

# Preparing for Sea Level Rise: Options for Purposeful Adaptation

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# Navy Concerns about Sea Level Rise

- Naval bases are on the coast
- Naval bases are flooding more often
- Arctic's Northwest Passage is now open to ship traffic



# The Roadmap

- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
- Why does a little bit of sea level rise matter?
- What are my adaptation options?



Source: UK DailyMail.com

# How Much Has Sea Level Risen?

- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
- Why does a little bit of rise matter?
- What are my adaptation options?

- Global Sea Level Rise

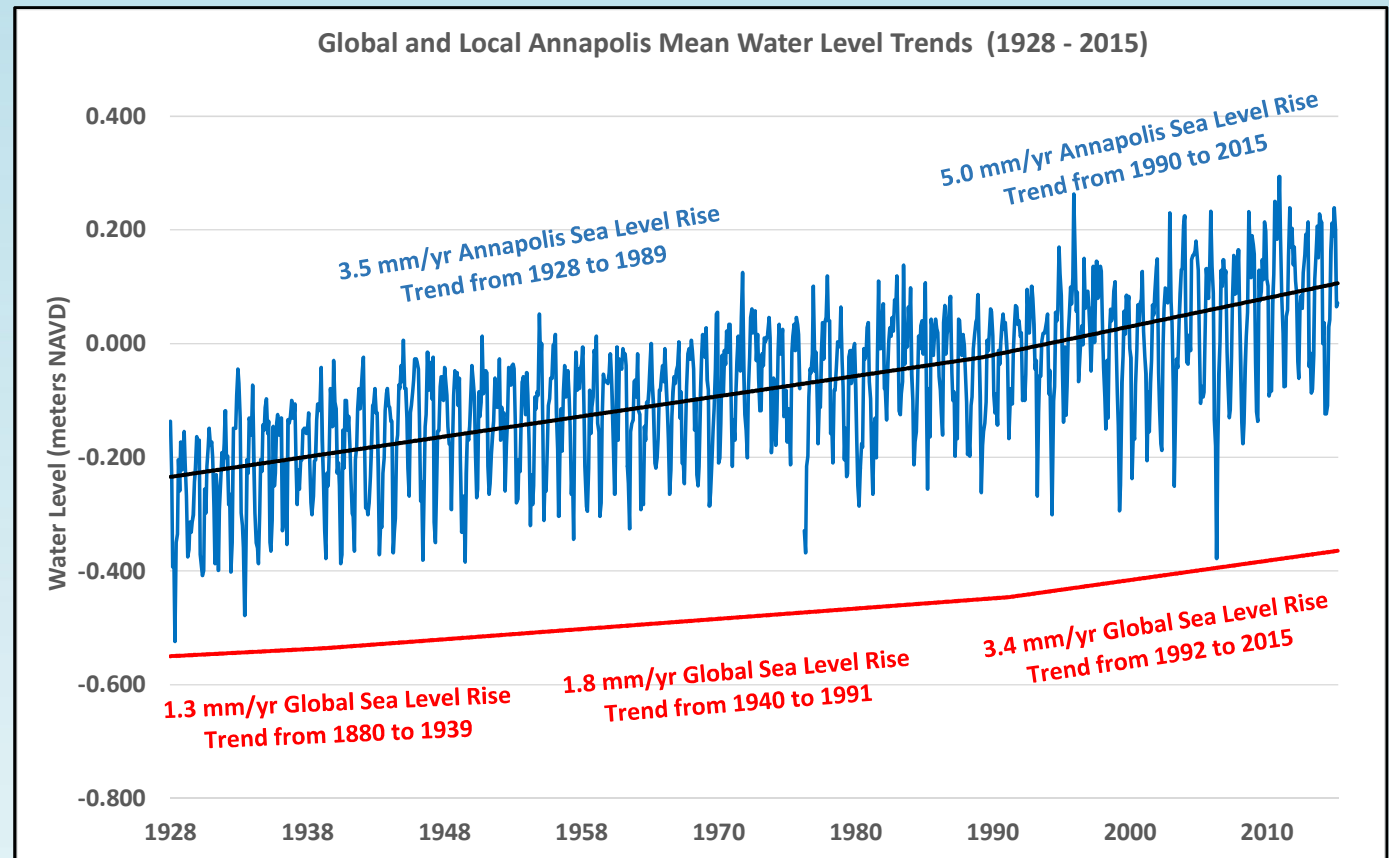
1.7 mm/yr since 1900

3.4 mm/yr since 1992

- Local Sea Level Rise in Annapolis, MD

3.6 mm/yr since 1928

5.0 mm/yr since 1990



Sources: Adapted from National Climate Assessment (2014), Church & White (2011), NOAA tidesandcurrents.noaa.gov

# How Much Has Sea Level Risen?

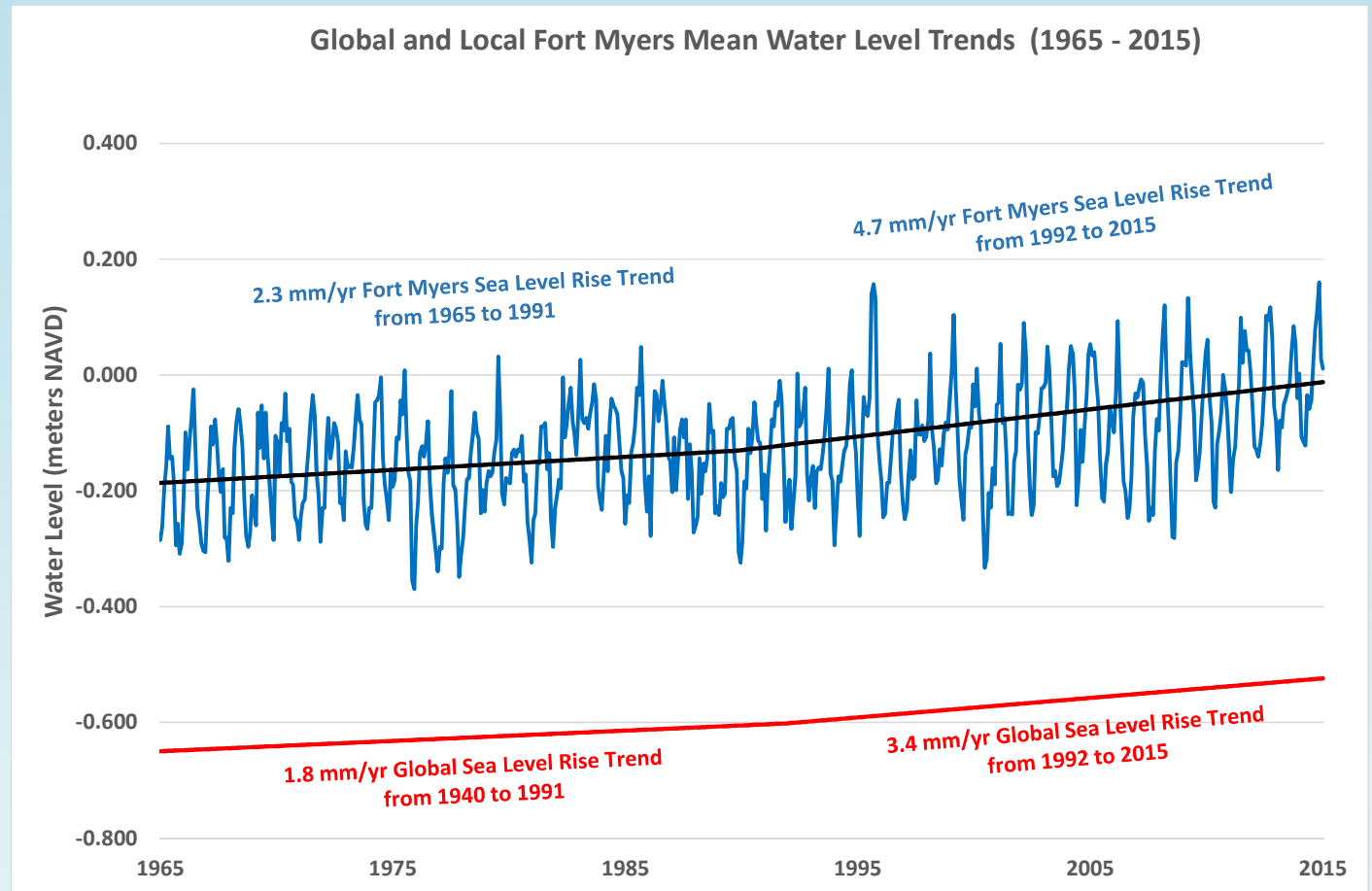
- Local Sea Level Rise across Florida also exceeds global trend
- 240 mm of Global Sea Level Rise Since 1880

