

Climate Trends, Resilience Challenges, and a Strategy for Broward

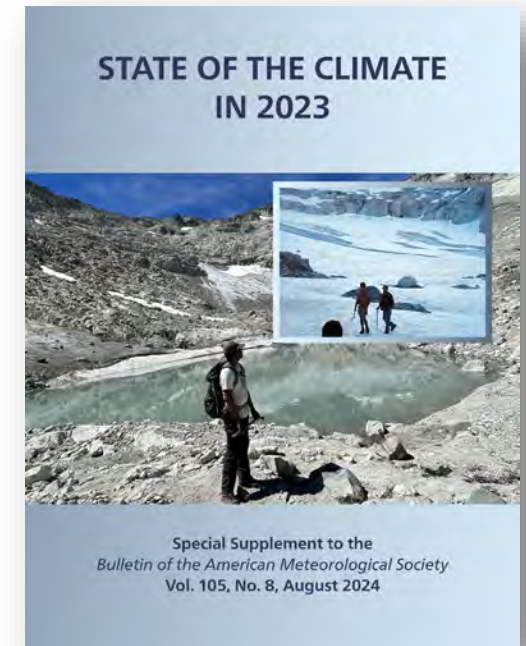
Presented to the City of
Pompano Beach

December 2, 2024

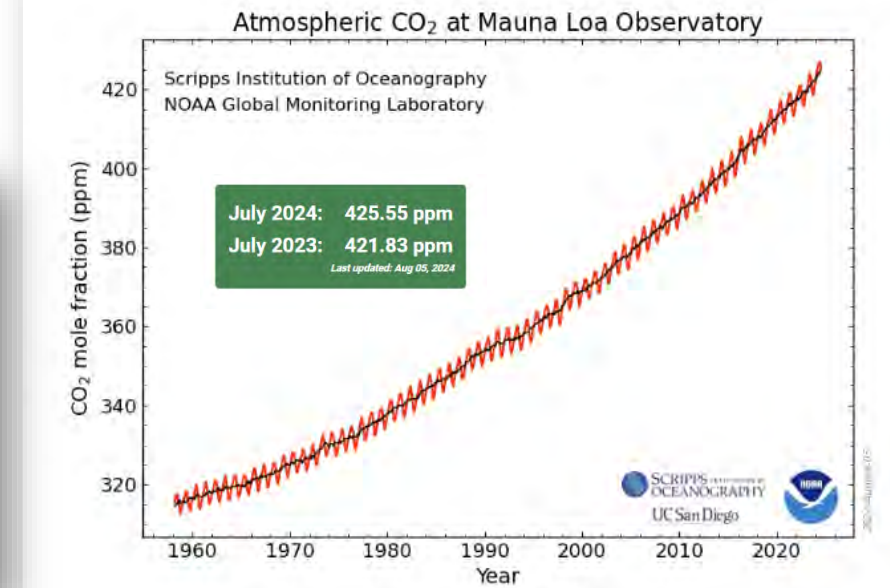
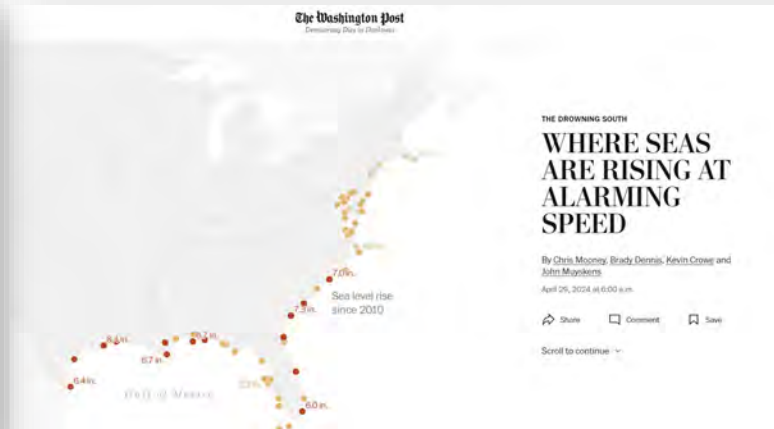
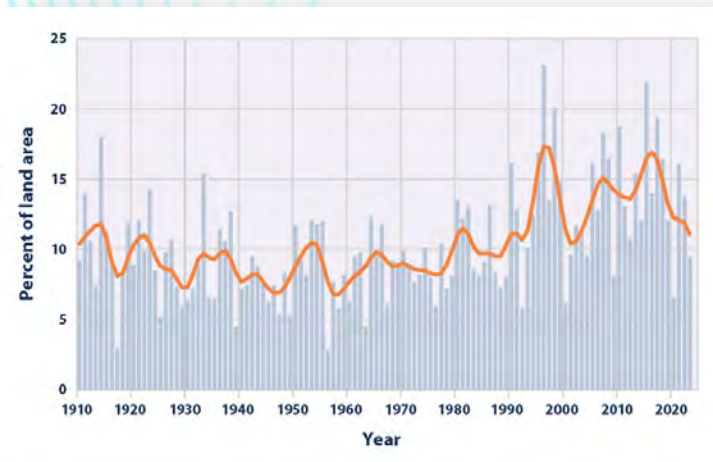


Global Climate Trends

- Greenhouse gas concentrations, global temperature across land and oceans, global sea level and ocean heat content all reached record highs in 2023
- The rate of sea level rise increase over the last 10 years is more than twice the rate from 1993 to 2002.



Extreme One-Day Precipitation Events in the Contiguous 48 States, 1910–2023



Extreme Rainfall and Compound Flooding

Rank	Precipitation (in.)	Date
1	8.42"	12 April 2023
2	6.99"	6 June 2017
3	6.72"	3 October 2000
4	6.51"	3 June 2022
5	6.39"	12 June 2024
6	6.05"	15 November 2023
7	5.97"	4 November 1998
8	5.96"	8 November 2020
9	5.38"	27 May 2003
10	4.69"	7 June 1999

■ Last 5 years

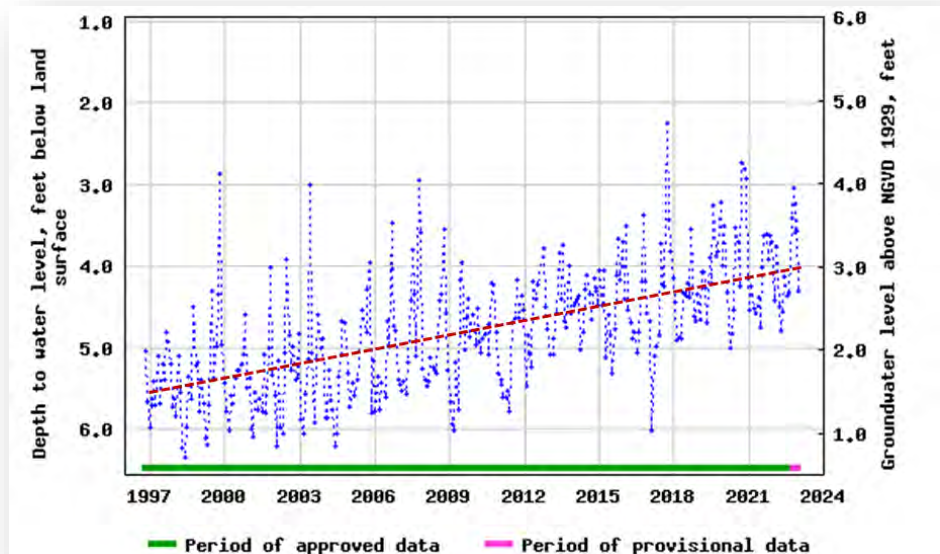
Hollywood – June 2024

‘Catastrophic flash flooding possible’ with heavy rain falling on still-flooded South Florida

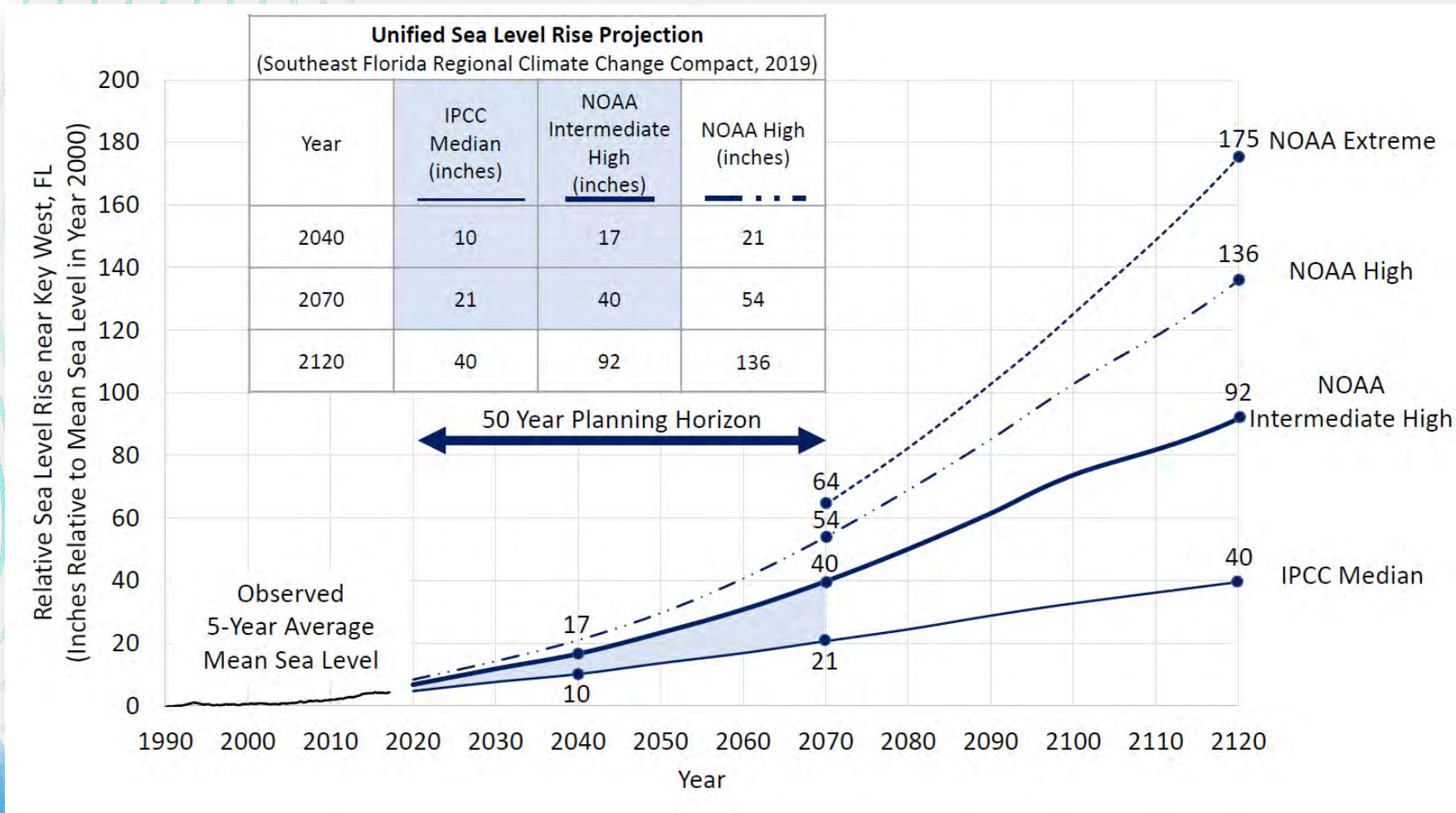
By Elizabeth Wolfe, Robert Shackelford, Mary Gilbert and Taylor Gaigano, CNN
 ⌚ 5 minute read · Updated 7:37 PM EDT, Thu June 13, 2024



