Shoreline Highway at Highway 101. Credit: Caltrans

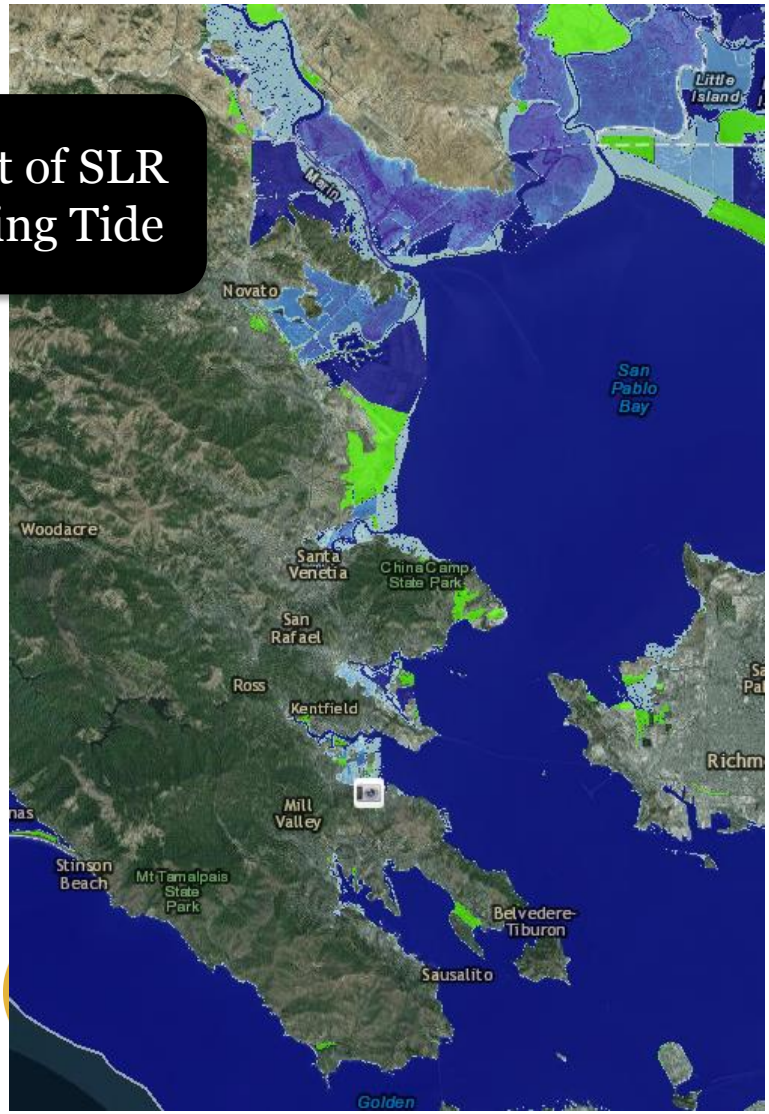
Marin Countywide Sea Level Rise Planning

BAYWAVE AND CSMART VULNERABILITY ASSESSMENTS

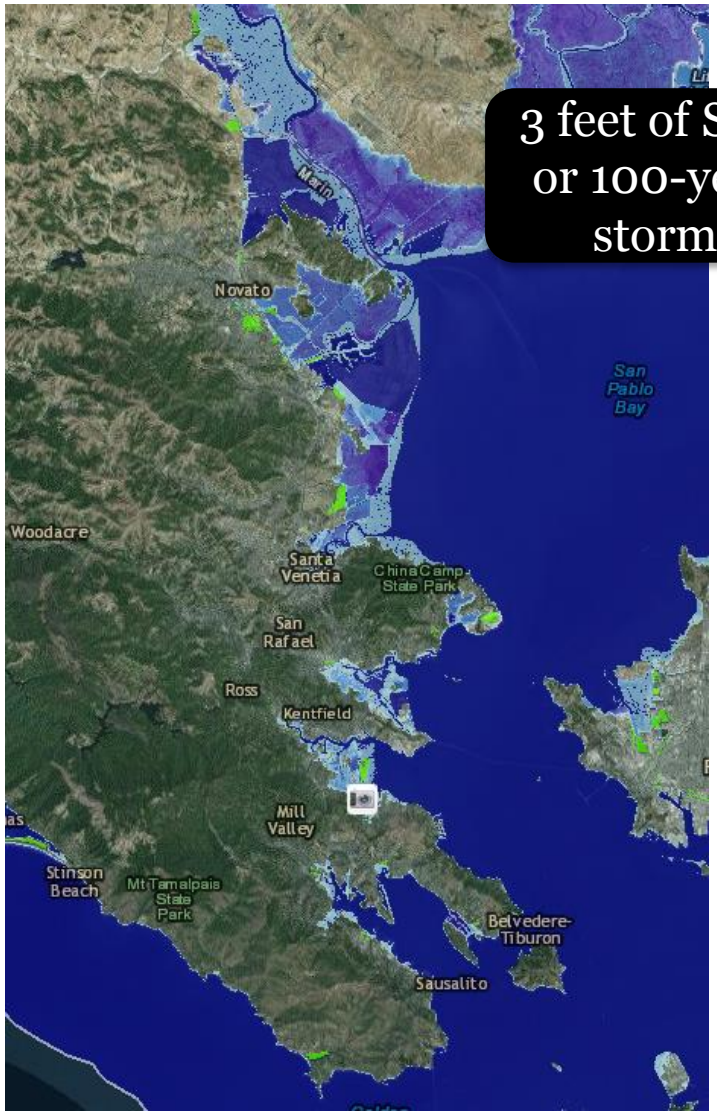
Countywide approach to assessing risk

COORDINATING LEADERSHIP AND LOCAL JURISDICTIONS

1 foot of SLR or King Tide



3 feet of SLR or 100-year storm



BayWAVE Deliverables

PHASE I

Vulnerability Assessment

- Identify a model and scenarios
- Map exposed areas
- Identify assets and assess vulnerability
- Vulnerability Assessment summary

Public meetings

Early Actions

- Coordinate early warning strategies
- Create an adaptation toolkit
- Summarize demonstration projects

Summary Report

- Draft
- Final

Public meetings

BayWAVE Committees

EXECUTIVE STEERING COMMITTEE, POLICY GROUP, TECHNICAL GROUP

ESC

- Guidance and direction
- Input on tasks, review of deliverables prior to release
- Meets quarterly as deliverables are complete

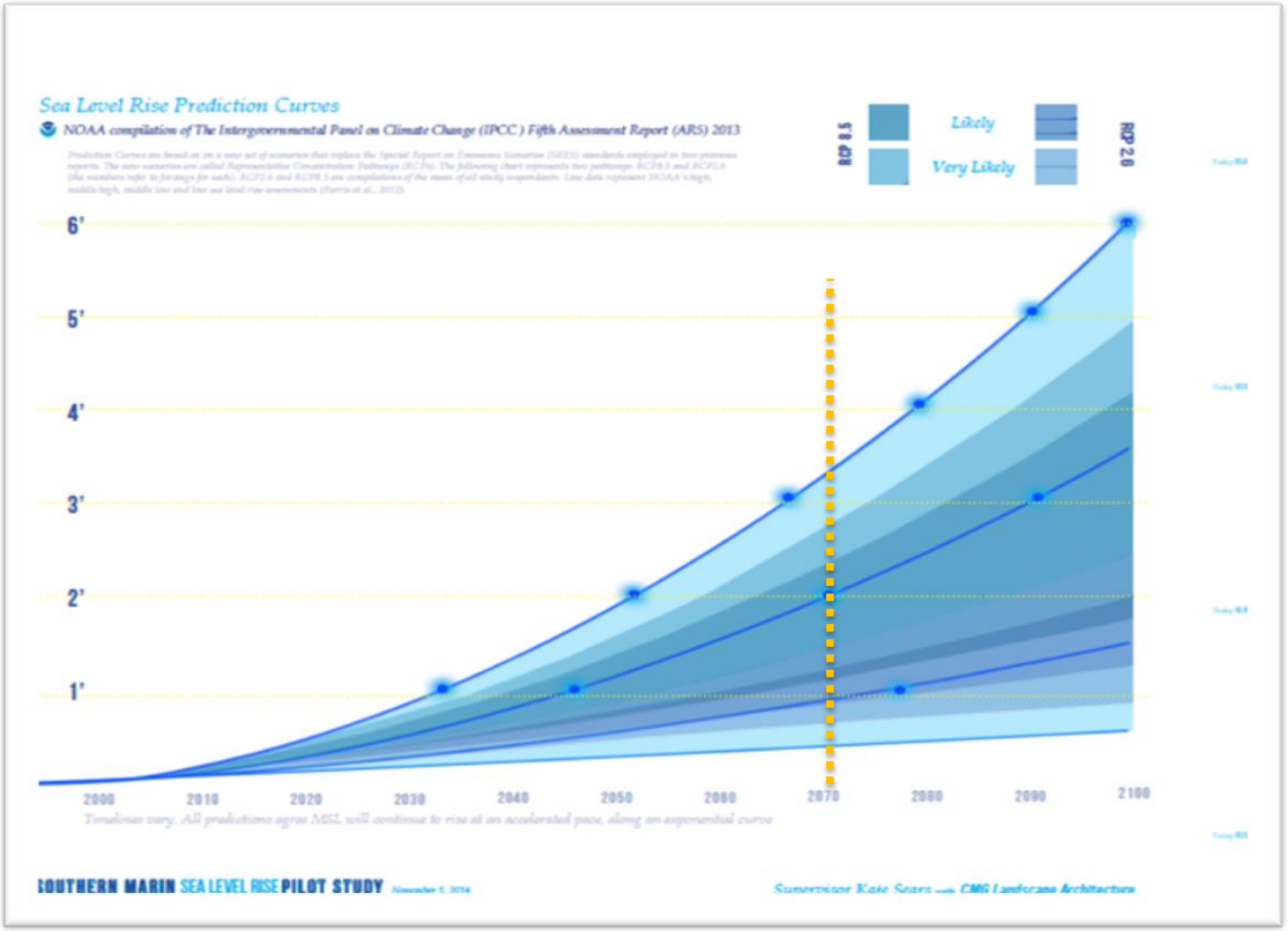
Policy

- Outreach to councils, staff, and constituents
- Carry information out to communities, bring feedback to BayWAVE staff
- Meets semi-annually before public release of deliverables

Technical

- Draw upon staff to support the BayWAVE deliverables
- Communications liaison between staff
- Meets quarterly as specific input is needed

Uncertainty in Estimates



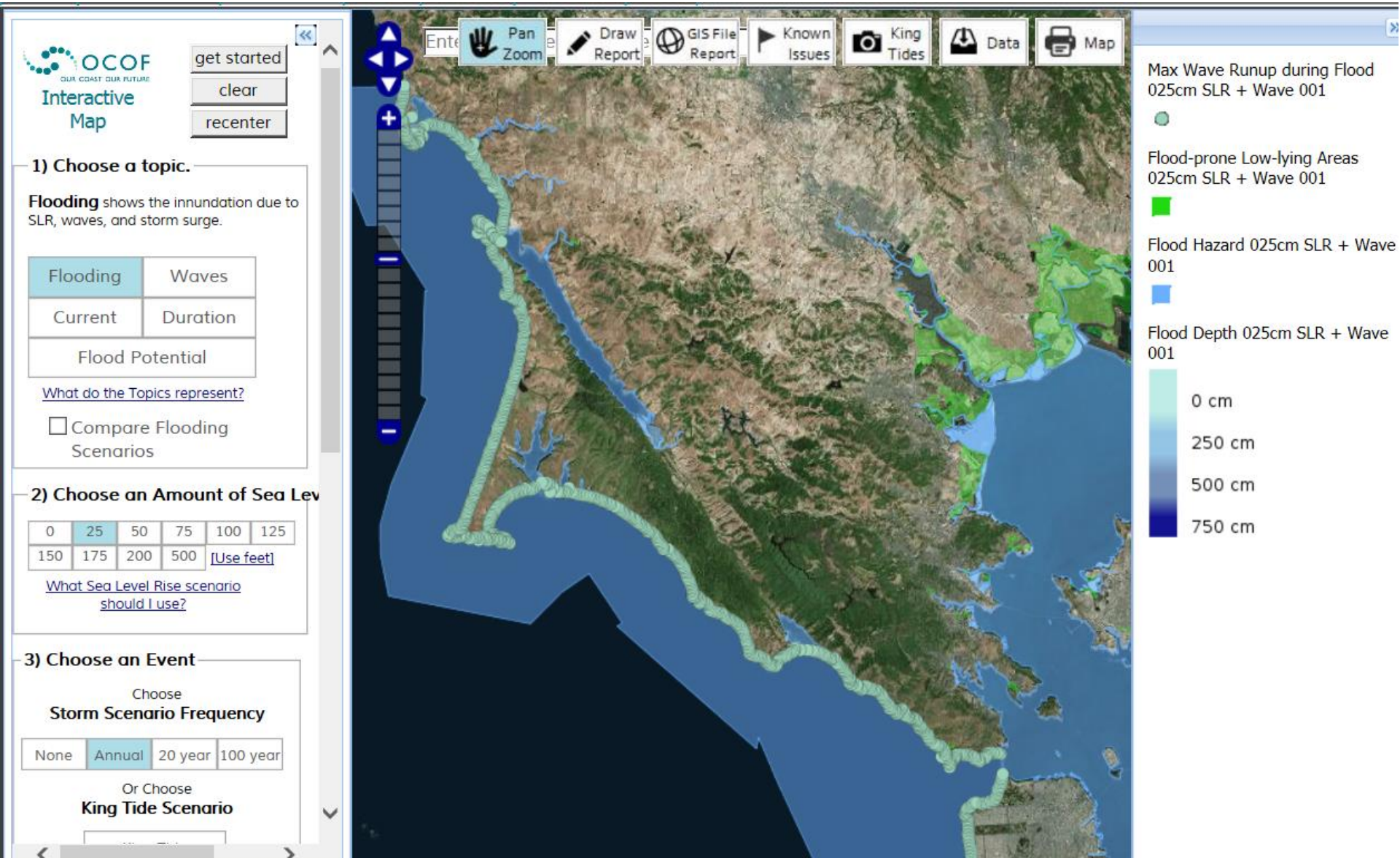
Model and Scenario Selection

OCOF WITH 6 SCENARIOS

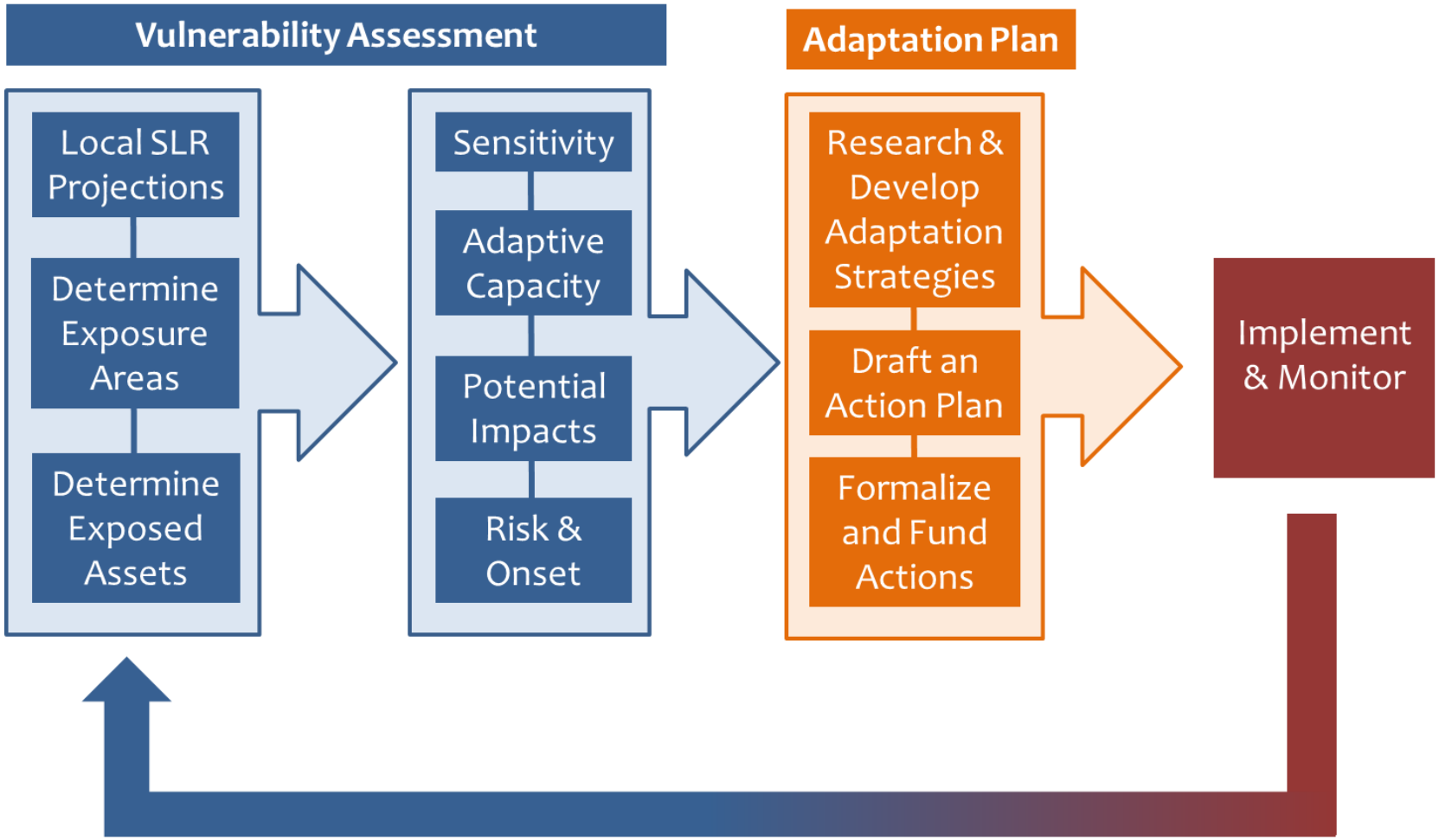
- Technical Group met in November for an introduction to the BayWAVE Program and to select the model and scenarios used for the Vulnerability Assessment
- USGS's Our Coast Our Future model was selected with 3 scenarios: 25-, 50-, and 150-centimeters of sea level rise plus the 100-year storm with each scenario

