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MEMORANDUM

DATE: March 14, 2023
TO: Azalea Mitch, PE and Matt Fabry, PE (City of San Mateo)
FROM: Charles D. Anderson, PE and Justin R. Maynard, PE
SUBJECT: Marina Lagoon Performance during New Years Eve 2022 Storm

Introduction

The City of San Mateo retained Schaaf & Wheeler to perform an evaluation of Marina Lagoon Pump Station performance during the New Years Eve 2022-23 storm.

Marina Lagoon (Lagoon) is a mapped FEMA Special Flood Hazard Area (SFHA). The Lagoon is mapped as a Zone AE with a water surface elevation of 2 feet NAVD88 (96.9 feet on the City of San Mateo Datum, or CSM). This designation was assigned to the area as part of a Letter of Map Revision effective August 6, 2015. It is noted that the mapped BFE designation is rounded to the nearest foot. The calculated BFE is 2.4 feet NAVD (97.3 feet CSM).

The Lagoon is fed by three major open channel drainages – 16th Avenue Channel (Leslie Creek), 19th Avenue Channel (Borel Creek), and Laurel Creek to the south – as well as numerous smaller drainage areas served by closed conduit systems with outfalls directly to the Lagoon. The study location may be seen in Figure 1.

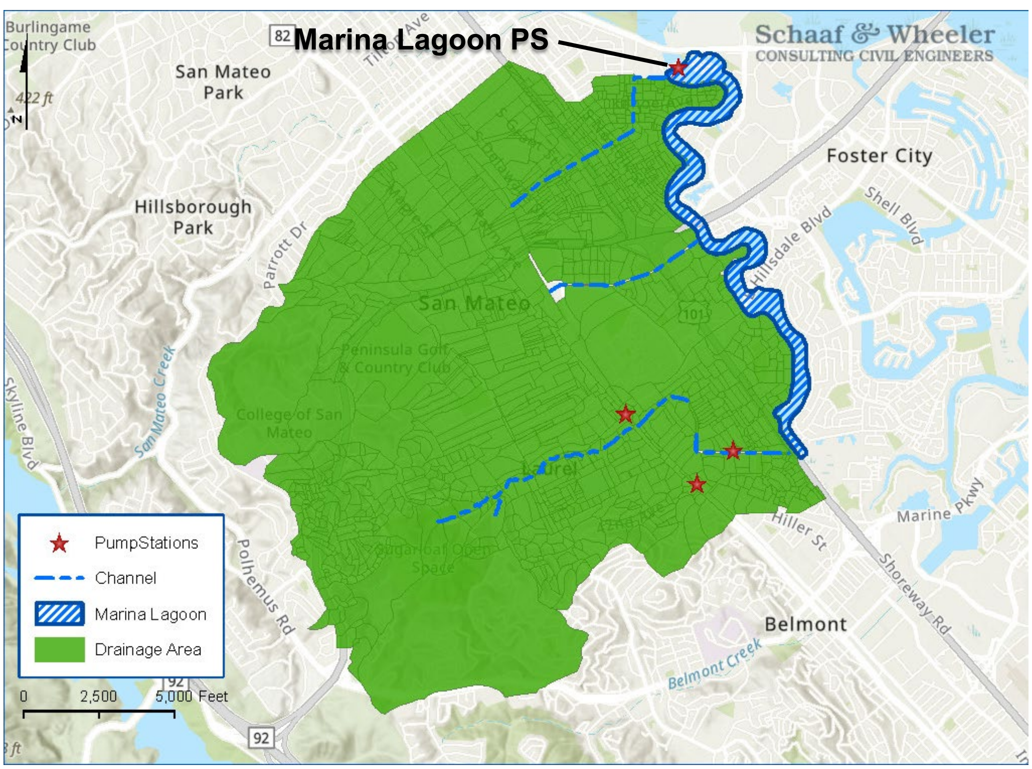

Figure 1. Study Area Overview

Methodology

This study is based on prior modeling performed for the 2004 City of San Mateo Storm Drain Master Plan (SDMP). The SDMP utilizes the Danish Hydraulic Institute (DHI) MIKE URBAN software with the MOUSE solver to model storm drain systems and overland flow throughout the City. The City SDMP model consists of three interrelated products:

1. MOUSE, which computes surface runoff and routes the runoff through the storm drain pipe network using a hydrodynamic pipe flow module;

2. MIKE FLOOD (MIKE 21), which is a two-dimensional (2-D) modeling module that connects the modeled ground surface to the one-dimensional pipe network and routes flows out of or into the storm drain system based on calculated hydraulic grades.

3. MIKE URBAN, an ArcMap based graphical user interface.

Recently, DHI began to phase out MIKE URBAN in favor of MIKE+, which streamlines the use of the three modules described above with improved model management.

Schaaf & Wheeler first imported existing MIKE URBAN models into MIKE+ software (three MU models were imported into a single MIKE+ model capable of modeling the entire Lagoon), then reviewed rainfall data and statistics to develop a calibrated hydrologic and hydraulic model of the entire Marina Lagoon drainage area and tributary pipe and open channel systems. A 2-D overland model has also been developed to evaluate potential flooding from pipe systems and channels.

Baseflow recession parameters have been calibrated to the USGS San Francisquito Creek at Stanford streamflow gage. These parameters were not included in the SDMP models. However, they are an important factor in evaluating the New Years Eve storm, given the depth and duration of rainfall that occurred.

Rainfall Data

Rainfall data has been provided by the City for three local gages including gage AU981 near Laurel Creek. Additional data has also been retrieved from CDEC for the Pulgas gage to evaluate a longer time period and acquire useful data for calibrating the hydrologic model to the USGS San Francisquito Creek stream gage at Stanford.

Data are available on a five-minute interval for the AU981 gage (shown in Figure 2). Pulgas gage data are available in hourly intervals (shown in Figure 3) from December 25, 2022 to January 24, 2023.

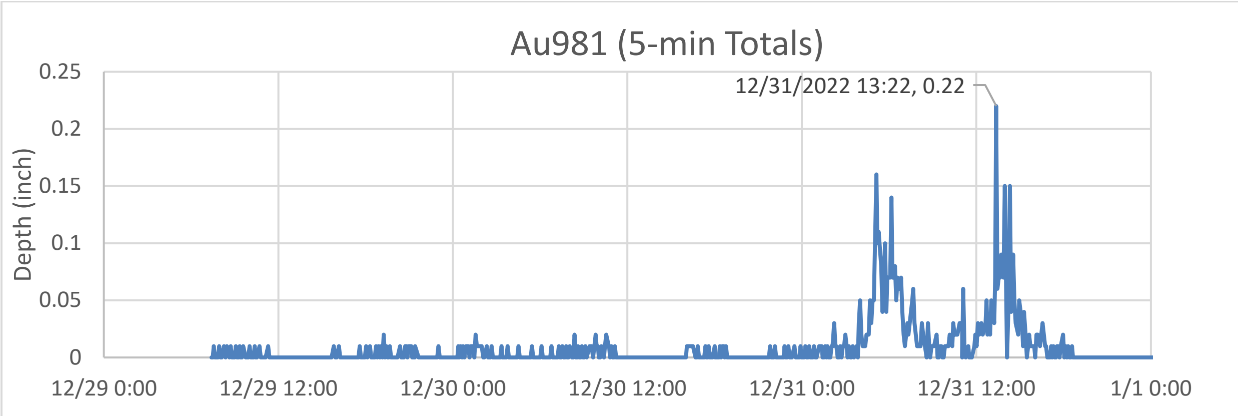

Figure 2: AU981 Gage Rainfall Depth from 12/29/22 to 1/1/23

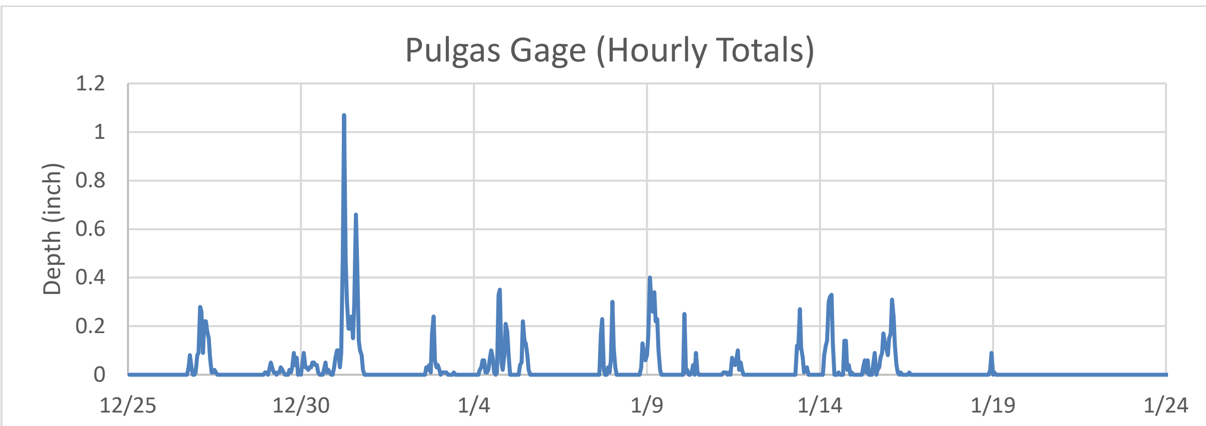

Figure 3: Pulgas Gage Rainfall Depth from 12/25/22 to 1/24/23

One important hydrologic consideration is antecedent moisture. By observing a longer record than the storm that may have been the direct cause of system surcharge and/or flooding, it is apparent that there was some rainfall in the days leading up to the storm that may have caused greater than average antecedent moisture conditions (AMC).

During the storm itself, a depth-duration-frequency analysis of the AU981 gage indicates the overall severity of the storm. Defining the return period of a storm is meaningless without context. In this case, durations of interest are not defined by very short bursts of rainfall. Watershed lags are on the order of an hour or two, and based on SCADA information provided by the City the Lagoon water level rose through approximately a 12-hour period.

The pump station's original design is documented as providing capacity for a 100-year inflow. This inflow has historically been calculated using a statistically balanced event spanning 24 or 72 hours. Recorded rainfall events are not usually balanced like this, however, so it is important to evaluate the frequency of the storm at various durations. The AU981 precipitation depth data has been aggregated into running totals for various durations, by summing the previous hour for each 5-minute interval.

Maximum depths have been compared with Valley Water 2013 TDS equations, which were used to establish the Lagoon BFE, for a mean annual precipitation of 22 inches, and NOAA ATLAS 14 precipitation frequency (PF) values at the location of the gage. The return period of the maximum depth at each frequency is estimated based on both TDS and NOAA Atlas 14 PF values. This analysis is summarized in Table 1 and Table 2, with return periods at or above the design 100-year magnitude highlighted.