Groundwater Table Rise



2019 Regional Sea Level Rise Projection (Reaffirmed)

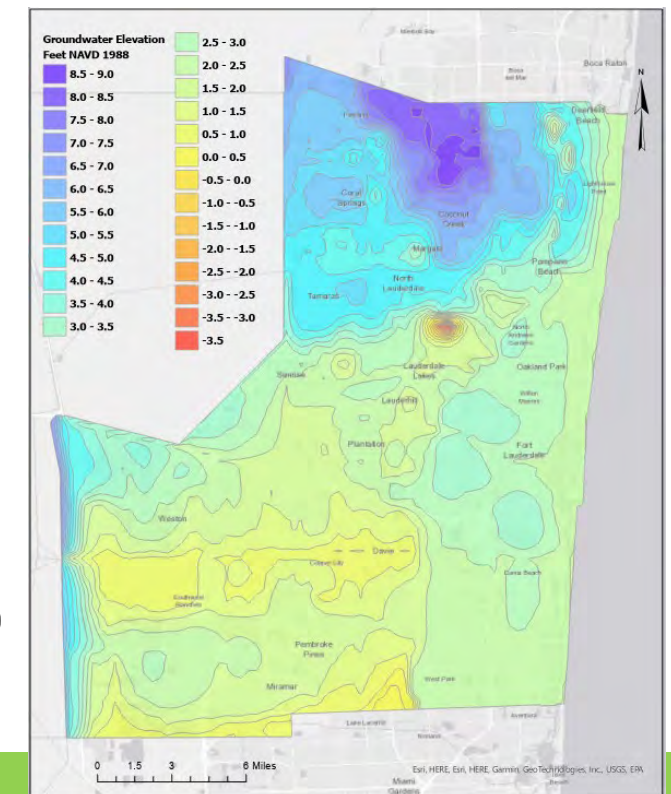


Actions: Updates to Resilience Standards



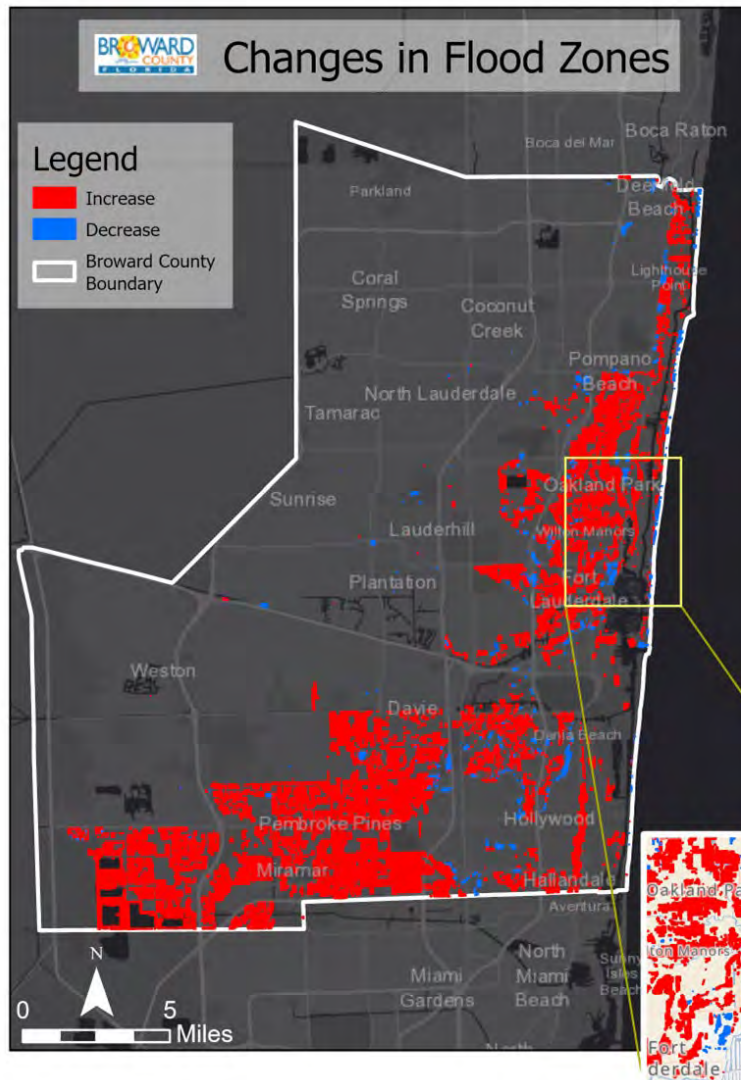
- Sea Level Rise Projection - 2012, 2015, 2019
- Priority Planning Area Map - 2012, 2015, 2020
- Future Conditions Map Series - 2017
- Resilience Standards
 - Drainage infrastructure – 2017, 2024
 - Tidal flood barriers - 2020
 - 100-Yr Flood elevations – 2021, 2025*
- FEMA Flood Maps – July 2024 (90K new parcels)

Future Conditions
Groundwater Map – 2024

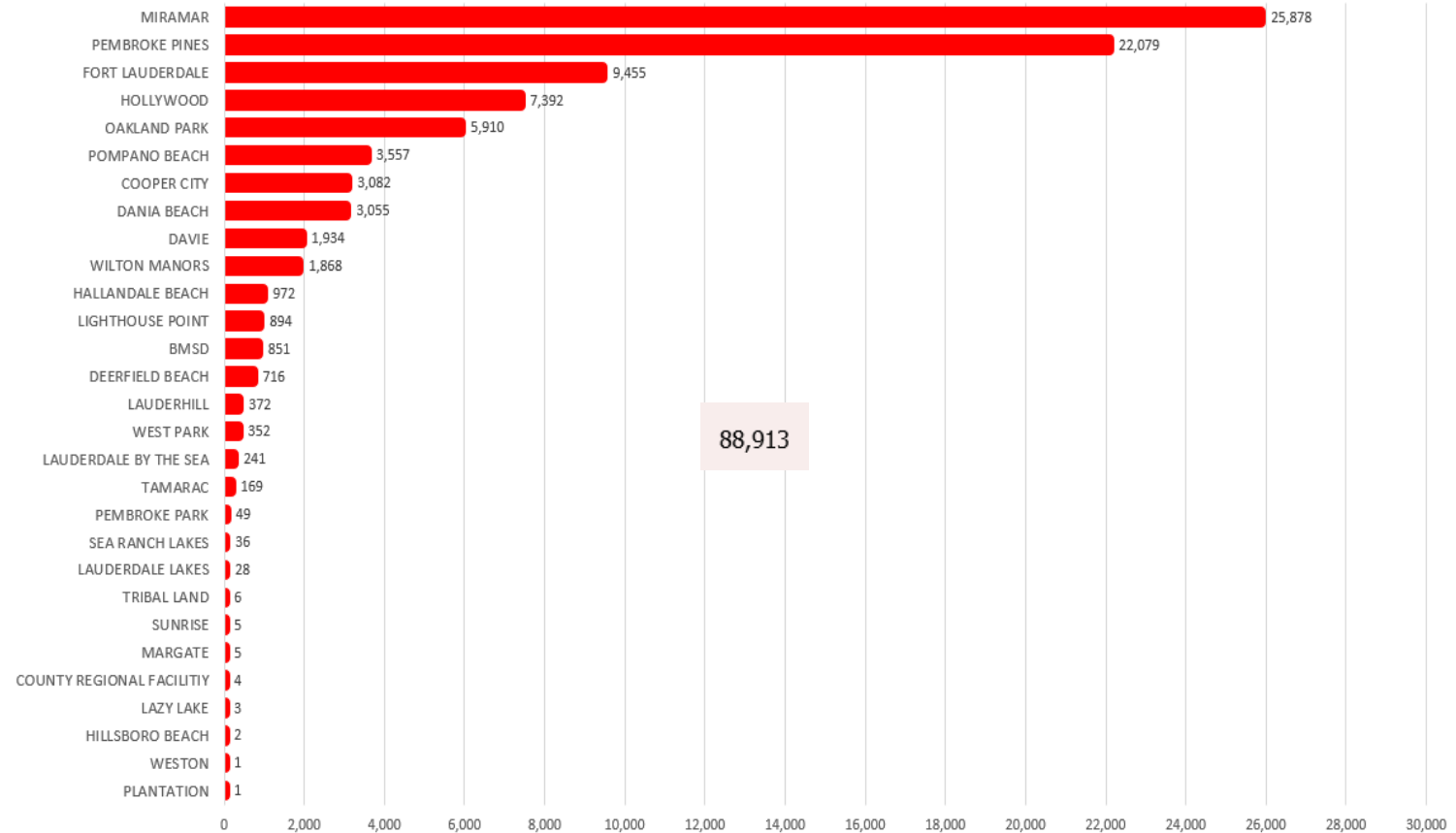


NFIP Update: 90K Parcels added to 100-yr Flood Zone

50% of parcels now in Special Flood Hazard Area



Flood Insurance NOW needed
("Added to Flood Zone")



