Adapting to Rising Tides

Contra Costa County Sea Level Rise Vulnerability Assessment

Final Report • February 2016

Contra Costa Public Works

Contra Costa County Flood Control & Water Conservation District

bcdc

Acknowledgments

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THE PROJECT TEAM WOULD LIKE TO THANK THE FOLLOWING INDIVIDUALS:

Paul Detjens and the Contra Costa Water Conservation and Flood Control District, and Mark Boucher and the Contra Costa County Public Works Department.

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This report was completed for the San Francisco Bay Conservation and Development Commission's Adapting to Rising Tides (ART) Program with funding from the State of California Climate Resilience Account Funds

EXECUTIVE SUMMARY

The Contra Costa County Adapting to Rising Tides (ART) Program, led by the San Francisco Bay Conservation and Development Commission (BCDC), provides support, guidance, tools, and information to help agencies and organizations understand, communicate, and begin to address complex climate change issues. The ART project helps to identify and assess the community assets and natural resources that are most at risk to climate impacts, in particular, sea level rise (SLR) and storm surge. The ART project initially focused on Alameda County, and the tools and products developed for Alameda County have now been extended to Contra Costa County with funding from BCDC using California Climate Resilience Account funds.

This report presents a broad assessment of Contra Costa County's shoreline exposure to flooding or inundation from SLR scenarios of 0 to 66 inches and extreme tide events from the 1-year to the 500-year extreme tide event. The analyses presented in this report show that, as sea levels rise, shoreline assets will become increasingly exposed to extreme tide levels and will no longer provide the same level of flood protection that they do today. Such shifts in the frequency of extreme tide levels will have important design implications for flood protection infrastructure and for the resilience and persistence of valuable shoreline habitats.

The data sets and information provided in this report can inform design and operational strategies, assist in managing climate change-related risks, and help identify trigger points for implementing adaptation strategies to increase the likelihood that a consistent level of flood protection can be provided over the coming decades and into the next century.

This study provides an overview of SLR and coastal hazards in Contra Costa County, a summary of the state of the relevant climate science, and a discussion of the SLR scenario selection. The maps and data sets developed include:

- A county-specific matrix of SLR and extreme tide elevations;
- Inundation and overtopping maps for evaluating potential exposure to future SLR and extreme tide conditions;
- Shoreline delineation and shoreline type maps, which identify the highest point—or crests—of shoreline features and categorize these features into seven types of shoreline, such as engineered flood protection structure, embankment, and wetland;
- Normalized shoreline maps, which provide an additional approach for assessing shoreline exposure by depicting the elevation of shoreline features relative to existing water levels; and
- Mapping assumptions and caveats.

The SLR and extreme tide inundation maps created for Contra Costa County use an approach that allows one map to represent multiple potential future SLR and extreme tide combinations. This information can inform when intervention may be required to reduce potential future inland flooding risks. In addition, the shoreline delineation, shoreline type, and overtopping potential maps and products can be used to identify shoreline areas where adaptation strategies may be warranted and provide information to support the development of appropriate adaptation strategies.

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INTRODUCTION

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1. INTRODUCTION

The Contra Costa County Adapting to Rising Tides (ART) Program, led by the San Francisco Bay Conservation and Development Commission (BCDC), provides support, guidance, tools, and information to help agencies and organizations understand, communicate, and begin to address complex climate change issues. The ART Program helps to identify and assess the community assets and natural resources that are most at risk to climate impacts, in particular, sea level rise (SLR) and storm surge. ART Program initially focused on Alameda County, and the tools and products developed for Alameda County have now been extended to Contra Costa County with funding from BCDC using California Climate Resilience Account funds.

This report presents a broad assessment of Contra Costa County's shoreline exposure to flooding or inundation from sea level rise scenarios of 0 to 66 inches and extreme tide events from the 1-year to the 500-year extreme tide event. Shoreline exposure to oceanic climate change stressors (e.g., SLR and storm surge) can be characterized by the magnitude and frequency of inundation. Permanent *inundation* occurs when an area is regularly inundated by daily tidal fluctuations. As sea level rises, additional areas will potentially be subjected to permanent inundation. In contrast, *flooding* occurs when an area is exposed to episodic, short-duration, extreme tide events of greater magnitude than normal tide levels. Inland areas may be temporarily flooded during an extreme tidal event while maintaining at least a portion of their functionality once the floodwaters recede. The analyses presented in this report show that, as sea levels rise, shoreline assets will become increasingly exposed to tide levels currently considered extreme and will no longer provide the same level of flood protection that they do today. For example, the analysis demonstrates that elevations currently associated with today's 50-year extreme tide will be reached annually after 24 inches of SLR. After 36 inches of SLR, that same elevation will be reached by daily tides. Such shifts in the frequency of extreme tide levels will have important design implications for flood protection infrastructure and for the resilience and persistence of valuable shoreline habitats.

The data sets and information provided in this report can inform design and operational strategies, assist in managing climate-change-related risks, and help identify trigger points for implementing adaptation strategies to increase the likelihood that a consistent level of flood protection can be provided over the coming decades and into the next century.

1.1 STUDY GOALS

Through the collective efforts of the various project partners, a stepwise and systematic approach for investigating shoreline resilience has been developed:

1. Use county-scale SLR and extreme tide inundation maps to conduct high-level shoreline assessments.
2. Ground-truth findings with local experts and identify locations where the inundation maps do not represent local, on-the-ground knowledge of past flood events.
3. Conduct refined shoreline analyses to assess more-detailed vulnerabilities and identify locations where short-term actions would provide benefits.
4. Identify resilience building actions and implementation options that could reduce shoreline vulnerabilities.
5. Investigate the feasibility of resilience building actions.

The goal of this study is to develop the data sets and tools needed to support steps 1, 2, and 3, above. To meet this goal, new SLR and extreme tide inundation maps were created for Contra Costa County

(Figure 1-1) using an approach that allows one map to represent multiple potential future SLR and extreme tide scenarios (Step 1). Using local knowledge, areas where the maps do not accurately represent past coastal flood events, such as inundation that occurs along the shoreline during King Tides, the underlying data were examined to refine the maps to more appropriately portray existing shoreline vulnerabilities (Step 2). In addition, the shoreline delineation approach developed for the ART Program to assess both shoreline type and overtopping potential can be used to highlight where along the shoreline adaptation strategies may be warranted and to inform when intervention may be required to reduce potential future inland flooding risks (Step 3).

Figure 1-1. Contra Costa County ART Project Area

1.2 OVERVIEW OF REPORT

The organization of this report is summarized below:

- **Section 2, Sea Level Rise Science,** provides an overview of sea level rise and coastal hazards, a summary of the state of the science, and a discussion of SLR scenario selection.
- **Section 3, Inundation Mapping,** describes the leveraged model data, water level analysis, topographic data, and the inundation mapping methods used to create the SLR inundation maps.
- **Section 4, Shoreline Delineation,** describes the approach to delineate the shoreline and identify shoreline type (e.g., engineered flood protection structure, non-engineered berm).
- **Section 5, Shoreline Overtopping Potential,** describes the methods used to calculate overtopping potential along the shoreline (and adjacent areas) and outlines applications of the maps to identity potential shoreline vulnerabilities.
- **Section 6, Normalized Shoreline Elevations,** presents the normalized shoreline approach for assessing shoreline exposure and vulnerabilities.
- **Section 7, Mapping Assumptions and Caveats,** provides the key caveats associated with the overall approach for developing SLR and storm surge inundation maps that are appropriate as a screening-level tool for assessing exposure.
- **Section 8, Conclusions and Next Steps,** provides a summary of the approach and an introduction to the more detailed focused area analyses completed using these data. The focus area studies are included as additional appendices.
- **Section 9, References.**

1.3 ACRONYMS/ABBREVIATIONS

AR5	The IPCC's Fifth Assessment Report (IPCC 2013)
ART	Adapting to Rising Tides Program
Bay	San Francisco Bay
BCDC	San Francisco Bay Conservation and Development Commission
CCC	California Coastal Commission
CCMP	California Coastal Mapping Program
DEM	Digital Elevation Model
ENSO	El Niño–Southern Oscillation
FEMA	U.S. Department of Homeland Security's Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
ft	foot or feet
GHG	greenhouse gas
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
LiDAR	light detection and ranging
m	meter(s)
MHHW	Mean Higher High Water (tidal datum)
MLI	Midterm Levee Index
NAVD88	North American Vertical Datum of 1988
NCEI	National Centers for Environmental Information
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NTDE	National Tidal Datum Epoch
OPC	California Ocean Protection Council
QA/QC	quality assurance/quality review
SFEI	San Francisco Estuary Institute
SLR	sea level rise
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

1.4 GLOSSARY

The following definitions describe each term as it is used in this report:

Annual maxima: The highest water level recorded during each year in a time series based on a July through June "storm year."

El Niños (within the El Niño–Southern Oscillation [ENSO][1] cycle): A phenomenon in the Pacific Ocean characterized by warmer-than-usual waters in the Eastern Pacific. El Niños are caused by specific changes in winds and currents across the equatorial Pacific, driven by an oscillation in air pressure differences across the Eastern and Western Pacific called the Southern Oscillation. El Niños may result in higher sea levels and larger, more frequent storms along the California coast.

Extreme tide: Extreme tides are relatively infrequent water level events that are a result of relatively high astronomical tides coupled with a storm surge event. The absolute elevations reached during these events are due to short-term meteorological processes (such as low atmospheric pressure due to storms) and large-scale oceanographic conditions (such as King Tides or El Niño conditions). The extreme tide elevations discussed in this assessment do not include any local wind and wave effects.

Hydrodynamic zones: Due to the geometry and hydrodynamics of San Francisco Bay (Bay), tidal characteristics vary spatially. Tides are amplified in the South Bay, and daily Mean Higher High Water (MHHW) and extreme tide elevations vary along the Bay shoreline. Regions of roughly similar hydrodynamic characteristics are referred to as "hydrodynamic zones." The analysis within each hydrodynamic zone is averaged to simplify application of the results.

Mean Higher High Water: Average height of the higher high tides of each day during the current National Tidal Datum Epoch (NTDE), which is a specific 19-year period (1983 to 2001) adopted by the National Oceanic and Atmospheric Administration (NOAA) to perform tidal computations.

Normalized shoreline elevation: Shoreline elevation data can be normalized by dividing each shoreline elevation value by the local MHHW tide level. By normalizing the shoreline asset elevations, an asset's flooding threshold can be determined by comparing the "normalized shoreline elevation" to the normalized extreme tide curve. A normalized elevation value of 1.0 indicates an elevation equal to the local MHHW tide level. A normalized elevation value greater than 1.0 indicates an elevation above the local MHHW tide level, and a value less than 1.0 is below MHHW. The normalized shoreline elevation maps and extreme tide curves can be used together to assess exposure to flooding.

Normalized extreme tide curves: Normalizing elevation data allows the original data to be compared using a different scale. Elevation data are normalized by dividing each elevation value by a common denominator. For example, in the Bay, both the MHHW tide level and the 100-year tide level vary spatially; however, the ratio of a given extreme tide to MHHW is relatively constant across large geographic areas. For example, the ratio of the 100-year tide level divided by the MHHW tide level (the common denominator) is approximately constant within the project area (approximately 9.7 feet [ft] / 6.1 ft = 1.6). Normalized extreme tide curves were created to show the elevations of a 1-year through 100-year extreme tide event normalized to the MHHW elevation for both existing conditions and future conditions with SLR. The normalized elevation data allow comparisons across different spatial areas.

[1] El Niño–Southern Oscillation(ENSO) is a natural oceanic-atmospheric cycle. El Niño conditions are defined by prolonged warming in the Pacific Ocean sea surface temperatures. Typically, this happens at irregular intervals of two to seven years, and it can last anywhere from nine months to two years.

Overtopping potential calculation: Overtopping potential refers to the condition where the water surface elevation associated with a particular SLR scenario exceeds the elevation of a shoreline asset. Overtopping potential does not account for the physics of wave run-up and overtopping. It also does not account for potential vulnerabilities along the shoreline protection infrastructure that could result in complete failure of the flood protection infrastructure through scour, undermining, or breach after the initial overtopping occurs. The overtopping potential results visually show which segments of the shoreline are first impacted and the depth to which each segment is overtopped during the mapped scenarios.

Storm surge: A storm surge is an abnormal rise of water generated by high winds and low atmospheric pressure in the presence of a storm that is over and above the predicted astronomical tide. The magnitude of a storm surge and the height of an astronomical tide are additive: when the sum of the two is unusually large, an extreme tide occurs.

Tidal datum: A tidal datum is the daily tide water level computed using records observed during the current NTDE.

Tides: The regular upward and downward movement of the level of the ocean due to the gravitational attraction of the moon and the sun and the rotation of the earth. Also called "astronomical tides." The Bay experiences two high tides and two low tides of unequal height each day.

2.0

SEA LEVEL RISE SCIENCE


Photo Courtesy of Avanti Tamhane

2. SEA LEVEL RISE SCIENCE

2.1 SUMMARY OF THE SCIENCE

The science associated with SLR is continually being updated, revised, and strengthened. Although there is no doubt that sea levels have risen and will continue to rise at an accelerated rate over the coming century, it is difficult to predict with certainty what amount of SLR will occur within any given time frame. The uncertainties increase over time (i.e., the uncertainties associated with 2100 projections are greater than those associated with 2050 projections) because of uncertainties in future greenhouse gas (GHG) emissions trends, the sensitivity of climate conditions to GHG concentrations, and the overall capabilities of climate models. The projections presented in this document draw on the best available science for California as of January 2016.

In March 2013, the California Ocean Protection Council (OPC) adopted the National Research Council (NRC) report *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future* (NRC 2012) as the best available science on SLR for the state (OPC 2013). The California Coastal Commission (CCC) also supported the use of the NRC 2012 report as best available current science, noting that SLR science is continually advancing and future research may enhance the scientific understanding of how the climate is changing, resulting in the need to regularly update projections (CCC 2015). The NRC report includes discussions of historic SLR observations, three likely SLR projections for the coming century, high and low extremes for SLR, and insight into the potential impacts of a rising sea for the California coast. After the release of the NRC 2012 report, the Intergovernmental Panel on Climate Change (IPCC) released the Fifth Assessment Report (AR5), *Climate Change 2013: The Physical Science Basis*, which provides updated consensus estimates of global SLR (IPCC 2013).

The NRC projections for San Francisco relative to the year 2000 can be applied to Contra Costa County. Table 2-1 presents the local projections (mean ± 1 standard deviation). These projections (for example, 6 ± 2.0 inches in 2030) represent the *likely* SLR values based on a moderate level of greenhouse gas emissions and extrapolation of continued accelerating land ice melt patterns plus or minus one standard deviation. The extreme limits of the *ranges* (for example, 2 and 12 inches for 2030) represent *unlikely but possible* levels of SLR using both low and very high emissions scenarios and, at the high end, including significant land ice melt that was not anticipated at the time of publication but acknowledged as having potential to occur. The NRC report also provides regional estimates of *net SLR* for the Oregon, Washington, and California coastlines that include the sum of contributions from the local thermal expansion of seawater, wind-driven components, land ice melting, and vertical land motion. The chief differentiator among net SLR projections along the western coast of North America derives from vertical land motion estimates, which generally show uplift (reducing net SLR) of lands north of Cape Mendocino and subsidence (increasing net SLR) of lands south of Cape Mendocino.

The NRC ranges are higher than the global estimates presented in IPCC AR5, though the projections in the NRC report are similar to IPCC estimates. At this time, the use of NRC projections and ranges is appropriate for Contra Costa County because they encompass the best available science, they were derived considering local and regional processes and conditions, and their use is consistent with current state guidance.

Table 2-1. Sea Level Rise Estimates Relative to the Year 2000

Year	Most Likely Projections (inches)	Upper Range (inches)
2030	6 ± 2	12
2050	11 ± 4 *	24
2100	36 ± 10	66

Source: NRC 2012.

* As a simplifying assumption, the 2050 most likely value selected for the inundation mapping effort is 12 inches rather than the 11 inches noted in the table.

2.2 SEA LEVEL RISE AND COASTAL HAZARDS

The Contra Costa County shoreline comprises a variety of shoreline types and features, including natural tidal marshes and mudflats, a network of non-engineered berms, engineered flood protection structures (e.g., levees) and features such as railroads not specifically designed for flood protection but that may serve as a first line of defense to protect the densely built inland areas from coastal floods. Many facilities of economic importance are near the shoreline, including the Port of Richmond, private marine terminals and wharfs, four of the five refineries in the Bay Area, pipelines, critical rail infrastructure, interstates and major thoroughfares with connections to three transbay bridges, and commercial and industrial job sites. Also, the communities of Richmond, Pinole, Hercules, Rodeo, and Martinez are located along the shoreline and have varying levels of coastal flood protection.

Bay waters experience two low tides and two high tides of unequal height each day. MHHW is the average elevation of the highest daily tides. King Tides are unusually high but predictable astronomical tides that occur approximately two to four times per year, generally between December and February. As seas have risen, King Tides have begun to cause annual flooding of low-lying coastal areas. Due to a relatively steep coastal topography, most low-lying areas in the Contra Costa County ART project area (project area) are associated with tidal creeks and channels. However, there are some low-lying areas along the shoreline, including the Point Edith Wildlife Area and Point Pinole Regional Shoreline, where existing tidal marshes and coastal wetlands already experience inundation during King Tides. Also, there is already nuisance flooding of Waterfront Road within the Lower Walnut Creek watershed near the City of Martinez/Contra Costa County line during high astronomical tides.

In addition, there are short-term factors that elevate the waters of the Bay along the Contra Costa County shorelines, such as El Niño, storm surge and waves, and for the eastern portions of the county, freshwater inflow from the Delta. When one or more of these factors combine to raise Bay waters above predicted tide levels, the result is a temporarily higher water level called an *extreme tide*. Extreme tides can reach several feet higher than King Tides and result in damaging coastal floods. Understanding the additive impact of such factors to produce temporary flooding is crucial for planning in the coastal environment. Extreme tides are generally characterized in terms of probability: a 1 percent annual chance tide (or 100-year extreme tide) is the coastal water level elevation that Bay waters have a 1 percent chance of reaching in any given year. Likewise, a 20 percent annual chance tide (or 5-year extreme tide) is the coastal water level elevation that Bay waters have a 20 percent chance of reaching in any given year. The actual water level elevation of various extreme tides in Contra Costa County is discussed in Section 2.3.

Table 2-2 summarizes several factors affecting existing water levels along the county shoreline. The table represents the relative magnitude of these components rather than a particular elevation.

Table 2-2. Factors That Influence Local Water Level Conditions in Addition to Sea Level Rise

Factors Affecting Water Level	Typical Magnitude [1, 2]	Period of Influence	Typical Frequency
Daily tidal range	5 to 7 ft	Hours	Twice daily
King tides	1 to 1.3 ft	Hours	One to four times/year
Storm surge	0.5 to 3 ft	Days	Several times a year to every 100 years, depending on height
Wind-driven waves	0.5 to 3 ft	Hours	Daily to several times a year
El Niño	0.3 to 1.5 ft	Months to Years	2 to 7 years
Delta freshwater inflow [3]	0.5 to 5 ft	Days	Variable: rainfall dependent

[1] DHI 2011.

[2] BakerAECOM 2013.

[3] Tide gage analysis of the Rio Vista (9415316), Mare Island (9415112), and Port Chicago (9415144) tide gages.

The following coastal flood hazards may increase due to SLR and other climate-change-induced changes to atmospheric-oceanic processes:

- **Daily tidal inundation:** As sea levels rise, the elevation of MHHW will continually increase. Without action, this increase in elevation will result in increased permanent future inundation of low-lying areas.
- **Annual high tide inundation (King Tides):** King Tides result in temporary inundation, particularly associated with nuisance flooding, such as inundation of low-lying roads, boardwalks, and waterfront promenades. Typical King Tides raise coastal waters approximately 14 inches above MHHW. In the winter (December, January, and February), King Tides may be exacerbated by winter storms, making these events more dramatic. Without protective action, this regular, predictable flooding will occur more frequently and affect larger areas as seas rise.
- **Extreme high tide inundation (storm surge):** Depending on the type and intensity of cause(s), extreme tides range from 12 inches above MHHW (1-year extreme tide) to 41 inches above MHHW (100-year extreme tides) or higher. One such event occurred on December 11, 2014, when Bay waters rose 18 inches above predicted tide levels due to coastal storm conditions during a heavy rain event.
- **Weather and weather cycles:** Climate change may affect the frequency and/or intensity of coastal storms, El Niño cycles, and related processes. During El Niño winters, atmospheric and oceanographic conditions in the Pacific Ocean produce severe winter storms that impact Bay shorelines. No clear consensus has emerged about these changes, but a commonly identified trend is a tendency toward increased elevation of snowpack and correspondingly more precipitation falling in Delta watersheds as rain. This trend may increase the frequency of higher Delta flows into the Bay.
- **Waves:** Large waves, whether generated within the Bay or by large Pacific storms, can damage unprotected shorelines and drive floodwaters even higher. Typical impacts include damage to coastal structures such as levees, docks and piers, wharves, and revetments; backshore inundation due to wave overtopping of structures; and erosion of natural shorelines.
- **Precipitation combined with high tides:** When large rainfall events co-occur with particularly high tides, coastal waters can impede the drainage of rivers, creeks, and stormwater systems to the Bay, resulting in inland flooding during storms. Typical impacts during high or extreme tides

include failure of storm drainage infrastructure, drainage restrictions through outfalls, backup of floodwaters into low-lying areas during precipitation events, road closures, and neighborhood flooding.

2.3 SCENARIOS

SLR is often visualized using inundation maps. Typically, maps represent specific SLR scenarios (e.g., 16 inches of SLR above MHHW) or extreme tide water level (e.g., the 1 percent annual chance tide). However, selecting the most appropriate SLR scenario to map in support of project planning, exposure analyses, or SLR vulnerability and risk assessments is not simple. This approach requires pre-selecting appropriate SLR and extreme tide scenarios that meet all project needs.

Rather than pre-selecting specific SLR scenarios for Contra Costa County, ten individual sets of inundation maps were developed to represent a range of possible scenarios associated with extreme tide levels and SLR, ranging from 12 to 108 inches, representing combinations of 0 to 66 inches of SLR with extreme tides from the 1-year to the 100-year extreme tide. The scenario selection relied on the extreme water level analysis described in Section 3. The goal of scenario selection was to identify six scenarios that could represent the current NRC SLR projections, as presented in Section 2.1, and approximate a range of storm surge events.

Each of the following scenarios approximates either (1) permanent inundation scenarios likely to occur before 2100 or (2) temporary flood conditions from specific combinations of SLR and extreme tides. For example, the water elevation associated with 36 inches of SLR is similar to the water elevation associated with a combination of 24 inches of SLR and a 1-year extreme tide (King Tide). Therefore, a single map can be used to visualize either event. Although inundation maps can be used to approximate the temporary flood extent associated with an extreme tide, they illustrate neither the duration of flooding nor the potential mechanism(s) for draining floodwaters once the extreme tide recedes. Figure 2-1 presents a representative cross section of a shoreline that illustrates the distinction between permanent inundation and temporary flooding.

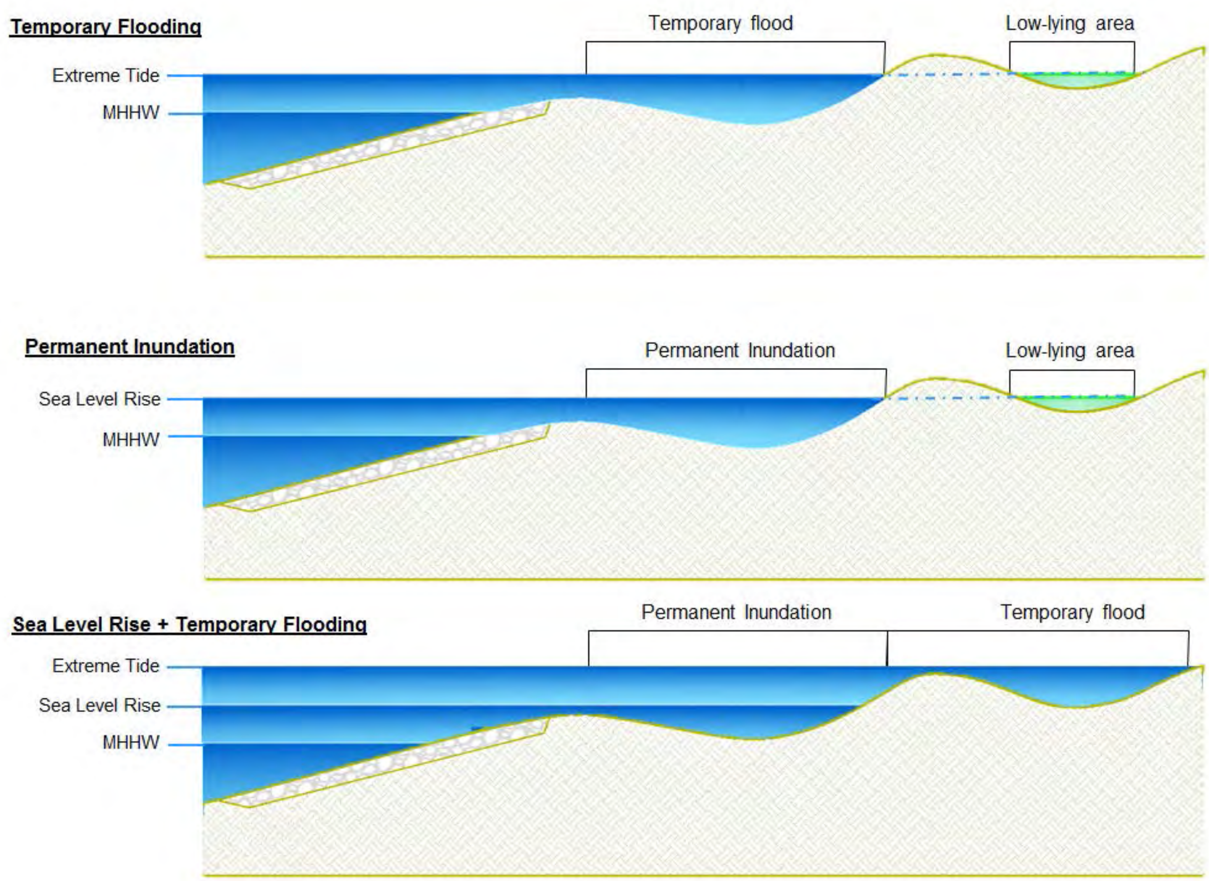

Figure 2-1. Shoreline Cross Section Showing Permanent Inundation and Temporary Flooding

The first six scenarios (12, 24, 36, 48, 52, and 66 inches of SLR above MHHW) relate directly to the NRC SLR estimates, and they capture a broad range of scenarios between the most likely scenario and the high-end of the uncertainty range at both mid- century and at the end of the century.

1. 12-inch sea level rise ≈ 2050 most likely SLR scenario
2. 24-inch sea level rise = 2050 high end of the range; or an existing 5-year extreme tide
3. 36-inch sea level rise = 2100 most likely SLR scenario; or an existing 50-year extreme tide
4. 48-inch sea level rise ≈ 2100 upper 85% confidence interval; or 6 inches of SLR plus a 100-year extreme tide
5. 52-inch sea level rise ≈ existing conditions 500-year extreme tide; or 12-inch SLR plus 100-year extreme tide
6. 66-inch sea level rise = 2100 upper end SLR scenario; or 24-inch SLR plus 100-year extreme tide

In addition to the scenarios listed above, Bay water elevations 77, 84, 96, and 108 inches above MHHW were mapped. These levels are above current predictions for SLR likely to occur before 2100, but they illustrate short-term flooding that could occur in that time frame when extreme tides are coupled with SLR.

1. 77 inches above MHHW ≈ 36-inch SLR plus 100-year extreme tide
2. 84 inches above MHHW ≈ 42-inch SLR plus 100-year extreme tide
3. 96 inches above MHHW ≈ 54-inch SLR plus 100-year extreme tide
4. 108 inches above MHHW ≈ 66-inch SLR plus 100-year extreme tide

The water levels along the shoreline were binned using a tolerance of ± 3 inches to increase the applicable range of the mapped scenarios. For example, Scenario 3 (MHHW + 36 inches) can be used to approximate all extreme tide/SLR combinations that produce a water level in the range of MHHW + 33 inches to MHHW + 39 inches (Table 2-3).

Although Table 2-3 presents the ten mapped scenarios, Table 2-4 presents over 90 combinations of SLR and extreme tide levels that can be represented by the 10 inundation maps. For example, from Table 2-4, the inundation map of Scenario 3 (MHHW + 36 inches, dark orange cells, Table 2-4) represents all of these combinations:

- 1-year extreme tide event coupled with 24 inches of SLR;
- 2-year extreme tide event coupled with 18 inches of SLR;
- 5-year extreme tide event coupled with 12 inches of SLR;
- 25-year extreme tide event coupled with 6 inches of SLR, and
- 50-year extreme tide event under existing conditions (no SLR).

The colors shown in Table 2-3 are replicated in the matrix of water levels shown in Table 2-4 to indicate the combinations represented by each inundation map. Table 2-4 also identifies the combinations of SLR and extreme tide that may produce flooding at the higher end of the spectrum at the end of the century. For example, Scenario 9 (96 inches above MHHW) approximates the following (see light blue cells, Table 2-4):

- 66 inches of SLR with a 25-year extreme tide event;
- 60 inches of SLR with a 50-year extreme tide event; and
- 54 inches of SLR with a 100-year extreme tide event.

These scenarios provide a rich data set with which to evaluate vulnerabilities and risk from SLR and to better define the timing for effective adaptation strategies.

Table 2-3. Sea Level Rise Mapping Scenario (inches above MHHW)

Mapping Scenario	Water Level	Applicable Range for Mapping Scenario (Reference ± 3 inches)
Scenario 1	MHHW + 12"	MHHW + 9 to 15”
Scenario 2	MHHW + 24"	MHHW + 21 to 27”
Scenario 3	MHHW + 36”	MHHW + 33 to 39”
Scenario 4	MHHW + 48”	MHHW + 45 to 51”
Scenario 5	MHHW + 52”	MHHW + 49 to 55”
Scenario 6	MHHW + 66”	MHHW + 63 to 69”
Scenario 7	MHHW + 77”	MHHW + 74 to 80”
Scenario 8	MHHW + 84”	MHHW + 81 to 87”
Scenario 9	MHHW + 96”	MHHW + 93 to 99”
Scenario 10	MHHW + 108”	MHHW + 105 to 111”

Table 2-4. Contra Costa Sea Level Rise and Extreme Tide Matrix

Sea Level Rise Scenario	Daily Tide *Permanent Inundation*	Extreme Tide (Storm Surge) *Temporary Flooding*						
	+SLR	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
	Water Level above MHHW (inches)							
Existing Conditions	0	14	18	23	27	32	36	41
MHHW + 6 inch	6	20	24	29	33	38	42	47
MHHW + 12 inch	12	26	30	35	39	44	48	53
MHHW + 18 inch	18	32	36	41	45	50	54	59
MHHW + 24 inch	24	38	42	47	51	56	60	65
MHHW + 30 inch	30	44	48	53	57	62	66	71
MHHW + 36 inch	36	50	54	59	63	68	72	77
MHHW + 42 inch	42	56	60	65	69	74	78	83
MHHW + 48 inch	48	62	66	71	75	80	84	89
MHHW + 52 inch	52	66	70	75	79	84	88	93
MHHW + 54 inch	54	68	72	77	81	86	90	95
MHHW + 60 inch	60	74	78	83	87	92	96	101
MHHW + 66 inch	66	80	84	89	93	98	102	107

The development of this matrix is discussed in Section 3.6.

3.0

INUNDATION MAPPING


Photo Courtesy of BCDC ART Program

3. INUNDATION MAPPING

Inundation maps are a valuable tool for evaluating potential exposure to future SLR and extreme tide conditions, and the most up-to-date maps should be used during project planning and design. The maps are typically used to evaluate when (under what amount of SLR and/or extreme tide) and by how much (what depth of inundation) an asset will be exposed. This section presents the overall methods and data sources used to develop the detailed inundation maps presented in Appendix A. Figure 3-1 illustrates the project area for which SLR scenarios were mapped. The hydrodynamic zone illustrated on Figure 3-1 represents the portion of the project area to which the extreme tide matrix (Table 2-4) applies.

Figure 3-1. Contra Costa County ART Project Area, with Hydrodynamic Zone and Sample Model Output Locations

3.1 LEVERAGED DATA SOURCES

The Contra Costa County SLR and extreme tide inundation mapping relied on two primary data sources:

- **Hydrodynamic modeling data:** Hydrodynamic model output was required to assess daily and extreme tide levels throughout Contra Costa County. The use of modeled water levels was preferred over individual tide gage analyses because of the high spatial density provided in the model output for the entirety of the Contra Costa County shoreline. This study leveraged water levels from a regional San Francisco Bay hydrodynamic modeling study completed as part of the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) San Francisco Bay Area coastal study (DHI 2011).

The FEMA model output was archived in 15-minute time steps, as described in DHI (2011). The water level simulations extended from January 1, 1973, to December 31, 2003 (31 years). The regional model was calibrated and validated to observed historical data from nine tide stations within the Bay. A total of 108 output points along the Contra Costa County shoreline were used to characterize the spatial variability of water levels throughout the study area.

- **Topographic data:** High-quality topographic data were leveraged for the shoreline delineation task. The primary data set was the light detection and ranging (LiDAR)[2] data collected by NOAA as part of the California Coastal Mapping Program (CCMP) (OPC 2016). NOAA managed the data collection in central and northern San Francisco Bay. The central and northern Bay LiDAR data were collected in February to April 2010. This data set provides complete coverage of the coastal areas, up to the 16-foot (5-meter [m]) elevation contour. The collected LiDAR data for the central and northern Bay have a vertical accuracy of +/- 0.05 m based on the tested root mean square error for all checkpoints (Dewberry 2011a, 2011b). This accuracy exceeds the United States Geological Survey (USGS) National Geospatial Program LiDAR Guidelines and Base Specifications (USGS 2010). Additional topographic and bathymetric data sets were leveraged to build a new seamless Digital Elevation Model (DEM). This complete set of data includes:

    1. 2011 OPC LiDAR
    2. 2010 NOAA LiDAR
    3. 2010 USGS LiDAR
    4. 2008 Contra Costa County LiDAR
    5. 2009 USACE Bathy
    6. 2005-2009 NOAA NCEI Bathy

  The total 1 m DEM built using these data sets extends inland well past the 10 m contour. The NOAA LiDAR and the associated DEM derived from the LiDAR data provided the topographic base data for the mapping and shoreline delineation effort. The bare-earth LiDAR was used, which means that all vegetation, buildings, and structures (e.g., bridges and buildings) have been removed. The shoreline delineation effort was completed using the raw LiDAR elevation data points and a 1 m DEM derived from the NOAA LiDAR. The inundation mapping, overtopping potential calculations, and shoreline normalization effort were completed on the 1 m DEM. The DEM is of sufficient resolution and detail to capture the shoreline levees and flood protection assets.

3.2 EXISTING TIDAL DATUMS AND EXTREME TIDE LEVELS

This section describes the calculation of the existing conditions daily and extreme tide levels at each model output point along the project area shoreline. The daily and extreme tide levels are primary data sets used to develop the extreme tide matrix (Table 2-4) and normalized shoreline elevation maps (Section 6).

The MHHW tide level was selected to represent the typical daily high tide. The MHHW tide level for existing conditions was calculated using model hindcast data corresponding to the most recent NTDE (1983 through 2001). The MHHW tide level is defined as the average of the higher high tides of each day recorded during the NTDE.

The extreme tide levels were computed using the 31-year record of the simulated time series from the FEMA model output locations. The water level statistics used to represent the extreme tides include the

[2] LiDAR, which stands for light detection and ranging, is an aerial based topographic survey method that uses optical sensors to map topographic landforms and elevations.

1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year extreme tide levels. The 500-year extreme tide levels are presented for reference and to convey to stakeholders that the potential exists for events with greater than 100-year severity to occur; however, estimates of the 500-year tide level are only approximate, given the relatively short duration of the hydrodynamic model hindcast. These values are consistent with FEMA's effective Flood Insurance Rate Maps (FIRMs) and Flood Insurance Studies (FISs) for Contra Costa County as of September 30, 2015.

The following steps were completed to calculate the extreme tide elevations using the time series of modeled water levels from each model output point:

- Annual maximum water levels were extracted based on a July–June "storm year," consistent with the FEMA coastal hazard analysis.
- A Generalized Extreme Value probability distribution was fit to the annual maxima data set, and extreme tide elevations were calculated at each return period.
- The 1-year extreme tide elevation for each model output point was determined by extrapolating the extreme tide curves out to the 1-year level.
- An example water level time series and the extracted annual maxima for one model output point are shown on Figure 3-2. A subset of computed daily and extreme tide levels at 15 model output points are shown in Table 3-1. Points are taken at roughly equidistant intervals from the southwestern project limits (Point 1) to the northeastern project limit (Point 15). See Figure 3-1 for point locations.

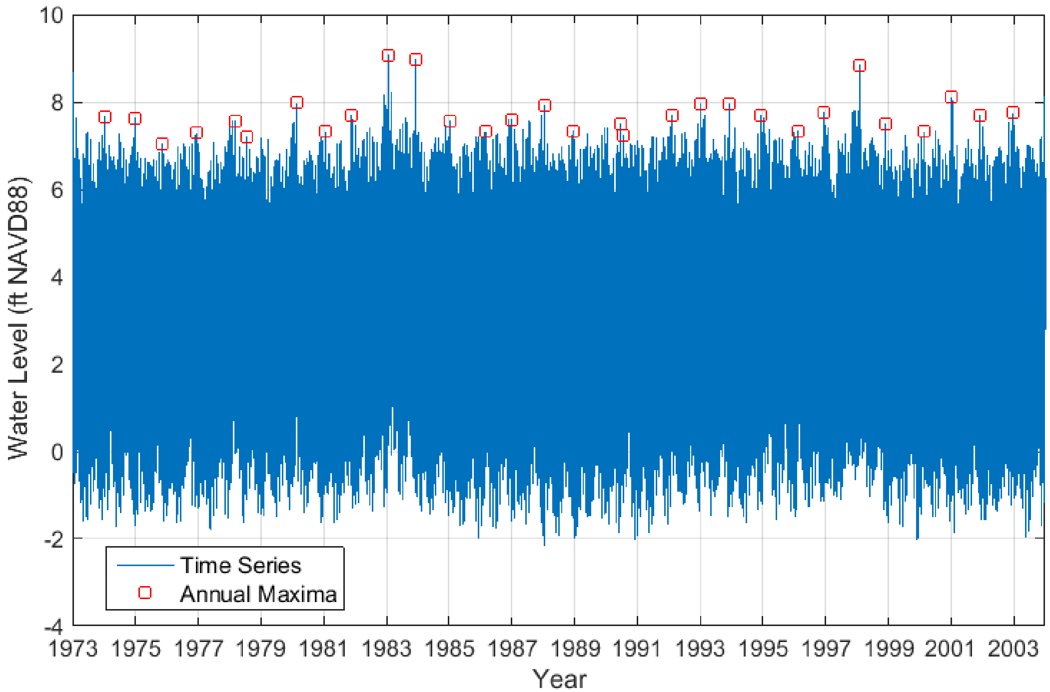

Figure 3-2. Example Water Level Time Series and Annual Maxima Data Set

Table 3-1. Sample Existing Conditions Daily and Extreme Tide Elevations

Point ID	MHHW (ft NAVD88)	Extreme Tide Elevations (ft North American Vertical Datum of 1988 [NAVD88]) 1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
1	6.20	7.42	7.76	8.17	8.49	8.96	9.35	9.80	11.03
2	6.17	7.40	7.73	8.15	8.47	8.94	9.34	9.78	11.03
3	6.10	7.32	7.63	8.03	8.34	8.77	9.14	9.54	10.64
4	6.11	7.33	7.63	8.04	8.35	8.79	9.15	9.54	10.62
5	6.12	7.33	7.62	8.03	8.34	8.77	9.12	9.51	10.55
6	6.21	7.40	7.70	8.10	8.40	8.82	9.18	9.57	10.63
7	6.23	7.44	7.74	8.15	8.46	8.90	9.27	9.67	10.77
8	6.26	7.48	7.78	8.19	8.49	8.93	9.30	9.70	10.79
9	6.21	7.45	7.74	8.15	8.46	8.89	9.25	9.63	10.66
10	6.10	7.34	7.61	8.03	8.33	8.75	9.08	9.44	10.37
11	5.98	7.18	7.44	7.86	8.16	8.57	8.90	9.24	10.13
12	6.09	7.28	7.54	7.94	8.24	8.64	8.96	9.31	10.20
13	6.12	7.27	7.55	7.97	8.27	8.69	9.04	9.40	10.37
14	6.15	7.27	7.58	8.00	8.32	8.77	9.14	9.55	10.64
15	6.13	7.23	7.57	8.03	8.38	8.88	9.30	9.76	11.01

3.3 FUTURE TIDAL DATUMS AND EXTREME TIDE LEVELS

This section presents the methodology for estimating future tidal datums and extreme tide levels within the project area.

Tide levels (tidal amplitude and range) in the Bay generally remain stationary over time, which was confirmed with the FEMA San Francisco Bay regional modeling effort and by the modeling efforts completed by Holleman and Stacey (2014), which considered both existing conditions and future SLR. Based on current modeling and neglecting significant changes to the landscape such as constructing levees around large portions of the Bay, SLR does not result in a significant change to the tidal hydraulics. Therefore, future Bay water levels can be approximated by linearly adding SLR to existing MHHW. Holleman and Stacey (2014) showed that this linear approach is appropriate within the Bay. Although small changes in tidal range were observed, the changes were small compared to the amounts of SLR.

For simplicity, this linear approach has also been used to approximate future extreme tide levels (i.e., SLR has been added to the existing 100-year extreme tide levels). However, it should be noted that this approach may be a conservatively low estimate for future extreme conditions because it does not consider climate change factors that may increase the frequency and severity of large storm events over time. However, at the present time, trends in increasing storm surge associated with climate change are not clear for the Northern California coast and the San Francisco Bay Area (NRC 2012).

3.4 WATER SURFACE DIGITAL ELEVATION MODEL CREATION

The first step in creating the inundation maps was to create the MHHW water surface DEM. The calculated MHHW water level at each model output point was projected inland along shore perpendicular transects to provide complete coverage across the entire shoreline delineation. The transects were drawn inland beyond the expected extent of inundation under the highest SLR scenario and were spaced at an appropriate density to capture variations in tidal surface and the underlying topography. The resulting MHHW DEM has a horizontal resolution of 1 m by 1 m to match the resolution of the topographic DEM. Each SLR scenario (e.g., 12, 24, 36, 48 inches) was added to the MHHW water surface to develop the future conditions tidal water surfaces. The resulting water surface DEMs are an extension of the tidal water surface at the shoreline over the inland topography. This approach represents a conservative estimate of the inland area that may be inundated every day by tidal action. The MHHW tidal water surface represents an average of the daily high tide conditions over the 19-year NTDE, and therefore daily high tide levels may exceed this average elevation approximately 50 percent of the time.

This method does not take into account the associated physics of overland flow, dissipation, levee overtopping, storm duration, or potential shoreline or levee erosion associated with extreme water levels and waves. To account for these processes, a more sophisticated modeling effort would be required. However, given the uncertainties associated with SLR and future land use changes, development, and geomorphic changes that will occur over the next 100 years, a more sophisticated modeling effort may not necessarily provide more accurate results.

3.5 DEPTH AND EXTENT OF FLOODING

Depth of flooding raster[3] files were created by subtracting the land surface DEM from the water surface DEM. Both DEMs were generated using a 1 m horizontal resolution with the same grid spacing to allow for grid cell to grid cell subtraction. The resultant DEM (or “inundation depth raster”) provides both the inland extent and the depth of inundation without considering hydraulic connectivity.

The final step used in creating the depth and extent of flood maps is an assessment of hydraulic connectivity. The method described by Marcy et al. (2011) employs two rules for assessing whether a grid cell is inundated. A cell must be below the assigned water surface DEM elevation value, and it must be connected to an adjacent grid cell that was either flooded or open water. NOAA’s method applies an “eight-side rule” for connectedness, where the grid cell is considered “connected” if any of its cardinal or diagonal directions are connected to a flooded grid cell. This approach decreases the inundated area over earlier inundation mapping efforts that considered a grid cell to be inundated solely based on its elevation (i.e., even if there was no hydraulic pathway to the Bay to allow flooding). This assessment removes areas from the inundation zone if they are protected by levees or other topographic features that prevent inland inundation. This assessment also removes areas that are low lying but inland and not directly connected to an adjacent inundated area.

The ten SLR inundation maps are presented in Appendix A. The shades of blue represent various depths of inundation, shown in 2-foot depth increments, ranging from 0 feet to greater than 16 feet of inundation. Also, hydraulically disconnected low-lying areas are displayed in green. These areas are lower in elevation than the relevant water surface, but a flow path from the Bay has not been identified. It is possible that the low-lying areas are, or may become, connected through culverts, storm drains, or other features not captured within the DEM; therefore, it is important to note that there may be an existing or future flood risk within these areas. In addition, these low-lying areas may be at risk of flooding from below due to increasing groundwater elevations. Figure 3-3 illustrates an inland disconnected low-lying area.

[3] A raster consists of a matrix of pixels organized into a surface area grid where each grid cell contains a value representing information (e.g., water depth values).

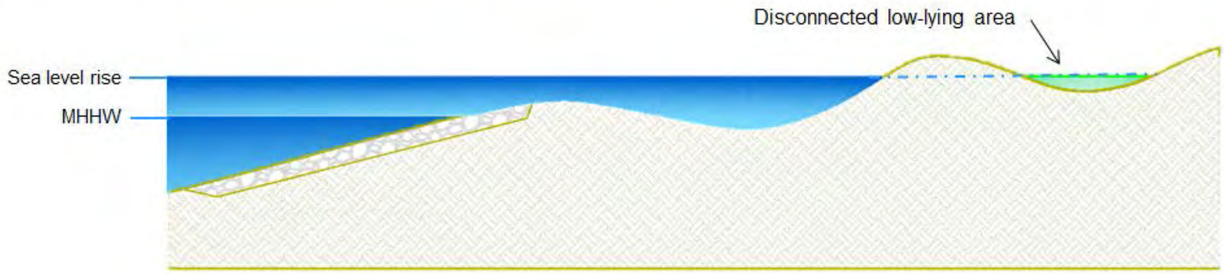

Figure 3-3. Example Shoreline Cross Section Showing Disconnected Low-Lying Area

3.6 HYDRODYNAMIC ZONES

Due to the Bay's geometry and hydrodynamics, tidal characteristics such as the elevation of MHHW and the magnitude of extreme tides vary along the Bay shoreline. In general, daily and extreme tide elevations increase with increasing distance from the Golden Gate Bridge into the North Bay. For example, the MHHW tide level increases from approximately 6.0 to 6.25 ft NAVD88 along the project area. Similarly, the 100-year tide level increases from 9.2 to 9.8 ft NAVD88.

To simplify understanding of the daily and extreme tide levels within the Bay, "hydrodynamic zones" can be created for areas of the shoreline where tide levels are roughly homogeneous (±3 inches). The model output points are used to assess the spatial variability of tidal characteristics along the shoreline and to identify regions within the Bay with roughly similar hydrodynamics. The daily and extreme tide levels above MHHW presented in the matrix represent an average of the water levels at all points within the hydrodynamic zone.

Using this method, a single hydrodynamic zone was designated for the project area. This zone includes all of the shoreline from the Alameda County border to the western shoreline of Bay Point near Nichols Road (Figure 3-1). This zone is consistent with prominent geographic features that influence circulation patterns within the Bay, but excludes approximately 3 miles of the eastern shoreline where extreme water level elevations derived from the FEMA hydrodynamic model are dominated by freshwater inflow events from the Delta, not by San Francisco Bay extreme tide events.

The Contra Costa County matrix presented in Section 2.3 (Table 2-4) is applicable within this hydrodynamic zone. The application of the SLR and extreme tide matrix can improve understanding of the increasing frequency of periodic flooding as seas rise.

4.0

SHORELINE DELINEATION

4. SHORELINE DELINEATION

Shorelines within the project area were delineated to evaluate levels of shoreline flood protection and coastal flood vulnerability. Although not all shoreline features provide equal flood protection, in general shoreline features such bluffs, dunes, berms, embankments, roads, railroad embankments, sea walls, levees, tide gates, and upland hills all act to constrain the tidal influence of the Bay. The shoreline delineation identifies the highest point—or crests—of these features as they occur along the shoreline, and the delineation includes information on the feature type and its crest elevation. The delineation also includes river and creek banks within the downstream tidally influenced areas.

This shoreline delineation is used in three ways:

1. To produce shoreline by type maps (Section 4.2). Nine types of shoreline features were identified in Contra Costa County. This information aids in understanding both the level of existing flood protection and the appropriate adaptation strategies necessary to prevent local flooding.
2. To produce overtopping maps (Section 5). Overtopping maps identify shoreline low points and flood pathways for each of the 10 mapped scenarios. In many cases, large areas of flooding may occur through localized low points. Overtopping maps are necessary to identify the scale of strategy necessary to prevent local flooding.
3. To produce normalized shoreline maps (Section 6). The normalized shoreline layer depicts the elevation of shoreline features relative to existing MHHW and provides an indication of whether delineated features are near, below, or above MHHW. Shoreline features below existing MHHW may occur on the bayward side of levees, berms, dunes, or wetland shorelines.

4.1 SHORELINE TYPE DELINEATION

The shoreline was classified into types to support coastal vulnerability and risk assessments. An understanding of shoreline type is helpful for examining how a certain shorelines may respond to future conditions. For instance, assets behind highly erodible shorelines may be at increased risk compared to assets behind less erodible shorelines of the same elevation. Also, some types of low coastal areas may in fact provide significant flood protection. For example, while wetlands will react to SLR differently than levees, they may provide additional flood protection, depending on the specific characteristics of the feature.

The shoreline categorization identified the main lines of shoreline defense. Seven shoreline type categories were identified within the project area. Figure 4-1 shows the profiles of the seven shoreline type categories. The final shoreline type delineation maps are presented in Appendix B.