Table 1: PF Analysis Based on Valley Water TDS Method

Duration	NYE 2022 Max Depth (in)	100-yr TDS Design Storm Max Depth (in)	200-yr TDS Design Storm Max Depth (in)	Est. Return Period (22" TDS)
10-min	0.29	N/A	N/A	N/A
15-min	0.37	0.512	0.551	**10**
30-min	0.52	0.66	0.71	**14**
1 hr	***0.93***	***0.93***	0.99	**100**
2-hr	***1.61***	1.39	***1.47***	**400**
3-hr	***1.97***	1.77	***1.88***	**300**
6 hr	2.42	2.70	2.88	**45**
12 hr	***4.54***	***3.81***	***4.07***	***600***
24 hr	***5.1***	***4.88***	5.21	**150**
48 hr	5.79	6.38	6.79	**43**
72-hr	5.97	7.35	7.85	**18**

Table 2: PF Analysis Based on ATLAS 14 Return Periods

Duration	NYE 2022 Max Depth (in)	NOAA ATLAS 14 100-year Depth (in)	NOAA ATLAS 14 200-year Depth (in)	Est. Return Period (ATLAS 14)
10-min	0.29	0.48	0.54	**10**
15-min	0.37	0.58	0.66	**10**
30-min	0.52	0.80	0.91	**12**
1 hr	0.93	1.14	1.29	**35**
2-hr	***1.61***	***1.53***	1.70	**125**
3-hr	***1.97***	***1.89***	2.08	**115**
6 hr	2.42	2.70	2.96	**46**
12 hr	***4.54***	3.93	***4.32***	***300***
24 hr	5.1	5.58	6.17	**55**
48 hr	5.79	7.11	7.90	**30**
72-hr	5.97	8.42	9.37	**15**

It is apparent based on both TDS and NOAA Atlas14 that the New Year's Eve storm exceeded the 100-year design magnitude for several durations based on maximum values. The "double-barreled" nature of the rainfall, with back-to-back peaks on various durations may also affect the Lagoon, particularly if the time between peaks is not sufficient to draw down Lagoon levels. Plots of running rainfall depth totals for select durations are shown in Figure 4. Based on NOAA Atlas 14 PF tables, these peaks are characterized by duration as:

- 1-hour: Two ~35-year peaks
- 2-hour duration: 125-year peak followed by a second 75-year peak
- 3-hour duration: 115-year peak followed by a second 60-year peak
- 12-hour: Converges to a single ***300-year peak***

While the second peaks are generally smaller than the first, by the time the second peak comes, soils in the drainage area may be fully saturated. Combined with contributions of baseflow generated by shallow groundwater left behind by the first peak, the second peak may have greater runoff potential than the first.

Hydrologic Analysis

Calibration and Baseflow Recession

Schaaf & Wheeler has utilized existing models of the San Francisquito Creek gage to calibrate Rainfall Dependent Infiltration (RDI) parameters in MIKE+. The Pulgas gage is not located within the San Francisquito drainage area. As such, the calibration does not focus heavily on AMC or peak matching. The goal of this analysis is primarily to calibrate the shape of baseflow recession based on recorded San Francisquito streamflow gage data throughout the month of January. The calibration basin is shown relative to the Marina Lagoon drainage area, along with an assortment of precipitation depths in the vicinity of the study area as Figure 5.

MIKE+ RDI is characterized by several parameters defining lag times for overland flow, interflow, and groundwater flow, as well as percentages of the drainage areas contributing to groundwater and overland flows resulting from rainfall abstraction into soils. These parameters are then used as a starting point and further modified in the Marina Lagoon drainage area to better match Lagoon water levels recorded by SCADA. It is not unreasonable to expect that overland lag in particular might be less for the somewhat smaller Marina Lagoon drainage areas, which are also modeled on a much finer scale than the 37.5 square mile San Francisquito Creek watershed used for calibration. Parameters are summarized in Table 3 and the results of the San Francisquito Creek watershed model are compared with gage data in Figure 6.

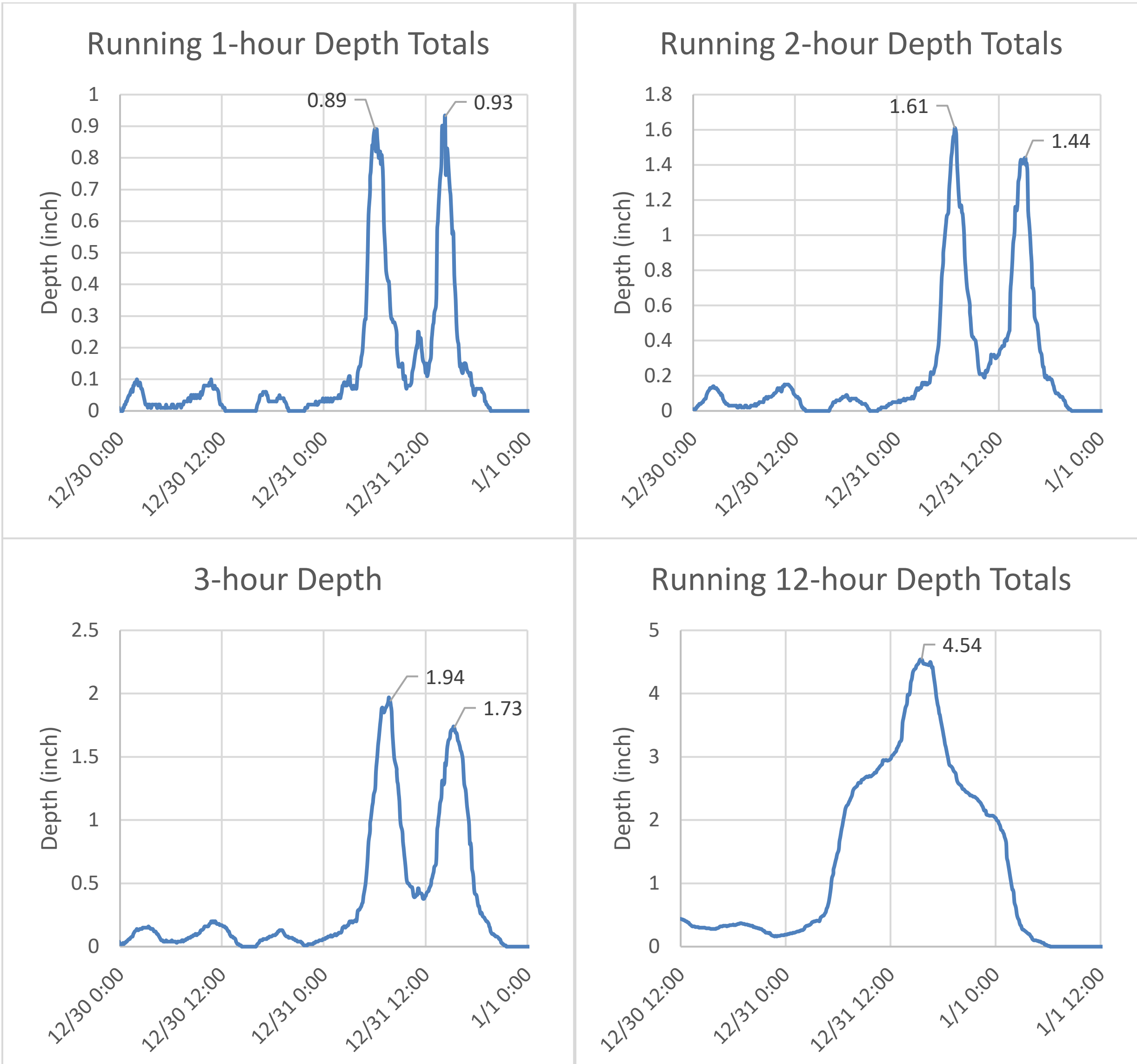

Figure 4: Running Precipitation Depth Totals for Gage AU981 for Various Durations

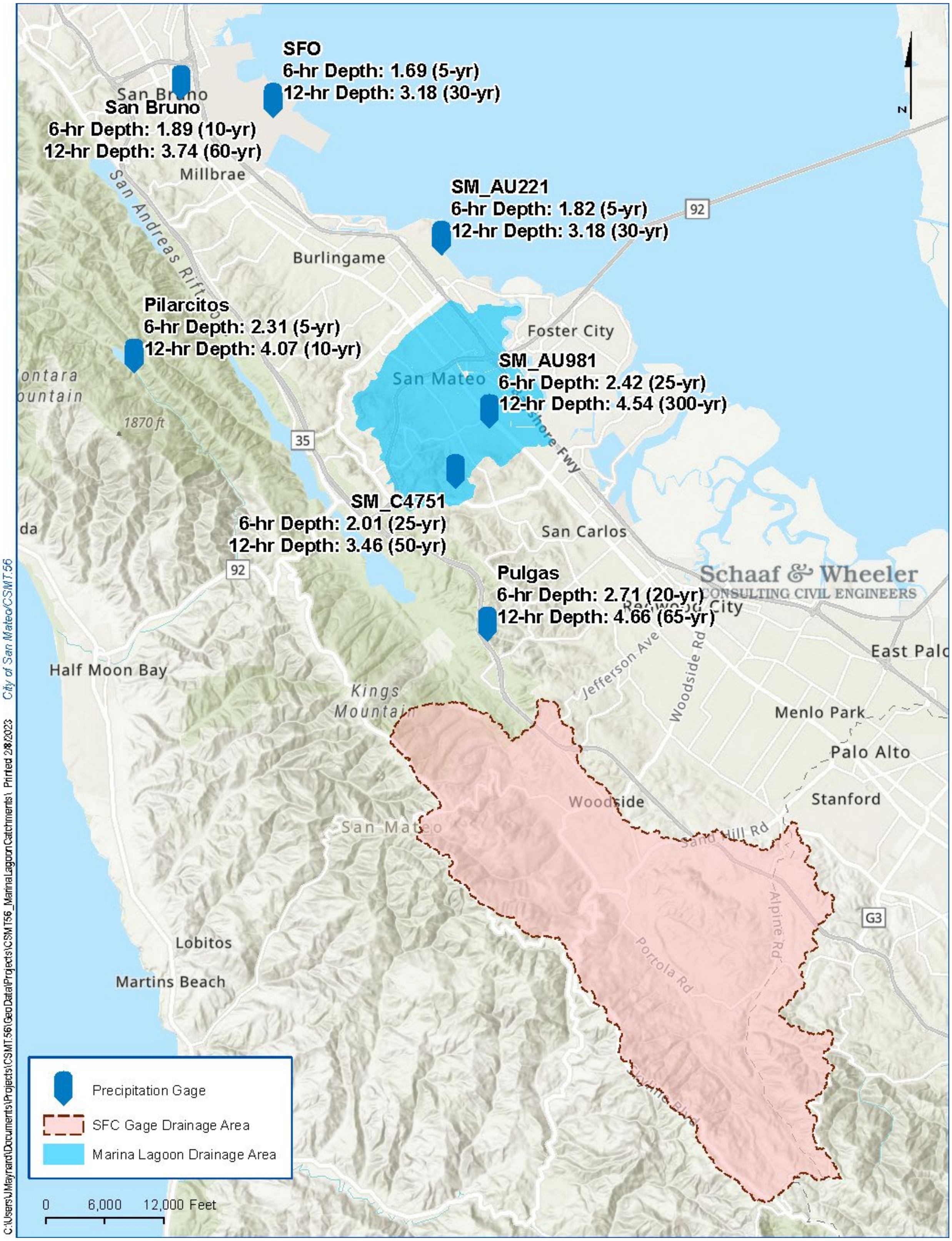

Figure 5: Calibration Basin and Precipitation Depths for 6- and 12-hour Durations (Various Gages)

Table 3: RDI Parameters for the MIKE+ Hydrology Model

Parameter	Default	San Francisquito Basin	Selected for Marina Lagoon Hydrology
Surface Storage (ft)	0.833	0.25	0.25
Root Zone Storage (ft)	8.333	3	3
TC Overland (hours)	20	*12**	*6**
TC Interflow (hours)	500	600	600
TC Baseflow (hours)	2,000	1,000	1,000

