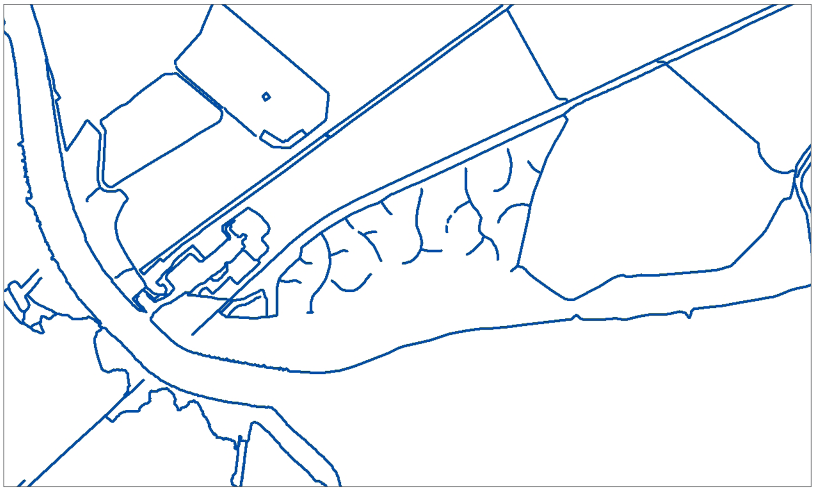
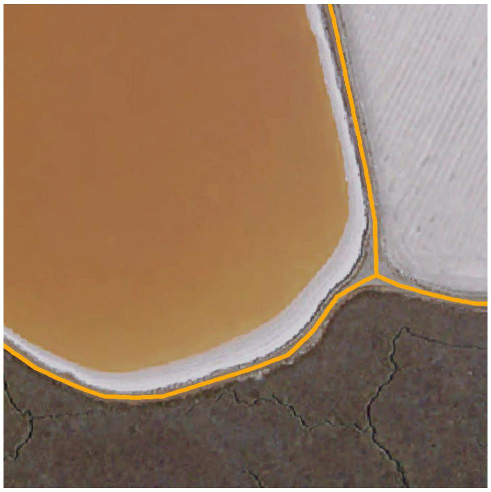


SAN FRANCISCO BAY SHORE INVENTORY

Mapping for Sea Level Rise Planning



PREPARED BY

San Francisco Estuary Institute-Aquatic Science Center

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Bay Area Clean Water Agencies

FUNDED BY

Department of Water Resources:
Integrated Regional Water Management Plan

SFEI CONTRIBUTION #779

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BAY AREA CLEAN WATER AGENCIES

DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

SAN FRANCISCO ESTUARY PARTNERSHIP

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REPORT & DATASET AVAILABILITY

Report and dataset are available on SFEI's website at http://www.sfei.org/projects/SFBayShoreInventory

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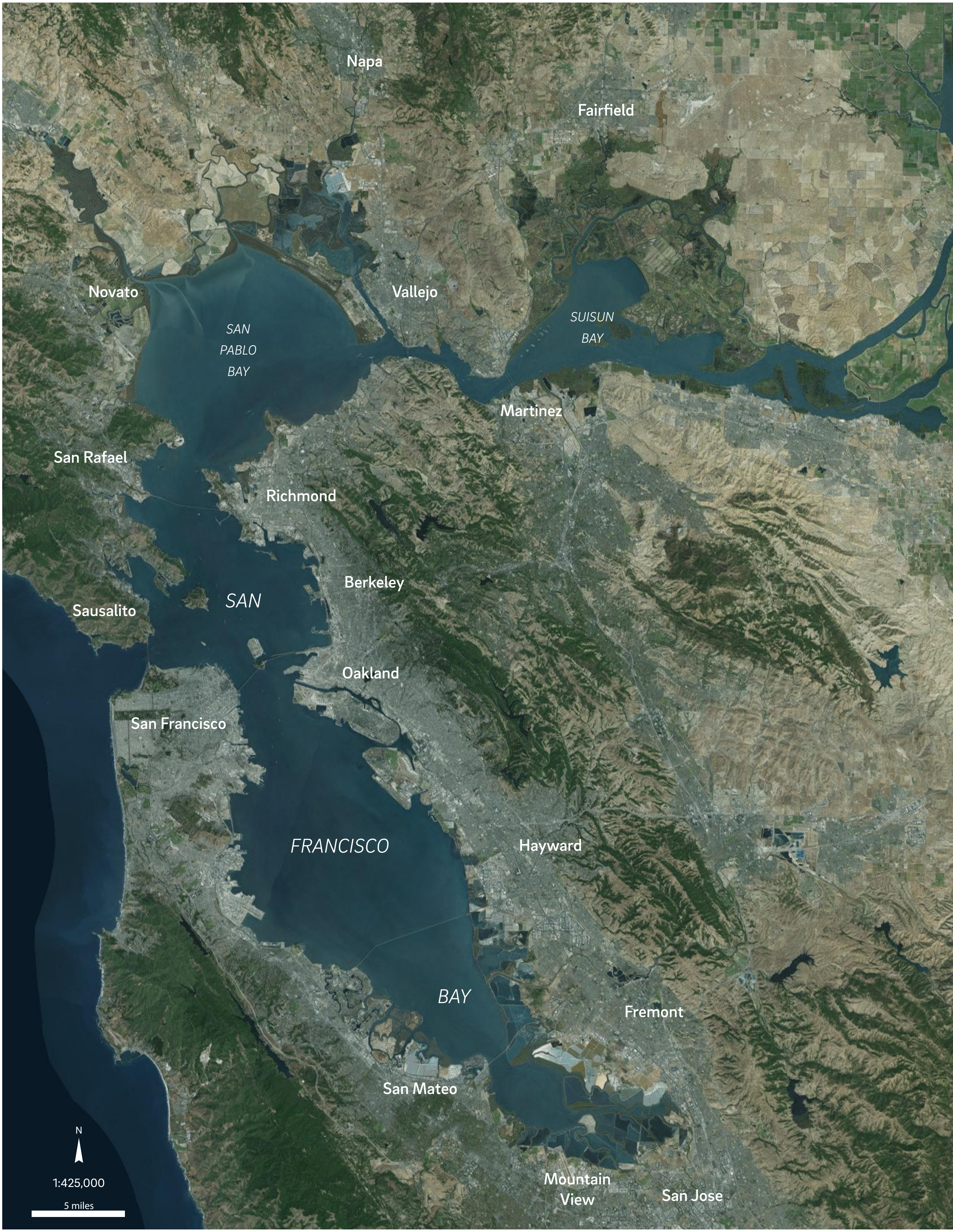
CONTENTS

Bay shore at Don Edwards National Wildlife Refuge. Photo by Shira Bezalel, January 2015.


Napa
Fairfield
Novato
Vallejo
SAN PABLO BAY
SUISUN BAY
Martinez
San Rafael
Richmond
Berkeley
SAN
Sausalito
Oakland
San Francisco
FRANCISCO
Hayward
BAY
Fremont
San Mateo
N
1:425,000
5 miles
Mountain View
San Jose

1. INTRODUCTION

With rising sea levels and the increased likelihood of extreme weather events, it is important for regional agencies and local municipalities in the San Francisco Bay Area to have a clear understanding of the status, composition, condition, and elevation of our current Bay shore, including both natural features and built infrastructure.

The purpose of this Bay shore inventory is to create a comprehensive and consistent picture of today's Bay shore features to inform regional planning. This dataset includes both structures engineered expressly for flood risk management (such as accredited levees) and features that affect flooding at the shore but are not designed or maintained for this purpose (such as berms, road embankments, and marshes). This mapping covers as much of the 'real world' influence on flooding and flood routing as possible, including the large number of non-accredited structures.

This information is needed to:

1. identify areas vulnerable to flooding;
2. identify adaptation constraints due to present Bay shore alignments; and
3. suggest opportunities where beaches, wetlands, and floodplains can be maintained or restored and integrated into flood risk management strategies.

The primary focus of the project is therefore to inform regional planners and managers of Bay shore characteristics and vulnerabilities. The mapping presented here is neither to inform FEMA flood designation nor is it a replacement for site-specific analysis and design.

The mapping consists of two main elements:

1. Mapping of Bay shore features (levees, berms, roads, railroads, embankments, etc.) which could affect flooding and flood routing.
2. Attributing Bay shore features with additional information including elevations, armoring, ownership (when known), among others.

SFEI delineated and characterized the Bay shore inland to 3 meters (10ft) above mean higher high water (MHHW) to accommodate observed extreme

San Francisco Bay. (imagery courtesy ESRI) water levels and the commonly used range of future sea level rise (SLR) scenarios. Elevated Bay shore features were mapped and classified as engineered levees, berms, embankments, transportation structures, wetlands, natural shoreline, channel openings, or water control structures. Mapped features were also attributed with elevation (vertical accuracy of <5cm reported in 30 meter (100ft) segments from LiDAR derived digital elevation models (DEMs), FEMA accreditation status, fortification (e.g., riprap, buttressing), frontage (e.g., whether a feature was fronted by a wetland or beach), ownership, and entity responsible for maintenance. Water control structures, ownership, and maintenance attributes were captured where data was available (not complete for entire dataset). The dataset was extensively reviewed and corrected by city, county, and natural resource agency staff in each county around the Bay. This report provides further description of the Bay shore inventory and methods used for developing the dataset. The result is a publicly accessible GIS spatial database (www.sfei.org/projects/SFBayShoreInventory).

This project was financed under the Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006, administered by State of California, Department of Water Resources under a grant to the Bay Area Clean Water Agencies (BACWA) and by an agreement with the local project sponsor, the Association of Bay Area Governments/San Francisco Estuary Partnership. Support and technical advice was also provided by the Bay Area Flood Protection Agencies Association (BAFPAA). This dataset was developed by SFEI in collaboration with many local partners and with guidance from the Bay Area Regional Collaborative (including BCDC, MTC, and ABAG), as well as the State Coastal Conservancy. The dataset builds on data developed for Alameda and San Francisco Counties by BCDC and AECOM, as further described in the imagery and data sources section of this report.

Examples of Bay shore types. Highway 580 and the Bay Trail fronted by wetlands in Albany (below); berm fronted by wetlands at Don Edwards NWR (top right); residential housing along the Richmond shoreline (bottom right). Photos (below) by Carolyn Doehring and (right) by Shira Bezalel.

2. OVERVIEW: SF Bay Shore Inventory Mapping

Present

The San Francisco Bay has a diversity of natural Bay shore types ranging from mudflats and marshes to bluffs and beaches. Similarly, the degree of urbanization varies from the crowded cities of the South Bay to the hayfields in the North Bay. As a consequence the need for, and type of, Bay shore features (levees, berms, embankments, etc.) reflects both the natural and man-made Bay.

The types of Bay shore features mapped also have varying vulnerabilities to sea level rise depending on a range of factors including among others: whether the feature is specifically designed for flood risk management, the height and location of a feature within the Bay, and future maintenance. Engineered levees and floodwalls are designed to provide flood risk management to inland areas. Many of the mapped berms in the Bay regulate water levels within managed ponds/wetlands, although in most cases they are not constructed or maintained for flood management purposes. Shoreline protection structures and road embankments could help alleviate floods but again are not designed to protect against specific flood conditions. Given adequate height and width, wetlands and beaches buffer the shoreline by attenuating waves but are not generally considered in flood risk management planning and design.

