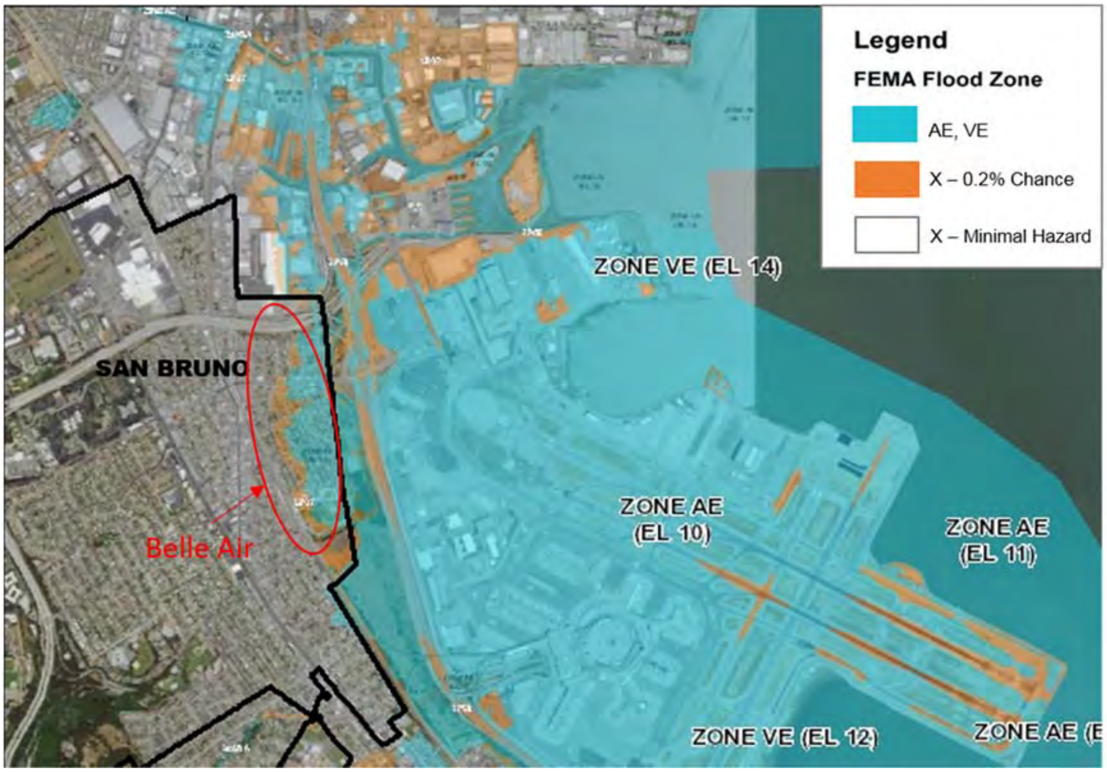
FEMA APPEAL DOCUMENT
City of San Bruno



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APPENDICES

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FIGURES

1. FEMA PRELIMINARY MAPPING FOR THE CITY

FEMA preliminary FIRMs for the County of San Mateo is dated in August 2015. It is intended to supersede the current effective FIRMs dated in October 2012. There are significant changes in SFHA zone designations within the City jurisdiction. This section summarizes the flood zone mapping in the City and factors contributing to the preliminary FIRMs.

1.1 Overview of FEMA Coastal Mapping

The NFIP was established in 1968. Since then, the FIRMs have been produced to inform local communities and residents about flood risks. The flood hazard analyses and mapping studies by FEMA produce FIRMs and other flood risk products. The FEMA flood hazard study and coastal mapping consists of the following steps (FEMA, 2016):

1) Define base topography data sets sufficient for modeling, flood analysis, and mapping;
2) Identify flood water levels using historic flood data and computer models;
3) Define cross-shore transects to represent the terrain and variability of shoreline features;
4) Conduct an analysis to characterize storm-induced erosion;
5) Conduct wave modeling to define coastal flood hazard areas and establish BFEs;
6) Map coastal flood hazard areas using the results of the modeling and analysis; and
7) Produce the FIRM and non-regulatory flood risk products to indicate the coastal flood risks within communities.

Coastal flooding is usually caused by coastal storms. In the California, high ocean water levels are caused by king tides (astronomical tides) together with barometric pressure tide, wind setup, seiche, and the El Niño Southern Oscillation. For the San Francisco Bay area, the FEMA coastal flood mapping analysis is divided into three steps:

- First, the hydrodynamic and wave modeling studies of the North and Central San Francisco Bay were performed by Danish Hydraulic Institute (DHI 2011), which defined SWELs of the 1% and 0.2% annual-chance flood events.
- Next, a separate overland wave analysis using the Wave Height Analysis for Flood Insurance Studies (WHAFIS) model was performed for each transect to determine elevations to which wave runup extends during a storm, and
- Finally, the BFEs and flood zones were designated.

In the County of San Mateo, the primary coastal hazards are wave runup, overtopping, overland wave propagation and inundation from elevated SWELs (Baker/AECOM 2014). These hazards were evaluated using a transect-based analysis with transects starting at the +3.2 feet NAVD88 contour (approximately MSL) and extending no more than 500 feet into the landward-most Zone X. The analysis of the coastal hazards at each transect location was performed based on guidelines outlined in the “Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States” (FEMA 2005). Flood risk designations within San Mateo County include Zone VE, Zone AE, and Zone X. Their zone definitions are listed in the following:

- Zone VE is defined as an area with a high coastal hazard from wave action and/or high velocity water causing structural damage during the 1% annual chance storm.

- Zone AE are areas of inundation by the 1% annual chance flood with wave heights and runup levels less than 3 feet above the SWEL.
- Zone X is further divided into Shaded and Unshaded. The Shaded Zone X are areas between the limits of the 1% annual flood and a 0.2% annual chance flood. The Unshaded Zone X are areas not inundated by the 0.2% annual chance flood.

Only Zones VE and AE are included in SFHAs. Figure 1 illustrates the FEMA's flood zone schematics, together with the definitions of SWELs and BFEs. The 100-year stillwater elevation is the water level with a 1% annual chance of being exceeded in a given year.

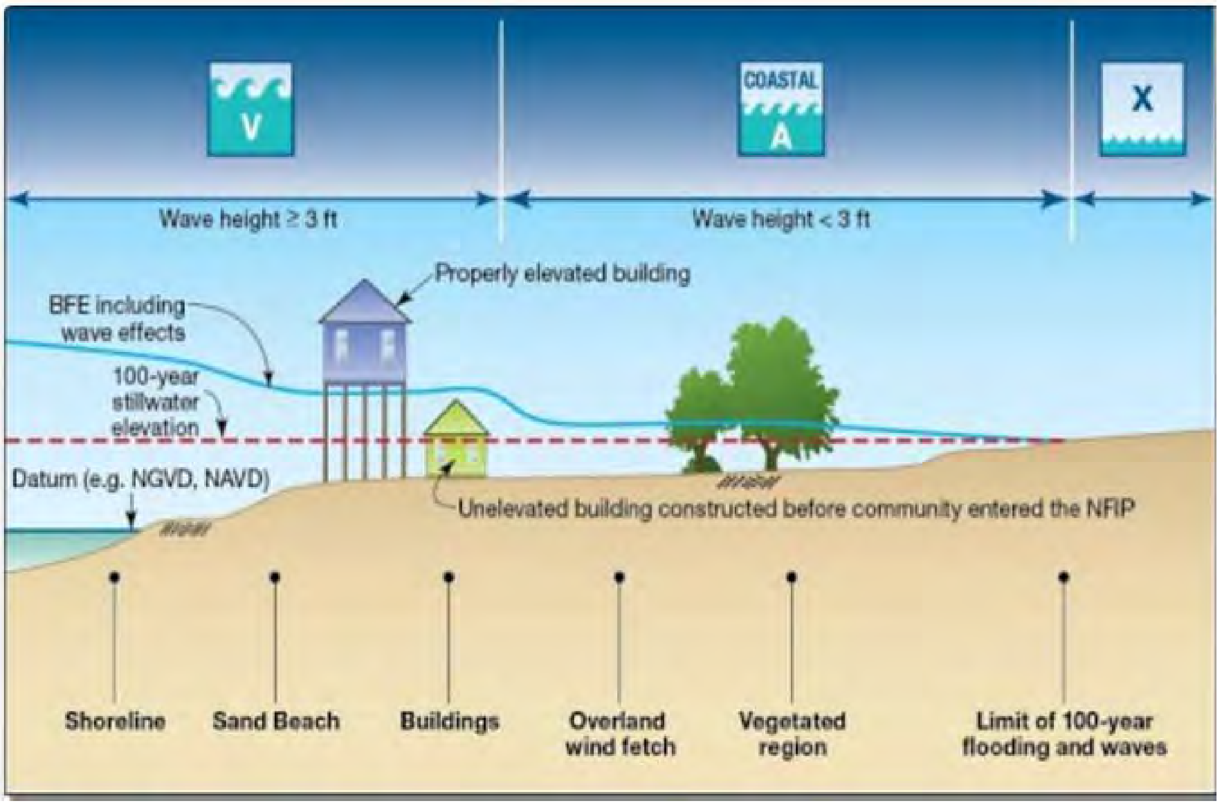


Figure 1: Coastal V and A zones and the added effects of waves on coastal BFEs

The SFHAs within the City are mapped as a Zone AE with a BFE of 10 feet above NAVD88. Because the city limits are inland of the Bay, no wave action is experienced in these areas; therefore, the only coastal hazard is inundation due to high SWEL. A 1% annual chance flood SWEL of +10.4 feet NAVD88 reported in the Coastal Hazard Study for San Mateo County (Baker/AECOM 2014 & 2015) was adopted in the development of the preliminary FIRMs.

Areas inundated by stillwater flooding with minimal wave hazard effects are mapped as Zone AE and the flood hazard boundary is located at the point where the ground elevation equals the SWEL (FEMA 2015). For areas within the City, the inundation extent was taken to the point where the SWEL of +10.4 feet NAVD88 meets ground elevations. Therefore, all areas within the City mapped as SFHA Zone AE are at or below +10.4 feet NAVD88 and have a direct pathway to a flooding source.

1.2 Stillwater Elevations

The FEMA coastal flood studies producing FIRMs with SFHAs includes two major components: storm surge analysis and overland wave modeling. Figure 1 in the previous section illustrates the relationship between the base flood elevation including wave effects, the 1% annual chance SWEL, and the ground profile. In many coastal areas, storm surge is the principle component of flooding. The extent of the 1% annual chance floodplain is determined from the total stillwater elevation (storm surge plus wave setup) for the 1% annual chance storm. In some areas, the 1% annual chance floodplain is derived based on the limit of wave runup or wave overtopping for the 1% annual chance storm surge.

The Coastal Hazard Study for San Mateo County reports a 1% annual chance of flood SWEL of +10.4 feet NAVD88 that was adopted for analysis in the development of the preliminary FIRMs. This SWEL was computed by preforming the General Extreme Value Distribution (GEV) analysis with a 54-year water level time series developed at the site during the Coastal Hazard Modeling Study for North and Central San Francisco Bay (DHI 2011).

The City requested and received the coastal flood hazard study reports for both San Mateo County and San Francisco County. Both reports were prepared by Baker/AECOM team in 2014 and 2015, respectively. The SWELs of the 1% and 0.2% annual chance floods at transects within this appeal study area are listed in Table 1 in north to south order. The complete transect maps and data are included in Appendix A.

The highest 1% SWEL in this study area is +10.46 feet NAVD88 at Transect 13, which is very close to the SWEL of +10.4 feet NAVD88 from FEMA' s Coastal Hazard Study. Similarly, the 0.2% SWEL of +12.05 feet NAVD88 at the same transect is very close to the +12 feet NAVD88 adopted in the preliminary FIRMs. Therefore, the elevations of +10.4 feet NAVD88 for 1% annual chance flood and +12.0 feet NAVD88 for 0.2% annual chance flood are used in this appeal analysis.

