Beach Nourishment as a Management Tool to Adapt to Sea Level Rise

Jim Houston and Bob Dean

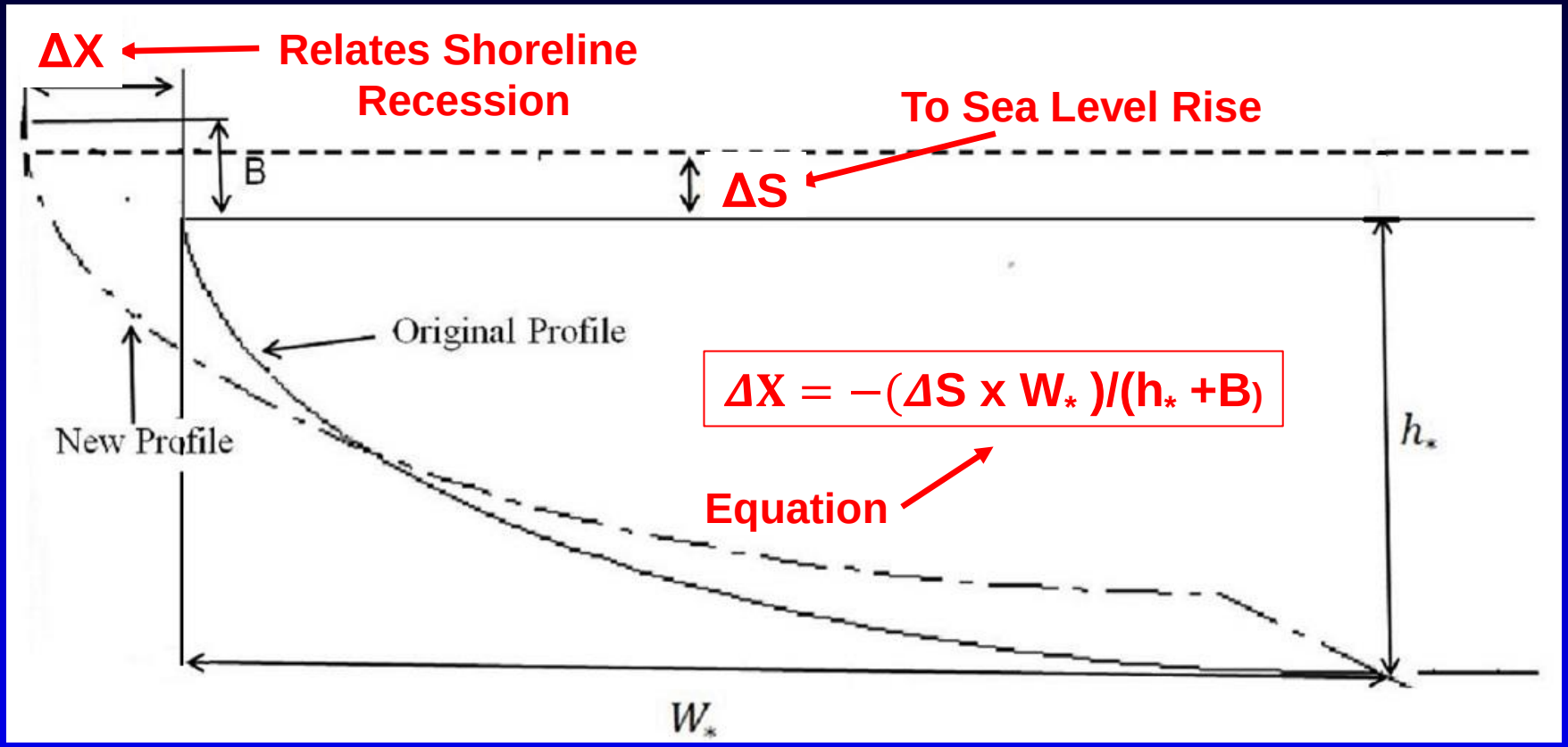
Shore and Beach (2016) **and** ***Coastal Engineering (2016)***

Future of Florida's Beaches

- Should we look to the future with optimism or pessimism in the face of sea level rise?
- Approach
  - Analyze historical shoreline change on the east and southwest coasts
  - Use sand budgets from previous studies
  - Project shoreline change with and without beach nourishment

  >50-year period (2015 - 2065)
  >To year 2100 (2015 - 2100)

Bruun Rule

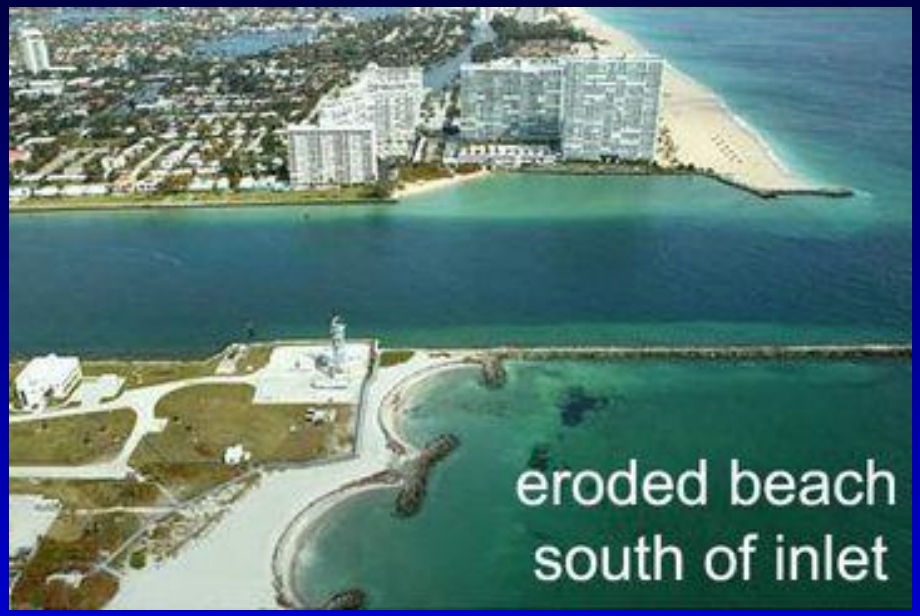


- Most widely used method to determine shoreline response to sea level rise
- But, studies show that it works well only if other factors causing shoreline change are negligible

Other Factors Not Negligible

- For example, 70% of erosion on the Florida east coast is caused by modified inlets
  - 88% St Lucie
  - 99% Martin
  - 94% Palm Beach
  - 92% Broward
  - 95% Dade

  (Houston & Dean, 2016)
- Moreover, the shorelines of east and southwest Florida accreted on average from 1880-2016 despite a sea level rise of 1 ft, completely contradicting the Bruun rule



Project Shoreline Change

- **Must consider all phenomena affecting shoreline change**

Sea Level Rise (Bruun Rule) | Onshore Sand Transport | Sink (e.g., modified inlets) | Source (e.g., beach nourishment)

$$\frac{dX}{dt} = -\frac{dS}{dt}\left(\frac{W_*}{h_* + B}\right) + \frac{\phi}{(h_* + B)} - \frac{1}{L\,(h_* + \mathrm{B})}\frac{dV_{sink}}{dt} + \frac{1}{L(h_* + \mathrm{B})}\frac{dV_{source}}{dt} - \frac{1}{(h_* + B)}\frac{dQ}{dy}$$

Shoreline Change

Longshore Sand Transport Gradients

(Dean and Houston, 2016)

- **Determined onshore sand transport using historical data**

$$\frac{\phi}{(h_* + B)} = \left\{\frac{1}{L\Delta T}\right\} * \left\{L\Delta X + \frac{\Delta S\, W_*\, L}{(h_* + B)} + \frac{\Delta V_{sink}}{(h_* + B)} + \frac{L\Delta T}{(h_* + B)}\frac{dQ}{dy} - \frac{\Delta V_{source}}{(h_* + B)}\right\}$$

Dean and Houston (2016)

- **Project shoreline change due to future sea level rise using these equations**

Data Sources

- Shoreline position measured since the 1800s at 2900 monuments
- Determined shoreline change rates at all monuments using least squares regression method

- County-level sediment budgets from earlier studies (Houston & Dean, 2014; Houston, 2015)
- Use sea level rise projections of the Intergovernmental Panel on Climate Change (IPCC) (2013)

Paradox

- All US agencies accept carbon dioxide and temperature projections of IPCC 2013
- They do not accept IPCC 2013 sea level rise projections
- Agencies with little expertise use old papers/ reports to choose projections that differ among themselves and with the IPCC