OCOF model	Near term	Mid term	Long term
Sea level rise	25 cm (10 in)	50 cm (20 in)	150 cm (60 in)
100 year storm (~3 feet)	25 cm + 100 year storm	50 cm + 100 year storm	150 cm + 100 year storm
Total depths	3.8 feet	4.7 feet	8 feet

Our Coast Our Future Online Viewer

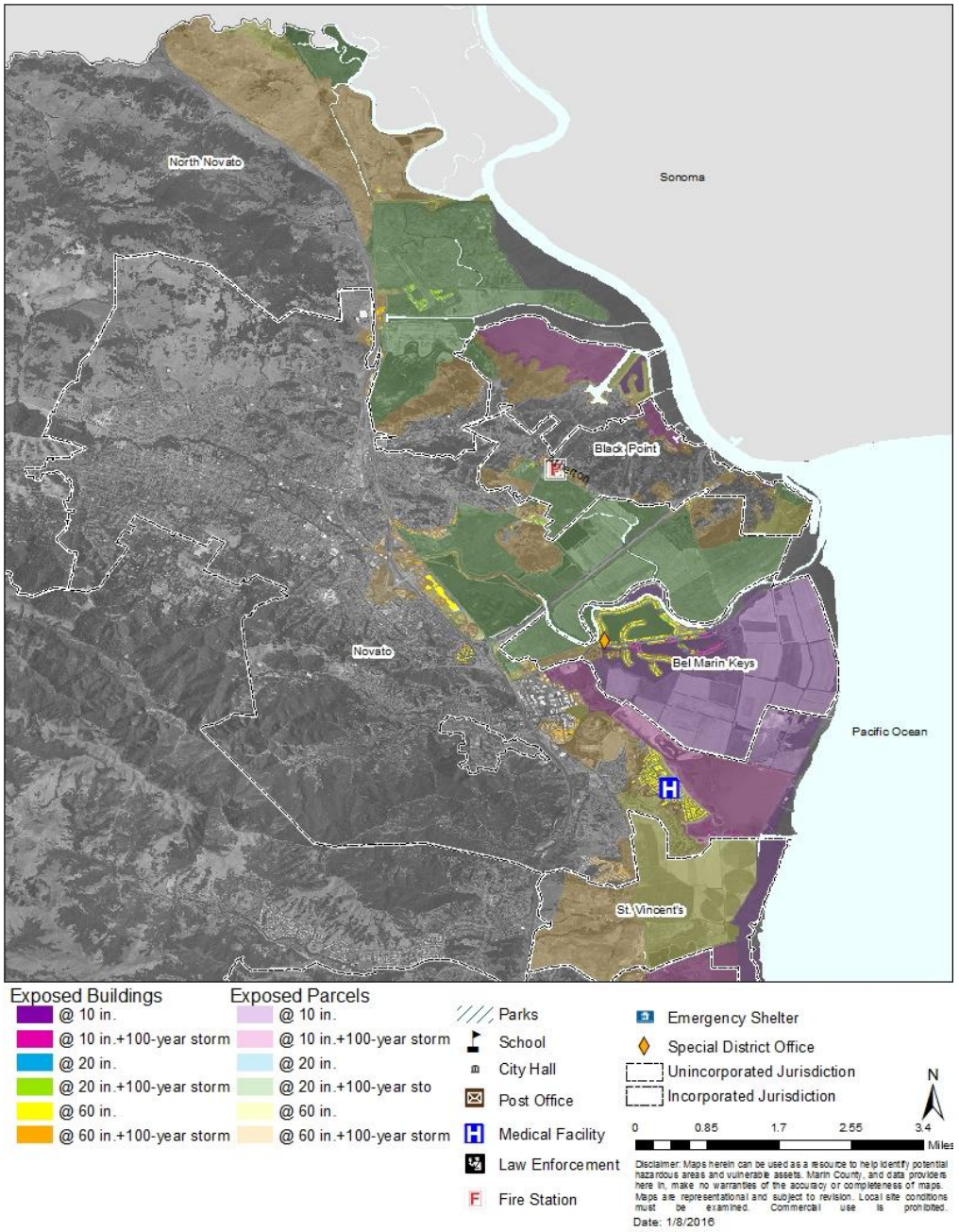


CSMART and BayWAVE Process



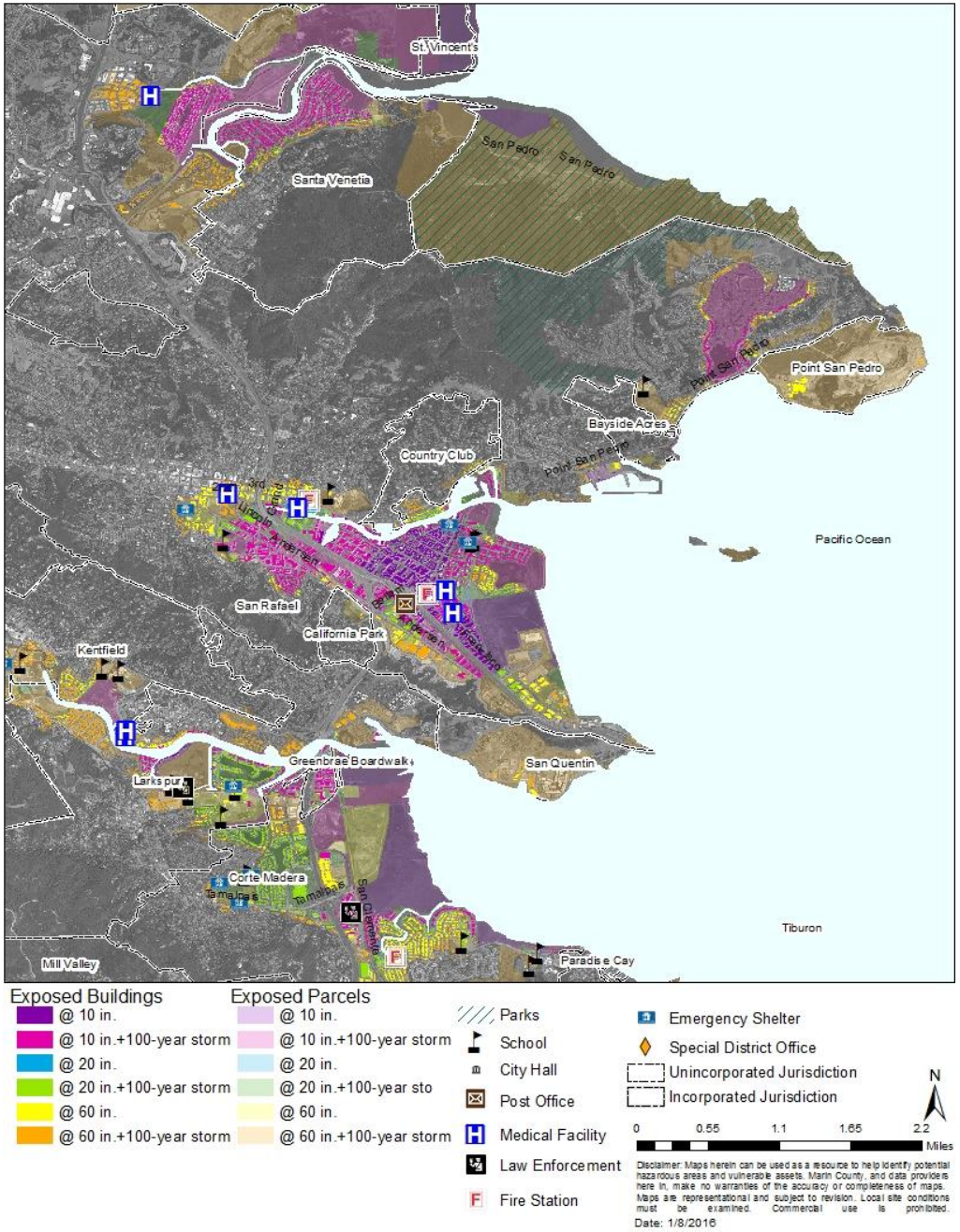
Northern reach

PARCELS AND BUILDINGS



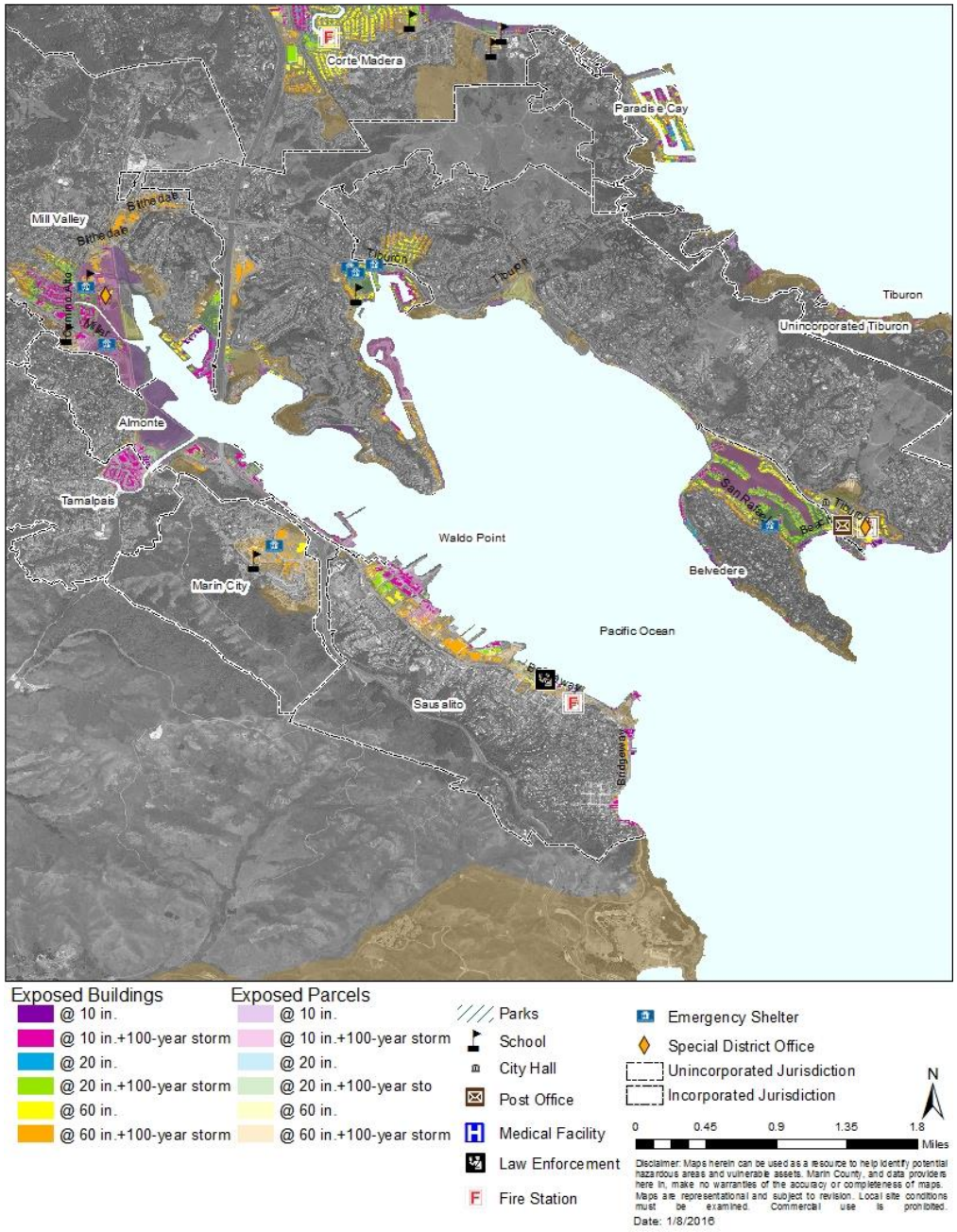
Central reach

PARCELS AND BUILDINGS



Southern reach

PARCELS AND BUILDINGS



Vulnerability Assessment

ASSETS AND COMMUNITY PROFILES

- Assets
  - Parcels and buildings
  - Roads and waterways
  - Water, wastewater, stormwater, gas, electricity, and telecommunications
  - Agriculture and aquaculture
  - Habitats and wildlife
  - Recreation and public access
  - Emergency services
  - Historic and archeological resources

- Communities
  - 11 Cities and towns
  - Unincorporated areas

Coastal VA

WWW.MARINSLR.ORG TO DOWNLOAD AND VIEW THE VA

PARCELS &

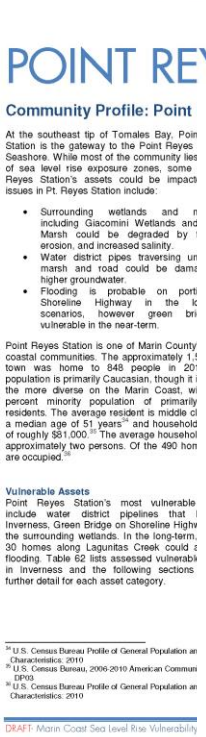
Asset Profile: Parcels & Bui

Properties and the buildings on them are signif assets along the Marin coast that provide for ho goods and services providers, public faci worship, education and the ability to create e and income in some cases. While a majority c parcels feature buildings, many others agricultural or natural in use and have u vulnerabilities (see Working Lands and N Resources Profiles). The first threats to building likely be the drinking water and disposal sys these buildings depend on (see Utilities Profil addition, road closures could prevent needed ac to and from homes, schools, businesses, and p open spaces (see Transportation Profile). Ultim in low lying coastal locations, the struc themselves will likely face severe storm dan and, eventually, near daily flooding at high tides

As exposed buildings and land become increas vulnerable, property owners will be faced deciding how to respond. The following are ge key issues related to building vulnerability:

- Almost all buildings along Marin's open are vulnerable to storms, though some pro owners are at higher risk due to constru materials, elevation, and location over or di bordering waterways, and subject to forc moving water (FEMA A and V zones) (see
- According to utility managers, the ea threats of flood damage may be to non-stru building component such as utility mechanical systems and equipment at or b grade. Malfunctions could make a unlivable.
- According to Stinson Beach and Bolinas managers, oceanfront and bluff properties subject to erosion, and have seen en impacts and restructuring expenses in the p
- Properties untouched by rising ocean water still become isolated and cut off from ess services and access routes could compromised if roads become flooded, blo with mudslides, or wash out).
- A few public facilities, including Stinson B Fire Station No. 2, are vulnerable in the ne medium-term. Most others, such as the offices in Inverness and Bolinas, are vulne nearing the end of the century.

DRAFT- Marin Coast Sea Level Rise Vulnerability Assessment



POINT REYES STATION

Community Profile: Point

At the southeast tip of Tomales Bay, Poin Station is the gateway to the Point Reyes Seashore. While most of the community lies of sea level rise exposure zones, some Reyes Station's assets could be impact issues in Pt. Reyes Station include:

- Surrounding wetlands and including Giacomini Wetlands and Marsh could be degraded by erosion, and increased salinity.
- Water district pipes traversing un marsh and road could be dama higher groundwater.
- Flooding is probable on port Shoreline Highway in the scenarios, however green bri vulnerable in the near-term.

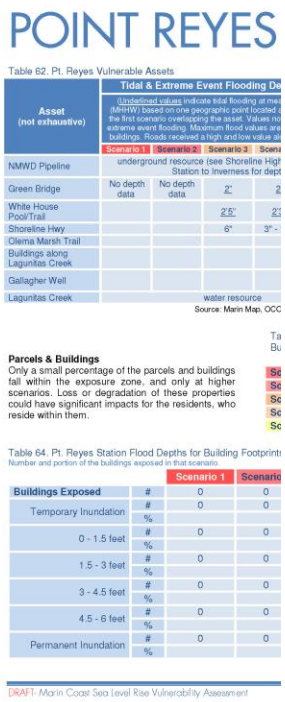
Point Reyes Station is one of Marin County coastal communities. The approximately 1,! town was home to 848 people in 20! population is primarily Caucasian, though it the more diverse on the Marin Coast, wi percent minority population of primarily residents. The average resident is middle cl a median age of 51 years[32] and household of roughly $81,000.[33] The average household approximately two persons. Of the 490 hon are occupied.[34]

Vulnerable Assets

Point Reyes Station's most vulnerable include water district pipelines that Inverness, Green Bridge on Shoreline Highv the surrounding wetlands. In the long-term, 30 homes along Lagunitas Creek could flooding. Table 62 lists assessed vulnerabi in Inverness and the following sections further detail for each asset category.

