Suggestions for
Living with Sea Level Rise

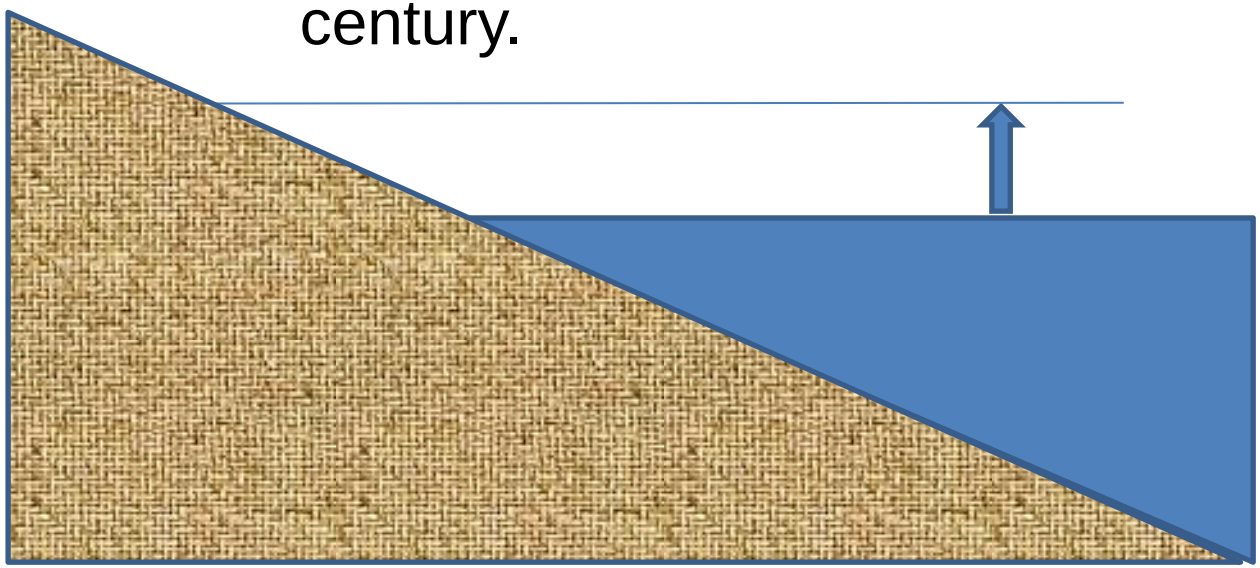
By

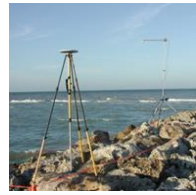
Douglas W. Mann, P.E., D.CE

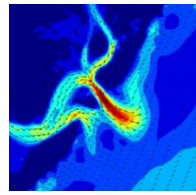
Relative sea level has historically risen for centuries.

Relative sea level is rising today.

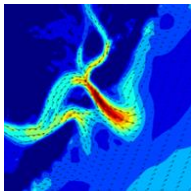
Relative sea level is expected to continue to rise during the next century.





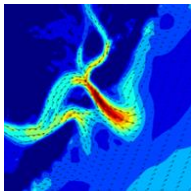


Unpredictable above average high tides



Photos courtesy of J. Linkogle.

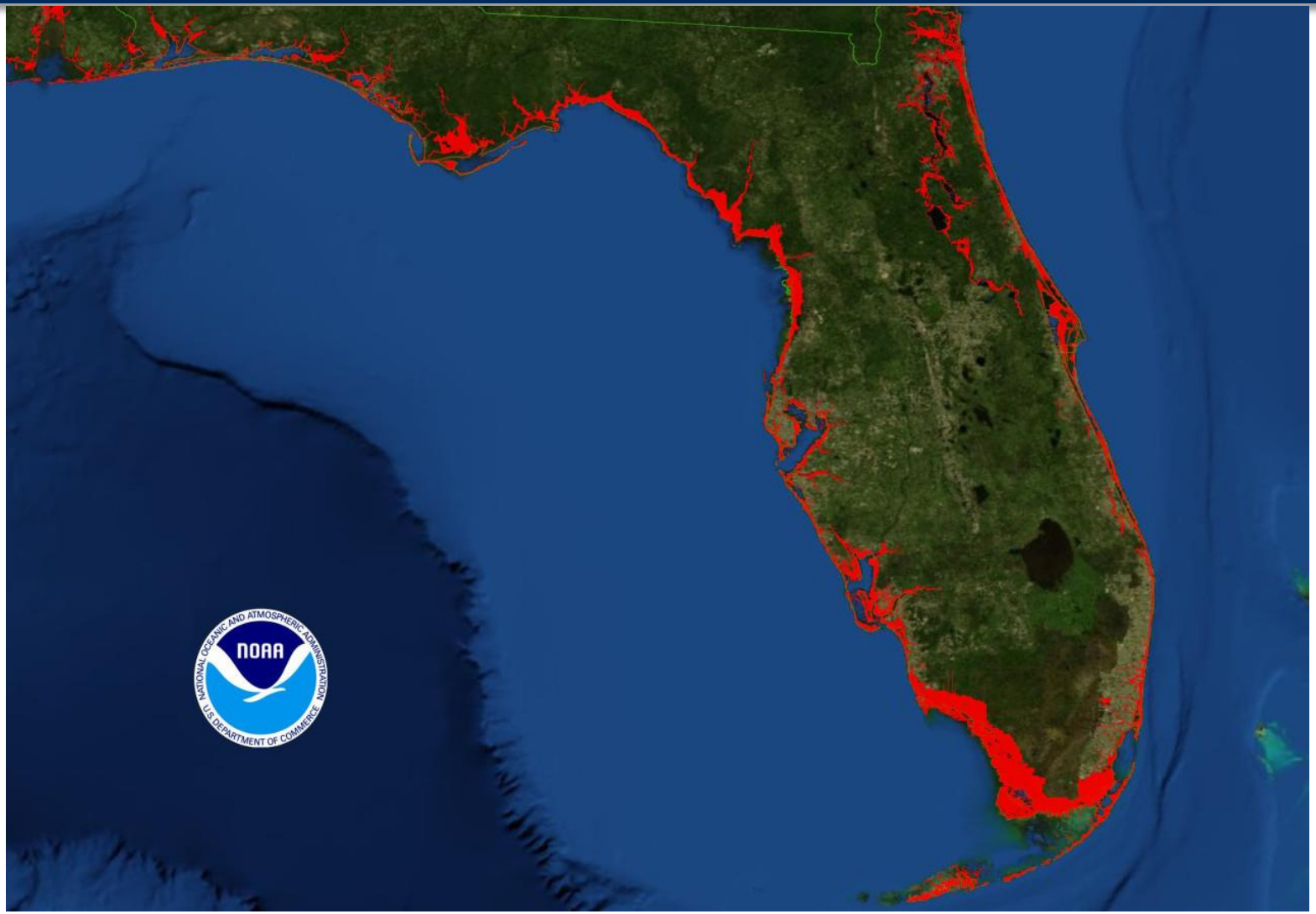
Predictable Seasonal King Tides

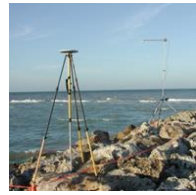


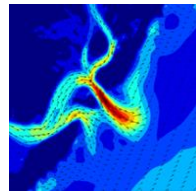
“FLOODED STREETS: Miami Beach resident, Ben Ponds, wades through the flooded streets along Alton Road on October 17, 2013. For a third day in row, streets in parts of Miami Beach flooded with nary a raindrop insight. The water came from the autumn high tides which caused canals, rivers and coastlines to flood without any rain.” Hector Gabino / EL NUEVO HERALD

Typical High Tide

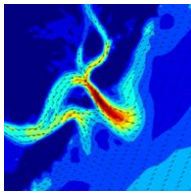
Projections of a Possible Future







"The most recent modeling data for a three-foot rise in sea levels, which climate scientists project could happen in Florida by 2100." (U.S. National Oceanic and Atmospheric Administration) from April 22, 2014 news article.



