An Initial Assessment of the Impacts of Sea Level Rise to the California Coast

Photo by D. Revell – 2/23/08

California Coastal Records Project

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Outline

- Background
- Project Objectives
- Overview of Methods
- Initial Results
- Policy Recommendations

Project Objectives

Map Flood and Erosion Hazards

Identify vulnerable infrastructure and some costs of adaptation

Photo by D. Revell

Project funded by the California Energy Commission's Public Interest Energy Research Program, CalTrans, and the California Ocean Protection Council

Report due out end of February

General Approach - Vulnerability

- Adopt CA climate scenarios developed for CEC projects.
- Develop maps of flood and erosion hazards for CA coast.
- Identify and quantify populations and infrastructure at risk.
- Evaluate cost of some protective responses.
- Offer policy guidance and recommendations.

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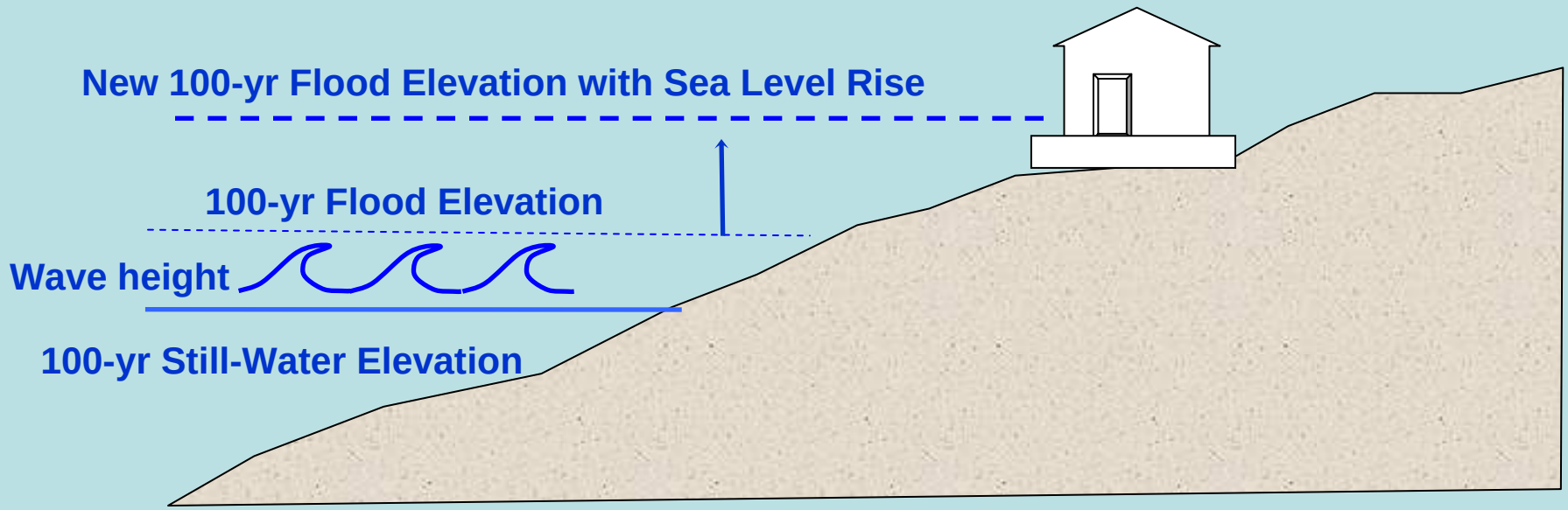
Mapping Flood Hazards



- Review all existing FEMA Flood Insurance Studies
- Extract Coastal Base Flood Elevations into GIS
- Add Sea level rise scenarios to BFE elevations
- Map inundation using terrain datasets

