Anticipated Impacts of Sea Level Rise on the Myakka River Watershed, Florida : Ecosystems, Infrastructure, and Adaptation

3 meters Sea Level Rise

Source of Graphic: New York Times 2012

2012

2100: 1% Probability IPPC 3
2200: 5% Probability IPPC 3
2153: IPCC 4 A1Fl "worst case"
3324: At the current empirical measured rate

James W Beever III

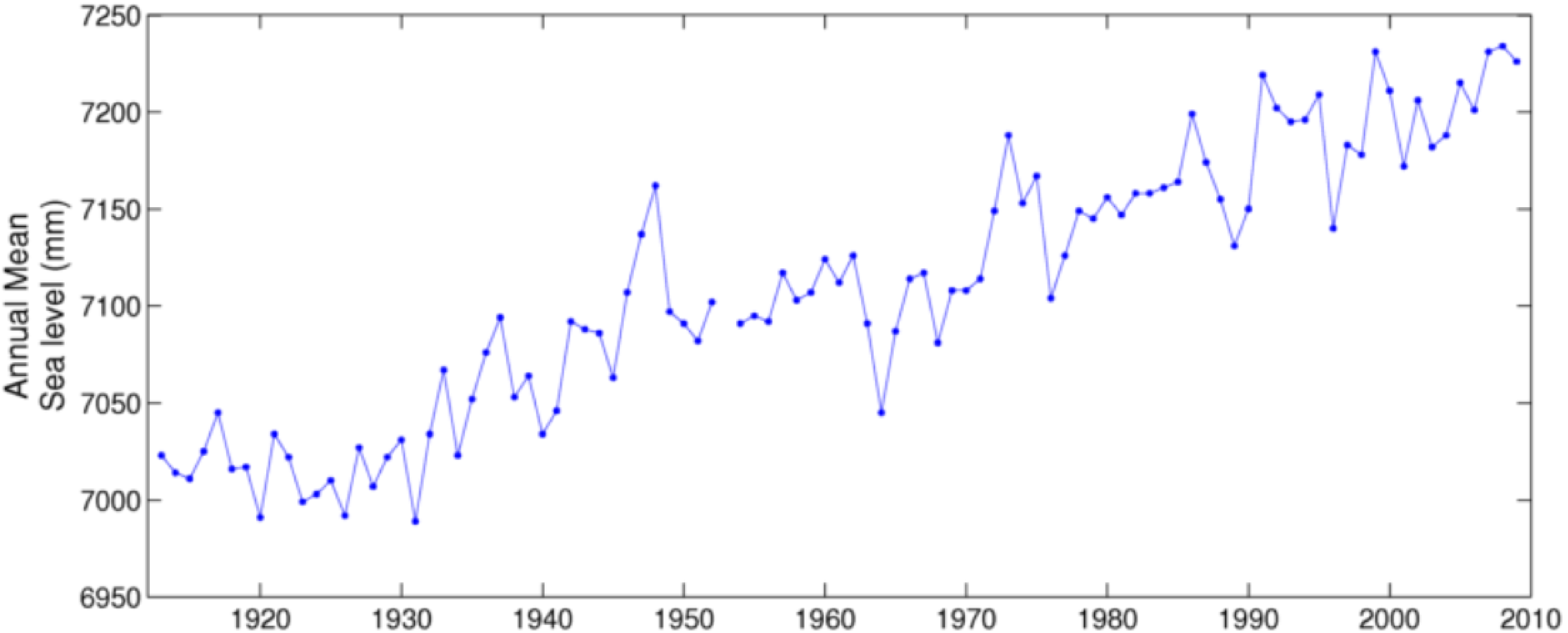
SWFRPC

http://www.swfrpc.org/climate_change.html

Sea level rise is currently occurring and more change is to be expected.

The question for Southwest Floridians is not *whether* they will be affected by sea level rise, but *how much* they will be affected and in what ways including the *degree* to which it will continue, *how rapidly* change will occur, *what type* of changes will occur, and what the *long-term effects* of these changes will be.

In the last 100 years sea level has increased by 9 inches in Southwest Florida.

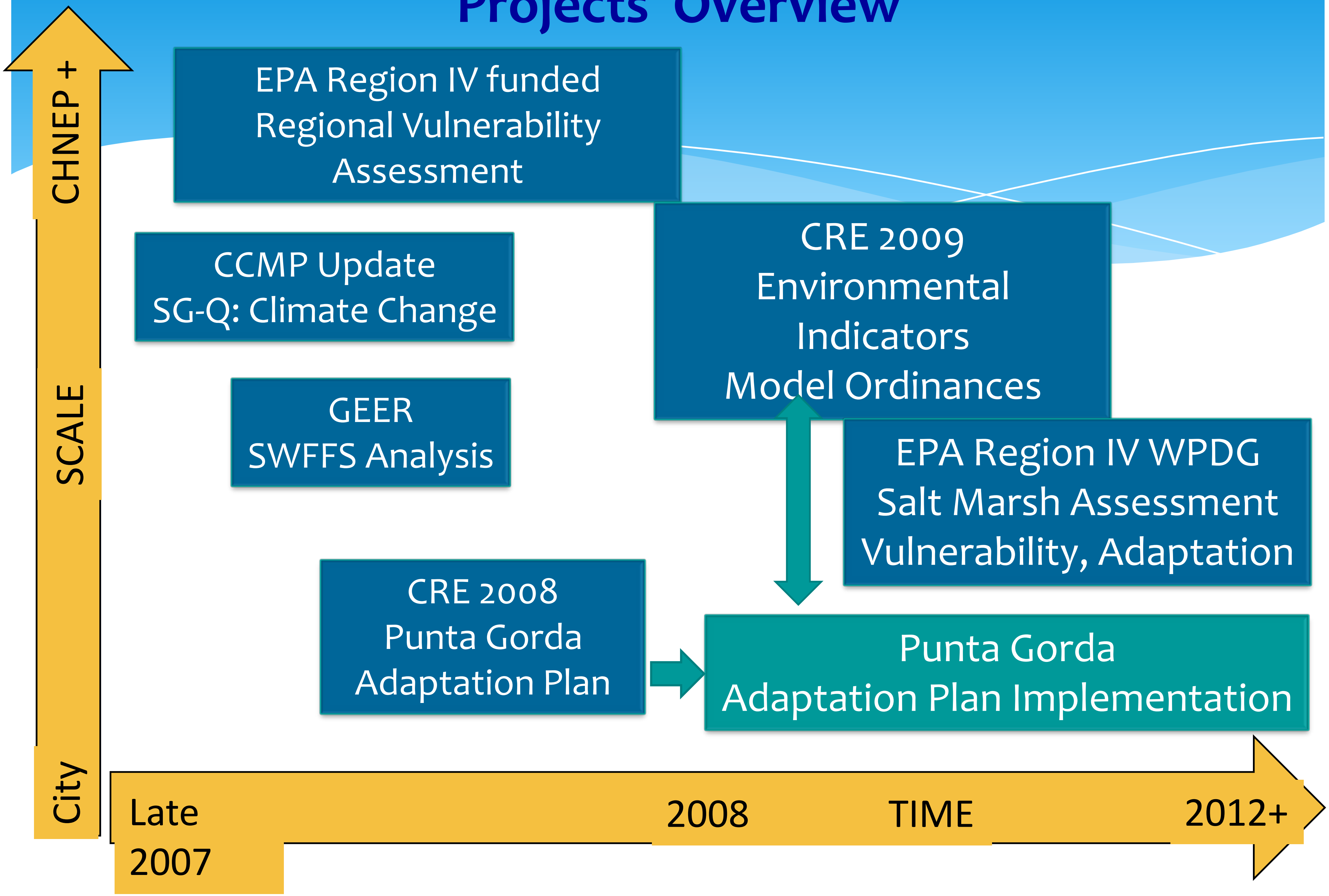


NOAA Tide Chart for Key West, FL

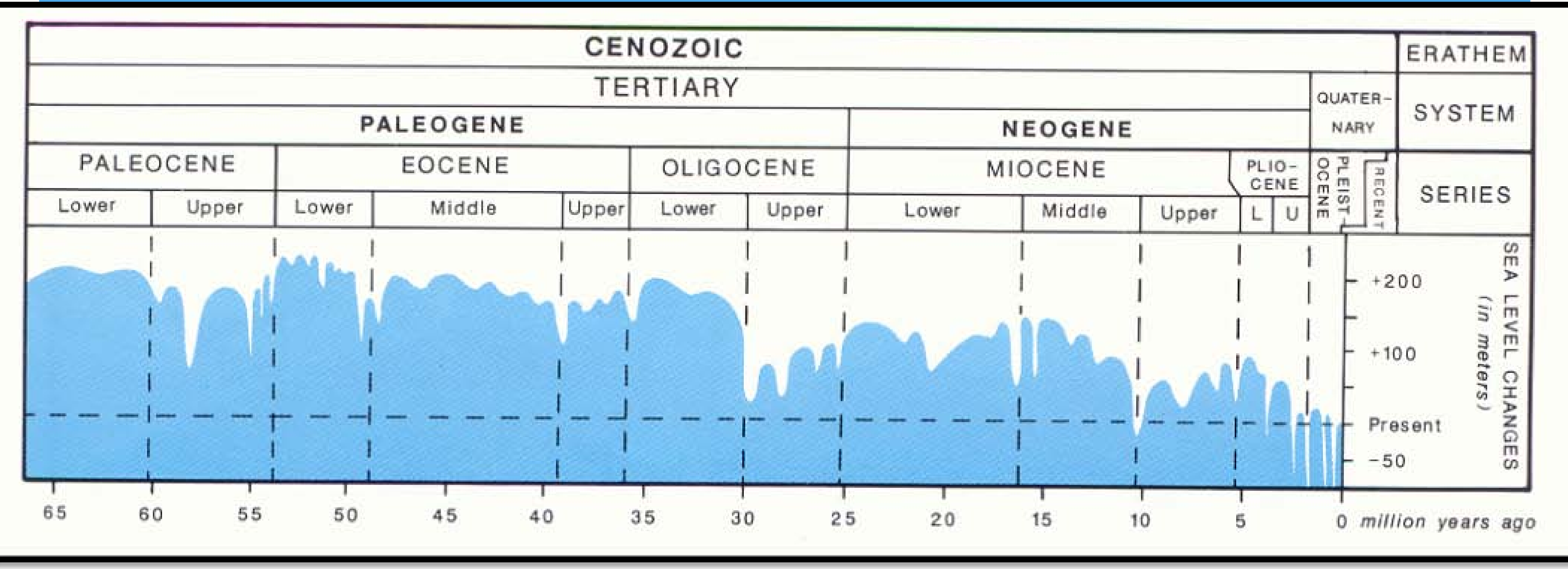
	1900	2008	Scenario	2100	Citation
Average Air Temperature (F)	72.3	73.5	Lower	75.7	Stanton and Ackerman 2007
			Intermed.	76.5	Analysis of local data since 1968
			Upper	84.5	USGCRP 2009
Days per year over 90°	77.7	90.4	Lower	91.8	Rate applied from 1931-1949
			Intermed.	104.6	Rate applied from 1901-1919
			Upper	180	USGCRP 2009
North Atlantic Water Temperature [1](F)	80.6 [2]	81.7	Lower	82.8	IPCC 2007a
			Intermed.	82.9	FOCC 2009
			Upper	85.3	IPCC 2007a
Global Air CO_2 Levels (ppm)	298.0	387.0	Lower	450.0	USGCRP 2009
			Intermed.	680.0	USGCRP 2009
			Upper	950.0	USGCRP 2009
Ocean pH	8.2	8.1	Lower	8.0	Royal Society 2005
			Intermed.	7.8	Royal Society 2005
			Upper	7.7	Royal Society 2005
Rainfall (inches)	54	54	Lower	54	Stanton and Ackerman 2007
			Intermed.	52	10-year rolling average rate
			Upper	49	Stanton and Ackerman 2007
Rainfall Delivered in Rainy Season (6/1 through 9/30)	62%	68%	Lower	70%	10-year rolling average rate
			Intermed.	74%	USGCRP 2009
			Upper	82%	USGCRP 2009
Sea Level Rise (inches)	0.0	8.0	Lower	7.1 + 8	Stanton and Ackerman 2007
			Intermed.	19.8 + 8	Titus and Narayanan 1995
			Upper	45.3 + 8	Stanton and Ackerman 2007

- Regional Vulnerability Assessment (2007-2009)
- Punta Gorda Adaptation Plan (CRE 2008-2009)
- Vulnerability Assessment Lite (2009-2010)
- Climate Change Environmental Indicators (CRE 2009-2010)
- Model Ordinances/Comprehensive Plan (CRE 2009-2010)
- Punta Gorda Comprehensive Plan Amendments (2009-2010)
- Climate Change Vulnerability Assessment and Adaptation Opportunities for Salt Marsh Types in Southwest Florida (2009-2012)
- Seagrass response to SLR (2009)
- Lee County Vulnerability Assessment & Resiliency Strategy (2009-2010)
- Conceptual Ecological Models (CRE 2010-2011)

CHNEP/SWFRPC Climate Ready Estuary Projects Overview



What is the science telling us about sea level rise?

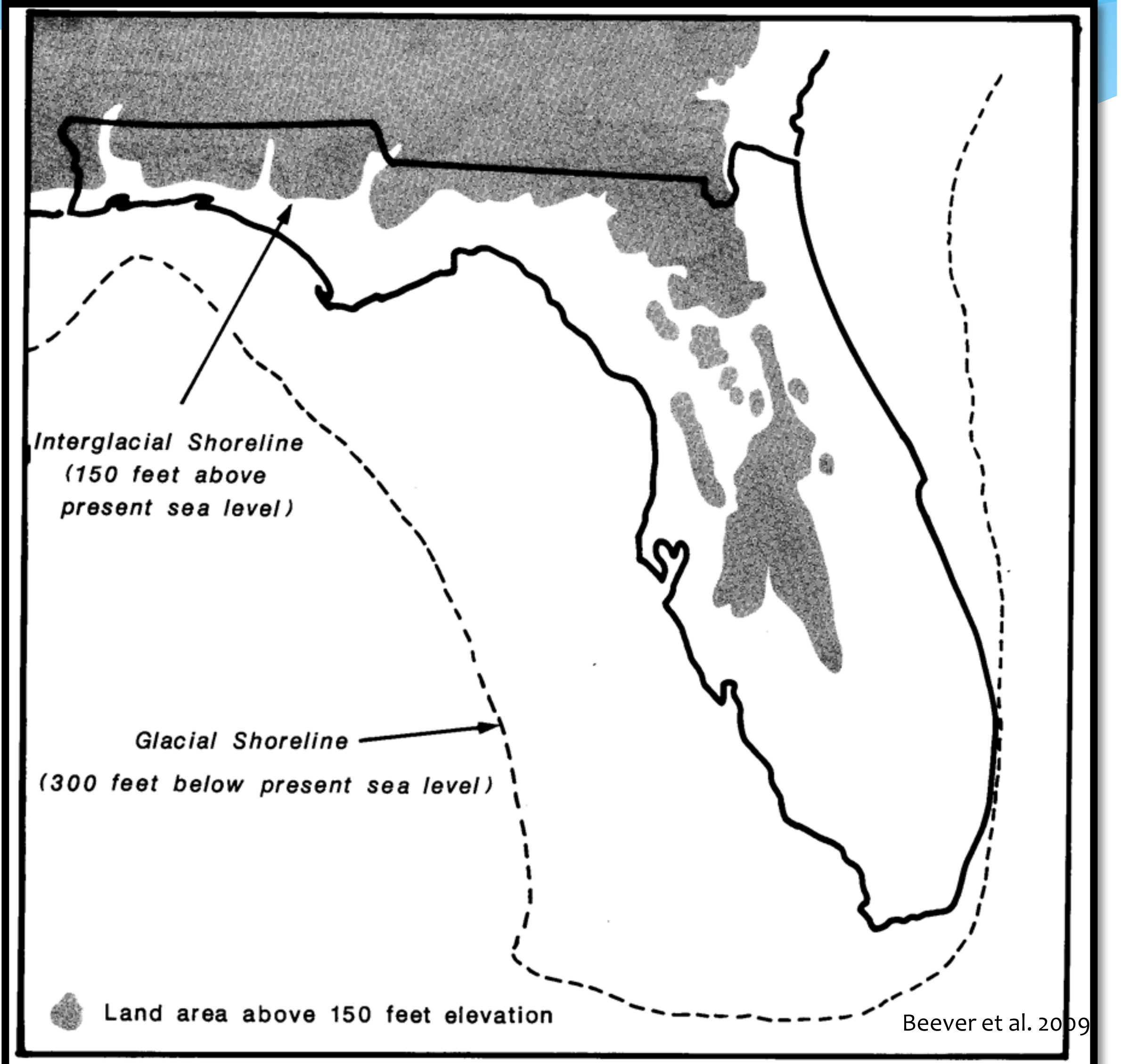


Beever et al. 2009

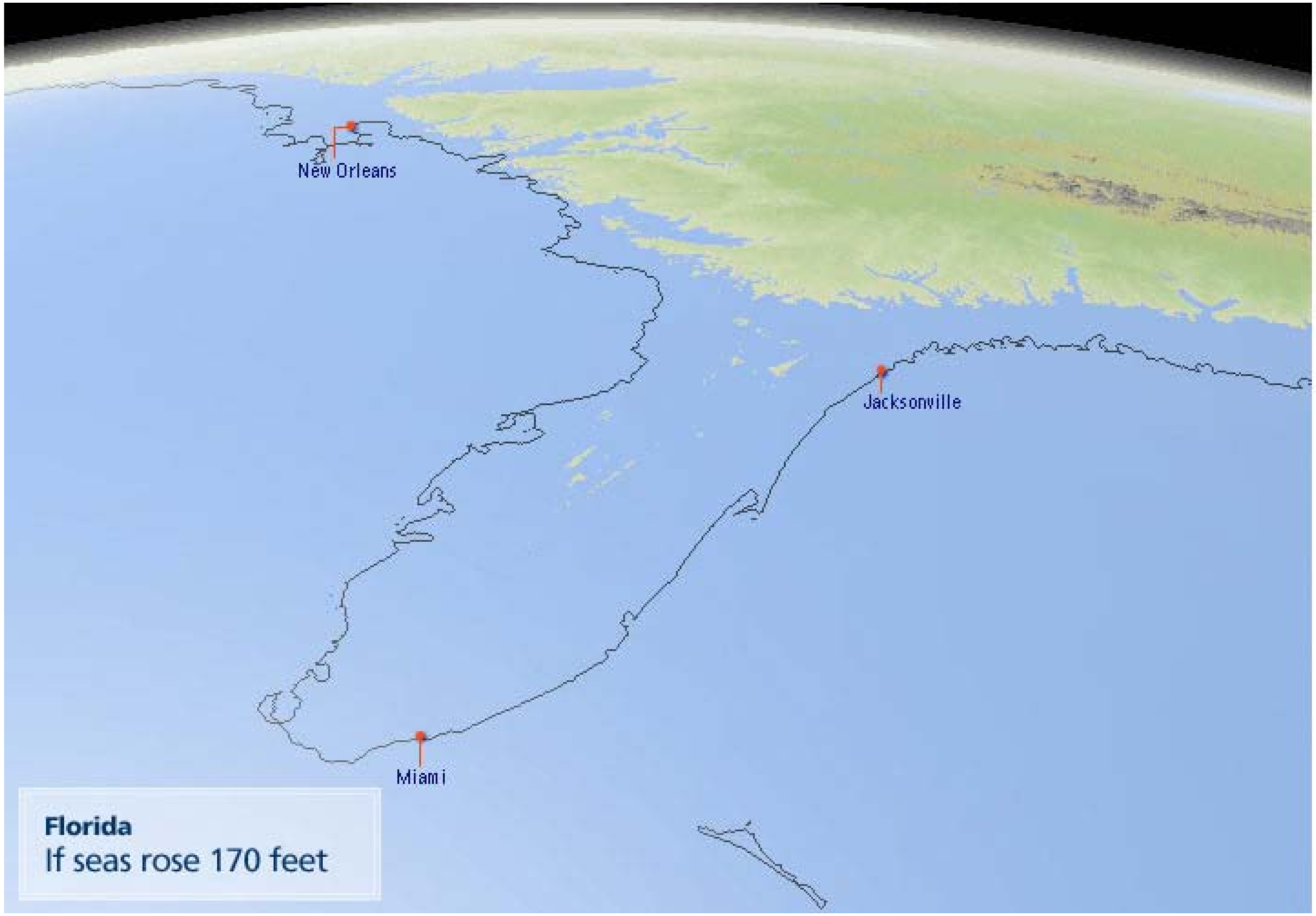
Over the last 65 million years sea level has changed *dramatically*.

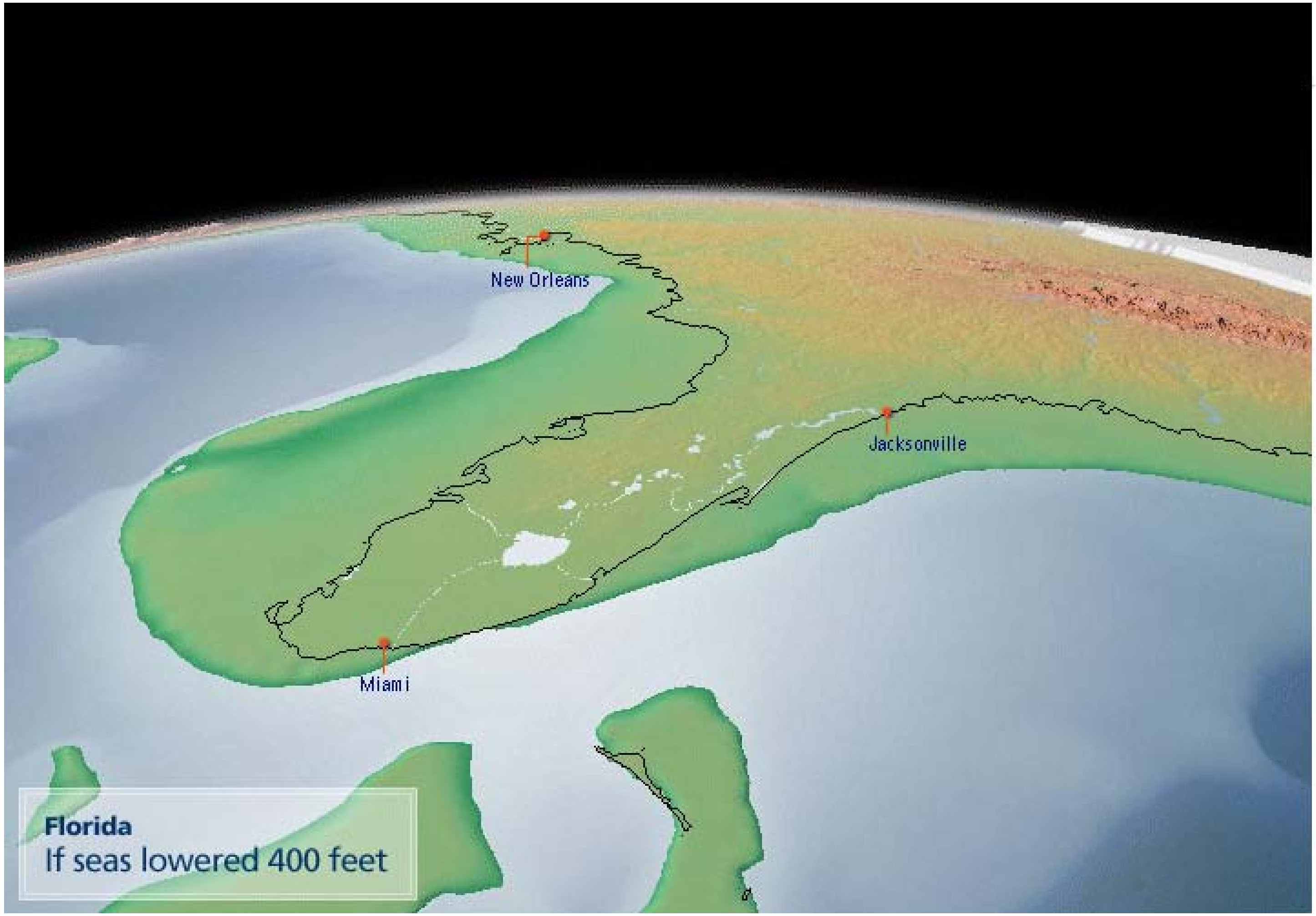
Florida has a loooong history of sea level rise…

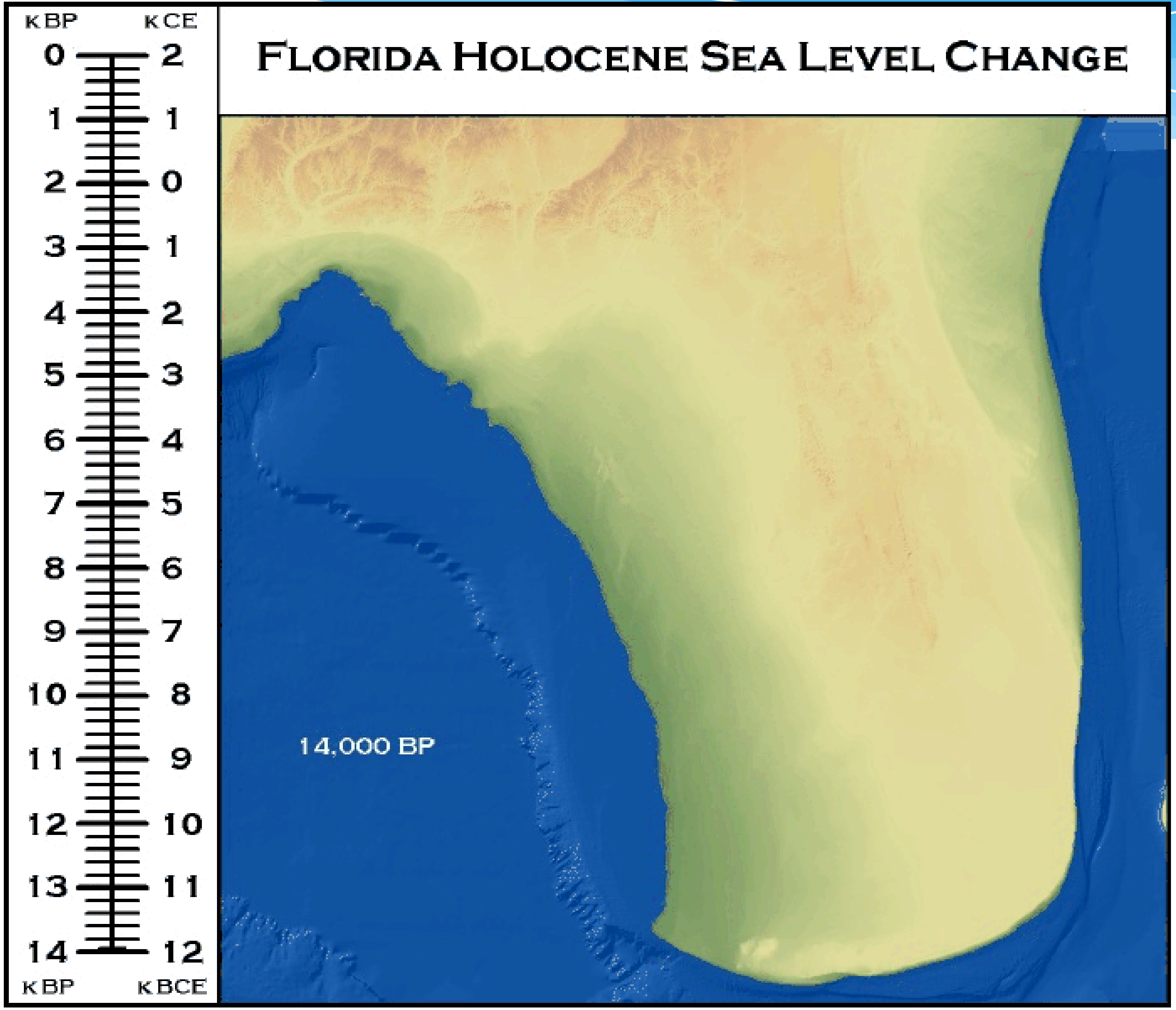
* The gray shows the dry land 1.8 million years ago…
* The dotted line shows the shoreline 10,000 years ago.