Development of a County-wide Resilience Plan



**COMMUNITY
OUTREACH**



**RISK
ASSESSMENT**



**ECONOMIC
MODELING**

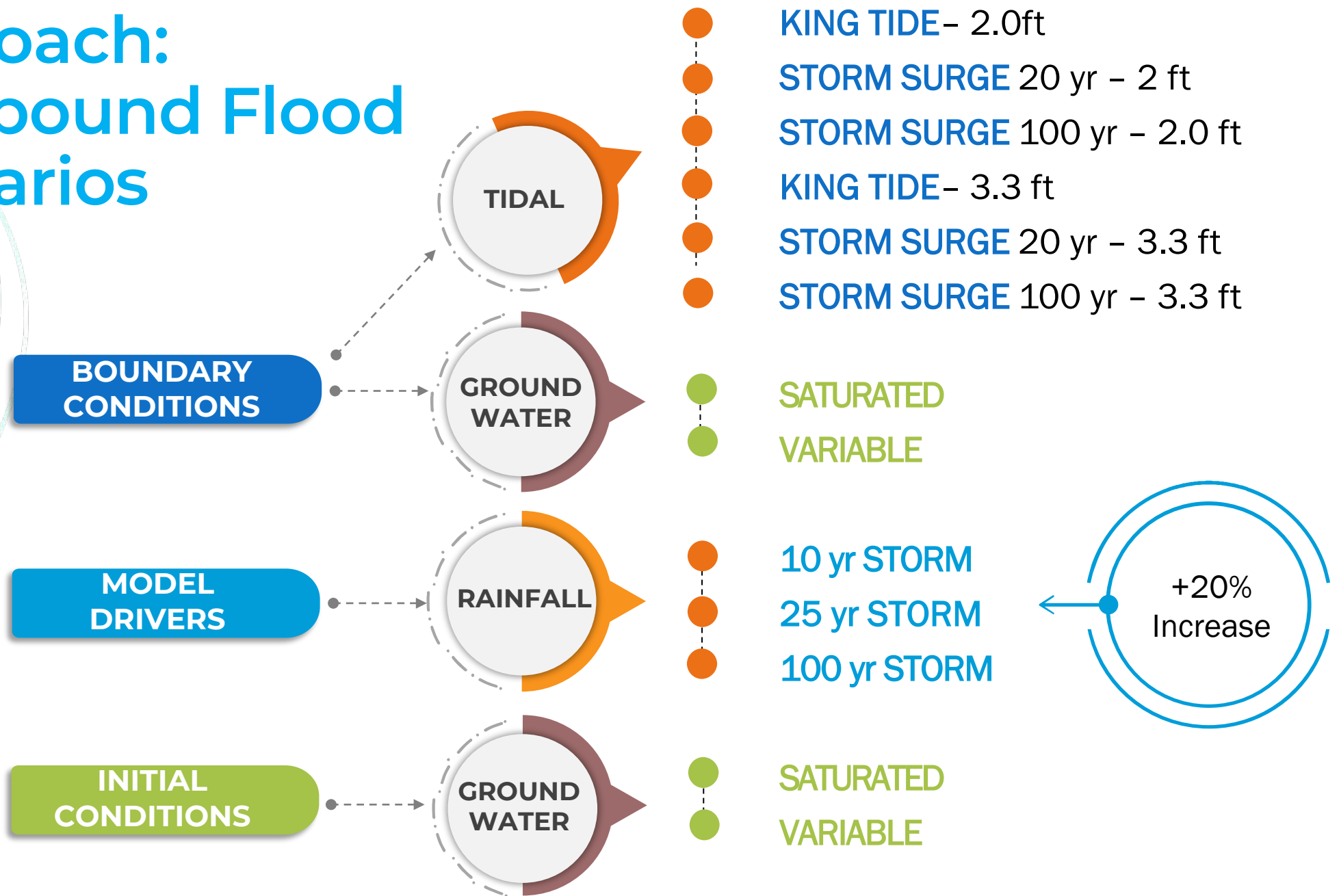


**ADAPTION
PLAN**

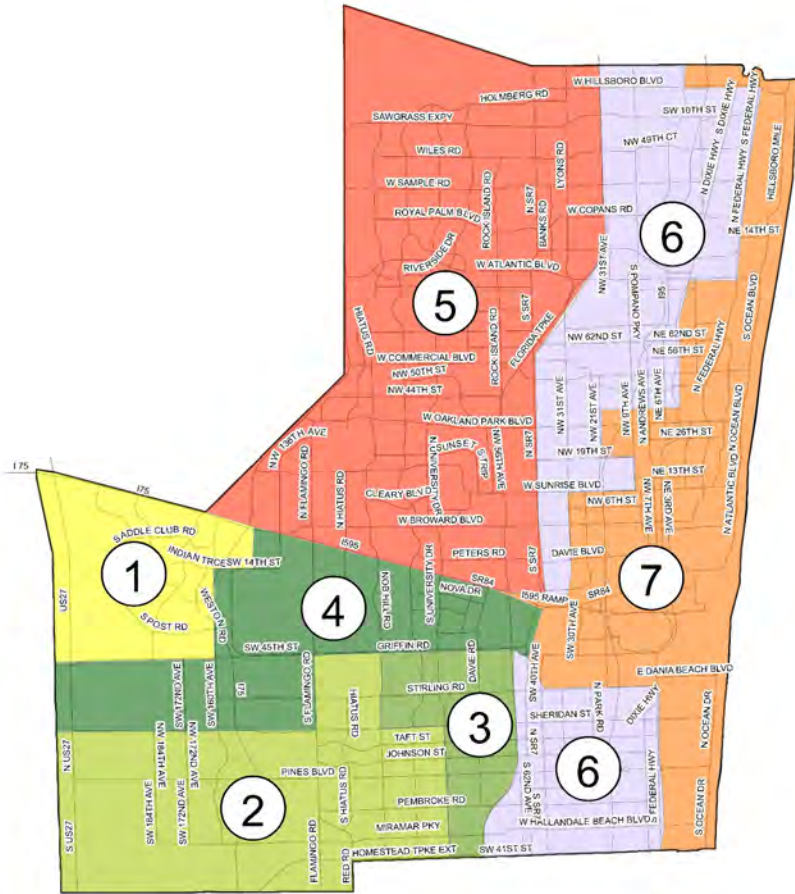


**ONLINE
PLATFORM**

Approach: Compound Flood Scenarios



Initial Adaptation Approach



Zone	Preliminary Strategy
1	<ul style="list-style-type: none"> • Explore Pre-storm operations to gain storage ahead of storm. • Manage discharges to allow other areas to drain.
2	<ul style="list-style-type: none"> • Explore Pre-storm operations to gain storage ahead of storm. • Manage discharges to allow other areas to drain. • Maintain beneficial site storage.
3	<ul style="list-style-type: none"> • Add conveyance improvements, probably based on energy. • Identify storage opportunities.
4	<ul style="list-style-type: none"> • Maintain beneficial site storage. • Target flooding spots based on cost of damages. • Explore Pre-Storm Operations to gain storage.
5	<ul style="list-style-type: none"> • Identify storage to reduce runoff. • Manage storage ahead of the storm.
6	<ul style="list-style-type: none"> • Minor opportunities for storage. • Improve gravity-based conveyance. • Add energy.
7	<ul style="list-style-type: none"> • Manage and protect coast. • Add artificial and natural barriers. • Incorporate energy-based conveyance improvements.

Adaptation Strategies Evaluated

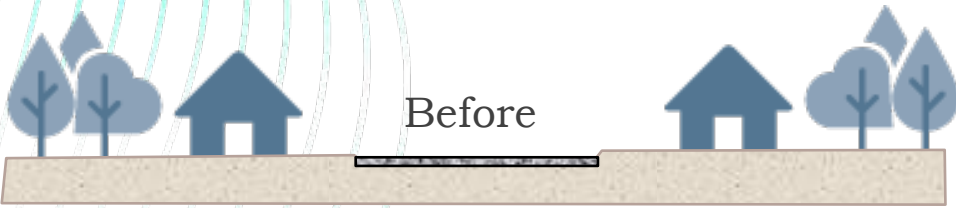
- Storage
 - Above ground storage (large)
 - Recovering underground storage
- **Green Infrastructure**
- Reducing Impervious area
 - Adding localized surface storage
- Conveyance
 - Improving existing conveyance structures (canals, culverts, etc.)
 - Additional Pumping
- Barriers
 - Property level seawalls
 - Nature-based and/or engineered structures
 - Large scale levees and other close out structures

This adaptation strategy is linked to the development of Green Infrastructure. Most Green Infrastructure solutions are based on the idea of increasing infiltration by reducing impervious area. Infiltration can only be increased if there is available ground storage to receive rainwater.



Green Infrastructure – One-way roads/swale recovery

All local roads in the County were reviewed to analyze the potential conversion from two-way roads to one-way road.



Converting

1,760

Miles of two-way roads to one-way road plus swales



Additional Infrastructure Adaptation Strategies



Increased Pervious



Swales



Canal Operational Improvements

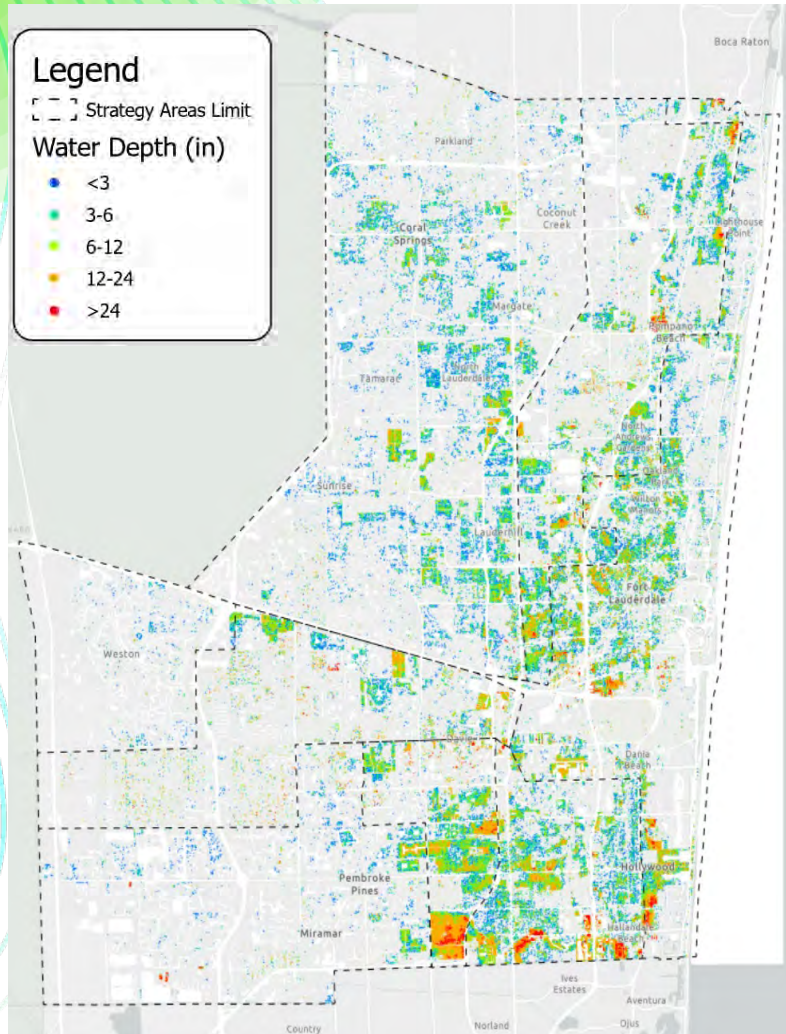


Bio Swales

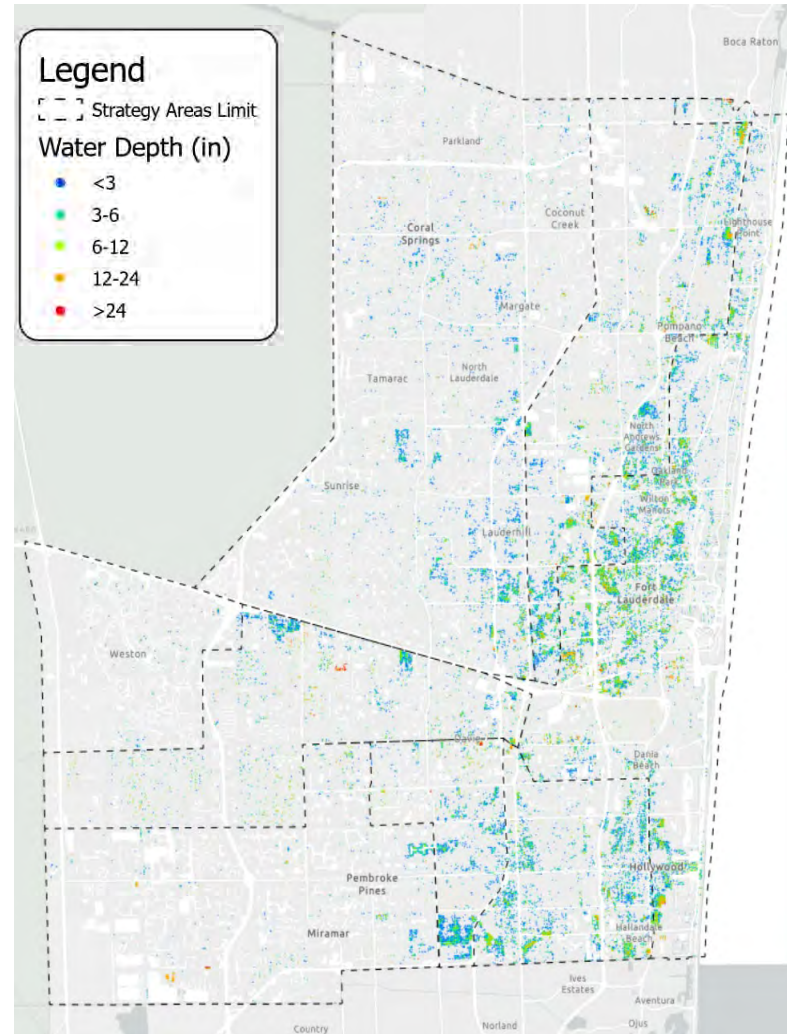


Stormwater Storage

Full Adaptation Suite – 2ft SLR, 100-yr Rain, No Surge



Base Scenario Structures Water Depth (inches)



Adaptation Strategy Structures Water Depth (inches)