1. **Get good tidal data.**

2. Evaluate your infrastructure.
    A. Beaches and barriers
    B. Stormwater
    C. Groundwater

3. Move forward.

Get Good Data from Reliable Sources

USACE Sea Level Change Curve Calculator (2014.88)

Item	Display
SLC Curve Chart	☑
SLC Curve Table	☑
Gauge Datum Chart	☑
Gauge Datum Table	☑
SLC Curves	☑
SLC Table	☑
NOAA EWL Chart	☑
Gauge Map	☑

Project Name: Clearwater Beach SPP

Select NOAA Gauge: Clearwater Beach, FL

FEMA BFE (ft): ? Information 0 (NAVD88) Search for BFE here

Project Start Year: 1992

Interval Year: 5

Project End Year: 2100

Output Units: ◉ Feet ○ Meters

Output Datum: ○ LMSL ◉ NAVD88

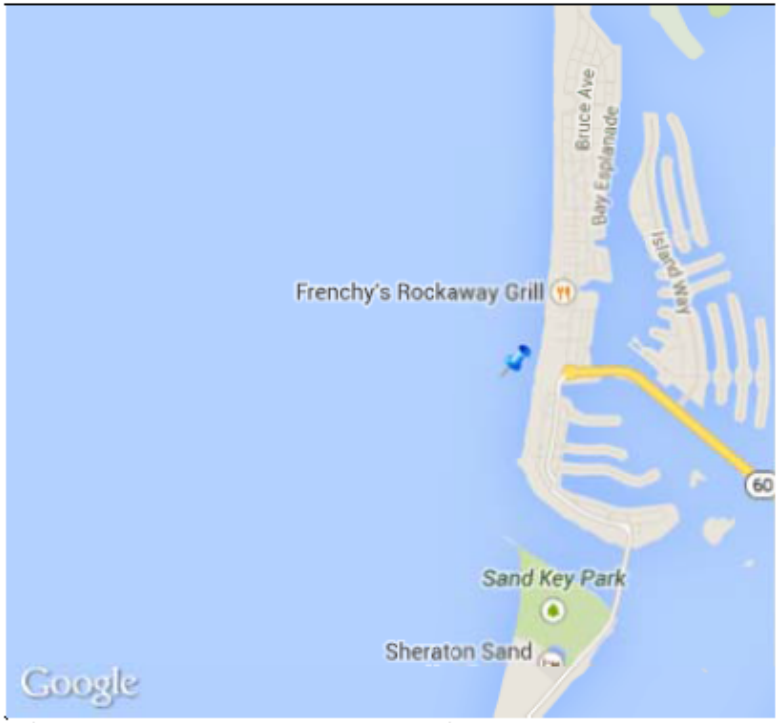
Output Agency: ◉ USACE ○ NOAA ○ Both

SLC Rate: ◉ Published ○ Regionally Corrected or User Entered: (ft/yr)

Display Data

EWL Type: ◉ Highs ○ Lows

EWL Source: NOAA Website ◉ NOAA (GEV) ○ USACE (Percentile) 100 yr difference (m) = 0.40



Click on project area, The nearest NOAA gauge will be used to d
based on ER 1100-2-8162, Incorporating Sea Level Change in Civi
Dec 2013 and NOAA Technical Report OAR CPO-1, Global Sea l

Get Good Data from Reliable Sources

Clearwater Beach SPP
8726724, Clearwater Beach, FL
NOAA's Published Rate: 0.00797 feet/yr
All values are expressed in feet relative to NAVD88

Year	USACE Low	USACE Int	USACE High
1992	-0.29	-0.29	-0.29
1995	-0.27	-0.27	-0.26
2000	-0.23	-0.22	-0.20
2005	-0.19	-0.17	-0.12
2010	-0.15	-0.12	-0.03
2015	-0.11	-0.06	0.09
2020	-0.07	0.00	0.22
2025	-0.03	0.07	0.38
2030	0.01	0.14	0.55
2035	0.05	0.22	0.74
2040	0.09	0.30	0.95
2045	0.13	0.38	1.17
2050	0.17	0.47	1.42
2055	0.21	0.57	1.68
2060	0.25	0.66	1.97
2065	0.29	0.77	2.27
2070	0.33	0.87	2.59
2075	0.37	0.98	2.93
2080	0.41	1.10	3.28
2085	0.45	1.22	3.66
2090	0.49	1.35	4.05
2095	0.53	1.47	4.46
2100	0.57	1.61	4.90

