Maintaining Military Missions: Coordinated Approach to Sea Level Rise Infrastructure Impacts

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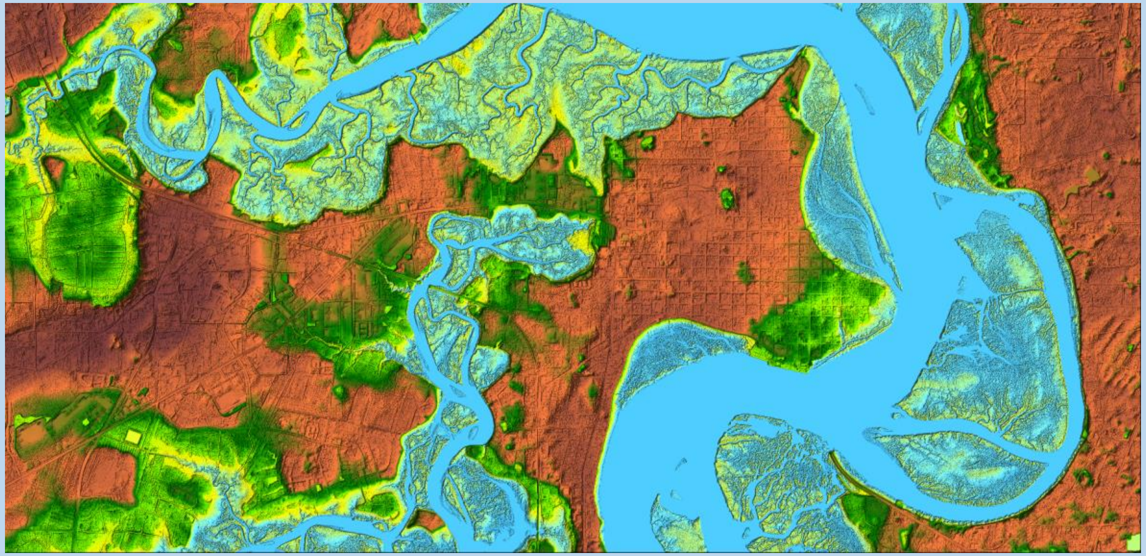
- Project Overview
- Techniques
    - Scoping
    - Mapping
    - Infrastructure
- Engineering
- Costs
- Summary/Lessons Learned



Project Overview – 5 Step Process

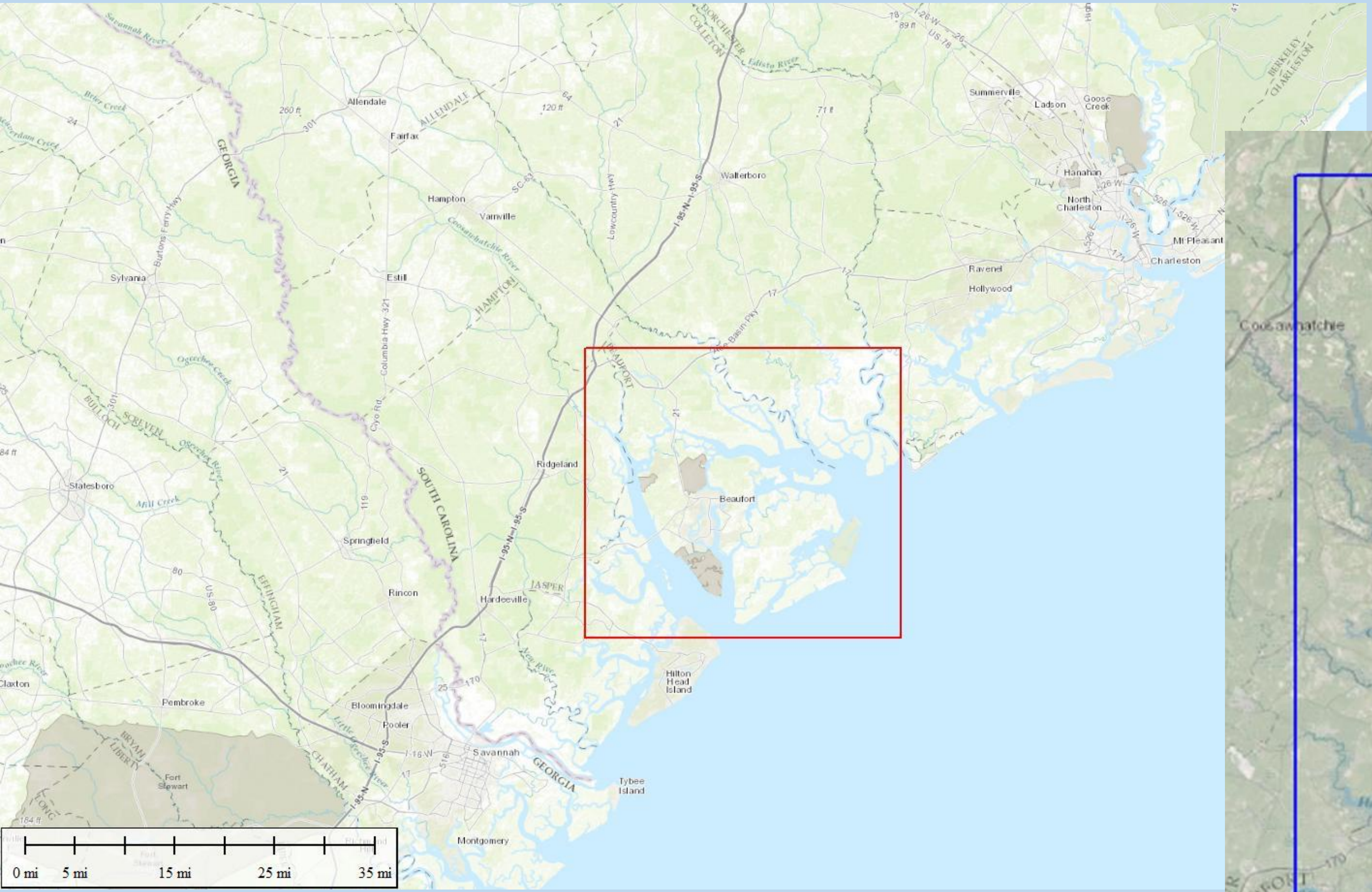
Tech Notes 1, 2, 3 Mapping Memo 1	SCOPING	•1.1 Establish a team, engage stakeholders; establish a framework for the project, and establish project boundaries. •1.2 Determine geographic and temporal scope of study •1.3 Investigate climate change; gather data; identify climate threats to understand climate trends, projections, and threats.
Tech Note 4	INFRASTRUCTURE ASSESSMENT	•2.1 Screen for “asset exposure ” based on SLR levels. •2.2 Assess “asset sensitivity” based on functionality, susceptability, and adaptive capacity (optional). •2.3 Define Vulnerable Assests
Tech Note 5	CRITICALITY AND VULNERABILITY ASSESSMENT	•3.1 Define criticality factors •3.2 Screen for “asset criticality” based on socioeconomic operational, and health and safety importance. •3.3 Assess Critical and Vulnerable assets based on exposure, sensitivity, and criticality screening.
Engineering Report 1	ENGINERING ANALYSIS/ASSET PRIORITIZATION	•4.1 Determine asset values •4.2 Estimate the expected value for each action, assess whether investments will reduce risk. •4.3 Determine viable options
Leverage Final Report	DEVELOPING A PATH FORWARD	•5.1 Consolidate actions, develop a sequence to reduce risks •5.2 Estimate expected value of action in reducing risk. •5.3 Evaluate trade-offs. •5.4 Develop a timeline and milestones

