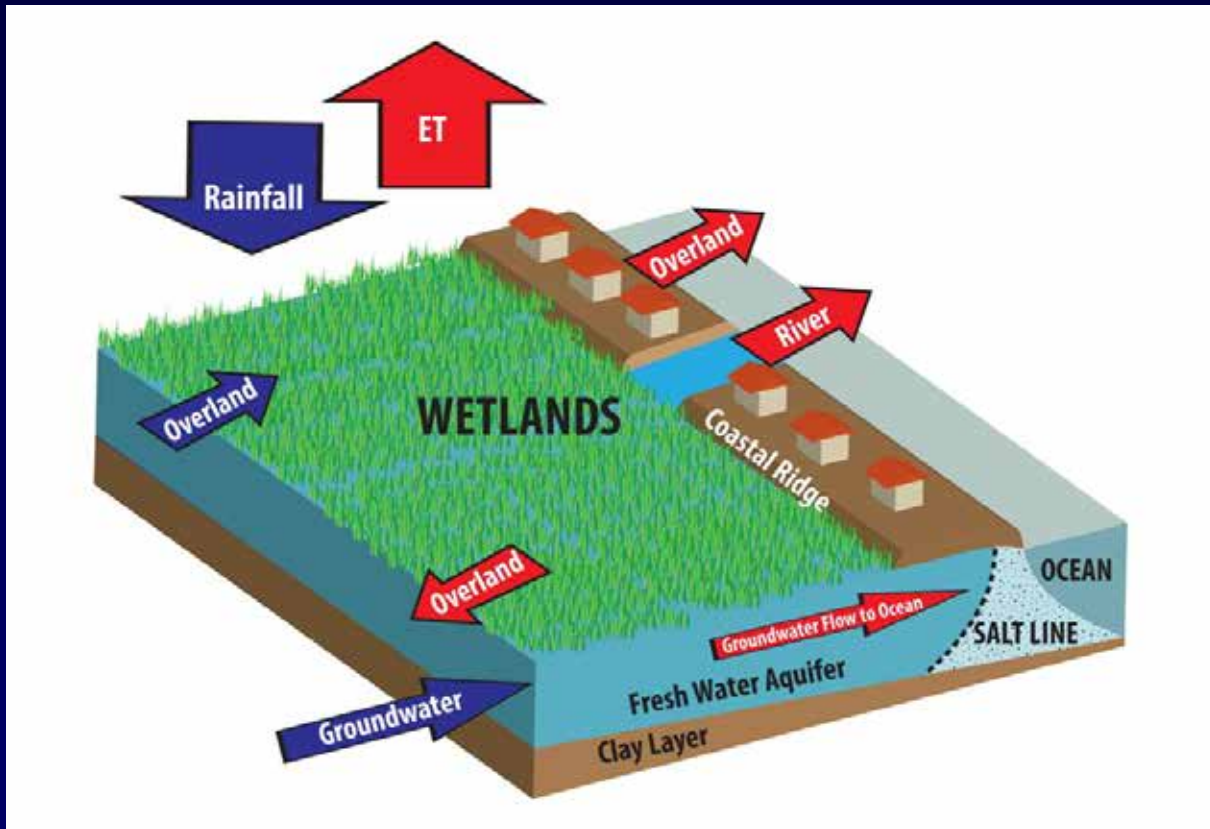


Southeast Florida's Resilient Water Resources: Adaptation to Sea Level Rise and Other Impacts of Climate Change

Frederick Bloetscher, Ph.D., P.E., DWRE
Barry N. Heimlich, and Daniel E. Meeroff, Ph.D., E.I.
Florida Atlantic University

A. Randolph Brown, Don Bayler and Maria Loucraft,
City of Pompano Beach

Historical SE Florida Water System



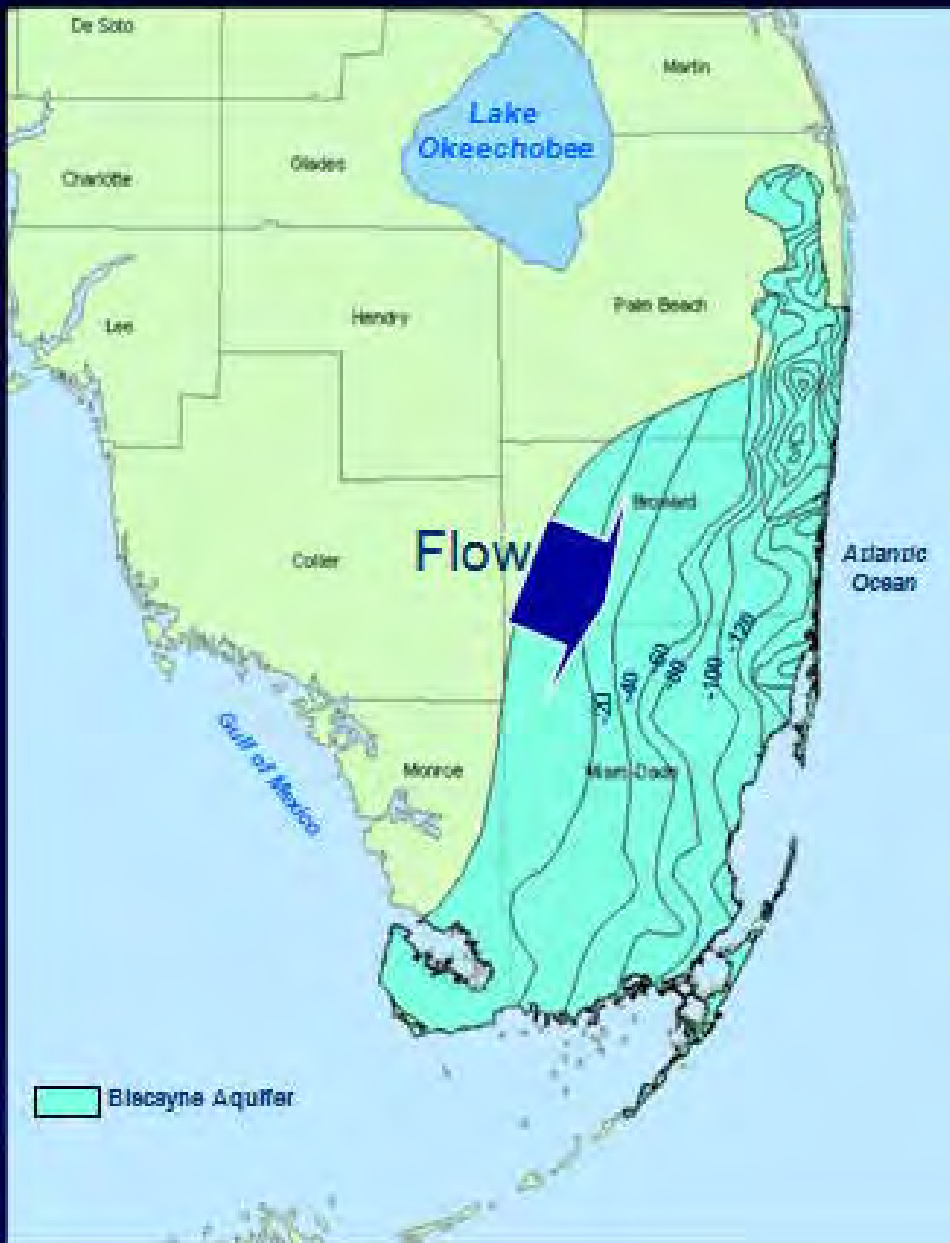
Things to Note

- The surface water flowed slowly to the south
- Percolation into the Biscayne aquifer was high
- Lots of ET
- But Groundwater moved SE!

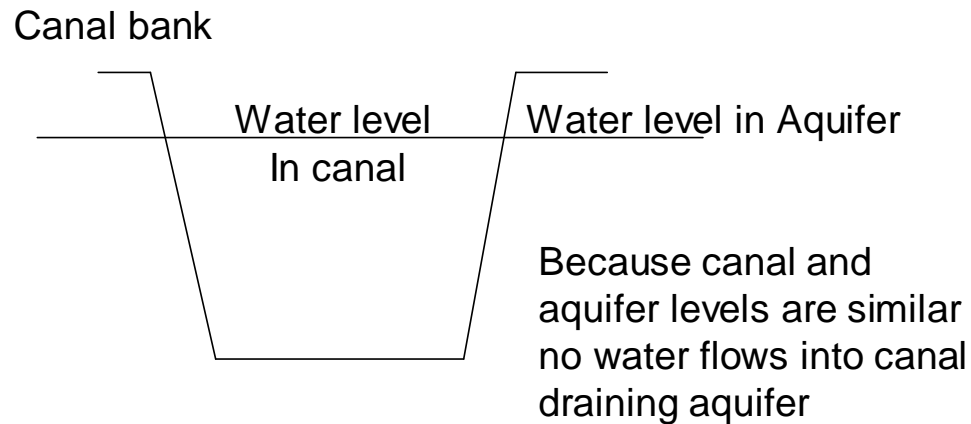
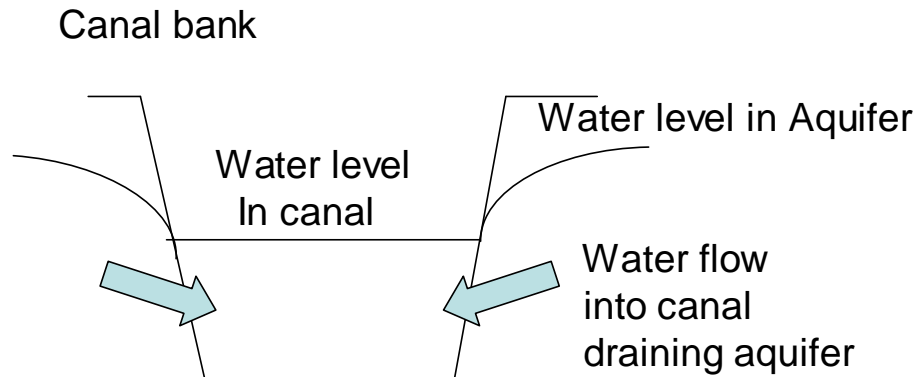


The Historical Biscayne Aquifer

Conclusion –
the Everglades
Recharges the
Biscayne
Aquifer

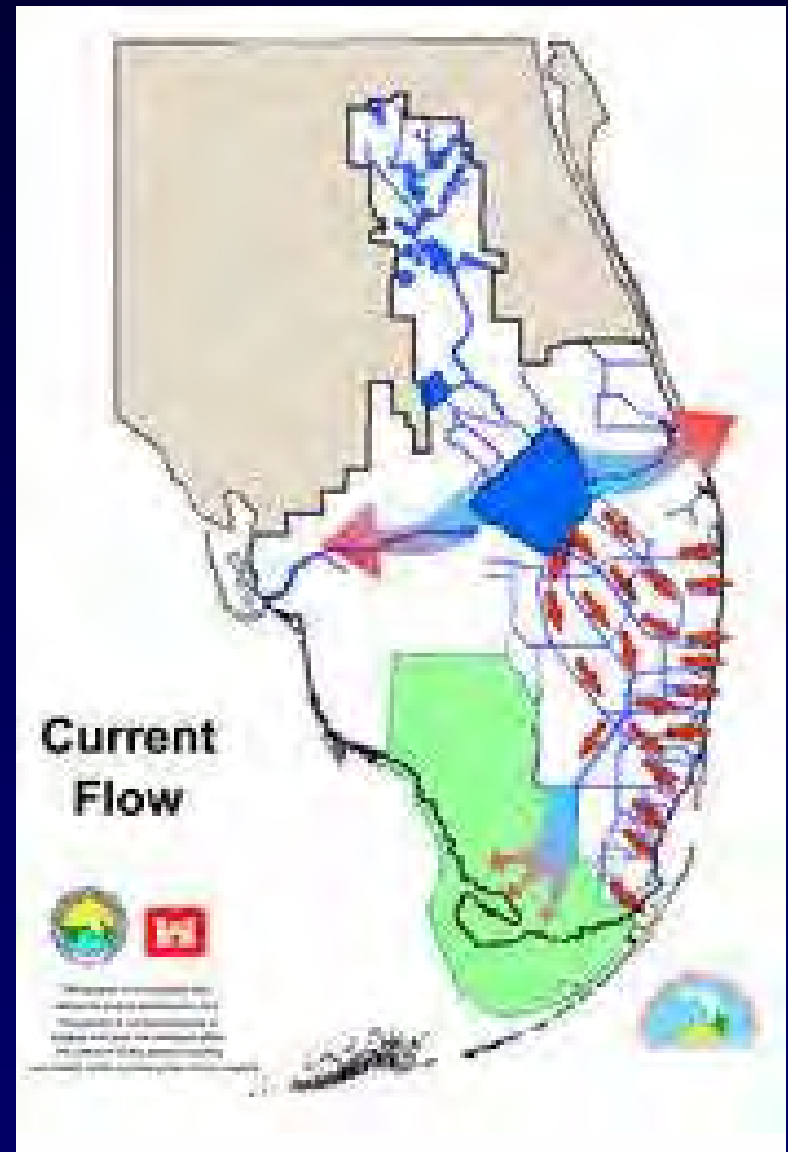
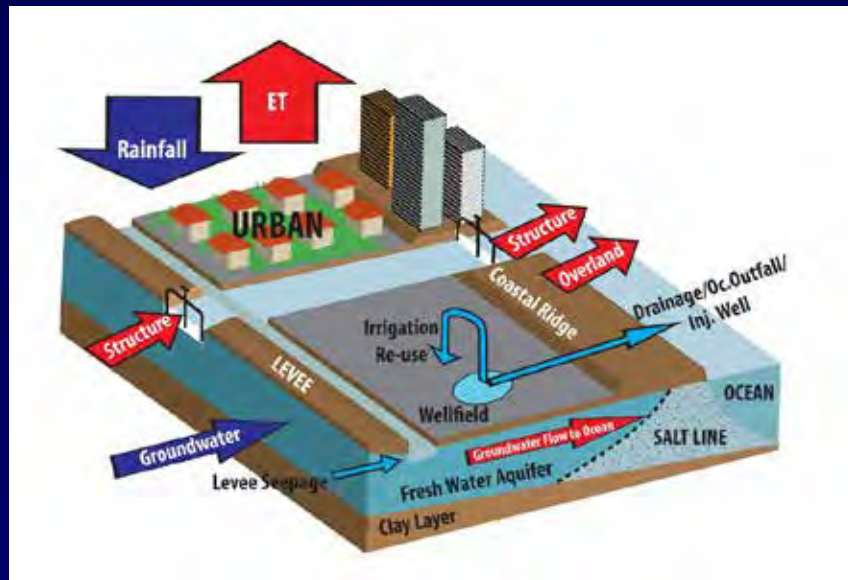