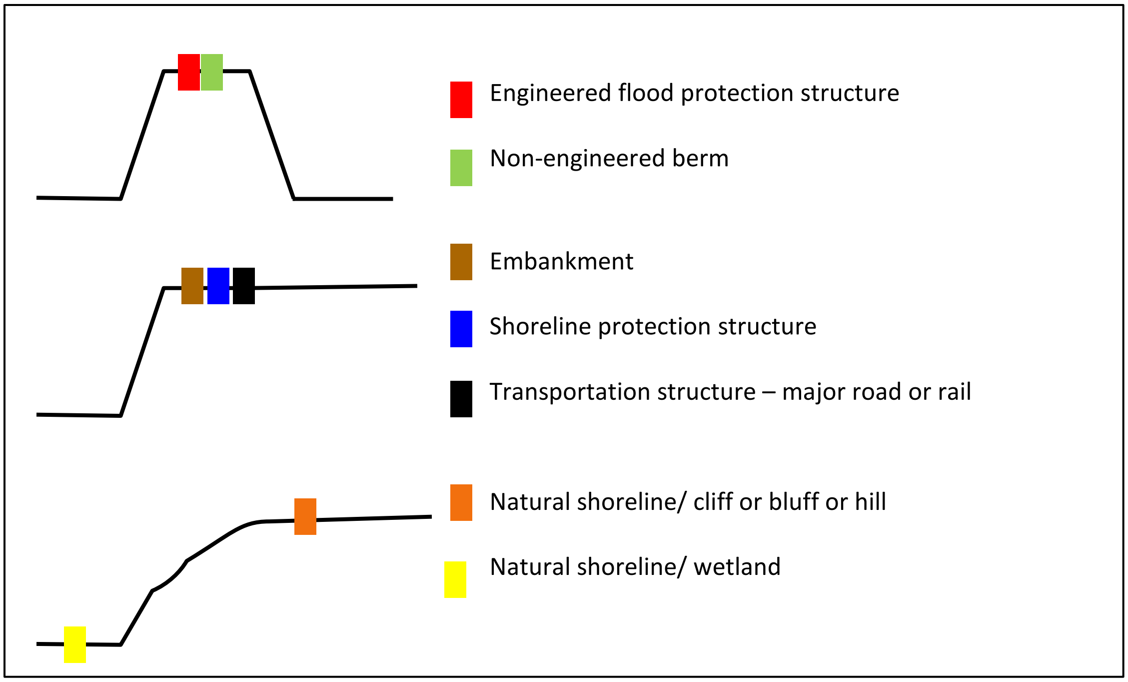

Figure 4-1. Shoreline Type Profiles

- **Engineered flood protection structures:** These structures are designed and built to protect inland areas from flooding, including from major storm events and extreme water levels that may also be accompanied by waves. This category includes both engineered levees and flood walls. Levees within this category have a FEMA accreditation date in the FEMA Midterm Levee Index (MLI) Database or Contra Costa County provided information stating that the structure has been engineered. A flood wall is a vertical barrier with a similar design standard to that of a levee. These features were delineated following the high point on the DEM.
- **Non-engineered berms:** Non-engineered berms include other levees or levee-like structures that do not have current or previous FEMA accreditation. These features are similar in shape to a levee, but do not provide a standard level of flood protection. They may still serve as a line of defense against flood hazards during storm events. These features were delineated following the high point on the DEM.
- **Embankments:** Embankments are typically an earthen slope within an inland area (e.g., channel banks upstream of the coastal shoreline) that transitions to flat or hilly inland areas. Unlike levees and berms, which have a crest and two slopes, embankments have only one slope. These barrier features do not provide a standard level of flood protection, but serve as a line of defense against flood hazards during storm events. Embankments were delineated at the top of slope on the DEM.
- **Shoreline protection structures:** These features share the same single-slope profile as embankments, but are Bay-facing, rather than inland. They generally abut development or a modification to the Bay shoreline. These features were delineated at the top of slope on the DEM.
- **Transportation structures – major roads/rail:** These features were built for transportation purposes and do not provide a standard level of flood protection, but can serve as a line of defense against flood hazards during storm events. Only major roads and rail lines were delineated for this assessment to evaluate potential hazards to these assets. These features were delineated following the high point on the DEM.

- **Natural shorelines/wetlands:** These features include tidal marshes along the edge of the Bay or within larger creek channels. Boundaries were defined by identifying the high point on the DEM either adjacent to a channel or tidal flat and digitizing an isoline (contour) to terminus with the nearest identified levee or protection structure. The hardscape behind each wetland has also been defined primarily by the most Bay-ward levee.
- **Natural shorelines/cliffs, bluffs, or hills:** These features are areas where engineered flood protection or shoreline protection structures are absent, and no clear landward structure that provides a level of flood protection is visible. The natural landscape provides a steep elevation in the form of a cliff, bluff, or hill. Such areas may have a defined high point in the DEM profile, but are not engineered structures.
- **Tide gates:** These structures are barriers that span creeks or channels, but allow tidal flushing to occur and can provide a level of flood protection for upstream areas. Only one tide gate was identified within the shoreline delineation for Contra Costa County.

In addition to the maps contained in this report, the shoreline delineation layer for Contra Costa County is available as a digital shapefile. The digital shapefile contains information on the most Bayward shoreline type ("Frontage") for each of the major shoreline types listed above. Features that are too narrow to be useful for this assessment, such as fringe wetlands, beaches, or a combination of the two, are only identified under the primary backshore shoreline segment and are not delineated. For example, narrow fringe wetlands in front of a non-engineered berm segment of the shoreline are only tagged under the Frontage sub-category and were not delineated in a Geographic Information System (GIS). In addition, fortified shoreline segments (i.e., with riprap or concrete on the bayward slope) are attributed within the digital shoreline shapefile.

4.2 APPROACH

The shoreline for Contra Costa County leveraged a delineation completed by the San Francisco Estuary Institute (SFEI) using GIS tools (SFEI 2016). The approach used by SFEI to digitize the shoreline follows the methods used for the ART Program (AECOM et al. 2011) and the Alameda County Shoreline Vulnerability Assessment (AECOM 2015). SFEI's shoreline delineation includes information on the major shoreline types that may impact coastal flooding (SFEI 2016, and Section 3.2 of this memorandum) and was used for the overtopping potential and normalized shoreline analyses following a quality assurance/quality review (QA/QC) review by AECOM.

Major features that could provide flood protection up to a Bay water level of 120 inches (10 ft) above existing MHHW[4] were delineated, including embankments along open channels of rivers and creeks. LiDAR data were used as the primary source for locating and delineating the shoreline, in conjunction with high-resolution aerial photography. Levee information from Contra Costa County and the FEMA MLI were also used for reference (FEMA 2012).

A combination of both high-resolution planar and oblique imagery was also crucial in distinguishing both the locations and the types of features. Aerial imagery (planar) from ArcGIS Online was used while digitizing in GIS. This imagery was flown in October 2014 and has a 0.1 m horizontal resolution. Oblique imagery was used from Google maps (45 degree) to assist in delineating and reviewing shoreline segments.

[4] This scenario was not selected for inundation mapping as part of this assessment, but is used by SFEI to complete the shoreline delineation for the entire Bay and represents an upper boundary beyond the extent of inundation and flooding expected for the remainder of the century.

In locations where shorelines had natural features in the foreshore (e.g., wetlands) and man-made or natural features in the backshore (e.g., levees), both features were delineated. In these cases, the shoreline feature at the backshore was used to evaluate overtopping. Also, flood barriers (e.g., tide gates) in channels, major roads, rail lines, and embankments are included in the shoreline delineation.

5.0

SHORLINE OVERTOPPING POTENTIAL

Photo Courtesy of Contra Costa Flood Control and Water Conservation District

5. SHORELINE OVERTOPPING POTENTIAL

5.1 METHODS

Overtopping potential refers to the condition where the water surface elevation under a particular SLR scenario exceeds the elevation of the shoreline. This method that uses overtopping potential provides a high-level assessment of where Bay waters may be overtopping the shoreline, resulting in inland inundation. The overtopping potential layer depicts the depth of water over the delineated shoreline features described in Section 4 under each of the 10 SLR scenarios. Overtopping could occur temporarily during a large flood or permanently after a particular amount of SLR. This layer illustrates not only where overtopping may occur, but how deep the water may be on average over any particular section of shoreline.

The pathways for inundation from the Bay and overland cannot always be assessed when viewing the inundation maps by themselves. The overtopping data identify the potential sources of future flood events and, when combined with the inundation layer, help to determine the actual flow paths that lead to inland flooding. By identifying specific locations along the shoreline that are overtopped, this layer provides critical insight for flood protection planning.

The average depth of inundation along the shoreline delineation was evaluated for each 100 ft segment. Portions of the shoreline that are not overtopped (overtopping depth < 0.5 ft) were mapped as not overtopped. For these reaches, the freeboard height was calculated and is available digitally.

To calculate overtopping potential, the shoreline delineation described in Section 4 was overlain on each of the ten inundation depth rasters (i.e., one raster for each of the ten inundation scenarios described in Section 2), and average depths of inundation for each shoreline segment were extracted. Figure 5-1 illustrates overtopping depth (i.e., water level exceeds the shoreline elevation) and freeboard (i.e., shoreline elevation exceeds the water level). As sea level rises, additional lengths of shoreline are inundated.

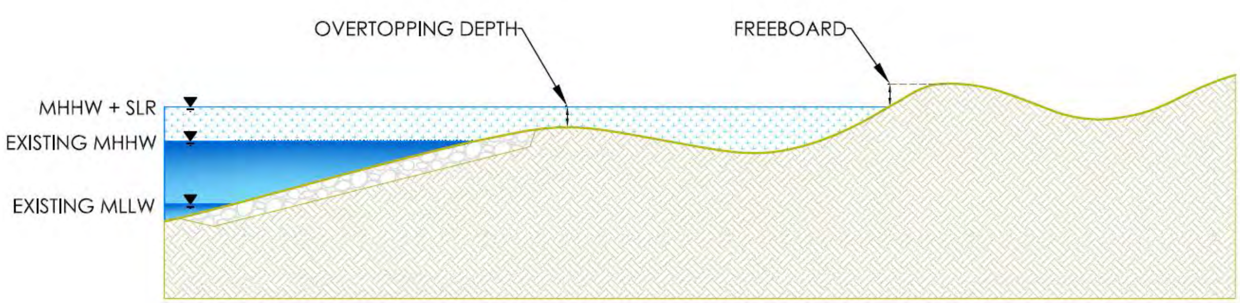

Figure 5-1. Representative Shoreline Cross Section Illustrating Overtopping Depth and Freeboard

5.2 APPLICATION OF OVERTOPPING POTENTIAL MAPS

Given the uncertainty in the modeling results and topography data sets, overtopping depths of less than 0.5 ft (0.2 meter) were excluded from the results. Therefore, it is possible for inundation to be shown over a particular shoreline segment without an associated overtopping potential value.

The overtopping potential for each of the 10 scenarios is presented in Appendix A. The legends for these figures were classified into 1 ft depth increments for visualization purposes only (excluding depths less than 0.5 ft) and the overtopping depths are more varied than shown. In addition to the maps contained in this report, the shoreline overtopping potential data layers are available as digital shapefiles that provide more detailed information on overtopping depth.

The overtopping assessment should be considered a planning-level tool only, as it does not account for the physics of wave run-up. This assessment also does not account for potential vulnerabilities along the shoreline protection infrastructure that could result in partial or complete failure of the flood protection infrastructure (or roadway or railway embankments that are providing ad hoc flood protection) through scour, undermining, or breach after an initial overtopping occurs.

6.0

SHORELINE EXPOSURE ANALYSIS


Photo Courtesy of BCDC ART Program

6. SHORELINE EXPOSURE ANALYSIS

6.1 NORMALIZED SHORELINE ELEVATIONS

The concept of “normalized elevation” is a key component of this study. The normalized shoreline layer compares the elevation of shoreline features relative to existing MHHW. It is calculated by dividing the shoreline elevation by the local MHHW elevation. For example, along the Contra Costa County shoreline, both the MHHW tide level and the 100-year tide level vary spatially. Although the absolute elevations of both daily and extreme tides varies, the ratio of a given extreme tide to MHHW is relatively constant across large geographic areas. For example, the ratio of the 100-year tide level divided by the MHHW tide level (the common denominator) is approximately constant within the project area (approximately 9.6 ft / 6.2 ft = 1.5).

A normalized value of 1.0 indicates the shoreline elevation is equal to the local MHHW elevation, or at an elevation with the potential to be wetted by Bay waters daily. A normalized elevation value greater than 1.0 indicates the shoreline is higher than the local MHHW elevation, and a value less than 1.0 indicates the shoreline area is below MHHW. These low values may occur on the bayward side of levees, berms, dunes, or wetland shorelines.

Normalized shoreline elevation maps may be used to visually identify existing and near-term vulnerable reaches of shoreline. Contra Costa County, compared to counties in the South Bay, tends to have steeper shorelines interspersed with tidal creeks and channels with minimal coastal floodplain, until the coastal marsh floodplains that begin in Bay Point. The majority of delineated shoreline within the county with a normalized value of less than 1 occurs along the Bayward edge of existing tidal marshes, particularly the southern portions of San Pablo Bay, the eastern portions of the Carquinez Strait, and into Suisun Bay. However, one vulnerable developed area along the Contra Costa County shoreline is the Martinez Waterfront and historic downtown area, where much of the shoreline has a normalized value of 1 to 1.4.

The normalized shoreline elevation maps are presented in Appendix C and can be used in combination with the normalized extreme tide curves presented in Sections 6.2 and 6.3 to assess flooding thresholds for shoreline assets under existing and future conditions. Section 6.4 describes applications of normalized tide curves in more detail.

The shoreline delineation layer described in Section 4 was used as a basis for calculating the normalized shoreline elevations. GIS-based tools were used to develop the normalized shoreline elevation maps as follows:

- An existing conditions MHHW water surface DEM was developed using the MHHW elevations calculated at the FEMA model outpoint points (Section 3).
- The shoreline delineation layer (Section 4) was subdivided into segments with a maximum length of 100 ft.
- The segmented shoreline delineation layer was overlain on the MHHW water surface DEM and the LiDAR-based topographic DEM.
- The average elevation of the MHHW water surface within each shoreline segment was computed using the MHHW water surface DEM.
- The average elevation of the shoreline within each segment was computed using the topographic DEM.
- The normalized shoreline elevation for each segment was computed by dividing the segment’s average elevation by its average MHHW value.

6.2 EXISTING NORMALIZED EXTREME TIDE CURVES

This section presents normalized tide curves for existing conditions within the project area. A higher normalized extreme tide level reflects a greater difference between an extreme tide elevation and the local MHHW at a particular model output point. As shown in Table 6-1, although there is moderate spatial variability in the elevation of the MHHW tide level throughout Contra Costa County, the ratio of a specified return period extreme tide level to MHHW (elevation/MHHW) remains remarkably constant, especially for adjacent model output points. This finding further justifies the consolidation of the extreme tide elevations into a single hydrodynamic zone, as discussed previously.

Table 6-1. Existing Conditions Normalized Extreme Tide Levels

		Normalized Extreme Tide Level (Elev./MHHW)							
Point ID	**MHHW (ft NAVD88)**	**1-yr**	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**500-yr**
1	6.20	1.20	1.25	1.32	1.37	1.45	1.51	1.58	1.78
2	6.17	1.19	1.25	1.31	1.37	1.44	1.51	1.58	1.78
3	6.10	1.18	1.23	1.30	1.35	1.41	1.47	1.54	1.72
4	6.11	1.18	1.23	1.30	1.35	1.42	1.48	1.54	1.71
5	6.12	1.18	1.23	1.30	1.35	1.41	1.47	1.53	1.70
6	6.21	1.19	1.24	1.31	1.35	1.42	1.48	1.54	1.71
7	6.23	1.20	1.25	1.31	1.36	1.44	1.50	1.56	1.74
8	6.26	1.21	1.25	1.32	1.37	1.44	1.50	1.56	1.74
9	6.21	1.20	1.25	1.31	1.36	1.43	1.49	1.55	1.72
10	6.10	1.18	1.23	1.30	1.34	1.41	1.46	1.52	1.67
11	5.98	1.16	1.20	1.27	1.32	1.38	1.44	1.49	1.63
12	6.09	1.17	1.22	1.28	1.33	1.39	1.45	1.50	1.65
13	6.12	1.17	1.22	1.29	1.33	1.40	1.46	1.52	1.67
14	6.15	1.17	1.22	1.29	1.34	1.41	1.47	1.54	1.72
15	6.13	1.17	1.22	1.30	1.35	1.43	1.50	1.57	1.78
Average	6.15	1.18	1.23	1.30	1.35	1.42	1.48	1.54	1.71

An example standard extreme tide curve is compared to an example normalized extreme tide curve on Figure 6-1. The standard extreme tide curve (Figure 6-1a) shows the actual elevations for each return period (from 1 to 100 years) on the y-axis, and the comparable normalized extreme tide curve (Figure 6-1b) shows the normalized ratio on the y-axis.

The existing conditions normalized extreme tide values for the corresponding points were averaged to create a single consolidated curve for the project area. The resulting normalized extreme tide levels are shown on Figure 6-2.

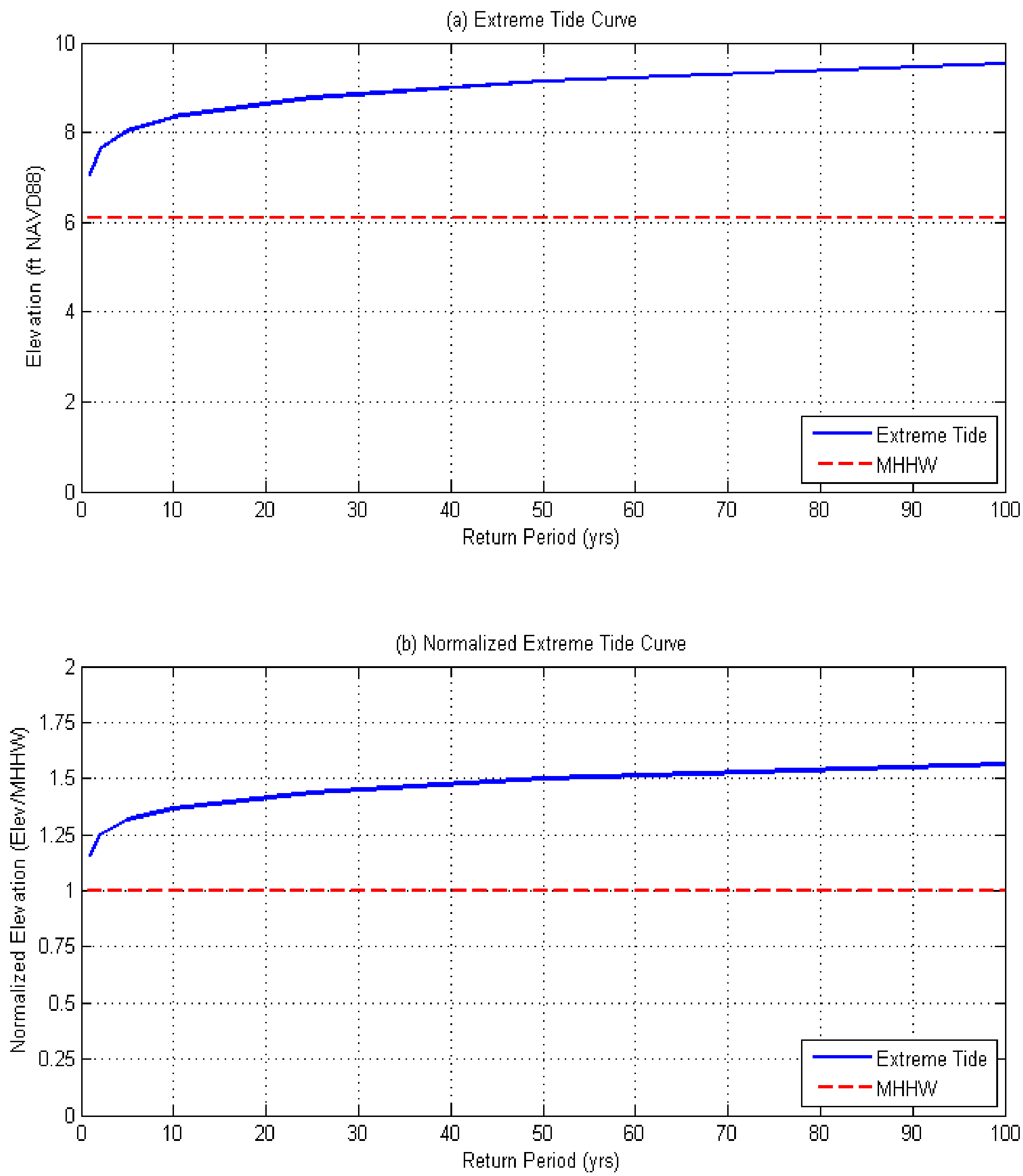

Figure 6-1. Example Tide Curves in San Francisco Bay:
(a) Extreme Tide Curve and (b) Normalized Extreme Tide Curve

6.3 NORMALIZED EXTREME TIDE CURVES (FUTURE)

To transform the existing conditions extreme tide curve to future conditions, the entire range of SLR values (from 6 to 66 inches) was added to the existing conditions tide elevations presented in Table 6-1, and the resulting curves were normalized using the present-day MHHW elevations. The future conditions normalized extreme tide curves are presented in Table 6-2. All normalized extreme tide levels are reported relative to the existing conditions average MHHW tide level for the project area. The normalized extreme tide curve is presented on Figure 6-2. The black curve represents the extreme tide curve derived from model output data for existing conditions. Each of the colored curves represents the future conditions normalized extreme tide curve for each SLR projection from 6 to 60 inches.

Table 6-2. Future Conditions Normalized Extreme Tide Curves

Return Period	Ex.	Inches of Sea Level Rise above Existing MHHW									
		+6	+12	+18	+24	+30	+36	+42	+48	+54	+60
Existing	1.00	1.08	1.16	1.24	1.33	1.41	1.49	1.57	1.65	1.73	1.81
1	1.19	1.28	1.36	1.44	1.52	1.60	1.68	1.76	1.85	1.93	2.01
2	1.24	1.32	1.41	1.49	1.57	1.65	1.73	1.81	1.89	1.98	2.06
5	1.31	1.39	1.47	1.56	1.64	1.72	1.80	1.88	1.96	2.04	2.12
10	1.36	1.44	1.52	1.61	1.69	1.77	1.85	1.93	2.01	2.09	2.18
25	1.43	1.51	1.60	1.68	1.76	1.84	1.92	2.00	2.08	2.17	2.25
50	1.49	1.57	1.65	1.74	1.82	1.90	1.98	2.06	2.14	2.22	2.31
100	1.56	1.64	1.72	1.80	1.88	1.96	2.04	2.13	2.21	2.29	2.37

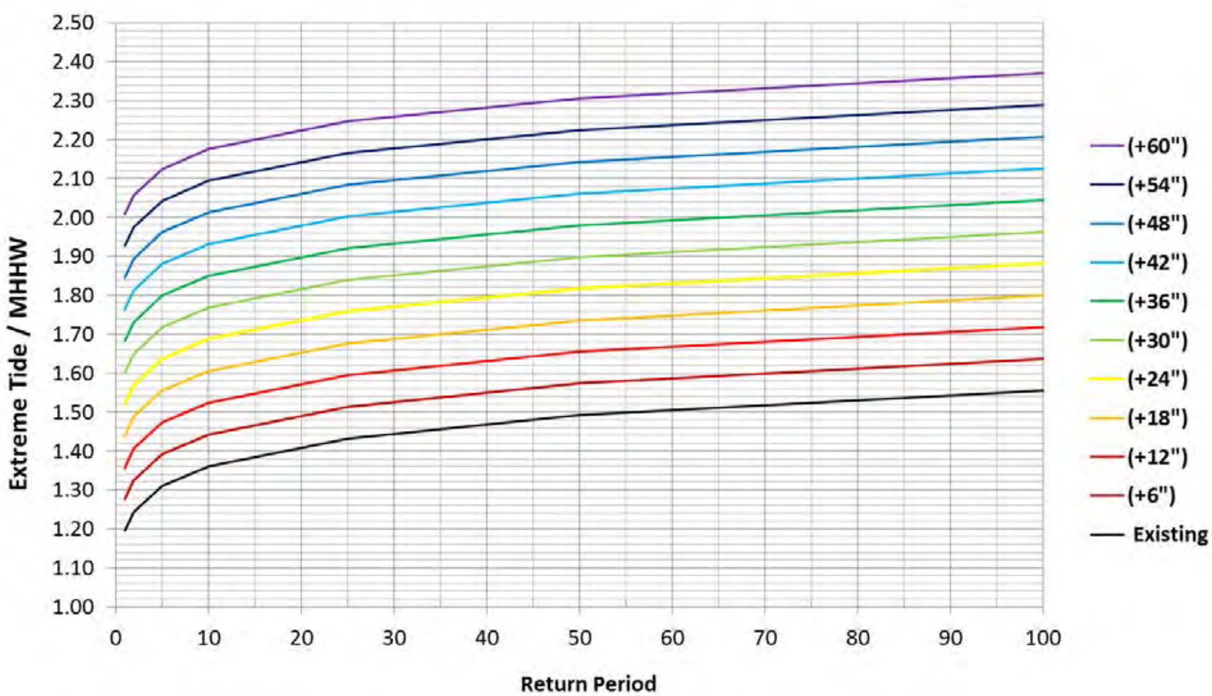

Figure 6-2. Existing and Future Conditions Normalized Extreme Tide Curves

6.4 APPLICATION OF NORMALIZED TIDE CURVES AND NORMALIZED SHORELINE MAPS

The existing and future conditions normalized extreme tide curves are presented in tabular and graphical format. The future conditions normalized extreme tide curves should be used in tandem with the normalized shoreline elevation maps presented in Appendix C. The information that can be extracted from the normalized extreme tide curves and corresponding values in tabular format is similar to the SLR and storm surge matrix. The normalized extreme tide curves shown on Figure 6-2 are a graphical representation of combinations of SLR and storm surge scenarios that can impact a selected shoreline segment. Table 6-2 shows the same information in tabular format—combinations of SLR and storm surge scenarios that can inundate shoreline segments above the same normalized extreme tide value.

The maps and curves can be used in various ways to assess flooding thresholds for existing and future conditions. Two potential scenarios for application are outlined below:

1. Determine the flooding threshold for a particular shoreline segment given a specified amount of SLR
2. Determine the approximate design elevation for a shoreline asset given a specified amount of SLR and preferred/required level of flood protection

In the first scenario, a stakeholder might be interested in the level of flood protection provided by a particular shoreline asset for some future condition with SLR. For example, an asset might provide 100-year flood protection under existing conditions, but with SLR, it is expected that the level of protection would decrease over time. Figure 6-3a illustrates this example for a shoreline asset with a normalized shoreline elevation of 1.5 (which indicates an elevation of 1.5 times MHHW). The flooding threshold can be evaluated by plotting a horizontal line at a normalized elevation of 1.5 and intersecting it with the selected extreme tide curve. For the selected extreme tide curve, this asset's flooding threshold would be reduced to the 50-year level for future conditions with SLR.

In the second scenario, a stakeholder might be interested to know approximately to what elevation a shoreline asset would need to be raised to provide a specified level of flood protection under future conditions with SLR. Continuing the example above, the stakeholder may wish to elevate the shoreline asset to continue provide 100-year flood protection in the future. Figure 6-3b illustrates this example. The approximate design elevation can be evaluated by plotting a vertical line at a return period of 100 years and intersecting it with the selected extreme tide curve. For the selected return period, a normalized shoreline elevation of 1.54 would be required. Using the local MHHW elevation to convert the normalized elevation to an absolute elevation (i.e., relative to NAVD88), an approximate design elevation for the shoreline asset could be determined. It should be noted that asset elevations determined in this manner would only be appropriate for planning-level assessments, not engineering design.

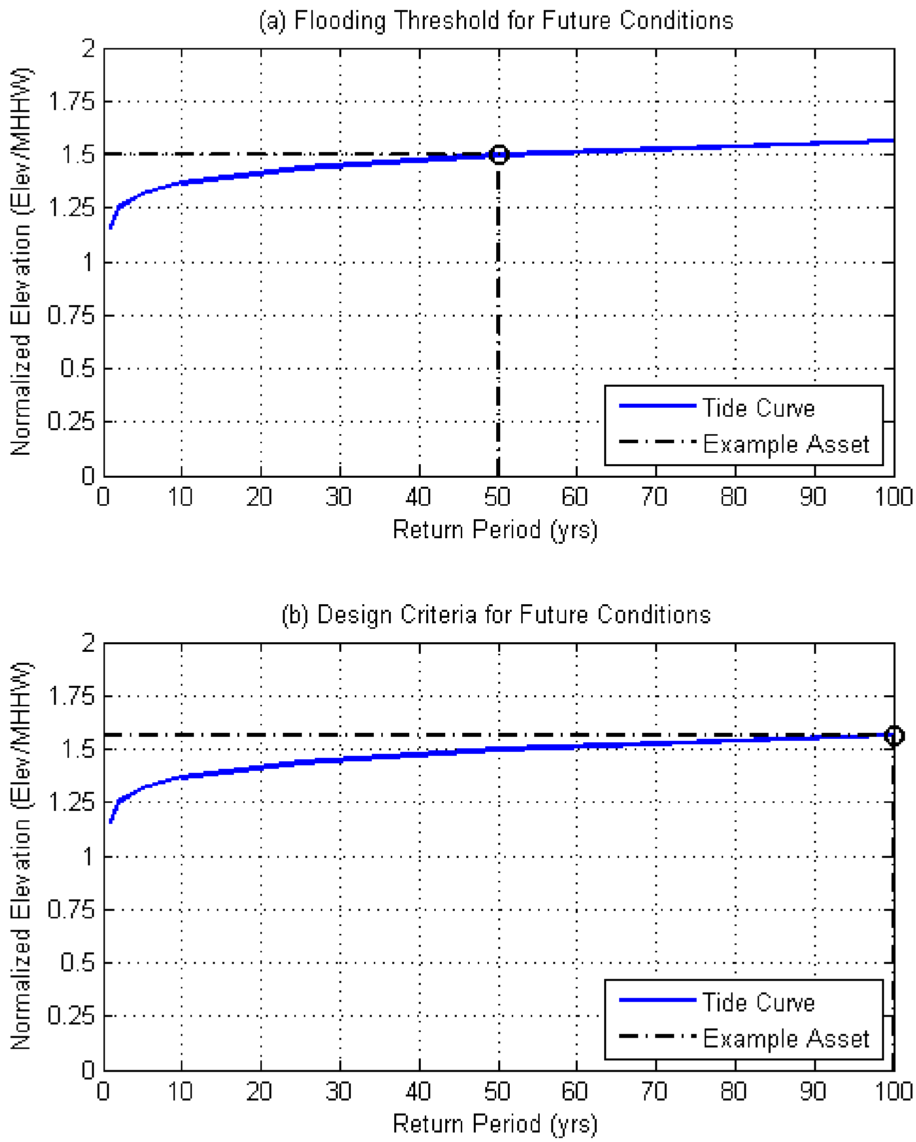

Figure 6-3. Example Application of Future Conditions Normalized Extreme Tide Curves

In summary, to interpret the flooding thresholds for a particular area of interest, the following steps can be used:

1. Identify the shoreline segment of interest and its normalized elevation using the shoreline maps in Appendix C.
2. Select an existing or future conditions normalized extreme tide curve for evaluation.
3. Intersect the existing or future conditions normalized extreme tide curve with either a horizontal or vertical line to determine the resulting normalized elevation or return period of interest.

7.0

MAPPING ASSUMPTIONS + CAVEATS

Photo Courtesy of BCDC ART Program

7. MAPPING ASSUMPTIONS AND CAVEATS

The inundation maps are intended as a screening-level tool to assess exposure to future SLR and extreme tide/storm surge-induced coastal flooding. These maps represent a “do nothing” future scenario, and although they rely on the best available and current information and data sources, they are still associated with a series of assumptions and caveats as detailed below.

- The inundation scenarios associated with an increase in future MHHW (SLR above MHHW) represent areas that could be inundated permanently on a regular basis by tidal action. The inundation scenarios associated with extreme tide levels and storm surge represent periodic or temporary inundation associated with a coastal flooding. The inundation maps for extreme tide scenarios do not consider the duration of flooding or the potential mechanism for draining the floodwaters from the inundated land once the extreme high tide levels recede.
- The bathymetry of San Francisco Bay and the topography of the landward areas, including levees and other flood and shore protection features, are assumed to remain constant. No potential physical shoreline changes are included in the analysis and mapping. The accumulation of organic matter in wetlands, potential sediment deposition and/or resuspension, and subsidence that could alter San Francisco Bay hydrodynamics and/or bathymetry are not captured within the SLR scenarios.
- The maps do not account for future construction or levee upgrades. The mapping methods also do not consider the existing condition or age of the shore protection assets. No degradation or levee failure modes have been analyzed as part of the inundation mapping effort.
- The maps do not account for flooding from potential increases in the groundwater table as sea levels rise.
- The maps do not account for water flow through water control structures such as culverts or tide gates.
- The levee heights and the heights of roadways and/or other topographic features that may affect floodwater conveyance are derived from the LiDAR data. Although this data set represents the best available topographic data, the data have not been extensively ground-truthed, and levee crests may be overrepresented or underrepresented by the LiDAR data. It is possible that features narrower than the 1 m horizontal map scale may not be fully represented.
- The inundation depth and extent shown on the MHHW maps are associated with the typical high tide to approximate the maximum extent of future daily tidal inundation. This level of inundation can also be referred to as “permanent inundation” because it represents the area that would be inundated regularly. Tides in San Francisco Bay exhibit two highs and two lows in any given day, and the daily high tide on any given day may be higher or lower than the MHHW tidal elevation.
- The depth and extent of inundation for an extreme coastal storm event (i.e., including local wind and wave effects) was not included in this study. These processes could have a significant effect on the ultimate depth of inundation associated with a large coastal wind/wave event, especially near the shoreline.
- The inundation maps do not account for localized inundation associated with any freshwater inputs, such as rainfall-runoff events, or the potential for riverine overbank flooding in the local tributaries associated with large rainfall events. Inundation associated with changing rainfall patterns, frequency, or intensity as a result of climate change is also not included in this analysis.
- The science of climate change is constantly evolving, and SLR projections have a wide range of values.

8.0

CONCLUSIONS + NEXT STEPS

Photo Courtesy of BCDC ART Program

8. CONCLUSIONS AND NEXT STEPS

This shoreline vulnerability assessment for Contra Costa County led to the development of a variety of geo-spatial tools and data layers that can assist with the next steps of identifying shoreline vulnerabilities and formulating and implementing adaptation strategies, where necessary. These tools and data layers include the following:

- SLR inundation maps;
- Shoreline overtopping potential maps;
- SLR and extreme tide matrix;
- Shoreline type delineation maps;
- Daily and extreme tide elevations;
- Normalized shoreline elevation maps; and
- Normalized existing and future extreme tide curves.

The SLR inundation and overtopping potential maps provide a first step for identifying assets that will be exposed to increased flooding and/or inundation from rising seas and the primary inundation pathways from the Bay. The depth of potential inundation over shoreline segments can be extracted from the overtopping potential maps for each inundation scenario. The normalized shoreline elevation maps also provide a useful tool for landowners and managers to identify flooding thresholds for existing and future conditions with SLR. The future conditions normalized extreme tide curves are applicable over a range of extreme tide levels, from the 1-year to 100-year events, and a range of SLR projections, from 0 to 66 inches. To simplify the application of the daily and extreme tide levels and normalized curves, a single hydrodynamic zone was used for the project area. Using these tools, stakeholders can further understand shoreline asset exposure to a much broader range of SLR projections than previously assessed. In addition to identifying where shoreline vulnerabilities may exist, these tools can help to roughly identify timing for adaptation actions to maintain or improve existing levels of shoreline flood protection. As sea levels increase, the level of flood protection for these areas will decrease and flooding will occur at a higher frequency and severity. The SLR and extreme tide matrix highlights when existing levels of flood protection will be inadequate and when adaptation strategies might need to be implemented.

To continue this analysis, these tools and data sets could be applied to specific focus areas within the county to understand the sources, mechanisms, and timing of inundation and flooding. This information would further support the development of appropriate adaptation strategies. With these tools, critical areas can be identified, and floodplain and shoreline asset managers can determine whether a localized or regional approach is necessary to maintain existing levels of flood protection against higher tide levels and more frequent flooding from storm surge.

The application of these tools and data layers should be used for planning-level assessments only; and these tools and data layers should not be used directly for engineering design or construction purposes without further detailed analysis in consultation with a qualified engineering professional. However, these products are useful for identifying where additional detailed information may be needed to confirm the shoreline vulnerabilities highlighted in the maps and to identify the next steps that are needed to perform more detailed analyses.

Beyond these tools, additional evaluations to strengthen the shoreline vulnerability assessment include examining the combined impact of coastal storm surge, waves, groundwater interactions, and precipitation-based drainage and runoff. The inclusion of wave hazards in this analysis, including wave processes such as wave run-up and overtopping, will enhance the overall understanding of shoreline vulnerability. The cumulative impacts of rainfall runoff and storm events occurring during periods of extreme tide levels were not considered in this analysis; however, these events would further exacerbate inland flooding and can be examined with more detailed modeling efforts. Changes in storm frequency and magnitude due to climate change were also not examined, but an evaluation of these dynamics may provide further insight into when adaptation strategies need to be implemented at specific shorelines or inland areas.

Rising groundwater tables, primarily associated with SLR, can impact flooding and drainage by reducing infiltration and sub-surface storage of runoff. The impacts of rising groundwater tables on watershed flooding in the county are not known, but can be explored as a next step. With higher groundwater tables and rising sea levels at the shoreline, the existing highway drainage systems will become less effective over time, and they may become completely ineffective with higher levels of SLR. These additional impacts were not considered in this assessment, but evaluation of these factors is recommended as a next step.

9.0

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Photo Courtesy of Avanti Tamhane

9. REFERENCES

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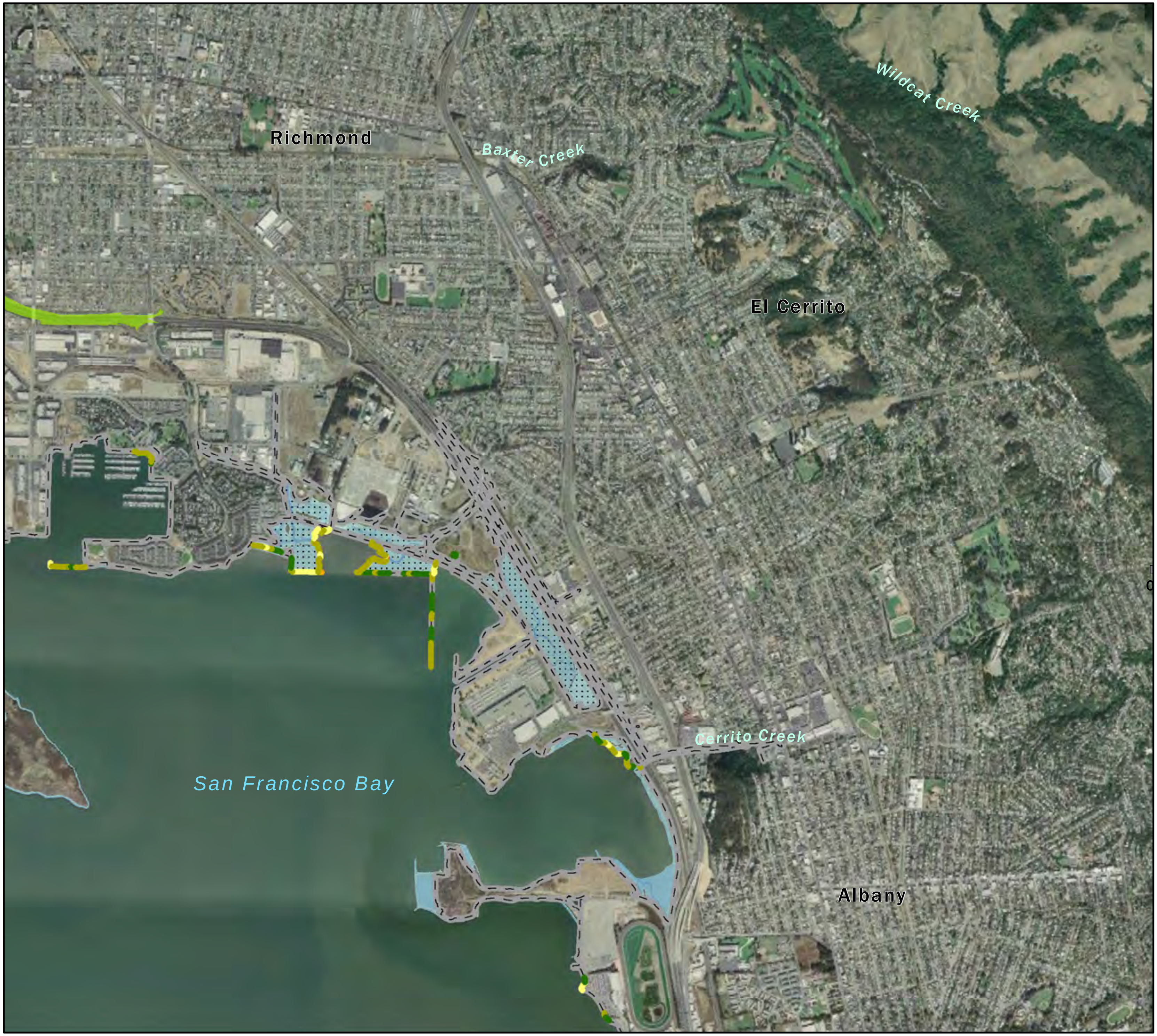
A

INUNDATION AND OVERTOPPING MAPS


Photo Courtesy of Avanti Tamhane



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 12" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 12" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

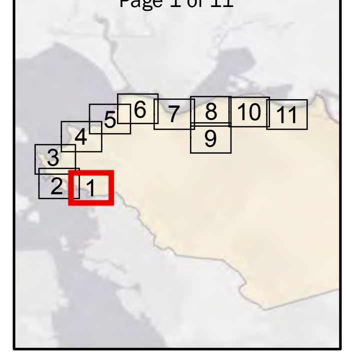
Miles: 0 0.2 0.4 0.6

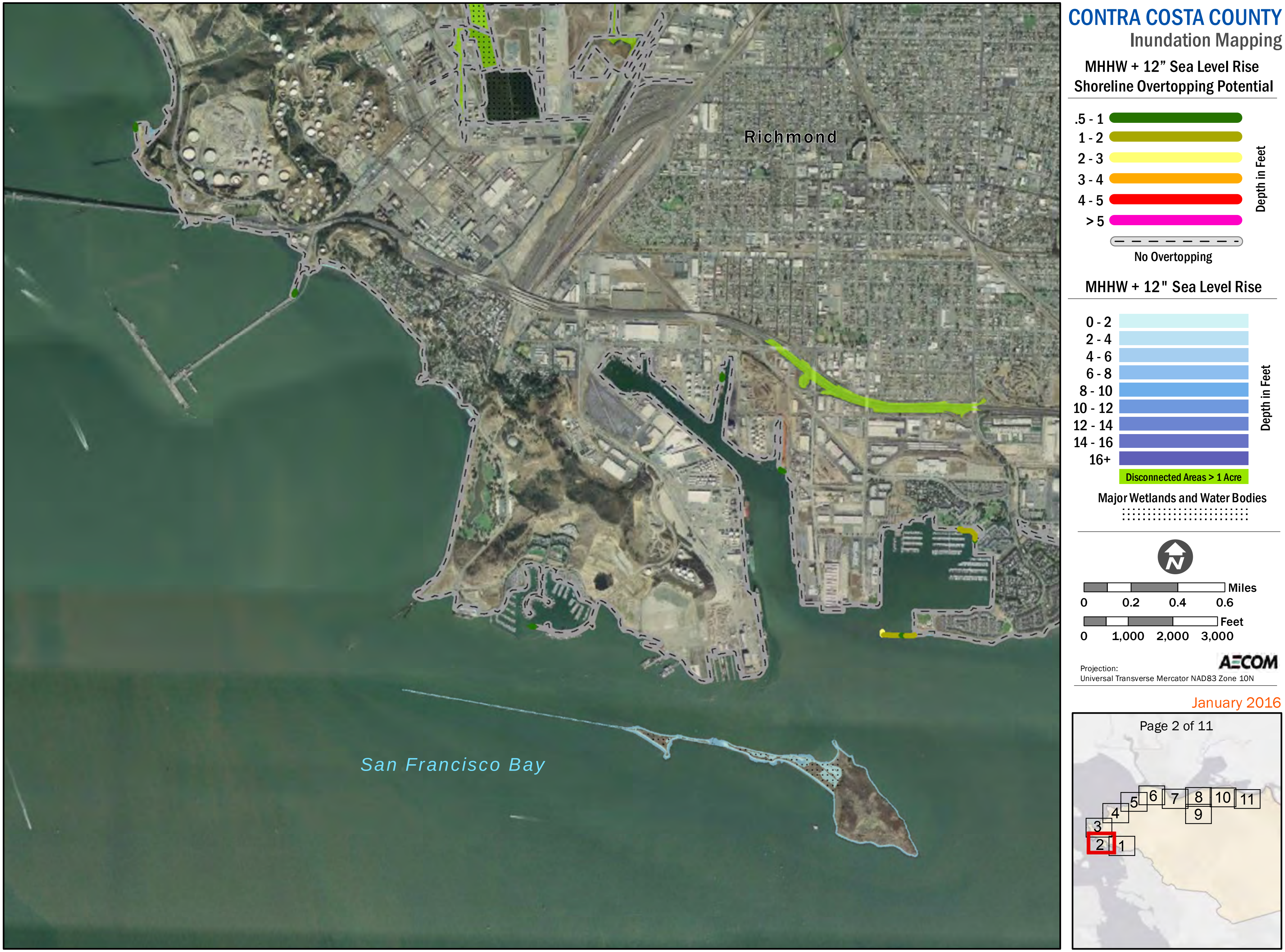
Feet: 0 1,000 2,000 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





Richmond
San Francisco Bay
CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 12" Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
MHHW + 12" Sea Level Rise
0 - 2
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Depth in Feet
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Major Wetlands and Water Bodies
N
Miles
0 0.2 0.4 0.6
Feet
0 1,000 2,000 3,000
AECOM
Projection:
Universal Transverse Mercator NAD83 Zone 10N
January 2016
Page 2 of 11
1 2 3 4 5 6 7 8 9 10 11

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 12" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
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- 1 - 2
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MHHW + 12" Sea Level Rise

Depth in Feet
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- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

Miles: 0, 0.2, 0.4, 0.6

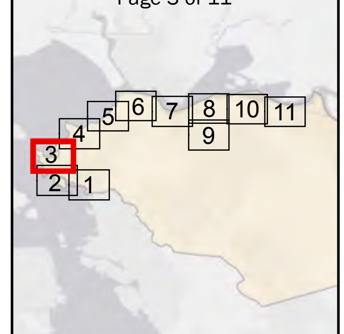
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016

Page 3 of 11



CONTRA COSTA COUNTY
Inundation Mapping

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Major Wetlands and Water Bodies

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Miles: 0, 0.2, 0.4, 0.6

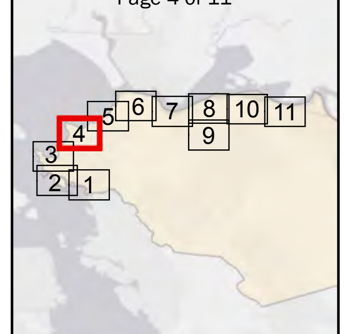
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016

Page 4 of 11



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 12" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

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MHHW + 12" Sea Level Rise

Depth in Feet

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Major Wetlands and Water Bodies

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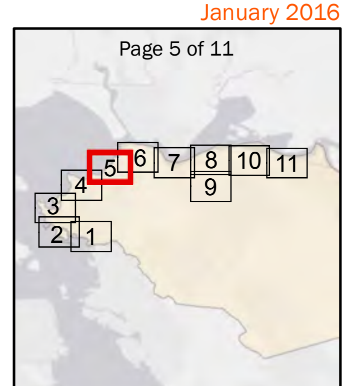
Feet: 0, 1,000, 2,000, 3,000

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 12" Sea Level Rise Shoreline Overtopping Potential

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Feet: 0 1,000 2,000 3,000

AECOM

Projection:
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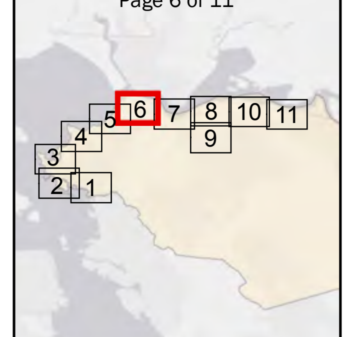
January 2016

Page 6 of 11



CONTRA COSTA COUNTY
Inundation Mapping

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Major Wetlands and Water Bodies

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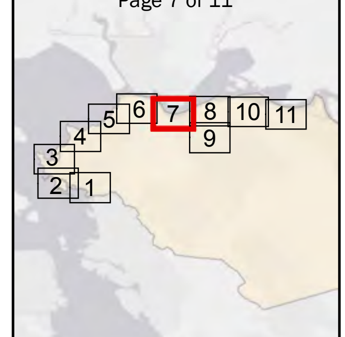
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 12" Sea Level Rise Shoreline Overtopping Potential

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MHHW + 12" Sea Level Rise

Depth in Feet
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- 16+
- Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016

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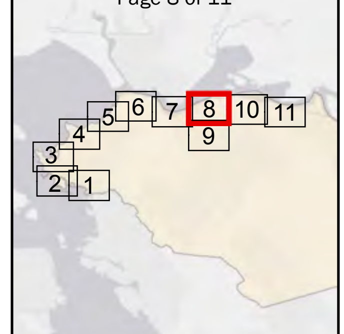

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 12" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

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No Overtopping

MHHW + 12" Sea Level Rise

Depth in Feet

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Major Wetlands and Water Bodies

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AECOM

Projection:
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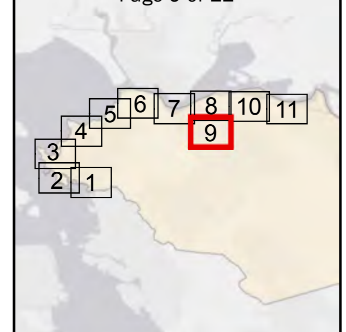
January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 12" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
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No Overtopping

MHHW + 12" Sea Level Rise

Depth in Feet
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- 2 - 4
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- 8 - 10
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- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