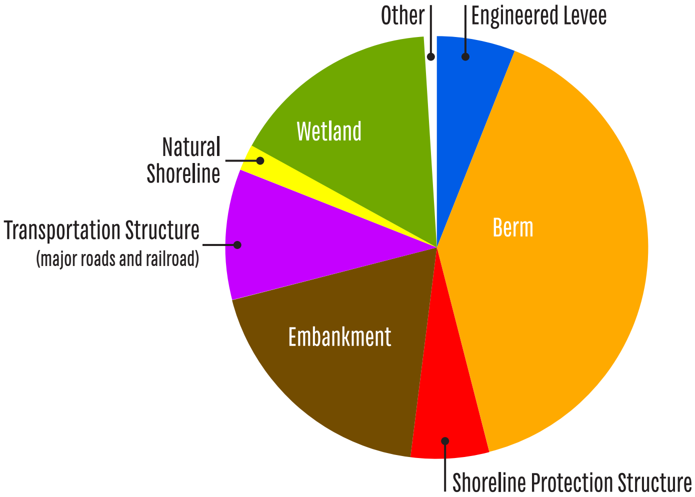
Future

Identifying the make-up of the existing Bay shore will be important for considering the vulnerabilities to sea level rise and opportunities for adaptation measures. As sea level rises, Bay shore features will be exposed to larger waves, which could weaken structures or erode natural areas and affect their ability to provide continued shoreline benefits. Adaptation would therefore include maintaining and strengthening existing structures as well as realigning and redesigning areas of the Bay shore. There may also be opportunities for incorporating natural and nature-based features in future flood risk management.

Examples of Bay Shore Types. From top to bottom: urbanized shoreline, largely mapped as shoreline protection structure along San Francisco; wetland frontage along Richmond shoreline; beach frontage at Keller Beach, Richmond; hardened shoreline at Pt. Isabel, Richmond. Photos by Shira Bezalel, January 2015.

Bay Shore Inventory Classification

The amount of different Bay shore features that exists within the study area are summarized on pages 6 and 7.



Key Findings:

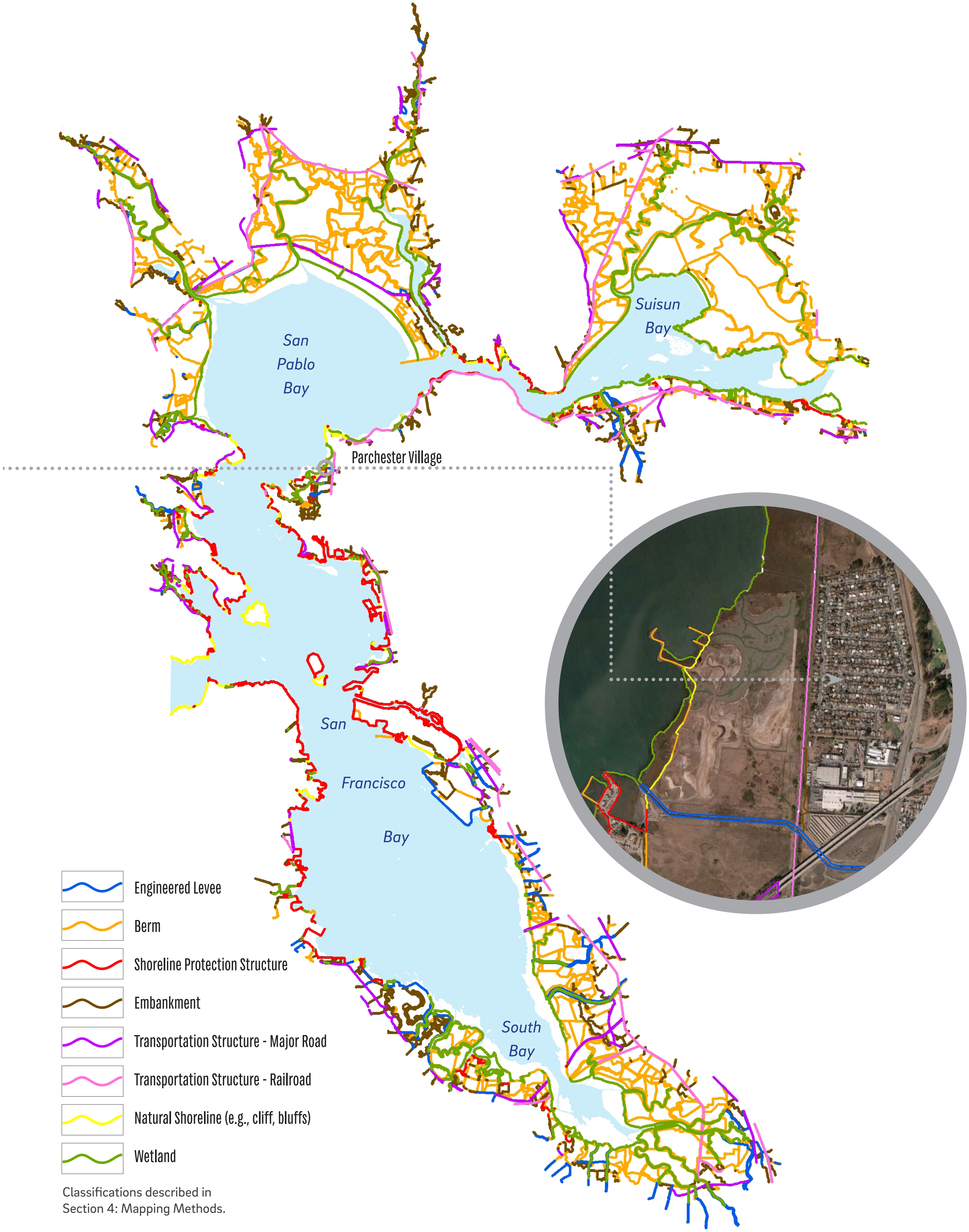
- 170 miles of engineered levees were mapped, primarily along stream channels. Engineered levees are designed for flood risk management under existing conditions but their level of protection will decrease with rising seas unless raised and reinforced.
- A large number of wetlands and berms are present in the North Bay, Suisun, and parts of South Bay. The creation of extensive salt pond complexes in the North and South Bays resulted in loss of wetlands but also the construction of miles of water control berms. Water control structures are also prevalent in Suisun, maintained for duck hunting. Only fragments of the historical wetlands remain.
- Berms are the most extensive Bay shore type, common around salt ponds, and are often the first defense from the Bay. Berms aren't specifically engineered for flood risk management, which puts them at risk especially due to elevated water levels with sea level rise.

Class	Percent	Miles
Engineered Levee	6%	170
Berm	40%	1,215
Shoreline Protection Structure	6%	175
Embankment	19%	558
Transportation Structure (major roads, railroad)	10%	313
Natural Shoreline	2%	66
Wetland	16%	486
Other	1%	29
TOTAL	**100%**	**3,012**

Beach and marsh at Pt. Pinole (East Bay Regional Park), Parchester Village and railroad in background. Photo by Shira Bezalel, February 2015.

Profile: Parchester Village

Parchester Village is a neighborhood of about 400 homes located in North Richmond. A railroad separates this community (and much of the Pinole-Hercules shoreline) from the Bay. Much of the transportation infrastructure around the Bay was not specifically built for flood risk management and therefore could be increasingly vulnerable with rising seas. The wetlands at Breuner Marsh and Giant Marsh, which front Parchester Village, do act as a natural buffer to attenuate waves, among other ecological and recreational benefits. With accelerated sea level rise, the railroad and this community could be vulnerable to higher water levels leading to increased flood risk.


San Pablo Bay
Suisun Bay
Parchester Village
San Francisco Bay
South Bay
Engineered Levee
Berm
Shoreline Protection Structure
Embankment
Transportation Structure - Major Road
Transportation Structure - Railroad
Natural Shoreline (e.g., cliff, bluffs)
Wetland

Classifications described in Section 4: Mapping Methods.

Classification of Shoreline Features by Region

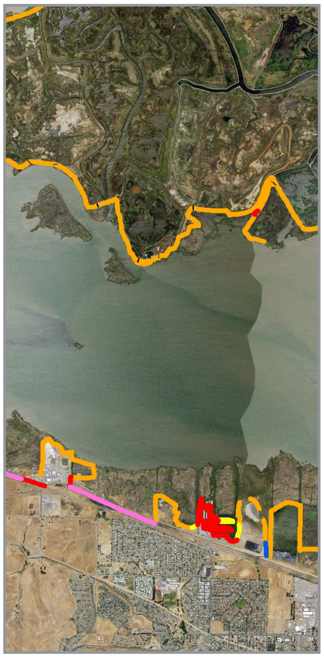
This and the following page focuses on the first non-wetland barrier to flooding along the Bay shore – referred to as the 'shoreline".

Key Findings:

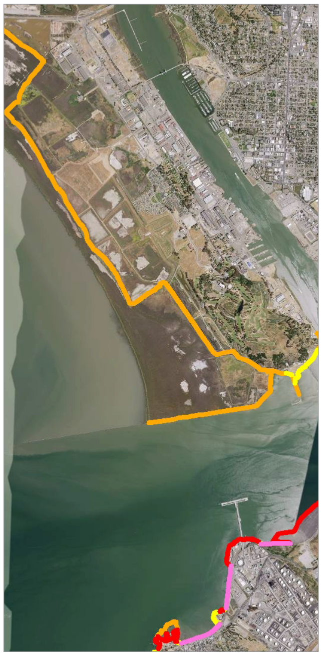
- Central Bay has primarily developed shorelines reflecting steep natural topography, fewer and smaller historical wetlands, large amounts of fill, and urbanization.
- Extensive berm complexes in the North and South Bay reflect former and current salt ponds which provide flood risk management benefits in conjunction with engineered levees.
- Suisun Bay has extensive berms associated with duck clubs on the north side of Carquinez Straits, with more shoreline protection structures and transportation structures on the south side.
- Transportation structures are common as the first line of defense including Highway 37 in the North Bay, railroads along the Hercules and Pinole shorelines, the Eastshore Highway (I-80), and Highway 101 at Brisbane Lagoon.

	SUISUN BAY		NORTH BAY		CENTRAL BAY		SOUTH BAY	
Class	**Miles**	**% of Suisun Bay**	**Miles**	**% of North Bay**	**Miles**	**% of Central Bay**	**Miles**	**% of South Bay**
Engineered Levee	2	2%	<1	<1%	12	6%	10	15%
Berm	48	53%	32	47%	15	7%	43	64%
Shoreline Protection Structure	18	20%	10	14%	134	65%	12	18%
Transportation Structure	11	12%	11	16%	8	4%	1	2%
Natural Shoreline	11	13%	16	23%	37	18%	1	2%
Other	<1	<1%	0	0%	<1	<1%	<1	<1%
TOTAL	**90**	**100%**	**69**	**100%**	**207**	**100%**	**67**	**100%**
Total of SF Bay		**21%**		**16%**		**48%**		**15%**