Canal Issues



Modern System

- The surface water flows in many directions but primarily east/west
- Faster runoff = less percolation
- Faster runoff = less ET

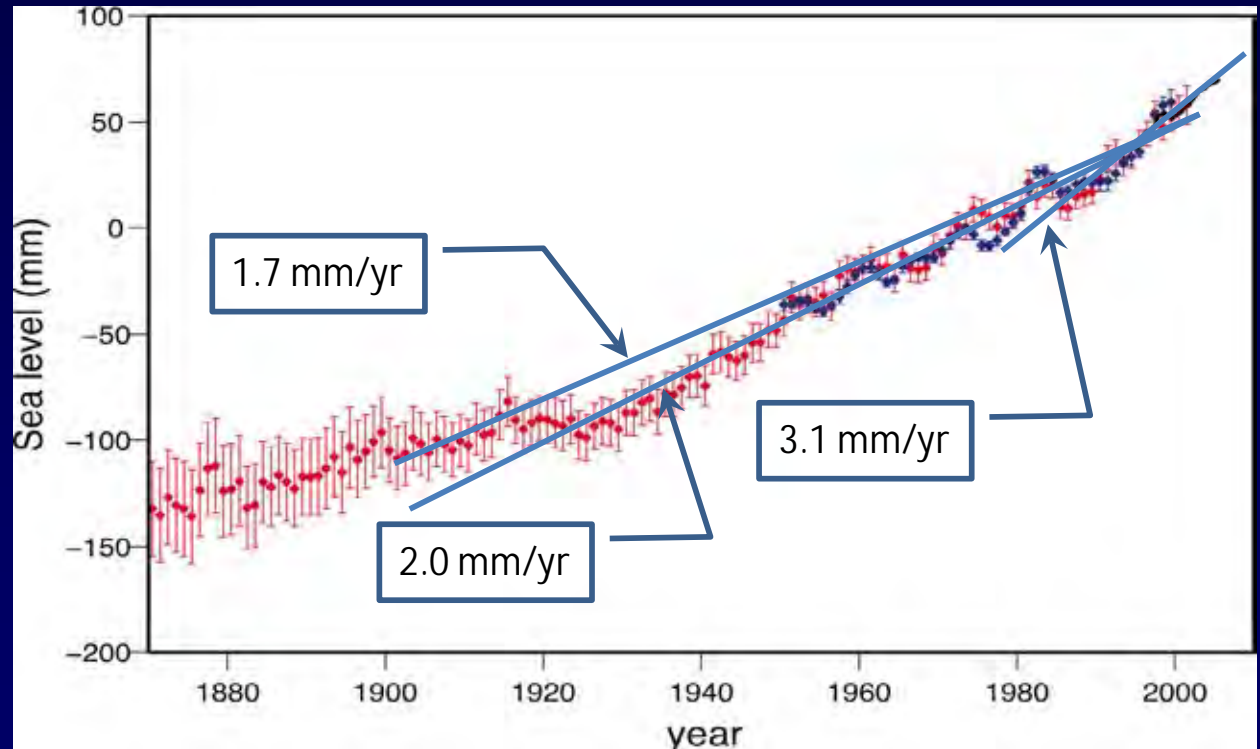


What We are Afraid of:

Temperature increase

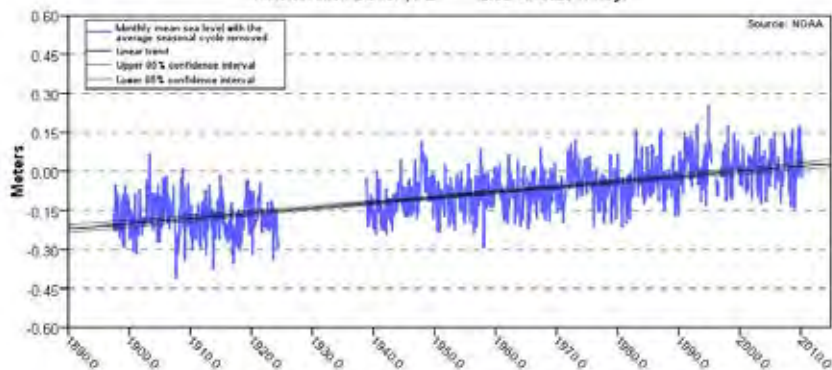
= sea level rise

Observations indicate this is ongoing

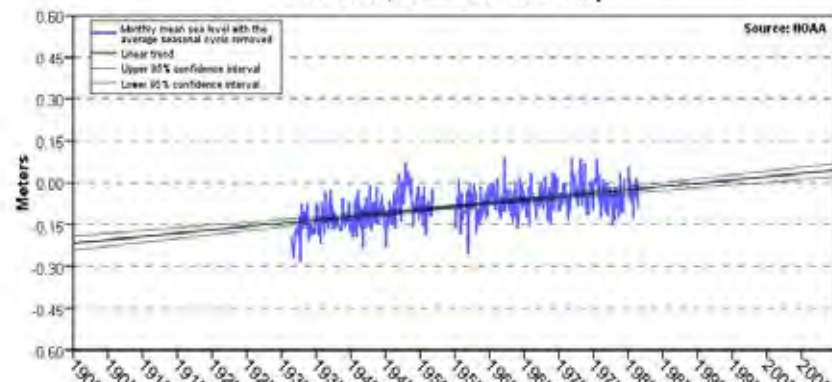


Atlantic Coast Tide Gauges

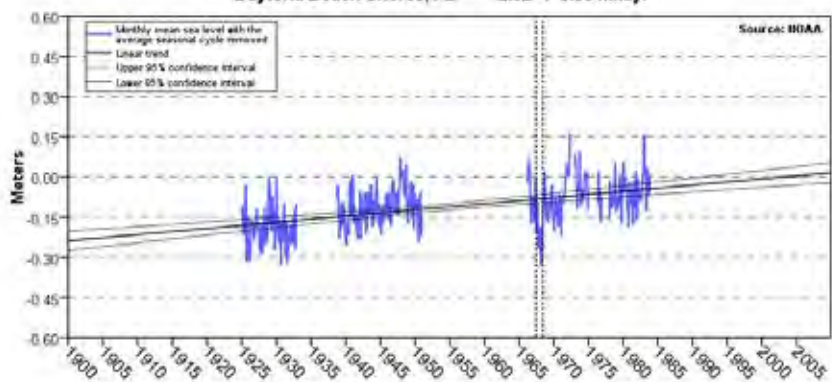
Fernandina Beach, FL 2.02 +/- 0.20 mm/yr



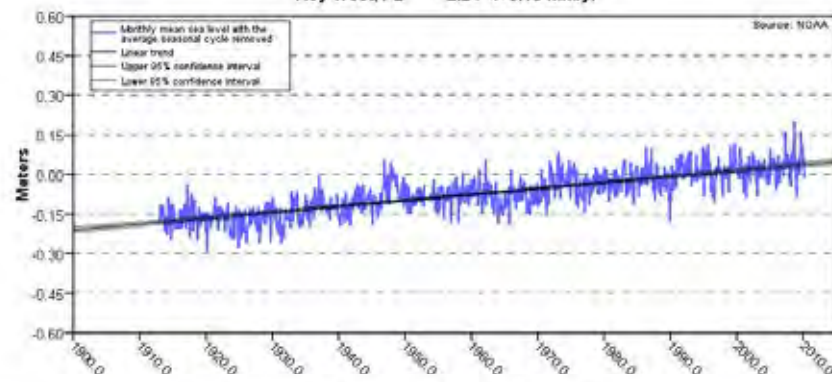
Miami Beach, FL 2.39 +/- 0.43 mm/yr



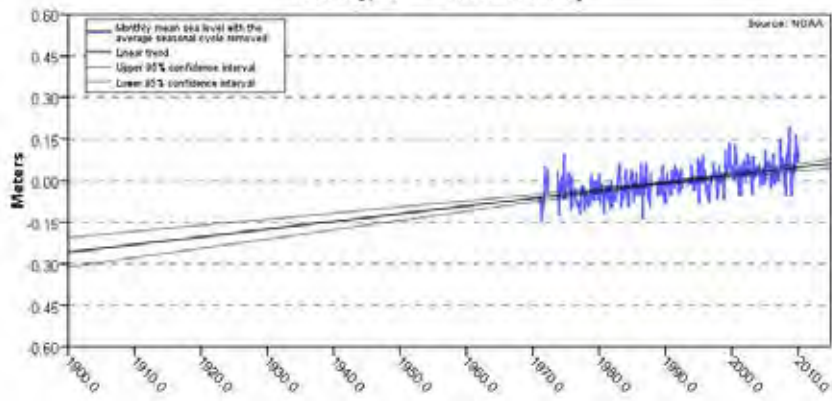
Daytona Beach Shores, FL 2.32 +/- 0.63 mm/yr