Beever et al. 2009


New Orleans
Jacksonville
Miami
Florida
If seas rose 170 feet


New Orleans
Jacksonville
Miami
Florida
If seas lowered 400 feet



kBP
kCE
0
2
1
1
2
0
3
1
4
2
5
3
6
4
7
5
8
6
9
7
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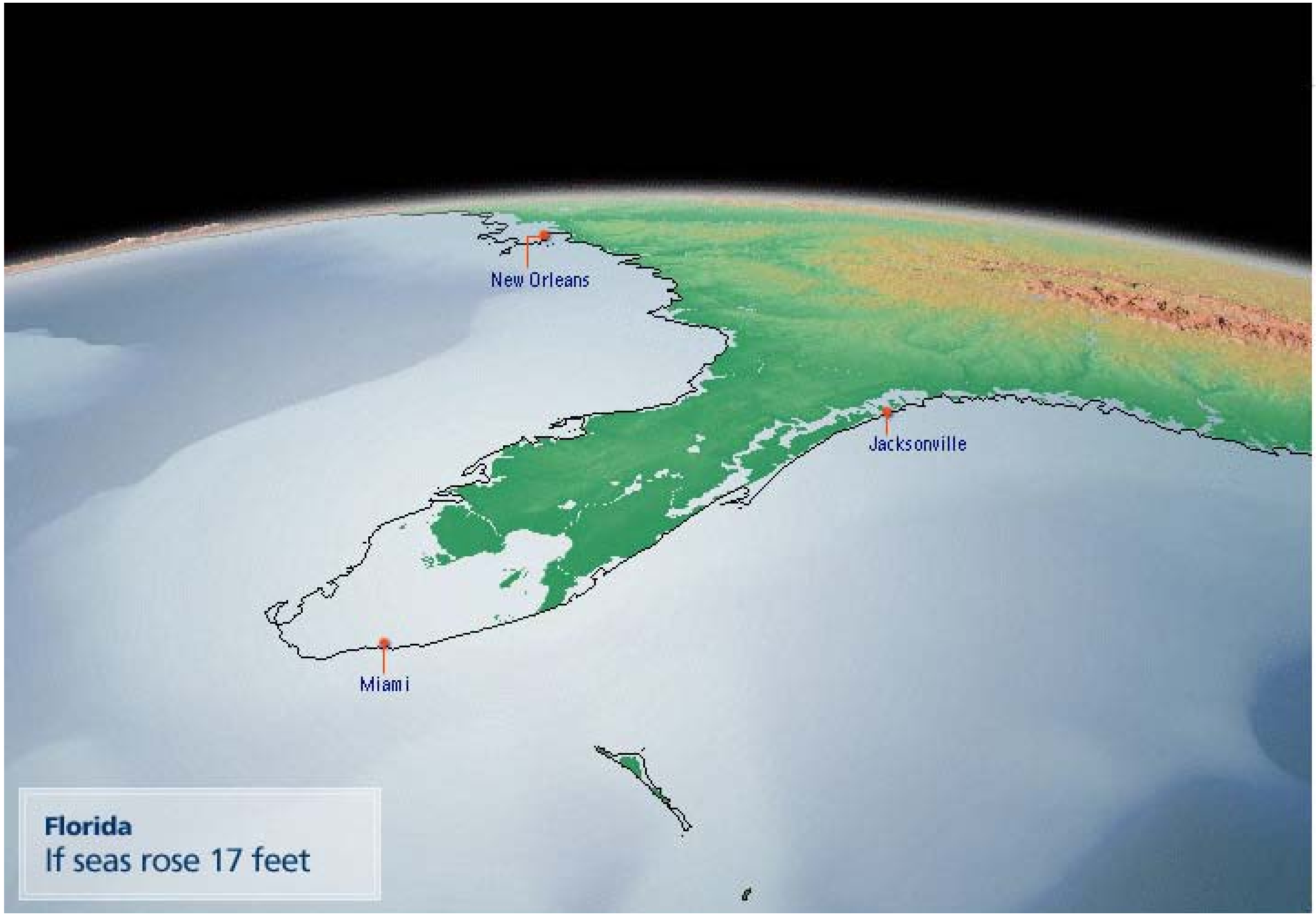
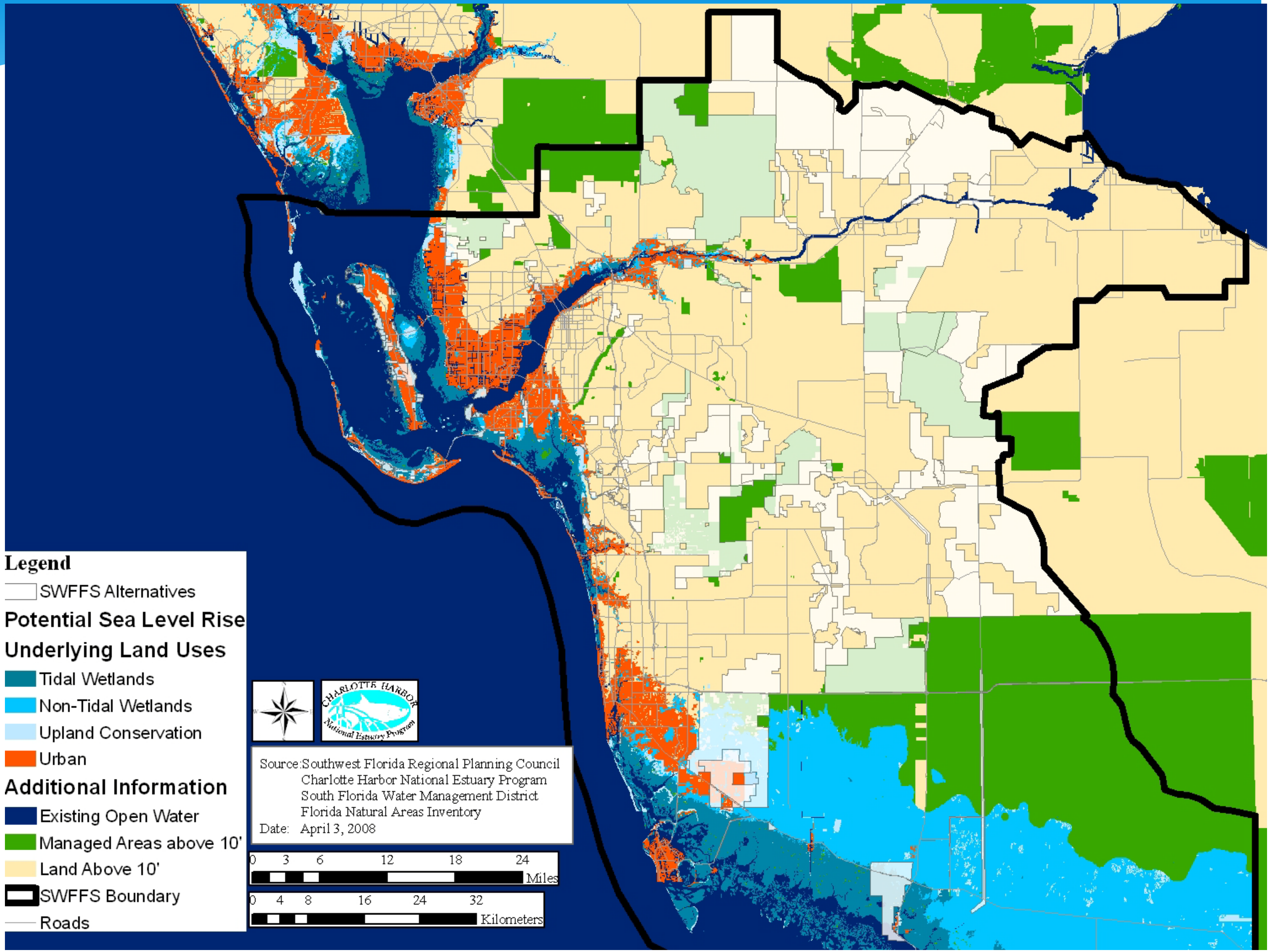
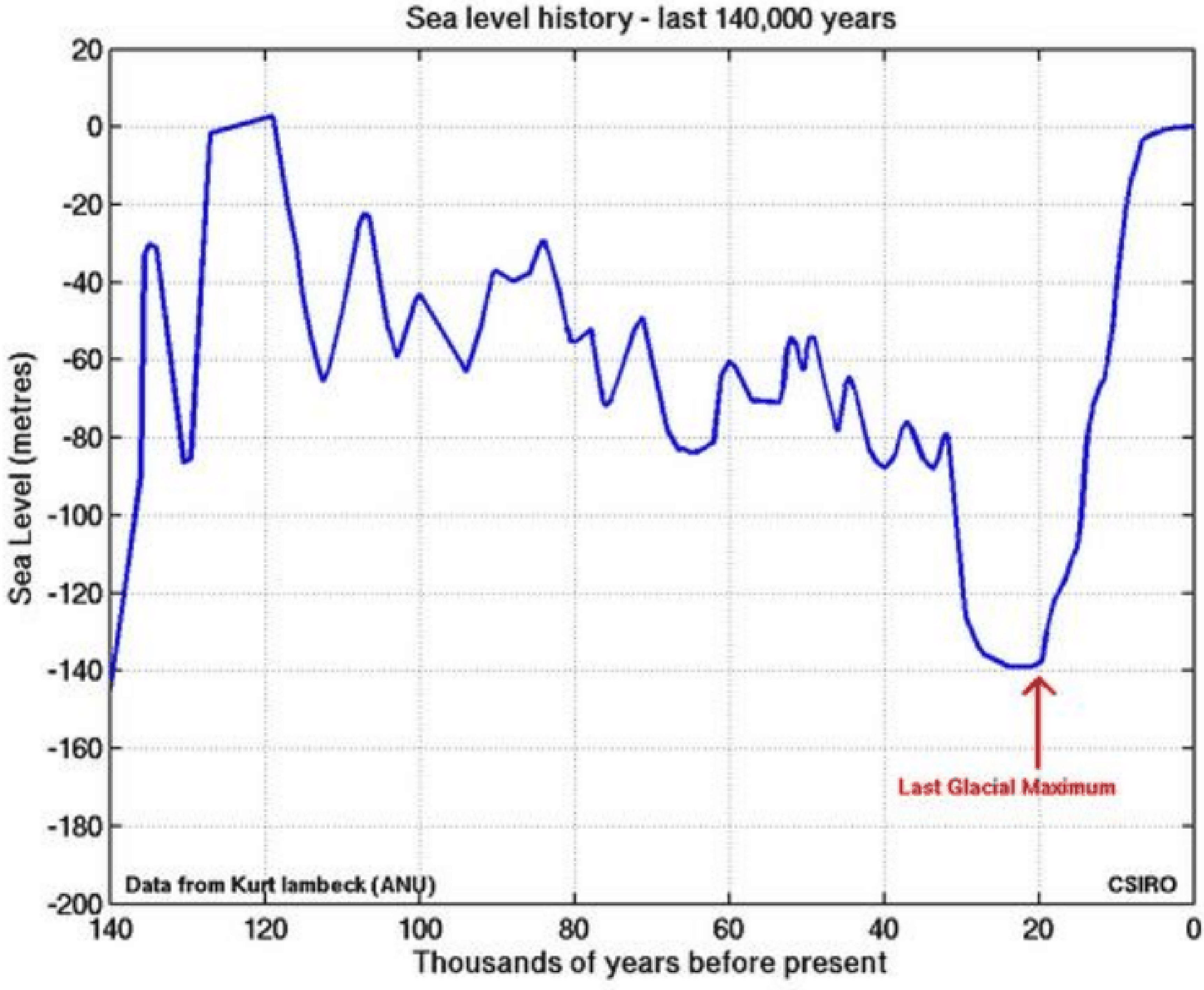
13
11
14
12
kBP
kBCE
Florida Holocene Sea Level Change
14,000 BP

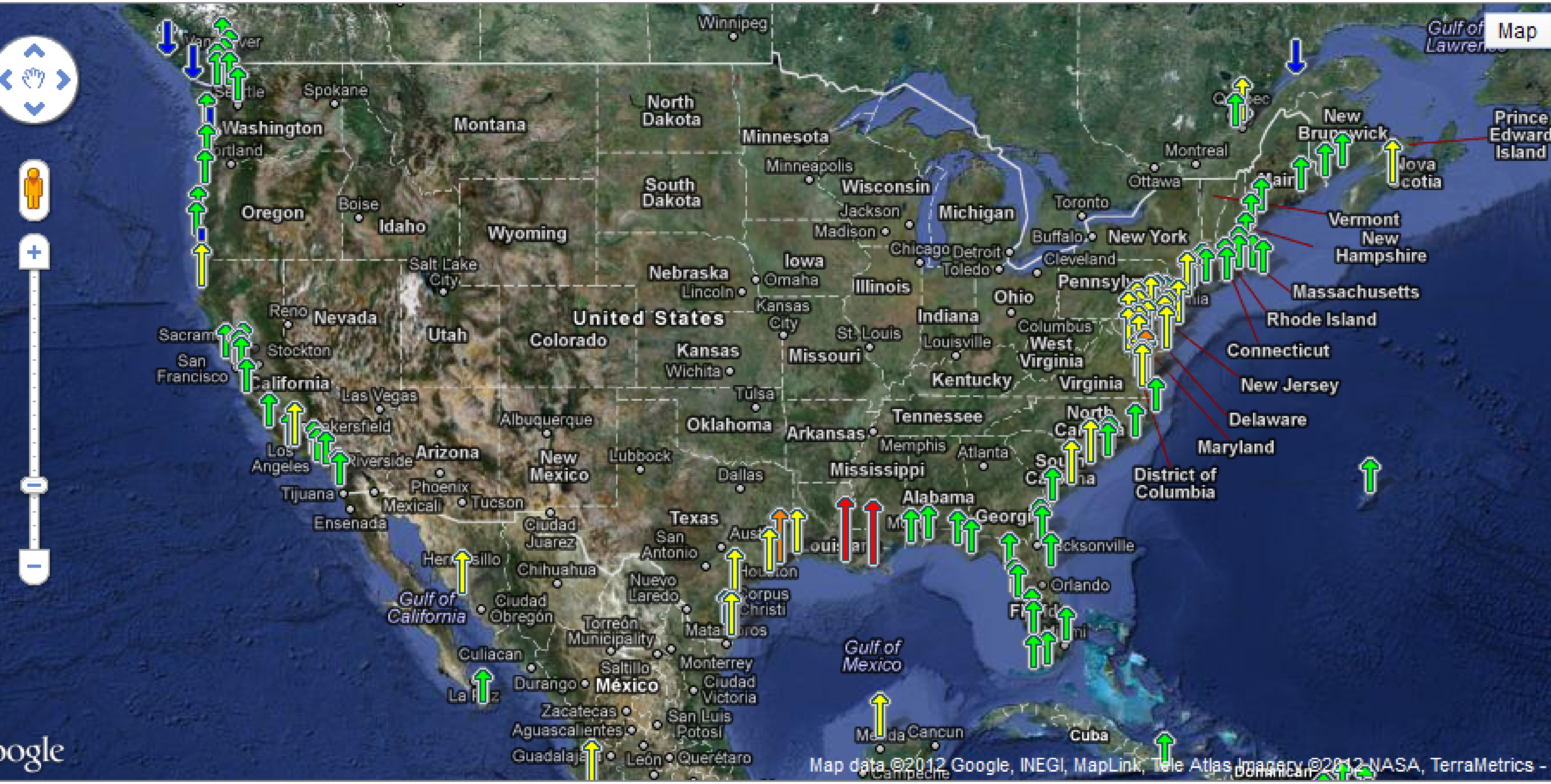

New Orleans
Jacksonville
Miami
Florida
If seas rose 17 feet


Legend
SWFFS Alternatives
Potential Sea Level Rise
Underlying Land Uses
Tidal Wetlands
Non-Tidal Wetlands
Upland Conservation
Urban
Additional Information
Existing Open Water
Managed Areas above 10'
Land Above 10'
SWFFS Boundary
Roads
CHARLOTTE HARBOR National Estuary Program
Source: Southwest Florida Regional Planning Council
Charlotte Harbor National Estuary Program
South Florida Water Management District
Florida Natural Areas Inventory
Date: April 3, 2008
0 3 6 12 18 24 Miles
0 4 8 16 24 32 Kilometers



Source: CSIRO, available at
http://www.cmar.csiro.au/sealevel/sl_hist_intro.html

East Coast | West Coast | Gulf Coast | Alaska | Pacific | Global

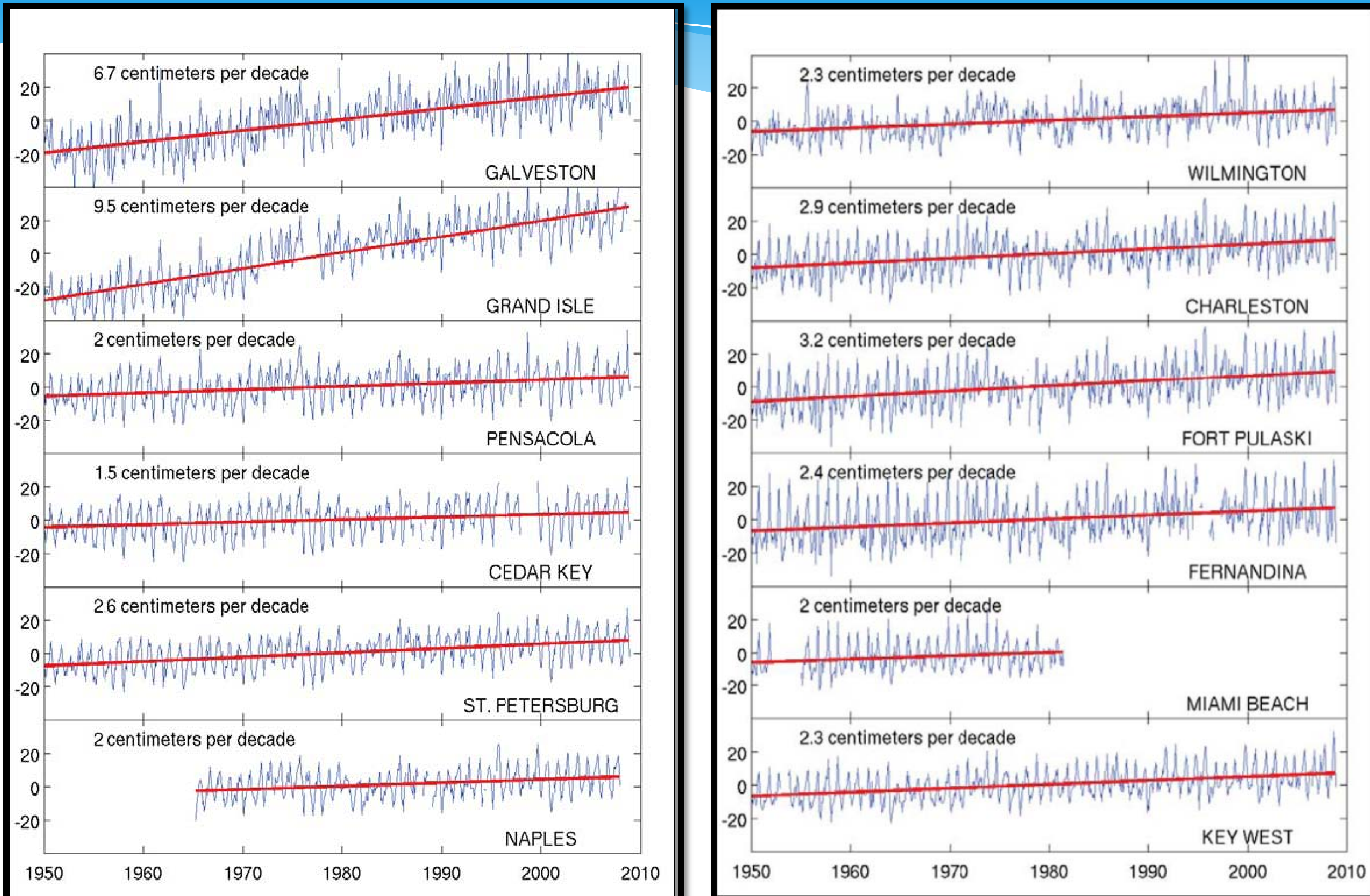


map above illustrates regional trends in sea level, with arrows representing the direction and magnitude of change. Click on an arrow additional information about that station.

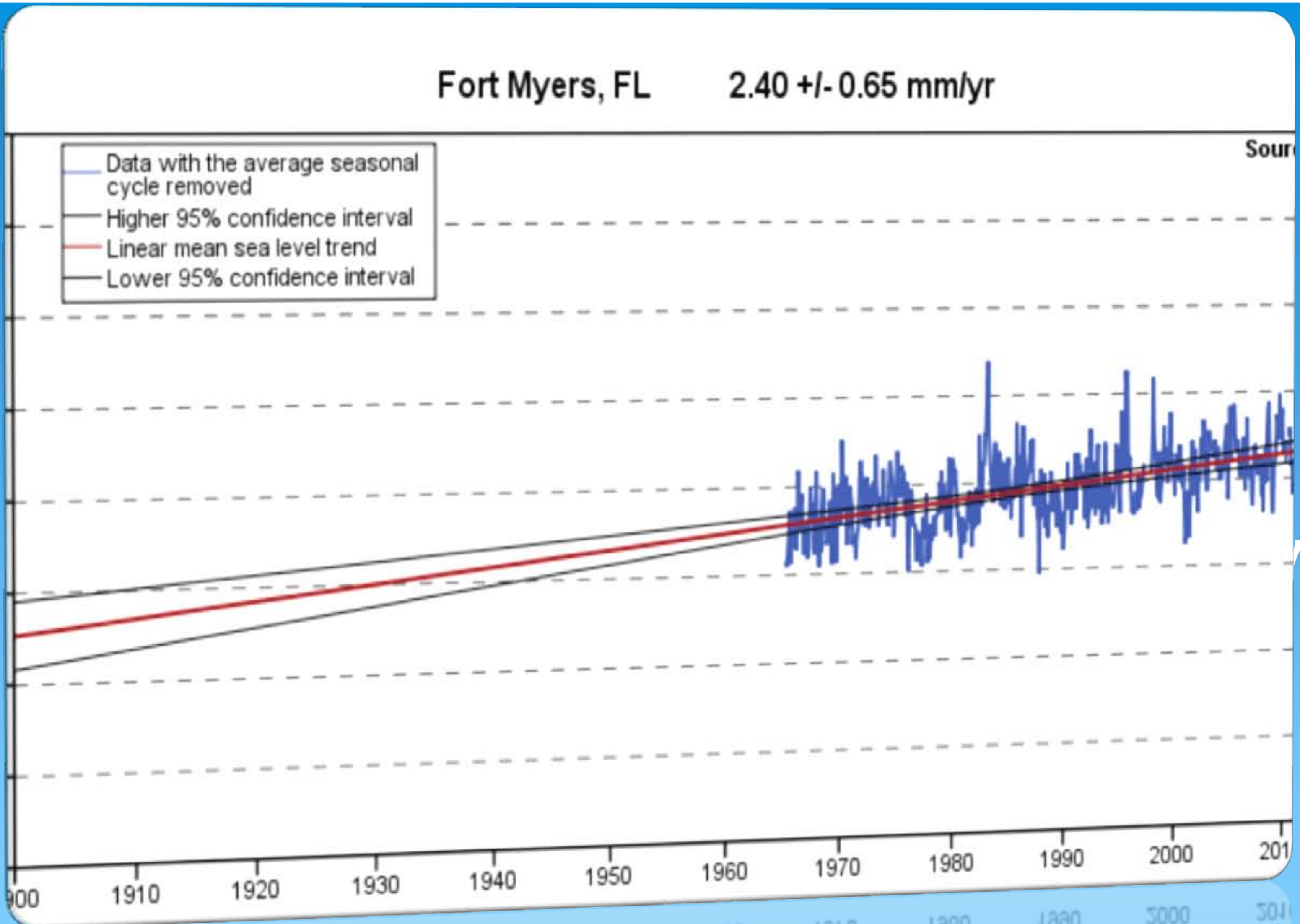
Sea Level Trends

mm/yr (feet/century)

9 to 12 (3 to 4)	3 to 6 (1 to 2)	-3 to 0 (-1 to 0)	-9 to -6 (-3 to -2)	-15 to -12 (-5 to -4)
6 to 9 (2 to 3)	0 to 3 (0 to 1)	-6 to -3 (-2 to -1)	-12 to -9 (-4 to -3)	-18 to -15 (-6 to -5)



