Economic Impacts Of Sea-Level Rise

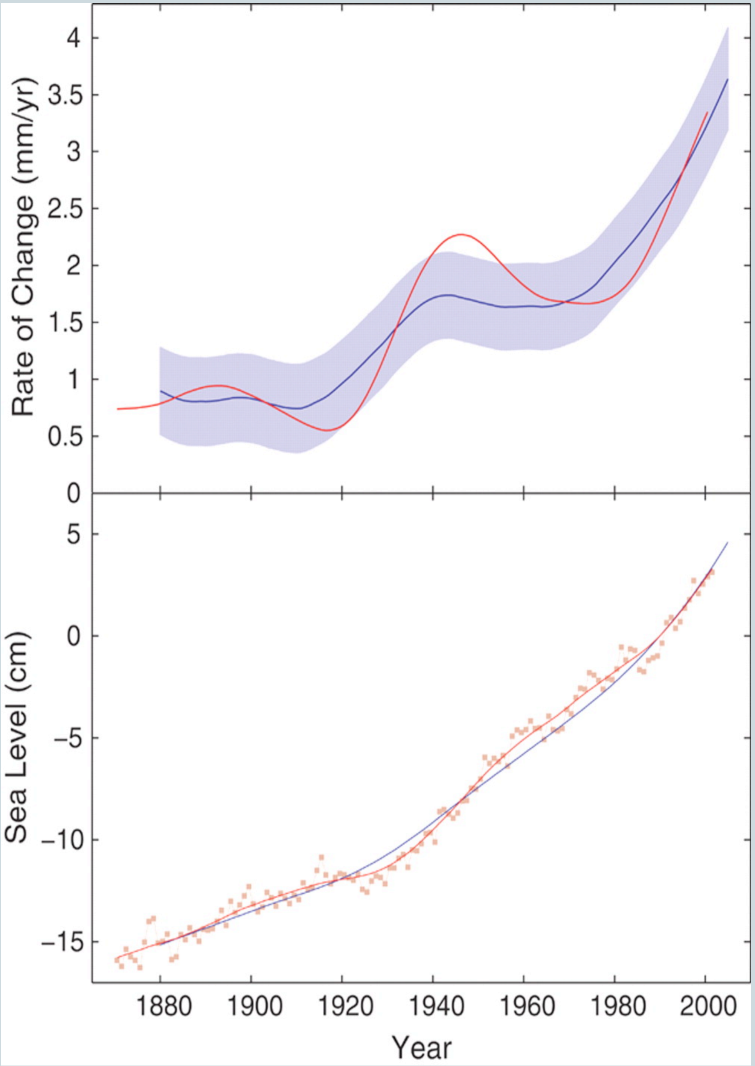
To California Beach Communities

UC Berkeley
10-5-2011

Philip King - Aaron McGregor - Justin Whittet

Sea-Level Rise:

- Global climate change is accelerating SLR worldwide
- Thermal expansion of the oceans
- Excessive melting of polar ice and glaciers
- Top: *Rate* of SLR (note recent acceleration)
- Bottom: Sea level (zero at 1990)



S. Rahmstorf, *Science* 315, 368-370 (2007)

SLR Cost Studies:

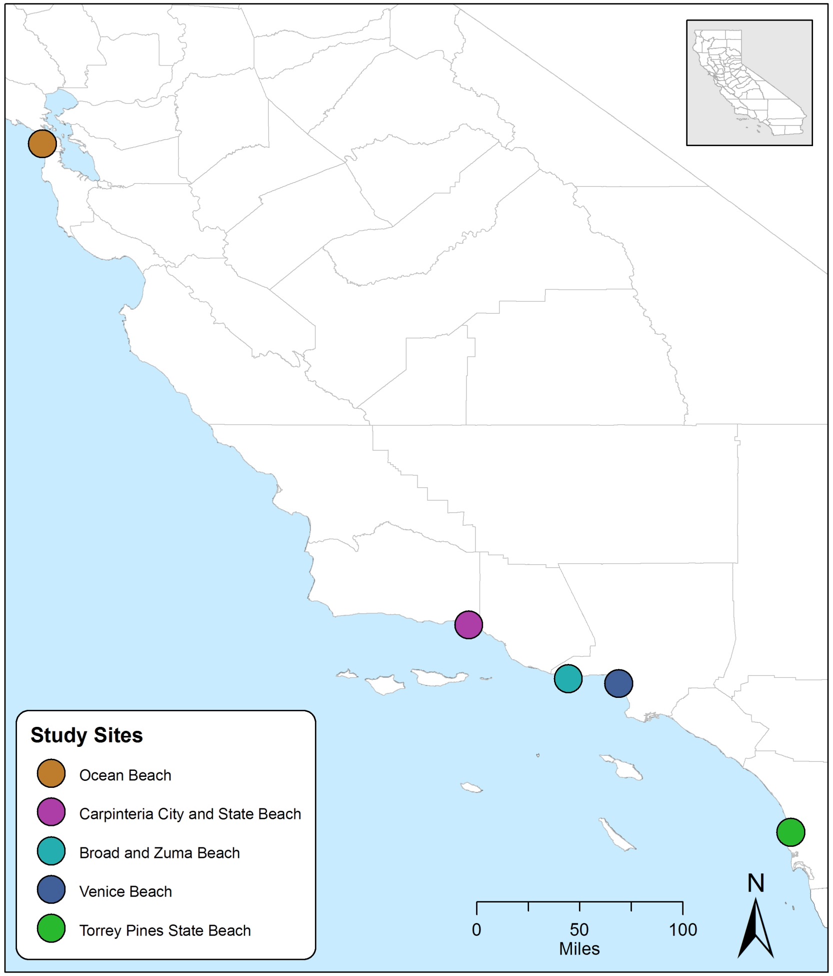
- Yohe Approach (1989, 1996, 1998)
  - Cost-benefit analysis: Protection vs. abandonment
  - Examines change in mean sea level, ignoring storm surge and extreme events
  - Assumes perfect adaptation foresight
- Pacific Institute (2009)
  - Updated climate scenarios, modern analytical tools (GIS)
  - Inundation from 100-yr storm event + 1.4 (m) SLR
  - Erosion analysis (PWA) with 1.4 (m) rise in sea level
  - Comprehensive planning study of entire California coast

Study Objective:

- Disaggregated analysis
  - Increased precision with object-oriented approach that evaluates type of infrastructure and land at-risk
- Multiple GCM-based scenarios
  - Marginal analysis that evaluates rates of change and potential tipping points
- Diversity of scope
  - Storm flooding
  - Erosion
  - Recreation and habitat value
  - Adaptation responses

Study Areas:

- Ocean Beach, San Francisco
- Carpinteria City and State Beach, Carpinteria
- Broad and Zuma Beach, Malibu
- Venice Beach, Los Angeles
- Torrey Pines State Beach, San Diego