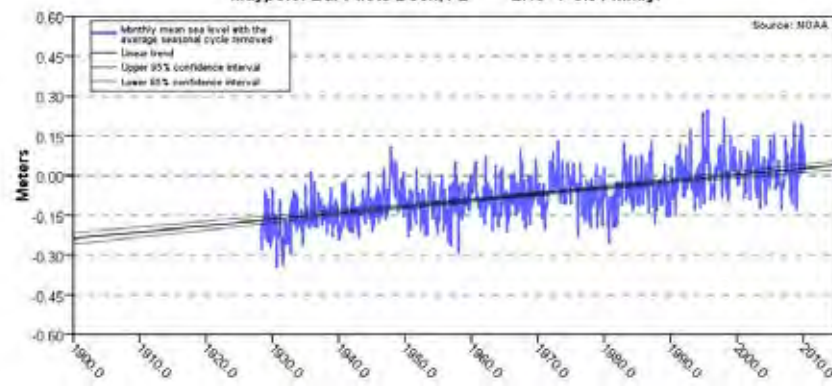
Key West, FL 2.24 +/- 0.16 mm/yr



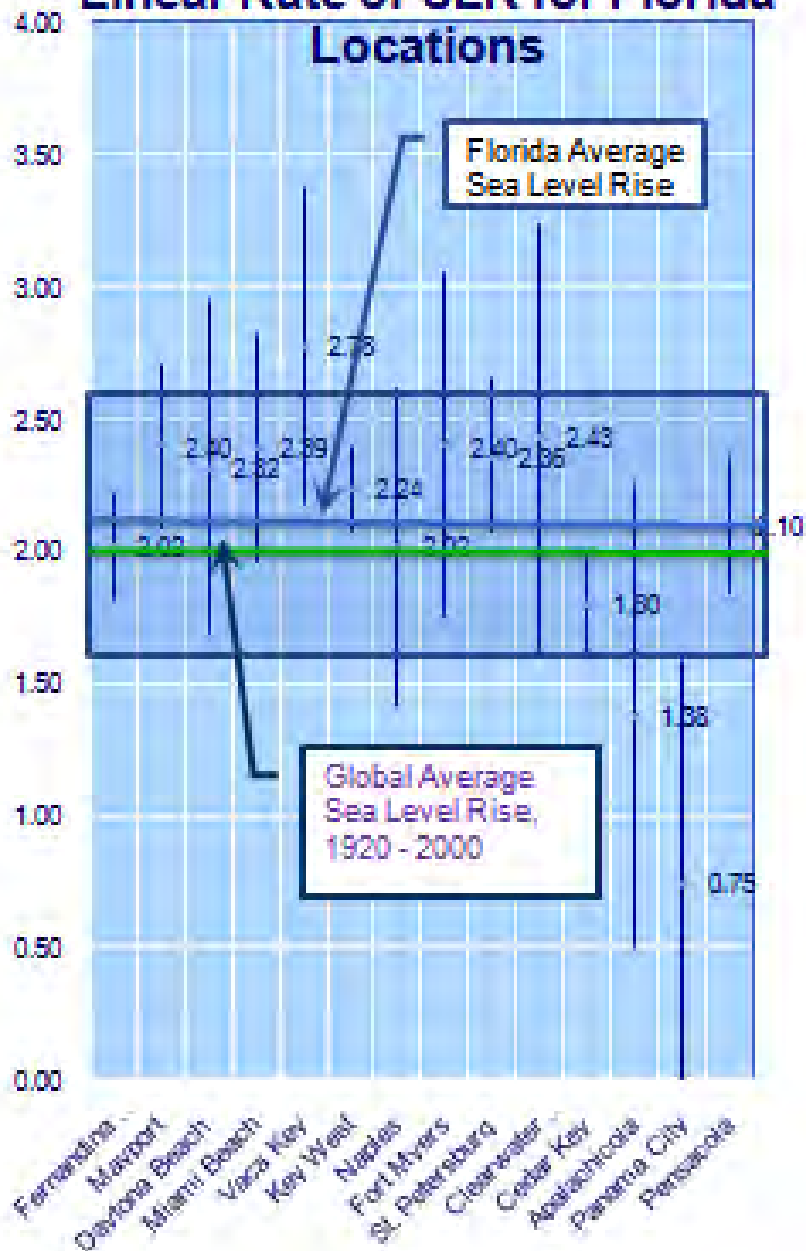
Vaca Key, FL 2.18 +/- 0.60 mm/yr



Mayport / Bar Pilots Dock, FL 2.40 +/- 0.31 mm/yr



Linear Rate of SLR for Florida Locations

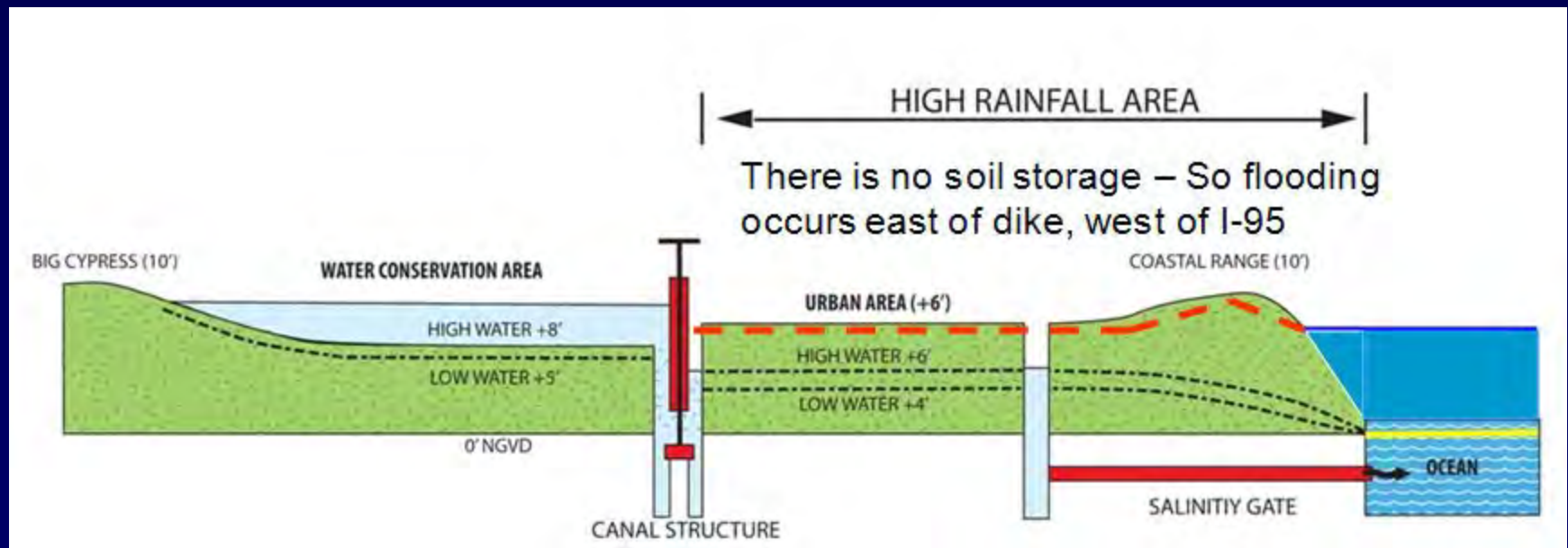


Conclusions:

1. Relative 95% Conf Limits vary inversely with Time Span.
2. Florida avg. sea level rise is 2.10 ± 0.49 mm/yr for 14 Florida locations
3. All but one location within the 95% Conf Limits range.
4. Exception is Panama City with SLR of 0.75 ± 0.83 mm/yr.
5. Apalachicola, Panama City, and Vaca Key are only locations where mean SLR rate is not in range of 2.10 ± 0.49 mm/yr.
6. Therefore, none of SLR rates differ statistically .
7. Average Global SLR for 1920-2000 was 2.0 mm/yr – within 95% Conf Limits for Florida locations.
8. Conclusion: Global projections of SLR can be used for Florida

Consequences...

- Saltwater Intrusion may be offset with GW rise
- Flooding during storms, mostly because GW rise = Loss of soil storage capacity
- Hurricane frequency uncertain, but 3 ft SLR is a problem