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Mapping Erosion Hazards

Bluff

Total Water Levels

- Sea Level Rise
- Tides
- Wave Run-up
- Storm Surge
- El Ninos

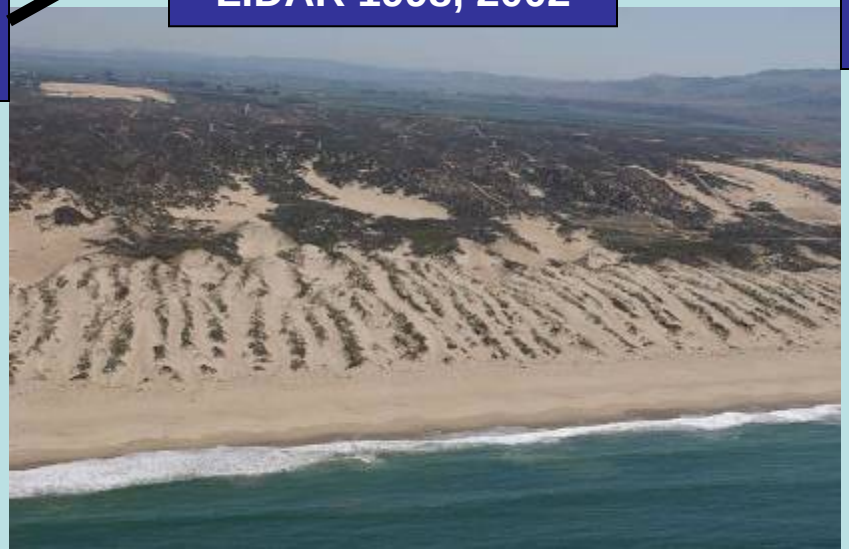
Elevation of the Toe

-LIDAR 1998, 2002

Geomorphic Erosion Response

- Backshore Type/Location
- Geology

Dune



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Geospatial (GIS) data sets - Erosion

Name	Description	Source
Shoreline Inventory	Backshore (Habel and Armstrong 1977 digitized by Melanie Coyne 1999)	CCC, CSMW
Geology	Geology updated from CGS and USGS digital data for Griggs et al 2005.	UCSC
Shoreline Armoring	Inventory of CA coastal defenses	CCC
Landslides	Landslides for several coastal counties	CGS
LIDAR	1998 (and 2002) 2m elevation data	NOAA
Bathymetry	10m depth contours of California	DFG
Sandy shoreline change rates	Long term shoreline change data (~1870s to 1998)	USGS
Cliff Erosion rates	Cliff erosion data (~1930s to 1998)	USGS

Non GIS references:
Griggs et al 2005 Living with the Changing California Coast
California Coastal Records Project – *californiacoastline.org*

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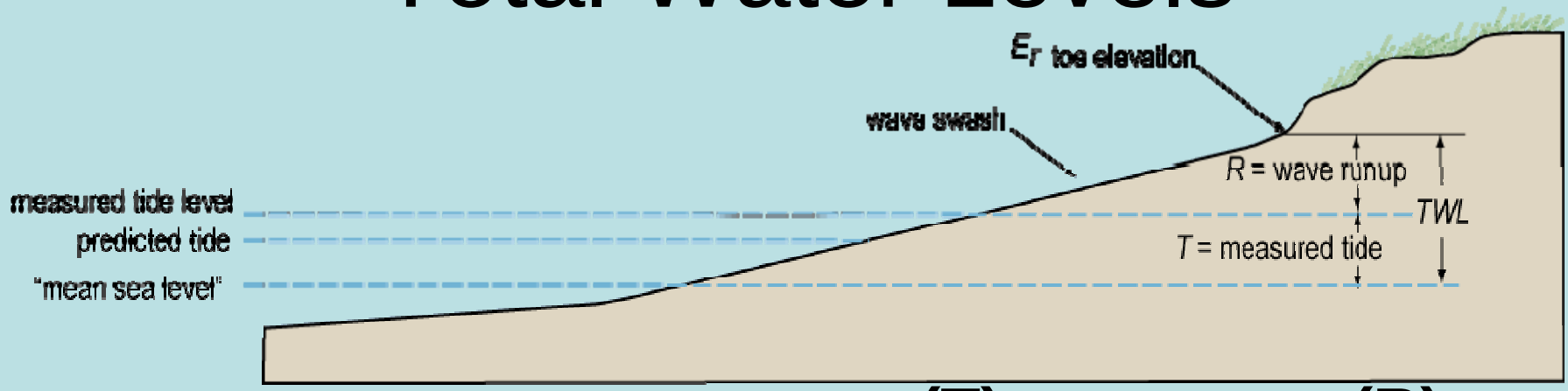
Total Water Levels



Total Water Level, TWL = "measured" Tides, **(T)** + Wave Runup, **(R)**

T = Sea level rise scenarios (Cayan et al), 100 years at 3 hour tides coupled waves and storm effects (ENSO, surge) for 3 scenarios
2 locations – SF, Crescent City

R = Wave run-up - Deepwater waves (Cayan et al) for three sites – Pt. Conception, San Francisco, Crescent City

- CDIP models to transform waves at 140 nearshore locations at 10m
- Calculated wave run-up (Stockdon et al 2006).