Print Table

Clearwater Beach SPP
8726724, Clearwater Beach, FL
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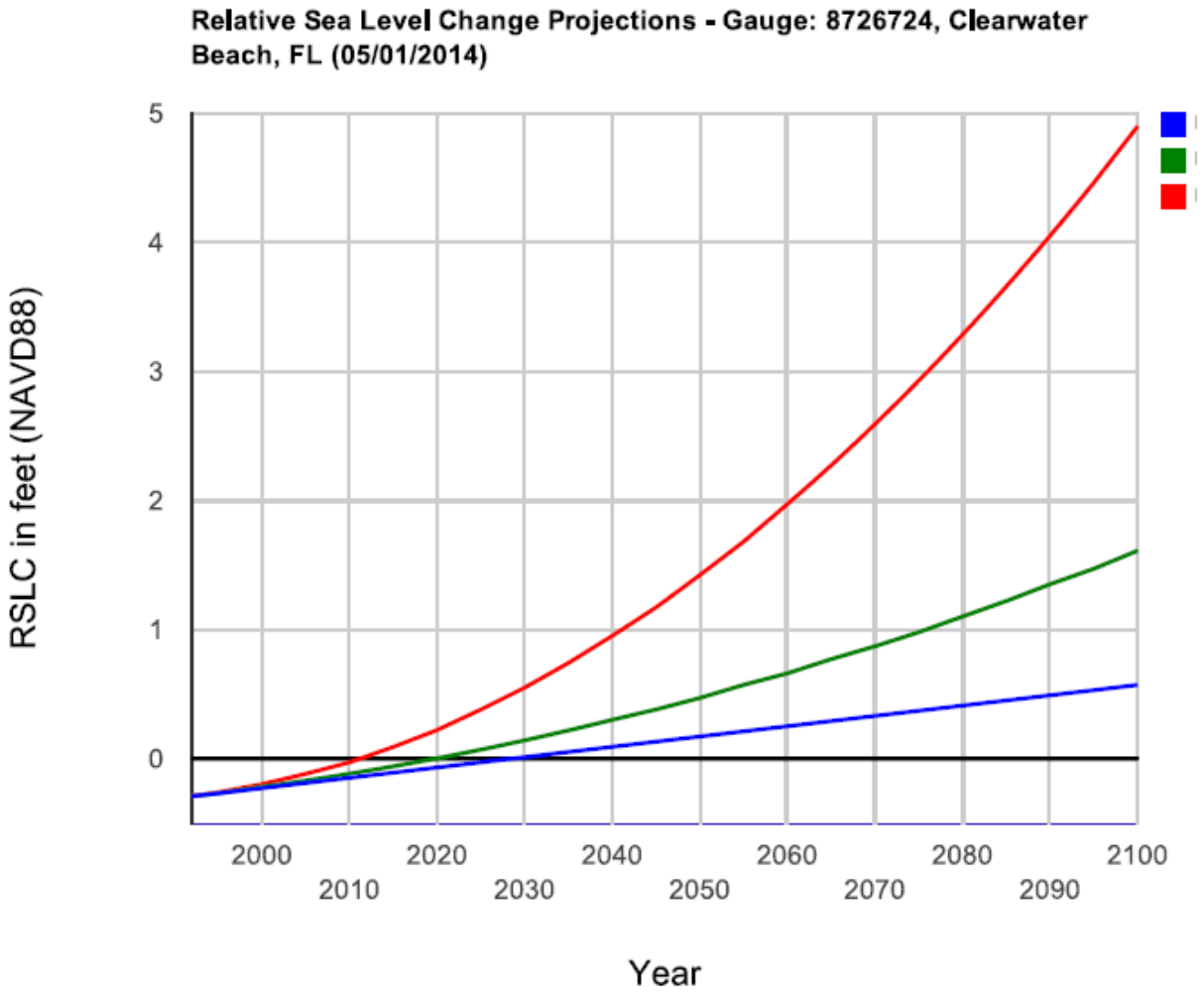
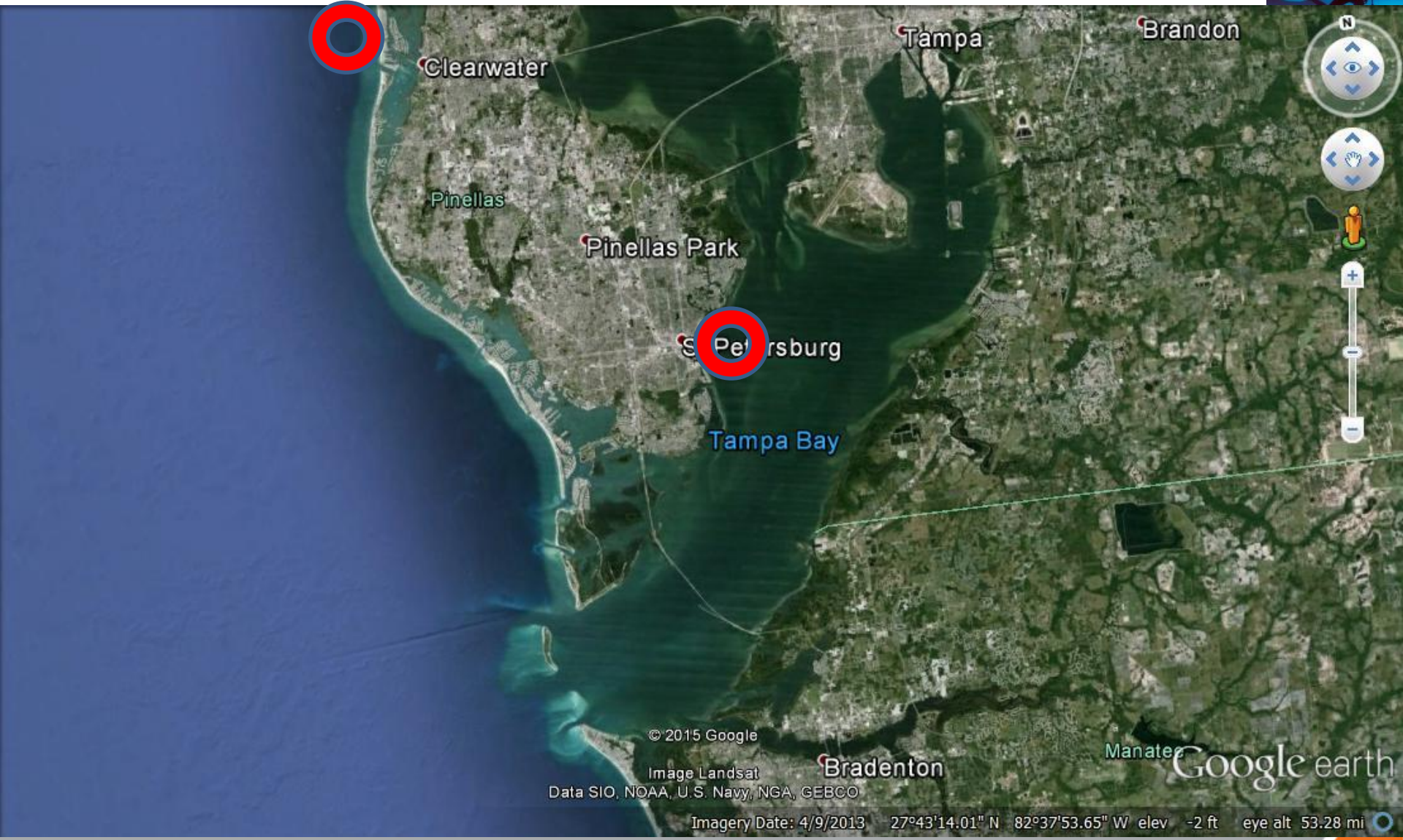
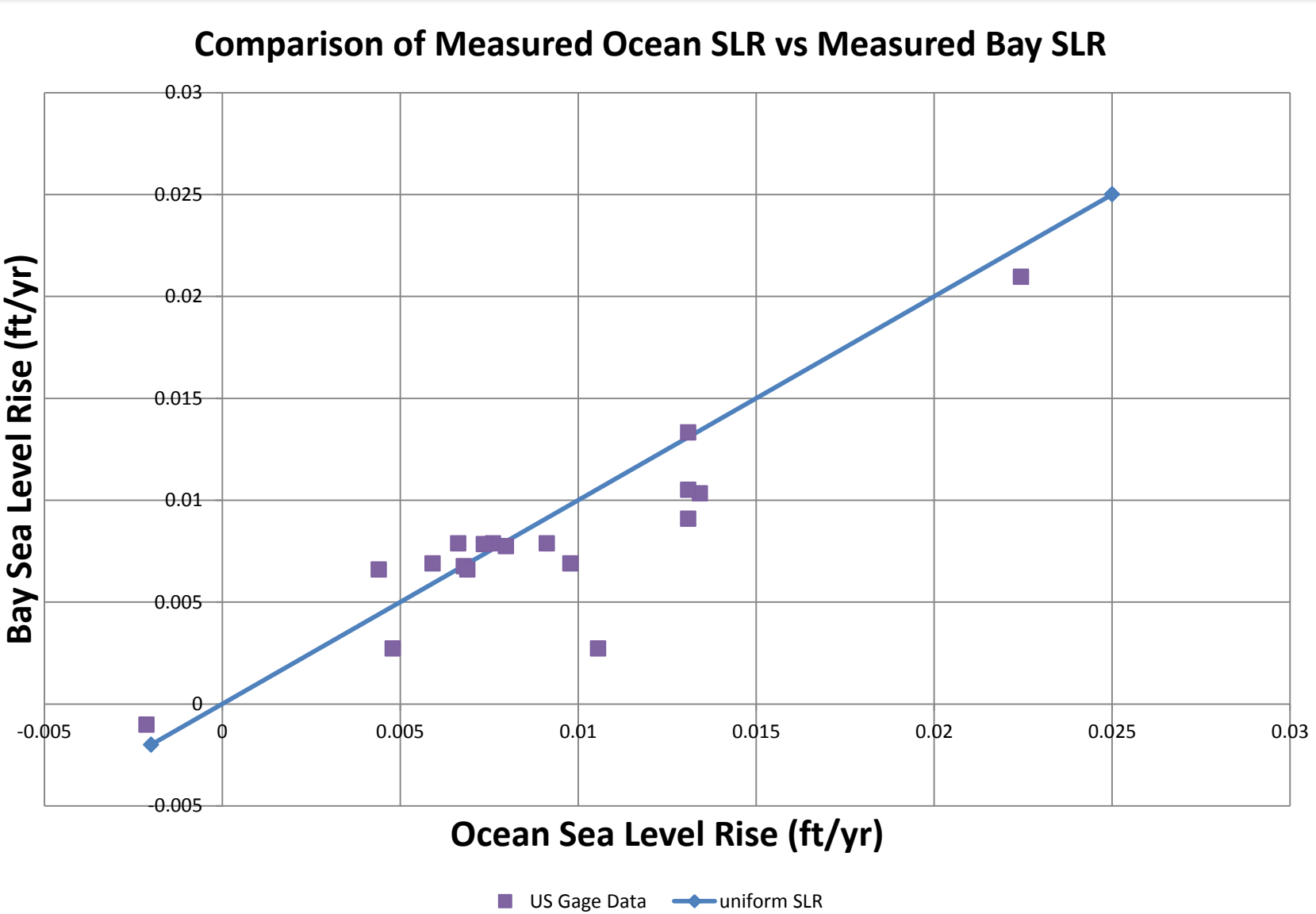
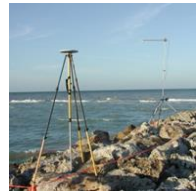