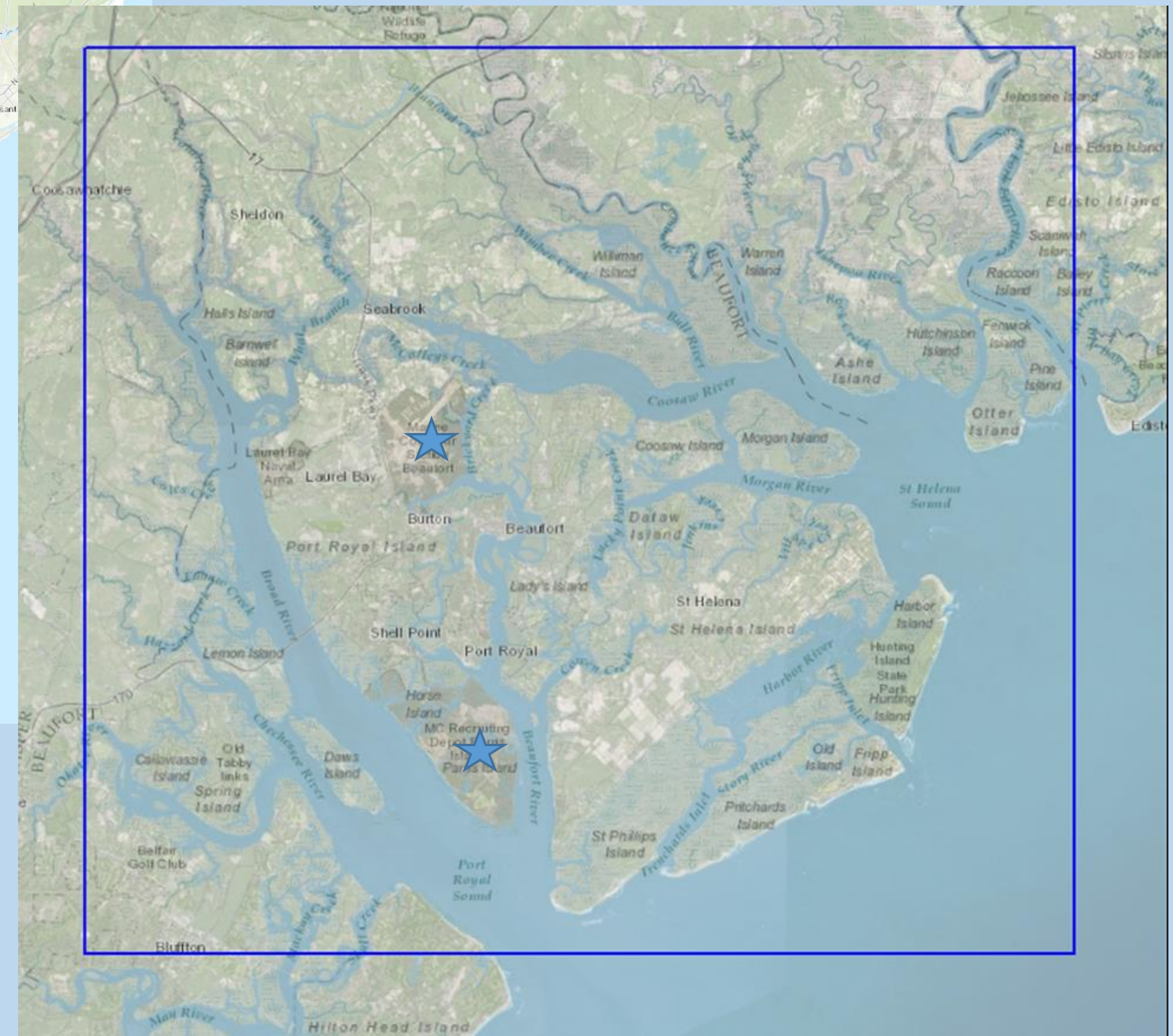
Scoping

Joint Land Use Studies (JLUS) help military communities and military installations become aware of the impacts they have on each other and become accustomed to collaborating with each other on land use issues.