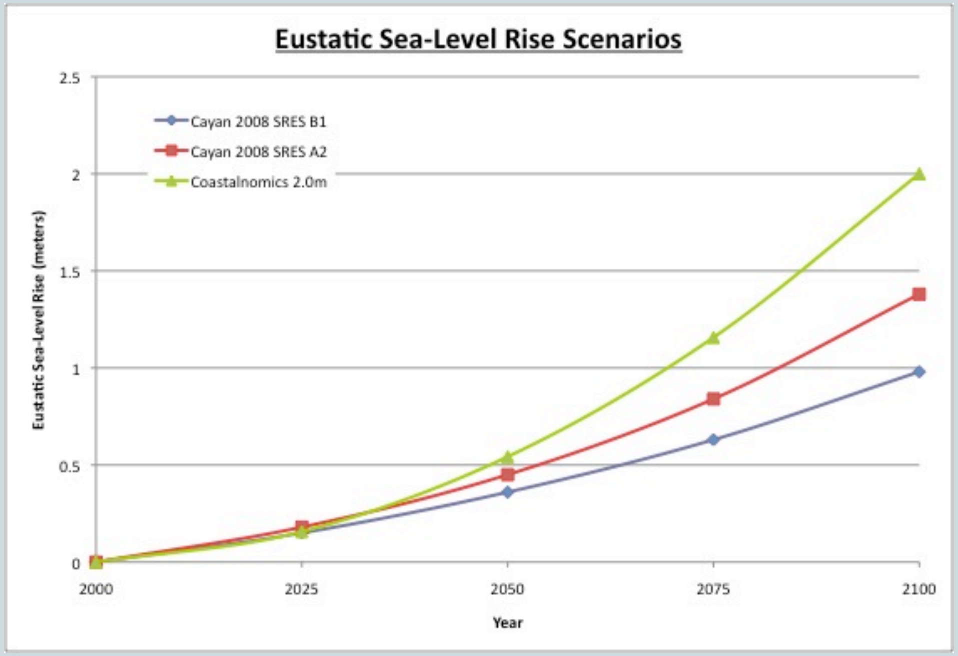
Califronia Study Region

Economic sea-level rise analysis of flooding, beach erosion, and upland erosion

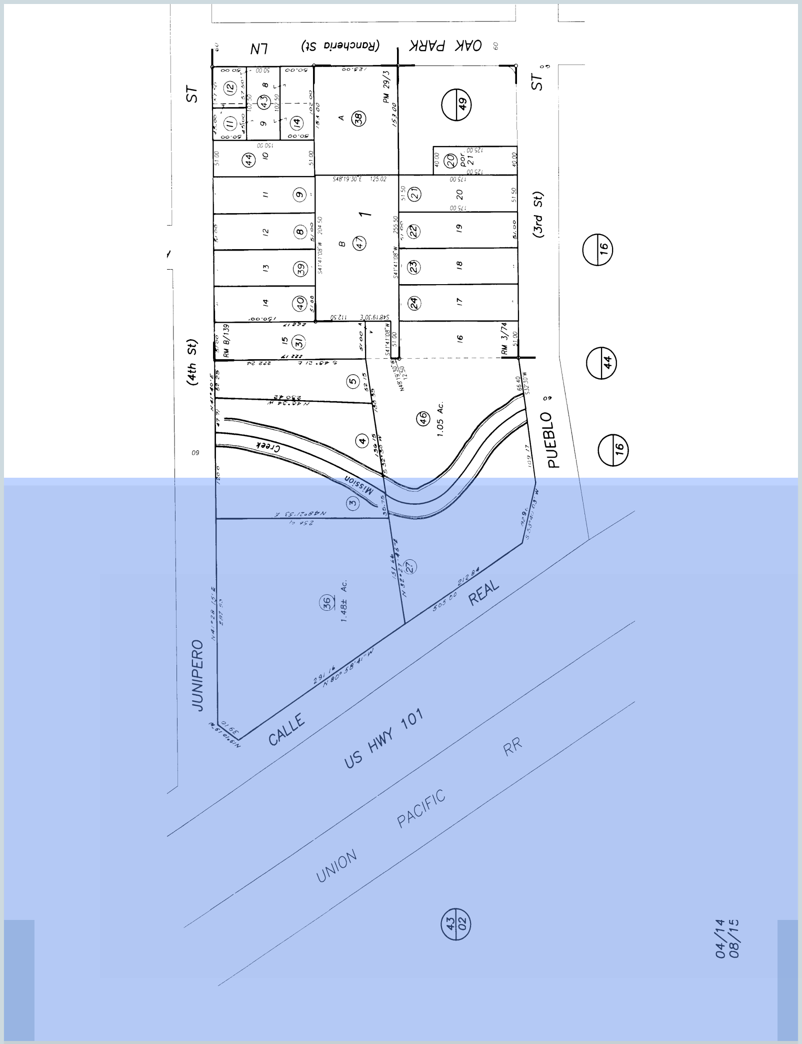
Data Sources: ESRI

Methods: 100-yr Storm + SLR

- 100-year Storm
  - Base Flood Elevations (PWA + PI)
- Sea Level Rise
  - 1.0 m - SRES B1 (Cayan 2008)
  - 1.4 m - SRES A2 (Cayan 2008)
  - 2.0 m - (Pfeffer 2008, USACE/NRC)



Footprint Analyses:



Assumption:

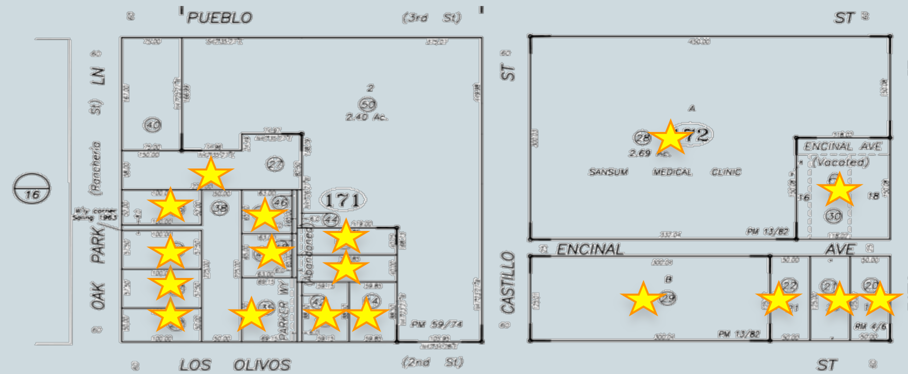
- Building inventory is evenly distributed spatially throughout a geographic area
- If 30% of census block is flooded -> 30% of total assets are at-risk

Ramifications:

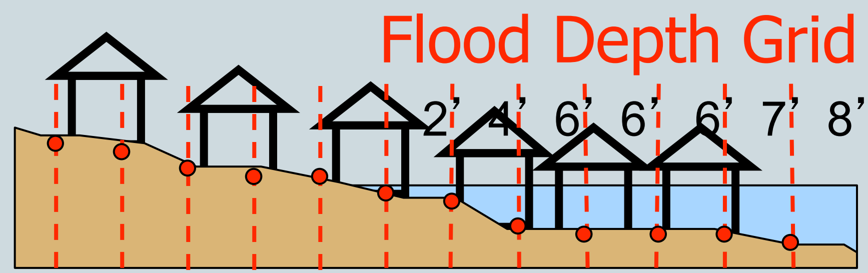
- (Under/Over)estimation of losses
- Does not account for depth of flooding

…Methods: 100-yr Storm + SLR

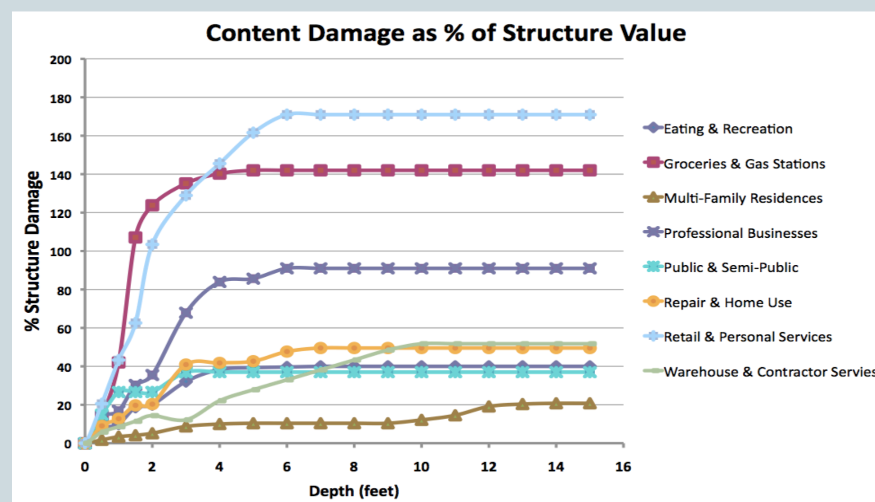
- Parcel-by-Parcel analysis with detailed parcel characteristic data
  - Problems with Assessor data
  - Valuation -NIBS (cost sq/ft)

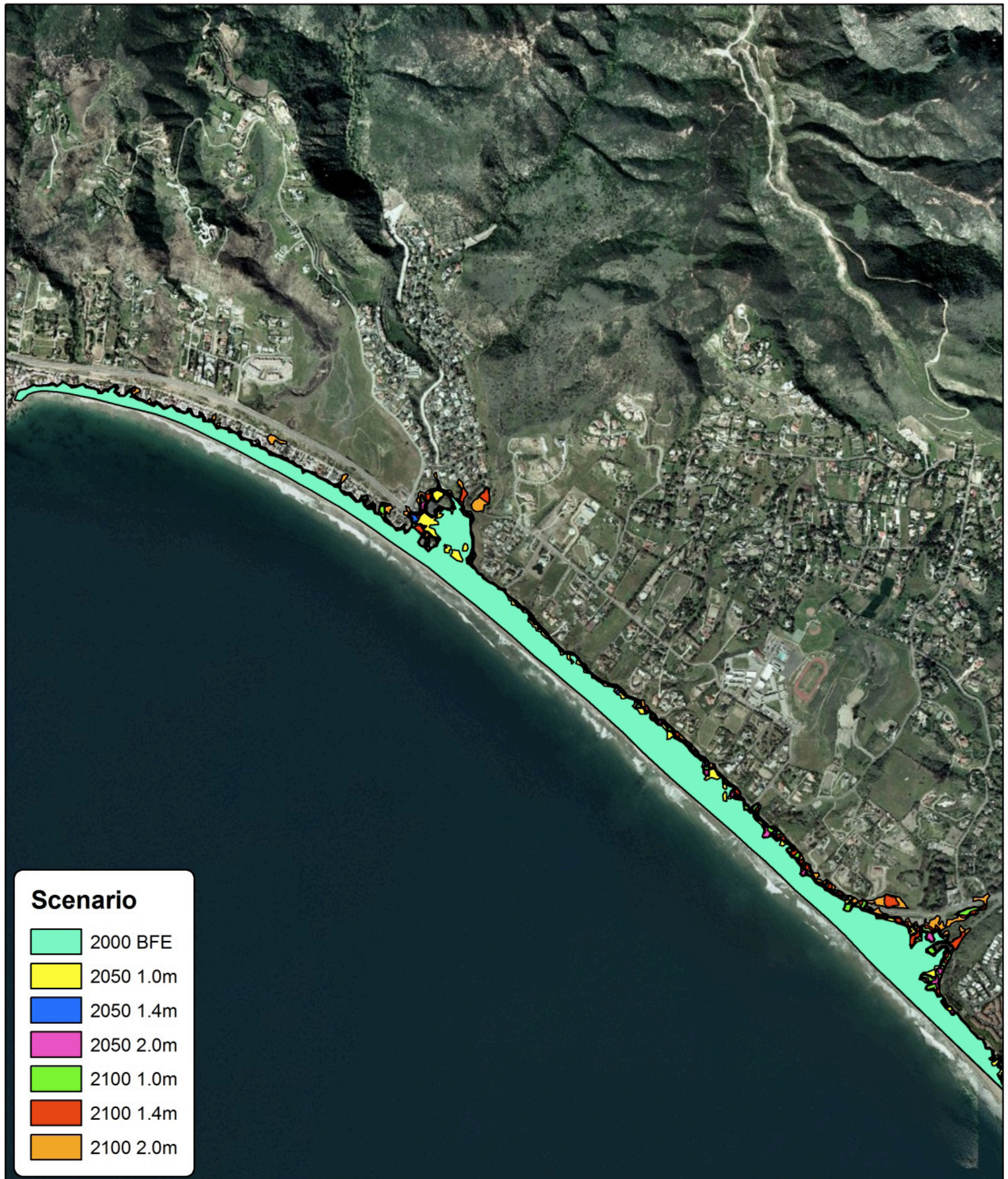


- Evaluate flood depth per 100-yr storm and SLR scenario



- USACE Stage Damage Curves (Coastal A/V Zone)
  - Structure damage
  - Content damage (indirect)





Flood Inundation at Zuma and Broad Beach, Malibu

Year 2000 base flood elevation with sea-level rise of 1.0, 1.4 and 2.0 (m)