Mitchum 2012

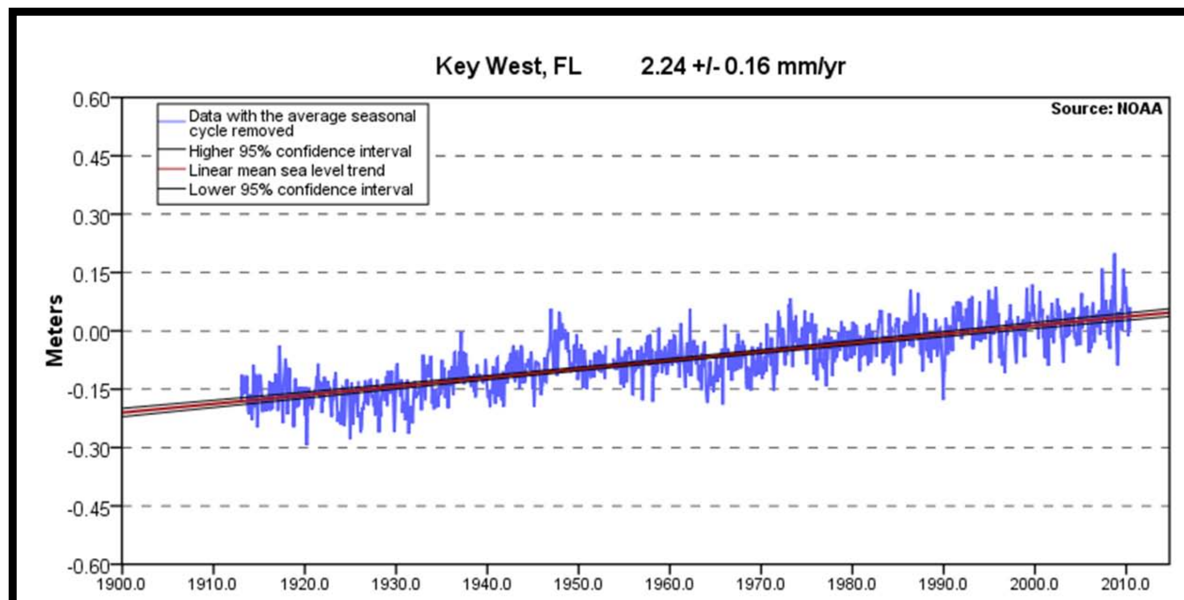


Relative Sea Level at the Fort Myers Tide Station

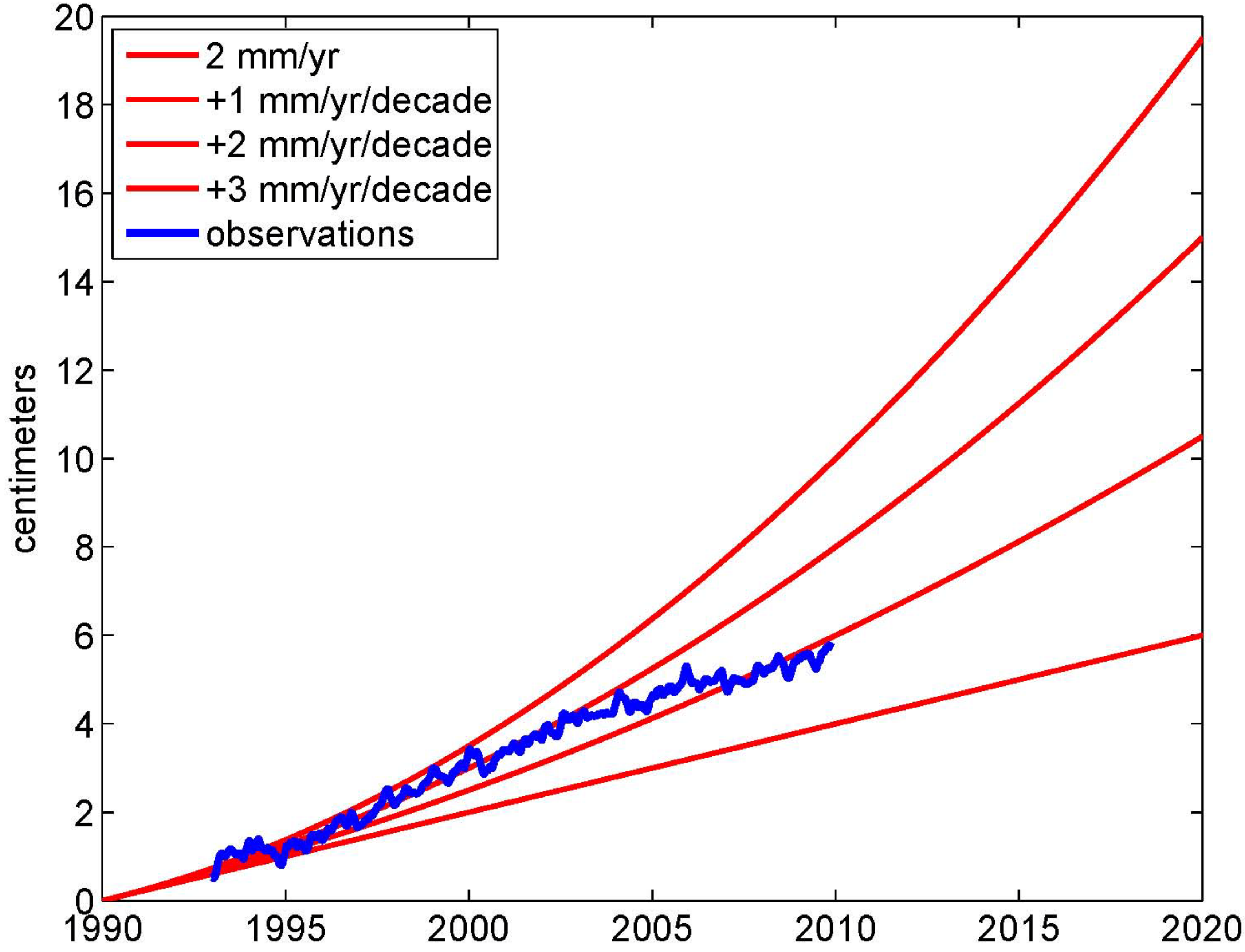
About 3 mm per year…

About the thickness of a Kraft Single each year

9 inches in Key West in the past 100 years



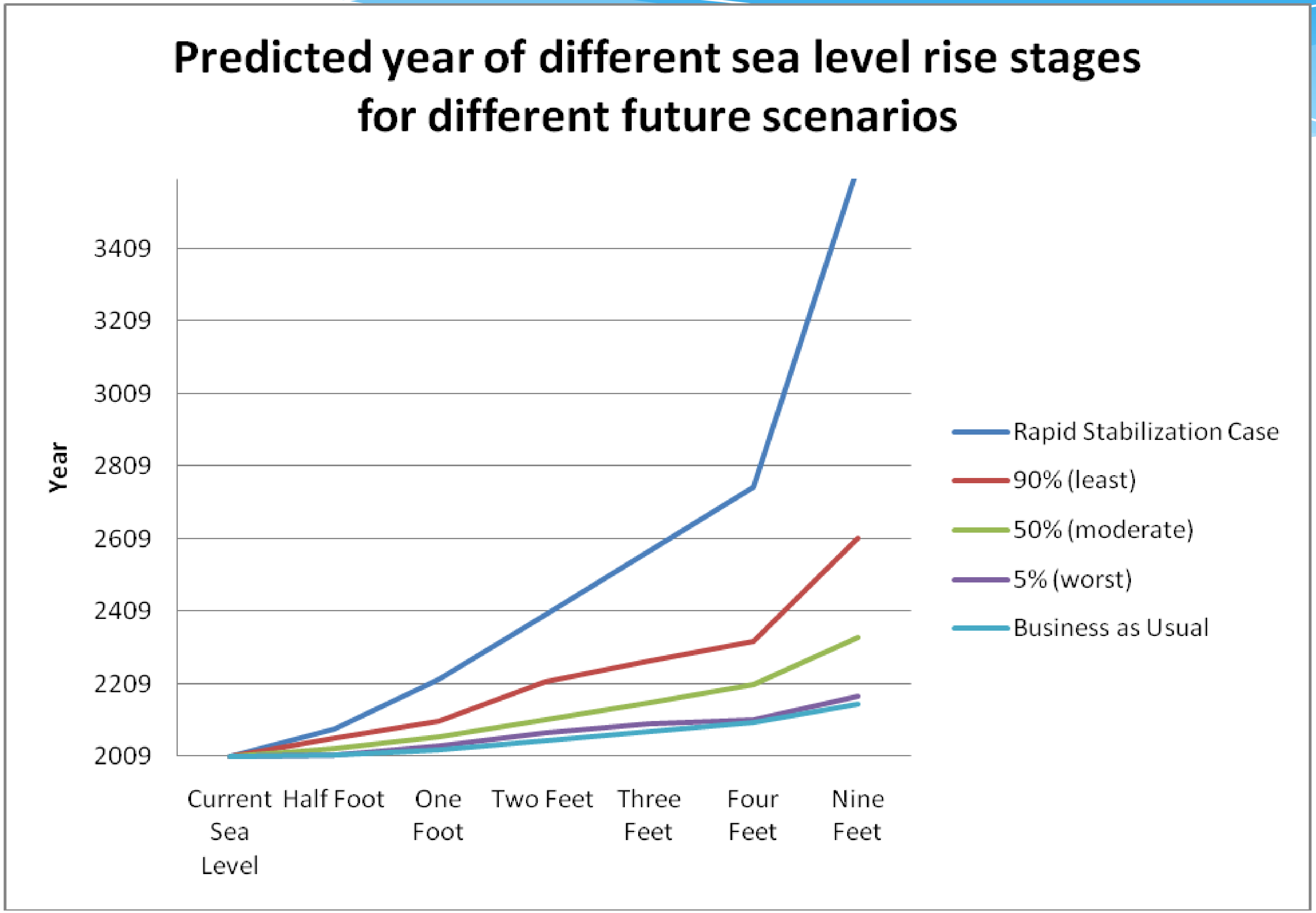
Beever 2011



Mitchum 2011

SLR Predictions

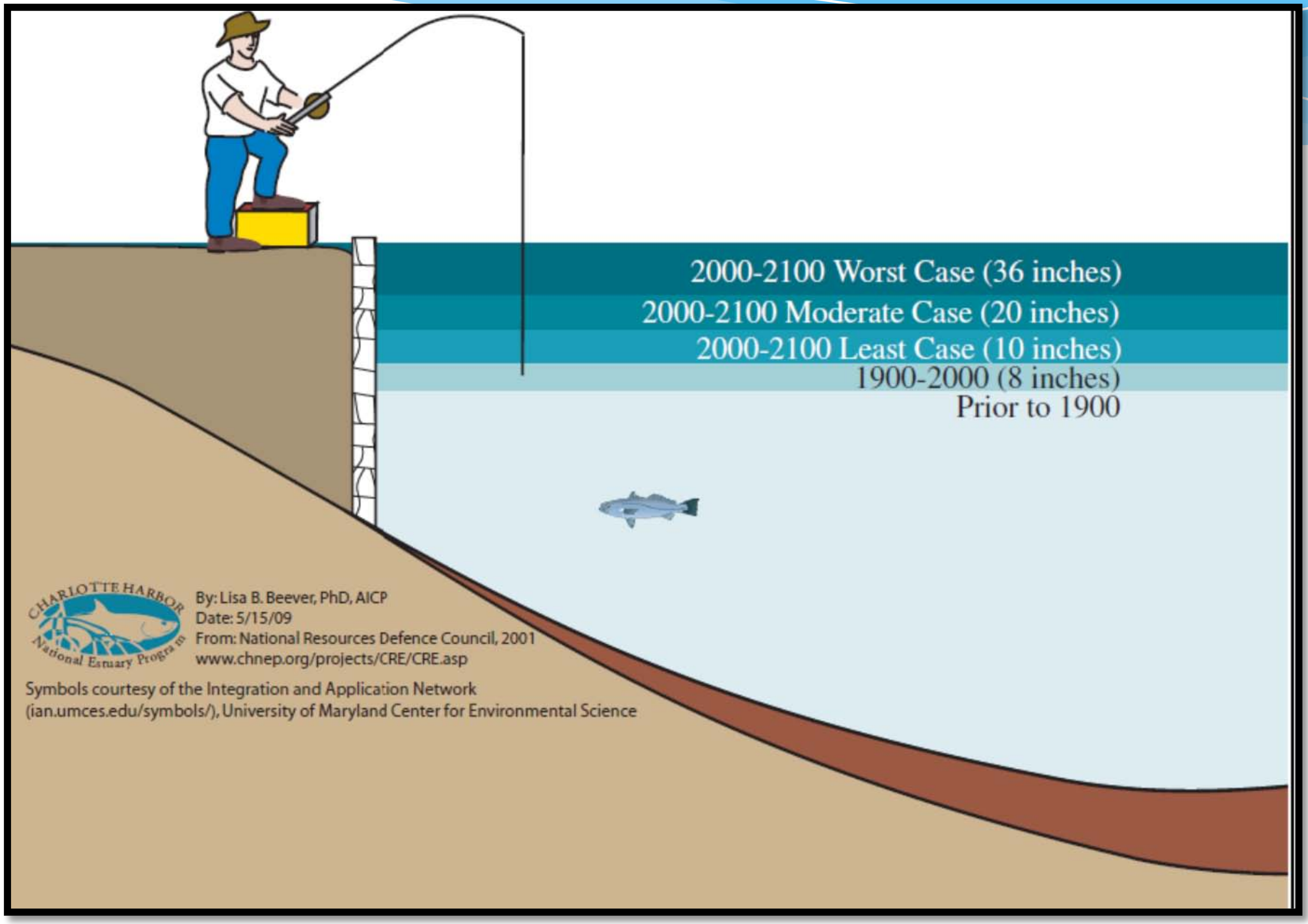
* USACOE (for Florida)
  * 0.5-1.5 meters by 2100 (20 inches to 5 feet)
* SE Florida Climate Compact (Broward, Miami-Dade, Monroe, Palm Beach)
  * 2030: 3-7 inches
  * 2060: 9-24 inches
* Punta Gorda Adaptation Plan (SWFRPC)
  * 2050: 5-16 inches
  * 2075: 8-25 inches
  * 2100: 21-110 inches (10 ft.)



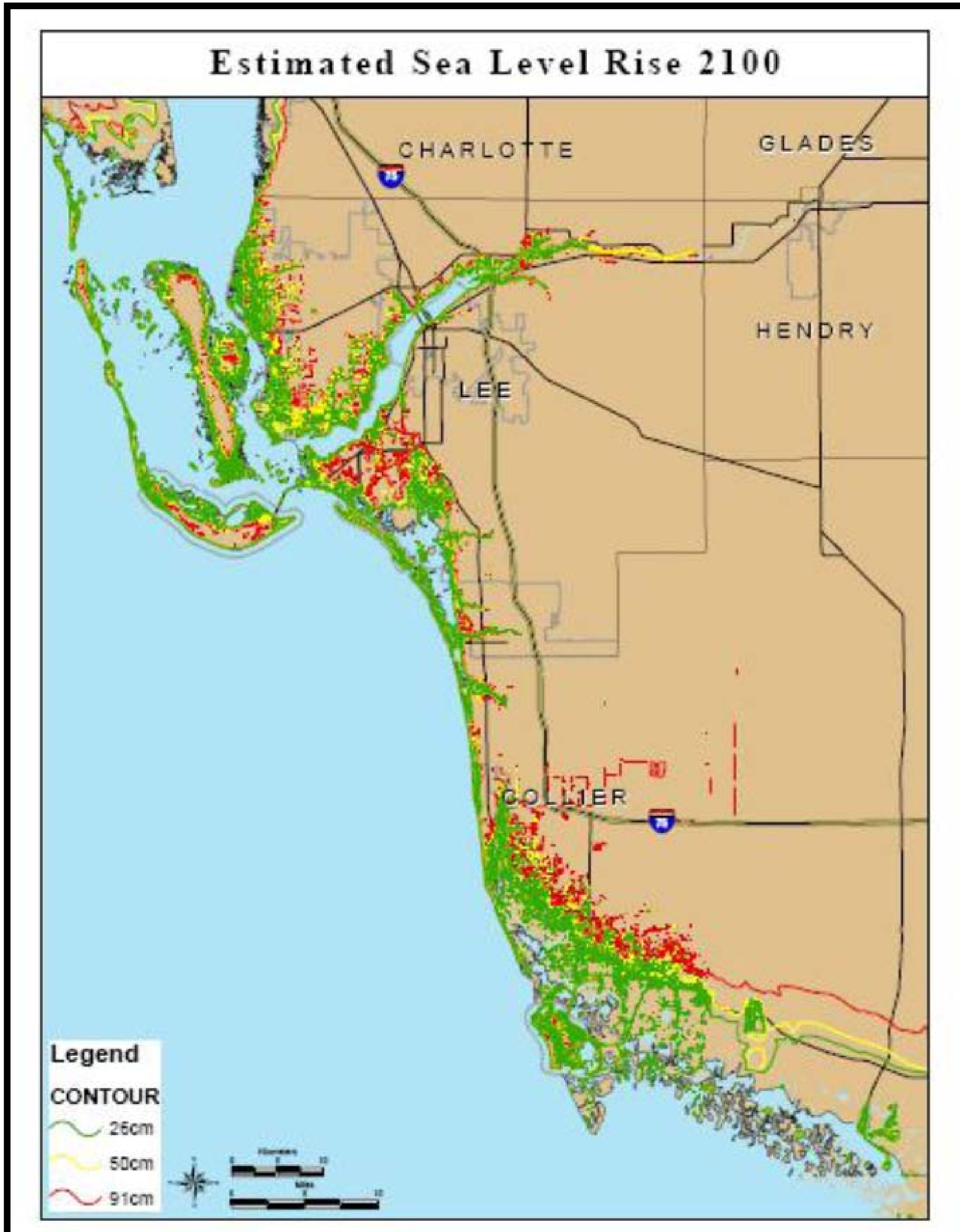
Approximate predicted year of different elevation levels (NGVD) of sea level rise for different future scenarios

By 2100…

- 80 cm (about 32 inches, or about 233 slices of cheese) of sea level rise



Beever 2009



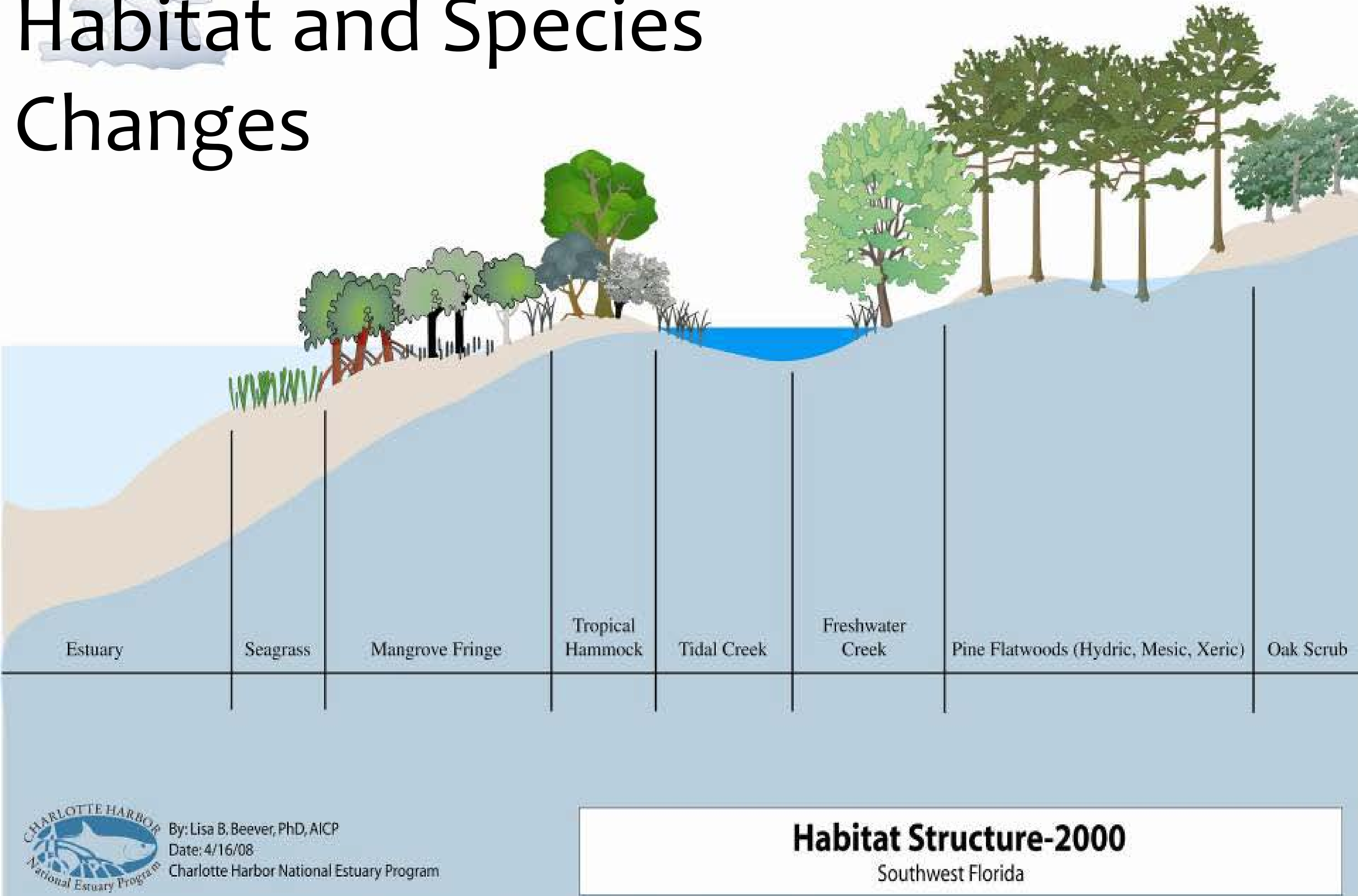
What does the modeling show?

SLAMM modeling shows tidal inundation reaching inland between the red and yellow zones in Southwest Florida.

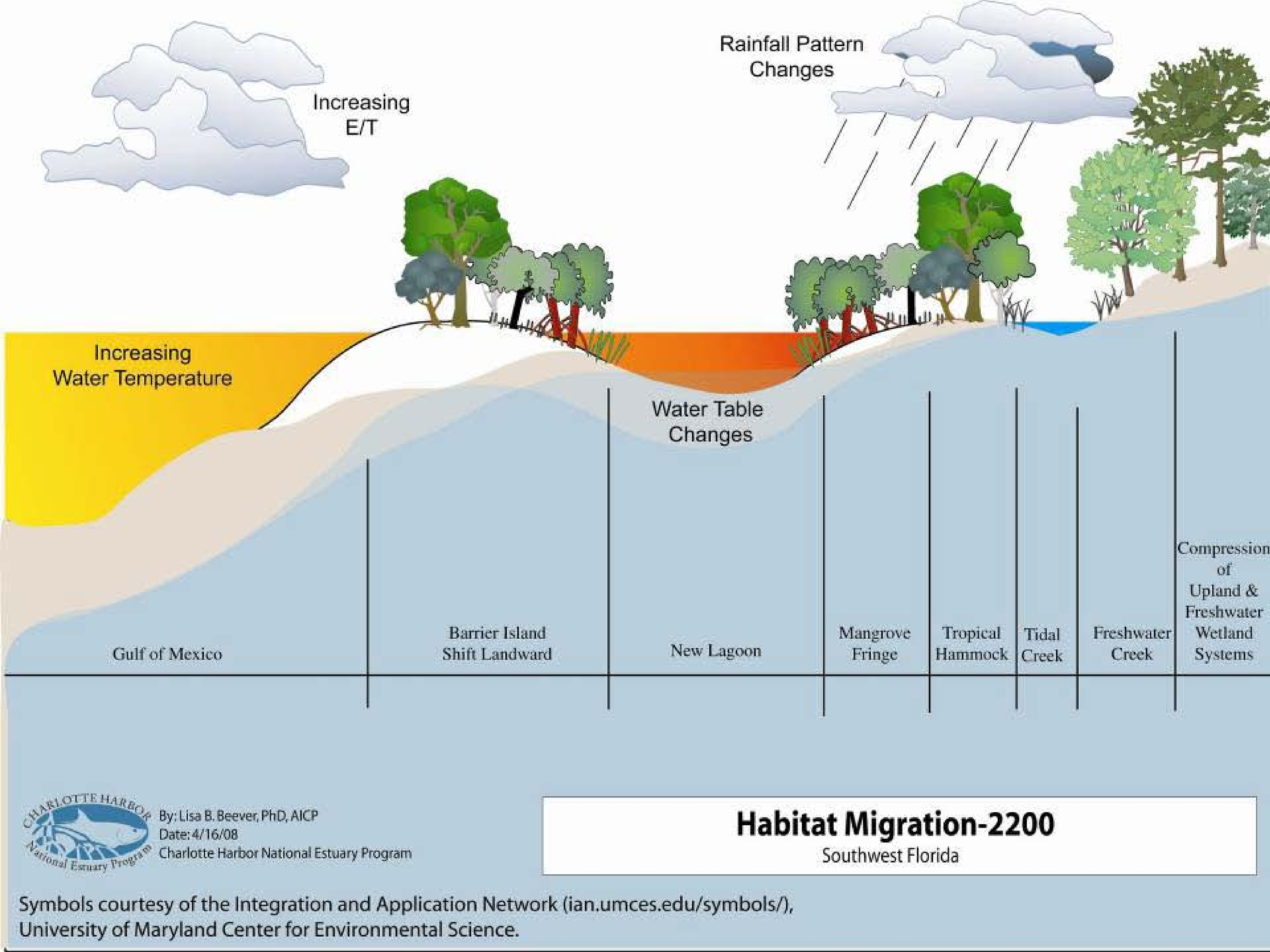
Different regions of Florida will have different results…