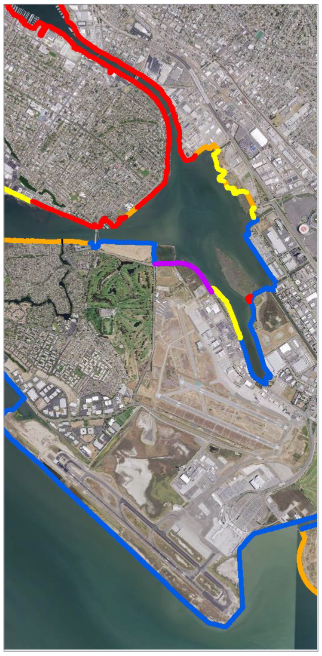
SUISUN BAY



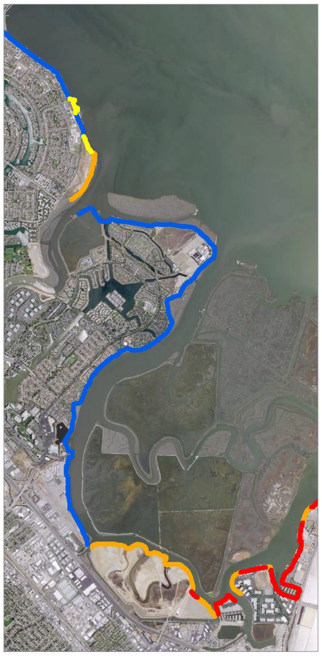
NORTH BAY

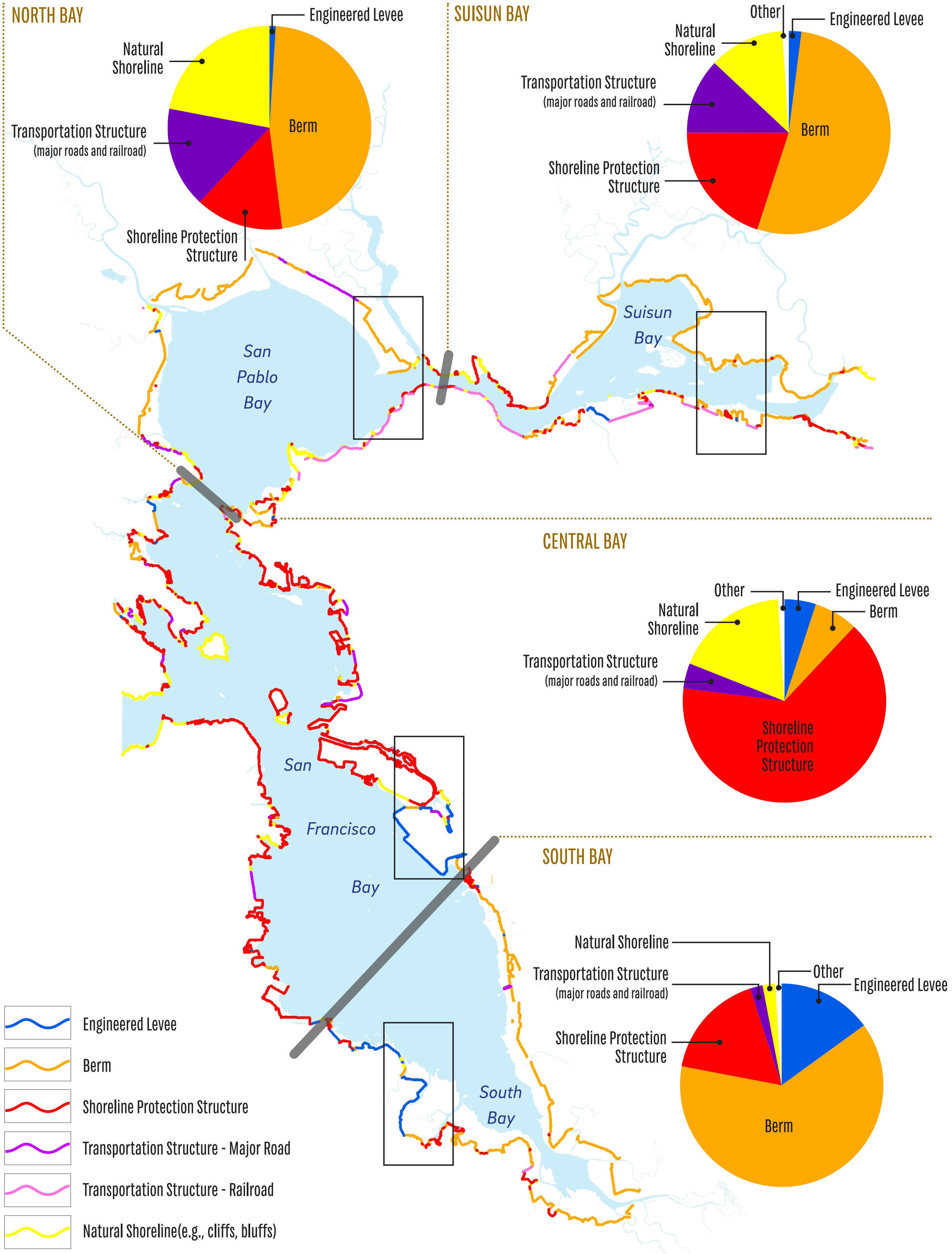


CENTRAL BAY



SOUTH BAY




NORTH BAY
Engineered Levee
Natural Shoreline
Berm
Transportation Structure (major roads and railroad)
Shoreline Protection Structure
SUISUN BAY
Other
Engineered Levee
Natural Shoreline
Transportation Structure (major roads and railroad)
Berm
Shoreline Protection Structure
San Pablo Bay
Suisun Bay
CENTRAL BAY
Other
Engineered Levee
Berm
Natural Shoreline
Transportation Structure (major roads and railroad)
Shoreline Protection Structure
San Francisco Bay
SOUTH BAY
Natural Shoreline
Transportation Structure (major roads and railroad)
Other
Engineered Levee
Shoreline Protection Structure
Berm
South Bay
Engineered Levee
Berm
Shoreline Protection Structure
Transportation Structure - Major Road
Transportation Structure - Railroad
Natural Shoreline(e.g., cliffs, bluffs)

No 'Wetland' or 'Embankment' classifications shown.

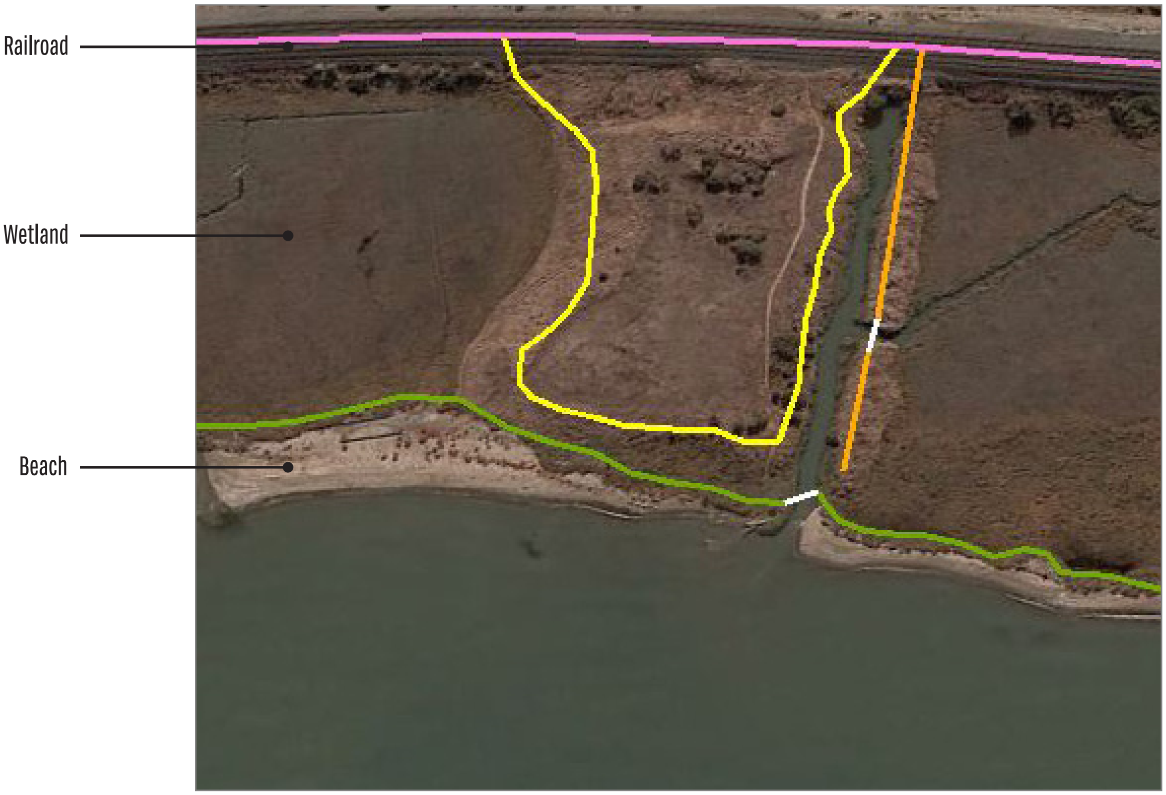
Location of Wetland and Beach Frontage Along Bay Shoreline

Pages 10 and 11 show where shoreline features are benefiting from protection by Bayside marshes and beaches. There are many opportunities to maintain exisitng 'natural infrastructure' or expand areas where it is not currently present.

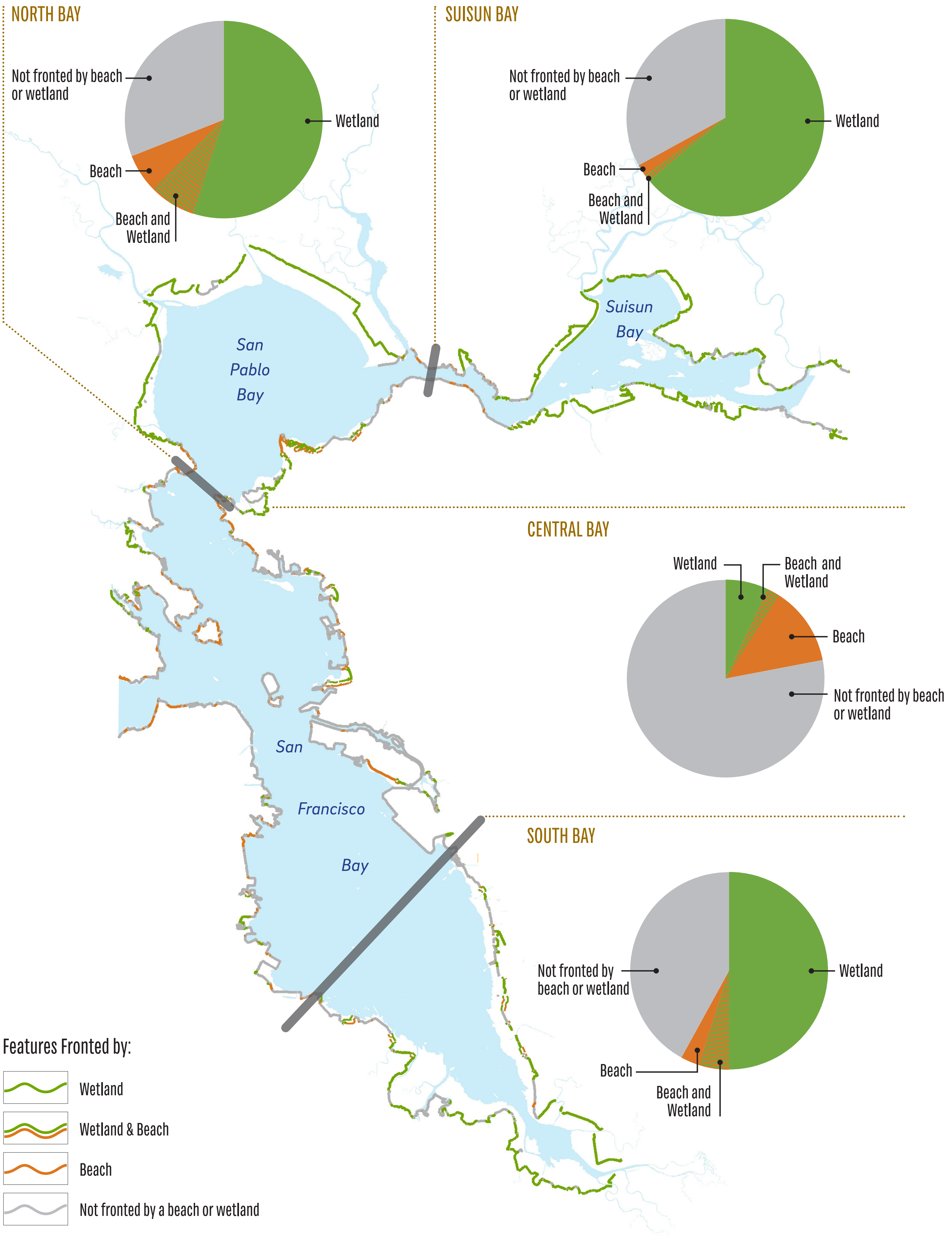
Key Findings:

- Central Bay has the largest extent of shoreline features fronted by beaches (27 miles).
- Suisun (57 miles), North Bay (38 miles), and South Bay (34 miles) all have extensive shoreline fronted by wetlands.
- Natural infrastructure- especially tidal marsh- is providing wave attenuation and coastal flood protection along a substantial portion (44%) of the shoreline.

