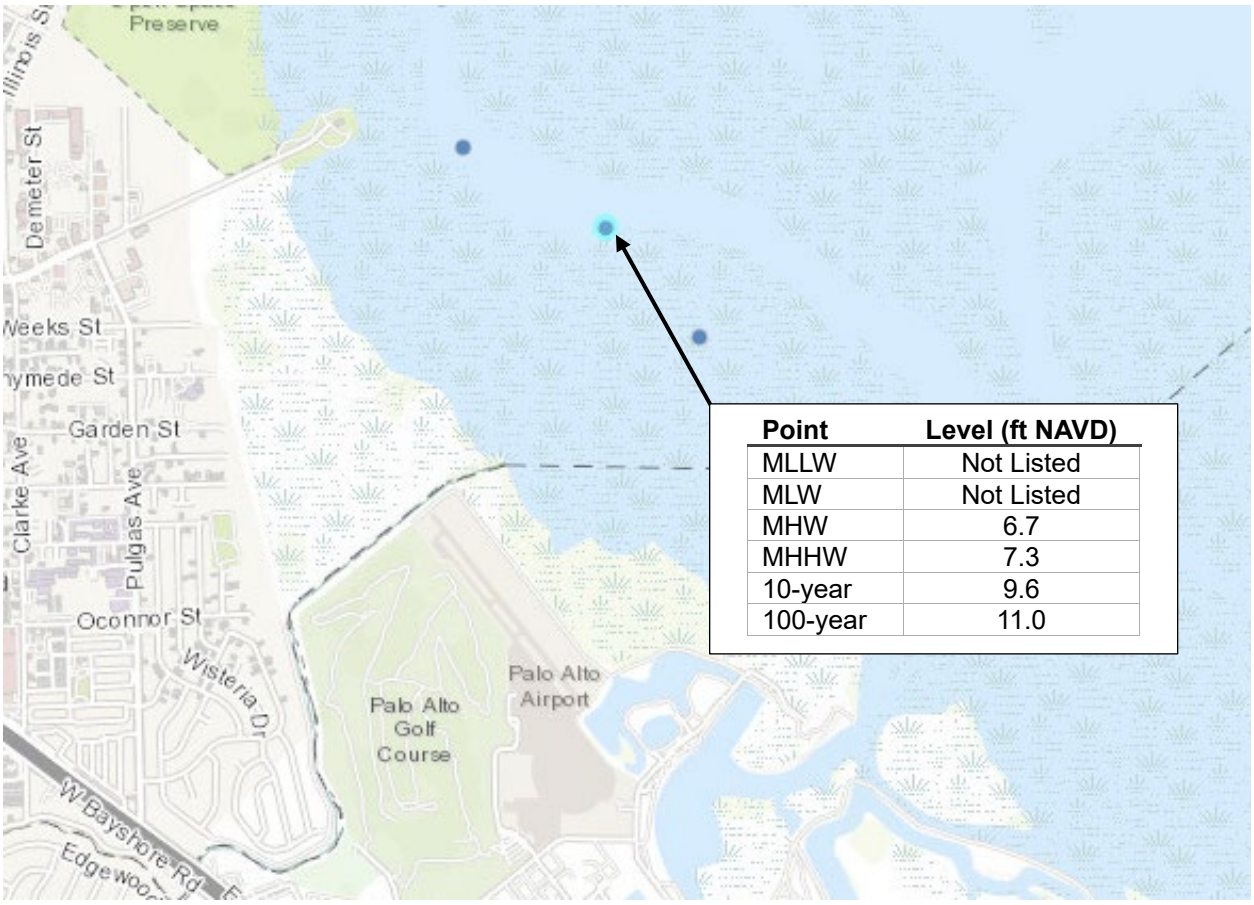


Figure 3-13: Tidal Datums Near San Francisquito Creek Mouth

3.4.1 NYE22 Tide Data

NOAA tide gage data from the (closest) Redwood City station is shown in Figure 3-13 for December 28, 2022 through January 3, 2023. This is used as input without modification at the San Francisquito Creek discharge and at the Bayward edge of the ICM 2D mesh. It is noted that the published difference in high tide between the Redwood City gage location and the mouth of San Francisquito Creek is about 0.2 foot and roughly 40 minutes shifted in time. There is no published difference in low tide between the two locations, and the low-tide shift is about 16 minutes.

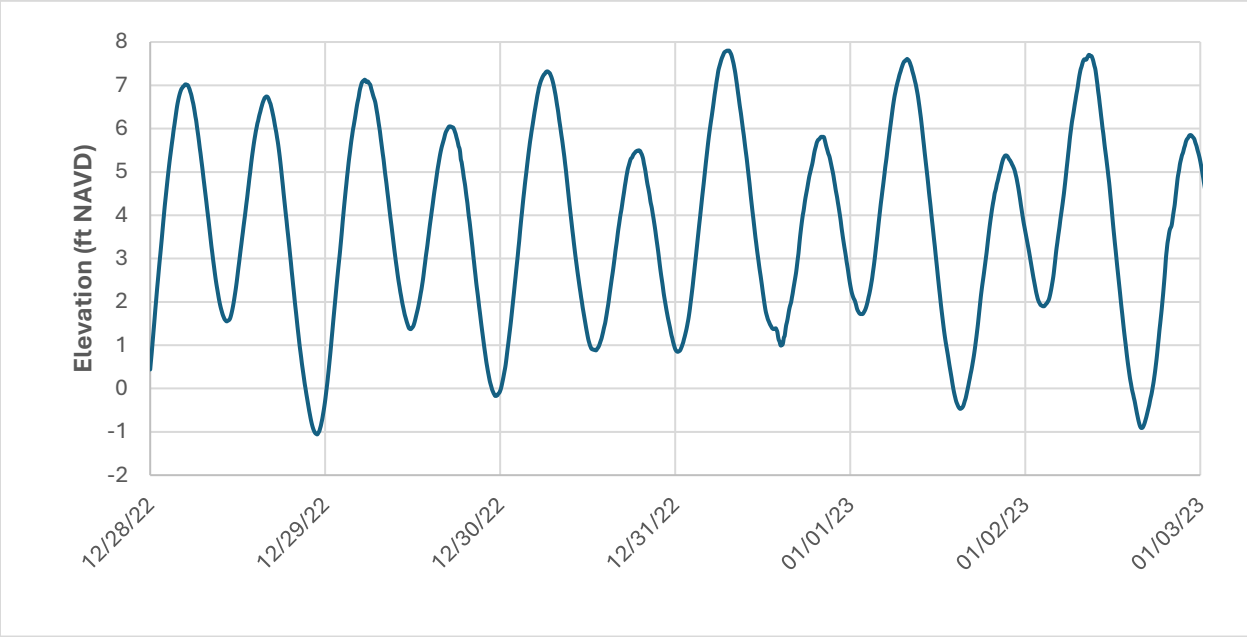


Figure 3-14: Redwood City Tide Record During NYE22

3.4.2 Design Tide Cycles

For design storm events, repeating synthetic harmonic tide cycles can be generated that resemble real tidal fluctuations but achieve specified extrema (lower low, low, high, and higher high-water points).

A single harmonic cycle for the mean and 10-year tide inputs is shown in Figure 3-14. These tide cycles are repeated as necessary to cover multi-day simulation periods and shifted in time so that the mean higher high water occurs coincident with peak discharge from San Francisquito Creek as the most conservative random timing possibility.

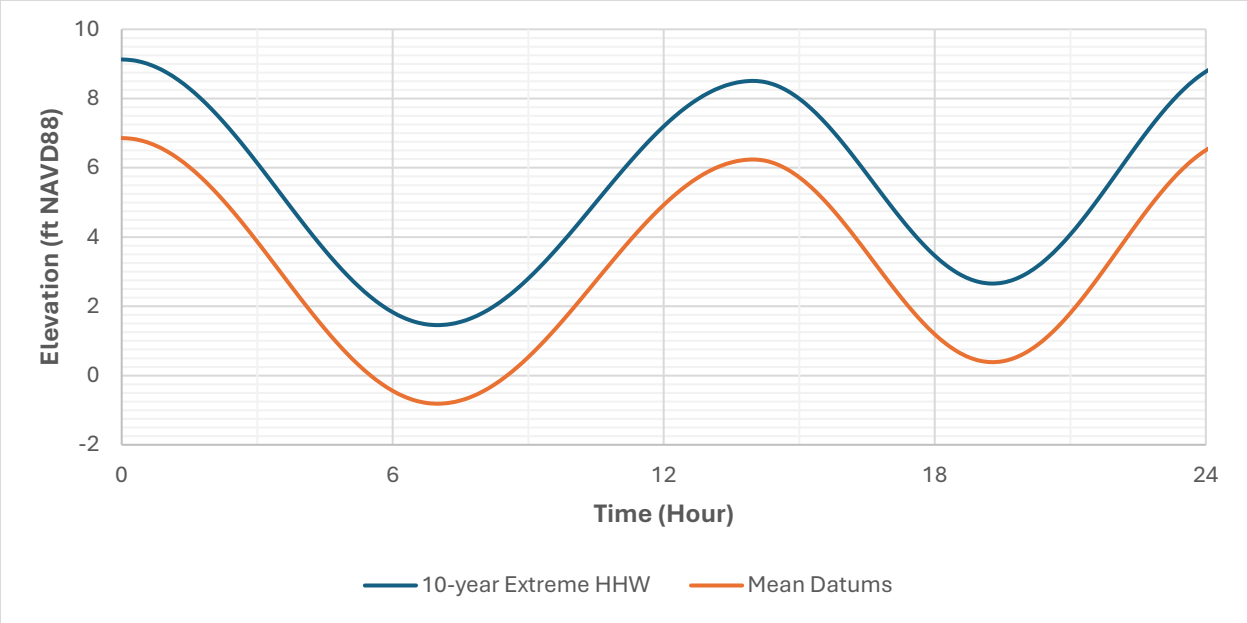


Figure 3-15: Synthetic Mean and 10-year Tide Cycles

3.4.3 Coincident Tide Assumptions

Schaaf & Wheeler completed a detailed study of tide coincidence to the maximum annual recorded discharge at the San Francisquito Creek streamflow gage.[4] To model an appropriate San Francisco Bay tidal cycle during a storm event of particular return period (with tides adjusted to the Redwood City location), elevations for each critical point in the tide cycle are adjusted based on the one-percent conditional probability of coincident occurrence with the annual maximum discharge of San Francisquito Creek at Stanford. This procedure is as described by Dixon (1986), whose hypothesis was that high tide events tend to occur the same day as flood flow events using conditional probability:

$$P_{(x,y)} = P(x|y)\,P(y)$$

where P(x,y) is the probability of occurrence of x and y; P(x|y) is the probability of occurrence of x given y; P(y) is the probability of occurrence of y; x is tide elevation; and y is maximum annual peak discharge. Since we are interested only in annual maximum discharges, P(y) is one and the probability of joint occurrence, P(x,y), is equal to the probability of x given y.

Tide cycle points are taken from fitted probability curves of published data using the median plotting position for every recorded tide extreme that occurred within 24 hours of the recorded maximum annual discharge. Figure 3-15 shows the probability distribution for the higher-high tides and Table 3-6 provides coincident values for the 65- and 100-year fluvial return periods. Observed tide elevations at Golden Gate are translated to the Redwood City Location on the mean lower-low (MLLW) datum by adding 2.5 feet to high tides recorded at Golden Gate and then converting to the NAVD vertical datum at the creek mouth.[5]

[4] Schaaf & Wheeler, "Palo Alto Flood Basin Hydrology," Corrected Final Report Prepared for Santa Clara Valley Water District, March 2020.
[5] University of Nevada Reno, "NOAA Tide and Current Tables, San Francisco Bay, California, 2022," San Francisco Bay Tidal Differences. https://www.cse.unr.edu/~edc/Homepage/tides/Diffs/sfgg_diff.html

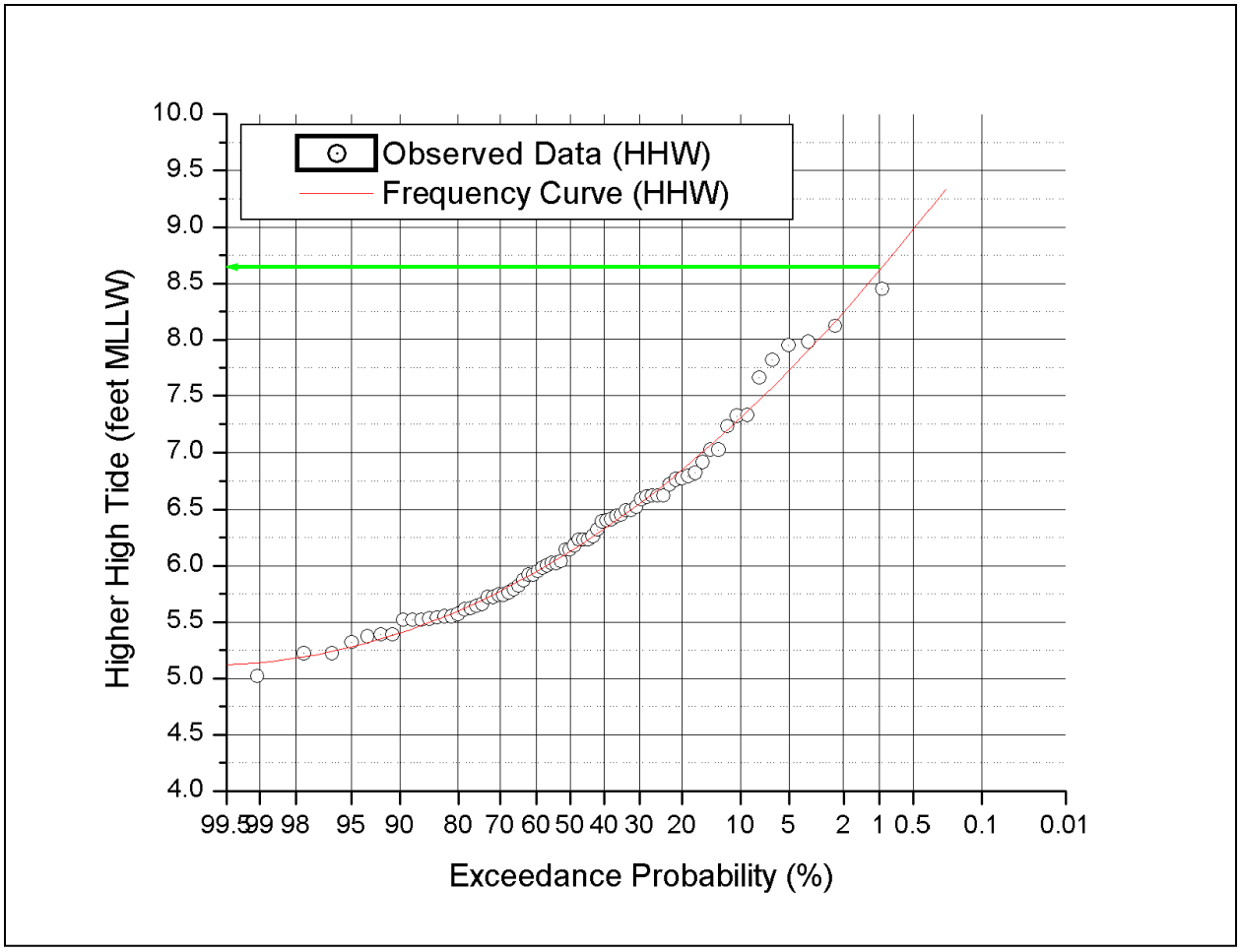


Figure 3-16: Joint Probability of High Tide with Maximum Annual Discharge

Table 3-6: Summary of Tidal Coincidence

Fluvial Return Period	HHT at Golden Gate (feet MLLW)	HHT at Creek Mouth (feet MLLW)	HHT at Creek Mouth (feet NAVD)	10-year Tide at Creek Mouth (feet NAVD)	Difference in Tidal Elevation Used (foot)
70-year	8.35	10.85	9.40	9.65	+0.25
100-year	8.70	11.20	9.75	9.65	-0.10

The conversion of tidal elevations on the MLLW datum to NAVD at the creek mouth is accomplished using NOAA's Online Vertical Datum Transformation program.[6] The 10-year tide is established as the downstream model boundary for both the 70-year and 100-year design storms. This is consistent with local practice and the small differences in tidal elevation used are not worth more complicated modeling or making a very slight adjustment between the 70-year fluvial event and the 100-year fluvial event.

[6] https://www.vdatum.noaa.gov/vdatumweb/vdatumweb?a=205301120260821

3.4.4 Modeled Tidal Boundary Conditions

The same tidal boundary conditions for all runs are applied at five points in the ICM, shown in Figure 3-16. Model boundary condition locations are the same whether applying the NYE22 conditions or either of the two design storm scenarios.