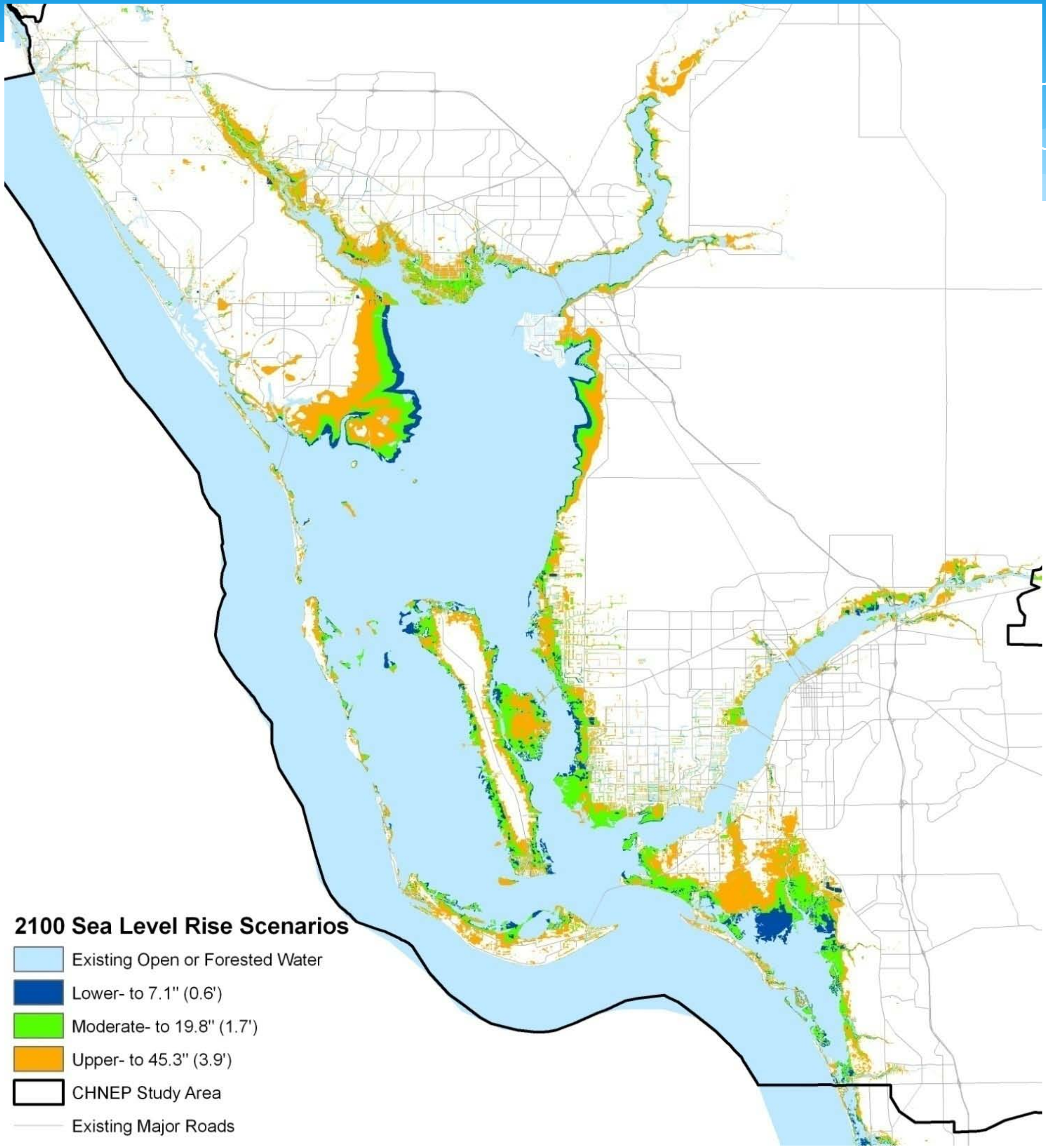
SWFRPC 2008

Habitat and Species Changes

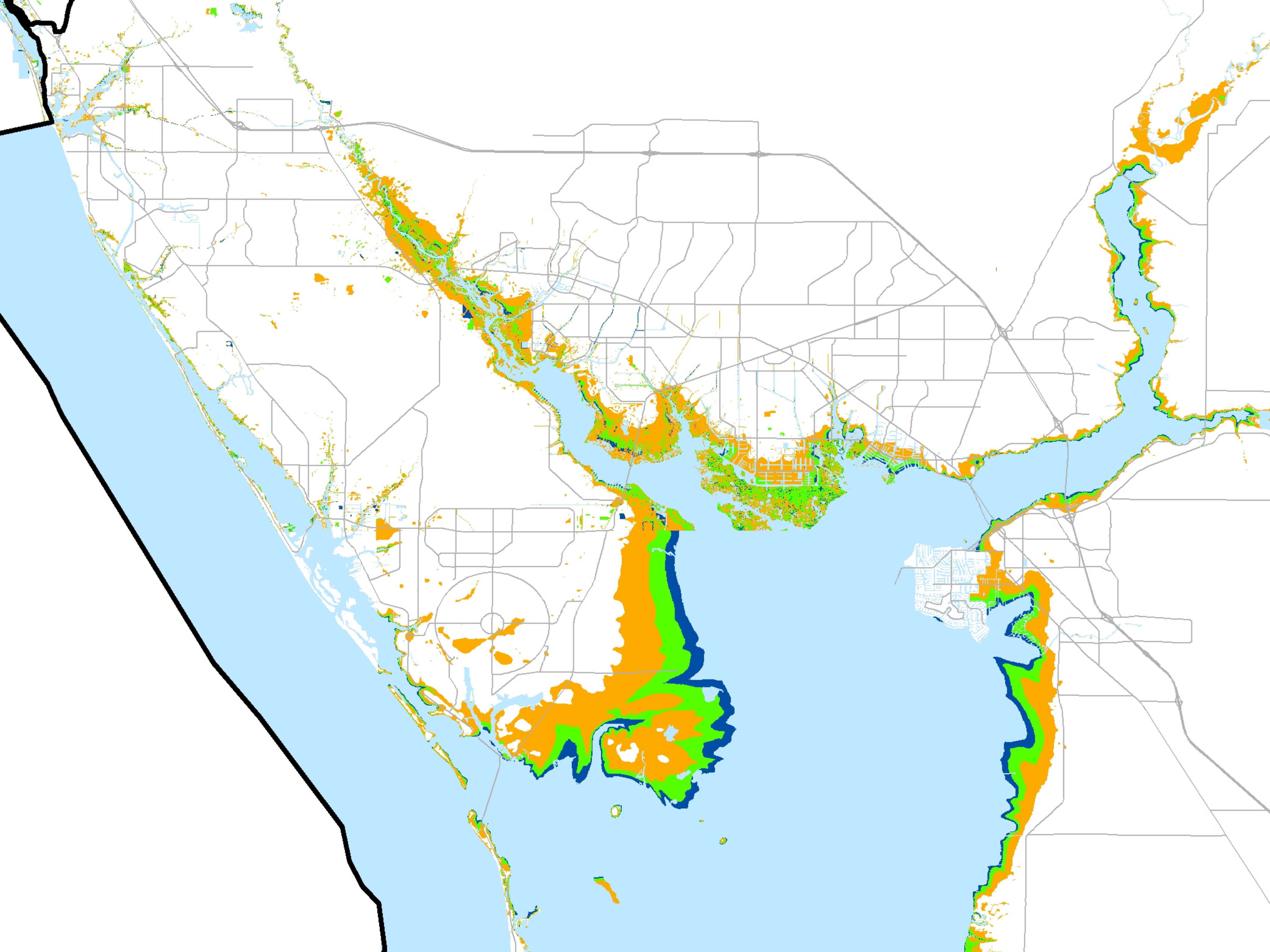


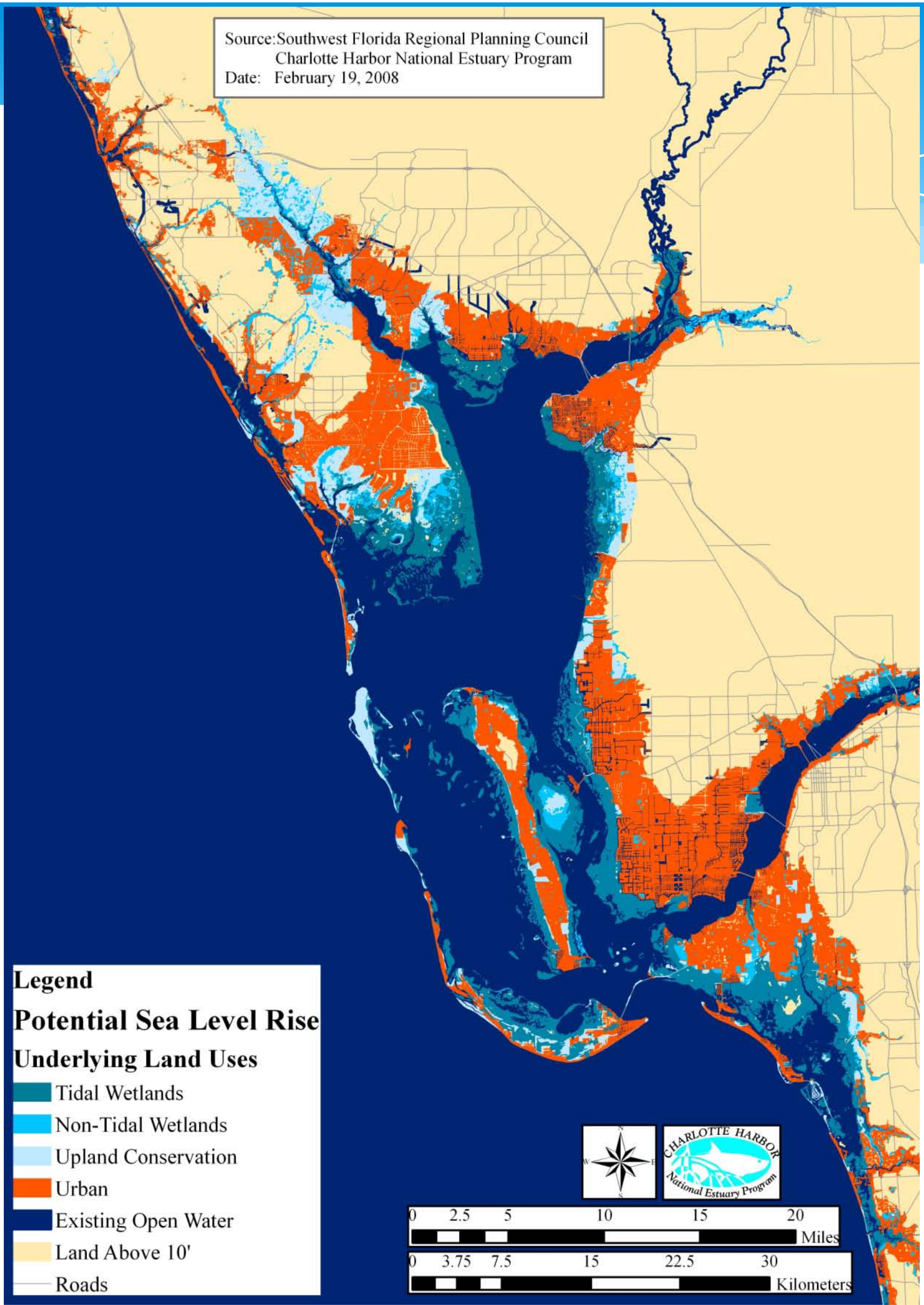
Symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols/), University of Maryland Center for Environmental Science.


Increasing
E/T
Rainfall Pattern
Changes
Increasing
Water Temperature
Water Table
Changes
Gulf of Mexico
Barrier Island
Shift Landward
New Lagoon
Mangrove
Fringe
Tropical
Hammock
Tidal
Creek
Freshwater
Creek
Compression
of
Upland &
Freshwater
Wetland
Systems
Charlotte Harbor National Estuary Program
By: Lisa B. Beever, PhD, AICP
Date: 4/16/08
Charlotte Harbor National Estuary Program
Habitat Migration-2200
Southwest Florida
Symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols/),
University of Maryland Center for Environmental Science.



2100 Sea Level Rise Scenarios
Existing Open or Forested Water
Lower- to 7.1'' (0.6')
Moderate- to 19.8'' (1.7')
Upper- to 45.3'' (3.9')
CHNEP Study Area
Existing Major Roads




Source:Southwest Florida Regional Planning Council
Charlotte Harbor National Estuary Program
Date: February 19, 2008
Legend
Potential Sea Level Rise
Underlying Land Uses
Tidal Wetlands
Non-Tidal Wetlands
Upland Conservation
Urban
Existing Open Water
Land Above 10'
Roads
Charlotte Harbor National Estuary Program
0 2.5 5 10 15 20 Miles
0 3.75 7.5 15 22.5 30 Kilometers

What are the coastal ecosystems of Charlotte County, Florida?

* Seagrass Bed
* Oyster Bar
* Mangroves
* Salt Marsh
* Brackish Marsh
* Low Dunes
* Coastal Strand
* Coastal Xeric Scrub
* Hydric, Mesic and Xeric Pinelands

What are the effects of sea level rise on ***coastal habitats*** in Florida?

Increased vulnerability to coastal flooding and storm surge

» *Habitat damage/destruction during storms*

Increased shoreline erosion

» *Habitat loss/migration*

Salt water intrusion into fresh water sources

» *Changes to plant and animal communities*

Changes to tides and tidal regimes

» *Changes to plant and animal communities*

Increased inundation

» *Habitat loss, habitat migration*

Deterioration of coastal infrastructure

» *Hazard to wildlife from debris*

Seagrass

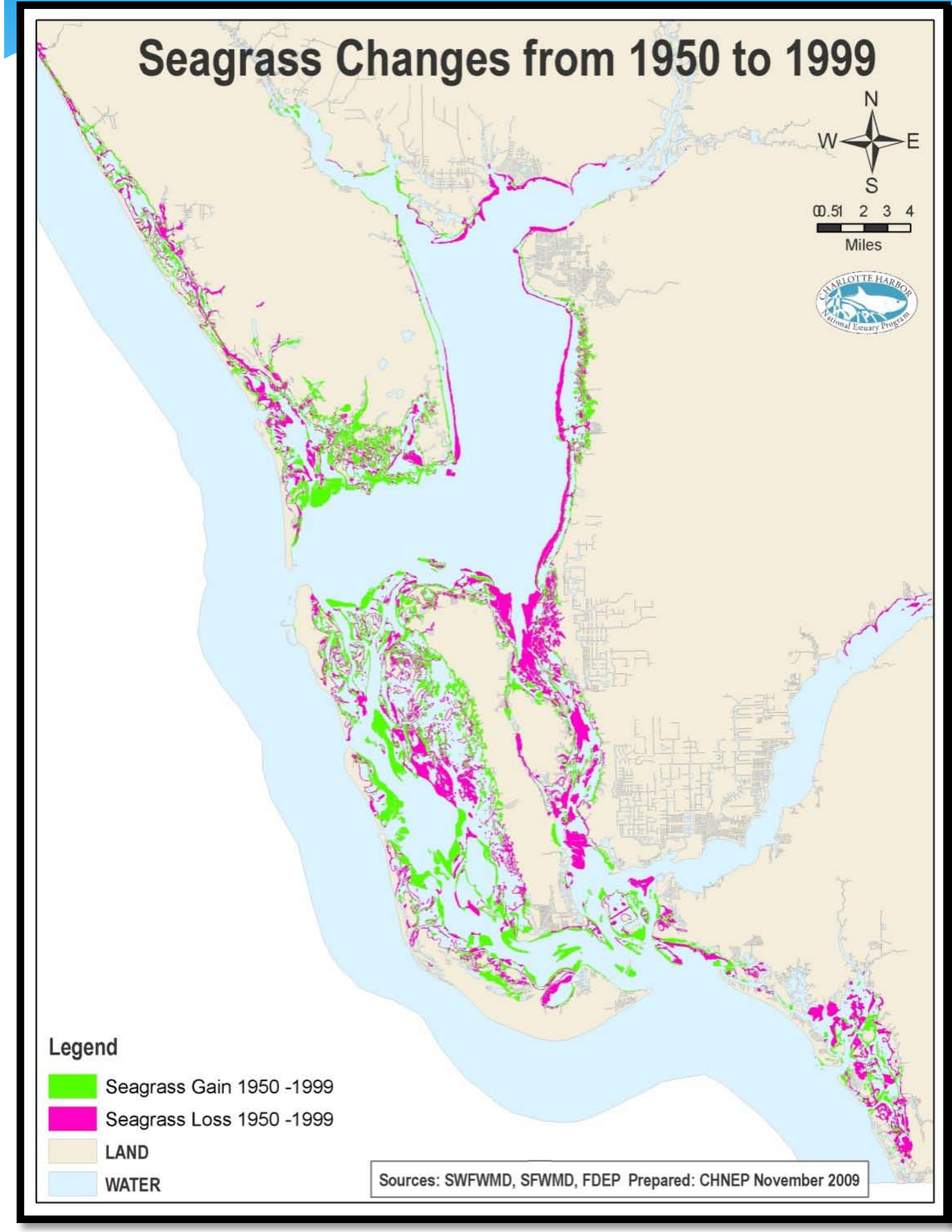
* Sea level rise is expected to cause migration of seagrass beds landward …due to less penetration of sunlight… Where natural shoreline exists, seagrass beds are expected to migrate into appropriate depths. Where opportunities for landward migration of the shallow subtidal zone is blocked by bulkheads or other barriers, the seagrass beds will be reduced and then disappear if the water depths at the sea wall barriers exceeds the light extinction coefficient for the seagrasses…

Beever et al. 2009

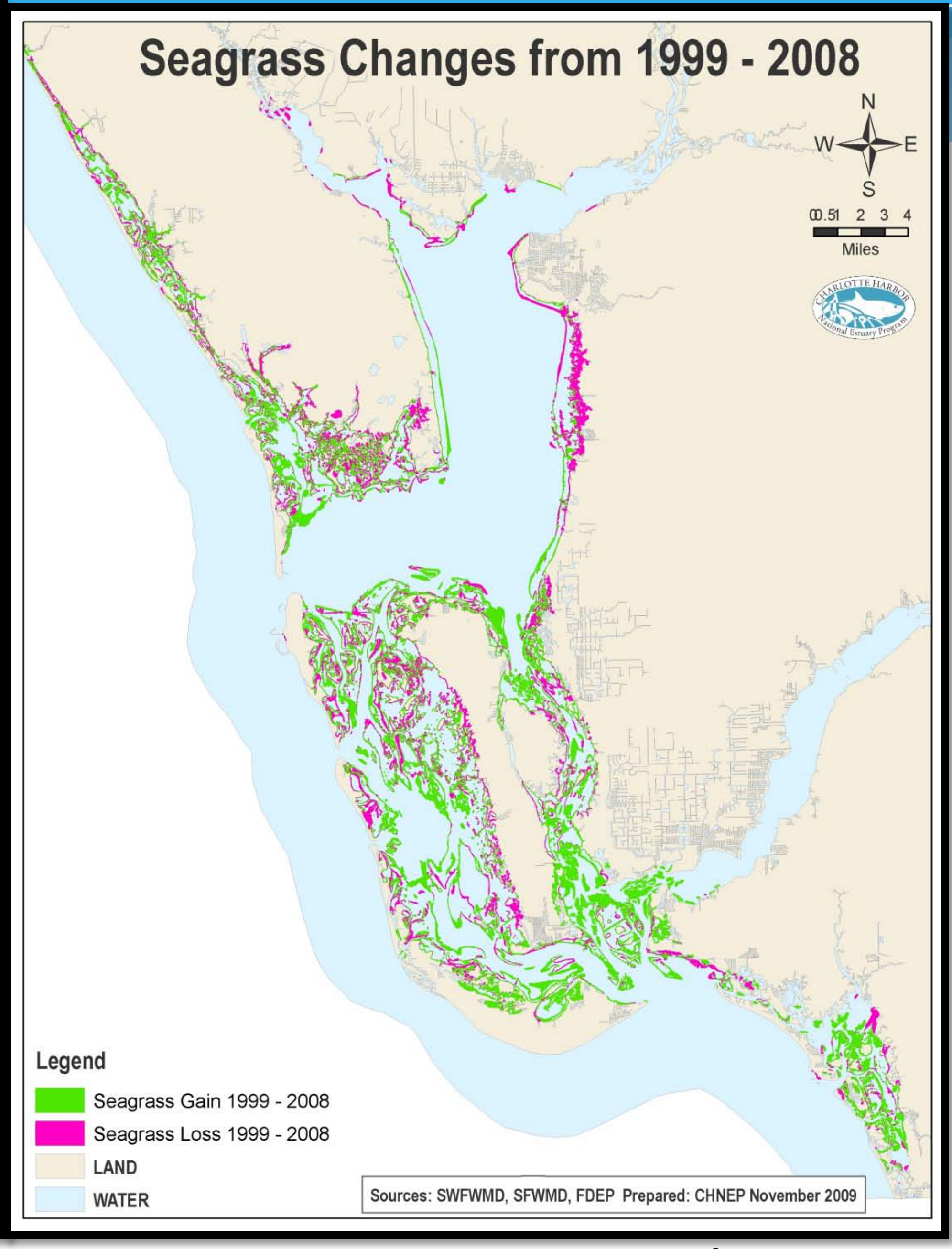
Vulnerable Species:

Argopectin irradians

http://www.tbep.org/portrait/featured_creature_12.html



Seagrass Changes from 1950 to 1999
N
W
E
S
0 0.5 1 2 3 4
Miles
Legend
Seagrass Gain 1950 -1999
Seagrass Loss 1950 -1999
LAND
WATER
Sources: SWFWMD, SFWMD, FDEP Prepared: CHNEP November 2009



Seagrass Changes from 1999 - 2008
N
W
E
S
0 0.5 1 2 3 4
Miles
Legend
Seagrass Gain 1999 - 2008
Seagrass Loss 1999 - 2008
LAND
WATER
Sources: SWFWMD, SFWMD, FDEP Prepared: CHNEP November 2009

Ott 2010

Oysters

http://www.dep.state.fl.us/northwest/ecosys/section/restorationoyster.htm

Oyster restoration used as protection for the shoreline against SLR

* Oyster reefs will become **less productive and prolific,** particularly in southwestern Florida where oysters are restricted to intertidal habitat. Higher rates of sea level rise will result in upstream movement of optimal salinity regimes for oysters, and **reef production will shift upstream** into the narrow portions of estuaries and rivers. Given the reduced amount of space, area for **reef development will be decreased.** This may have the confounding effect of altering estuarine ecology by reducing the amount of oyster reef habitat in estuarine areas (Savarese and Volety, 2001).

Estuaries, mangroves, salt marsh and brackish marsh

Emergent Habitats

Mangroves

- Can migrate landward if sea level rises slowly
- Sediment surface elevations are not keeping pace with current rate of SLR (Gilman et al. 2008)
- Because mangroves may replace other species, overall coverage may increase.
- For example, Charlotte Harbor may gain at least 75% area of mangroves by 2100 if rate of rise is slow.

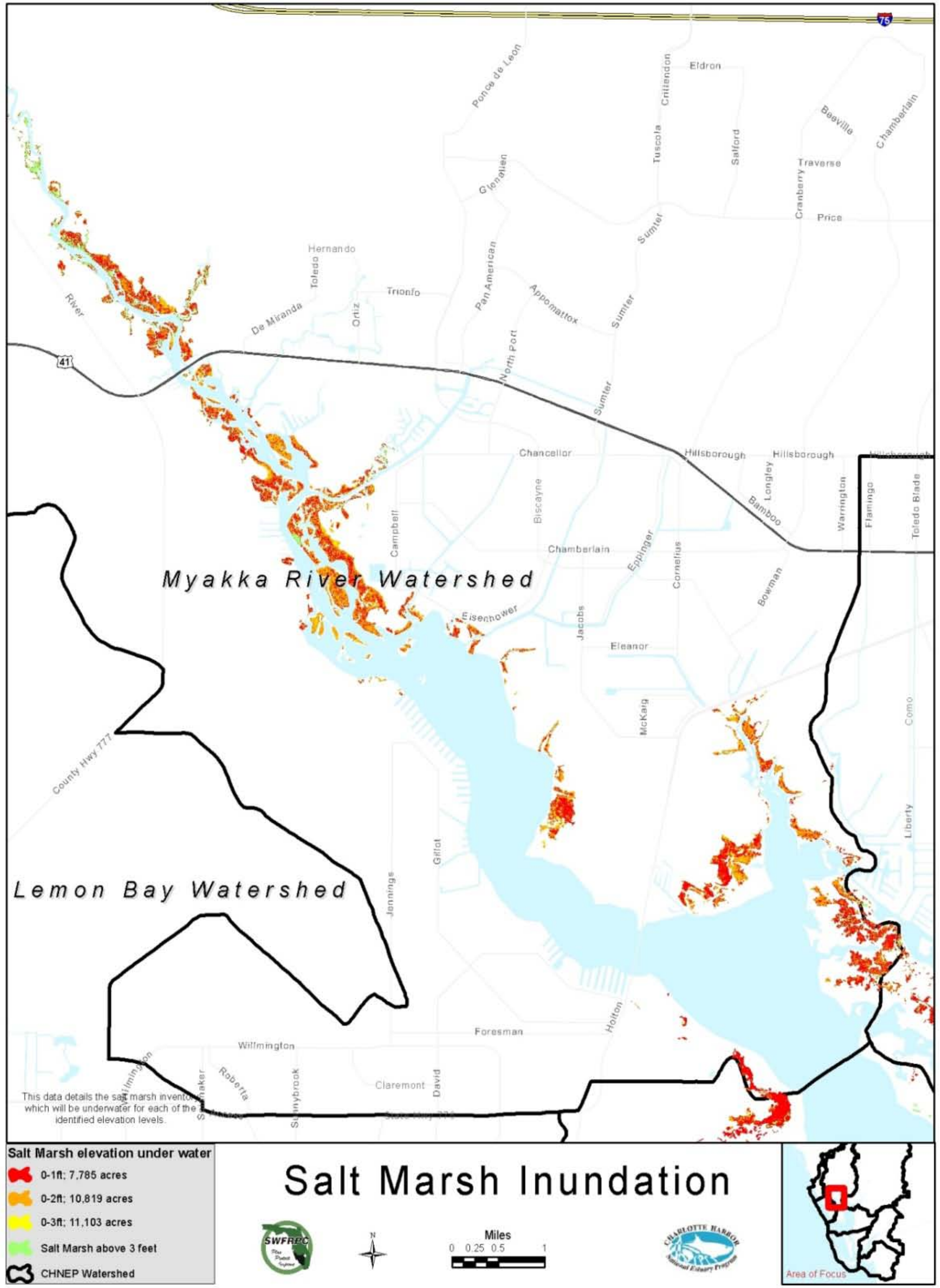
Salt Marsh

Vulnerable Species:

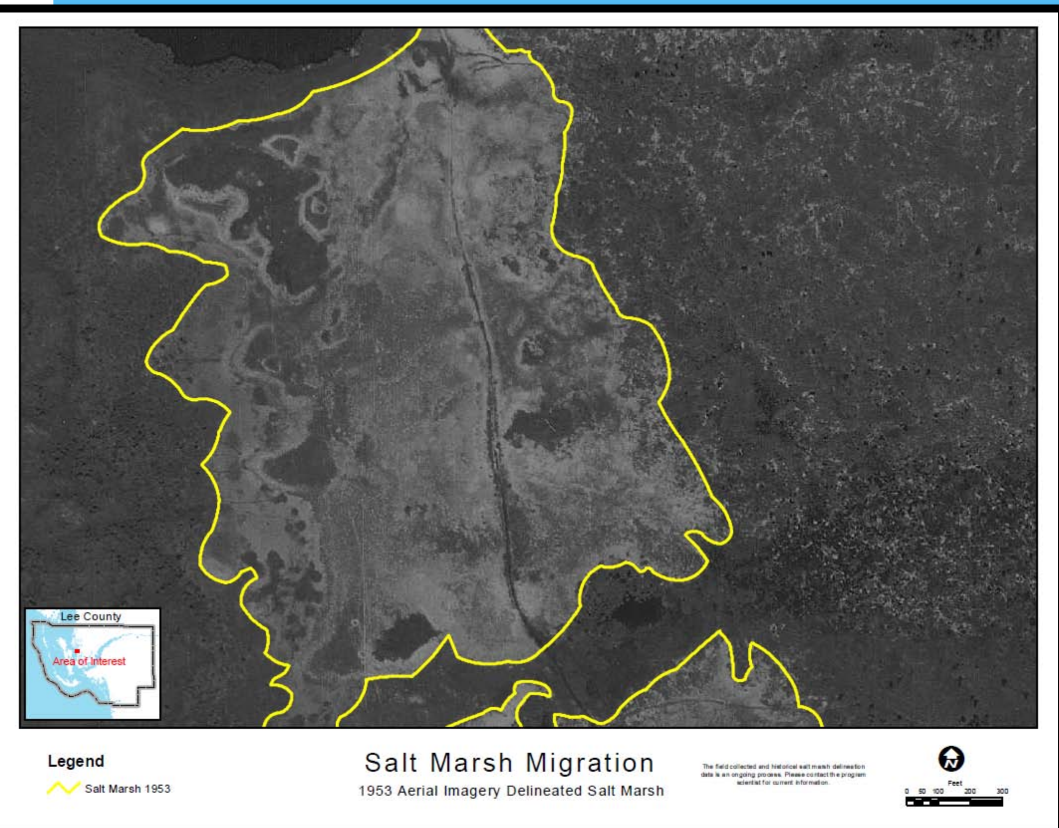
Black-necked Stilt

Potentially 89% loss of current salt marsh acreage in Charlotte Harbor by 2100.