- Goals
  - An initial assessment of the potential costs/Techniques to adapt infrastructure for present and future potential tidal flooding to maintain functionality of the local DoD bases.
    - Identifying potential infrastructure risks that could exist as a result of SLR
    - Determining how those risks can be minimized or mitigated to safeguard needs of both local communities and military facilities
  - Not meant to be A SLR/Inundation resiliency plan for Beaufort and Port Royall communities.
    - That said – the techniques and logic can used to help with a plan; and the direct results are directly applicable to the SLR Adaptation Report for Beaufort, SC.
  - Provide a flexible approach – SLR is not universally embraced

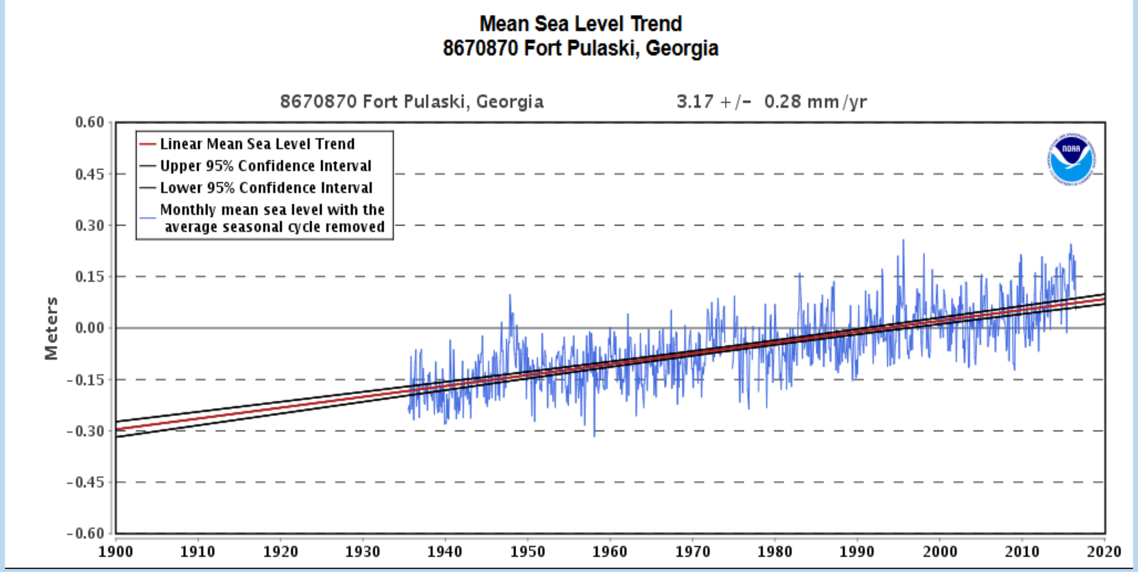
Scoping – Lowcountry Study Area

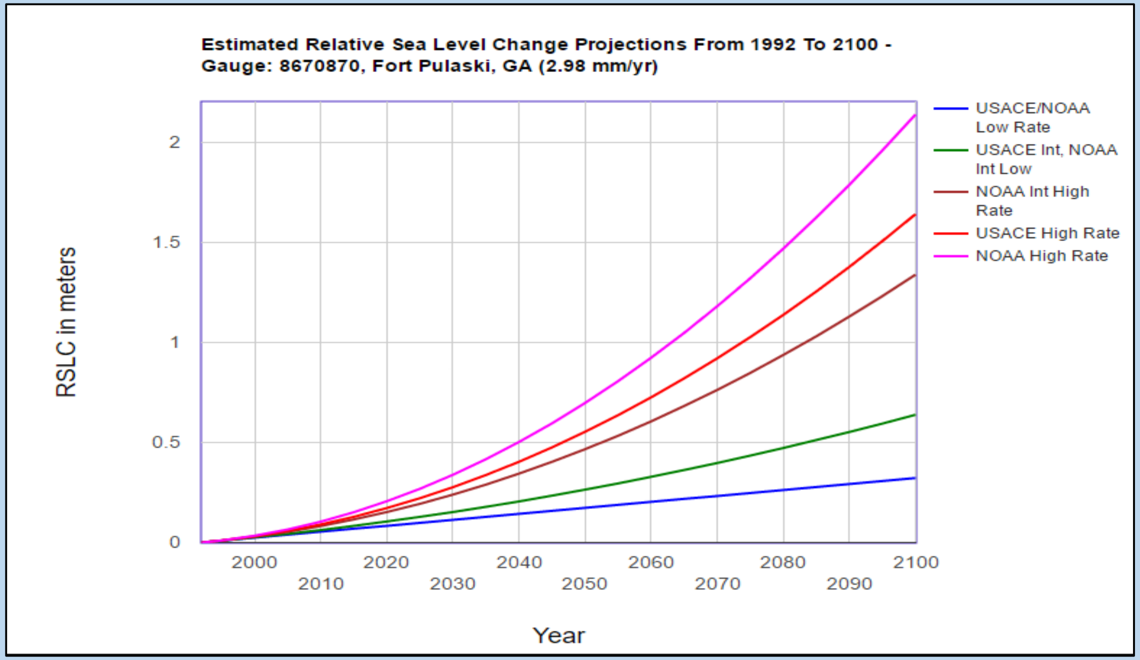




Scoping – Exposure Risk

- The Issue at Hand – Increasing Sea Level
  - Trend from 1935 to Present – 3 mm/yr; about 1 ft/100 yrs; relates to Low Rate
  - Lots of variability (which is what we experience)
  - Future is unknown, but there is a possibility that relative SLR trend will accelerate
  - Variability will continue into the future (not really smooth curves)
  - Local rates differ from global rates
  - Use of USACE SLR Calculator – Ft Pulaski