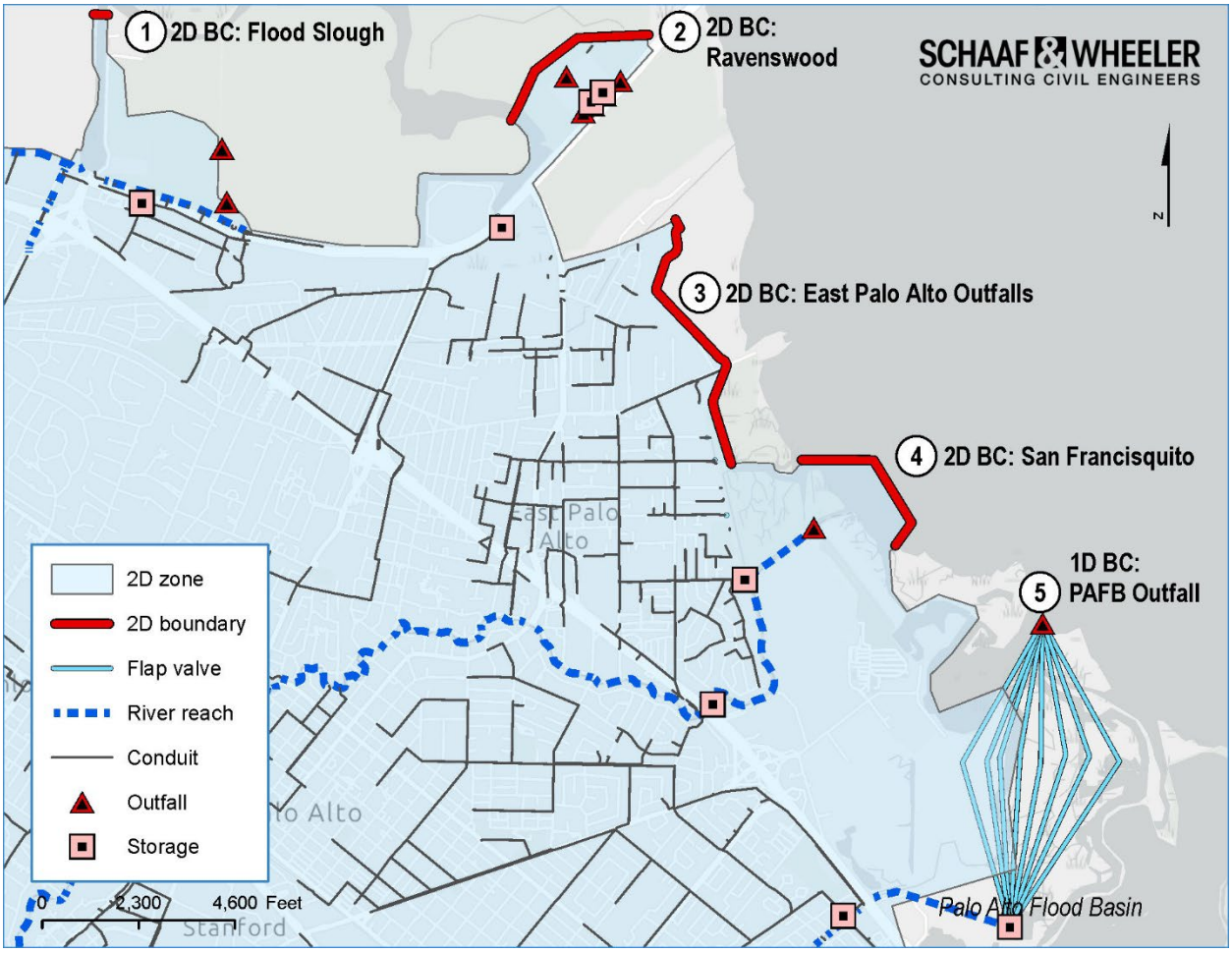


Figure 3-17: Tidal Boundary Model Locations

4. Integrated Model Updates

Updates to the integrated model that are shown in Figure 4-1 include:

- Incorporation of additional storm drainage systems.
- 2-dimensional mesh modifications:
  - Expansion of the 2-dimensional mesh model domain
  - Refined, additional roughness zones including building footprints
  - Incorporation of highway barriers
- Updates to channel roughness to better replicate HEC-RAS model results across the full range of modeled events.

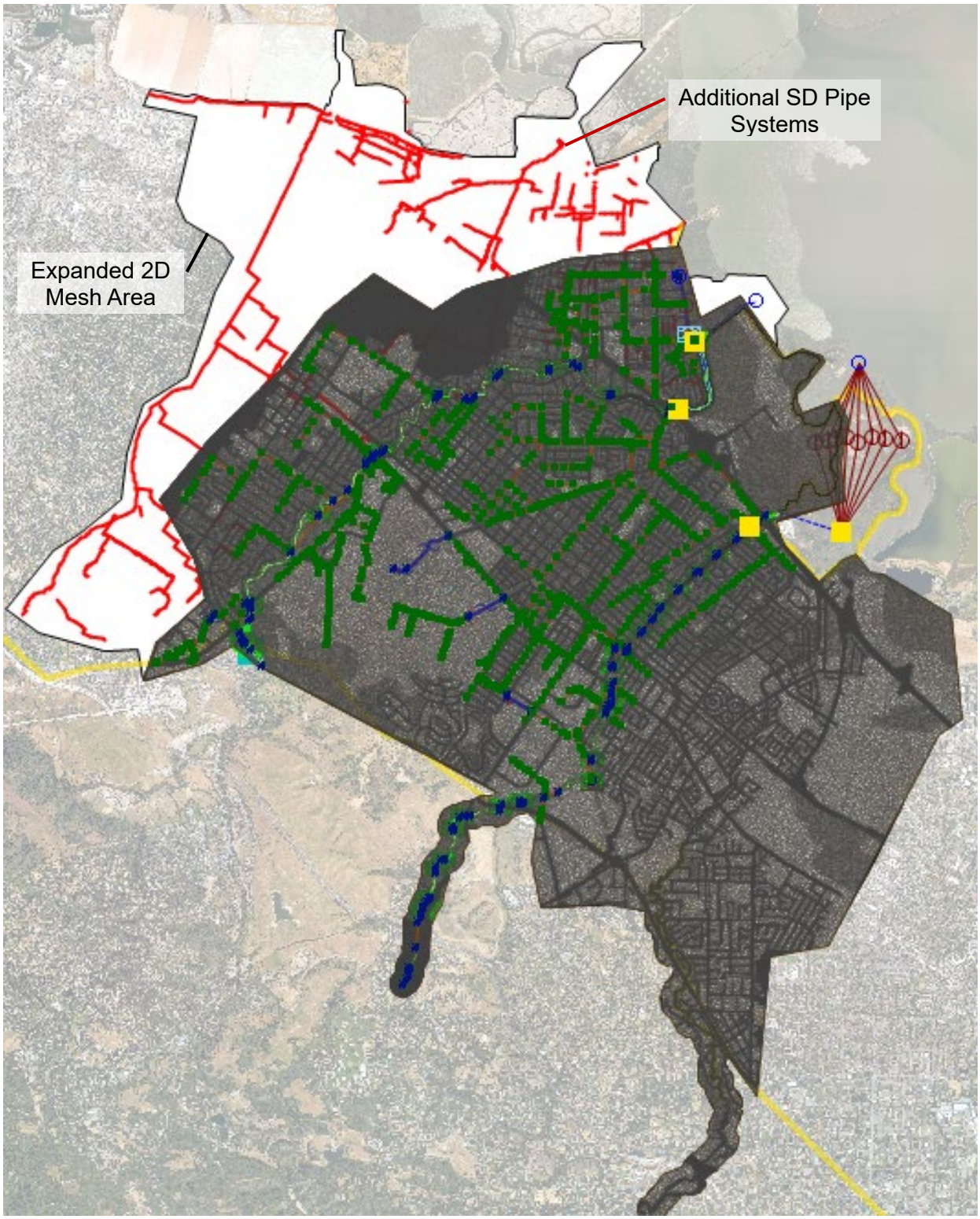


Figure 4-1: Evolution of ICM Geometry

4.1 Additional Storm Drain Systems

The SAFER Bay ICM incorporates additional storm drain system data in Menlo Park and East Palo Alto that were not included in prior iterations of the San Francisquito Creek model. Figure 4-2 shows the model geometry obtained from the SAFER project.

Storm drain system information extracted from the SAFER model is imported into the San Francisquito Creek network, replacing the prior modeling of existing systems in East Palo Alto that drain to O'Connor Pump Station and appending systems to the north and west that were not previously included in the model. The updated network geometry is shown in Figure 4-3.

Based on where spill occurs and interacts with pipe systems and highway barriers, node definition is refined to better represent local inlet capacity. Previously, nodes were defined as 2D connections to the surface with exchange between the 1D and 2D model domains using the entire node area. In some areas, particularly West Bayshore near Euclid, there was documented flooding during the NYE22 storm event that was not well represented in the model results until limited inlet capacity in the area was better defined using sag inlet parameters, including grate dimensions, clogging factors, and curb opening characteristics.

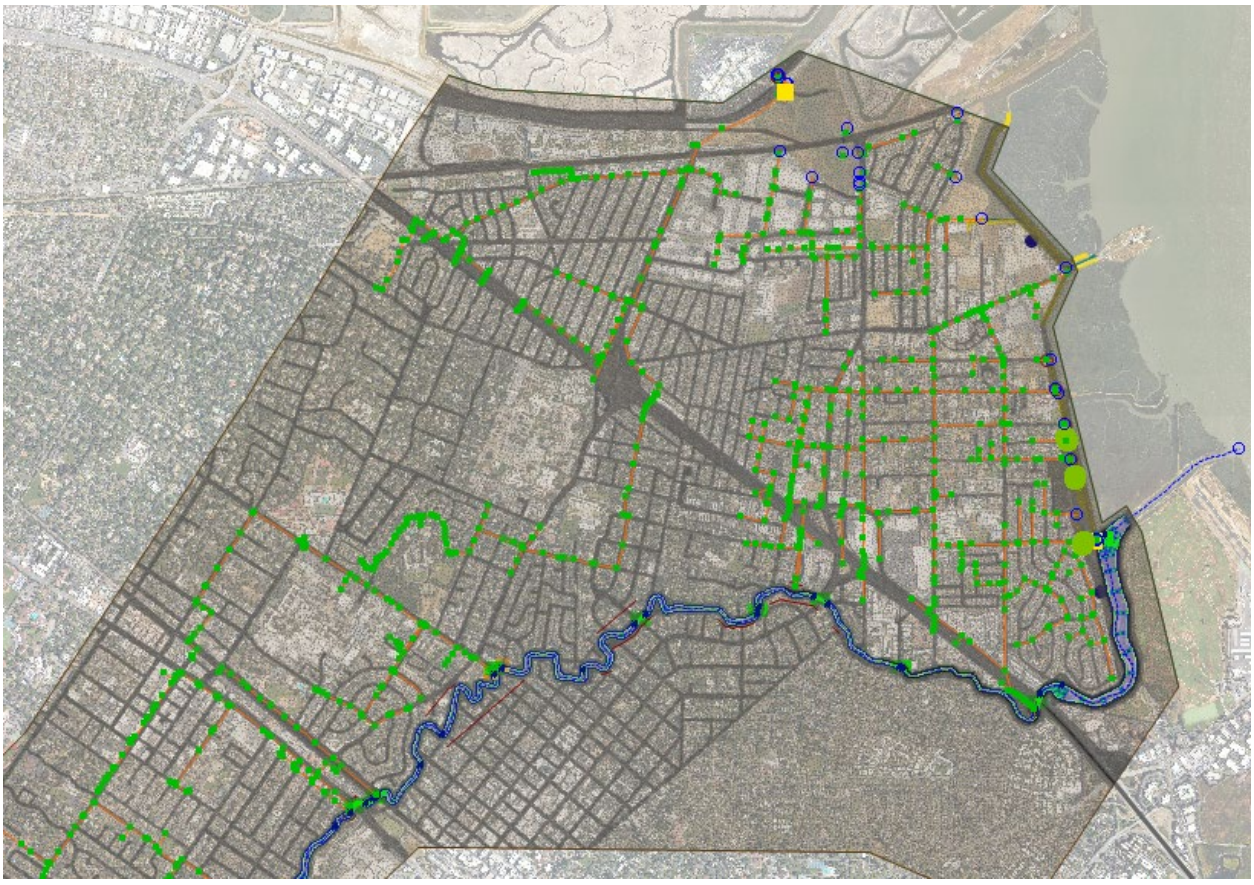


Figure 4-2: SAFER Bay ICM Geometry

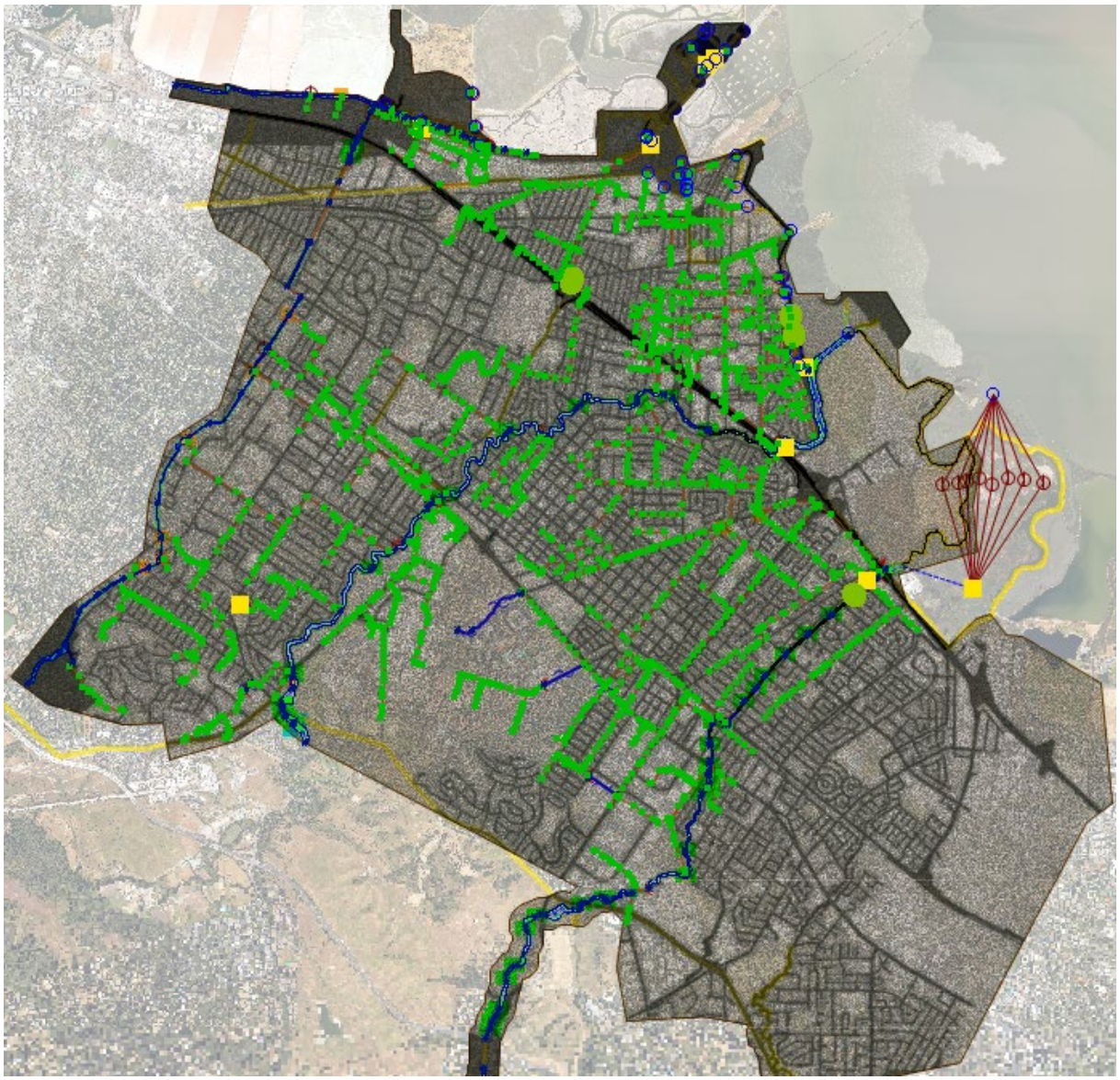


Figure 4-3: Updated Unified ICM Geometry

4.2 2D Mesh Improvements

In addition to an outer perimeter and default mesh size and roughness settings, ICM uses mesh and roughness zones to supplement and refine 2-dimensional (2D) model domains. Mesh zones allow a user to define minimum and maximum element sizes that deviate from defaults. Likewise, roughness zones define a Manning's 'n' surface roughness that could represent features like vegetation, fences, or buildings that are not well defined in the underlying terrain.

Prior iterations of the model included mesh area, mesh zones, and roughness zones sufficient to capture NYE22 event flooding. Expanding the model to cover additional flooding extents for larger events, and additional storm drain system data also requires an extension of mesh and roughness zone layers. The northern limits of mesh and roughness zones in the previous iteration of the NYE22 model geometry are shown in Figure 4-4 and Figure 4-5, which are displayed as purple and pink polygons, respectively. The SAFER model includes additional coverage, as shown in Figure 4-6.

4.2.1 Domain Extents and Roughness

Additional parcel shapefile data acquired and processed in GIS software is combined with prior ICM geometry inputs that support the extension of the updated ICM geometry to the north and west (Figure 4-7 and Figure 4-8).