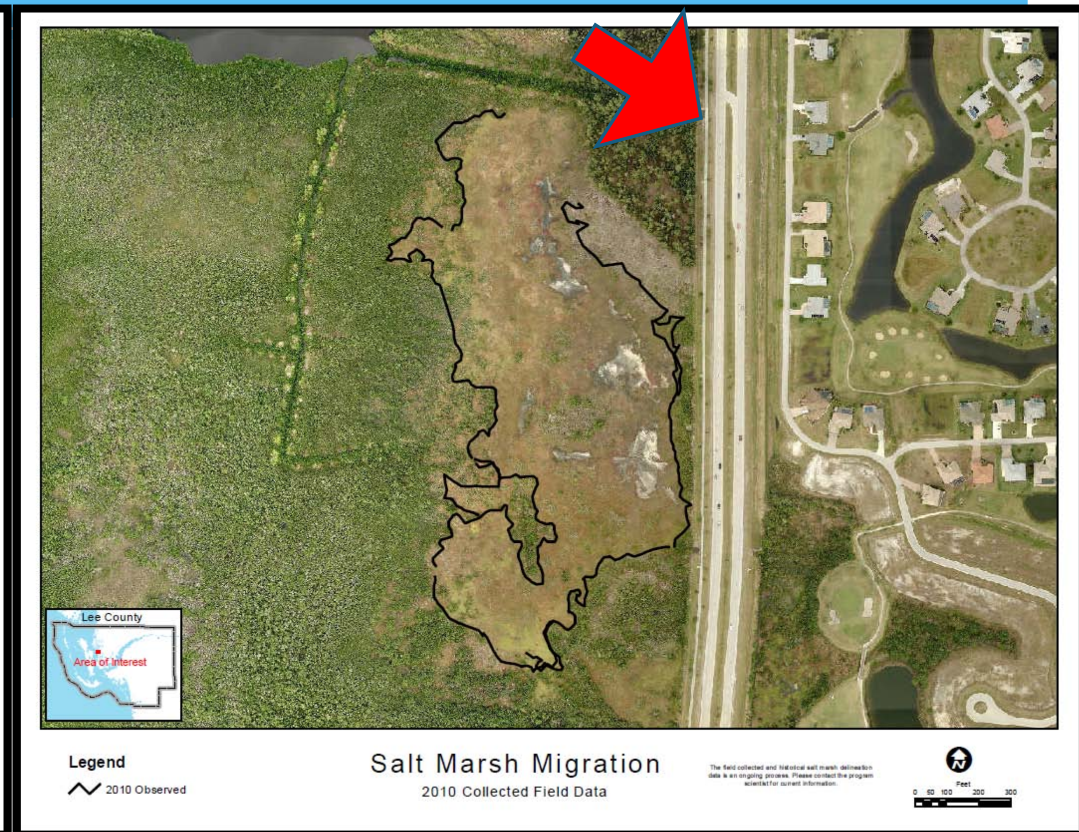
- If there is no accretion of inorganic sediment or peat, the seaward portions of the salt marsh become flooded so that marsh grass drowns and marsh soils erode; portions of the high marsh become low marsh; and adjacent upland areas are flooded at spring tide, converting to high marsh.
- If sea level rise rates are slow enough, marshes may migrate up-gradient until they encounter an obstacle.


Salt Marsh Inundation
Myakka River Watershed
Lemon Bay Watershed
Salt Marsh elevation under water
0-1ft; 7,785 acres
0-2ft; 10,819 acres
0-3ft; 11,103 acres
Salt Marsh above 3 feet
CHNEP Watershed
This data details the salt marsh inventory which will be underwater for each of the identified elevation levels.
Miles
0 0.25 0.5 1
Area of Focus
Eldron
Traverse
Price
Hernando
Trionfo
De Miranda
Chancellor
Hillsborough
Chamberlain
Eisenhower
Eleanor
Foresman
Wilmington
Claremont
County Hwy 777

Salt Marsh Migration

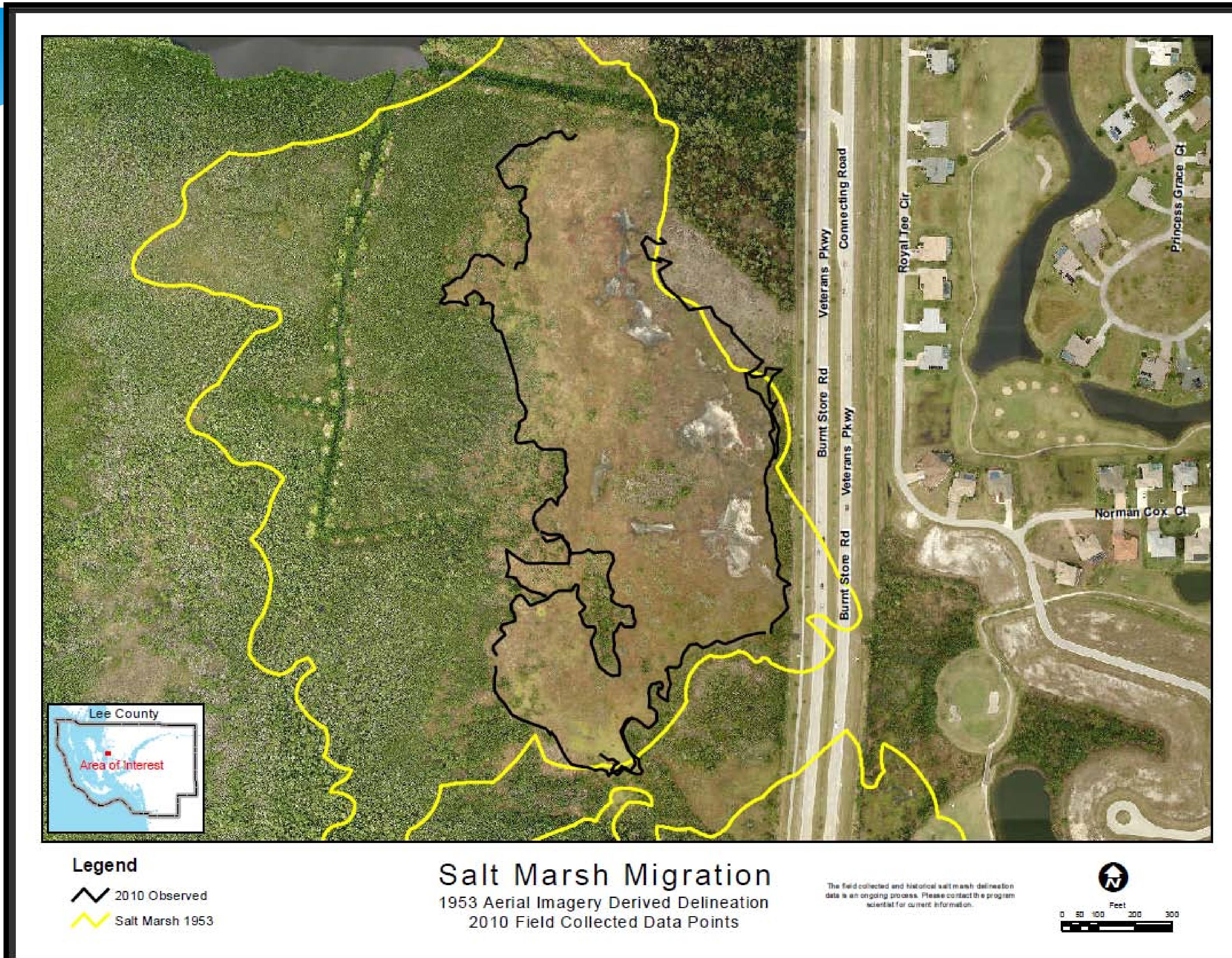


1953

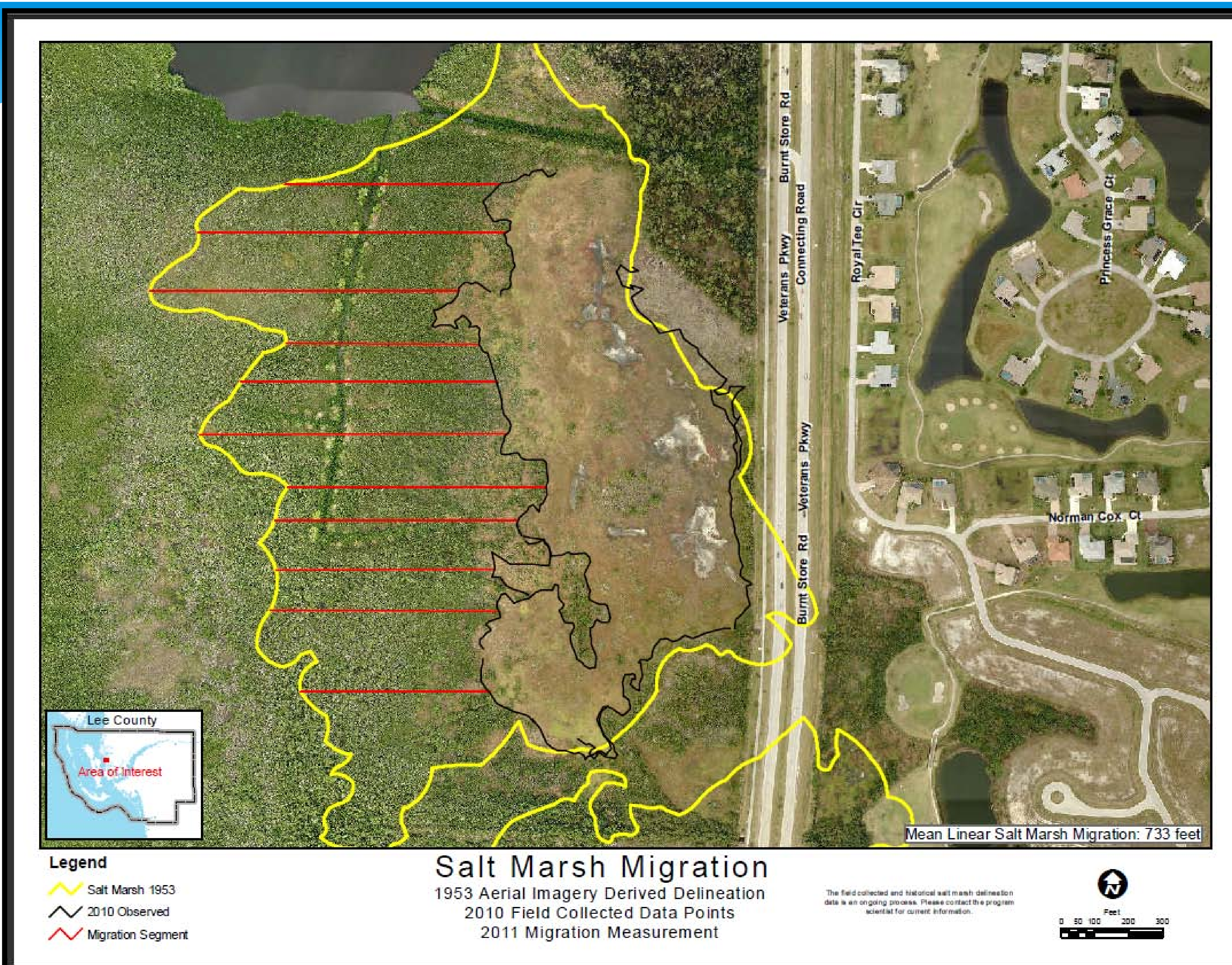


2010

SWFRPC 2011


Veterans Pkwy
Connecting Road
Royal Tee Cir
Princess Grace Ct
Burnt Store Rd
Veterans Pkwy
Burnt Store Rd
Norman Cox Ct
Lee County
Area of Interest
Legend
2010 Observed
Salt Marsh 1953
Salt Marsh Migration
1953 Aerial Imagery Derived Delineation
2010 Field Collected Data Points
The field collected and historical salt marsh delineation data is an ongoing process. Please contact the program scientist for current information.
N
Feet
0 50 100 200 300

SWFRPC 2011


Burnt Store Rd
Connecting Road
Veterans Pkwy
Royal Tee Cir
Princess Grace Ct
Veterans Pkwy
Burnt Store Rd
Norman Cox Ct
Lee County
Area of Interest
Mean Linear Salt Marsh Migration: 733 feet
Legend
Salt Marsh 1953
2010 Observed
Migration Segment
Salt Marsh Migration
1953 Aerial Imagery Derived Delineation
2010 Field Collected Data Points
2011 Migration Measurement
The field collected and historical salt marsh delineation data is an ongoing process. Please contact the program scientist for current information.
N
Feet
0 50 100 200 300

Brackish Marsh

- Altered tidal ranges
- Tidal asymmetry leading to changes in tidal mixing
- Changes in sediment transport
- Migration of estuarine salinity gradients inland
- Migration inland of marsh species zonation
- Altered diversity dominant plant species
- Structural and functional habitat changes, and
- Less sunlight available to submerged marsh plants

Vulnerable Species:

Wood Stork

Dunes, coastal scrub, coastal strand, coastal pinelands

Uplands

Beaches and Dunes

Vulnerable Species:

Vulnerable Species:
Least Tern

* Dunes provide good protection for uplands against wave action and storm surge.
* BUT…
* Erosion of beaches and dunes can be expected to accelerate with sea level rise and much of the remaining low-lying landscape will likely be overtopped without significant topographic change; i.e., after exceeding local topographic elevations, the shoreline will simply advance landward to the next emergent feature until it too is overtopped.
* On barrier islands the porosity and permeability of unconsolidated sands will allow infiltration beneath and behind as rising waters migrate in response to hydrostatic pressure.

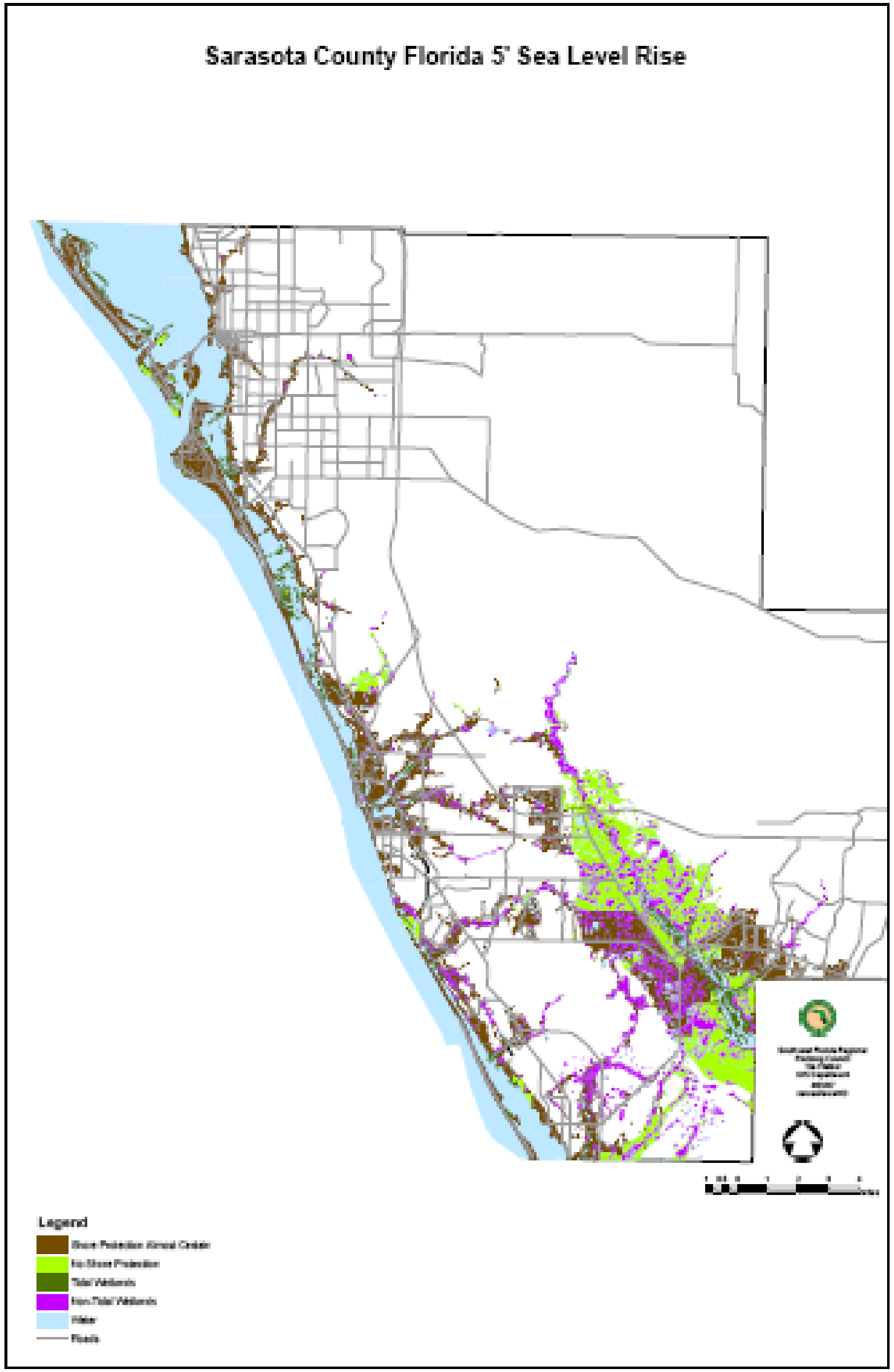
Coastal Scrub, Strand and Pinewoods

Vulnerable Species:

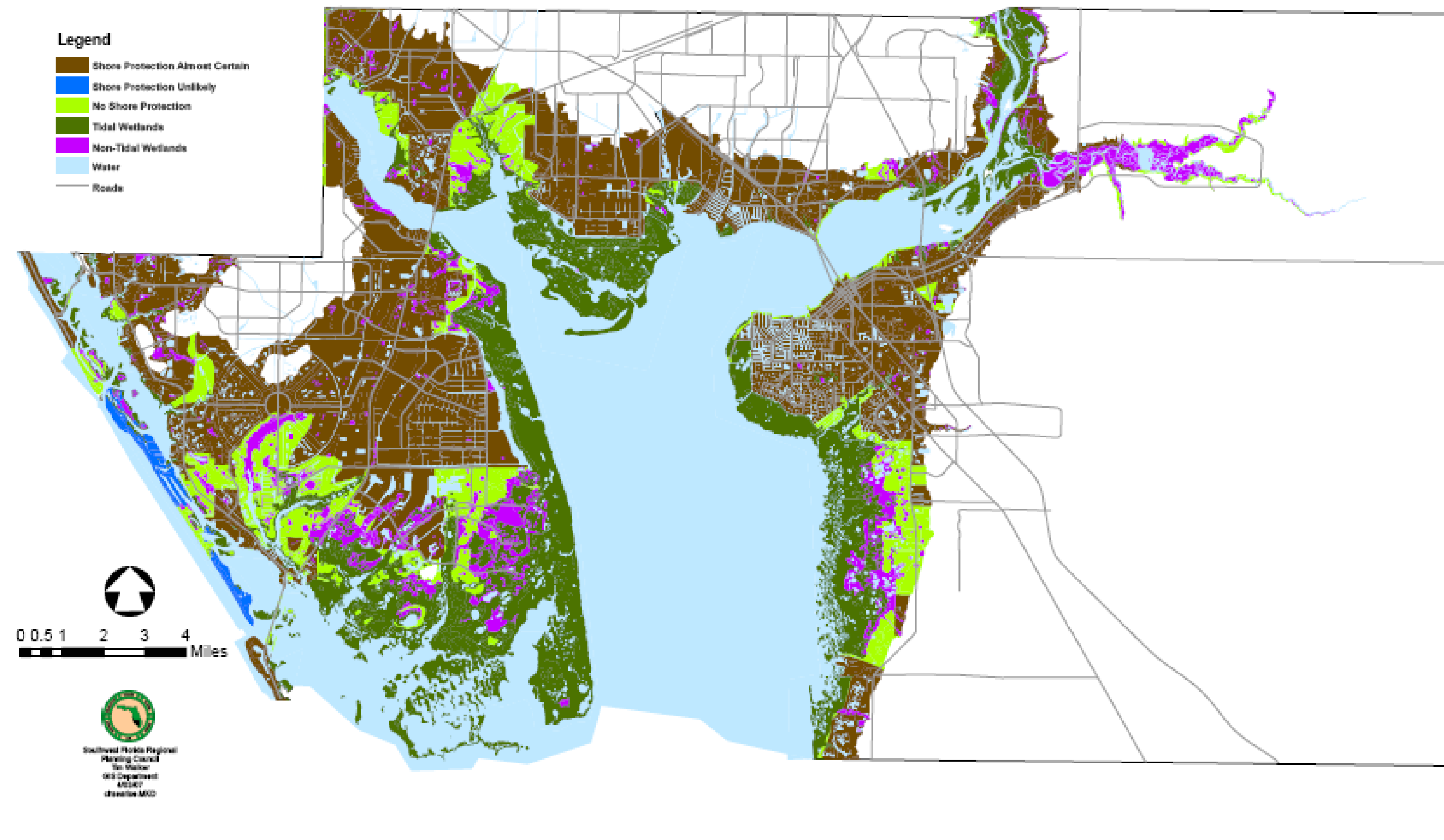
* Human relocation will eliminate the rarest of the upland habitats along with endemic animals, such as the Florida scrub jay, and plants, such as the wild rosemary.
* Conflicts with wildlife may become more common.

Vulnerable Species:
Florida scrub jay

Habitat	SLR Effect	Potential Response
Seagrass bed	Increased depths	Migration up-gradient (rate?)
Oyster bar	Increased salinity, Increased depths	Species loss, habitat migration up-gradient (rate?)
Estuary	More open water, less seagrass, less tidal flat, more mangroves	Loss of submerged species, changes to communities
Mangroves	Migration, Drowning from overtopping pneumatophores, species change from altered salinities	Changes to species compositions and associated species, loss and/or increase of mangroves
Salt marsh	Migration, drowning, conversion to mangrove	Migration, habitat loss, change to communities, conversion to open water
Brackish marsh	Increased salinity, inundation	Changes to plant/animal communities, conversion to open water
Beaches and Dunes	Erosion	Overtopping of dunes, loss of habitat, migration
Coastal strand	Use by humans who relocate	Competition for space, migration, loss
Coastal scrub	Use by humans who relocate	Competition for space, migration, loss
Coastal pinewoods	Use by humans who relocate	Competition for space, migration, loss

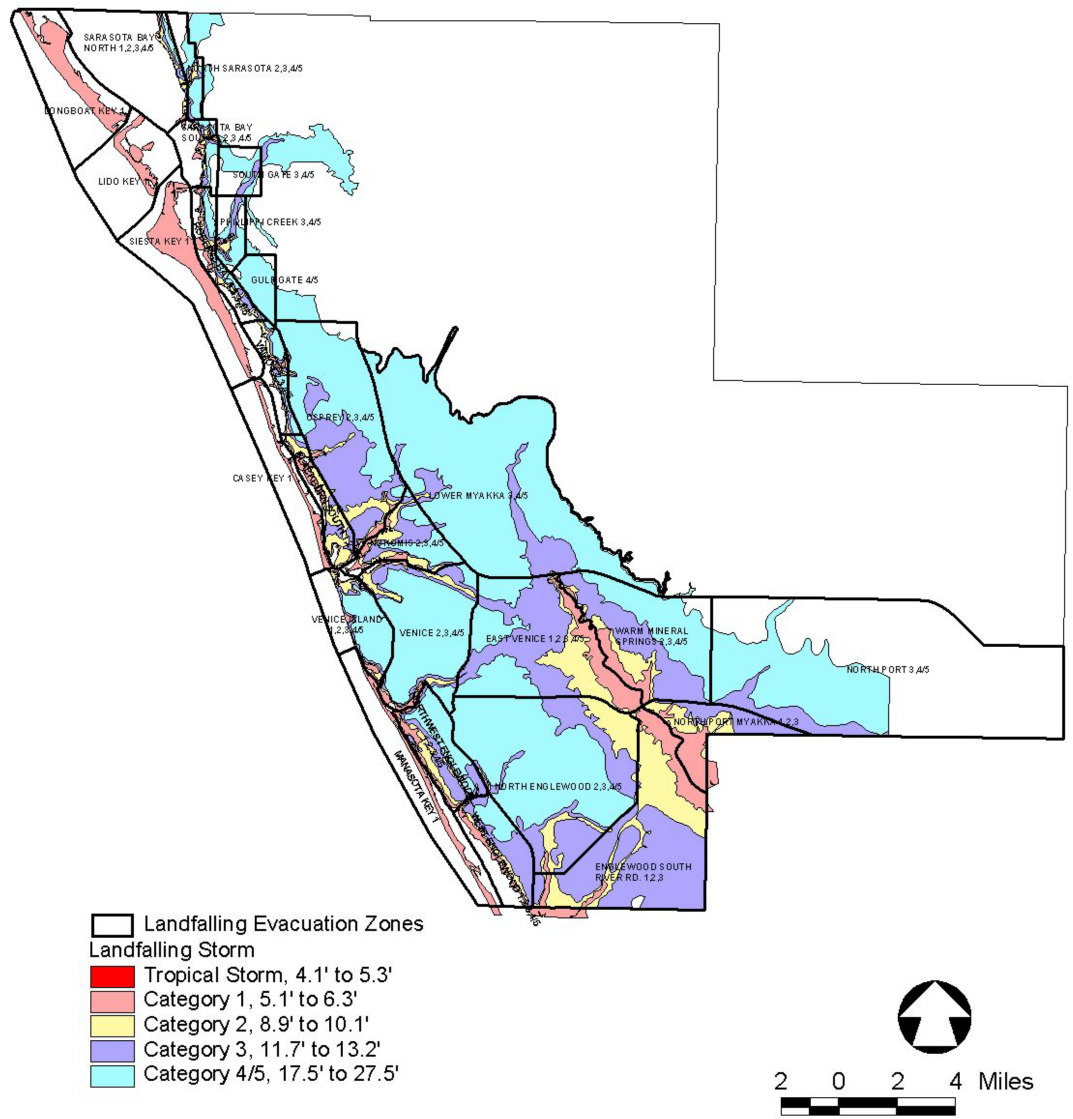

Sarasota County Florida 5' Sea Level Rise
Legend

Charlotte County Florida 5' Sea Level Rise



Acres of habitat or land use at and below different storm surge elevations in Sarasota County 2009, Note number includes the prior acreage.