Data Sources: Pacific Institute, Philip Williams and Associates, ESRI

0 200 400
Meters

N

Parcel Inundation

2000
Base flood

Parcel Inundation

2000

Base flood

Parcel Inundation

2050

Low Scenario

Parcel Inundation

2050

High Scenario

Parcel Inundation

2050

High-High Scenario

Parcel Inundation

2100

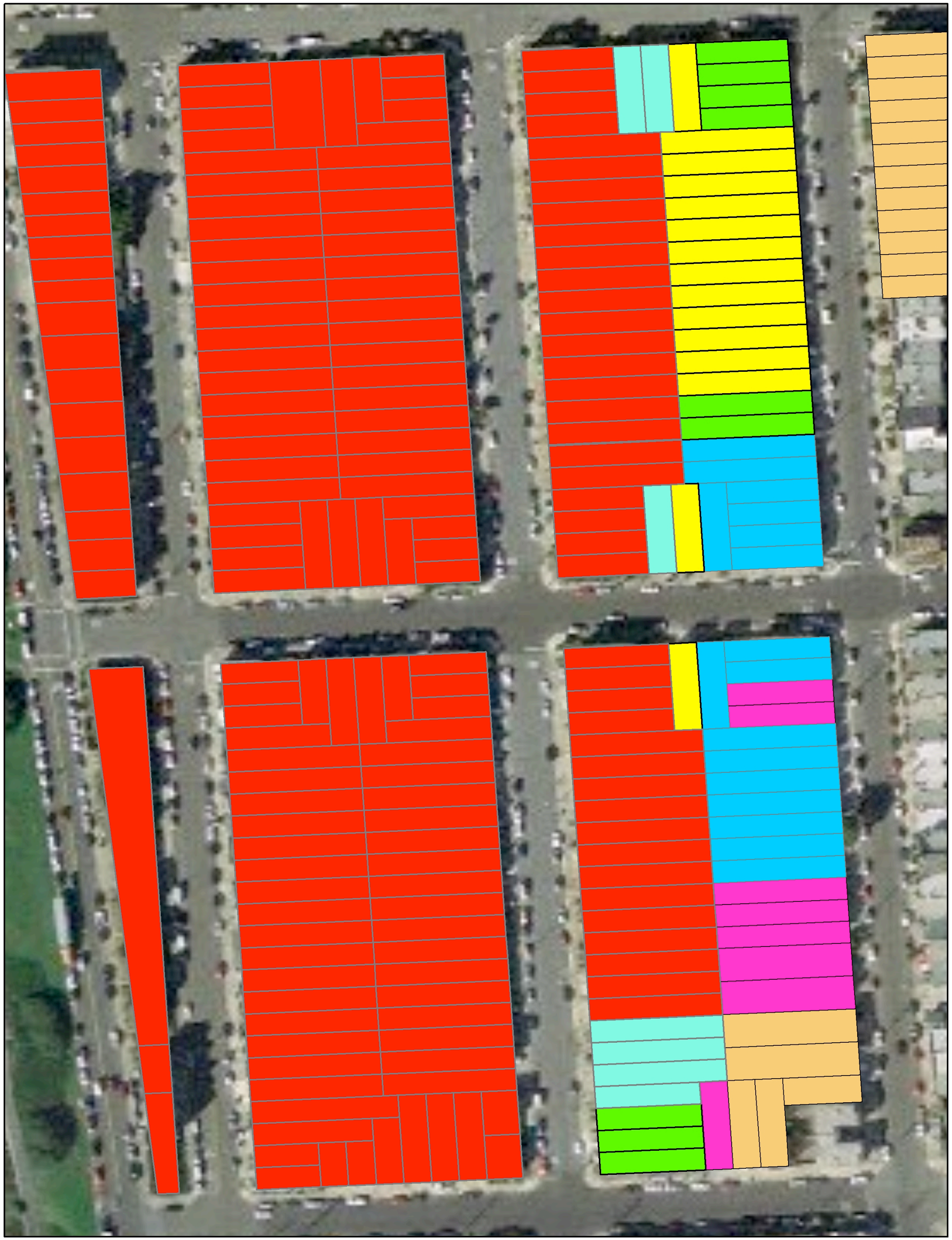
Low Scenario

Parcel Inundation

2100

High Scenario

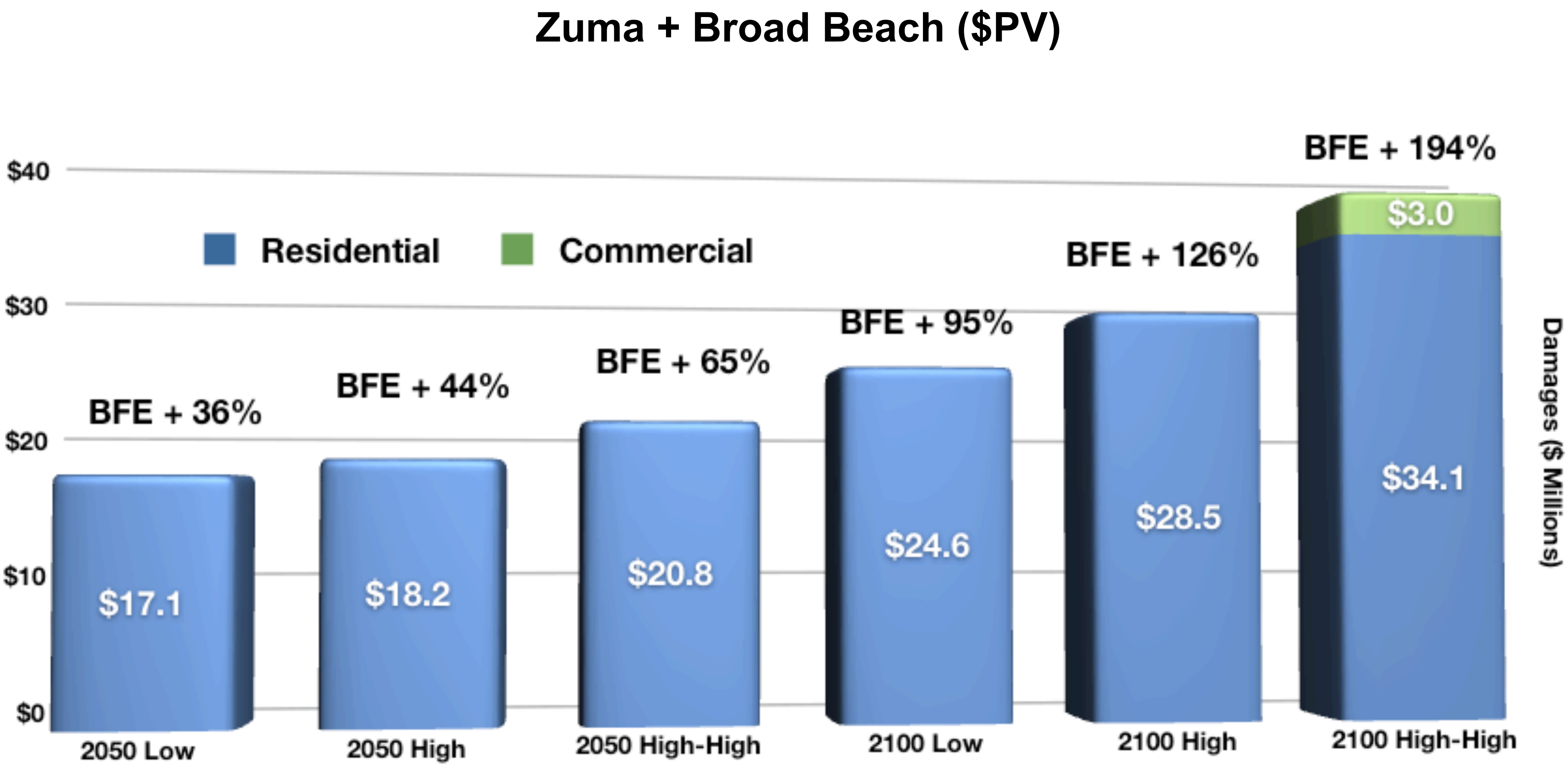
Parcel Inundation



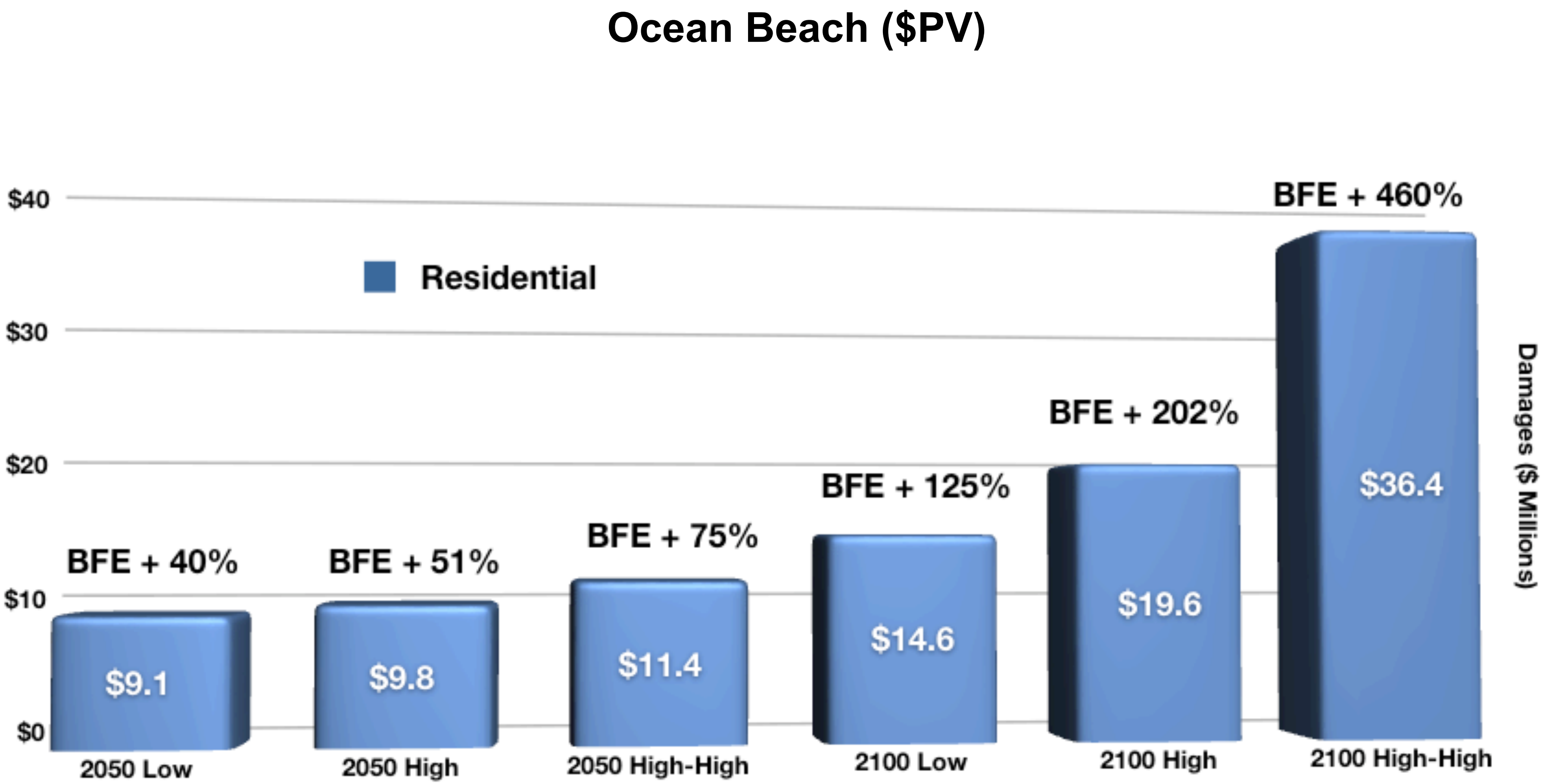
2100

High-High Scenario

Flood Replacement Costs



Flood Replacement Costs



Methods: Erosion

- Northern CA
  - PWA + PI 1.0 and 1.4 (m) combined dune and bluff erosion
    - Net out existing armoring
- Southern CA
  - Long-term accretion at all dunes, adopt the Bruun Rule
  - Historical long-term cliff erosion rates ramped up for SLR
- Infrastructure and land losses
  - Buildings + Land
    - Zestimate, secured roll, MLS, sales
  - Open Space and Vacant Land
    - Recent land transactions
  - Transportation
    - Generalized structural adjustment

Erosion at Ocean Beach, San Francisco

Dune erosion with sea level rise of 1.0 and 1.4 (m)

Data Sources: Pacific Institute, Philip Williams and Associates, ESRI