Confusion, lack of credibility, and undercutting of IPCC

IPCC has the Expertise in Sea Level Rise

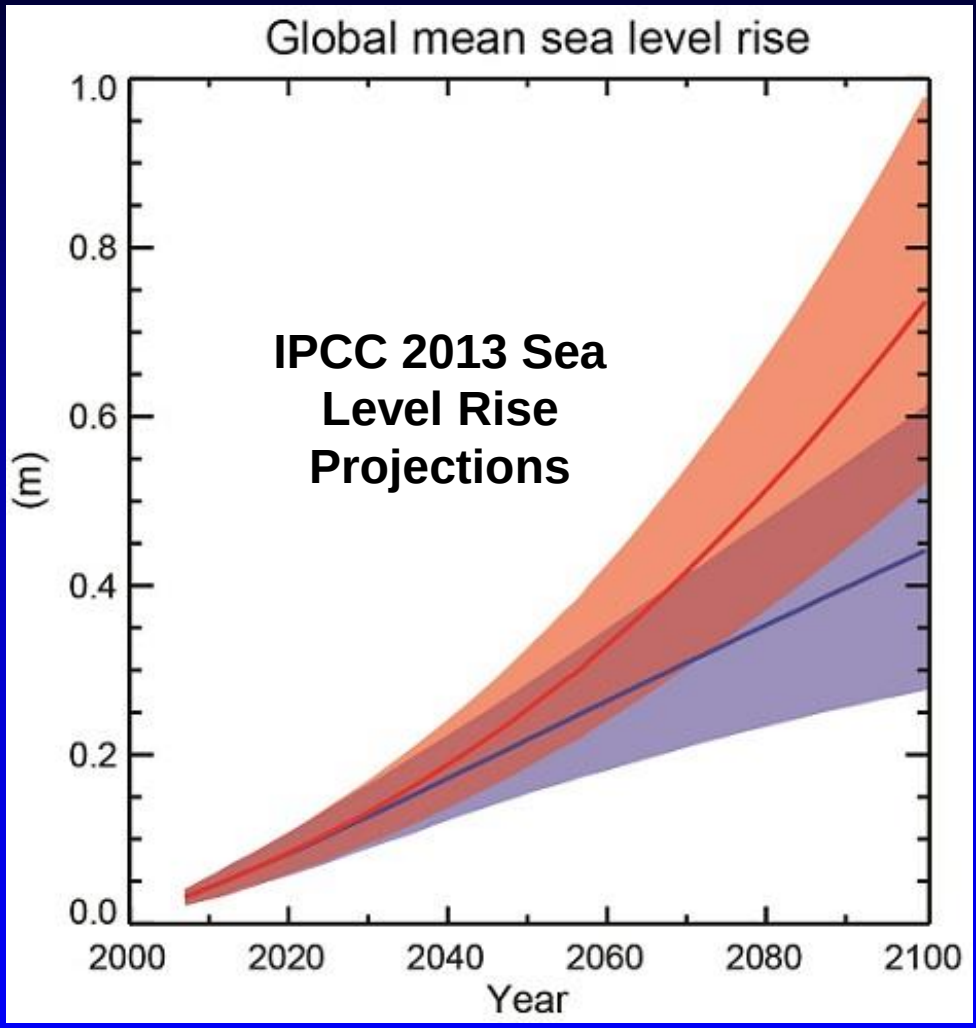
71 of the world's experts on all aspects of sea level rise made the IPCC 2013 projections

Country	Number	Country	Number
USA	19	Norway	2
Great Britain	12	Sweden	2
Netherlands	10	Austria	2
Australia	7	Belgium	2
Germany	5	Japan	2
Canada	4	Denmark	1
France	2	India	1

- **"Do Not Undercut the IPCC", Coastal Forum, *Shore and Beach*, Vol 84, No. 1, Pages 1-3, Winter 2016**

IPCC Sea Level Rise Projections

- IPCC has four climate change scenarios (RCP 2.6, 4.0, 6.0, 8.5)
- Consider all four scenarios for 50 years (2015 - 2065) and to 2100 (2015 - 2100)



Project Shoreline Change at Three Scales on East Coast

- Entire East Coast (360 miles)
- Flagler County (18 miles)
- Boca Raton in Palm Beach County (4.8 miles)

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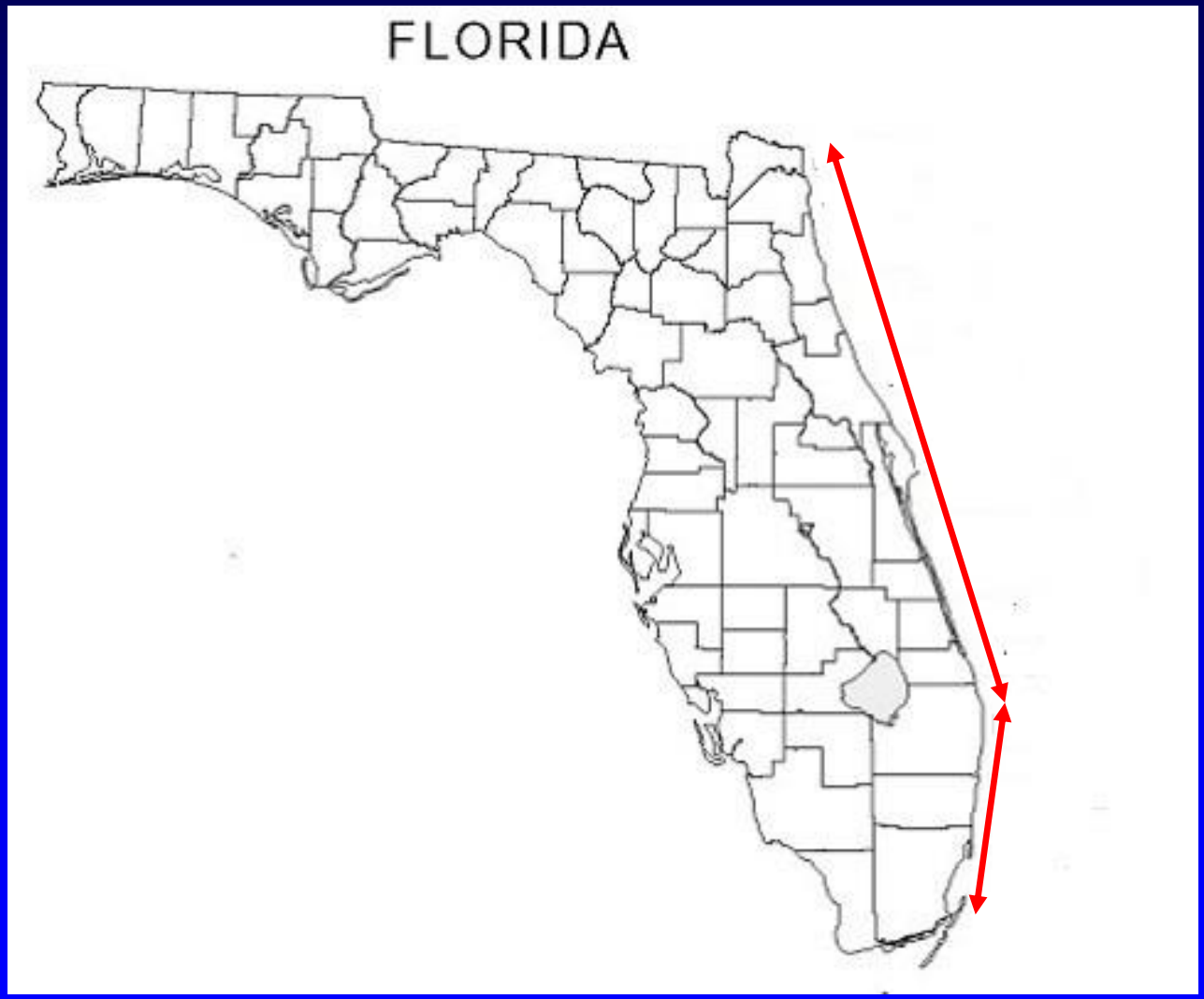