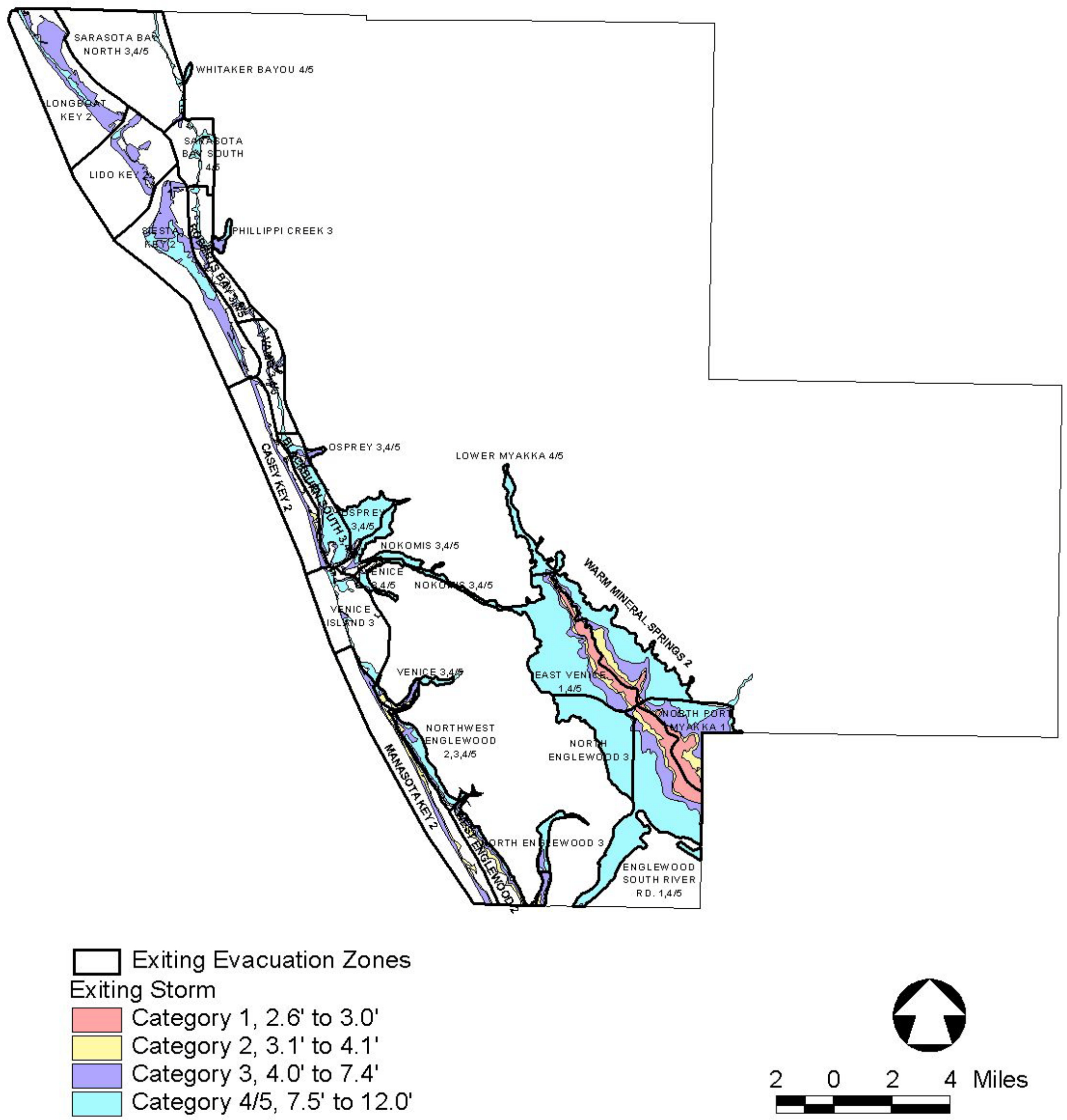
Sarasota	Cat 1	Cat 2	Cat 3	Cat 4
	5.1' to 6.3'	8.9' to 10.1'	11.7' to 13.2'	17.5' to 27.5'
Coastal Strand	37.1	37.1	37.1	37.1
Sand/Beach	346.8	356.8	366.3	366.3
Xeric Oak Scrub	12.3	35.2	118.9	130.8
Sand Pine Scrub	6.3	10.0	17.0	26.7
Dry Prairie	308.8	2,706.1	11,135.2	20,995.3
Mixed Pine-Hardwood Forest	357.9	920.3	2,339.2	4,224.3
Hardwood Hammocks and Forest	535.6	1,381.4	3,384.6	5,809.0
Pinelands	1,397.1	3,898.7	8,803.4	16,759.2
Freshwater Marsh and Wet Prairie	159.6	1,121.9	2,870.8	7,705.7
Shrub Swamp	191.2	536.5	1,112.2	2,761.7
Bay Swamp	0.0	0.0	4.4	5.3
Cypress Swamp	153.1	274.8	536.9	1,070.5
Cypress/Pine/Cabbage Palm	0.7	0.7	0.7	0.7
Mixed Wetland Forest	285.4	453.7	780.4	1,255.1
Hardwood Swamp	454.5	1,041.4	2,368.7	4,419.5
Salt Marsh	1,198.7	1,283.3	1,300.1	1,319.9
Mangrove Swamp	665.9	695.2	699.7	701.1
Open Water	2,134.2	2,489.8	3,436.2	6,164.0
Shrub and Brushland	72.9	212.8	614.7	1,478.9
Grassland	3.4	12.1	86.3	239.4
Bare Soil/Clear-cut	100.8	143.0	352.1	685.1
Improved Pasture	6.7	186.2	1,399.9	8,614.8
Citrus	0.0	2.4	64.3	536.6
Row/Field Crops	0.0	0.0	58.4	216.4
Other Agriculture	1.2	7.2	97.8	244.0
High Impact Urban	4,649.6	8,722.6	17,695.0	41,594.7
Low Impact Urban	948.5	2,157.1	5,588.7	13,592.4
Extractive	0.0	0.0	5.9	379.7
Total	14,028.4	28,686.5	65,275.1	141,334.1



MAP 3
SARASOTA COUNTY
LANDFALLING STORM SURGE AND EVACUATION ZONES

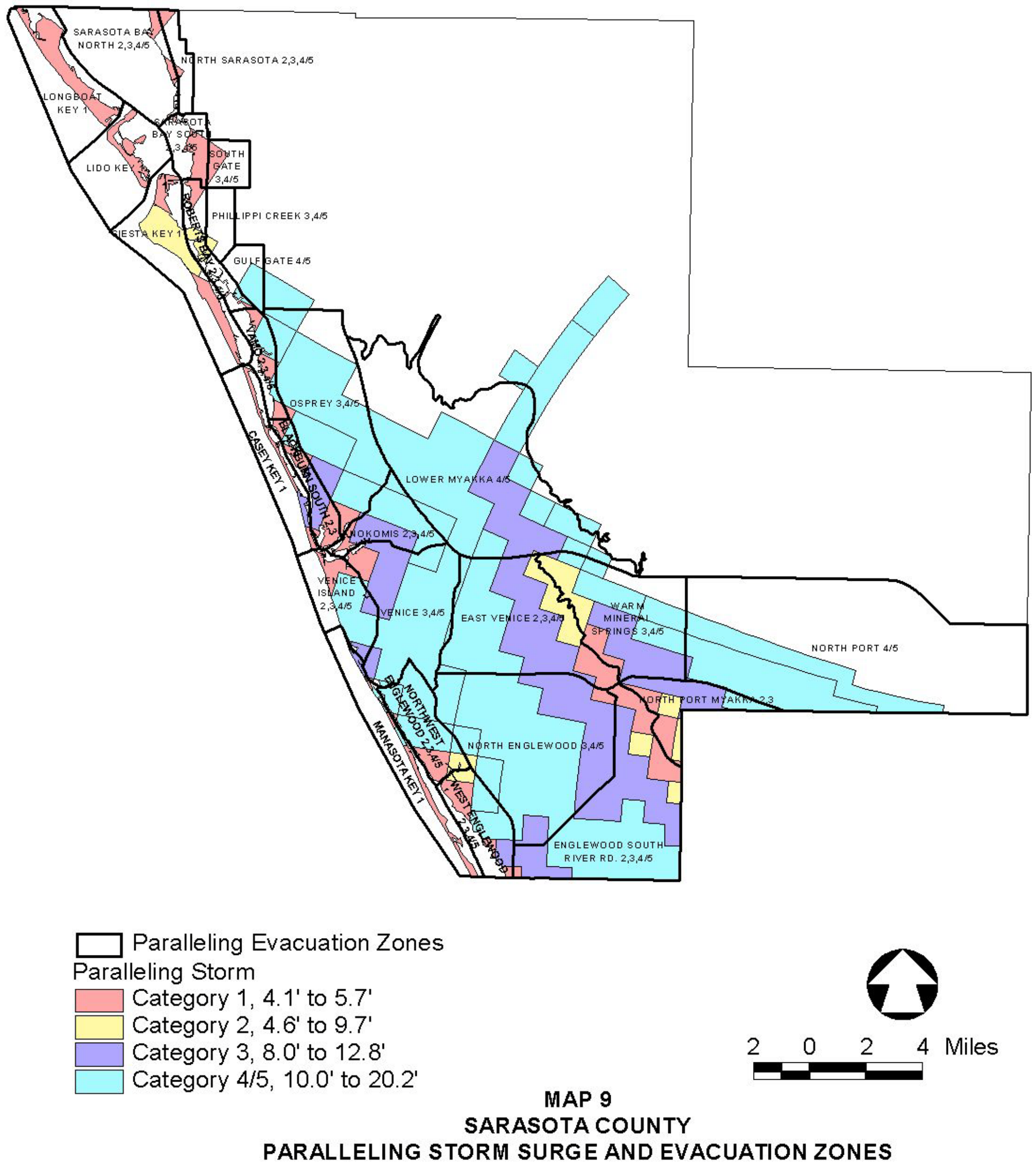
Land Falling Storm

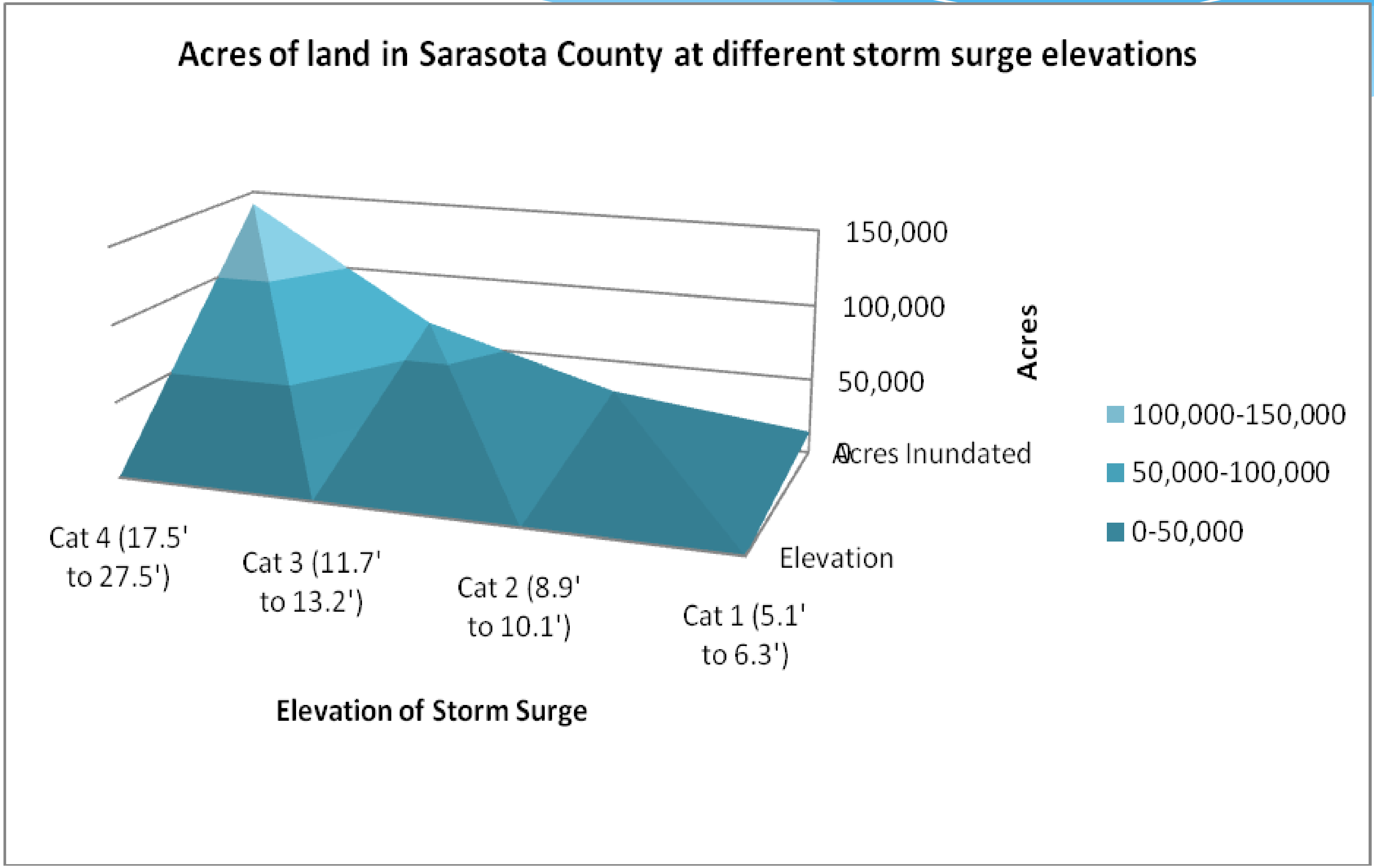
Exiting Storm



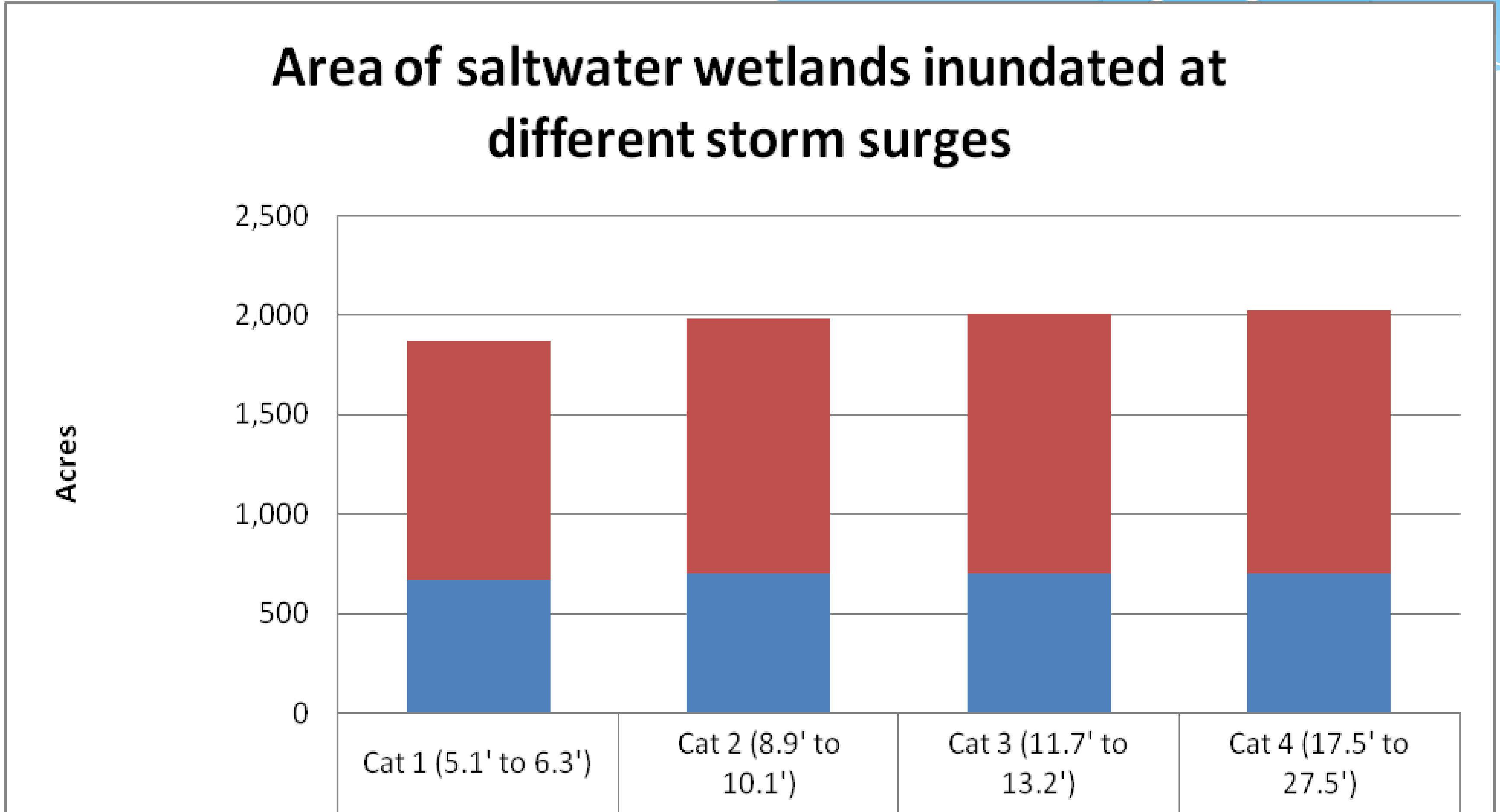
MAP 10
SARASOTA COUNTY
EXITING STORM SURGE AND EVACUATION ZONES

Paralleling Storm





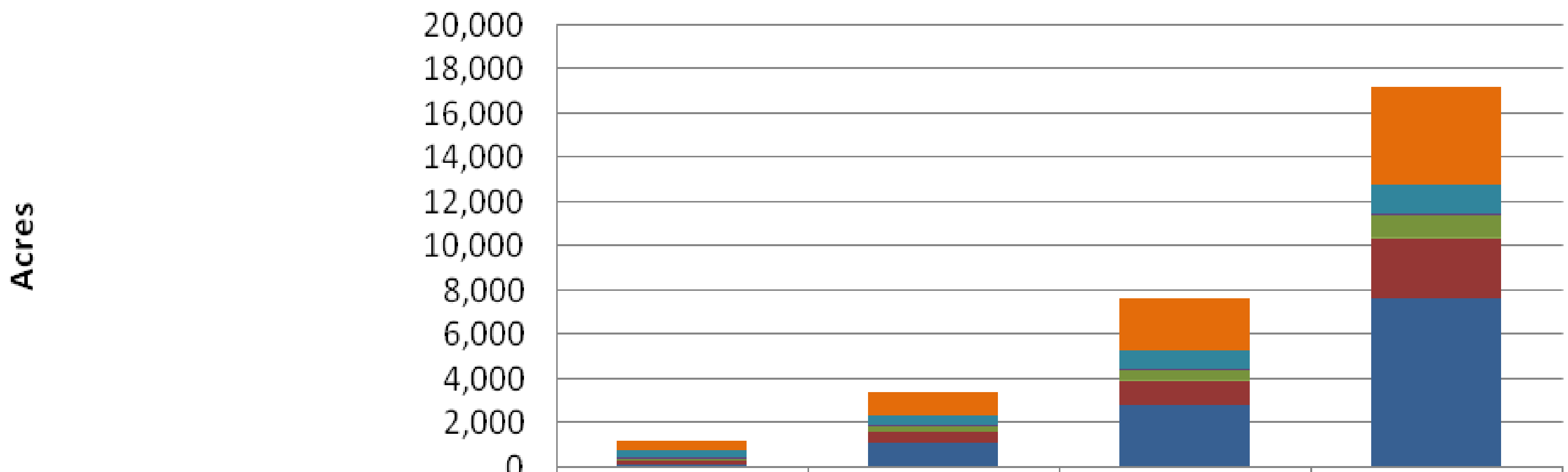
Acres of habitat or land at and below different storm surge elevations in Sarasota County 2009



	Cat 1 (5.1' to 6.3')	Cat 2 (8.9' to 10.1')	Cat 3 (11.7' to 13.2')	Cat 4 (17.5' to 27.5')
Salt Marsh	1,198.7	1,283.3	1,300.1	1,319.9
Mangrove Swamp	665.9	695.2	699.7	701.1

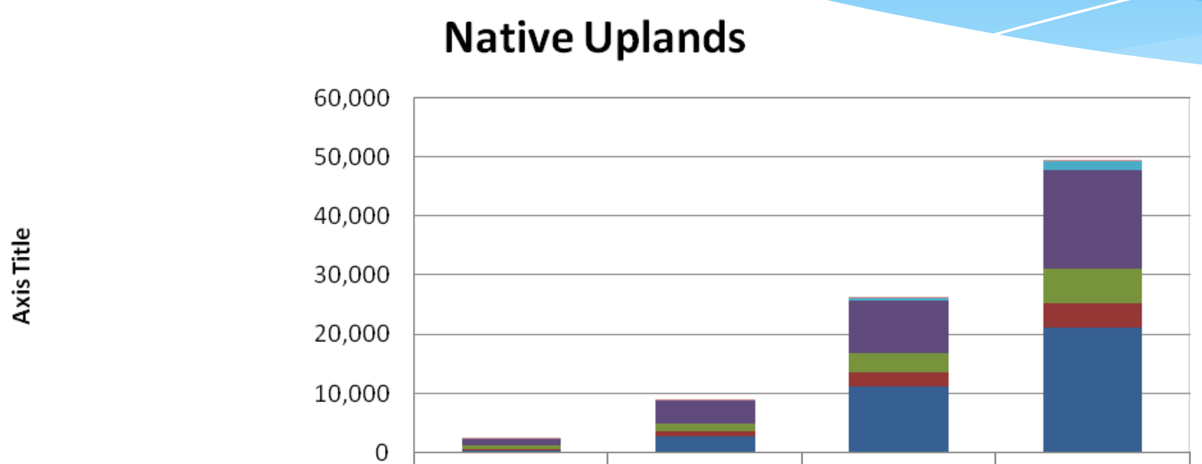
Acres of mangrove and salt marsh habitat at and below different storm surge elevations in Sarasota County 2009

Freshwater Wetlands



	Cat 1 (5.1' to 6.3')	Cat 2 (8.9' to 10.1')	Cat 3 (11.7' to 13.2')	Cat 4 (17.5' to 27.5')
Hardwood Swamp	454.5	1,041.4	2,368.7	4,419.5
Mixed Wetland Forest	285.4	453.7	780.4	1,255.1
Cypress/Pine/Cabbage Palm	0.7	0.7	0.7	0.7
Cypress Swamp	153.1	274.8	536.9	1,070.5
Bay Swamp	0.0	0.0	4.4	5.3
Shrub Swamp	191.2	536.5	1,112.2	2,761.7
Freshwater Marsh and Wet Prairie	159.6	1,121.9	2,870.8	7,705.7

Acres of freshwater wetlands habitat in Sarasota County at and below different storm surge elevations 2009



	Cat 1 (5.1' to 6.3')	Cat 2 (8.9' to 10.1')	Cat 3 (11.7' to 13.2')	Cat 4 (17.5' to 27.5')
Grassland	3.4	12.1	86.3	239.4
Shrub and Brushland	72.9	212.8	614.7	1,478.9
Pinelands	1,397.1	3,898.7	8,803.4	16,759.2
Hardwood Hammocks and Forest	535.6	1,381.4	3,384.6	5,809.0
Mixed Pine-Hardwood Forest	357.9	920.3	2,339.2	4,224.3
Dry Prairie	308.8	2,706.1	11,135.2	20,995.3
Sand Pine Scrub	6.3	10.0	17.0	26.7
Xeric Oak Scrub	12.3	35.2	118.9	130.8

Acres of uplands habitat in Sarasota County at and below different storm surge elevations 2009

Note; tropical storm maps were not available from Sarasota County

Future Land Use	Sarasota
Agriculture	1,188
Commercial	1,082
Estate	2,894
Industrial	382
Multi-Family	3,891
Preserve	22,737
Single Family	45,991
Total Acreage	78,165

Region Future Land Use Acreage Subject to 10 Feet NGVD Sea Level Rise (equivalent to 9.2 feet above mean sea level or subject to daily tidal inundation with 8.2 feet of sea level rise)

Protection Scenarios	Sarasota
0' to 10' NGVD Uplands, Not Protected	16,608
0' to 10' NGVD Uplands, Protection Likely But Wetland Migration Possible	17,979
0' to 5' NGVD Uplands, Protection Not Likely	0
Wetlands	8,807
Total Acreage	**43,393**

No Protection and Limited Protection Acreage Subject to 10 Feet NGVD Sea Level Rise (equivalent to 9.2 feet above mean sea level or subject to daily tidal inundation with 8.2 feet of sea level rise)

SLR Impacts on our Built Environment

* SLR vs. Storm Surge
* Flooding
  * Tidal
  * Rain-fall induced and poor drainage
* Infrastructure Damage
* Erosion: damage and need for more nourishment

Storm Surge & SLR

- SLR will dramatically exacerbate the frequency of serious surge events
- New Climate Central Report:
  - SW Fla. can expect 100-year storm surge events as frequently as every 30 years*
  - Other areas much worse—as often as every 1-5 years

*Tebaldi, *et al*. Figure 4

Critical Facilities & Surge: Facilities Already Subject to TS/Cat. 1 Surge

1 airport	3 boat locks
2 clinics	4 law-enforcement facilities
19 communication towers	7 elementary/middle schools
14 community centers	3 high schools
15 electrical facilities	2 private schools
10 EMS stations or facilities	1 community college
18 government facilities	1 telephone remote building
1 hospital	12 telephone switching stations

Source: Comprehensive Southwest Florida/ Charlotte Harbor Climate Change Vulnerability Assessment

Flooding

* Increased tidal flooding
  * Intersection of Berry and Retta in Punta Gorda

Photo: Mitchell Austin, City of Punta Gorda

Roads

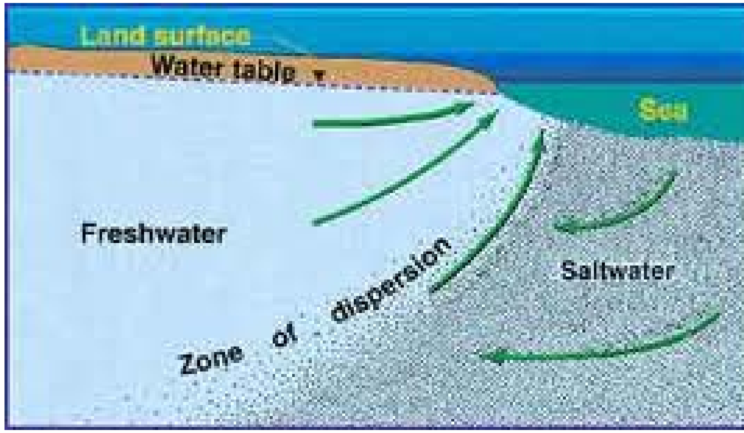
	Limited Access Highways (Miles)	Other Highways (Miles)	Major Roads (Miles)	Railroads (Miles)
Florida Total	75.5	390.8	1,972.4	181.3
Charlotte County	1.9	6.1	51.4	--

Road infrastructure vulnerable to 27” of SLR

Source: Table 28 of Comprehensive Southwest Florida/ Charlotte Harbor Climate Change Vulnerability Assessment

Increase Saltwater Intrusion

- Increased saltwater intrusion
- Increased water table levels
    - Decreased drainage potential
    - Infrastructure damage
- Alternative water supplies and other advanced water management strategies
- Low-elevation water & wastewater facilities subject to more frequent flooding
- Exacerbated by likelihood of increased drought: less water for irrigation & greater need for irrigation