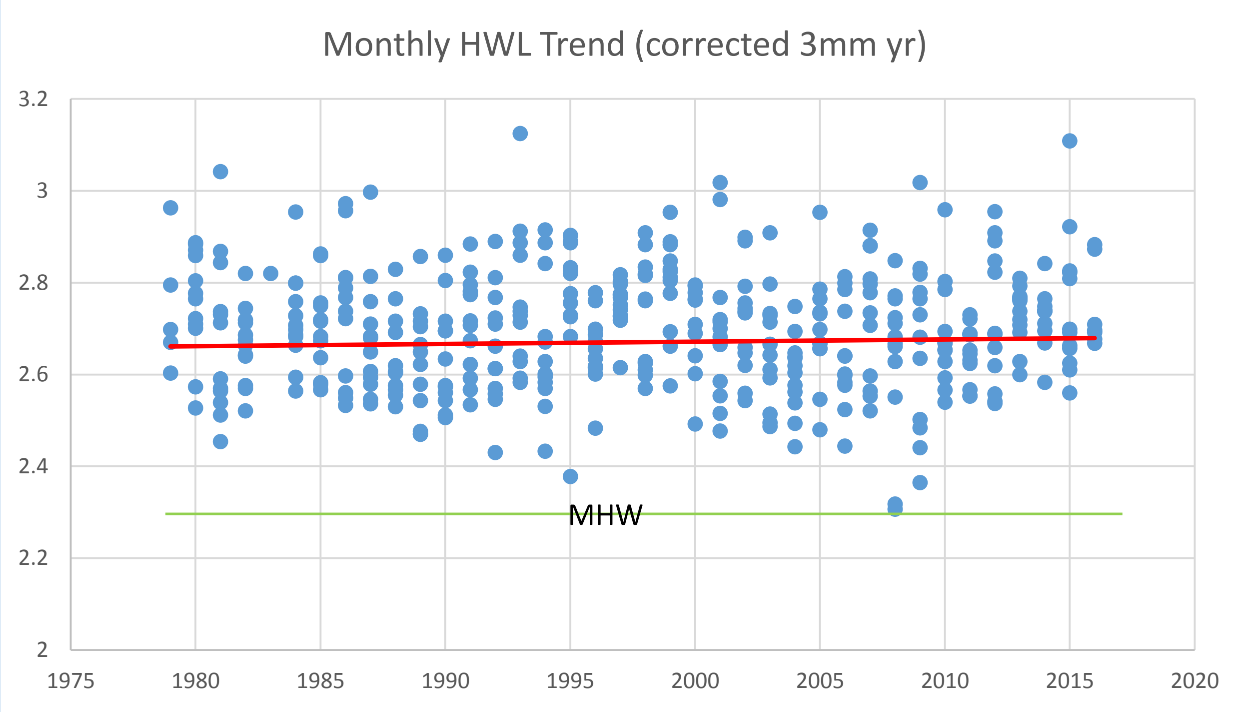
Scoping -Thresholds

- Water Level is Important
  - Moving from tidal to inundation frequency includes weather
  - This is what actually affects us (e.g., heat index)
  - Monthly High Water used as a guide for real-world inundation

Monthly High Water

- 2.5 m above MLLW: occurs **at least** once a month 95% of the time and is about six inches above MHHW.
- 2.7 m above MLLW: occurs **at least*** once a month 50% of the time and is a little more than one foot above MHHW.
- 2.8 m above MLLW: occurs **at least** once a month 20% of the time and is approaching 1.5 ft. above MHHW (~Shallow Coastal Flooding).

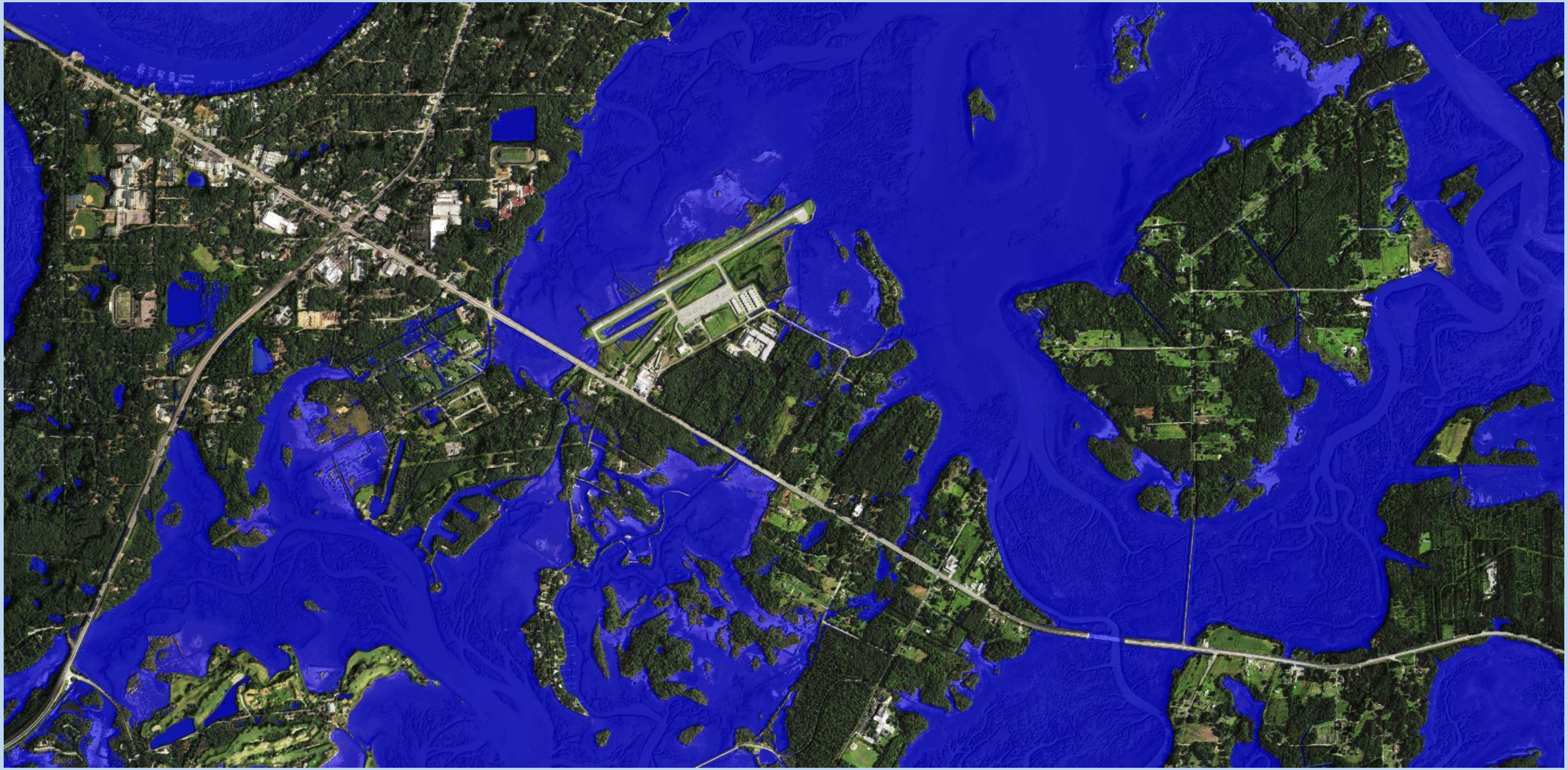
*2.7 m (about 9 ft.) above MLLW occurred about 55 times in 12 month span at Ft Pulaski gauge