Table 1: Transect Data of Stillwater Elevation (Baker/AECOM 2014 & 2015)

Transect	County	SWEL (feet NAVD 88)	
		1% Annual Chance	0.2% Annual Chance
13[1]	San Mateo	10.46	12.05
55[2]	San Francisco	10.00	11.00
56[2]	San Francisco	10.10	11.00
57[2]	San Francisco	10.10	11.00
58[2]	San Francisco	10.10	11.10
59[2]	San Francisco	10.10	11.20
60[2]	San Francisco	10.20	11.20
61[2]	San Francisco	10.10	11.10
62[2]	San Francisco	10.10	11.10
63[2]	San Francisco	10.10	11.10
14[1]	San Mateo	10.18	11.26

[1]. *Baker/AECOM 2014.*
[2]. *Baker/AECOM 2015.*

1.3 Topography Data

The original topographic data used in FEMA coastal flood hazard study to produce preliminary FIRMs was also available to the City for use in this appeal. Figure 2 shows that elevations in the City range from below +9 feet NAVD88 to over +830 feet NAVD88. The low elevations occur along the eastern border of the city and are also of the closest proximity to the Bay. The areas with low elevation, and consequently the areas at risk of flooding during the 1% annual chance flood, are within the Belle Air neighborhood.

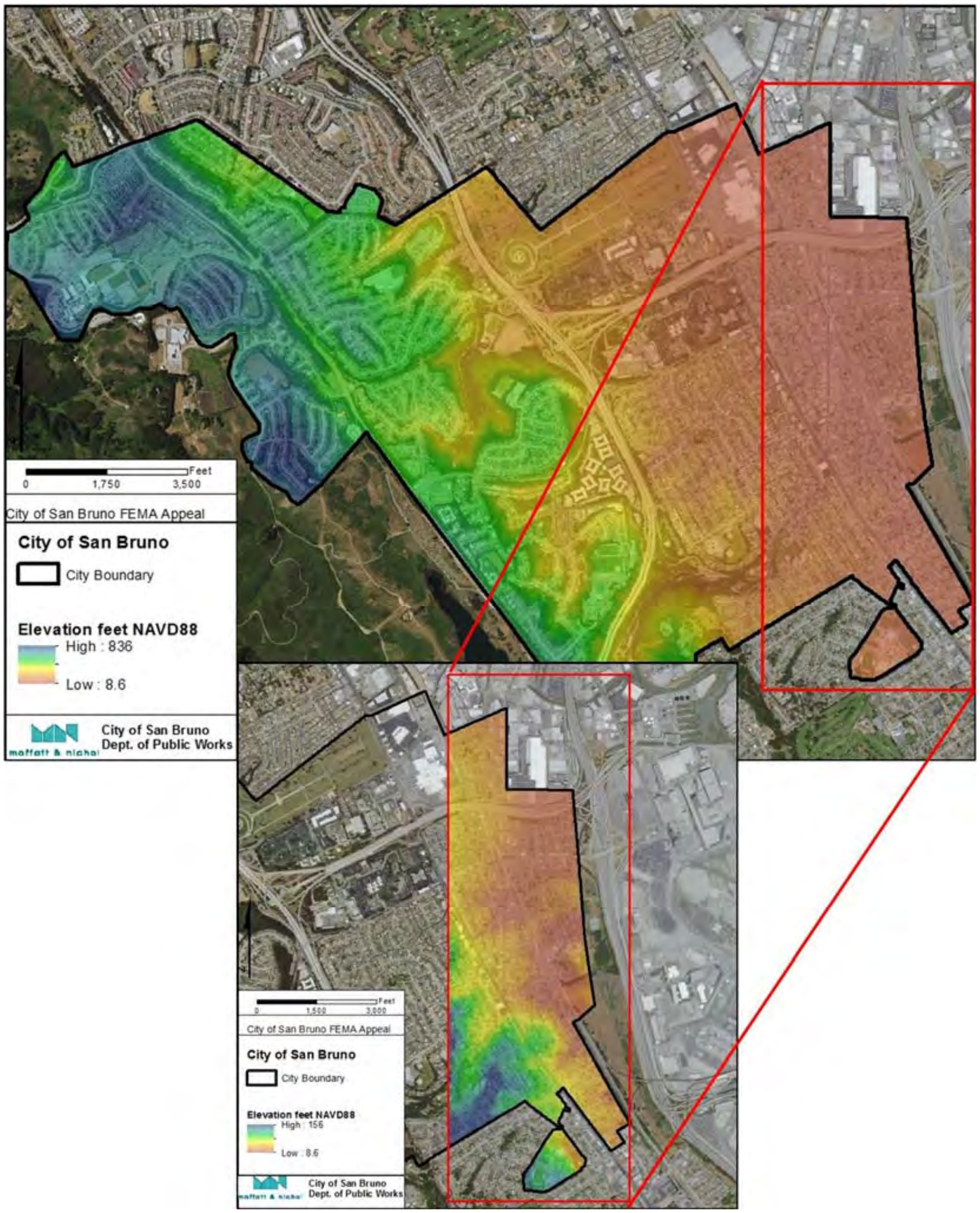


Figure 2: San Bruno Elevations

1.4 FEMA FIRMs Changes within the City of San Bruno

Prior to the release of the San Mateo County preliminary FIRMs, the City of San Bruno was mapped as a Zone D, or area of undetermined flood risk (Figure 3). The preliminary FIRM has re-mapped the east side of the City as Zone X (unshaded). An area of approximately 275,000 square feet (6.3 acres) and 75,000 square feet (1.7 acres) have been mapped as a Zone AE and Zone X (shaded), respectively. The remapped areas are located in the Belle Air neighborhood with residential homes. Residents living within the SFHA Zone AE area, or area inundated by the 1% annual chance flood, will be required to purchase flood insurance. Figure 3 and Figure 4 show the effective FIRMs and the preliminary FIRMs, respectively, for the San Mateo County centered in the City. The inundation area in Belle Air neighborhood is marked as Zone AE and Zone X.

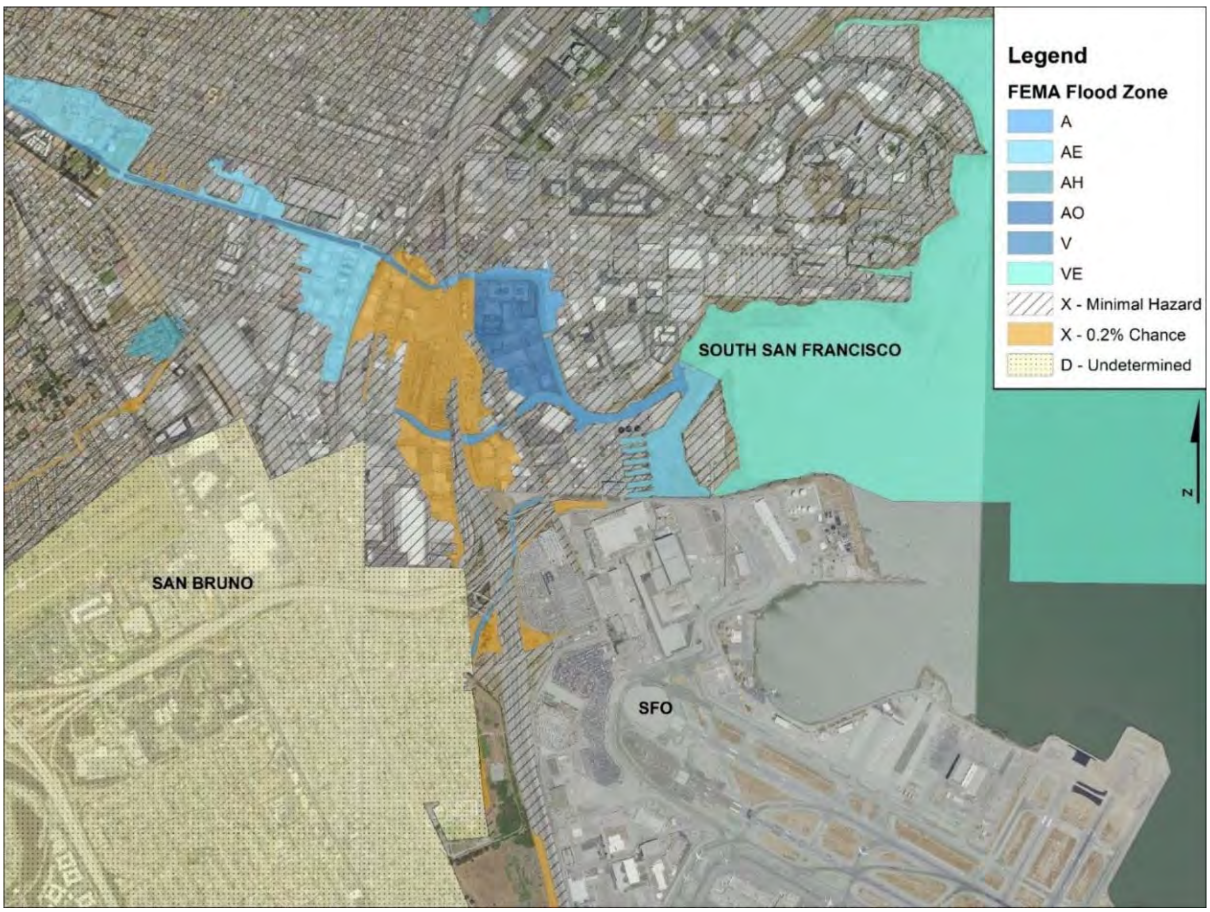


Figure 3: Existing and Effective FEMA Flood Zones (FEMA, 2012)

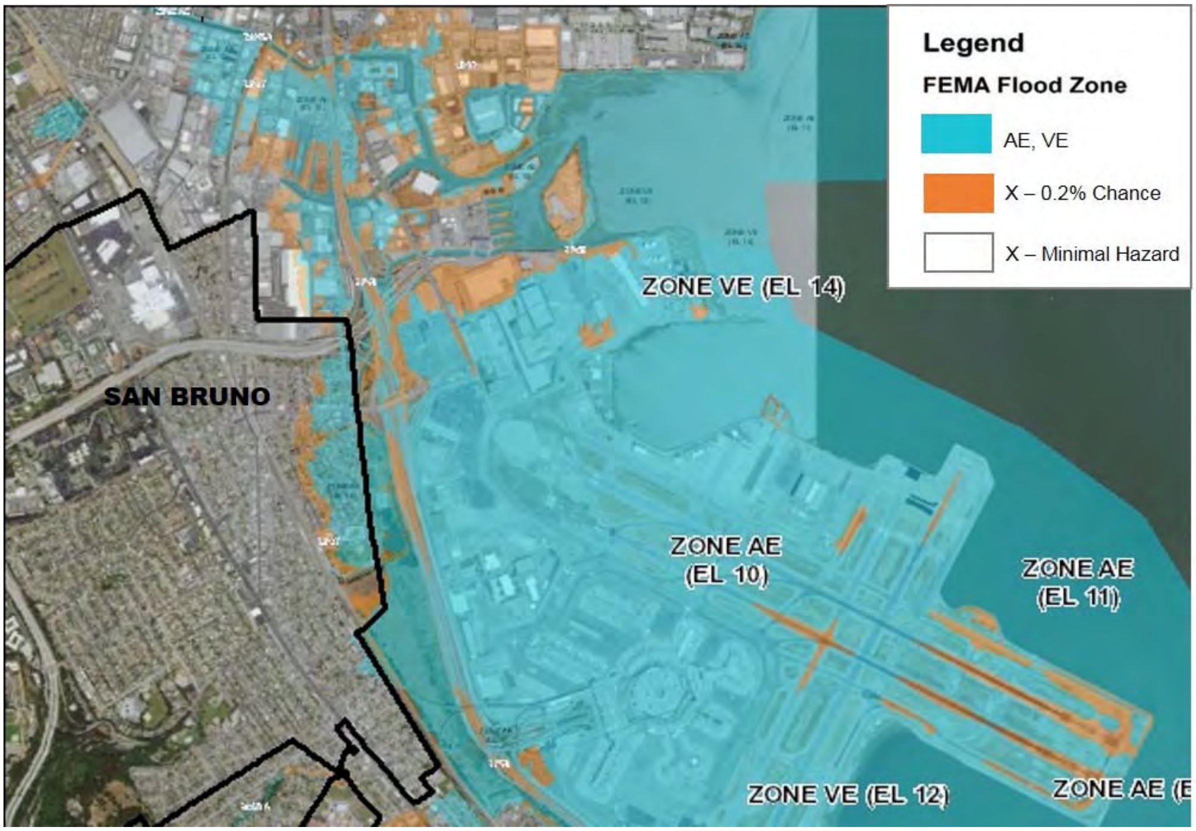


Figure 4: Preliminary FEMA Flood Zones (FEMA, 2015)

2. FEMA APPEAL PROCESS

The preliminary FIRMs for San Mateo County were issued on August 13, 2015. Because these maps include new or modified flood hazard information, the 90-day appeal period for City of San Bruno starts on May 27th, 2016. The following subsections discuss the general requirements of an appeal and how they specifically apply to the City appeal.