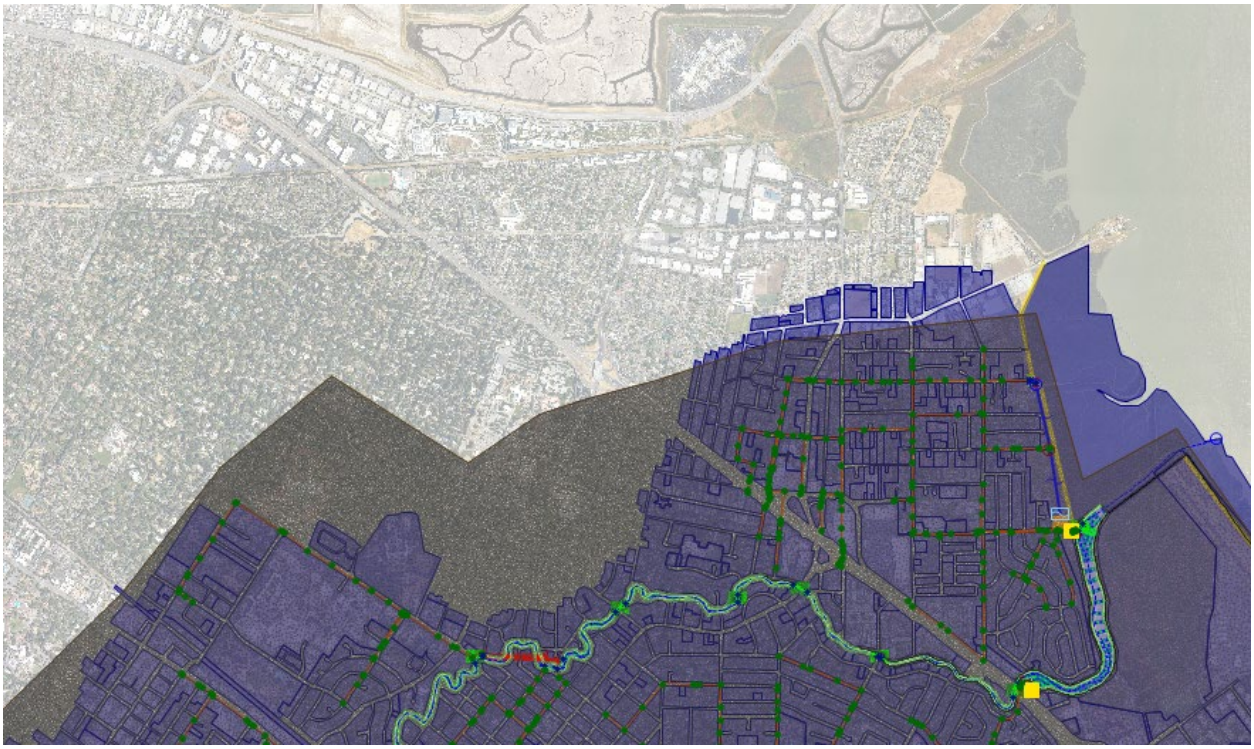


Figure 4-4: 2023 Mesh Zones

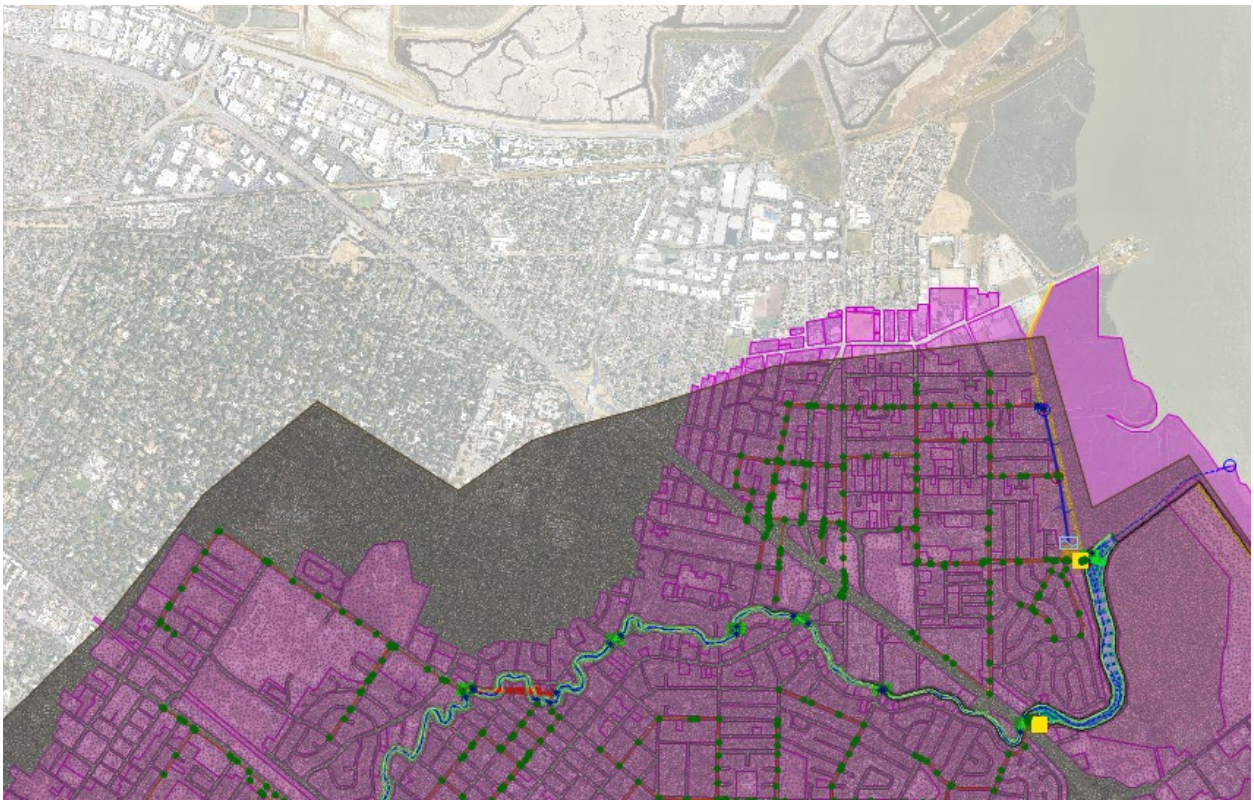


Figure 4-5: 2023 Roughness Zones



Figure 4-6: SAFER Bay Roughness Zones

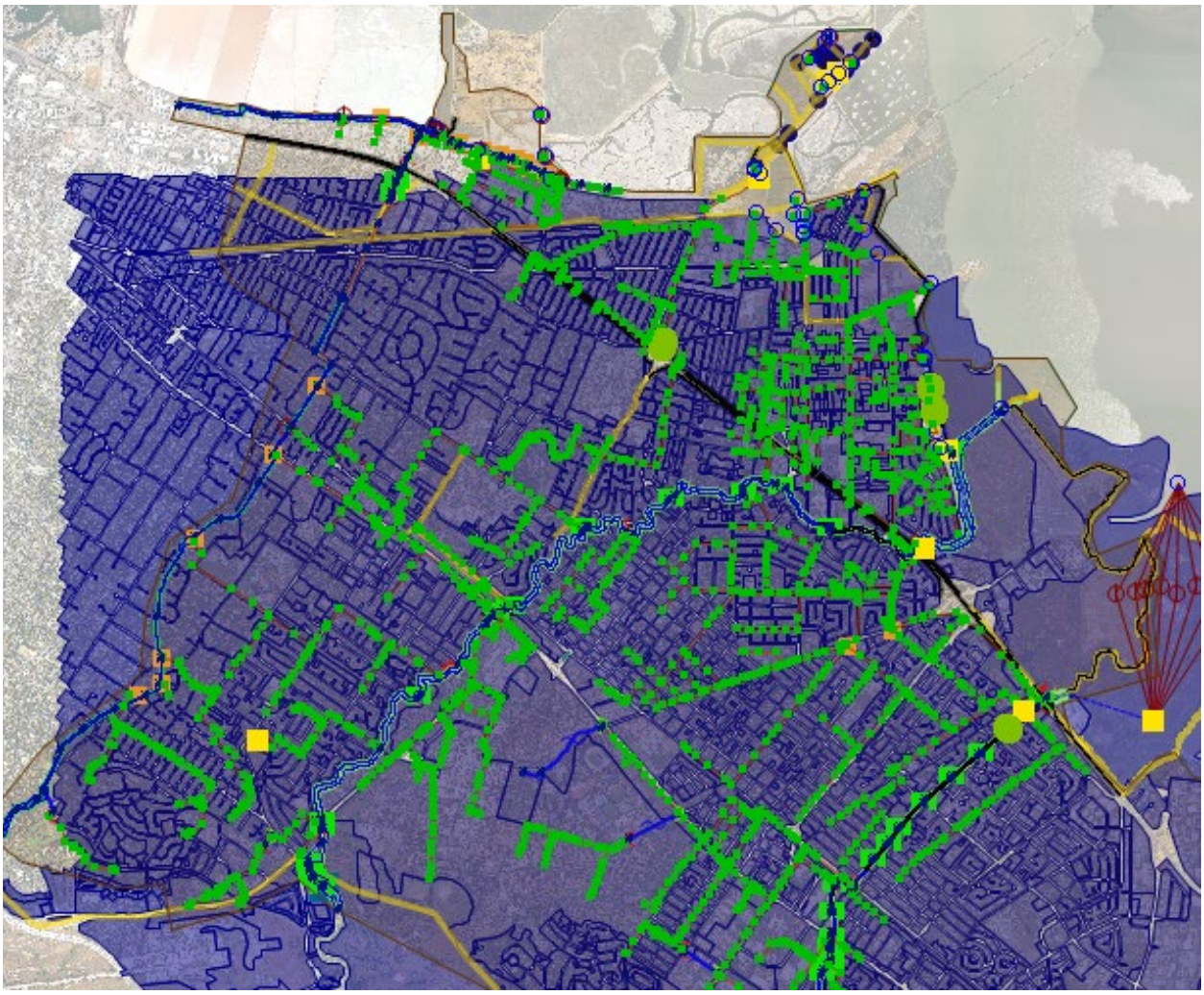


Figure 4-7: Expanded Model Mesh Area with Enlarged Mesh Zone Layer

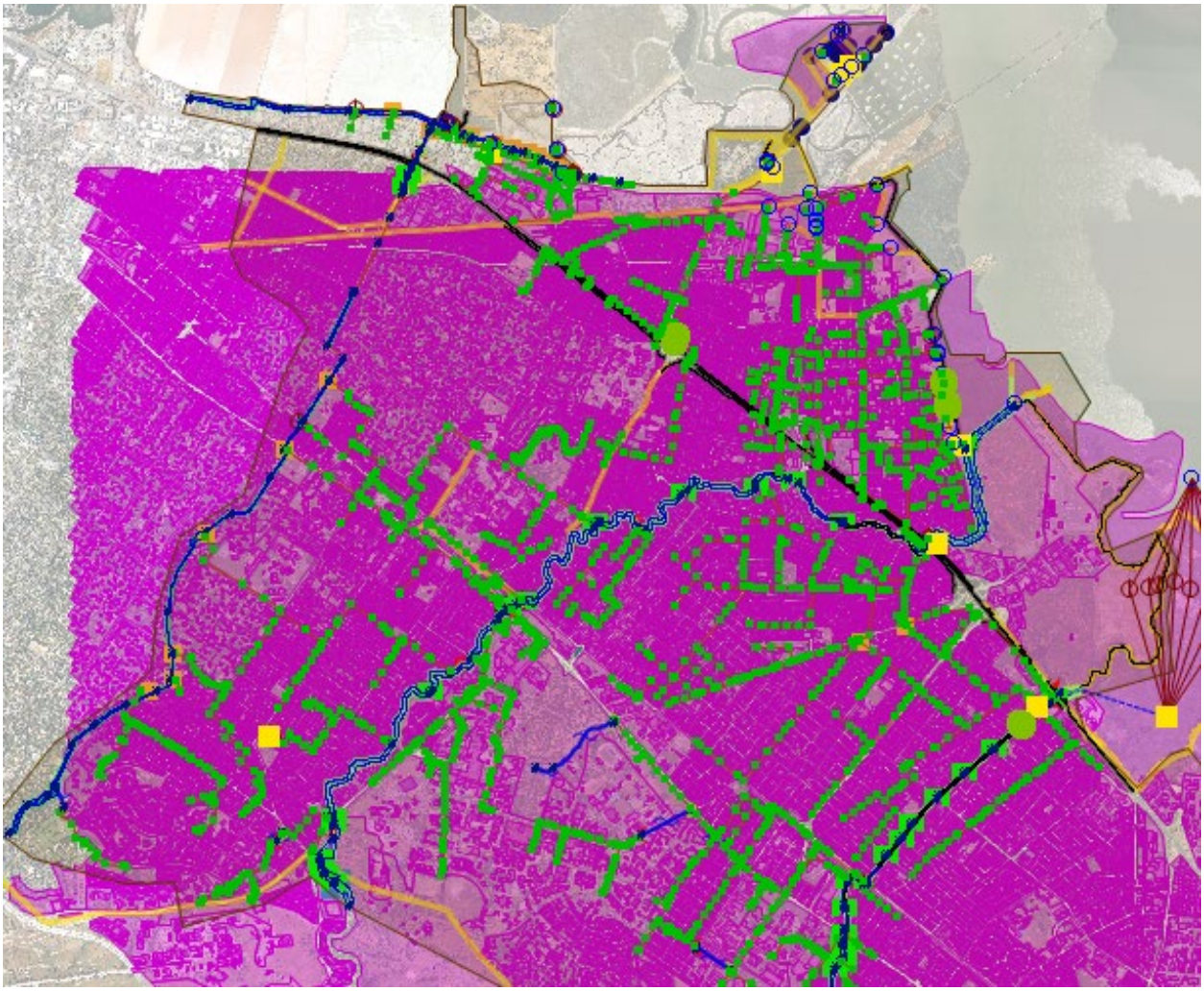


Figure 4-8: Expanded Model Mesh Area with Enlarged Roughness Zone Layer

The most substantial change to these inputs is the method of considering surface roughness. Prior models utilized composite ‘n’ values outside of the creek right-of-way, applying generalized values of 0.03, 0.12, or 0.13 depending on the degree of vegetation growth, structures, and other impedances to overland flow.

Surface roughness representation is improved in two ways:

1. Building footprints are separated from underlying parcel boundaries, placing a higher degree of blockage within a more concentrated footprint (Figure 4-9). An ‘n’ value of 5.0 is applied to building areas, representing more concentrated, localized blockage to active flow conveyance while allowing water to be stored within a flooded building.

2. Outside of the building footprints, the model now uses composite roughness values derived from NOAA C-CAP 2021 impervious grids. This expands representation of actual development characteristics throughout the floodplain.

Aggregated parcel shapes are overlain with C-CAP grids, and an average percent impervious evaluated for the entire area (including the buildings). Building footprints are then subtracted from the impervious area. Composite Manning’s n values are assigned to the remaining area using values of 0.015 for impervious areas and 0.035 for developed pervious areas.



Figure 4-9: Updated Roughness Zone Layer with Prioritized Building Footprints

4.2.2 Flow Barriers

The updated ATR HEC-RAS model expands the extents of the 2D model area to encompass Highway 101 and the areas to the north, adding the physical barriers to northward flow during larger storm events. This includes highway soundwalls, concrete median barriers, and other barriers including those along shoulders and off-ramps.

The ICM geometry is also extended to allow for use of the model for larger storm event simulation. The same barriers are imported to ICM as “Base Linear Structure (2D)” elements, with height over the underlying terrain as the primary input parameter. The barriers vary in height, but to simplify model input, sound walls are assumed to be ten feet tall, median barriers are assumed to be 42 inches tall, and other barriers are assumed to be 36 inches tall. Examples of these barriers are shown from Google Maps Street View in Figure 4-10. The left image is of the soundwall near Euclid; the center image is the median barrier where Highway 101 crosses San Francisquito Creek; and the right image is the shoulder barrier near the Willow Road interchange. A map of identified barriers is shown in Figure 4-11.

Identified discontinuities in the barriers are included in the model to better evaluate flow paths and depths accumulating at or around the highway. An example of a break in the soundwall on the south side of Highway 101 near Willow Road is shown in Figure 4-12.