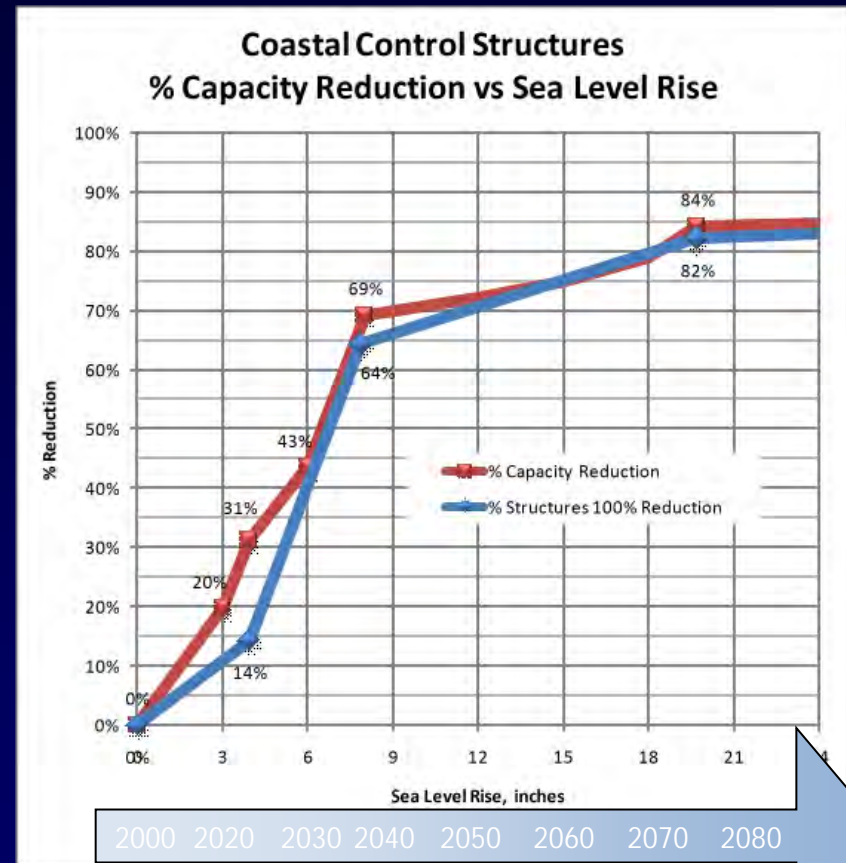


Coastal structures will lose capacity as sea level rises



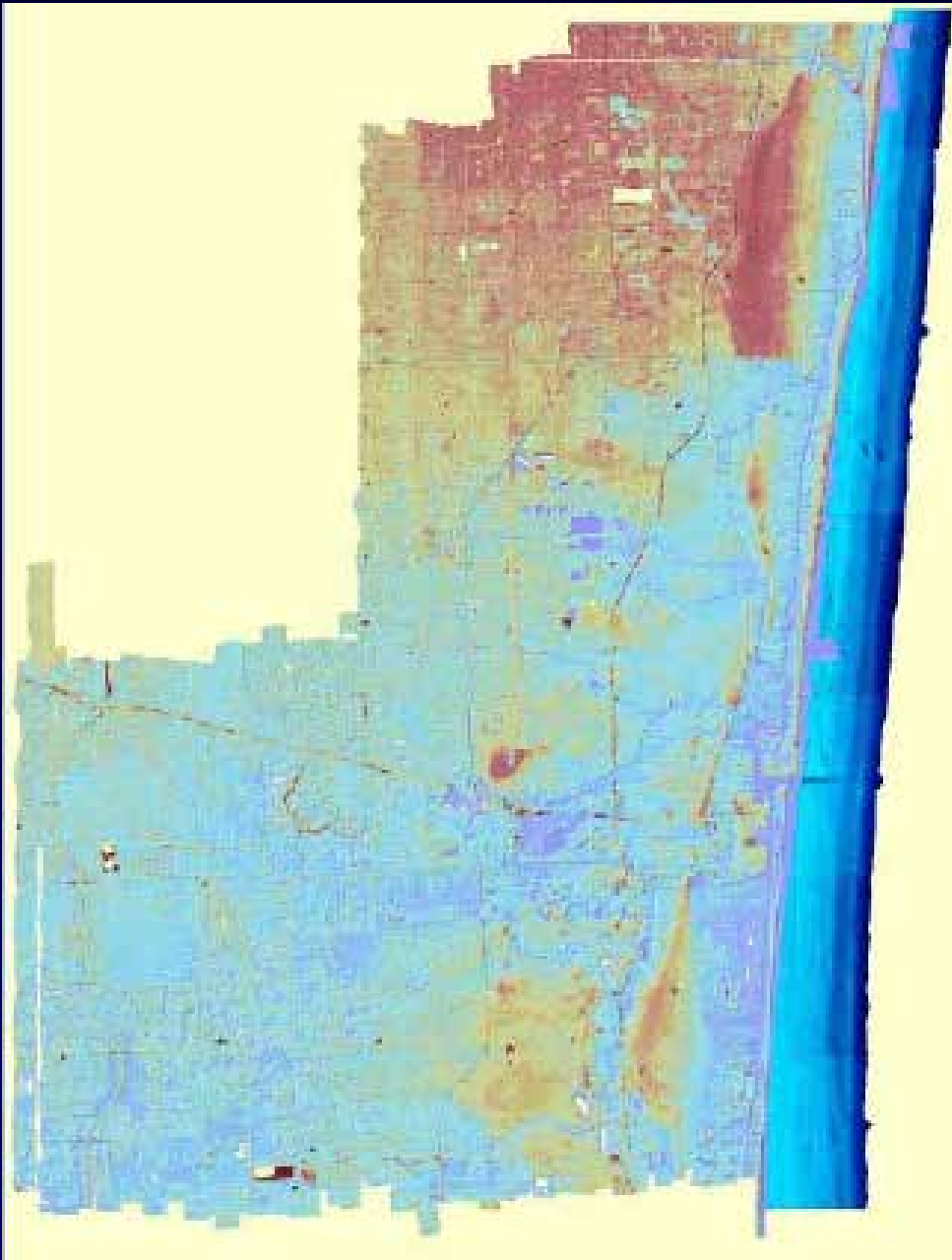
S-13 Pumping Station

- Capacity = 540 cfs = 14.5 million gal/hr



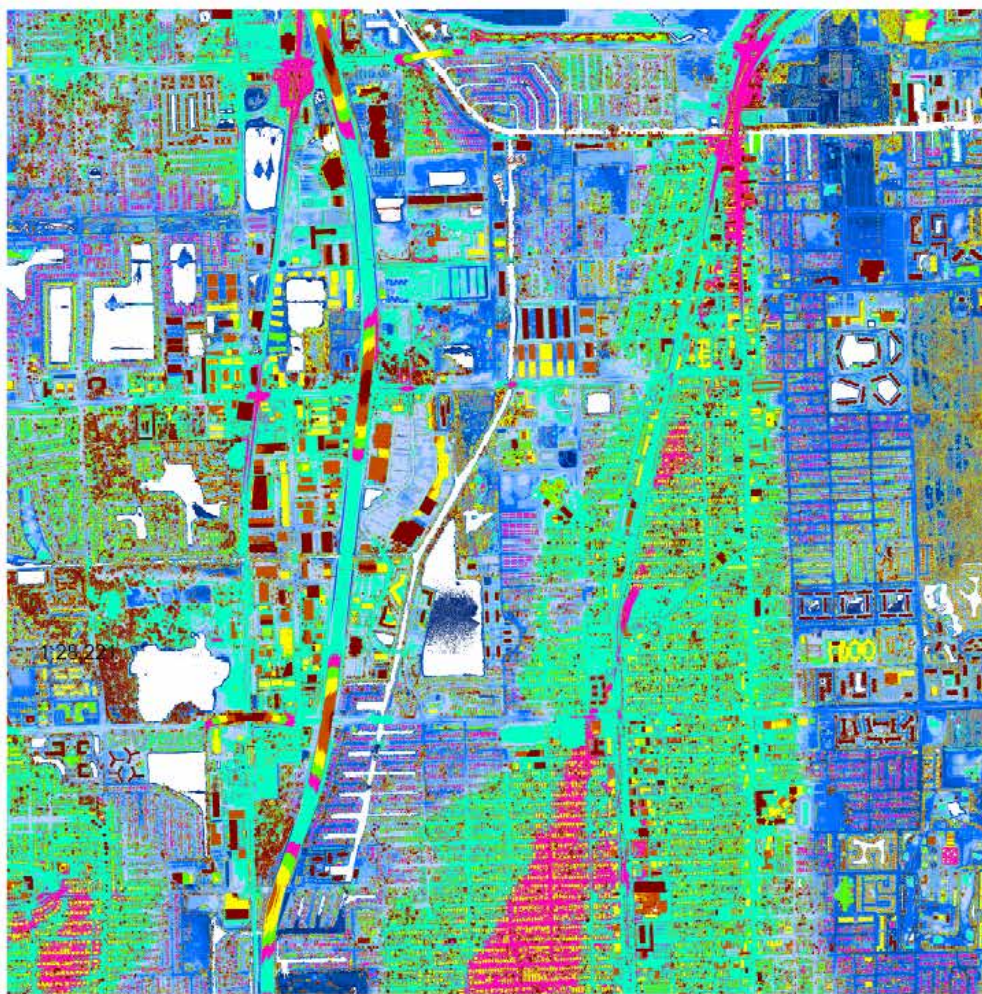
Based on data from Obeysekera, SFWMD, 2009)

Areas Potentially Vulnerable to Flooding



What it
Really
Looks like

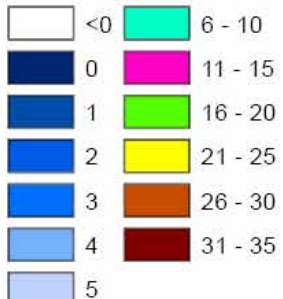
Roads
Flood



Legend

Elevations (ft)

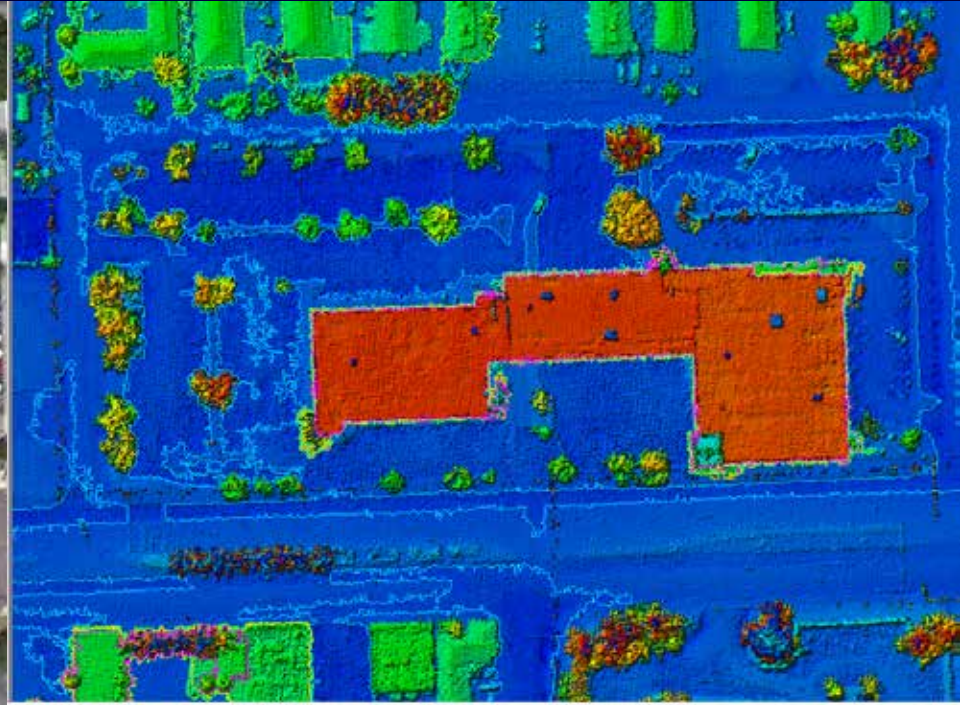
0 0.25 0.5 1 Miles





Clearly it's
the Roads,
not the
structures

LIDAR gives us good, results,
but when inches matter....



Utility Impacts

(over the next century)

- Inundation of certain low-elevation areas with salt water
- Contamination of groundwater from sea water inundation and storm surge
- Higher water table means less capacity to store rainfall, which means less potential for irrigation with reclaimed water or other sources
- Inundated land on which septic tanks operate.

Utility Impacts

(over the next century)

- Increased manhole leakage/inflow (from saltwater intrusion and surface flooding)
- An associated increase in chlorides in raw wastewater and hence added treatment required for reclaimed water
- Saltwater migration toward eastern raw water wellfields

What to Do?

(given the uncertainty in timing)

- Protect infrastructure from the impacts of climate change
- Adapt to the change
- Retreat from the change (worst case?)

Corrective Actions

- Rely less on existing wellfields (saltwater intrusion or inundation from storm surge)
- Convert septic tank areas to central sewers
- Need to harden the sewer system to prevent inflow that would be contrary to their reuse goals
- Need to reconsider reuse efforts in light of lessened soil storage capacity
- Infrastructure to protect the wellfields

Options to Protect

- Stormwater improvements,
- Beach re-nourishment efforts
- Protection of wetlands,
- Protection of sanitary sewer systems,
- Altering wastewater disposal patterns to include beneficial reuse and salinity barriers
- Water conservation – short term, delaying
- Create protected reservoirs to capture water runoff to tide, such as the L8 reservoir

Short Term Options to Adapt

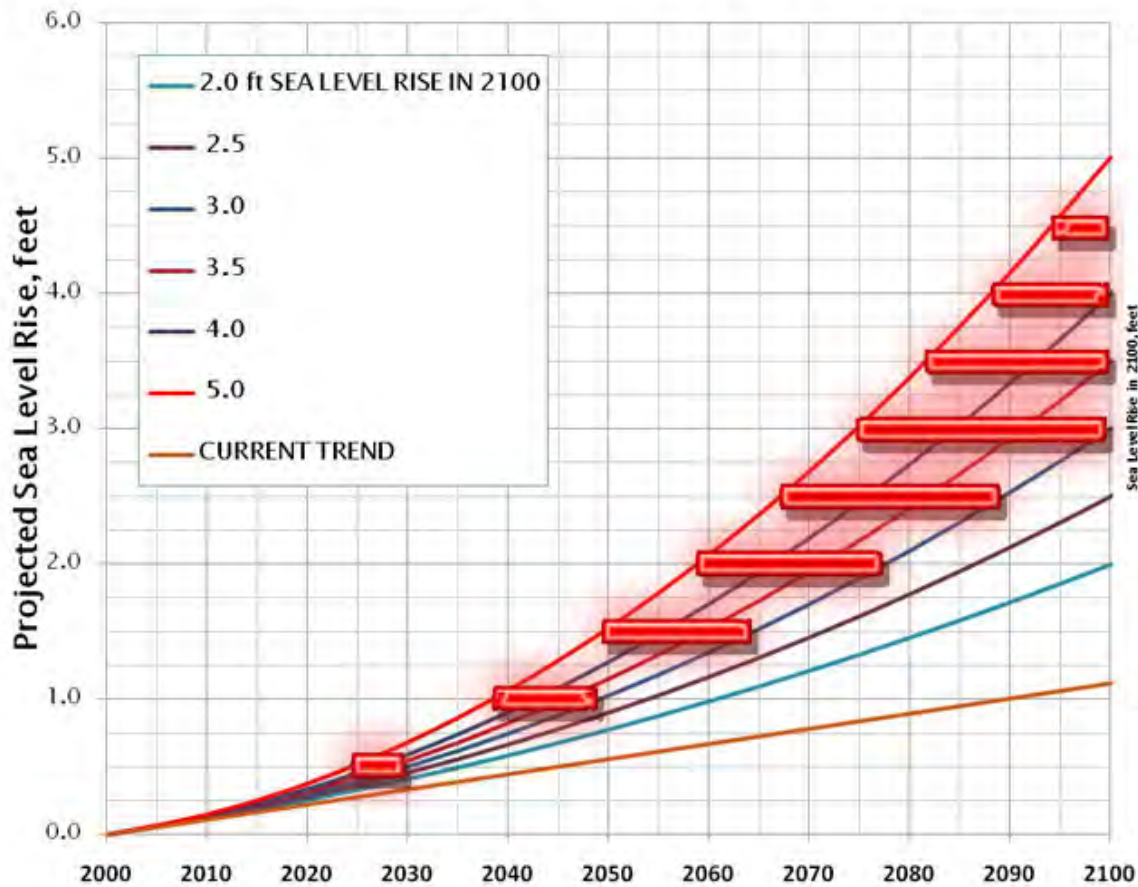
- Water conservation
- Regionalization of water supply utilities
- Protection of recharge areas
- Install pumping stations in low lying areas to reduce storm water flooding Armoring the sewer system (“G7 Program”)
- Additional reclaimed water production
- Artificial recharge/salinity barrier scenarios

Future Options to Adapt

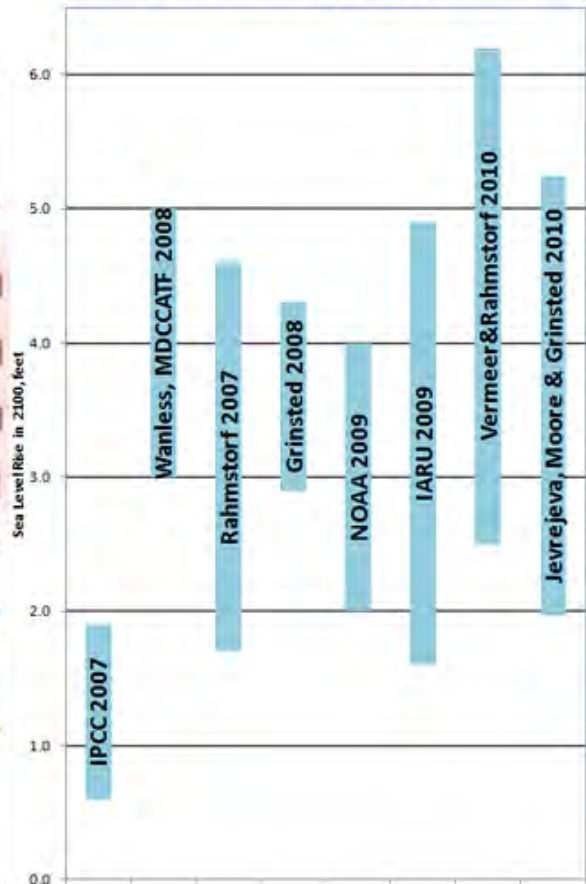
- Desalination
- Control flooding west of the coastal ridge
- Central sewer installation in OSTDS areas
- Closing of private wells
- Relocation of wells
- Water capture technology including horizontal wells
- Installation of additional salinity control/lock structures closer to the ocean

The Question is When?