2.1 Appeal Process and Requirements

Criteria for Appeals of Flood Insurance Rate Maps (FEMA 2011) list the following eligible areas for appeal:

- Areas showing new or revised BFEs or base flood depths
- Areas showing new or revised SFHA boundaries (including both increases and decreases in the extent of the SFHA)
- Areas where there is a change in SFHA zone designation
- Areas showing new or revised regulatory floodway boundaries (including both increases and decreases in the extent of the regulatory floodway).

If the appellant believes the BFE and/or base flood depths are incorrect, the appeal must show that better methodologies could have been used, better assumptions could have been made, or better data could have been used. Additionally, the appellant must provide an alternative analyses that incorporates more appropriate methodologies, assumptions, or data and quantify the effects on the BFE and/or base food depths (FEMA 2011). An appeal must be submitted by the community CEO, FPA, city planner or city engineer.

In order to appeal the BFEs, base flood depths, SFHA boundaries, SFHA zone designation or regulatory floodway boundaries, the appellant must show these are based on data that is either scientifically or technically incorrect. Scientifically incorrect BFEs, base flood depths, SFHA boundaries and zone designations, and floodway boundaries result from using inappropriate or incorrect methodology and/or assumptions. Therefore, the appeal must provide an alternative methodology and/or assumptions that will produce more accurate results as well as an explanation of superiority of the alternative methodology and/or assumptions. For technically incorrect BFEs, base flood depths, SFHA boundaries and zone designations, and floodway boundaries, the data is incorrect due to methodology being applied incorrectly, incorrect or out-of-date data used, or errors committed in the application. For this case, the appeal must include the correct application of the methodology, correct or updated data and the revision of errors originally committed. Revised BFEs, base flood depths, SFHA boundaries and zone designations, and/or floodway boundaries must also be submitted, in digital form, with the appeal.

Additional technical guidelines for the appeal include:

- All analyses and data submitted by appellants must be certified by a Registered Professional Engineer or Licensed Land Surveyor, as appropriate.
- New flood elevations, flood zone boundaries, and regulatory floodway boundaries must tie into existing, unrevised areas on map.
- If new flooding information from one flooding source affects the information from another flooding source, appellants must provide information for all areas affected.
- Appeals cannot be based on effects of proposed project or future conditions.

- Analyses must be performed for the same recurrence interval floods as those performed for study/mapping project
- Unless appeal is based on alternate model or methodology, analyses should be performed with models used in the study/mapping project.
- For alternative model or methodology, the new model used must meet the following conditions:
    - o Must have been reviewed and accepted by a Federal agency responsible for floodplain identification or regulation or by a notable scientific body
    - o Model is well documented (user's manual including source codes)
    - o Model is available to all present and future parties affected by flood insurance mapping developed or amended through the use of the model
- Delineation of flood zone boundaries must show the 1% and 0.2% annual chance flood zone boundaries on a digital topographic map with reasonable accuracy

2.2 Basis of Appeal

The City is filing a written appeal to contest the flood zone boundaries for portions of San Mateo County as scientifically incorrect. FEMA's methodology of mapping all areas below the BFE contiguous to a flooding source, regardless of duration of elevated water levels and terrain changes, is believed to provide a too conservative estimate of flood extents within the City of San Bruno. The following discussion will detail the basis of this appeal.

The effective FIRMs published in 2012 show that there is no anticipated flooding within the limits of the City from fluvial flooding. Therefore, it can be inferred that the SFHA within the City in the preliminary FIRMs results from coastal flooding derived from the 1% annual base flood elevation in San Francisco Bay.

FEMA's methodology of mapping all areas below the base flood elevation contiguous to a flooding source is appropriate for areas where extreme water levels are the result of large storm surges associated with hurricanes that can last for several hours or even days. During these events, flood waters could be elevated sufficiently long to flood all areas below the base flood elevation. However, extreme water levels within San Francisco Bay are typically not a result of storm surge, rather, are "influenced by El Niño, setup, and tide" (FEMA 2005). For the 9414750 Alameda Tide Gauge, which has been in service since 1939 (NOAA 2016), one of the highest recorded water levels of +9.2 feet NAVD88 resulted from the combination of a King Tide (+7.5 feet NAVD88 astronomical tide) in a strong El Niño year (1983). Because these extreme events follow a semi-diurnal tidal cycle, the 1% annual chance flood level in the Bay will only be elevated for a few hours and recede as the tide ebbs. Figure 5 shows the difference in water levels one hour before and after the maximum water level, indicating that elevated water levels within the Central San Francisco Bay are only experienced for a limited time.

The duration of elevated water levels becomes increasingly important for areas such as the City of San Bruno, which is offset from San Francisco Bay. Flooding from the Bay must travel through channels or overland in order to inundate this area. The new hydrodynamic analysis conducted by M&N is to apply similar unsteady flood events over the area, using a time series from extreme high tide events and elevated to FEMA 1% and 0.2% SWELs. The unsteady state modeling will be discussed in Section 3 with more details. In summary, the hydrodynamic modeling performed in this study shows that the water level is not elevated long enough to flood the extent of areas shown in the preliminary FIRMs.

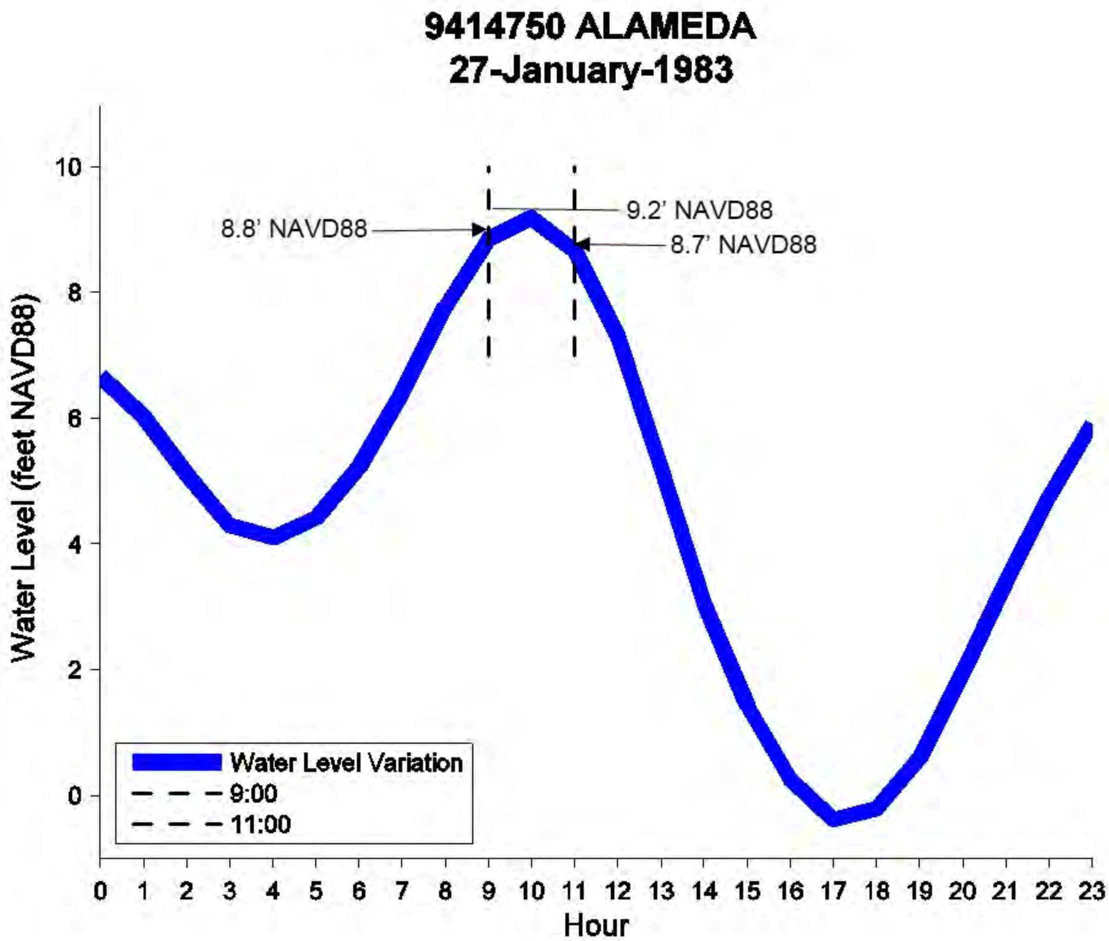


Figure 5: Measured High Tide Event at Alameda, CA

3. ALTERNATIVE METHODOLOGY FOR COASTAL FLOOD ANALYSIS

The basis of appeal for the City is that FEMA's methodology of mapping all areas below the BFE contiguous to a flooding source, irrespective of the duration of elevated water levels and terrain changes is incorrect. This steady state approach leads to overly conservative results for SFHA zones in the City. The City used an unsteady state approach of simulating the base flood and 0.2% flood events for the San Mateo County. This section and its subsections discuss the XPSWMM model development and setup, flood scenarios modeled for appeal, and the resulting revised BFEs and SFHA boundaries.

The XPSWMM model is a fully dynamic hydraulic and hydrologic modeling software that combines 1D calculations for upstream to downstream flow with 2D overland flow calculations. It is approved by FEMA for 2D flood modeling and mapping for the NFIP since 2011. The XPSWMM simulates 2D free surface flows by solving the full-dimensional, depth-averaged, momentum and continuity equations. It utilizes the EPA Stormwater Management Model (SWMM) 1D analytical engine for running rainfall-runoff simulations for single event or long-term simulations of runoff quantity and quality. SWMM simulates runoff from sub-catchment areas and routes it through systems of pipes, channels, pumps, and storage devices. XPSWMM also incorporates a 2D analytical module for the routing of surface flood flows, based on the TUFLOW program. A powerful feature of TUFLOW is its ability to dynamically link to the 1D network of the SWMM engine, i.e. the 2D and 1D domains are linked to form one model. Strong capabilities in simulating urban floodplains, open and closed channels, surface and sub-surface flows make XPSWMM a powerful and suitable tool for this specific study.

3.1 Model Development and Model Domain

The XPSWMM 1D/2D integrated hydraulic model was developed to cover the entire project area. 1D nodes and links were used to simulate tidegates and culverts at San Bruno Creek, Colma Creek and Navigable Slough. A 2D surface model was developed to represent both the floodplain and open channels. The 1D and 2D components are dynamically linked, and the surface flows in the 2D model can be routed through the 1D model.

In order to model both the base flood and 0.2% annual chance flood, the model domain was setup to cover the entire possible floodplain under the peak elevation of +12 feet NAVD88 during the 0.2% chance flood, and not limited to the City boundaries. Therefore, the developed model covers the SFIA, part of the City of South San Francisco, City of Millbrae, and the City of San Bruno. The model captures the bay shoreline and extends further east to cover all the areas with a ground elevation below FEMA's 0.2% SWEL (+12 feet NAVD88). The original topographic data from the FEMA Coastal Hazard Study was utilized to determine the extent of the +12 feet NAVD88 contour line. Figure 6 presents the outline of the model domain (yellow polygon), overlaid with jurisdictional boundaries in black solid line.