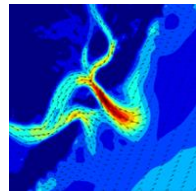
Understand the Data



Does it matter where you measure SLR?







After Hicks (1984).

$$b\frac{\partial \bar{\eta}}{\partial t} + \frac{\partial}{\partial x}\left[bU(h+\bar{\eta})\right] = 0 \qquad (16)$$

$$b\frac{\partial}{\partial x}\left[\bar{u}^2(h+\bar{\eta})\right] + b\frac{\partial}{\partial x}\left[\overline{u'^2}(h+\bar{\eta})\right]$$

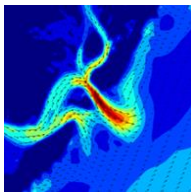
$$+ b\frac{\partial}{\partial x}\left(\overline{2\bar{u}u'\eta'}\right) + b\frac{\partial}{\partial x}\left(\overline{u'^2\eta'}\right)$$

$$+ \left[\bar{u}^2(h+\bar{\eta}) + \overline{u'^2}(h+\bar{\eta}) + \overline{2\bar{u}u'\eta'} + \overline{u'^2\eta'}\right]\frac{\partial b}{\partial x}$$

$$+ gb(h+\bar{\eta})\frac{\partial \bar{\eta}}{\partial x} + g\frac{b}{2}\frac{\partial}{\partial x}\left(\overline{\eta'^2}\right)$$

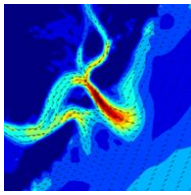
$$+ \frac{bgn^2}{K^2}\left[\frac{\overline{(\bar{u}+u')\left|(\bar{u}+u')\right|}}{(h+\eta)^{1/3}}\right] = 0 \qquad (17)$$

Mann and Mehta, (1993).



Hydrodynamic Explanation (Cont'd)

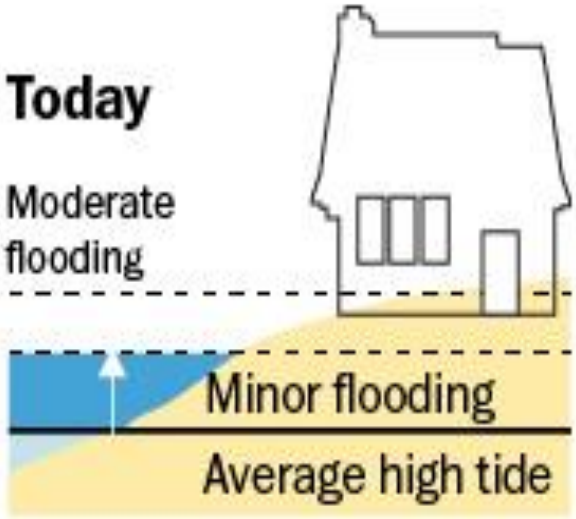
1. We should expect differences in SLR measured in the ocean and in an adjoining bay.
2. Measuring SLR in an inlet is probably the worst location, particularly if it is dredged.
3. So use ocean measurements for open coast management considerations.
4. Use bay measurements for bay management considerations. Bay measurements may include a range of sources of data (Water Management Districts, USGS staff gages, etc.).

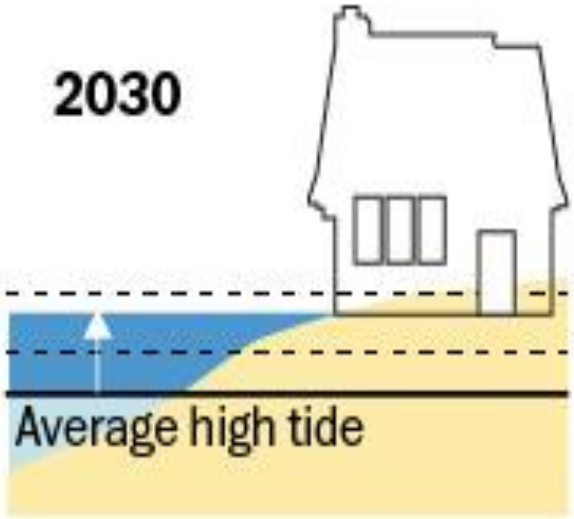


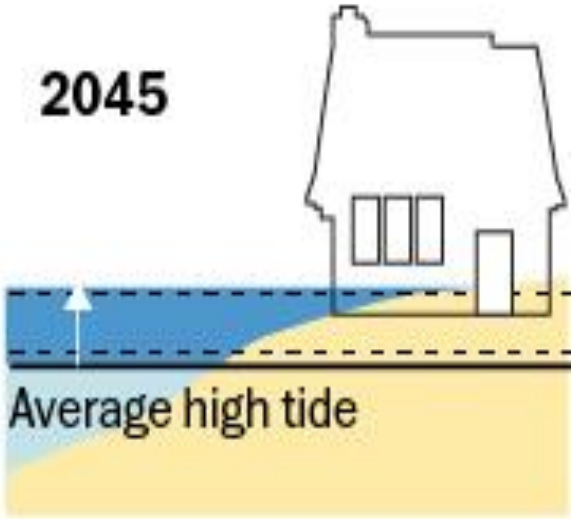
For example, Published October 17, 2014, Washington Post

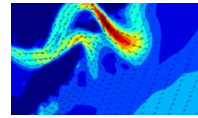
The growing reach of tidal flooding

A tide causing a minor flood today is a nuisance (white arrow). In the future, higher sea levels will allow high tides to push water deeper into coastal communities.