Figure 4-10: Highway 101 Barrier Types

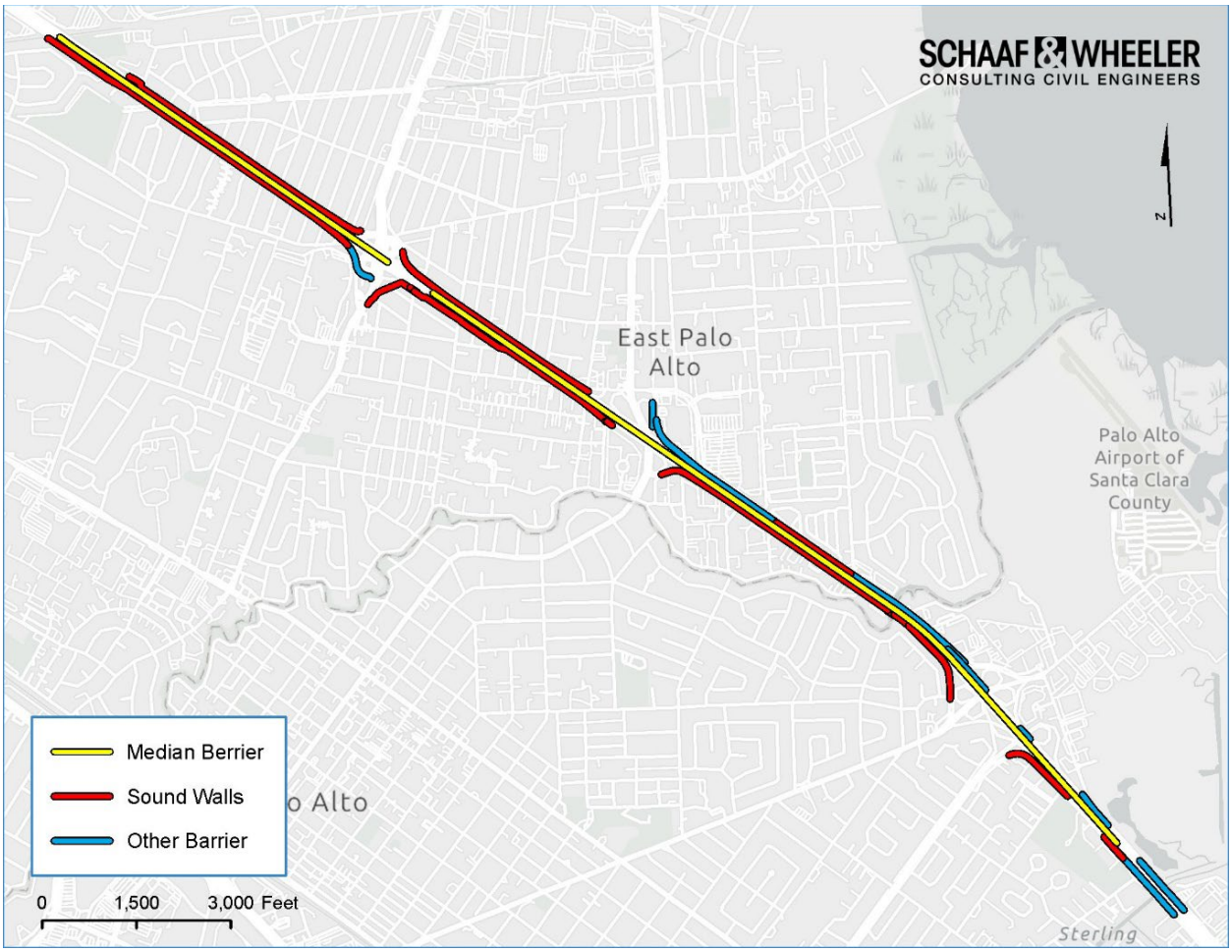


Figure 4-11: Highway 101 Flow Barriers

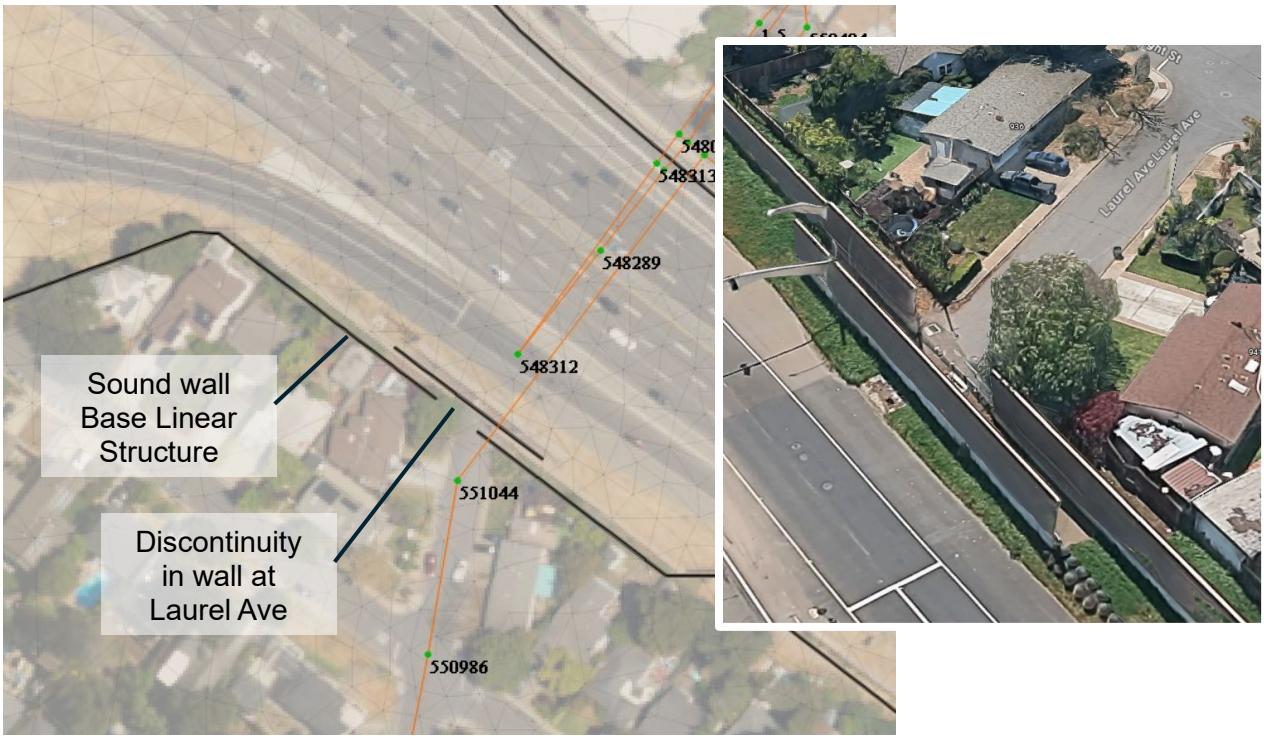


Figure 4-12: Barrier Discontinuity Near Willow Road Interchange

4.3 Open Channel Model Improvements

Previously, HEC-RAS cross sections and bridges were imported to the ICM after the HEC-RAS model was calibrated to reproduce certain spills that occurred during the New Years Eve 2022 event. This allowed for evaluation of how those spills interacted with storm drain systems and pump stations that significantly reduced flooding estimated by the HEC-RAS model.

The model reproduced capacity restrictions at bridge openings well without significant adjustment. Those crossing capacity restrictions were the primary cause of major spills that occurred upstream of Pope-Chaucer bridge during that storm event. However, the model underestimated some observed spills that were apparently more related to channel conveyance capacity, like the one that occurred onto Euclid Road from the left bank of the channel between Pope-Chaucer Bridge and University Avenue.

4.3.1 Bank Line Characteristics

ICM Channel Bank Lines define the connections between open channel reaches and the adjacent 2D mesh. Automatic bank line definition in ICM is possible but effectively builds the banks by drawing a straight-line segment from the end of one cross section to the end of the next.

Using the ICM interface and tools in external GIS software, a significant number of points are added to bank lines throughout the San Francisquito Creek model. Bank line resolution is therefore increased to better capture low points where spills occur in the HEC-RAS model. A comparison of a short reach just downstream of Pope-Chaucer bridge is shown in Figure 4-13 (2023 version on the left and updated version on the right) and Figure 4-14 with the 2023 version on the top and the updated version on the bottom of the graphic.

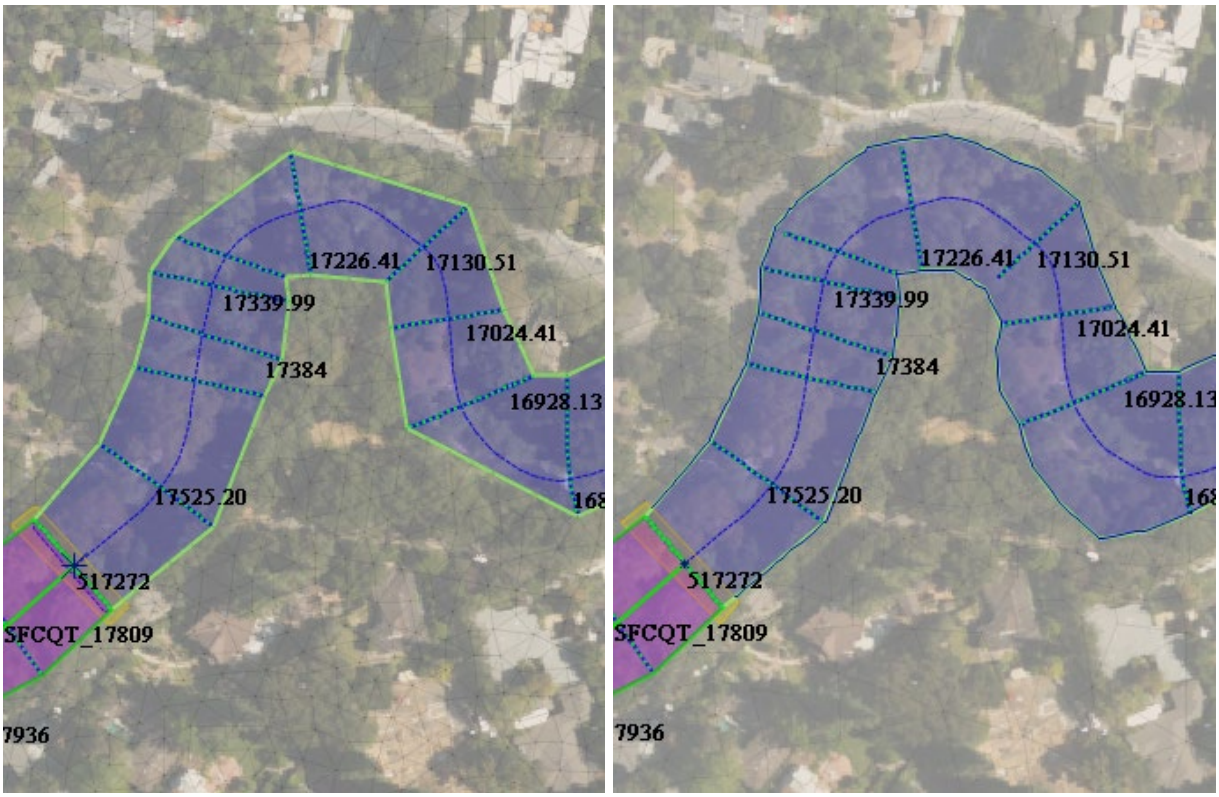
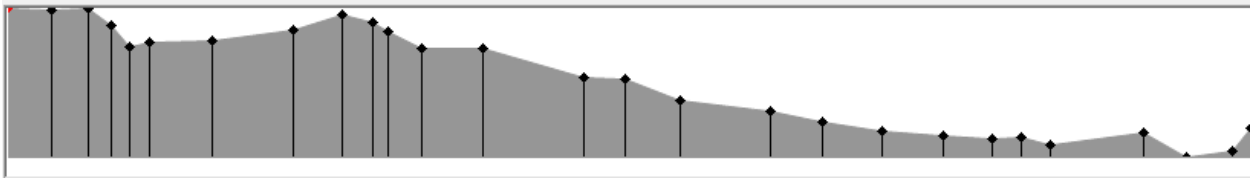


Figure 4-13: River Reach and Bankline Layout

	Offset (ft)	X coordinate (ft)	Y coordinate (ft)	Bank level (ft AD)	Discharge coeff - cd	Modular limit	RTC Definition
1	0.000	6081819.943	1993113.643	46.460	1.0000	0.9000	
2	88.516	6081877.269	1993181.089	46.430	1.0000	0.9000	
3	163.355	6081909.227	1993248.761	46.470	1.0000	0.9000	
4	210.280	6081920.979	1993294.191	45.690	1.0000	0.9000	
5	249.644	6081922.817	1993333.512	44.750	1.0000	0.9000	
6	287.399	6081944.195	1993364.631	45.000	1.0000	0.9000	
7	415.277	6082047.524	1993439.971	45.050	1.0000	0.9000	
8	579.983	6082205.148	1993392.196	45.540	1.0000	0.9000	
9	677.887	6082236.502	1993299.448	46.220	1.0000	0.9000	
10	742.298	6082263.516	1993240.976	45.860	1.0000	0.9000	
11	771.649	6082292.851	1993241.944	45.430	1.0000	0.9000	
12	841.000	6082355.794	1993271.059	44.680	1.0000	0.9000	
13	965.587	6082480.373	1993269.617	44.700	1.0000	0.9000	



	Offset (ft)	X coordinate (ft)	Y coordinate (ft)	Bank level (ft AD)	Discharge coeff - cd	Modular limit	RTC Definition
1	0.000	6081819.943	1993113.643	46.531	1.2000	0.9000	
2	88.516	6081877.269	1993181.089	47.281	1.2000	0.9000	
3	163.355	6081909.227	1993248.761	45.844	1.2000	0.9000	
4	210.280	6081920.979	1993294.191	45.000	1.2000	0.9000	
5	249.644	6081922.817	1993333.512	44.531	1.2000	0.9000	
6	288.222	6081935.791	1993369.843	44.312	1.2000	0.9000	
7	317.528	6081954.476	1993392.420	45.156	1.2000	0.9000	
8	357.545	6081986.396	1993416.555	44.800	1.2000	0.9000	
9	396.472	6082017.537	1993439.911	44.680	1.2000	0.9000	
10	428.392	6082048.679	1993446.918	44.688	1.2000	0.9000	
11	467.598	6082087.606	1993451.589	45.031	1.2000	0.9000	
12	495.938	6082114.855	1993443.804	44.937	1.2000	0.9000	
13	526.231	6082142.103	1993430.568	45.031	1.2000	0.9000	

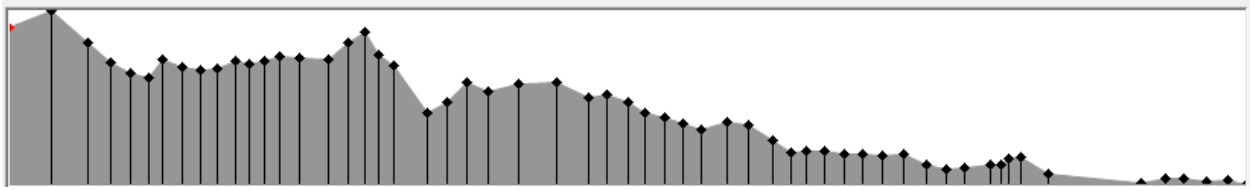


Figure 4-14: Left Bank Line Profiles Downstream of Pope-Chaucer Bridge

4.3.2 Channel Roughness

ICM utilizes “panels” in defining cross section roughness, where horizontal breaks in each channel section are placed where significant changes in roughness occur (for example, at the transition point from a heavily vegetated channel bank to a less vegetated main channel bottom). Within each panel, composite roughness is calculated using an “equivalent grain” roughness approach (Wallingford and Barr, 1994) and the conveyance is calculated within the panel. Conveyance is then summed across all panels to create the composite conveyance curve that ICM uses to solve.

HEC-RAS evaluates channel side slopes to determine whether roughness is composited or if a "subdivided" approach to calculating conveyance is taken. If the slopes are steeper than 5:1 within the main channel, HEC-RAS uses a composite roughness value, calculated based on wetted perimeter.

This creates a potentially substantial difference in how the two models handle roughness and conveyance calculation for the same cross section geometry. This update of the ICM also includes a re-evaluation of the channel roughness to better match the water surface profiles between bridges that the calibrated HEC-RAS model produced. This has also allowed for some further refinement of culvert and bridge crossing loss and capacity.

Roughness values are adjusted within individual reaches to replicate primarily breakout locations by scaling n values upwards by 5-10% at a time iteratively (up to a maximum of 0.2 at any given point) until spills produced by ICM better matched those recorded during the NYE22 storm event. An example section is shown in Figure 4-15 and Figure 4-16.