[32] U.S. Census Bureau Profile of General Population an Characteristics: 2010
[33] U.S. Census Bureau, 2006-2010 American Commun DP03
[34] U.S. Census Bureau Profile of General Population an Characteristics: 2010

DRAFT- Marin Coast Sea Level Rise Vulnerability



POINT REYES STATION

Table 62. Pt. Reyes Vulnerable Assets

Asset (not exhaustive)	Tidal & Extreme Event Flooding De
	(Underlined values indicate tidal flooding at mea (MHHW) based on one geographic point located the first scenario overlapping the asset. Values no extreme event flooding. Maximum flood values are buildings. Roads received a high and low value at
	Scenario 1 / Scenario 2 / Scenario 3 / Scena
NMWD Pipeline	underground resource (see Shoreline High Station to Inverness for dept
Green Bridge	No depth data / No depth data / 2' / 2
White House Pool/Trail	2'5" / 2'3
Shoreline Hwy	6" / 3" -
Olema Marsh Trail	
Buildings along Lagunitas Creek	
Gallagher Well	
Lagunitas Creek	water resource

Source: Marin Map, OCC

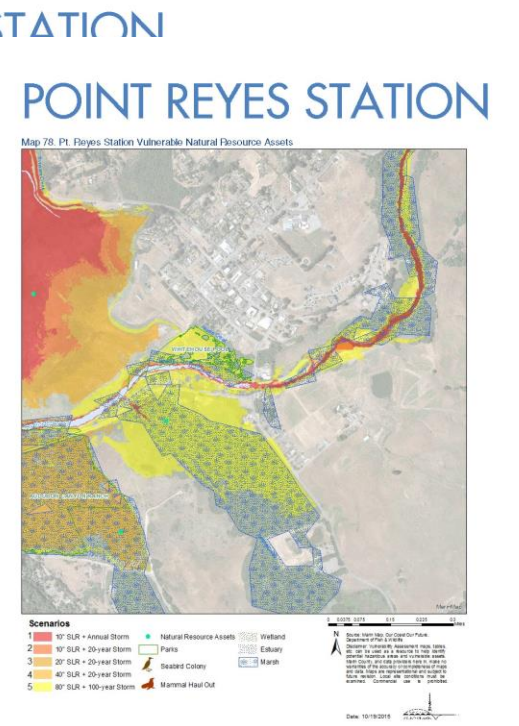
Parcels & Buildings

Only a small percentage of the parcels and buildings fall within the exposure zone, and only at higher scenarios. Loss or degradation of these properties could have significant impacts for the residents, who reside within them.

Table 64. Pt. Reyes Station Flood Depths for Building Footprint
Number and portion of the buildings exposed in that scenario

		Scenario 1	Scenario
Buildings Exposed	#	0	0
Temporary Inundation	#	0	0
	%		
0 - 1.5 feet	#	0	0
	%		
1.5 - 3 feet	#	0	0
	%		
3 - 4.5 feet	#	0	0
	%		
4.5 - 6 feet	#	0	0
	%		
Permanent Inundation	#	0	0
	%		

DRAFT- Marin Coast Sea Level Rise Vulnerability Assessment



POINT REYES STATION

Map 78. Pt. Reyes Station Vulnerable Natural Resource Assets

Scenarios
1 10" SLR + Annual Storm
2 10" SLR + 20-year Storm
3 20" SLR + 20-year Storm
4 40" SLR + 20-year Storm
5 80" SLR + 100-year Storm
Natural Resource Assets
Parks
Seabird Colony
Mammal Haul Out
Wetland
Estuary
Marsh

DRAFT- Marin Coast Sea Level Rise Vulnerability Assessment Page 190

BayWAVE deliverables

PHASE I MAJOR DELIVERABLES WITH SCHEDULE

Vulnerability Assessment

- Identify a model and scenarios (11/2015)
- Map exposed areas (12/2015)
- Identify assets and assess vulnerability (1-3/2016)
- Vulnerability Assessment summary (6/2016)

Public meetings (9/2016)

Early Actions

- Coordinate early warning strategies (1-9/2016)
- Create an adaptation toolkit (4-9/2016)
- Summarize demonstration projects (9/2016)

Summary Report

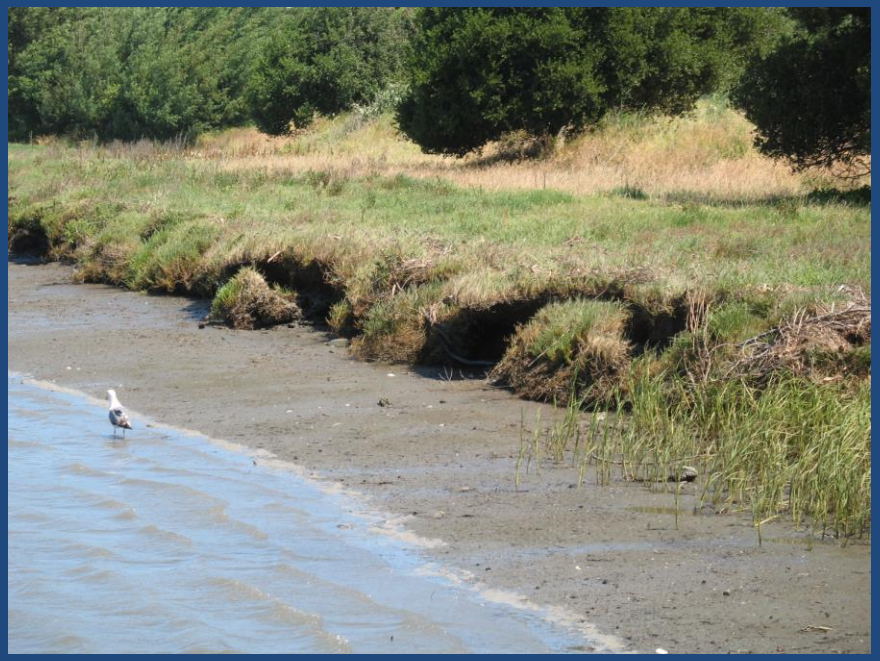
- Draft (11/2016)
- Final

Public meetings (12/2016 or 1/2017)

Richardson Bay Shoreline Study and the Game of Floods

Miller Ave King Tide 2012

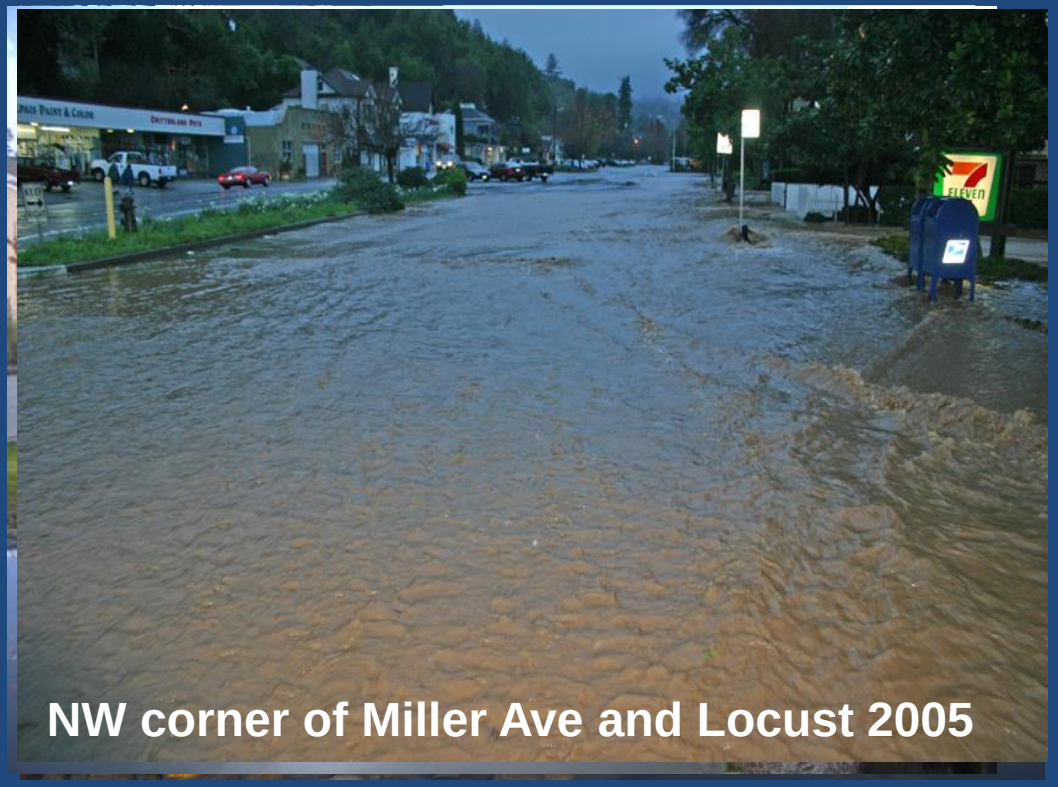
Roger Leventhal, P.E.
Senior Engineer
Marin County FCD



Mill Valley Shoreline

Planning for Richardson Bay

- Currently floods on “King” tides
- Flooding from both ends (river/tidal)
- SLR Impacts to everything…
  - infrastructure flooding
  - residential/commercial
  - roads/utilities
  - wetlands
  - public access/users



NW corner of Miller Ave and Locust 2005

Shoreline Study- Part I

Part I – Vulnerability Assessment (what is impacted)

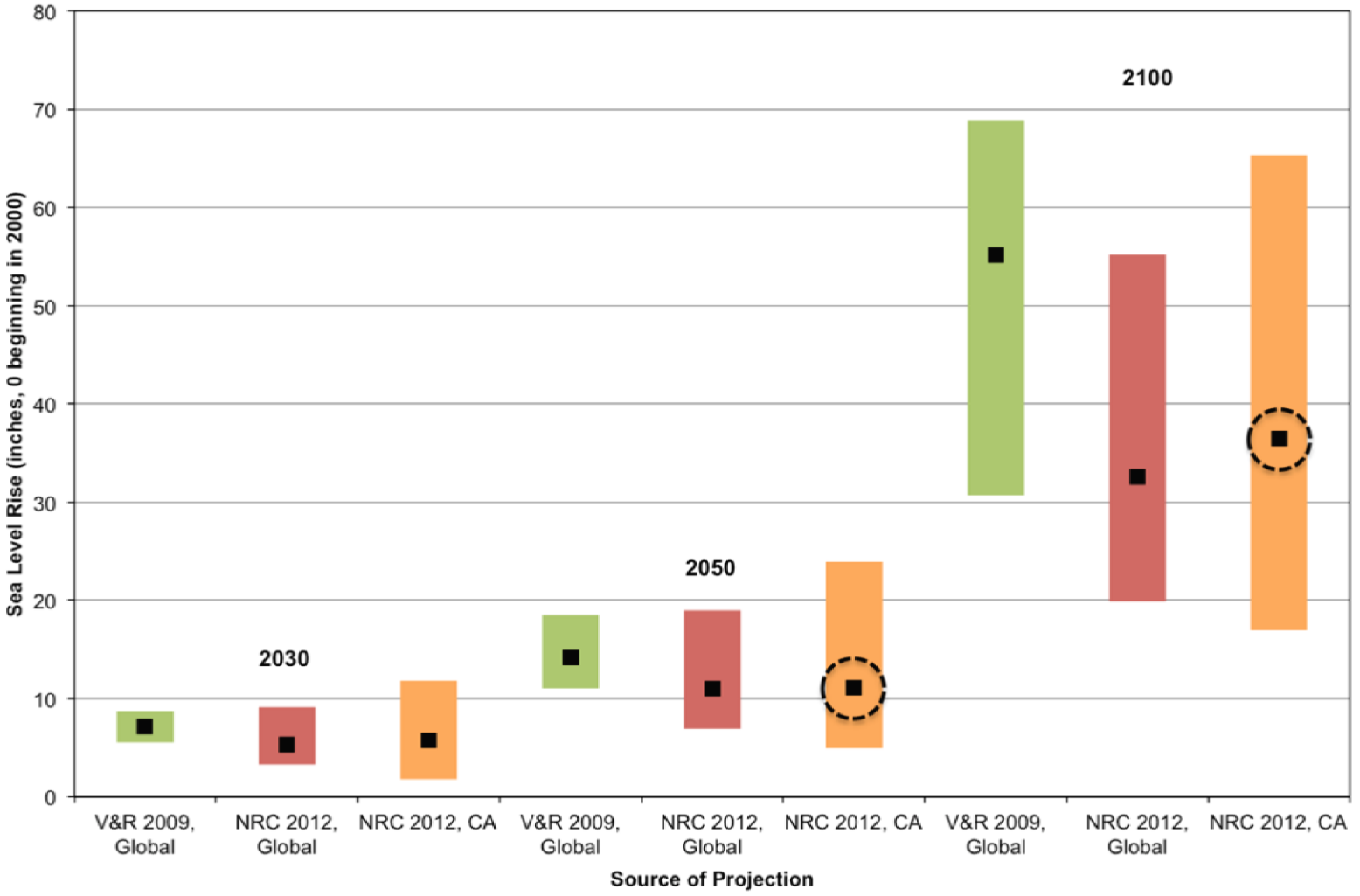
- What is flooded under 3 future SLR scenarios (1, 3 and 5 feet)?
- Adds up impacted assets and rough costs
- SLR added onto MHHW (not storm tides)
- Mapped impacted assets from MarinMap

Shoreline Study- Part II

Part II – Adaptation Options

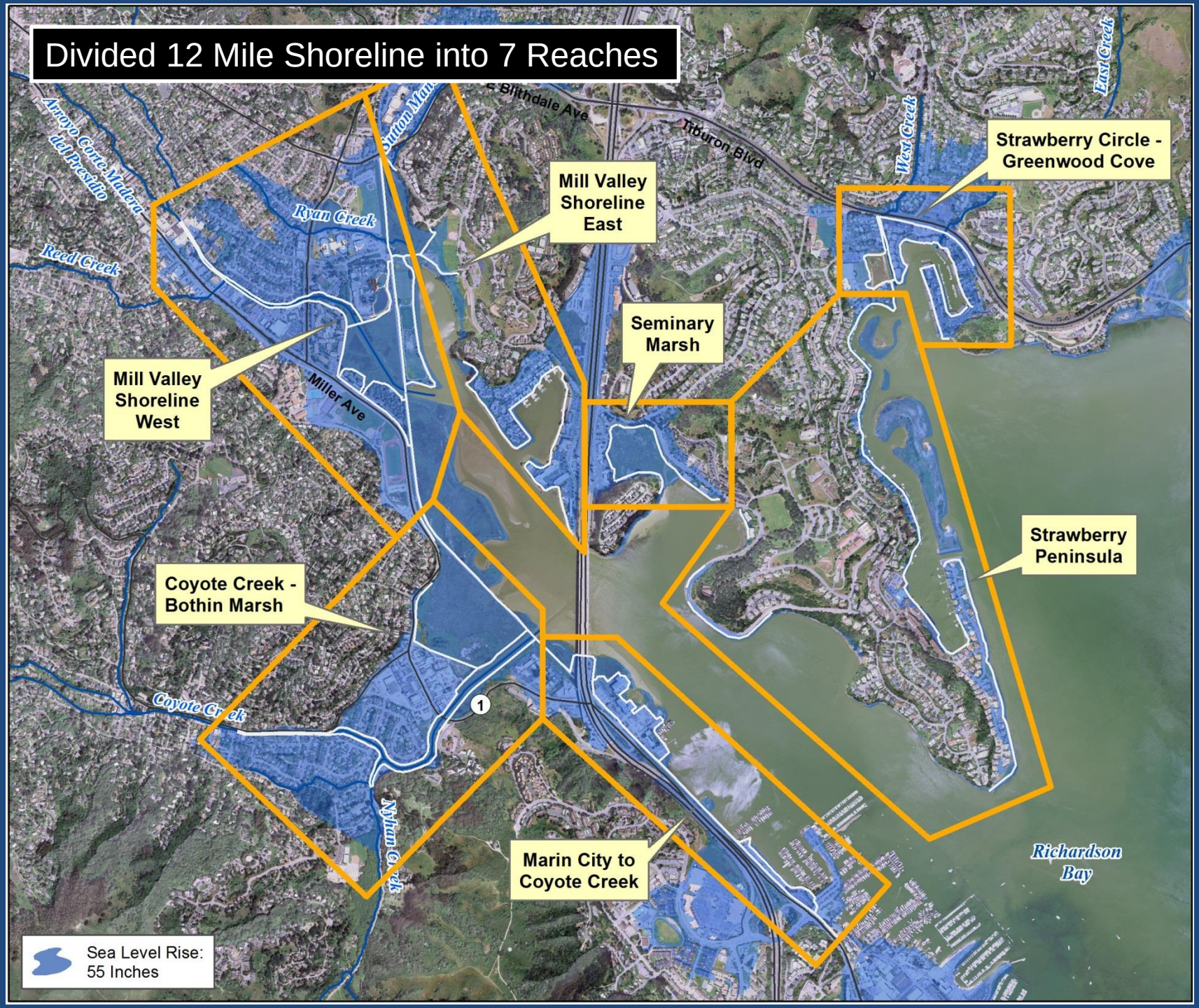
- Describes adaptation options (pros/cons, $) – focus on engineering barrier options
- Presents different alignments to inhibit daily tides (protects built edge)
- Adds up concept level costs (min/max)
- Discusses impacts and limitations