Figure 6: XPSWMM Model Domain

3.2 Modeling Setup

The hydrodynamic model is based on the same topographic/bathymetry data used by FEMA for FIRM purposes and the model is set up such that the 1% and 0.2% annual chance floods can be appropriately applied at the model boundary. This section discusses model setup.

3.2.1 Boundary Conditions

In order to develop tail water conditions during extreme SWELs, the 54-year water level time series developed for FEMA's "Regional Coastal Hazard Modeling Study for North and Central San Francisco Bay" (DHI 2011) were utilized. This study developed hourly water levels between 1956 and 2009 along the entire San Francisco Bay coast. Figure 7 shows twelve model points where time series of water surface elevations were available (DHI, 2011). The three storm time series with the highest water elevations were extracted from the 54-year time series and are presented in Figure 8. The figure shows that the highest water level was measured in January 1983. However, the February 1998 event has the longest duration of elevated water levels. Since the duration of the elevated water levels affects flood depth and extents, the most conservative approach would be to utilize the time series with the longest duration of elevated water level. Therefore, the February 1998 event was selected as the prototype time series and the time series was then elevated such that the peak elevation reaches the FEMA's 1% SWEL (+10.4' NAVD88) for the 1% annual chance flood unsteady modeling and FEMA's 0.2% SWEL (+12.0' NAVD88) for the 0.2% flood unsteady modeling. The resulting time series shown in Figure 9 were applied at the model offshore boundary.

The model simulation started at Mean Higher High Water (MHHW), approximately +6.8' NAVD88, and the initial water elevation for the entire modeling domain was also set to the MHHW. The overall duration of water level higher than +9' NAVD88 is about 4 hours for the 1% annual chance flood and 6 hours for the 0.2% annual chance flood.

Figure 7: Locations of Available Time Series from 1956 to 2009 (DHI, 2011)

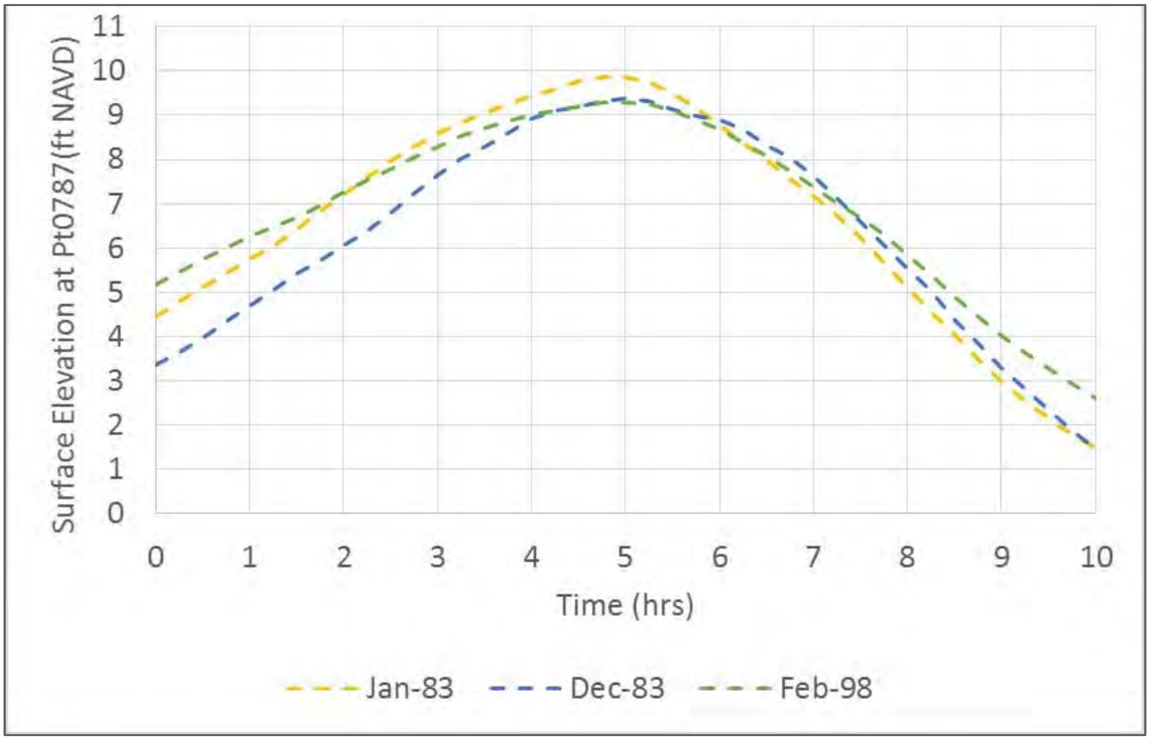


Figure 8: Time Series of Three Highest Water Level Events from 1956 to 2009

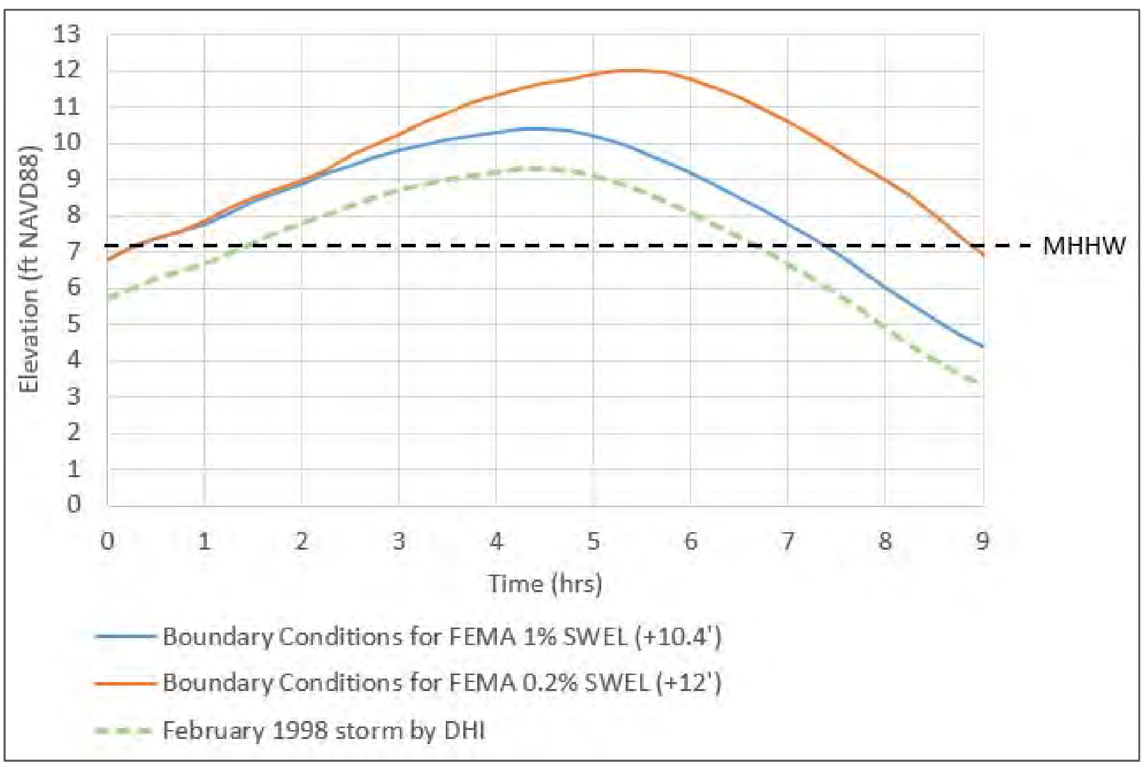


Figure 9: Boundary Conditions Developed for Unsteady Modeling

3.2.2 Topography Data

The XPSWMM model was developed based on the digital terrain model (DTM) developed by Baker/AECOM and was provided to the City via data request for the appeal. It is the same topographic data used in FEMA's coastal hazard analysis. The DTM data is received in raster format with a 10 feet grid resolution. Based on the information provided in Topographic Data Development report (Baker/AECOM 2012), the San Francisco Coastal LiDAR Project dataset collected in 2010 by USGS is the basis for the 10 feet resolution DEM of the San Mateo County.

In the XPSWMM model, the 2D model grid was developed based on the DTM. The 10ft resolution DTM provided by Baker/AECOM is sufficient to developing the 2D grids with a 15 feet grid size. Figure 10 below shows the topographic data received from Baker/AECOM.

The only revisions to the topographic data are the San Bruno Creek tidegates and levees along the SFIA since these structure are not currently FEMA certified and are, therefore, not included in the hydrodynamic analysis. Their potential positive impacts in flood defending are not considered in this study. Detailed discussion is in Section 3.2.3.

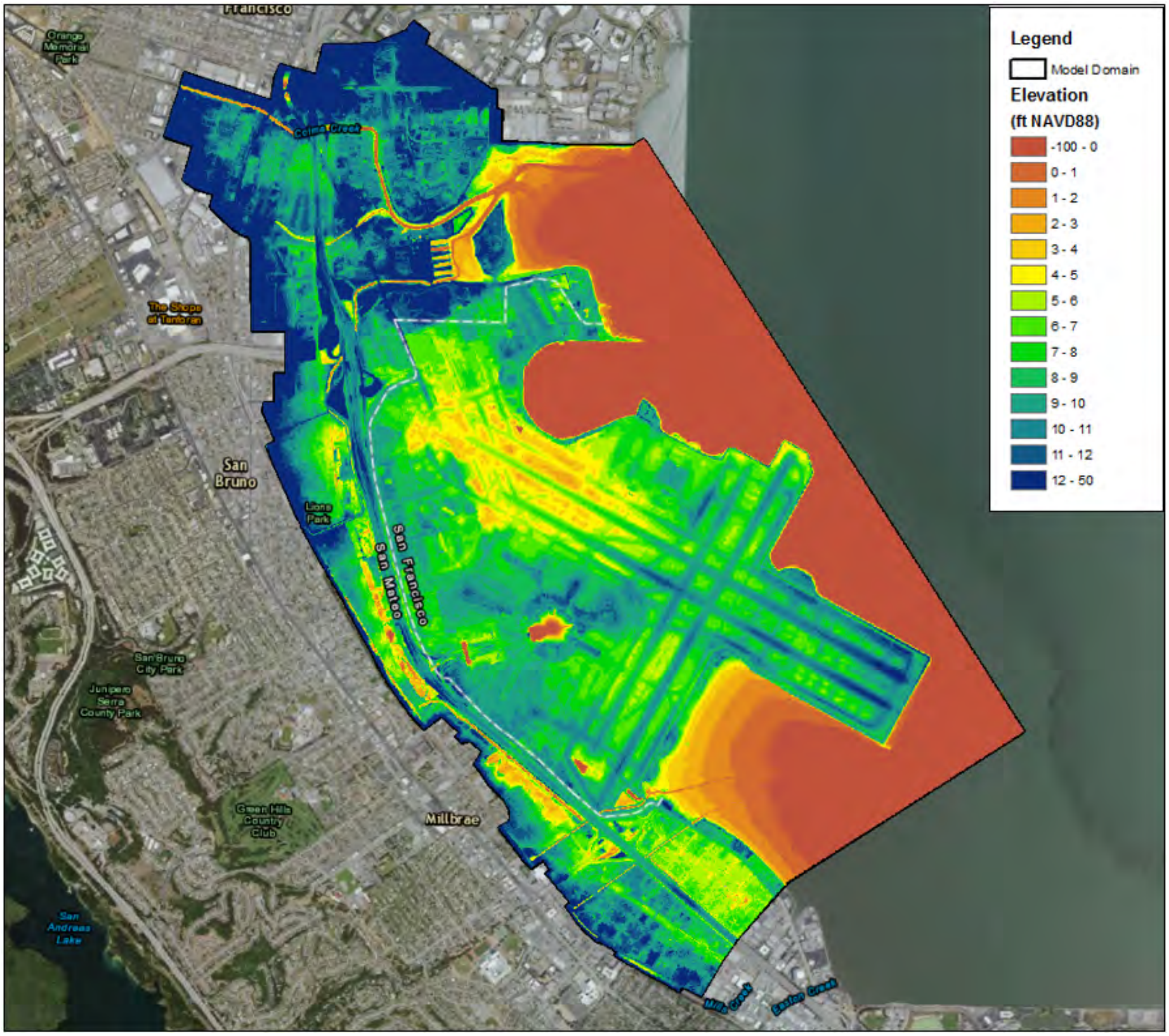


Figure 10: Model Topographic Data (Provided by Baker/AECOM)

3.2.3 Tidegates, Levees and Other 1D Structures

San Bruno Creek Tidegate

The San Bruno Creek tidegate near North Access Road is close to its exit to the Bay. The tidegate structure consists of four 5-foot diameter circular culverts with one-way flapgate on the downstream side, shown in Figure 11. The San Bruno Creek Tidegate is not currently FEMA certified, hence, it is excluded in the model for this analysis. As no clear guidance on tidegate structure removal is found, the following two options of tidegate removal were simulated:

1) Remove the entire tidegate structure by connecting open channels from both ends of the gate; and
2) Leave the tidegate structure in place and leave all flapgates open.