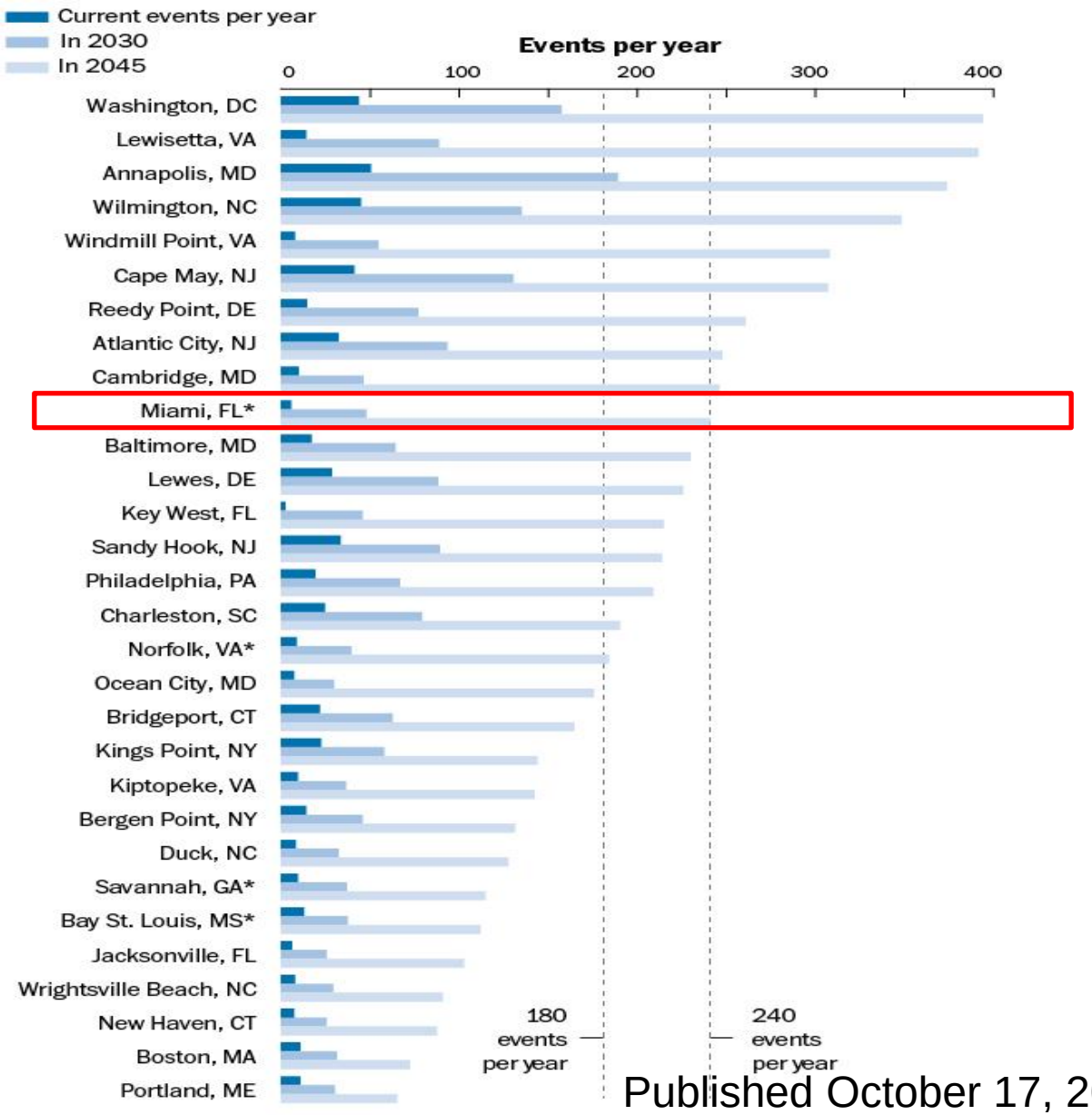


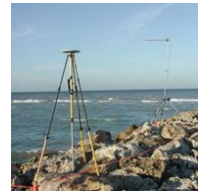


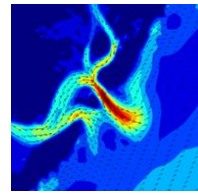




Get Good Data- Be Cautious with Media Reports

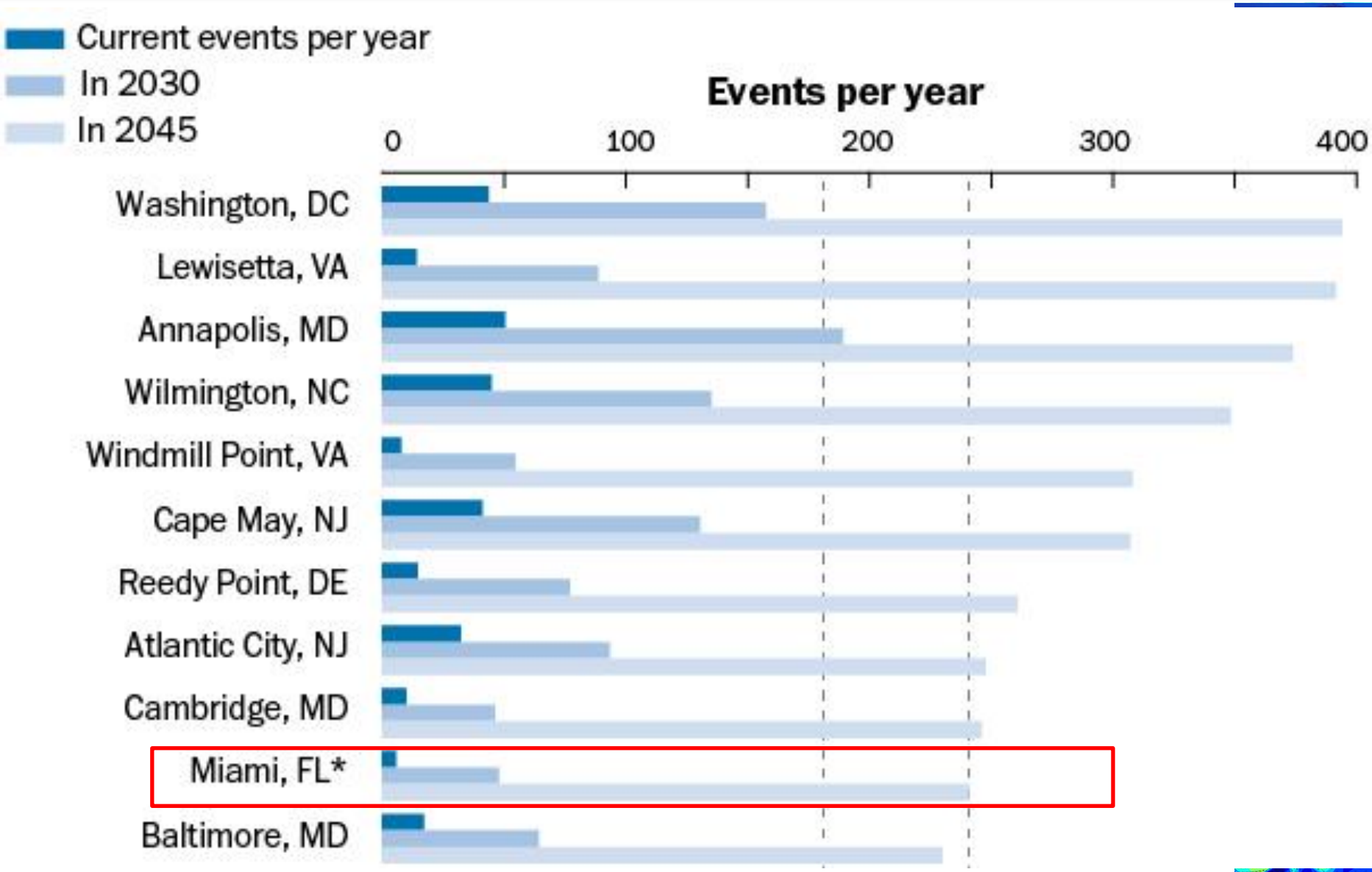






Published October 17, 2014, Washington Post

Get Good Data- Be Cautious with Media Reports



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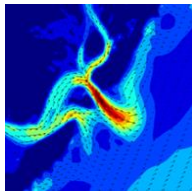