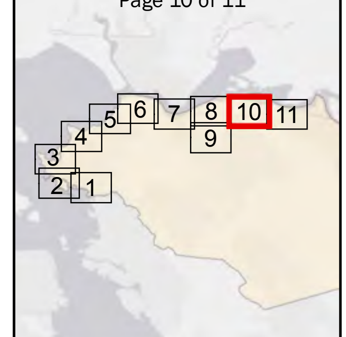
Miles: 0, 0.2, 0.4, 0.6

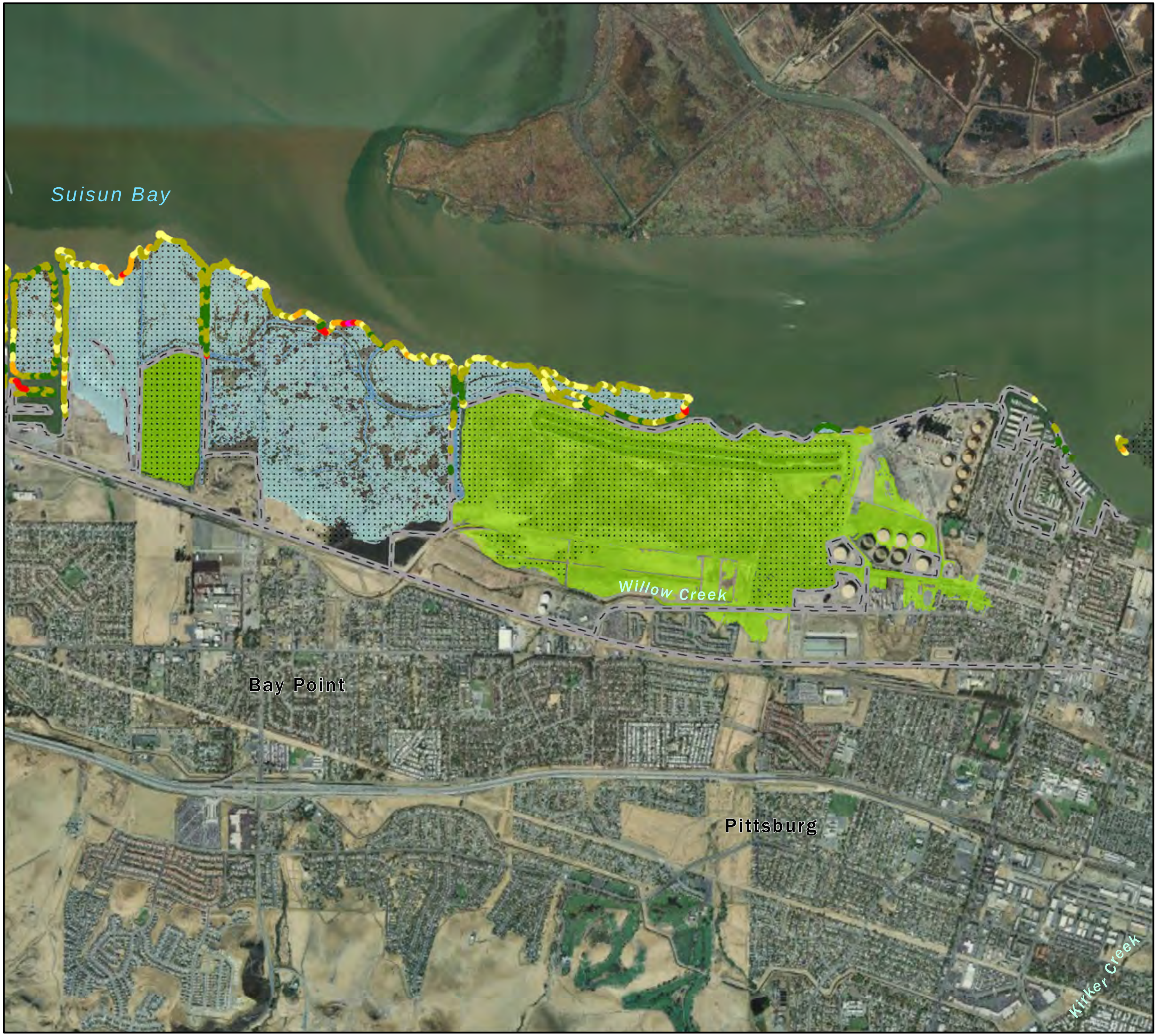
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 12" Sea Level Rise
Shoreline Overtopping Potential

Depth in Feet
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping

MHHW + 12" Sea Level Rise

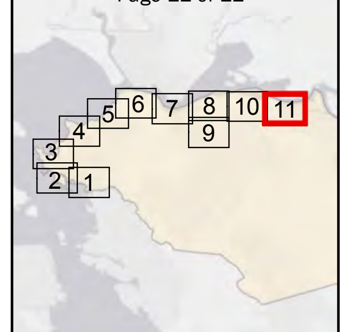
Depth in Feet
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies

Miles: 0 0.2 0.4 0.6
Feet: 0 1,000 2,000 3,000

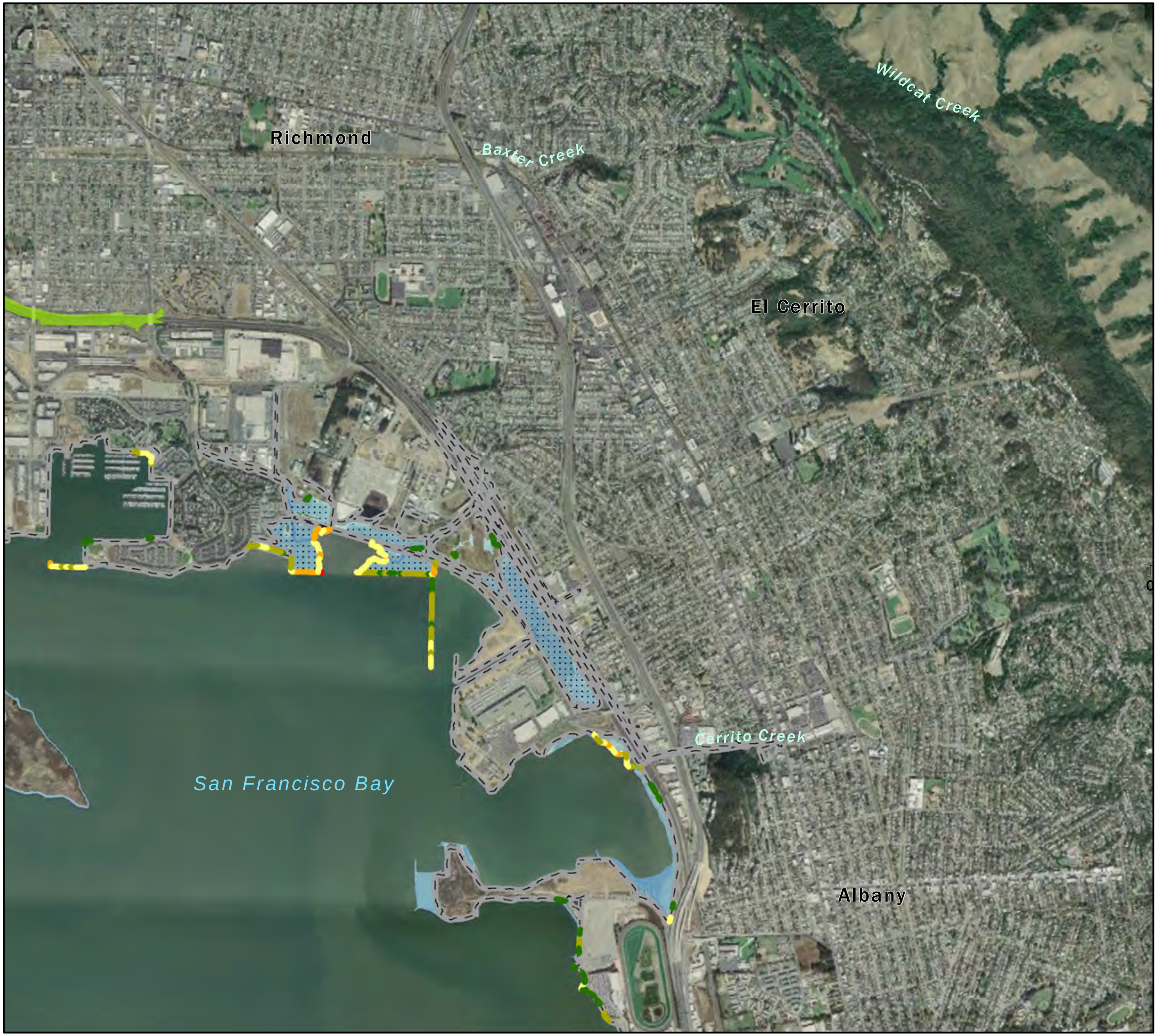
AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping



MHHW + 24" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5
- No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+
- Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

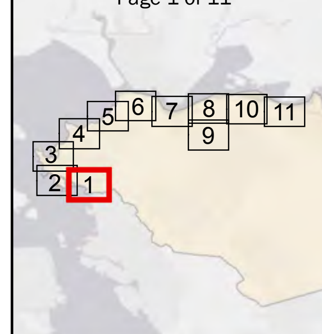
Miles: 0, 0.2, 0.4, 0.6

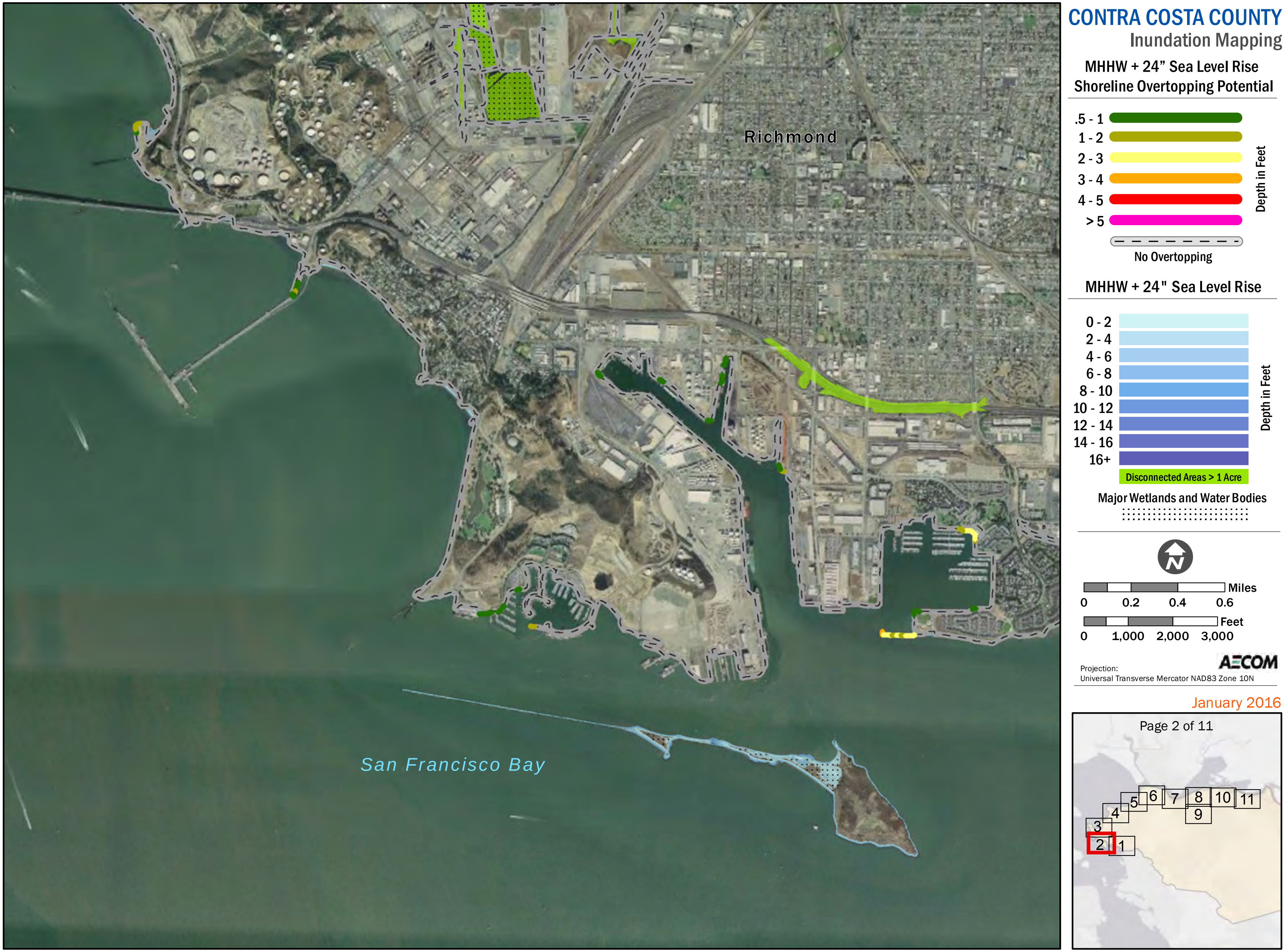
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





Richmond
San Francisco Bay
CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 24" Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
MHHW + 24" Sea Level Rise
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies
N
Miles
0 0.2 0.4 0.6
Feet
0 1,000 2,000 3,000
AECOM
Projection:
Universal Transverse Mercator NAD83 Zone 10N
January 2016
Page 2 of 11
1 2 3 4 5 6 7 8 9 10 11

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 24" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

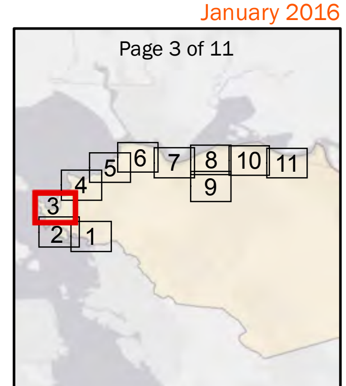
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 24" Sea Level Rise
Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

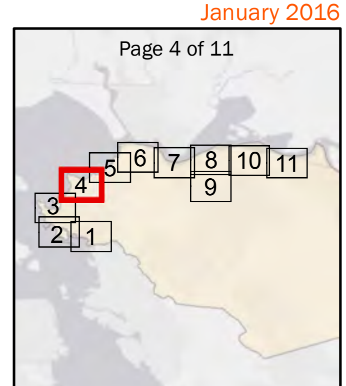
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 24" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

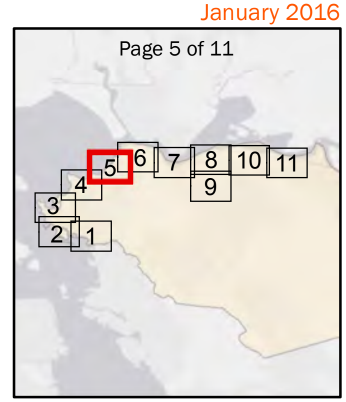
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 24" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

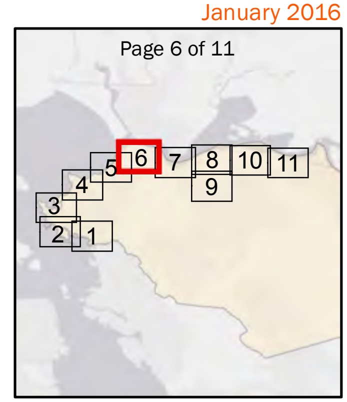
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 24" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5
- No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+
- Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

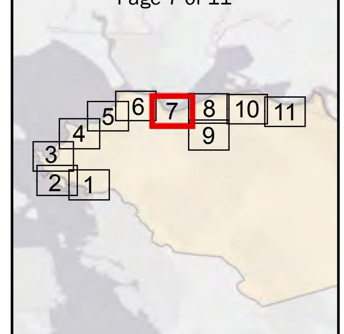
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 24” Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

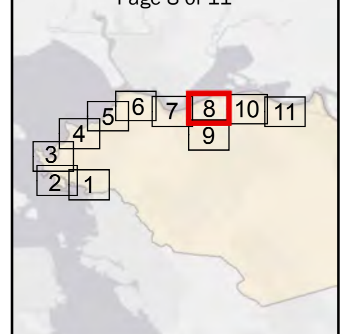
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 24" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5
- No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+
- Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

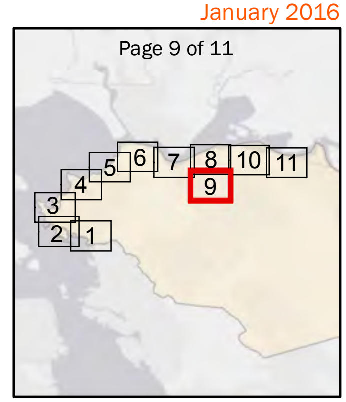
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 24" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

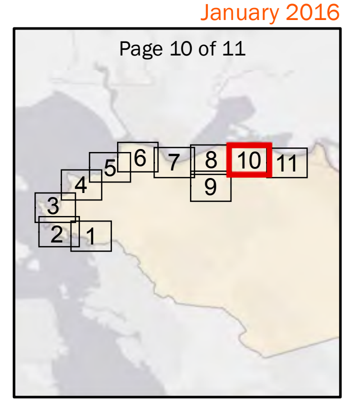
Miles: 0 0.2 0.4 0.6

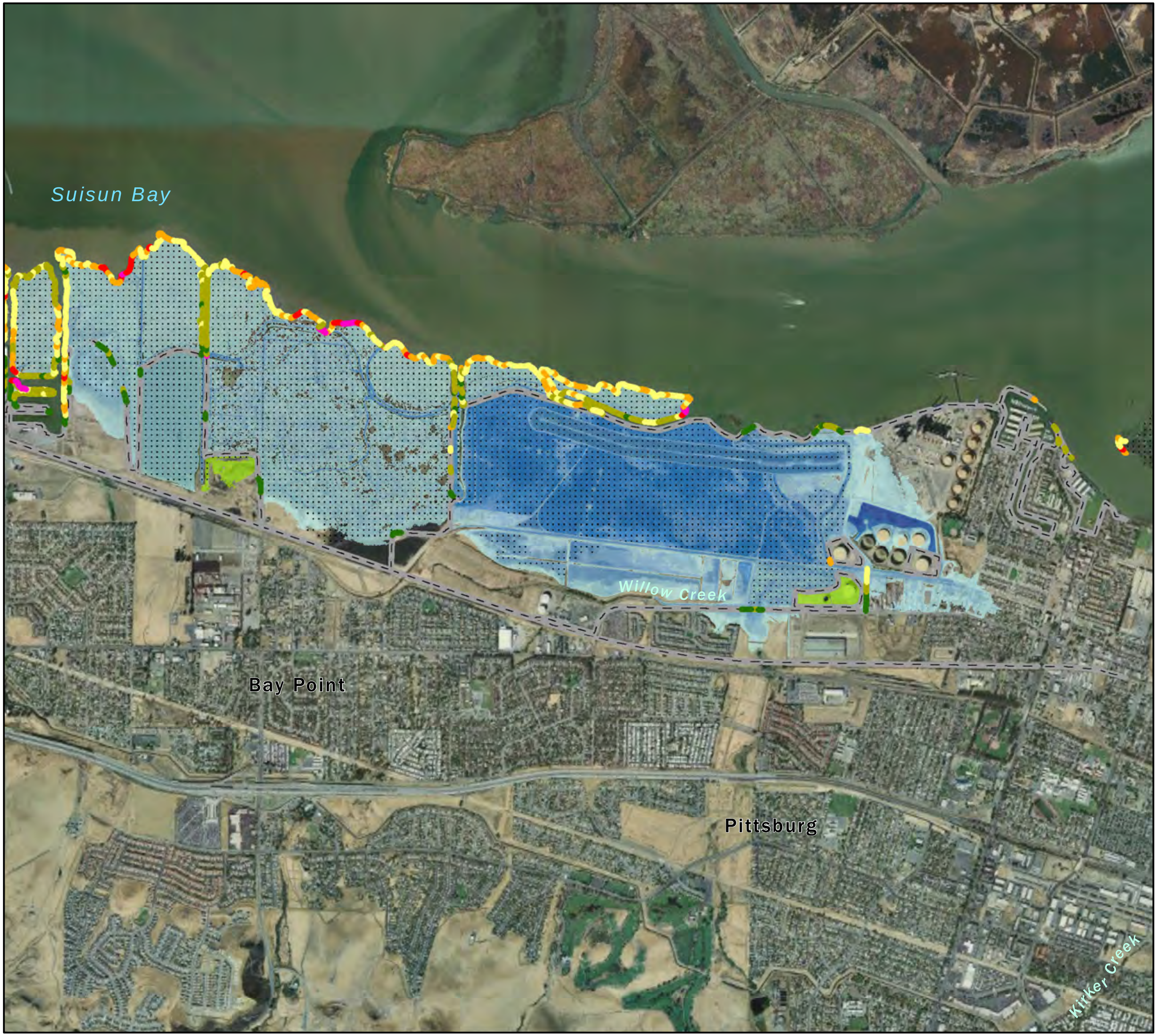
Feet: 0 1,000 2,000 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 24" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5
- No Overtopping

MHHW + 24" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+
- Disconnected Areas > 1 Acre
- Major Wetlands and Water Bodies

N

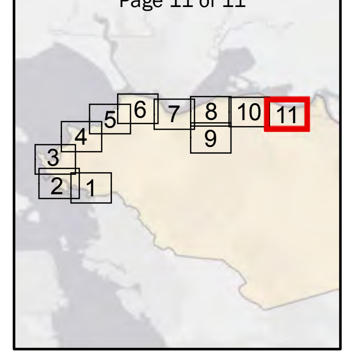
Miles: 0, 0.2, 0.4, 0.6

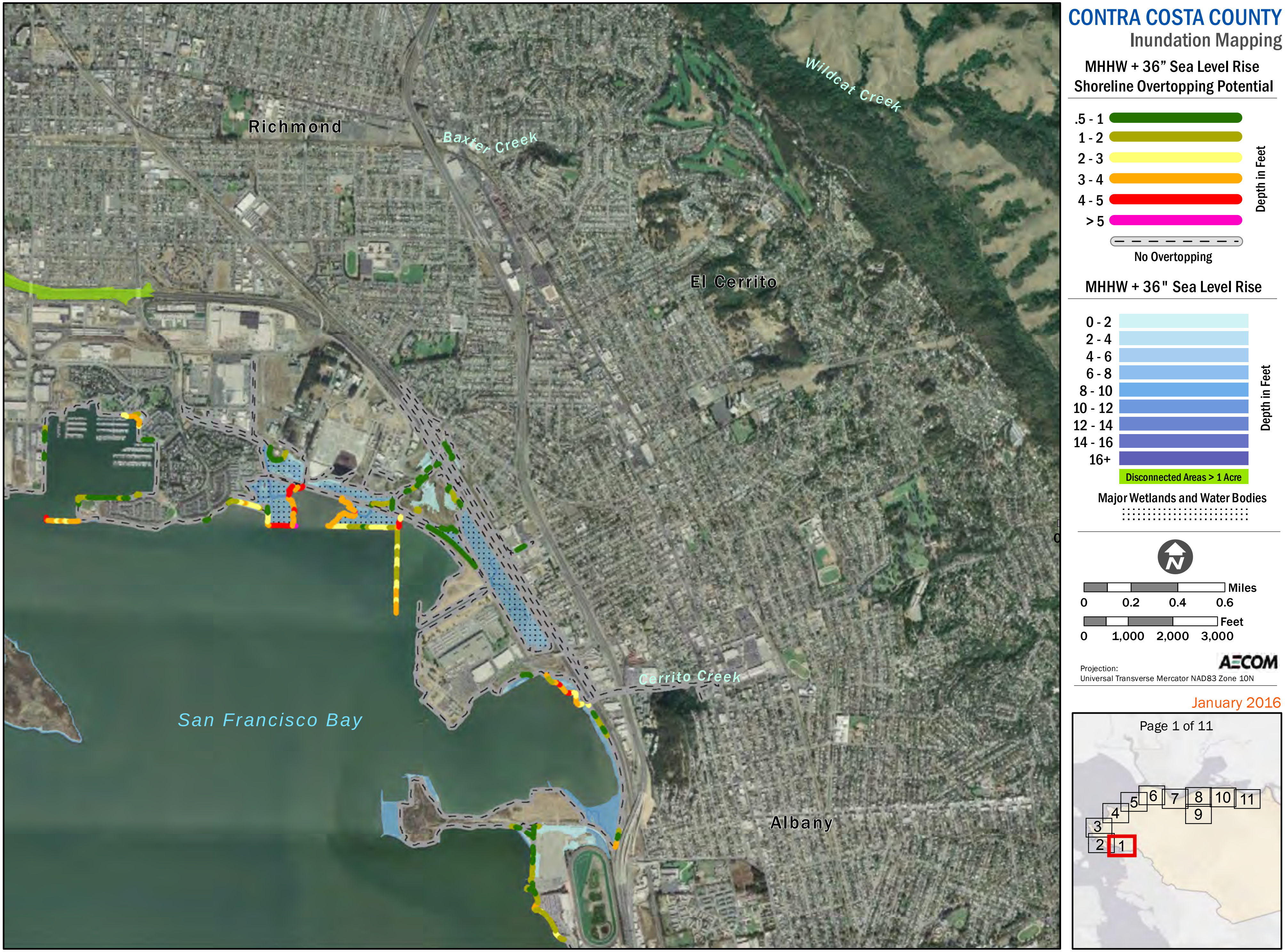
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

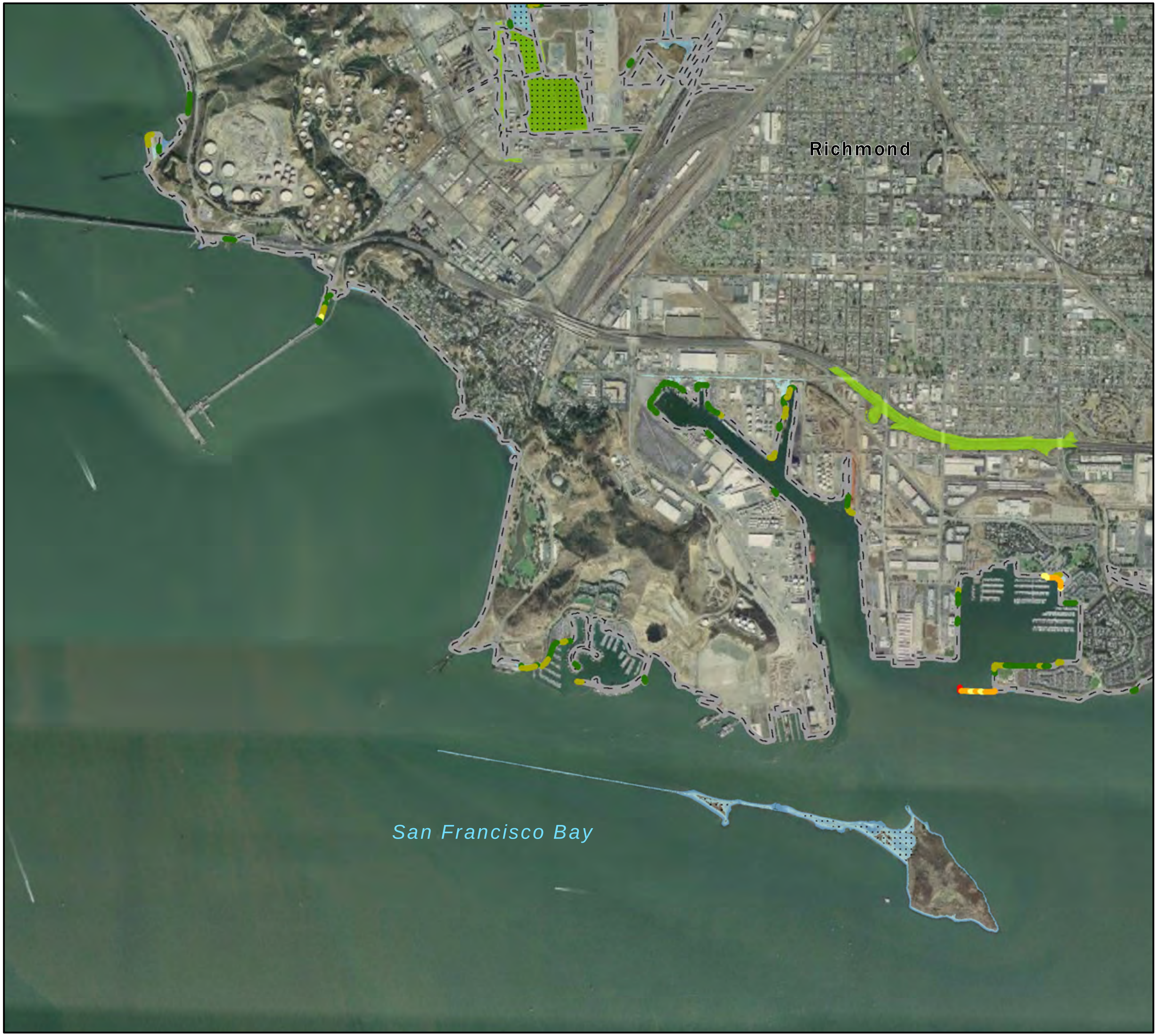
January 2016





Richmond
Baxter Creek
Wildcat Creek
El Cerrito
Cerrito Creek
Albany
San Francisco Bay
CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 36” Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
MHHW + 36" Sea Level Rise
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies
N
Miles
0 0.2 0.4 0.6
Feet
0 1,000 2,000 3,000
AECOM
Projection:
Universal Transverse Mercator NAD83 Zone 10N
January 2016
Page 1 of 11
1 2 3 4 5 6 7 8 9 10 11

CONTRA COSTA COUNTY
Inundation Mapping



MHHW + 36" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet	
.5 - 1	
1 - 2	
2 - 3	
3 - 4	
4 - 5	
> 5	

No Overtopping

MHHW + 36" Sea Level Rise

Depth in Feet	
0 - 2	
2 - 4	
4 - 6	
6 - 8	
8 - 10	
10 - 12	
12 - 14	
14 - 16	
16+	

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

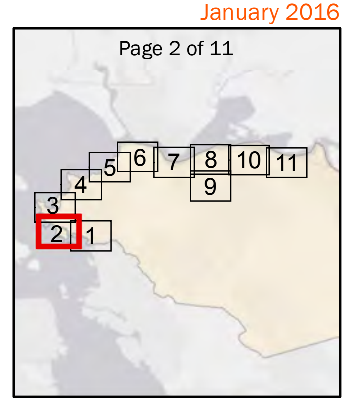
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 36" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 36" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

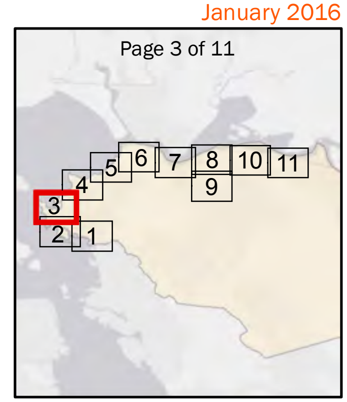
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 36" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 36" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

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Miles: 0, 0.2, 0.4, 0.6

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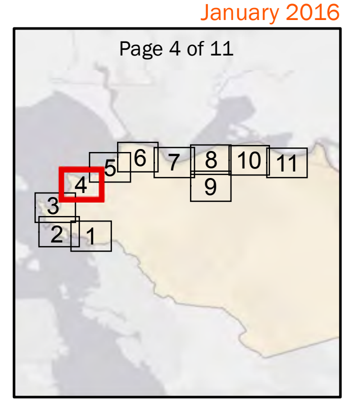
Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 36” Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
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No Overtopping

MHHW + 36" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

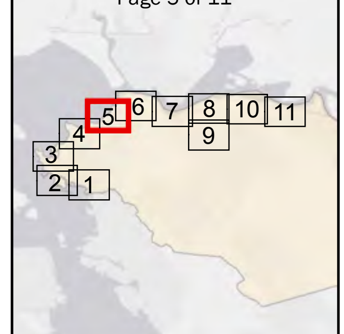
Miles: 0 0.2 0.4 0.6

Feet: 0 1,000 2,000 3,000

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 36" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
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No Overtopping

MHHW + 36" Sea Level Rise

Depth in Feet

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- 8 - 10
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Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

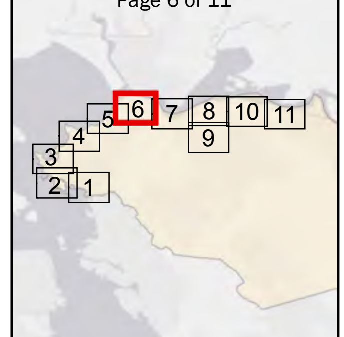
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 36" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
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MHHW + 36" Sea Level Rise

Depth in Feet

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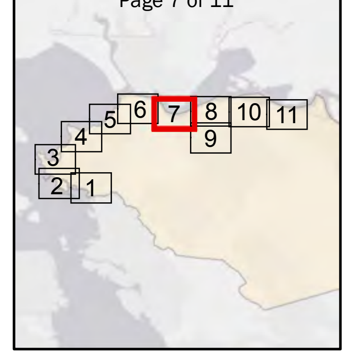
Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 36" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
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No Overtopping

MHHW + 36" Sea Level Rise

Depth in Feet

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Disconnected Areas > 1 Acre

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Miles: 0, 0.2, 0.4, 0.6

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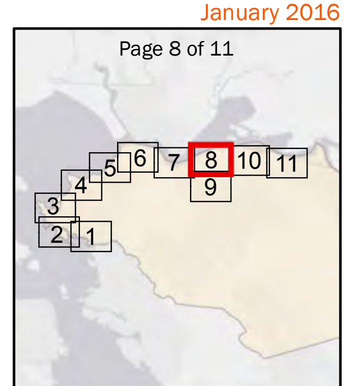
Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 36" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 36" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

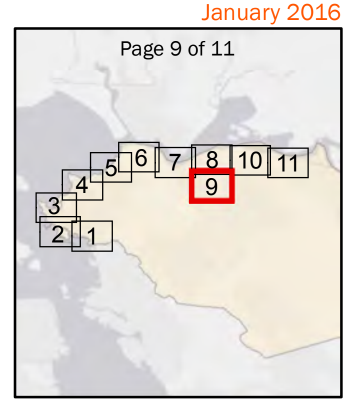
Miles: 0, 0.2, 0.4, 0.6

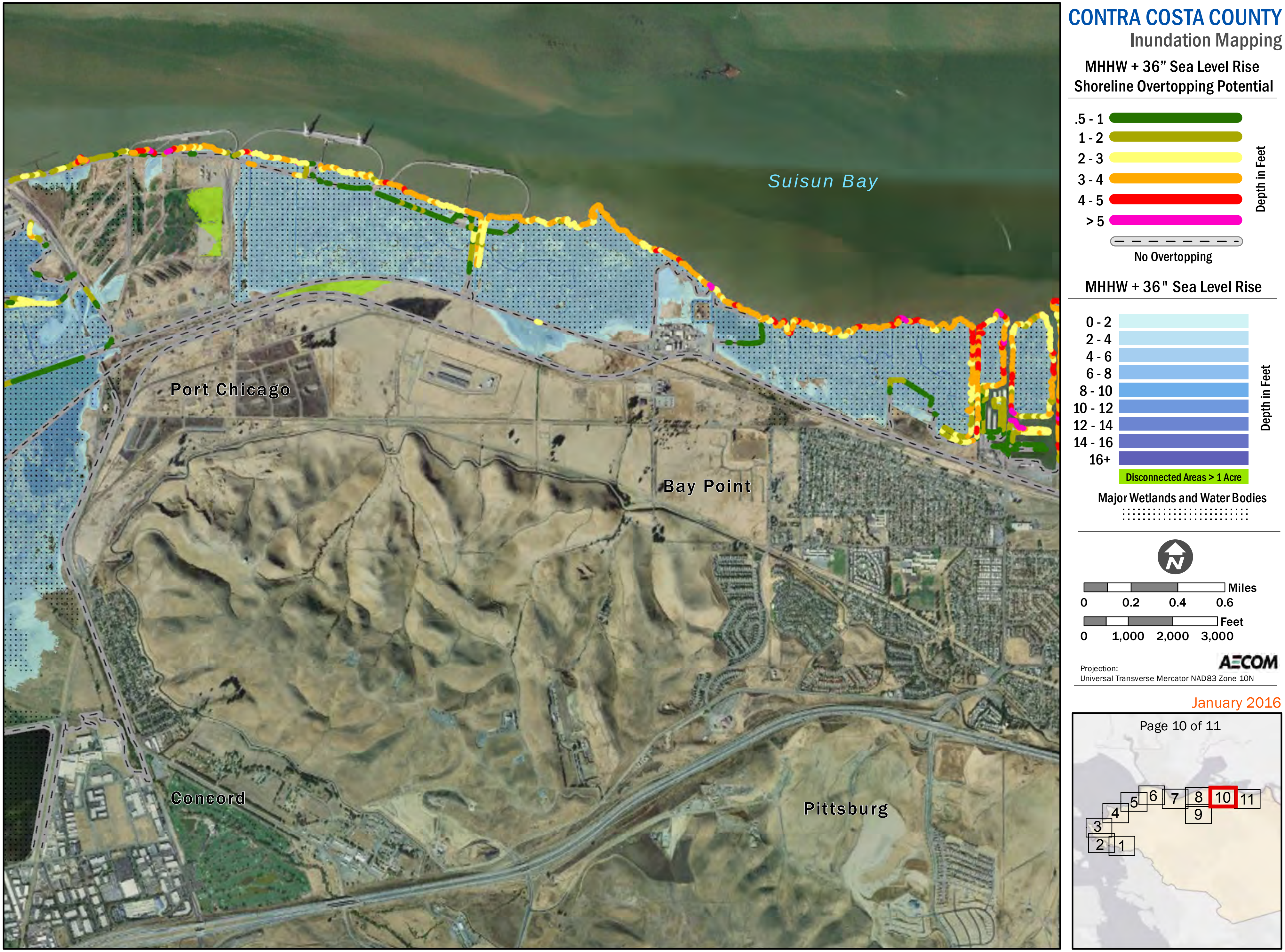
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





Suisun Bay
Port Chicago
Bay Point
Concord
Pittsburg
CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 36” Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
MHHW + 36" Sea Level Rise
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies
N
Miles
0
0.2
0.4
0.6
Feet
0
1,000
2,000
3,000
AECOM
Projection:
Universal Transverse Mercator NAD83 Zone 10N
January 2016
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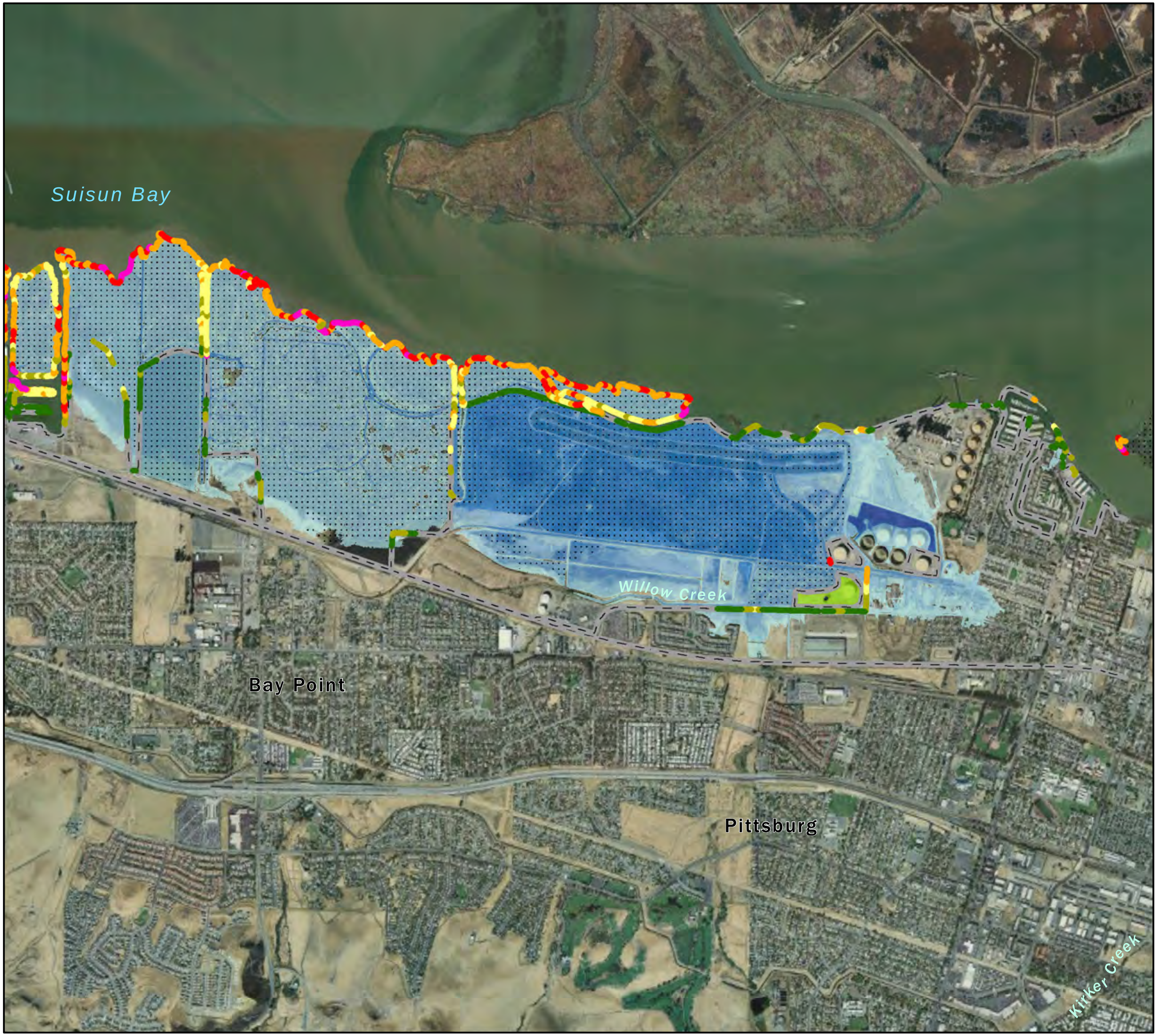


CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 36" Sea Level Rise
Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5
- No Overtopping

MHHW + 36" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+
- Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

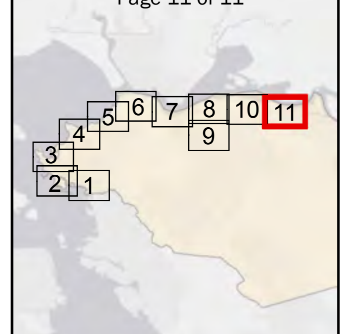
Miles: 0, 0.2, 0.4, 0.6

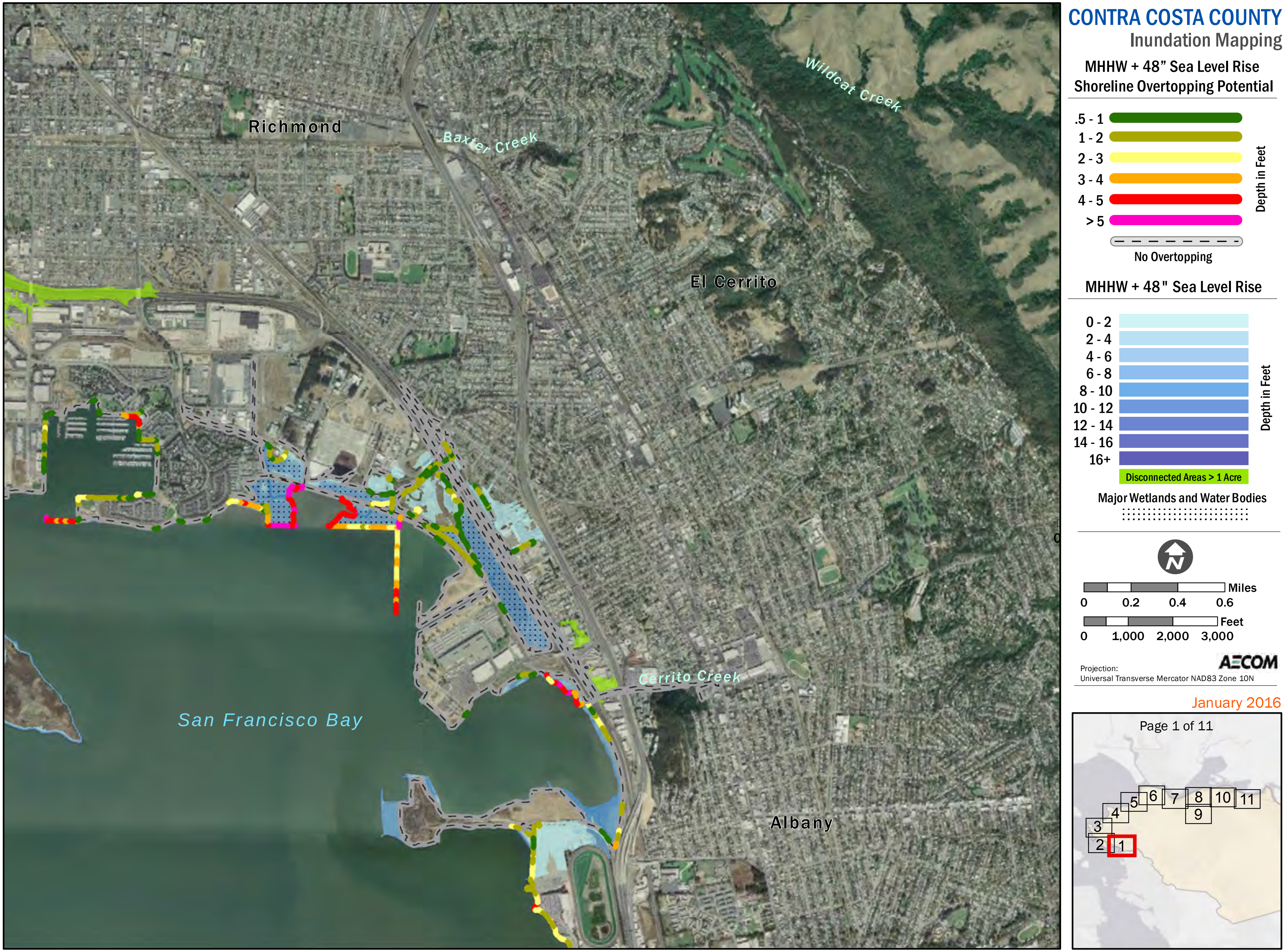
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016




CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 48" Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
MHHW + 48" Sea Level Rise
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies
Miles
0
0.2
0.4
0.6
Feet
0
1,000
2,000
3,000
Projection:
Universal Transverse Mercator NAD83 Zone 10N
AECOM
January 2016
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1
2
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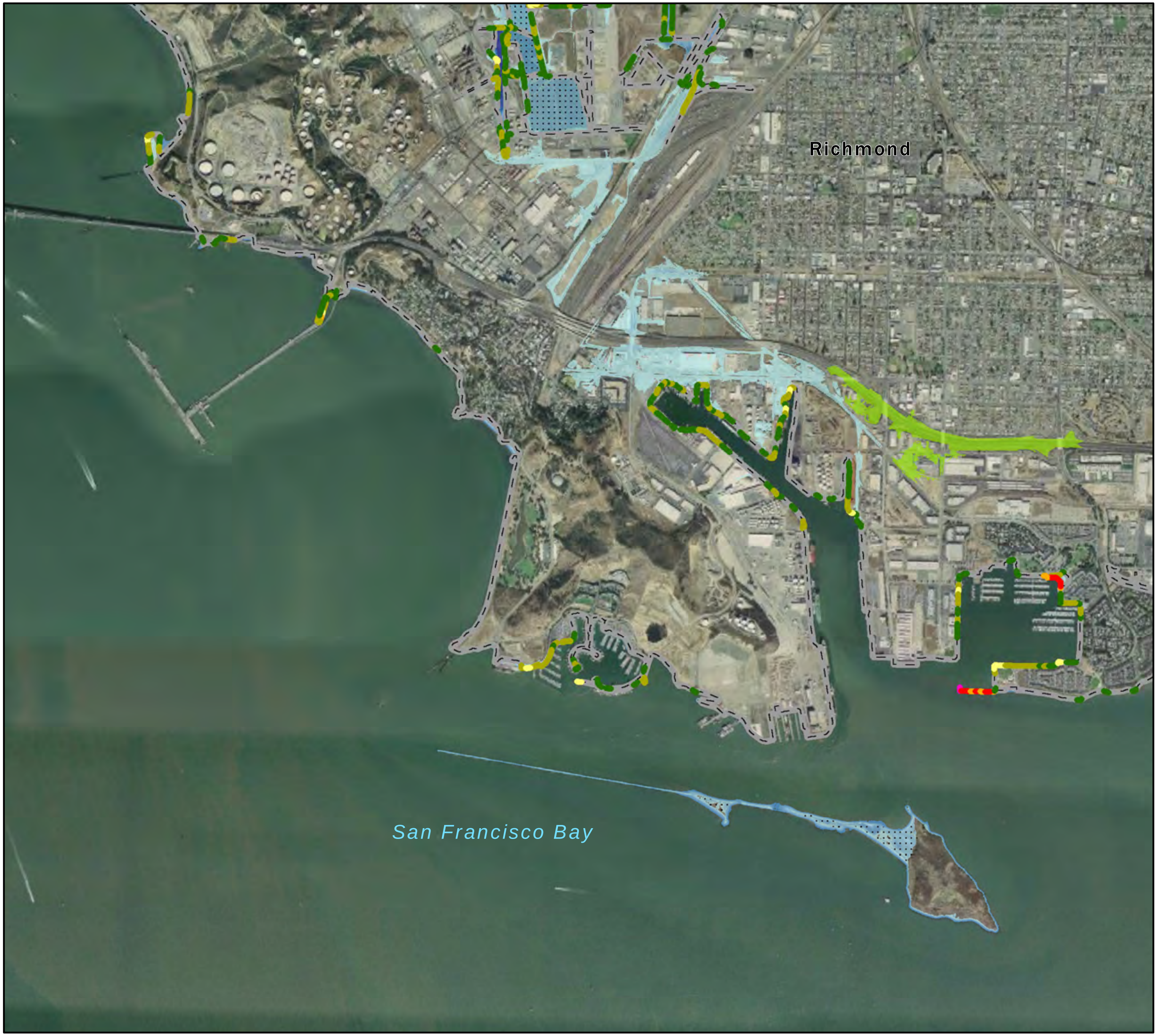
Richmond
Baxter Creek
Wildcat Creek
El Cerrito
Cerrito Creek
San Francisco Bay
Albany



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 48" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

.5 - 1

1 - 2

2 - 3

3 - 4

4 - 5

> 5

No Overtopping

MHHW + 48" Sea Level Rise

Depth in Feet

0 - 2

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AECOM

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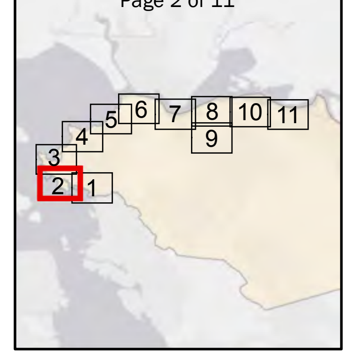
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 48" Sea Level Rise Shoreline Overtopping Potential

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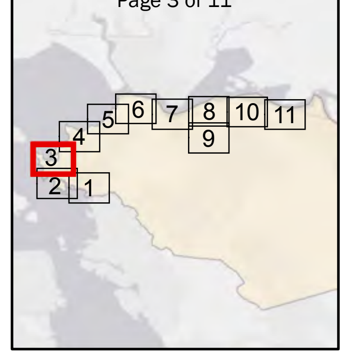
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 48" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

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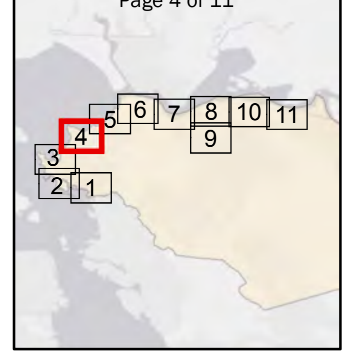
AECOM

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 48" Sea Level Rise Shoreline Overtopping Potential

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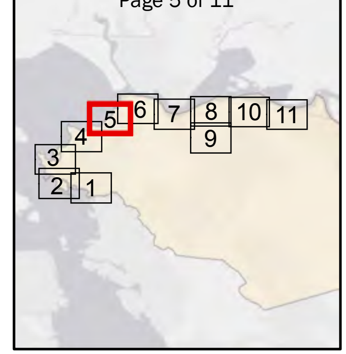
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 48" Sea Level Rise Shoreline Overtopping Potential