	SUISUN BAY		NORTH BAY		CENTRAL BAY		SOUTH BAY	
Class	**Miles**	**% of Suisun Bay**	**Miles**	**% of North Bay**	**Miles**	**% of Central Bay**	**Miles**	**% of South Bay**
Wetland	57	64%	38	55%	15	7%	34	50%
Wetland & Beach	<1	<1%	5	7%	3	2%	3	5%
Beach	2	2%	5	7%	27	13%	2	3%
Other	30	34%	22	31%	162	78%	28	42%
TOTAL	**90**	**100%**	**69**	**100%**	**207**	**100%**	**67**	**100%**
Total of SF Bay		**21%**		**16%**		**48%**		**15%**



Example of a railroad which is attributed in the dataset with both wetland and beach frontage.


NORTH BAY
Not fronted by beach or wetland
Wetland
Beach
Beach and Wetland
SUISUN BAY
Not fronted by beach or wetland
Wetland
Beach
Beach and Wetland
San Pablo Bay
Suisun Bay
CENTRAL BAY
Wetland
Beach and Wetland
Beach
Not fronted by beach or wetland
San Francisco Bay
SOUTH BAY
Not fronted by beach or wetland
Wetland
Beach
Beach and Wetland
Features Fronted by:
Wetland
Wetland & Beach
Beach
Not fronted by a beach or wetland

3. IMAGERY AND DATA SOURCES

Many datasets were used to map and attribute Bay shore features around the Bay. High resolution digital elevation models (DEMs) derived from both Ocean Protection Council (OPC) 2010 LiDAR and U.S. Geological Survey (USGS) 2010 LiDAR were used to interpret specific features and attribute elevations. Other imagery was referenced to classify features viewed in the DEMs and identify newly constructed features including National Agriculture Imagery Program (NAIP) imagery and orthoimagery covering Contra Costa, Napa, Marin and the San Francisco Presidio regions. Bing Maps aerial imagery was also used as a reference to take advantage of the high detail oblique imagery.

Existing datasets were used to help identify and attribute flood infrastructure features. These datasets included the Federal Emergency Management Agency Mid-term Levee Inventory (FEMA MLI), which helped to identify currently and formerly accredited engineered levees and floodwalls. SFEI's Bay Area Aquatic Resources Inventory (BAARI, 2014) was used to help identify tidal channels and water control structures. In addition to these data sources, city, county, and natural resource agencies provided flood infrastructure (e.g., tidegates) and ownership GIS layers as well as information regarding the engineered state of structures, ownership, and other information less apparent in the LiDAR and imagery sources. The main sources used for mapping are summarized on the next page.

AECOM, in partnership with BCDC, provided initial mapping for Alameda (2014) and San Francisco (2015) counties with funding provided by Alameda County Flood Control & Water Conservation District and San Francisco Public Utilities Commission. In applying the mapping protocol described here, SFEI made edits to mapping in both counties to ensure consistency with revised mapping methods across all nine Bay Area counties.

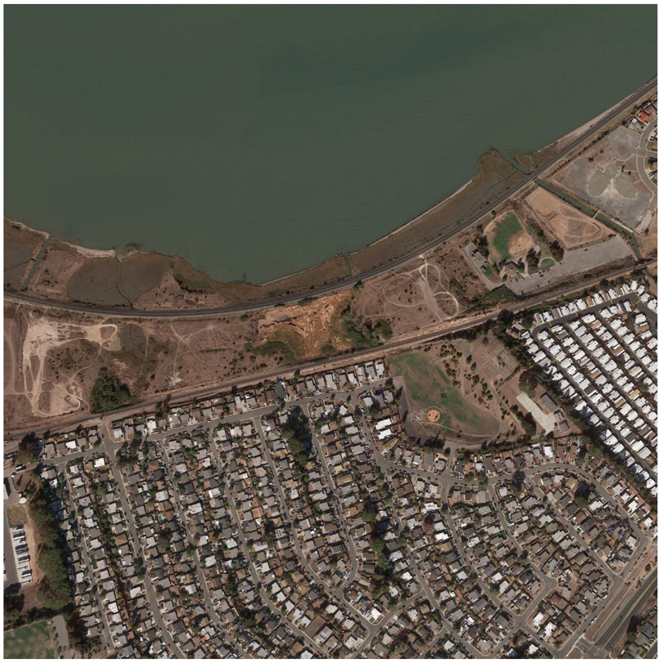
NAIP 2014

Orthoimagery 2014

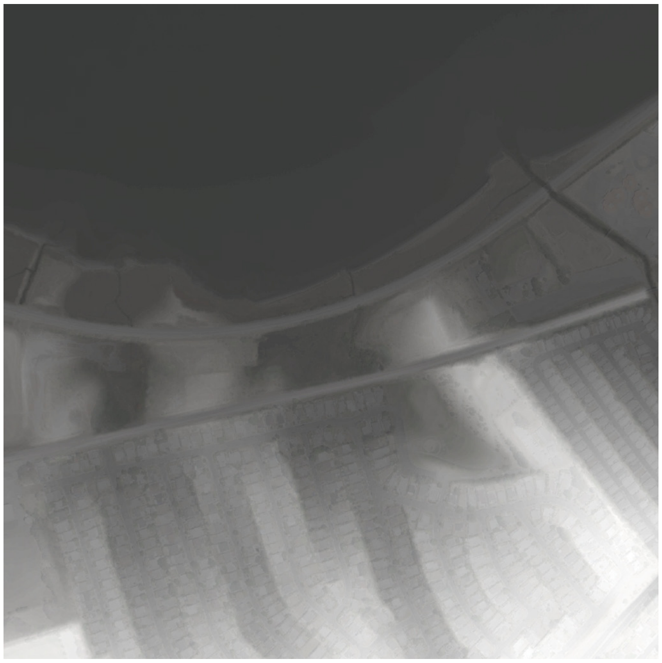
Dataset Name	Year	Notes	Dataset Link
DEM derived from OPC LiDAR	2010	1 meter resolution. Used for Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano and Sonoma counties. Vertical accuracy is 4.8cm RMSE.	https://coast.noaa.gov/dataviewer/index.html
DEM derived from USGS LiDAR	2010	2 meter resolution. Used for Alameda, Contra Costa, San Francisco, San Mateo and Santa Clara counties. Vertical accuracy is 12cm RMSE.	http://earthexplorer.usgs.gov/
National Agriculture Imagery Program (NAIP) Imagery	2009, 2010, 2012, 2014	1 meter resolution. Used for all counties.	http://www.atlas.ca.gov/download.html#/casil/imageryBaseMapsLandCover/imagery/naip
Orthoimagery (SFEI and Quantum Spatial)	2014	10cm and 15cm resolution. Used for Contra Costa, Marin and Napa counties.	http://www.sfei.org/project/san-francisco-bay-area-digital-orthoimagery-collection
Google Earth Imagery (Digital Globe and others)	2012-2015	<=1 meter resolution. Used for all counties.	https://www.google.com/earth/
Federal Emergency Management Agency Mid-term Levee Inventory (FEMA MLI)	2014*	MLI is less spatially accurate based on a visual comparison with high resolution DEMs, estimated 5-10m horizontal offset in levee locations. *SF Bay region features were generally last updated 2008-2009. Used for all counties.	Contact FEMA for this dataset.
Bing Maps Bird's Eye/Pictometry Oblique Aerial Imagery	2012-2015	Multiple viewing angles aid in interpretation of shoreline attributes.	http://www.bing.com/mapspreview

List of primary data sources used in mapping.

Google Earth Imagery 2016



LiDAR + NAIP 2014



4. MAPPING METHODS

This section details the methods used for mapping Bay shore features. Mapping methods used in this study built off of methods developed by AECOM for the Adapting to Rising Tide project (ART, 2015).

The San Francisco Bay Shore Inventory was classified into ten primary categories to capture the diversity of today's Bay shore. The categories reflect both features which were built for flood risk management (e.g., floodwalls) and natural features (e.g., wetlands) which could indirectly provide coastal protection but were not specifically designed for this purpose. Detailed descriptions of each category can be found on pages 16-22. A number of other attributes (e.g., features hardened by riprap, features fronted by beaches) are present in the dataset and further describe Bay shore conditions. Refer to page 21 for a full list of dataset attributes.

Mapping of Bay shore features was accomplished by digitizing the highest ridge or edge of the highest surface that was visible in the LiDAR derived DEM (USGS 2010, NOAA/OPC 2010) datasets. This was completed for the first raised feature along the Bay shoreline and a sub-set of raised features within the landscape and along waterways inland to MHHW plus three meters (10ft) in elevation.

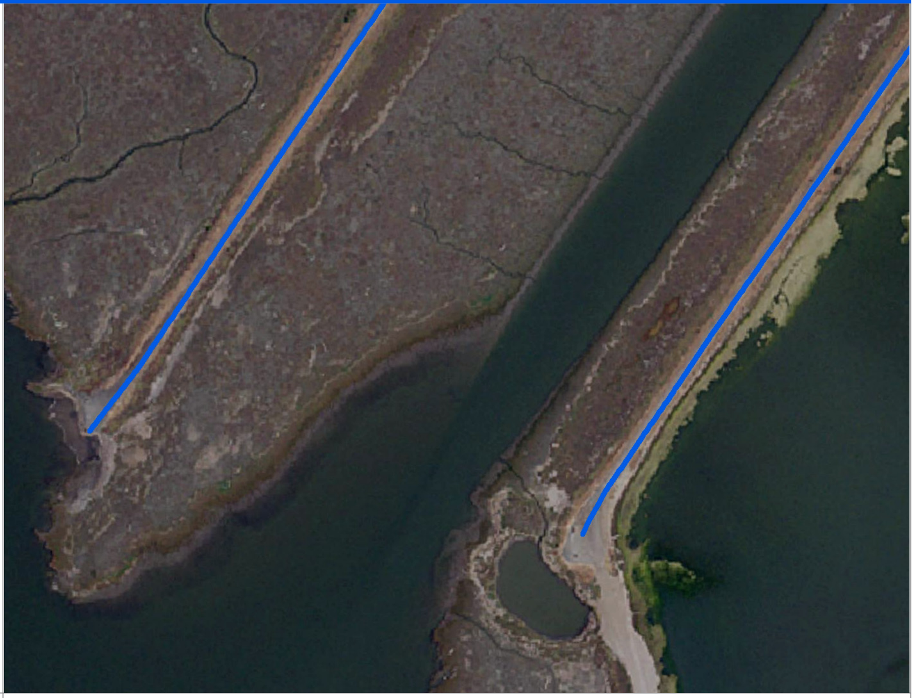
Hardening of Bay shore with riprap along Pt. Isabel Regional Shoreline. Photo by Shira Bezalel, January 2015.

ENGINEERED LEVEE

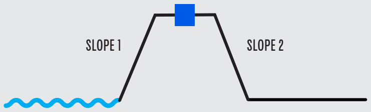
DESCRIPTION

Features were designated as 'Engineered' if a feature 1) was assigned as 'accredited' or 'once accredited' in FEMA's MLI (2014) or 2) a city, county, or agency representative confirmed that the levee had been engineered for flood protection. Generally these features have two slopes, a classic levee shape, but in some cases engineered levees only had one slope. Slope (sides of levee) was useful for determining the bounds of the features in the DEM. The existing FEMA MLI levee layer often did not match perfectly with the LiDAR, however best judgement was used to assign the status of each mapped feature. SFEI met with cities, counties, and other natural resource agency staff to identify additional engineered levees not represented in FEMA's MLI (2014) dataset. Further details on engineered levees can be found in ART (2015).