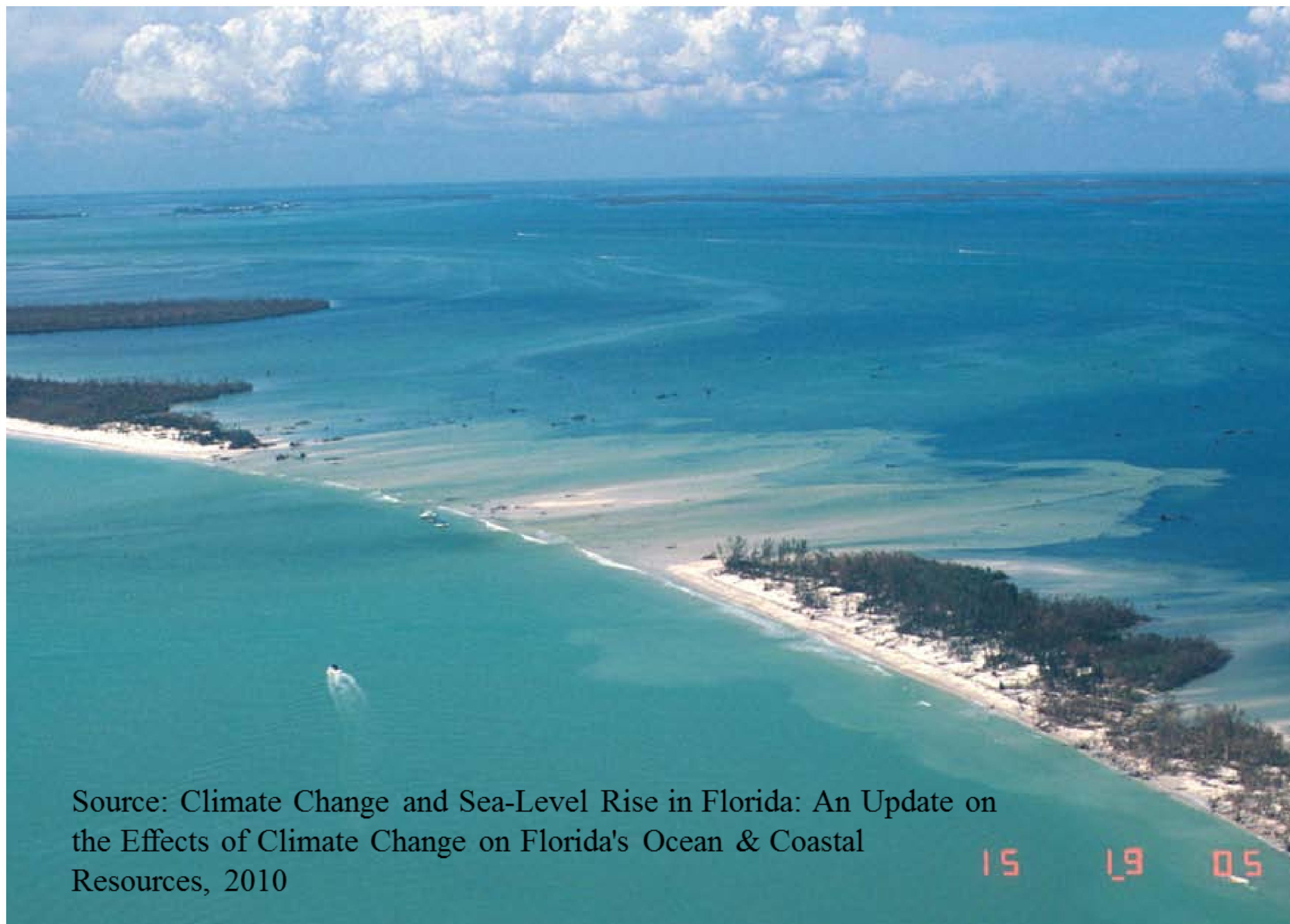


Source: Climate Change and Sea-Level Rise in Florida: An Update on the Effects of Climate Change on Florida's Ocean & Coastal Resources, 2010

Effects on barrier islands

- Increased erosion
- More frequent breaching of barrier islands
- Sand-starved barrier islands migrate landward or lost
- More beach nourishment

Charley Pass. A breach in North Captiva Island created by Hurricane Charley



Source: Climate Change and Sea-Level Rise in Florida: An Update on the Effects of Climate Change on Florida's Ocean & Coastal Resources, 2010

Effects on coastal flooding

- Increased coastal flooding.
- Increased risk to gravity-drained areas
- By 2040, 6 to 9 inches of sea-level rise likely to reduce the capacity of flood control systems by 70% in south Florida
- Storm surges penetrate further inland

Economic Impacts

* Increased costs for nourishment
* Higher infrastructure costs for repair, replacement, relocation
* Costs for armoring
* Costs for water supply: costs x3 or more
* Increased electricity need/cost
* Availability of insurance and disaster aid
  * Citizens—more limitations, higher premiums
  * FEMA increasingly worried

Economic Impacts

- $26 billion tourism & recreation in Florida
  - Coastal econ. Grew faster than that of CA, combined Gulf states, or the nation
  - #1 coastal destination; 22 million visitors in 2000
- Top diving destination in U.S.; top 5 worldwide
- Fishing
  - Anglers spent $4.6 billion on related expenses in 2005
  - $174 million dock-side value of commercial fish in 2005; $530 million impact for seafood processing, seafood markets, aquaculture, and related industries

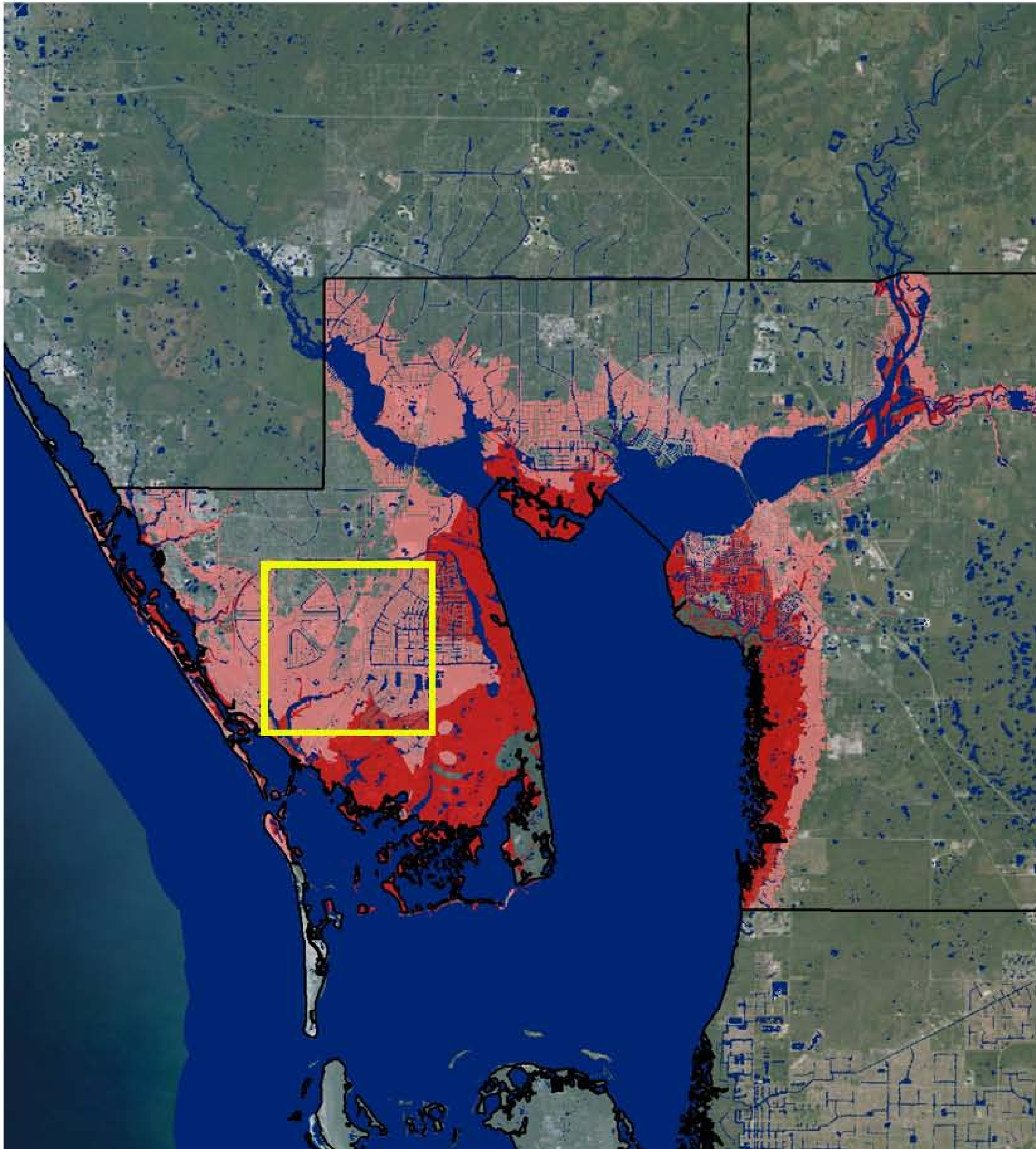
Charlotte County

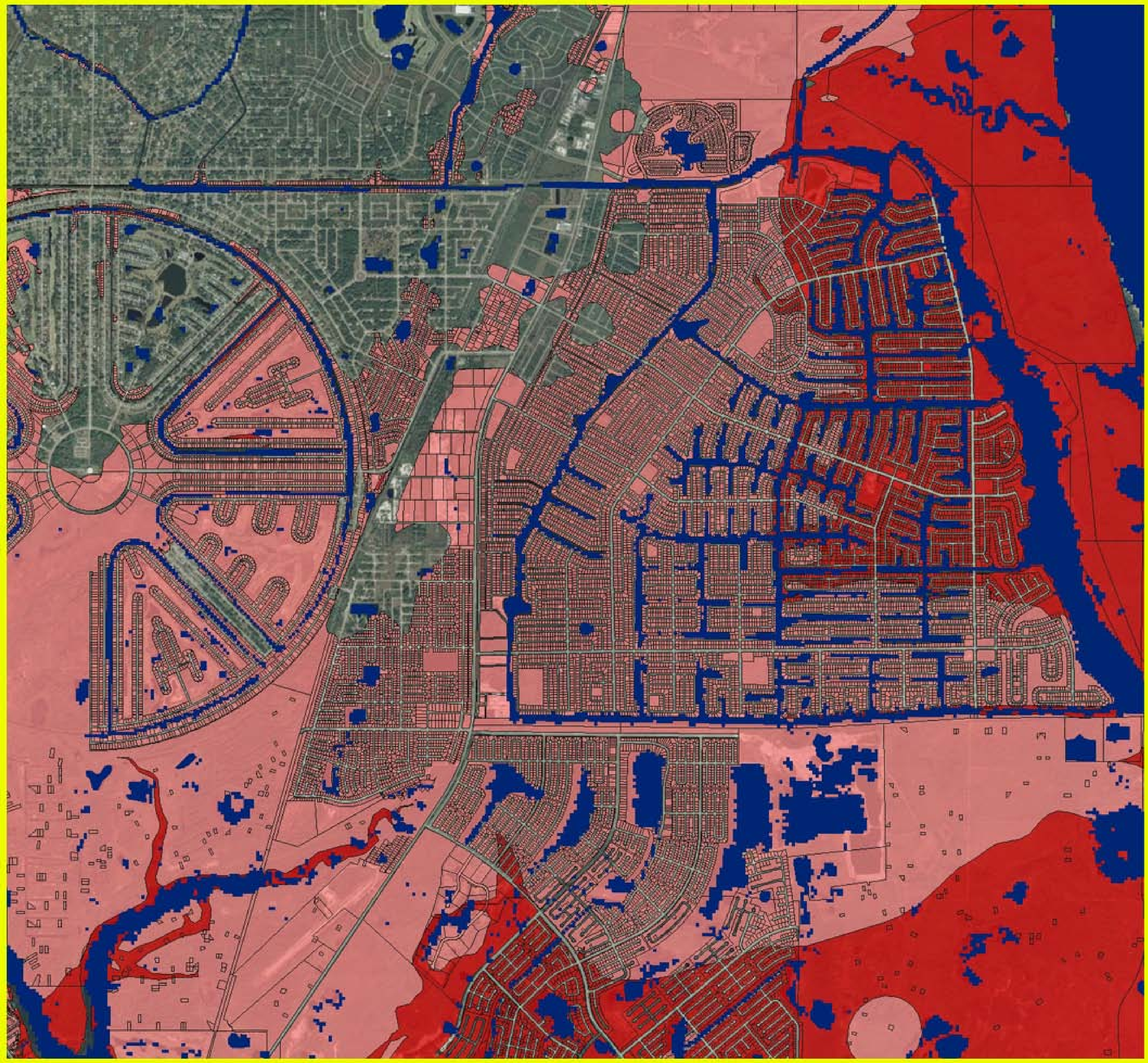
2008 Population is 165,781.

The Projected BEBR 2035 Medium Population is 228,400

CENSUS 2000

Population		141,627
Average Population Density		1.99
Total Area	(us_ac)	465,502
Water Area	(us_ac)	78,785
Total House Units		79,758



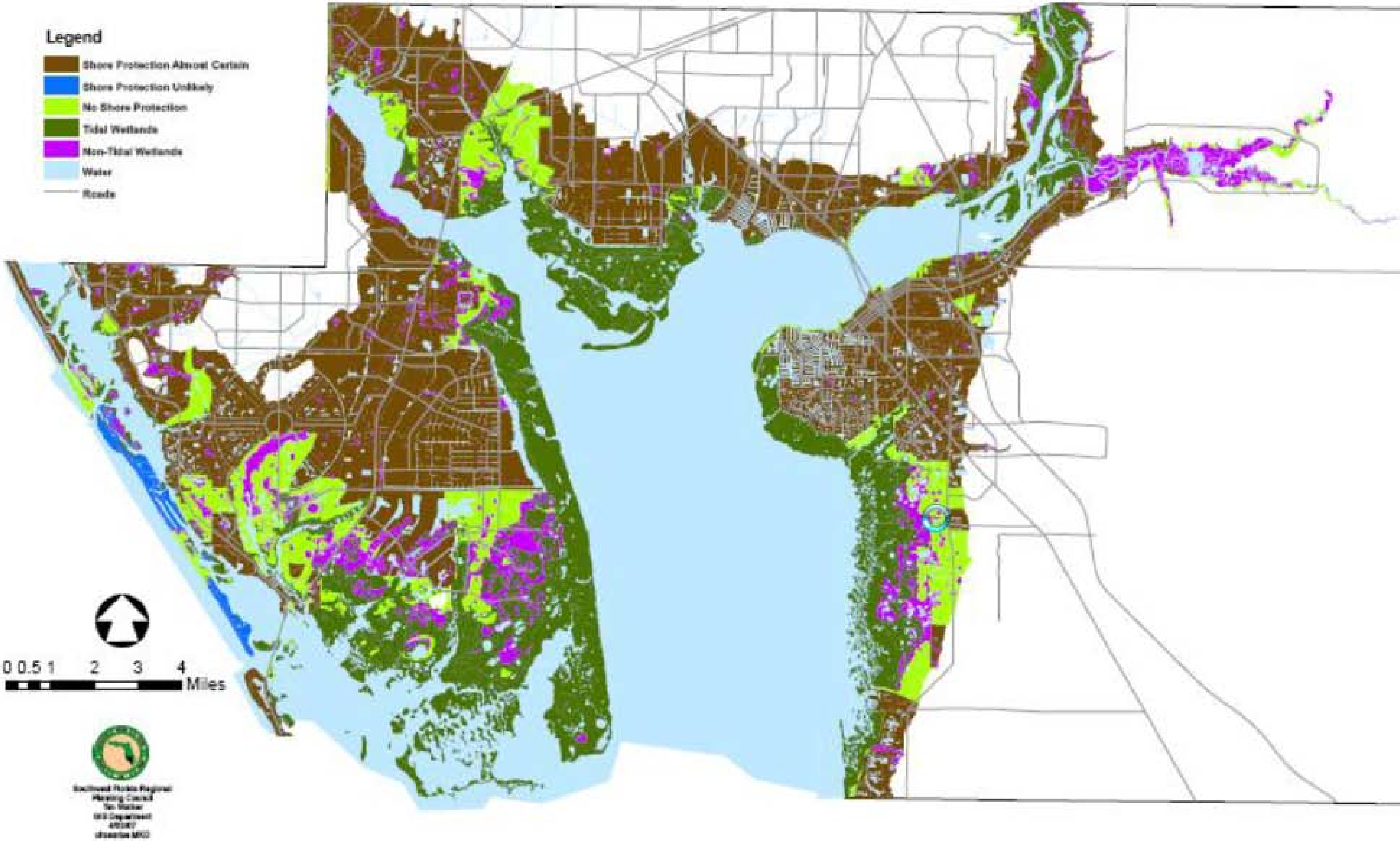


MAJOR USE	PARCEL COUNT	JUST VALUE	PARCEL ACRES	FLOOD ACRES	LOST DOLLARS
Agriculture	346	216864574	23082.7	1790.4	6723155
Commercial	2021	634481505	5826.8	3593.2	498147303
Entertainment	10	2087747	3.6	3.4	1870369
Extraction Mining	6	2908454	17.0	13.1	2556566
Government	670	557948895	100501.1	15710.6	284736905
Industry	254	92809786	1210.8	779.7	79671401
Institutional	1823	341816153	67383.6	1043.8	260972381
Mixed Use	29	61139563	36.2	26.6	39627293
Not zoned agriculture	88	12047029	2232.5	630.3	4291667
Recreation	453	386610341	66186.7	19731.2	174318970
Residential	113197	14216890287	110172.1	50825.4	13343122536
Retail	603	378760493	1440.8	902.5	311168206
Service	169	162816052	702.9	165.9	109993848
Transportation & Utilities	502	113945067	45169.8	13190.0	70388957

How to Respond?

* **Armor**
  * Seawalls, bulkheads, revetments, groins, etc.
  * “Soft” protection: nourishment & living shorelines
* **Accommodate**
  * Elevate structures
  * Flood proofing of structures
  * Flood proofing of infrastructure
* **Relocation**

Charlotte County Florida 5' Sea Level Rise



Source: Comprehensive Southwest Florida/Charlotte Harbor Climate Change Vulnerability Assessment

Response Costs

- **Armoring:** Costs vary: $300-$4,000 per linear foot
  - Est. for Punta Gorda: almost **$382 million for bulkhead + $935 million for fill + $252 million for salary = $1.57 billion**
  - DOES NOT consider legal feasibility of backfilling PG to 6 feet above current MHW
  - Typical estimates for armoring cost DO NOT include cost for drainage—a very important and costly consideration
- **Nourishment:** Statewide for 39" of SLR--$6-$39 billion; go to Bahamas for sand?
  - Severe sand shortage in Sarasota and Charlotte County
- **Elevation:** $58/sq. ft. for existing, single-story slab
  - Does not include impacts to roads/neighborhood

Planning as a Response

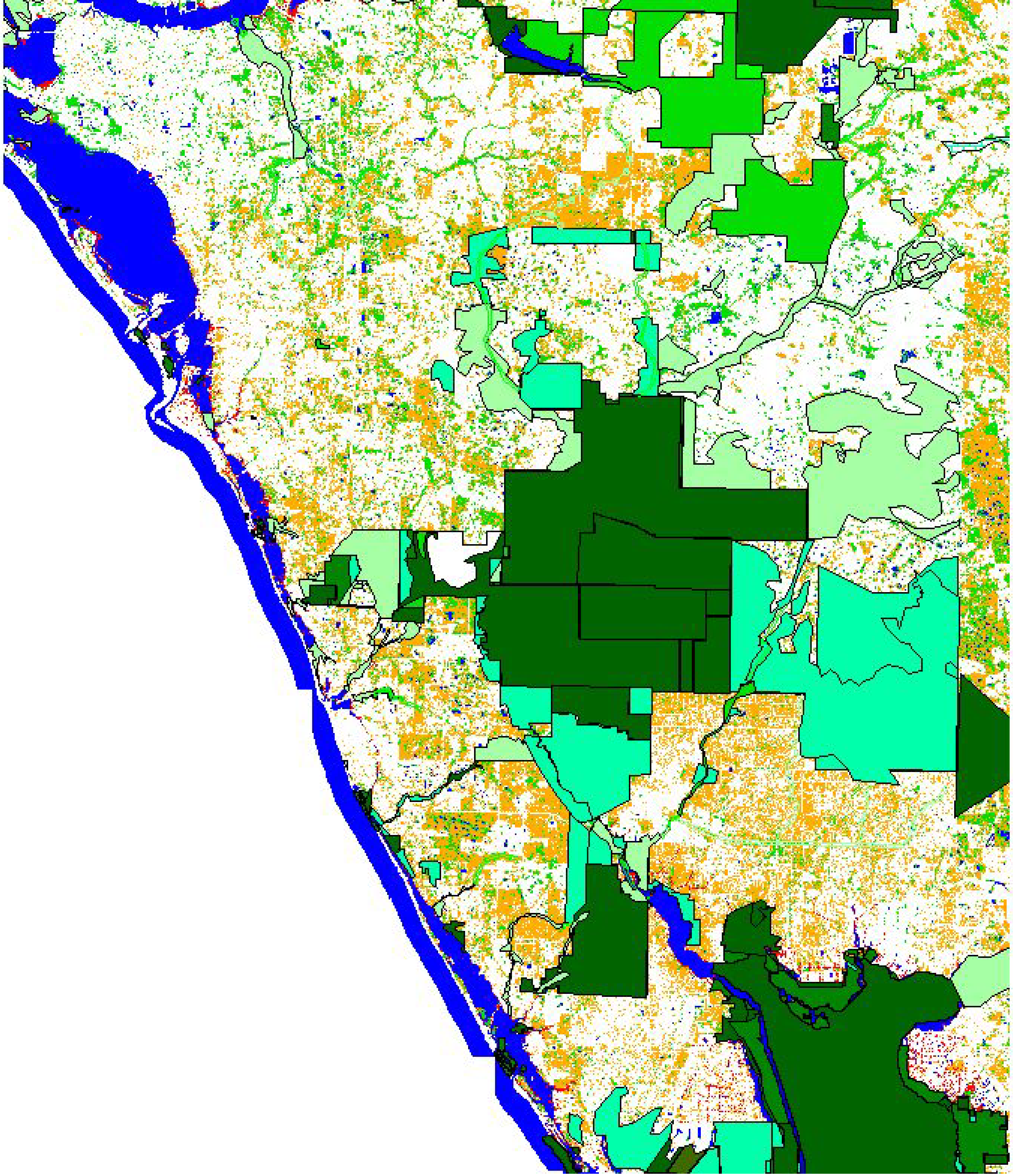
- City of Punta Gorda Comprehensive Plan Climate Change Objective and Policy:
- Objective 2.4.2: Address the impacts of sea level rise, and seek strategies to combat its effects on the shoreline of the City.
- Policy 2.4.2.1: The City will work with the SWFRPC to determine potential sea level rise impacts on the Coastal Planning Area.
- Measurement: Completion and implementation of developed coastal studies or development of model scenarios.

Adaptation Options

* 246 options for adaptation in Comp. Vuln. Assess. & in Punta Gorda Adaptation Plan
  * Seagrass protection & restoration
  * Water conservation through xeriscaping/native plants
  * Include in comp. plan areas that will retain natural shorelines
  * Limit locations for high-risk infrastructure
* Focus on "no-regrets" and "low-regrets" options first
* New statutory tool: Adaptation Action Areas

Potential adaptations and recommended strategies to implement the AMMA options

* Maintain the existing marsh migration corridors that have been established on Cape Haze, Eastern Charlotte Harbor shoreline, and Estero Bay Buffer.
* Identify the highest priority marsh migration corridors so that they can protect these areas from future development. Followed by acquisition of inland buffer zones to provide an opportunity for habitats and wildlife to migrate inland.
* Support restoration of existing salt marshes by removal of exotic vegetation, removal of barriers to tidal connection, and degradation of exotic dominated adjacent uplands
* Discourage or stop shoreline hardening including seawalls, bulkheads, rip-rap, and "living shorelines" backed by rip-rap.
* Re-engineer existing vertical shoreline infrastructure to a sloped soil based shoreline with GeoWeb or other permeable stabilization.
* Restore impaired water flows to enhance sediment supply for marsh deposition
* Elevate roadway berms by bridging and culver ting or abandon coastal road corridors with associated beamed road beds..
* Back-fill mosquito control ditches to reduce depth and sediment loss
* Back fill borrow pits, agricultural pits, and spreader waterways to allow salt marsh establishment and establishment of marsh migration corridors
* Sediment-slurry addition to assist in marsh building processes

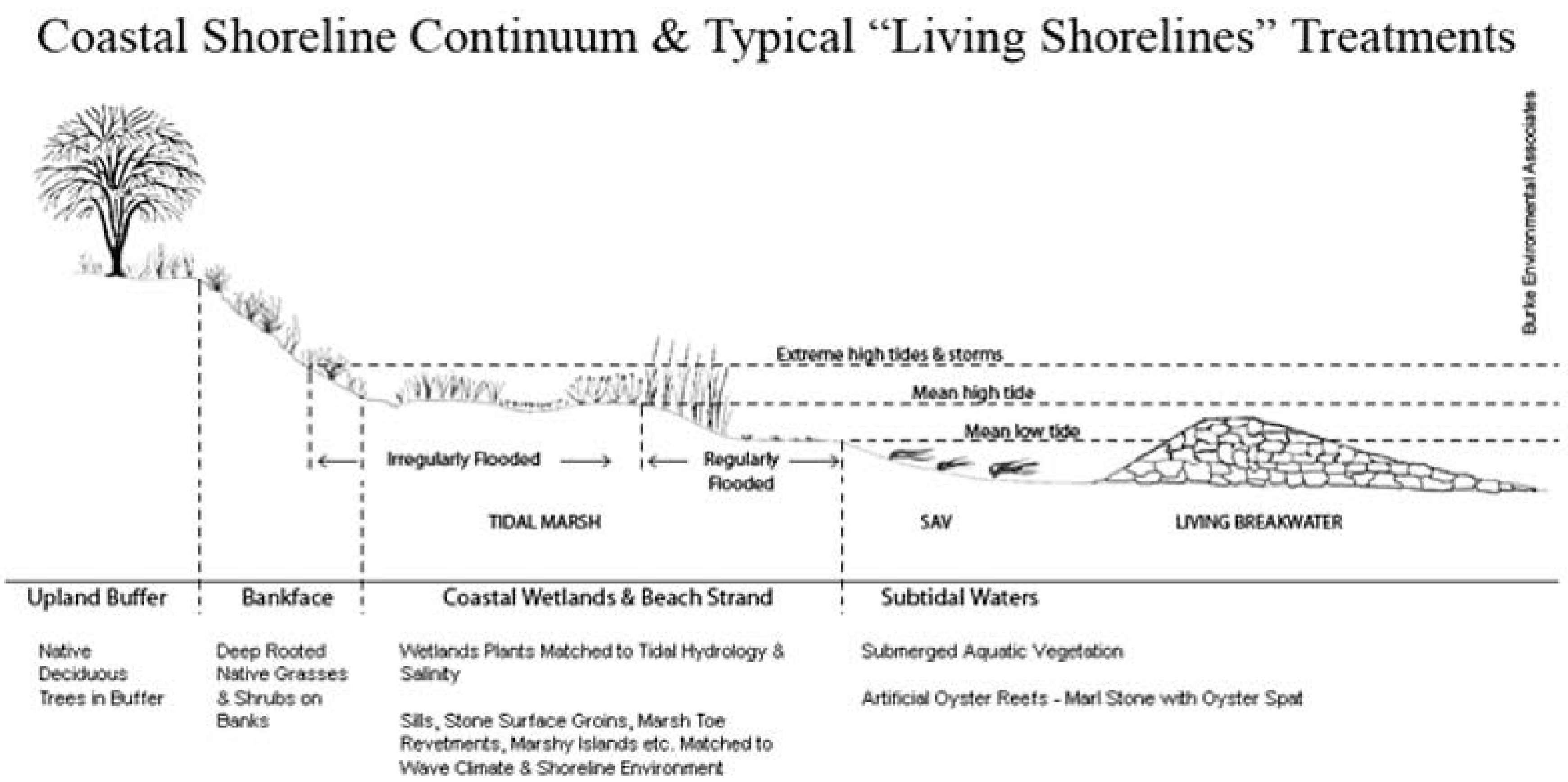


County	Location	Level of Connection to adjacent Public Lands	Path of Connection	Potential extent of migration
Sarasota	Myakka River Riparian Corridor	High	North to Myakka River State park	High
Sarasota	Gottfried Creek	Low	North and East to Myakka River	Low
Sarasota	Rock Creek	Low	North and East to Myakka River	Low
Charlotte	Cape Haze State Preserve	High	North into Cape Haze	High Initially. Can be expanded with acquisitions to remain High
Charlotte	Tippecanoe Bay	High	North into Charlotte County Lands	High then Medium. Could be expanded north of SR 776
Charlotte-DeSoto	Peace River	Low	North up river	High but not extensive as River shoreline elevations become steeper
Charlotte	Shell Creek	Low	East toward headwaters	High then Low when blocked by water control structure
Charlotte	Charlotte Harbor State Buffer Preserve	High	East to extensive Public Lands include the Yucca Pens and Cecil Webb Wildlife Management Areas, Babcock Ranch, and Fisheating Creek	High. Perhaps the best in the CHNEP and southwest Florida if roadway barriers can be addressed.
Lee	Burnt Store Creek	Medium	East to extensive Public Lands include the Yucca Pens, Cecil Webb Wildlife Management Areas, Babcock Ranch, and Fisheating Creek	Medium. Connection is narrow and Burnt Store Road is a potential barrier.
Lee	Estero Bay Preserve- North	Medium	Further into preserve	Initially High but block by urban lands uses
Lee	Estero Bay Preserve	Medium	East on State lands and then along Estero River and	Initially High but narrow with several road barriers until connection to the