≈1/3 in First 6 Decades

≈1/3 in Next 5 Decades

≈1/3 in Last 2.5 Decades

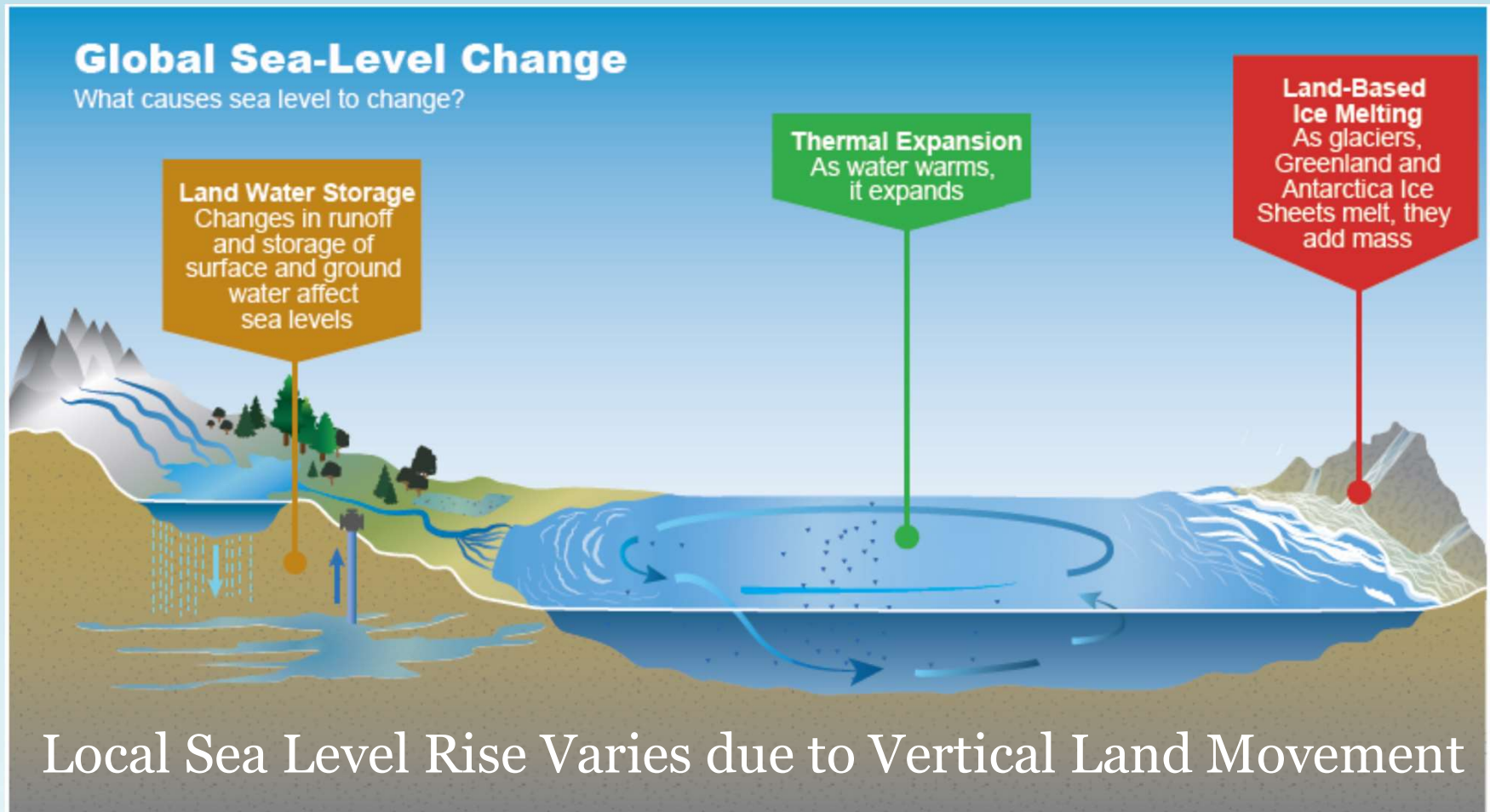
- How much has sea level risen?
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Sources: Adapted from National Climate Assessment (2014), Church & White (2011), NOAA tidesandcurrents.noaa.gov

# How Much More Will Sea Level Rise?

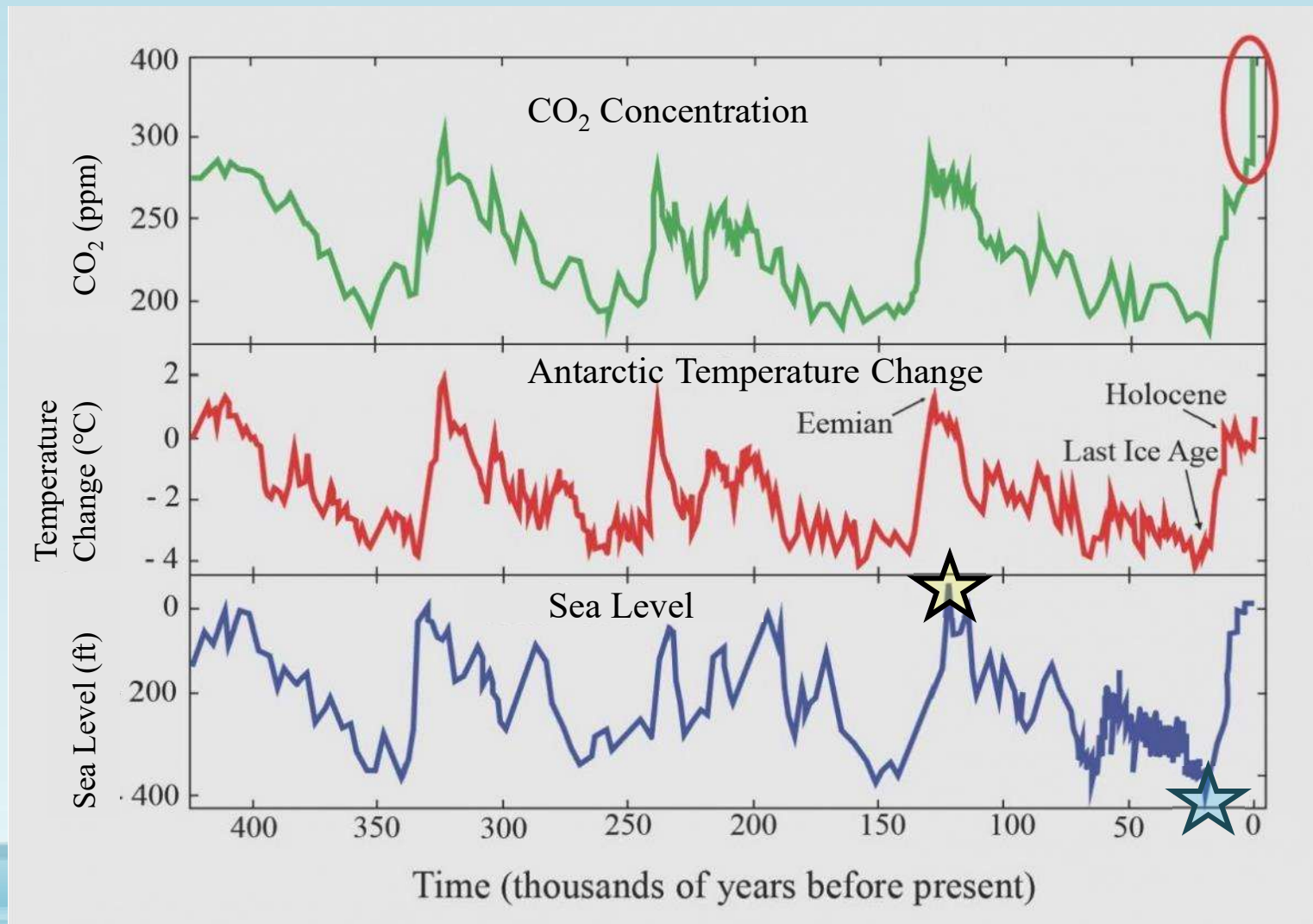
- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
- Why does a little bit of rise matter?
- What are my adaptation options?