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2. **Evaluate your infrastructure.**
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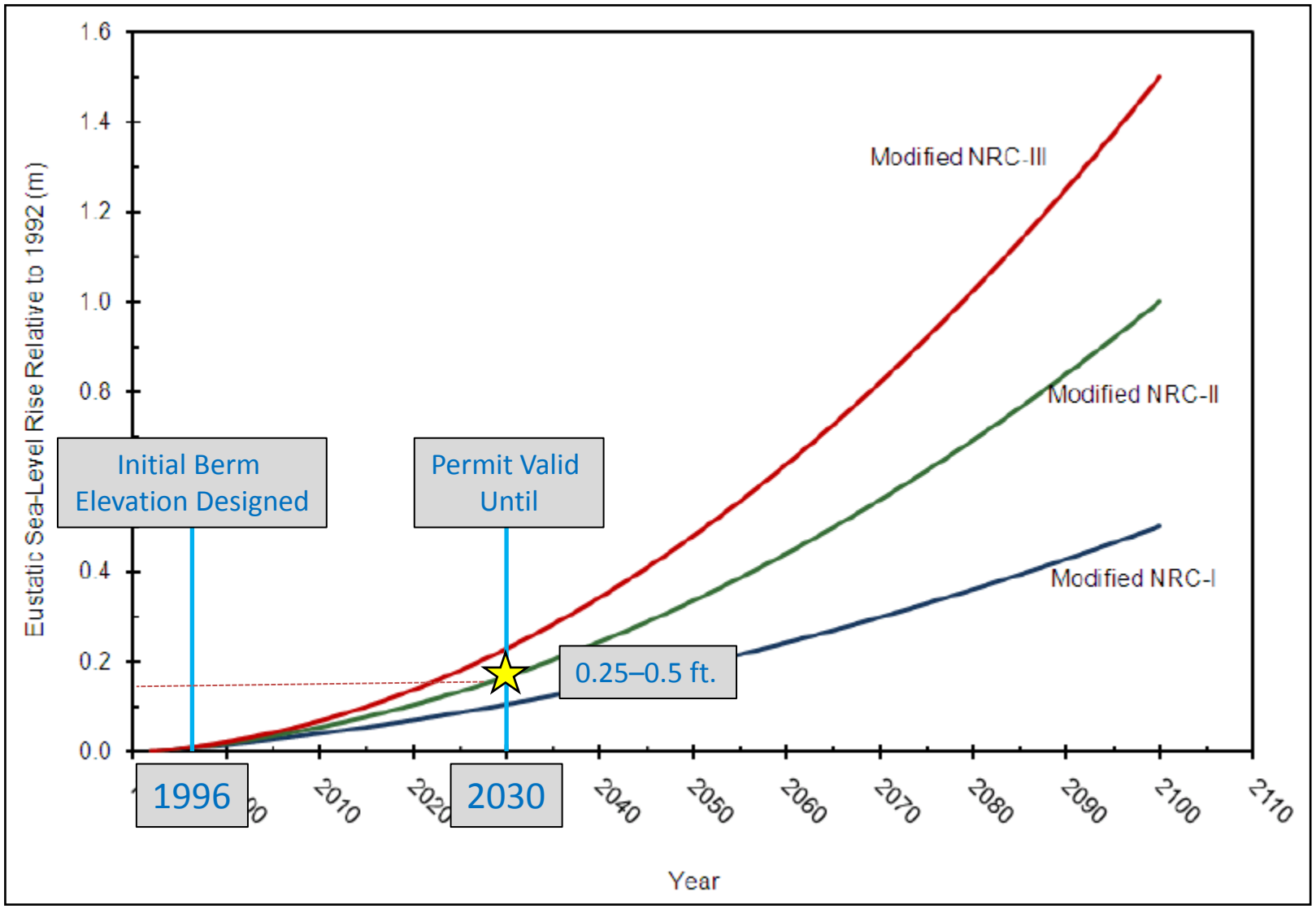
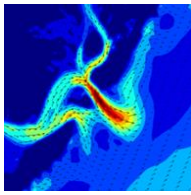
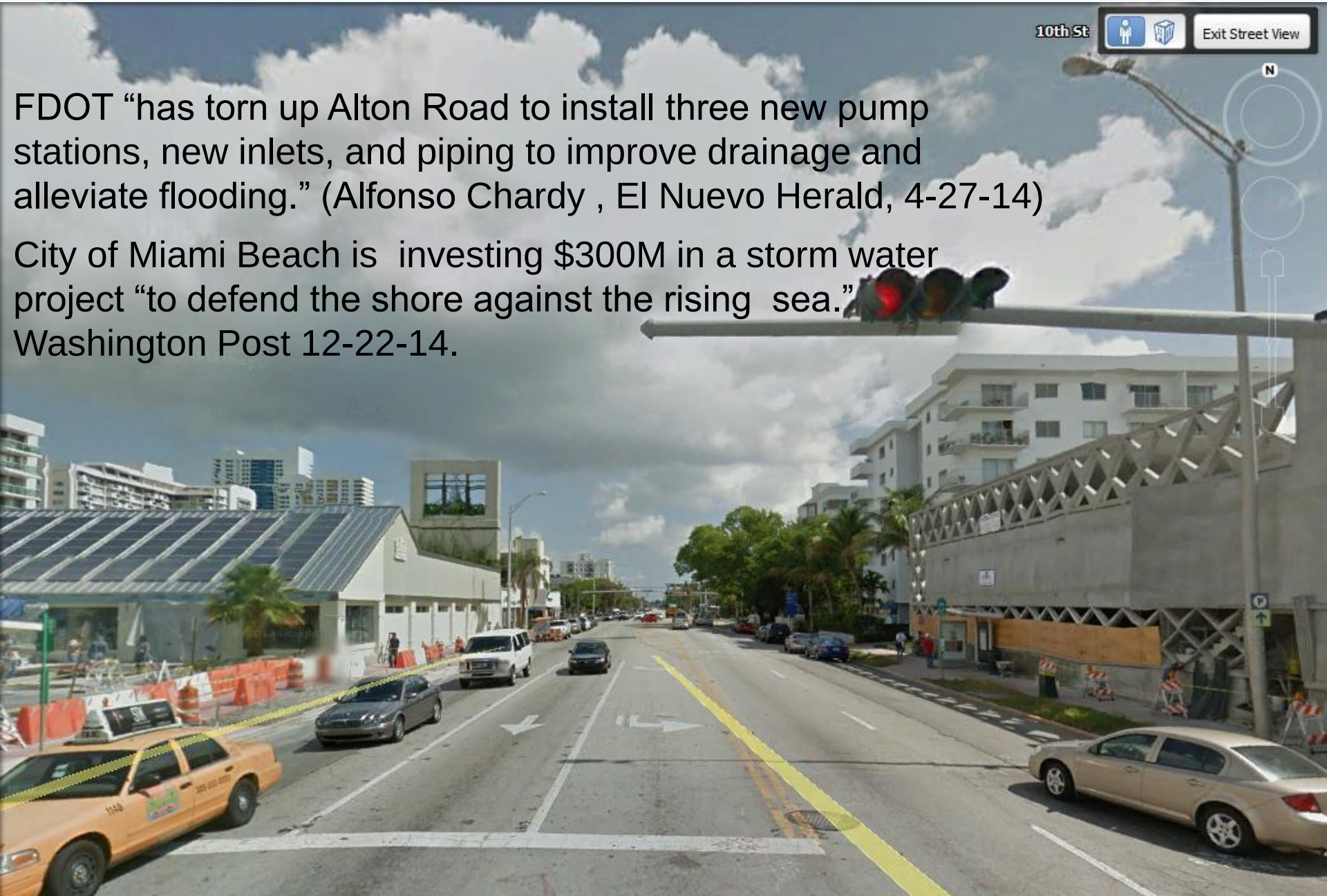
Future Beach Projects Can Address Sea Level Rise



Scenarios for Global Mean Sea Level Based on 1987 NRC Equation (USACE, 2011)



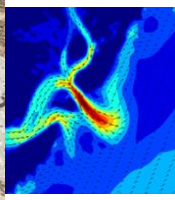
Alton Road Miami Beach Elev 2.8 ft.