	X coordinate (ft)	Y coordinate (ft)	Bed level (ft AD)	Roughness Manning's n	New panel
7	6084297.126	1993550.324	15.590	0.0350	☐
8	6084297.805	1993545.441	15.910	0.0350	☐
9	6084298.589	1993539.806	16.070	0.0350	☐
10	6084299.302	1993534.675	16.140	0.0440	☐
11	6084299.665	1993532.070	18.020	0.0440	☐
12	6084300.481	1993526.197	20.010	0.0440	☐
13	6084301.453	1993519.214	33.720	0.0440	☐
14	6084301.860	1993516.282	36.550	0.0440	☐
15	6084302.096	1993514.588	36.470	0.1500	☐
16	6084302.192	1993513.895	36.580	0.1500	☐
17	6084302.234	1993513.598	36.530	0.1500	☐
18	6084302.316	1993513.003	36.520	0.1500	☐

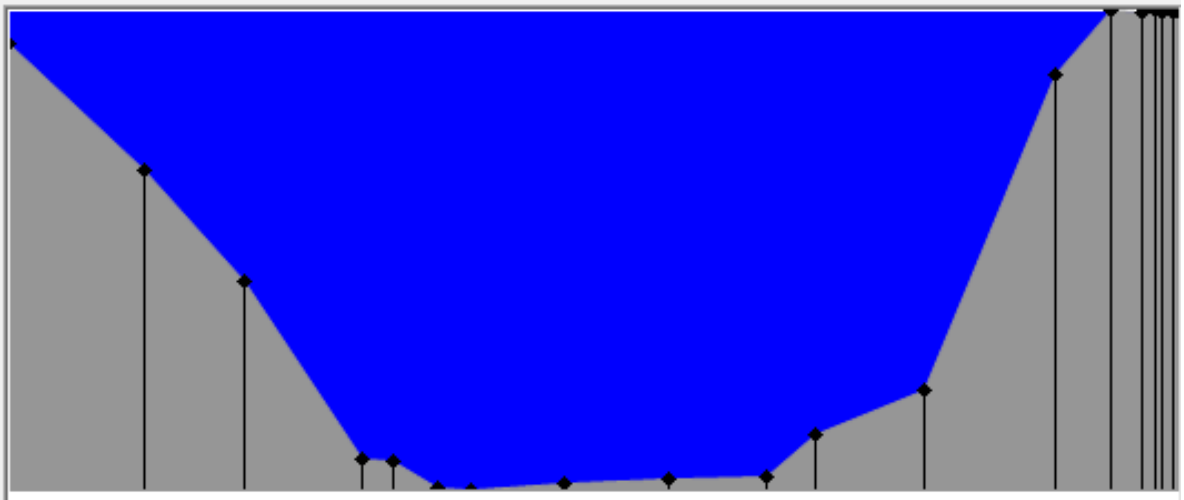


Figure 4-15: Example Cross Section Imported to 2023 ICM from the Calibrated HEC-RAS Model

	X coordinate (ft)	Y coordinate (ft)	Bed level (ft AD)	Roughness Manning's n	New panel
7	6084297.126	1993550.324	15.590	0.0482	☒
8	6084297.805	1993545.441	15.910	0.0482	☐
9	6084298.589	1993539.806	16.070	0.0482	☐
10	6084299.302	1993534.675	16.140	0.0601	☒
11	6084299.665	1993532.070	18.020	0.0601	☐
12	6084300.481	1993526.197	20.010	0.0601	☐
13	6084301.453	1993519.214	33.720	0.0601	☐
14	6084301.860	1993516.282	36.550	0.0601	☐
15	6084302.096	1993514.588	36.470	0.2000	☒
16	6084302.192	1993513.895	36.580	0.2000	☐
17	6084302.234	1993513.598	36.530	0.2000	☐
18	6084302.316	1993513.003	36.520	0.2000	☐

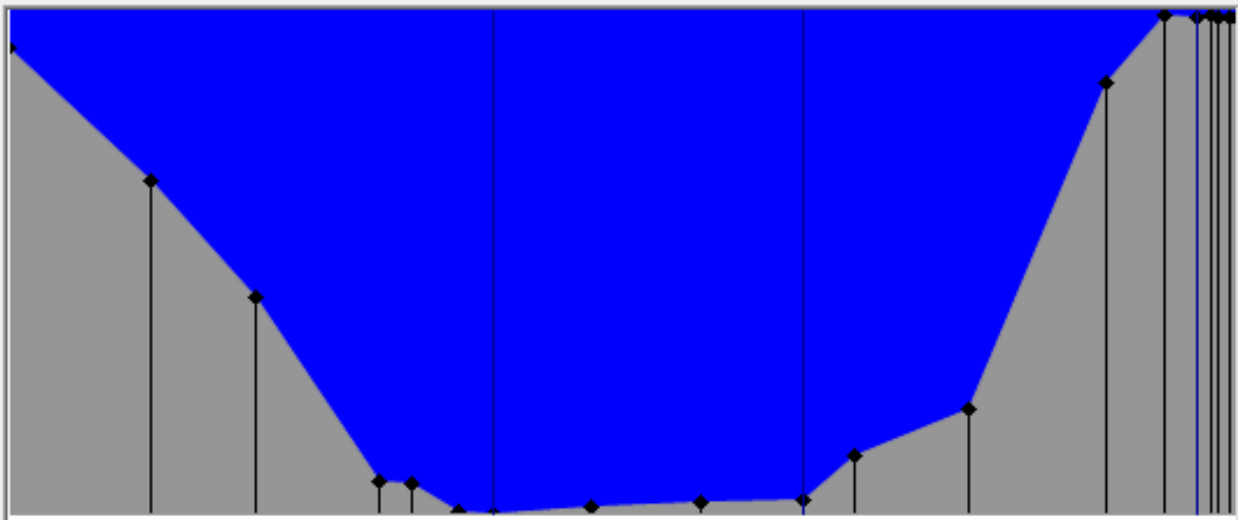


Figure 4-16: Example Cross Section from the Model Update

5. Updated Model Results

This section presents updated ICM results while providing a comparison to the New Year's Eve 2022 (NYE22) model validation storm event. It is noted that designs storms were not evaluated when the ICM was previously updated in 2023.

5.1 New Year's Eve 2022 Storm

The NYE22 storm event is re-analyzed in the updated ICM geometry to evaluate the impact of revisions at the channel. The primary source of flooding during that event was spill from upstream of Pope-Chaucer Bridge. The water surface profile from the prior effort and this model update are compared in Figure 5-1 with the updated profile on the bottom.

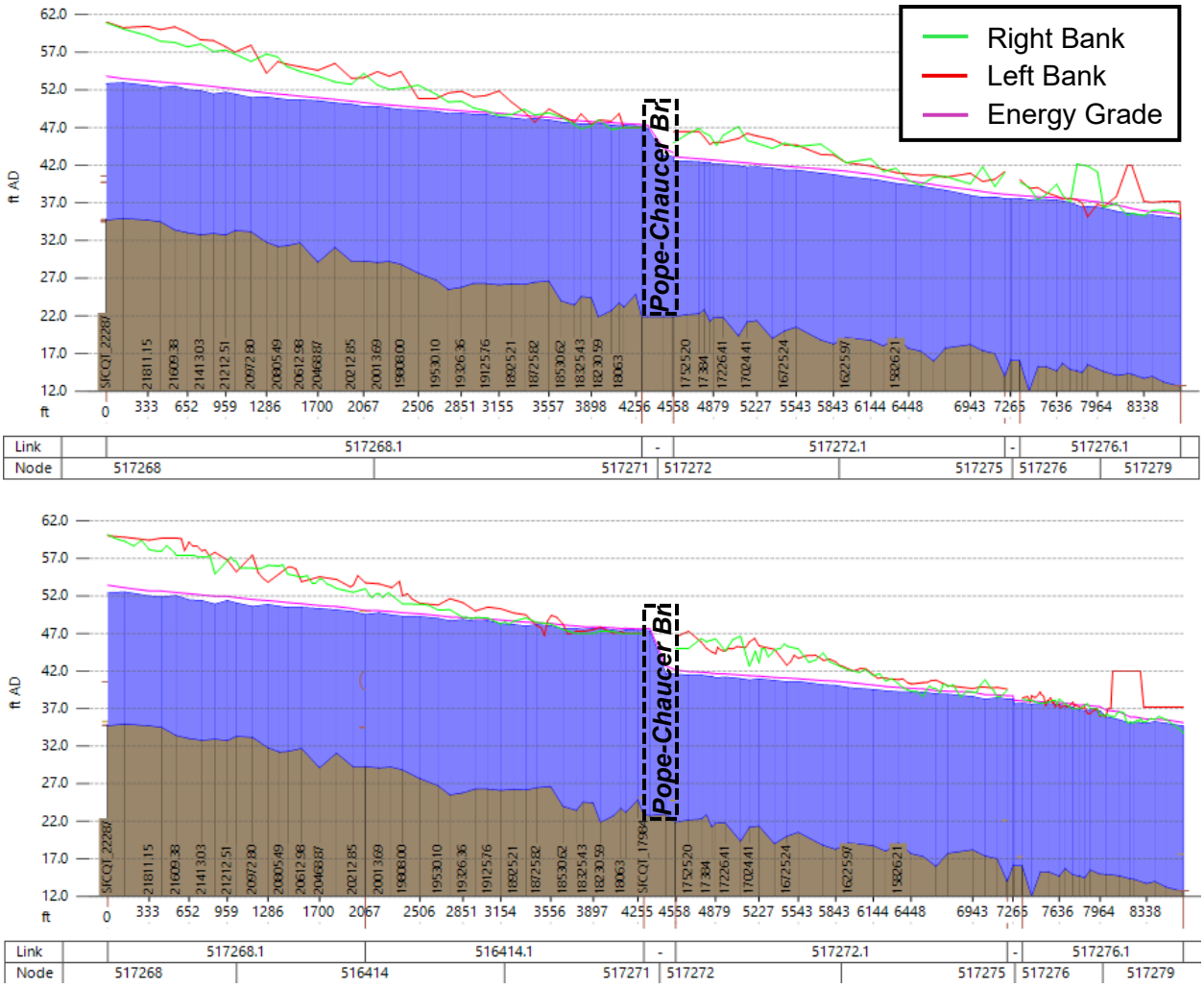


Figure 5-1: Comparison of NYE22 Profiles Between ICM Versions

Maximum flood depth results for the current model update are shown in Figure 5-2. An enlarged view of the same results is provided as Figure 5-3. Comparative results from the 2023 ICM are provided in the same enlarged view as Figure 5-4. Modeled extents of inundation from the 2023 modeling effort are compared the updated modeled extents in Figure 5-5. The 2023 model results show spill occurring just upstream of Pope-Chaucer bridge but lack spills that were documented as occurring upstream of University Avenue.