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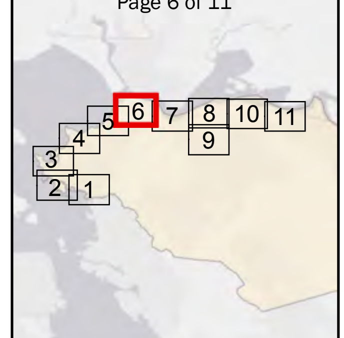
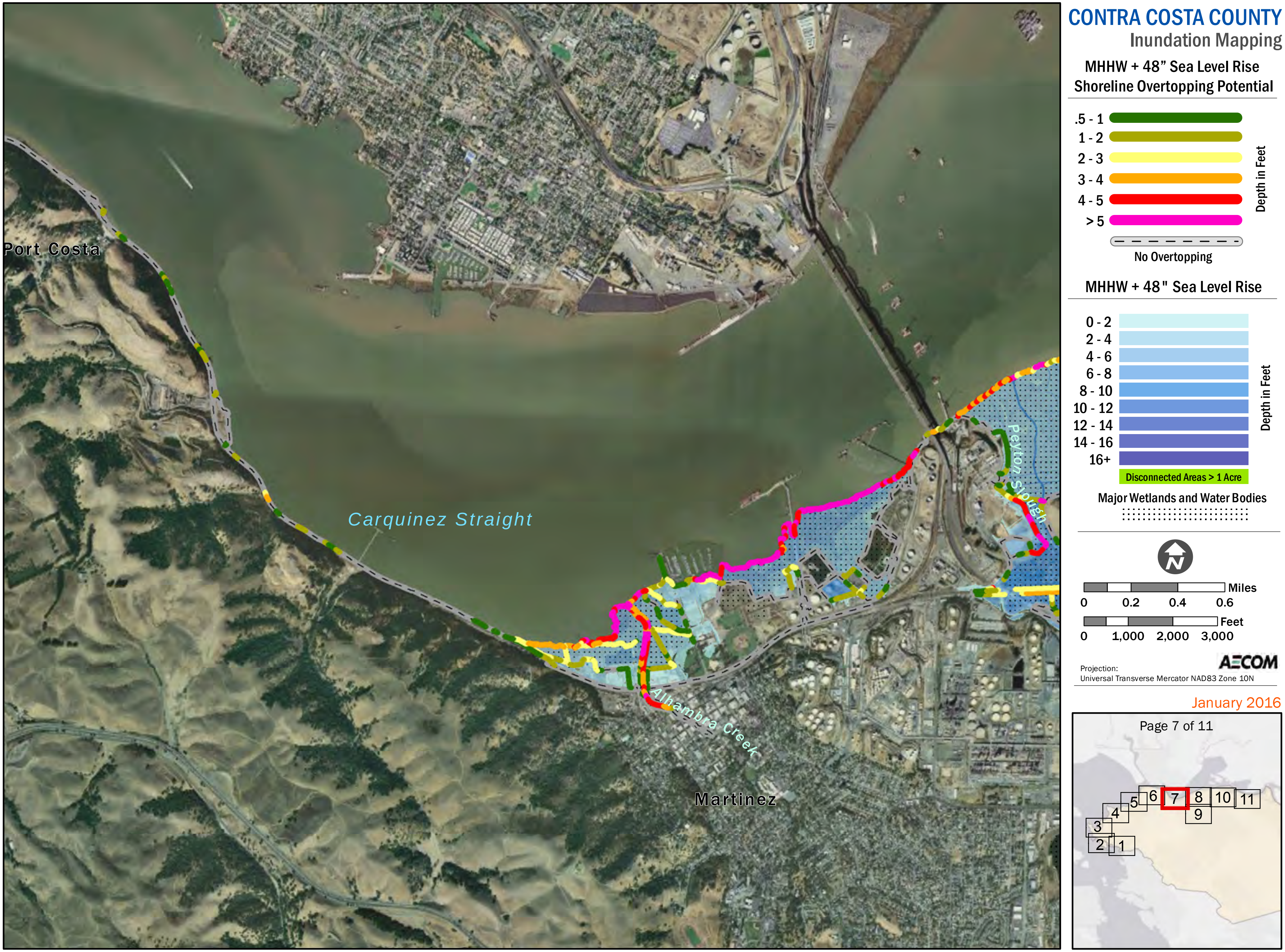
Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016




CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 48" Sea Level Rise
Shoreline Overtopping Potential
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N
Miles
0 0.2 0.4 0.6
Feet
0 1,000 2,000 3,000
Projection:
Universal Transverse Mercator NAD83 Zone 10N
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1
2
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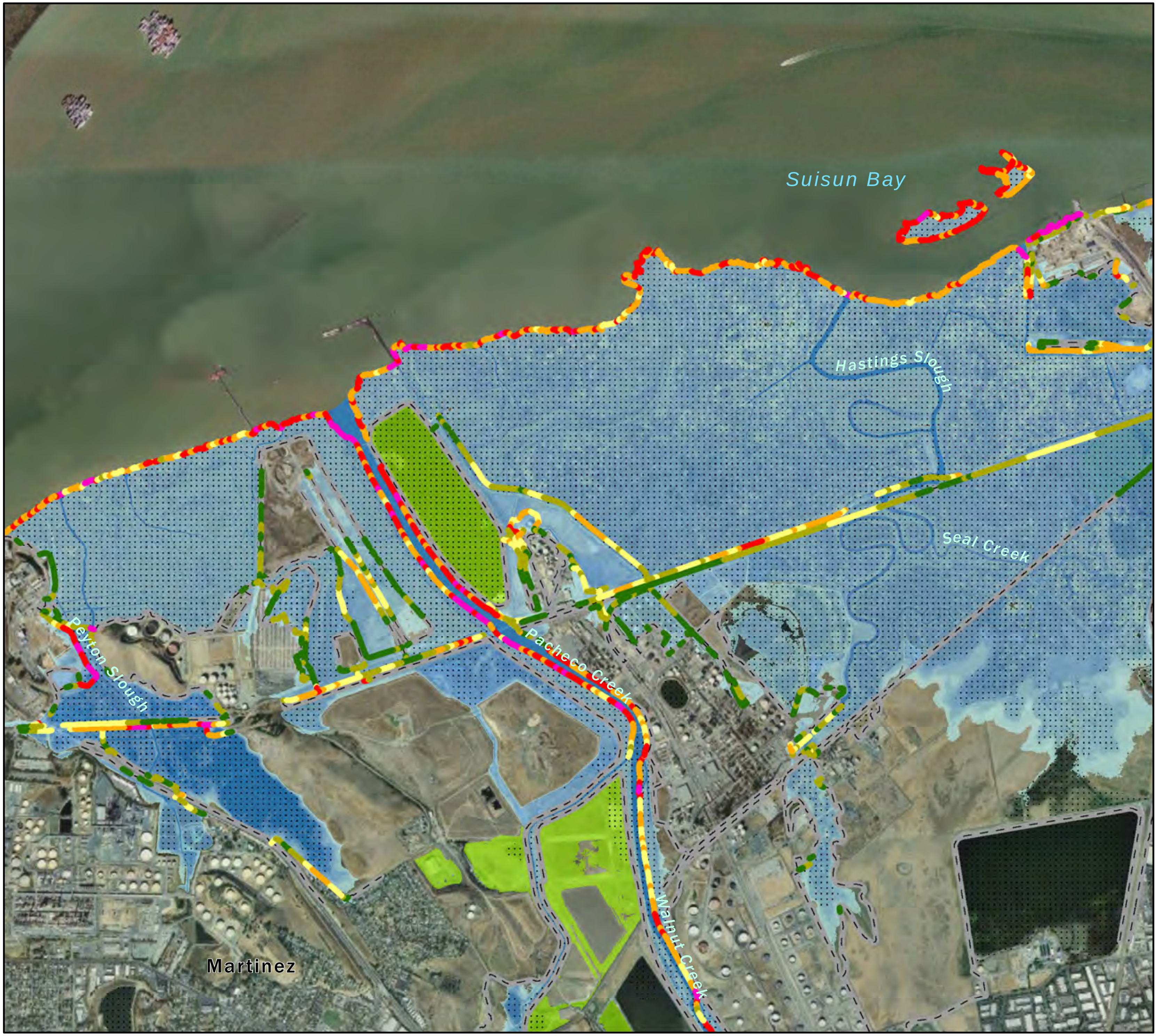
Port Costa
Carquinez Straight
Peyton Slough
Alhambra Creek
Martinez



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 48" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
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MHHW + 48" Sea Level Rise

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Projection:
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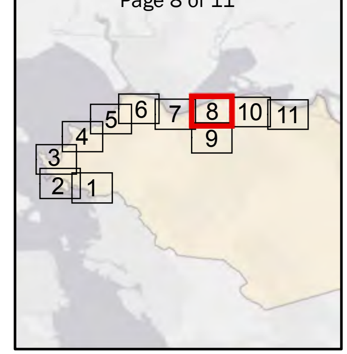
AECOM

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 48" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
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Miles: 0, 0.2, 0.4, 0.6

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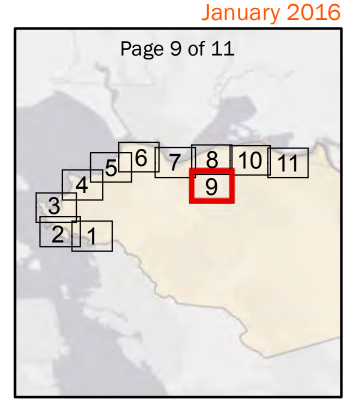
AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 48” Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
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MHHW + 48" Sea Level Rise

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- 12 - 14
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Major Wetlands and Water Bodies

N

Miles: 0, 0.2, 0.4, 0.6

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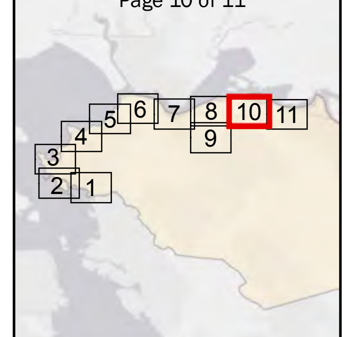
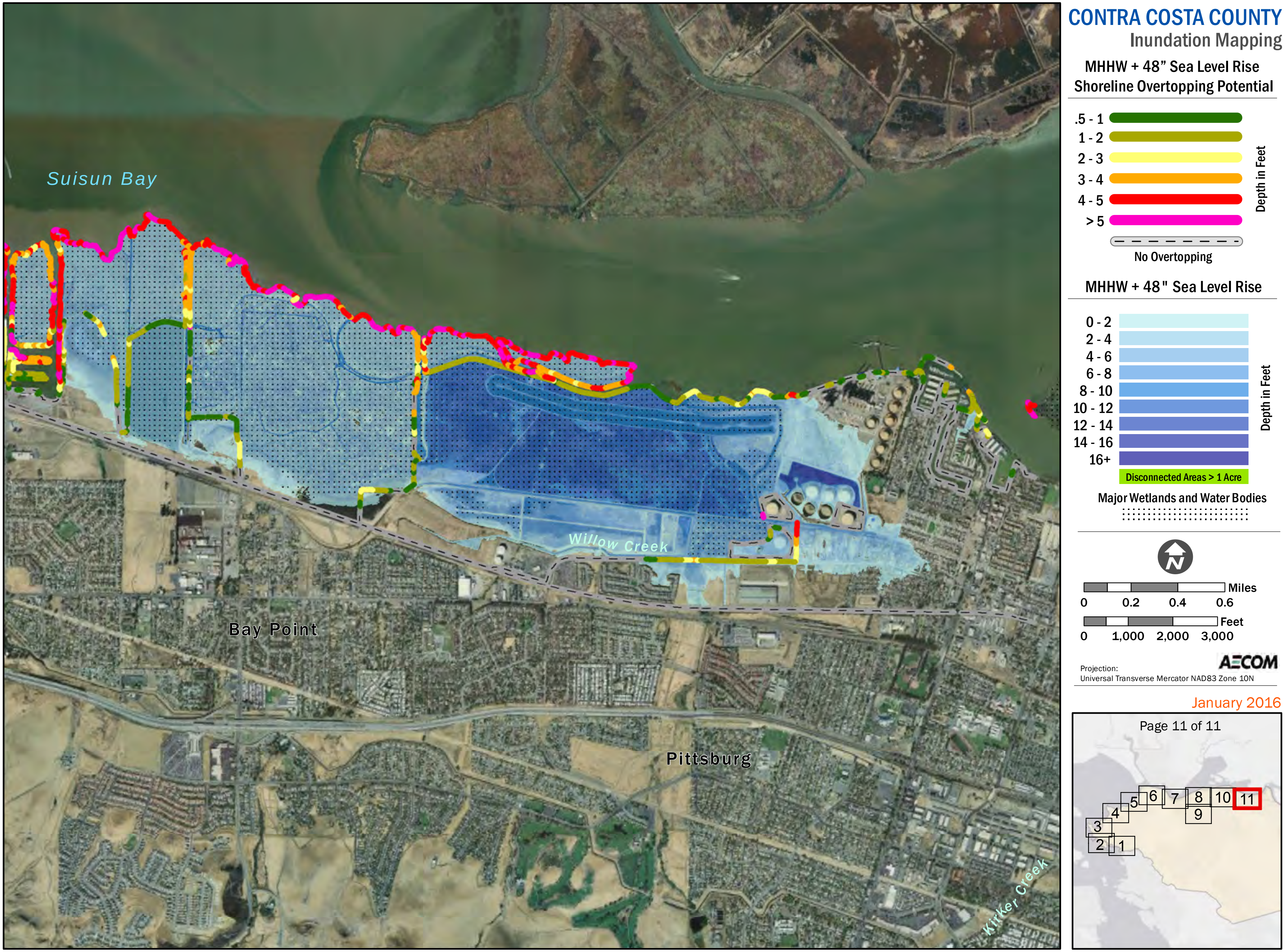
AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016




Suisun Bay
Willow Creek
Bay Point
Pittsburg
Kirker Creek
CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 48" Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
1 - 2
2 - 3
3 - 4
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> 5
Depth in Feet
No Overtopping
MHHW + 48" Sea Level Rise
0 - 2
2 - 4
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12 - 14
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Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies
N
Miles
0 0.2 0.4 0.6
Feet
0 1,000 2,000 3,000
AECOM
Projection:
Universal Transverse Mercator NAD83 Zone 10N
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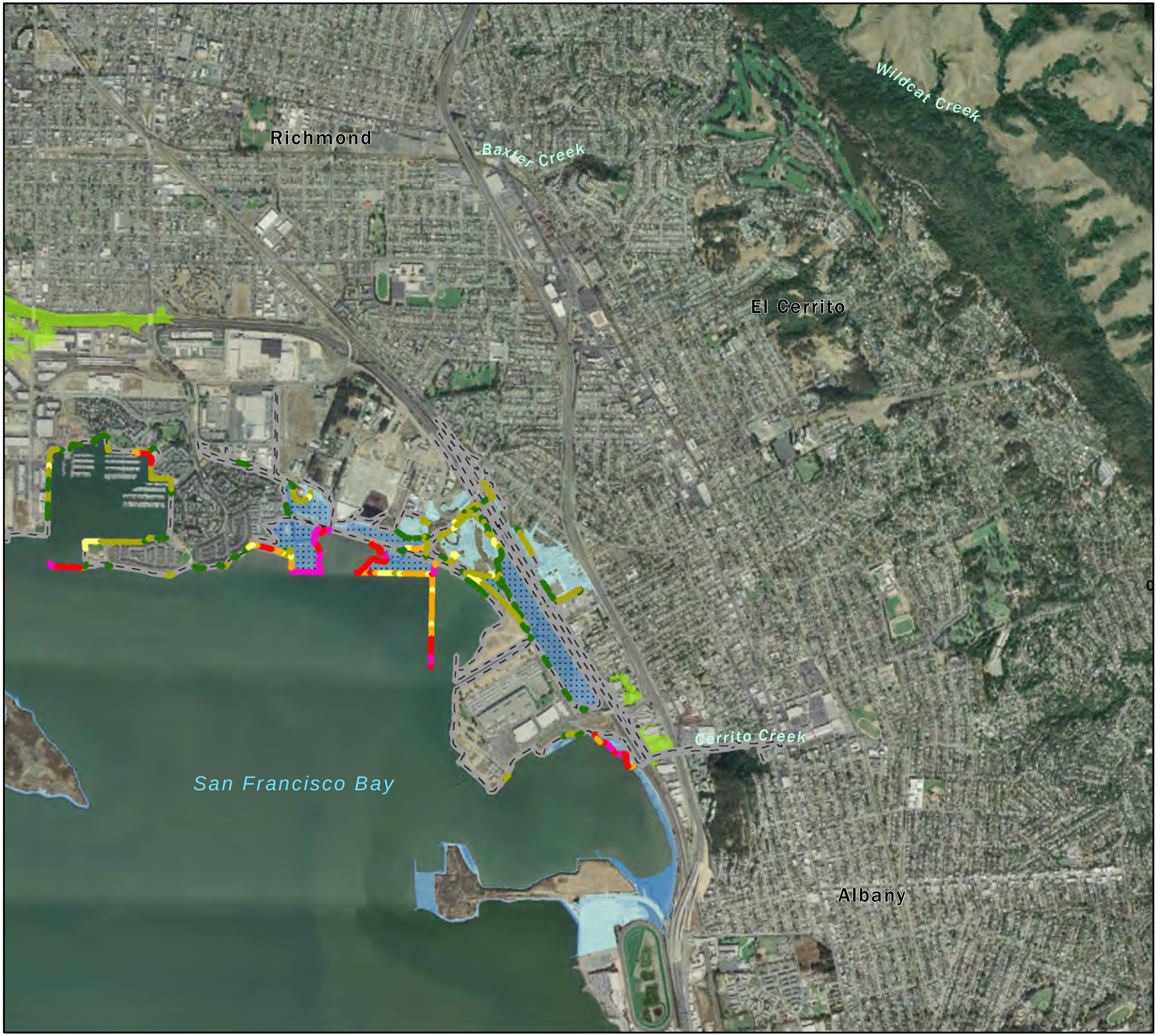
1 2 3 4 5 6 7 8 9 10 11

CONTRA COSTA COUNTY
Inundation Mapping



MHHW + 52" Sea Level Rise
Shoreline Overtopping Potential

Depth in Feet
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping

MHHW + 52" Sea Level Rise

Depth in Feet
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

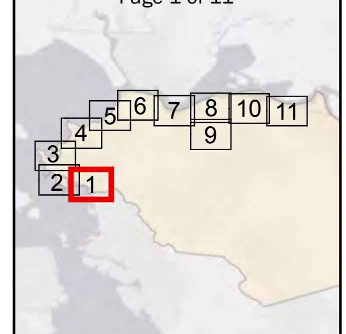
Miles
0 0.2 0.4 0.6

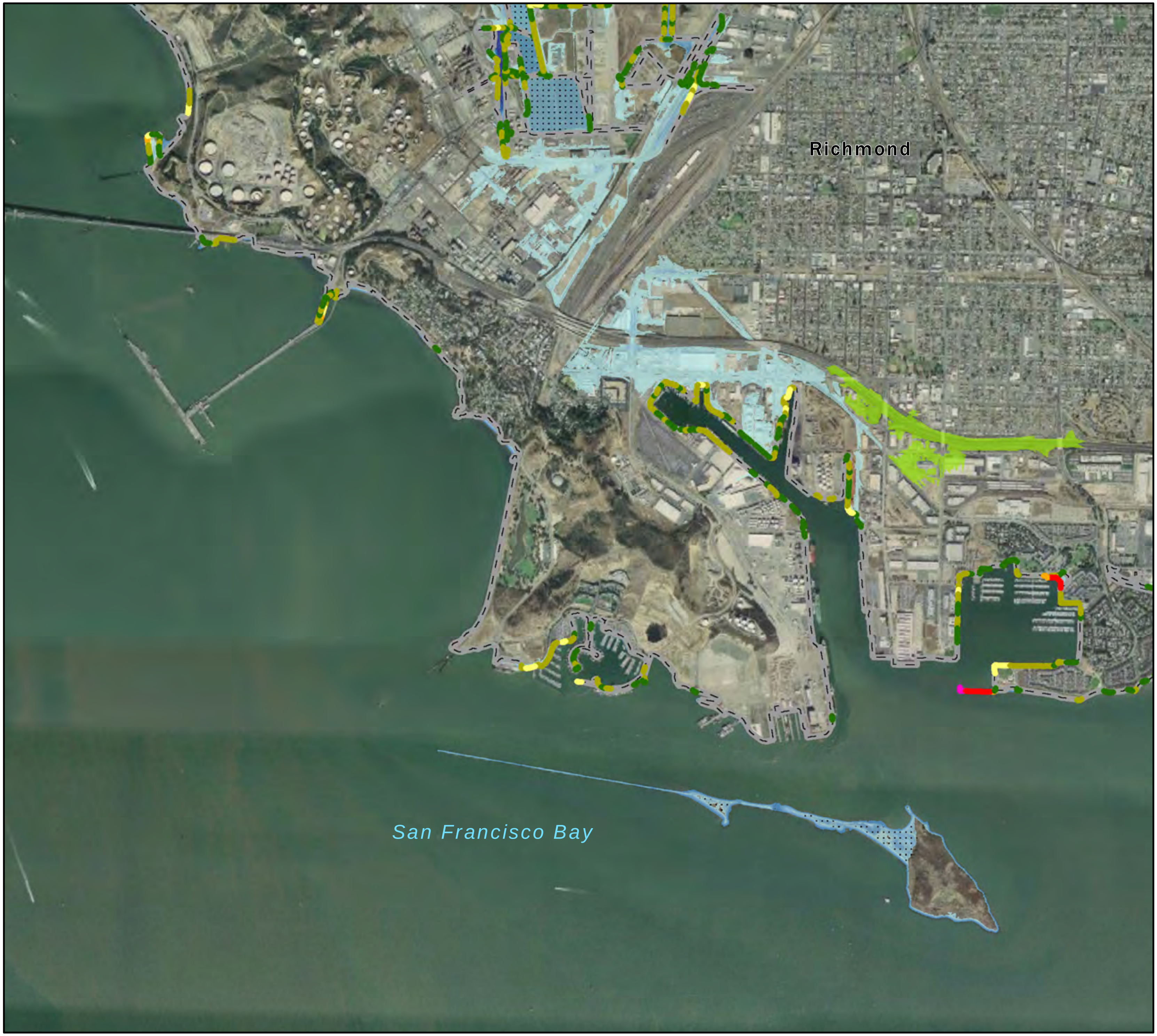
Feet
0 1,000 2,000 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 52" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 52" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
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- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

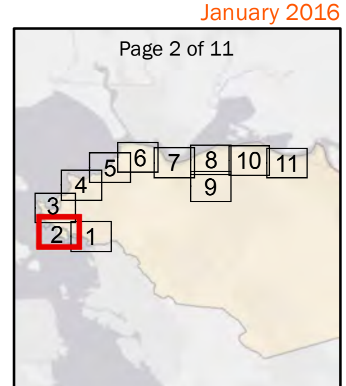
Miles: 0, 0.2, 0.4, 0.6

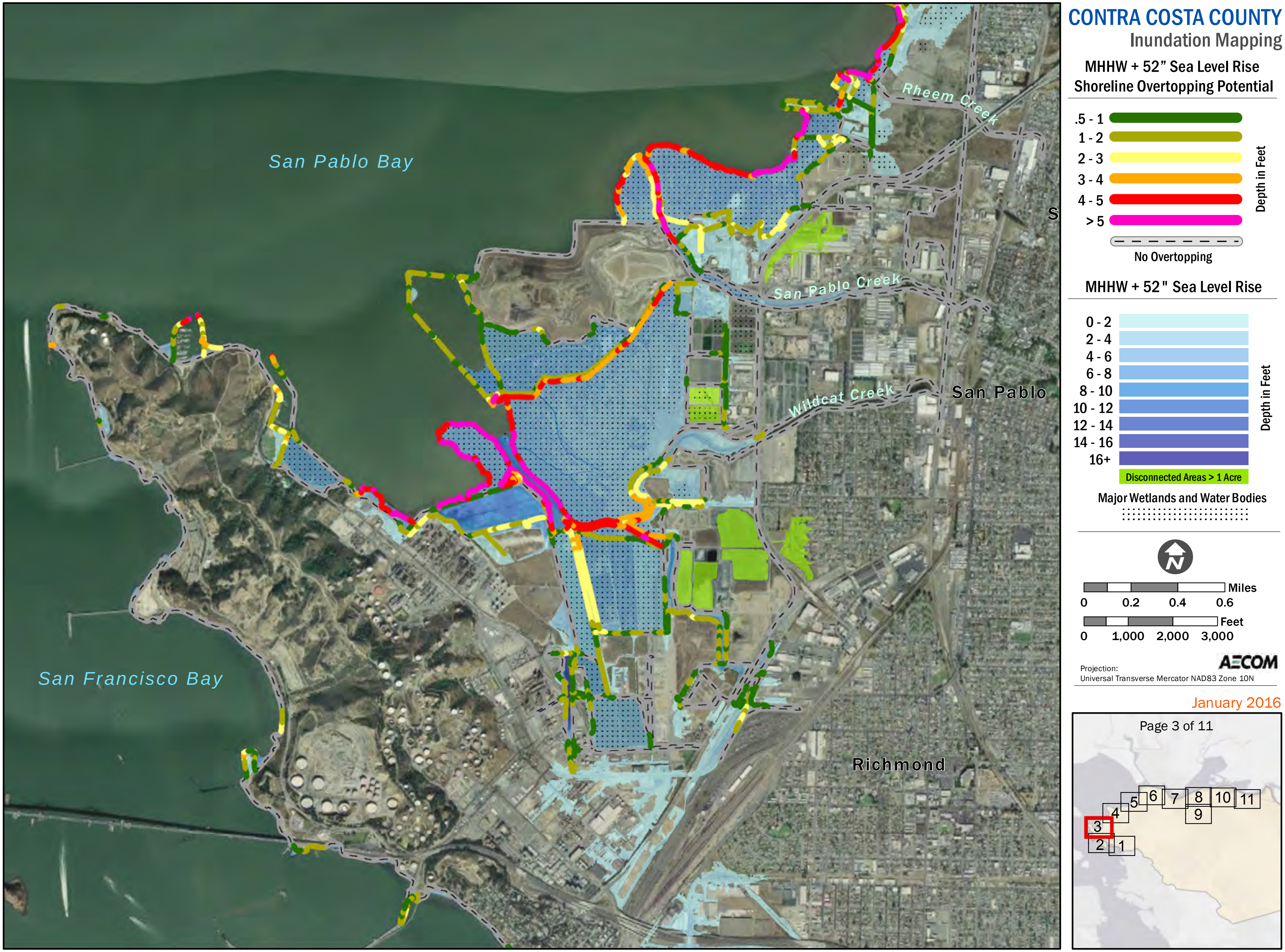
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016




CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 52" Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
1 - 2
2 - 3
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> 5
Depth in Feet
No Overtopping
MHHW + 52" Sea Level Rise
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Depth in Feet
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Major Wetlands and Water Bodies
Miles
0
0.2
0.4
0.6
Feet
0
1,000
2,000
3,000
AECOM
Projection:
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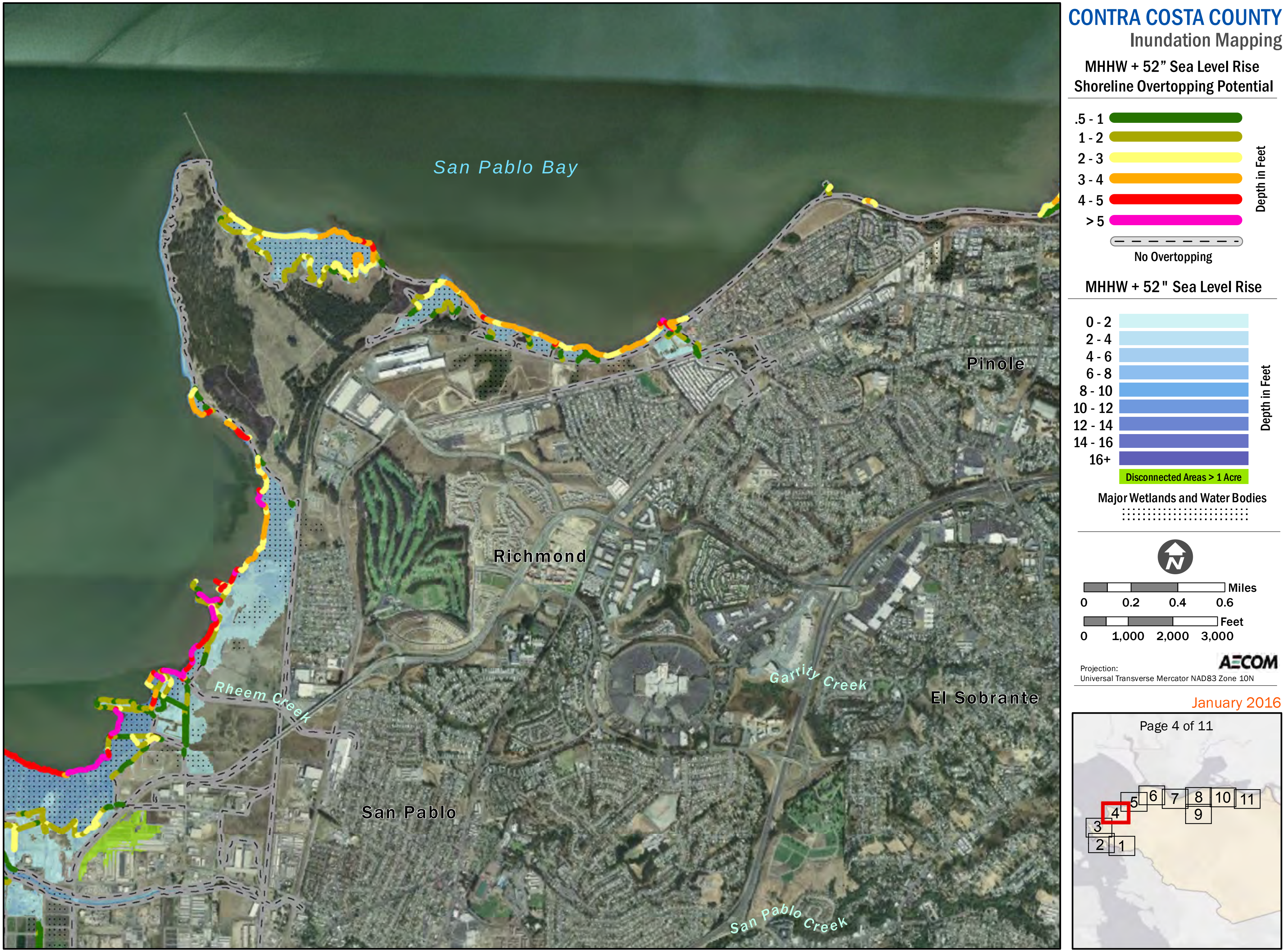
San Pablo Bay
San Francisco Bay
Rheem Creek
San Pablo Creek
Wildcat Creek
San Pablo
Richmond



San Pablo Bay
Pinole
Richmond
Rheem Creek
Garrity Creek
El Sobrante
San Pablo
San Pablo Creek
CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 52" Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
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Feet
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Universal Transverse Mercator NAD83 Zone 10N
AECOM
January 2016
Page 4 of 11
1 2 3 4 5 6 7 8 9 10 11

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 52” Sea Level Rise Shoreline Overtopping Potential

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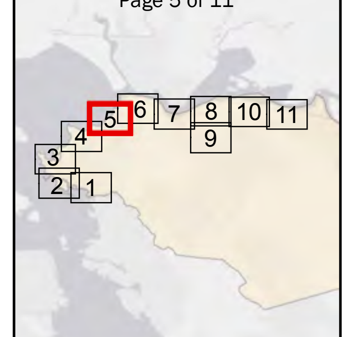
January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 52" Sea Level Rise Shoreline Overtopping Potential

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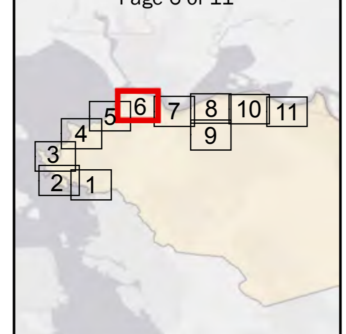

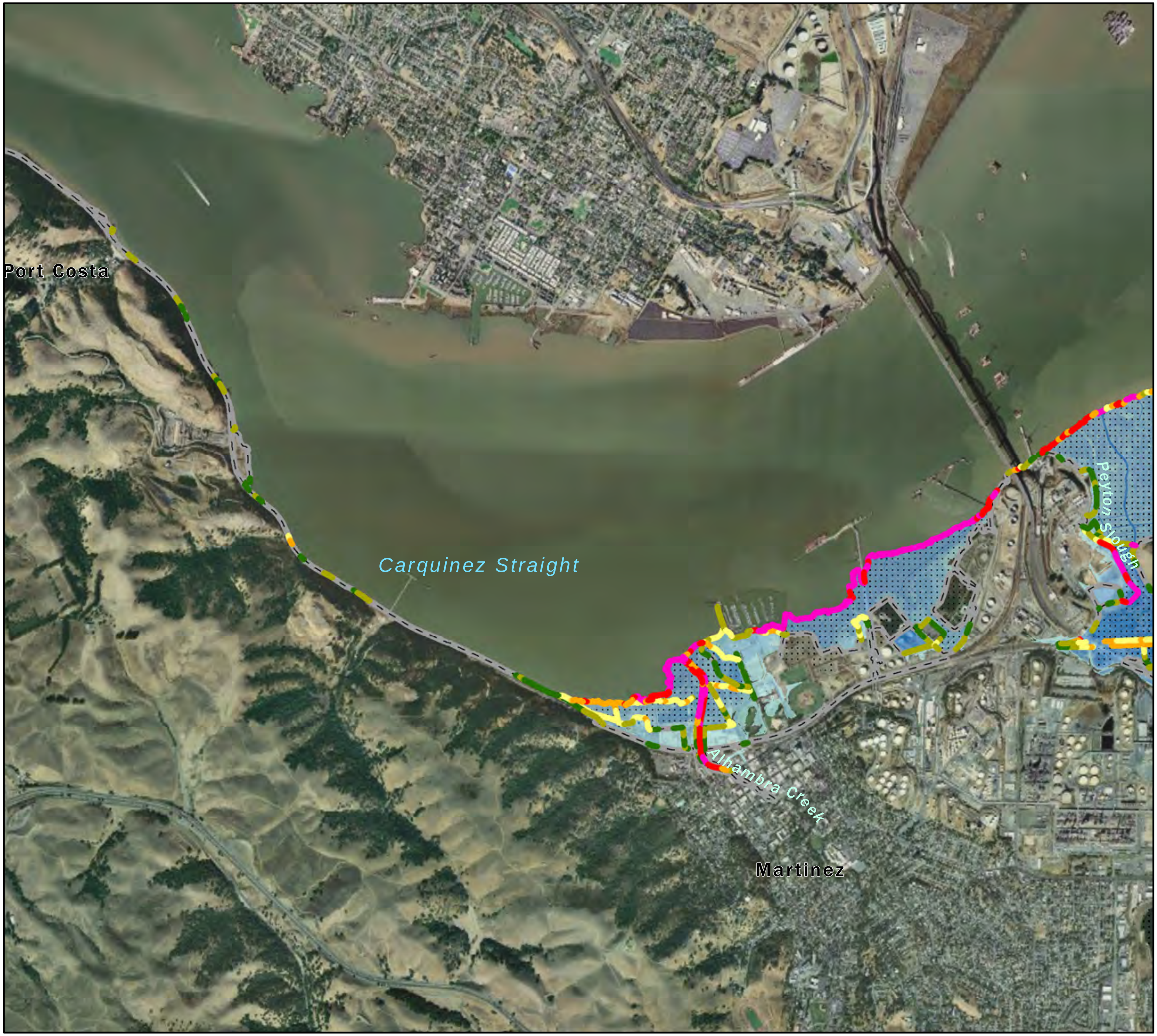

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 52" Sea Level Rise
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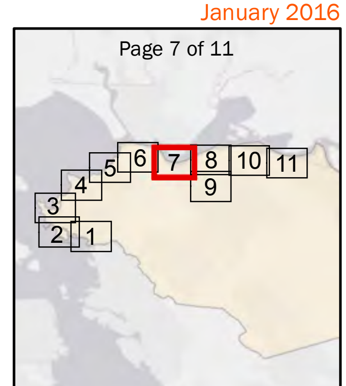

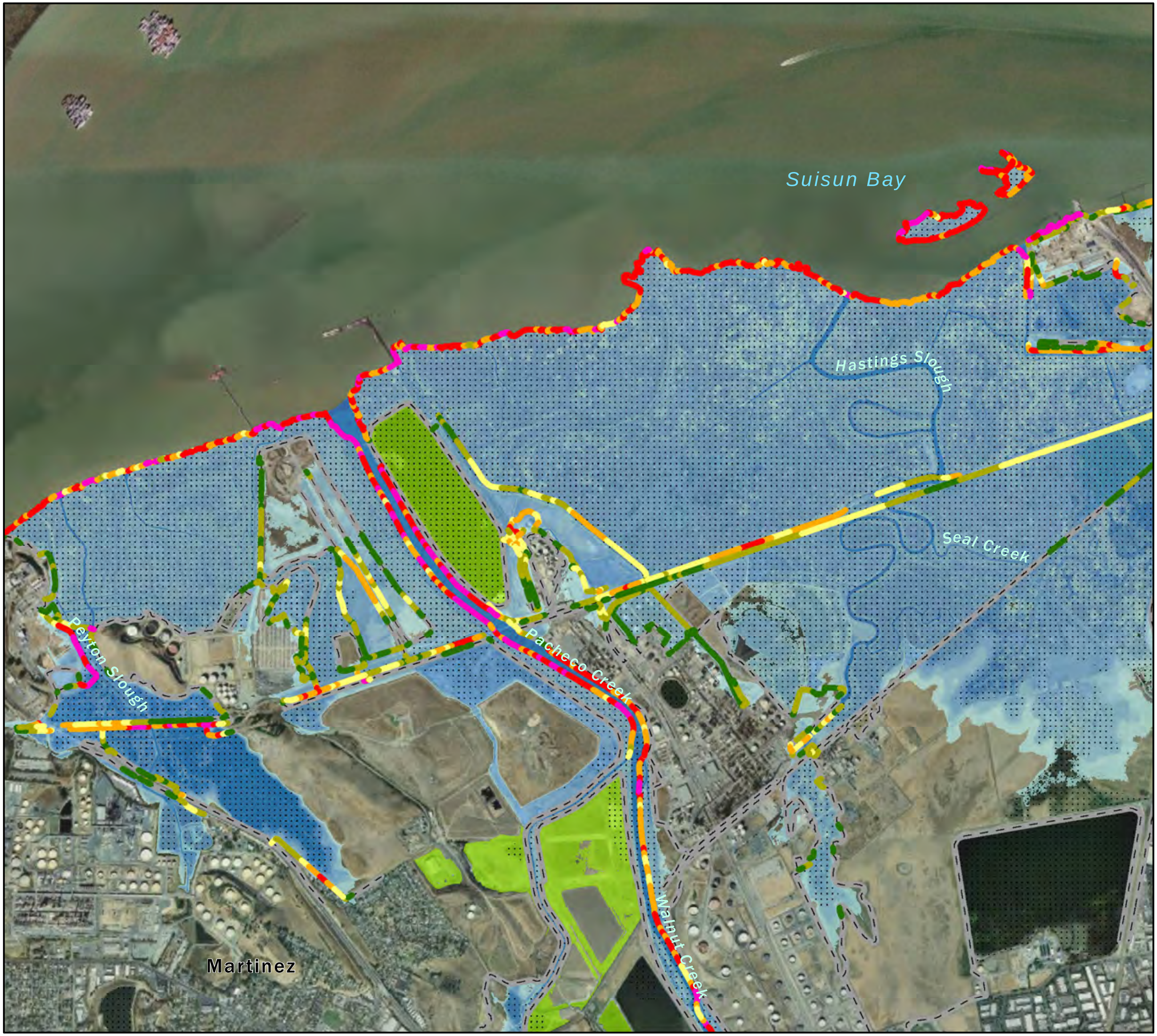

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 52" Sea Level Rise Shoreline Overtopping Potential

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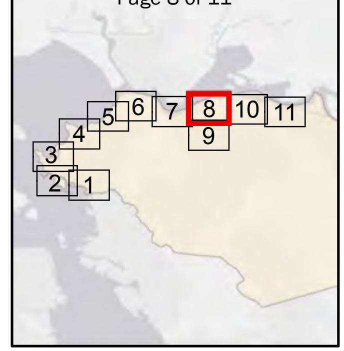
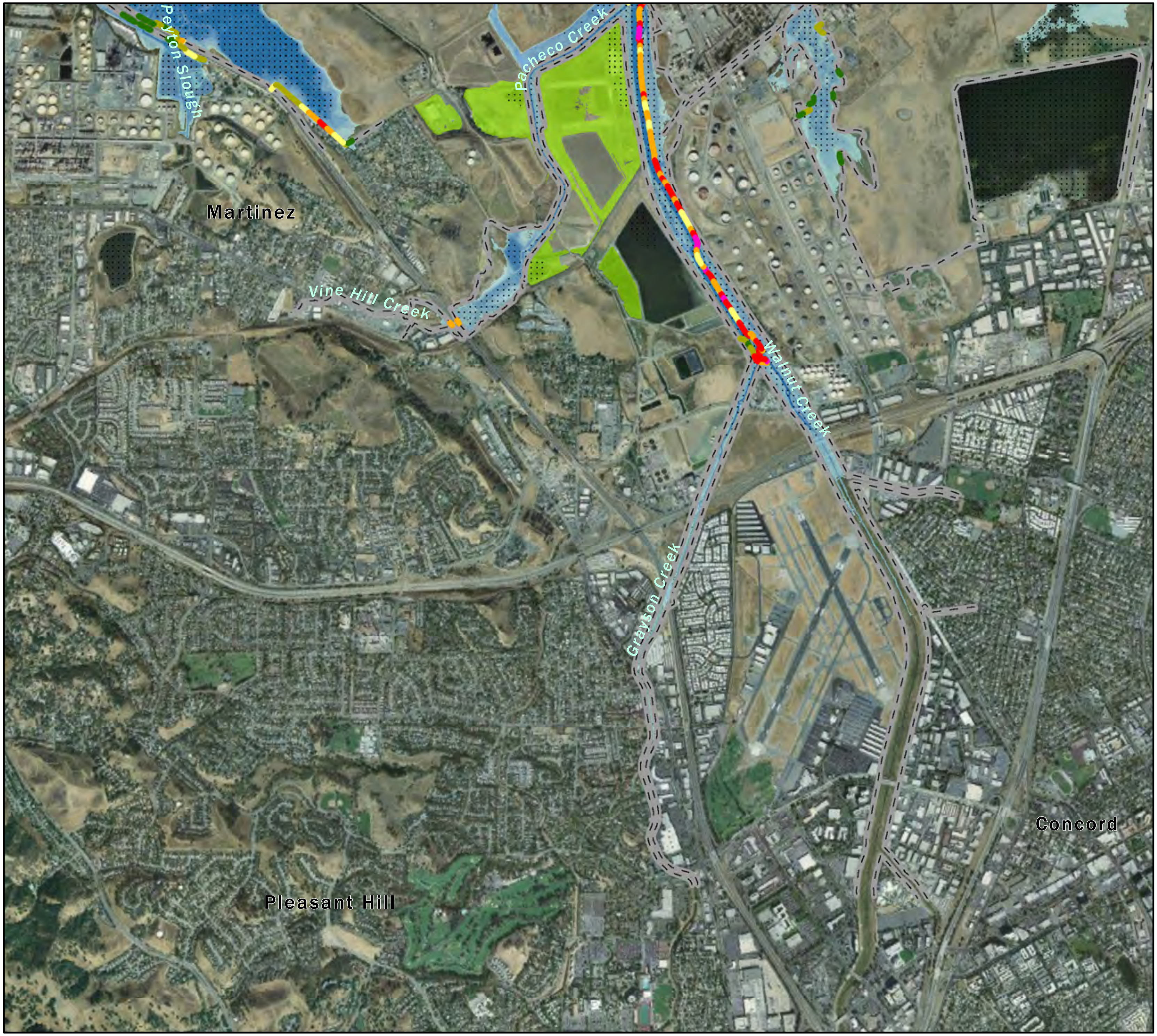
January 2016





CONTRA COSTA COUNTY

Inundation Mapping

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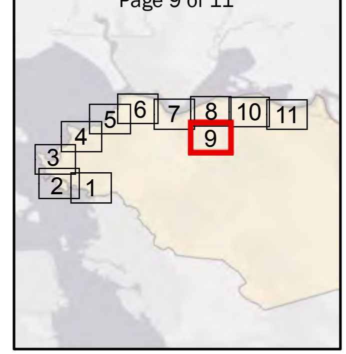

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 52" Sea Level Rise Shoreline Overtopping Potential

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- 4 - 5
- > 5

No Overtopping

MHHW + 52" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

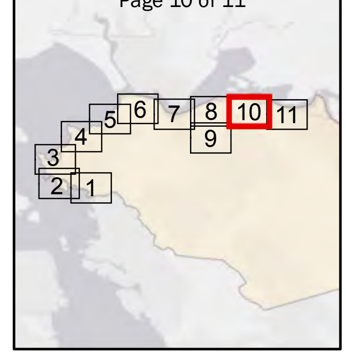
Miles: 0, 0.2, 0.4, 0.6

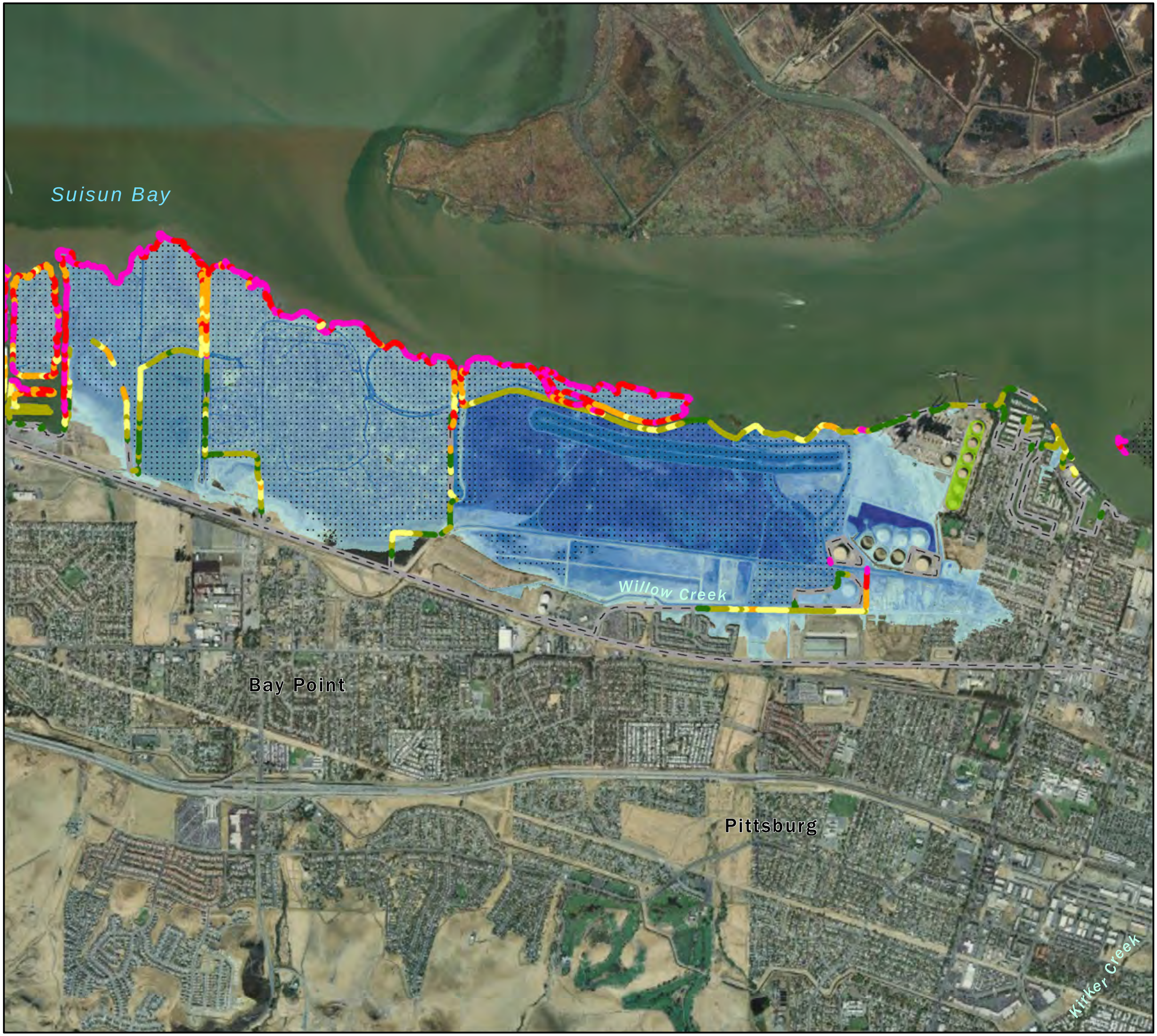
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 52" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 52" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

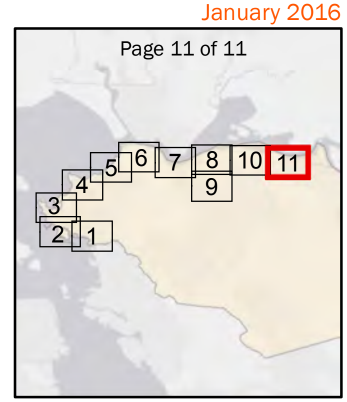
Miles: 0 0.2 0.4 0.6

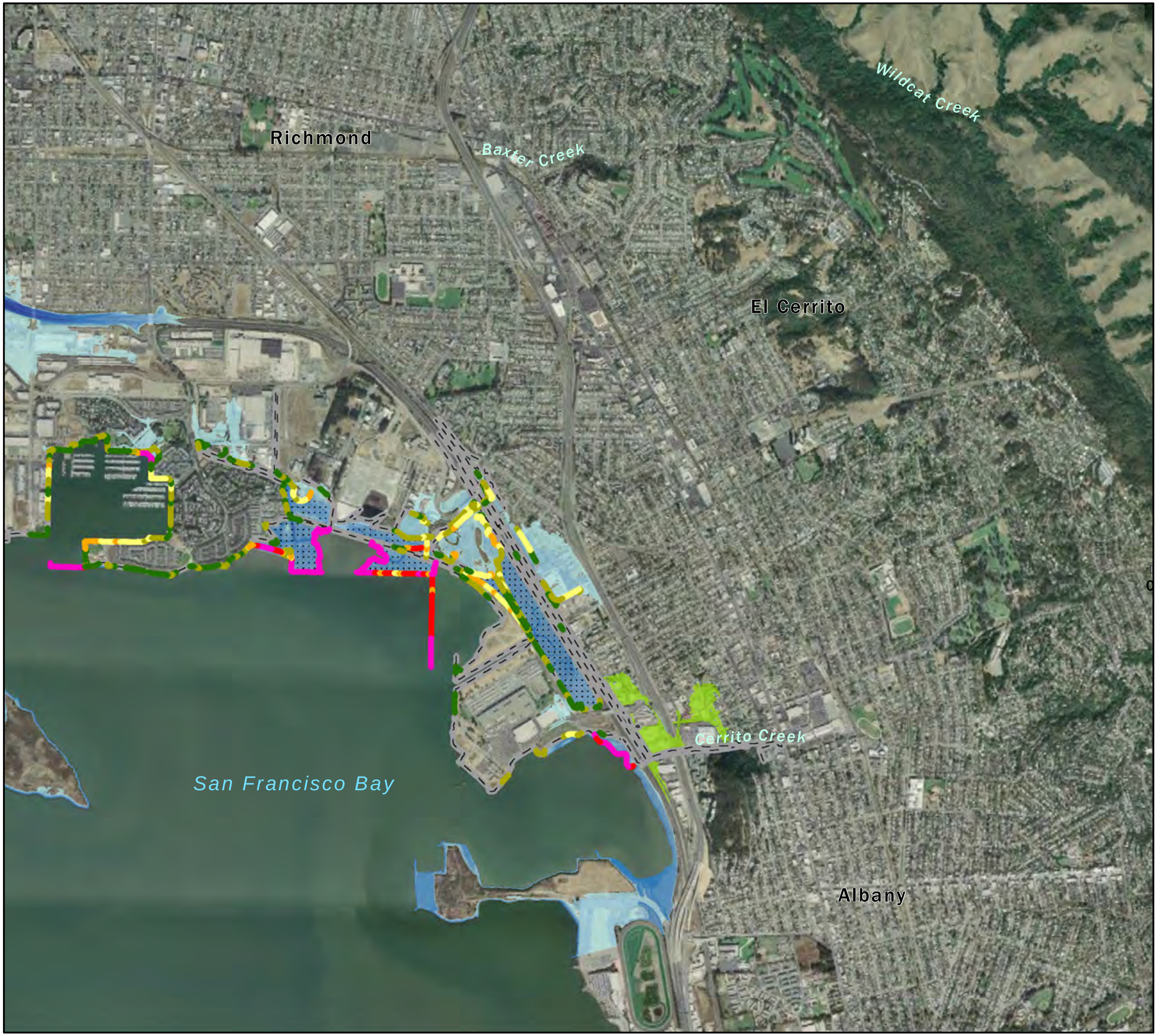
Feet: 0 1,000 2,000 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 66" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 66" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