Parcel Erosion

2050

Low Scenario

Parcel Erosion

2050

High Scenario

Parcel Erosion

2100

Low Scenario

Parcel Erosion

2100

High Scenario

Ocean Beach

Upland Erosion Impacts

(millions of 2010 dollars)

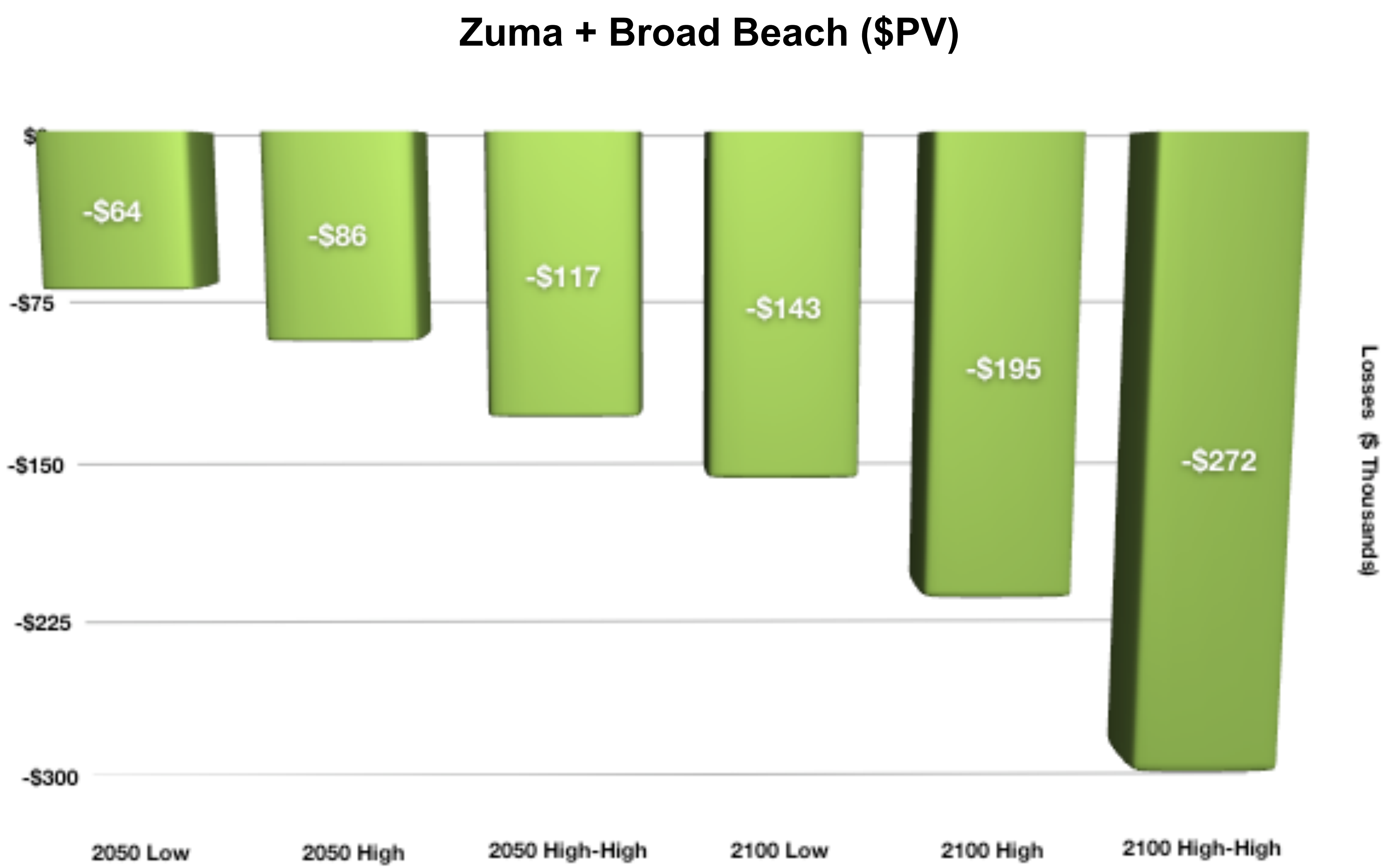
Scenario	1.0 m Sea-Level Rise		1.4 m Sea-Level Rise	
	2050	2100	2050	2100
Residential Land Damages	2.0	23.3	2.0	160.7
Residential Structure Damages	0.5	6.3	0.5	54.9
Commercial Land Damages	0.0	0.0	0.0	5.4
Commercial Structure Damages	0.0	0.0	0.0	4.0
Institutional Land Damages	0.0	0.0	0.0	1.4
Institutional Structure Damages	0.0	0.0	0.0	0.2
Miscellaneous Land Damages	0.0	0.0	0.0	1.7
Miscellaneous Structure Damages	0.0	0.0	0.0	0.1
Major Road Damages	47.0	133.1	95.0	264.7
Local Road Damages	0.0	14.4	2.0	47.2
Total Damages	**49.5**	**177.1**	**99.5**	**540.3**

Habitat

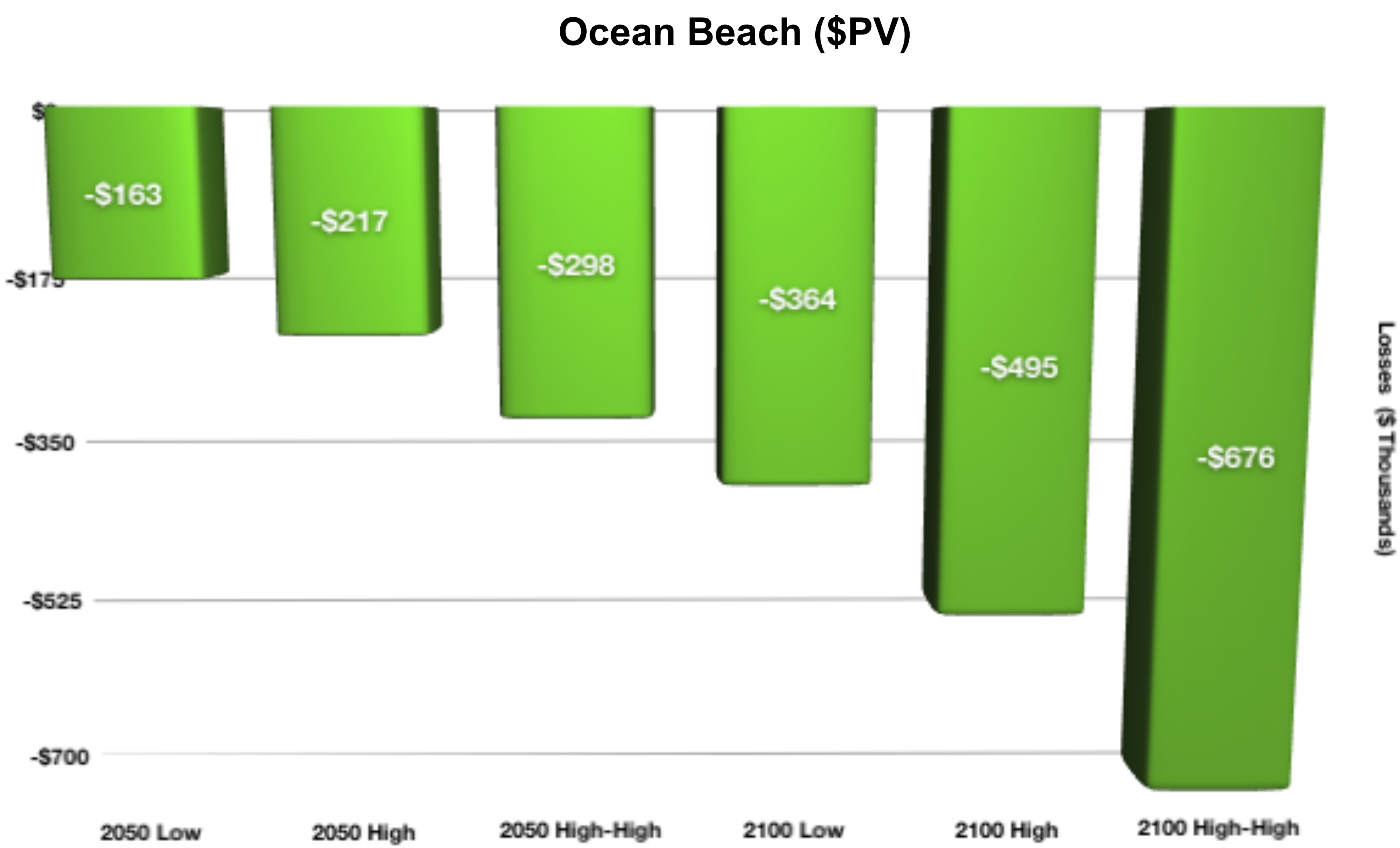
- Problems with Ecosystem Valuation
  - Uncertainty: underestimate (many unknowns)
  - Additive/overlapping values
  - Conceptual Values [Option Value/Existence Value] often ignored, hard to quantify
  - Complicated systems: interdependency; emergent values
  - Limitations on resources to calculate
  - Some things impossible to estimate/calculate?