Distribution of Structures by Flood Depth Impact

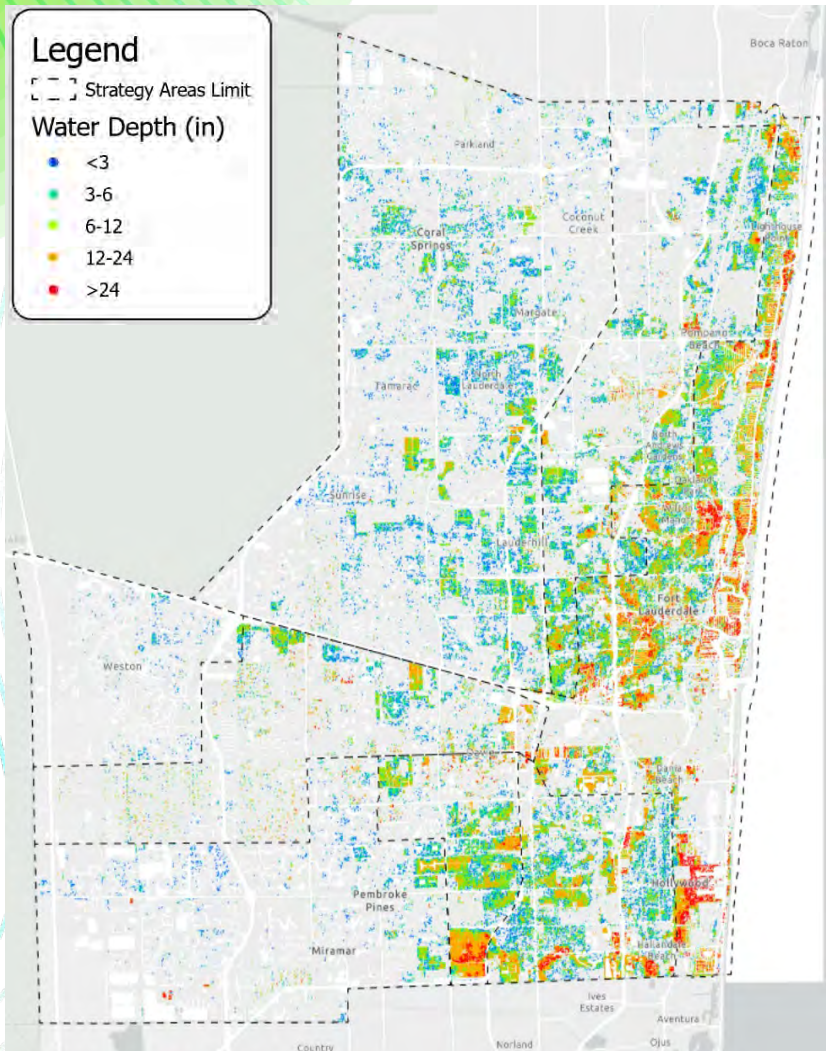
Flood Depth (in)	BASE (NO ADAPTATION)	ADAPTATION
<3"	28,209	13,982
3"-6"	32,056	12,252
6"-12"	38,166	8,949
12"-24"	25,254	2,607
>24"	33,757	169
TOTAL	157,442	37,959

76% Reduction

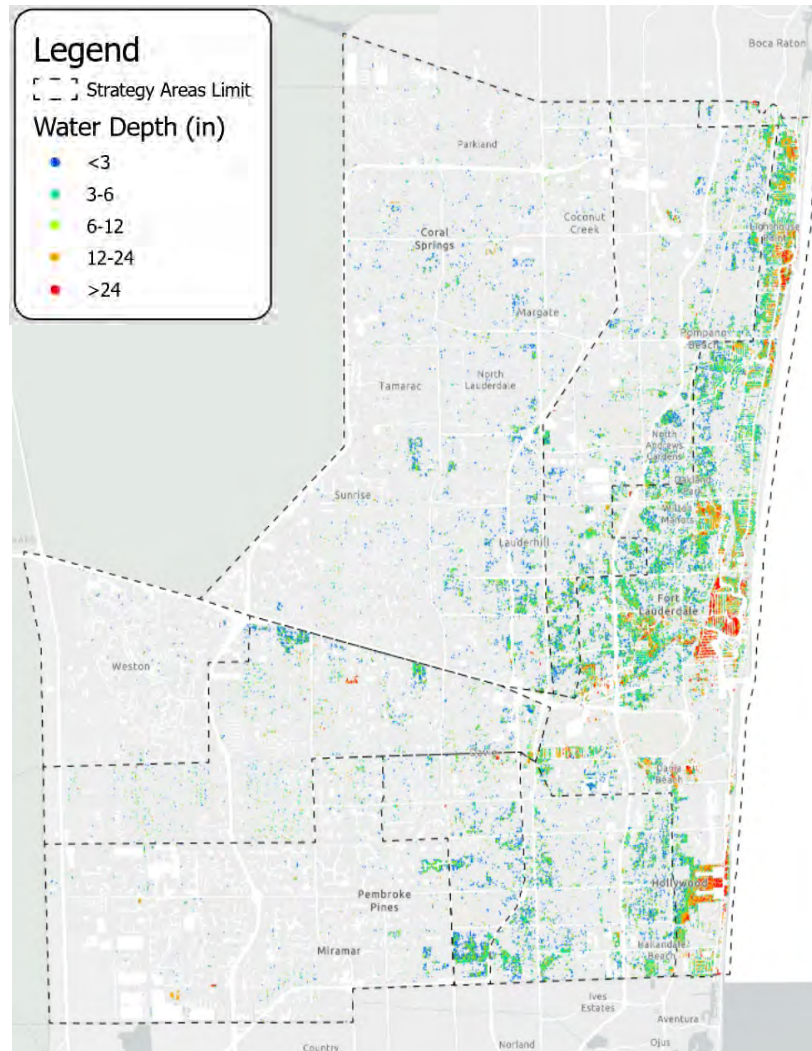
Scenario

Rain	SLR	Tidal
100-yr. 3d	2 ft	King Tide, No Surge

Full Adaptation Suite – 2ft SLR, 100-yr Rain, 100-yr Surge



Base Scenario Structures Water Depth (inches)



Adaptation Strategy Structures Water Depth (inches)

Distribution of Structures by Flood Depth Impact

Flood Depth (in)	BASE	ADAPTATION
<3"	27,548	15,587
3"-6"	32,942	15,449
6"-12"	44,440	15,401
12"-24"	39,883	10,584
>24"	12,784	3,027
TOTAL	157,597	60,048

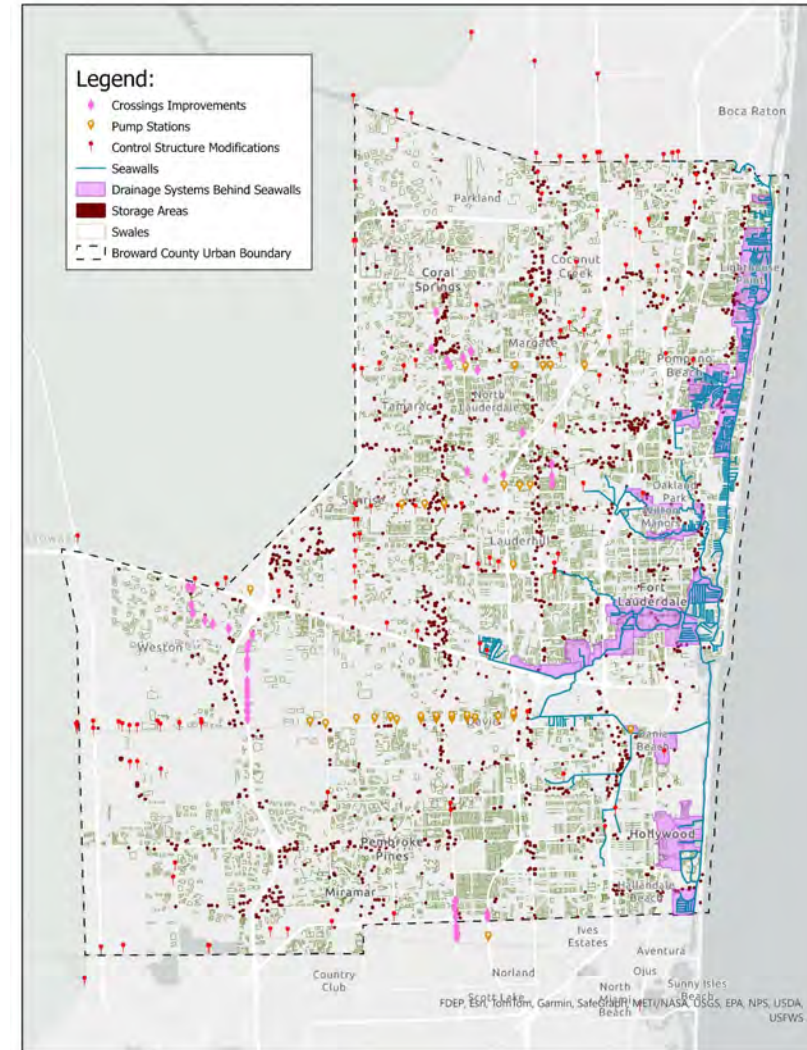
62% Reduction

Scenario

Rain	SLR	Tidal
100-yr. 3d	2.0 ft	King tide, 100-yr. Surge

Full Suite of Adaptations – 2- and 3-foot Sea Level Rise, through 2070

- Tier 1
 - Pumping stations
 - Culvert improvements
 - Storage areas
 - Control structures
 - Two-way road conversions (swales)
 - 5-ft. sea walls
- Tier 2
 - Drainage systems
 - Seawall elevated to 7 ft.



190+ Miles
enhanced
Seawalls

169
Controls
Structures

28
New Pump
Stations

50
Upgraded
Crossings

1,247
Acres-ft of
storage

Dollar value of five benefit categories



Property damage savings from avoided costs of repairing and replacing assets damaged by floods



Economic activity (Gross Value Added) benefits from avoided business and transport disruption



Increased Flood Insurance Coverage as risk and premia are lower due to flood mitigation



Increased Real Estate Value resulting from lower flood damage costs, insurance premia savings, and rental income losses