**Primary calibration parameter for Marina Lagoon based on smaller basin sizes*

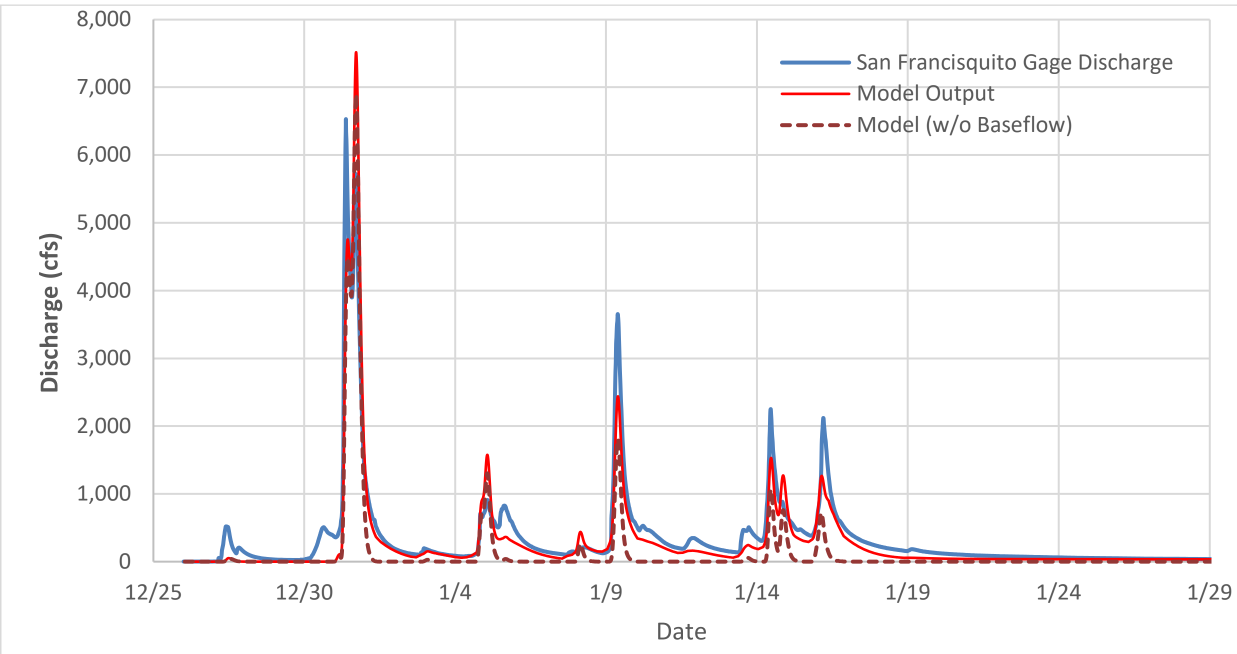

Figure 6: San Francisquito Creek RDI Calibration Model Result Comparison to Gage Data

Although not the focus of this analysis, prior calibrations of curve number for the San Francisquito Creek gage (CN 64 with an AMC value of II) are shown to remain representative of the watershed's runoff potential. The four highest peaks are on the same order of magnitude as gaged discharge. Three are lower than the gaged peaks by approximately 35 percent on average. However, this deviation could just as easily be a result of rainfall at the Pulgas gage being somewhat lower than the actual rainfall over the San Francisquito Creek watershed during the same storm. Curve numbers from the SDMP models for the San Mateo systems have also been assigned AMC II values and therefore have not been altered for this analysis.

The model underestimates peak magnitude for subsequent peaks when only the surface runoff (Curve Number without baseflow/RDI) is considered. Significant runoff volume is also missing when baseflow recession is not included. These are crucial considerations for the Marina Lagoon model.

Marina Lagoon Drainage Area

For the Marina Lagoon model, precipitation data from the AU981 gage is used directly, without increase or reduction. Actual precipitation throughout the drainage area may have varied somewhat during the New Year's Eve storm. However, this is the nearest gage to the drainage area and an initial assumption is made that this may be representative of an average condition across the basin without adjustment. Ultimately, the results of the model well replicate the SCADA data (discussed in the next section), so no further adjustments were made.

The full drainage area to the Lagoon is shown in Figure 7. In general, catchments from the SDMP models are used in this study as well. However, the boundaries of catchments have been examined and adjusted as necessary based on 2017 San Mateo County LiDAR data.

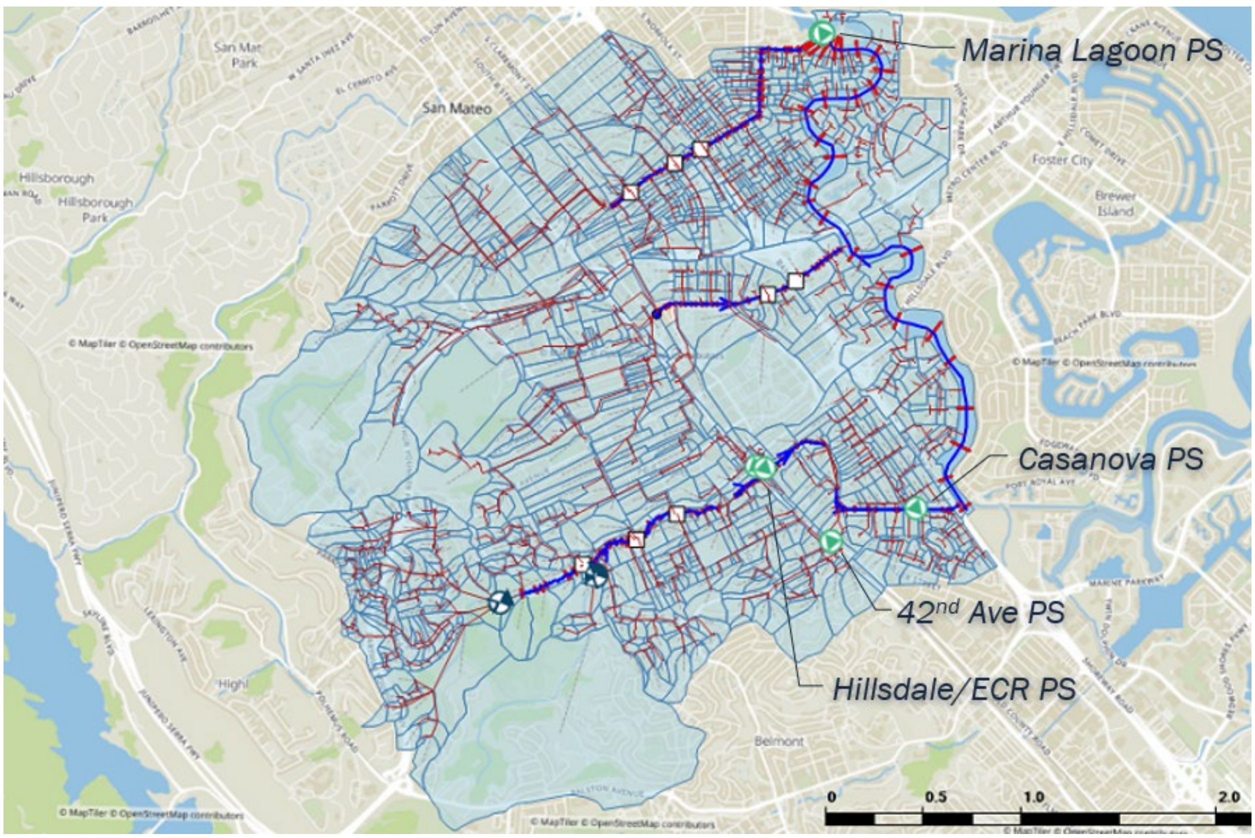

Figure 7: Marina Lagoon Model Drainage Area

The drainage area on the east side of the lagoon surrounding Mariner's Island Boulevd and within San Mateo City limits has also been added to the model, with curve number and lag assumed to be similar to nearby catchments located on the west. This assumption does not fully consider the storm drain properties of those added drainage areas. However, it does ensure that the model captures runoff volume from the full drainage area to the Lagoon.

Hydraulic Analysis

Hydraulic Model Setup

Schaaf & Wheeler first imported three individual SDMP models into a single MIKE+ model. Various modifications to the model are required to form a complete picture of the operation of the lagoon and the behavior of its full tributary area:

- Pipe systems within the small drainage area within City limits at the northeast end of the lagoon are added.
- The two dams on Laurel Creek have been refined to better reflect their behavior throughout the storm. (An orifice and a weir are added, representing the hydraulics of the low-level outlets and the spillways.)
- A 2D domain is added to the lower reaches of the model generally covering the area from just upstream of El Camino Real to the western edge of the Lagoon.
- The 42nd Avenue Pump Station is added to the model.
- The three channels conveying flow into the Lagoon have been converted from “Generic Shape” 1D elements to “River” elements with cross sections and culverts to better reflect conveyance capacity and spill over the channel banks.
- Marina Lagoon is added to the model as an open channel element, allowing for the connection of each outfall along the full length of the lagoon, capturing any variation in hydraulic grade along the length of the lagoon during the storm, and fully considering lag throughout the system.

The pipe system and river centerlines are shown in Figure 7, along with the catchment areas. The 2D domain is shown in Figure 8. Most of the 2D area extends from just upstream of El Camino Real to the western edge of Marina Lagoon. The exception is along Laurel Creek where the domain extends further upstream to ensure any potential capacity deficiency is captured along the creek that might impact the timing and magnitude of runoff reaching the Lagoon.

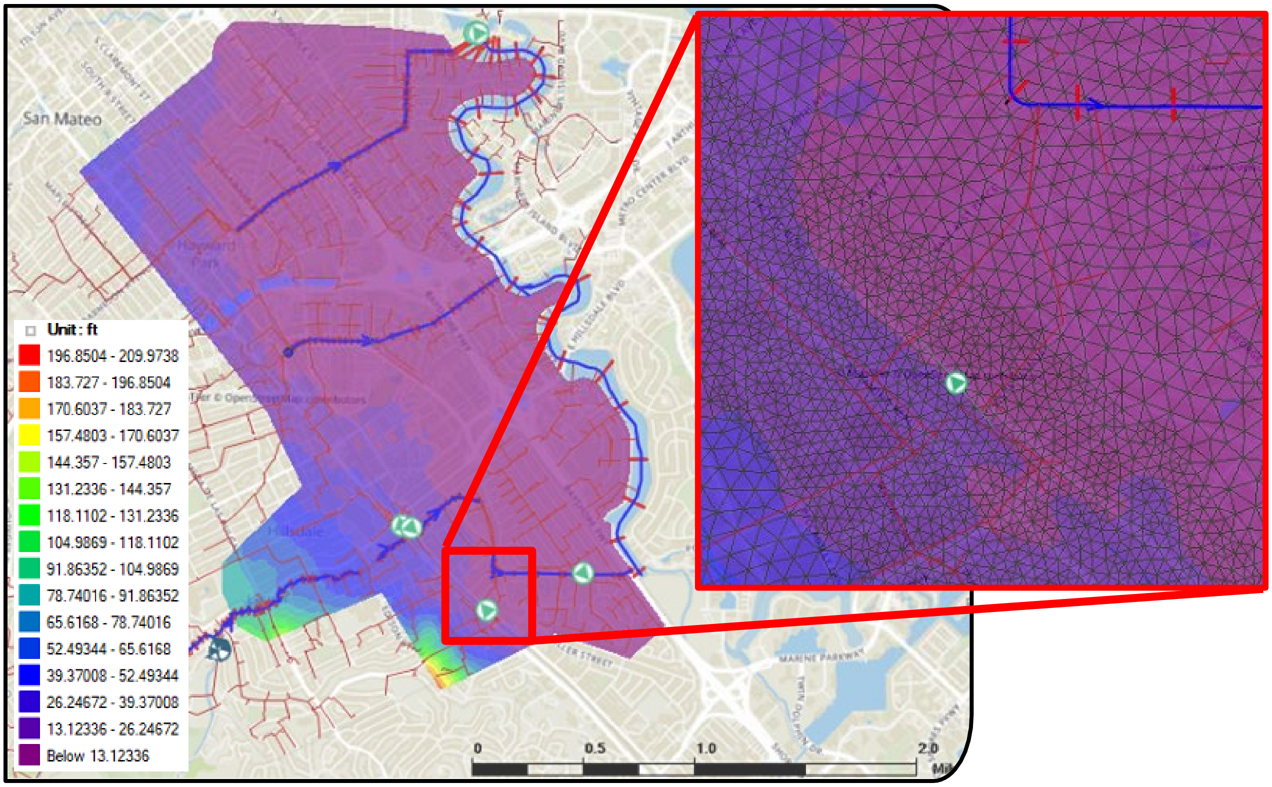

Figure 8: Elevation Map Within the 2D Domain Area with Inset Detail of Triangular Elements.