Various SLR Studies

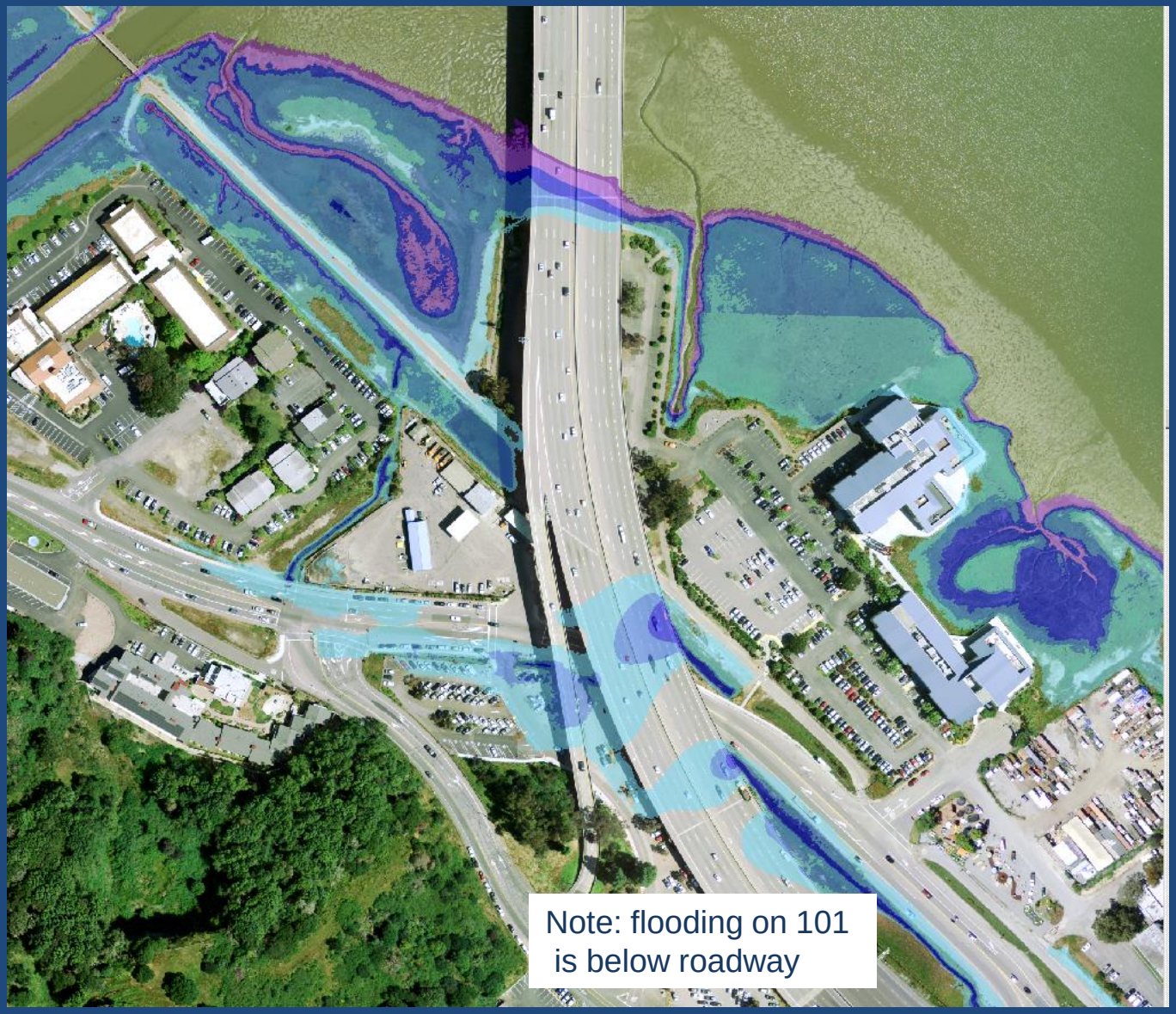


Projections – NRC 2012

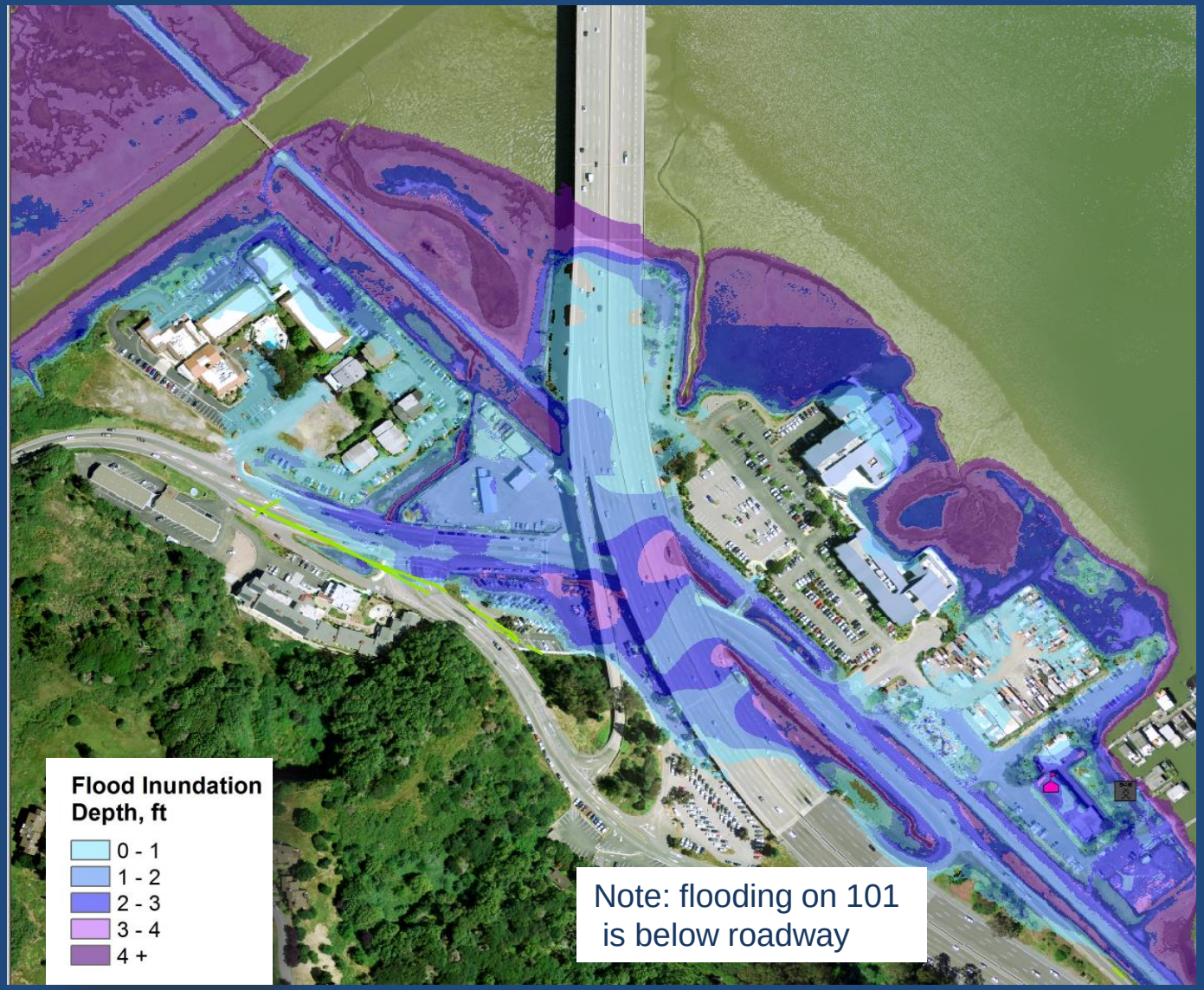
	from NRC 2012 for Northern California		
year	Range low (in)	Mean (in)	Range high (in)
2030	1.7	5.7	11.7
2050	4.8	11.0	23.9
2100	16.7	36.1	65.5


Divided 12 Mile Shoreline into 7 Reaches
Arroyo Corte Madera del Presidio
Reed Creek
Ryan Creek
Miller Ave
E Blithdale Ave
Tiburon Blvd
West Creek
East Creek
Mill Valley Shoreline East
Mill Valley Shoreline West
Seminary Marsh
Strawberry Circle - Greenwood Cove
Strawberry Peninsula
Coyote Creek - Bothin Marsh
Coyote Creek
Nyhan Creek
Marin City to Coyote Creek
Richardson Bay
1
Sea Level Rise: 55 Inches

Manzanita “King Tide” Flooding



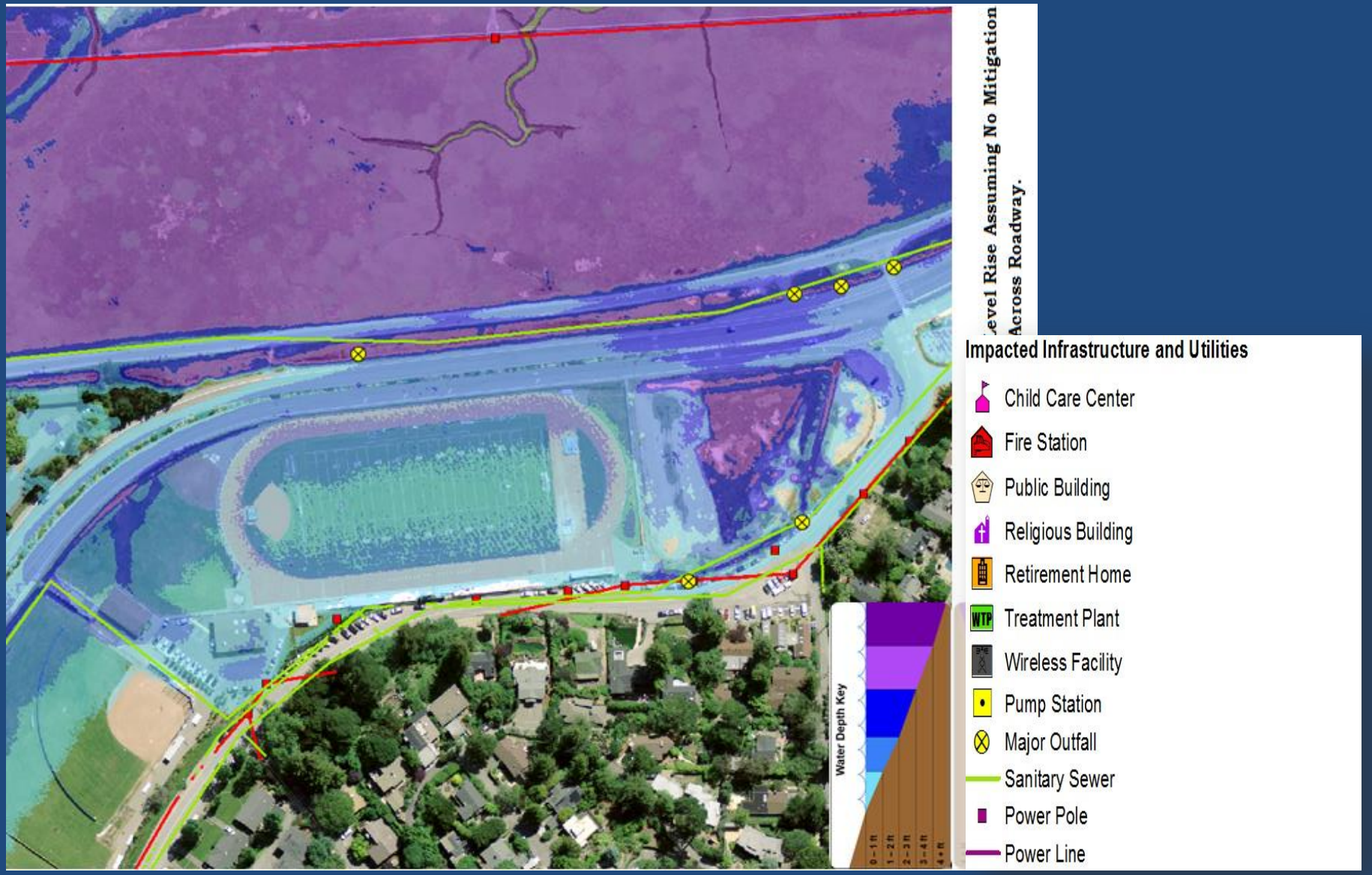
Manzanita 36-inch Flooding



Miller Avenue

Figure 26: Flood Focus Figure Miller Avenue at Tam High. 12 Inch Sea Level Rise.

Mill Valley 36 inches SLR



Added Up Parcel Tax ID Impacts

SLR Scenario	Count	Land Value	Improved Value	Total Value[7]
Parcels intersecting 1 foot SLR	394	$187,592,105	$211,296,297	$398,888,402
Parcels intersecting 3 feet SLR	889	$371,298,461	$366,134,667	$737,433,128
Parcels intersecting 5 feet SLR	1545	$649,217,099	$636,736,662	$1,285,953,761

Park And Ride Lot	1	3	3
Pump Station	1	7	7
Religious Facility	0	0	1
Wireless Facility	1	3	5

DRAFT

Major Adaptation Strategies

Protect

- HARD
  - Build dikes, seawalls (armoring)
  - Install tide gates (small/large)
  - Raise grades
  - Increase pumping
- SOFT
- Natural beach systems
- Tidal wetlands
- Horizontal levees

Manage Retreat

- Land and structure acquisition /relocation
- Building/Planning code and regulation changes
- Allow erosion /migration of natural areas (phasing)

Accommodate

- Elevate buildings and infrastructure
- Floodproof critical structures
- Floodable buildings/tiered developments

…and combinations of any above

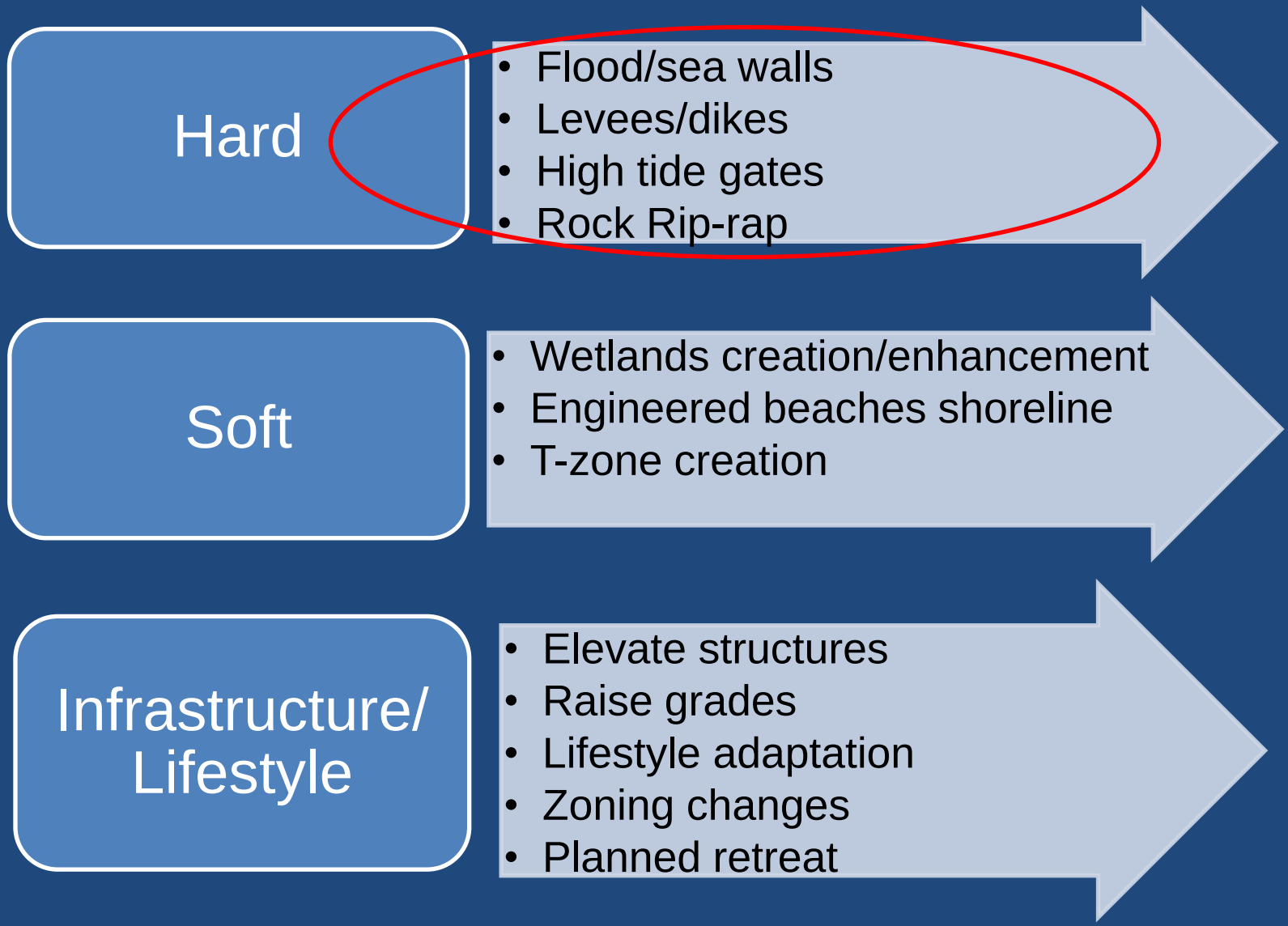
Famous adaptors throughout history…

Dutch Boy built protection

Moses implemented phased managed retreat

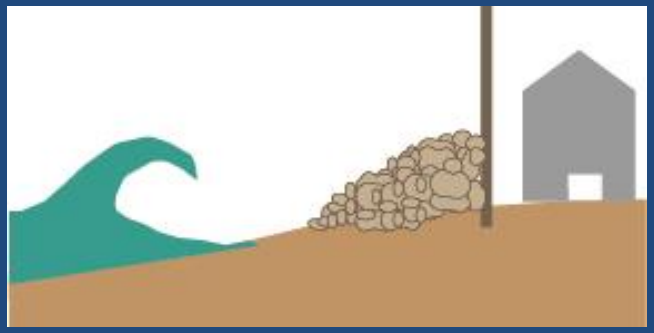
Noah went for accommodation (floodable structures)