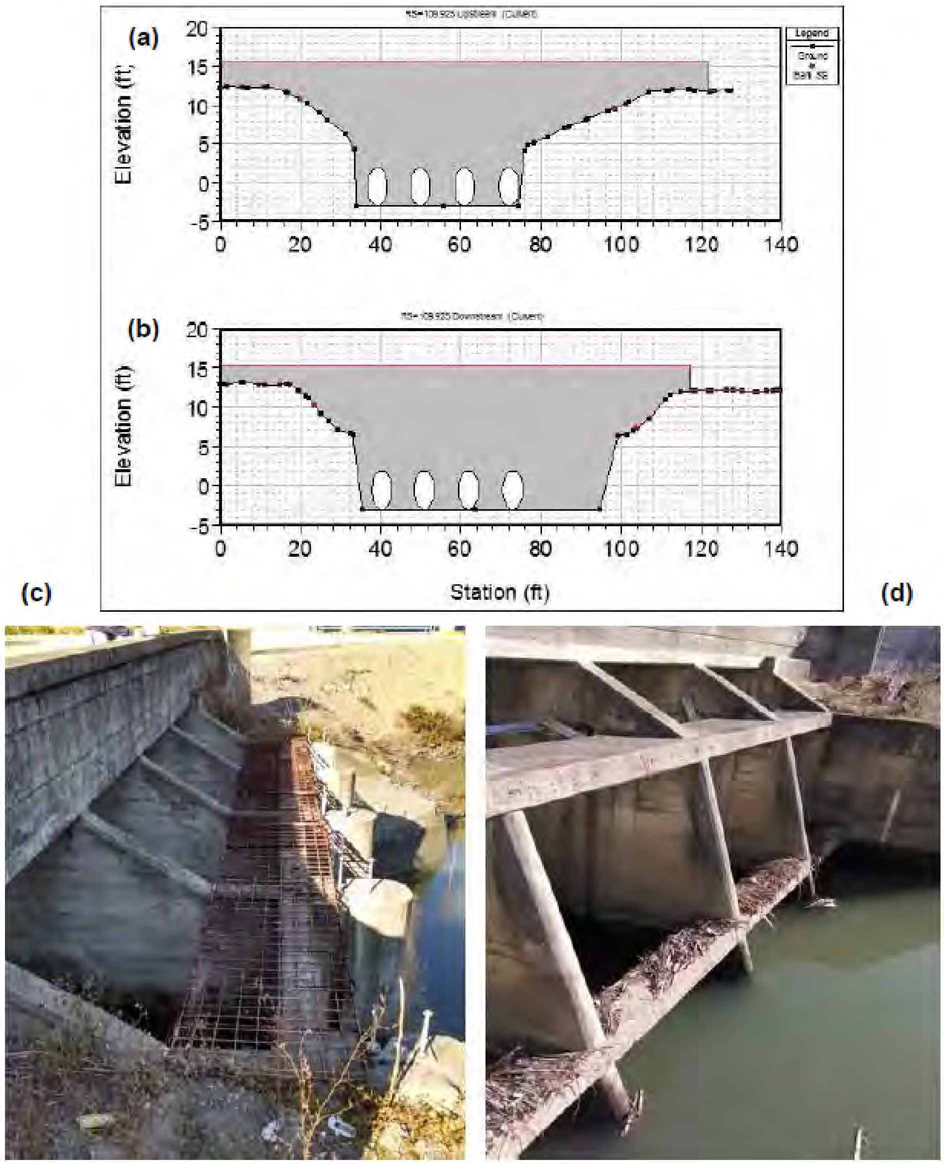


Figure 11: San Bruno Creek Tidegate (a) Upstream Cross Section, (b) Downstream Cross Section, (c) Downstream Photo, and (d) Upstream Photo

<u>San Francisco International Airport Levees</u>

The City borders with the SFIA on the east. The SFIA encompasses approximately 8 miles of San Francisco Bay shoreline. The 8 mile shoreline was divided into a number of reaches with different shoreline and levee structures (Figure 12). Similar to the San Bruno Creek Tidegate, the SFIA levee system is not a FEMA accredited structure. Therefore, all these levees were removed in the model analysis.

Figure 12: San Francisco Airport Shore Protection Structures

Other 1D Structures

There are total of 16 structures/links modeled as 1D structure in the model. The sizes of these tidegates and culverts are based on as-built drawings, previous reports, and communications with County staffs. Site visits were also conducted to confirm dimensions used in the model. Figure 13 and Figure 14 show the location of these 1D structures/links, and their shapes and sizes are listed in Table 2.

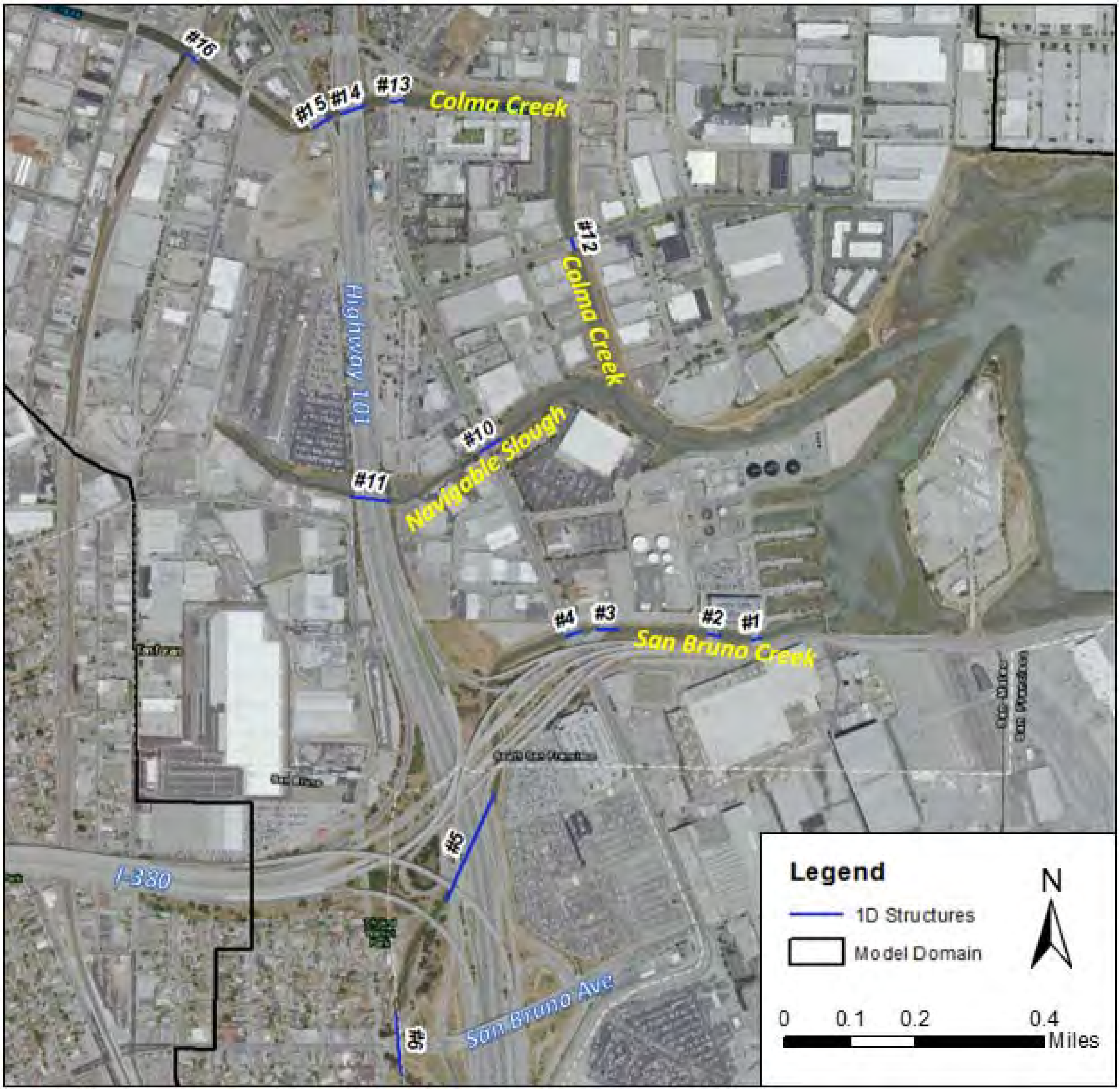


Figure 13: Map of 1D Structures Modeled along Colma Creek, Navigable Slough and San Bruno Creek (Shown in Blue)

Figure 14: Map of 1D Structures Modeled along Millbrae Creek (Shown in Blue)

Table 2: Table List of 1D Structures in the XPSWMM Model

No.	Stream	Location	Shape	Dimension (feet)	No. of Barrels
1	San Bruno Creek	Creek exit to the San Francisco Bay	circular	5**	4
2	San Bruno Creek	At crossing of San Francisco Bay Trail (downstream side)	rectangular	53’ by 11’	1
3	San Bruno Creek	At crossing of San Francisco Bay Trail (upstream side)	rectangular	55’ by 10’	1
4	San Bruno Creek	At crossing of S. Airport Boulevard	rectangular	50’ by 12’	1
5	San Bruno Creek	At crossing of Highway 101	rectangular	10’ by 8’	4
6	San Bruno Creek	At crossing of San Bruno Avenue	circular	3.5	3
7	Millbrae Creek	Channel exit to the San Francisco Bay	rectangular	12’ by 10’	2
8	Millbrae Creek	At crossing of Highway 101	rectangular	10’ by 6’	3
9	Millbrae Creek	At crossing of Aviator Avenue	rectangular	10’ by 6’	3
10*	Navigable Slough	At crossing of S. Airport Boulevard	circular	8’	1
10*	Navigable Slough	At crossing of S. Airport Boulevard	circular	5’	1
11*	Navigable Slough	At crossing of Highway 101	rectangular	10’ by 6’	1
11*	Navigable Slough	At crossing of Highway 101	rectangular	5’ by 4’	1
12	Colma Creek	At crossing of Utah Avenue	rectangular	80’ by 13’	1
13	Colma Creek	At crossing of S Airport Boulevard	rectangular	94’ by 15’	1
14	Colma Creek	At crossing of Highway 101	rectangular	72’ by 14’	1
15	Colma Creek	At crossing of Produce Avenue	rectangular	70’ by 15’	1
16	Colma Creek	At crossing of Caltrain	rectangular	70’ by 15’	1

** Multiple links with different sizes*

*** Diameter for circular culverts*

3.2.4 Buildings and Other Types of Obstructions

The XPSWMM model covers significant amount of urban development areas. Buildings such as commercial buildings and residential houses were carefully treated in the model setup.