Source: Hall et al. (2016), IPCC AR5 (2013)

# How Much More Will Sea Level Rise?

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- How much more will it rise?
- Is coastal flooding getting worse?
- Why does a little bit of rise matter?
- What are my adaptation options?

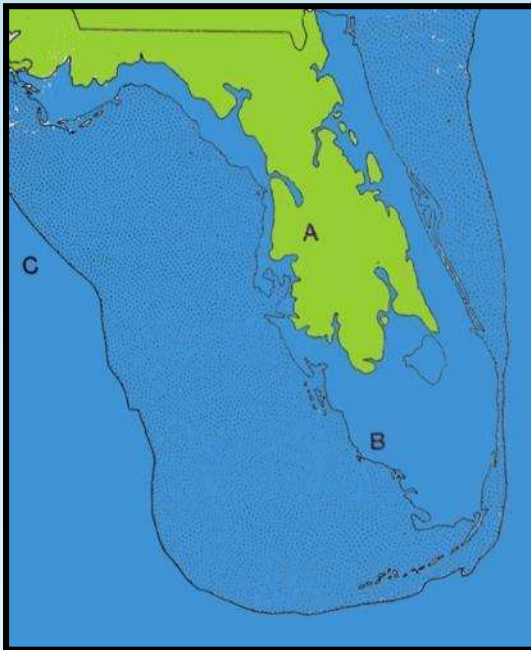


Source: Adapted from Hansen et al. (2008)

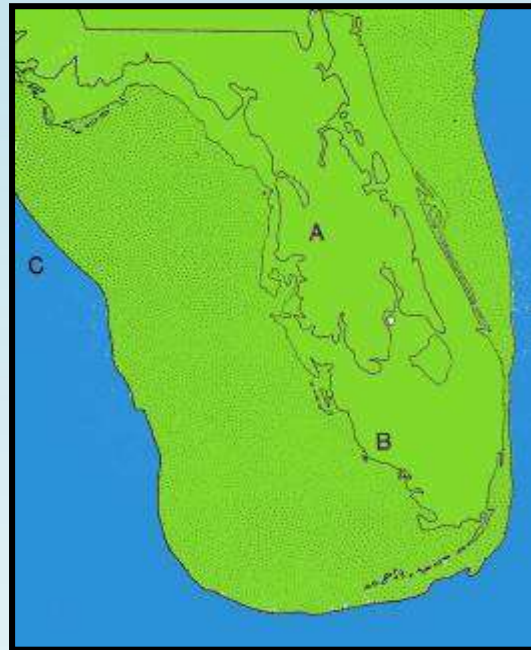
# How Much More Will Sea Level Rise?

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120,000 yrs ago  
★ 20 ft higher



18,000 yrs ago  
★ 420 ft lower



Today

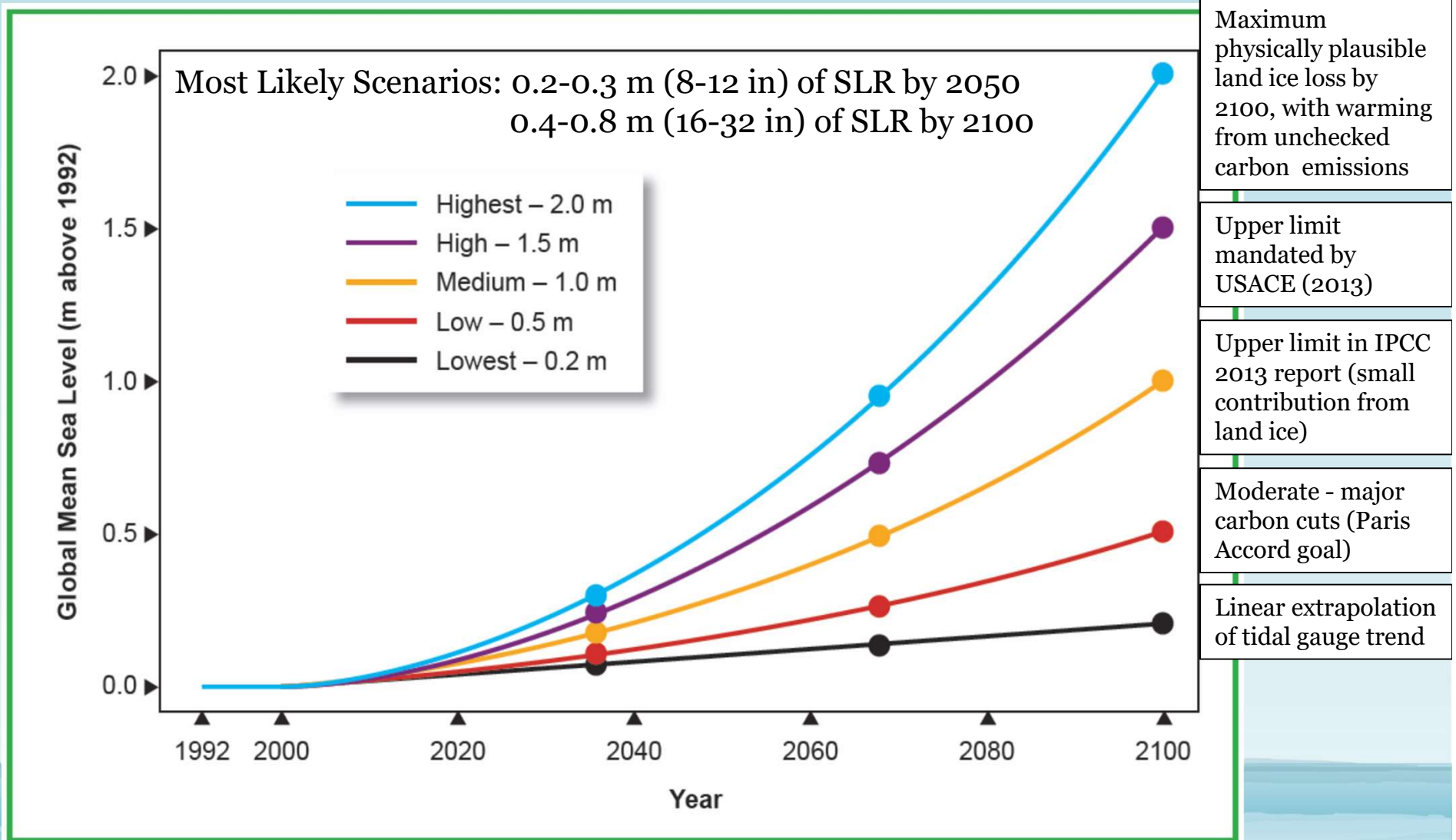


Source: Adapted from Dr. Wanless presentation to Miami-Dade County Board of Commissioners (2008)



# How Much More Will Sea Level Rise?

- How much has sea level risen?
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- Is coastal flooding getting worse?
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Source: Adapted from Hall et al (2016)

# Is Coastal Flooding Getting Worse Too?

- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
- Why does a little bit of rise matter?
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Why the strongest storms are getting stronger



Hurricanes Have Doubled Due to Global Warming, Study Says



Megadisasters devastated America in 2017. And they're only going to get worse.