Part II: Major Adaptation Strategies

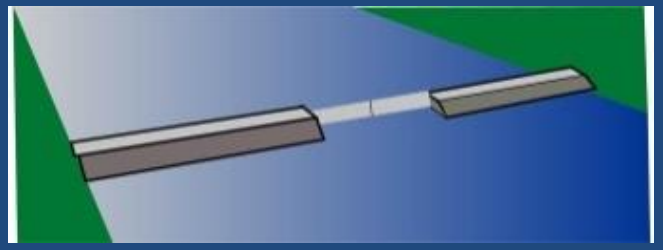


1.
PROTECT
Hard (Traditional) Engineering

Traditional levee

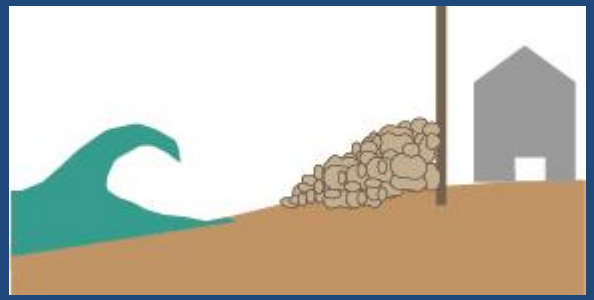


Seawall/Revetment



Tide gate

Flood wall & Pump station



Seawall

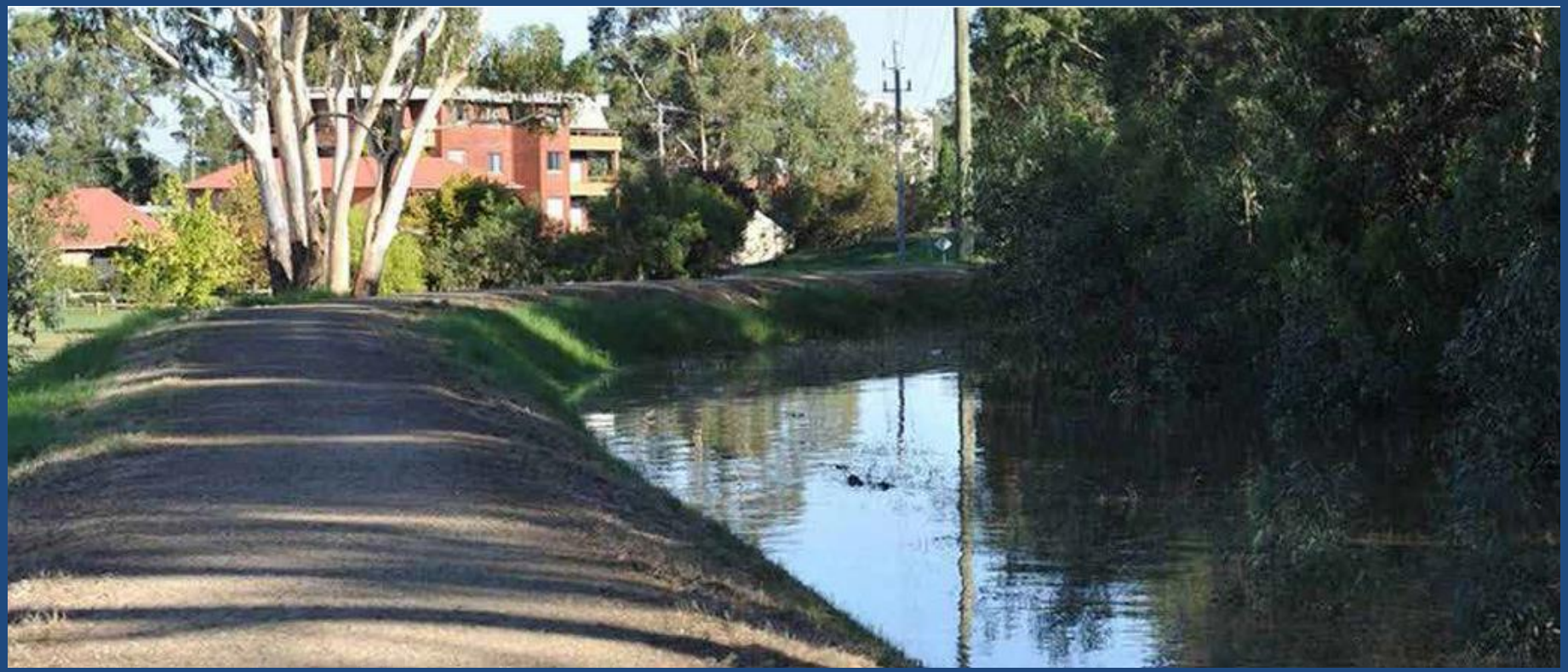
Pros: Limited ROW required
Cons: Cost, Impacts

Bulkhead seawall in Seadrift neighborhood

Westhoff

Levee

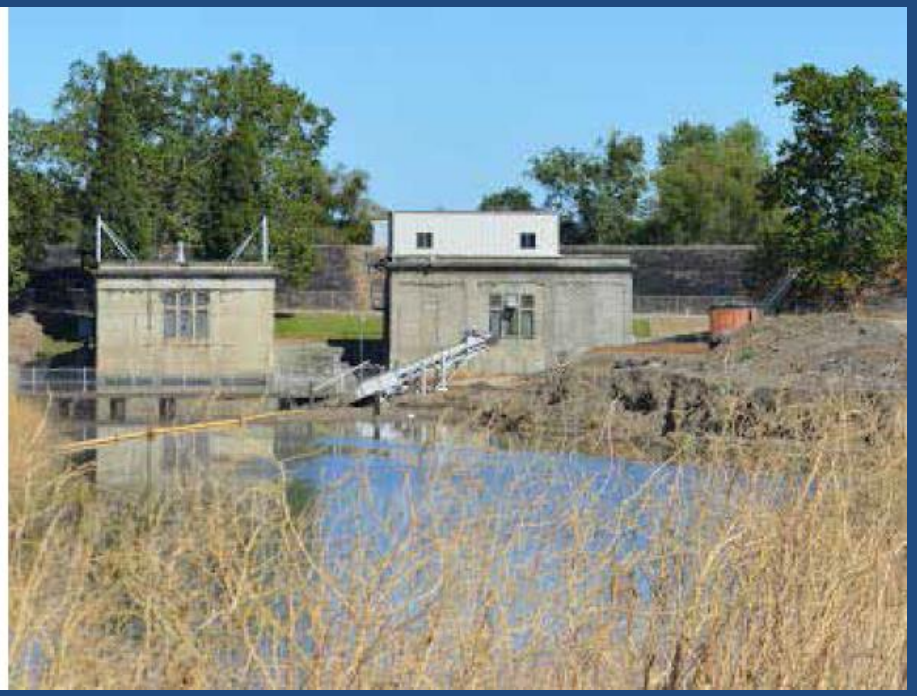
Pros: Stability if maintained, Cost lower then wall
Cons: Large ROW required



Flood wall & Pump station

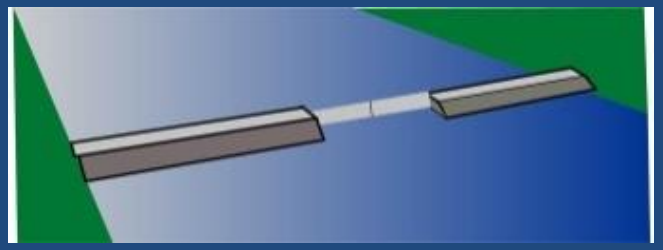
Pros: Lower ROW than levees

Cons: Capital and maintenance costs



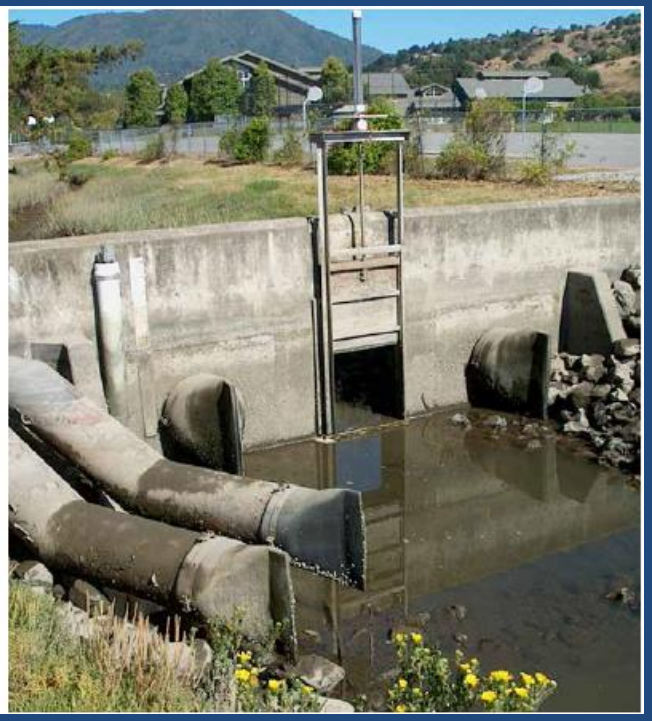
Holland and Germany Large Gates…

Tidal gate



Pros: Temp solution to tidal riverine flooding

Cons: Cost, limited effectiveness over time



101
1
Richardson
Bay Bridge
Tidal Barrier
Richardson
Bay
"Folding Water™"

Major Adaptation Strategies

Hard

- Flood/sea walls
- Levees/dikes
- High tide gates
- Rock Rip-rap

Soft

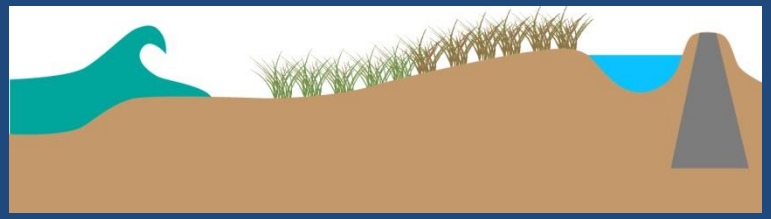
- Ecotone Levees
- Wetlands creation/enhancement
- Engineered beaches shoreline

Infrastructure/ Lifestyle

- Elevate structures
- Raise grades
- Lifestyle adaptation
- Zoning changes
- Planned retreat

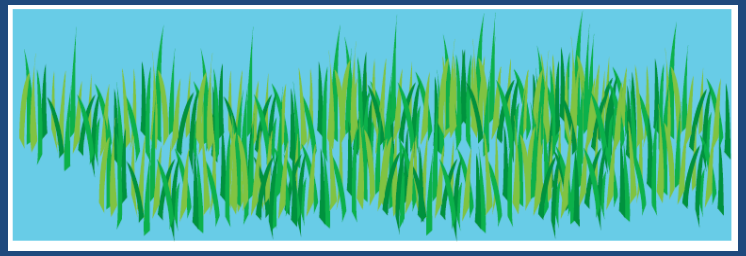
1. PROTECT

Soft (Nature-based) Engineering

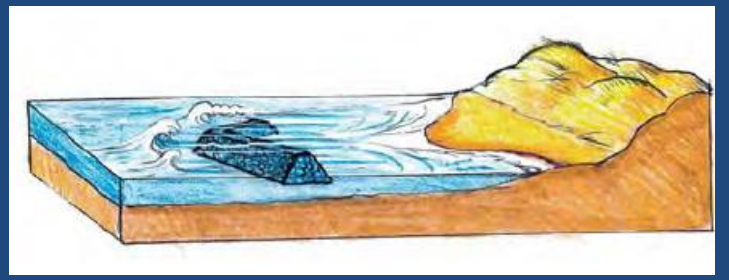


Horizontal levee

Dune restoration &
Beach maintenance

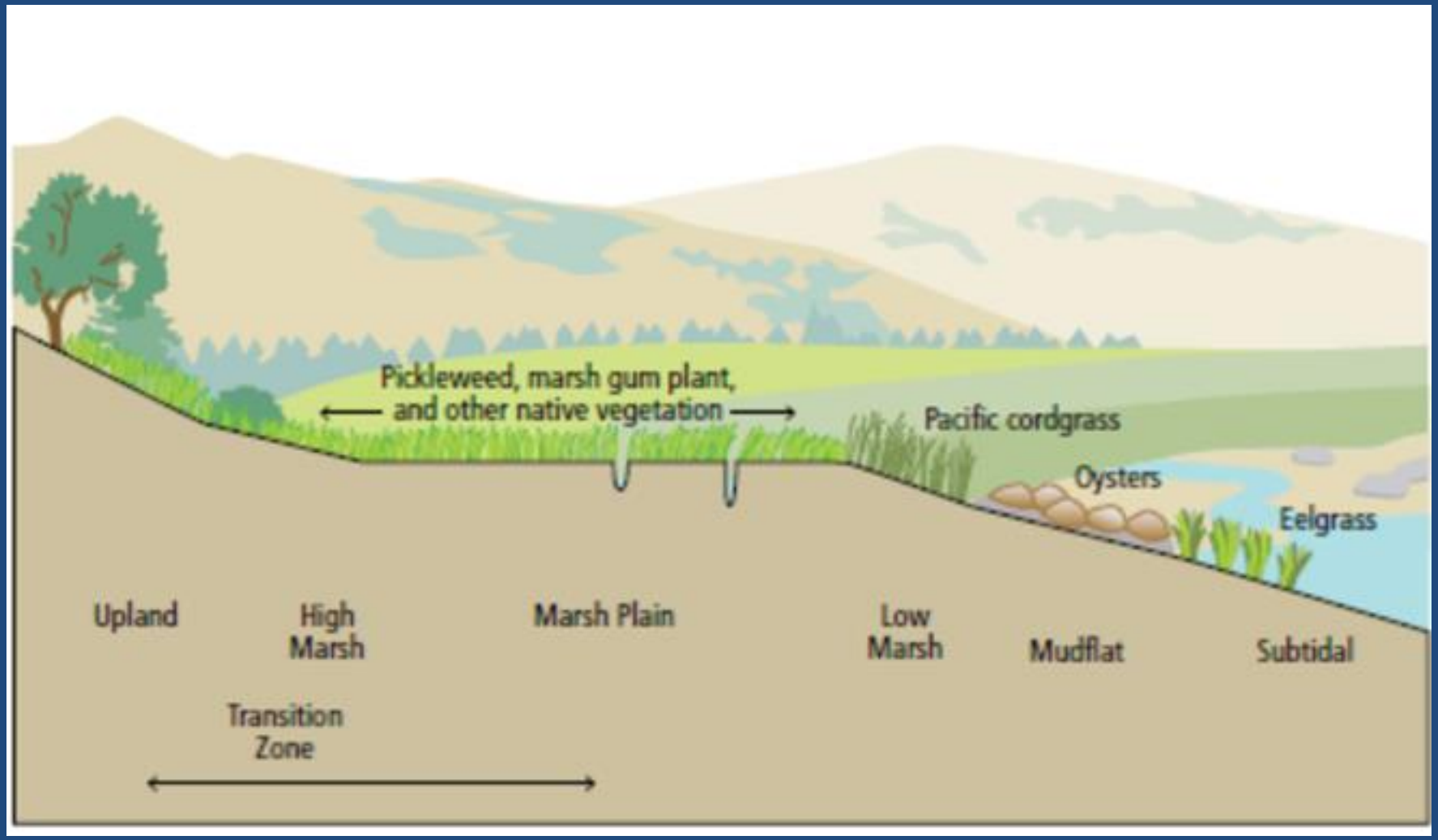


Wetland/ shoreline
vegetation

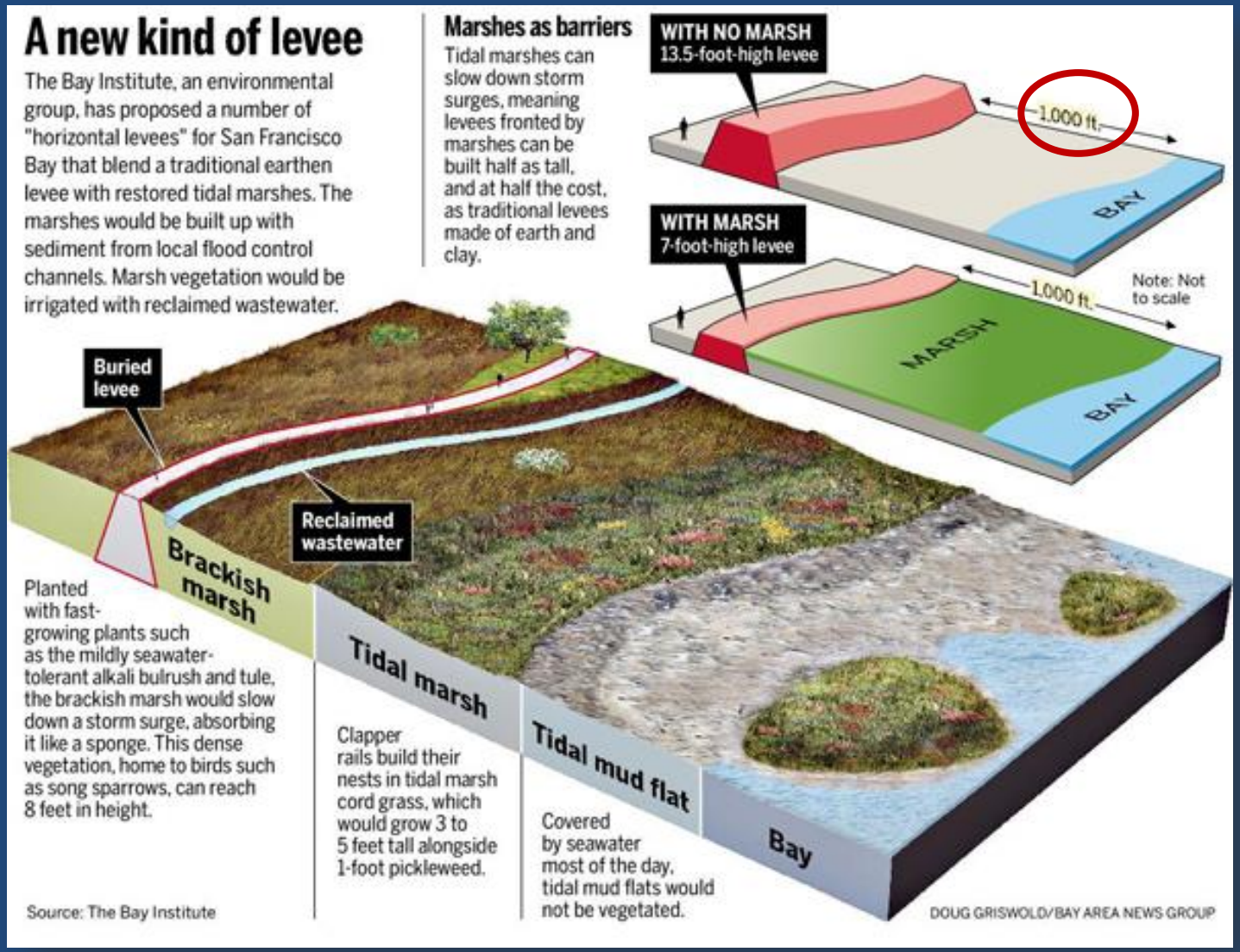


Offshore structure

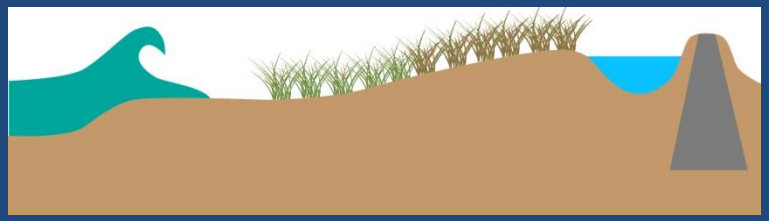
The Living Shoreline Concept



Horizontal “Eco” Levee

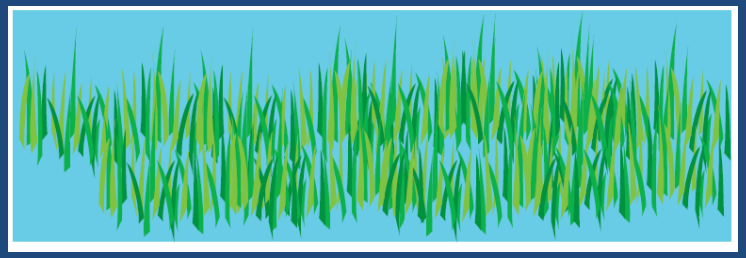


Horizontal levee



Pros: Uses landscape to attenuate waves, provides habitat
Cons: Cost for earthwork, larger ROW