Red Line = Mean (adjusted for SLR)

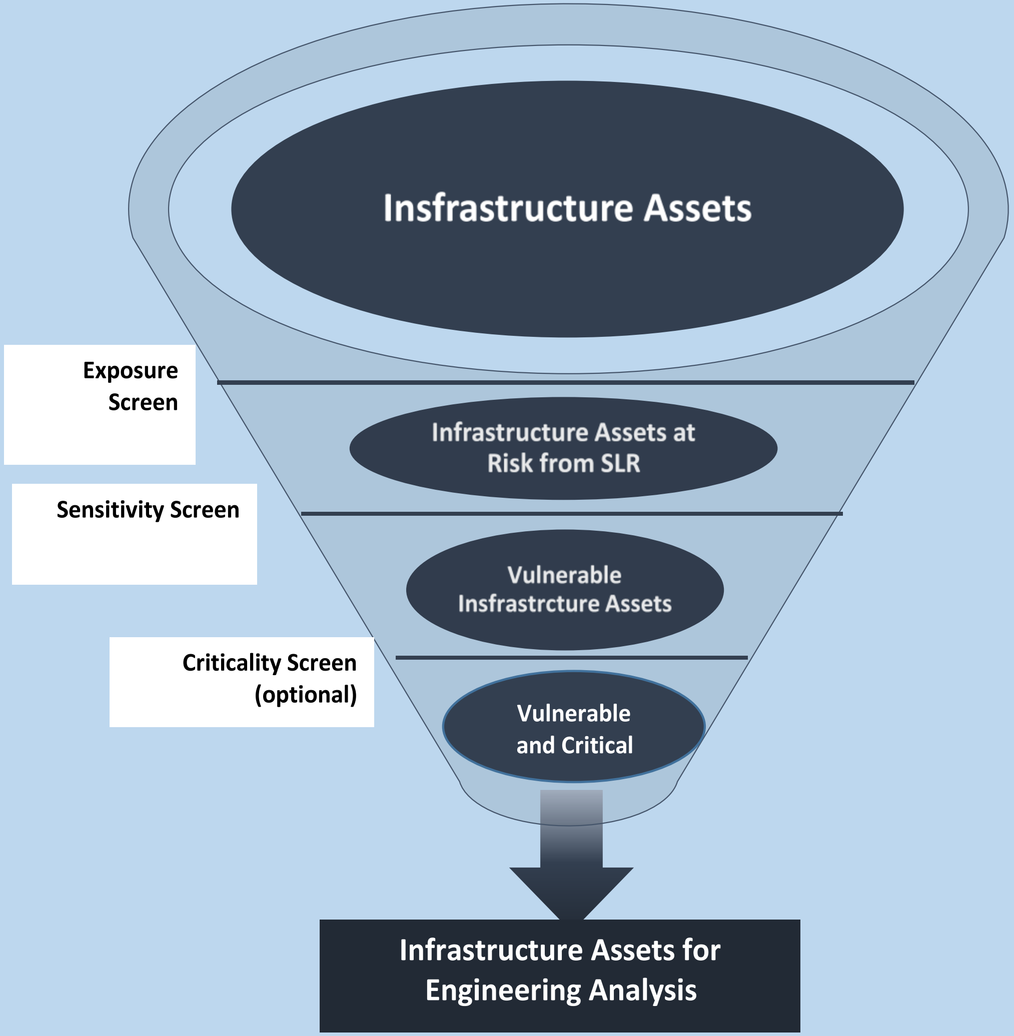
Example – Flooding at MHHW vs Frequency Defined Water Level

The differences in inundation extents (blue) at the Beaufort Airport at MHHW and at 2.7m above MLLW



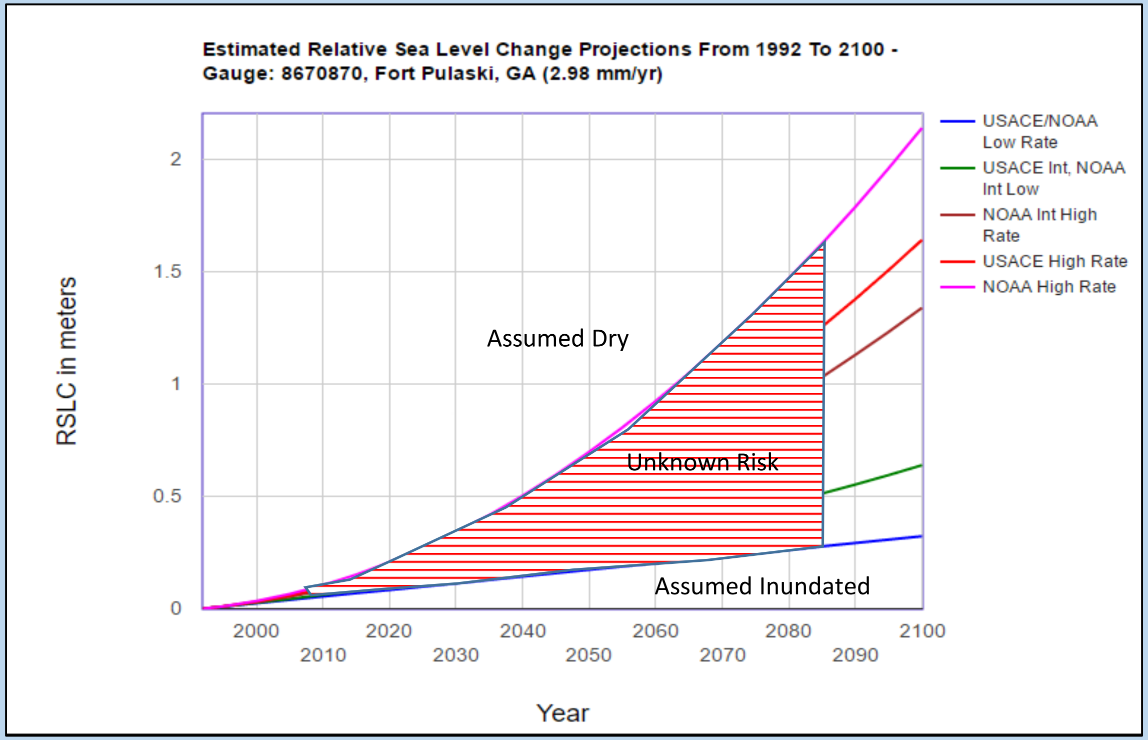
Concepts – Logic (steps 2 & 3)