Extreme weather becoming more common, study says



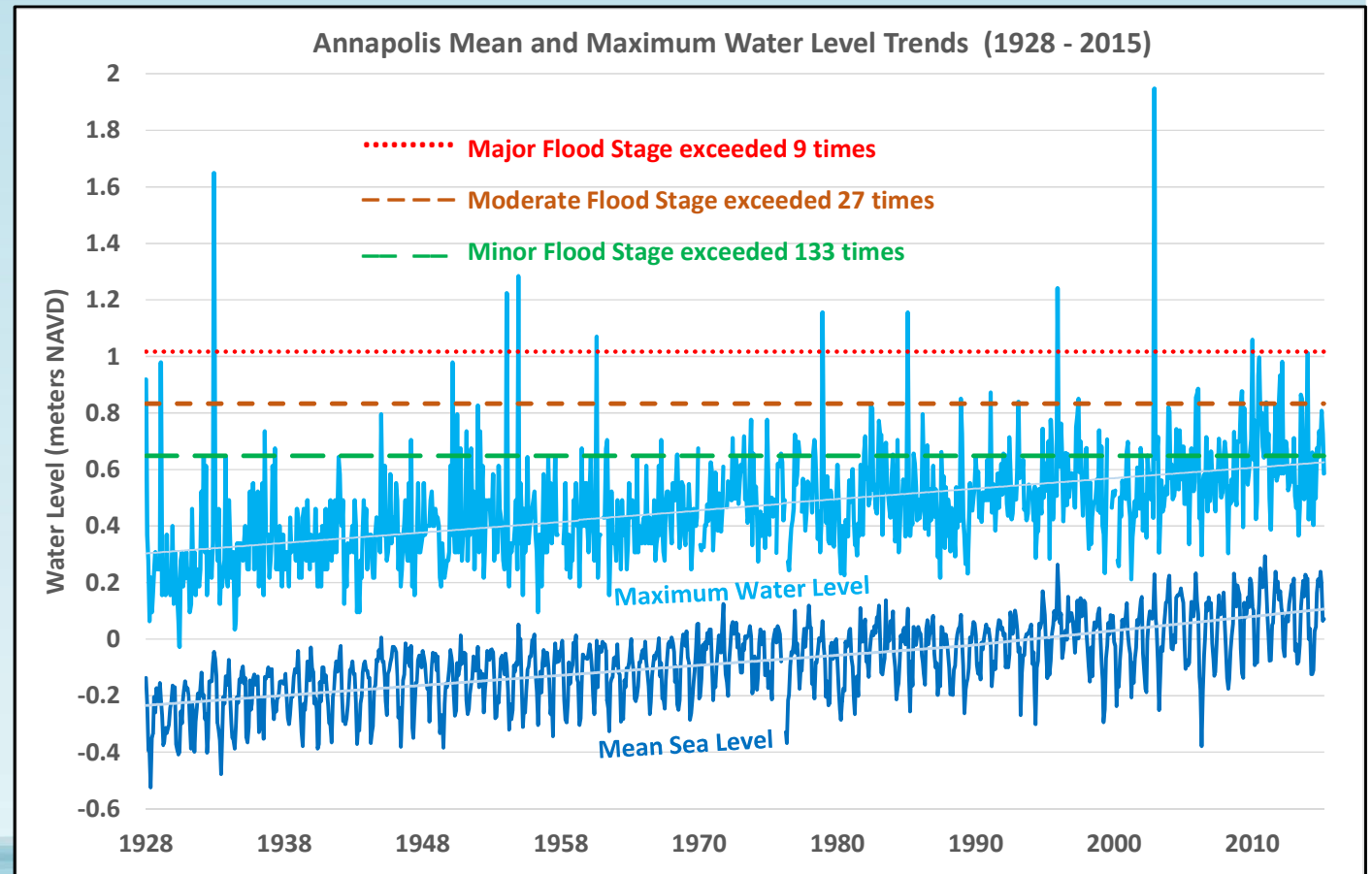
Hell and high water: Floods are getting worse, failure to plan ahead is not an option

Source: <http://animal-mix.blogspot.com/2014/03/memory-record-of-storm-damage.html>

# Is Coastal Flooding Getting Worse Too?

- How much has sea level risen?
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- Mean sea level for Annapolis: **3.6 mm/yr**
- Maximum trend for Annapolis: **3.7 mm/yr**
- Note the increasing frequency of flood events

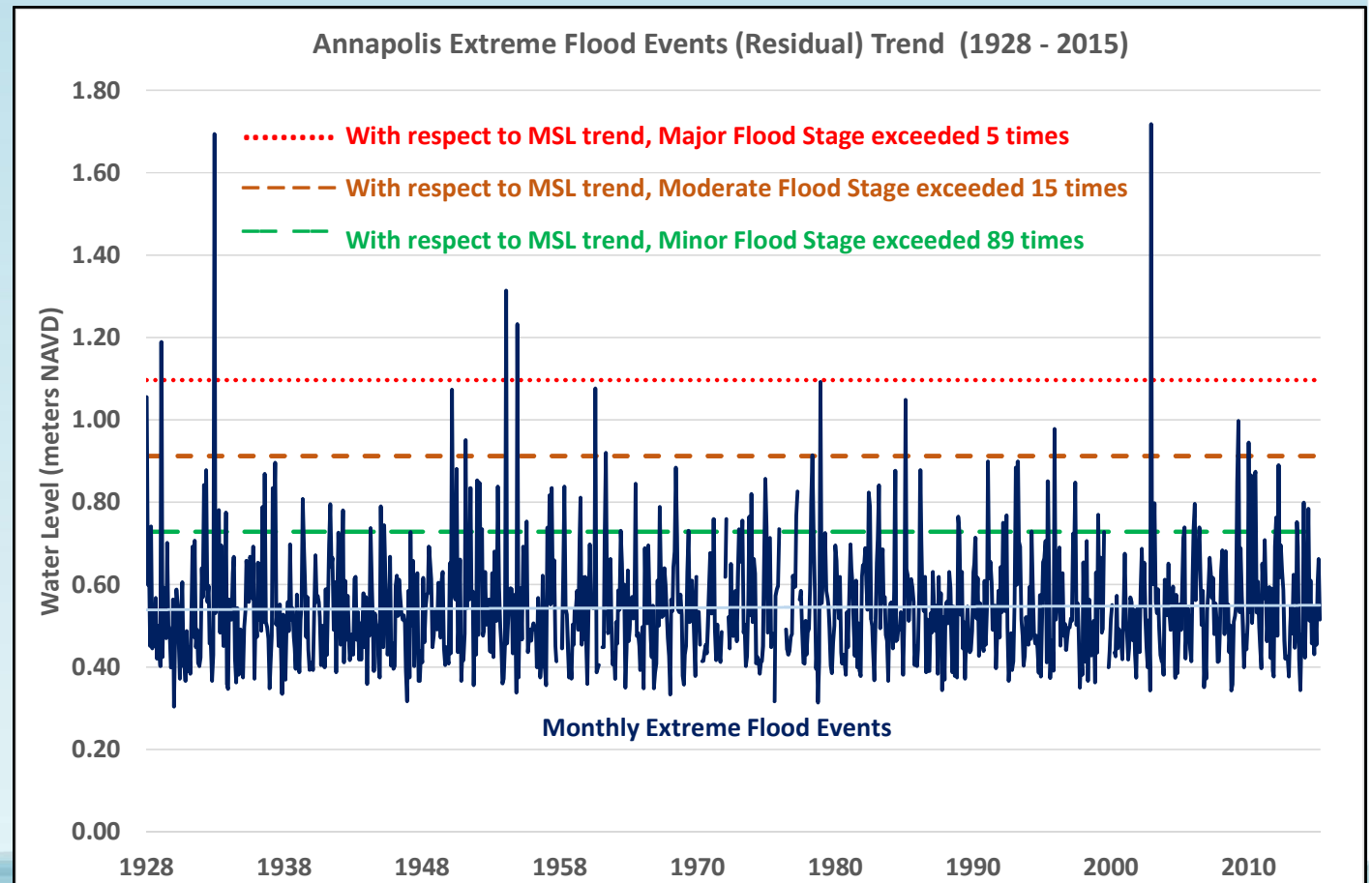


Sources: Adapted from NOAA tidesandcurrents.noaa.gov, National Weather Service, water.weather.gov

# Is Coastal Flooding Getting Worse Too?

- Maximum minus mean
- Are flood events occurring more often or more severely?