Literature review of prior studies for FEMA flood mapping and hydrodynamic modeling with XPSWMM indicate that the buildings were often treated as:

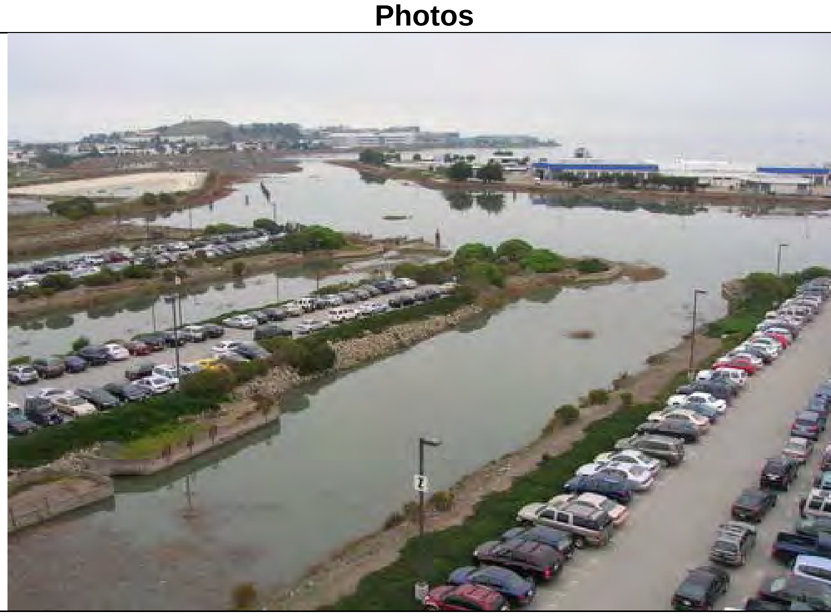
- Buildings with large foot print were set as inactive cells; and
- High density residential subarea with smaller building footprints were set as active cells with high roughness.

Smith (2012) conducted a study on the influence of building treatment in the numerical models on flooding. He compared different ways of building treatment in TUFLOW and DHI MIKE models, and also measured velocity fields around the buildings in physical models. He concluded that "the best way to treat buildings in numerical models was to either remove the computational grids under the building footprint completely or to increase the elevation of the building footprint to be above the maximum expected flood height". His conclusions agree well with the floodplain analysis and mapping guidance prepared by Dewberry (2008) for larger buildings. The Dewberry's guidance on modeling buildings for floodplain mapping using HEC-RAS unsteady model states: "Modeling Buildings: Accounted for through the use of Manning's n adjustments (general case) or blocked obstructions (extreme case)." In this appeal study, buildings with a footprint larger than 10,000 square feet were treated as inactive cells.

3.2.5 Bottom Roughness

In the XPSWMM hydrodynamic model, the primary calibration parameter is the roughness coefficient or the Manning's n value. In this appeal study, Manning's n values were assigned based on different land uses. The various types of land uses are listed in Table 3 with photos and assigned Manning's n values. Manning's n values were assigned based on literature reviews and past similar hydraulic modeling experience as calibration data were not available for the project area. The high density urban area with numerous buildings/houses was assigned with a Manning's n value of 0.12 to include the building effects during the flood passages.

Table 3: Typical Land Uses and Manning's n Values

Land Uses	Photos	Manning's n
Creeks, Open Channels and Sloughs (including overbank)		0.04

Land Uses	Photos	Manning's n
Vegetated Open Area (grass, marsh with scattered trees)		0.04
Paved Roads		0.015
Airport Runway		0.015

Land Uses	Photos	Manning's n
High Density Urban Area (e.g. Belle Air)		0.12

3.3 Modeling Scenarios

Two SWELs: 1% and 0.2% annual chance floods were modeled with the unsteady time series boundaries discussed in Section 3.2.1. No riverine discharge is included in these simulations. The two options of tidegate removal discussed in Section 3.2.3 were modeled for the 1% annual chance flood and similar modeling results were obtained; hence, only the option with open flapgates was modeled for the 0.2% annual chance flood. Below are the two model scenarios simulated in this study:

1) FEMA 1% annual chance flood with open flapgates at San Bruno Creek tidegates
2) FEMA 1% annual chance flood with San Bruno Creek tidegate structure removed
3) FEMA 0.2% annual chance flood with open flapgates at San Bruno Creek tidegates

3.4 Modeling Results

3.4.1 Comparison of Tidegate Structure Removal Options

As discussed in Section 3.2.3, two options of tidegate structure removal were modeled for the 1% annual chance flood. Comparison of inundation areas between the two model runs indicates that there are no discernable differences between these two options for the purpose of flood mapping. Therefore, only the open flapgate option is modeled for the 0.2% annual chance flood, and results from the open flapgate option are compared with the preliminary FIRMs in the following sections for the 1% annual chance flood.

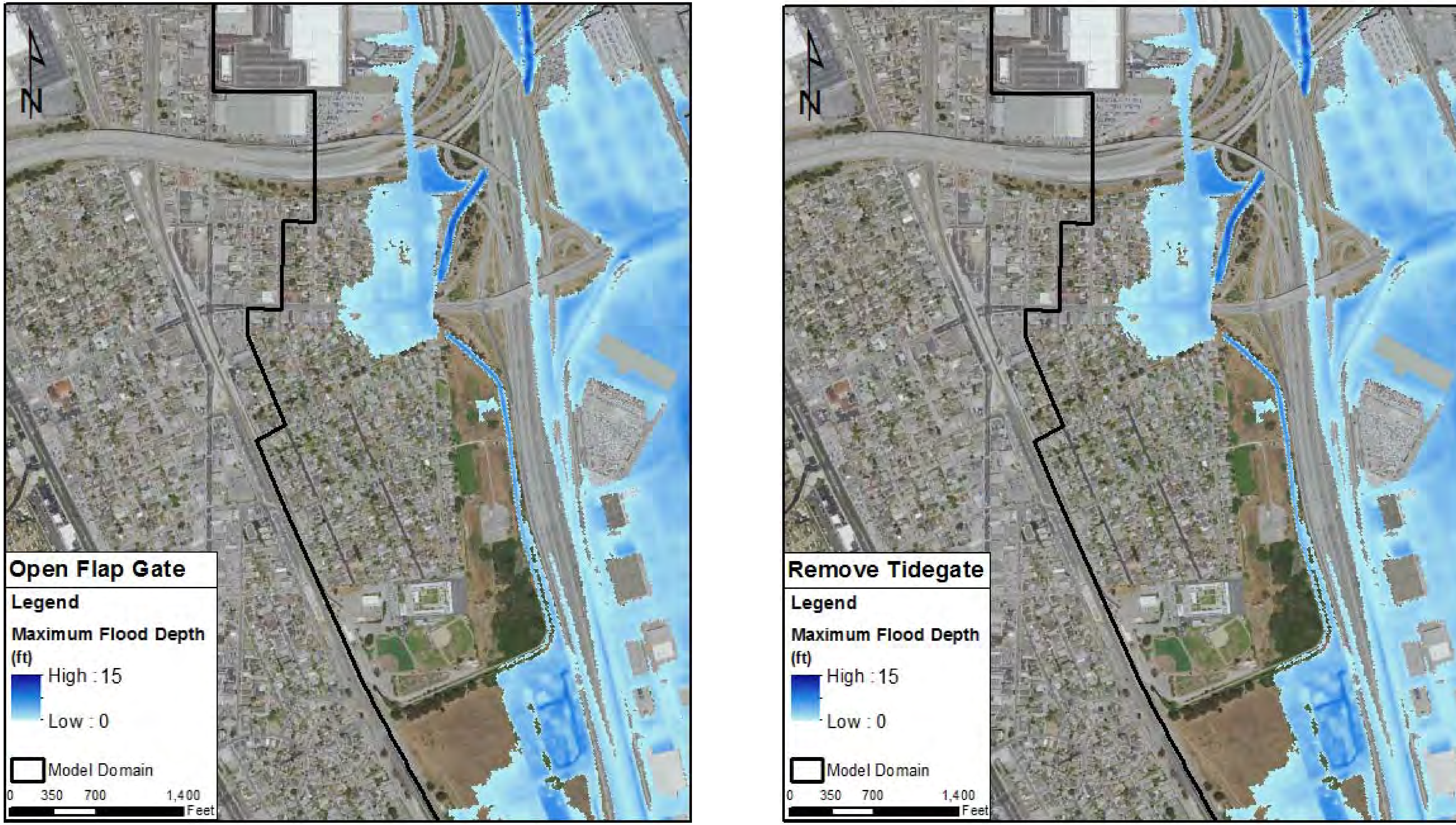


Figure 15: Comparison of Flood Areas Under 1% Annual Chance Flood Between Two Tidegate Removal Options

(Left: Tidegate Structure Remains, but Flapgates Open; Right: Entire Tidegate Structure Removed)

3.4.2 Modeling Results at Belle Air Neighborhood

In a prior San Bruno Creek/Colma Creek Resiliency Study (M&N, 2015), potential flooding sources for the Belle Air neighborhood were investigated through modeling and DTM elevation checks. The following section discusses flood sources/paths (shown in Figure 16) that were identified to have led to inundation of portions of the Belle Air neighborhood. The inundation areas in Belle Air neighborhood is divided into two sub-areas separated by Pine Street:

1) Areas of the neighborhood north of Pine Street will experience flooding from flood waters overtopping banks of Navigable Slough, traveling south along Shaw Road and crossing under I-380 to 7th Avenue. There appears to be low spots below the BFE along the south bank of Navigable Slough. Just north of Pine Street, there is an area of slightly higher elevation that is thought to prevent the flood water from Navigable Slough to travel farther south.

2) Areas of the neighborhood south of Pine Street will experience flood due to three potential sources:

    a) SFIA. Flood waters would enter the SFIA since SFIA is protected by a non-accredited levee system which was removed in the coastal flood analysis. The flood waters would first fill the topographic basin where the airport is located to an elevation of approximately +9.4 feet NAVD88, after which the flood waters would overtop Hwy-101, then get into the Belle Air neighborhood.

    b) Cupid Row Canal. There are low spots on banks along the Cupid Row Canal, allowing water to overflow the bank and to enter into the Belle Air neighborhood. Based on modeling results, this would occur before northward flowing flood water coming from Hwy-101 discussed in the next bullet.

    c) Millbrae. The low coastline of Millbrae located south of the SFIA would allow flood waters to enter and flow northward along Hwy 101, and then into the Belle Air neighborhood.

Figure 16: Flood Sources and Paths of Belle Air Neighborhood

(Inundation Area by 1% Annual Chance Flood Shaded in Light Blue)

Figure 17 compares flood hazard areas between FEMA's preliminary FIRM Zone AE in the City (aqua blue shaded area on left image) and the alternative analysis results. With the alternative analysis method of using an unsteady 2D model, the flooded areas within the City jurisdiction will be limited to the Belle Air neighborhood. The flooded area in south of Pine Street is significantly reduced compared to the FEMA preliminary FIRM. Hence, it is evident that using a scientifically more accurate alternative method accounting for the duration of the flood and the terrain impacts has a significant impact on the area that would be flooded during the 1% annual chance flood.