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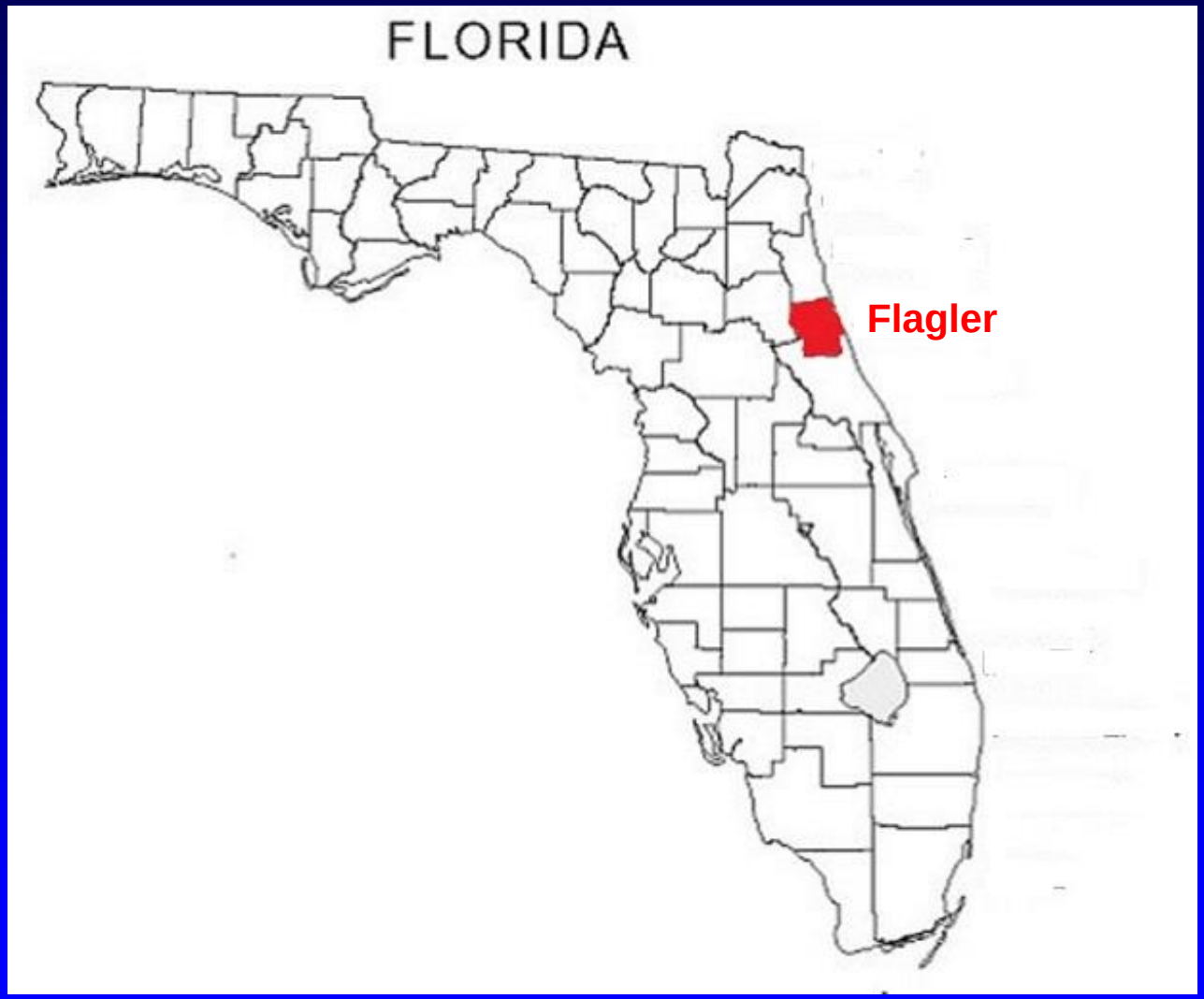

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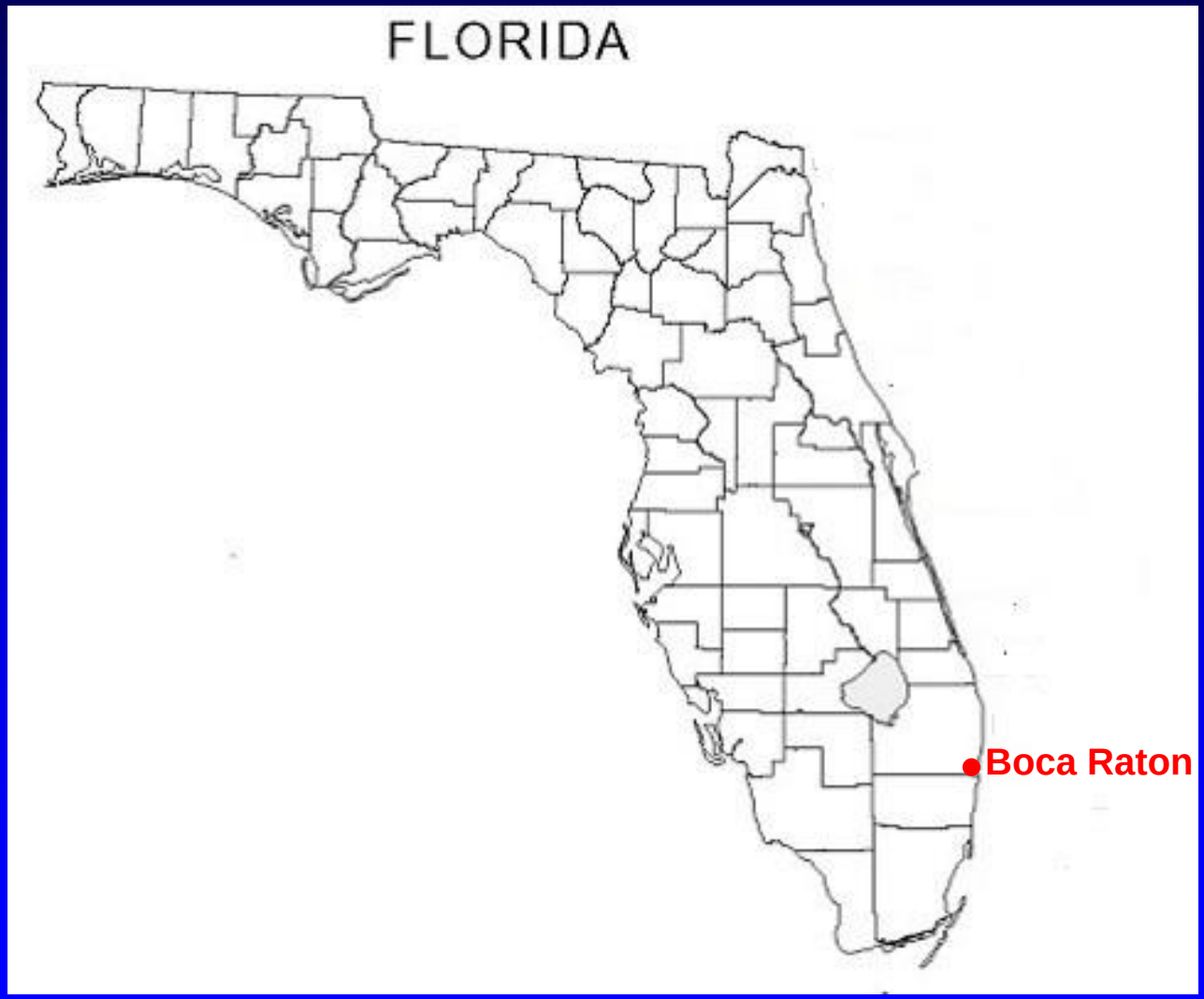
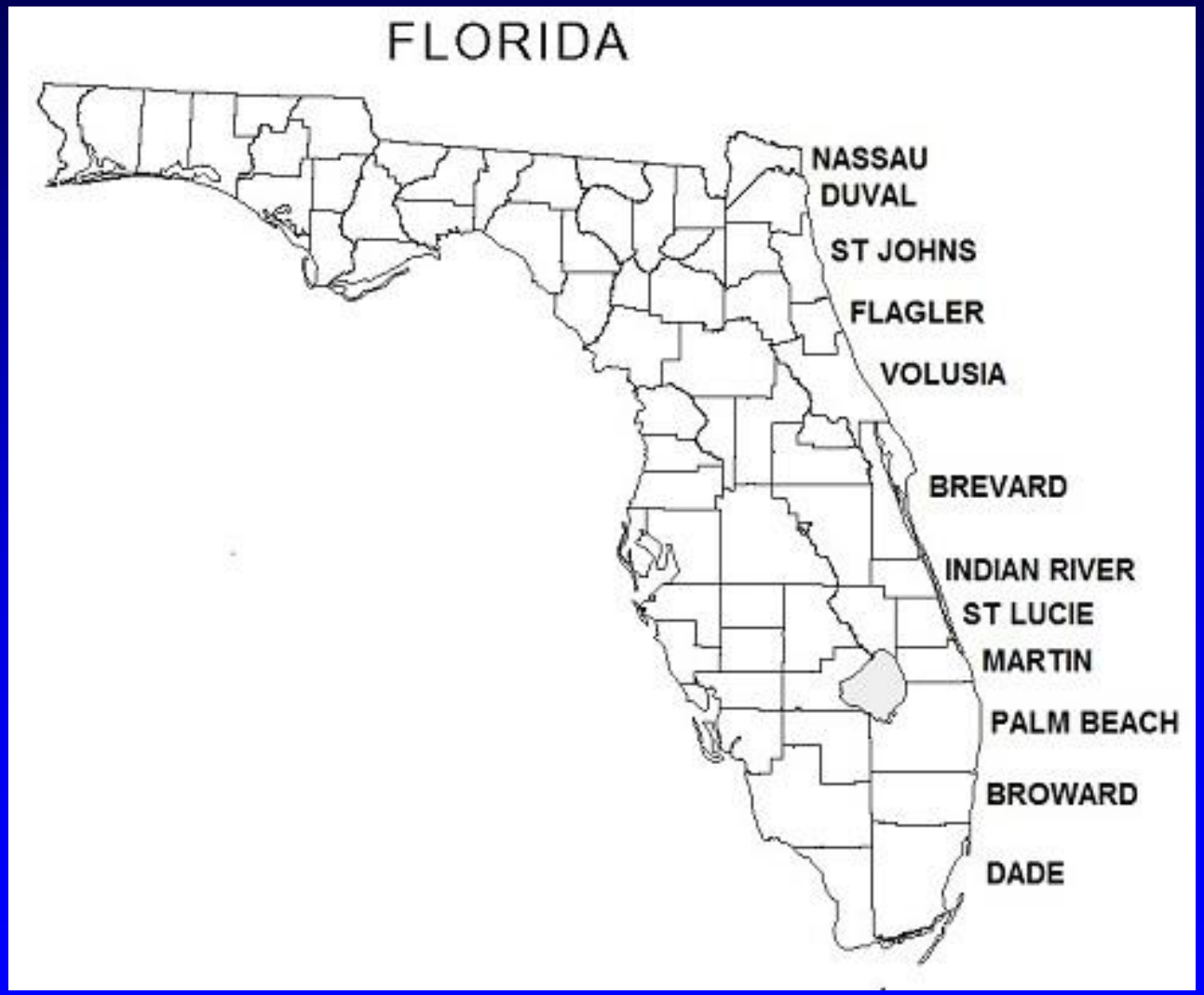