Generated excedance curves for each subdivided geologic unit (500m) using individual slopes and toe elevations

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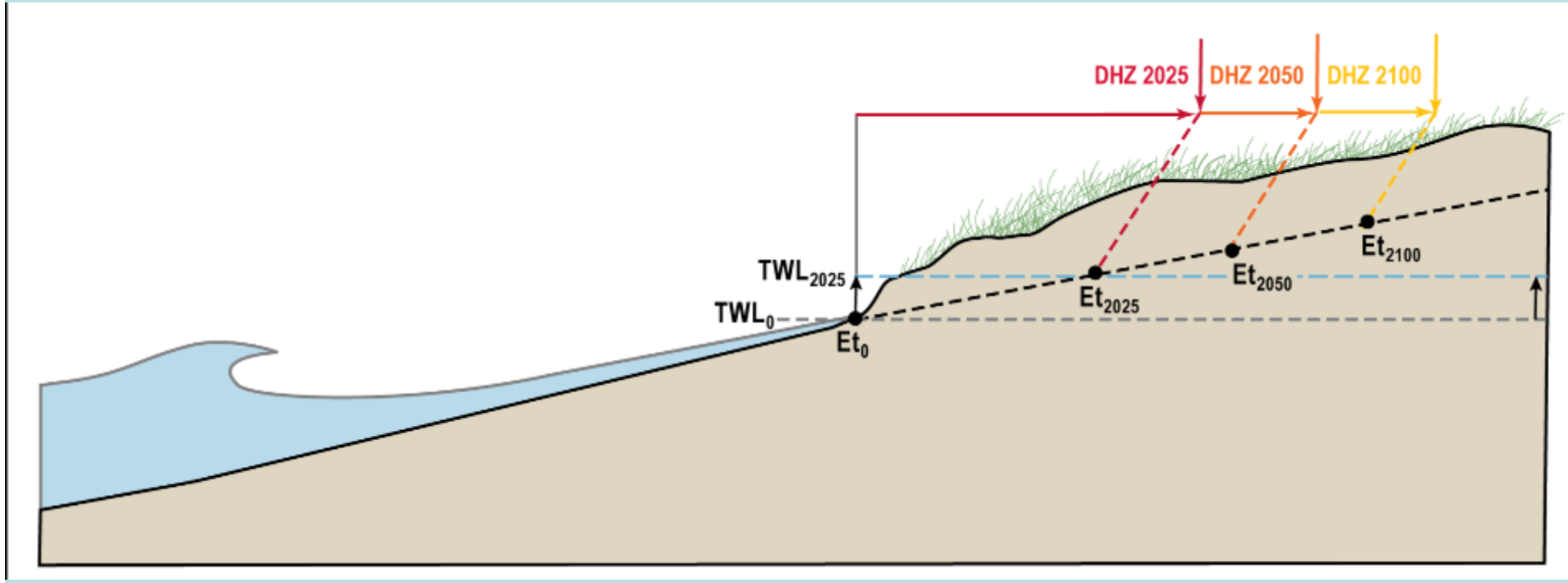
Dune Erosion Model



- 3 components –
  - Changes in TWL from SLR combined with shoreface slope
  - Historic shoreline trends (USGS)
  - Impact of a “100 year storm event”

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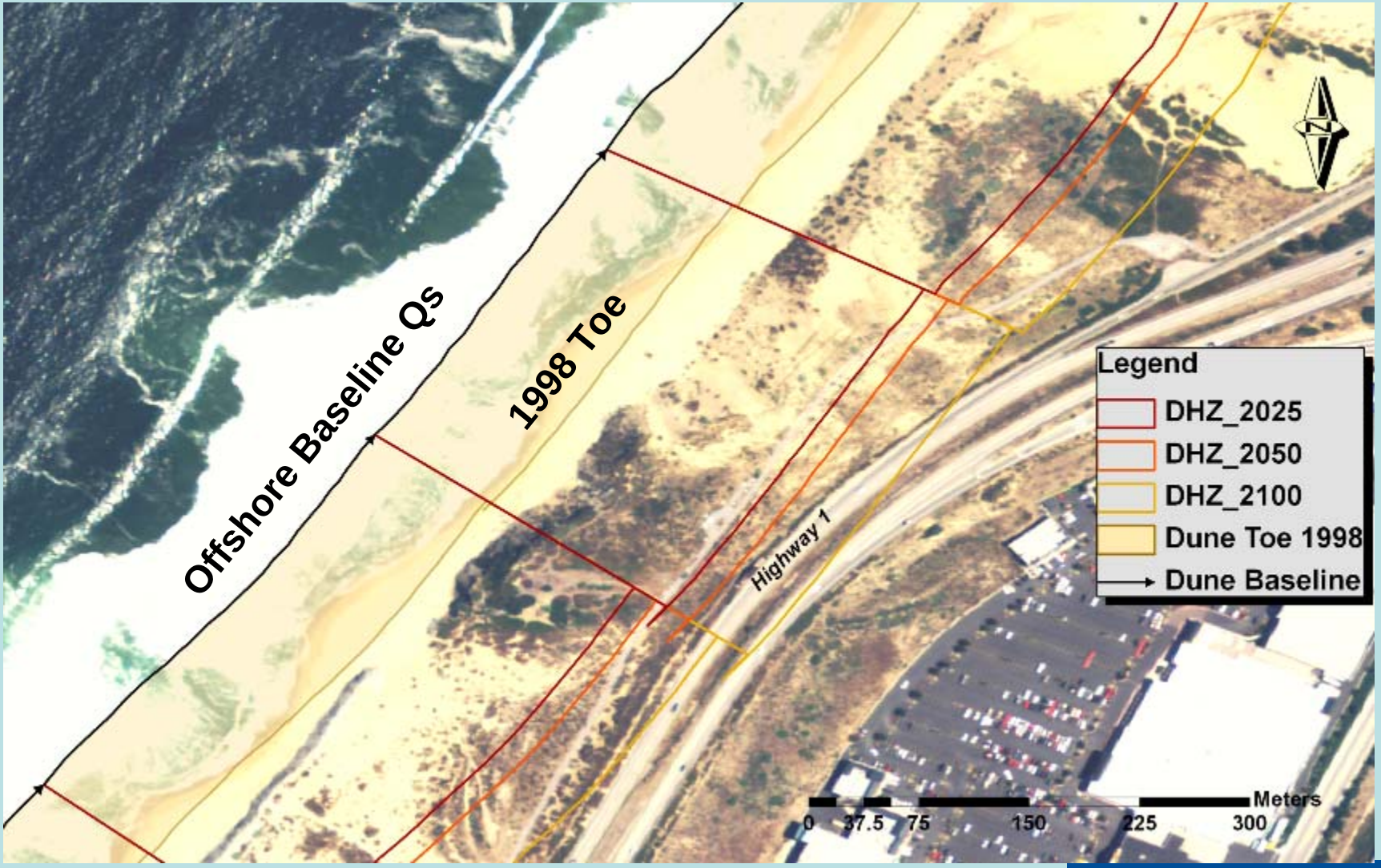
Dune Hazard Zones