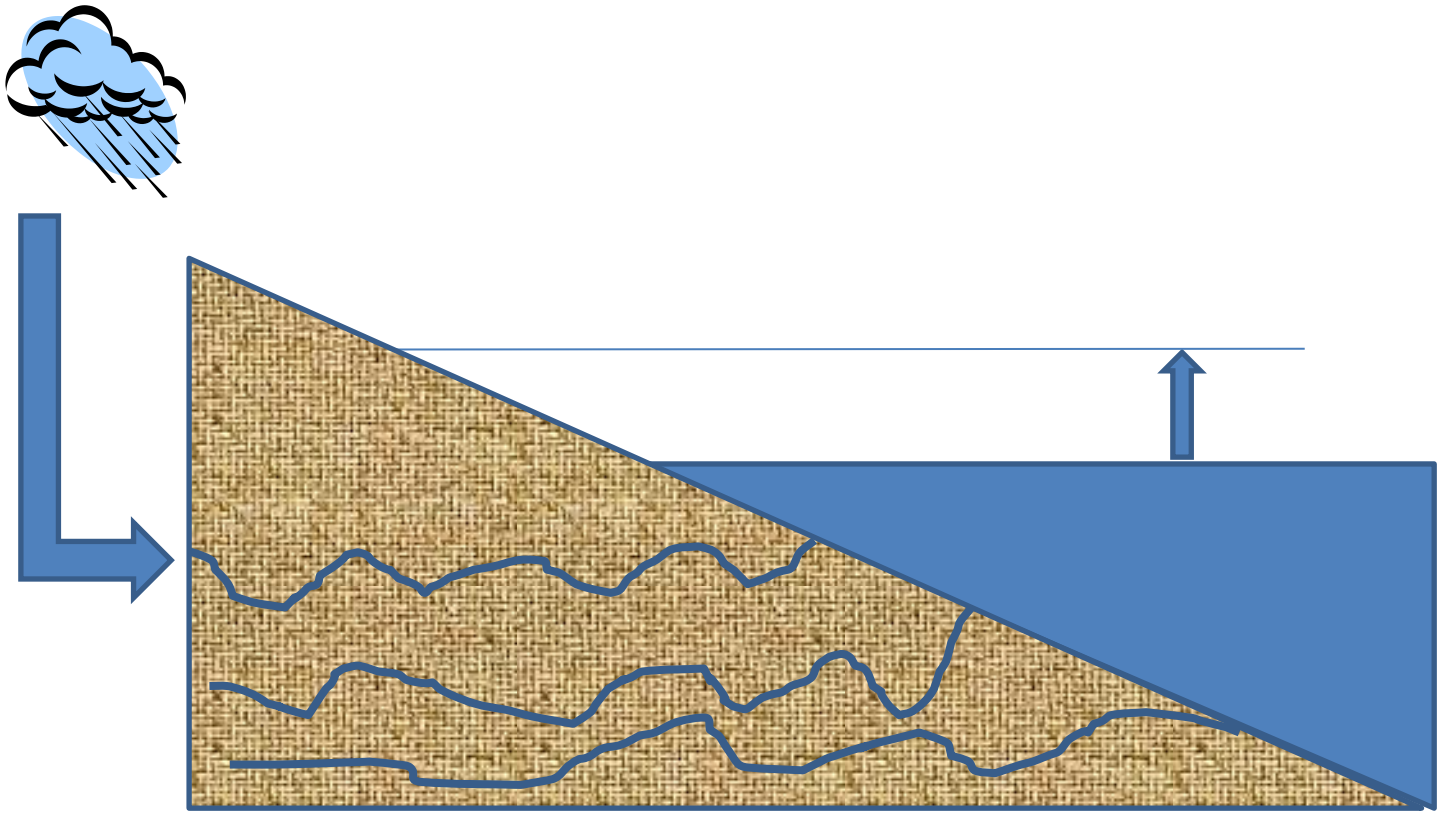
FDOT “has torn up Alton Road to install three new pump stations, new inlets, and piping to improve drainage and alleviate flooding.” (Alfonso Chardy , El Nuevo Herald, 4-27-14)

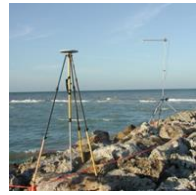
City of Miami Beach is investing $300M in a storm water project “to defend the shore against the rising sea.” Washington Post 12-22-14.

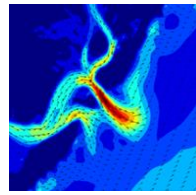
Infrastructure Assessment



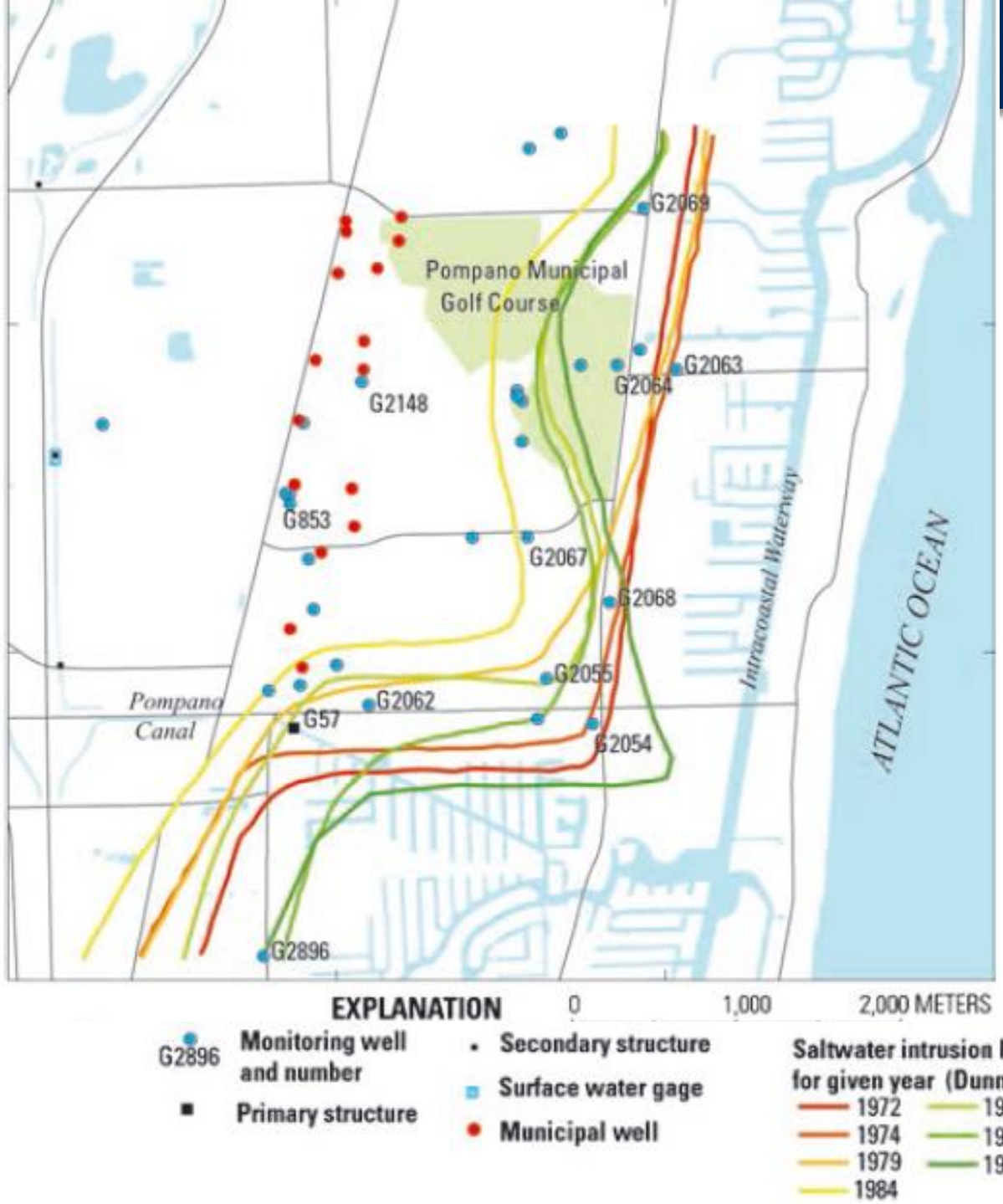
If SLR is small, is groundwater affected?