Project Shoreline Change
Entire East Coast



Analyzed
360 miles
12 counties

Beach nourishment/ onshore transport advanced the shoreline 80 ft on average since 1971

The Future - Findings

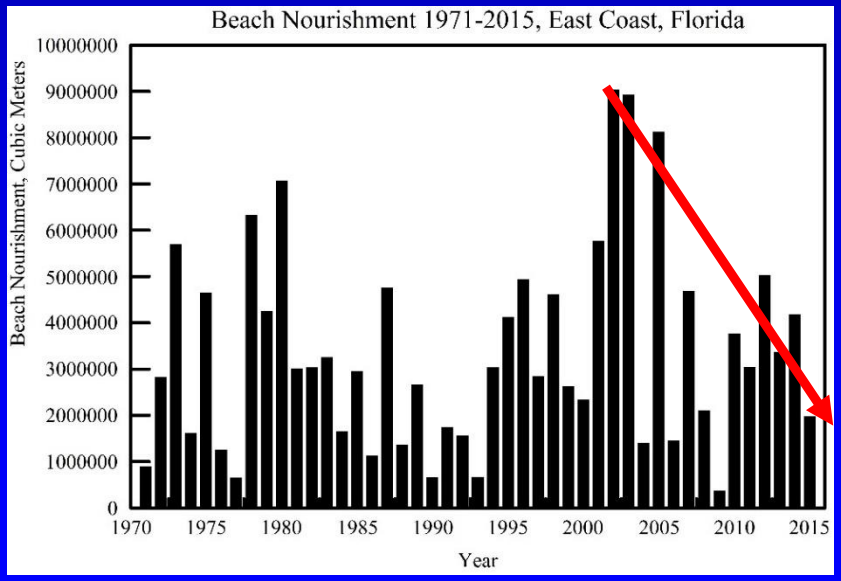
- Without future beach nourishment
  - There will be net shoreline recession for all sea level rise scenarios despite continued onshore sand transport

- With nourishment
  - Net shoreline advance for all scenarios for the next 50 years and to 2100

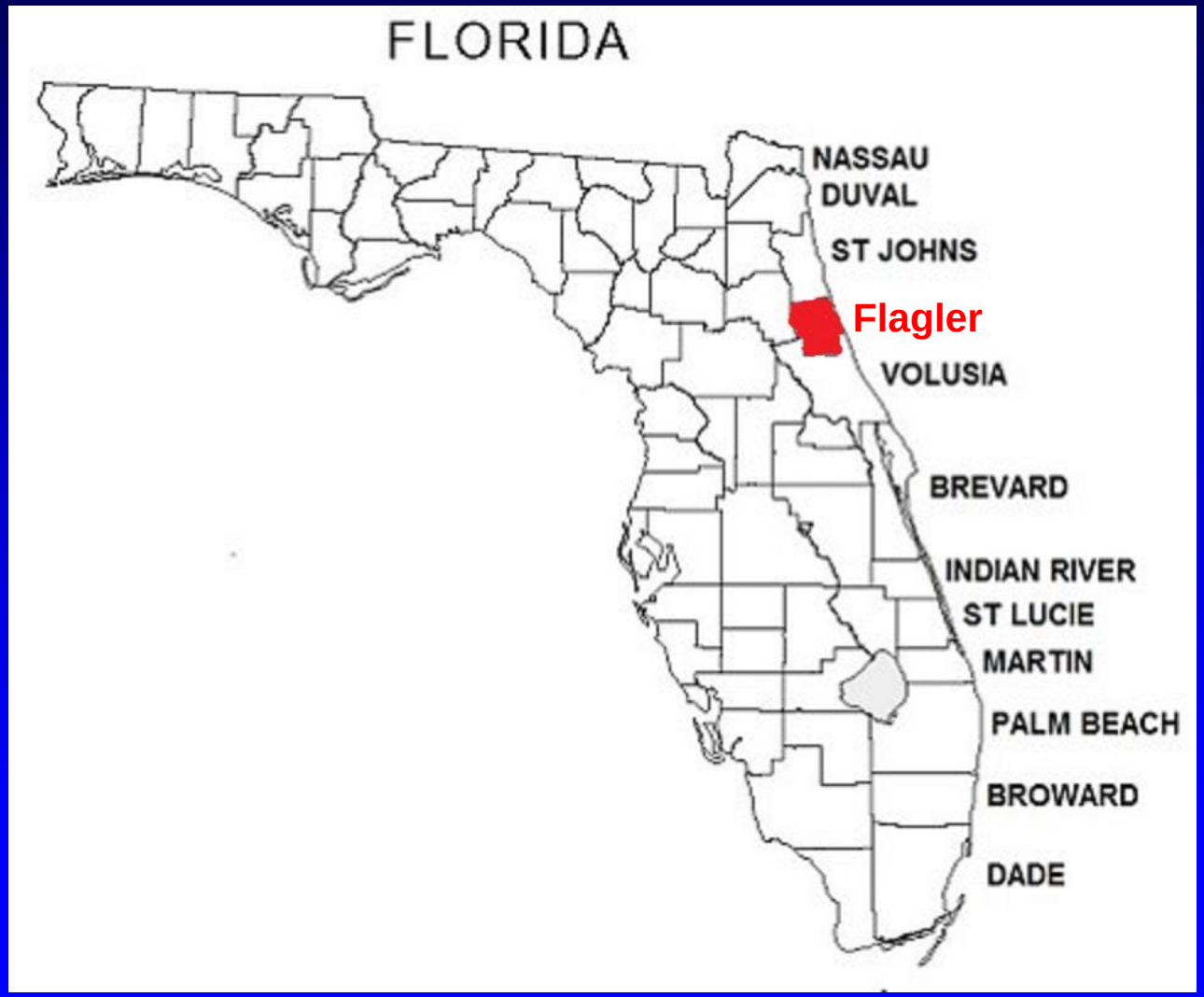
Caveat

- We assumed the annual rate of beach nourishment in the future would be the same as the rate since 1971

- However, the rate the past 10 years has been below the past rate even with special funding following Hurricane Sandy