Projected Sea Level Rise, in feet, Quadratic Acceleration Model



2100 Literature Projections



Case Study

Pompano Beach

Issues

- Water Table higher = less soil storage for water
- More frequent Flooding
- Canals do not flow east since the western edge is lower than new mean high tide

Vulnerable Areas

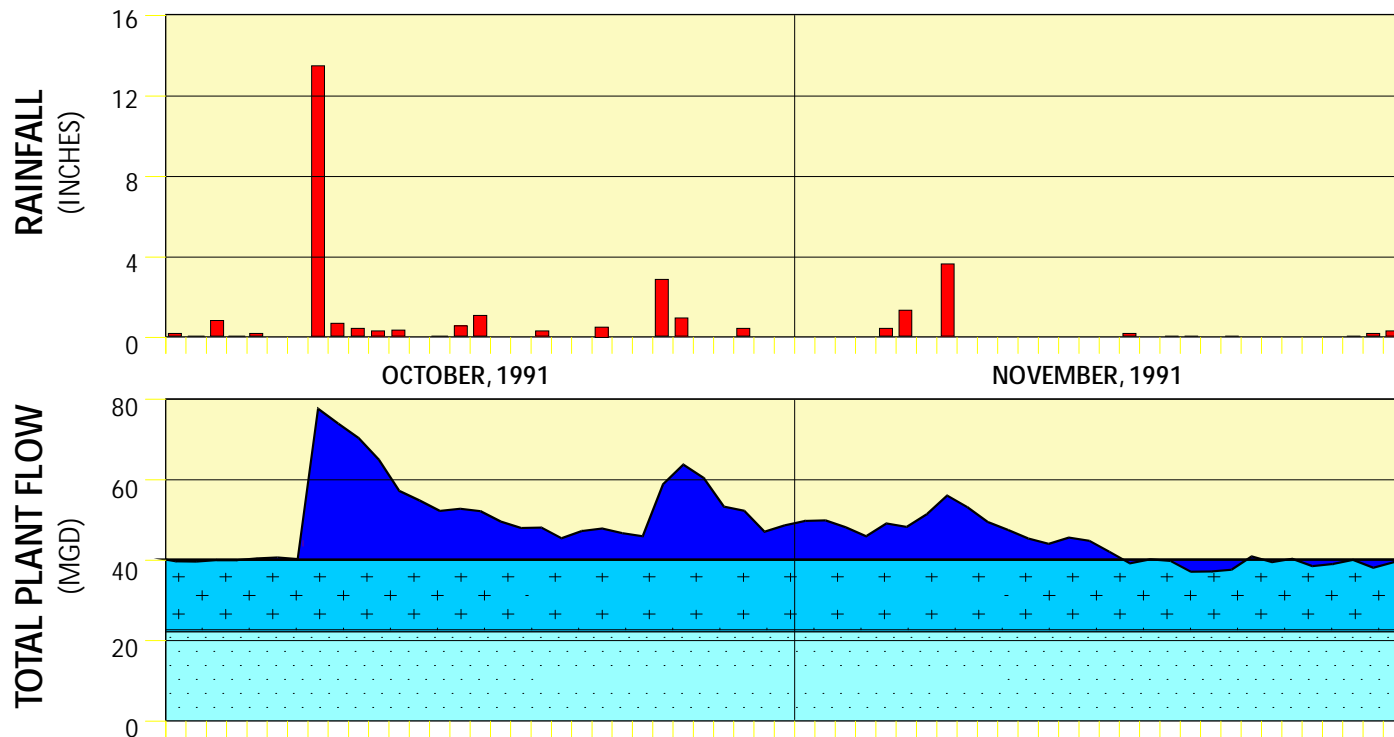
- Permanent inundation of certain areas
- Manhole leakage = salty reuse
- Saltwater intrusion into eastern wellfields

Water Conservation

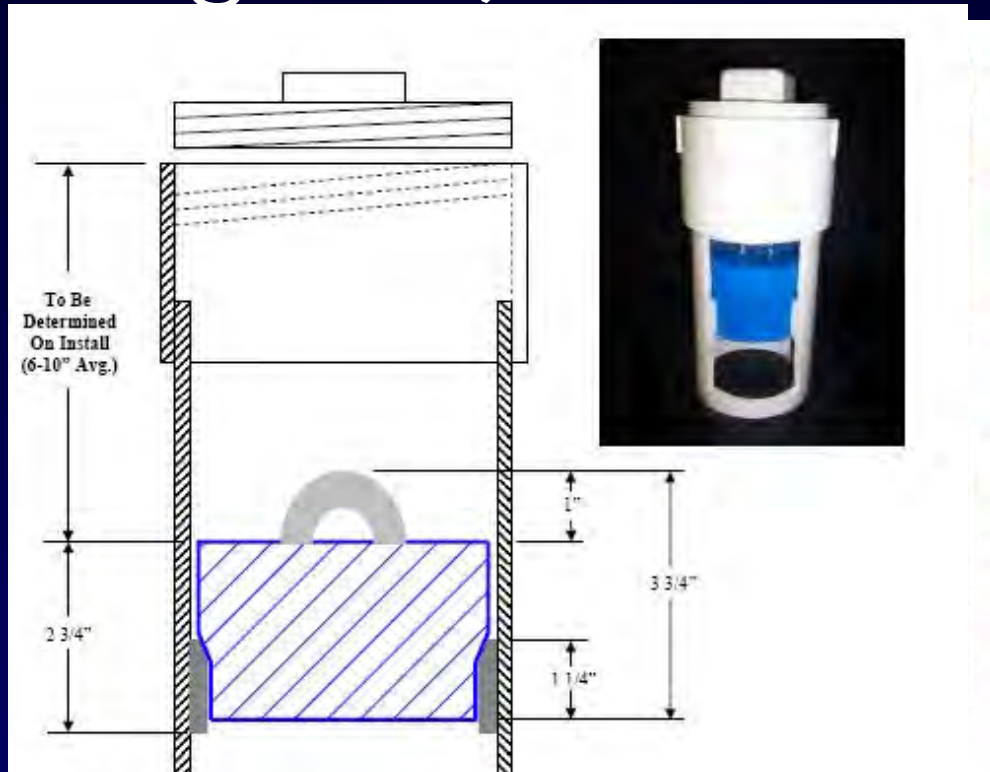
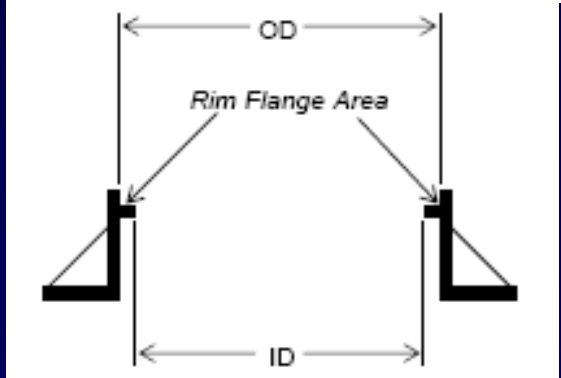
(as programmed)

- Training to residents on plant selection
- Training to residents on lawn maintenance
- Water conservation brochures
- Notices on water bills
- Special mailings
- Speakers bureaus
- Periodic water conservation workshops
- Advisory committee to utility

Remove Inflow by Armoring The Sewer System

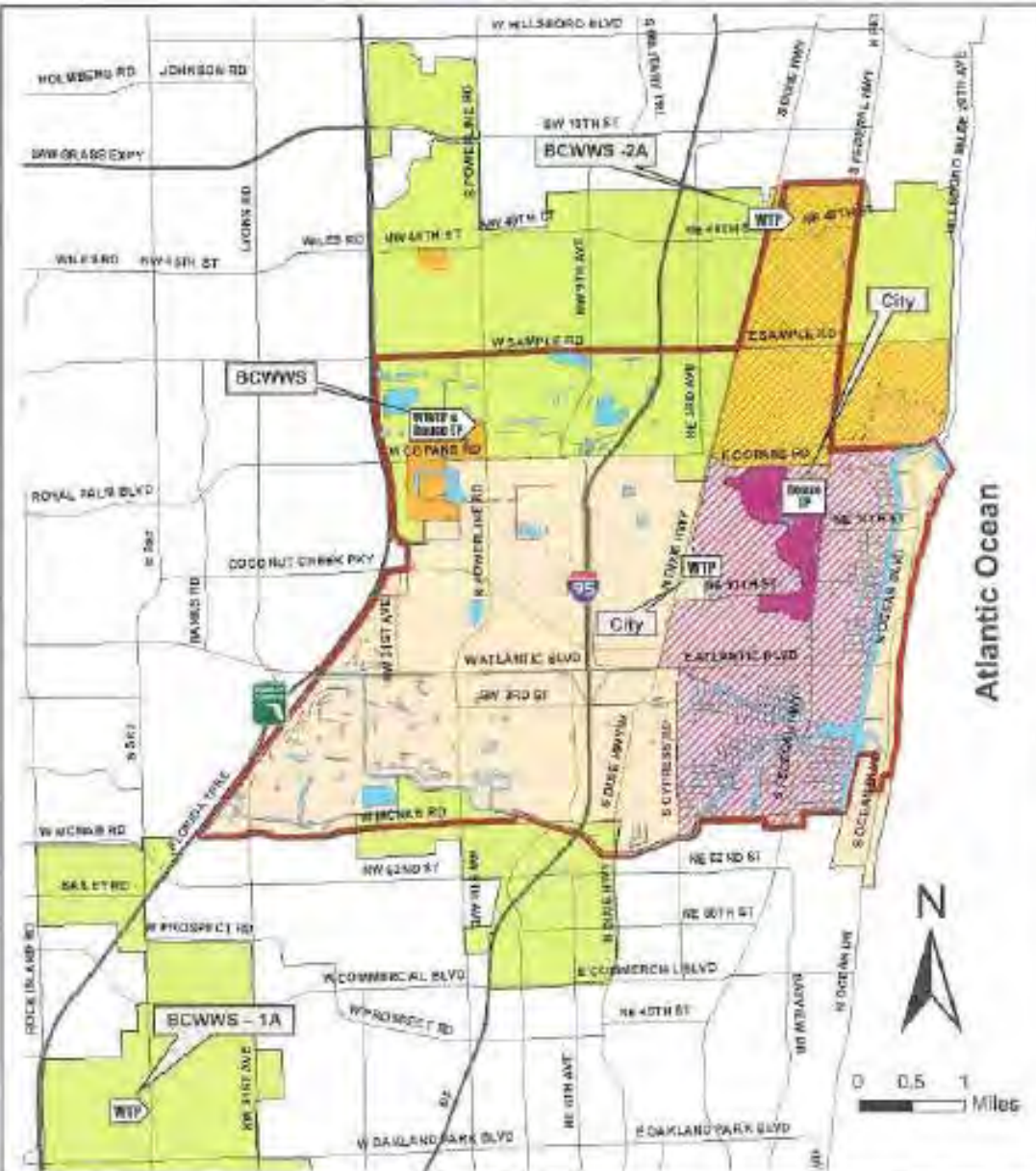


Sealing the Sewers!!! (G7 Program)