Wetland/ shoreline vegetation



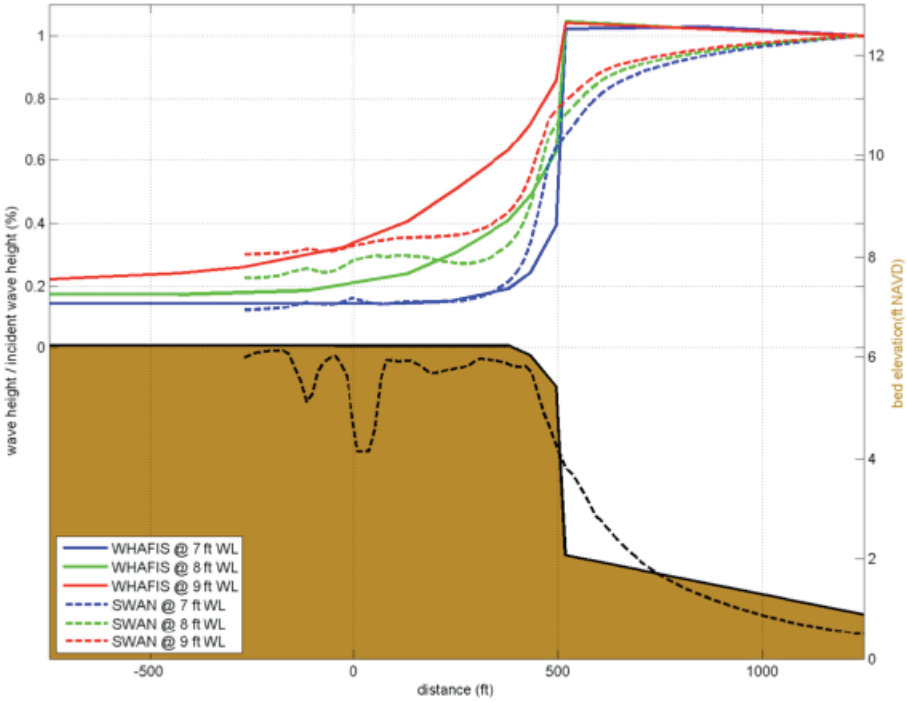
Pros: Habitat improvement and flood reduction

Cons: Large ROW required

Giacomini Wetland Restoration, 2008

Tidal Wetlands and Eco Levees

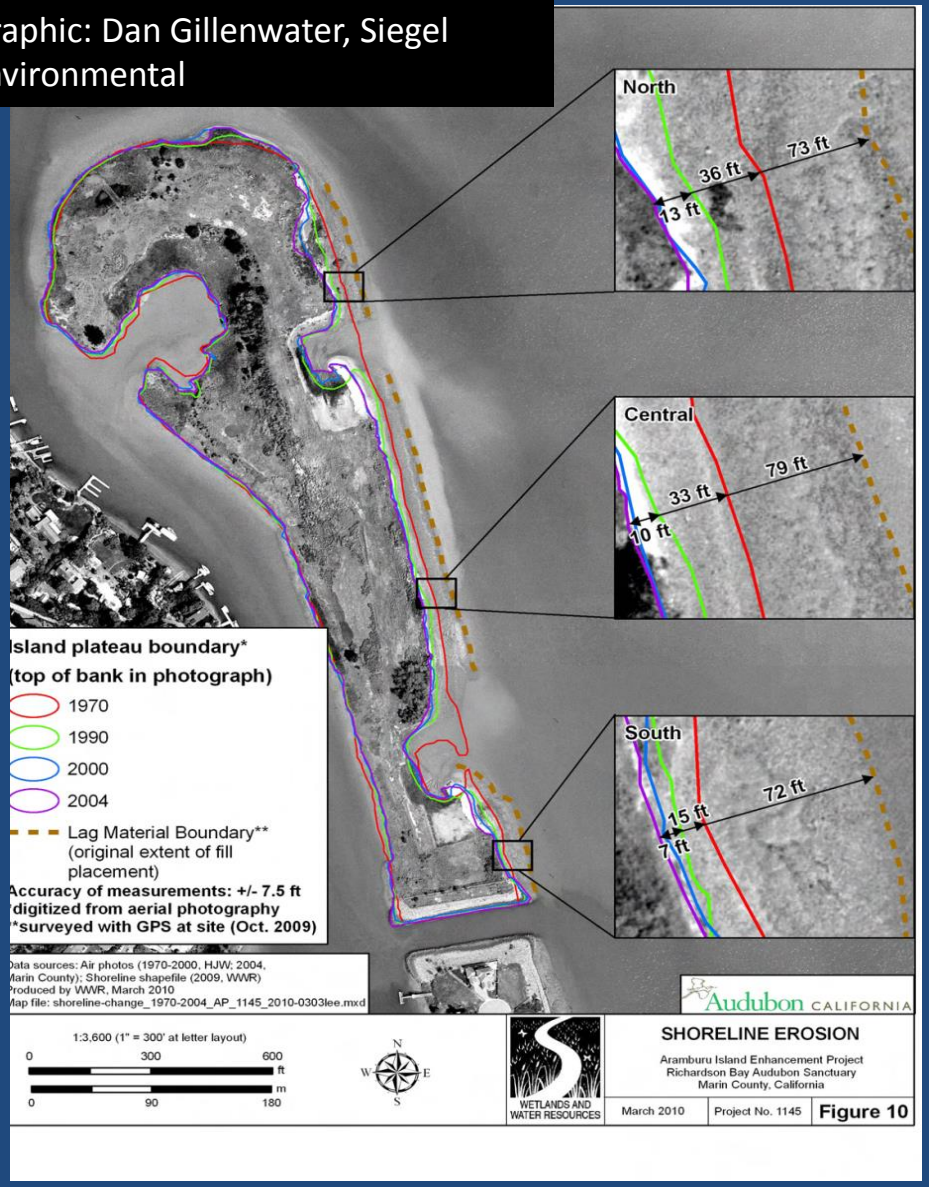
Wave modeling (1-D WHAFIS, 2-D SWAN)

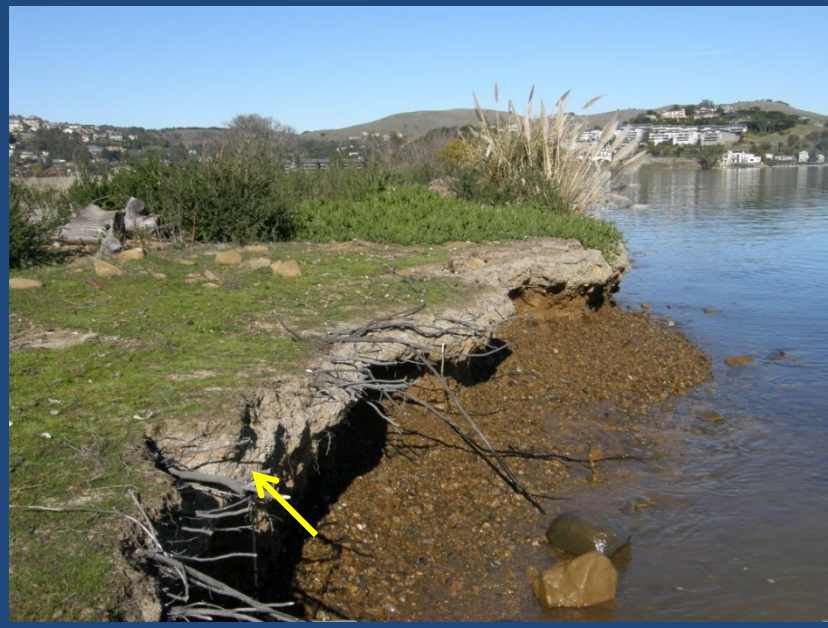


Aramburu Island, Richardson Bay

45+ yr shoreline retreat > 130 ft; boulder-cobble lag

Graphic: Dan Gillenwater, Siegel Environmental





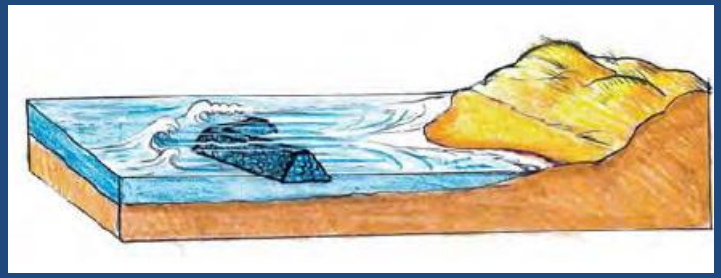
Engineered Bay Beach
Spring-Summer 2013 Aramburu Beach

Winter storm gravel and shell berm persists

Sand beachface slope accretes, steepens

Sand partially buries winter storm berm

Offshore structures



Pros: Reduces waves impacts – more when structure is higher

Cons: Costs to construct, maintain and limited effectiveness for SLR

San Clemente artificial reef experiment

Concrete

Quarry rock

Living Shorelines – Oysters/Reefs

- Living shorelines project – M. Latta (CC) and K. Boyle, (SF State)
- Off San Rafael
- Multi-year successful project

www.sfbaylivingshorelines.org

Major Adaptation Strategies

Hard

- Flood/sea walls
- Levees/dikes
- High tide gates
- Rock Rip-rap

Soft

- Wetlands creation/enhancement
- Engineered beaches shoreline
- T-zone creation

Infrastructure/ Lifestyle

- Elevate structures
- Raise grades
- Lifestyle adaptation
- Zoning changes
- Planned retreat

2. ACCOMMODATE

New floodable development

Elevate buildings

New/elevate road

Elevate buildings

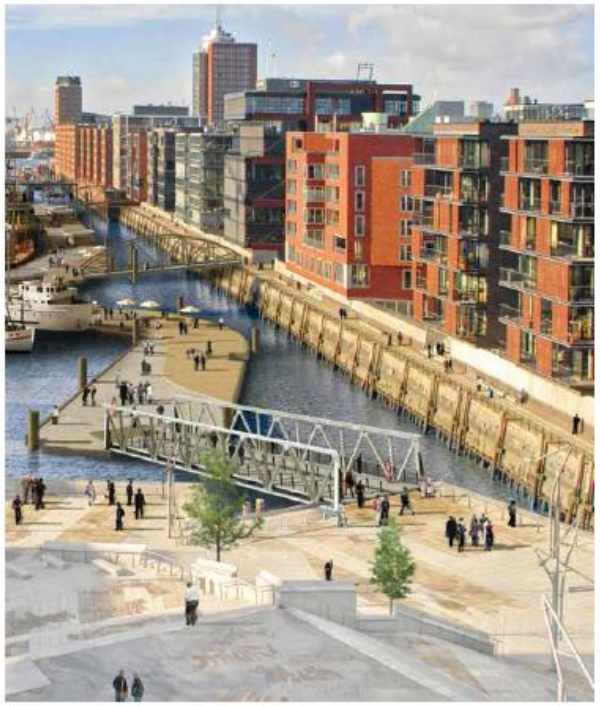
Pros: Effective for storm flooding

Cons: Costs, not effective for permanent tidal flooding

Floodable development

Pros: Potential solution that generates revenue

Cons: Impacts from more development – higher density to pay for costs



New/elevate road

Pros: Protects roads when designed correctly

Cons: Very high cost, ROW

3. RETREAT

Retreat

Rebuild here

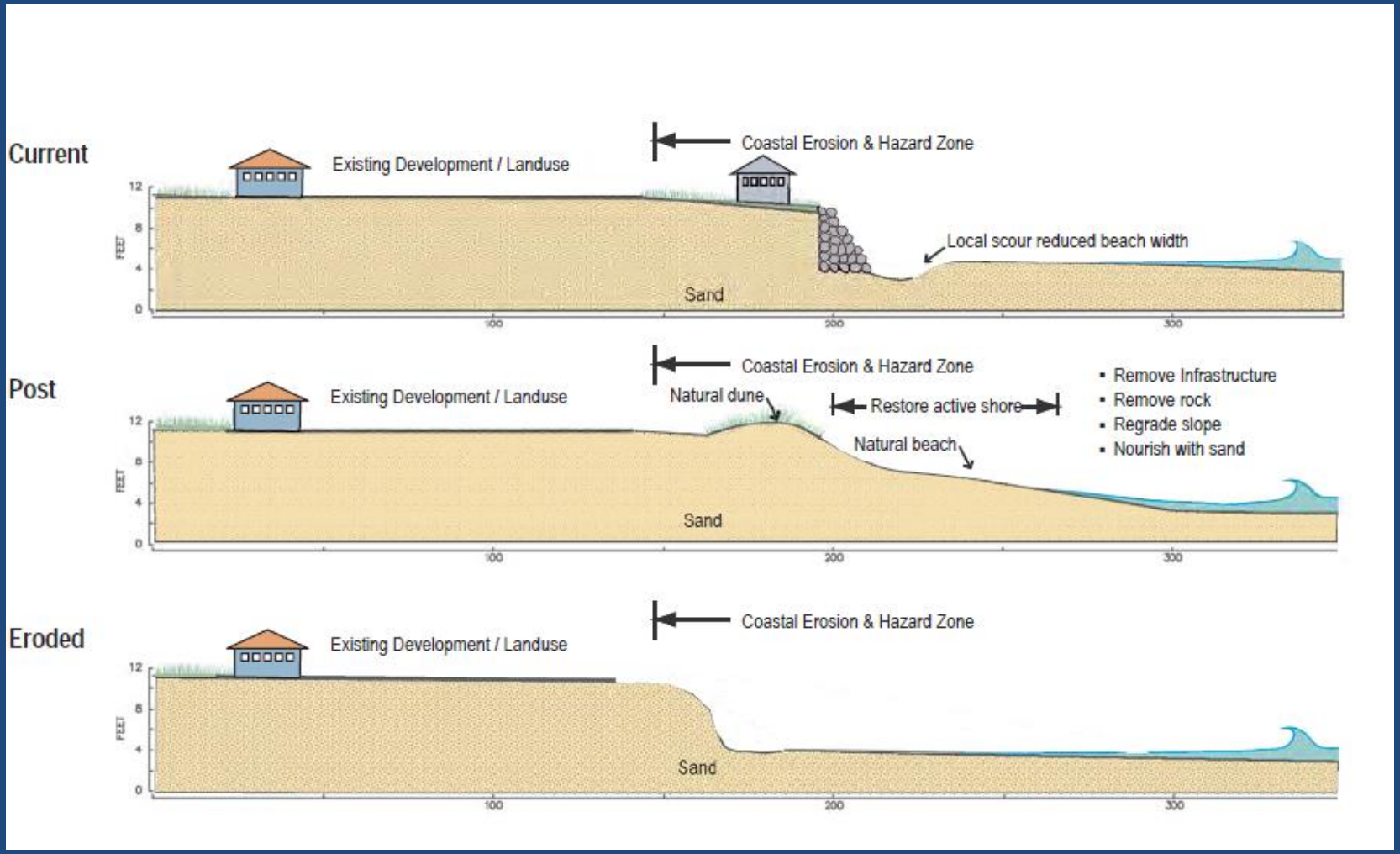
Post-storm prohibitions

Stricter land use zoning

Managed Retreat

Pros: Lower costs if no buyout

Cons: Costs for buy-out and community impacts, new infrastructure



Post Storm Restrictions and Stricter Land Use Zoning

- No or restricted rebuilding after storms?
- Rolling easements
- Extra technical studies
- Use of stricter codes (FEMA V)