- Screening logic used in this project to prioritize infrastructure
- Each screens ‘opening’ can be defined in planning process
- Vulnerable Infrastructure = Exposed + Sensitive to SLR (in this case)
- Criticality value is defined by stakeholders



Exposure – 1st Screen

- Not Scenario Specific
- Relative Risk Tolerance Dependent
- Mapping Envelope of Risk*
- Broken Down by Time Period
- Unknown Risk Assessed to be Within 10 to 90% of Likely Outcomes (Paris et al., 2014)
    - *Integrated into statistics to arrive at relative risk values (risk within envelope)
- Includes Errors in Lidar (2013) and Tidal Surfaces (VDatum)
    - A static 80% value of the MCU was used to offset mean flooding value.



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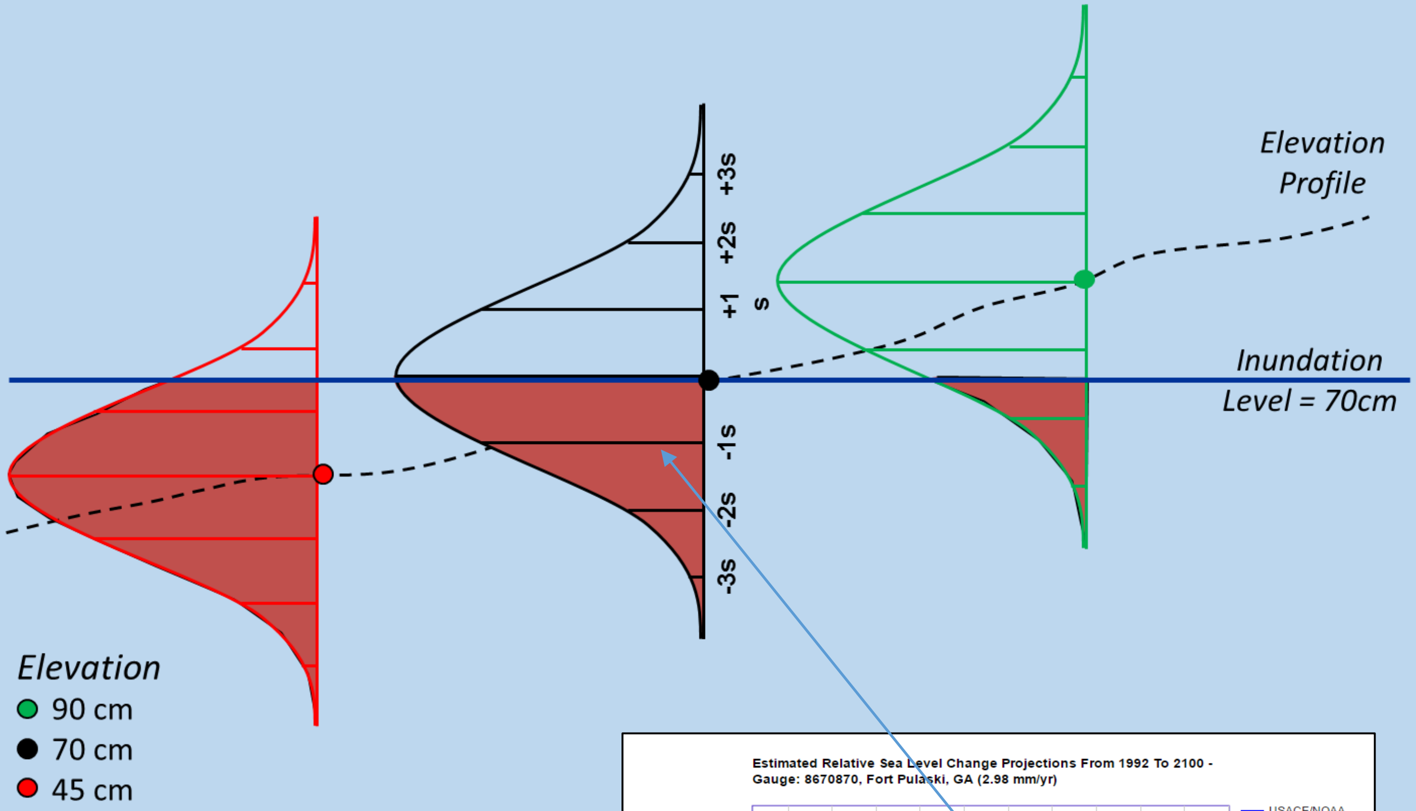
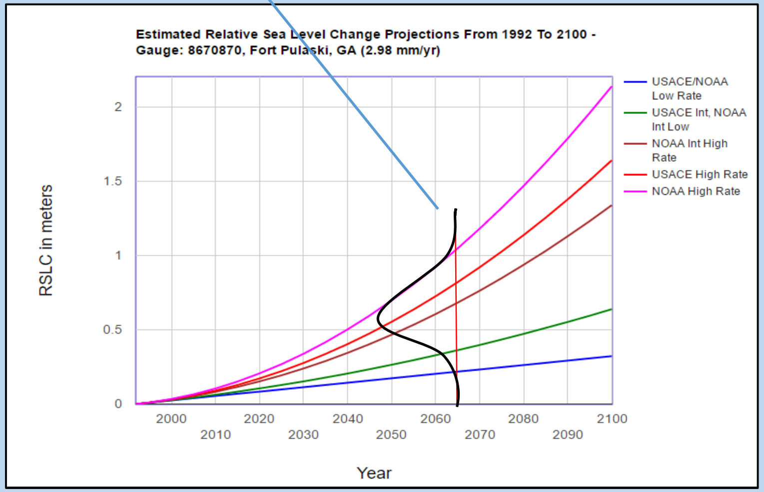
Exposure – Mapping Z-scores