Manhole Following Abatement

Additional reclaimed water production

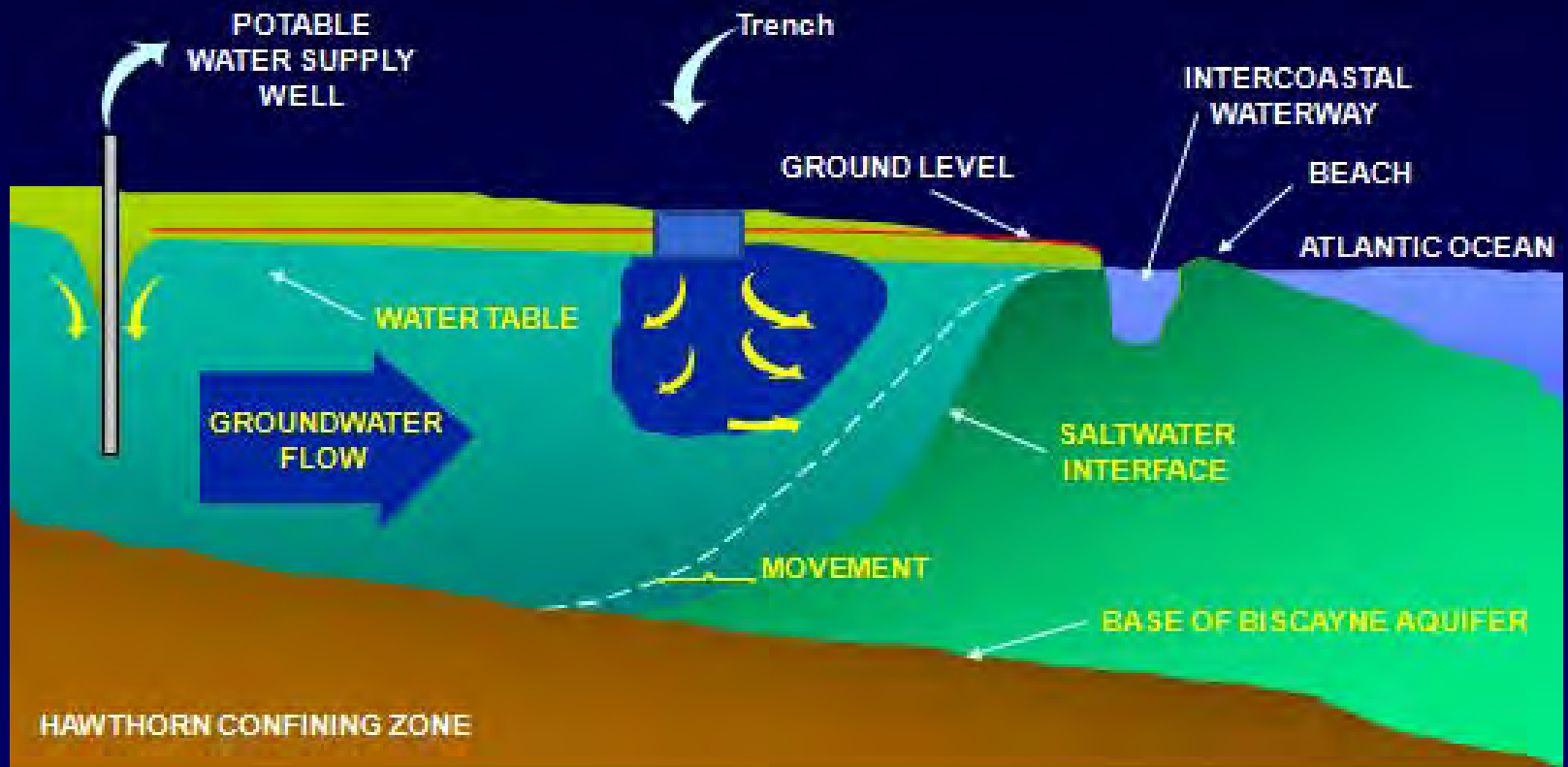


LEGEND

- | | | | |
|--------------------------|---|--|-------------------------------------|
| City Water Service Area | City Reuse Water Land Application Area | City Water Service Area and Reuse Water Proposed Land Application Area | City Reuse Treatment Plant |
| BCWWS Water Service Area | BCWWS Reuse Water Land Application Area | City and BCWWS Reuse Water Proposed Land Application Area | City WTP |
| City Limits | | | BCWWS WTP and Reuse Treatment Plant |
| | | | BCWWS WTP |

Salinity Barrier/Infiltration Trench

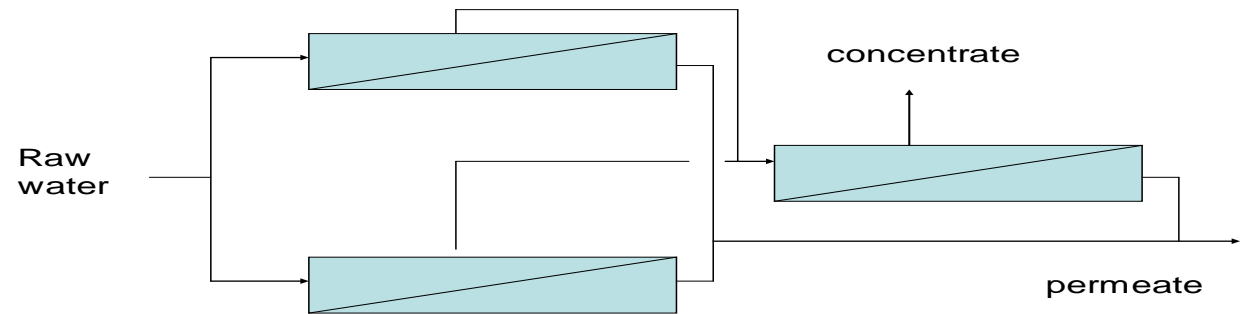
WATER MOVEMENT AFTER INJECTION



Desalination



- Floridan
- Ocean



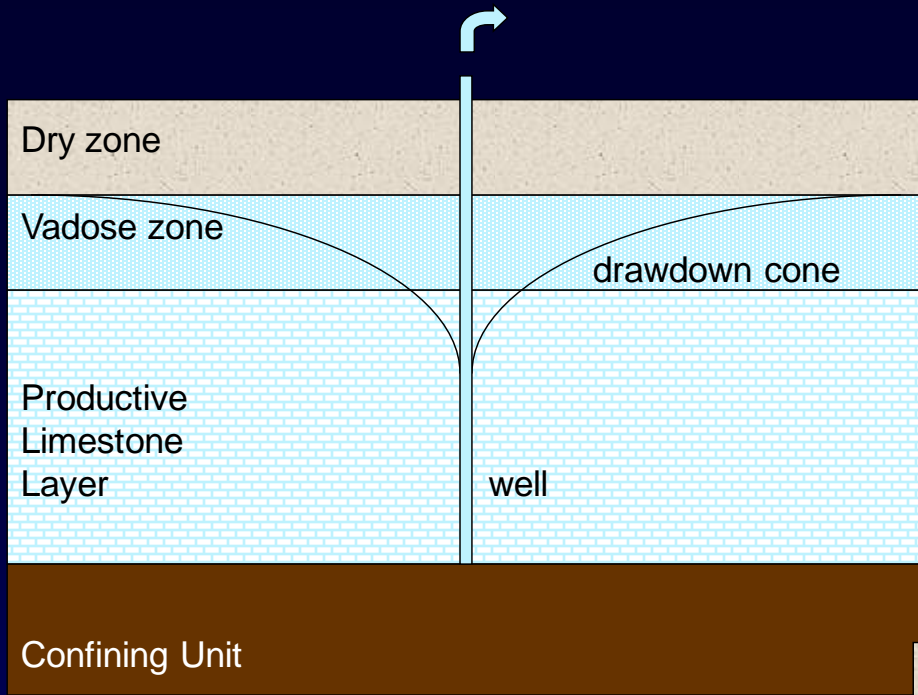


Figure 1 – Normal drawdown for vertical well

Drawdown Issues Vertical vs Horizontal

Moving Wellfields/ horizontal wells

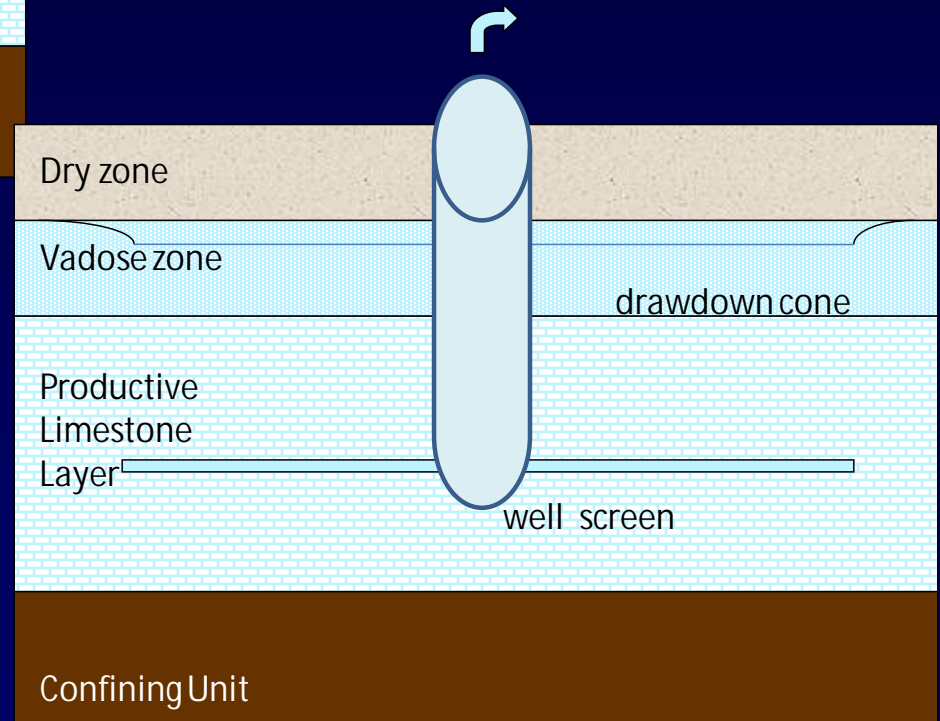
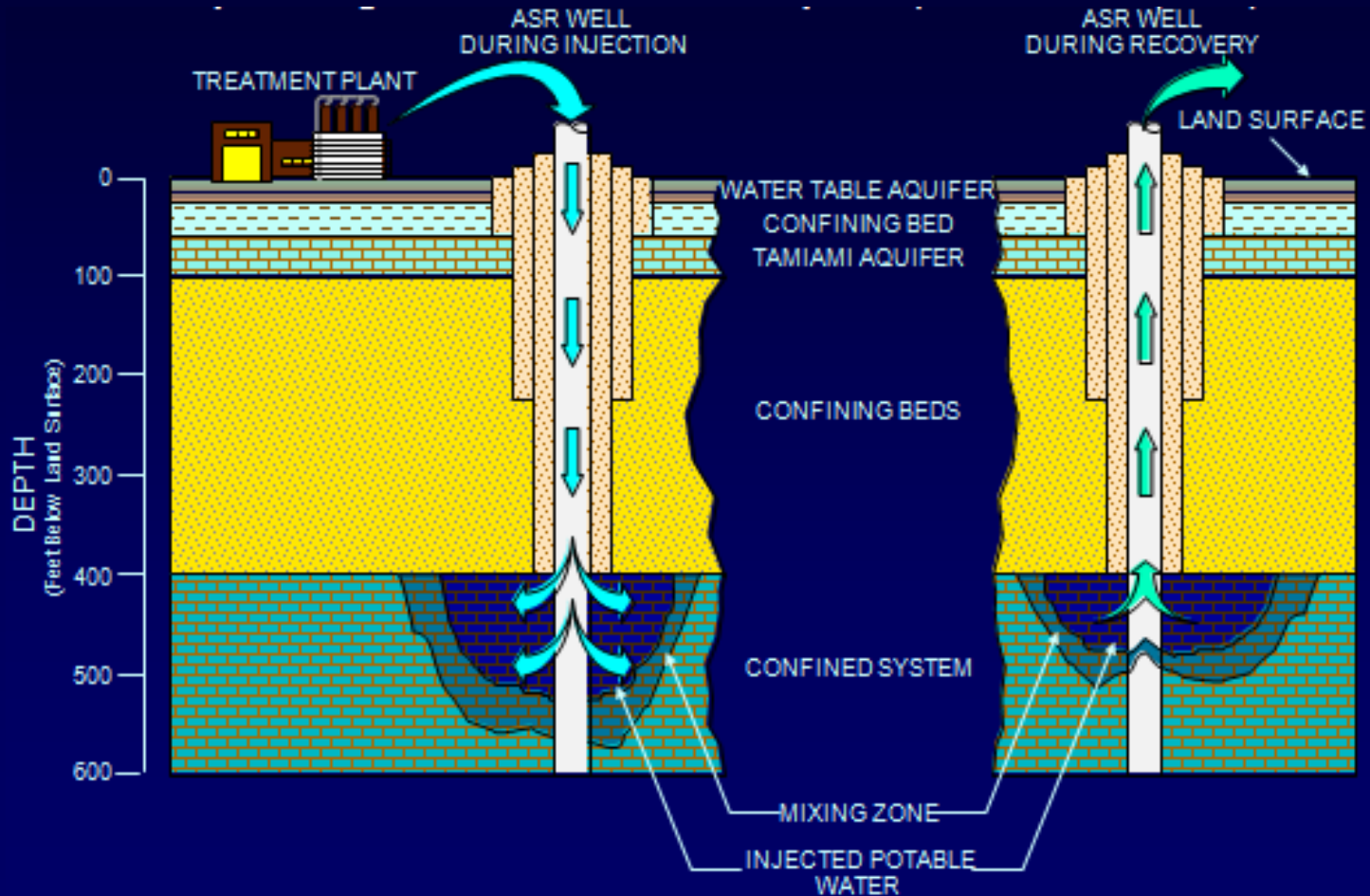