Richardson Bay Shoreline Study
Evaluation of Sea Level Rise Impacts and Adaptation Alternatives

Roger Leventhal, P.E.
Senior Engineer

PUBLIC REVIEW DRAFT
October 14, 2015***

Limit of Direct Coastal Flood Barrier Alignments

- Evaluated several alignments to inhibit direct coastal flooding (not a CIP design list)
- Added up public versus private ROWs
- Added up costs for various hard versus soft engineering adaptation alternatives

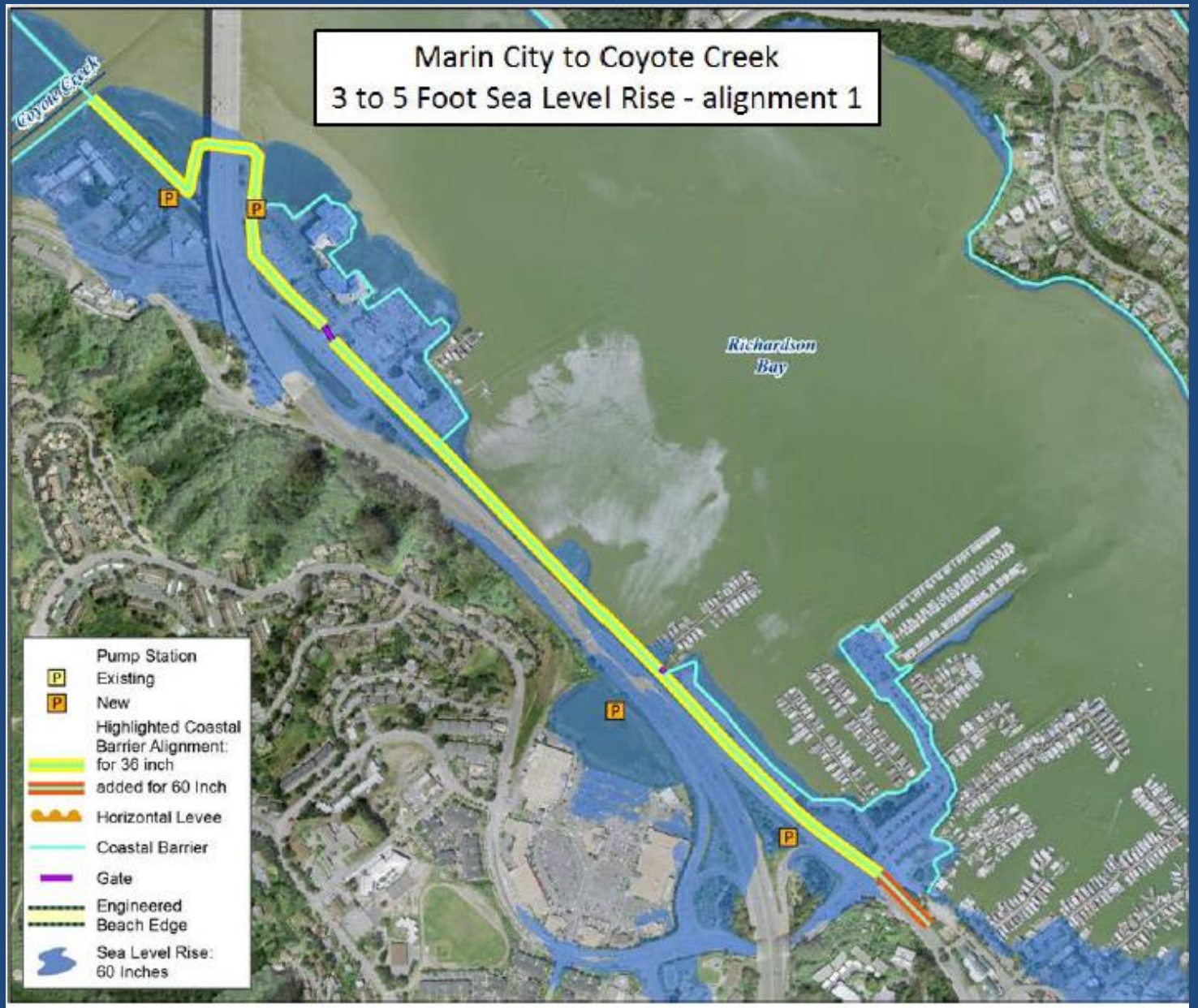
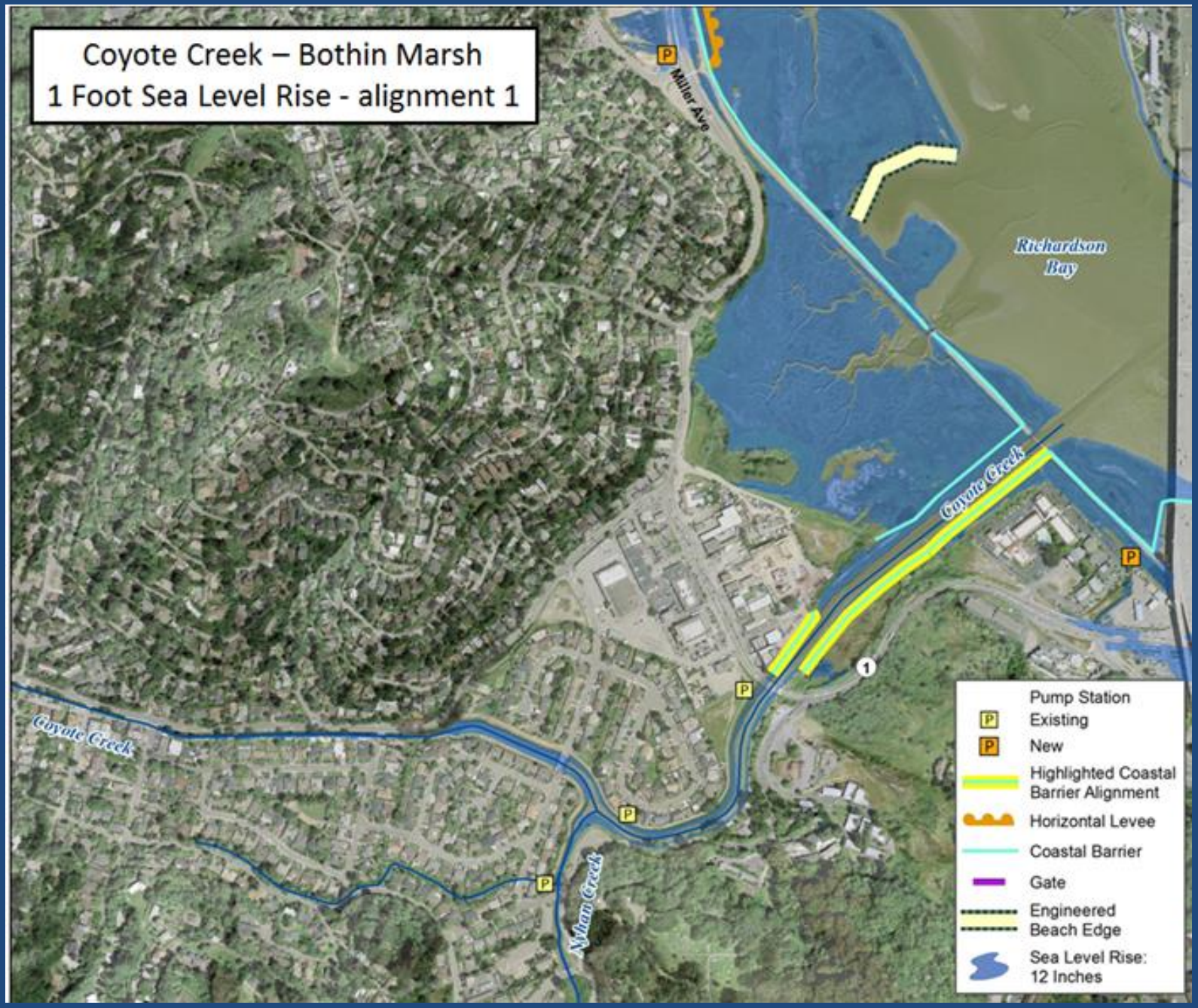
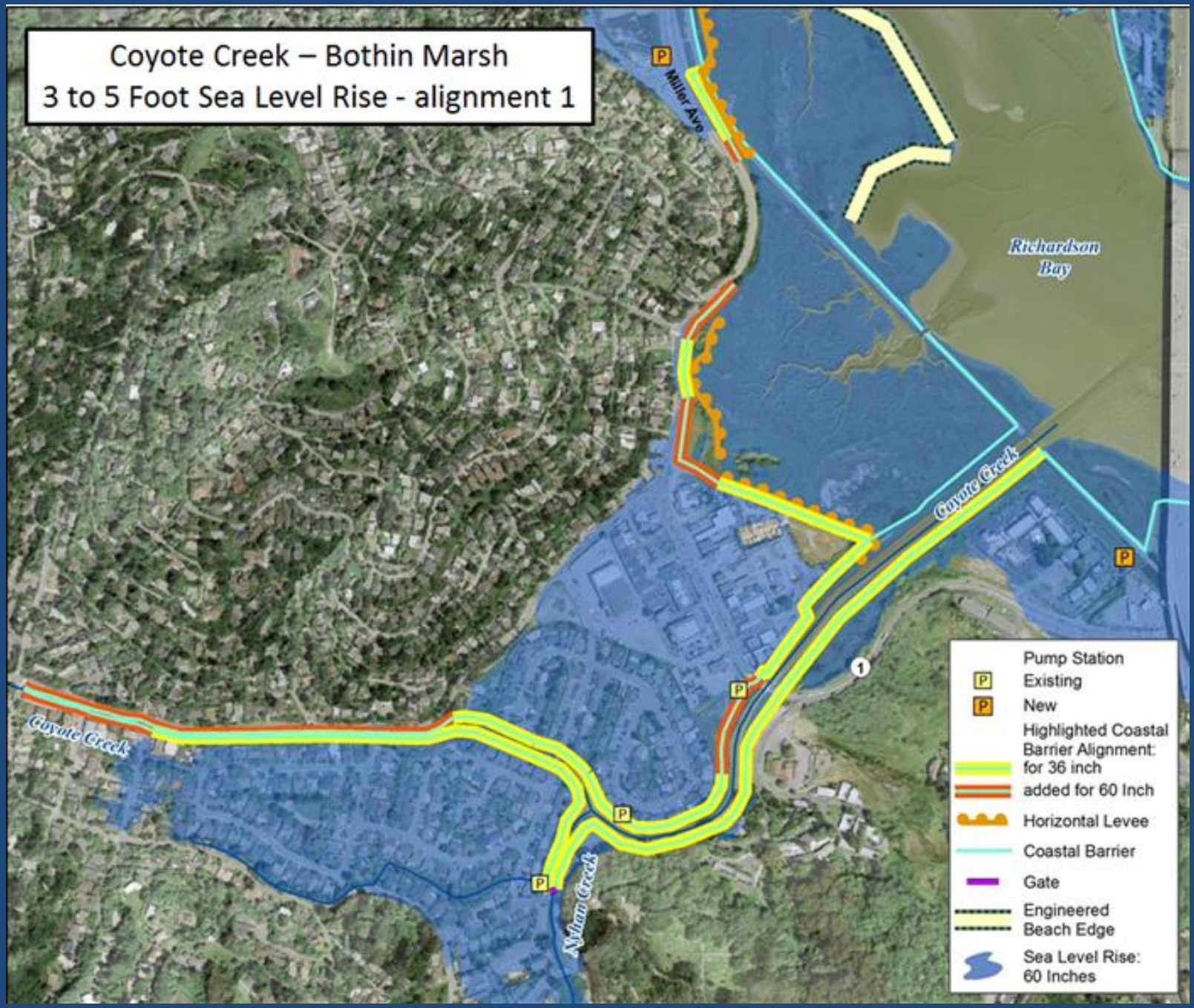


Figure 40: Reach 1, Alignment 1. 36 and 60 Inch Sea Level Rise LDCF Alignment (60 Inch Sea Level Rise Extensions In Red).


Coyote Creek – Bothin Marsh
1 Foot Sea Level Rise - alignment 1
Miller Ave
Richardson Bay
Coyote Creek
Coyote Creek
Nyhan Creek
1
Pump Station
Existing
New
Highlighted Coastal Barrier Alignment
Horizontal Levee
Coastal Barrier
Gate
Engineered Beach Edge
Sea Level Rise: 12 Inches


Coyote Creek – Bothin Marsh
3 to 5 Foot Sea Level Rise - alignment 1
Miller Ave
Richardson Bay
Coyote Creek
Coyote Creek
Arjhan Creek
1
Pump Station
Existing
New
Highlighted Coastal Barrier Alignment:
for 36 inch
added for 60 Inch
Horizontal Levee
Coastal Barrier
Gate
Engineered Beach Edge
Sea Level Rise: 60 Inches

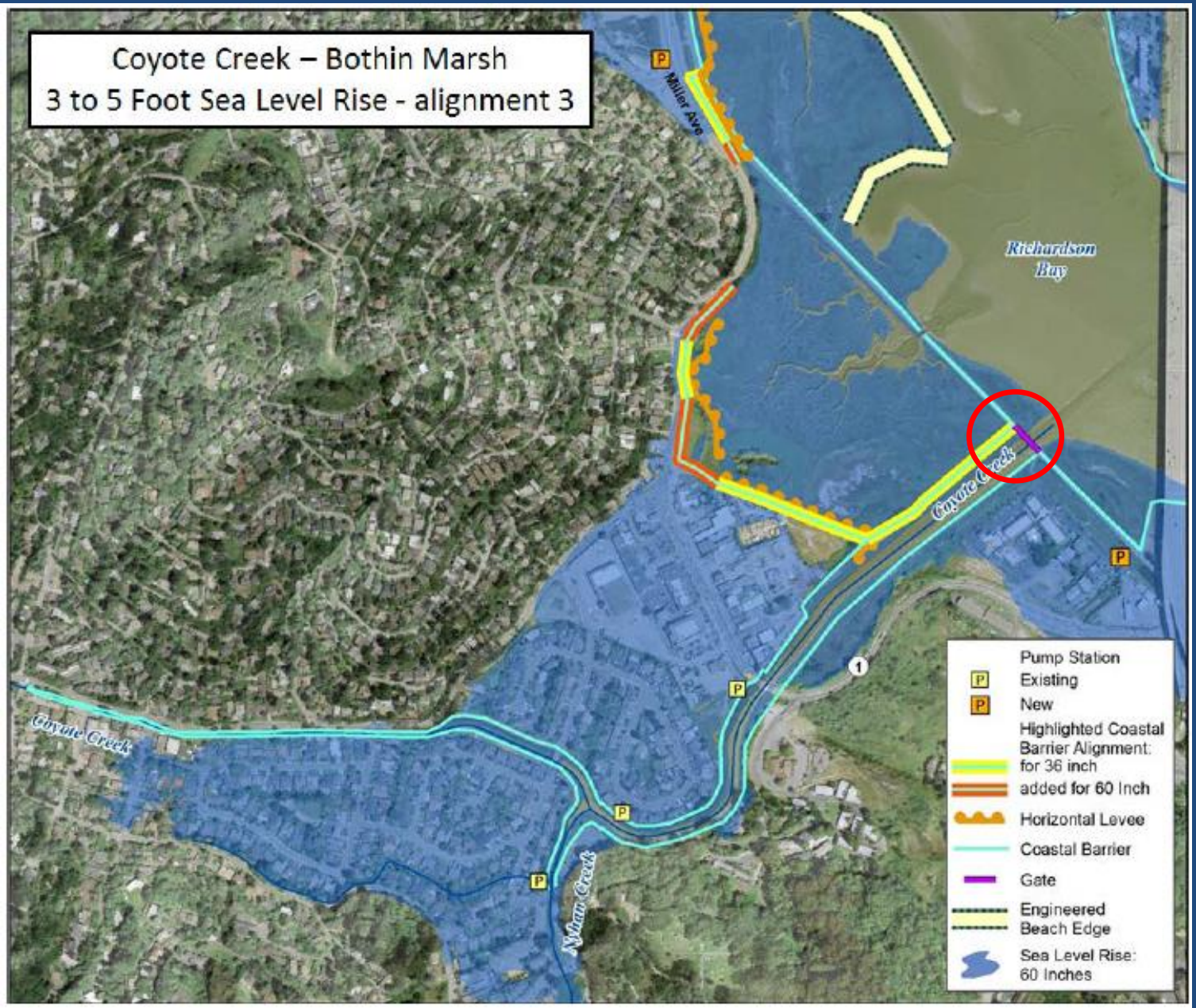
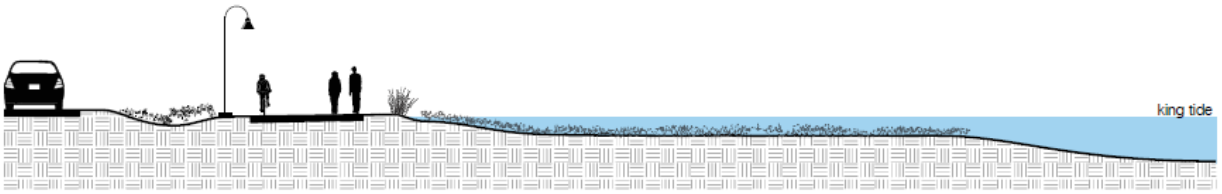


Figure 44: Reach 2, Alignment 3. 36- and 60- Inch LDCF Alignments.