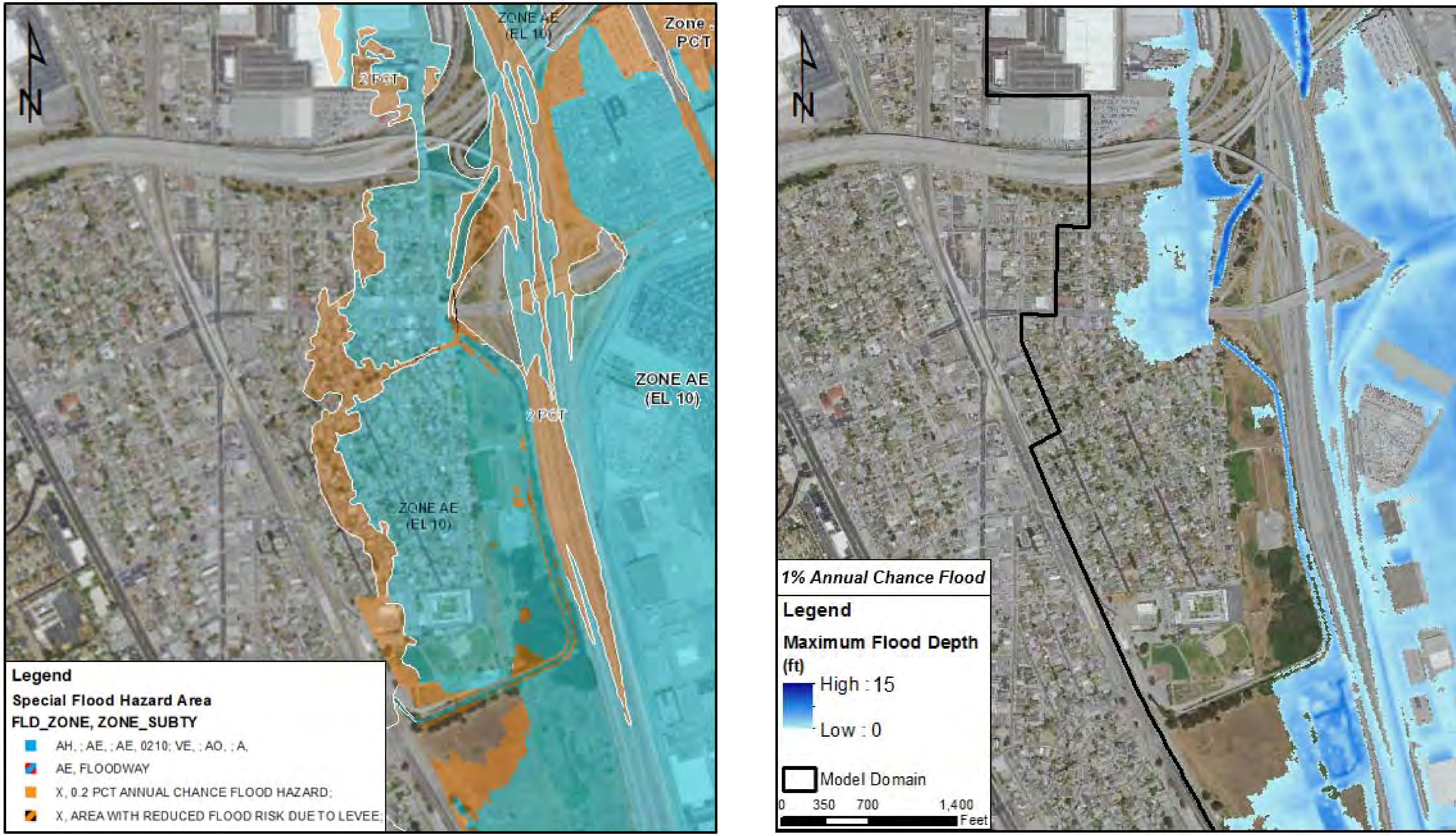


Figure 17: Comparison of Flood Areas Between Preliminary FIRM (left) and Alternative Analysis Results (right) for the 1% Annual Chance Flood

Figure 18 compares the flooded areas between FEMA's preliminary FIRMs (boundary of orange shaded area) and the alternative analysis modeling results for the 0.2% annual chance flood (SWEL of +12 feet NAVD88). Comparison indicates that the extent of flooding for this scenario is similar. This is because when the duration of high elevation gets long enough that the unsteady state modeling approach becomes similar to FEMA's steady state approach. The flood hazard area shows close alignment to the contour of +12 feet NAVD88.

3.4.3 Suggested BFEs and SFHA Boundaries Revisions

According to FEMA FIRM zone definitions described in Section 1.1, Zone AE are areas of inundation by the 1% annual chance flood with wave heights and runup levels less than 3 feet above the SWEL. Due to the fact that Belle Air neighborhood is located inland and is not subject to wave effects, the modeled inundation area under 1% annual chance flood defines the BFEs and Zone AE boundary for the Belle Air neighborhood. Similarly, Zone X areas are defined as areas that are subject to inundation during storms that are larger than the 1% annual flood but less than the 0.2% annual chance flood. Figure 19 and Figure 20 show the revised inundation areas under 1% and 0.2% annual chance floods with the more accurate alternative analysis.

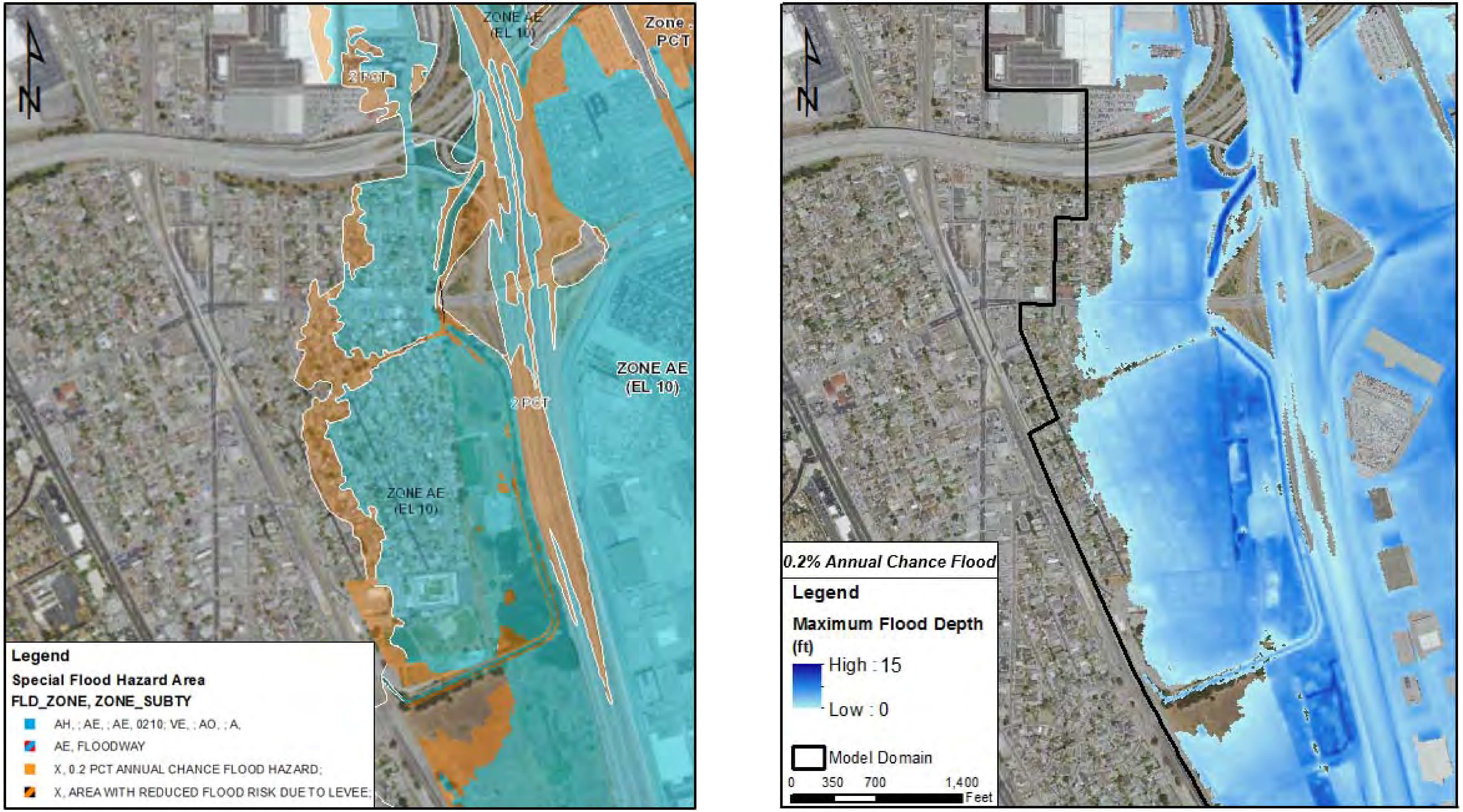


Figure 18: Comparison of Flood Areas Between Preliminary FIRM (left) and Alternative Analysis Results (right) for the 0.2% Annual Chance Base Flood

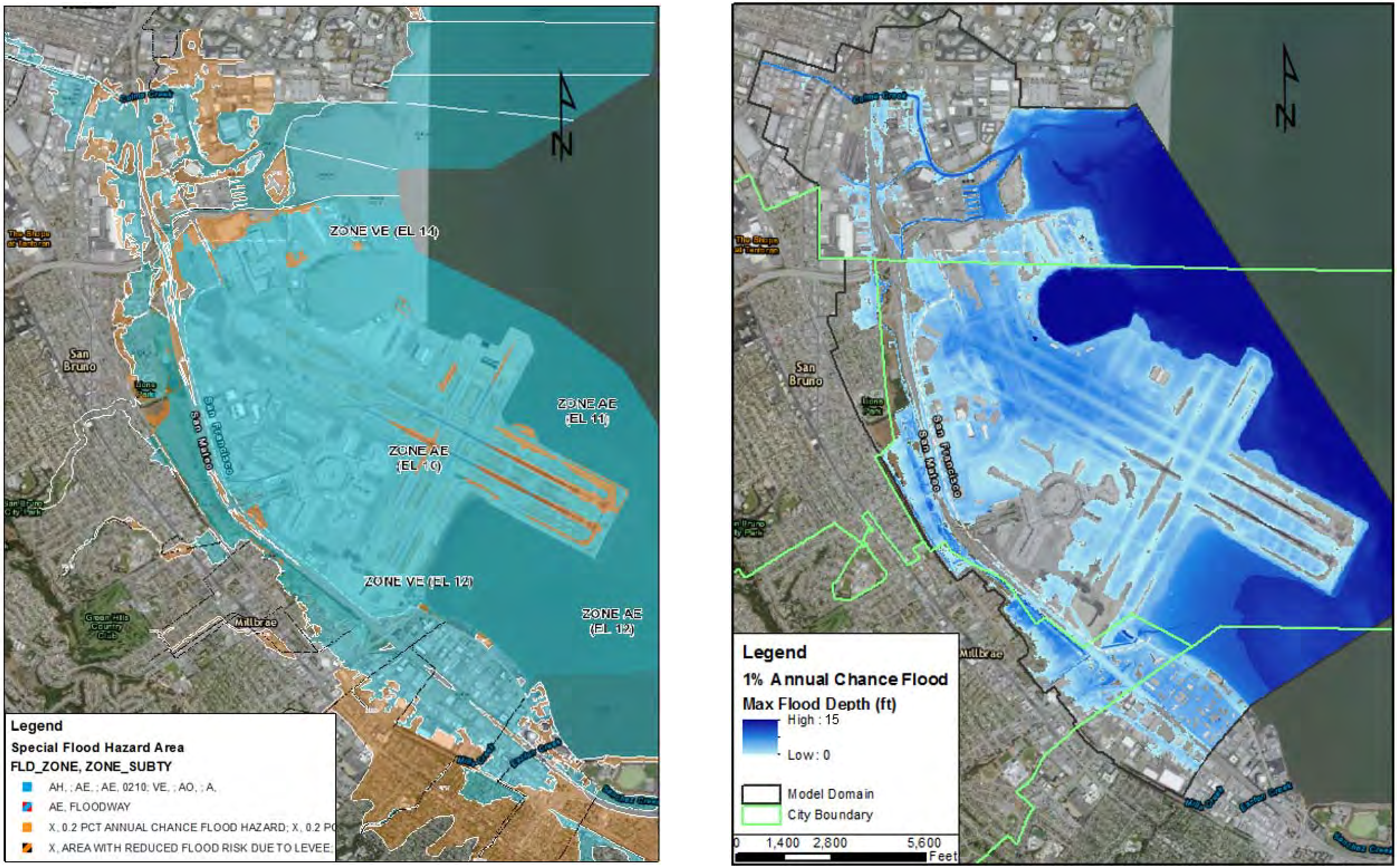


Figure 19: FEMA Preliminary FIRM (Left) and Revised Inundation Map under 1% Annual Chance Flood (Right)