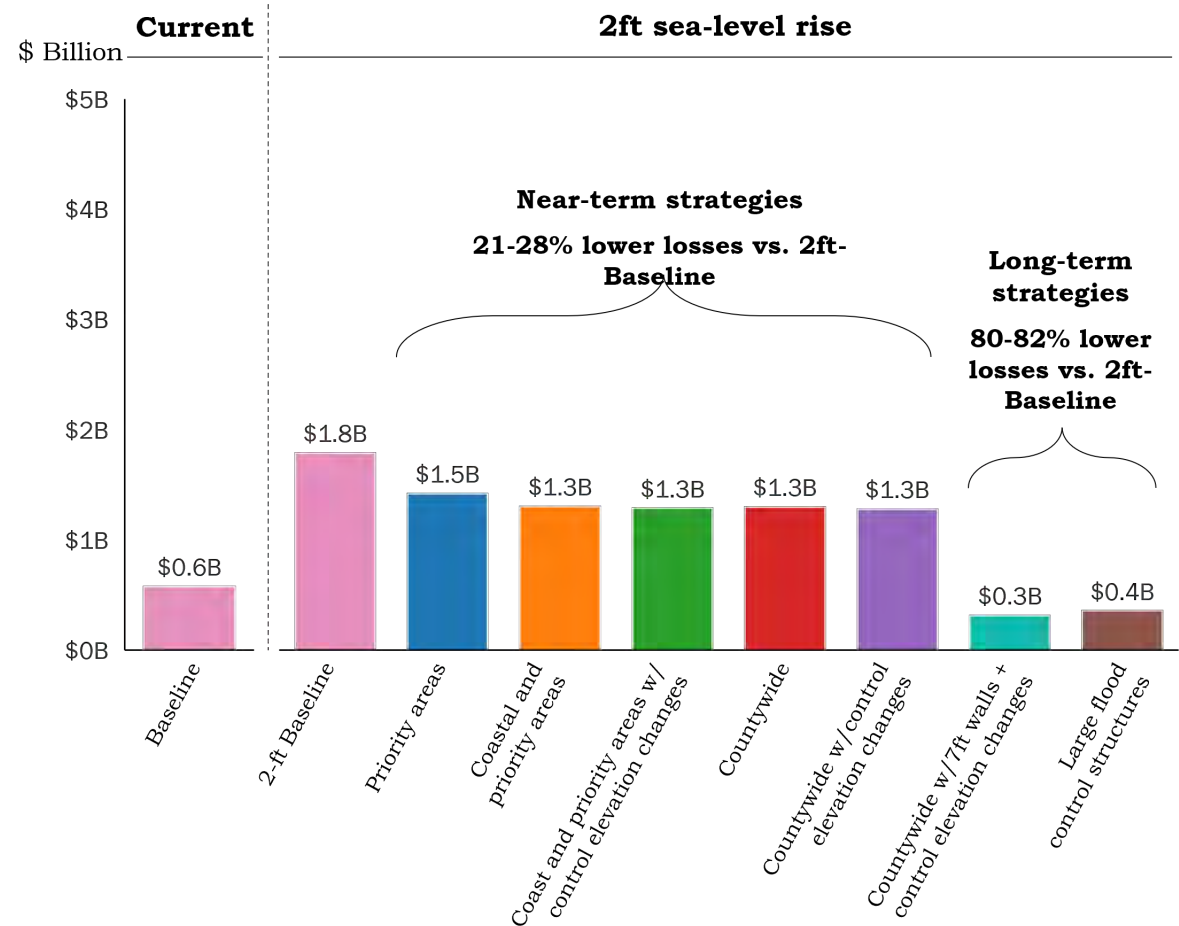
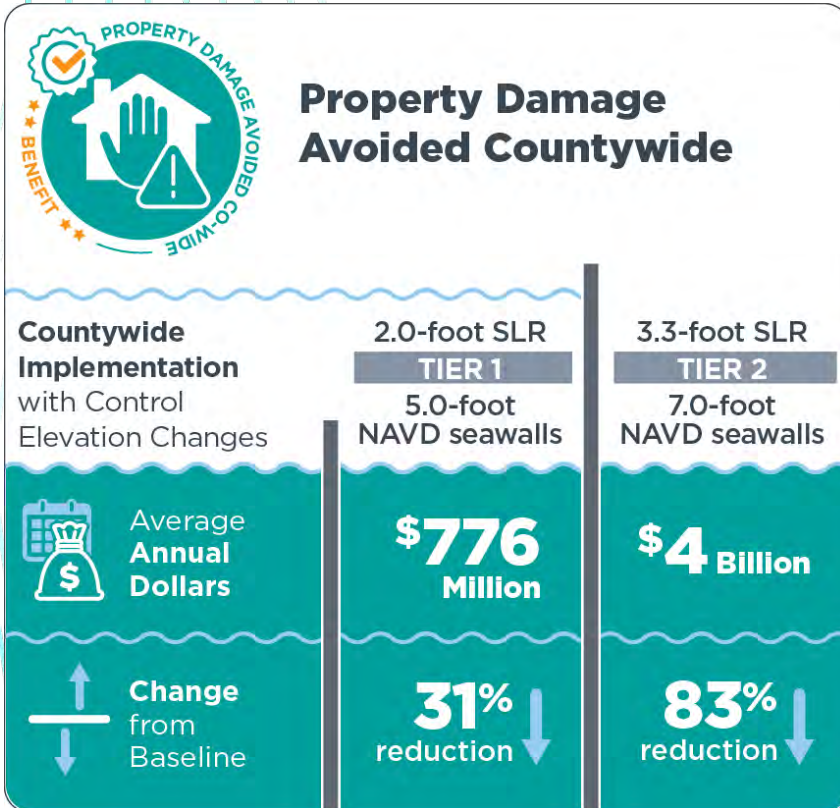


Increased Property Tax collections to County and cities because of higher property values

All dollar values are in 2024 (today's) dollars.

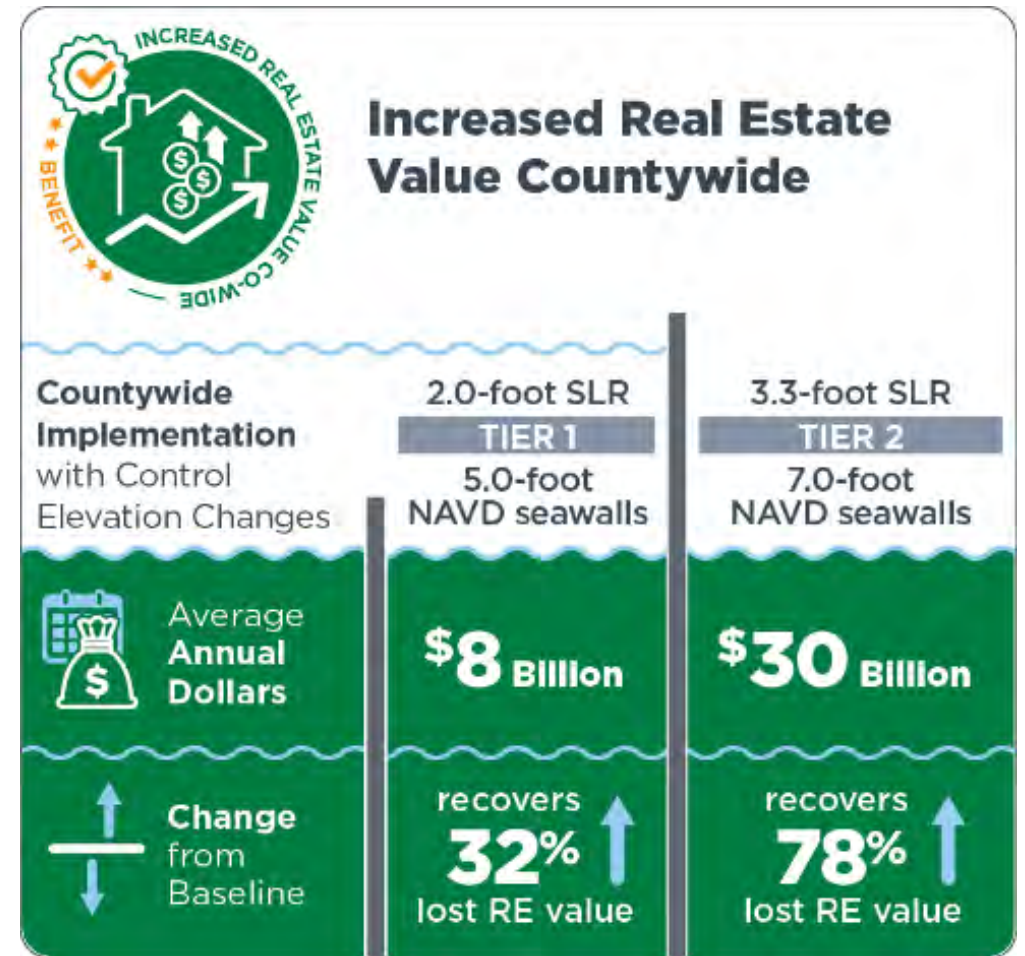
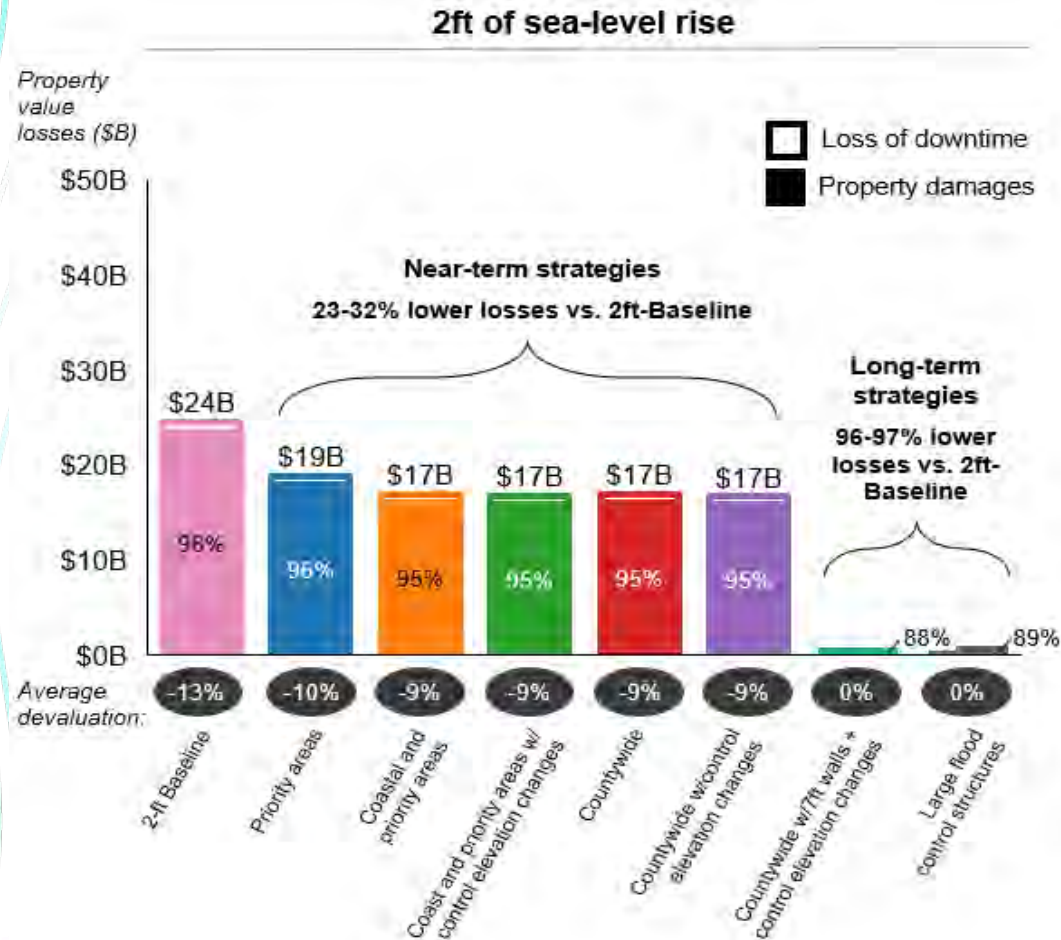
Reduces Direct Property Losses & Protects Property Value

Avoided residential damages relative to baseline (\$M)



Preserves residential property value - \$8B near-term to \$30B long-term

Residential Real Estate Devaluation



Tier 1 and Tier 2 reduce property damage across much of Broward County

Annual average damages to residential assets as share of property value across the county

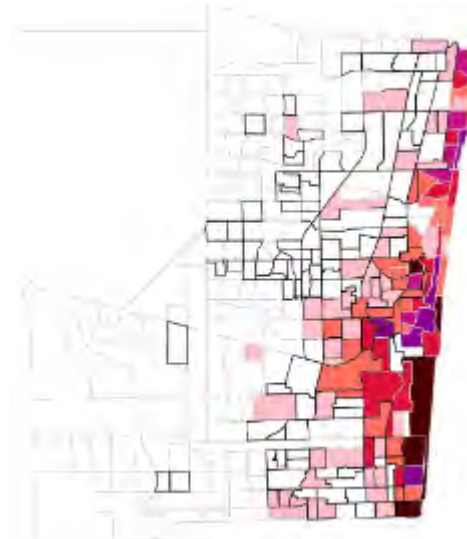
Baseline – 2ft



Countywide adaptations w/
control elevation changes –
2ft



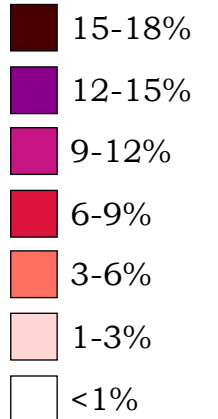
Baseline – 3.3ft



Countywide adaptations w/
control elevation & 7ft
seawalls- 3.3ft



Damages as
share of
property
value:



Areas outlined in black relate to zone 1

Benefits of higher property values across the County are evident under both Tiers

Real estate value losses across the County (\$M losses)

Baseline - 2ft

Countywide adaptations w/
control elevation changes -
2ft

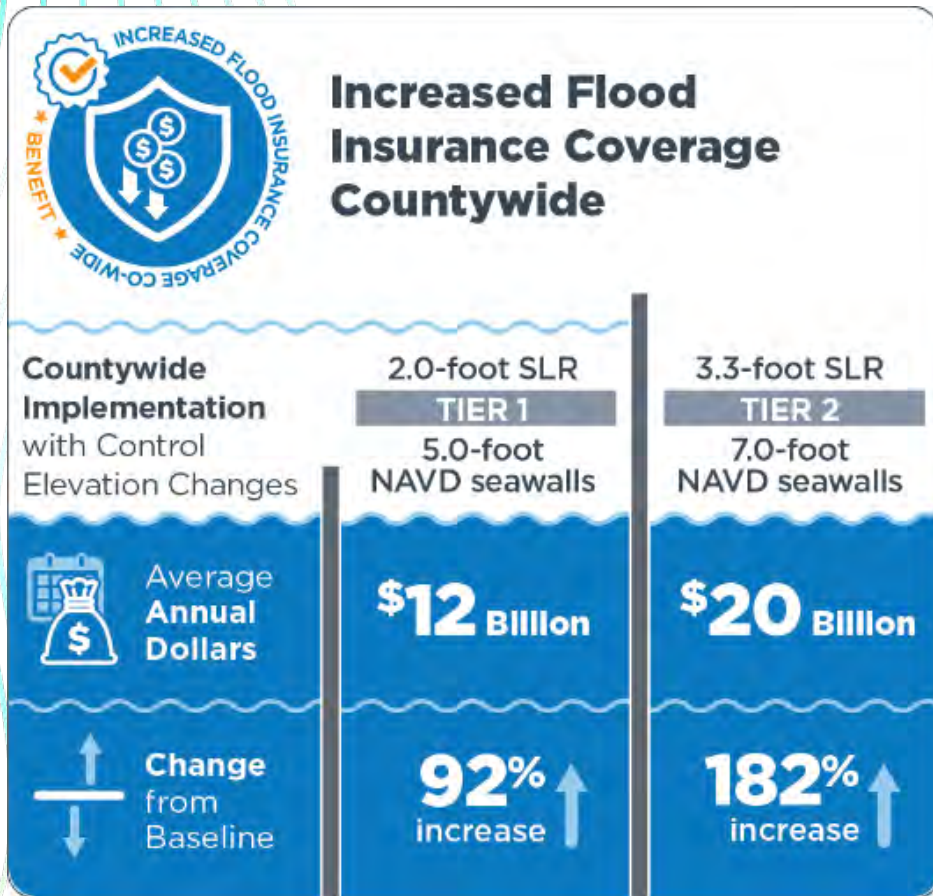
Baseline - 3.3ft

Countywide adaptations w/
control elevation & 7ft seawalls-
3.3ft



Areas outlined in black relate to zone 1

Tier 1 and Tier 2 Adaptation Strategies could increase flood insurance coverage countywide



Avoided flood damages could have several benefits for insurance markets including:

- Higher number of homes maintaining flood insurance policies (assuming pricing is risk-based)
- As a result, higher continued flood insurance coverage (and less uninsured costs to households)
- Lower average premiums for those that maintain insurance

Source: Hazen, FEMA

Benefits of reduced flood insurance premia across the County (Assumes all policies remain in place)

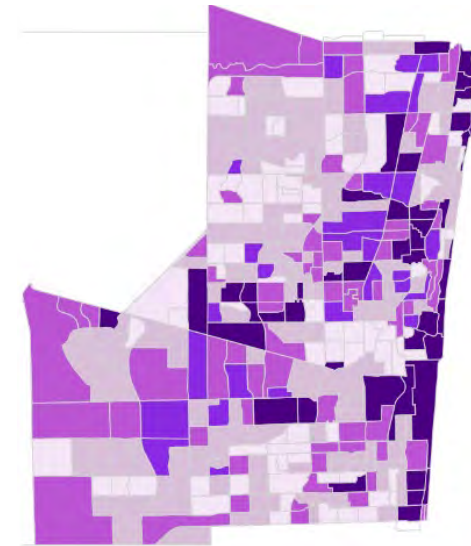
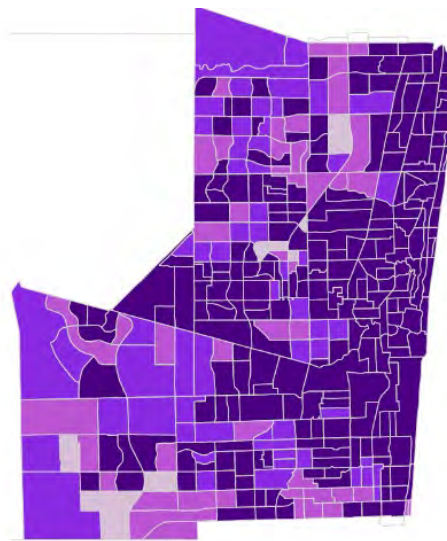
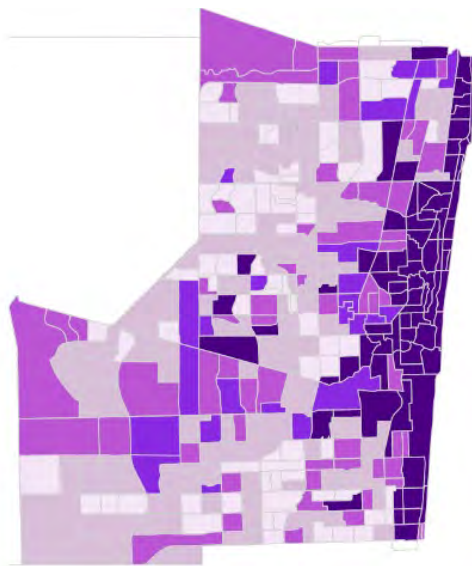
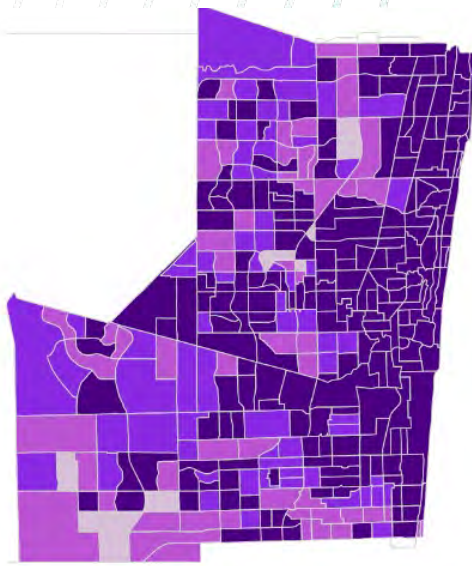
Single-family home premiums (\$ premium cost) adjusted for risk

Baseline - 2ft

Countywide adaptations w/
control elevation changes -
2ft

Baseline - 3.3ft

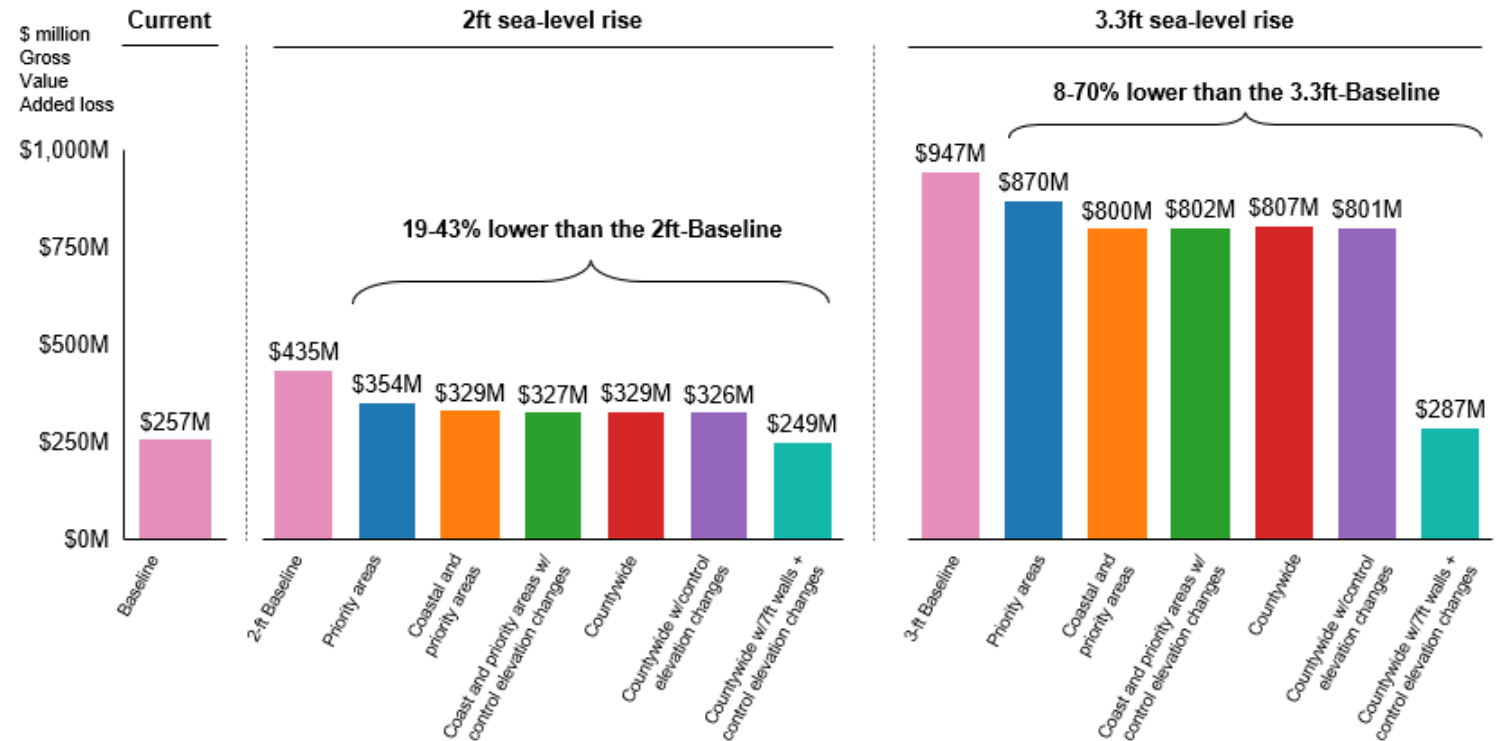
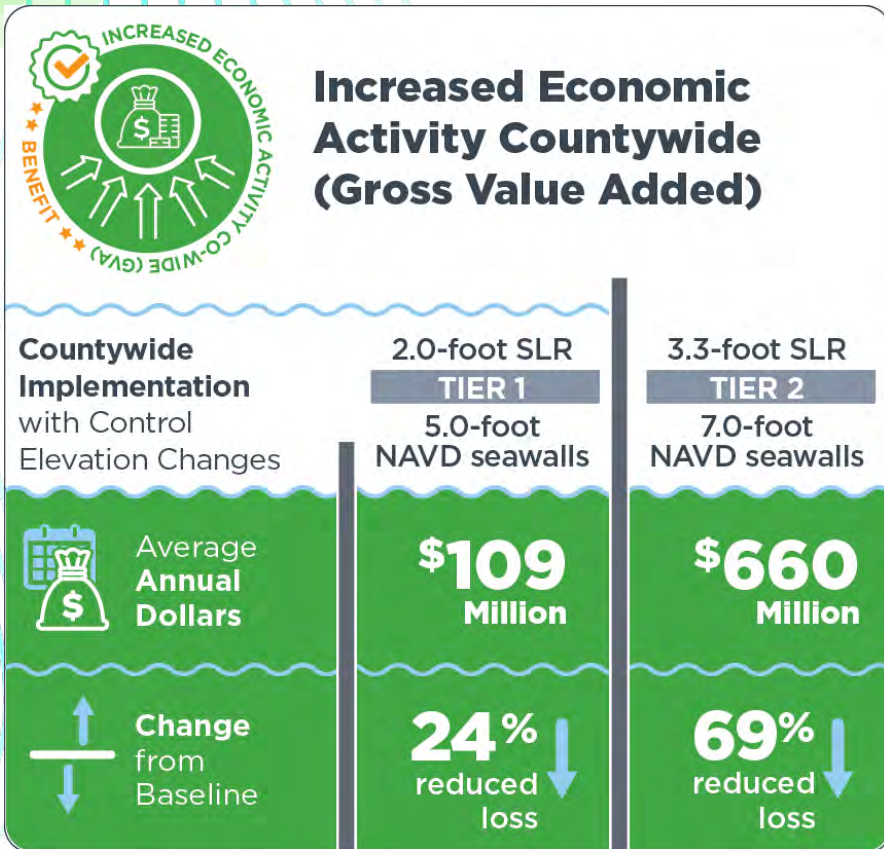
Countywide adaptations w/
control elevation & 7ft seawalls-
3.3ft