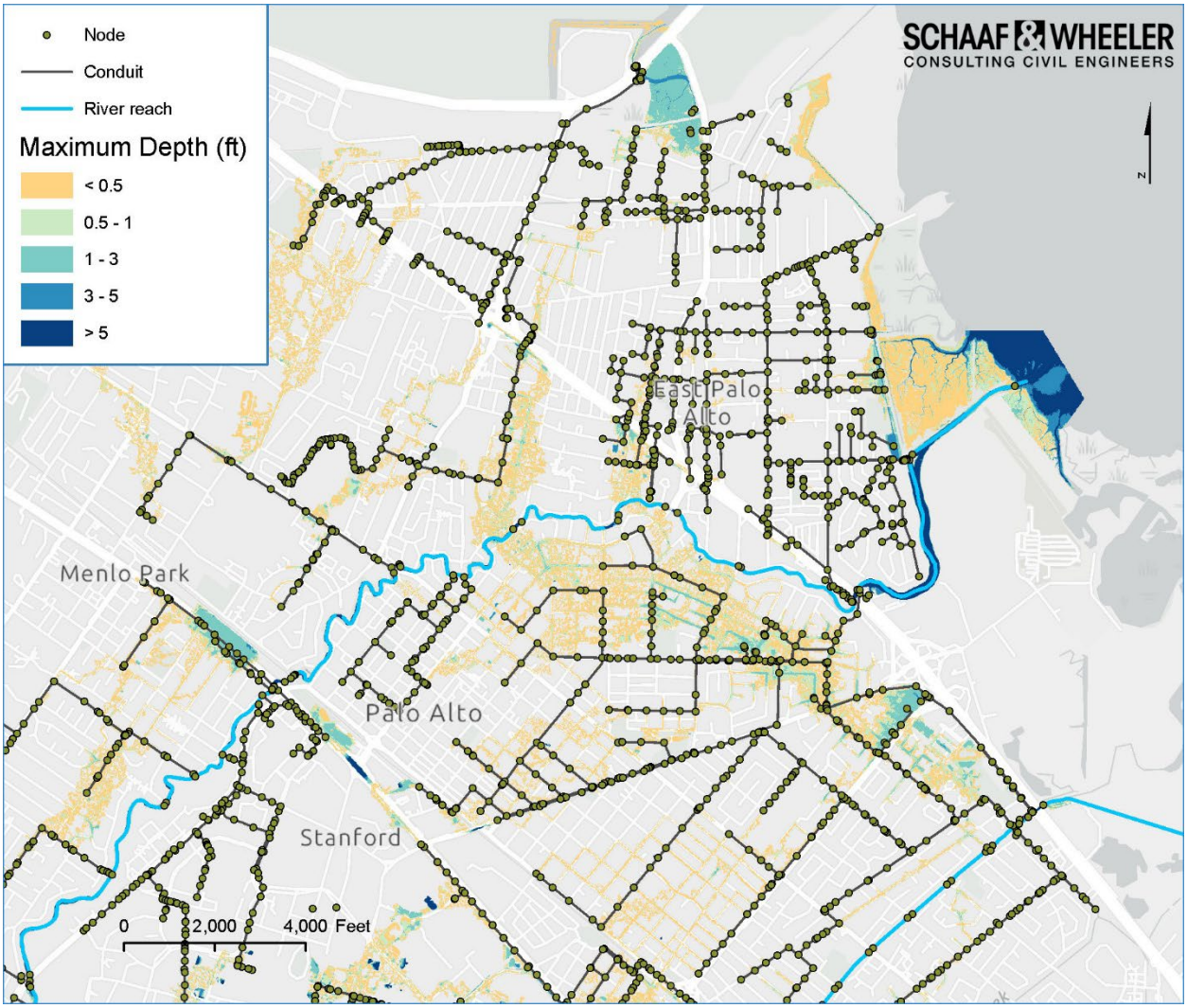


Figure 5-2: NYE22 Flood Depth Result

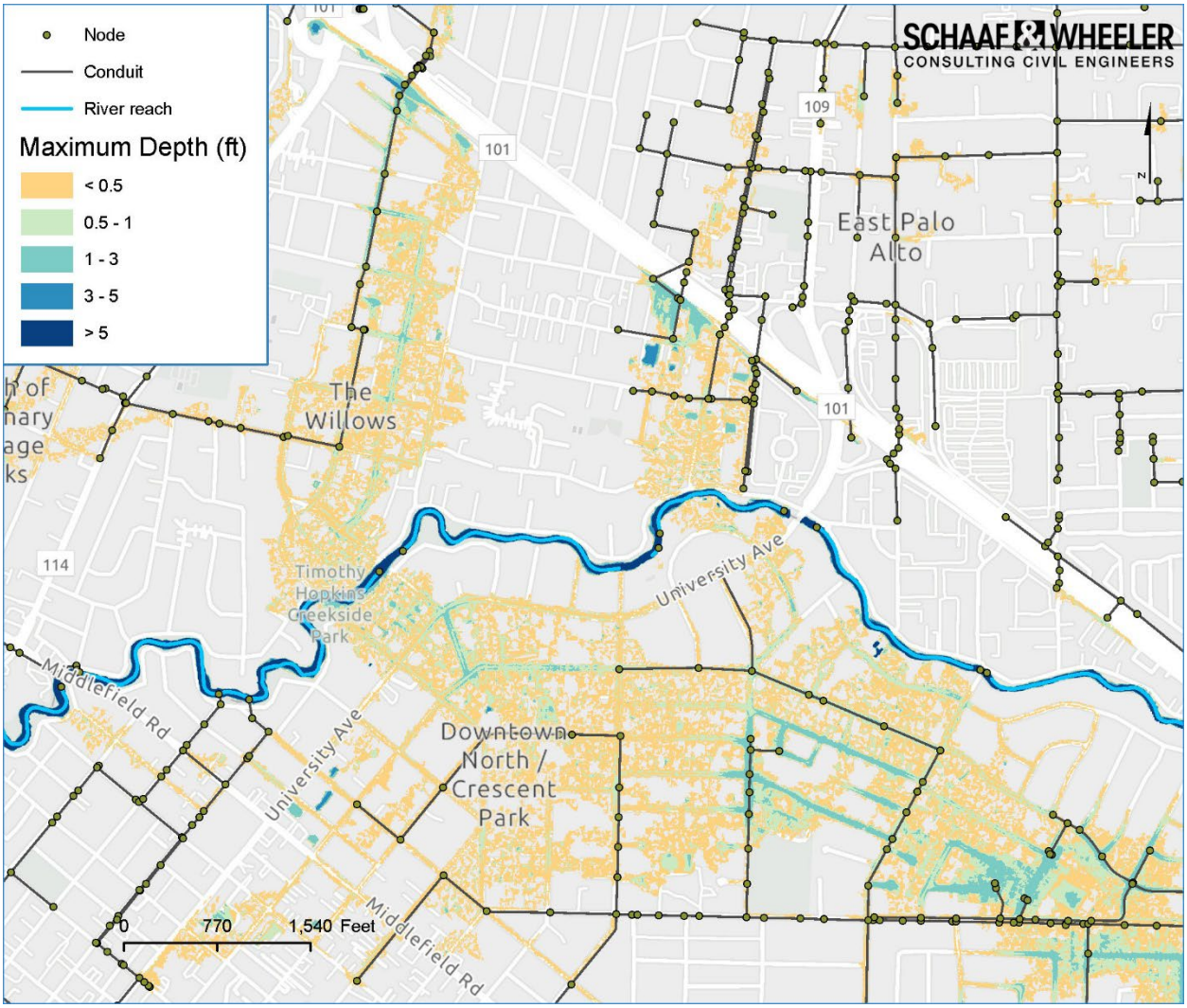


Figure 5-3: NYE22 Flood Depths – Middlefield Road to Highway 101

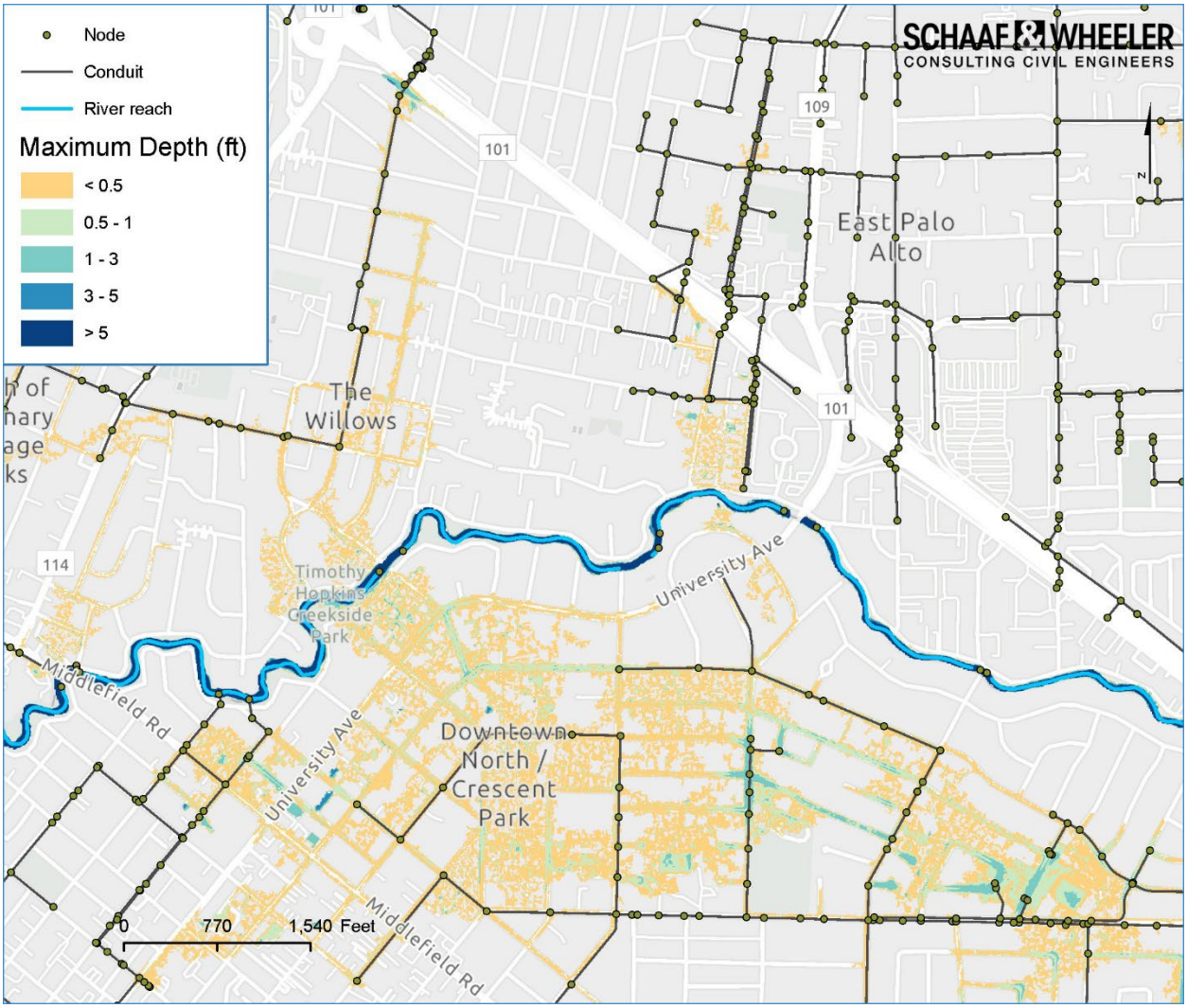


Figure 5-4: NYE22 Modeled Inundation Comparison

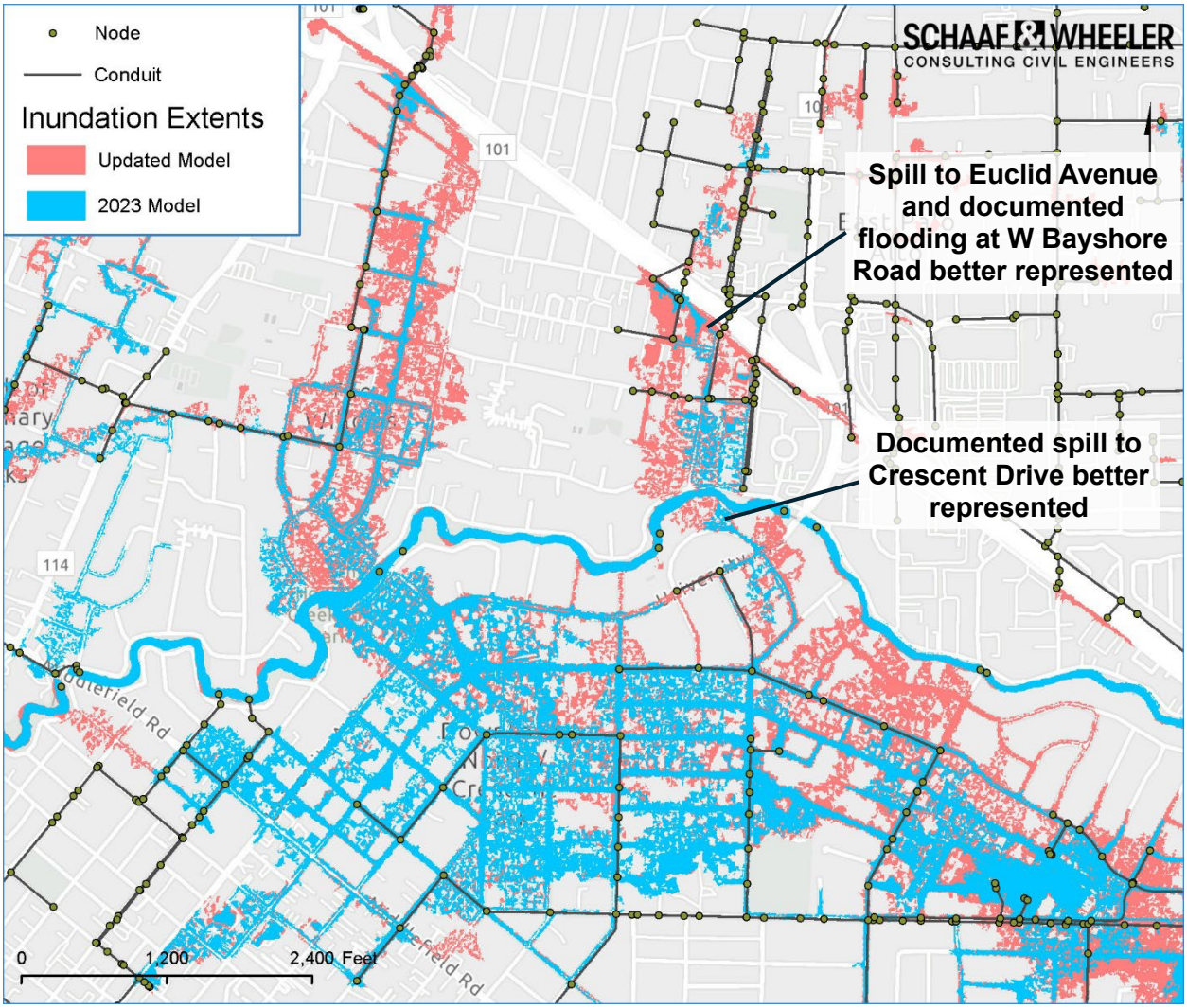


Figure 5-5: Direct Comparison of Modeled Inundation Extents for NYE22 Event

Photos of flooding at West Bayshore Road and Crescent Drive are used as references to evaluate the performance of the improved model (Figure 5-6 through Figure 5-8). An enlarged view of modeled maximum depths in the vicinity of Euclid Avenue and West Bayshore Road is shown in Figure 5-9. A plot of modeled depth on West Bayshore Road near the point of maximum flood depth locally shows depths of approximately 1.5 feet at the time these photos were taken. This appears to be on the correct order of magnitude when compared to the photo taken near 445 East Okeefe Street.

Event spill hydrographs from the creek are shown in Figure 5-11. Peak spill and volume are summarized by Table 5-1.



Figure 5-6: 1438 West Bayshore Road During NYE22 on December 31, 2022 (2:42 PM)



Figure 5-7: West Bayshore Road to East from Euclid Avenue on December 31, 2022 (2:36 PM)



Figure 5-8: Still Image from Video of Flooding at 79 Crescent Drive

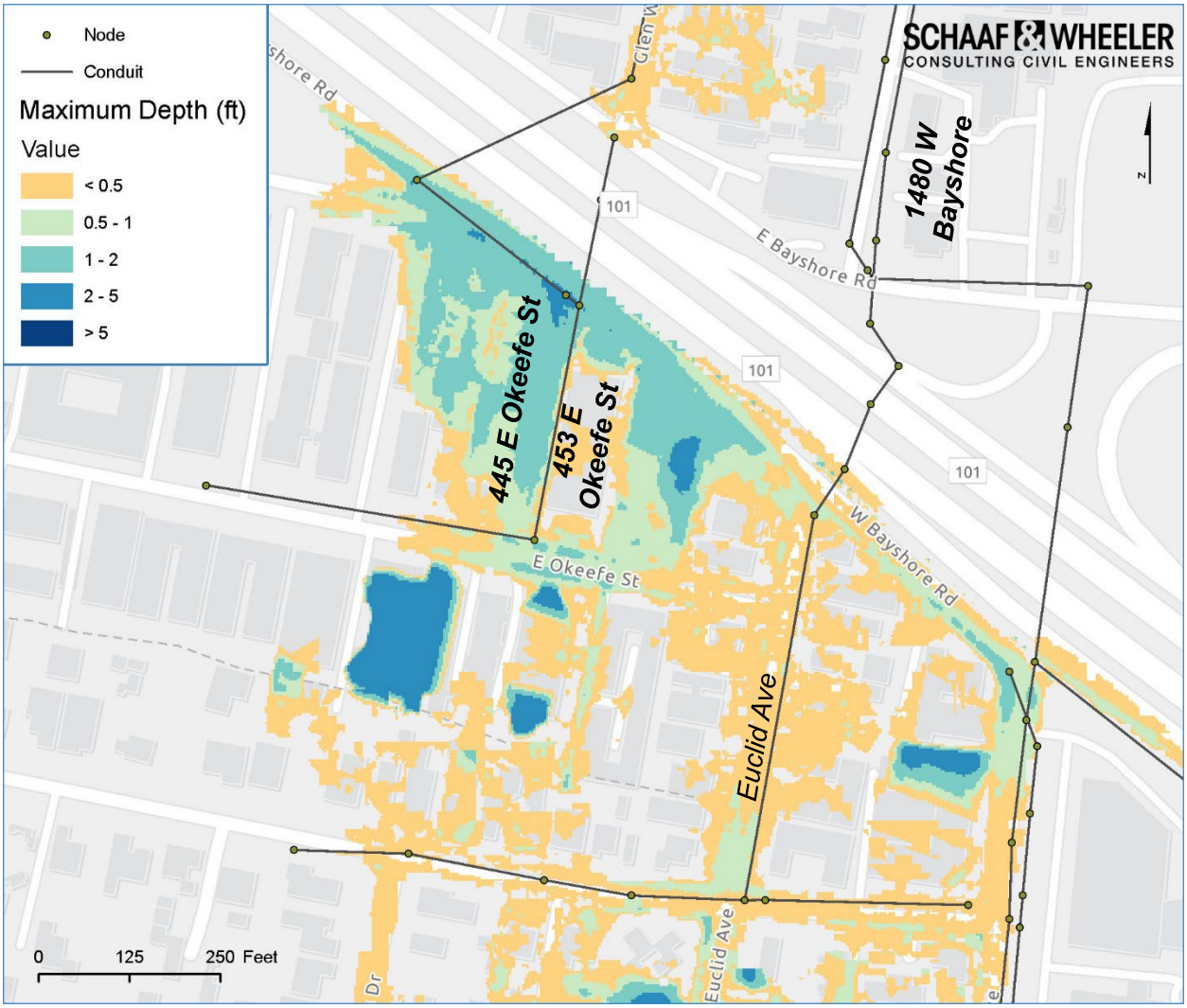


Figure 5-9: NYE22 ICM Result at West Bayshore Road near Euclid Avenue

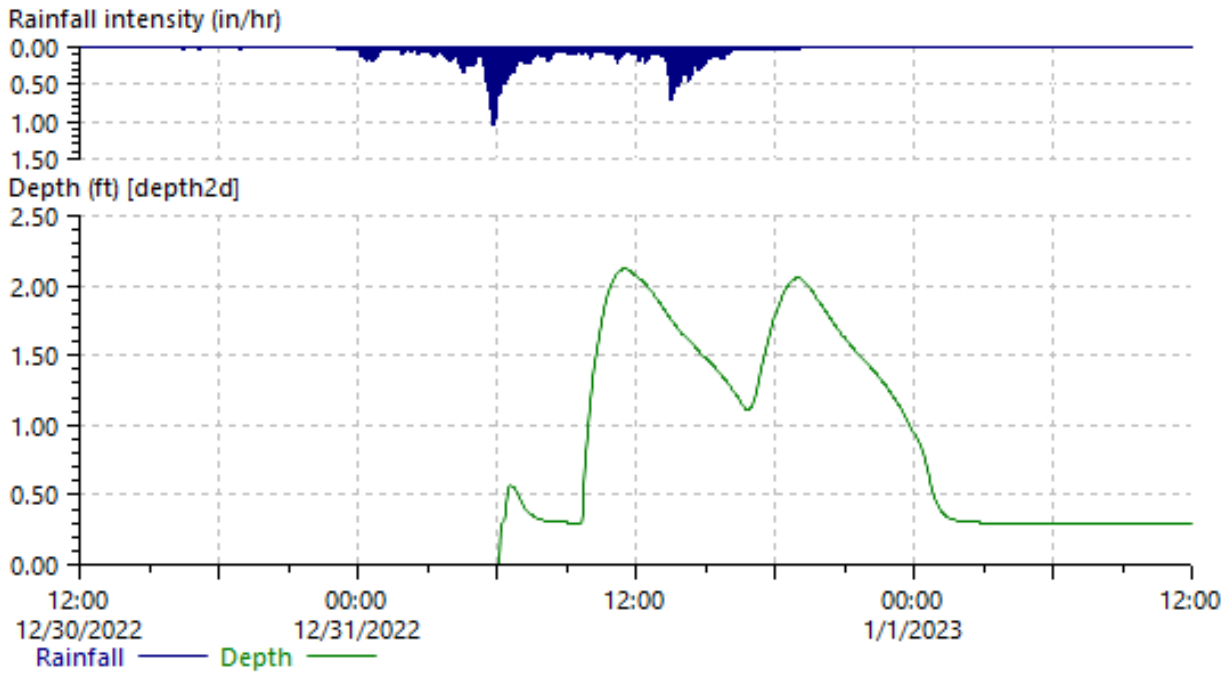


Figure 5-10: Modeled Rainfall and Flood Depth at West Bayshore Road

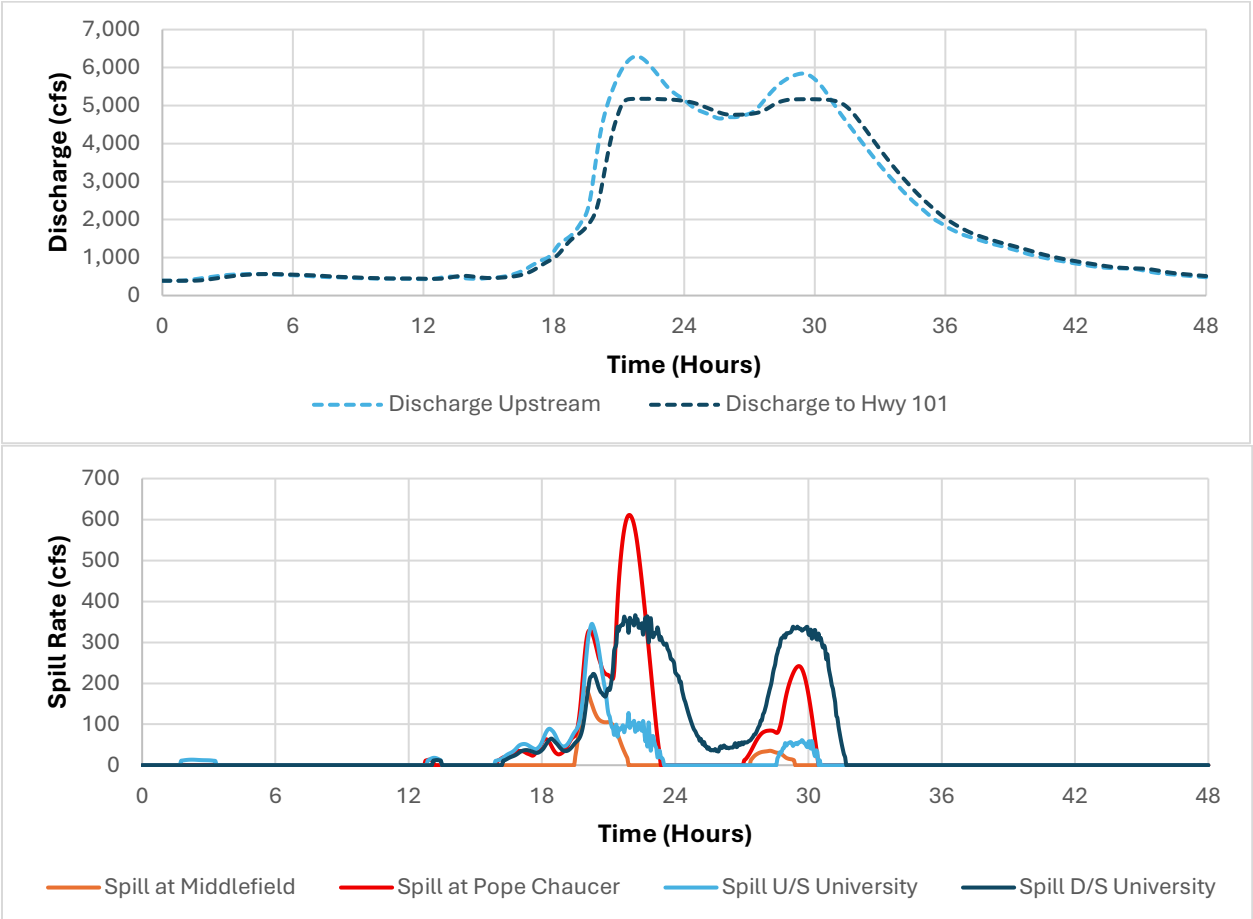


Figure 5-11: NYE22 Spill Hydrographs

Table 5-1: NYE22 Creek Spill Summary

Spill Location	Peak Rate (cfs)	Volume (AF)
At Middlefield Road	188	25
At Pope-Chaucer	611	147
Between Pope-Chaucer & University Avenue	345	68
Downstream of University Avenue	366	211

5.2 70-year Design Storm

The maximum recorded discharge at the USGS gage at Stanford University is 7,200 cfs, occurring on February 3, 1998. Based on a peak discharge statistical analysis through Water Year 2023, the return period of that annual peak discharge is about 70 years, or a roughly 1.5% annual chance exceedance probability. The modeled hydrograph for a 70-year design storm event is shown in Figure 3-8. Maximum depth results are shown in Figure 5-12. Approximate spill hydrographs are shown in Figure 5-13 and peak rates and volumes are summarized by Table 5-2.