- Inundation Level (prediction) = Monthly High Tide + 80% MCU of Lidar and VDatum.
- Mapping standard scores of SLR (projection) envelop into future
- SLR projections scores not co-mingled with error scores
- Mapping relative risk of infrastructure in relation to projections



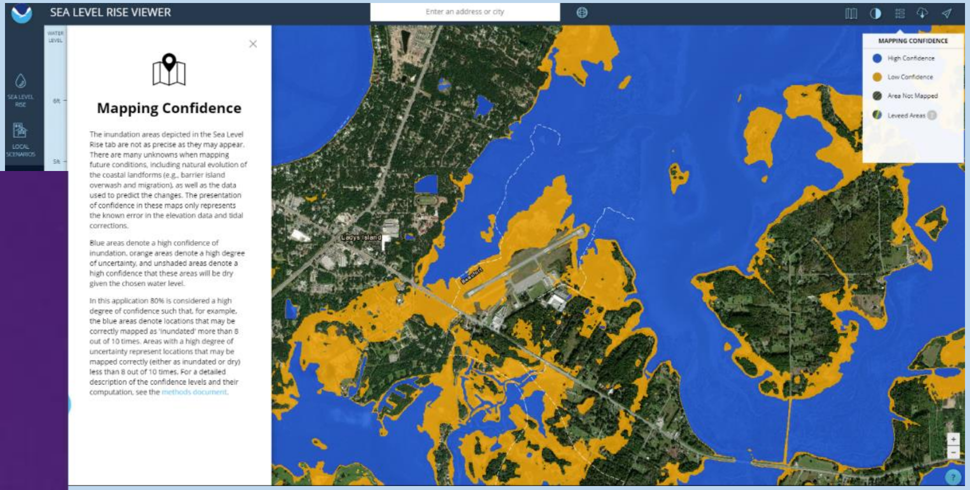
A prediction is a probabilistic statement that something will happen in the future based on what is known today.

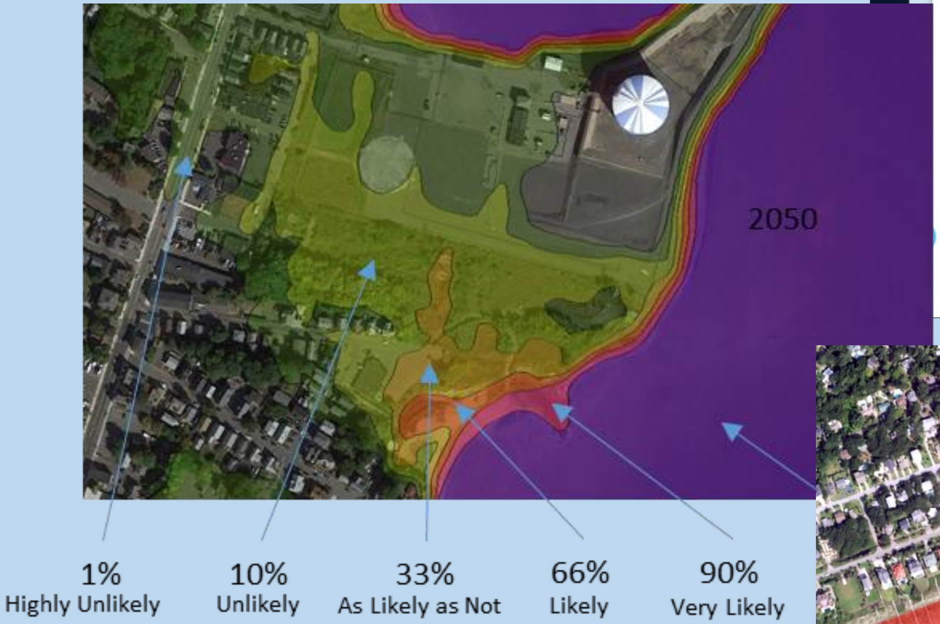
A projection is a probabilistic statement that it is possible that something will happen in the future if certain conditions develop