Tides

Tidal levels are also examined for the duration of the storm to verify whether they may have affected pump capacity. Tide data over the period of interest is acquired for the Redwood City tide gage from the NOAA Tides and Currents website (Figure 9). While tidal levels were likely slightly different at the Marina Lagoon Pump Station outfall, one would not expect to see significantly higher levels in such proximity to this gage, particularly to the point of adversely affecting the capacity of the pumps. The design operating point for the pumps considers a static head based on a pump station pipe discharge elevation of 103 feet CSM.

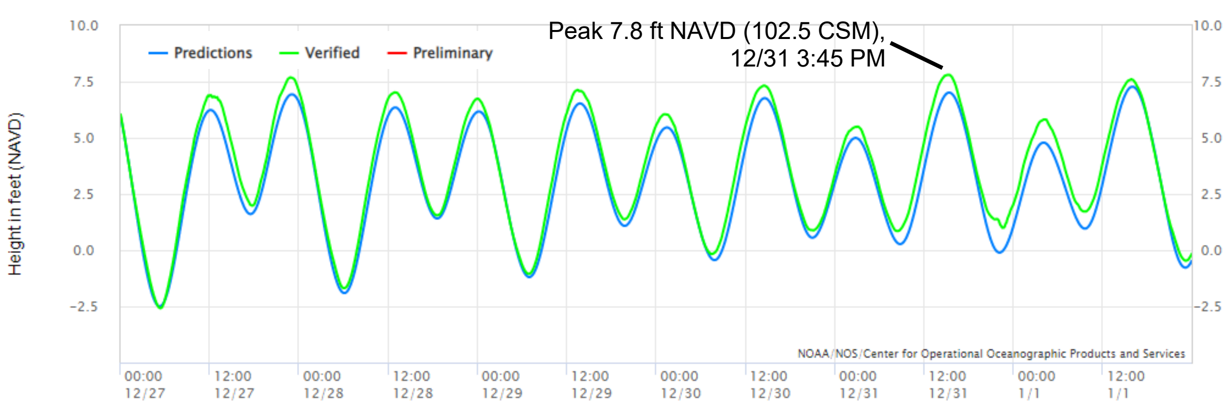

Figure 9: Redwood City Tide Data (NOAA Gage 9414523)

The highest tidal level of 102.7 feet CSM during the storm occurred on December 31 at approximately 3:45 PM. It is very unlikely that this tide elevation had any measurable impact on pumping capacity. Ultimately, therefore, a tidal boundary is not used as an input to the model.

Model Scenarios

The composite MIKE+ model has been utilized to evaluate the performance of the lagoon under various circumstances during the New Years Eve storm.

The three scenarios discussed in this analysis are:

1. Pump failures roughly match those indicated by SCADA;

2. Pumps operate at their current, intended set levels throughout the storm; and

3. Pumps operate at the set levels recommended in the 2014 *Marina Lagoon Operation* report by Schaaf and Wheeler. This document establishes pump set levels to obtain a BFE of 2.4 feet NAVD, or 97.3 ft CSM in the Lagoon.

Pumps and Boundary Conditions

Pumps are modeled with approximate system curves, based on static head differential between the discharge (103 feet CSM) and the variable Lagoon level. The MIKE+ model is currently only capable of turning pumps on and off at single input on and off points. Modeling failures within the operating range requires a means of shutting the pumps off regardless of their set points.

To mimic engine failures for Scenario 1, each pump is assigned an individual boundary condition, defined by a variable time series input based on SCADA information provided by the City. When a pump should be operating, its discharge boundary is set to a 103 feet elevation, indicating normal design operation. During periods when the engines are known to have failed, however, the discharge elevation is increased to 115 ft on City datum (beyond the expected operating range during the storm), and the pump curve has been modified so that the pump discharge drops abruptly to zero, as shown in Table 4.

Table 4: Pump Curve Inputs to the MIKE+ Model.

Static Head (ft)	Discharge (cfs)	Notes
0	340	Upper end of expected range (Lagoon elevation 98.4, Discharge 103)
6	330	
8	320	Low end of expected range (Lagoon elevation 94.4, Discharge 103)
10.7	310	
15	310	Threshold for forced failure
>= 15.01	0	Failure range including the discharge elevation boundary of 115

For model Scenarios 2 and 3, where the engine failures are omitted, the boundary condition is set to a constant 103 feet CSM discharge elevation for each pump, ensuring that capacity remains within the range of 310 cfs to 340 cfs.

Model Results

Results from the hydraulic model highlight the impact of pump failures during a storm of this magnitude. City Operations staff indicated that the level sensor is installed at approximately elevation 97 feet CSM. This impacted the ability of SCADA to capture the true high-water level in the Lagoon during this storm, as the sensor was submerged for a significant period of time. However, staff were able to provide a picture of a staff gage in the lagoon from December 31st at approximately 4:40 PM (Figure 10), providing a means to evaluate model performance in the absence of reliable SCADA levels with the sensor submerged. Lagoon water levels for the three modeled scenarios are provided as Figure 11.

Figure 10: Staff Gage During the Storm, Reading Approximately 98.4 feet CSM

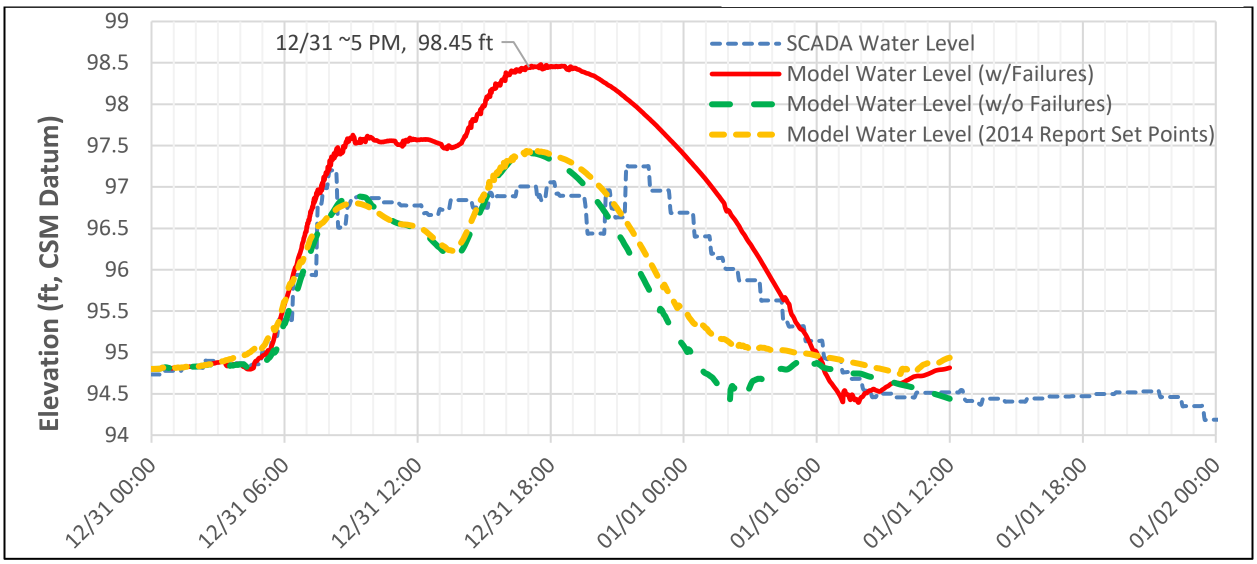

Figure 11: Model Results Overlain on SCADA Water Level Data

The model may be generating slightly too much volume on the tail end of the storm. However, the peak water surface estimated by the model matches the photo provided by operations to within a tenth of a foot. This may simply indicate that locally, an excess of baseflow volume is being generated after the second peak. The exact timing of baseflow at this point is only expected to impact lagoon drawdown after the storm. Most importantly, the model appears to adequately capture the contributions of baseflow rates concurrent with the second peak.

A plot of modeled pump discharge for Scenarios 1 and 2, over binary SCADA status (on/off) is provided for each engine in Figure 12.

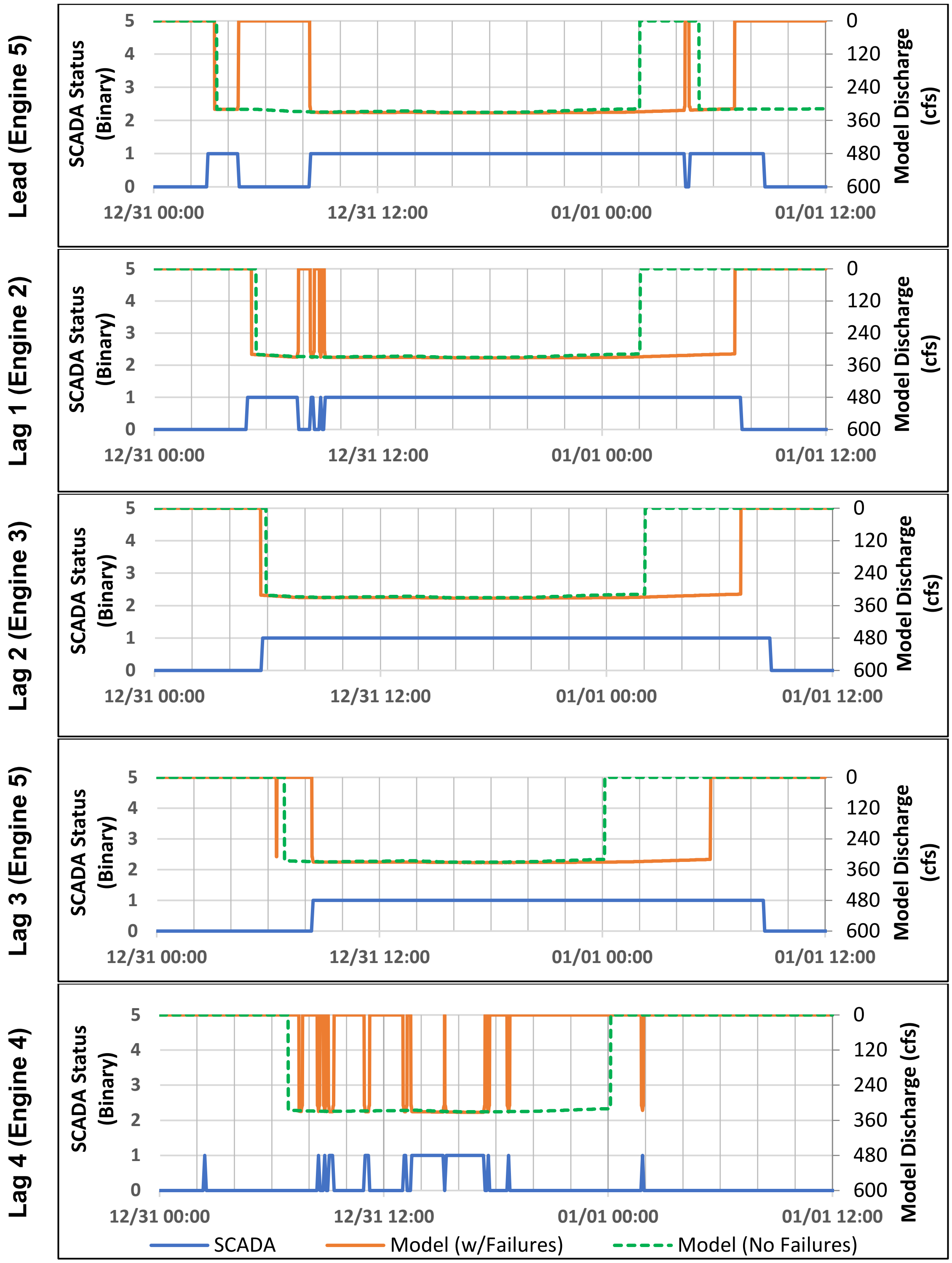

Figure 12: Model Pump Discharge and SCADA On/Off Status Plots

The number of pumps running through each model, compared with SCADA records is shown in Figure 13.