- Moving Forward
  - Costanza's Study and others are transferable with caution
  - Conservative Estimate: $4,000/hectare/year in "Ecosystem Services" for Shoreline Habitat, which is equivalent to flood protection benefits
  - Present Value of services: ~$100,000 per hectare at 3.0% discount rate

Habitat Value Losses



Habitat Value Losses

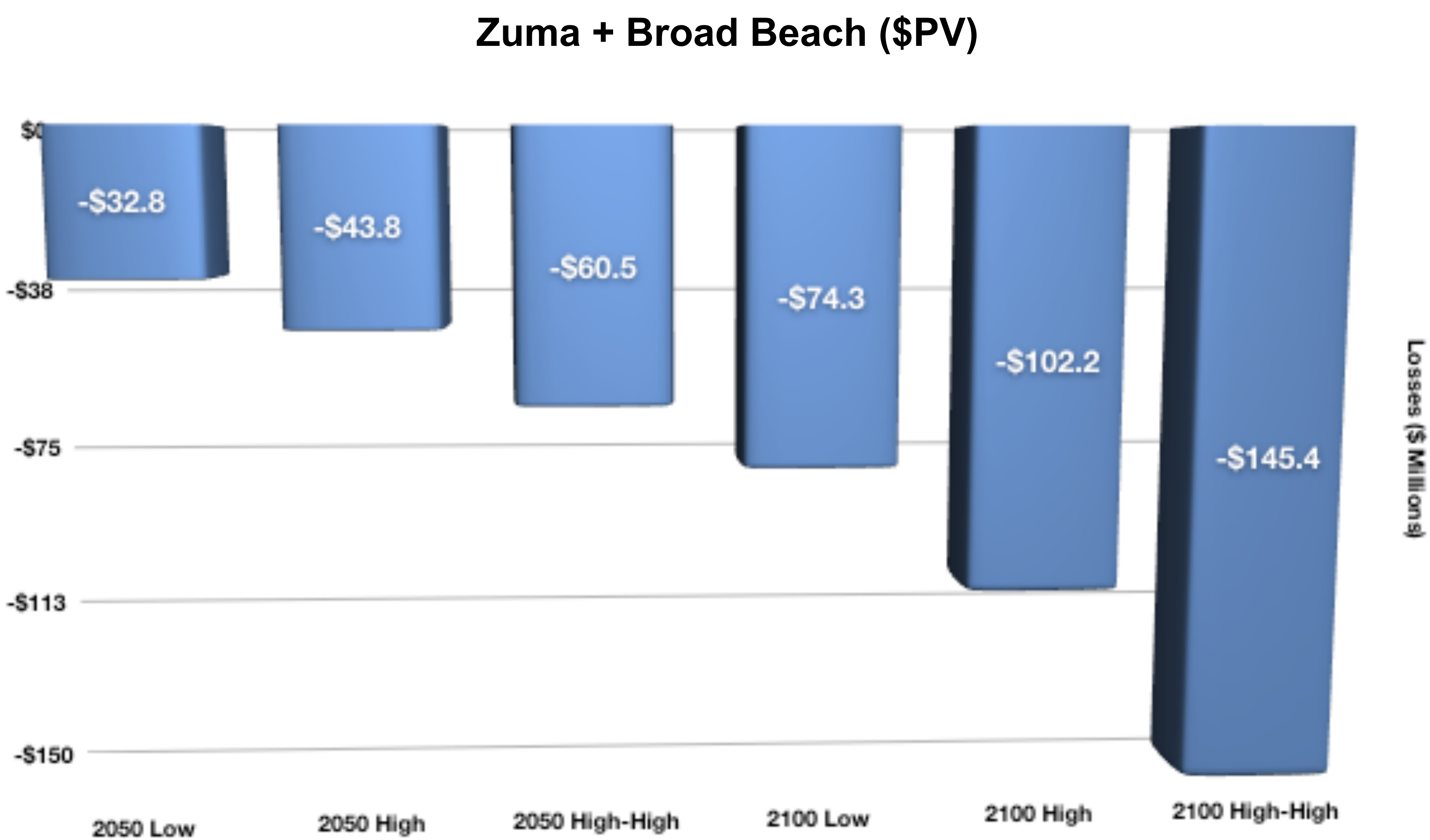


Recreation

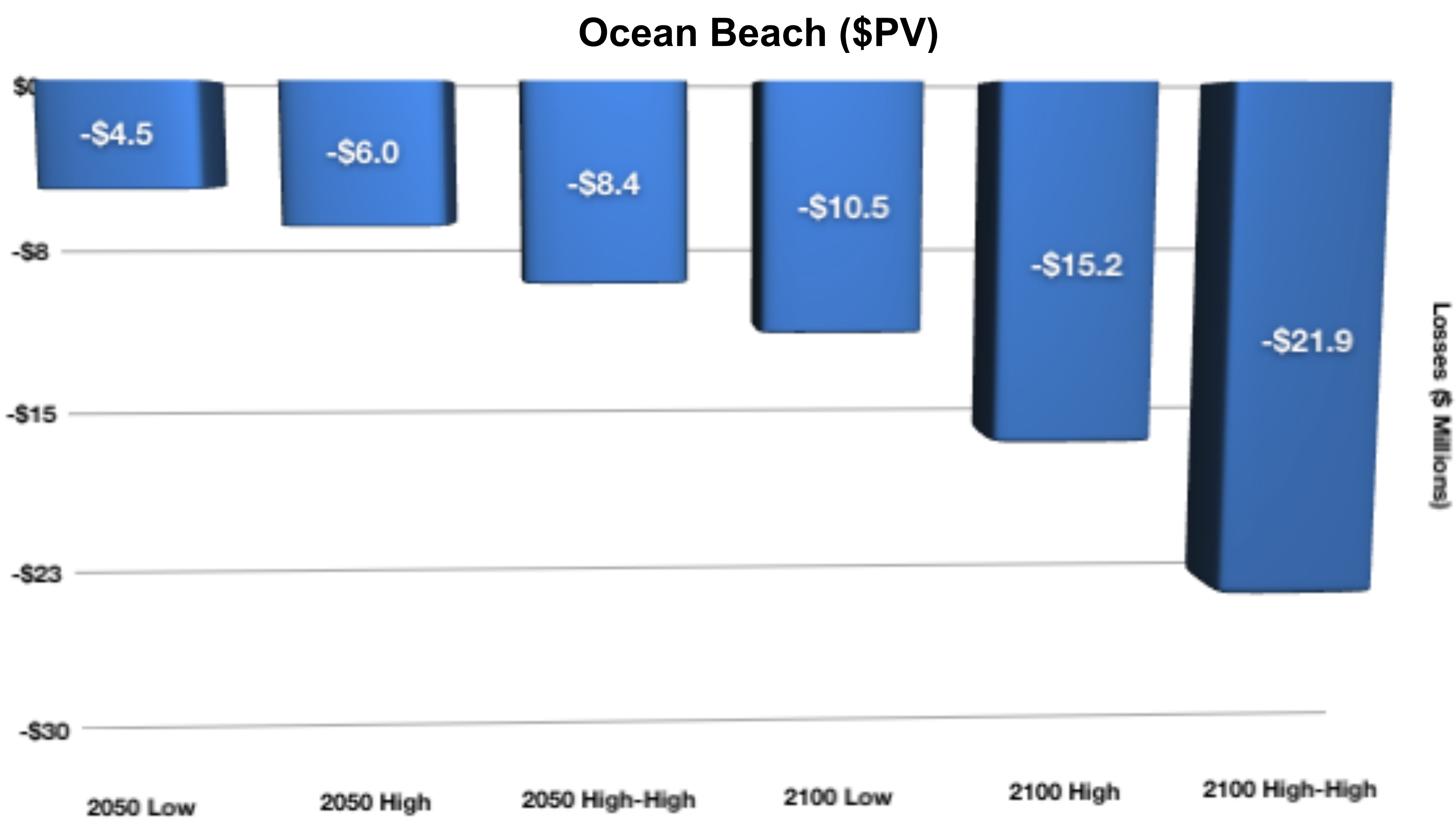
CSBAT Benefits Transfer Methodology

- Developed as part of CSMW (Coastal Sediment Management Workgroup) with USACE
- Purpose: To use other beach valuation studies and apply them to any California beach
- Standard USACE valuation model does not focus on Nourishment
- CSBAT Model calibrated with existing data and studies
    - In particular on changes in recreation value and attendance as beach width changes