Project Shoreline Change
Flagler County



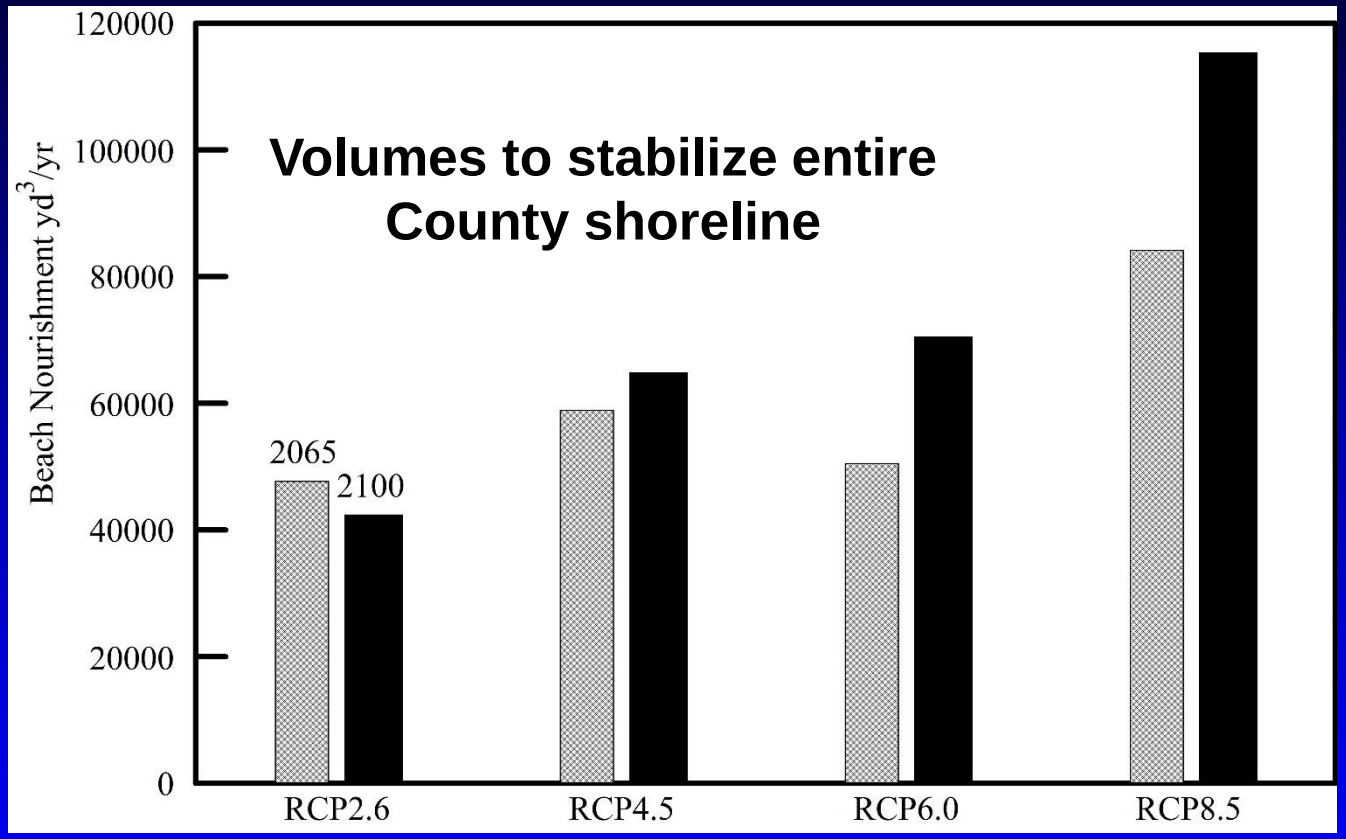
Flagler County - Past

- Only county without an inlet and without beach nourishment
- Historical measurements give slight net accretion rate (+ 0.2 ft/yr) (1872-2016)
- Equations show onshore sand transport more than offset a sea level rise of 1 ft during this period, making beach nourishment unnecessary

Flagler County - Present

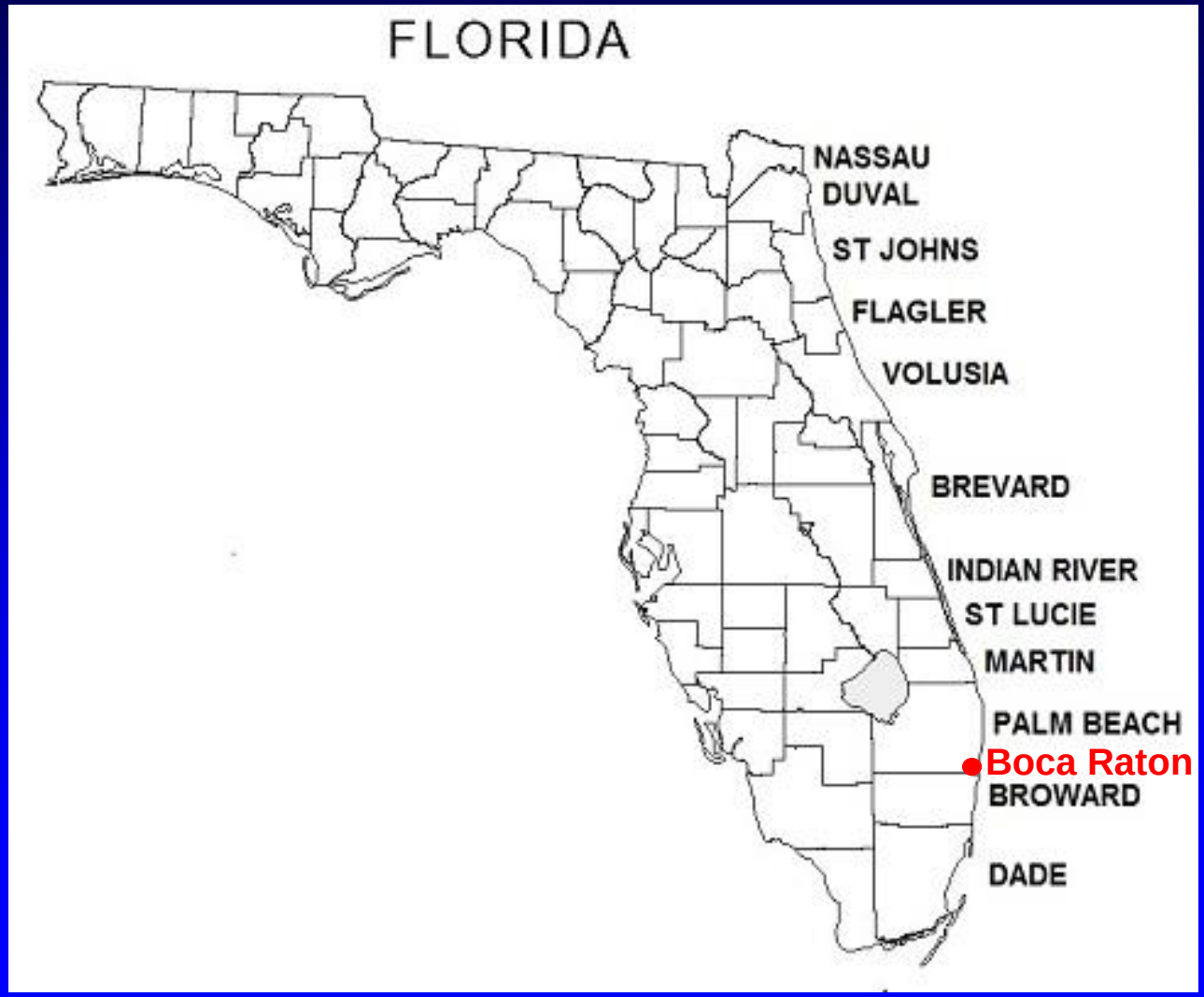
- Increased rate of sea level rise
  - 1.8 mm/yr in 20th century
  - 3.3 mm/yr from 1993 - 2016
- Equation 1 predicts this rate causes net recession (- 0.2 ft/yr), flipping the County from accretion to recession
- County/Corps have a 50-year plan for beach nourishment
  - Annual rate of 29,000 yd^3/yr along 2.6 miles of coast (Corps, 2014)

Flagler County - Future



- **Countering sea level rise for the entire county would require an increase in beach nourishment (from 29,000 to 40,000 - 115,000 yd^3/yr)**

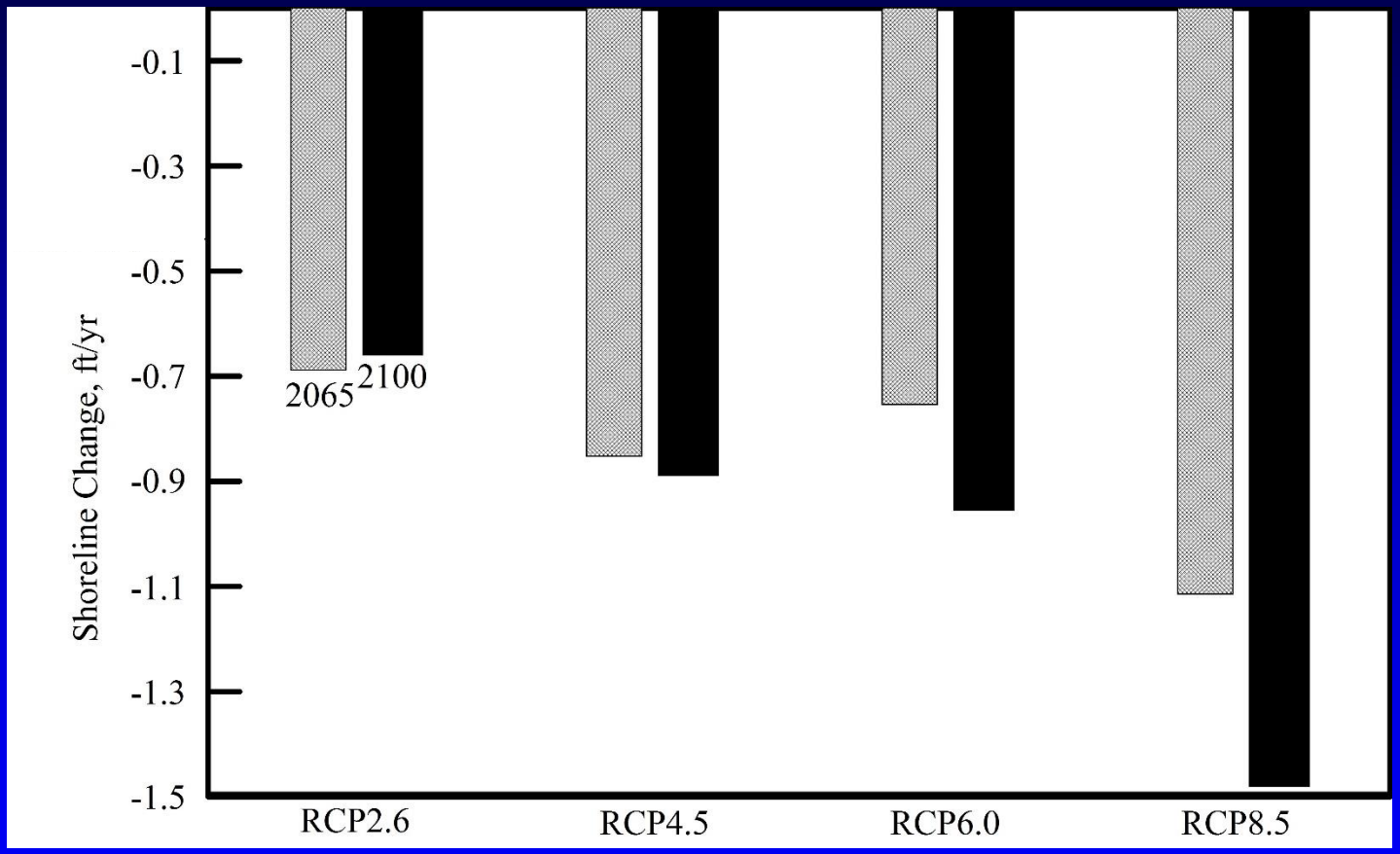
Project Shoreline Change
Boca Raton, Palm County