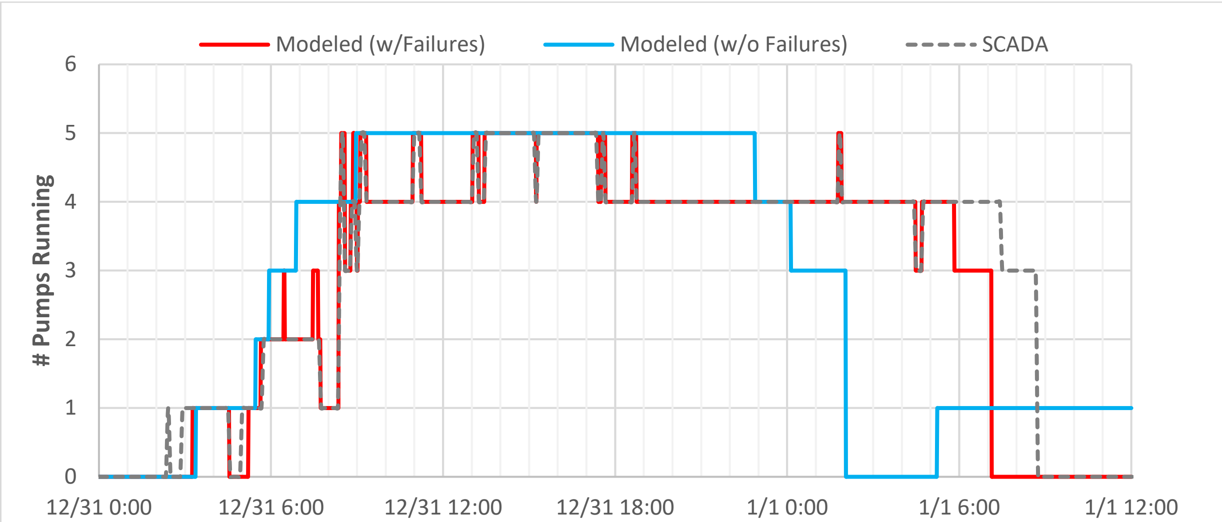

Figure 13: Number of Pumps Running in Simulations and from SCADA Records.

Inflows to the lagoon primarily come from three sources:

- Three tributary open channels. (16th Avenue, 19th Avenue, and Laurel Creek)
- A variety of smaller pipe systems with outfalls directly to the lagoon.
- Direct rainfall on the lagoon surface and on surrounding topography with surface drainage directly into the lagoon.

The three tributary open channel systems convey most inflow into the Lagoon. Discharge from each tributary channel is shown in Figure 14. The attenuation of the first peak in the Laurel Creek drainage area by the two dams is apparent in its hydrograph. However, by the time the second peak occurred, storage capacity in the dams was not available to provide that same level of attenuation. The first and second peak discharges are roughly equivalent for the other two channels.

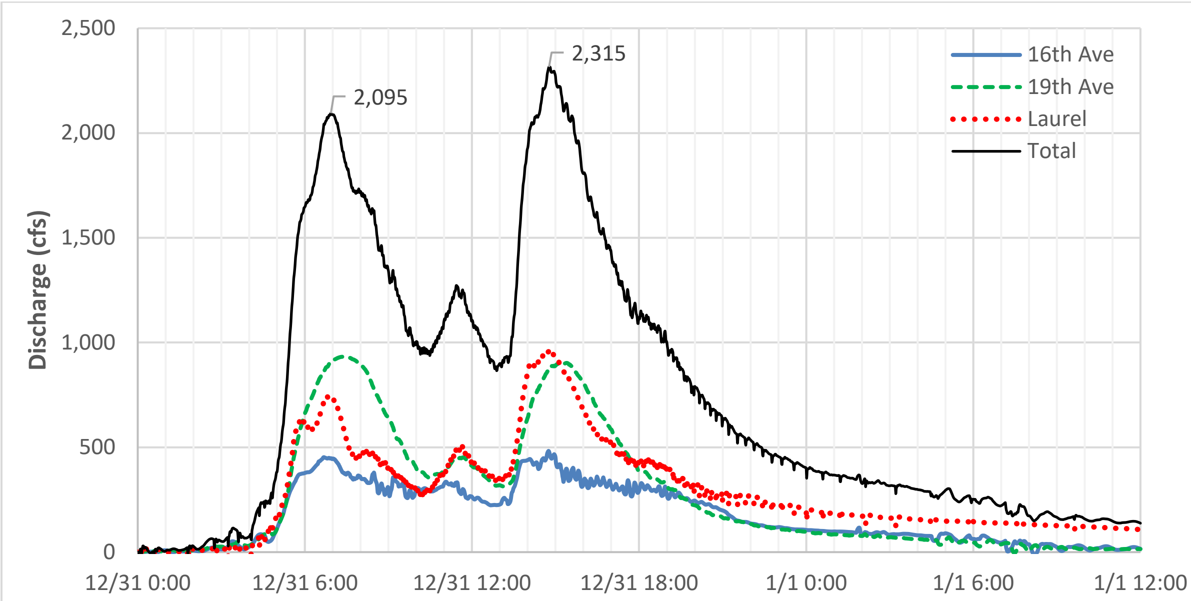

Figure 14: Discharge Hydrographs for the Three Major Lagoon Tributaries

Discharge from pipe systems as well as direct rainfall have been extracted from the model to develop an estimate of a total inflow hydrograph for the lagoon. The total inflow is examined against the capacity of the pumps throughout the storm (with and without engine failures) in Figure 15.

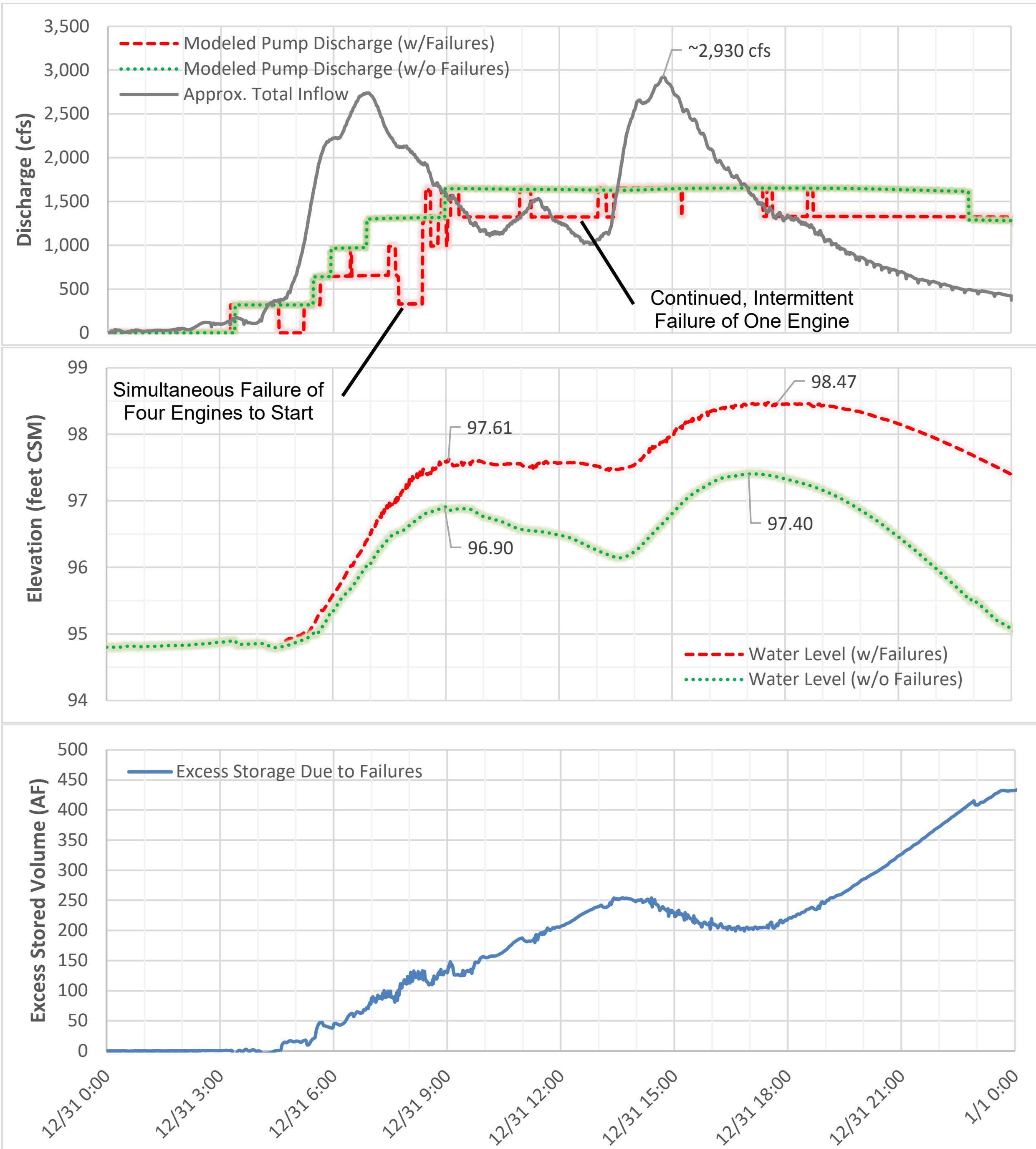

Figure 15: Lagoon Total Inflow and Pump Discharge Rates (Top) Over Lagoon Water Levels (Middle) and Excess Storage Volume (Bottom)

Potential Interior Flooding Impacts

Results from the MIKE21 2D model may be used to evaluate impacts of the engine failures, if any, on interior drainage systems tributary to the Lagoon. An overview of 2D model flooding results is shown for Scenarios 1 and 2 in Figure 16 and Figure 17. The 2D result for Scenario 3 is nearly identical to the result for Scenario 2 and is therefore not shown.