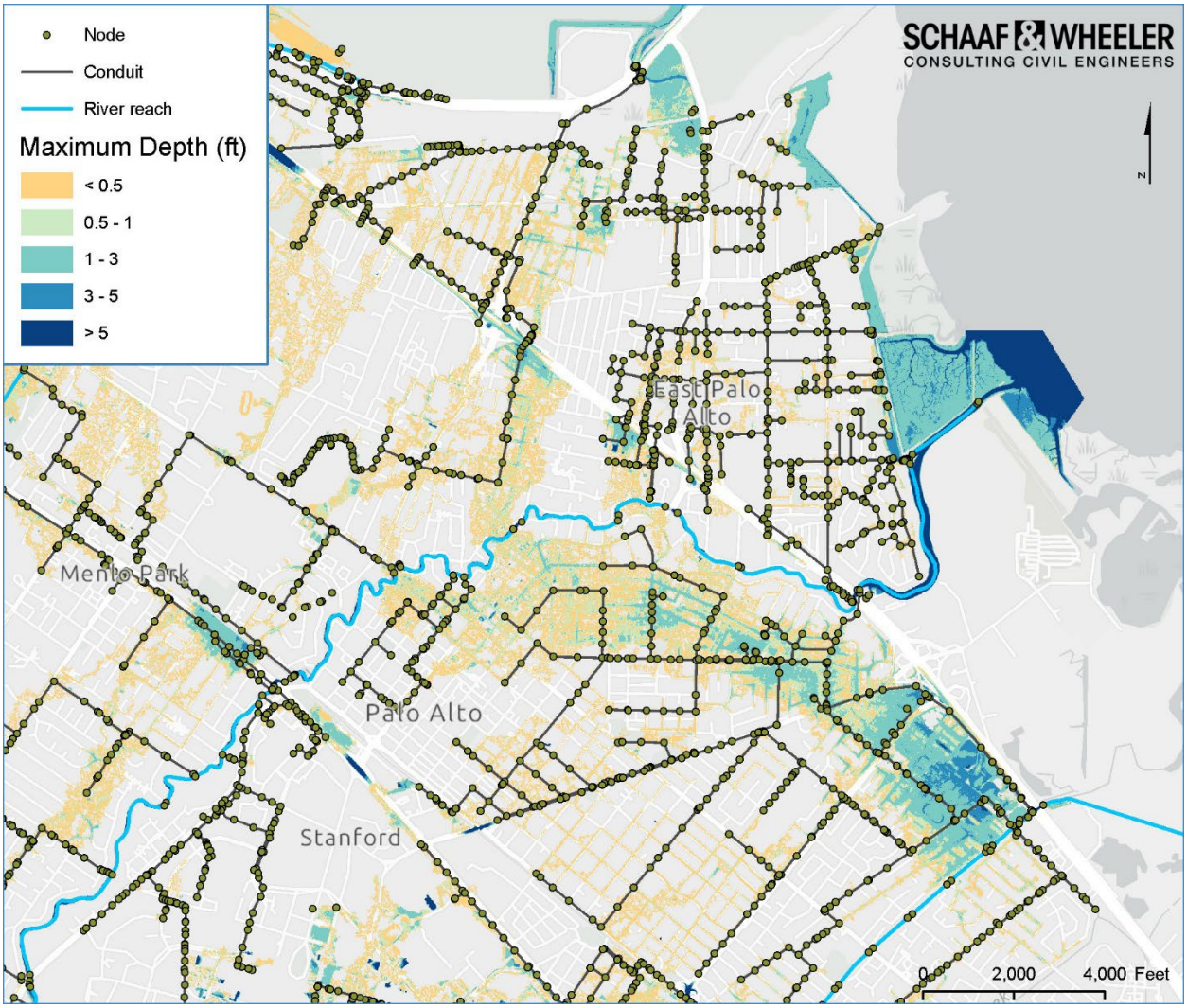
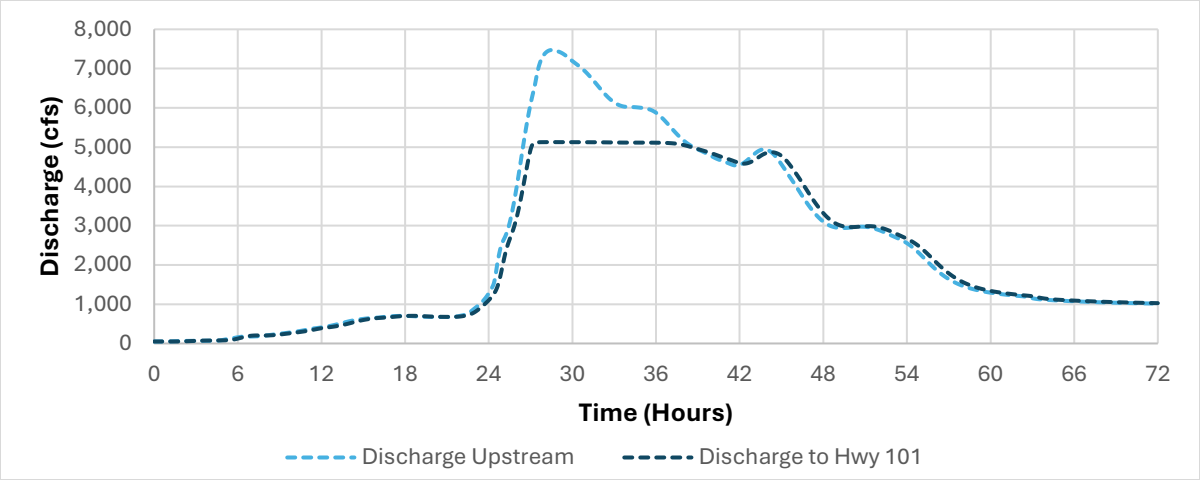


Figure 5-12: 70-year (7,200 cfs) Design Flood Depths



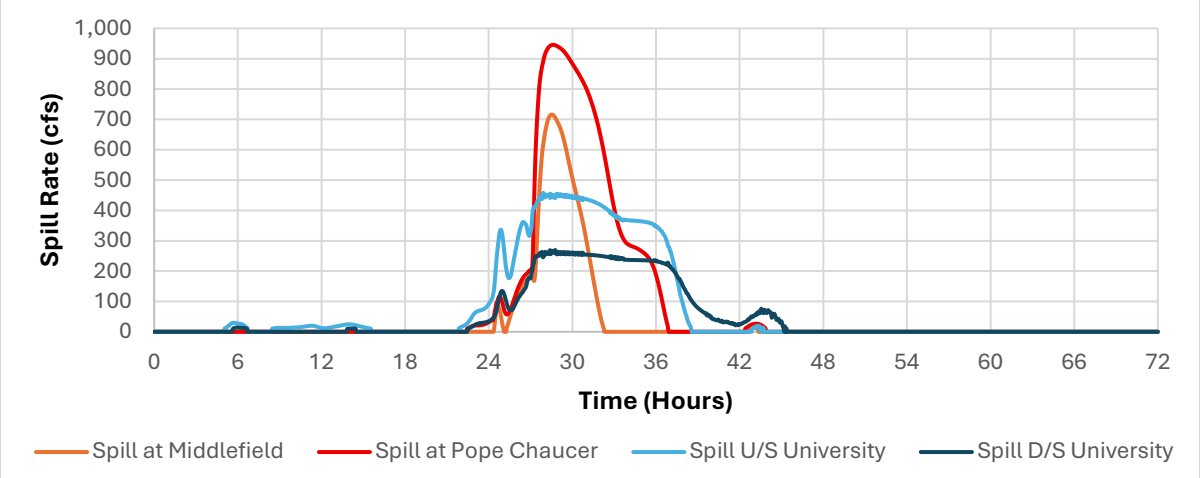


Figure 5-13: 70-year Design Storm (7,200 cfs) Hydrographs

Table 5-2: 70-year Creek Spill Summary

Spill Location	Peak Rate (cfs)	Volume (AF)
At Middlefield Road	716	207
At Pope-Chaucer	946	490
Between Pope-Chaucer & University Avenue	458	434
Downstream of University Avenue	269	280

5.3 100-year Design Storm

Updated statistical analysis of the USGS gage peak annual discharge dataset by Schaaf & Wheeler in 2023-24 yielded an estimated 100-year peak discharge of 7,890 cfs, with 5% to 95% confidence intervals defined by discharge rates of approximately 6,300 cfs and 10,400 cfs, respectively. For this analysis, the calibrated design storm event HEC-HMS model provides hydrograph input at the USGS gage. The 100-year balanced MetStat storm yields a hydrograph with a 100-year peak discharge rate of 8,200 cfs (Table 3-3). This exceeds the Bulletin 17B predicted peak discharge rate of 7,890 cfs; however, it falls well within the confidence intervals. Given its slight conservatism, the 8,200 cfs hydrologic model peak is maintained and used in the ICM.

Maximum 100-year depth results are shown in Figure 5-14. Creek flow hydrographs and spill hydrographs are shown in Figure 5-15, and spill rate and volume are summarized by reach in Table 5-3.

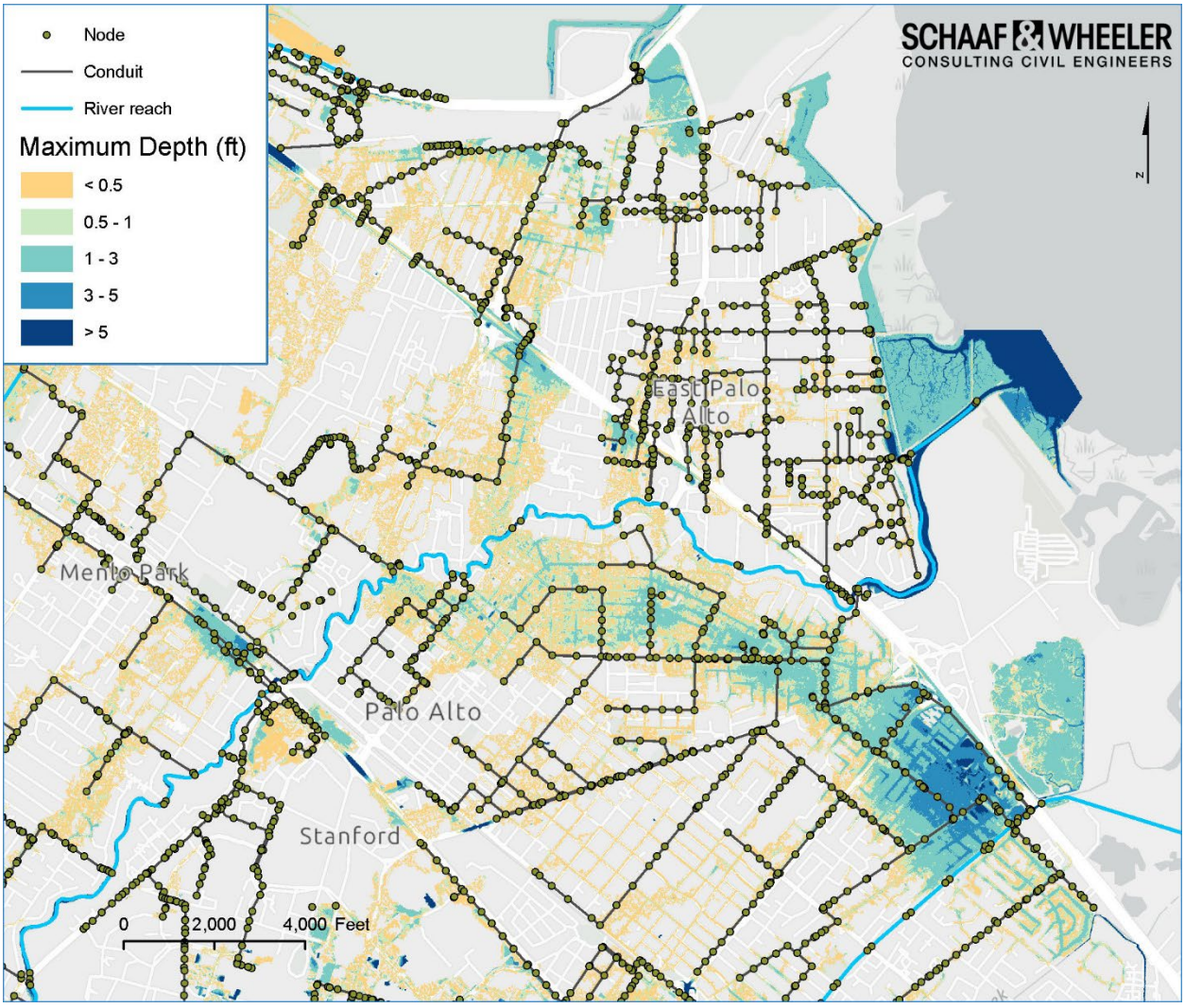


Figure 5-14: 100-year Design Event Flood Depths

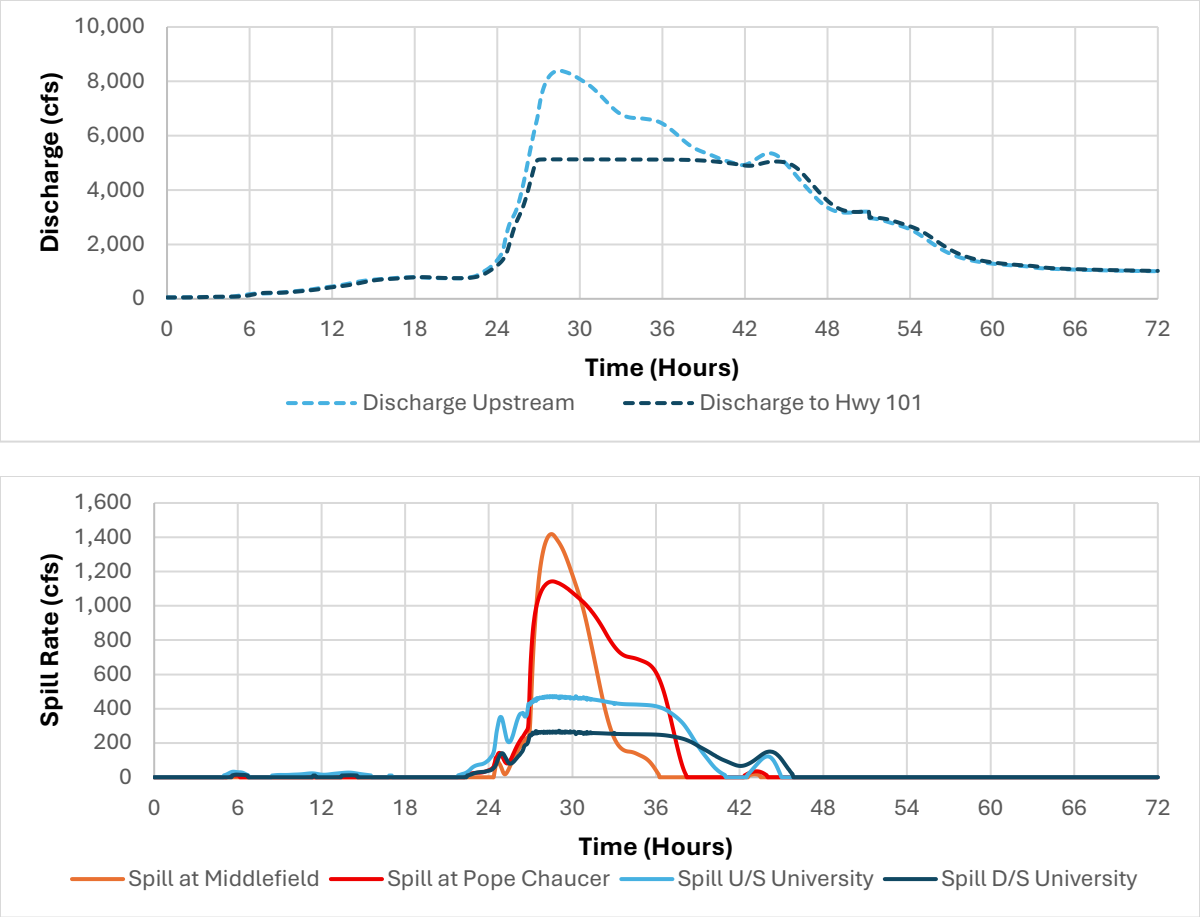


Figure 5-15: 100-Year Design Storm Hydrographs

Table 5-3: 100-Year Creek Spill Summary

Spill Location	Peak Rate (cfs)	Volume (AF)
At Middlefield Road	1,420	542
At Pope-Chaucer	1,140	777
Between Pope-Chaucer & University Avenue	473	538
Downstream of University Avenue	272	344

5.3.1 Tidal Boundary Sensitivity

Both the 100-year and the 70-year design storm events are evaluated using mean and 10-year tide cycle boundaries. For both events, maximum water surface profiles show that the difference between the two runs reaches no further upstream than the pedestrian bridge near O'Connor Pump Station.