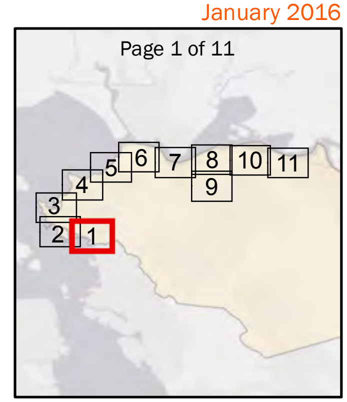
Miles: 0, 0.2, 0.4, 0.6

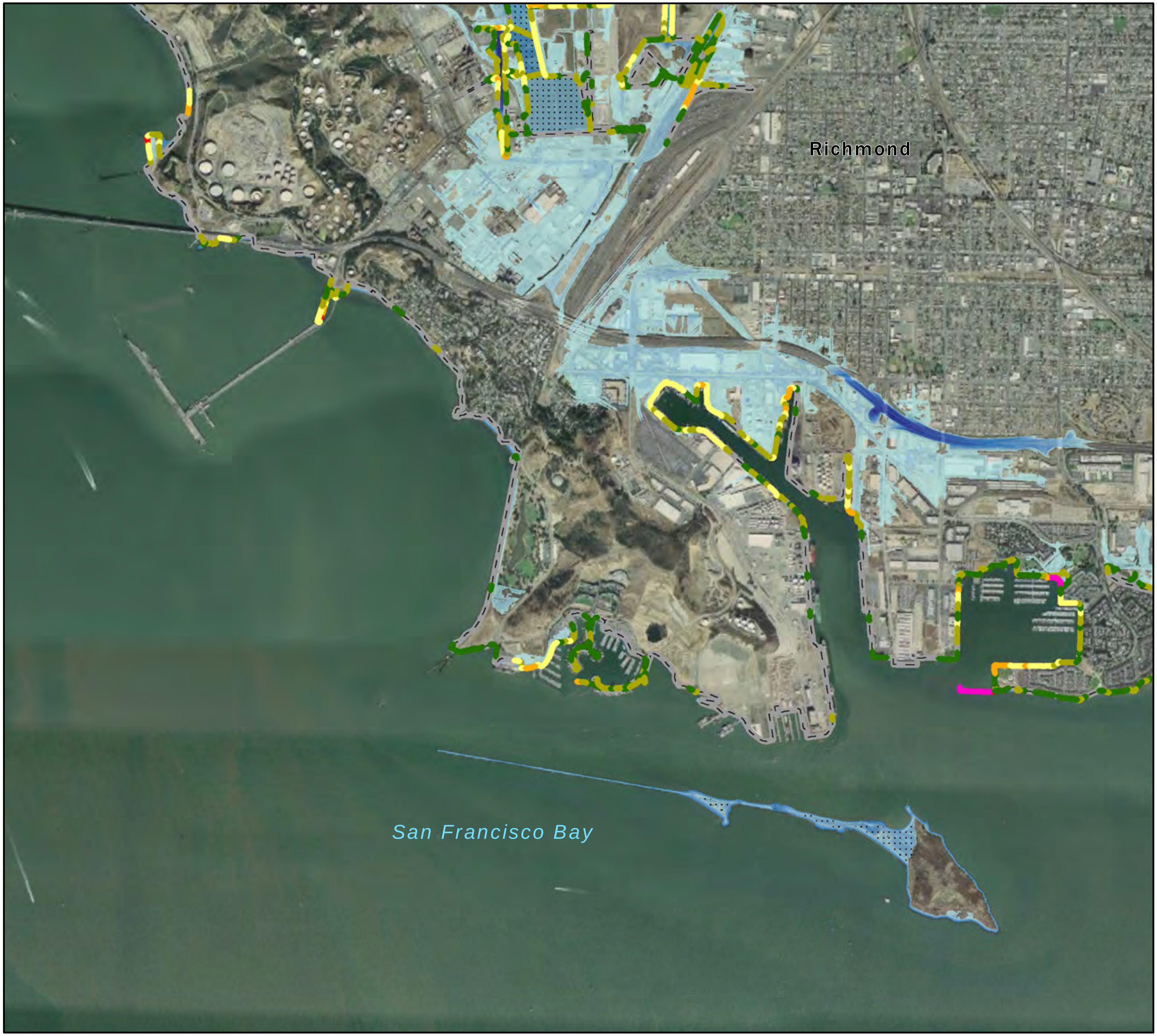
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 66" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping

MHHW + 66" Sea Level Rise

Depth in Feet
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16+
Disconnected Areas > 1 Acre

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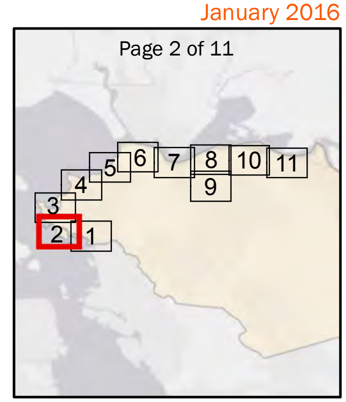
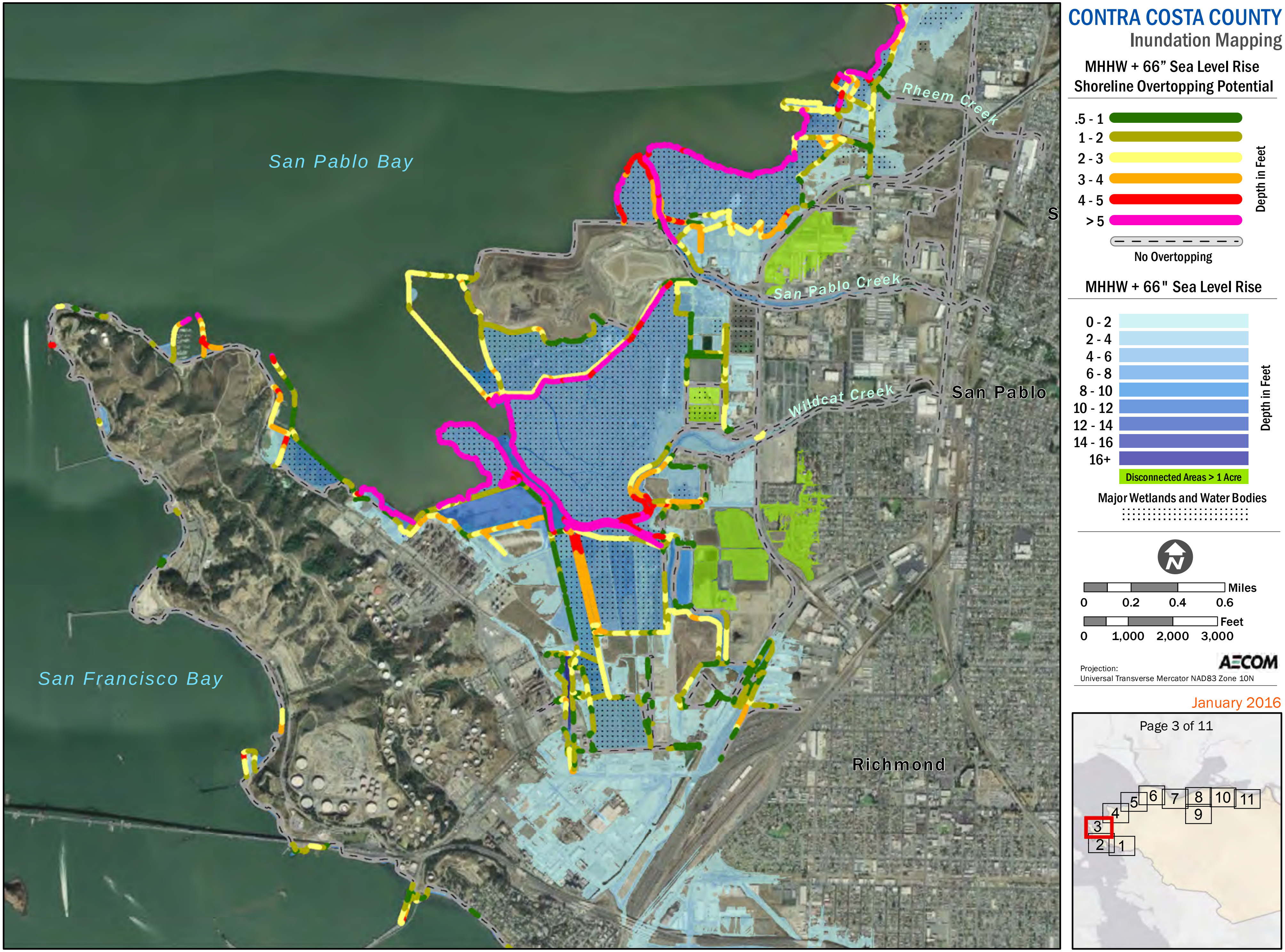
Miles: 0, 0.2, 0.4, 0.6
Feet: 0, 1,000, 2,000, 3,000

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016




CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 66" Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
MHHW + 66" Sea Level Rise
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12 - 14
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16+
Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies
N
Miles
0 0.2 0.4 0.6
Feet
0 1,000 2,000 3,000
Projection:
Universal Transverse Mercator NAD83 Zone 10N
AECOM
January 2016
Page 3 of 11
1 2 3 4 5 6 7 8 9 10 11
San Pablo Bay
San Francisco Bay
Rheem Creek
San Pablo Creek
Wildcat Creek
San Pablo
Richmond

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 66" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
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- 4 - 5
- > 5
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MHHW + 66" Sea Level Rise

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- 12 - 14
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- 16+
- Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

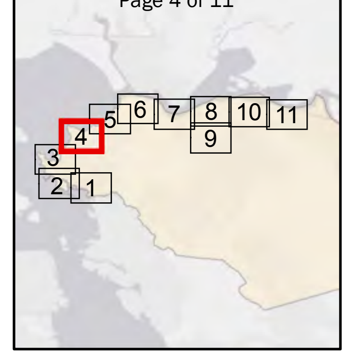
Miles: 0 0.2 0.4 0.6

Feet: 0 1,000 2,000 3,000

AECOM

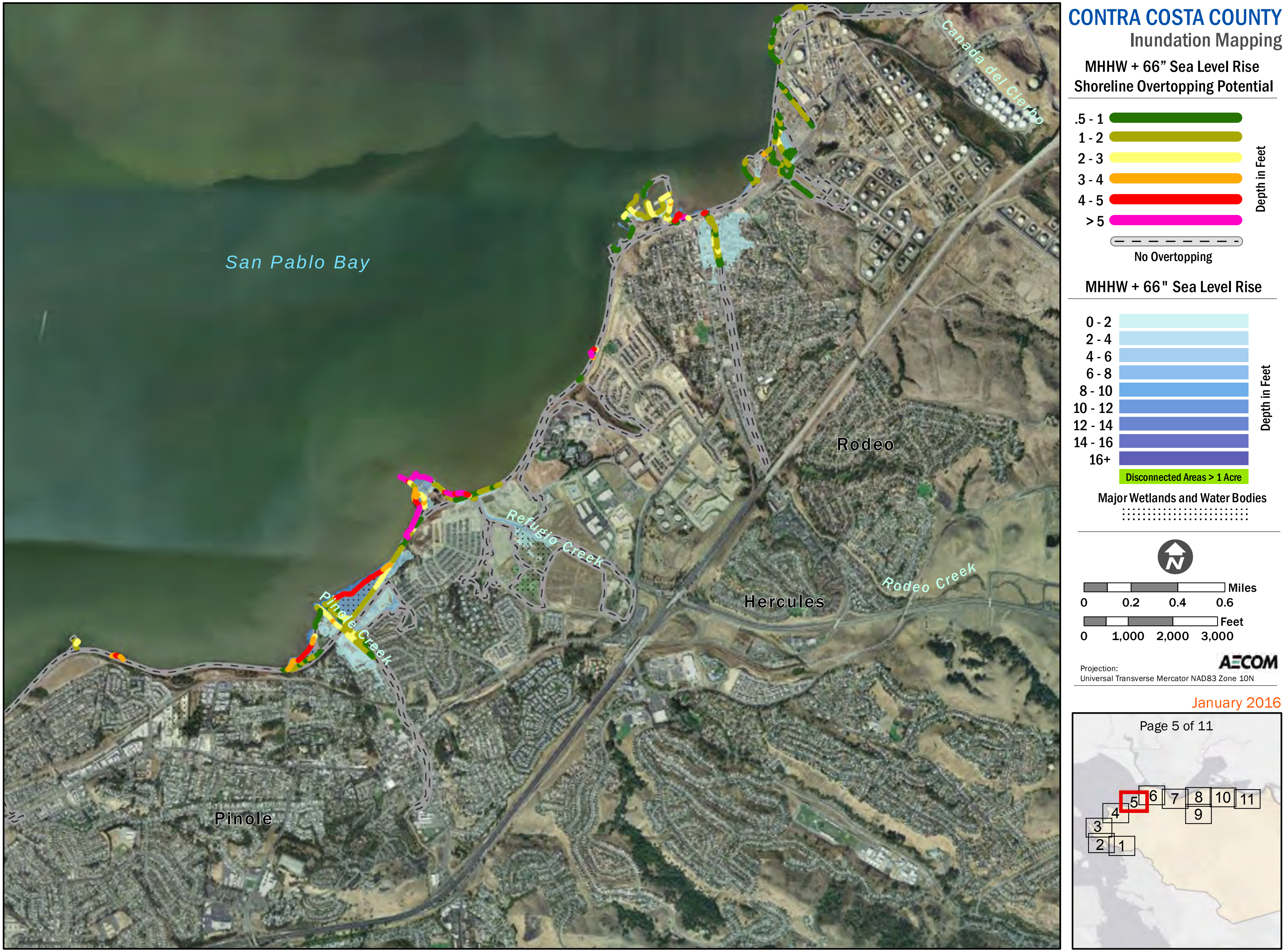
Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY

Inundation Mapping



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 66" Sea Level Rise
Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
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MHHW + 66" Sea Level Rise

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- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

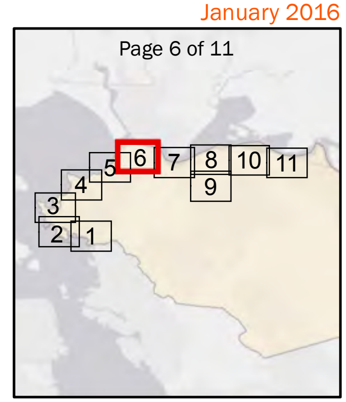
Miles: 0, 0.2, 0.4, 0.6

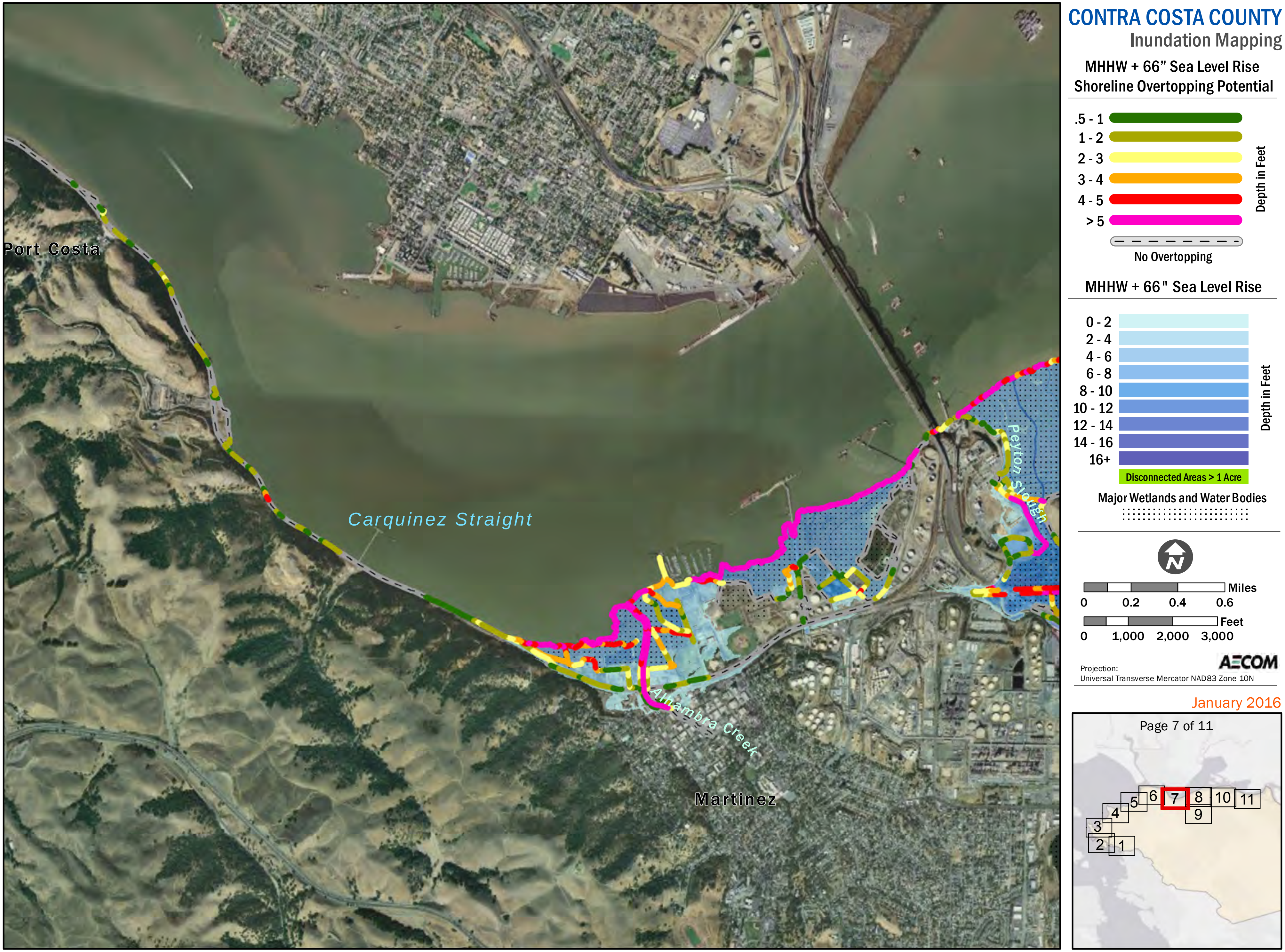
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016




CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 66" Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
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> 5
Depth in Feet
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MHHW + 66" Sea Level Rise
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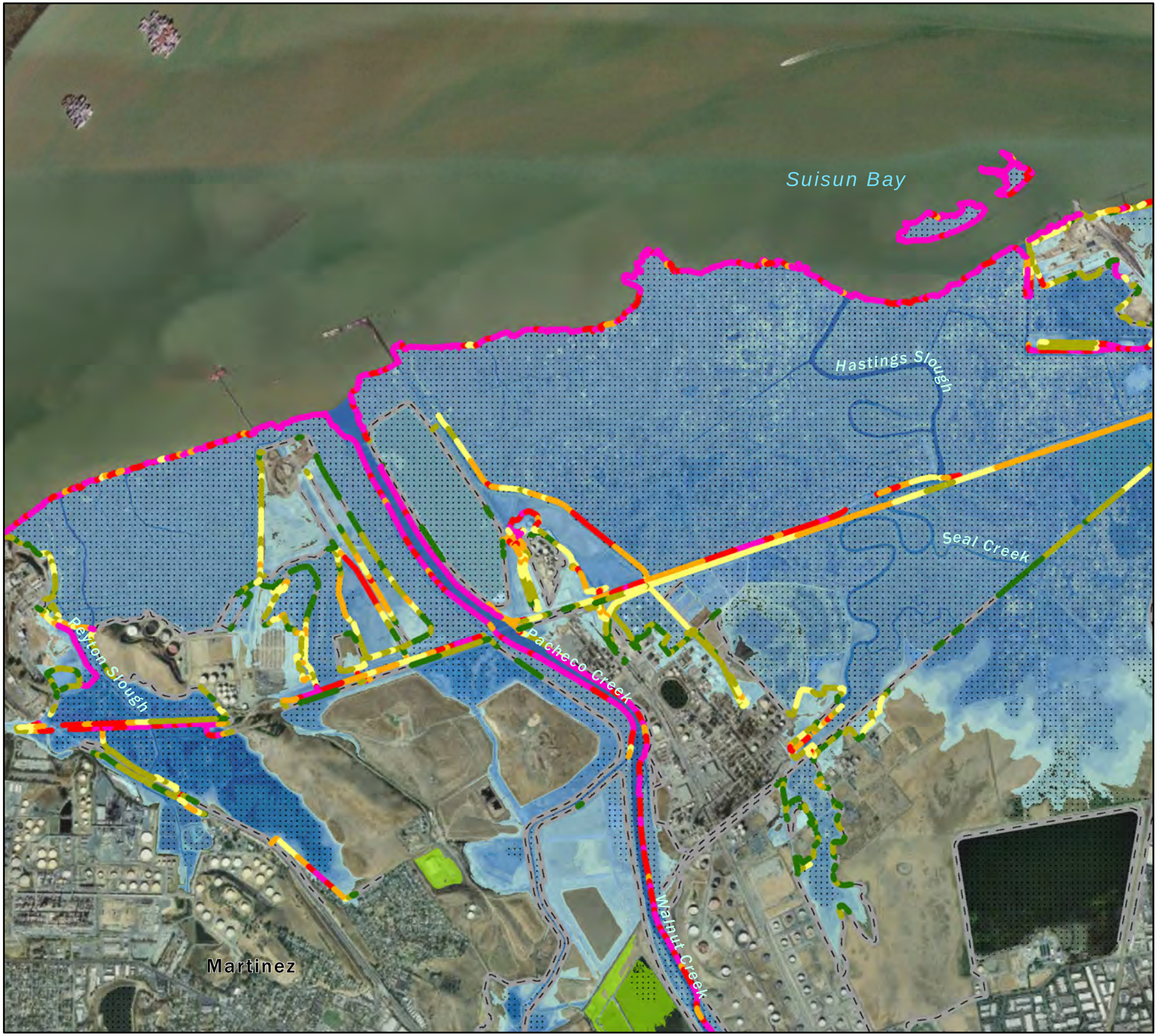
Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies
N
Miles
0 0.2 0.4 0.6
Feet
0 1,000 2,000 3,000
AECOM
Projection:
Universal Transverse Mercator NAD83 Zone 10N
January 2016
Page 7 of 11
1 2 3 4 5 6 7 8 9 10 11
Port Costa
Carquinez Straight
Peyton Slough
Alhambra Creek
Martinez



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 66" Sea Level Rise Shoreline Overtopping Potential

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MHHW + 66" Sea Level Rise

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Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

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Miles: 0, 0.2, 0.4, 0.6

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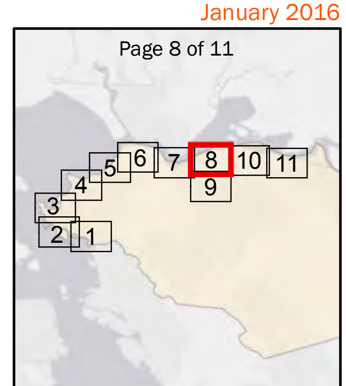
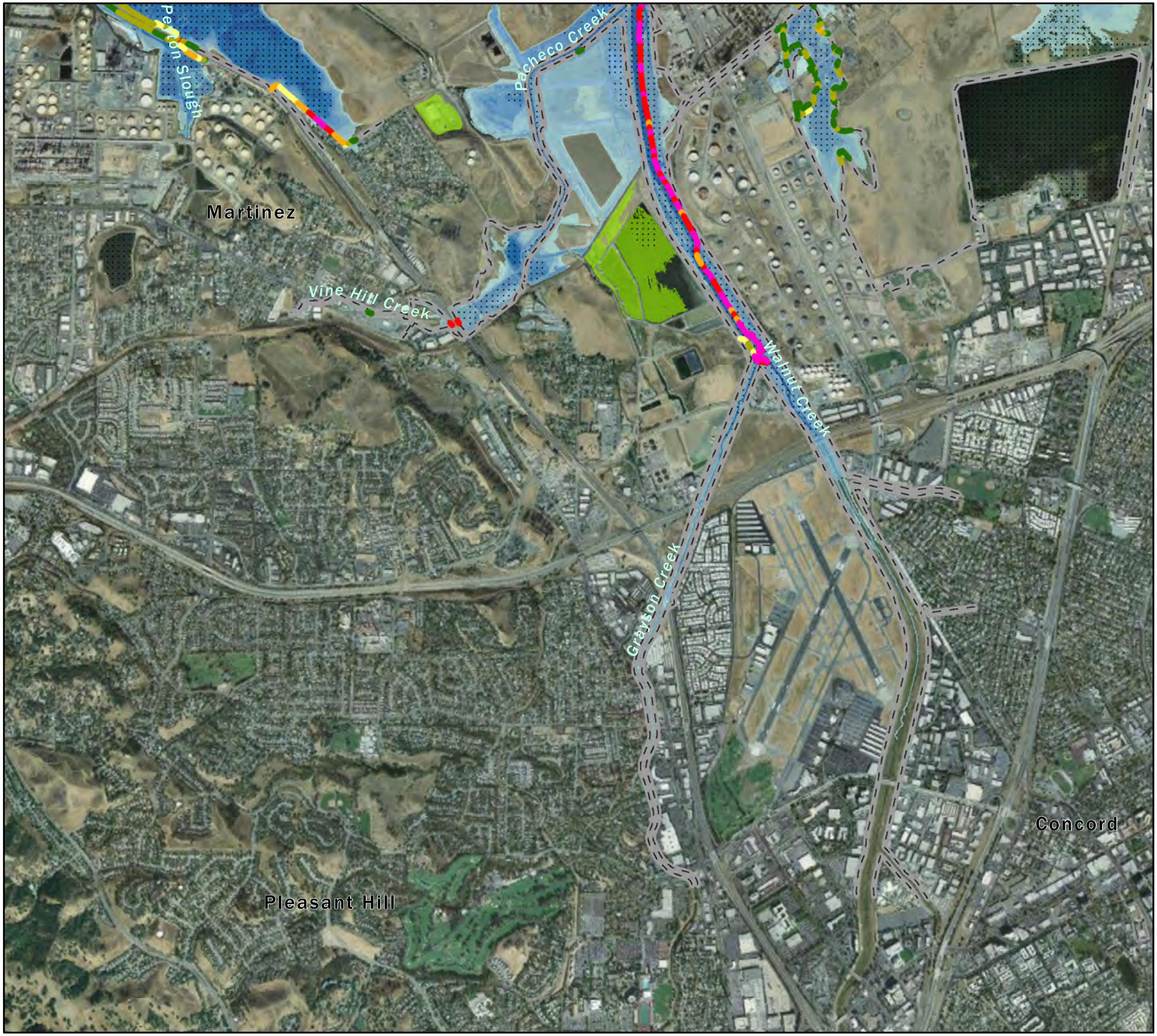
Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 66" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
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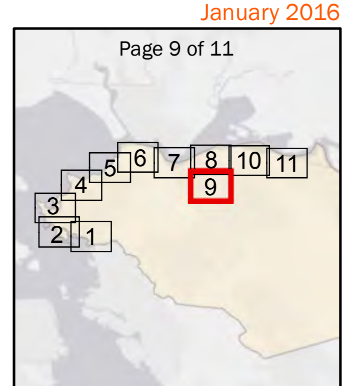
January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 66" Sea Level Rise
Shoreline Overtopping Potential

Depth in Feet
.5 - 1
1 - 2
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> 5

No Overtopping

MHHW + 66" Sea Level Rise

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2 - 4
4 - 6
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14 - 16
16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

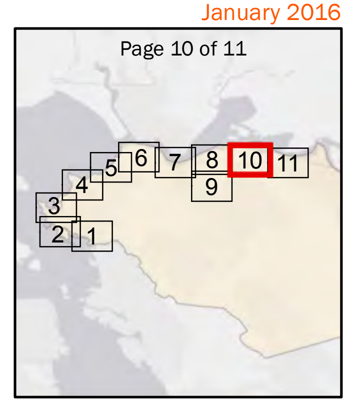
Miles
0 0.2 0.4 0.6

Feet
0 1,000 2,000 3,000

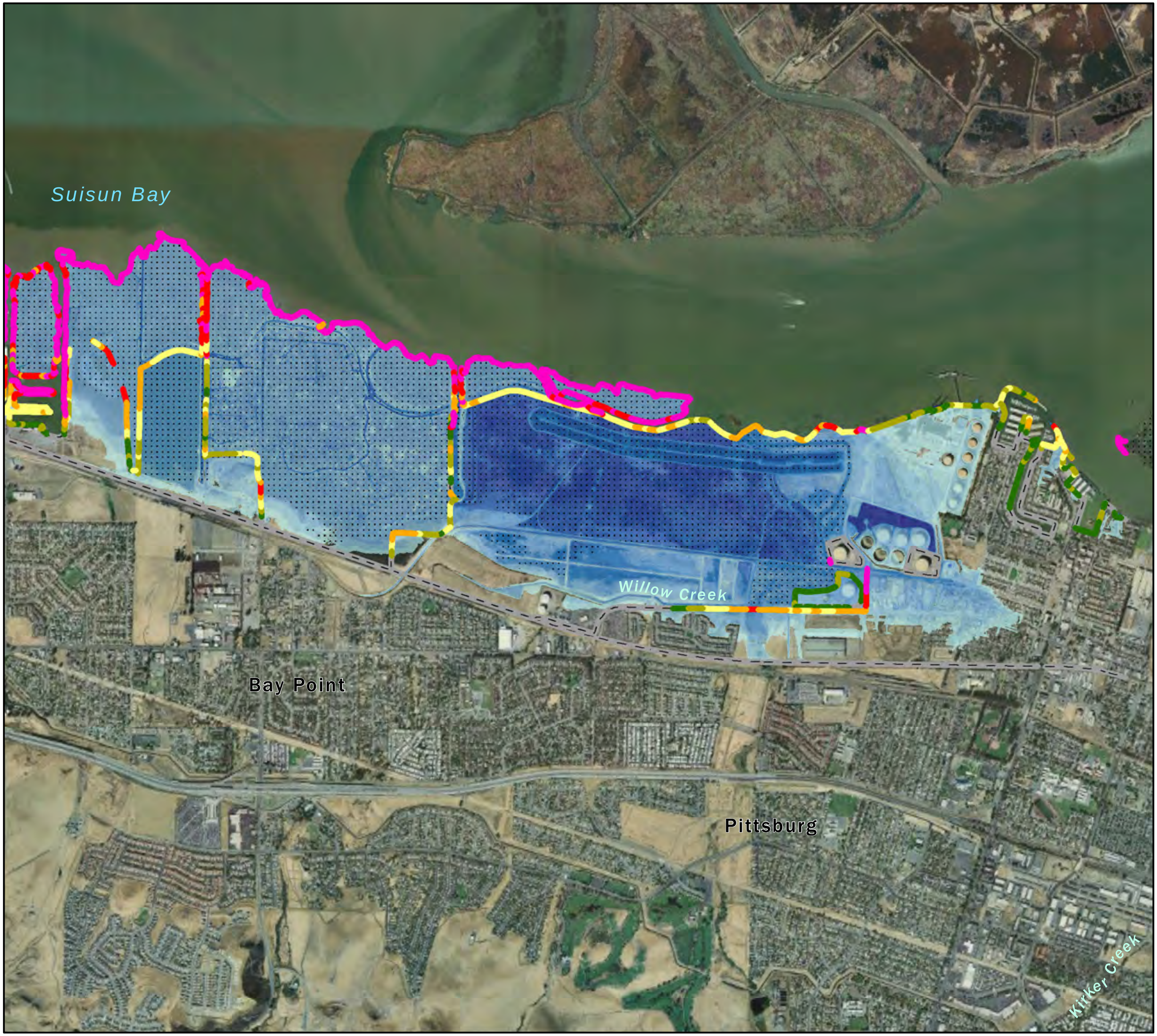
AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY
Inundation Mapping



MHHW + 66" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5
- No Overtopping

MHHW + 66" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+
- Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

Miles: 0, 0.2, 0.4, 0.6

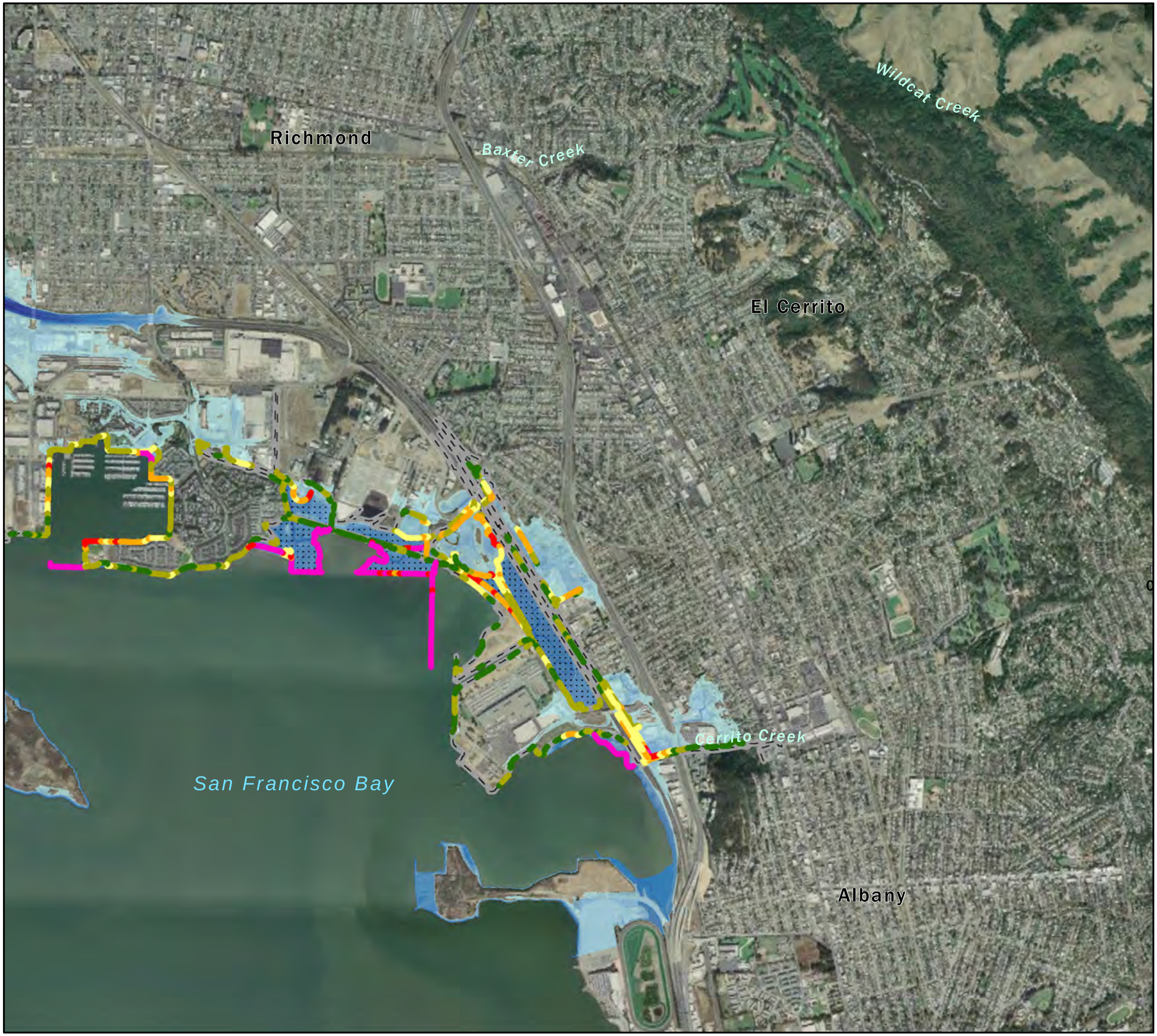
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016

1 2 3 4 5 6 7 8 9 10 11



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 77" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 77" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

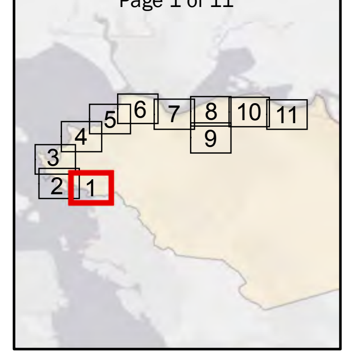
Miles: 0 0.2 0.4 0.6

Feet: 0 1,000 2,000 3,000

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 77" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 77" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

Miles: 0, 0.2, 0.4, 0.6

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AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

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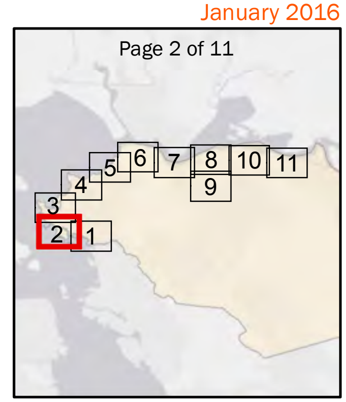

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 77" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
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MHHW + 77" Sea Level Rise

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- 0 - 2
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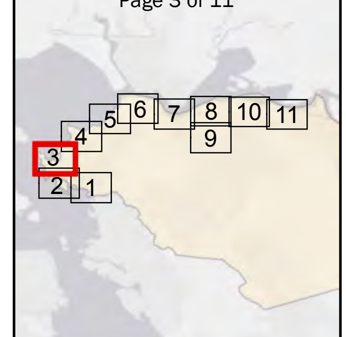
Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 77" Sea Level Rise
Shoreline Overtopping Potential

Depth in Feet
.5 - 1
1 - 2
2 - 3
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MHHW + 77" Sea Level Rise

Depth in Feet
0 - 2
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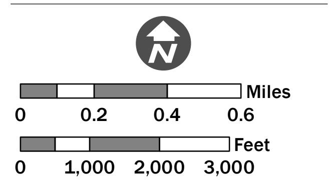
Disconnected Areas > 1 Acre

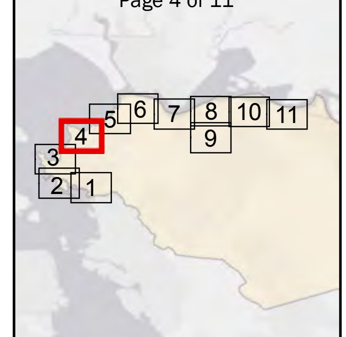
Major Wetlands and Water Bodies



AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 77" Sea Level Rise Shoreline Overtopping Potential

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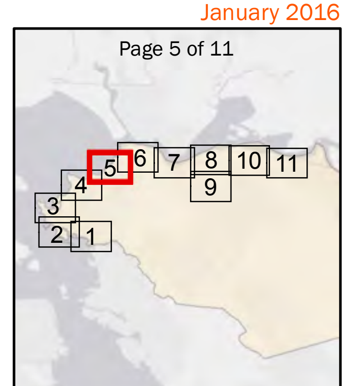
January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 77" Sea Level Rise Shoreline Overtopping Potential

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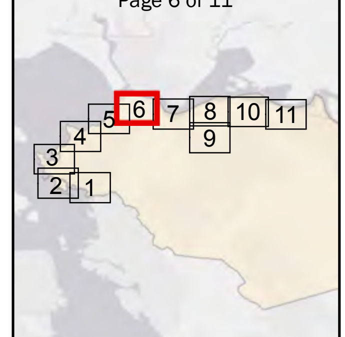
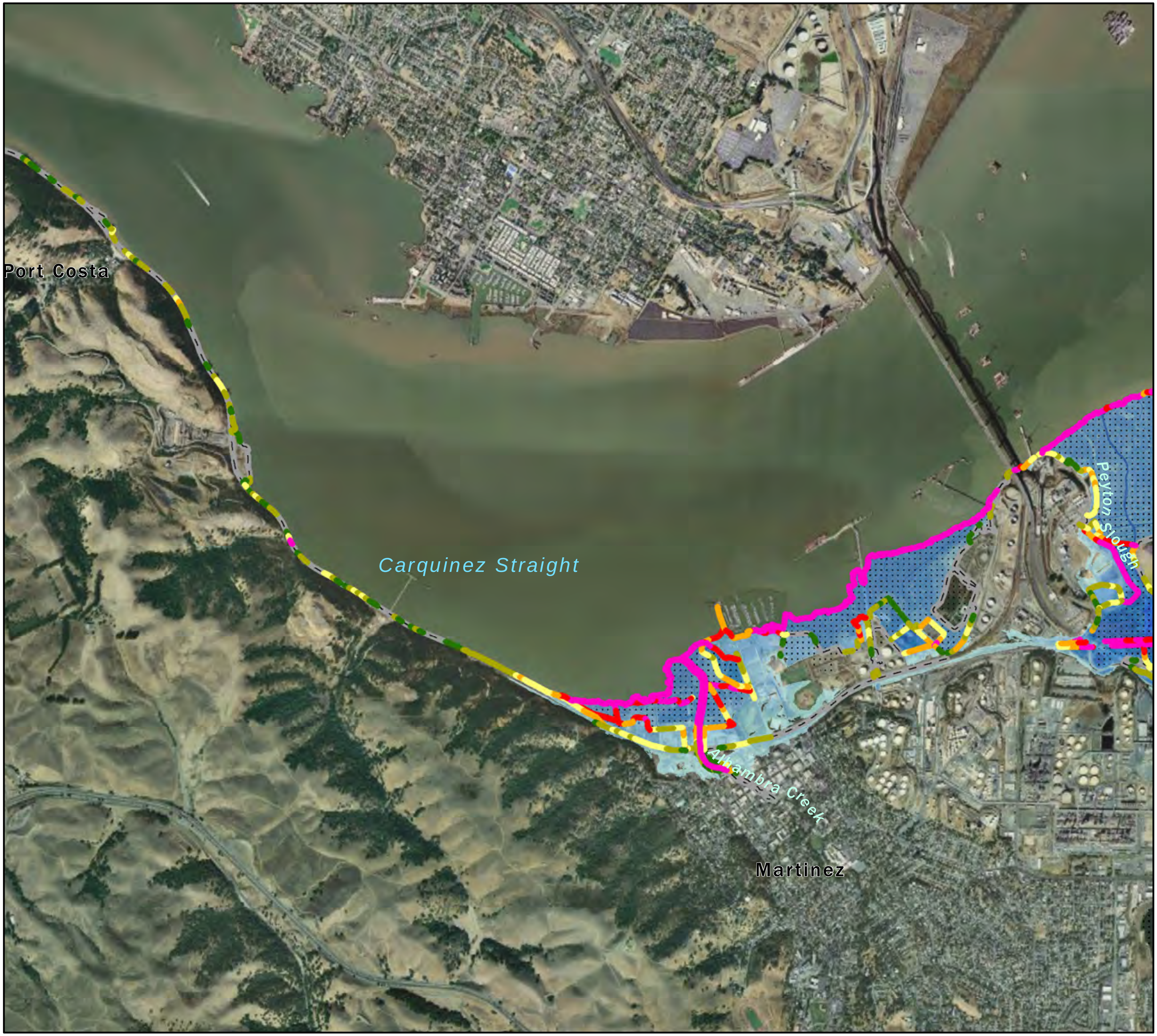
January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 77" Sea Level Rise Shoreline Overtopping Potential

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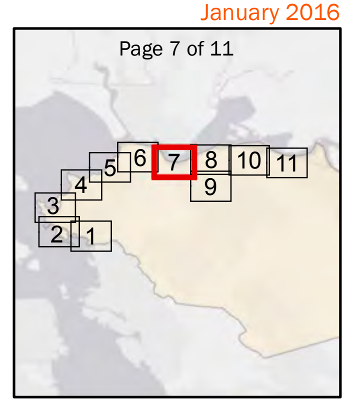
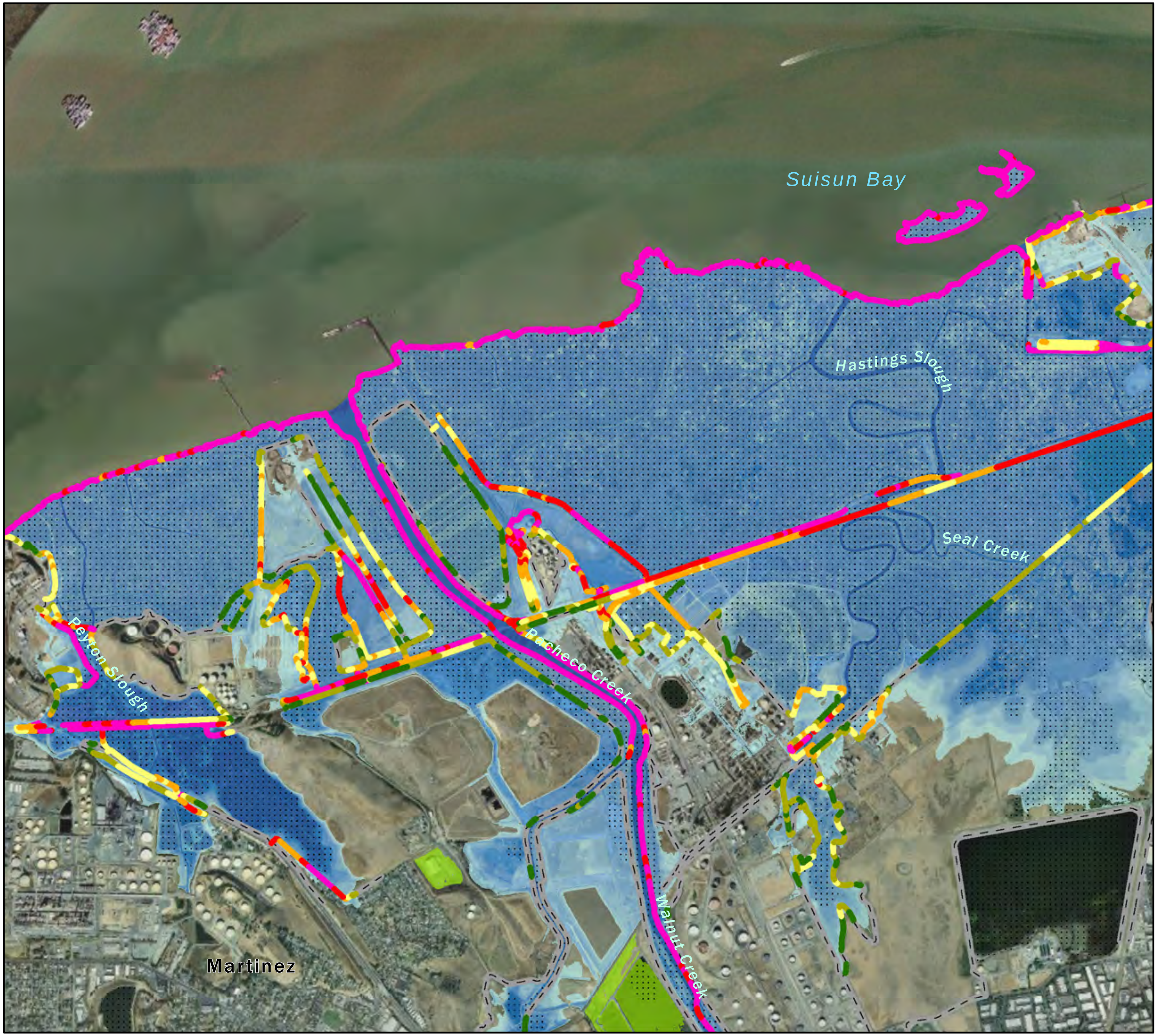
January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 77" Sea Level Rise Shoreline Overtopping Potential

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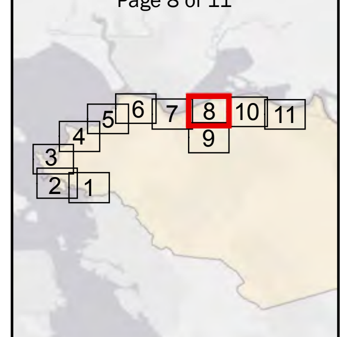
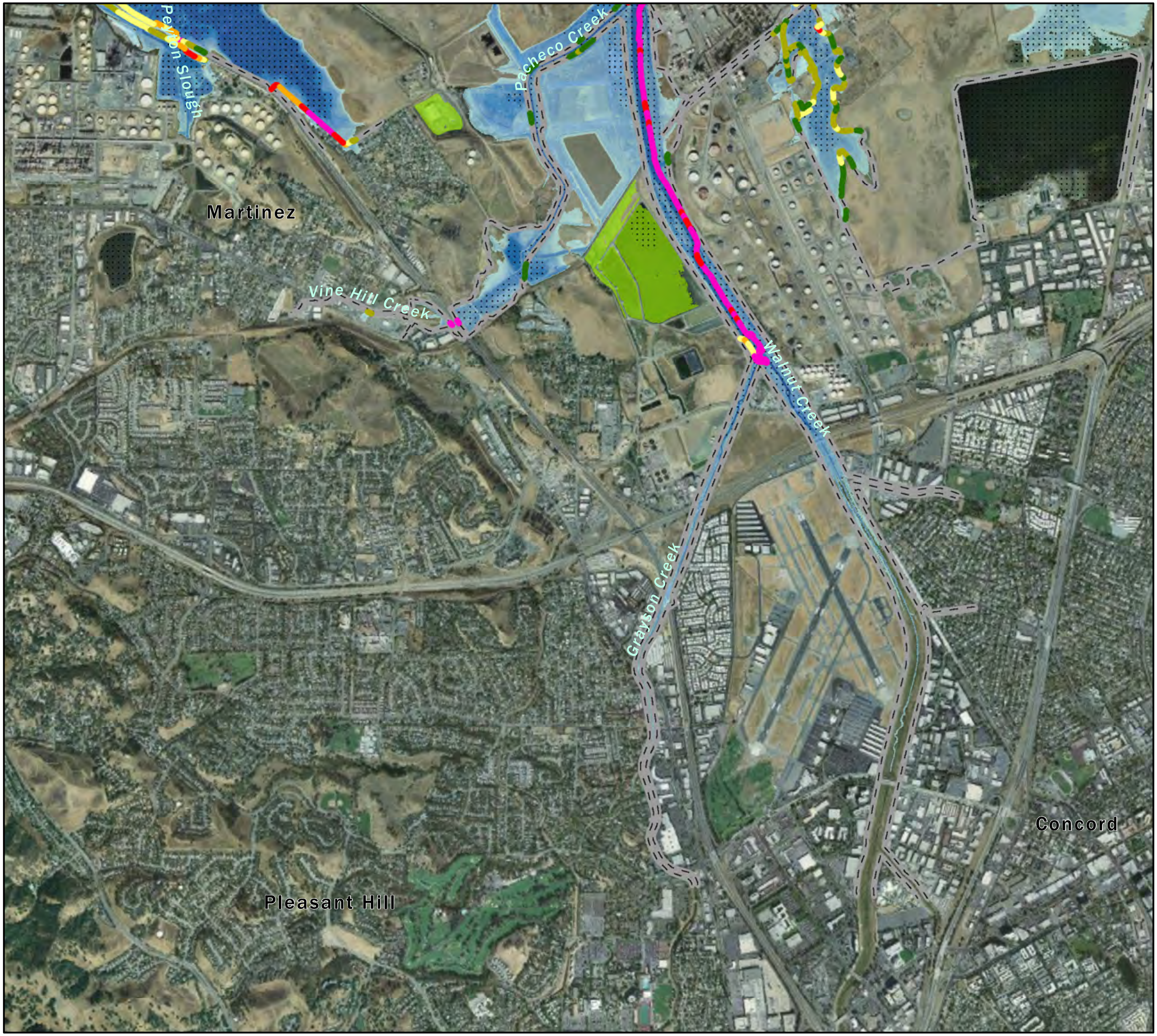
January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 77" Sea Level Rise Shoreline Overtopping Potential