EXAMPLE

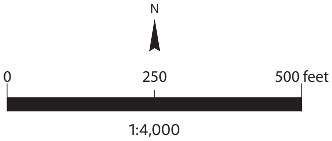


PROFILE



LOCATION

Mouth of Alameda Creek, Alameda County

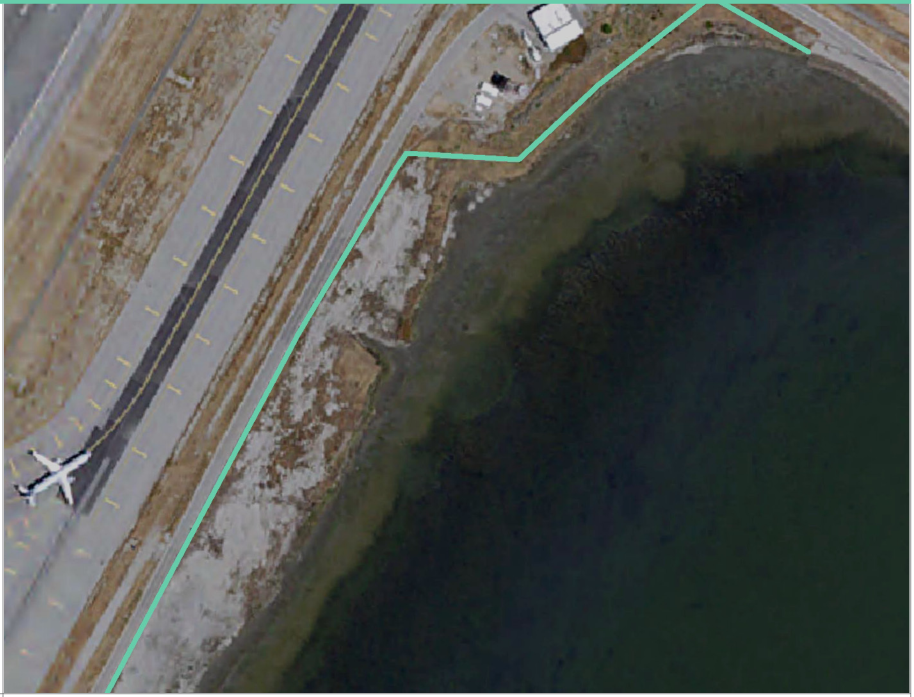


FLOODWALL

DESCRIPTION

Floodwalls (also with two distinct sides) are generally narrower than the LiDAR pixel size and were captured based on aerial imagery or local knowledge provided by stakeholders and/or agency representatives. If a floodwall was part of an engineered levee, the feature's class field was assigned, 'Engineered Levee' and a note was provided in the comments field.

EXAMPLE



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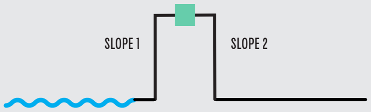
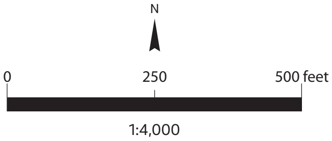


LOCATION

San Francisco International Airport, San Mateo County

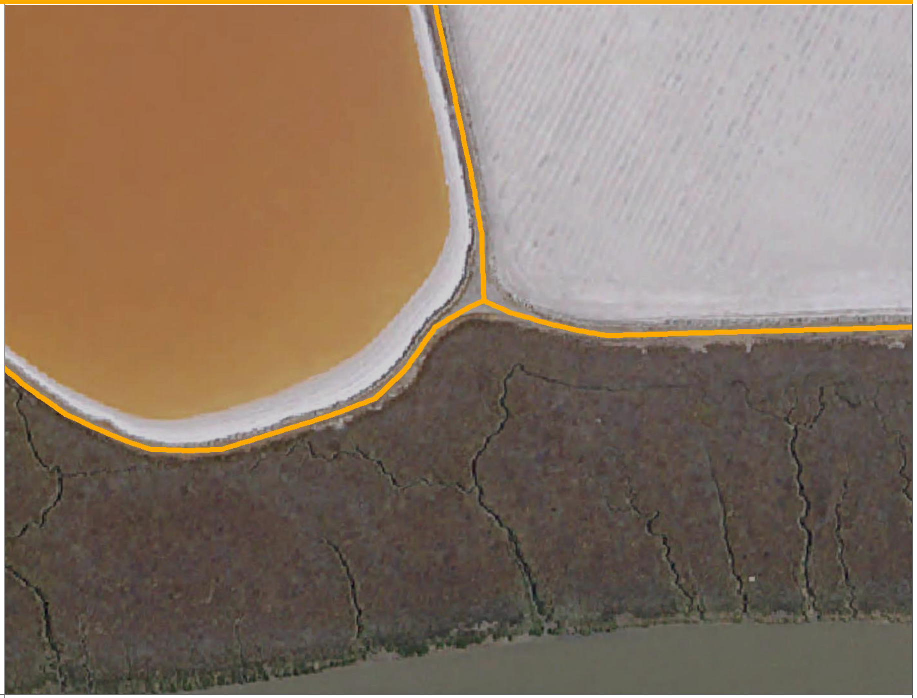


BERM

DESCRIPTION

Features with a “levee” shape (two slopes) were classified as ‘Berms’ by default. The term ‘Berm’ for this dataset refers to a raised feature that was created without specific engineering for flood risk management. Examples of this include berms around the salt ponds in the South Bay, or duck clubs in Suisun Bay which are managed for wildlife habitat. Features were only reclassified as ‘Engineered Levees’ if additional information was obtained from the FEMA MLI layer (2014) or during local stakeholder meetings.

EXAMPLE



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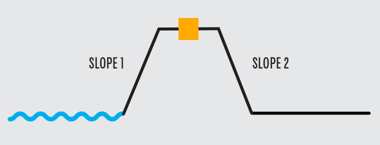
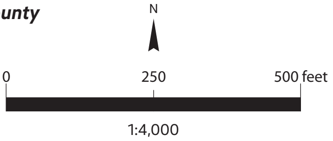


LOCATION

Salt ponds and tidal marsh near Dumbarton Bridge, Alameda County

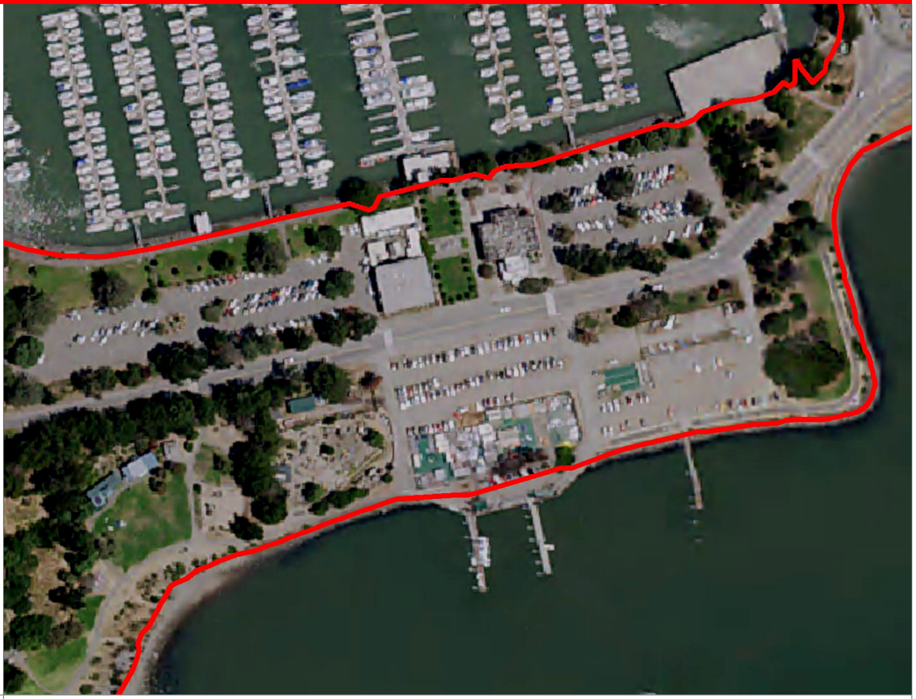


SHORELINE PROTECTION STRUCTURE

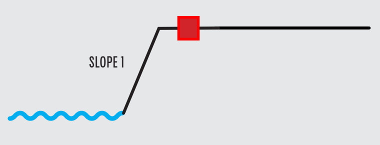
DESCRIPTION

Shoreline protection structures were classified as features which only have one sloped side, often protecting an area of fill and located in areas of heavy development along the Bay shoreline. For example, much of the San Francisco shoreline and Alameda Island is classified as shoreline protection structure. Many of these locations are fortified or hardened to reduce wave erosion; the ‘Fortified’ field within the dataset identifies these areas specifically. Features inland of the Bay shoreline with one slope, were classified ‘Embankments’ (pg. 18) rather than ‘Shoreline Protection Structures’.

EXAMPLE

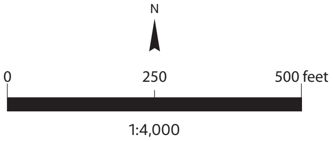


PROFILE



LOCATION

Berkeley Marina, Alameda County

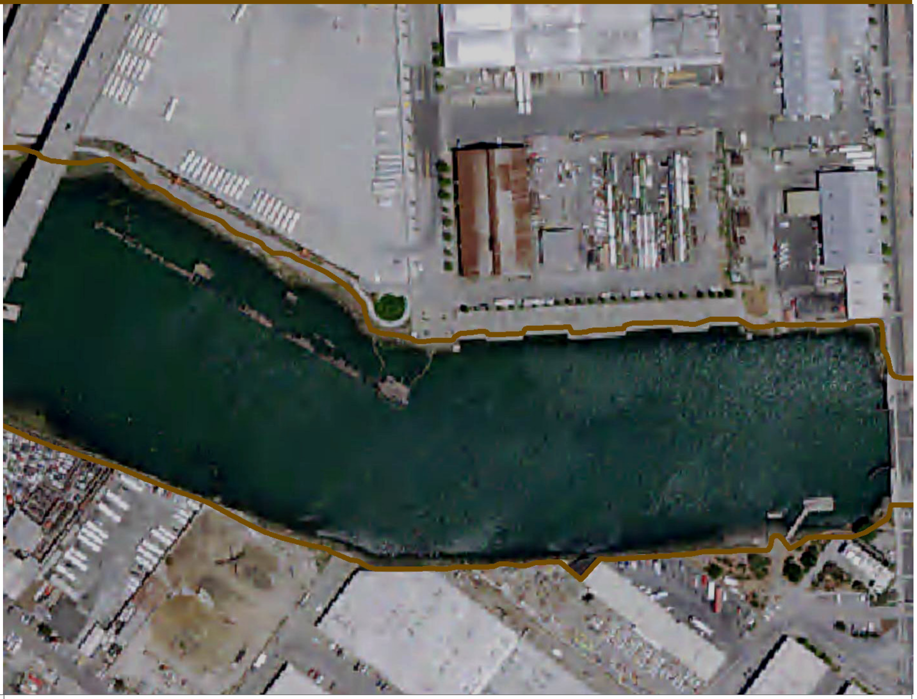


EMBANKMENT

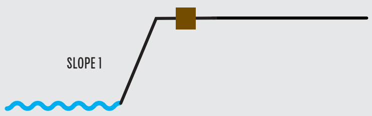
DESCRIPTION

Features which only have one sloped side and are inland of the Bay shoreline were classified as embankmants. Embankments generally line creek banks and sloughs, however in some cases embankments were mapped along natural slopes inland of the Bay shoreline (if it was the first feature inland of mapped wetlands).