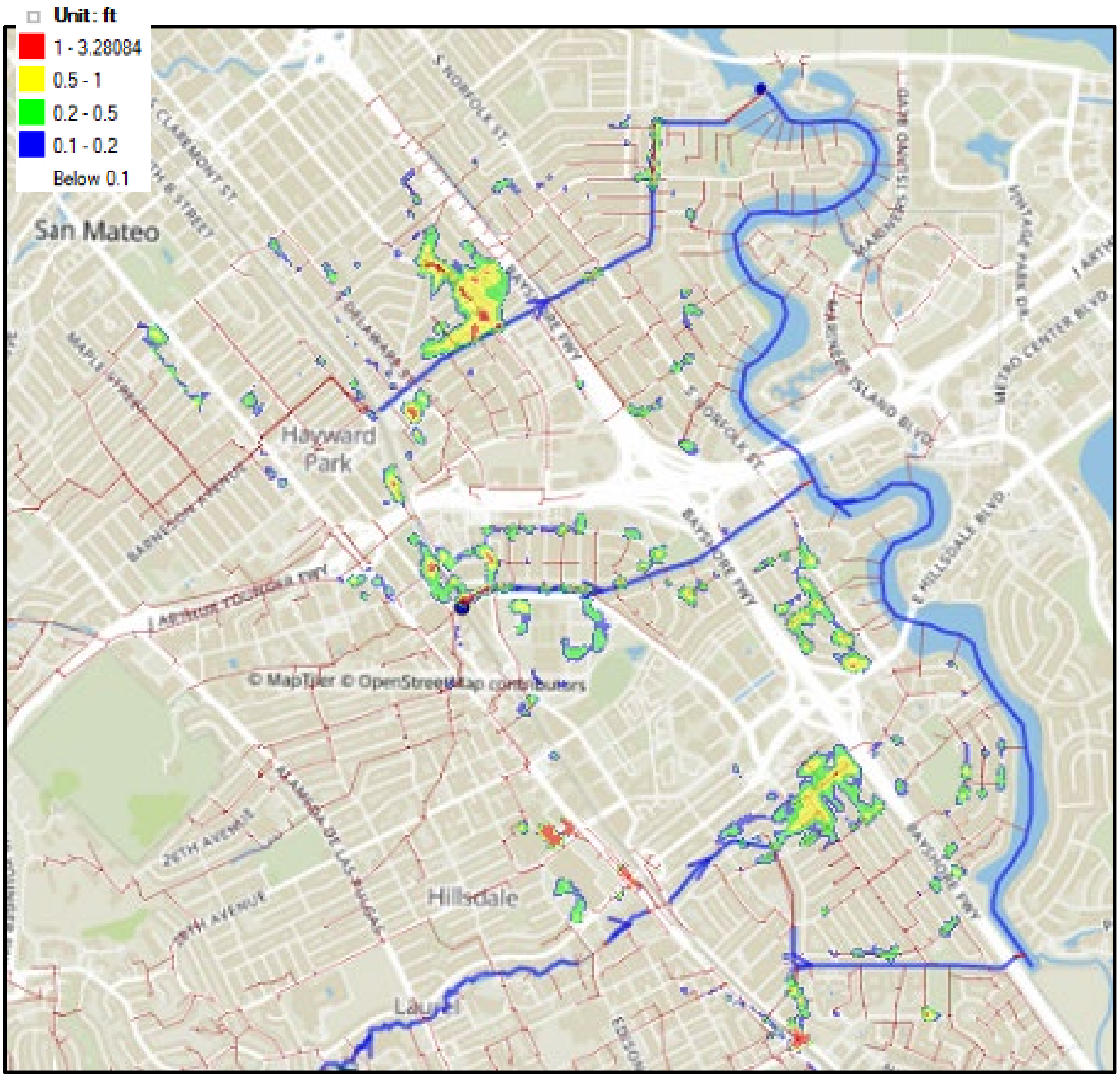

Figure 16: Interior Flooding with Engine Failures

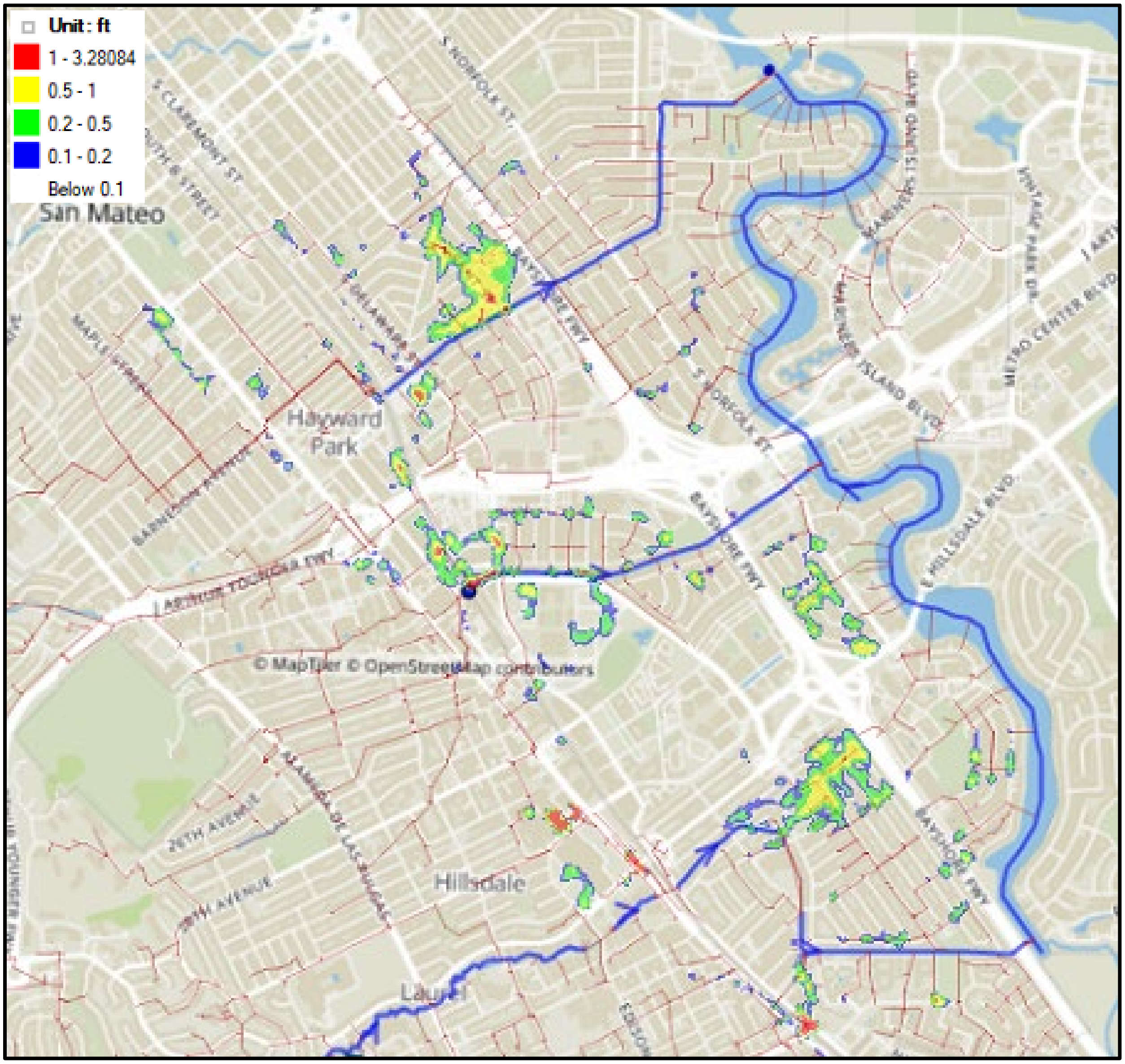

Figure 17: Interior Flooding without Engine Failures

At a glance, the difference between the two results is hardly apparent. Overlays have been generated where differences occur to highlight the impacts of the engine failures on interior flooding (Figure 18 through Figure 20).

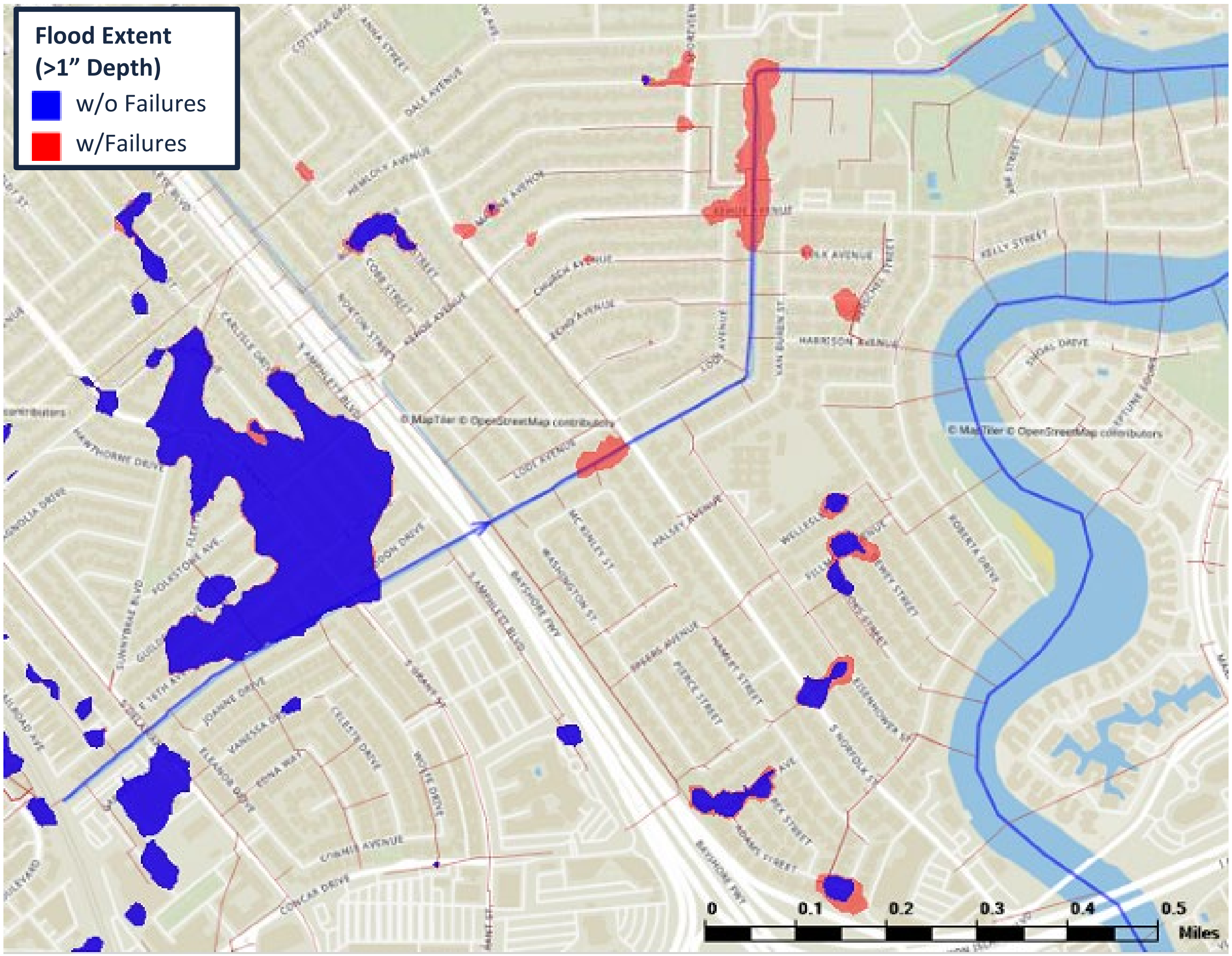

Figure 18: Interior Flooding Overlay (North)

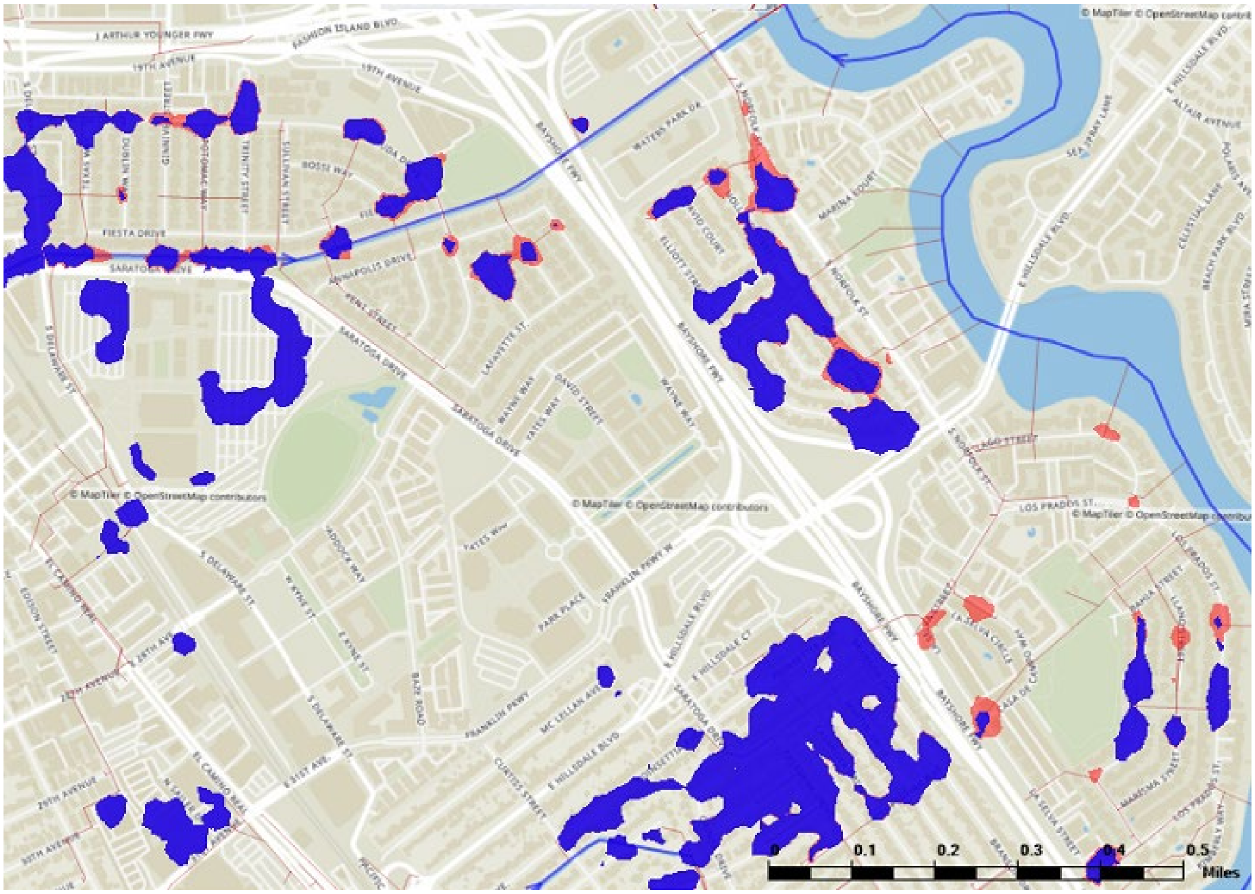

Figure 19: Interior Flooding Overlay (Central)