Air Photo from 2005

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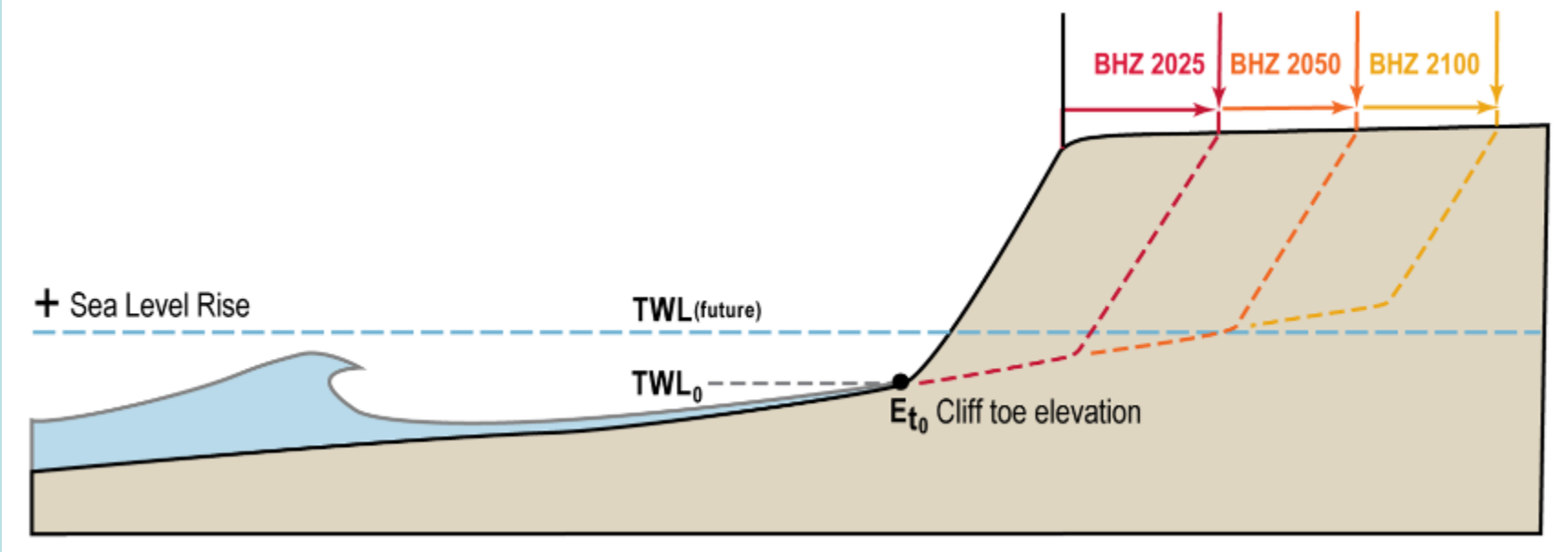
Bluff/Cliff Erosion Model