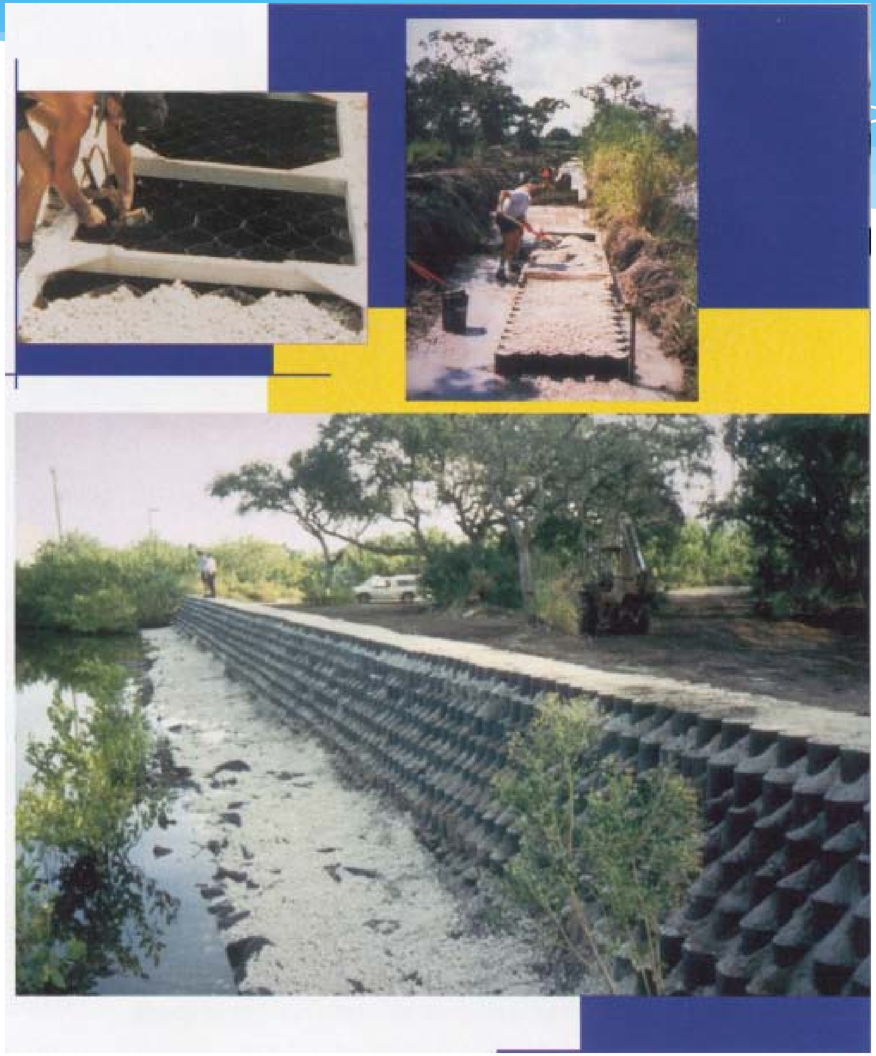
Island Park Area After Restoration.

Note return of saltern, mixed high marsh, grassy high marsh, and patches of succulent high marsh

"Living Shoreline" designs without landward slope hardening

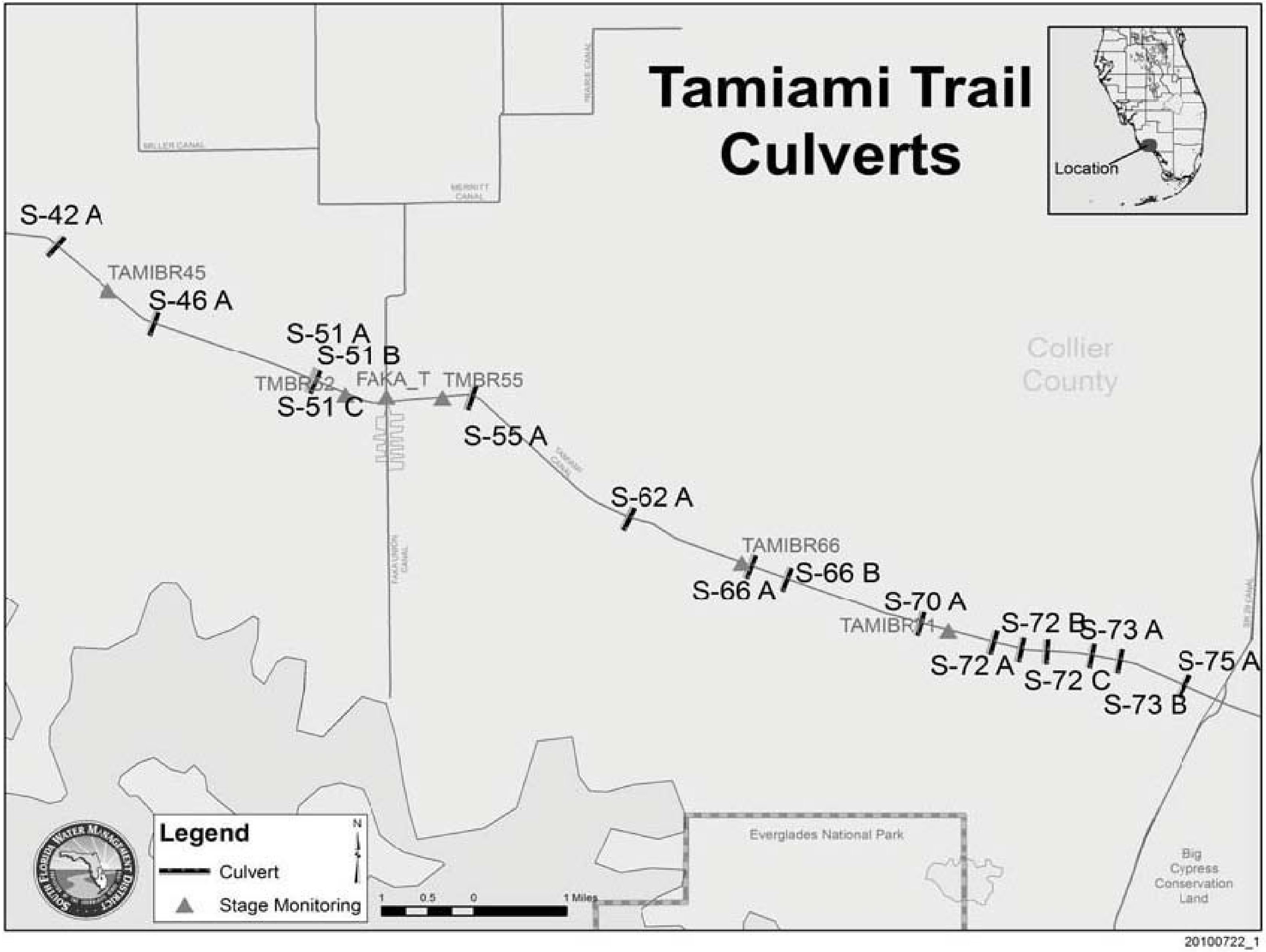


Stepped GeoWeb shoreline Vero Beach Florida 1994



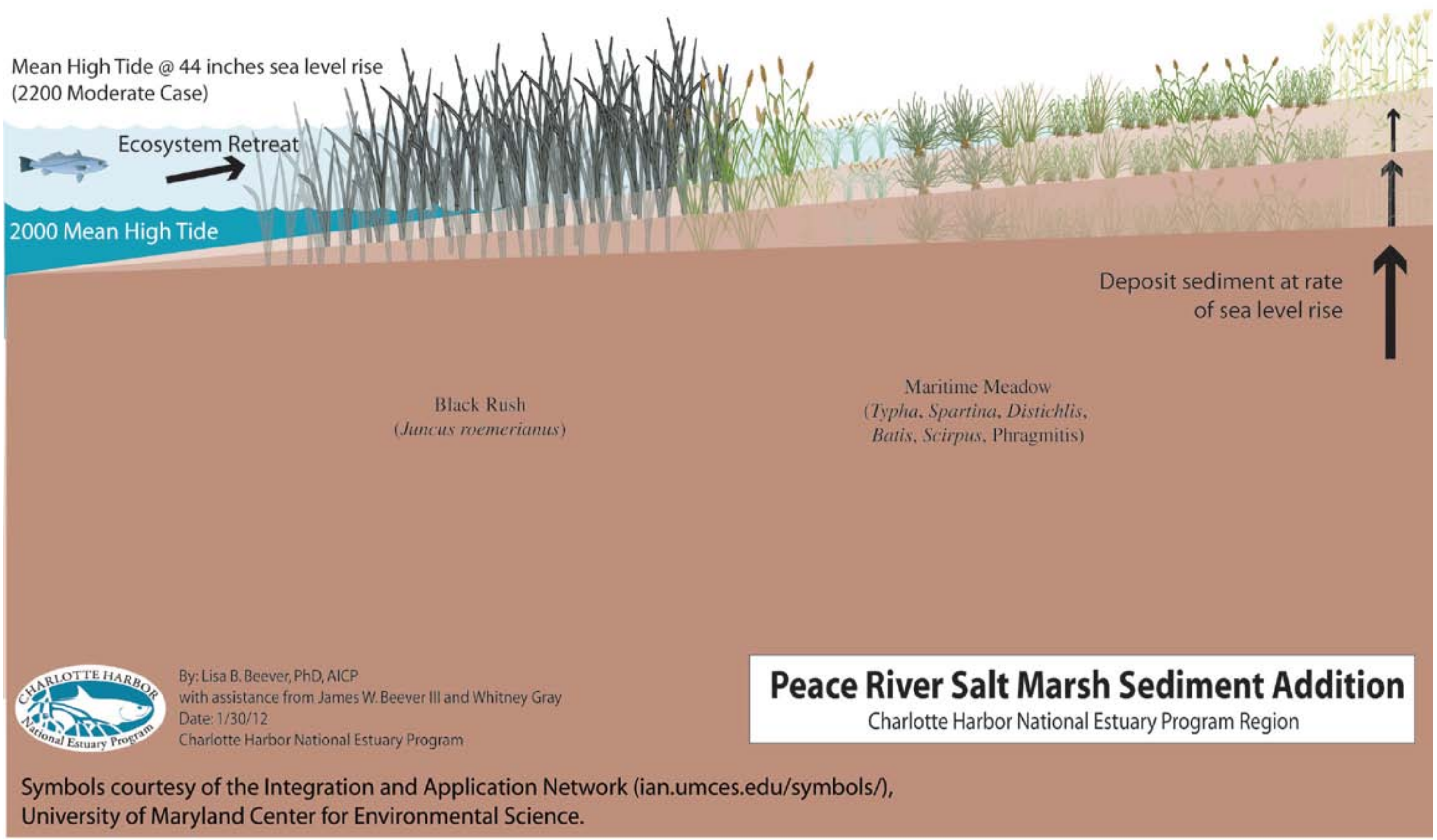
The Tamiami Trail culverts and the six stage monitoring sites.

Source: Abtew and Ciuca 2010



Restored backfilled mosquito control ditches on the Charlotte Harbor Preserve State Park

Sediment Slurry Addition



References

Beever, III, J.W., W. Gray, et al.2009. Comprehensive Southwest Florida/ Charlotte Harbor Climate Change Vulnerability Assessment. Southwest Florida Regional Planning Council and Charlotte Harbor National Estuary Program, Technical Report 09-3, 311 pages.

Beever, III, J.W., W. Gray, D. Trescott, D. Cobb, J. Utley David Hutchinson, John Gibbons, Moji Abimbola and L. B. Beever, Judy Ott 2009. *Adaptation Plan for the City of Punta Gorda.* Southwest Florida Regional Planning Council and Charlotte Harbor National Estuary Program, Technical Report 09-4, 406 pages. Adopted by the City of Punta Gorda on November 18, 2009.

Beever III, J.W., W. Gray, L. Beever, Beever, Lisa, B., D. Cobb, Walker, Tim 2011. Climate Change Vulnerability Assessment and Adaptation Opportunities for Salt Marsh Types in Southwest Florida. 379 pp.

Gesselbracht, Laura, K. Freeman, et al. 2011. Retrospective and prospective model simulations of sea level rise impacts on Gulf of Mexico coastal marshes and forests in Waccasassa Bay, Florida. Climatic Change. DOI 10.1007/s10584-011-0084-y

Mitchum, Gary T. Sea Level Changes in the Southeastern United States. Florida Climate Institute, 2011.

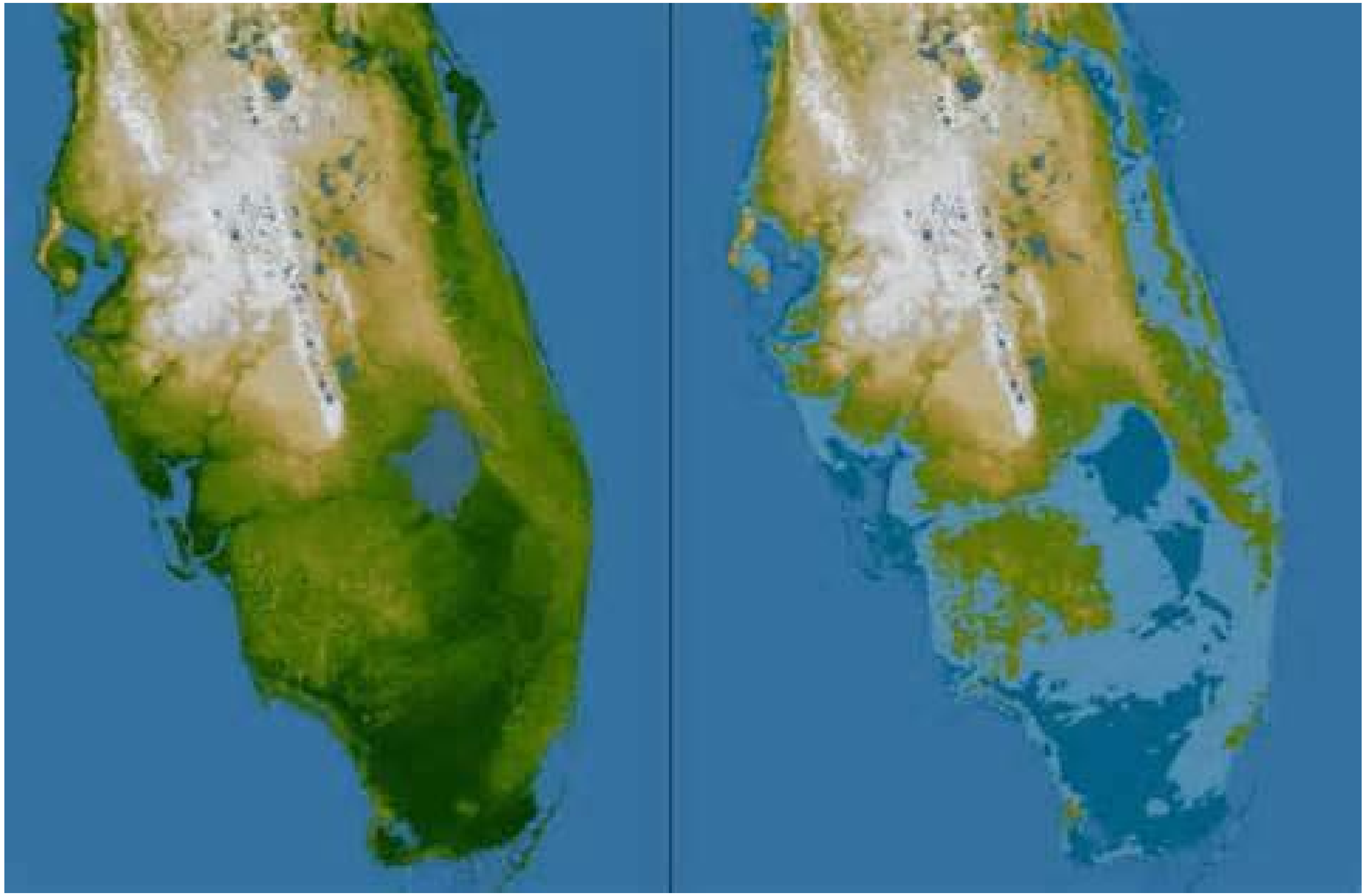
Noss, Reed. Impacts Of Climate Change and Sea Level Rise in Peninsular Florida – Can We Adapt? Presentation to FRRP. May 10-12, 2011.

Ott, Judith. Seagrass Changes Maps. 2010

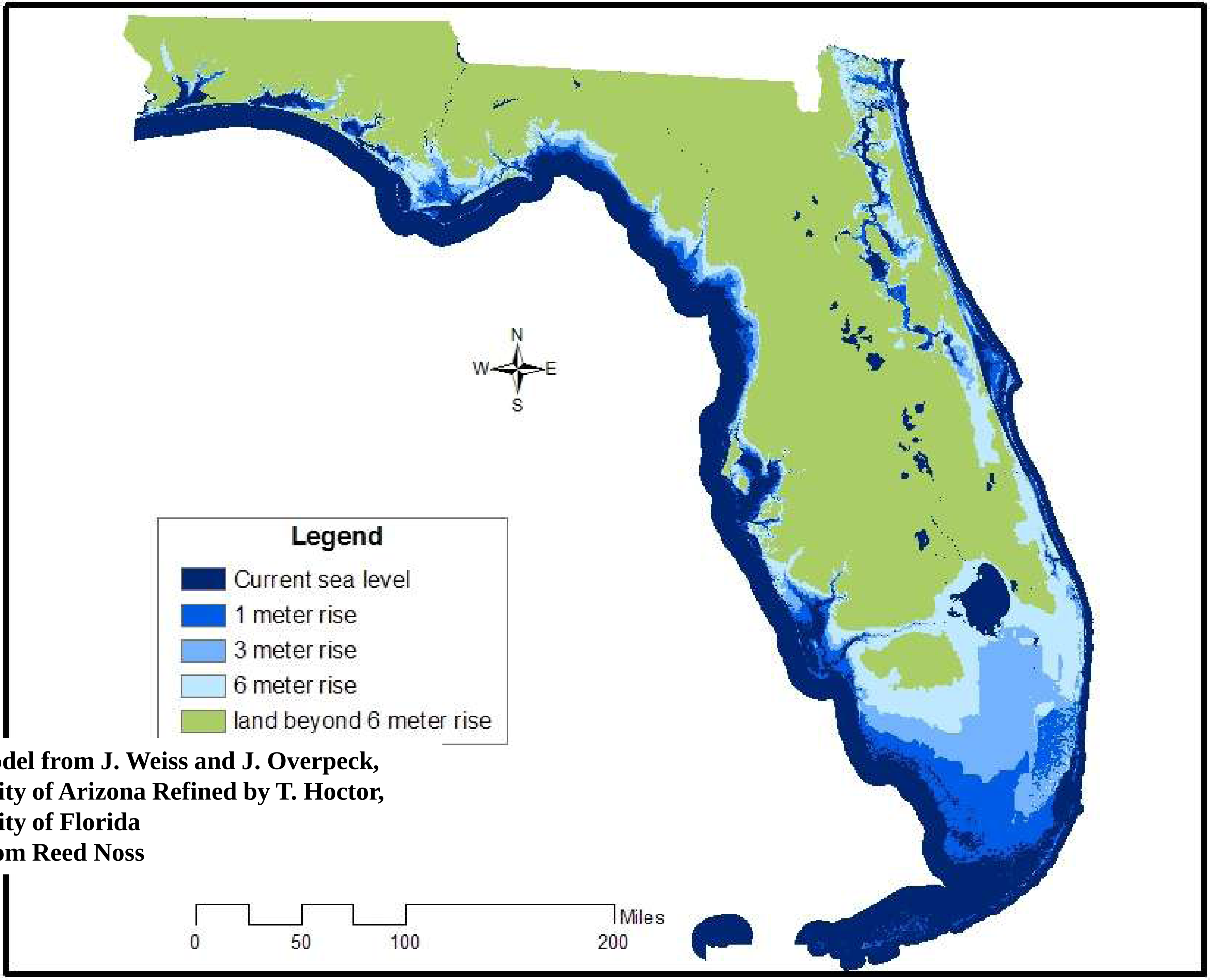
Savarese, M., and A. Volety. 2001. Oysters as indicators of ecosystem health: determining the impacts of watershed alteration and implications for restoration. South Florida Water Management District, Technical Report. 105 p.

Tebaldi, C., Strauss, B.H., & Zervas, C.E. 2012. Modelling sea level rise impacts on storm surges along US coasts. Environ. Res. Lett. 7 (2012) 014032

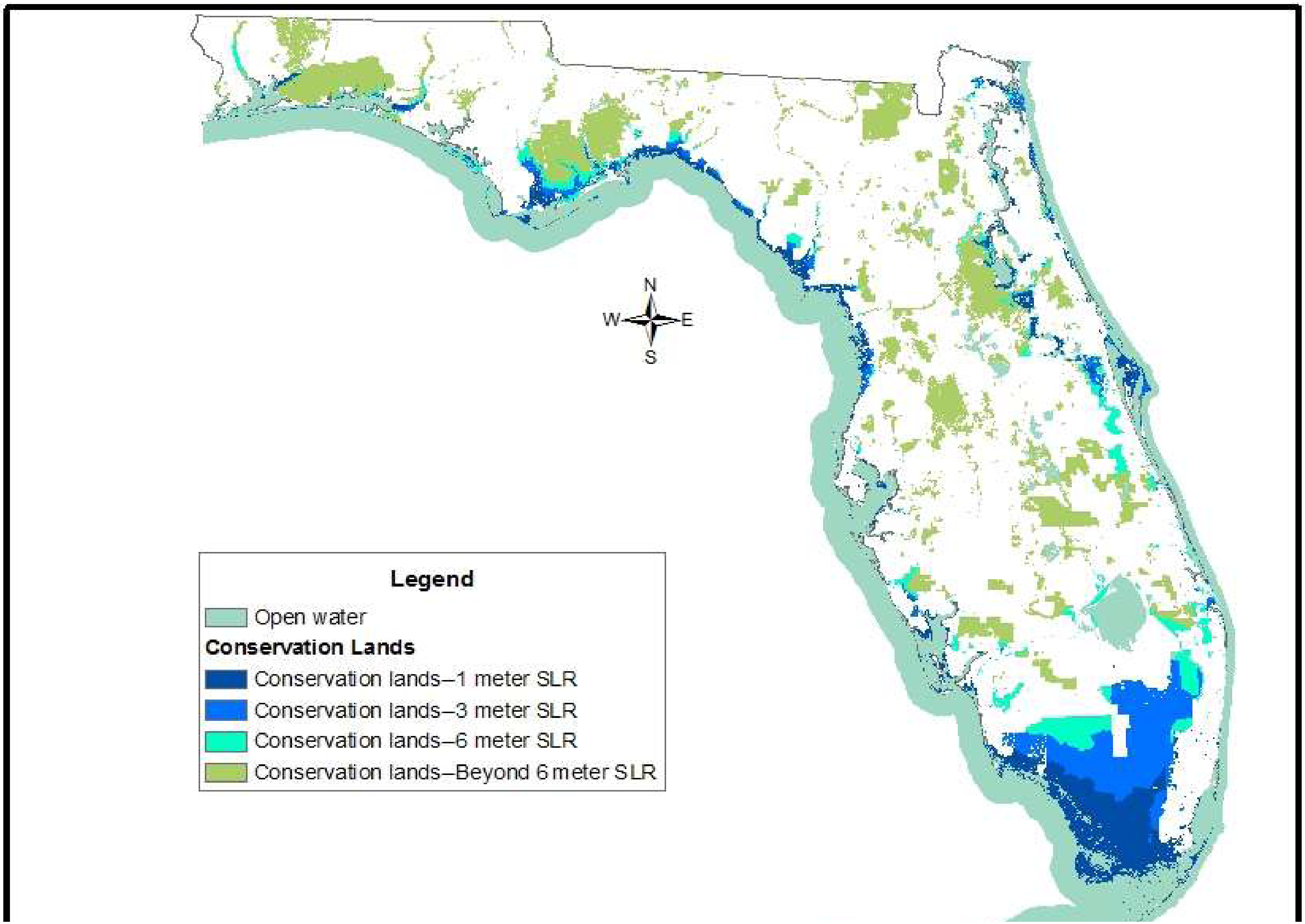
"[A] foolish man . . . . built his house on sand. The rain came down, the streams rose, and the winds blew and beat against that house, and it fell with a great crash." Matthew 7: 26-27



http://www.swfrpc.org/climate_change.html



SLR model from J. Weiss and J. Overpeck, University of Arizona Refined by T. Hoctor, University of Florida
Slide from Reed Noss



1 m SLR would result in 20% of existing conservation lands lost

3 m SLR would result in 38% of existing conservation lands lost

6 m SLR would result in 51% of existing conservation lands lost