Average premium for single-family home:

- >\$1,600
- \$1,200-\$1,600
- \$800-\$1,200
- \$400-\$800
- Up to \$400

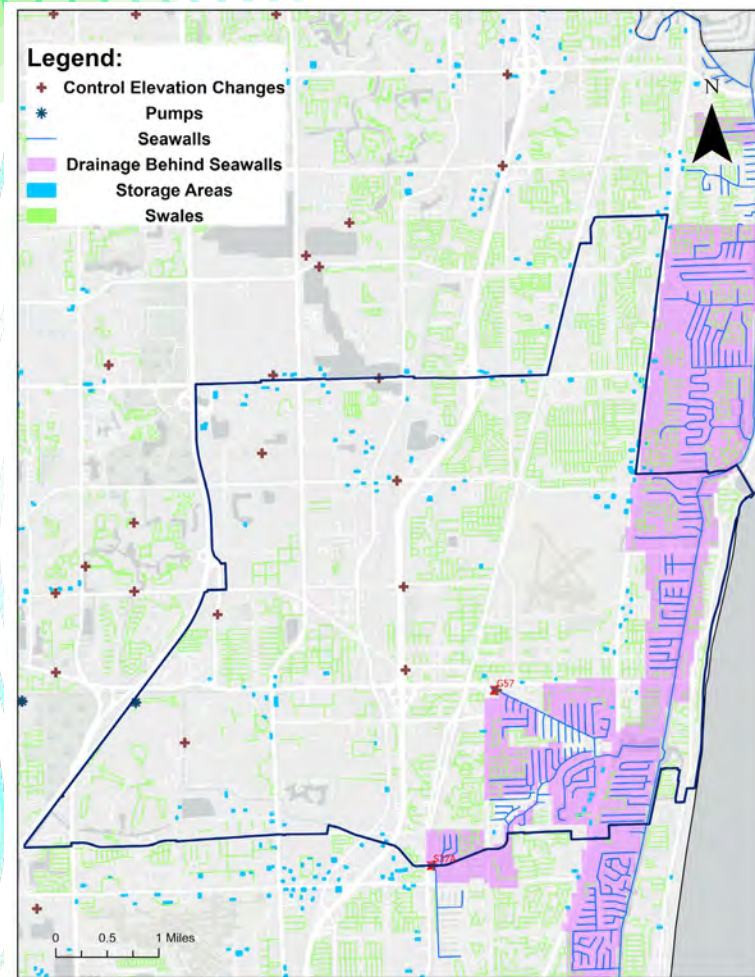
Delivers Increased Economic Activity - Gross Value Added Saves \$109 – \$660M Annually in Economic Production



Summary of Tier 1 and Tier 2 Benefit Value Estimates

Summary of Tier 1 and Tier 2 Benefit Value Estimates		
Benefit Category	Tier 1 Adaptation Strategy to Mitigate 2-foot SLR	Tier 2 Adaptation Strategy to Mitigate 3.3-foot SLR
Property Damage Avoided, average annual	\$776,000,000	\$4,000,000,000
Increased Short-term Economic Activity, average annual	\$109,000,000	\$660,000,000
Increased Property Tax Collected, average annual	\$211,000,000	\$962,000,000
Increased Flood Insurance Coverage	\$12,000,000,000	\$20,000,000,000
Increased Real Estate Value	\$8,000,000,000	\$30,000,000,000

Strategies Specific to the City of Pompano Beach



Adaptation	Attribute	Tier 1		Tier 2	
		Attribute	Cost	Attribute	Cost
Swales	Length (feet)	753,331	\$78,346,000		
Storage Areas	Area (acres)	24.86	\$237,564,000		
Seawall 5 ft NAVD	Length (miles)	58	\$2,381,355,000		
Seawall Extension to 7 ft NAVD	Length (miles)	-	-	58	\$1,166,864,000
Pump Stations	Number of Projects	1	\$15,954,000		
Culvert Improvements	Number of Projects	0	\$0		
Drainage Behind Seawalls	Number of Projects	-	-	13	\$340,734,000
Control Structures	Number of Projects	9	\$21,938,000		
Subtotal Tier 1 & Tier 2		\$2,735,157,000		\$1,507,598,000	
Total cost of adaptations for Pompano Beach			\$4,242,755,000		

Municipality	Baseline average annual flood damages and Tier 1 and Tier 2 percentage changes Relative to Baseline (negative % means reduction in property damage)			
	Baseline under 2ft SLR (\$M in damages to residential homes)	Tier 1 % change - Countywide w/ control elevation changes under 2ft SLR	Baseline under 3.3ft SLR (\$M in damages to residential homes)	Tier 2 % change - County-wide measures, w/ control elevation changes and 7ft seawalls under 3.3ft SLR
Lighthouse Point	\$58,620,000	-69%	\$176,000,000	-91%
Margate	\$13,170,000	-40%	\$13,270,000	-40%
Miramar	\$45,230,000	-57%	\$56,380,000	-63%
North Lauderdale	\$2,100,000	-87%	\$2,170,000	-88%
Oakland Park	\$42,440,000	-41%	\$72,060,000	-75%
Parkland	\$3,680,000	-26%	\$3,800,000	-28%
Pembroke Park	\$580,000	-90%	\$670,000	-89%
Pembroke Pines	\$15,500,000	-67%	\$16,100,000	-67%
Plantation	\$20,470,000	-60%	\$21,740,000	-51%
Pompano Beach	\$180,240,000	-20%	\$385,220,000	-82%
Southwest Ranches	\$2,920,000	-17%	\$2,950,000	-18%
Sunrise	\$4,830,000	-67%	\$5,290,000	-68%
Tamarac	\$3,890,000	-72%	\$4,170,000	-70%

Resilience Strategies - Planning Level Cost Summary



Estimated Costs of the Tier 1 and Tier 2 Adaptation Strategies, 2024 dollars			
Item	Tier 1	Tier 2	Additional Cost of Tier 2 Once Tier 1 is Constructed
	Countywide - 5ft NAVD seawalls	Countywide - 7ft NAVD seawalls	
(1)	(2)	(3)	(4) = (3) – (2)
Capital Cost	\$21,400,000,000	\$30,300,000,000	\$8,900,000,000
Annual O&M and R&R Cost	\$214,000,000	\$303,000,000	\$89,000,000

* Accounts for design, permitting, and construction with 30% contingency

Resilience Plan Performance – Positive Return on Investment

Economic Metric	Tier 1 and Tier 2	Tier 1 Only
	SLR is 2ft by 2050 and 3.3ft by 2070	SLR is 2ft by 2050 and no additional SLR after
Rate of Return on Investment, nominal annual	At least 10%	At least 7%
Benefit to Cost Ratio at 5% annual nominal discount rate	At least 3.4	At least 1.4

Tier 1 and Tier 2 to mitigate flood risk are economically feasible when compared to County’s 5% annual opportunity cost of money

Benefit categories included are estimated avoided property damage, increased short term economic activity, and increased real estate value.