- Acceleration of historic erosion rates (Rh)
- Prorated based on % increase in TWL exceeding the elevation of the toe of the beach/bluff junction
- Include geologic unit standard deviation x planning horizon to account for alongshore variability

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Bluff Hazard Zones

Air Photo from 2005

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Results - Dunes

- 300 km or 185 miles
- Majority of Norcal “accreting”
- Reversal in sign seen between 2050 and 2100

Hazard Zone Low - High	Mean Erosion Distance (m)	Total Erosion Area (acres)
2025	115 - 116	5,315 - 5,400
2050	119 - 128	5,625 – 6,205
2100	132 - 175	6,700 – 9,620

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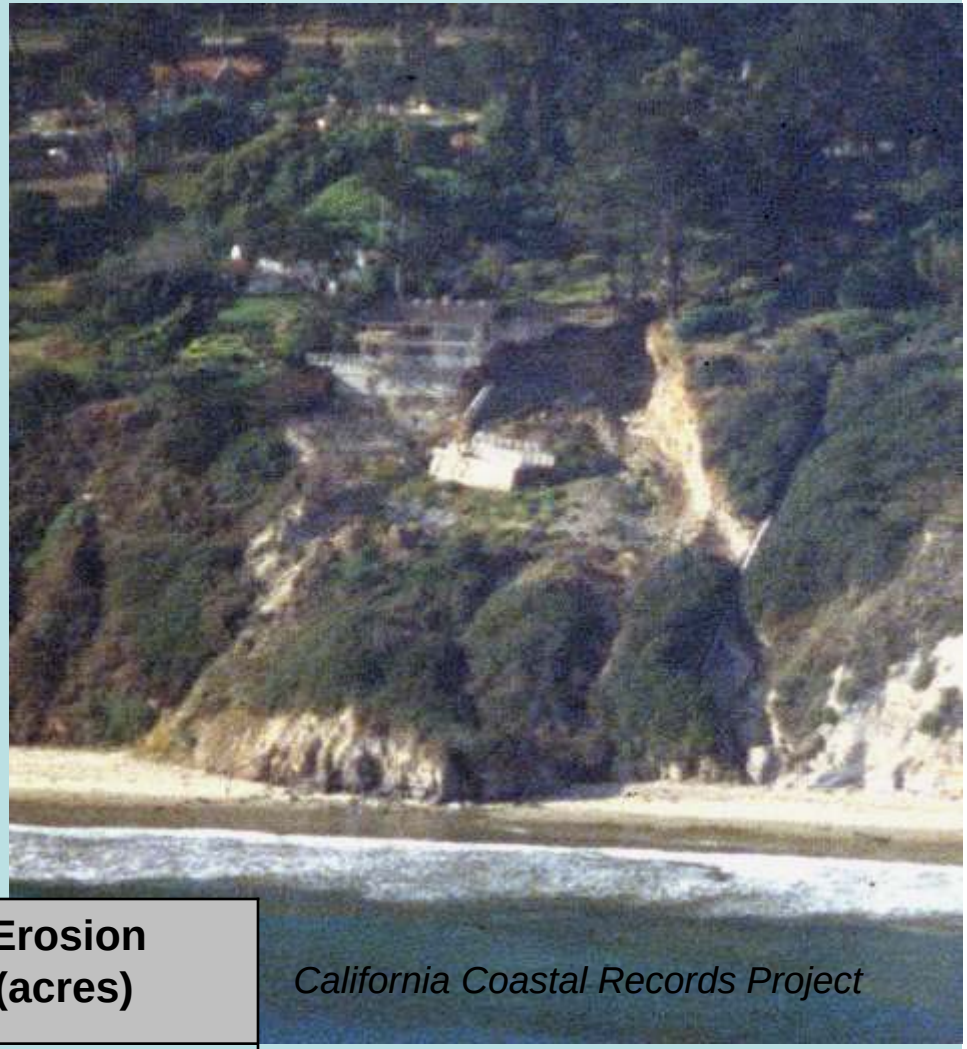
Results - Bluffs

- 1,140 km or 710 miles
- Geology exerts strong influence
- Wave exposure and toe elevation important



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Hazard Zone Low - High	Mean Erosion Distance (m)	Total Erosion Area (acres)
2025	**8 - 9**	**1,415 – 1,425**
2050	**23 - 24**	**5,250 – 5,375**
2100	**58 - 64**	**13,335 – 15,085**

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Erosion Method - Limitations

- Input Data Sets Accuracy
- Potential erosion **not** actual
- Single Climate Model Output
  - not an ensemble
  - no calibration of erosion rates with existing TWL data
- Single wave time series
  - no trends in wave climate
  - Waves transformed to 10m
- GIS buffering algorithms
- LIDAR
  - Post El Nino conditions are indicative of 2008