EXAMPLE

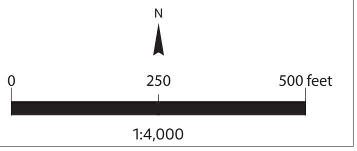


PROFILE



LOCATION

Islais Creek, San Francisco, County of San Francisco

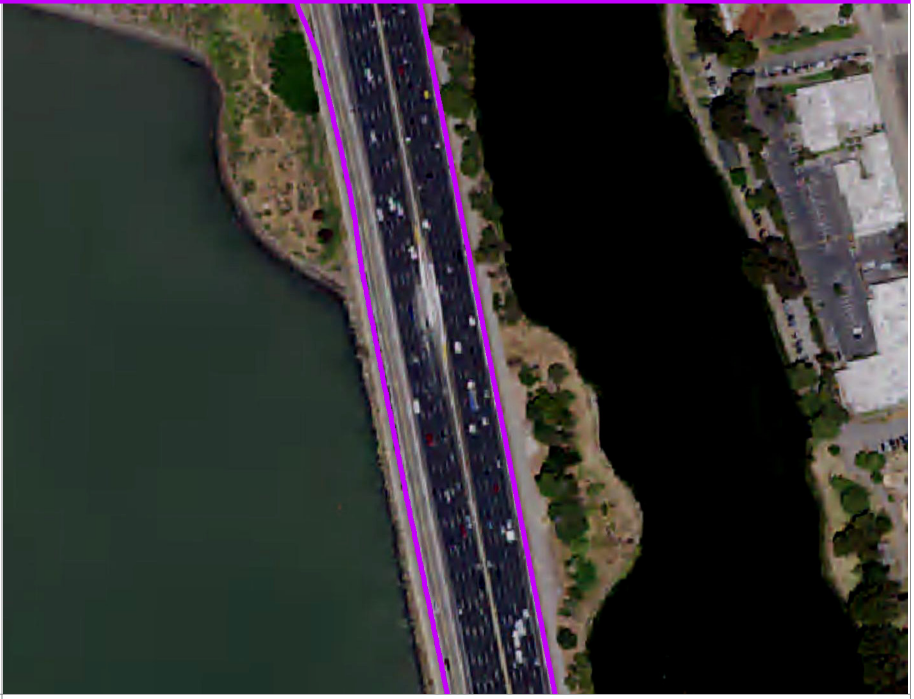


TRANSPORTATION STRUCTURE

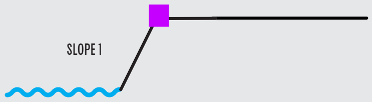
DESCRIPTION

Transportation structures were mapped on the edge (or centerline of narrower structures) of a railroad track or a major road. All railroads and a sub-set of major roads were classified as transportation structures regardless of the feature shape (e.g., one and two slopes). Smaller roads (e.g., private property access roads) were not attributed separately within the dataset, which was determined by referencing aerial imagery and existing GIS road layers. Only roads that were elevated from the surrounding landscape were mapped. Therefore, the dataset does not constitute a comprehensive layer of all roads within the mapped extent. If a road was part of an engineered levee, then the feature was mapped as an engineered levee.

EXAMPLE

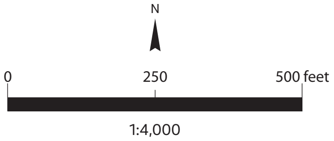


PROFILE



LOCATION

Interstate 80, Berkeley, Alameda County

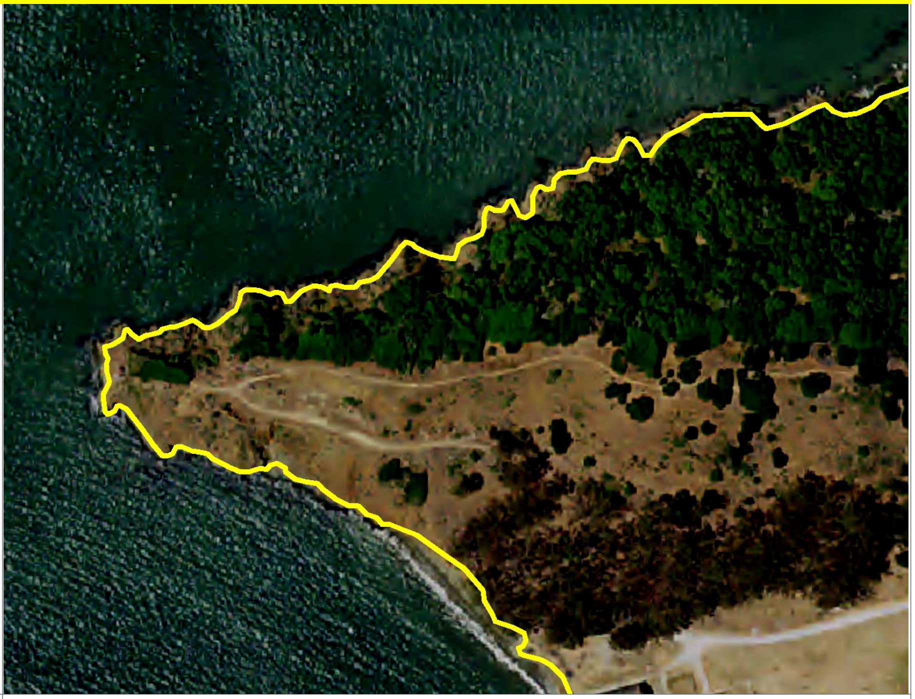


NATURAL SHORELINE

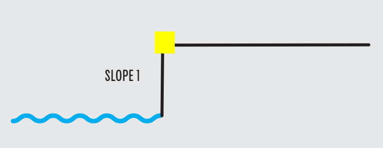
DESCRIPTION

The edge of predominantly natural land (e.g., cliffs, bluffs) were mapped as natural shoreline at the first major slope break along the Bay shoreline (natural shoreline was not mapped inland of the Bay shoreline).

EXAMPLE

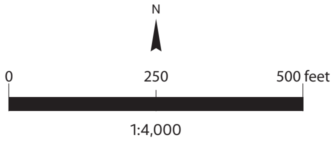


PROFILE



LOCATION

Angel Island State Park, Marin County

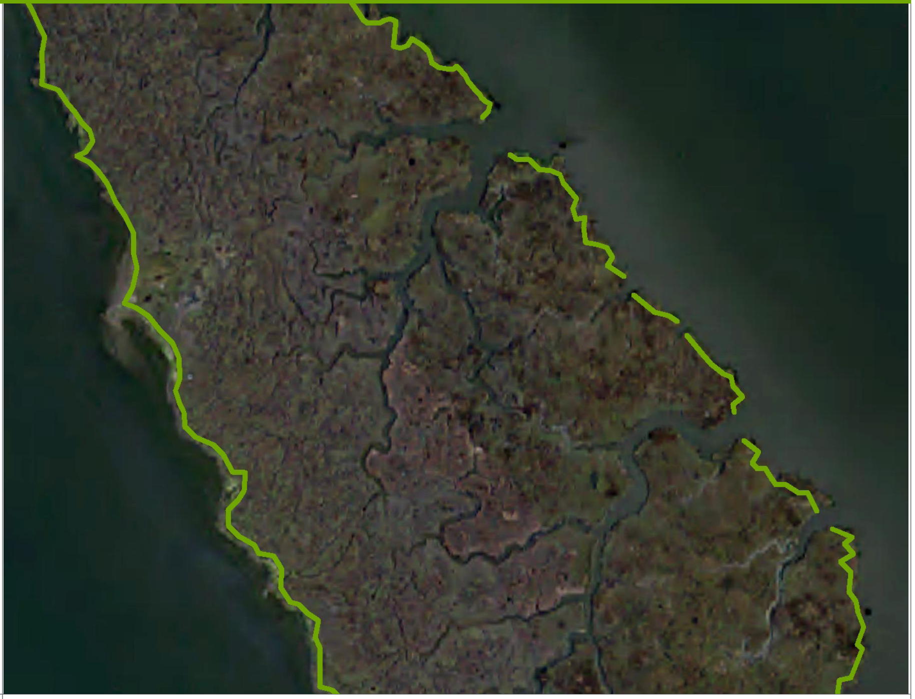


WETLAND

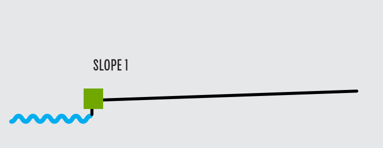
DESCRIPTION

Wetlands were mapped along the Bay shoreline and along major slough channels and tributaries to the Bay. The edge of wetlands were mapped corresponding to the marsh edge scarp in the DEM.

EXAMPLE

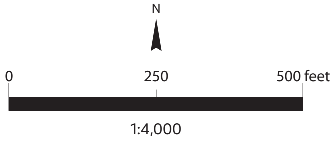


PROFILE



LOCATION

Arrowhead Marsh, Oakland, Alameda County

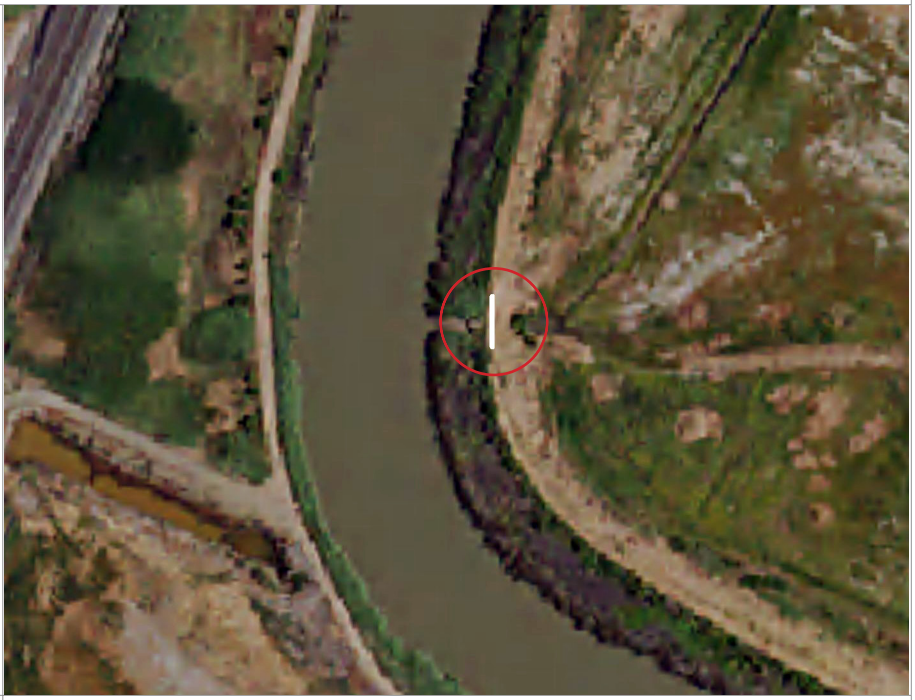


CHANNEL OR OPENING

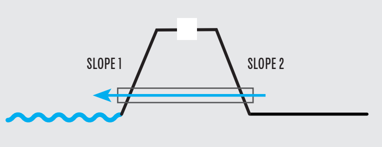
DESCRIPTION

This class mainly identified breaks in mapped features where openings were not apparent in the DEM, generally culverts running under levees or berm features. This class was also used to map some passive water control structures and tidal channels. This class was not mapped comprehensively, and is not intended to be used as a complete map of channel openings or penetration points within levees.