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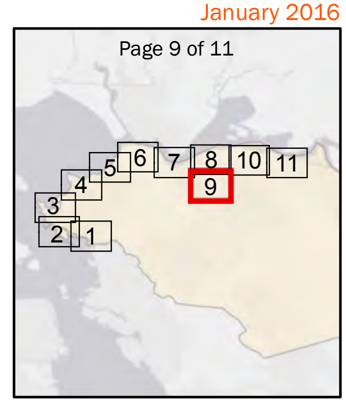
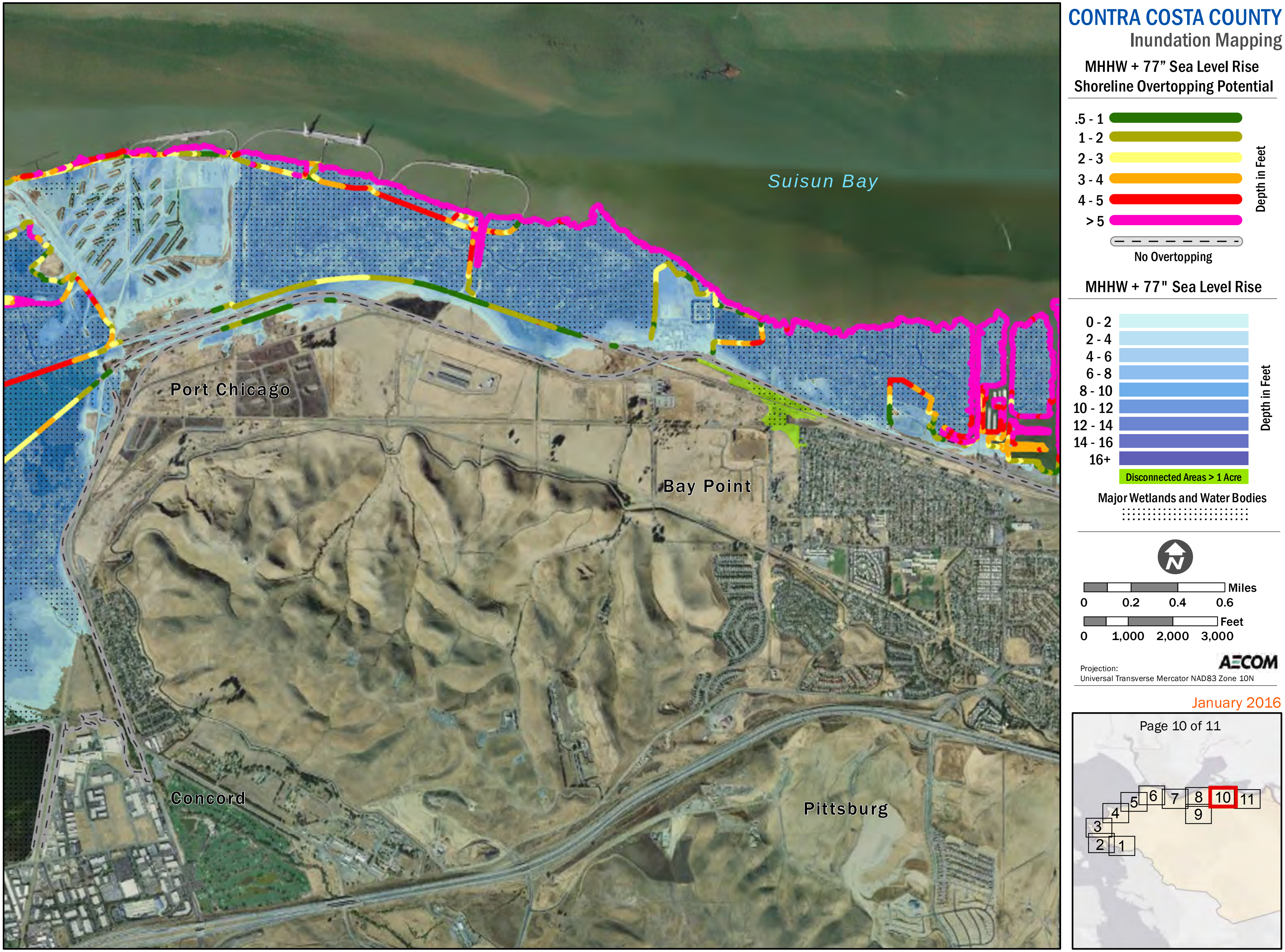
January 2016





Suisun Bay
Port Chicago
Bay Point
Concord
Pittsburg
CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 77" Sea Level Rise
Shoreline Overtopping Potential
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping
MHHW + 77" Sea Level Rise
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies
N
Miles
0 0.2 0.4 0.6
Feet
0 1,000 2,000 3,000
AECOM
Projection:
Universal Transverse Mercator NAD83 Zone 10N
January 2016
Page 10 of 11
1
2
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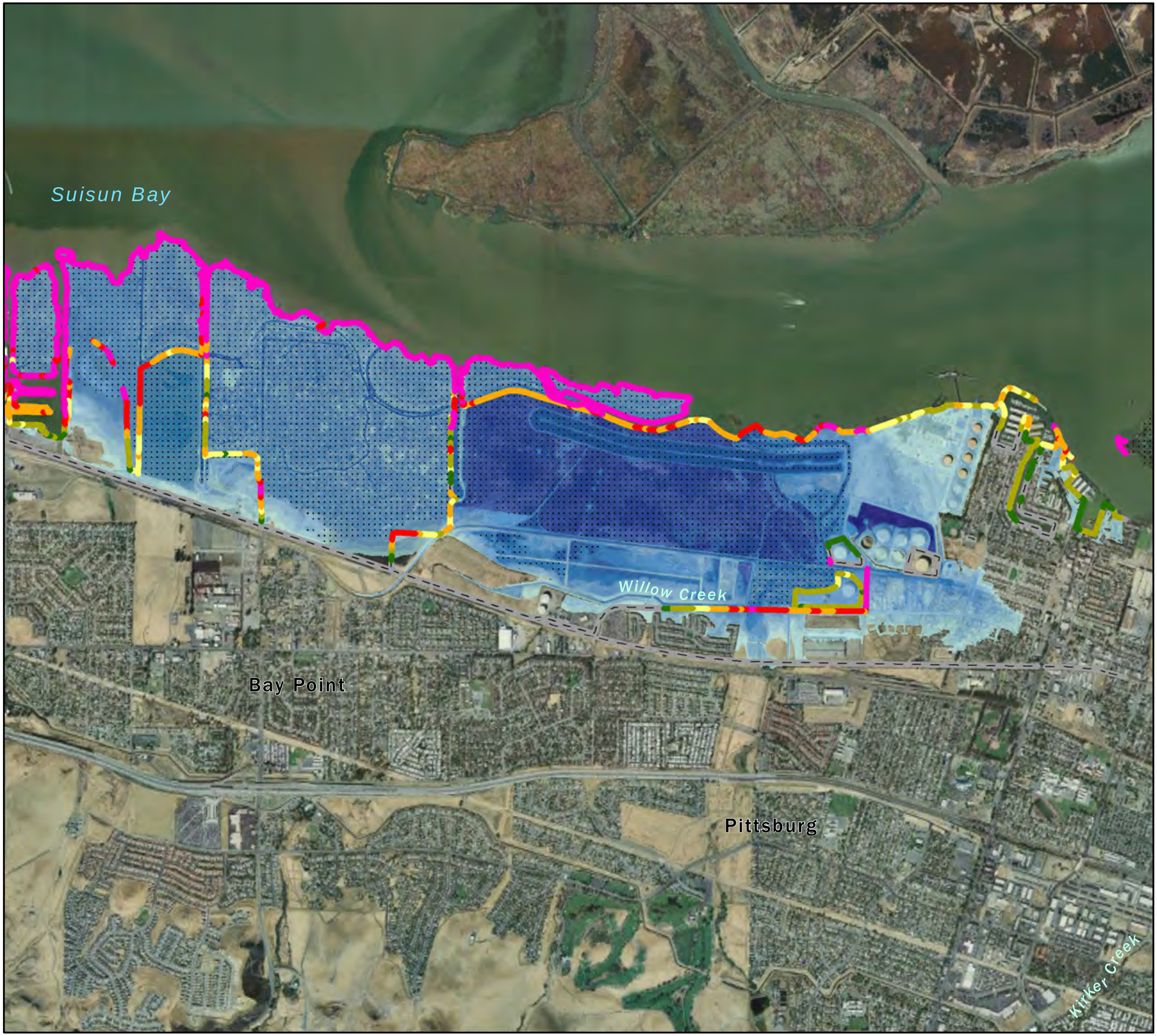

CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 77" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

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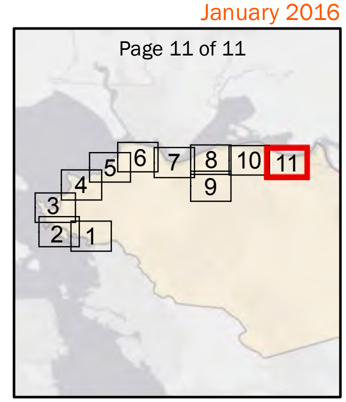
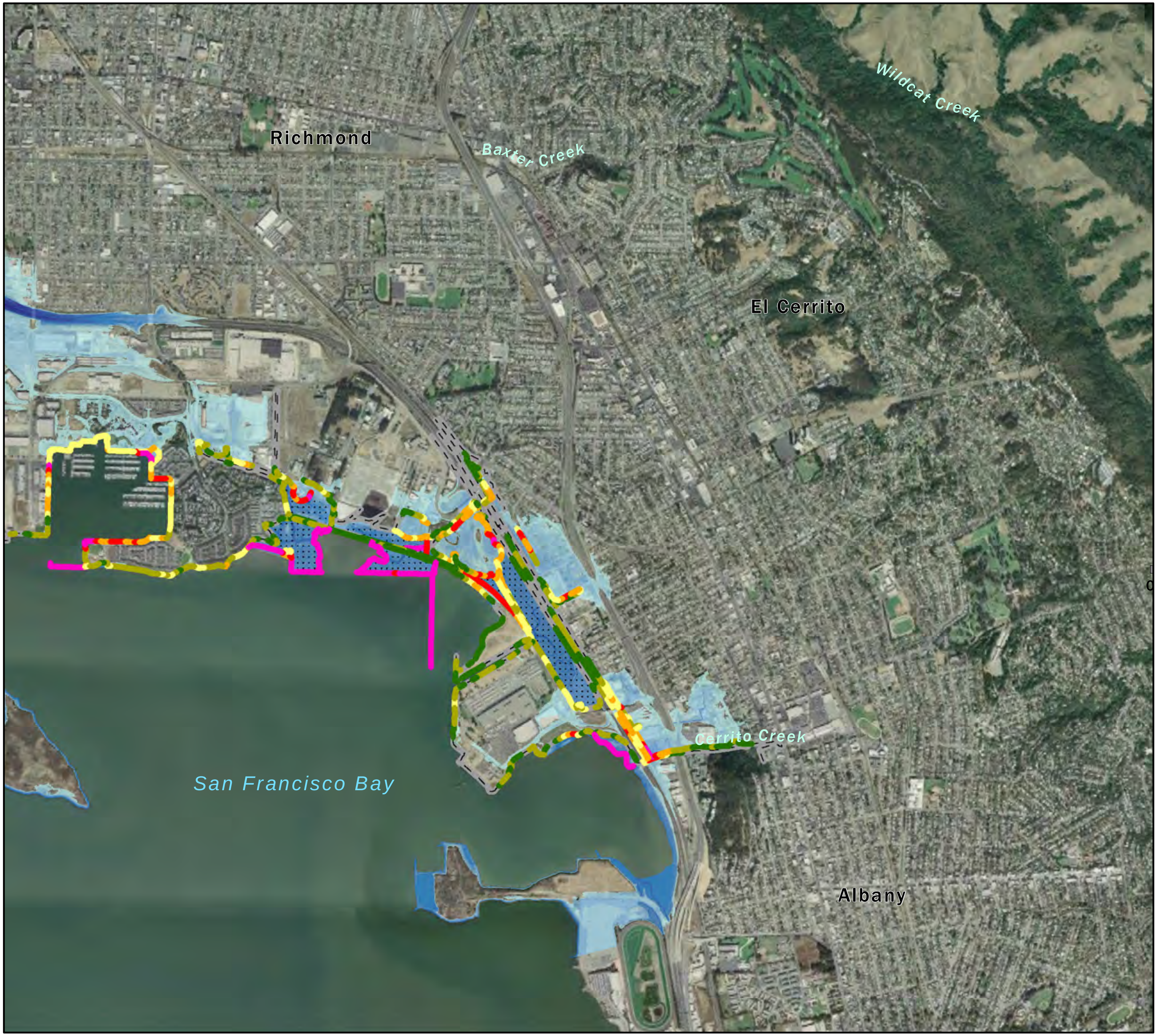


CONTRA COSTA COUNTY
Inundation Mapping



MHHW + 84" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
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- > 5

No Overtopping

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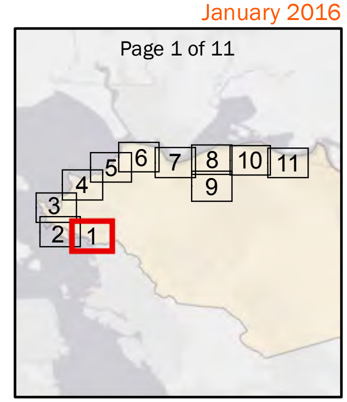

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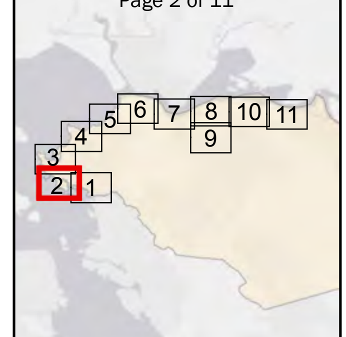

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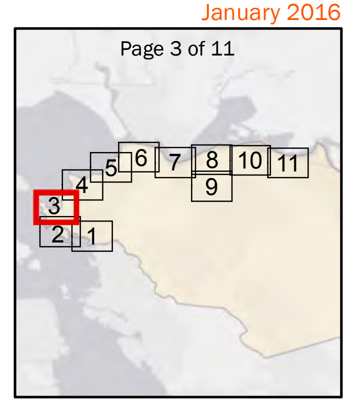

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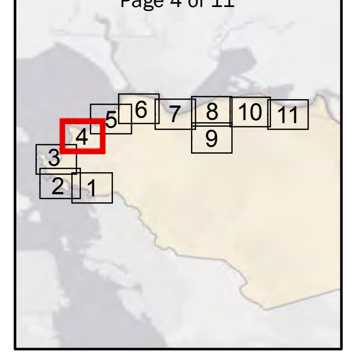

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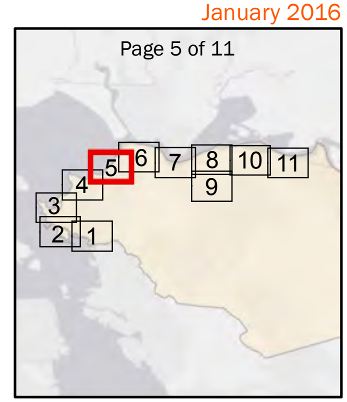

CONTRA COSTA COUNTY
Inundation Mapping

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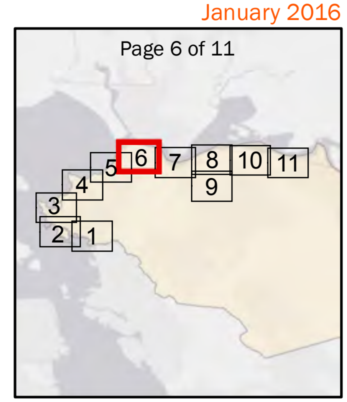

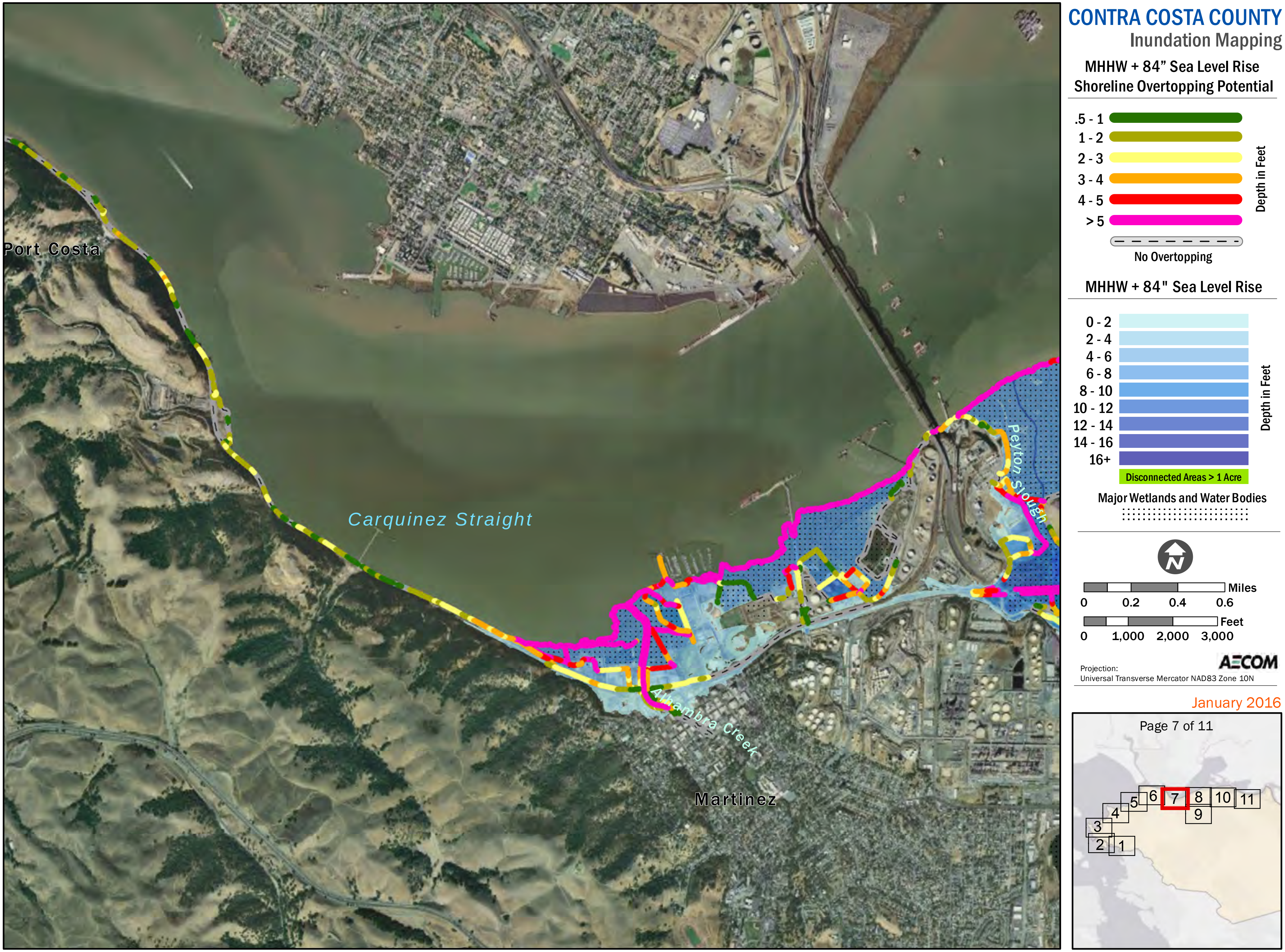
Port Costa
Carquinez Straight
Peyton Slough
Alhambra Creek
Martinez
CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 84" Sea Level Rise
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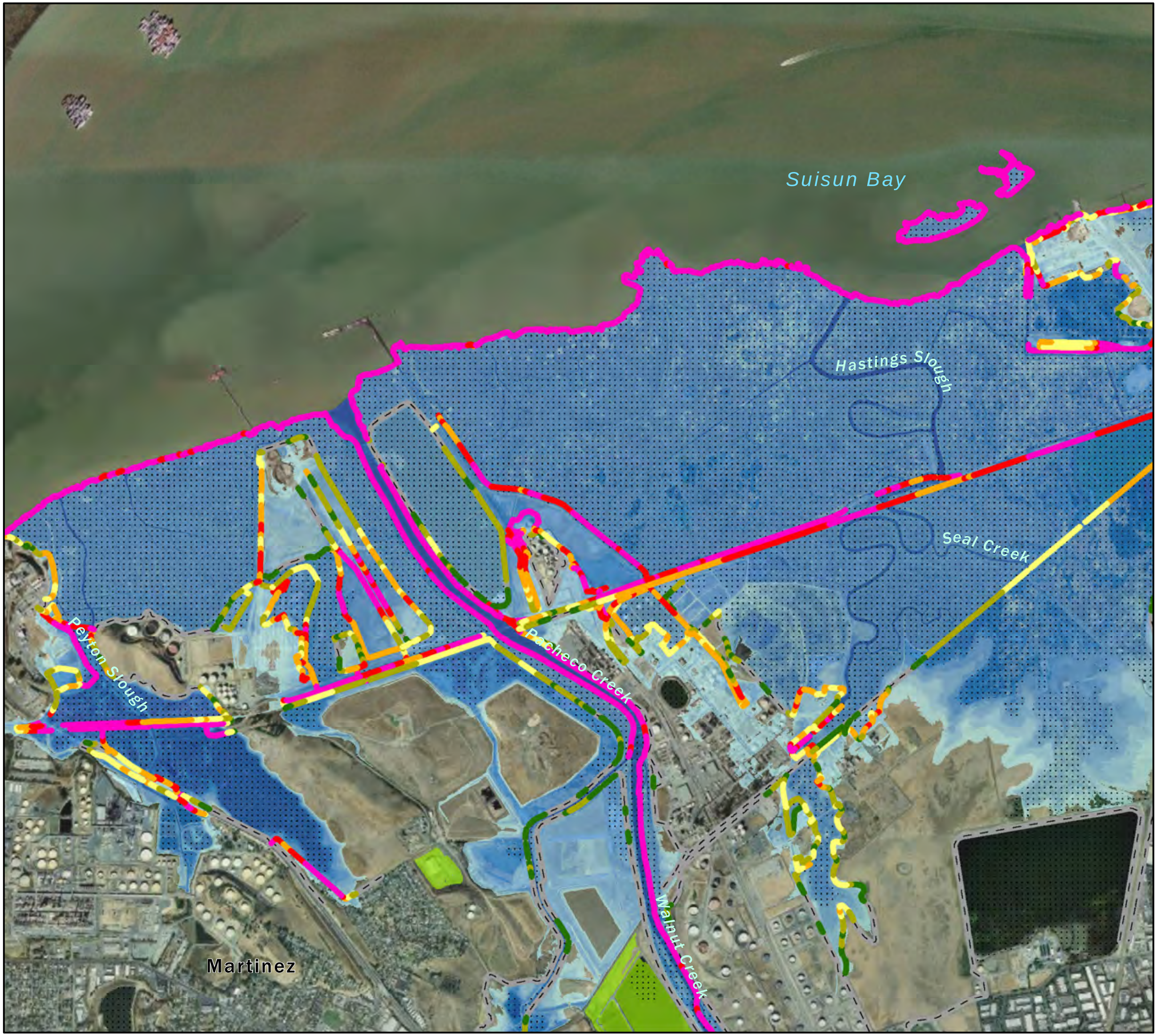

CONTRA COSTA COUNTY

Inundation Mapping

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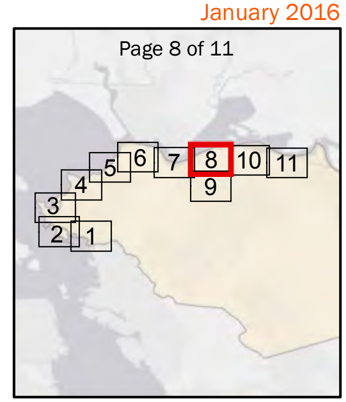

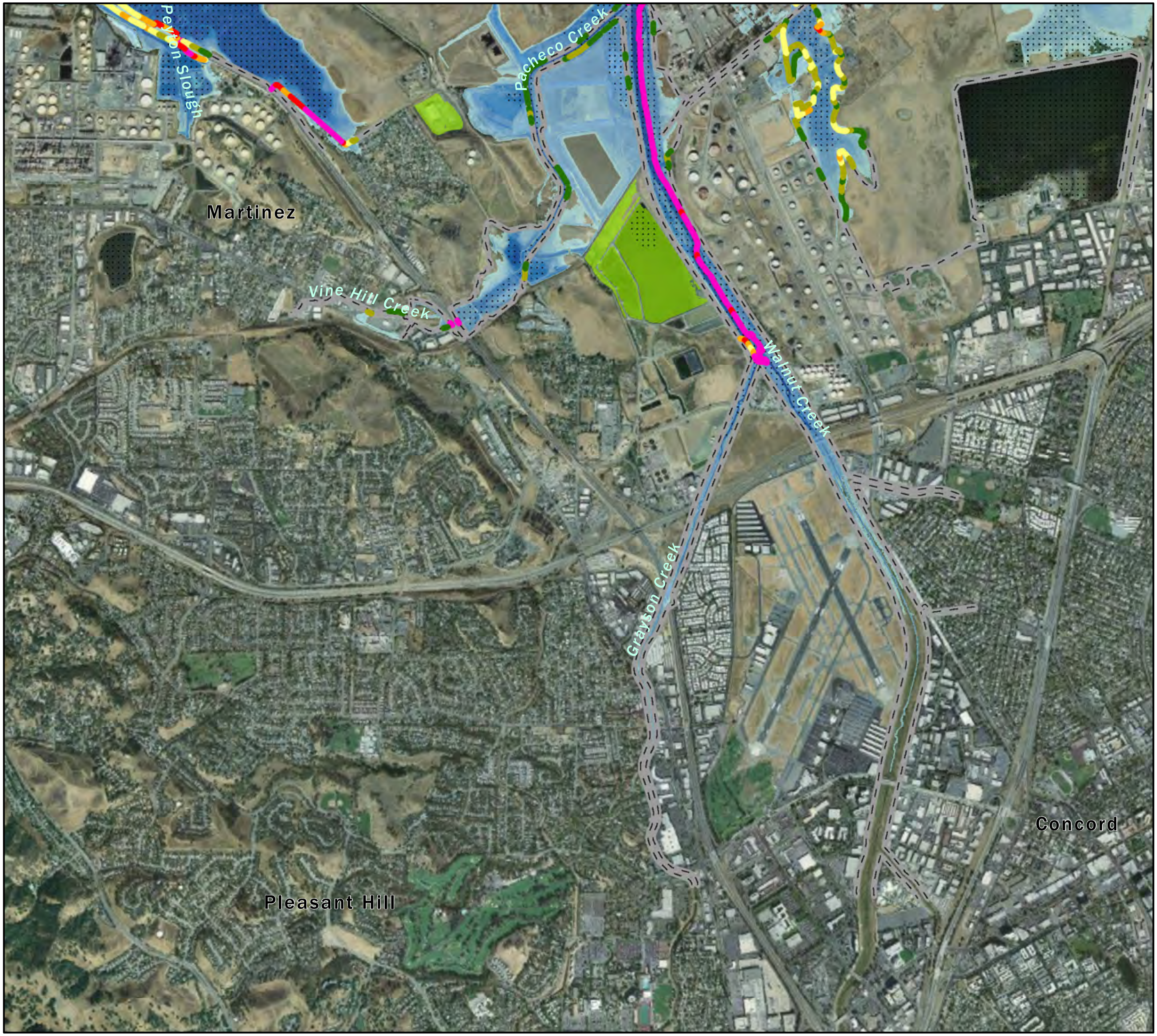

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 84" Sea Level Rise Shoreline Overtopping Potential

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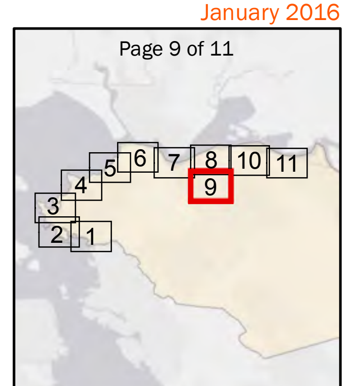

CONTRA COSTA COUNTY

Inundation Mapping

MHHW + 84" Sea Level Rise
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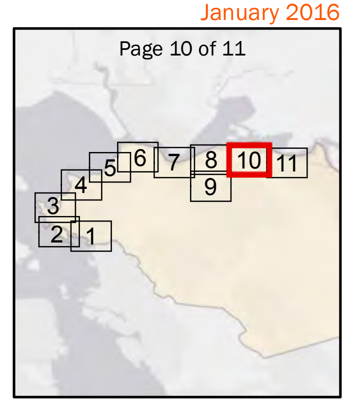

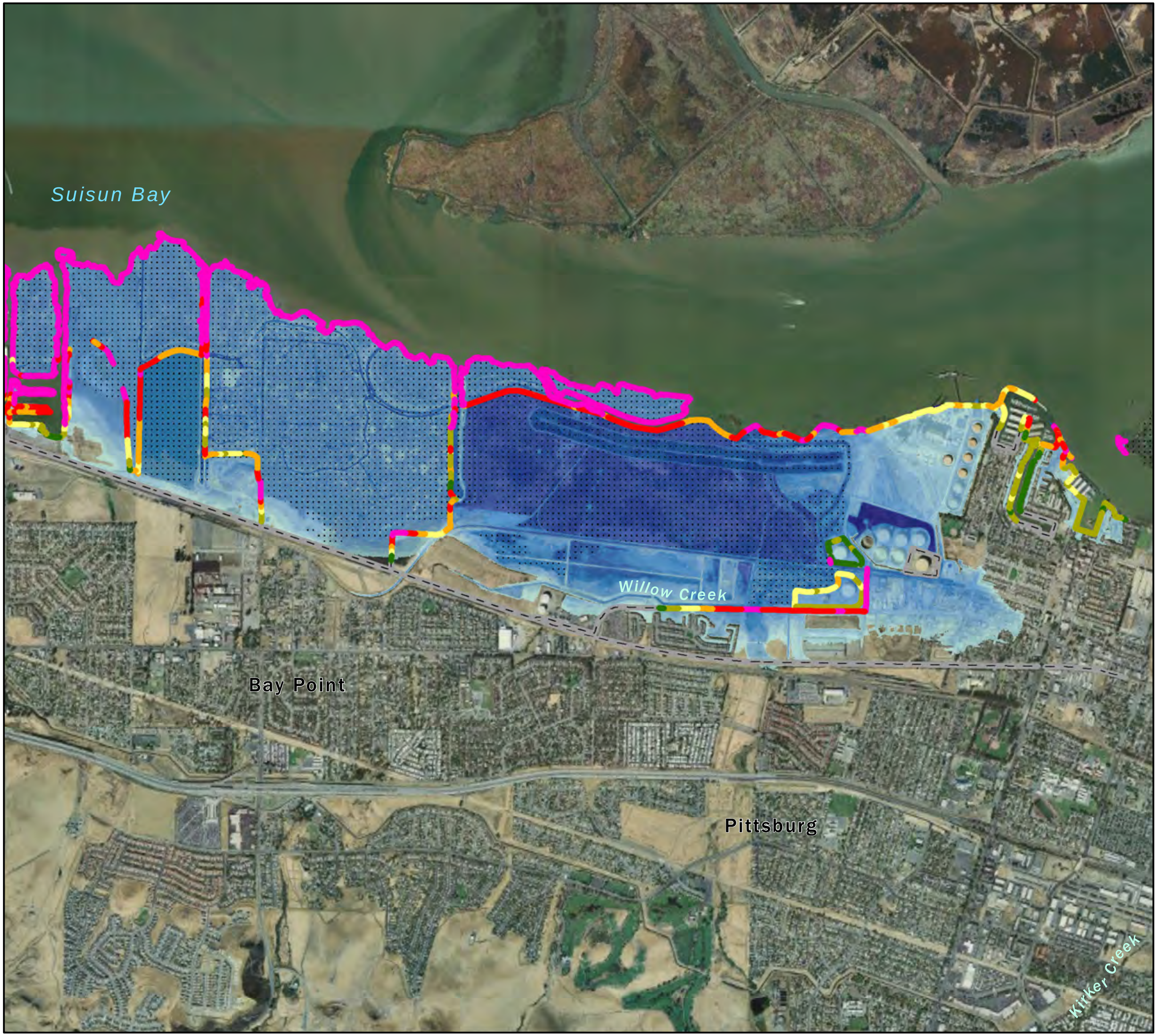

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 84" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
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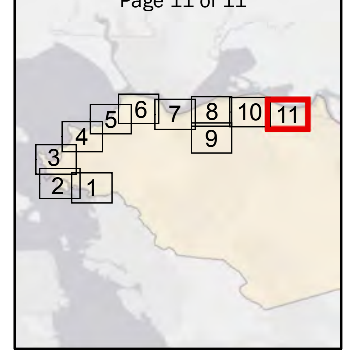

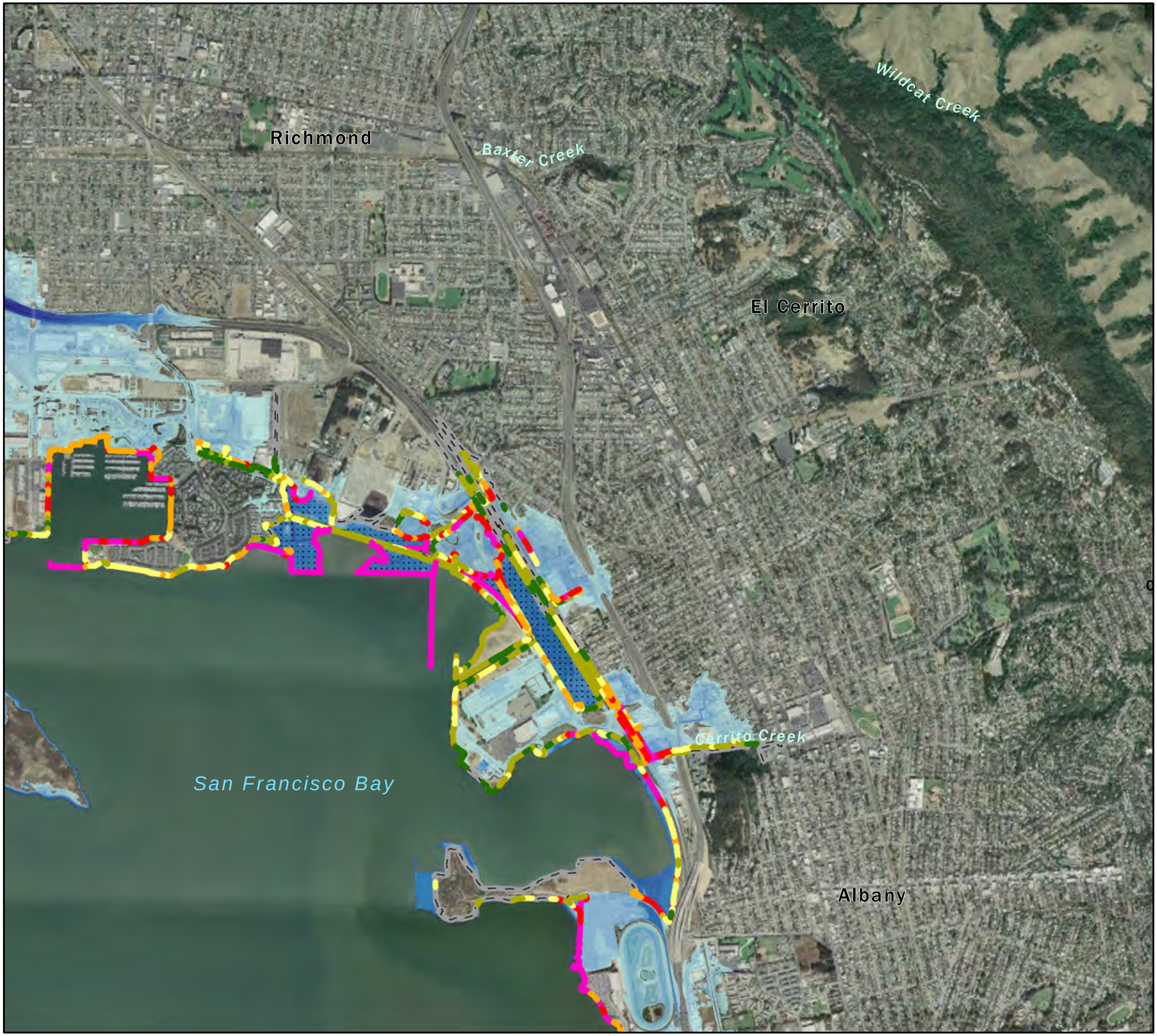

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 96" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 96" Sea Level Rise

Depth in Feet
- 0 - 2
- 2 - 4
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- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

N

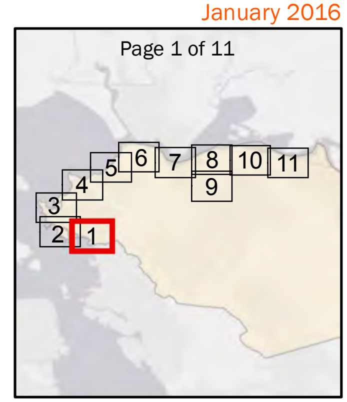
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 96" Sea Level Rise
Shoreline Overtopping Potential

.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
Depth in Feet
No Overtopping

MHHW + 96" Sea Level Rise

0 - 2
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16+
Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies

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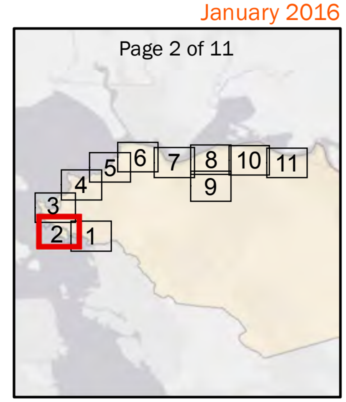
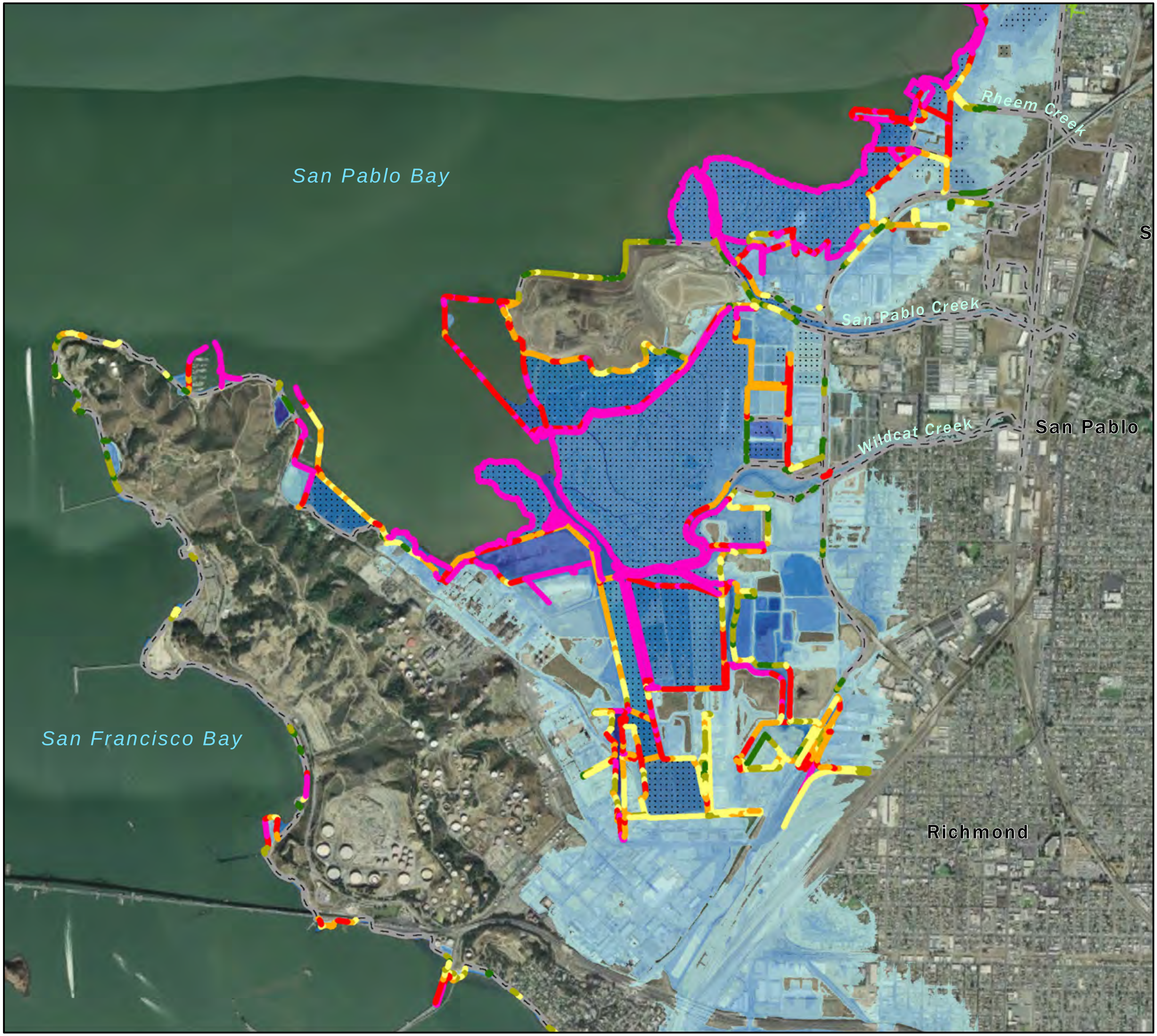


CONTRA COSTA COUNTY
Inundation Mapping



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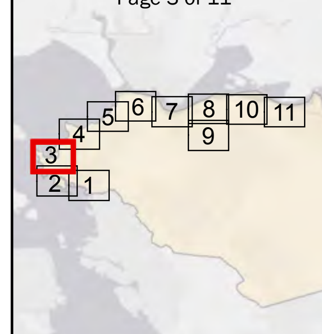

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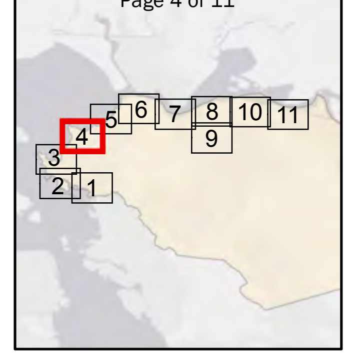

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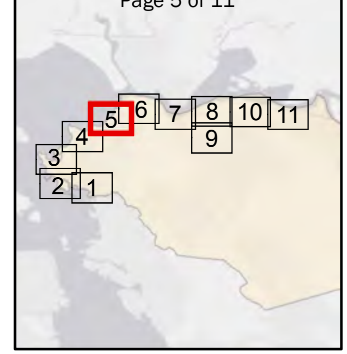

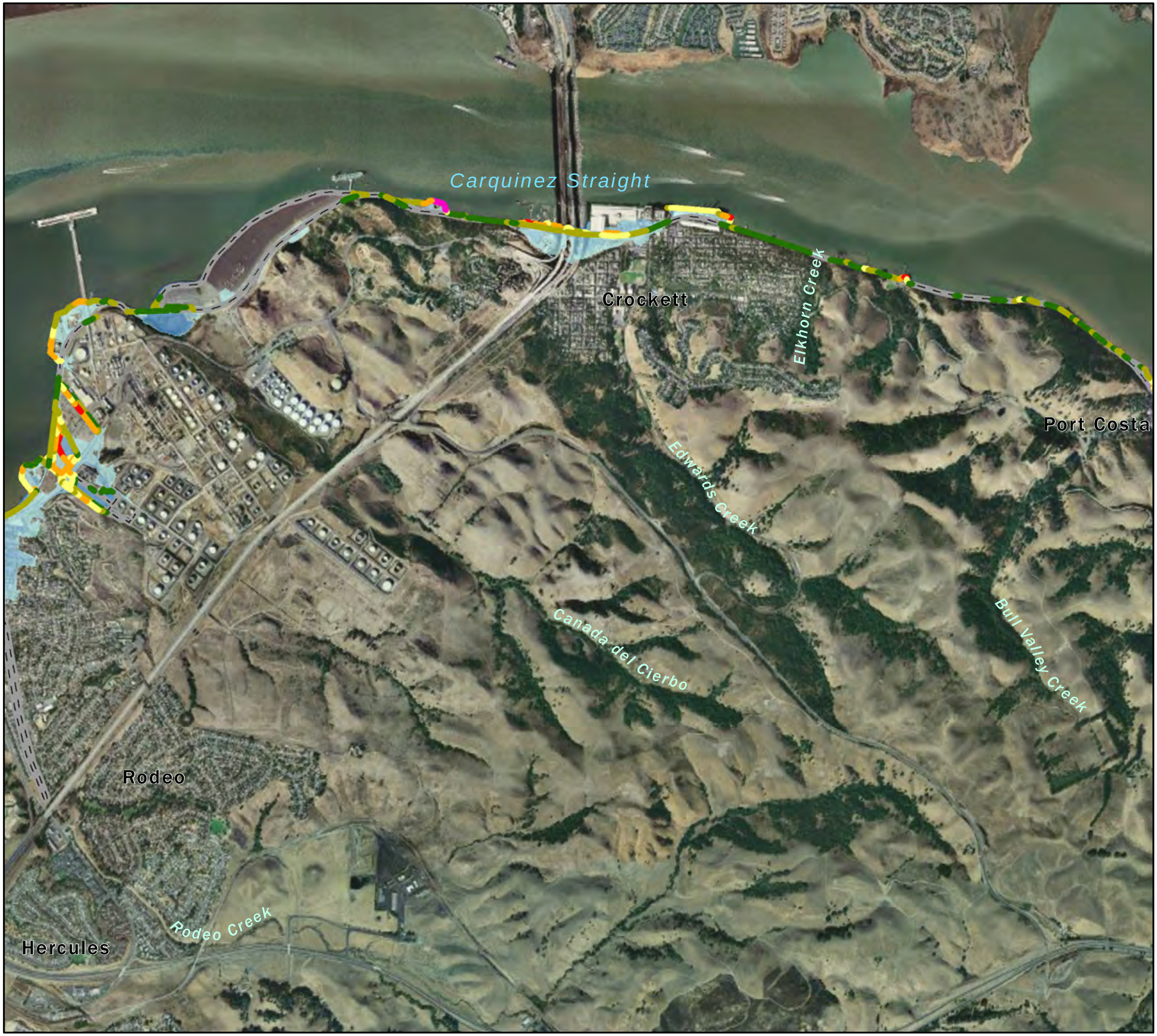

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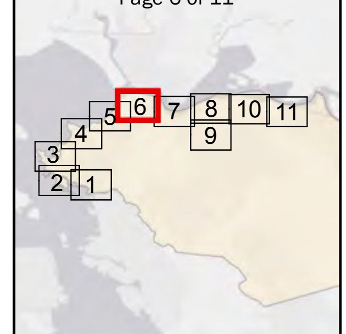

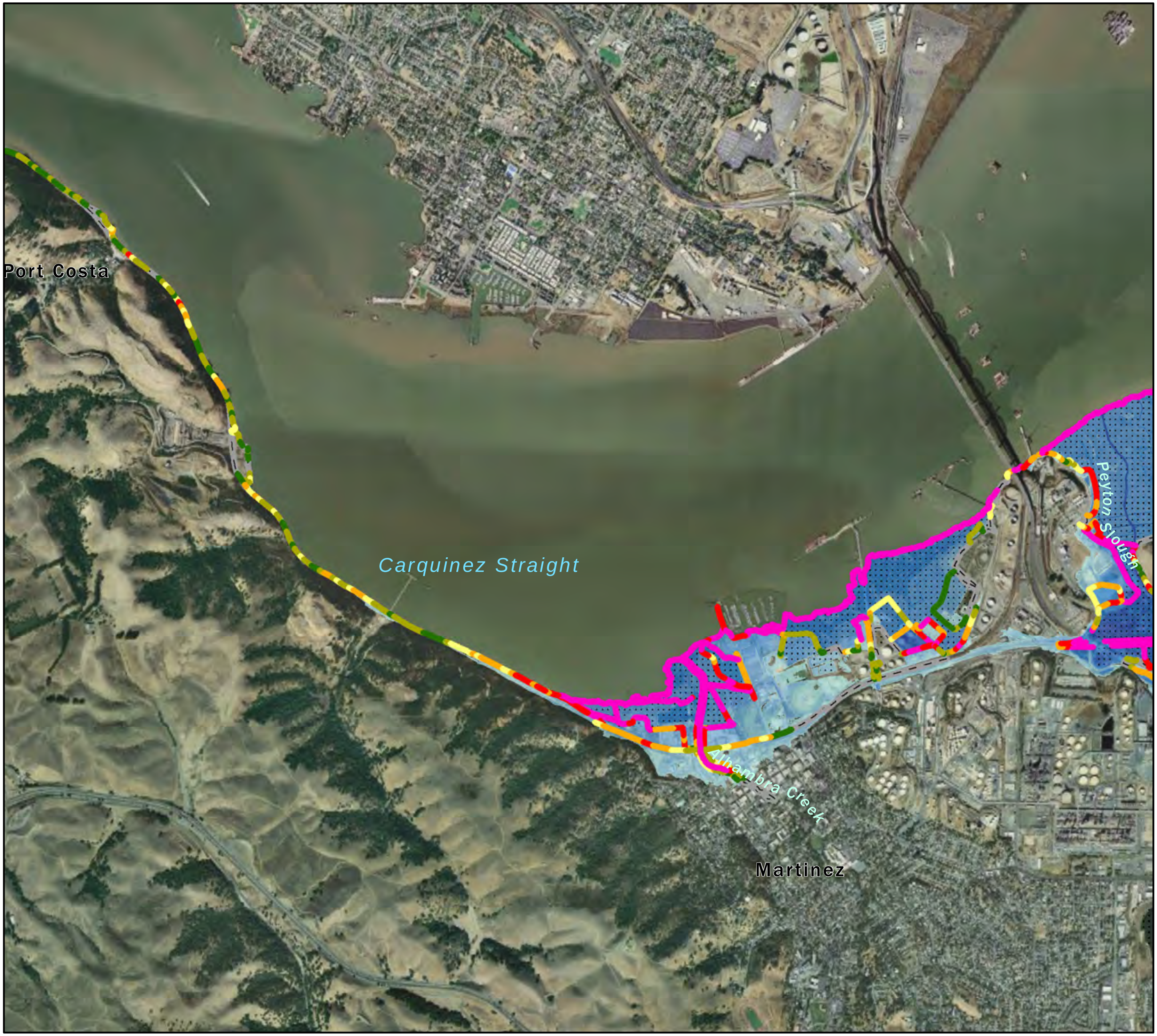

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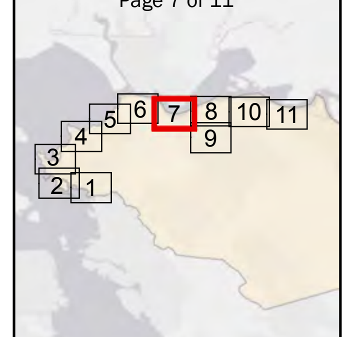