Recreation Value Losses



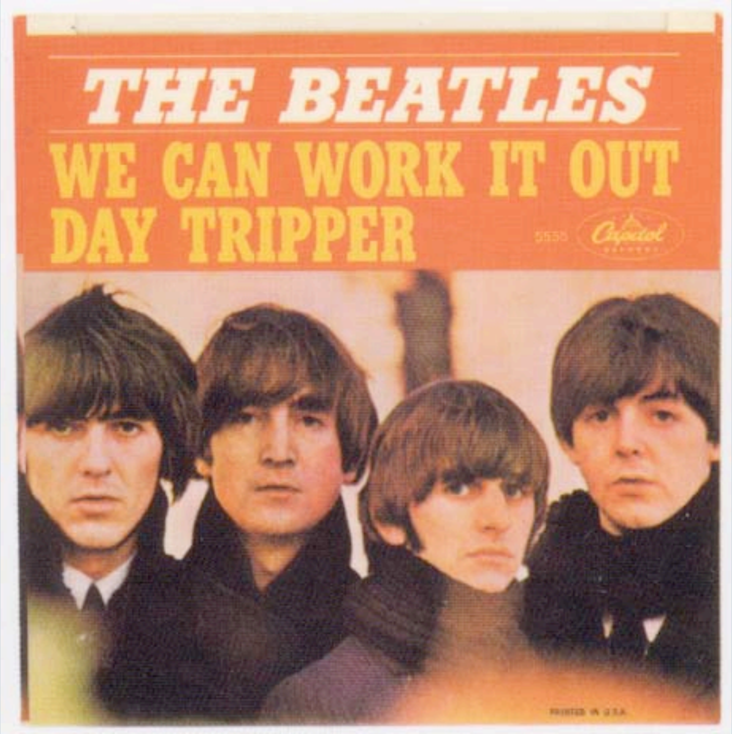
Recreation Value Losses



Recreation and Spending

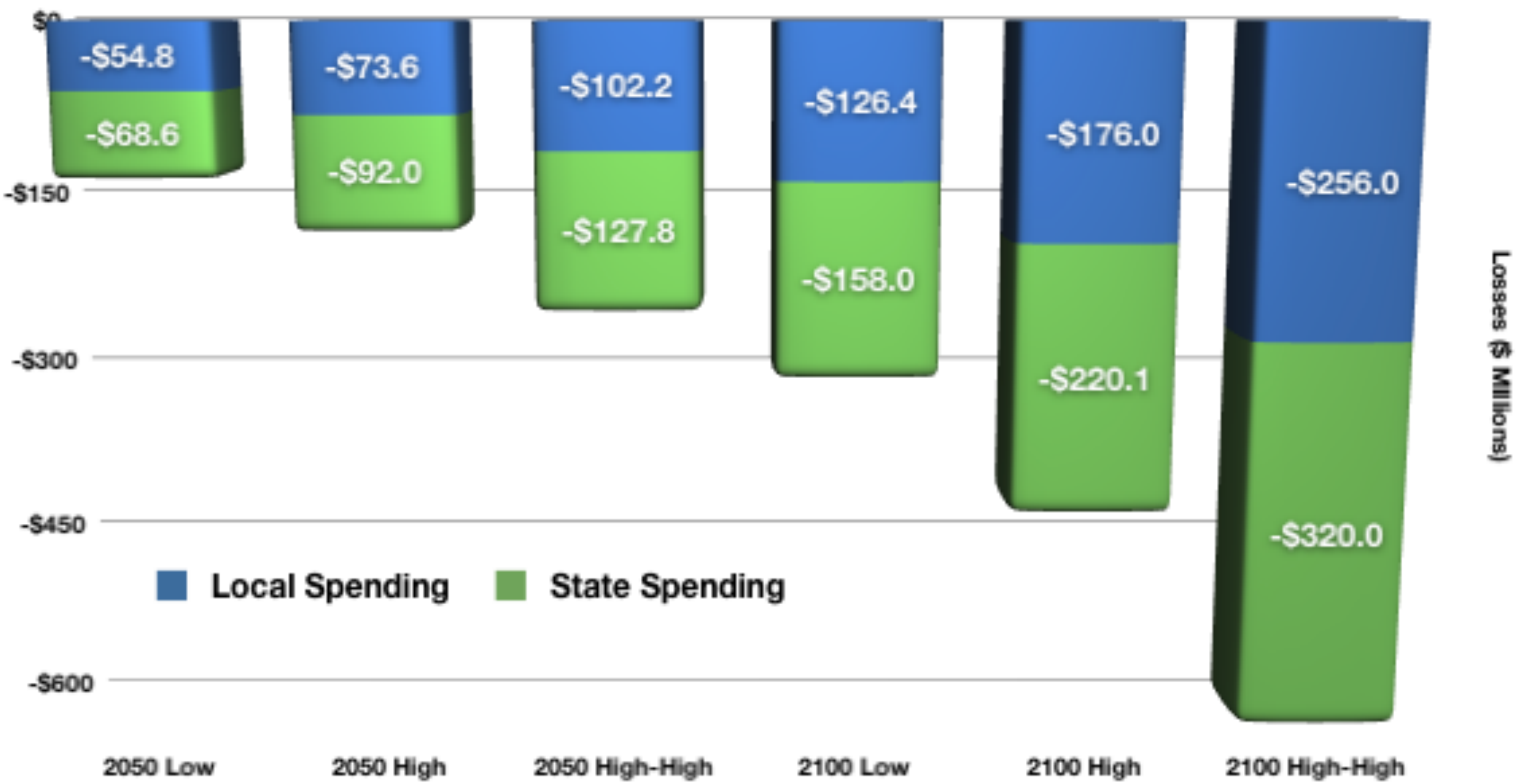
Economic/Tax Impacts

- Data from King and Symes
- Estimates spending and taxes per visitor
- Key variables:
  - Attendance
  - % Day Tripper/Overnighter

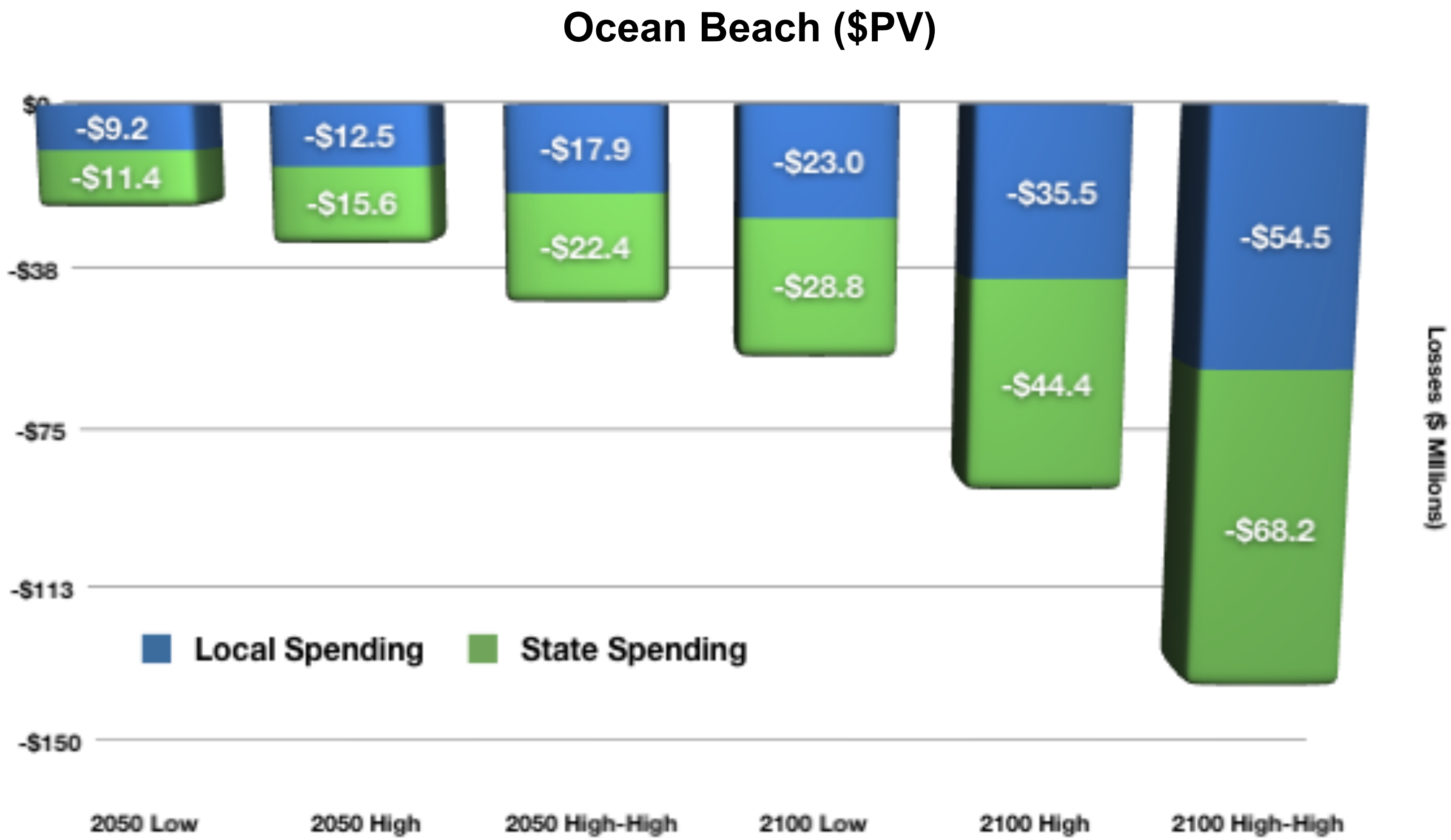


Spending Losses

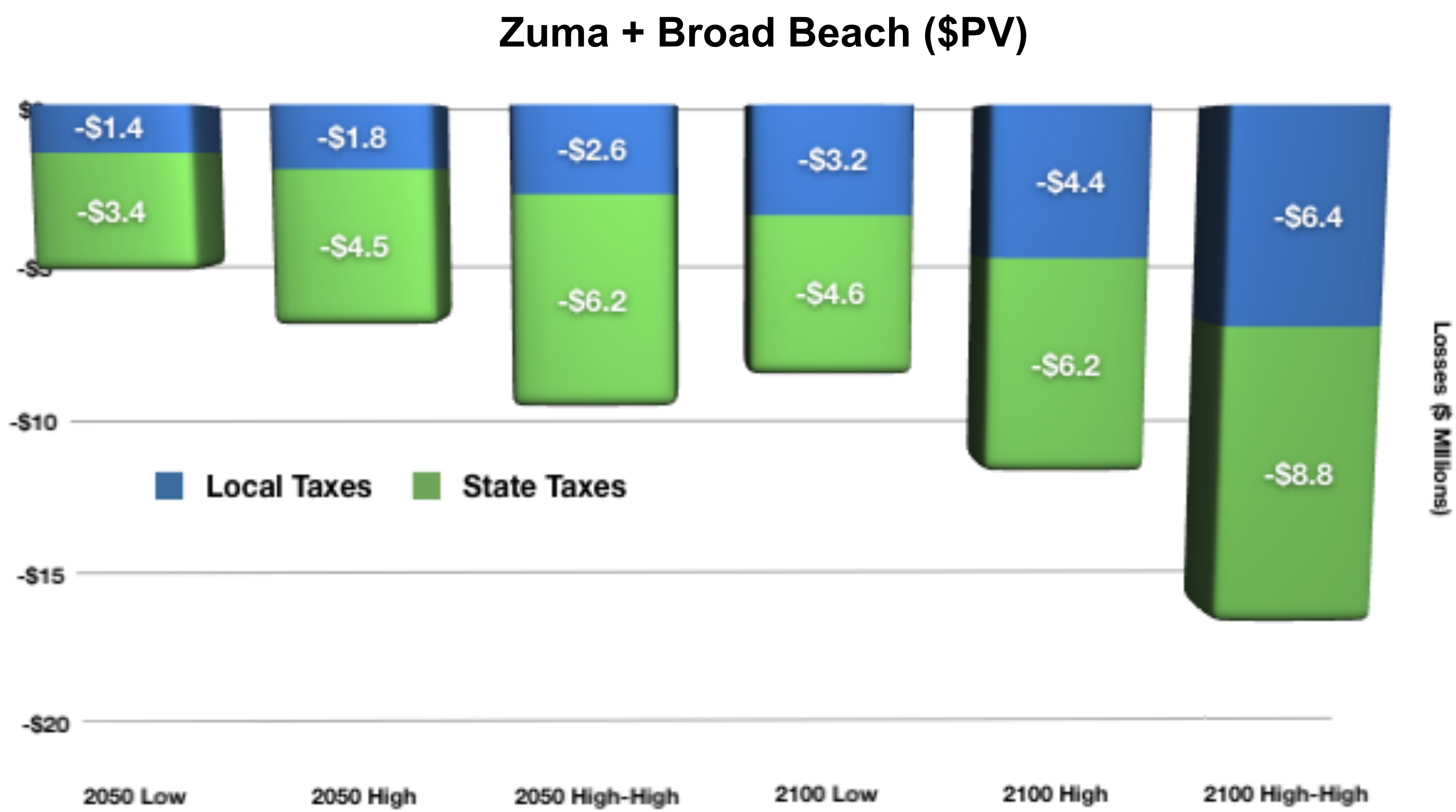
Zuma + Broad Beach ($PV)