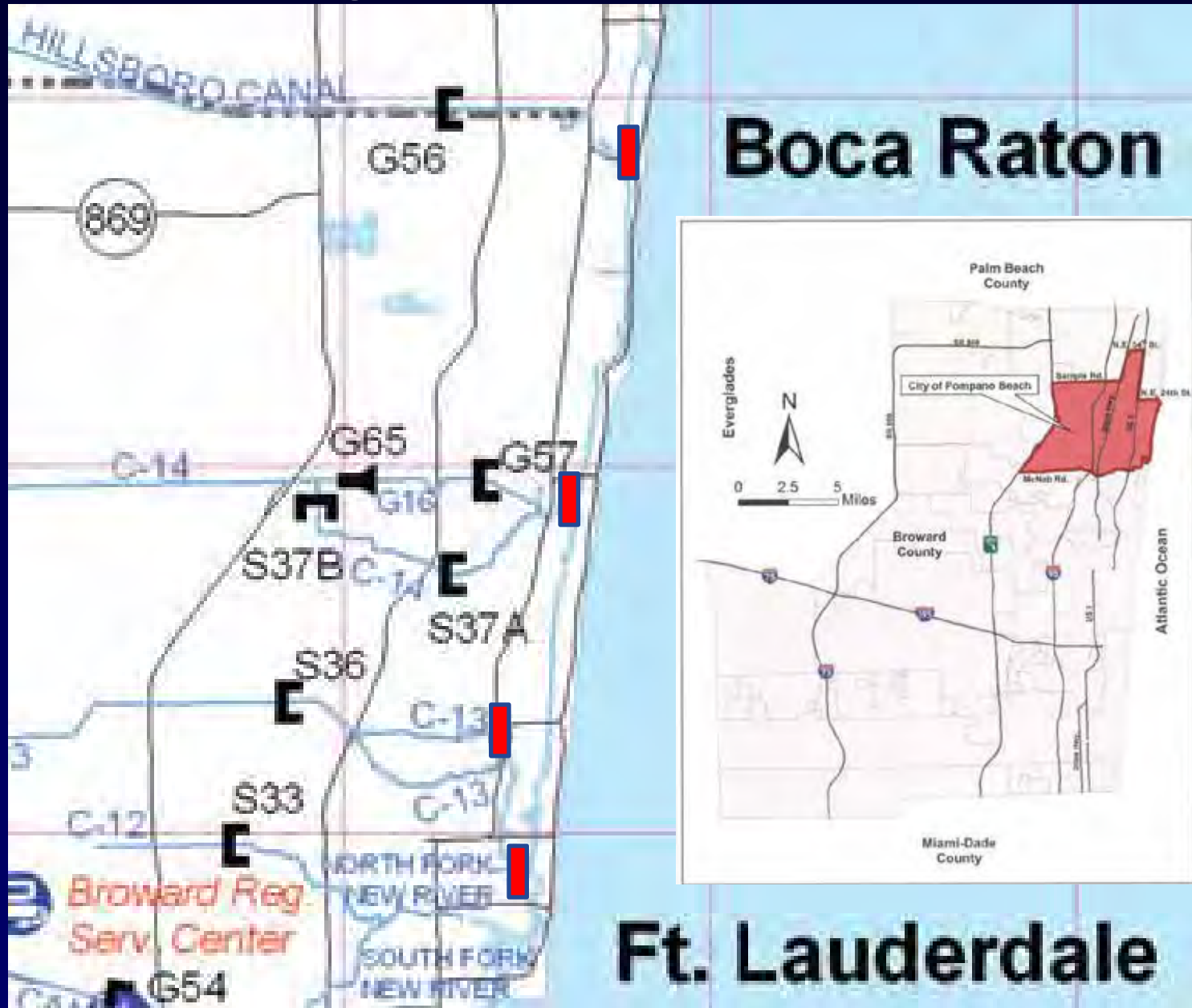
Figure 2 – much smaller drawdown with horizontal wells

Aquifer Storage and Recovery of Reclaimed Water?

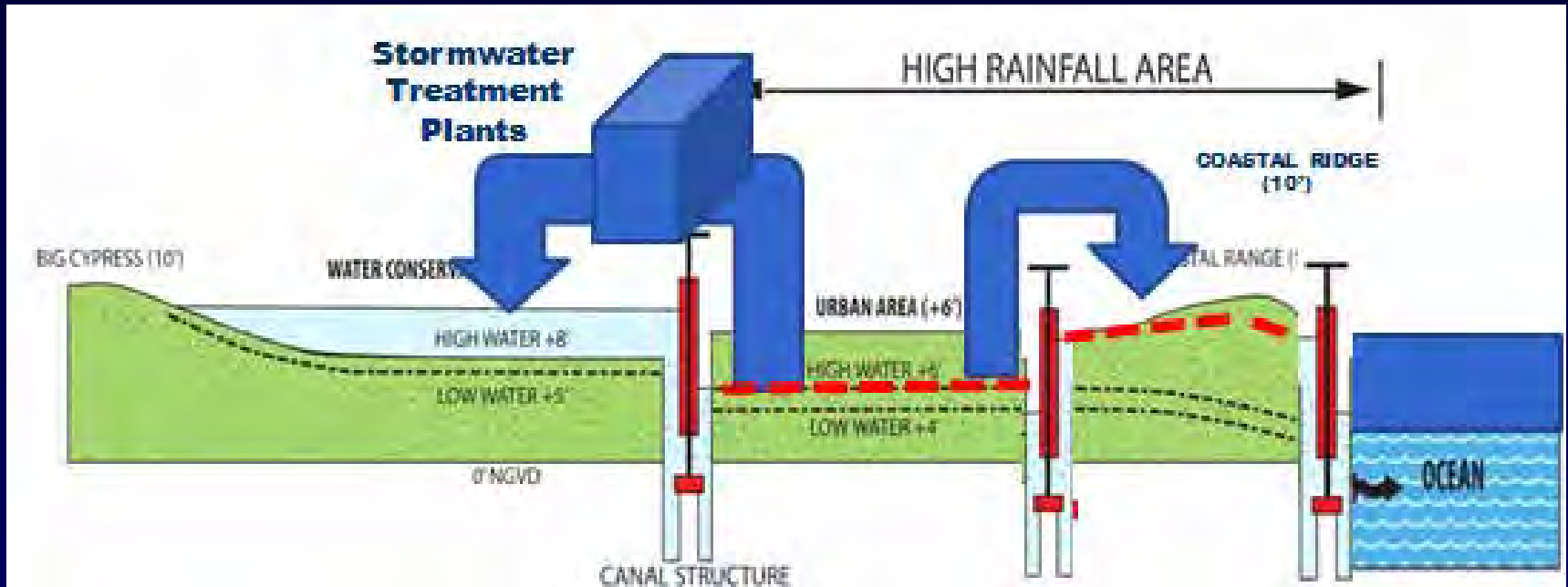
Conceptual Diagram For Brackish Water Aquifers (After Missimer, 1994).



Salinity/lock structures



A Regional Solution? Expensive win-win

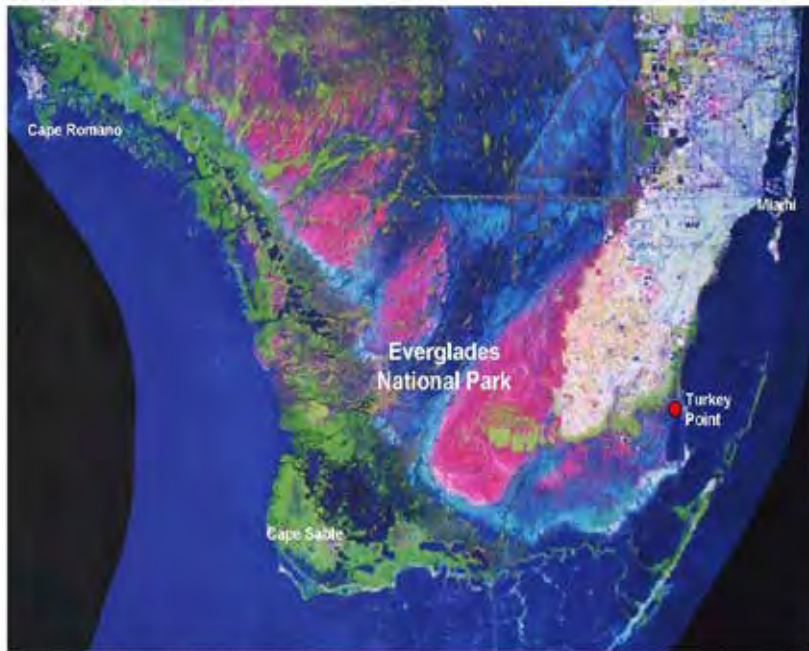


- More Structures
- Stormwater Treatment
- Wastewater Treatment
- Hydrate the Everglades

Sea Level Rise the Everglades

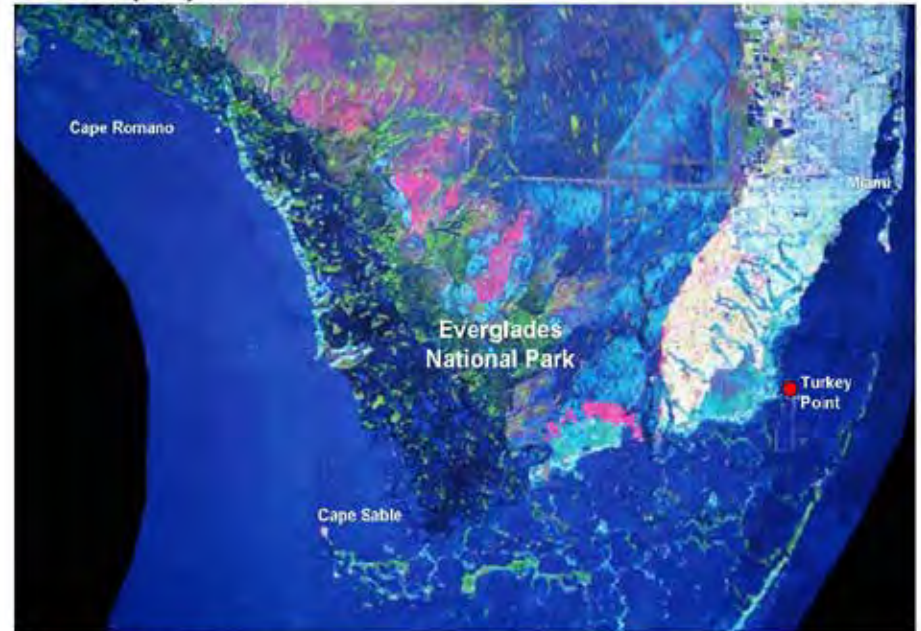
- A little less than 1 foot during the past century measured at Key West
- A 2 foot rise would have significant effects

South Florida 1995



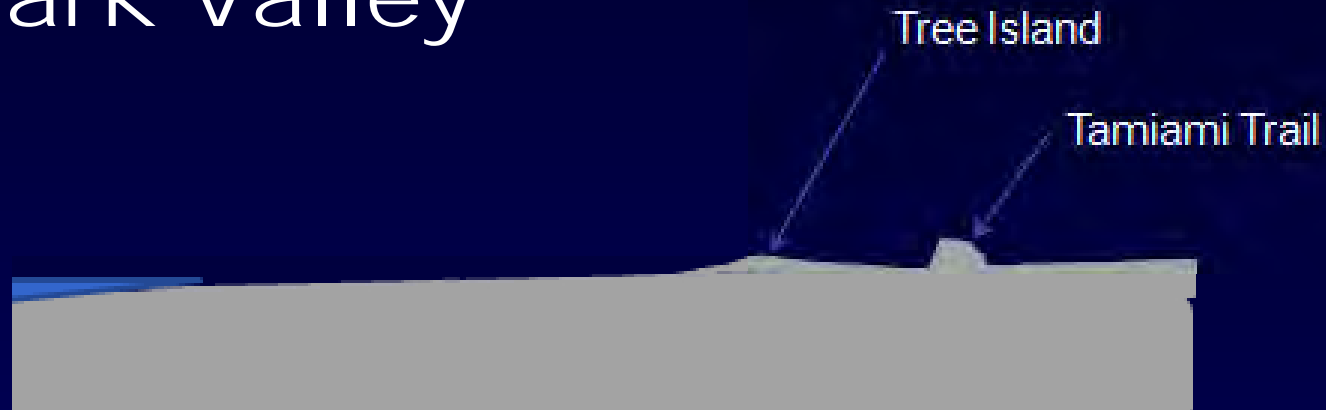
Credit: Dr. Harold R. Wanless; University of Miami, Department of Geological Sciences;
co-chair of Miami-Dade Climate Change Task Force