EXAMPLE

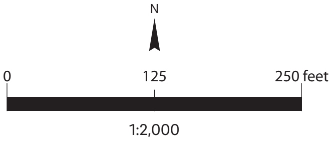


PROFILE



LOCATION

Near Cordelia, Solano County

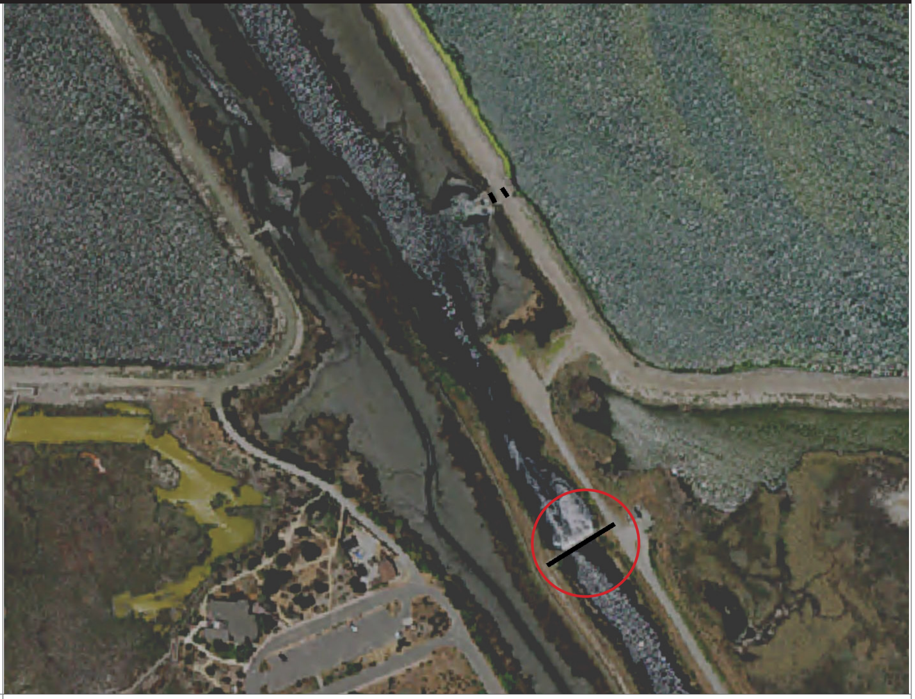


WATER CONTROL STRUCTURE

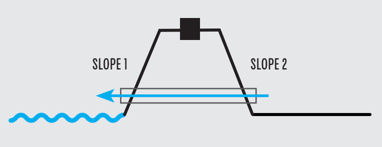
DESCRIPTION

This class identifies water control structures (e.g., tide gates, pump stations) based on aerial imagery or knowledge from agency representatives. This class was not mapped comprehensively, and is not intended to be used as a complete map of water control structures.

EXAMPLE

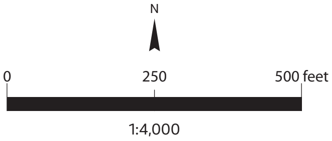


PROFILE

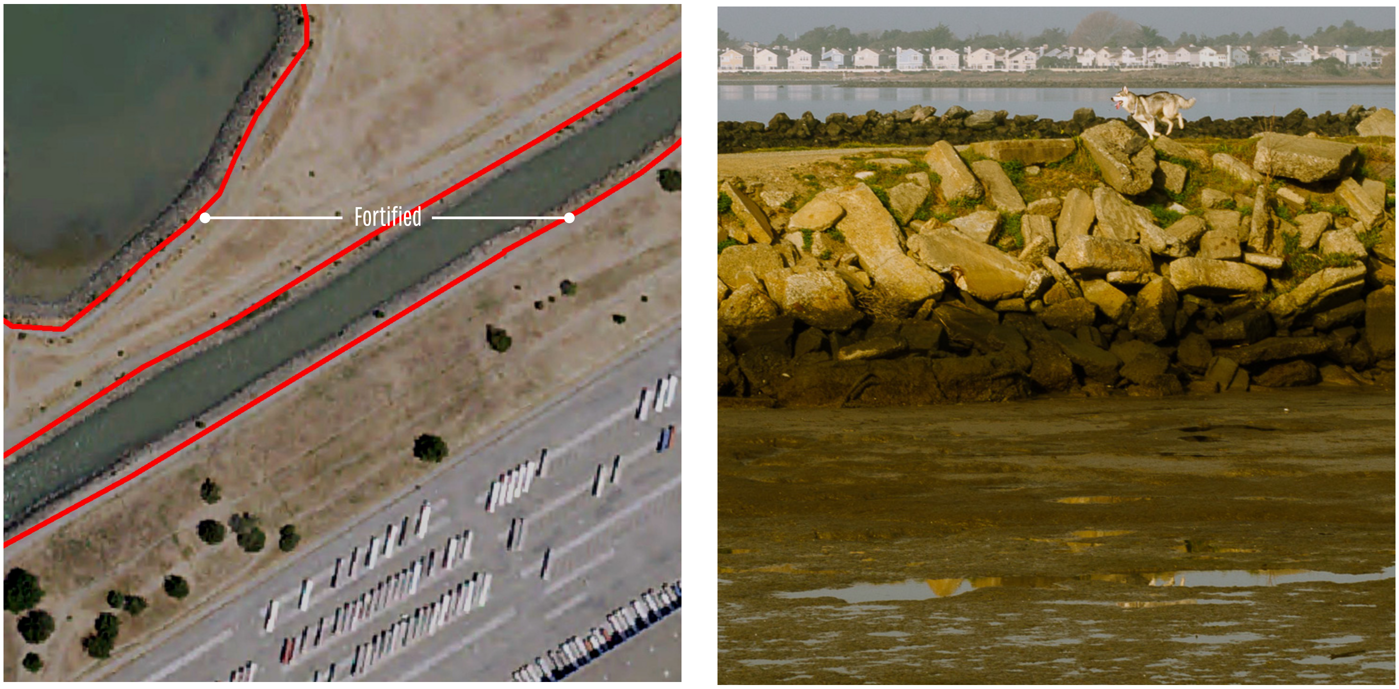


LOCATION

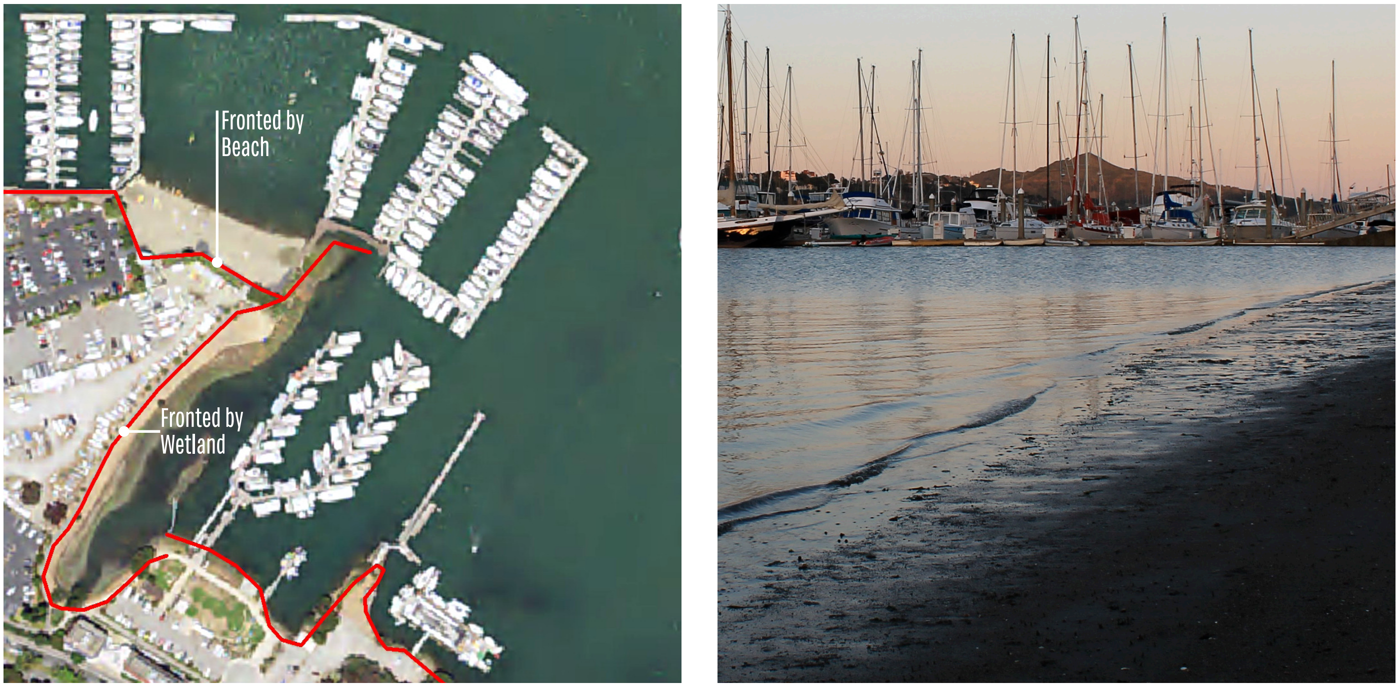
Artisan Slough, Santa Clara County



Field in GIS layer	Description	Attributes
Segment ID	A unique number for each line segment.	(e.g., 1, 2, 3, etc.)
Class	A description of the feature being mapped.	'Engineered Levee', 'Floodwall', 'Berm', 'Shoreline Protection Structure', 'Embankment', 'Transportation Structure', 'Natural Shoreline', 'Wetland', 'Channel or Opening', 'Water Control Structure'
Transportation Type	Separated 'Transportation Structure' classification into two sub-classes, 'Rail' and 'Major Road' based on aerial imagery.	'Major Road' or 'Rail'
Fortified	If features were artificially hardened, indicated by the presence of concrete, riprap, or buttressing, than the 'Fortified' category was assigned a value of 'Yes'. The best available aerial and satellite imagery (e.g., Bing Maps Aerial Imagery) was used to assign this field. Fortified field was assigned to all ten primary classification categories. Hardening of the mapped features could of been completed in an ad hoc manner or specifically designed to address wave erosion. Example shown on page 22.	'Yes' or 'No'
Frontage	Along the Bay shore, frontage was assigned to features where there is either a 1) wetland, 2) beach, or 3) wetland and beach in front of a feature. Category is assigned as 'Wetland', 'Beach', or 'Wetland and Beach', accordingly. "None' designates Bay shore features with no wetland or beach frontage. A variety of aerial and satellite imagery (e.g., Bing Maps Aerial Imagery) was used to assign this field. Beaches were also identified from our partners at BCDC and were not explicitly mapped as features themselves. Example shown on page 22.	'None', 'Wetland', 'Beach', or 'Beach and Wetland'
Bay Shore Defense	This field identifies the first line of features along the shoreline which would provide the 'first line of defense' to coastal flooding. Example shown on page 23.	'First line of shoreline defense' or 'Not first line of shoreline defense' or 'Wetland on Bay shore'
Agency Designation	Field is populated for all 'Engineered Levees' to show FEMA's designation (e.g., Accredited by FEMA, Formerly accredited by FEMA) as referenced from the FEMA MLI (2014) dataset or simply 'Engineered', if a feature was sourced as being engineered for flood management by an agency representative during dataset review meetings.	'Accredited by FEMA' or 'Formerly Accredited by FEMA' or 'Engineered' (if designated 'Engineered Levee' in Class field, or 'Engineered' if designated 'Floodwall' in Class field)
Agency Designation Source	Source for attributing the 'Engineered Levee' classification.	(e.g., FEMA MLI (2014), CCCFCWCD, provided by local stakeholders)
FEMA Accreditation Date	The year a structure was accredited by FEMA, based on the FEMA MLI (2014) dataset. Only attributed for 'Engineered Levee' features.	(e.g., 1/15/1990)
Primary Map Source	Refers to the primary DEM or other aerial imagery that was referenced for mapping.	(e.g., USGS 2010, NOAA/OPC 2010)
Geographic County	The represented Bay Area county.	(e.g., Marin County)
Public/Private	Features were assigned ownership (e.g., private, public) based on county parcel datasets or individual county, city, and agency knowledge, when data was available. The California Protected Areas Dataset (Green Info Network, 2014) was also referenced. While effort has been made to attribute ownership accurately, limitations exist as some mapped features bordered two different parcels and assigning ownership could not be differentiated within the parcel dataset.	'Private' or 'Public'
Owner Details	Specific names of owners, when data was available.	(e.g., NCFCWCD)
Maintained By	Designates who is responsible for maintenance of a feature. Information was gathered from city, county, and agency representatives, where information was available. Only limited information on maintenance was readily available.	(e.g., USFWS)
Comments	Additional comments for mapped features	(e.g., engineered levees that also have floodwalls)
Additional Sources	Provides additional sources for dataset attributes including ownership and imagery that was used in addition to DEMs.	(e.g., CPAD2014, CDFW)
Z_Min	The minimum elevation value from the available LiDAR derived DEM along the length of the segmented line at 30m (100ft) intervals.	(e.g., 3.3)
Z_Max	The maximum elevation value from the available LiDAR derived DEM along the length of the segmented line at 30m (100ft) intervals.	(e.g., 3.4)
Z_Mean	The mean elevation value from the available LiDAR derived DEM along the length of the segmented line at 30m (100ft) intervals.	(e.g., 3.5)