Spending Losses



Tax Revenue Losses



Tax Revenue Losses

Annual Beach Benefits: 1.4m Sea-Level Rise

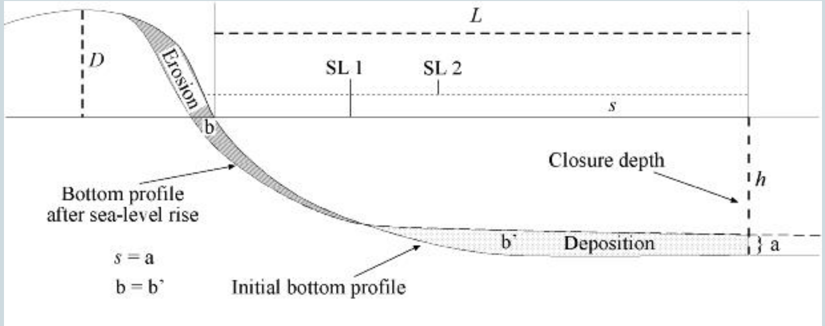
(millions of dollars)

Site	Category	Year 2000 Value	Year 2050 Value	Year 2100 Value
Ocean Beach	% Beach Area	**100%**	**69%**	**7%**
	Recreational Value	3.4	2.6	0.00
	Habitat Value	0.09	0.06	0.01
	Spending	22.3	18.4	0.00
	Tax Revenue	1.7	1.4	0.00
Carpinteria	% Beach Area	**100%**	**85%**	**65%**
	Recreational Value	15.7	14.0	10.0
	Habitat Value	0.06	0.05	0.03
	Spending	114.0	105.3	81.7
	Tax Revenue	9.7	9.0	6.9
Zuma	% Beach Area	**100%**	**89%**	**67%**
	Recreational Value	71.0	65.4	52.7
	Habitat Value	0.10	0.09	0.07
	Spending	390.6	369.0	315.0
	Tax Revenue	29.3	27.7	23.6
Venice	% Beach Area	**100%**	**95%**	**83%**
	Recreational Value	78.2	76.1	71.4
	Habitat Value	0.33	0.31	0.28
	Spending	884.5	860.9	808.0
	Tax Revenue	66.3	64.6	60.6
Torrey Pines	% Beach Area	**100%**	**75%**	**23%**
	Recreational Value	5.6	4.6	1.3
	Habitat Value	0.01	0.01	0.00
	Spending	35.5	30.6	10.6
	Tax Revenue	2.7	2.3	0.8

Methods: Adaptation

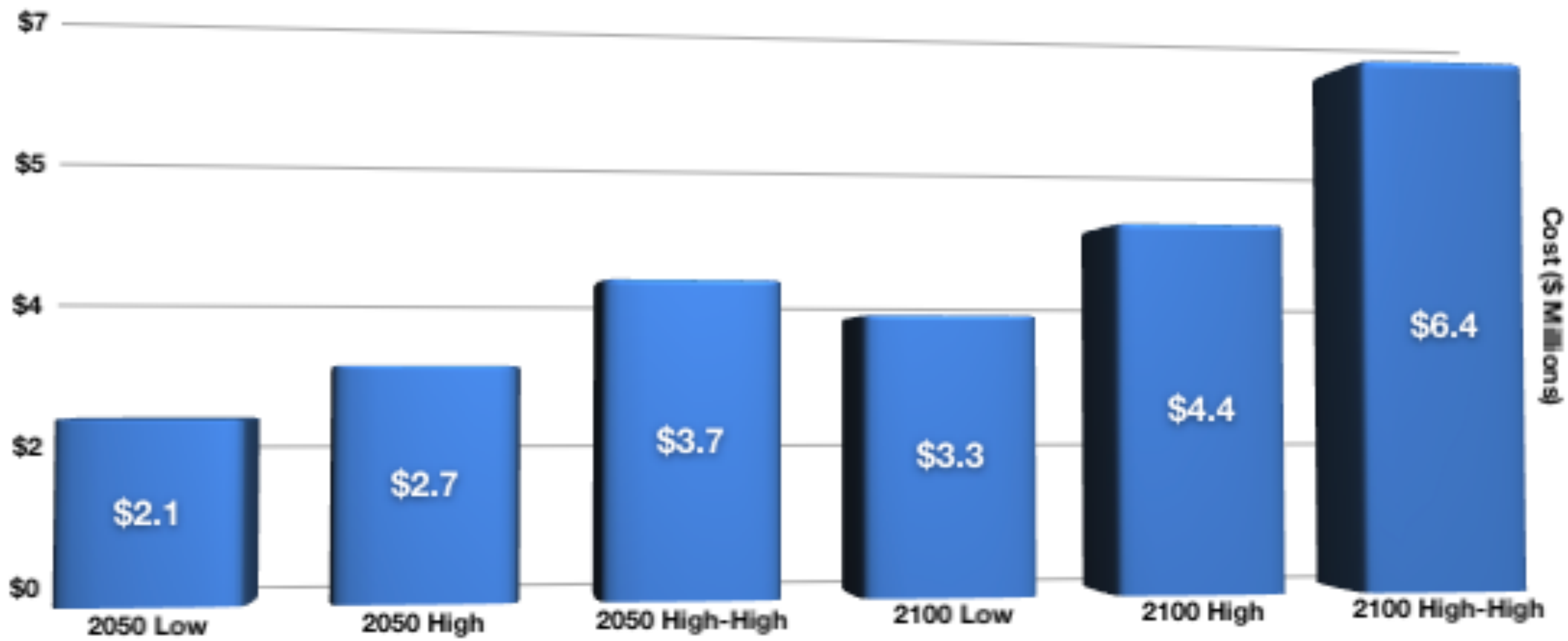
- Identify existing structures
- Determine area where armoring could be added
  - Capital costs
  - Maintenance cost

- Beach nourishment based on Bruun's Rule
  - Annual replenishment
  - 3 storm events