- Simplified geometric response
  - Equilibrium profile application
  - Assumed increase in erosion rates is linear
  - Feedback mechanisms ignored
- Shoreline Change Rates
  - Impact of 1998 Lidar uncertain
  - LT rates may not be indicative of current trends

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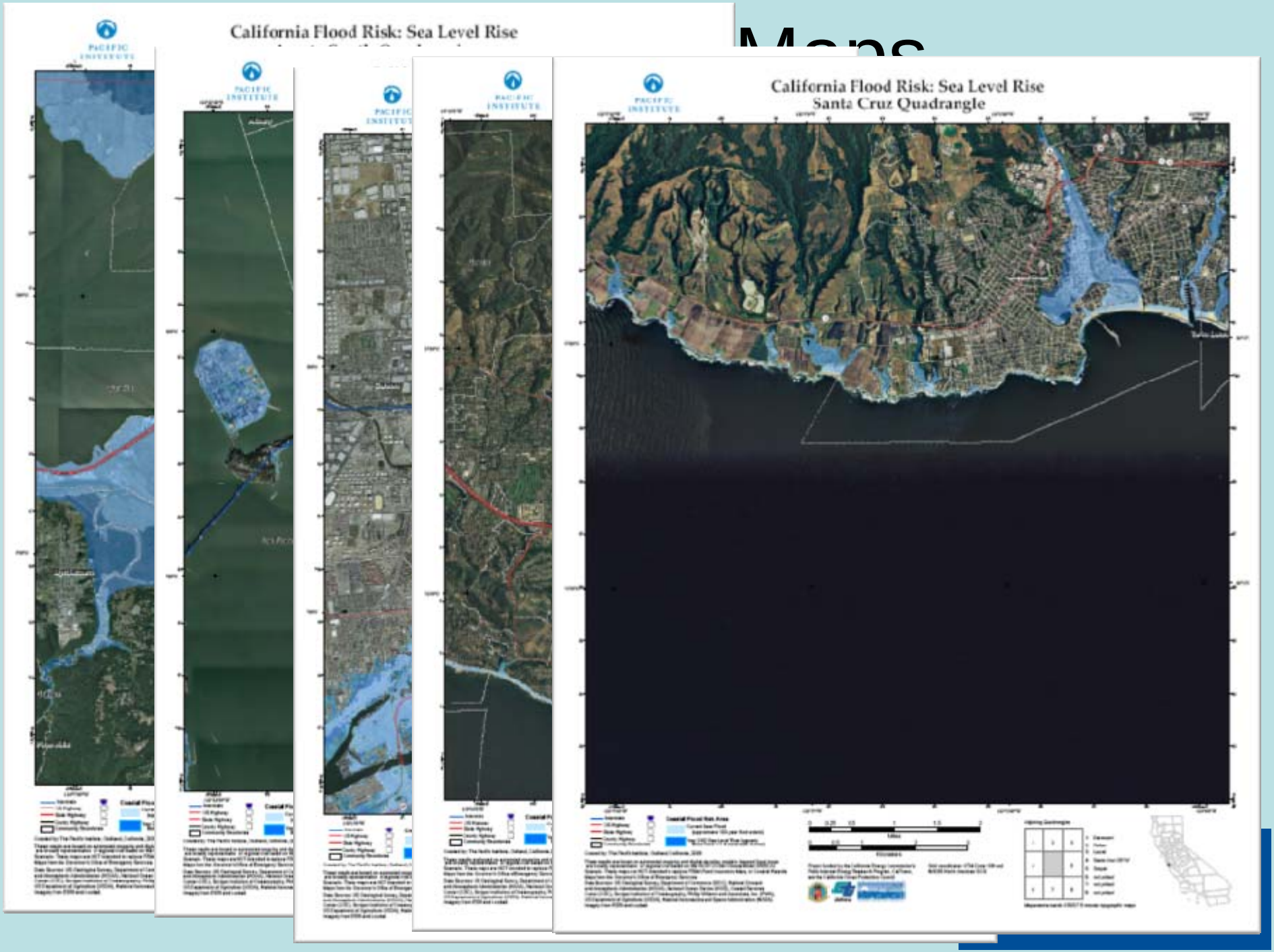
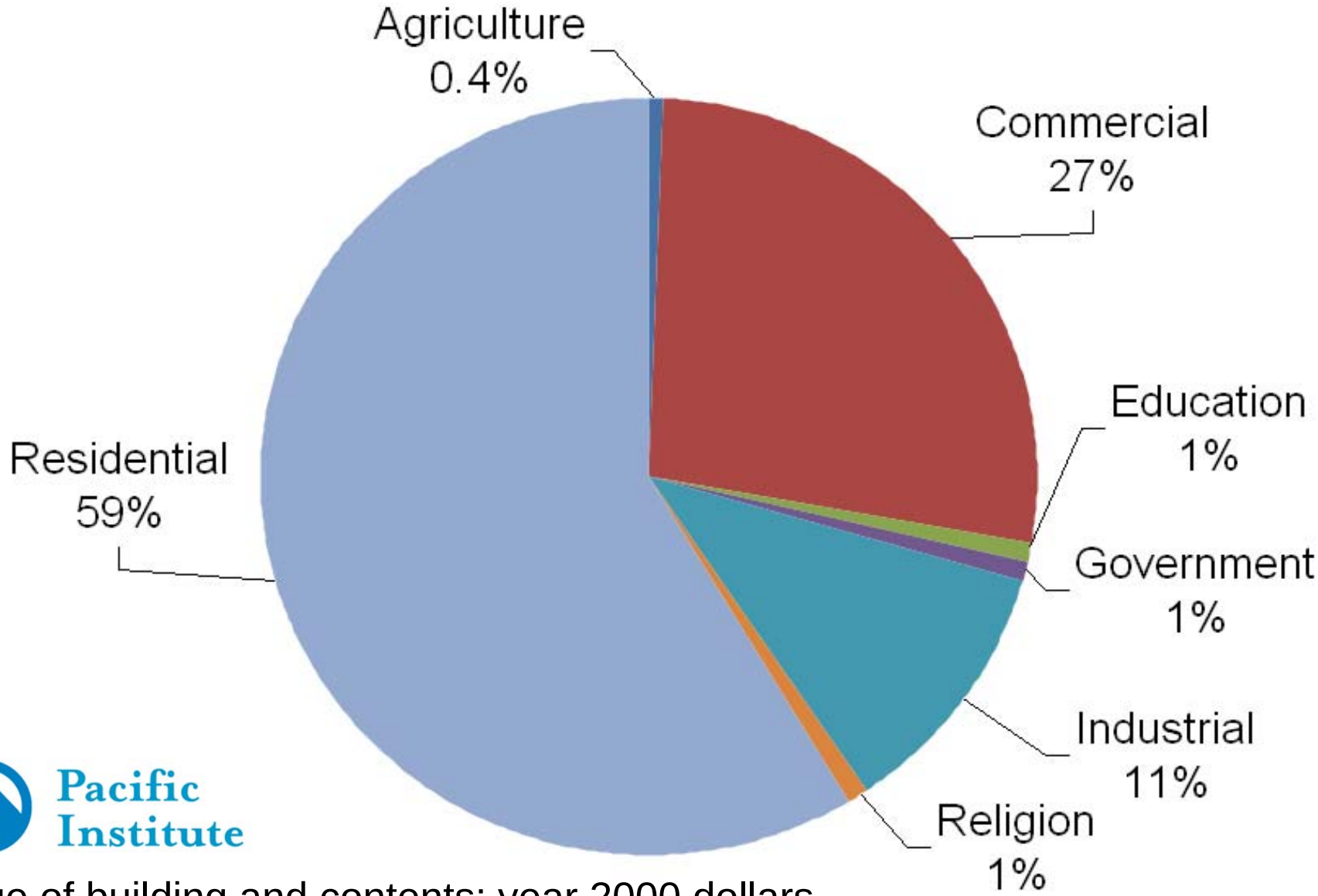
Maps