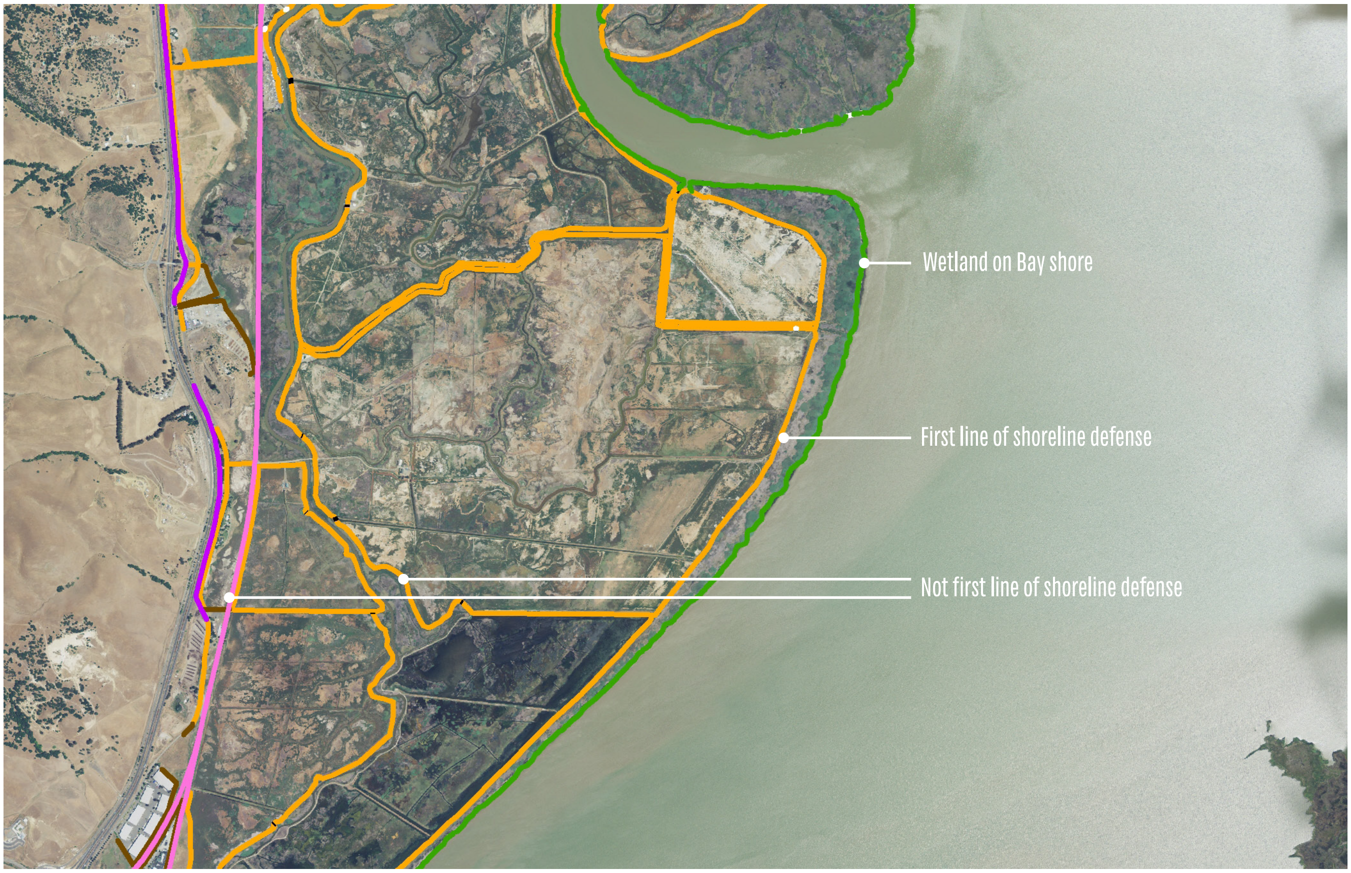


Example of *fortified* attribute. **Left,** Point Isabel, Contra Costa County, NAIP 2014; **right,** same location, photo by Shira Bezalel 2015.



Example of *frontage* attribute. **Left,** Sausalito, Marin County, NAIP 2014; **right,** Sausalito (photo by Patrick Nouhailler, Flickr Creative Commons, 2013).

〰 Shoreline Protection Structure


Wetland on Bay shore
First line of shoreline defense
Not first line of shoreline defense

Example of *bay shore defense* attribute. Solano County, NAIP 2009.

〜 Berm

〜 Embankment

〜 Transportation Structure - Major Road

〜 Transportation Structure - Railroad

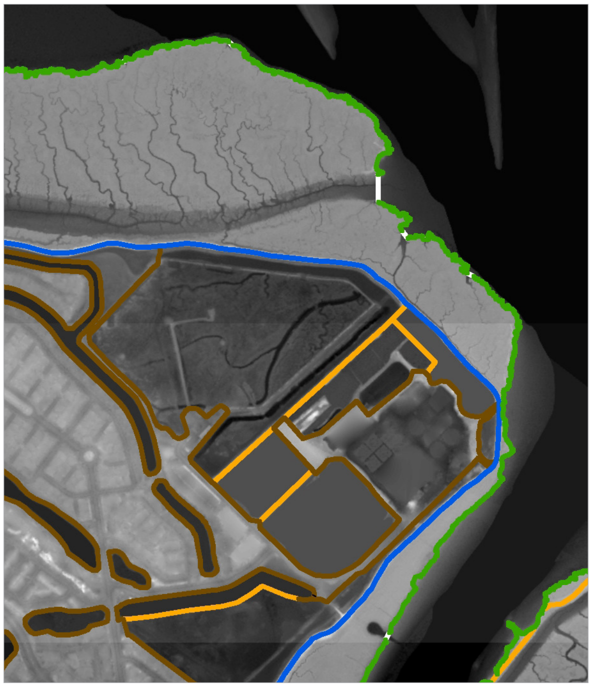
〜 Wetland

5. SEGMENTING AND ASSIGNING ELEVATION DATA

Once Bay shore features were mapped as lines and classified, all lines were split into 30m (100ft) segments to create a separate feature class for assigning elevations. Line segments were then sampled at every pixel of the DEM along the segment for the elevation using LiDAR-derived elevation data available for that area. The line segment was then attributed with the maximum, minimum, and mean elevation values using the same elevation information along the line.

Channels and openings have no elevation value assigned because the elevation values in the DEM would not be meaningful for these features, either because LiDAR does not penetrate water and capture the invert elevation, or because the opening passes through a raised feature, such as a berm, in a culvert and the LiDAR captures the top of the berm rather than the invert elevation of the opening itself.

Floodwalls were also assigned elevations differently. DEMs derived from LiDAR data did not capture the thin floodwall features within the resolution of the DEM. In a few cases the elevation data was manually updated from the raw LiDAR point cloud data. Only Z_mean elevation fields are populated for these features. For most of the floodwalls, LiDAR point cloud data was not sufficient and the standard method of segmenting and assigning elevations was used. In these cases the 'Comments' field notes that the elevation values are underestimated by the DEM.



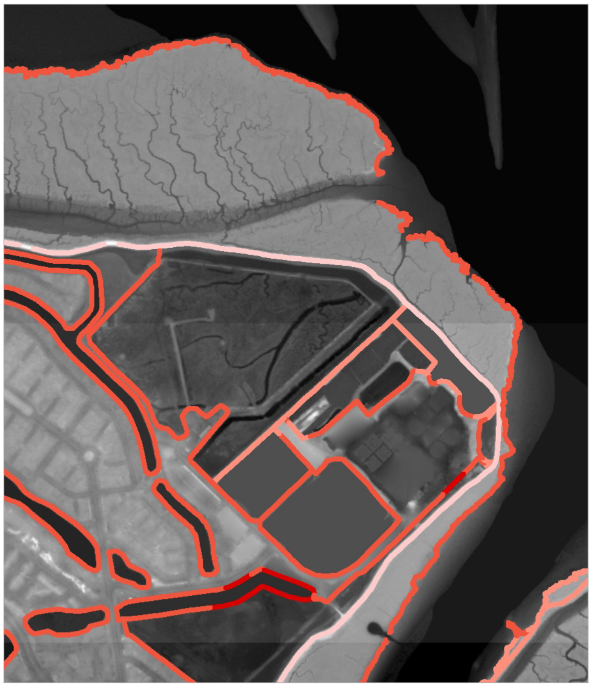
Bay shore classification

Engineered Levee

Berm

Embankment

Wetland



Bay shore elevation

3-4 meters

2-3 meters

1-2 meters

< 1 meter

6. REVIEW PROCESS

A thorough QAQC of the data was conducted to ensure accuracy and completeness. Many individuals contributed to dataset review and provided additional information on classification, presence of tide gates, ownership, maintenance, and recent landscape changes not reflected in sourced data (e.g., bypass channels, breached levees). We'd like to thank the following individuals who provided feedback and corrections on draft maps. Individuals who provided feedback are not responsible for the accuracy of the dataset.

Contra Costa County

Mark Boucher, CCCFCWCD
Paul Detjens, CCCFCWCD

Alameda County

Anna Fisher, USFWS
Anne Morkill, USFWS
Pat Mapelli, Cargill
Andy Otsuka, ACFCWCD
Rohin Saleh, ACFCWCD (AECOM held review)
Cheryl Strong, USFWS

Santa Clara County

Anna Fisher, USFWS
Anne Morkill, USFWS
Cheryl Strong, USFWS
Emily Zedler, SCVWD

San Mateo County

Chuck Anderson, Foster City
Michael Barber, San Mateo County
Sam Bautista, South San Francisco
Ralph Braboy, City of San Mateo
Randy Breault, City of Brisbane
Kamal Fallaha, East Palo Alto
Anna Fisher, USFWS
Ahmao Haya, Redwood City
Deborah Hirst, San Mateo County
Chris Hunter, San Mateo County
Khee Lim, City of Millbrae
Pat Mapelli, Cargill
Azalea Mitch, Menlo Park
Jeff Moneda, Foster City
Art Moritoto, City of Burlingame
Anne Morkill, USFWS
Afshin Oskoui, City of Belmont
Hilary Papendick, San Mateo County
Dave Pine, San Mateo County
Brian Schumacker, South San Francisco
Ann Stillman, San Mateo County
Cheryl Strong, USFWS
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Gordon Tong, San Mateo County
Brad Underwood, City of San Mateo
Jay Walter, City of San Carlos
Gilbert Yau, City of Belmont

San Francisco County

SFPUC (AECOM held review)

Sonoma County

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Don Brubaker, USFWS
Tom Huffman, CDFW
Jon Niehaus, SCWA

Marin County

Roger Leventhal, MCFCWCD

Napa County

Melisa Amato, USFWS
Don Brubaker, USFWS
Andrew Butler, NCFCWCD
Tom Huffman, CDFW
Jeremy Sarrow, NCFCWCD

Solano County

Steve Chappell, Solano RCD
Patrick Graham, CDFW
Tom Huffman, CDFW
Orlando Rocha, CDFW

7. NEXT STEPS

The SF Bay Shore Inventory dataset is available to download as KMLs for Google Earth and as feature classes in a file geodatabase for use in ArcGIS (http://www.sfei.org/projects/SFBayShoreInventory). The dataset will be integrated into an online interactive web tool from which users will be able view the dataset. The website also includes other Bay shore datasets developed by SFEI which illustrate resilience along the Bay shore under different sea level rise scenarios.

Bay shore viewed from Mount Tamalpais, 2015. Photo by Carolyn Doehring.

8. REFERENCES

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SFEI (San Francisco Estuary Institute) and Quantum Spatial. 2014. *LiDAR derived DEM of subset of Napa.* Ground resolution: 18in.

USGS (U.S. Geological Survey). 2010. ARRA Lidar [Lidar Point cloud data (LAS) and Lidar-derived DEM (2m Ground Resolution) of Bay Area counties].