- How much has sea level risen?
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Sources: Adapted from NOAA tidesandcurrents.noaa.gov, National Weather Service, water.weather.gov

# Is Coastal Flooding Getting Worse Too?

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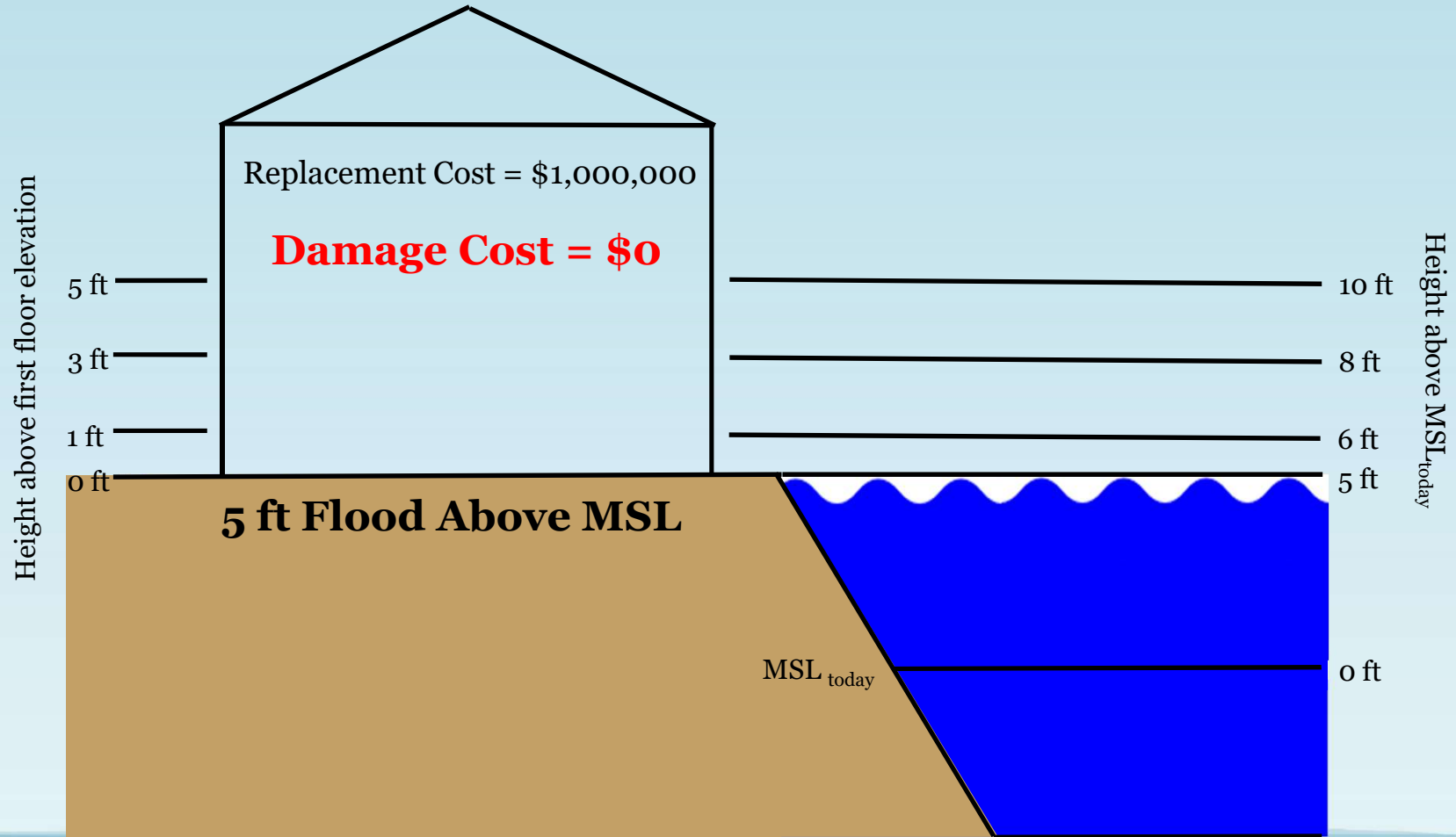
- Study of U.S. East Coast Locations
- Same Trend at All Sites

Location	Water Level Data Date Range	Number of Months with Data	Maximum Water Level Trend (mm/yr)	Mean Water Level Trend (mm/yr)	Extreme Flood Events Trend (mm/yr)
Portland, ME	1912 - 2015	1202	2.3	1.8	0.5
Boston, MA	1921 - 2015	1116	3	2.8	0.2
Newport, RI	1930 - 2015	1008	2.5	2.7	-0.1
New London, CT	1938 - 2015	908	1.9	2.5	-0.5
The Battery, NY	1920 - 2015	1147	3.4	3.1	0.2
Sandy Hook, NJ	1932 - 2015	995	4.3	4.1	0.2
Atlantic City, NJ	1911 - 2015	1153	4.0	4.1	-0.2
Annapolis, MD	1928 - 2015	1020	3.7	3.5	0.1
Solomon's Island, MD	1937 - 2015	901	3.6	3.8	-0.2
Norfolk, VA	1927 - 2015	1057	4.4	4.6	-0.2
Charleston, SC	1903 - 2015	1143	3.5	3.2	0.3
Fernandina Beach, FL	1897 - 2015	1250	2.3	2.2	0.1
Key West, FL	1913 - 2015	1225	2.5	2.4	0.1

Source: Adapted from NOAA tidesandcurrents.noaa.gov

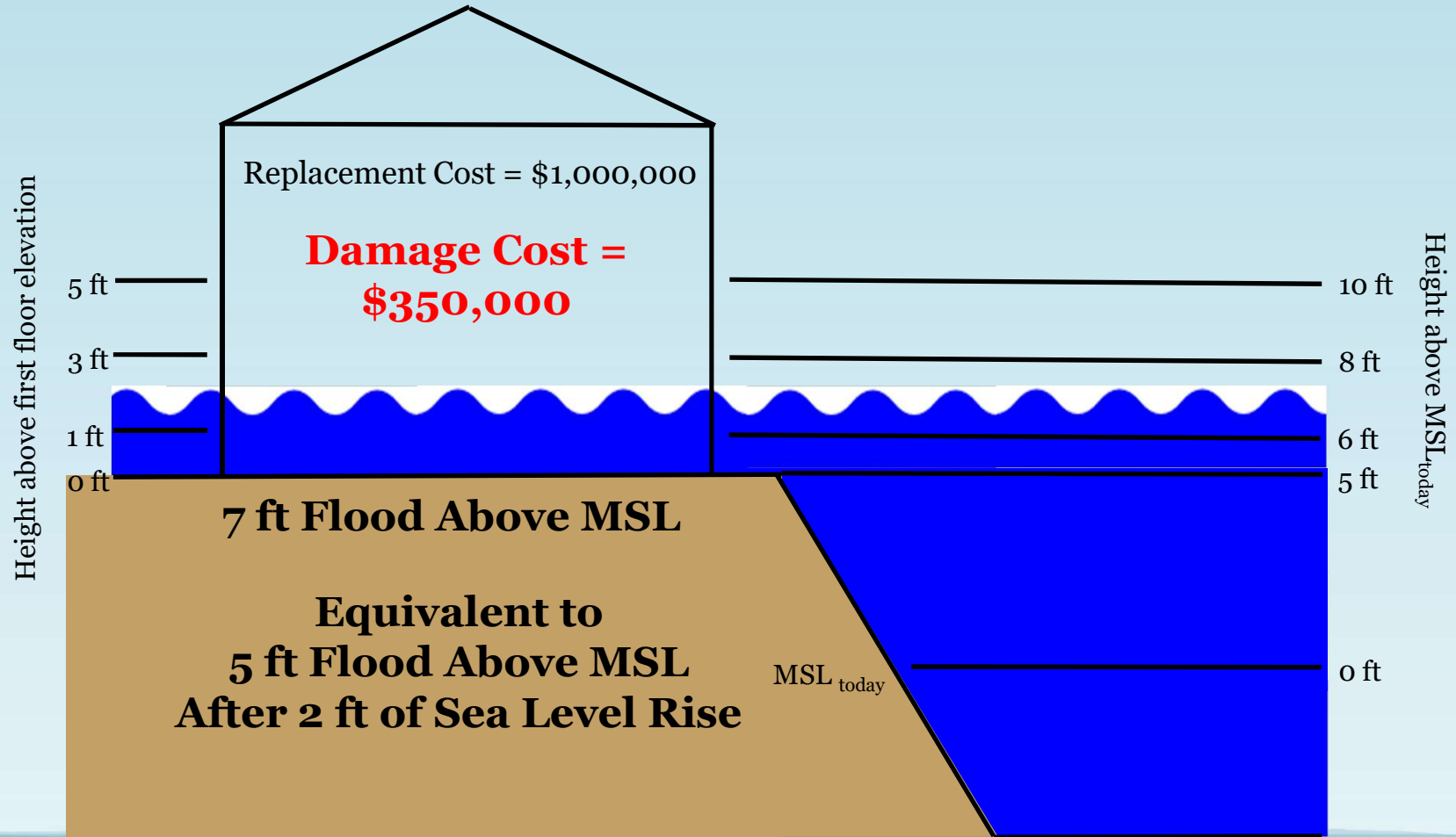
# Why Does a Little Bit of Sea Level Rise Matter?

- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
- Why does a little bit of rise matter?
- What are my adaptation options?



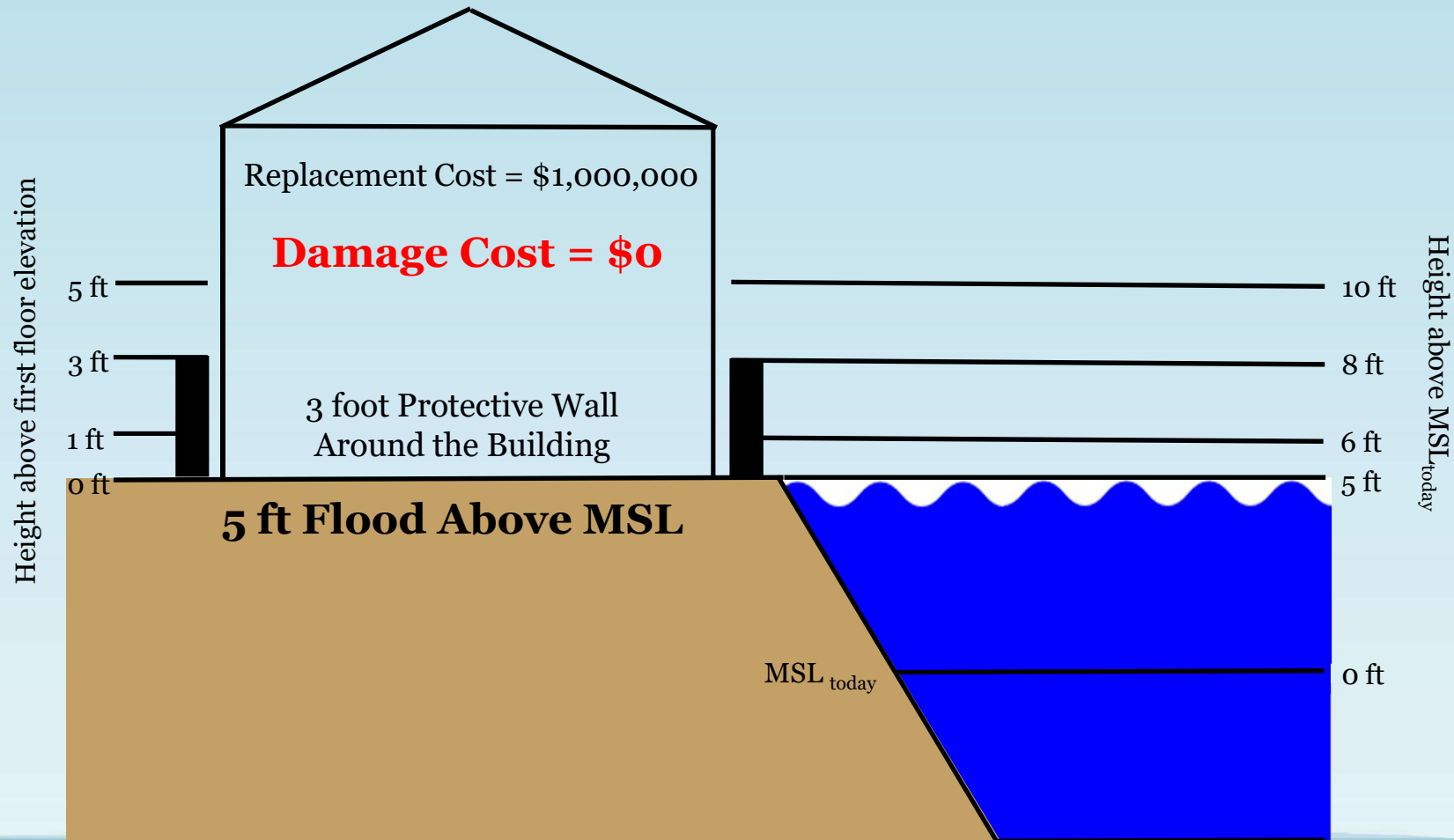
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# Why Does a Little Bit of Sea Level Rise Matter?

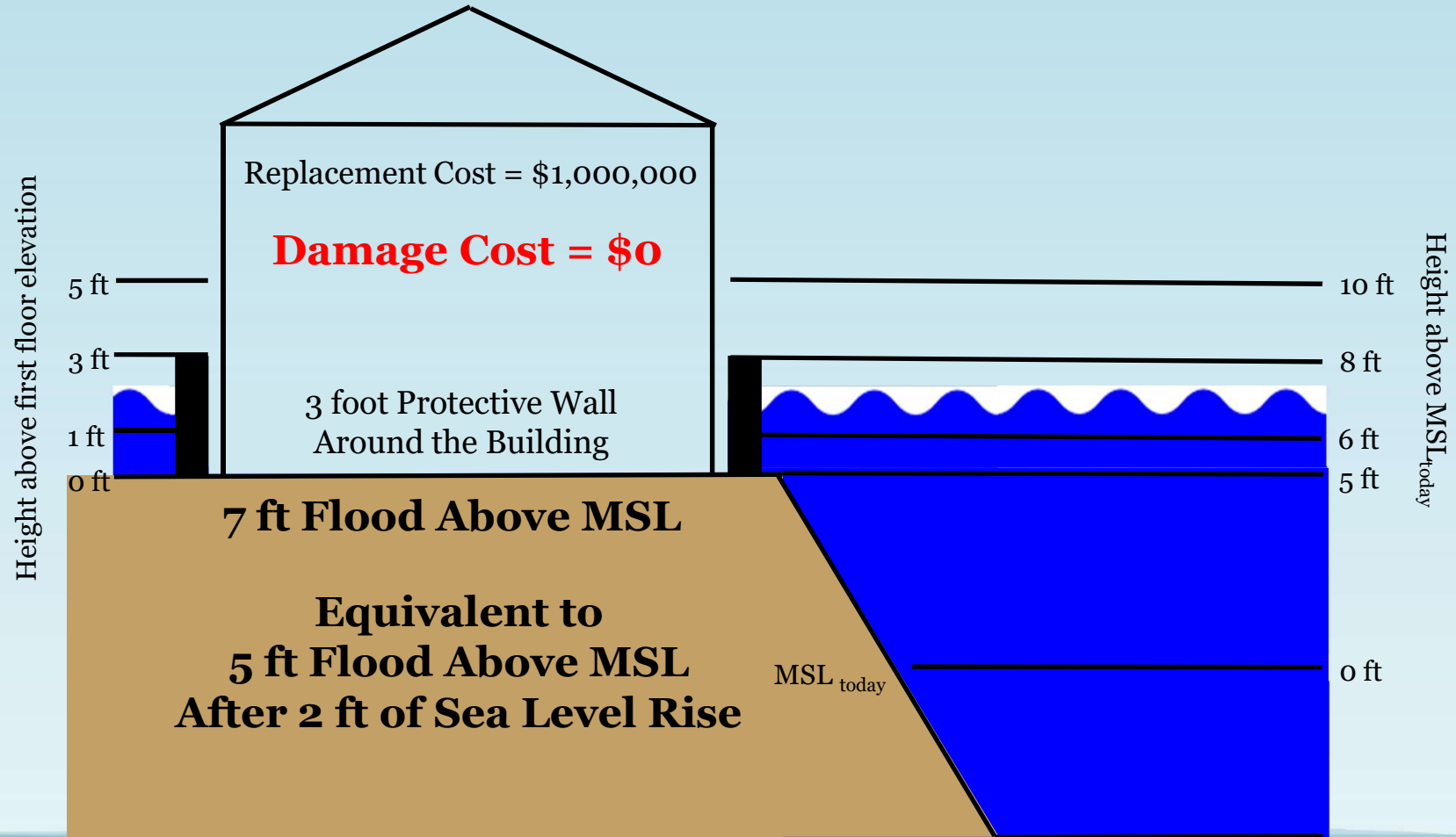
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# What Are My Adaptation Options?