California Flood Risk: Sea Level Rise
California Flood Risk: Sea Level Rise
Santa Cruz Quadrangle

Property Value at Risk

Value of building and contents; year 2000 dollars.

Property Value at Risk by Sector



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Value of building and contents; year 2000 dollars.

Year 2000 Population At Risk:

- Total “resident” population at risk:
  465,000 people
- Population in Pacific Coast Erosion Hazard Zone:
  14,000 people
- Workforce at risk flooding:
  610,000, with majority (**525,000**) in SF Bay
- Workforce in Erosion Zones : **6,600**
- Data on disparities in income and ethnic distributions also available.

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Transportation Infrastructure at Risk

- Highways: 330 miles
- Roads: 1,880 miles
- Railways: 280 miles

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- Plus, major airports, bridge access. and more

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Other Impacts and Vulnerabilities

Type	At Risk by 1.4 m SLR
Schools	137
Health Care Facilities	55
Power Plants	30
Wastewater Treatment Plants	28
Fire Stations	17
Police Stations	17

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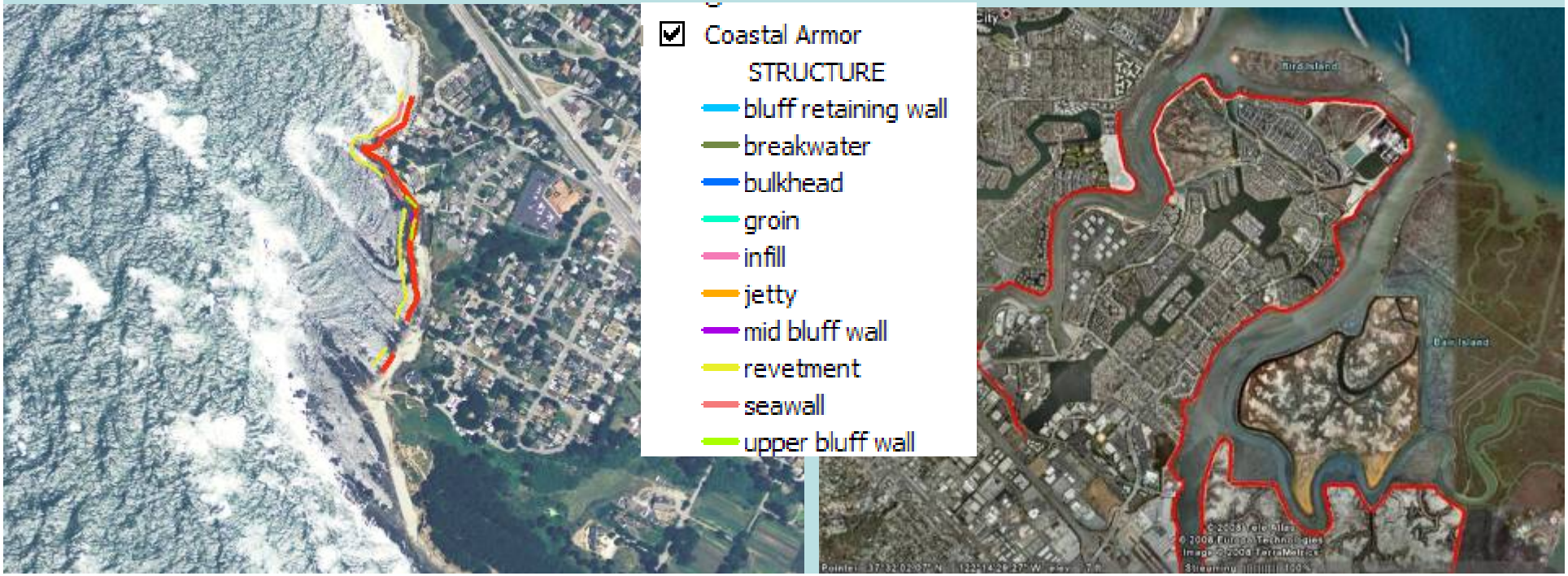
Coastal Defenses

- There are many options for responses:
  - Build or raise protective structures (levees, seawalls, breakwaters, others)
  - Abandon
  - Move
  - Nourishment
  - Restoration



Coastal Defenses

New study estimates that the cost to raise and strengthen existing levees, and construct new levees and seawalls would be approximately **$13 billion**, without including annual operation and maintenance costs.

Many areas receive no protection and would have to be abandoned. We include no estimate of economic costs for these areas.

We did not include estimates of bea

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Environmental Justice

	Pacific Coast		San Francisco Bay Area	
	Number in 100-year flood zone	Percent of total in flood zone	Number in 100-year flood zone	Percent of total in flood zone
Households:				
linguistically isolated	4,700	4%	9,700	9%
with no vehicle	7,600	7%	8,200	7%
People:				
earning less than 150% the federal poverty threshold ($30,000)	56,000	27%	51,000	19%
People of color	60,000	29%	148,000	55%
who rent (not own) their home	45,000	43%	47,000	41%

Data source: Census 2000

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Policy and Management Recommendations

1. Limit development in areas at risk from rising seas
2. Protect adjacent uplands to keep options open.
3. Maintain historic ecological linkages between oceans, beaches, dunes, and wetlands.
4. Integrate future sea level rise into coastal policies.
5. Review flood insurance programs in light of SLR
6. Cost-benefit analyses should explicitly evaluate the social, recreational and environmental tradeoffs of adaptation strategies.

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Future Research Needs

Data needs

- New LIDAR flight – top of bluffs, 10m contour; bathy would be fantastic.
- Long term monitoring program – sand levels, toe elevation, coastal evolution, storm impacts, wave climate, rock hardness, failure cycles
  - "Coastal Observation System"
- Ensemble of GCM outputs
- Human Uses and levels of activity
- Levee and coastal structure evaluation
- Habitat ecological and physical linkages important for erosion reduction
- More detailed localized and regional studies
- Additional research on vulnerable subpopulations

Methods

- Higher resolution geology and geomorphology
- Refine shoreline change rates at higher temporal scales
- Focused studies with improved resolution data sets
- Evaluation of alternative erosion models
- Evaluate changes to fluvial flooding from elevated sea levels

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THANK YOU!!!