City of Boca Raton

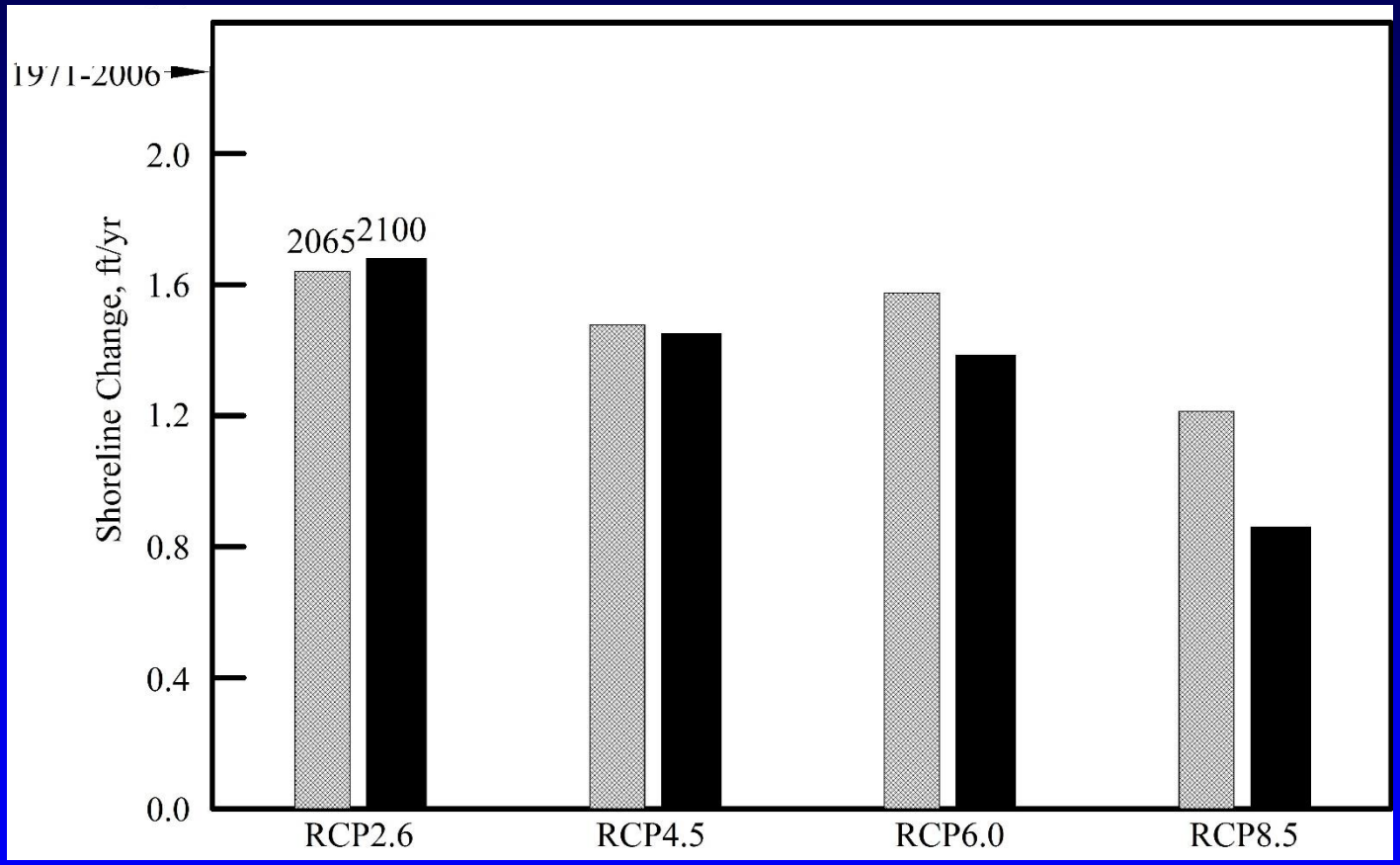
- Shoreline had net recession of - 40 ft before beach nourishment (1883-1971)
- Entire shoreline
  - Receded - 40 ft before beach nourishment (1883-1971)
  - Advanced + 77 ft due to beach nourishment (1971-2016)
  - Advanced +37 ft on average from 1883-2016 despite a sea level rise of about 1 ft

Boca Raton Future Without Beach Nourishment



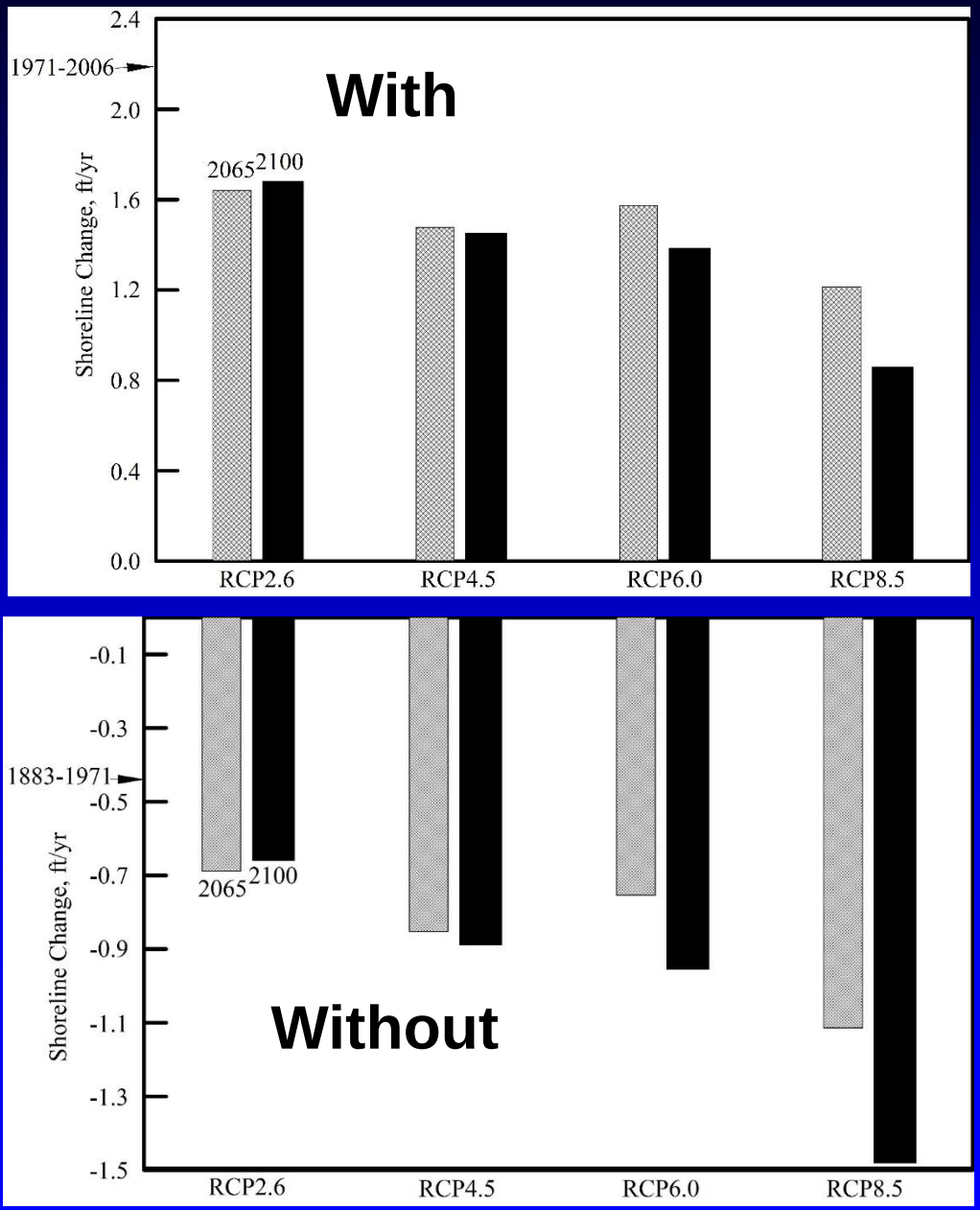
- The shoreline would recede at large rates for all scenarios