Scenario Viewer

RESILIENT BROWARD Scenario Viewer (Development Version) Find address or place

1a. Adaptation Scenario ⓘ

Tier 1	Tier 2	None
--------	--------	------

2a. Sea Level Rise ⓘ

Current SLR	2.0 ft	3.3 ft
-------------	--------	--------

3a. Rainfall Amount ⓘ

5-yr	25-yr	50-yr
	100-yr	

4a. Storm Surge ⓘ

No Surge	100-yr Storm Surge
----------	--------------------

Compare two scenarios

No Adaptation / 2.0 ft SLR / 50-yr Rainfall / 100-yr Storm Surge / Variable GW

FDEP, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA, USFWS

Powered by

1a. Adaptation Scenario ⓘ

Tier 1	Tier 2	None
--------	--------	------

1b. Adaptation Scenario ⓘ

Tier 1	Tier 2	None
--------	--------	------

2a. Sea Level Rise ⓘ

Current SLR	2.0 ft	3.3 ft
-------------	--------	--------

2b. Sea Level Rise ⓘ

Current SLR	2.0 ft	3.3 ft
-------------	--------	--------

3a. Rainfall Amount ⓘ

5-yr	25-yr	50-yr
100-yr		

3b. Rainfall Amount ⓘ

5-yr	25-yr	50-yr
100-yr		

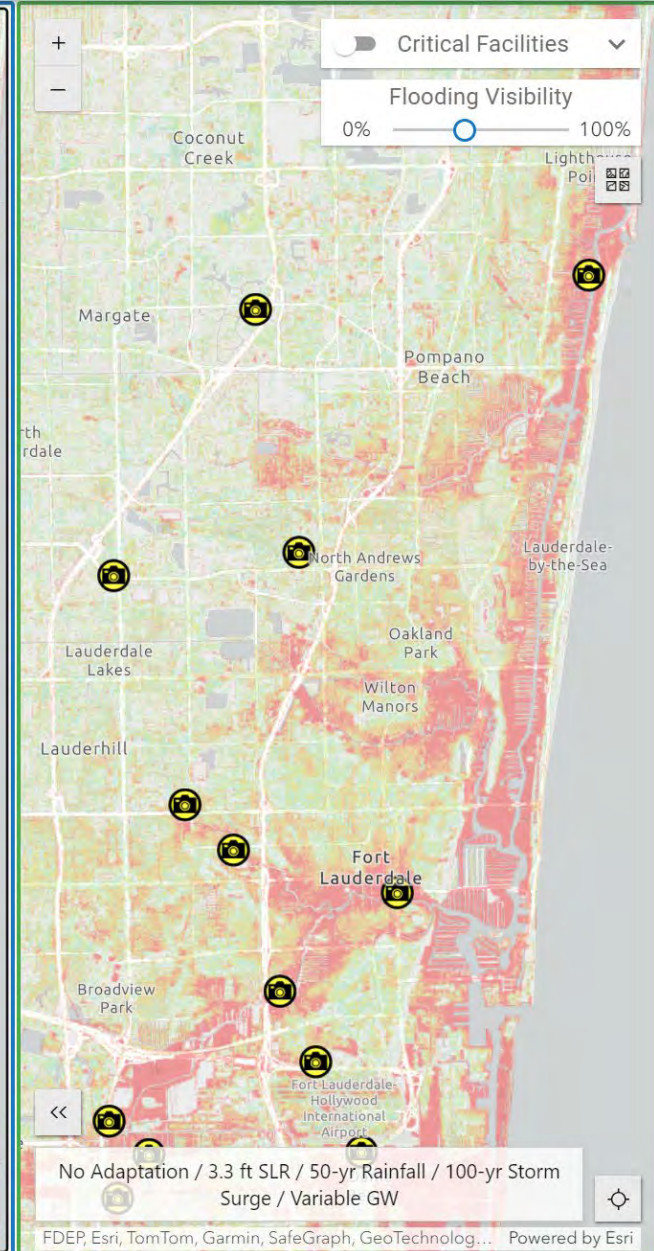
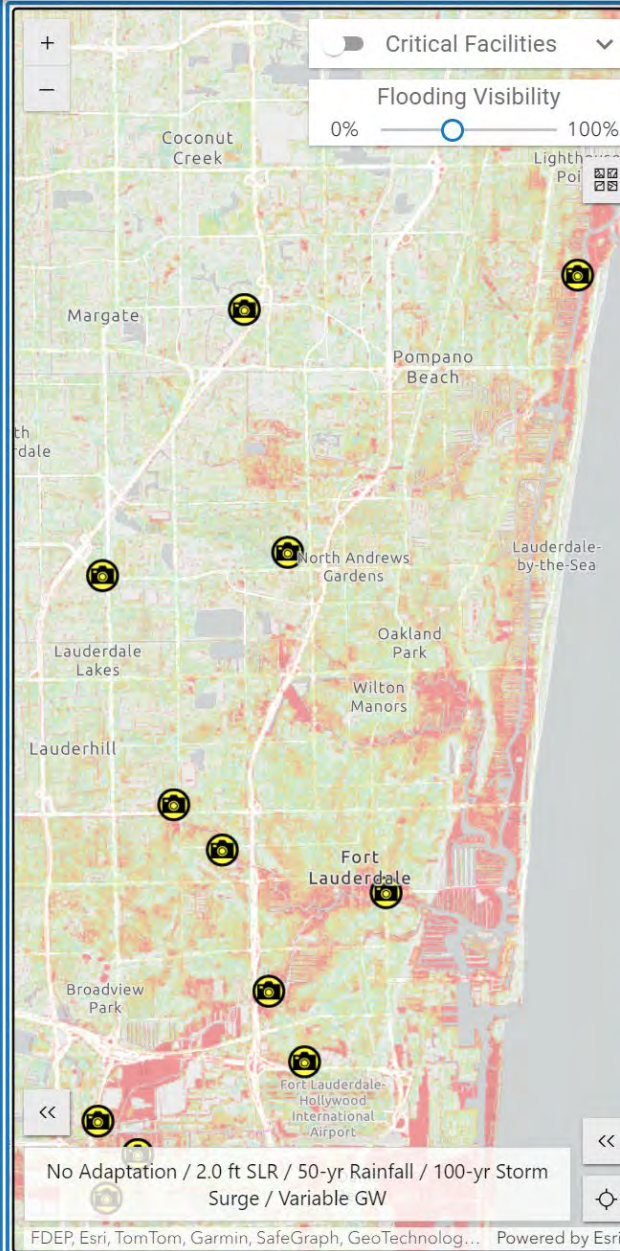
4a. Storm Surge ⓘ

No Surge	100-yr Storm Surge
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4b. Storm Surge ⓘ

No Surge	100-yr Storm Surge
----------	--------------------

Compare two scenarios



1a. Adaptation Scenario ⓘ

Tier 1	Tier 2	None
--------	--------	------

1b. Adaptation Scenario ⓘ

Tier 1	Tier 2	None
--------	--------	------

2a. Sea Level Rise ⓘ

Current SLR	2.0 ft	3.3 ft
-------------	--------	--------

2b. Sea Level Rise ⓘ

Current SLR	2.0 ft	3.3 ft
-------------	--------	--------

3a. Rainfall Amount ⓘ

5-yr	25-yr	50-yr
	100-yr	

3b. Rainfall Amount ⓘ

5-yr	25-yr	50-yr
	100-yr	

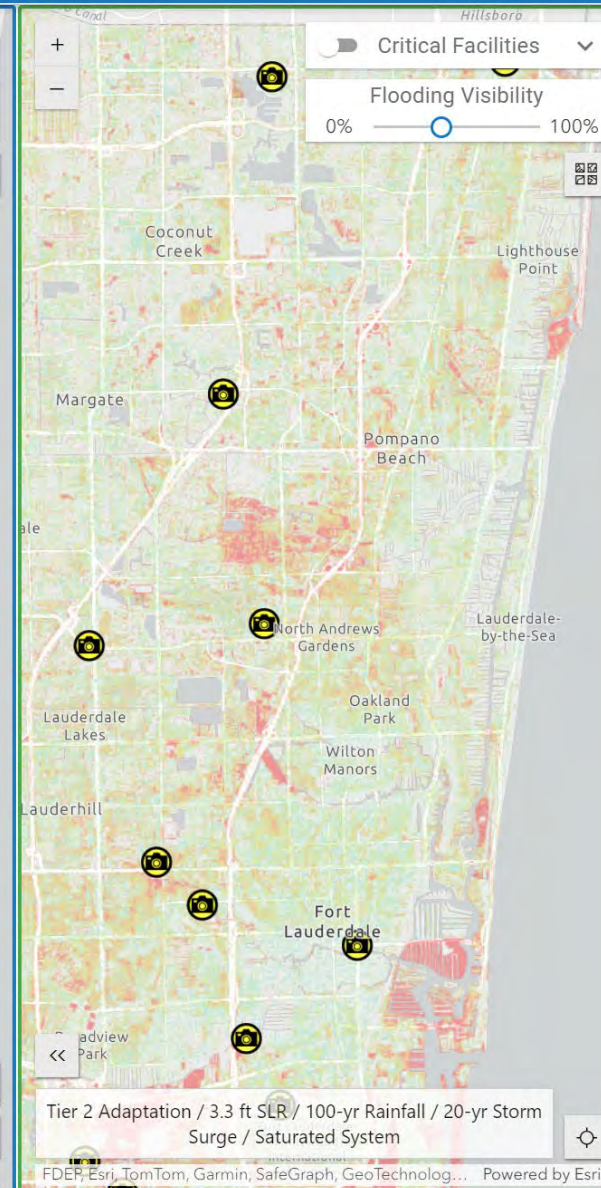
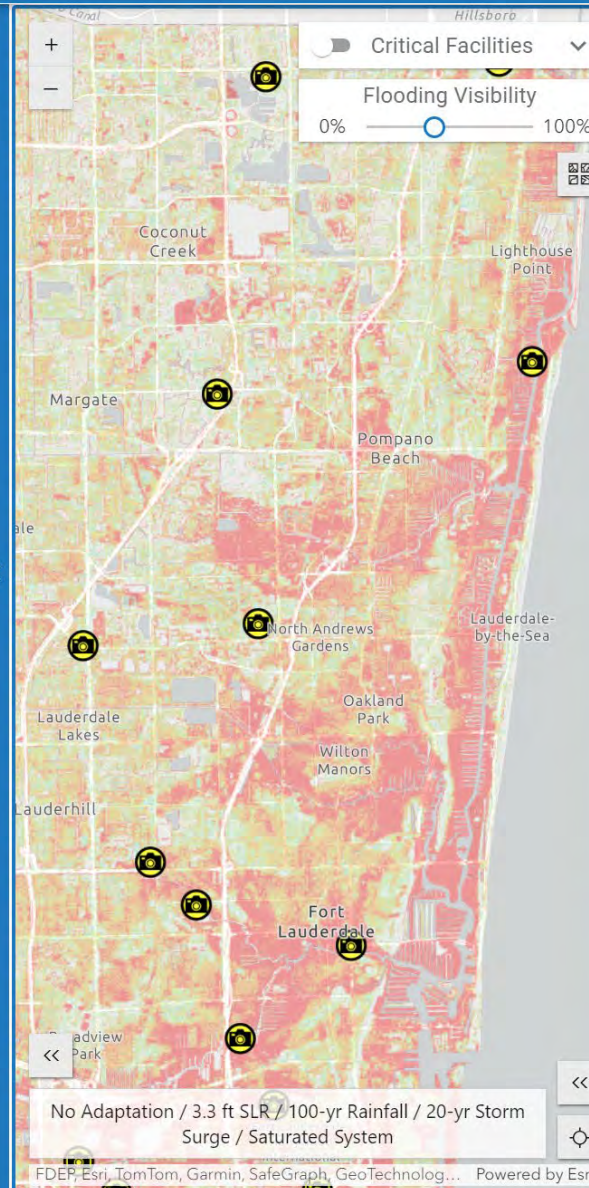
4a. Storm Surge ⓘ

No Surge	20-yr Storm Surge	100-yr Storm Surge
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4b. Storm Surge ⓘ

No Surge	20-yr Storm Surge	100-yr Storm Surge
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Compare two scenarios



Neighborhood Level Navigation

1a. Adaptation Scenario ⓘ

Tier 1 Tier 2 None

2a. Sea Level Rise ⓘ

Current SLR 2.0 ft 3.3 ft

3a. Rainfall Amount ⓘ

5-yr 25-yr 50-yr

100-yr

4a. Storm Surge ⓘ

20-yr Storm Surge 100-yr Storm Surge

Compare

RESILIENT BROWARD Scenario Viewer (Development Version)

Find address or place ?

Critical Facilities

Flooding Visibility
0% 100%

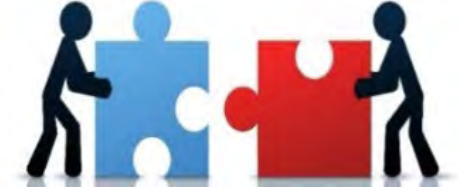
Tier 1 Adaptation / 2.0 ft SLR / 25-yr Rainfall / 20-yr Storm Surge / Variable GW

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Tier 1 Adaptation / 2.0 ft SLR / 25-yr Rainfall / 20-yr Storm Surge / Variable GW

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Summary



- Climate related flood and heat risk presents a growing physical hazard and economic exposure for Broward County.
- The County Resilience Plan provides a phased strategy for addressing our shared resilience needs with prioritization of socially vulnerable communities.
- Tier 1 strategies provide 19 municipalities with a 40% reduction in flood damage (or greater), 24 municipalities are similarly benefited with tier 2 strategies, with an 83% reduction in damages county-wide.
- Proposed strategies deliver \$8 to \$30 Billion in residential property value preservation, avoid up to \$4 Billion in asset damages, and preserve \$20 Billion in flood insurance coverage.

Summary

- Economics benefits provide a critical metric for plan performance, but the Broward community is the heart of the plan.
- Our goal is to deliver a more stable environment that protects our residents, businesses, assets, and jobs – with new opportunity for all who live, learn, work, and play in Broward County.
- Resilience is how we serve our community, reducing risk and losses, protecting personal finances, and forging a competitive future – innovating in infrastructure, leading in technology, driving industry, and growing jobs.
- Forthcoming conversation with Broward County commission regarding plan details and options for moving forward.

Questions ?

DR. JENNIFER JURADO

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Resilient Environment Department

jjurado@broward.org

954-519-1464



RESILIENT
ENVIRONMENT