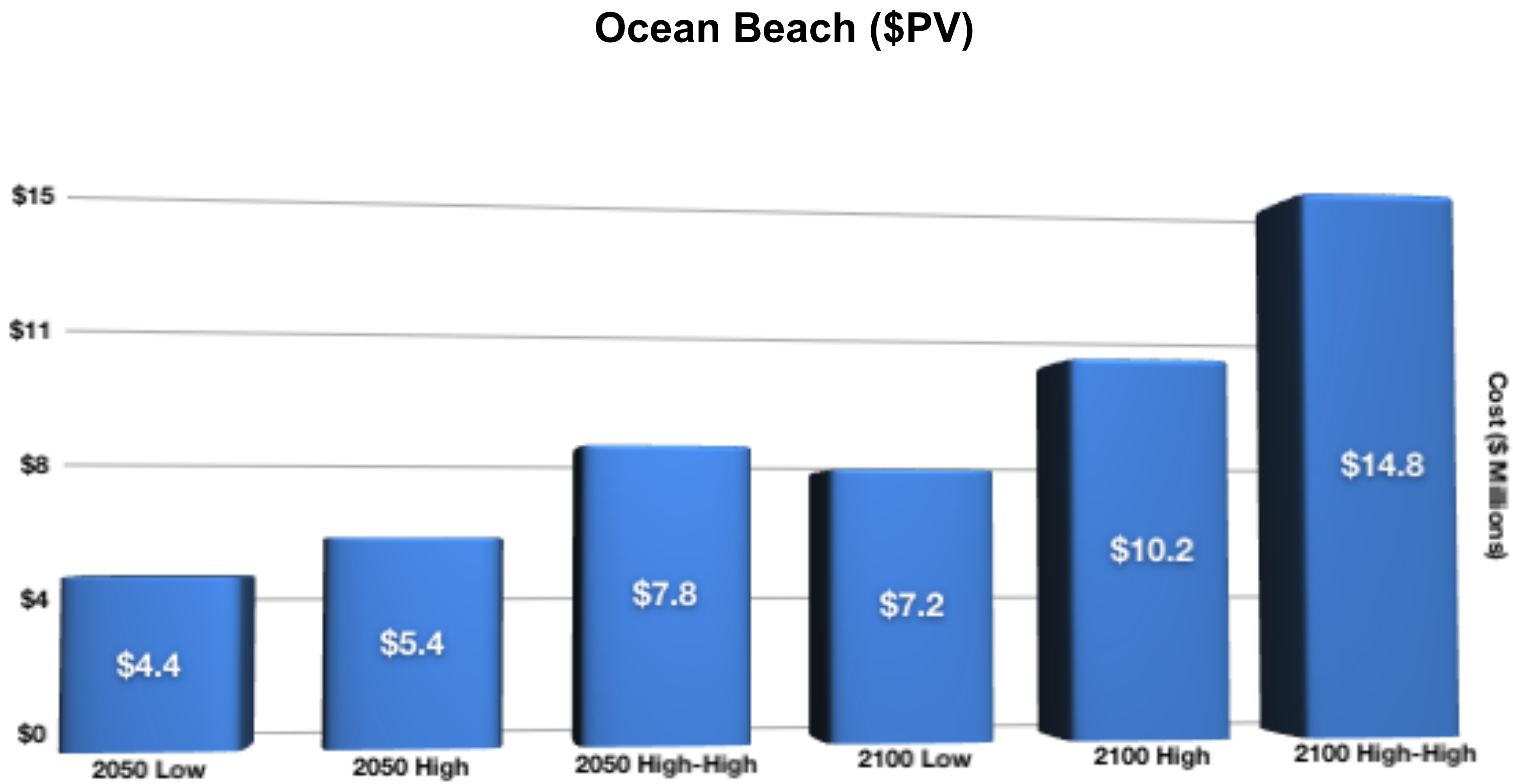


Beach Nourishment Costs

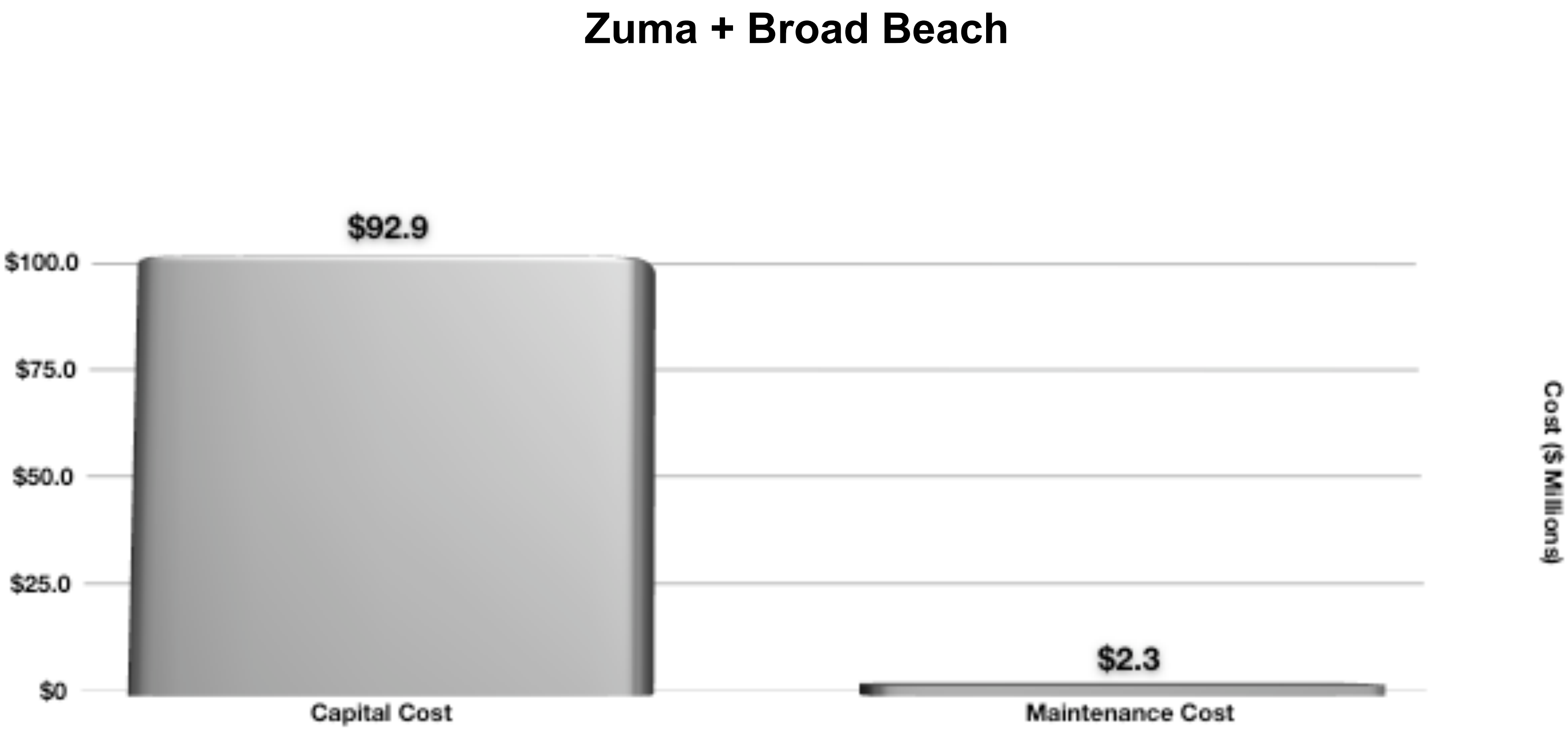
Zuma + Broad Beach ($PV)



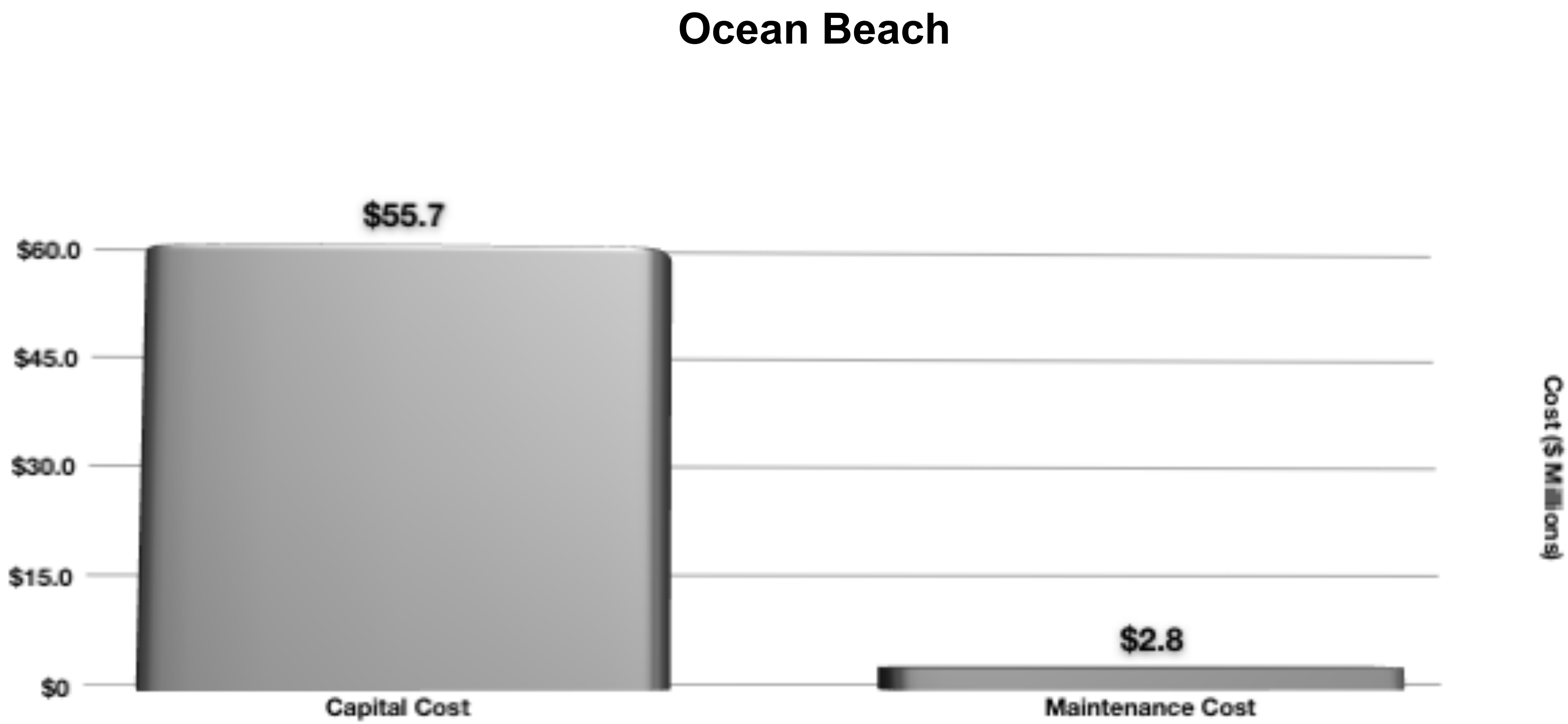
Beach Nourishment Costs



Armoring Costs



Armoring Costs



Limitations

- Parcel characteristic data
- Wetland data
- Erosion data
- Attendance data
- Ecosystem valuation data
- Finances and time

Education is the path from cocky ignorance to miserable uncertainty.

Mark Twain

Looking Forward

- What is the purpose of future studies?
  - Planning, feasibility, first-order, comprehensive, precision
- What stories do past studies tell (limitations)?
- What is feasible, scalable and adjustable?
- What data is available?
  - Garbage in = garbage out, methods/assumptions undermined
- Looking beyond direct impacts…indirect and social
- What things we did not experience but could expect?

Conclusion…

- **We have laid out a model that is:**
  - Comprehensive in scope;
  - Increases precision to an acceptable level when considering uncertainties,
  - Adjustable;
  - And can be carried out with far less resources than existing studies
- **What we do know:**
  - Impacts of SLR, storm-surges and erosion are significant even when conservatively modeled along small sections of the coast;
  - The economic impacts of a changing climate are diverse and highly site-specific
- **What we don’t know:**
  - How property values will adjust landward overtime as risks increase;
  - The ways that insurance regulations and public policy will influence existing and future development and industry along the coast
- **What we need in the future:**
  - Disaggregated studies for local coastal communities;
  - Studies that are comprehensive in scope;
  - Sensitivity and marginal analyses;
  - Increased coordination among physical, social scientists and policy makers;
  - Better Data

Many Thanks…

- Kim Sterrett, DBW
- Ron Flick, Scripps/DBW
- Dave Revell, PWA
- Matt Heberger, PI
- San Francisco State, UCSB, UCLA
- And the many others (insert your name here) who assisted in providing data and recommendations for this study