+60 cm (2 ft) rise

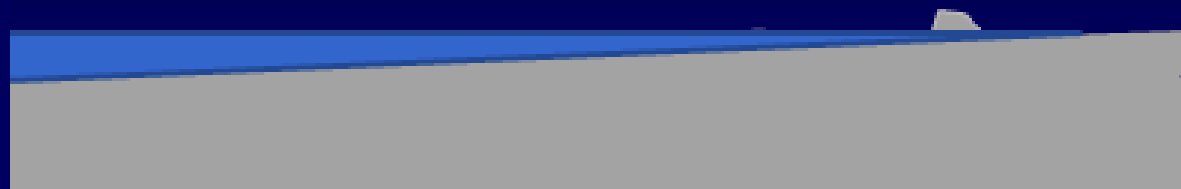


Credit: Dr. Harold R. Wanless; University of Miami, Department of Geological Sciences;
co-chair of Miami-Dade Climate Change Task Force

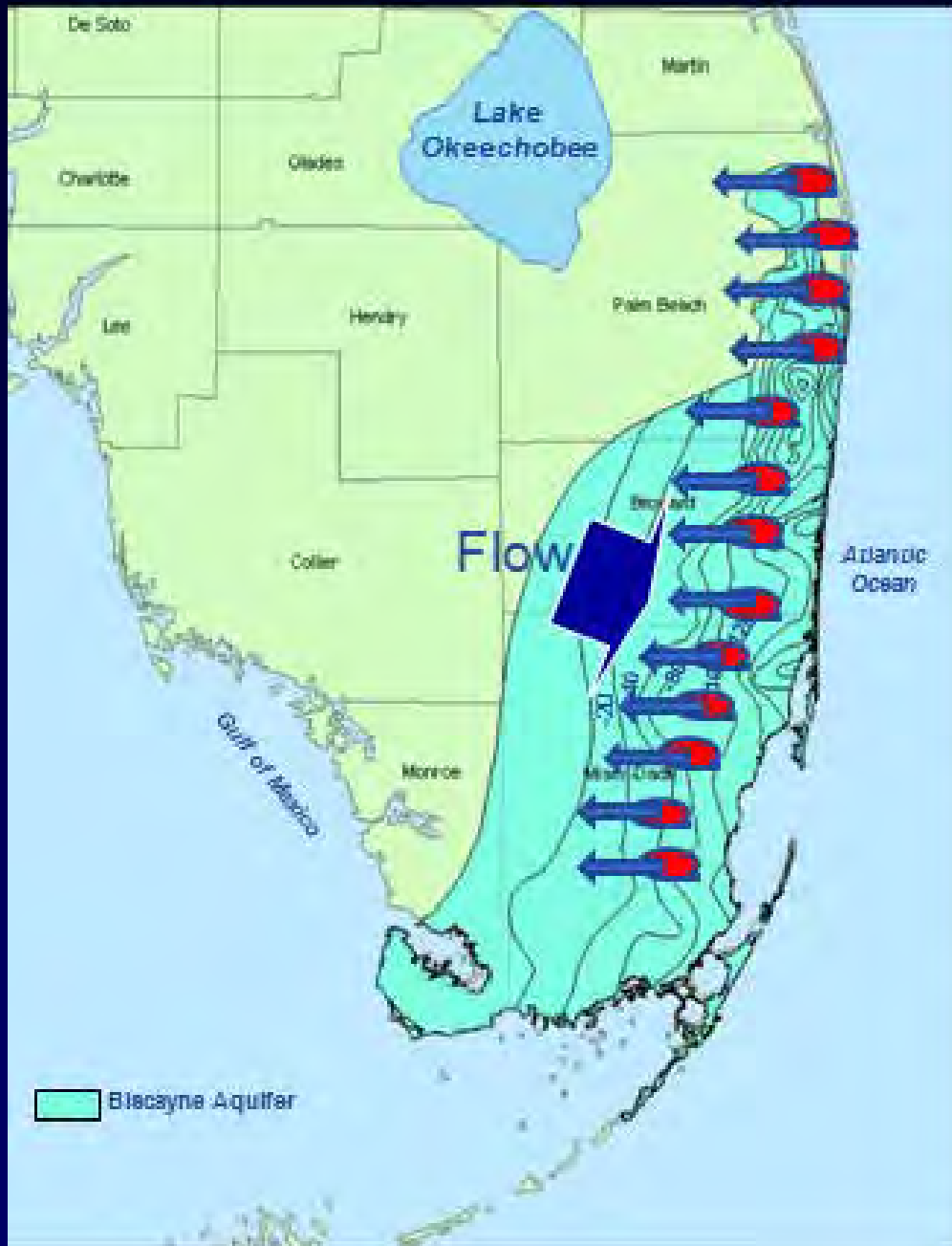
Transect up Shark Valley



Current – High tide at 2 ft ngvd



Future – High tide at 5 ft ngvd – flows past Trail
Entire Everglades is saltwater 24/7

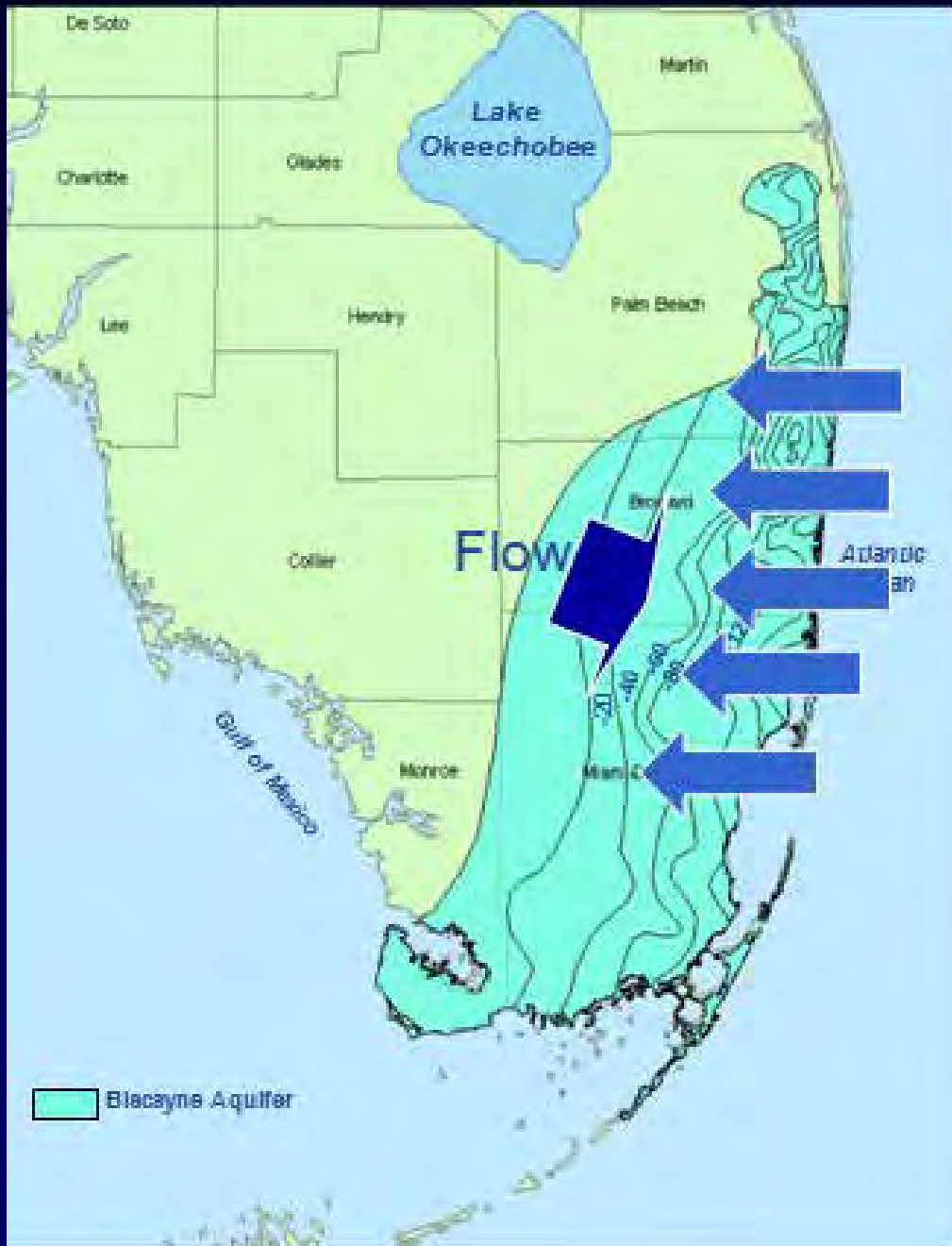


Regional
Solution?

Move Stormwater
Back to Natural
System ?

Recharge the
Biscayne Aquifer

Retard Saltwater

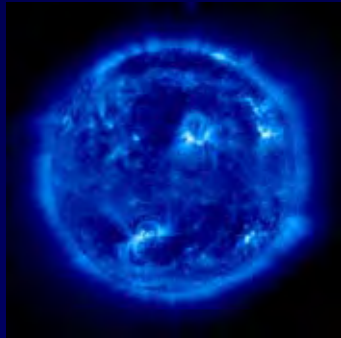


Regional Solution?

- Recharge Everglades with RO treated Wastewater to Recharge the Biscayne Aquifer
- Retard Saltwater

Cost is High

- Regional Wastewater Disposal Participation
- ASR of Reclaimed water for potable use
 - Reverse Osmosis
 - Ultraviolet



- Advanced Oxidation
- **HUGE CARBON**
- **FOOTPRINT**

\$

Only...

- For 600 MGD of Wastewater RO'ed = \$6 B capital
- Power Cost @ 3 MW/MGD = 1.8 GW power supply needed
- For 250 MGD of saltwater sources RO'ed = \$4.5 B
- Power cost @ 5 MW/MGD = 1.25 GW needed

Potential Pompano Beach Strategies < 1 ft

<i>Trigger</i>	<i>Implementation Strategy</i>	<i>Barriers to Implementation</i>	<i>Cost</i>	<i>When Action Abandoned</i>
Immediate	Install SW PS to reduce local flooding	NPDES permits, cost, land acquisition	Start at \$1.5 to 5 million each	inundation (>3-5 ft SLR)
	Water conservation	Budget, staff time, political will	Start at \$30 million + \$1 million/yr	n/a
	Armoring the sewer system (G7 program)	Budget , recurring expense	\$12.5 million start, plus annual cost allocation	When area served is inundated
0 – 1 ft Sea Level Rise	Additional reclaimed water production	Budget, lack of application sites in the city	Over \$40 million	Before 3 ft SLR makes soil saturation a problem
	Aquifer recharge/ salinity barriers	Regulations, public perception	Over \$200 million	Before 3 ft SLR - soil saturation a problem

Potential Pompano Beach Strategies < 2 ft

1 – 2 ft Sea Level Rise	Desalination	Cost, but plant and deep well are already in place	\$45-50 million to convert + wells (\$750,000 per MGD)	n/a
	Control flooding west of the coastal ridge	Cost, discharge location for water	Start at \$1.5 to 5 million each, est-\$25 million	inundation
	Central sewer installation in OSTDS areas	Cost, assessments against property owners	\$10,000 per household	inundation
	Closing of private wells	Private Property rights	Cost unknown	n/a
	Relocate Wellfields westward/ horizontal wells	Cost, saltwater intrusion east and west, permitting	\$20 million assuming Biscayne aquifer	inundation
	Salinity/lock structures	SFWMD, western residents, private property rights	Up to \$30 million, plus ancillary stormwater PS	n/a

Potential Pompano Beach Strategies > 2 ft

Before 3 ft Sea Level Rise	Regional desalination/ aquifer recharge/ Everglades	Perception, nutrients, cost	\$200 million	n/a – solution to retard sea encroachment
	Aquifer storage and recovery with reclaimed water	Regulations for indirect potable reuse, public perception,	Wells > \$30 million	n/a
3 – 5 ft Sea Level Rise	Massive groundwater dewatering, send to	Regulations for redirection of stormwater that likely has high phosphorous levels, public perception, cost	\$ billions	n/a – solution to retard sea encroachment

Not Useful to the City

- **Regionalization of Water Supplies –**
- **Protection of recharge areas - This has limited value since the City is mostly developed and has very little undeveloped land that could be used for recharge.**
- **Moving wellfields west of the coast to avoid saltwater intrusion**
- **Pumping the water directly to the Everglades - no access**

Questions?