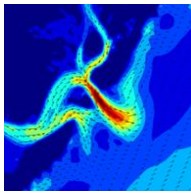




Groundwater Example



Langevin and Zygnerski, 2013 discussed Dunn (2001) data of the 250 mg/l contour lines for various years in Pompano Beach, Florida.



Fact:

Ground water wells show increased signs of saltwater intrusion.

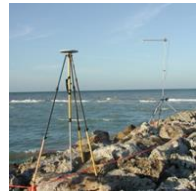
Media:

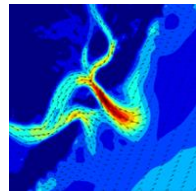
Frequently ties the intrusion to sea level rise.

Reality:

Primarily due to over-pumping due to growth in demand.

- In 2014, Florida became the third most populous state with 19.9 million people.
- Tourism driven economy that seeks 100 M visitors.
- FDEP (2014) predicts by 2034, freshwater demand will be at 1.3 Billion gallons per day.



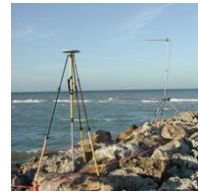


Coastal communities have already responded to increased salt content in groundwater by:

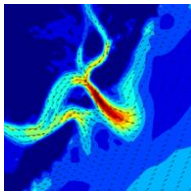
A. Moving Wells Inland (Broward County, Collier County)

B. Using Reverse Osmosis (Town of Jupiter, Town of Highland Beach, City of Sarasota) for at least part of their drinking water system.

C. Reducing demand through use of “reclaimed” water for irrigation (City of Boca Raton, City of Pompano Beach, Palm Beach County).



D. Recharging surface supplies (Palm Beach County).



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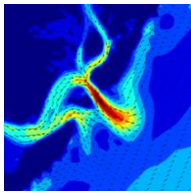
3. **Move forward.**

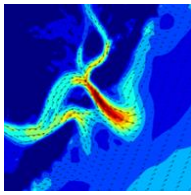
" Our nation [and all coastal countries] will face major decisions at various times in the future as to the most appropriate response to rising sea levels [and other causes of beach erosion]." Houston and Dean, 2013.



Local government will be forced to deal with the situation on a case by case basis. No one size fits all solution exists.

There is a role for the State governments to lead on regional issues.

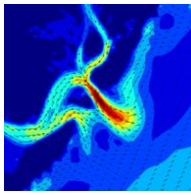
There is a role for the Federal government to lead on national issues.

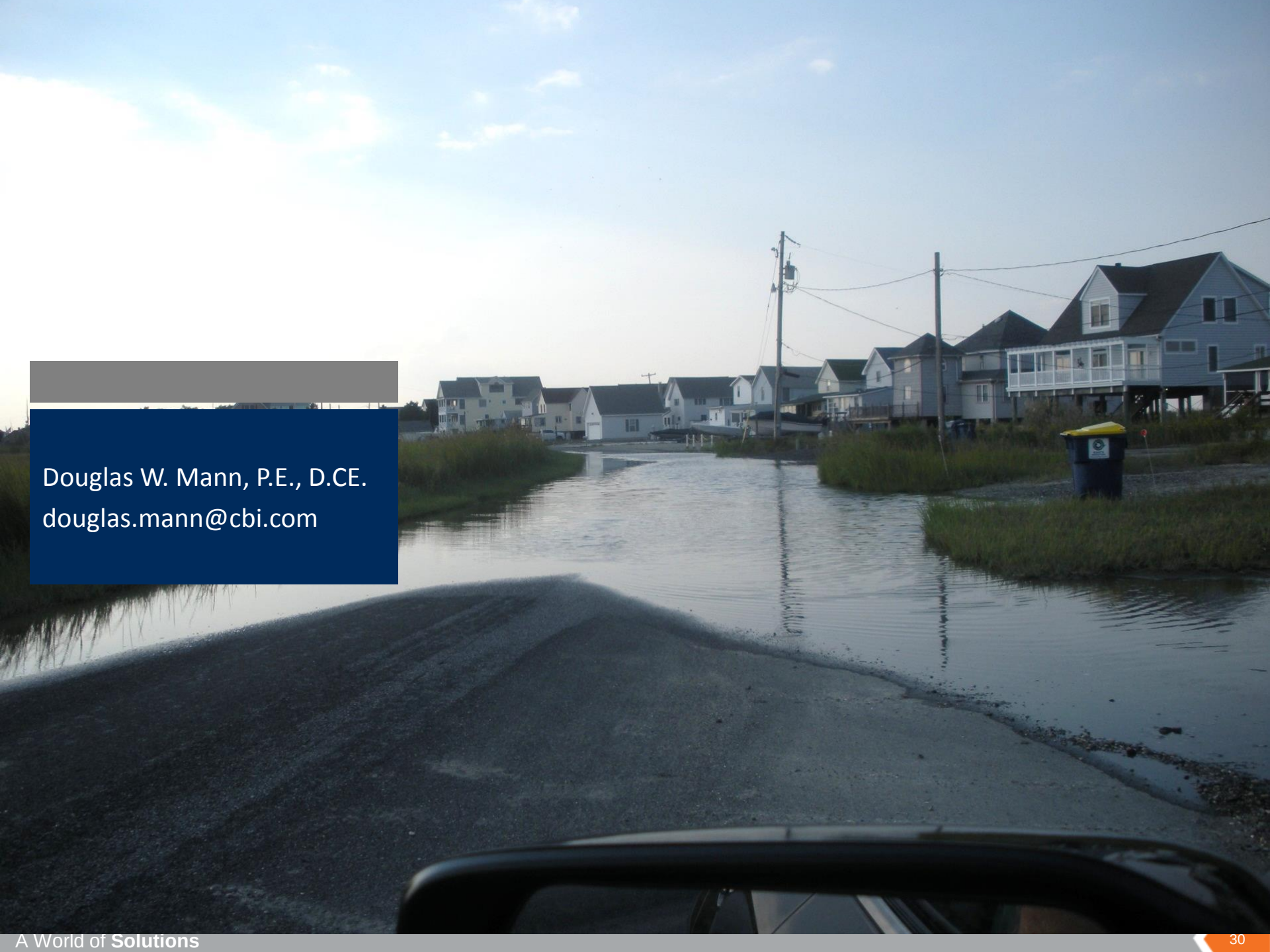


Is there an electric or fuel cell automobile in your future ?

Suggestions for Living with Sea Level Rise

1. Get good data. Understand what it means.
2. Evaluate your infrastructure. Determine what you can fix, retrofit, etc.
3. Move Forward.





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