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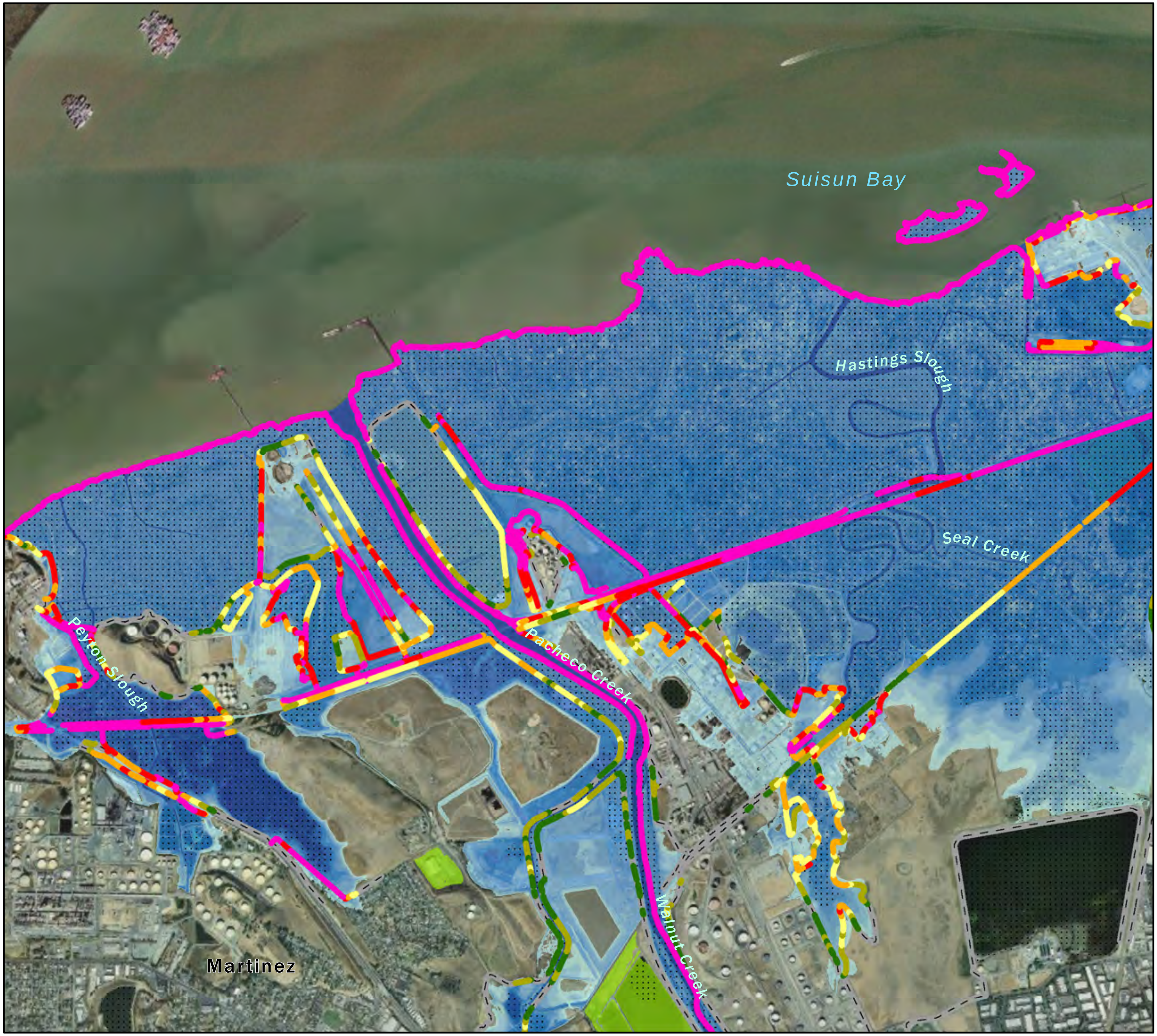

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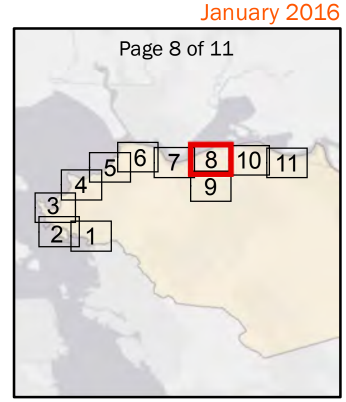
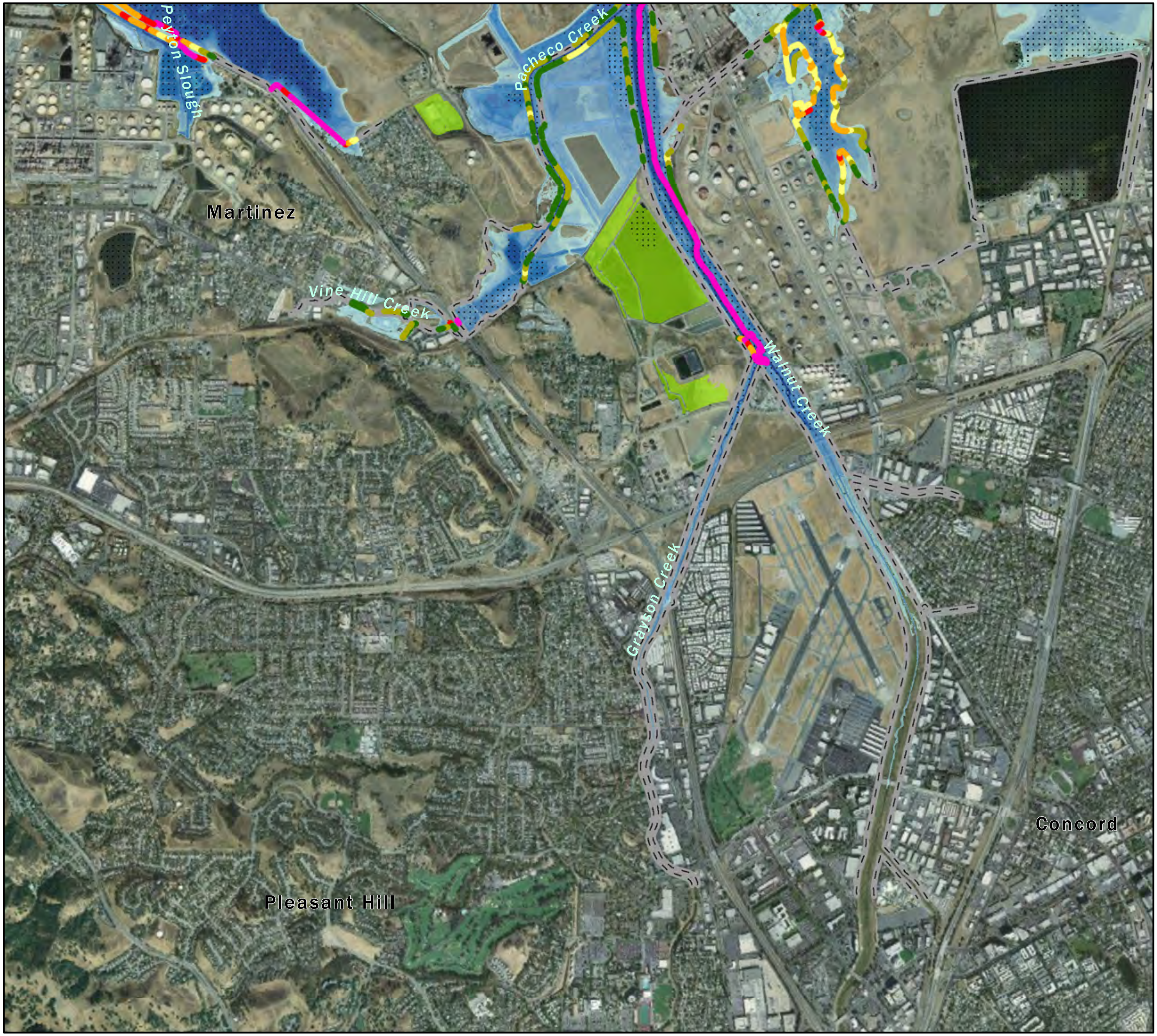
Universal Transverse Mercator NAD83 Zone 10N

January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 96" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet

- .5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

No Overtopping

MHHW + 96" Sea Level Rise

Depth in Feet

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16+

Disconnected Areas > 1 Acre

Major Wetlands and Water Bodies

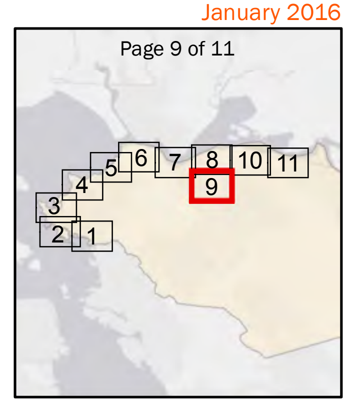
Miles: 0, 0.2, 0.4, 0.6

Feet: 0, 1,000, 2,000, 3,000

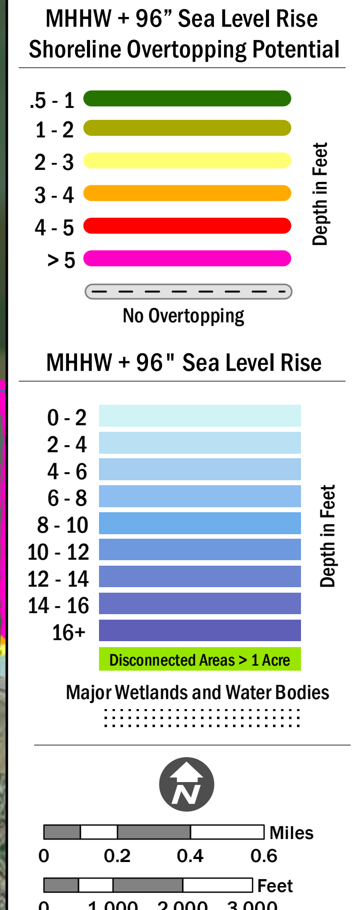
AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016



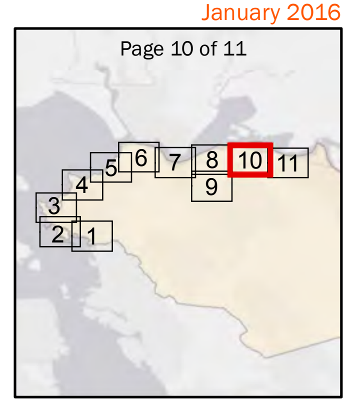
CONTRA COSTA COUNTY
Inundation Mapping

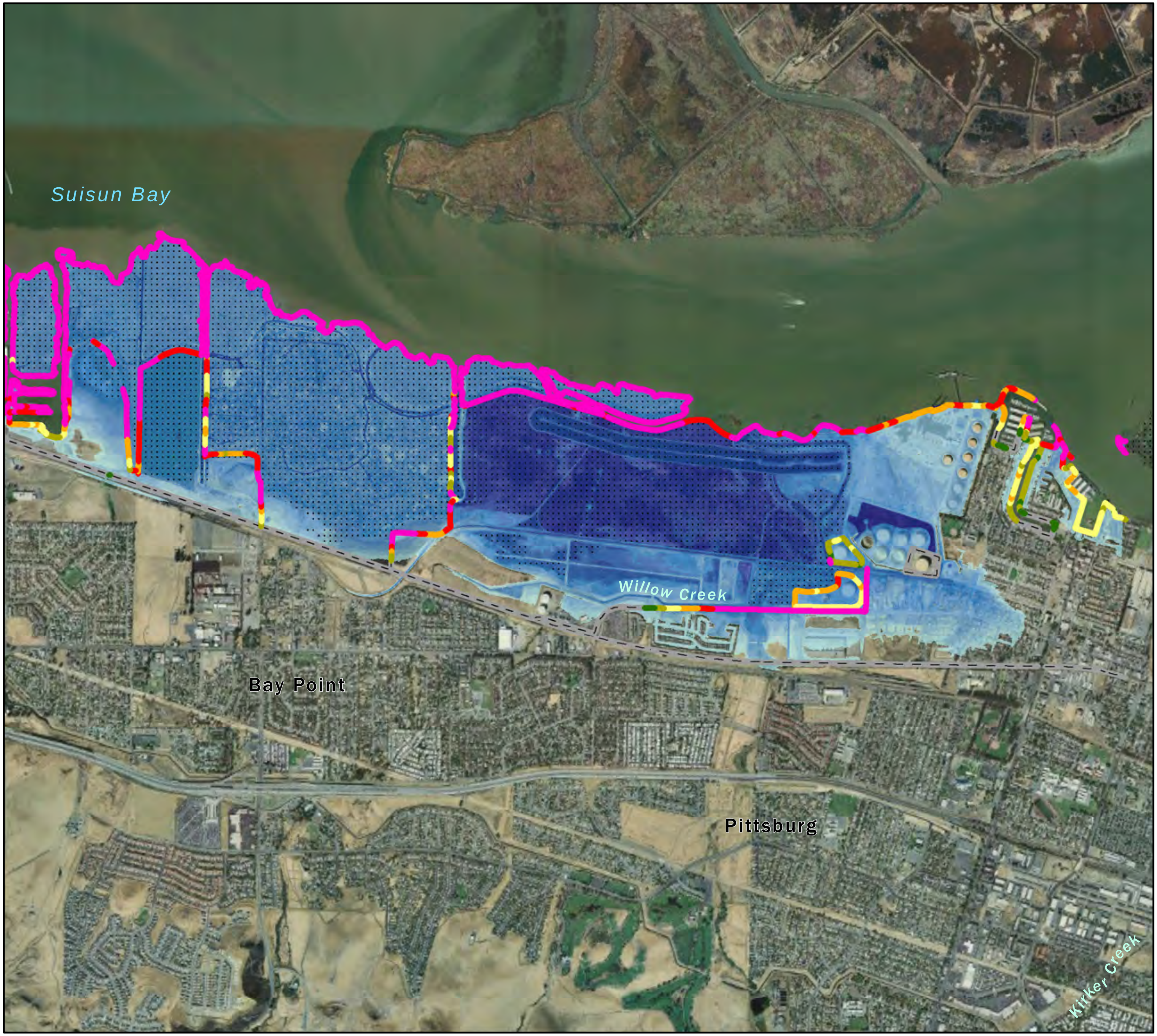


AECOM

Projection:
Universal Transverse Mercator NAD83 Zone 10N

January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 96” Sea Level Rise
Shoreline Overtopping Potential

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N

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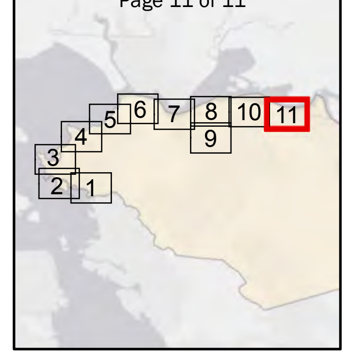
Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016



CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 108" Sea Level Rise Shoreline Overtopping Potential

Depth in Feet
.5 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
No Overtopping

MHHW + 108" Sea Level Rise

Depth in Feet
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
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Major Wetlands and Water Bodies

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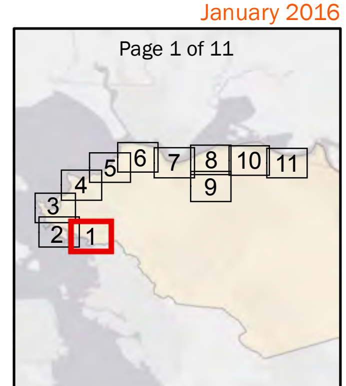
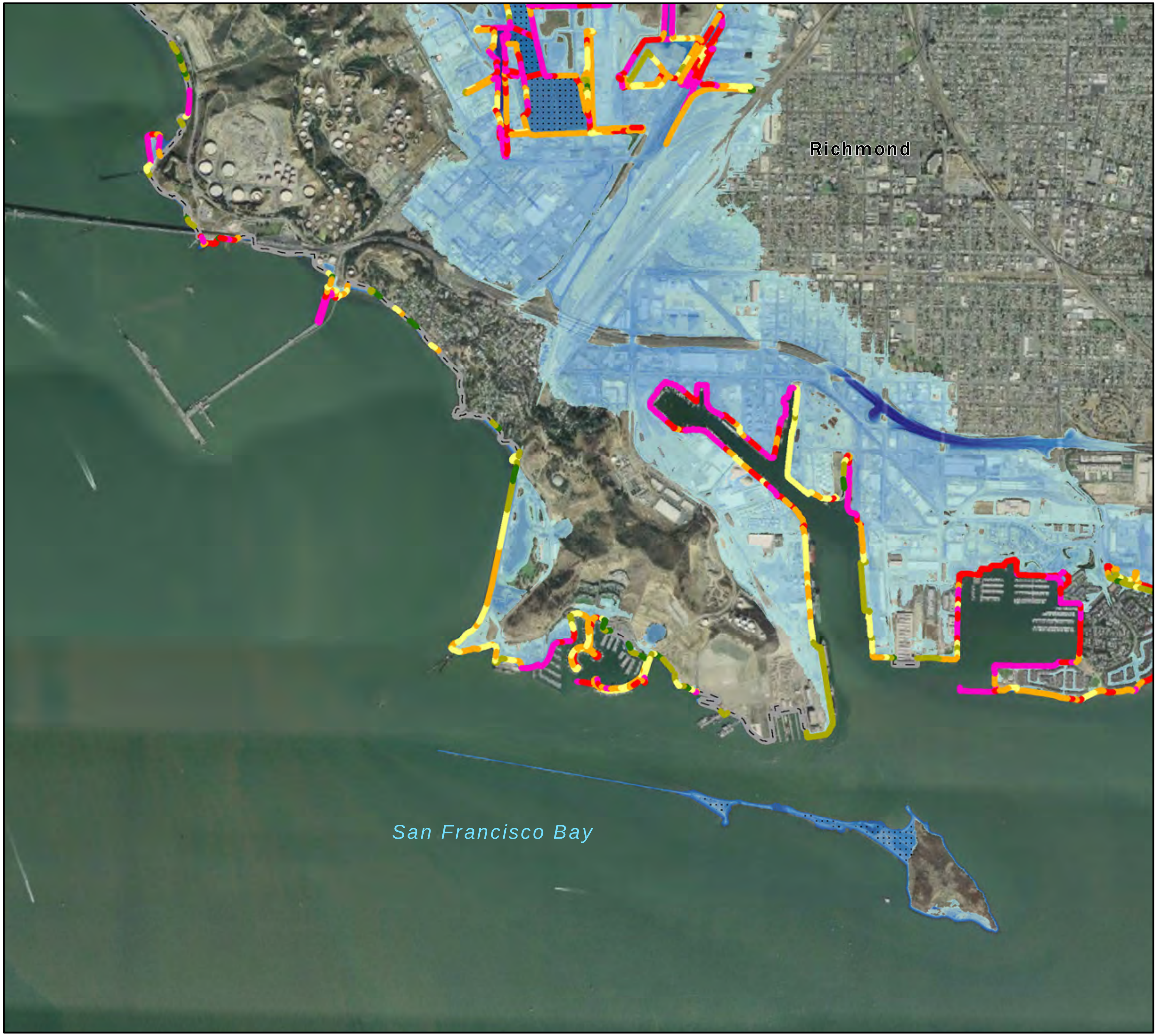
Projection:
Universal Transverse Mercator NAD83 Zone 10N

AECOM

January 2016





CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 108" Sea Level Rise Shoreline Overtopping Potential

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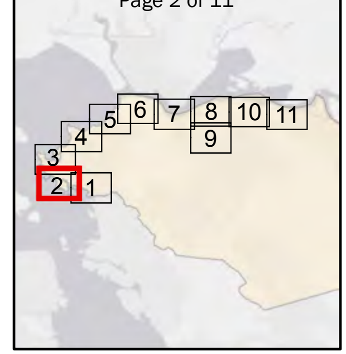
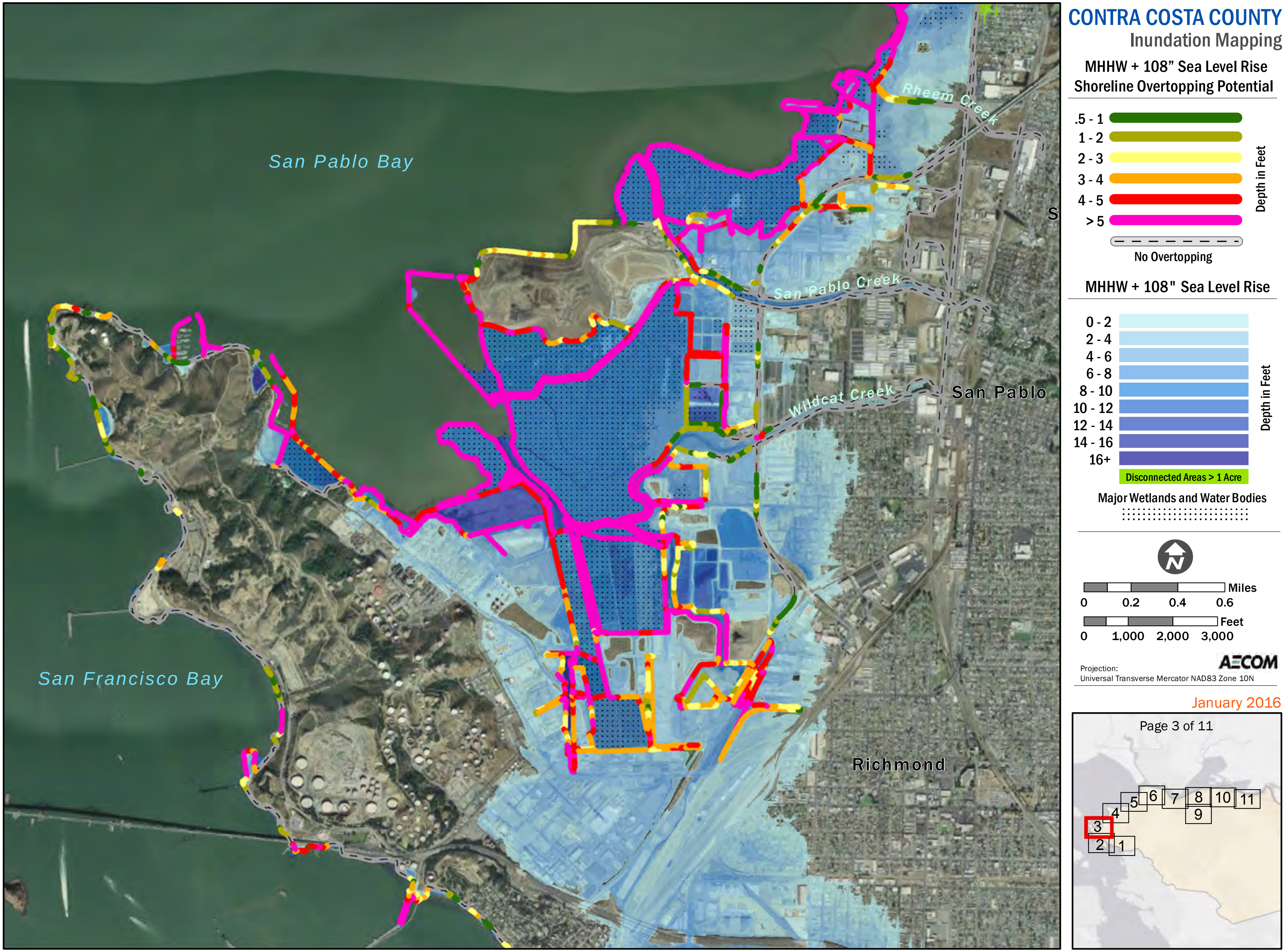
Universal Transverse Mercator NAD83 Zone 10N

January 2016




CONTRA COSTA COUNTY
Inundation Mapping
MHHW + 108" Sea Level Rise
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0 0.2 0.4 0.6
Feet
0 1,000 2,000 3,000
AECOM
Projection:
Universal Transverse Mercator NAD83 Zone 10N
January 2016
Page 3 of 11
1 2 3 4 5 6 7 8 9 10 11
San Pablo Bay
San Francisco Bay
Rheem Creek
San Pablo Creek
Wildcat Creek
San Pablo
Richmond

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 108" Sea Level Rise Shoreline Overtopping Potential

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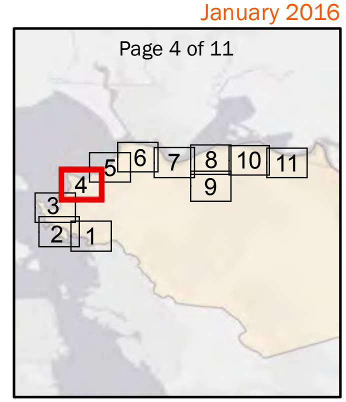
AECOM

January 2016



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Inundation Mapping

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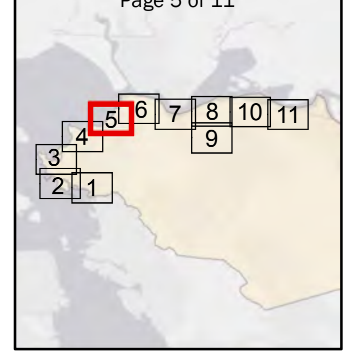

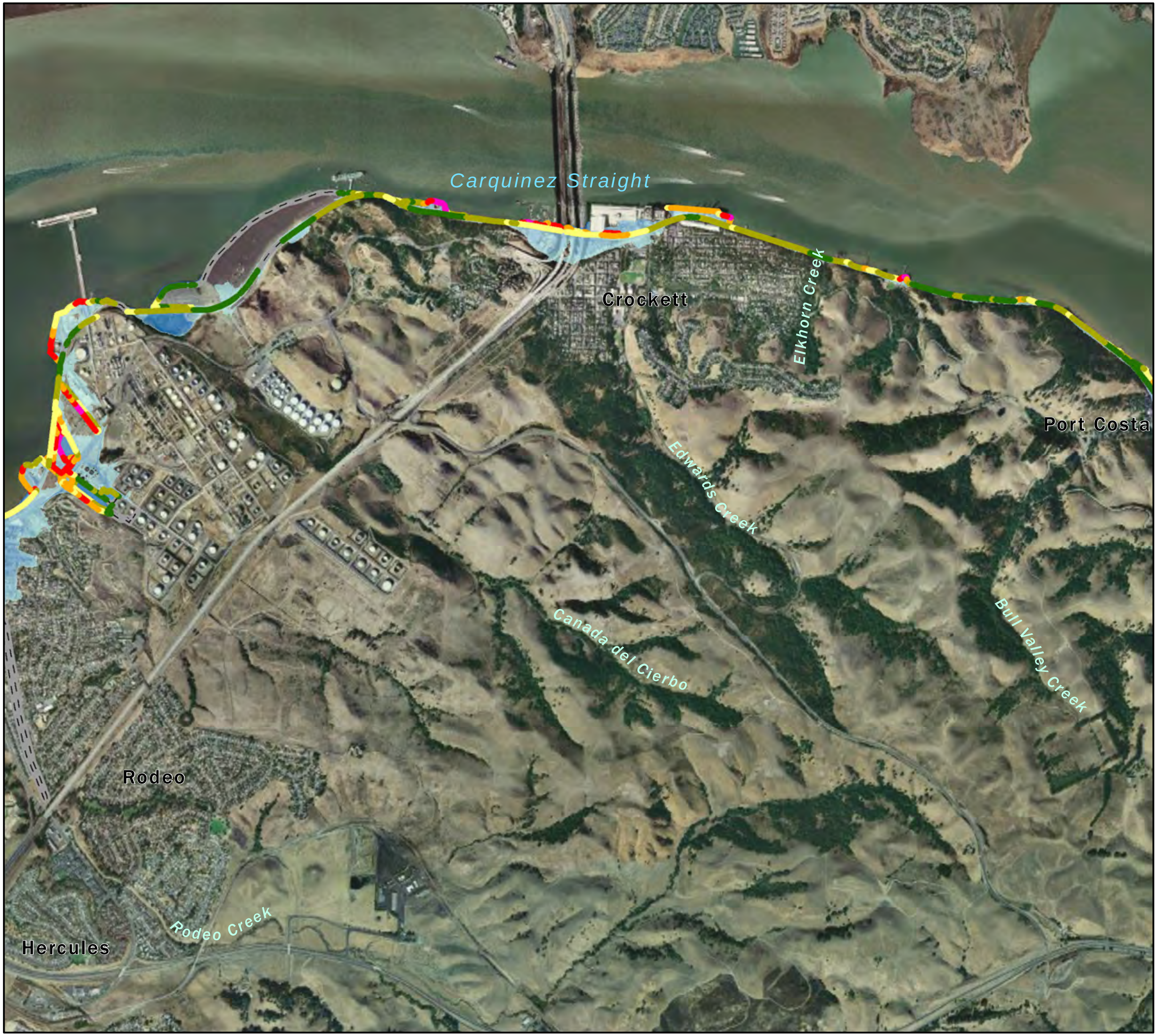

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 108" Sea Level Rise Shoreline Overtopping Potential

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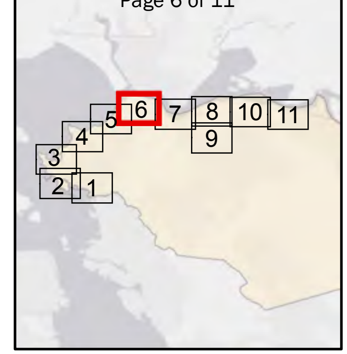

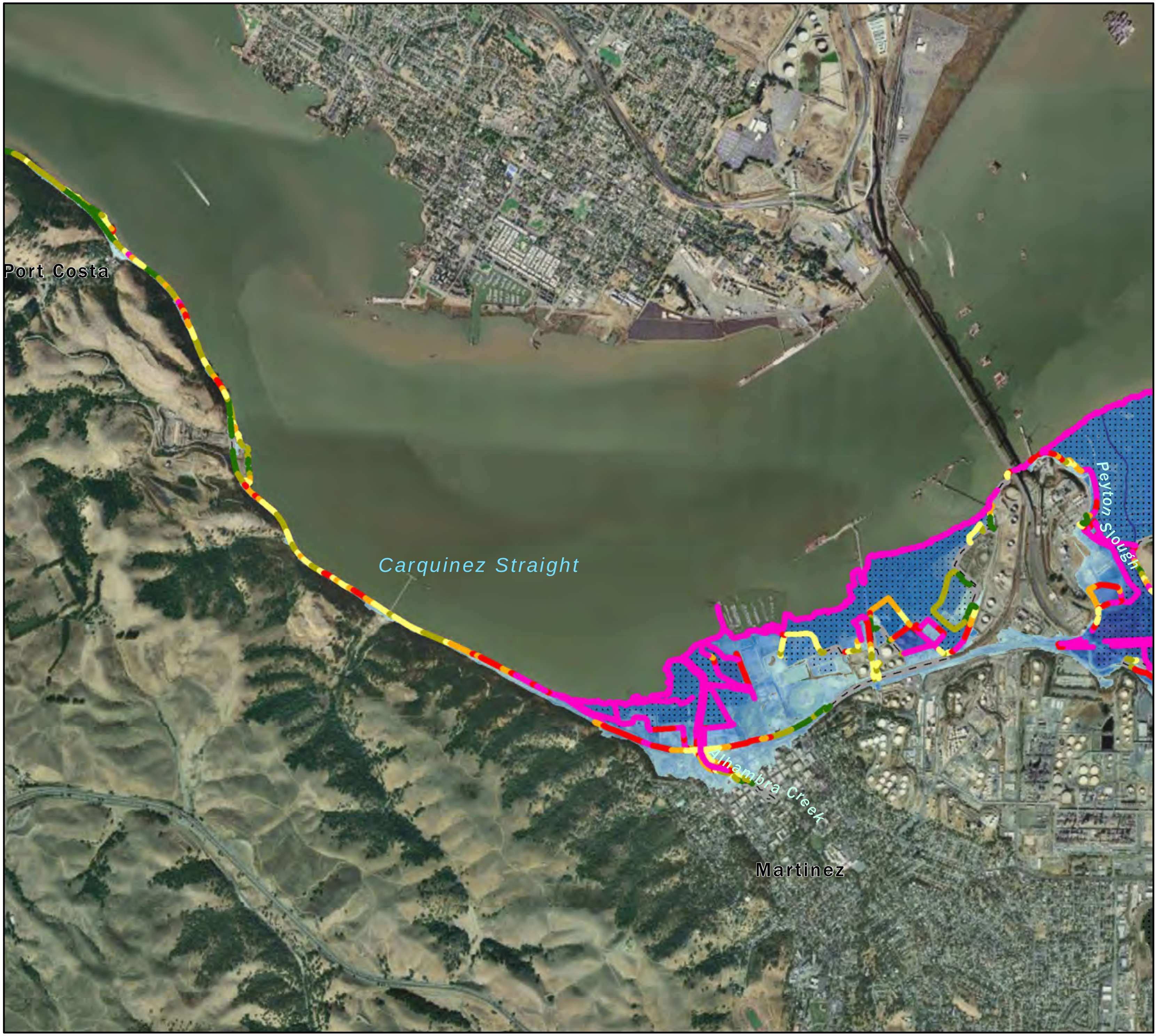

CONTRA COSTA COUNTY
Inundation Mapping

MHHW + 108" Sea Level Rise
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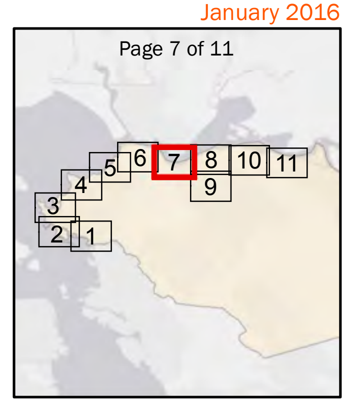

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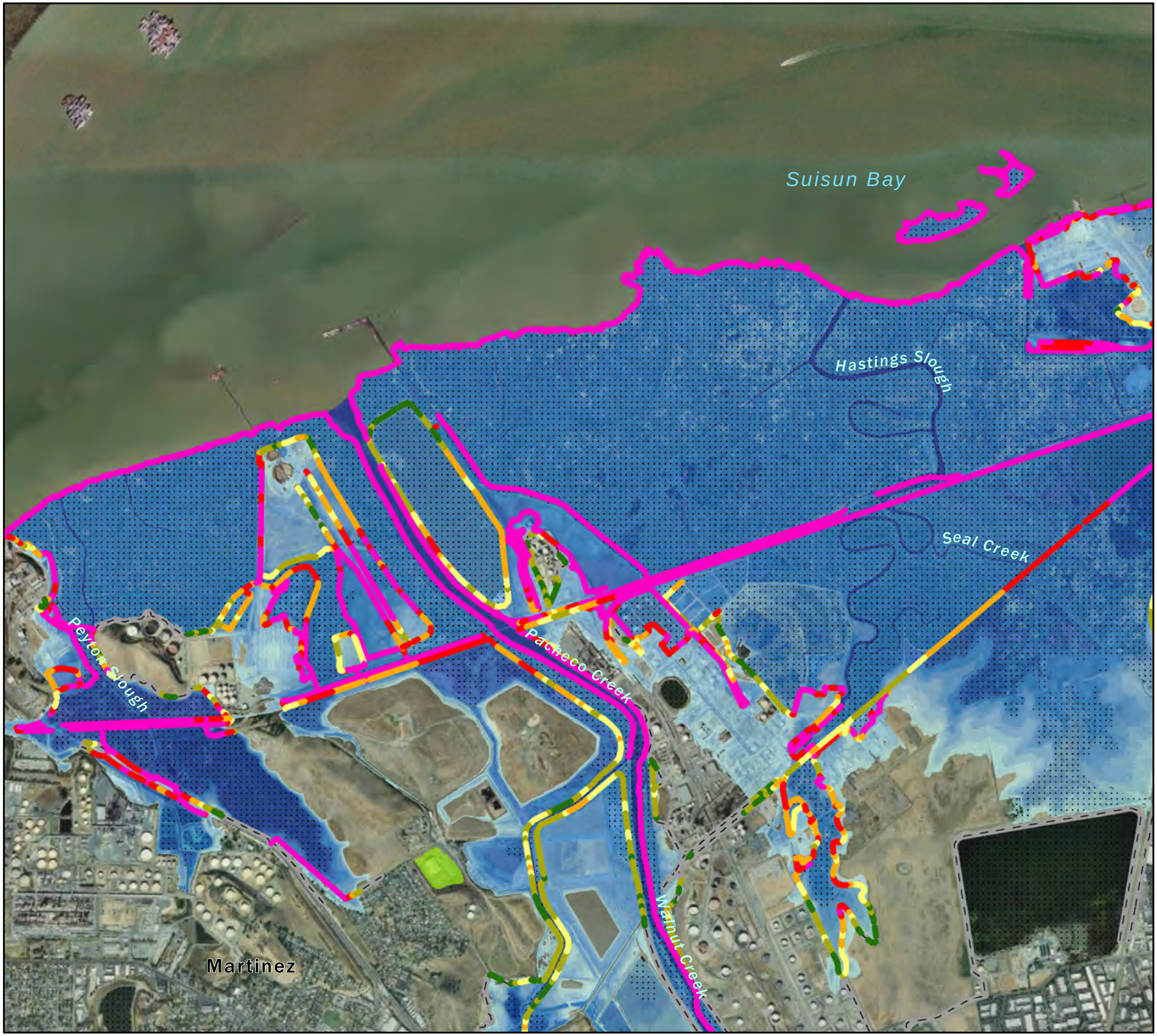

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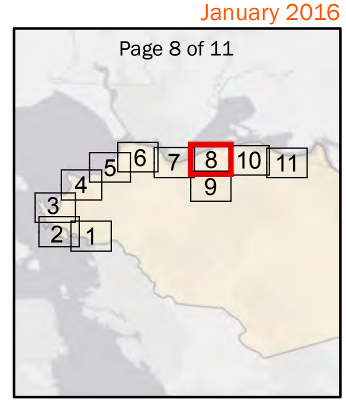

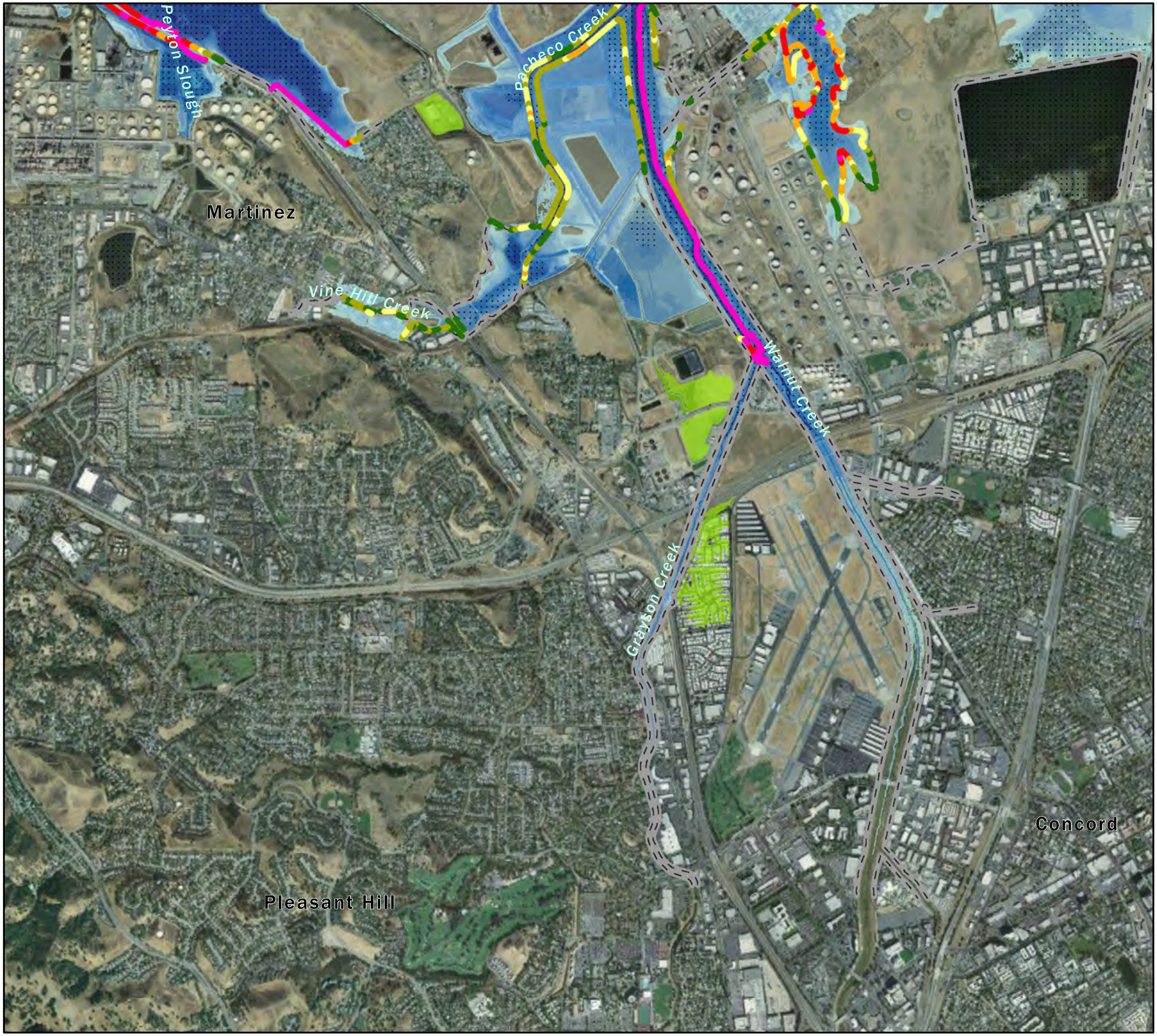

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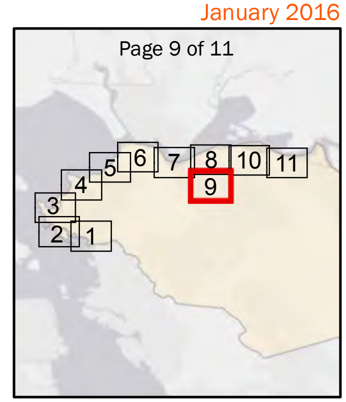

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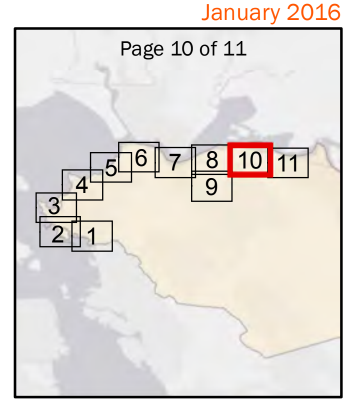

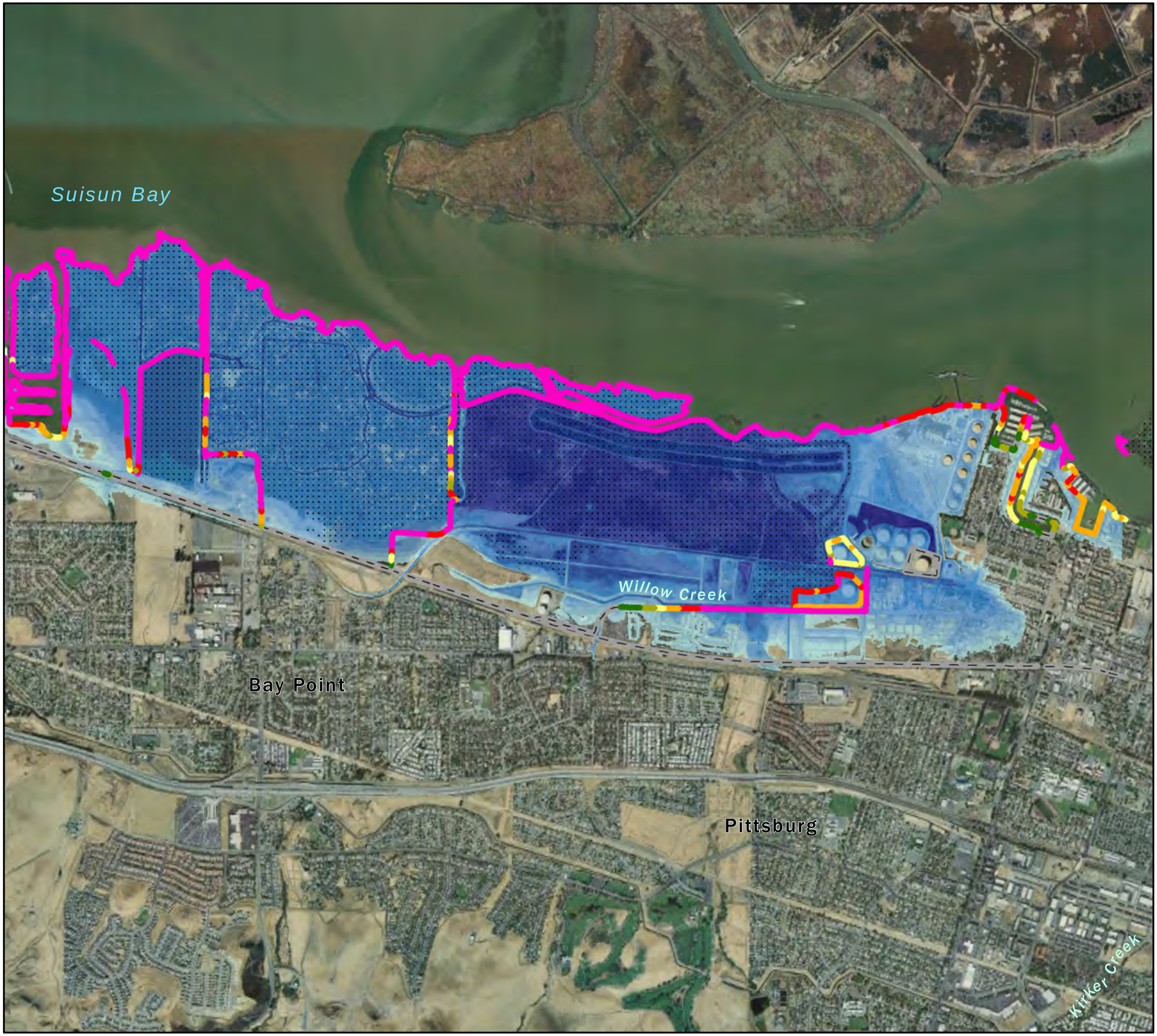

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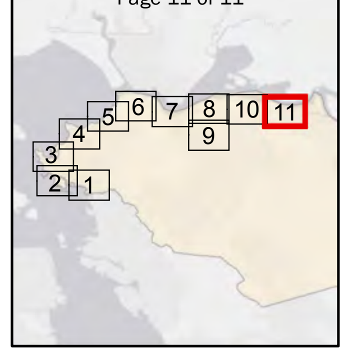


B

SHORELINE TYPE MAPS


Photo Courtesy of BCDC ART Program

CONTRA COSTA COUNTY
Inundation Mapping

Shoreline Type

- Shoreline Protection Structure
- Engineered Flood Protection Structure
- Transportation Structure (Major Road)
- Transportation Structure (Rail)
- Embankment
- Non Engineered Berms
- Natural Shoreline: Wetland
- Natural Shoreline: Cliff or Bluff or Hill

N

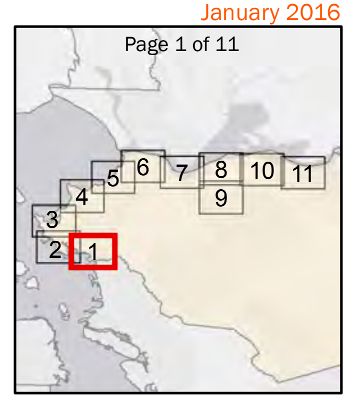
0 0.2 0.4 0.6 Miles

0 1,000 2,000 3,000 Feet

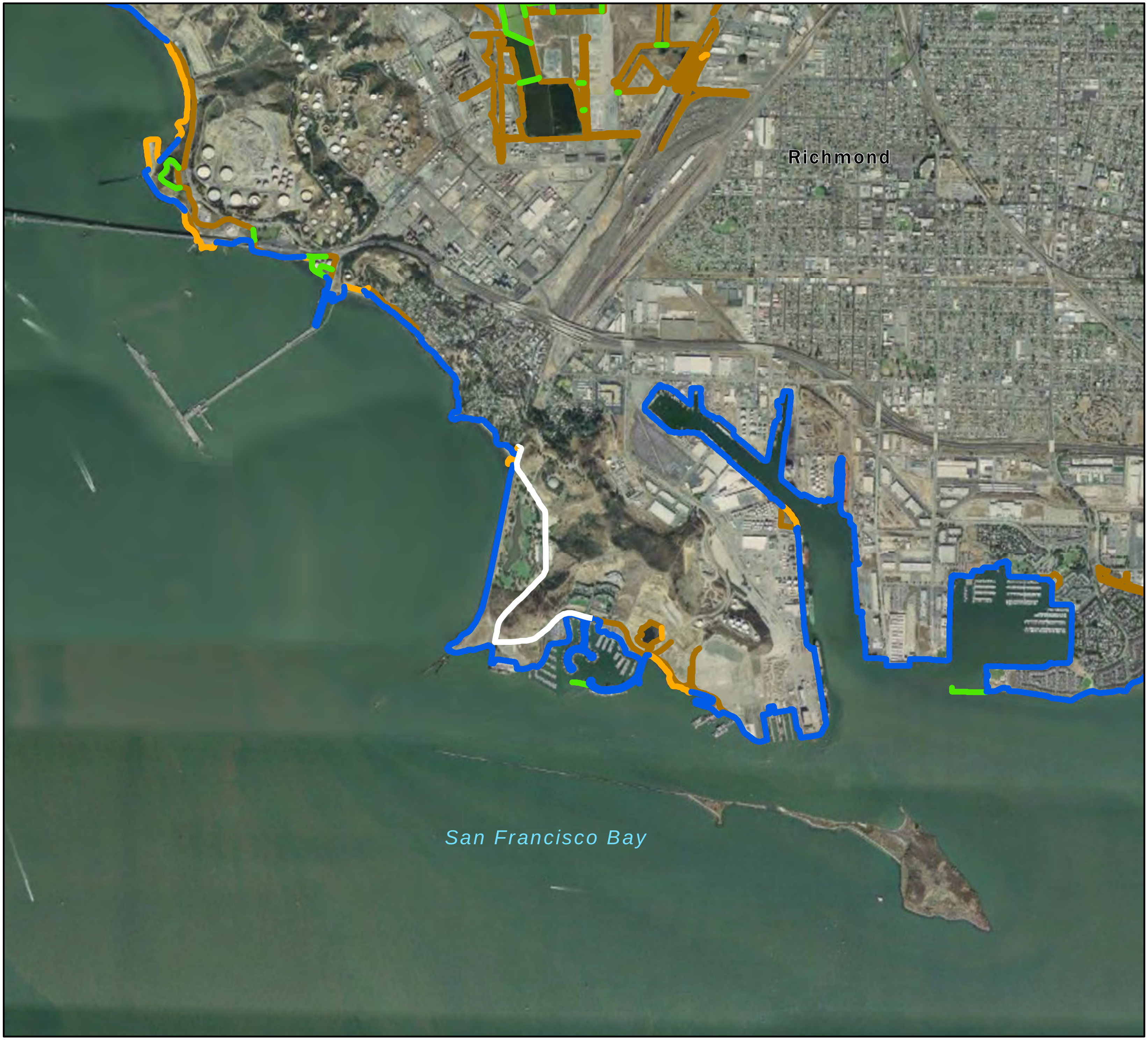
Projection:
Universal Transverse Mercator NAD83 Zone10N