Boca Raton Future Beach Nourishment at Rate since 1971



- The shoreline would advance for all scenarios

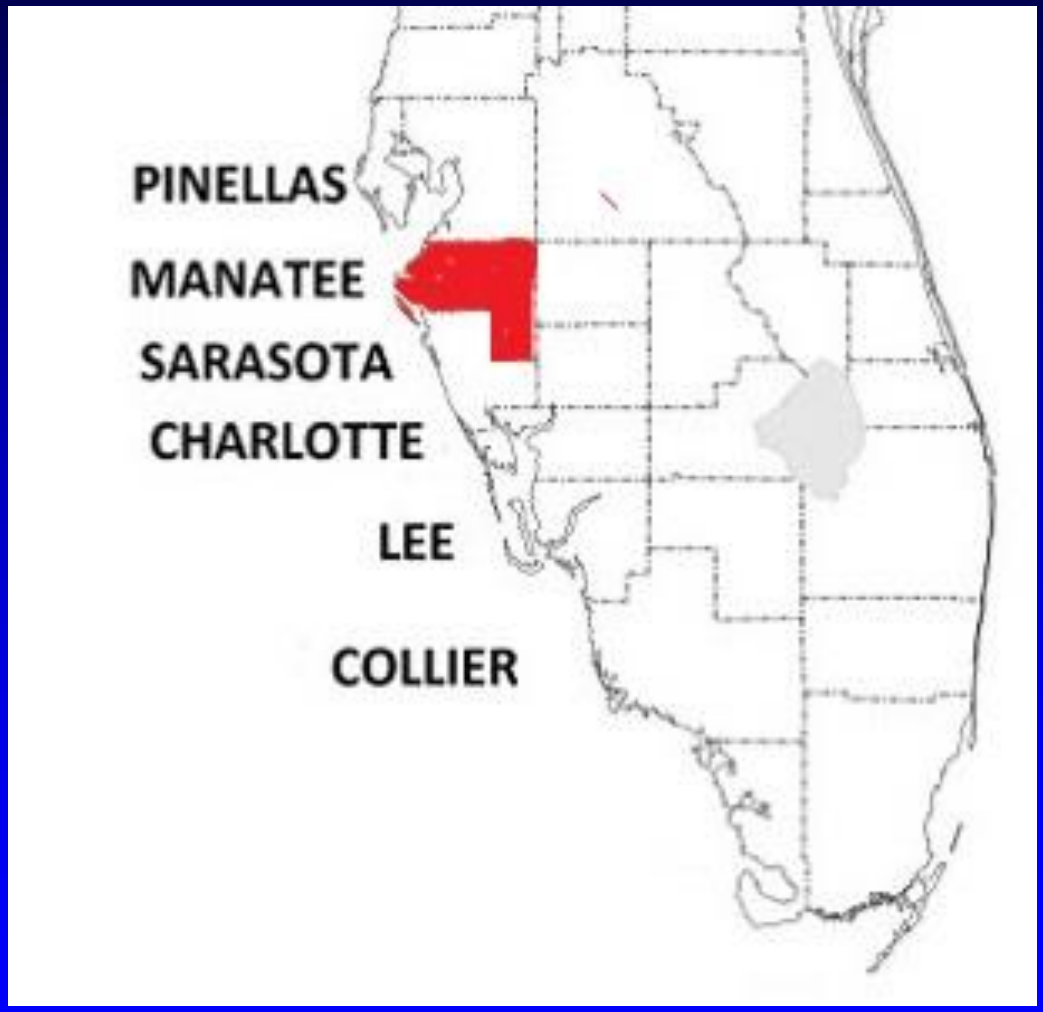
Beach Nourishment Boca Raton



Tremendous Difference

Southwest Florida - Two Scales

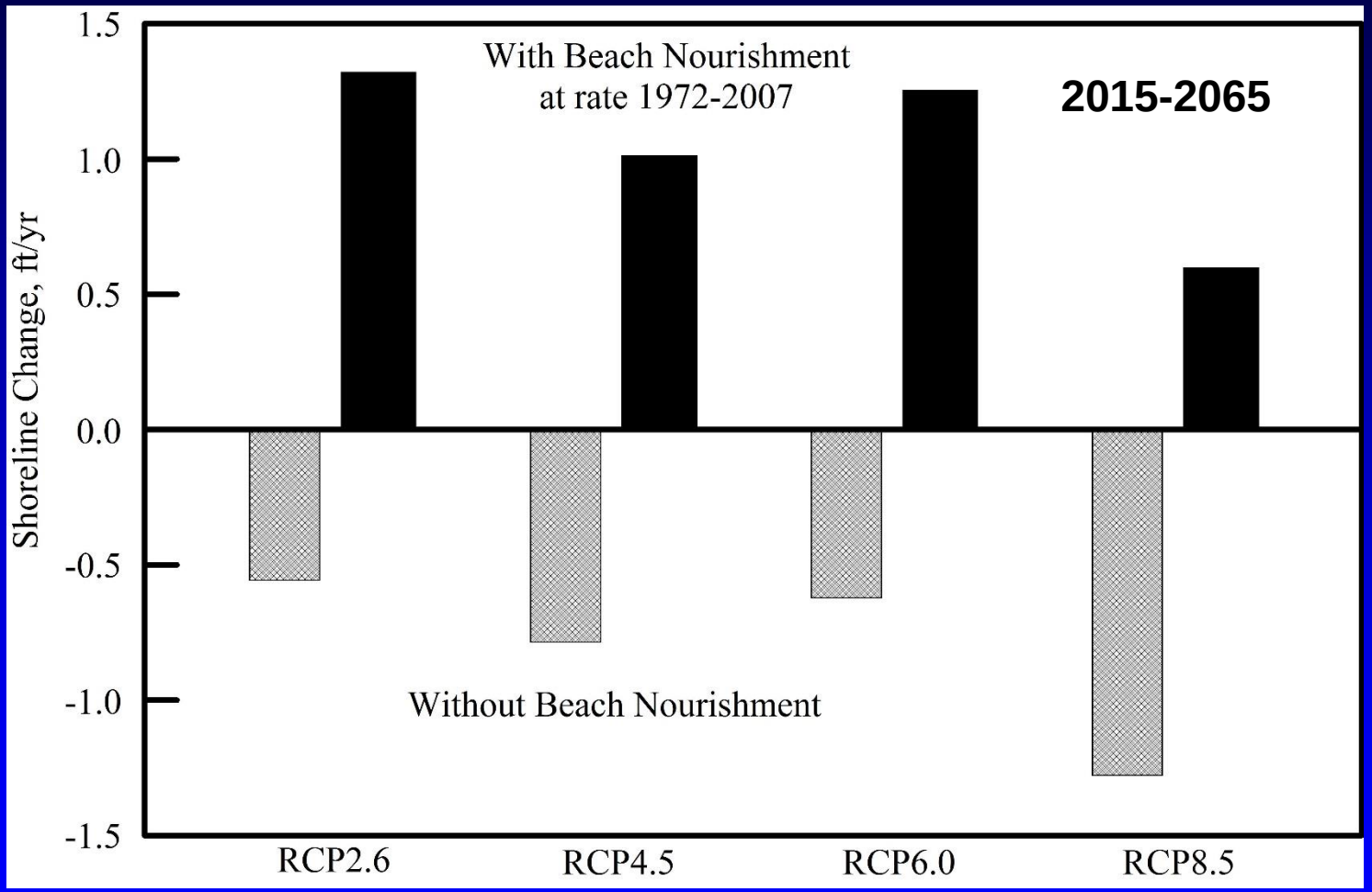
- Six county Southwest coast (170 miles)
- Manatee County Gulf beaches (12 miles)
- Same approach as used for the Florida east coast with 50-year results shown (2015-2065)



Southwest Florida

- Small accretion rate (+ 0.2 ft/yr) on average before beach nourishment (1872 - 1971)
- Onshore sand transport more than offset sea level rise
- Beach nourishment added a net 100 ft of beach since 1971