- More flood events due to Global SLR
- Flood damage costs exceed budgeted costs
- Can you afford not to adapt?
- Adaptation often costs less over time than flood damage

- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
- Why does a little bit of rise matter?
- What are my adaptation options?



Source: [adaptationstories.com/2013/06/28/norfolk-rises-above-the-rising-tide/](http://adaptationstories.com/2013/06/28/norfolk-rises-above-the-rising-tide/)

# Adaptation Options: Armor, Adapt, Abandon

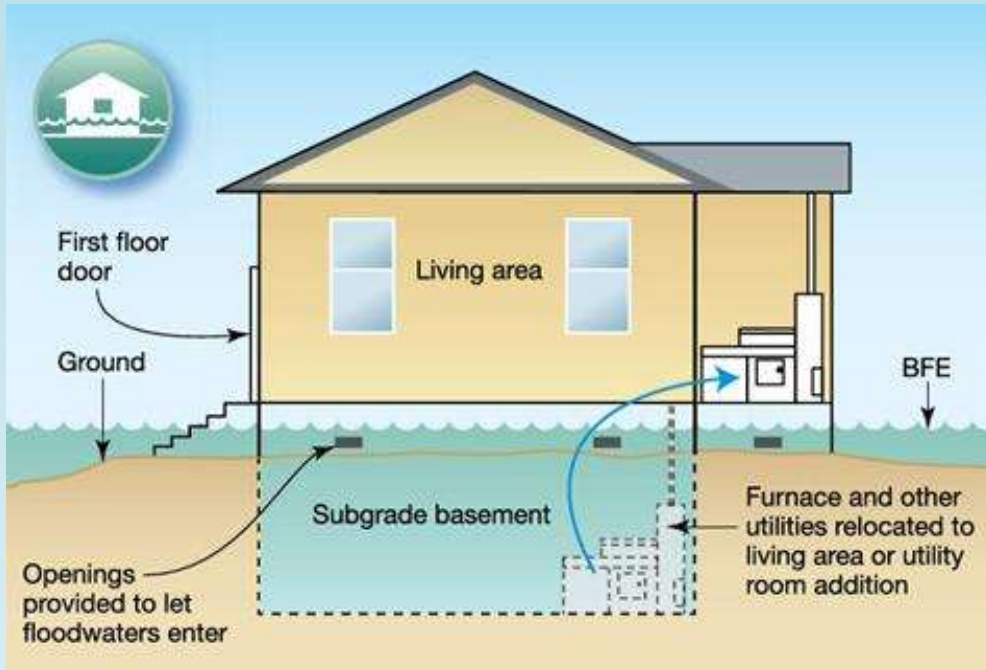
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Example of our “Armor:” Temporary door dams used at the U.S. Naval Academy as a flood preventive measure

# Adaptation Options: Wet Floodproofing

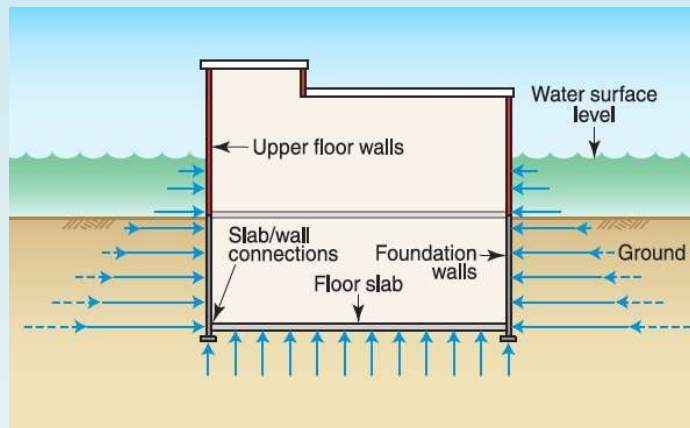
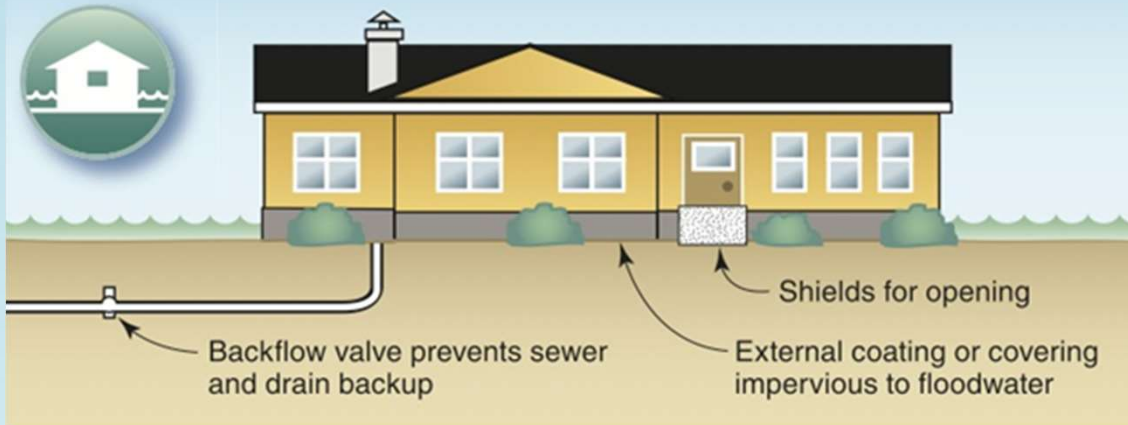
- How much has sea level risen?
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# Adaptation Options: Dry Floodproofing

- How much has sea level risen?
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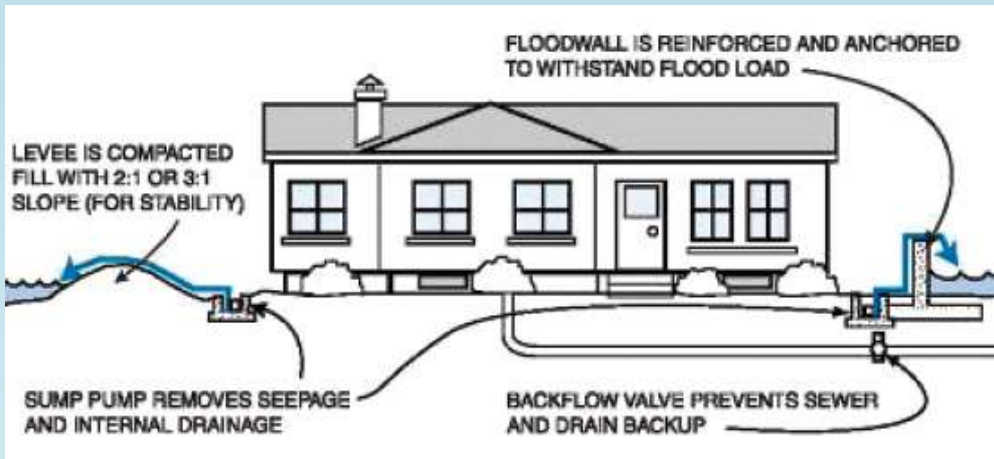
Maximum protection level is 3 feet (including freeboard)



Sources: [www.fema.gov](http://www.fema.gov)  
[www.resilientdesign.org/fundamentals-of-resilient-design-dry-floodproofing/](http://www.resilientdesign.org/fundamentals-of-resilient-design-dry-floodproofing/)  
[www.paragonstl.com/factors-consider-creating-flood-plan/](http://www.paragonstl.com/factors-consider-creating-flood-plan/)  
[www.thewaterfrontexpo.com/stormprotection.htm](http://www.thewaterfrontexpo.com/stormprotection.htm)