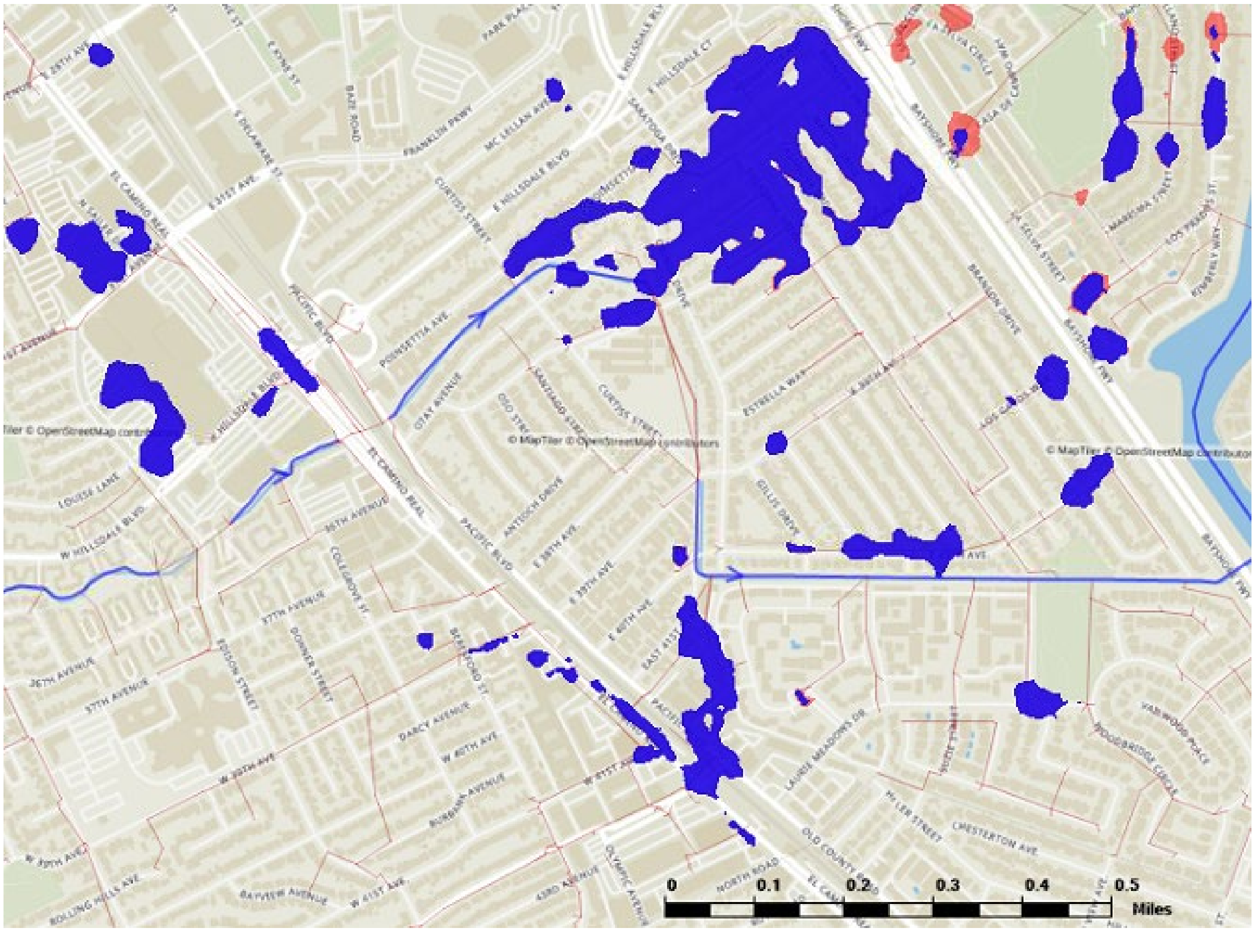

Figure 20: Interior Flooding Overlay (South)

Flow depths in the channels are not fully reflected in the 2D model result. They are accounted for instead in the 1D River model. Two-dimensional routing occurs only if the rivers or pipe systems spill onto the surface. To evaluate the full extent of impact on the three major open channel systems, profiles of each are provided as Figure 21.

The two areas experiencing the most significant interior flooding are 16th Avenue Channel just upstream of Highway 101 and Laurel Creek just upstream of George Hall Elementary School. Both areas are due to local capacity deficiencies. For the 16th Avenue Channel, the Highway 101 crossing is apparently undersized for peak flows of this magnitude. Three culverts exist at George Hall Elementary that have previously been identified as capacity deficient with complex hydraulics. However, spill from the channel is modeled in the vicinity of Curtiss Street. The culvert at this point was not included in prior modeling, and the sections are based on LiDAR. While the model could use further refinement to capture channel capacity more accurately, all else equal, it is apparent from the work completed that Lagoon performance is not impacting the hydraulic grades at this upstream location in Laurel Creek.

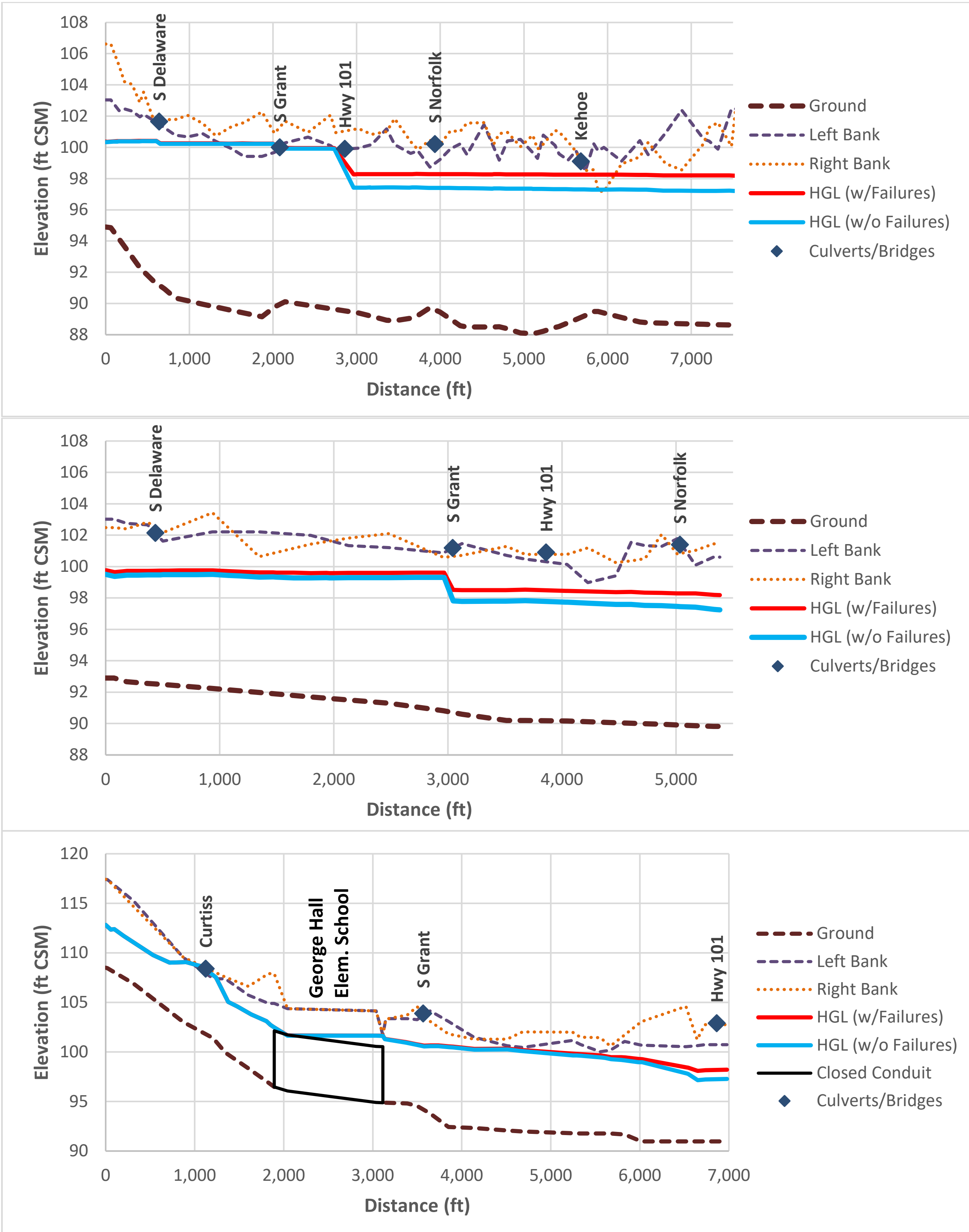

Figure 21: 16th Ave Channel (Top), 19th Ave Channel (Middle), and Laurel Creek (Bottom)

Additional Flood Mapping in the Lagoon

A simple 2-D HEC-RAS model is used to develop higher resolution mapping of the flood fringes along the perimeter of the Lagoon. Water levels extracted from the MIKE+ result are input to HEC-RAS as a water level boundary and allowed to fill the lagoon over the 2017 San Mateo County LiDAR topography DEM.

The results of this mapping are attached with an index map.

Additional Model Verification

Given the lack of definitive surveyed high-water marks and the submergence of the ultrasonic level sensor during the storm, it is difficult to fully evaluate the accuracy of the model. The model uses rainfall data from a single point in space for an approximately 1,600-acre drainage area, so there is bound to be some uncertainty.

Aside from the photograph of the staff gage shown in Figure 10, other photographs have been compiled from residents that provide some means of verifying that the model is providing at least reasonable results. One such photo on the north end of the Lagoon is provided as Figure 22. This photo, taken from a home within the Mariner's Island development, faces the small island and the opposite bank of the Lagoon to the south. A row of houses along Clipper Street is visible, with the waterline approaching the top of a wall at 2315 Clipper Street. Based on the 2017 County LiDAR, the top of this wall is approximately elevation 3.6 feet NAVD88 (approximately 98.5 feet CSM). That photo is time stamped approximately 3:45 PM on December 31. At that time, the model indicates a Lagoon elevation of 98.3 feet CSM.

A second photo from Mariner's Island is shown as Figure 23. This photo faces eastward, towards Fathom Drive and Mariner's Island Boulevard. (Gilead Sciences buildings appear in the background). A profile in the vicinity of the photo shows a ground elevation near the structures of approximately 2.9 feet NAVD88 (approximately 97.3 feet CSM). It is clear in the photos that concrete pads and at least the bottom step at these homes are submerged. Assuming these stairs have a rise of approximately 8 inches, landing on an elevated pad at their base, the water surface is likely higher than 98 feet CSM in the photos, which is consistent with model results.