AECOM

January 2016



CONTRA COSTA COUNTY
Inundation Mapping



Shoreline Type

- Shoreline Protection Structure
- Engineered Flood Protection Structure
- Transportation Structure (Major Road)
- Transportation Structure (Rail)
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- Non Engineered Berms
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Miles: 0 0.2 0.4 0.6

Feet: 0 1,000 2,000 3,000

Projection:
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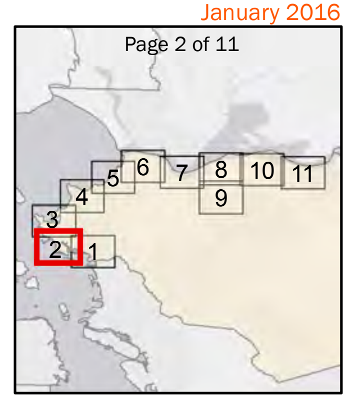
January 2016



CONTRA COSTA COUNTY
Inundation Mapping

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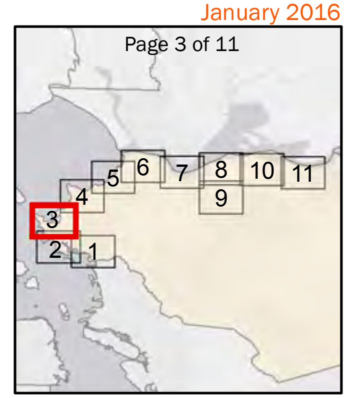

CONTRA COSTA COUNTY
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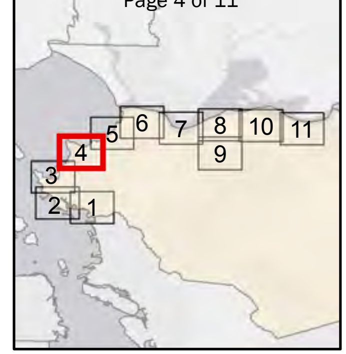

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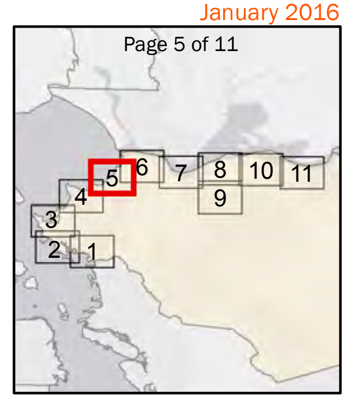

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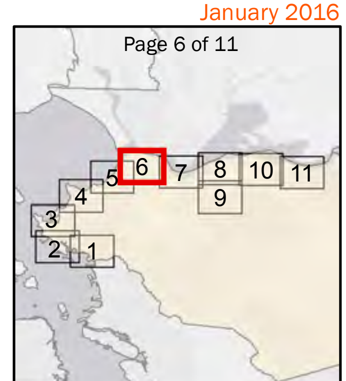

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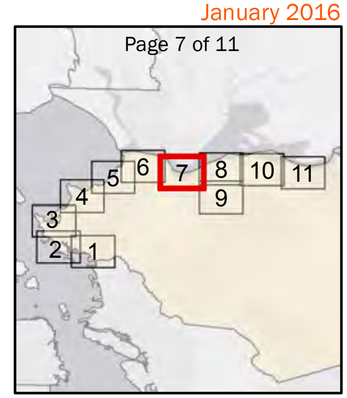

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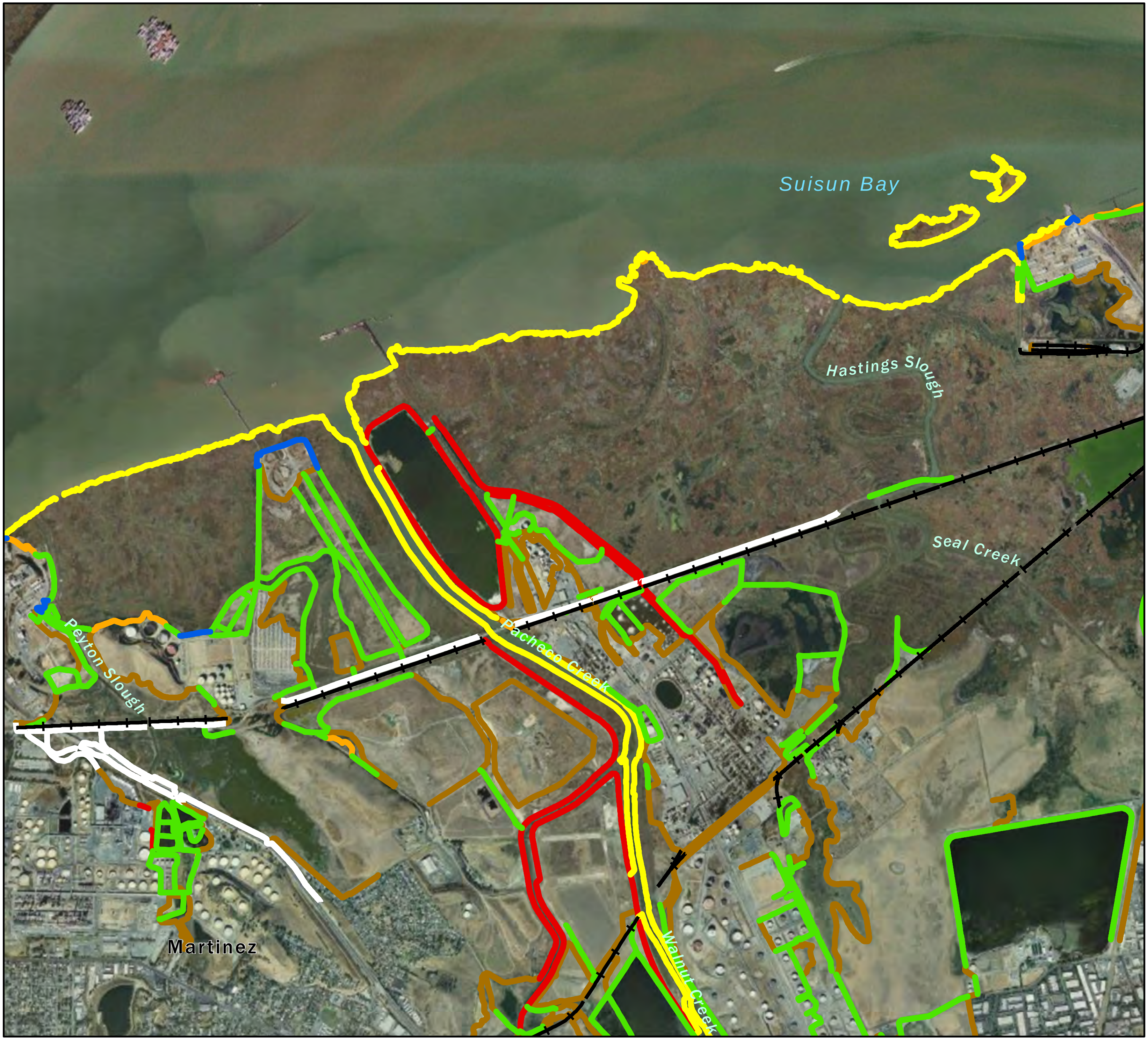

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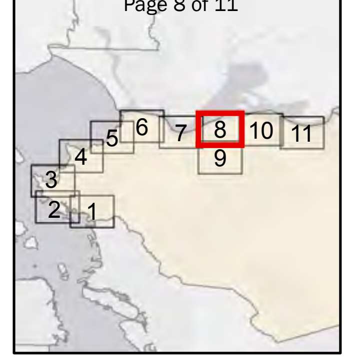

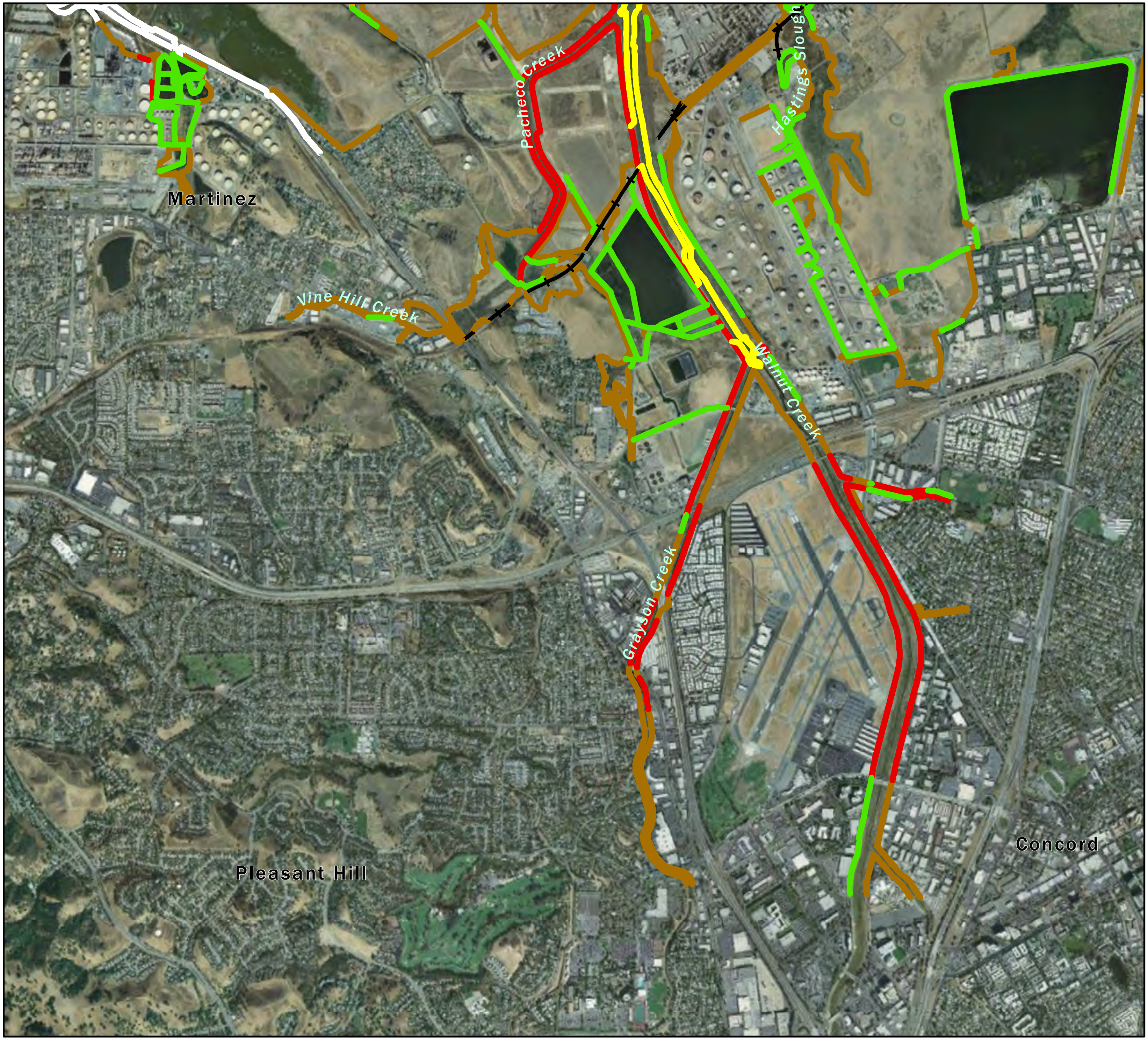

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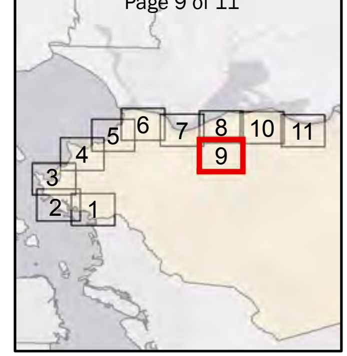

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- Transportation Structure (Rail)
- Embankment
- Non Engineered Berms
- Natural Shoreline: Wetland
- Natural Shoreline: Cliff or Bluff or Hill

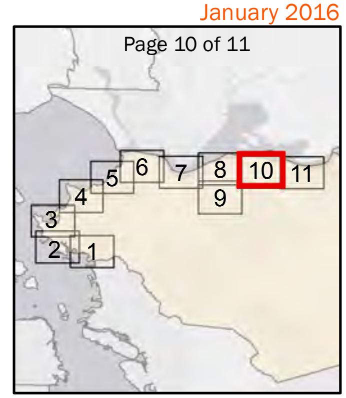
Miles: 0, 0.2, 0.4, 0.6

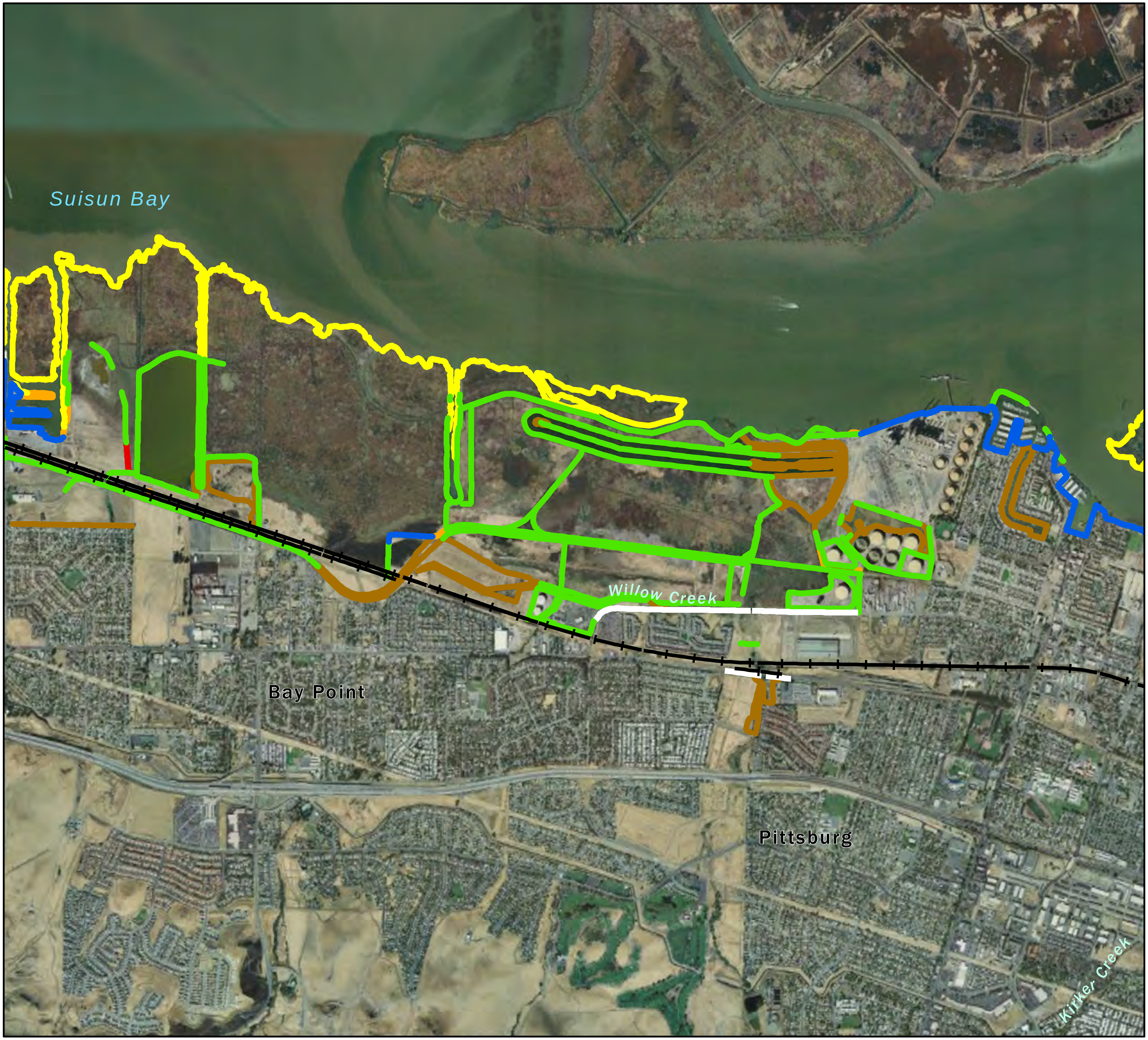
Feet: 0, 1,000, 2,000, 3,000

AECOM

Projection:
Universal Transverse Mercator NAD83 Zone10N

January 2016





CONTRA COSTA COUNTY

Inundation Mapping

Shoreline Type

- Shoreline Protection Structure
- Engineered Flood Protection Structure
- Transportation Structure (Major Road)
- Transportation Structure (Rail)
- Embankment
- Non Engineered Berms
- Natural Shoreline: Wetland
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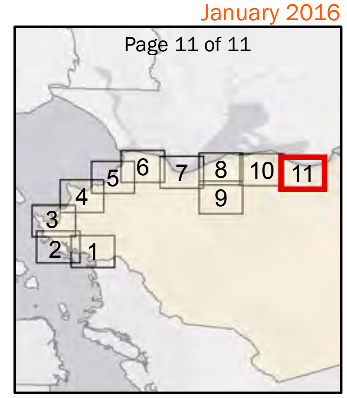
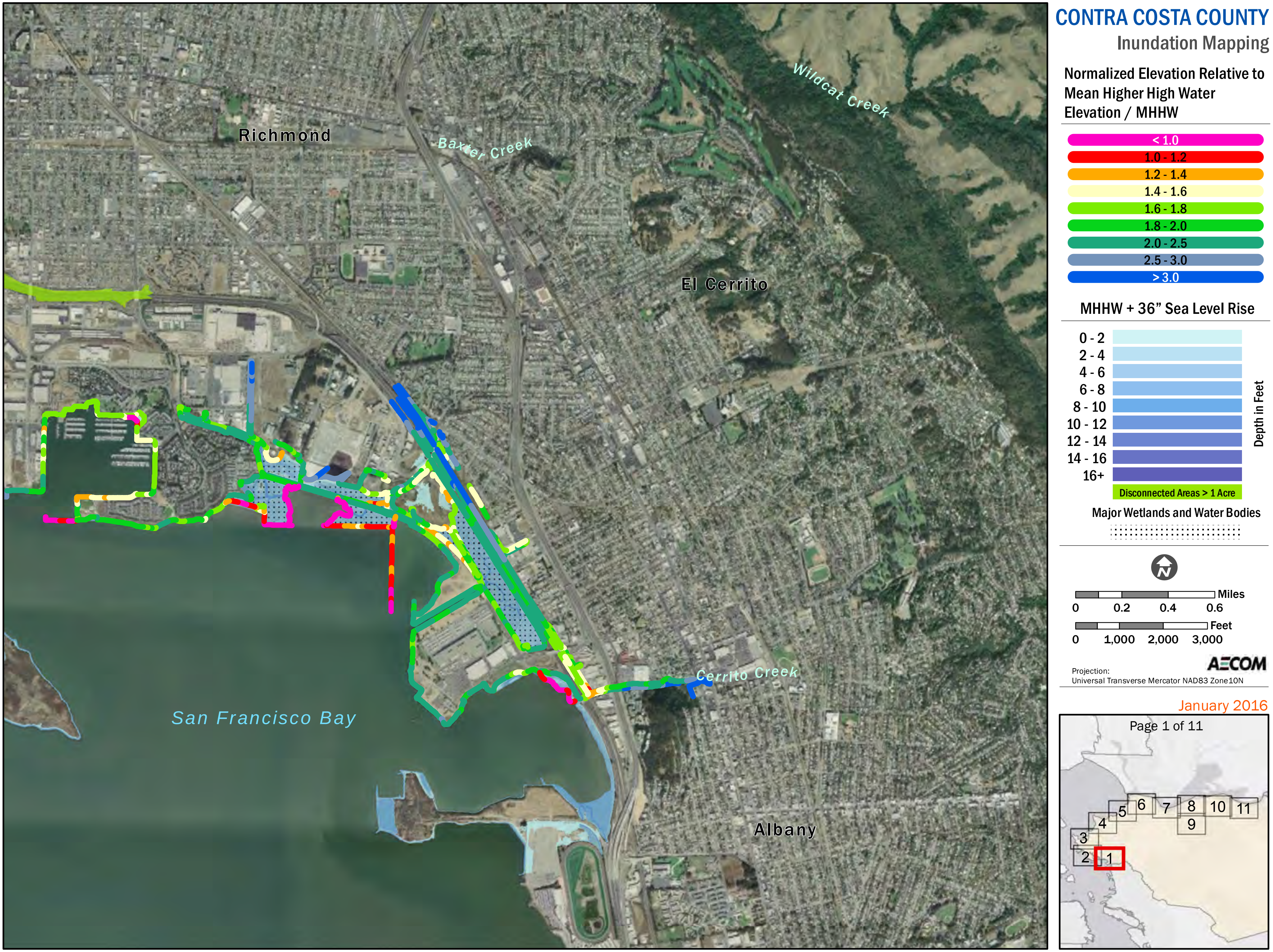
January 2016



C

NORMALIZED SHORELINE MAPS



Richmond
Baxter Creek
Wildcat Creek
El Cerrito
San Francisco Bay
Cerrito Creek
Albany
CONTRA COSTA COUNTY
Inundation Mapping
Normalized Elevation Relative to Mean Higher High Water Elevation / MHHW
< 1.0
1.0 - 1.2
1.2 - 1.4
1.4 - 1.6
1.6 - 1.8
1.8 - 2.0
2.0 - 2.5
2.5 - 3.0
> 3.0
MHHW + 36" Sea Level Rise
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16+
Depth in Feet
Disconnected Areas > 1 Acre
Major Wetlands and Water Bodies
N
Miles
0
0.2
0.4
0.6
Feet
0
1,000
2,000
3,000
AECOM
Projection:
Universal Transverse Mercator NAD83 Zone10N
January 2016
Page 1 of 11
1
2
3
4
5
6
7
8
9
10
11

CONTRA COSTA COUNTY

Inundation Mapping

Normalized Elevation Relative to Mean Higher High Water Elevation / MHHW

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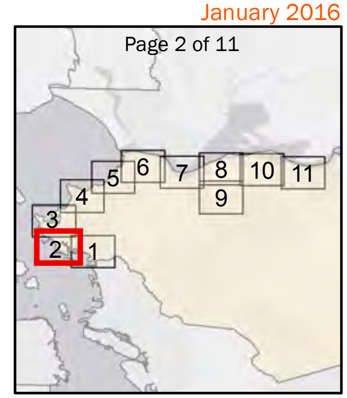
AECOM

Projection:
Universal Transverse Mercator NAD83 Zone10N

January 2016



CONTRA COSTA COUNTY

Inundation Mapping

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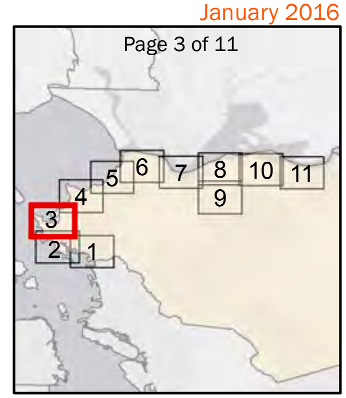

CONTRA COSTA COUNTY
Inundation Mapping

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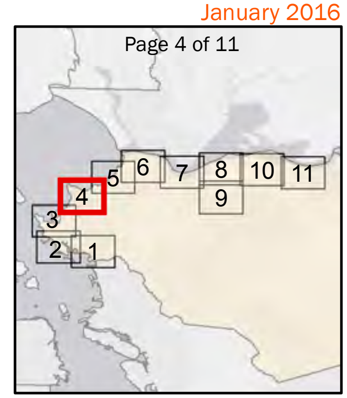

CONTRA COSTA COUNTY

Inundation Mapping

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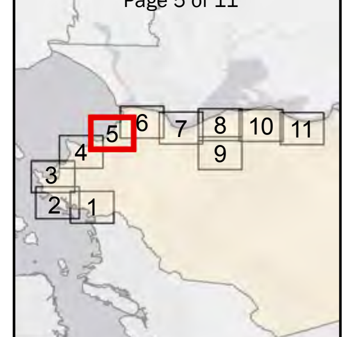

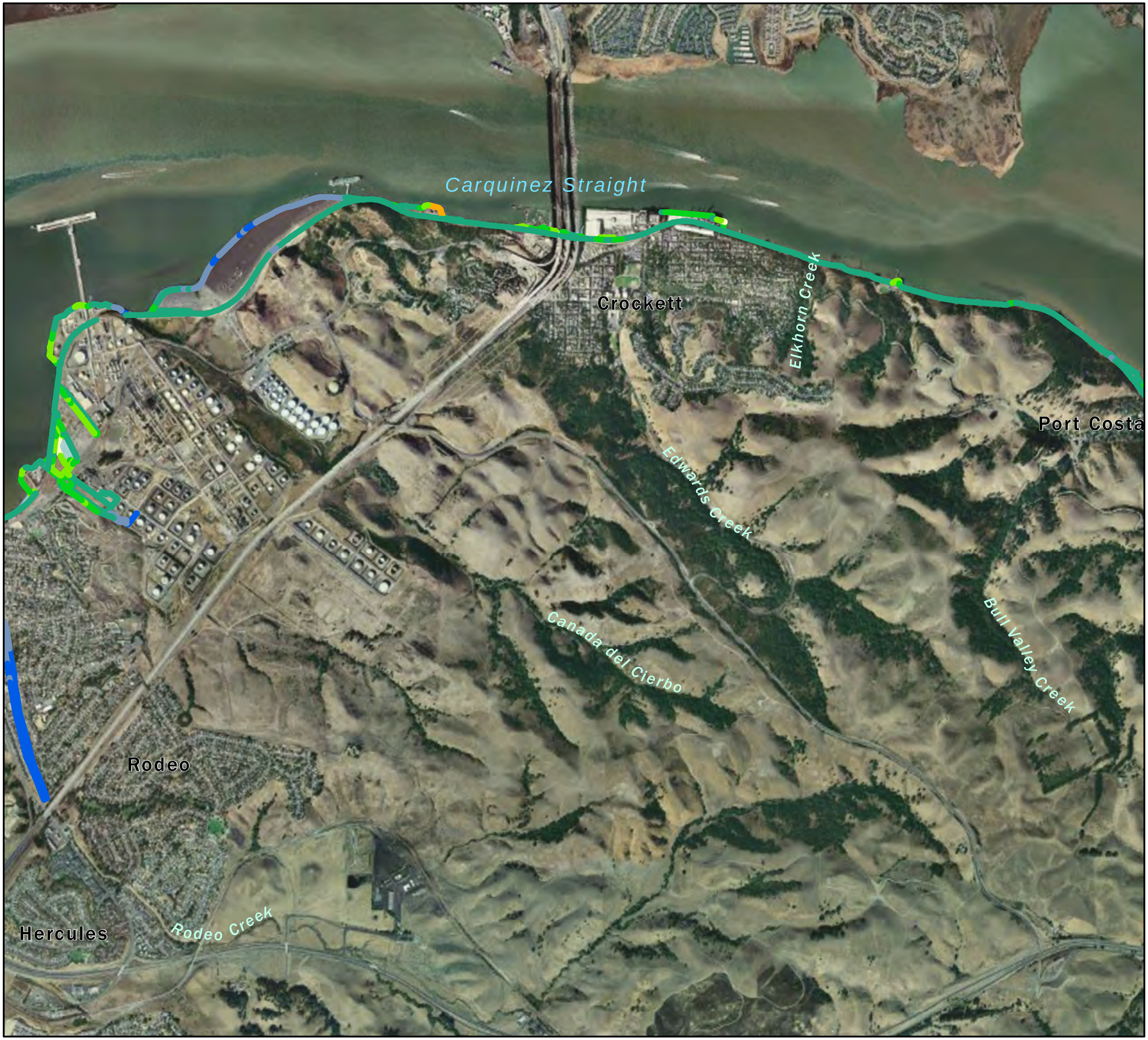

CONTRA COSTA COUNTY

Inundation Mapping

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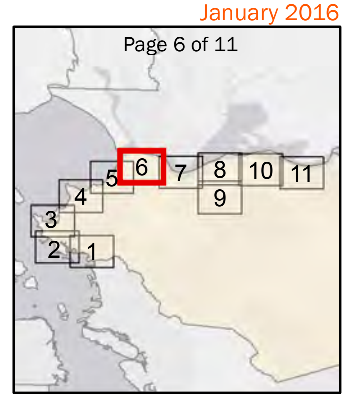

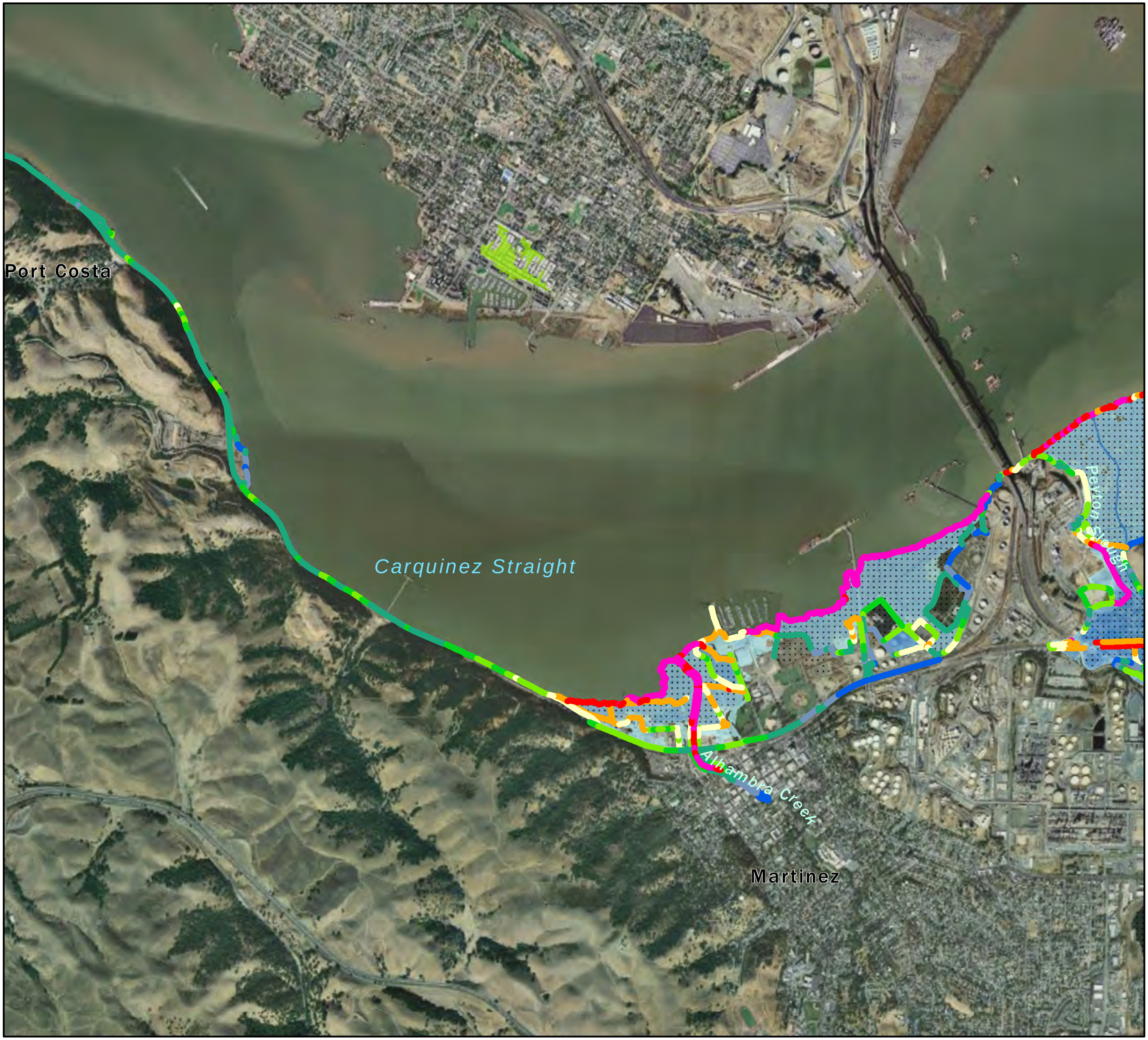

CONTRA COSTA COUNTY

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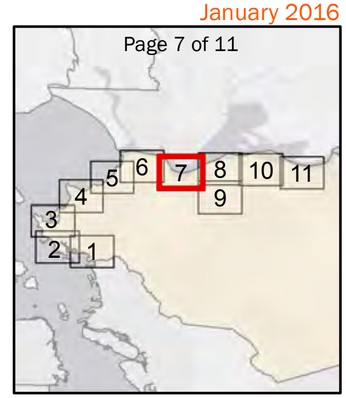
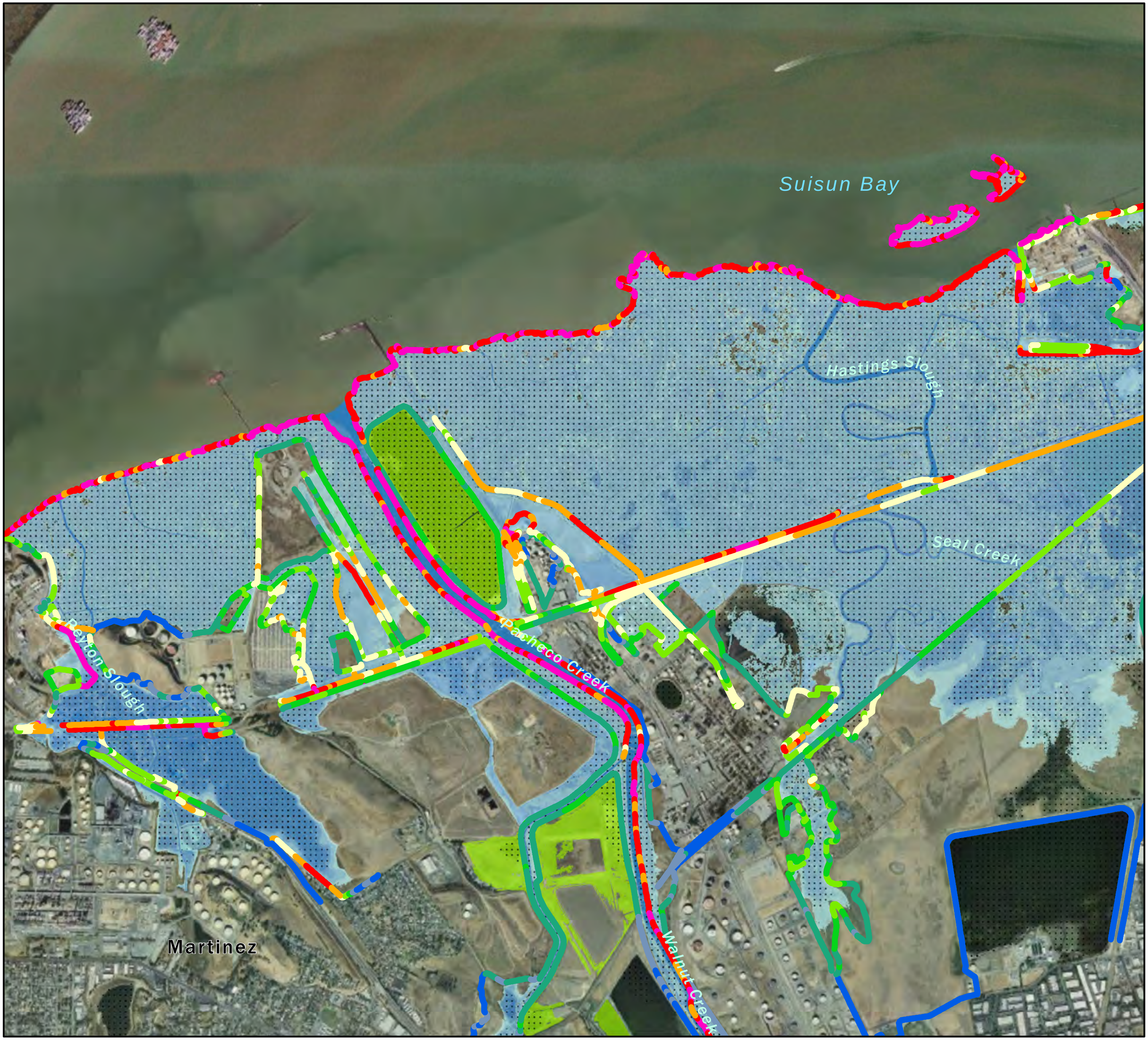


CONTRA COSTA COUNTY
Inundation Mapping



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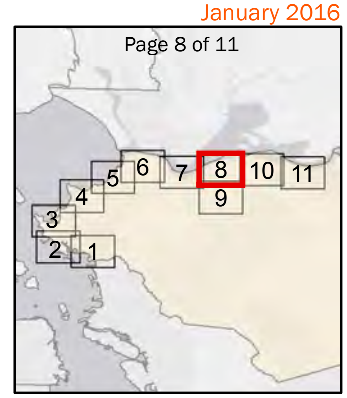

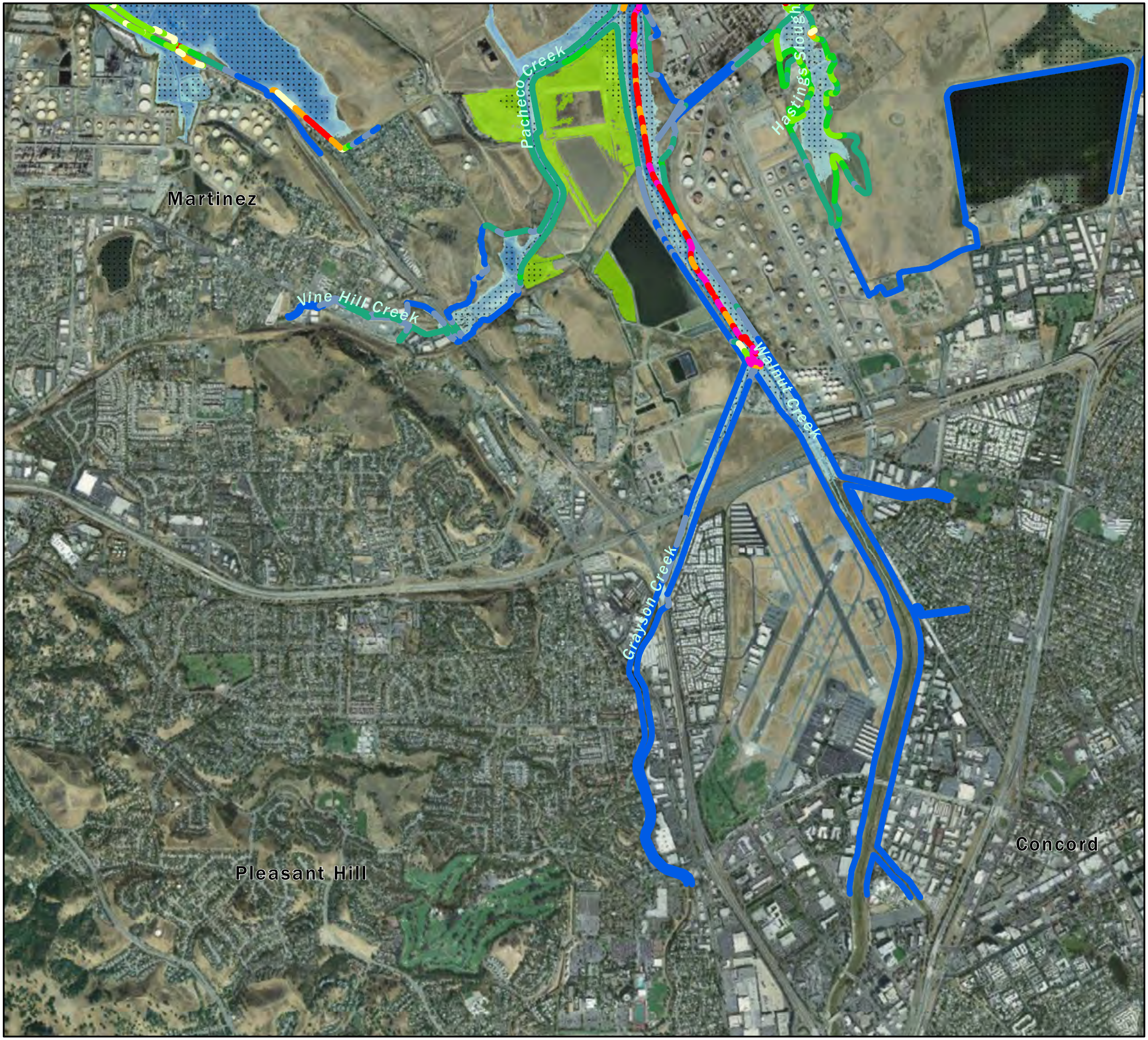

CONTRA COSTA COUNTY
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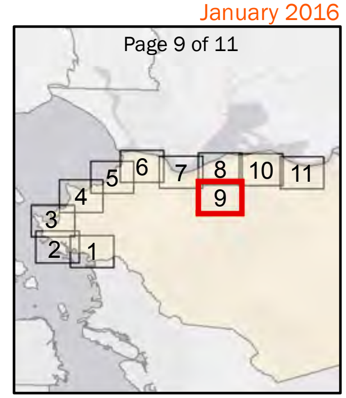

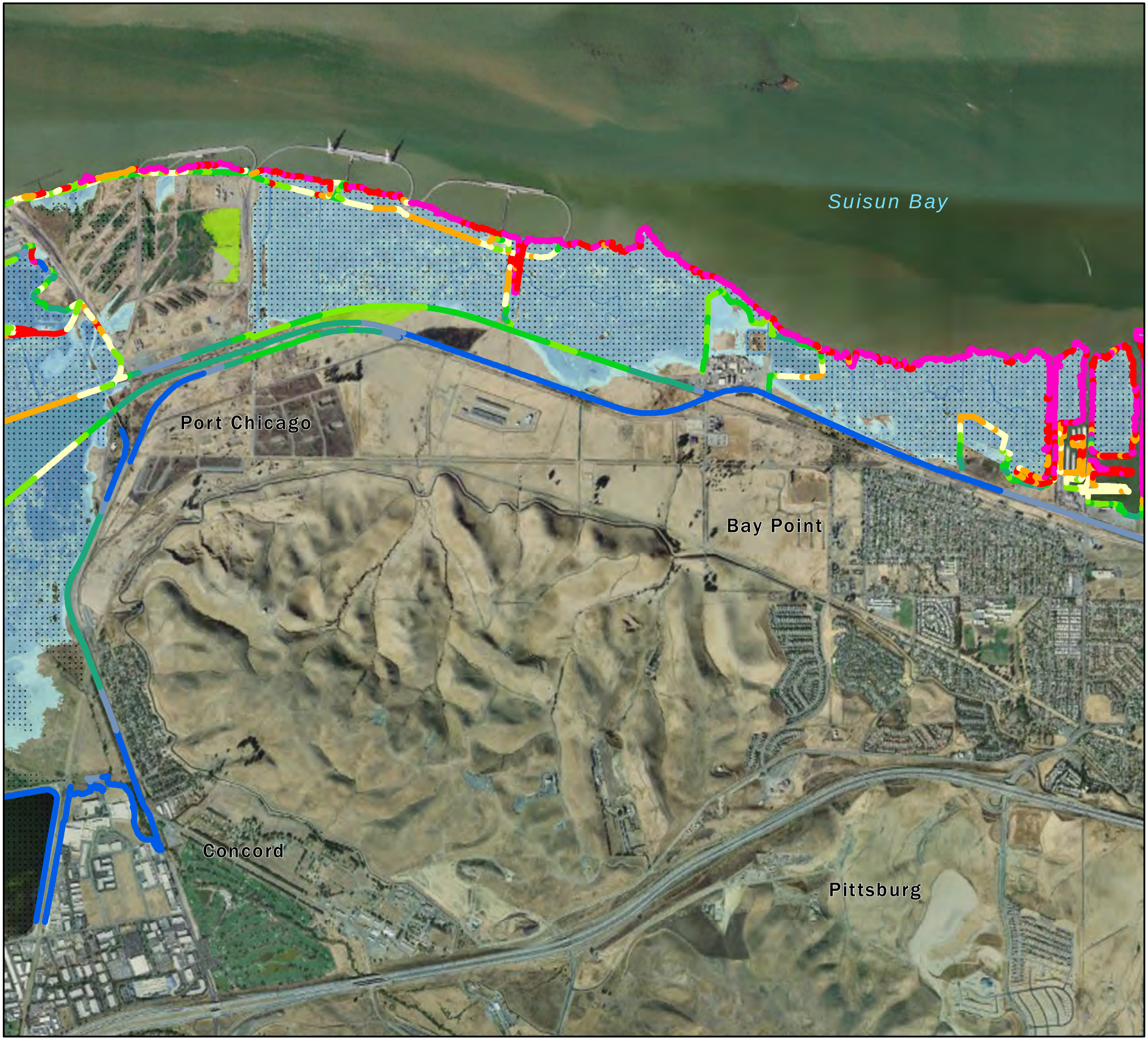

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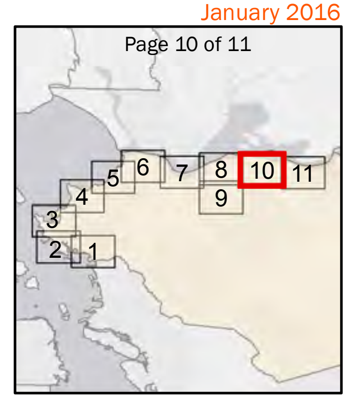

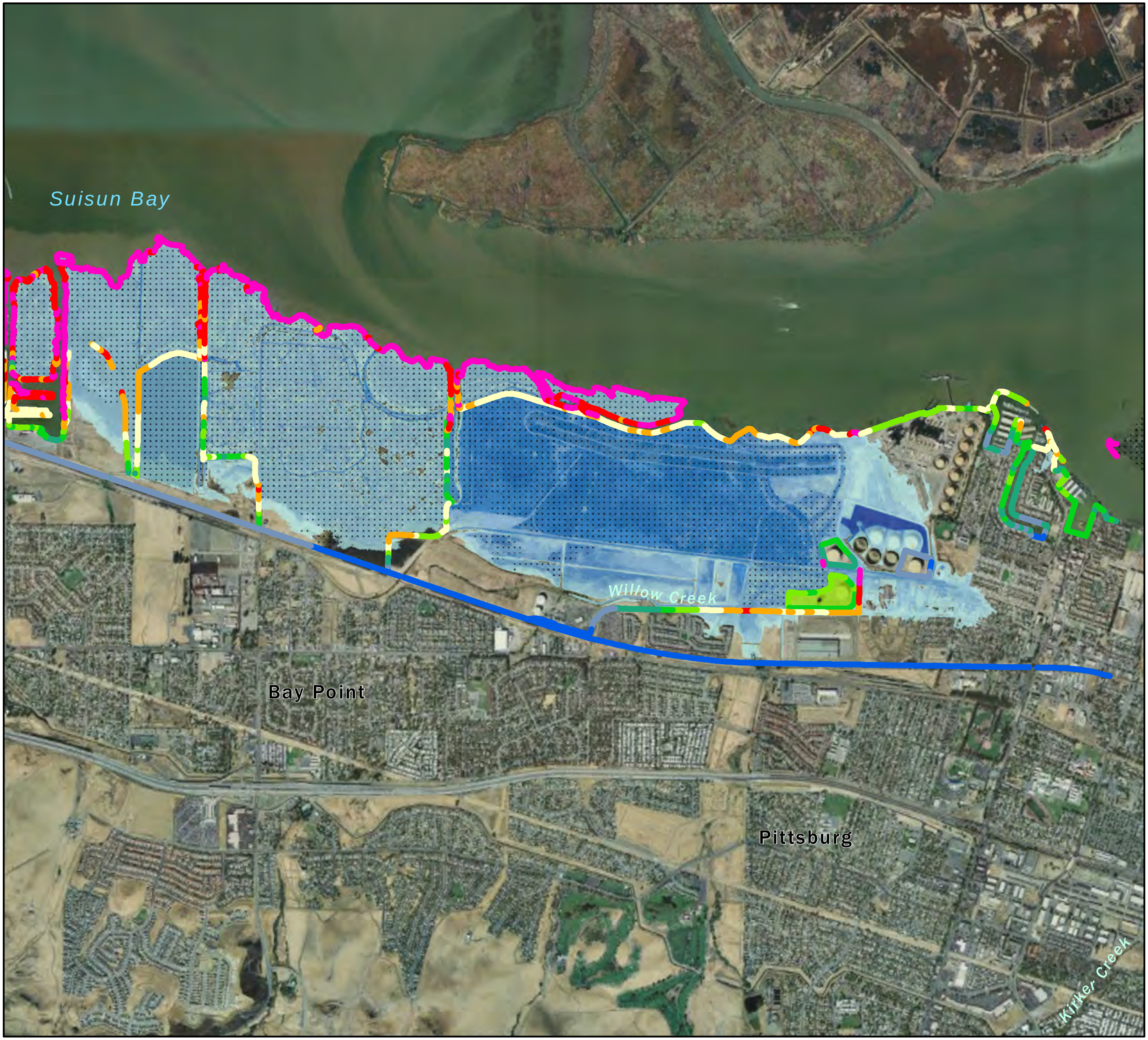

CONTRA COSTA COUNTY

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