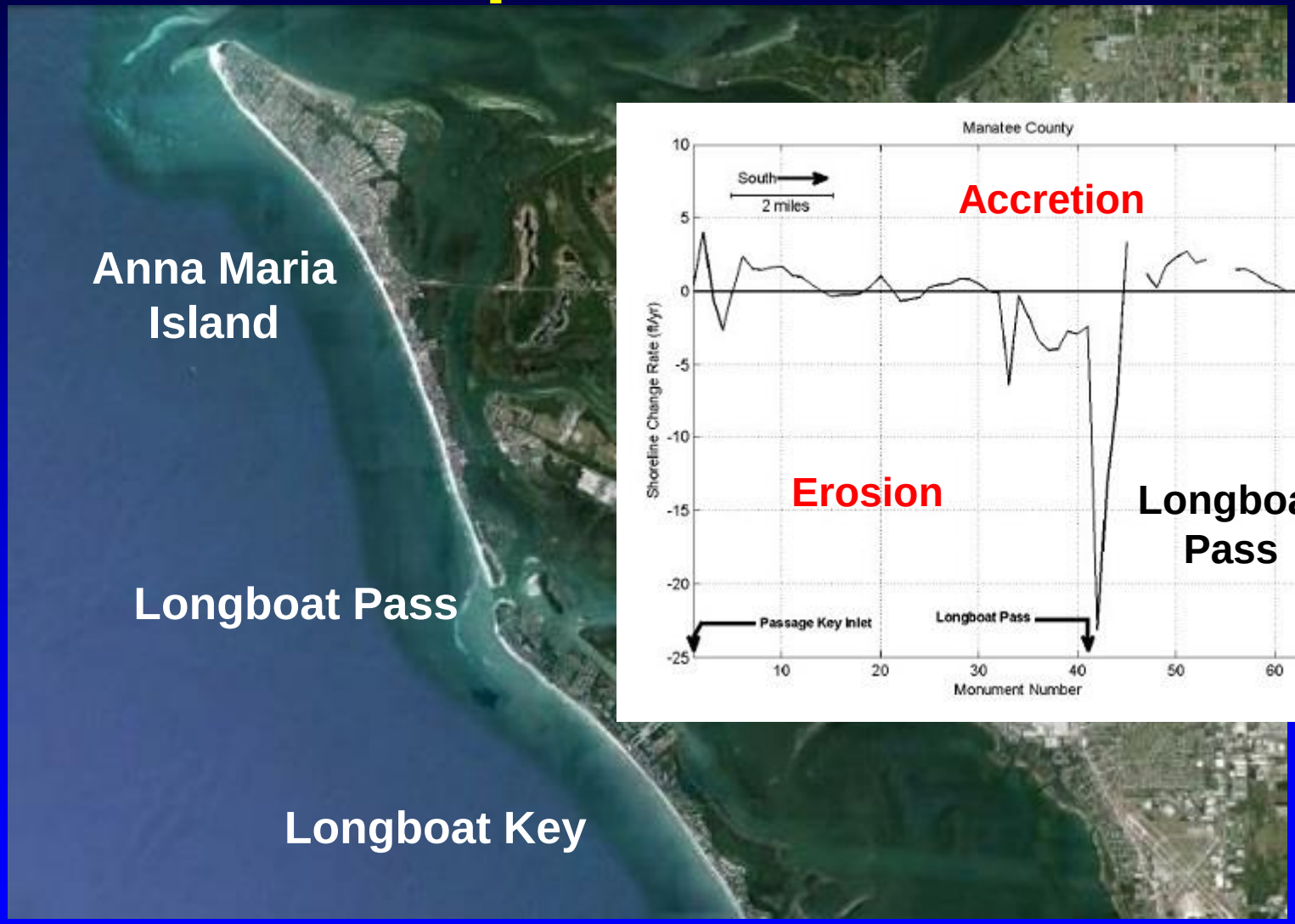
Shoreline Next 50 Years



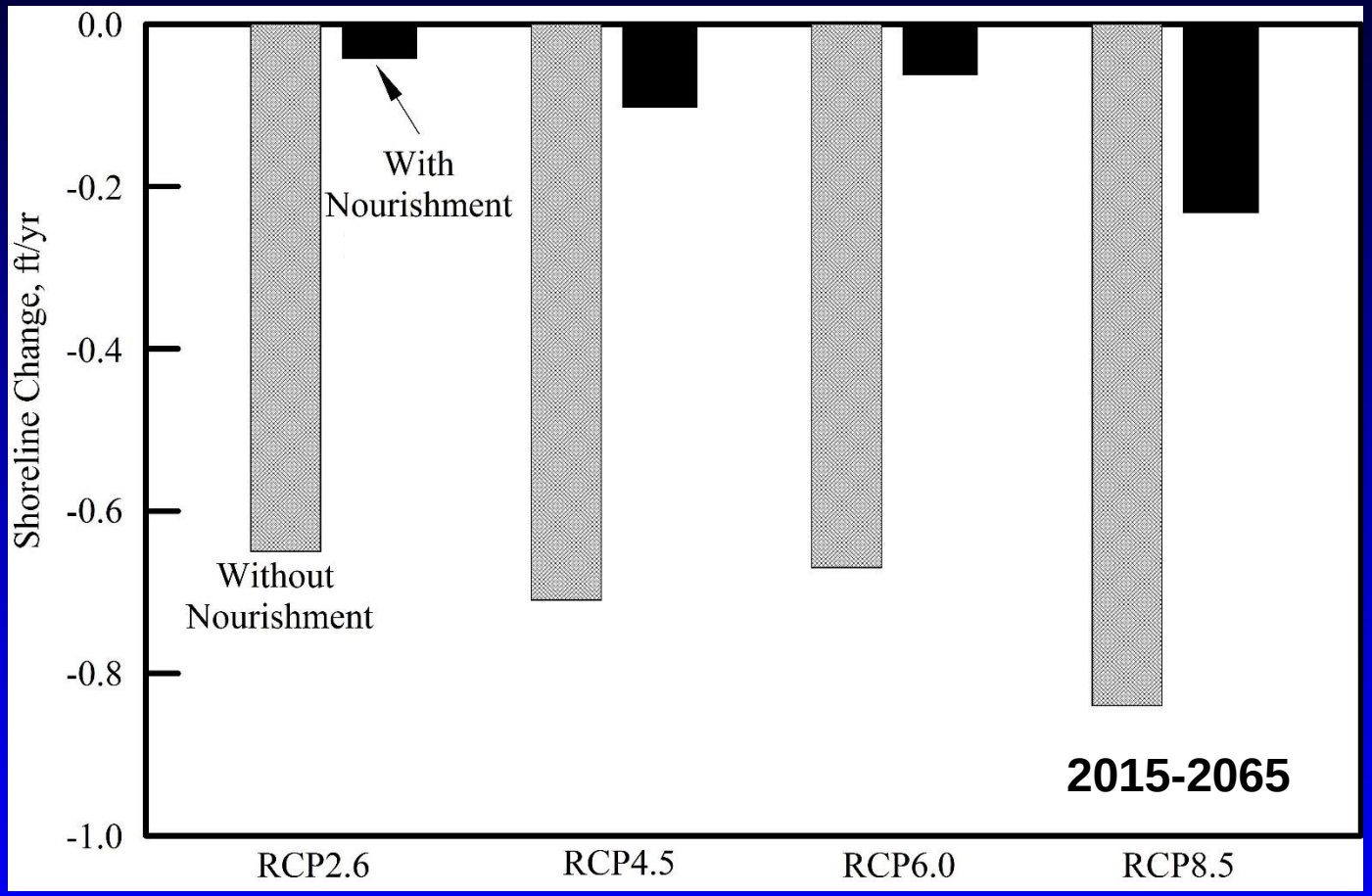
Beaches Advance

Beaches Recede

Manatee County – Net recession 1874 - 2016 Despite Beach Nourishment



50-Year Change

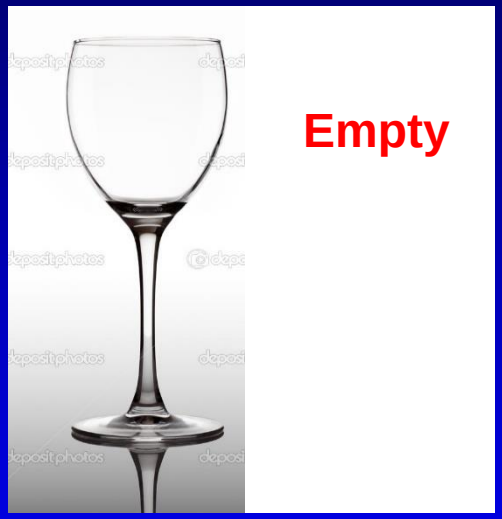


- A modest (5-35%) increase in nourishment over the past rate would counter sea level rise for next 50 years

The Future of Florida Beaches

- Glass half empty or half full?

Without nourishment



Beaches face disaster

With nourishment

Must nourish at at past rates

- Need sand bypassing of managed inlets - would reduce downdrift erosion and beach nourishment requirements

Conclusions

- All factors must be considered to project future shoreline change
- Without beach nourishment, Florida beaches face disaster
- With beach nourishment sea level rise can be countered to 2100 and beyond

  (Sea level rise will still cause significant problems – e.g., back-bay flooding, salinity intrusion, and environmental impacts)

Must Use Reasonable Projections

- "Harold Wanless said he predicts that Miami Beach will experience something in the range of *10 to 30* feet of sea-level rise by the end of the century"

  - Vanity Fair Magazine, 2015

- Pfeffer et al (2008) in the peer-reviewed journal *Science* determined a maximum conceivable rise by 2100 and said, "… increases in excess of 2 m are physically untenable"
- Pfeffer et al (2008) also said, "More plausible but still accelerated conditions lead to maximum sea-level rise by 2100 of about 0.8 meter" (2.6 ft)
- According to IPCC 2013, The "most probable" rise in world--wide sea level by 2100 is about 0.5 m or 1.6 ft

Final Conclusion

- **Beach nourishment is a remarkably good adaptation strategy to counter shoreline impacts of sea level rise**

Sand bypassing of managed inlets would push the strategy to excellent


The End