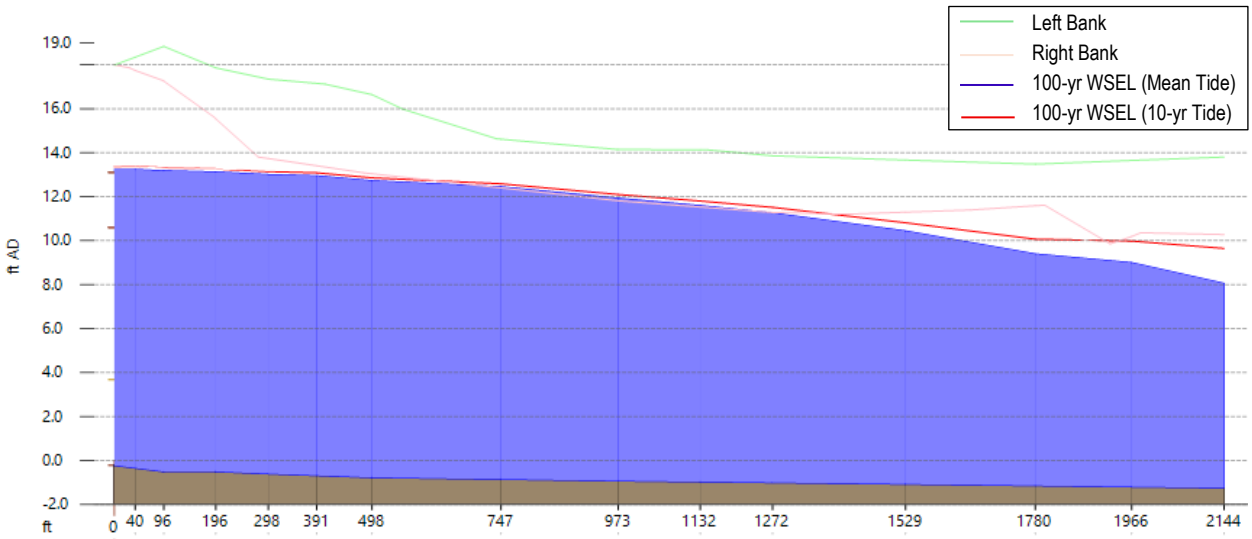


Figure 5-16: Tidal Boundary Sensitivity with 100-year Fluvial Runoff

The last modeled spill from the creek is just upstream of Newell Bridge, approximately 7,000 feet upstream from the apparent limit of tidal influence on the 100-year storm event water surface profile. Though the creek is tidally influenced to a greater extent, spill during substantial storm events appears entirely dependent on channel conveyance capacity rather than tidal tailwater.

6. Comparison to the ATR Model

The HEC-RAS ATR Model is run with the 100-year and NYE22 storm events to provide a reference point for spills from the San Francisquito Creek. Some corrections made to the ATR model geometry address inconsistencies in cross section hydraulic table (HTab) inputs, and the 2020 LiDAR surface is used throughout the modeling efforts described in this report. The ATR HEC-RAS model is also expanded at its downstream end to include a 2D tidal area like the updated ICM. These modifications allow for a more direct comparison of results from the two models. The HEC-RAS model maximum 100-year depth result is shown in Figure 6-1.

Inundation extents are shaded for both the HEC-RAS ATR model and the ICM and overlain in Figure 6-2. Overlaying inundation areas highlights the effect of including interior drainage systems in the San Francisquito Creek floodplain. North of Highway 101 in East Palo Alto and Menlo Park, pipe systems influence where flood waters cross Highway 101. Where the RAS model effectively treats the highway barriers as impermeable and direct flooding across the surface, pipe systems in ICM can intercept surface flows and introduce interior drainage capacity that is not modeled in HEC-RAS.

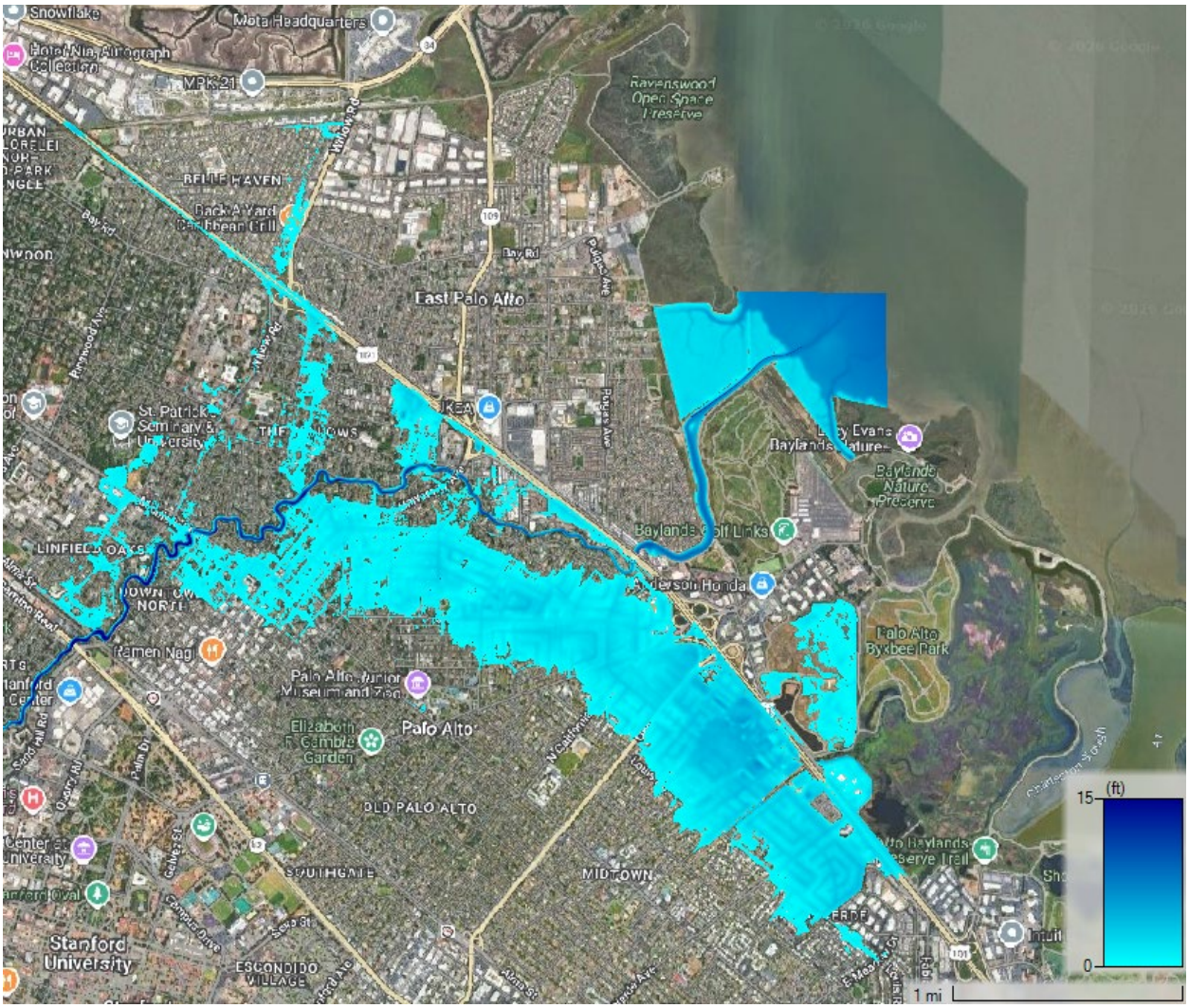


Figure 6-1: 100-year Updated HEC-RAS Model Result (Maximum Depth)

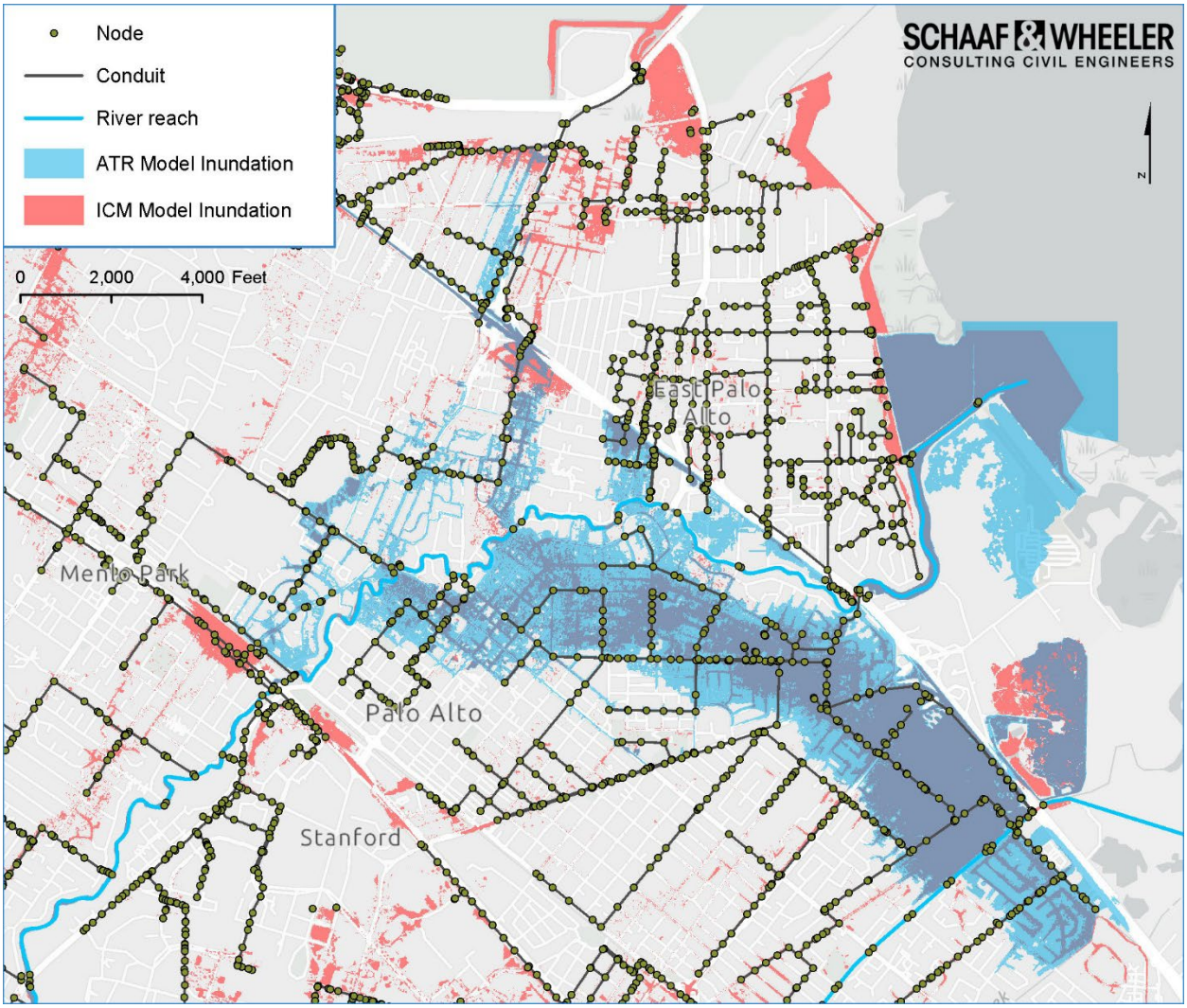


Figure 6-2: Overlay of 100-year ATR Model Inundation with ICM Inundation

South of Highway 101, inundation extents are reduced significantly as storm drain systems intercept spills and discharge them back to San Francisquito Creek downstream (via San Francisquito Creek Pump Station), and to Matadero Creek. Upstream of El Camino Real, differences in the results emphasize the impact of high levels in San Francisquito Creek on interior drainage. Namely, drainage from south of the Railroad and El Camino Real encounters a “bathtub” condition west of the Creek in a depression bound by the bank of San Francisquito Creek, the railroad embankment, and Ravenswood Ave. When water levels in the creek rise, the flap gates on El Camino Real drainage system outfall close and clear water floods that depression. This occurred during the New Years Eve 2022 event, presenting as “clear water” flooding; meaning that sediment and debris laden waters from San Francisquito Creek overtopping its banks were not the cause of that flooding.

Local drainage and clear water flooding are not reflected in the ATR because that is not that model’s function. While an interesting comparison, there is no intention in this study to directly compare the HEC-RAS ATR to the ICM and conclude one is “more correct” than the other.

6.1 ATR Model Sensitivity

While developing this integrated floodplain model update, Schaaf & Wheeler identified modifications made to the RAS model after the 2023 peer review and model calibration was completed. These included some additional cross sections around the Highway 101 bridge, which were inserted with hydraulic table (HTab) parameters inconsistent with surrounding cross sections. Upon correcting those HTab values (setting the invert level to match the section invert and improving the resolution of the HTab curve points), Schaaf & Wheeler obtained notably different model results than those that were provided with the ATR RAS model. Spill upstream of Pope-Chaucer bridge produced in the updated run was approximately an order of magnitude lower than with the previous ATR run.

WRA also re-examined the model inputs, made reasonable adjustments, and still obtained somewhat different results – though one of their runs yielded something more similar to Schaaf & Wheeler's result than to the previous ATR run. WRA and Schaaf & Wheeler mutually observed that certain bridges from Pope/Chaucer to University Ave are extremely sensitive to variations in water surface elevations. This sensitivity appears to cause changes in the bridge flow methodology the model chooses between computers or with relatively small changes in inputs. Without a CFD or physical model of Pope Chaucer bridge, it is extremely difficult to determine which method is most representative of reality. A summary of maximum energy grade results and bridge methodologies in the ATR model and the updated run with corrected HTab inputs is presented in Table 6-1.

Table 6-1: Comparison of Bridge Model Results Using the ATR Model

Bridge	USACE ATR Run Method	USACE ATR Run Upstream EGL (ft NAVD)	Updated Run Method	Updated Run Upstream EGL (ft NAVD)
Middlefield Road	Press/Weir	62.08	Press/Weir	62.02
Pope-Chaucer	Press/Weir	47.79	Press Only	47.24
Pedestrian Bridge (Sta. 15227)	Energy/Weir	40.45	Momentum	39.76
Pedestrian Bridge (Sta. 14900)	Press Only	39.27	Momentum	38.76
University Avenue	Press Only	35.35	Press Only	35.02
Newell Road	Energy only	29.89	Energy only	29.45
Highway 101	Energy only	17.71	Energy only	17.69

There is a very small difference in the energy grades produced by the two models at Highway 101; however, the divergence in water levels and energy grades becomes more pronounced upstream at Newell Road. The substantial difference is attributed to corrections to the HTab parameters at the two cross sections just upstream of Highway 101 bridge. At the pedestrian bridges and Pope-Chaucer bridge, this reduction in energy grades also importantly appears to result in a difference in bridge modeling methodology.

In aggregate, the HTab parameter modifications and bridge methodology changes yield a change in spill rates upstream of Pope Chaucer from approximately 600 cfs peak spill in the ATR model and 80 cfs in the updated Schaaf & Wheeler model run. The maximum water surface profiles are shown for the two runs just upstream of Pope-Chaucer in Figure 6-3. These result in different floodplains, with the updated Schaaf & Wheeler run floodplain resembling ICM results more closely than the ATR run. The difference in results diminishes significantly by Middlefield Road Bridge – although there is still some difference in spill rate and volume at Middlefield as well (447 cfs peak in the ATR run compared with 415 cfs in the updated run).

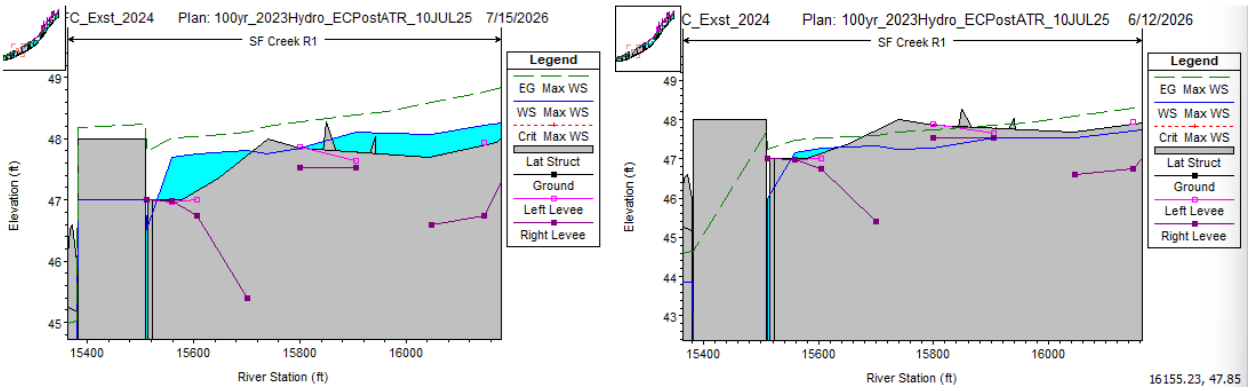


Figure 6-3: Results at Pope-Chaucer for the ATR Run (Left) and with Corrected HTab Inputs (Right)