Another photo, taken near the southern end of the lagoon along the Bay Trail is shown as Figure 24. This photo is taken on the western bank of the lagoon, facing south. Utility poles and the debris boom are clearly visible in the photo, as well a low point in the trail that was inundated by flood waters. A map of the area with 2017 LiDAR contours and an elevation profile through the low point in the trail is provided in Figure 25. The low point in the trail is approximately elevation 2.74 feet NAVD88 (97.64 feet CSM). It is reasonable to estimate from the profile and the photo that the low point in the trail was submerged by anywhere from six inches to a foot. It is not known at what time the photo was taken. However, this would indicate a high-water mark of approximately 98.1 feet to 98.6 feet CSM, which again is consistent with model results.

An evaluation of resident-provided photos (regardless of the exact time that they were taken) shows that the model produces results that reasonably replicate the experience of New Years Eve. Resident-provided photos appear to show maximum water surface elevations that are above 98 feet CSM.

Figure 22: Photo of Lagoon Island and South Bank from a Residence on the Northern Shore of the Lagoon (Top) Over Satellite Image and 2017 LiDAR Profile (Bottom)

Figure 23: Photos from a Home on Port Drive, Facing East

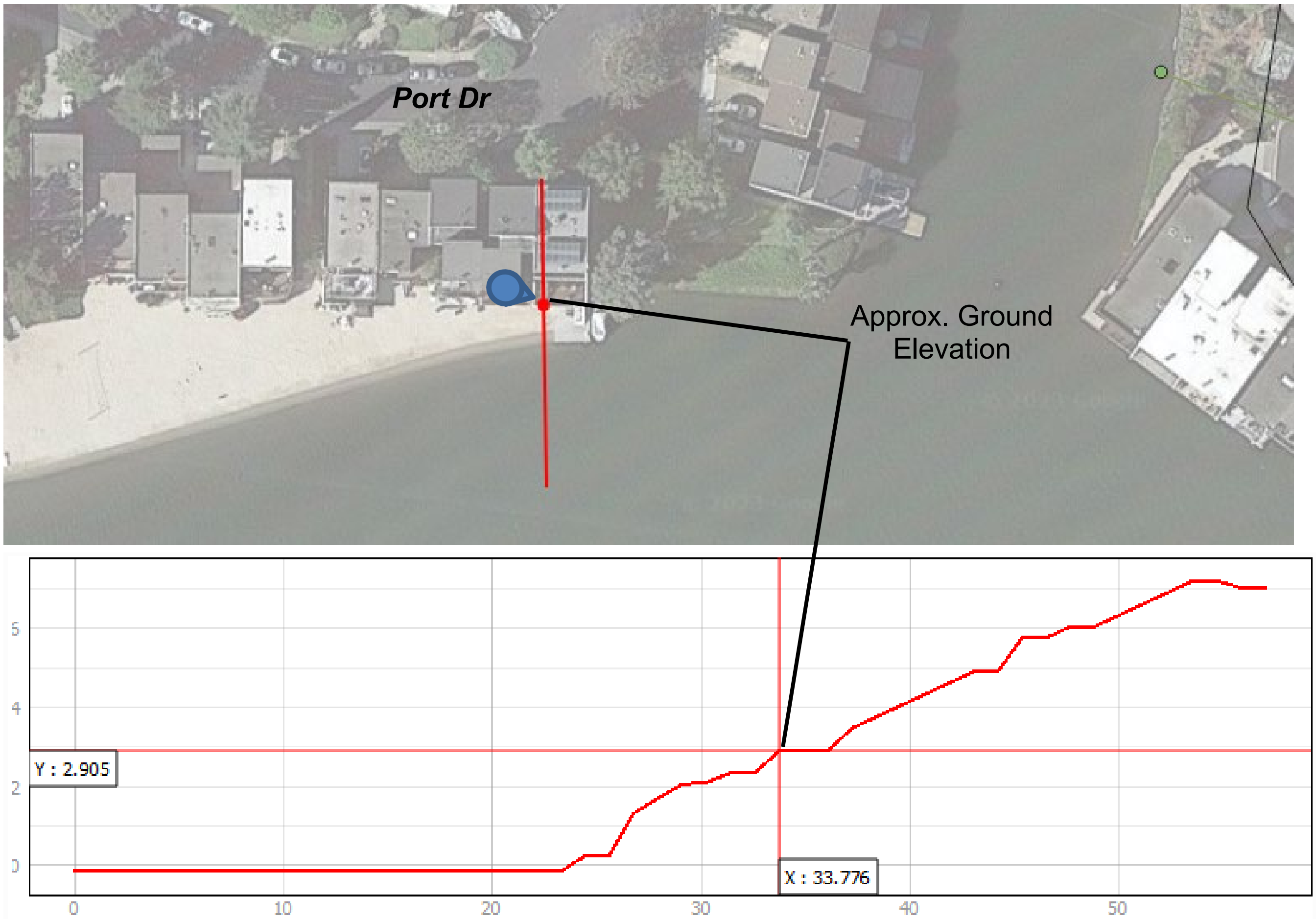

Figure 24: Map and Elevation Profile in the Vicinity of the Homes in Figure 23 Photos

Figure 25: Paved Trail near O'Neil Tide Gates During High Water (Left) and After the Lagoon was Pumped Down (Right)

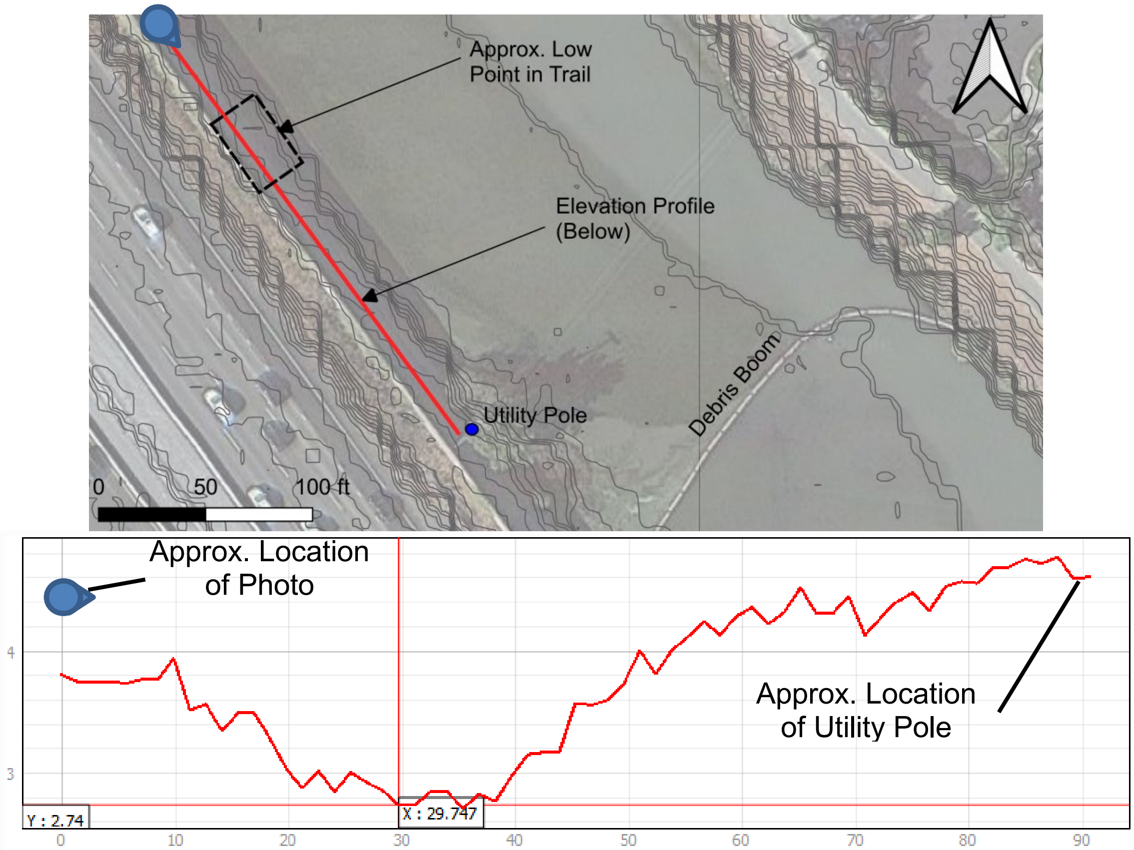

Figure 26: Map and Elevation Profile near Bay Trail Photos

Conclusions

Based on the data available, the MIKE+ model is calibrated well enough to replicate the behavior of the pump engines and the lagoon during the New Years Eve storm. Engine on and off status matches well with limited deviation from the SCADA output for each engine. Although it may be noted that the model does not consider manual operation after the lagoon was initially drawn down.

The rise in lagoon levels is well represented in the model, as is the peak level documented photographically by Operations staff in the afternoon on December 31. It is also apparent from photographs provided by residents that the model is accurately capturing peak water surface elevations higher than 98 feet CSM, based on an evaluation of documented water surfaces against 2017 County LiDAR. The model may overestimate baseflow volumes immediately after the second peak, which does not affect the evaluation of Lagoon performance. The modeled water level appears to remain elevated for an extended period, with drawdown occurring later than the ultransonic sensor data indicates. However, it is difficult to ascertain whether the sensor would have given accurate readings after being submerged. Either way, this is not likely to impact the overall conclusions of this analysis.

The model ultimately indicates that with all five pumps operating at their respective set levels during the storm (without failures), the water level in the lagoon should have fallen significantly during the trough between rainfall peaks to approximately elevation 96.2 feet CSM. The water level would have then peaked at approximately elevation 97.4 feet CSM, or 2.5 feet NAVD.

Instead, the failure of one engine to start as intended followed closely by the simultaneous failure of four engines for approximately 40 minutes allowed the water level to rise by 0.7 foot over the predicted first peak had all engines operated as planned. The continued failure of Engine 4 to start did not allow for drawdown to occur at all between peaks. Instead, the water level plateaued until the second influx of runoff occurred, pushing the water level to its maximum of approximately elevation 98.4 feet CSM, or 3.5 feet NAVD.

Water elevations in the Lagoon had little impact on interior flooding, as channel capacity is apparently the primary driver of flooding for areas that experienced it (16th Avenue Channel and Laurel Creek in particular). The Lagoon has the greatest impact on the hydraulic grade in the 19th Avenue Channel (Borel Creek), where the water surface difference propagated all the way to the railroad. In contrast, Lagoon tailwater impact diminishes at Highway 101 along 16th Avenue Channel and within approximately 1,500 feet of the Lagoon outlet for Laurel Creek. Based on the water surface profiles generated by the model, it is apparent why Lagoon performance made little difference to the overland flooding depths and extents.

Two-dimensional HEC-RAS modeling of the Lagoon water level provides higher resolution mapping of the flooding extents along the edge of the Lagoon. This shows that because of the engine failures there was likely increased risk to properties immediately adjacent to, or with foundations extending into the lagoon.

The New Years Eve storm exceeded the design capacity of the pump station, with inflow greater than a 100-year return period for several consequential durations. However, the model results presented here illustrate the importance of ensuring that the Marina Lagoon pump station can operate as intended to mitigate the impacts of such an extreme storm.

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0 75 150 Feet

FIGURE A-1:

Lagoon Inundation Mapping

Tile 1 of 8

City of San Mateo / CSMT-56

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0 75 150 Feet

FIGURE A-2:

Lagoon Inundation Mapping
Tile 2 of 8

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FIGURE A-3:

Lagoon Inundation Mapping

Figure Subtitle

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0 75 150 Feet

N

FIGURE A-4:

Lagoon Inundation Mapping

Tile 4 of 8

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0 75 150 Feet

N

FIGURE A-5:

Lagoon Inundation Mapping
Tile 5 of 8

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FIGURE A-2:

Lagoon Inundation Mapping

Tile 6 of 8

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FIGURE A-7:

Lagoon Inundation Mapping
Tile 7 of 8

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0 75 150 Feet

FIGURE A-8:

Lagoon Inundation Mapping

Tile 8 of 8

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