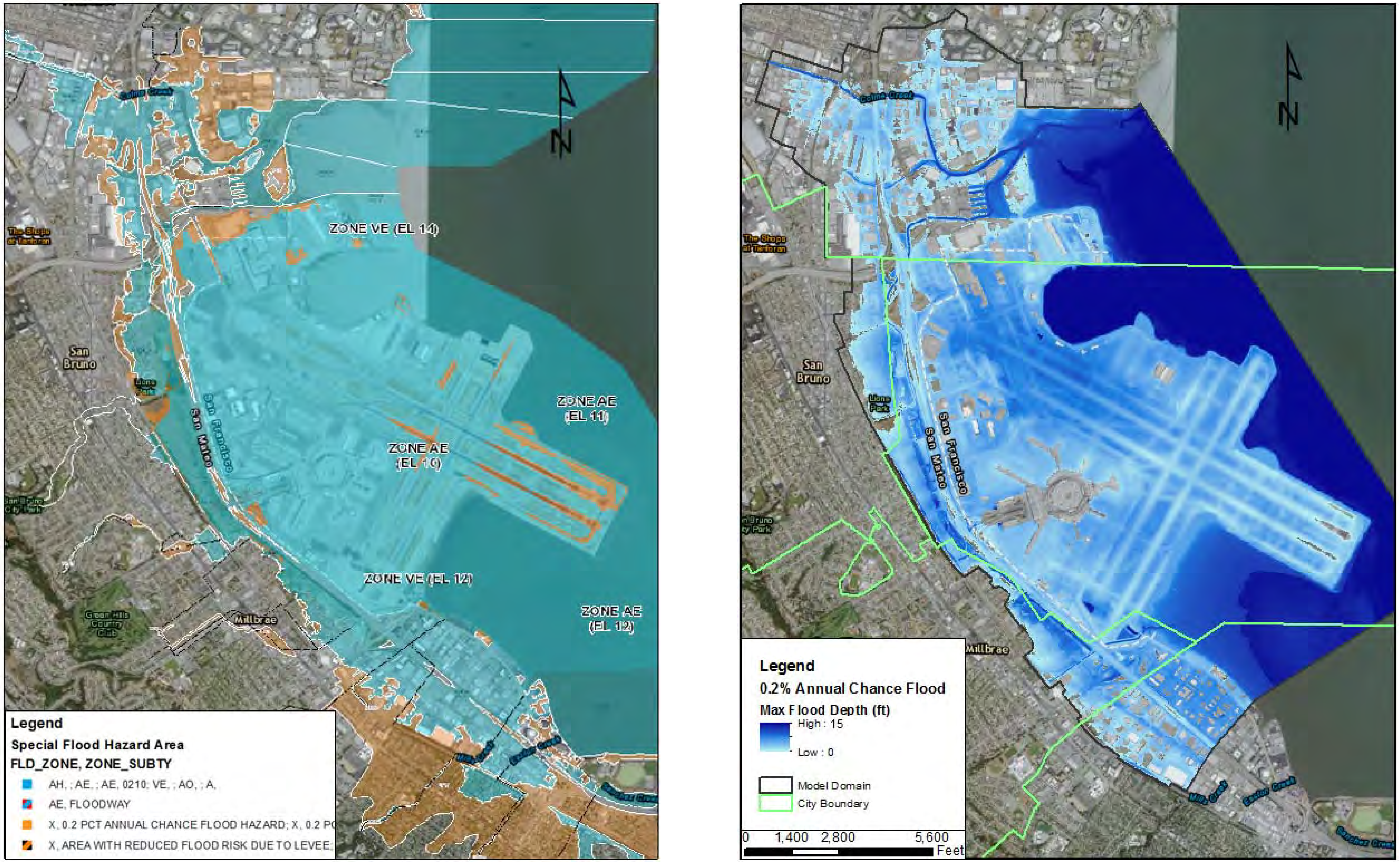


Figure 20: FEMA Preliminary FIRM (Left) and Revised Inundation Map under 0.2% Annual Chance Flood (Right)

4. CONCLUSIONS

The City is appealing FEMA preliminary FIRMs with scientifically incorrect BFEs and SFHA boundaries in its Belle Air neighborhood. The basis of appeal: An alternative method is used which results in more correct estimates of base flood elevations, thus demonstrating that FEMA's estimates are incorrect.

An assessment of FEMA's preliminary FIRM coastal analysis was performed by the City via its consultant (M&N). The City has identified that the primary source of scientific error that results in incorrect BFEs and SHFA boundaries is that FEMA's analysis applied a steady state ("bathtub") approach in mapping flood zones under the BFEs. FEMA's methodology of mapping all areas below the BFEs contiguous to a flooding source, regardless of the duration of elevated water levels and terrain changes, is believed to provide a too conservative estimate of flood extents within the City. The City applied an alternative method of using a FEMA approved unsteady 2D hydrodynamic XPSWMM model with the same 1% and 0.2% SWELs used in the preliminary FIRMs analysis and produced more accurate surface flooding areas under the 1% and 0.2% annual chance floods. The alternative modeling results show much less area of flooding in the Belle Air neighborhood. Therefore, the City is appealing the SFHA flood boundary and Zone designation revisions in its Belle Air neighborhood.

5. DATA SUBMITTAL

The data used in this study and generated from the study have been included in a flash drive attached to this document. The data in the flash drive are organized by modeling scenarios discussed in Section 3.3. The data for each scenario include XP-SWMM model files, model inputs and outputs in ArcGIS format, and an animation showing the inundation during the simulated flood event. Table 4 lists folder name, folder directory and content description of each sub-folder.

Table 4: Digital Data Files, Structures and Descriptions

Directory and Subdirectory	Data File Description
1 - 1% Annual Chance Flood	This folder contains data and files relevant to the simulation of 1% annual chance flood event
101-XPSWMM	This subfolder includes XP_SWMM modeling files
set01_c02b open flapgate	XP-SWMM modeling files for 1% annual chance flood with open flapgates at San Bruno Creek tidegates
set01_c03b remove tidegate	XP-SWMM modeling files for 1% annual chance flood with San Bruno Creek tidegate structure removed
102-ArcGIS	This subfolder includes ArcGIS files from XP-SWMM model inputs and outputs.
Input Files	This subfolder includes ArcGIS shape files for XP-SWMM model inputs including active model domain, head boundary location, 1D nodes and link locations, inactive areas, and land use assignment for roughness, elevation modification for SFO uncertified levees.
set01_c02b open flapgate	Model input files as ArcGIS shape files for 1% annual chance flood with open flapgates at San Bruno Creek tidegates
set01_c03b remove tidegate	Model input files as ArcGIS shape files for 1% annual chance flood with San Bruno Creek tidegate structure removed
Output Files	This subfolder includes XP-SWMM model outputs exported as ArcGIS files. The output files are seperated into water depth and surface elevation (relative to NAVD88).
set01_c02b open flapgate	Model output files as ArcGIS .asc files for 1% annual chance flood with open flapgates at San Bruno Creek tidegates
set01_c03b remove tidegate	Model output files as ArcGIS .asc files for 1% annual chance flood with San Bruno Creek tidegate structure removed
103-Animation	This subfolder includes two animations of modeled flood depth during 1% annual chance flood: 1) with open flapgates at San Bruno Creek tidegates; and 2) with San Bruno Creek Tidegate structure removed.
2 - 0.2% Annual Chance Flood	This folder contains data and files relevant to the simulation of 0.2% annual chance flood event
201-XPSWMM	This subfolder includes XP_SWMM modeling files
set01_c01b	XP-SWMM modeling files for 0.2% annual chance flood with open flapgates at San Bruno Creek tidegates
202-ArcGIS	This subfolder includes ArcGIS files from XP-SWMM model inputs and outputs.
Input Files	This subfolder includes ArcGIS shape files for XP-SWMM model inputs including active model domain, head boundary location, 1D nodes and link locations, inactive areas, land use assignment for roughness, and elevation modification for SFO uncertified levees.
Output Files	This subfolder includes XP-SWMM model outputs exported as ArcGIS files. The output files are seperated into water depth and surface elevation (relative to NAVD88).
203-Animation	This subfolder includes an animation of modeled flood depth during 0.2% annual chance flood (with open flapgates at San Bruno Creek tidegates).

6. REFERENCES

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APPENDIX A

Stillwater Elevations at Transects

A Central San Francisco Bay Coastal Flood Hazard Study

San Francisco County, California

Coastal Analysis Report

CONTRACT NUMBER: HSFEHQ-09-D-0368
TASK ORDER: HSFE09-09-J-0001
MIP Case Number 11-09-1225S
June 9, 2015

BakerAECOM
An Integrated Production Team

Figure 3. San Francisco County Transect Layout, South

Transect Number	Structure Description	Runup Method	WHAFIS	1% SWEL (ft NAVD)	0.2% SWEL (ft NAVD)	1% Seas Wave Crest Elevation (ft NAVD)	1% Swell Wave Crest Elevation (ft NAVD)	1% Runup Elevation (ft NAVD)	Overtopping
54	Vertical Wall	SPM	—	9.7	11.1	10.9	9.7	12.89	—
55	NA	TAW	—	10.0	11.0	12.0	10.5	13.90	YES
56	Revetment	TAW	—	10.1	11.0	10.5	10.5	10.85	YES
57	Revetment/ Vertical Wall	TAW	—	10.1	11.0	11.3	10.5	10.45	—
58	Revetment/ Vertical Wall	TAW	—	10.1	11.1	11.2	10.5	10.15*	—
59	Revetment/ Vertical Wall	TAW	—	10.1	11.2	11.6	10.5	10.58	—
60	Revetment	TAW	—	10.2	11.2	11.4	10.5	11.61	YES
61	NA/ Vertical Wall	TAW	—	10.1	11.1	10.6	10.6	14.01*	YES
62	NA	DIM/TAW	—	10.1	11.1	10.4	10.6	9.91	—
63	Revetment	TAW	—	10.1	11.1	11.0	10.6	9.82	YES

A Central San Francisco Bay Coastal Flood Hazard Study

San Mateo County, California

Coastal Analysis Report

CONTRACT NUMBER: HSFEHQ-09-D-0368
TASK ORDER: HSFE09-09-J-0001
MIP Case Number 11-09-1227S

July 25, 2014

BakerAECOM
An Integrated Production Team

Central San Francisco Bay Flood Hazard Study

Transect Layout
San Mateo County, California

Base Map Source: ESRI
Date: November 11, 2013

Table 10. Summary of Results

Transect Number	Shoreline Structure	Runup Method	WHAFIS	1% SWEL (ft NAVD)	0.2% SWEL (ft NAVD)	1% Wave Crest Elevation (ft NAVD)	1% Runup Elevation (ft NAVD)	Overtopping (Y/N)
1	Revetment	TAW	—	10.26	11.61	11.84	13.68	Y
2	Revetment	TAW	—	10.29	11.69	11.52	12.63	Y
3	Revetment	TAW	—	10.28	11.69	10.40	10.25	N
4	Revetment	TAW	—	10.35	11.82	11.91	13.71	Y
5	Revetment	TAW	YES	10.35	11.82	11.61	13.87	Y
6	Revetment	DIM	—	10.36	11.83	12.02	10.68	N
7	Revetment	TAW	—	10.41	11.95	11.63	13.31	Y
8	Revetment	DIM	—	10.41	11.94	12.07	11.10	Y
9	NA	TAW	—	10.43	11.99	11.76	12.25	N
10	Revetment	TAW	—	10.45	12.03	11.93	13.80	N
11	Revetment	TAW	—	10.47	12.06	10.27	11.49	N
12	NA	DIM	—	10.46	12.04	11.62	10.42	N
13	NA	TAW	—	10.46	12.05	11.67	12.97	Y
14	NA	DIM	—	10.18	11.26	11.48	10.56	Y
15	Revetment	TAW	—	10.18	11.26	10.50	10.67	N
16	Revetment	TAW	—	10.20	11.31	10.71	12.02	Y
17	Revetment	TAW	—	10.20	11.33	10.87	12.26	Y
18	Revetment	TAW	—	10.22	11.37	11.00	12.48	Y
19	Revetment	TAW	YES	10.23	11.39	11.29	11.81	Y
20	NA	TAW	—	10.24	11.42	11.14	15.89	N
21	NA	-	YES	10.30	11.55	11.48	—	—
22	NA	-	YES	10.31	11.58	11.23	—	—
23	Levee/ Revetment	TAW	YES	10.31	11.58	11.34	12.68	N