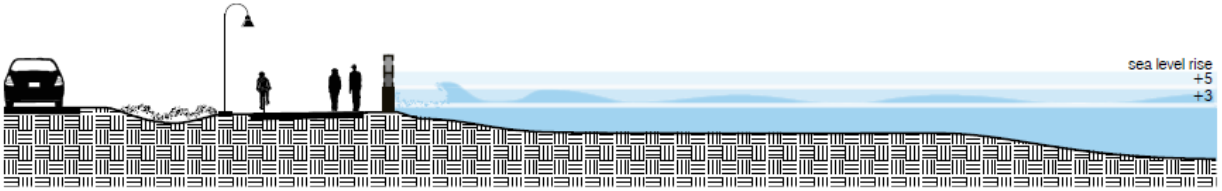
Table 17. Reach 2, Coyote Creek-Bothin Marsh Barrier Lengths (36 Inch Sea Level Rise).

Reach	Length Public ROW (feet)	Length Private ROW (feet)	Total Length (feet)	Number of Hydraulic Gate Structures
Alignment 1	5,675	4,006	9,681	1
Alignment 2 – protects bike path Requires mitigation for wetlands impacts	8,017	3,267	11,284	2
Alignment 3 – high tide barrier at creek mouth	1,697	738	2,435	1 (major tide gate across mouth of Coyote Creek)

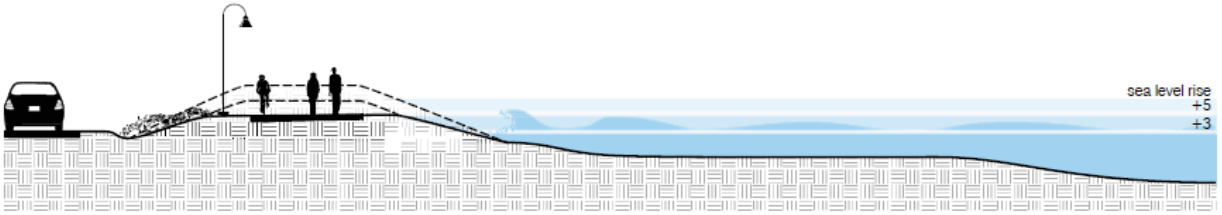
DRAFT



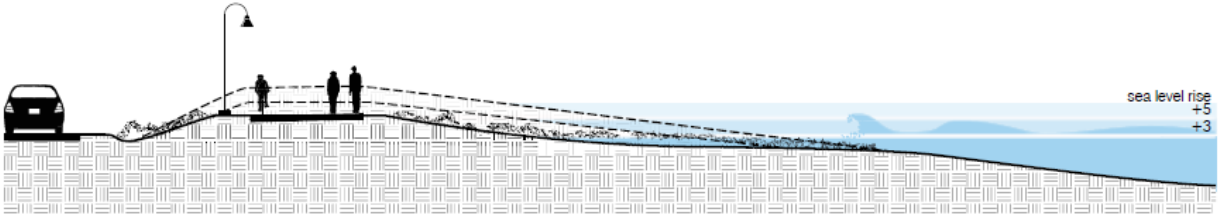
Existing



Sea Wall



Levee



Horizontal Levee

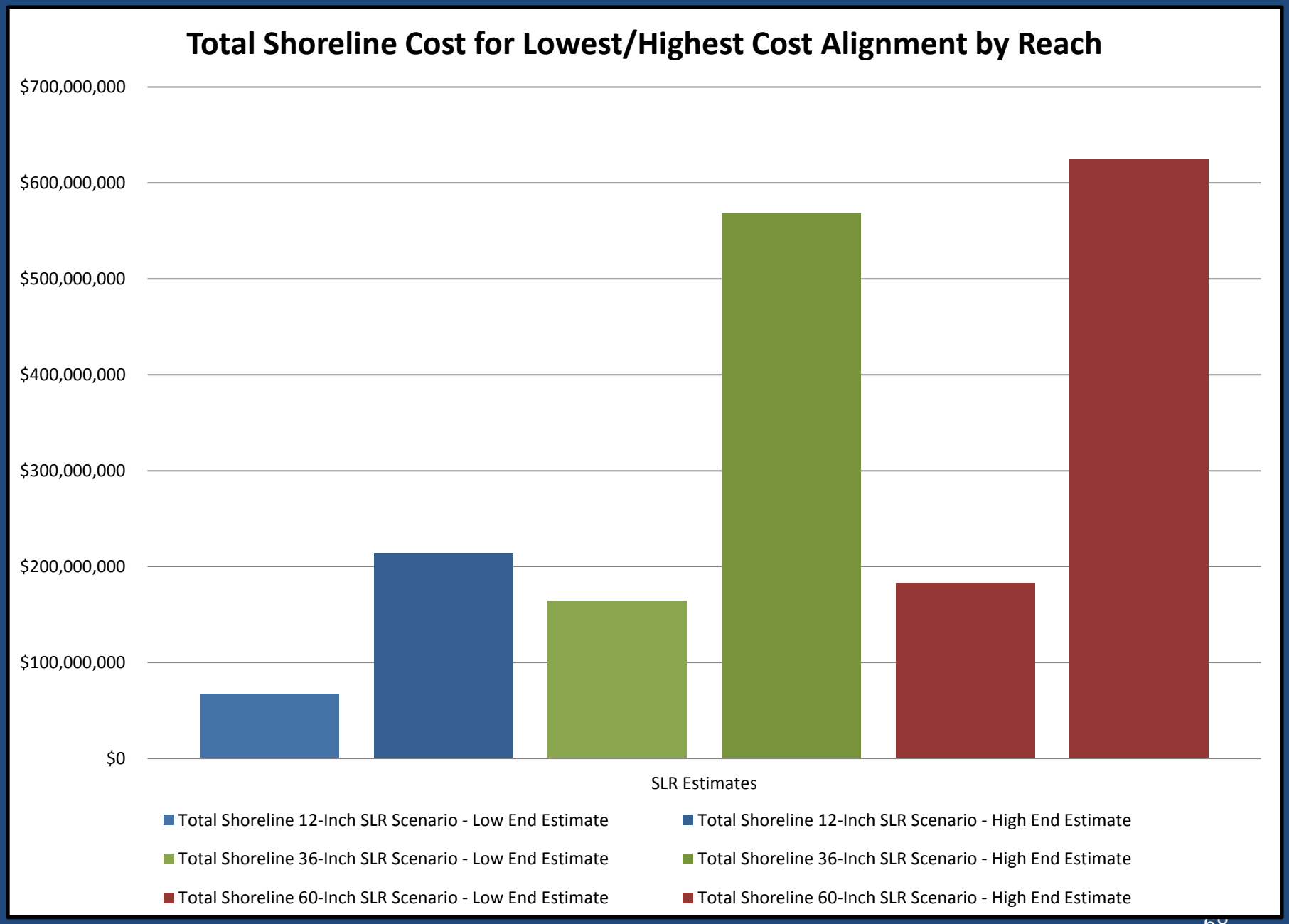
Southern Marin Sea Level Rise Diagrams

Restoration Design Group 07.02.15

Figure 6: The costs of flood protection in the Bay Area

The costs of flood protection vary by strategy. Generally, seawalls and levees bring additional costs, such as increasing erosion and removing habitat, while wetlands bring numerous additional benefits, including enhancing habitat and sequestering carbon.

Type of protection	Range of costs from Bay Area projects (in year 2000 dollars)	Maintenance costs
New levee	$725–$2,228 per linear foot	10% annually
Raised/upgraded levee	$223–$1,085 per linear foot	10% annually
New seawall	$2,646–$6,173 per linear foot	1–4% annually
Restored tidal marsh	$5,000–$200,000 per acre	unknown


Total Shoreline Cost for Lowest/Highest Cost Alignment by Reach
$700,000,000
$600,000,000
$500,000,000
$400,000,000
$300,000,000
$200,000,000
$100,000,000
$0
SLR Estimates
Total Shoreline 12-Inch SLR Scenario - Low End Estimate
Total Shoreline 12-Inch SLR Scenario - High End Estimate
Total Shoreline 36-Inch SLR Scenario - Low End Estimate
Total Shoreline 36-Inch SLR Scenario - High End Estimate
Total Shoreline 60-Inch SLR Scenario - Low End Estimate
Total Shoreline 60-Inch SLR Scenario - High End Estimate

Retreat/Relocation not specifically evaluated

- Study protects the built edge
- Not possible for DPW to “retreat” areas
- Needs to be a result of planning efforts
- Always an alternative

Pilot Project Education and outreach

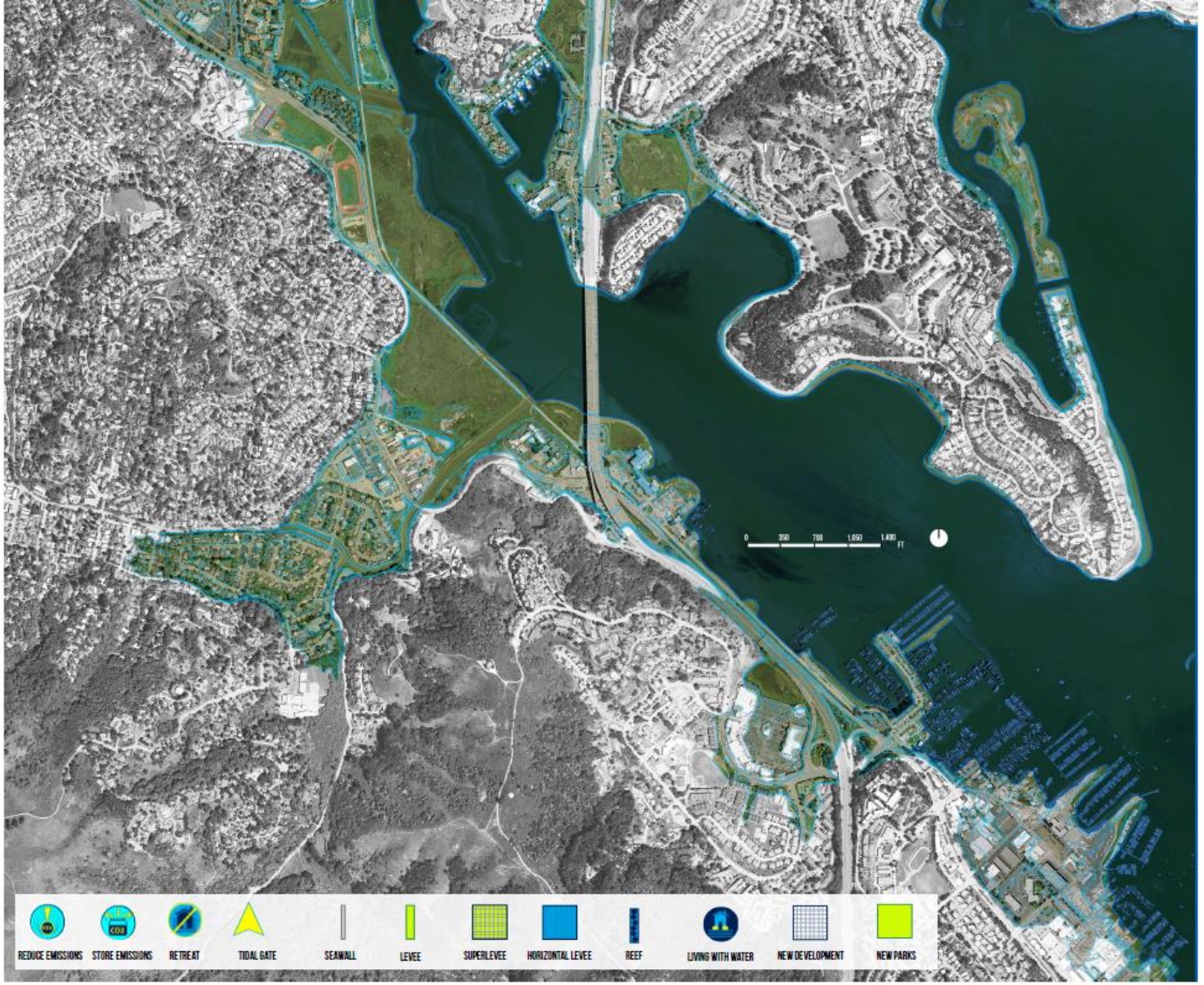
The Game of Floods

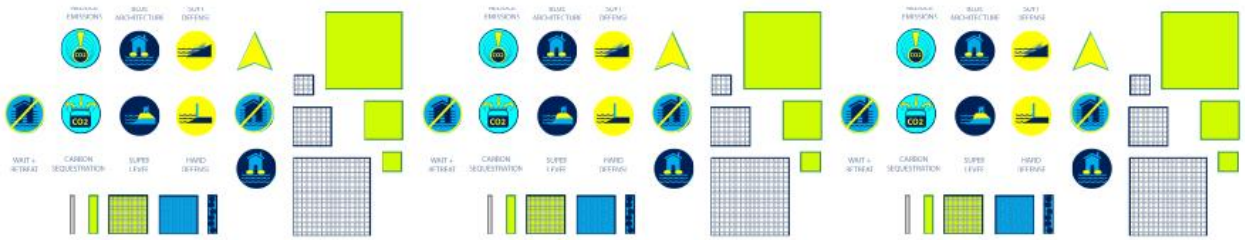
Community Driven Adaptation Planning for Sea Level Rise along the Inner Richardson Bay Shoreline

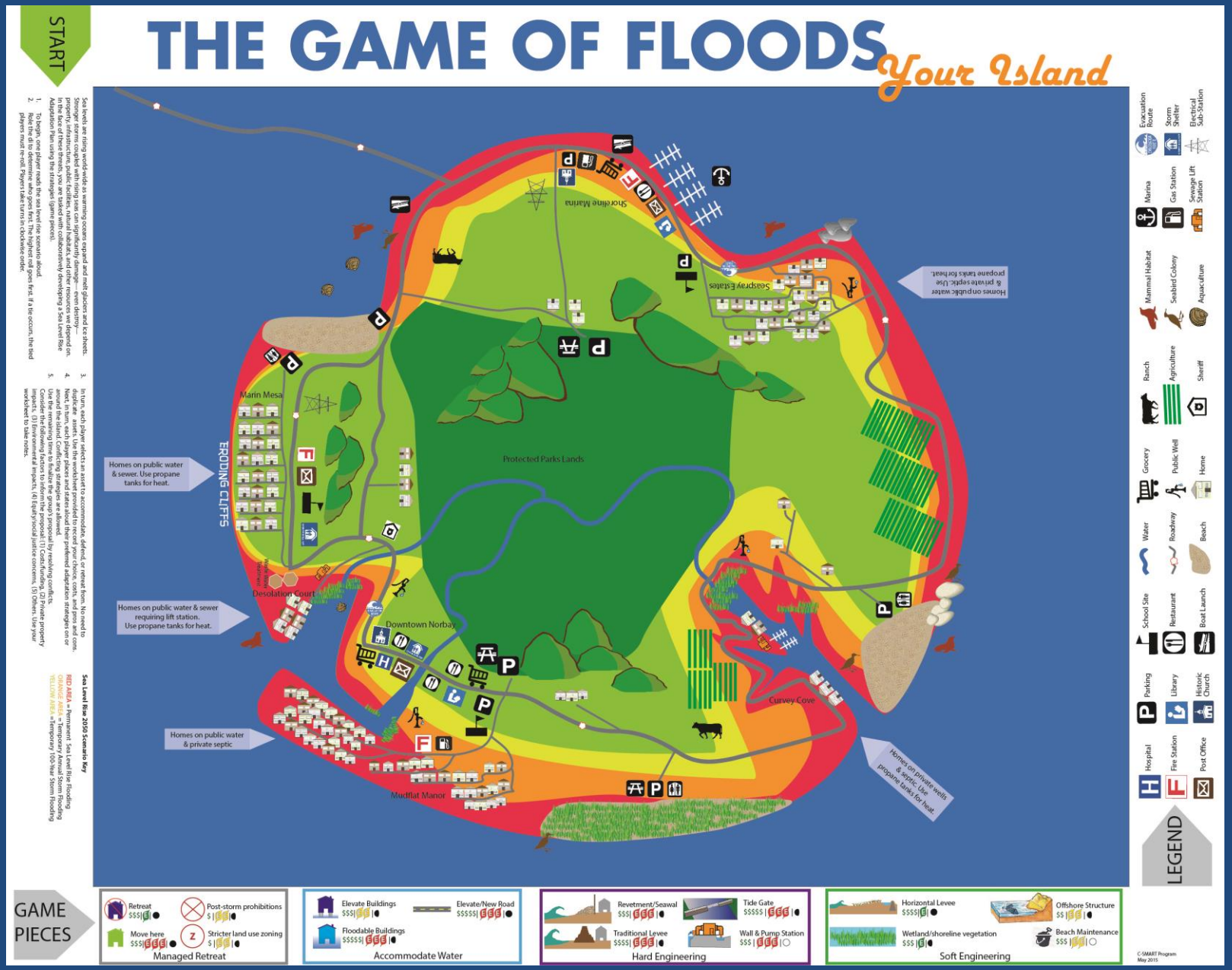
Just like HBO's Game of Thrones except for no sex and violence - but with lots more urban planning

Roger Leventhal, P.E., CFM

DRAFT


0 350 700 1,050 1,400 FT
REDUCE EMISSIONS
STORE EMISSIONS
RETREAT
TIDAL GATE
SEAWALL
LEVEE
SUPERLEVEE
HORIZONTAL LEVEE
REEF
LIVING WITH WATER
NEW DEVELOPMENT
NEW PARKS





Board design by Bridgit van Balleghem

8
9
4

Spotted Owls (KB + VLO)

Thank You

Visit www.MarinSLR.org for more information

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Novato Creek at Highway 101. Credit: Marin County staff