# Adaptation Options: Barrier Systems

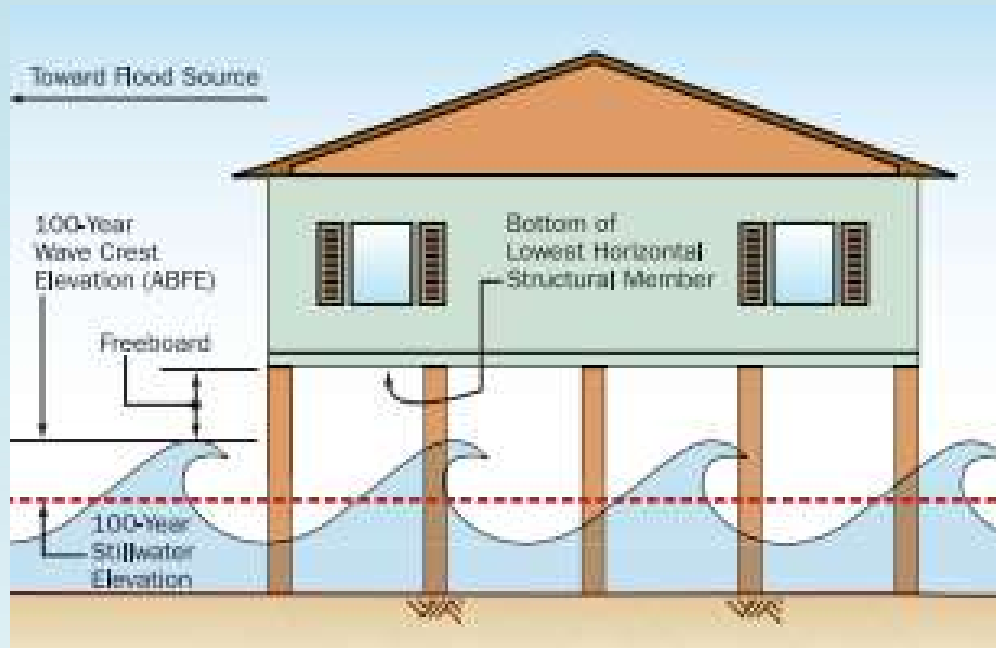
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Sources: [www.fema.gov](http://www.fema.gov)  
[floodbreak.com/about/success-stories/success-story-kensington-gate-great-neck-ny](http://floodbreak.com/about/success-stories/success-story-kensington-gate-great-neck-ny)  
[www.floodcontrolinternational.com/PRODUCTS/FLOOD-BARRIERS/glass-barriers.html](http://www.floodcontrolinternational.com/PRODUCTS/FLOOD-BARRIERS/glass-barriers.html)  
[www.reddit.com/r/videos/comments/4nh8u0/texas\\_man\\_uses\\_aquadam\\_to\\_protect\\_home\\_from/](http://www.reddit.com/r/videos/comments/4nh8u0/texas_man_uses_aquadam_to_protect_home_from/)

# Adaptation Options: Elevation

- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
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Sources: [www.fema.gov](http://www.fema.gov)  
[www.redfin.com/blog/2013/12/three-steps-to-prepare-for-a-flood.html](http://www.redfin.com/blog/2013/12/three-steps-to-prepare-for-a-flood.html)  
<http://www.searchinnorthcaptive.com/gallery/>

# Adaptation Options: Relocation

- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
- Why does a little bit of rise matter?
- What are my adaptation options?



Sources: [www.dbhousemovers.com/dbhousemovers.html](http://www.dbhousemovers.com/dbhousemovers.html)  
[www.fema.gov](http://www.fema.gov)  
[www.wolfehousebuildingmovers.com/faq/](http://www.wolfehousebuildingmovers.com/faq/)



# Large Scale Adaptation: Community

- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
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- What are my adaptation options?



Sources: [stormwater.wef.org/2014/03/first-full-scale-water-square-opens-rotterdam](http://stormwater.wef.org/2014/03/first-full-scale-water-square-opens-rotterdam),  
[www.waterworld.com/articles/wwi/print/volume-25/issue-5/editorial-focus/rainwater-harvesting/rotterdam-the-water-city-of-the-future.html](http://www.waterworld.com/articles/wwi/print/volume-25/issue-5/editorial-focus/rainwater-harvesting/rotterdam-the-water-city-of-the-future.html)

# Large Scale Adaptation: Region

- How much has sea level risen?
- How much more will it rise?
- Is coastal flooding getting worse?
- Why does a little bit of rise matter?
- What are my adaptation options?



Sources: [www.gizmodo.com.au/2013/10/these-gargantuan-gates-keep-europes-largest-port-from-drowning](http://www.gizmodo.com.au/2013/10/these-gargantuan-gates-keep-europes-largest-port-from-drowning),  
[www.dredgingtoday.com](http://www.dredgingtoday.com)

# What Can I Do Now?

- Sea level rise is felt by the Navy worldwide
- It's also felt by homeowners and businesses in Florida
- What can you do to protect your critical assets?



Sources: [wfla.com/2016/06/06/tropical-storm-colin-brings-flooding-to-st-pete-beach-pass-a-grille](http://wfla.com/2016/06/06/tropical-storm-colin-brings-flooding-to-st-pete-beach-pass-a-grille),  
[www.tampabay.com/news/humaninterest/anger-frustration-spill-over-at-flood-insurance-meeting-in-pasco/2157669](http://www.tampabay.com/news/humaninterest/anger-frustration-spill-over-at-flood-insurance-meeting-in-pasco/2157669)

# What Can I Do Now?

- Be informed about sea level rise and tell others
- Learn from other region's experiences
- Look for your vulnerabilities
- Take action, as needed, to Armor, Adapt or Abandon



Sources: [wfla.com/2016/08/31/tracking-tropical-depression-9-hillsborough-county](http://wfla.com/2016/08/31/tracking-tropical-depression-9-hillsborough-county),  
[www.nbcnews.com/slideshow/florida-surveys-damage-after-hermine-n642066](http://www.nbcnews.com/slideshow/florida-surveys-damage-after-hermine-n642066)

# Questions?

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[www.coastalsolutions.org](http://www.coastalsolutions.org)

# References

2006 U.S. Army Corps of Engineers. “Depth-Damage Relationships for Structures, Contents and Vehicles and Content-To-Structure Value Ratios (CSV) in Support of the Donaldsville to the Gulf, Louisiana Feasibility Study.”

[www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf](http://www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf)

2007 Stroeve et al. “Arctic sea ice decline: Faster than forecast.” *Geophys. Res. Lett.*, 34, L09501. [onlinelibrary.wiley.com/doi/10.1029/2007GL029703/full](http://onlinelibrary.wiley.com/doi/10.1029/2007GL029703/full)

2008 Hansen et al. “Target atmospheric CO<sub>2</sub>: Where should humanity aim?” *Open Atmos. Sci. J.*, 2, 217-231. [pubs.giss.nasa.gov/abs/ha00410c.html](http://pubs.giss.nasa.gov/abs/ha00410c.html)

2008 Wanless, H. “Statement on Sea Level in the Coming Century” presentation. [www.miamidade.gov/environment/library/brochures/08-04-22-statement-on-sea-level.pdf](http://www.miamidade.gov/environment/library/brochures/08-04-22-statement-on-sea-level.pdf)

2013 IPCC 5<sup>th</sup> Assessment Report. [www.ipcc.ch/report/ar5/wg1](http://www.ipcc.ch/report/ar5/wg1)

2014 National Climate Assessment. [nca2014.globalchange.gov](http://nca2014.globalchange.gov)

2016 Hall et al. Regional Sea Level Scenarios for Coastal Risk Management. U.S. Department of Defense. [www.serdp-estcp.org/News-and-Events/News-Announcements/Program-News/DoD-Report-on-Regional-Sea-Level-Scenarios](http://www.serdp-estcp.org/News-and-Events/News-Announcements/Program-News/DoD-Report-on-Regional-Sea-Level-Scenarios)