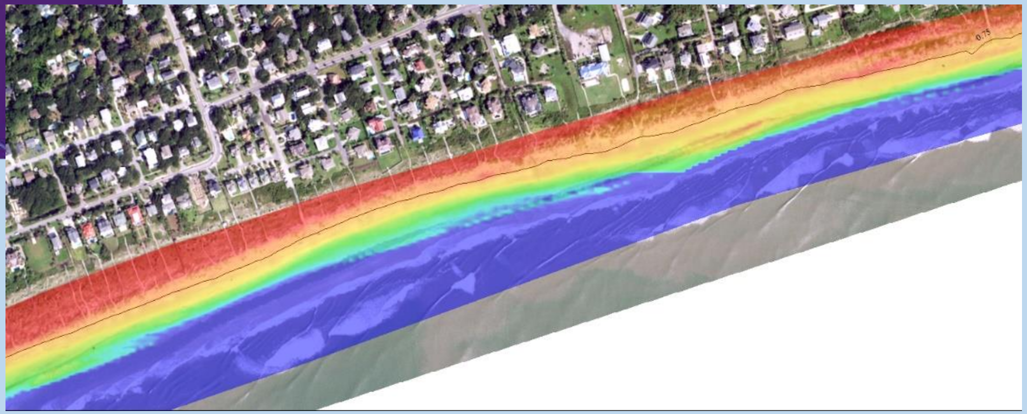


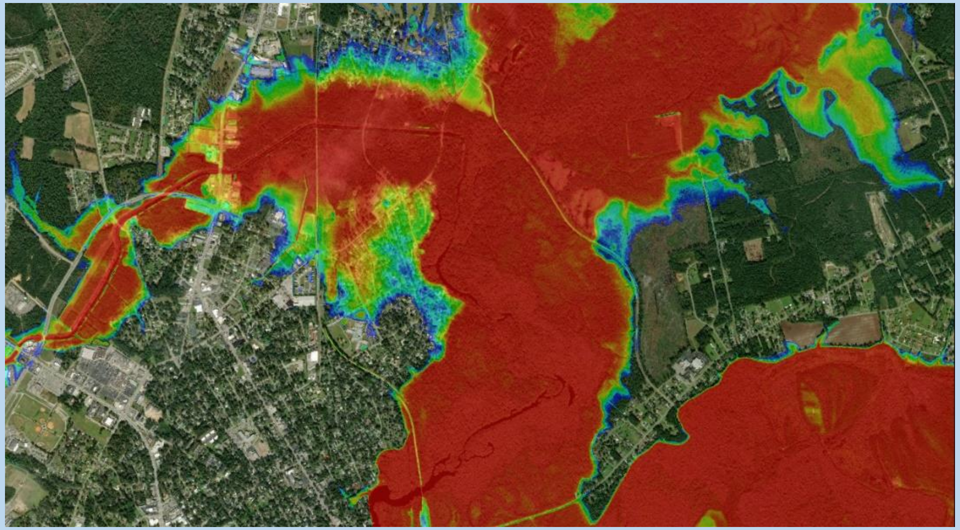
Other Mapping Z-scores Examples

- NOAA SLR Viewer
- Future Tidal Flooding & Storm Surge
- Beach Erosion
- Riverine Flooding









Example – Still Water Storm Surge

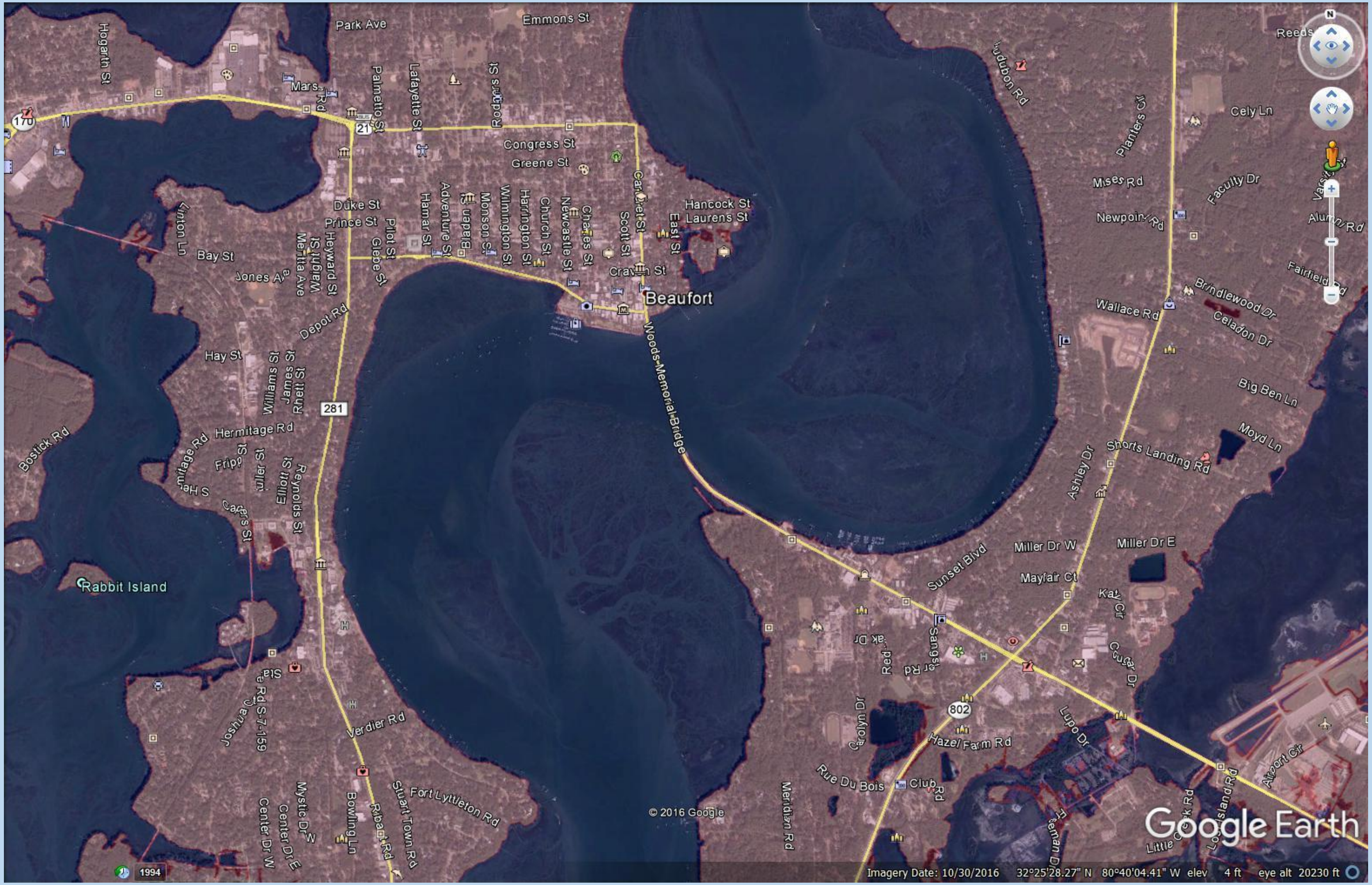
2015

2040

Example – Exposure

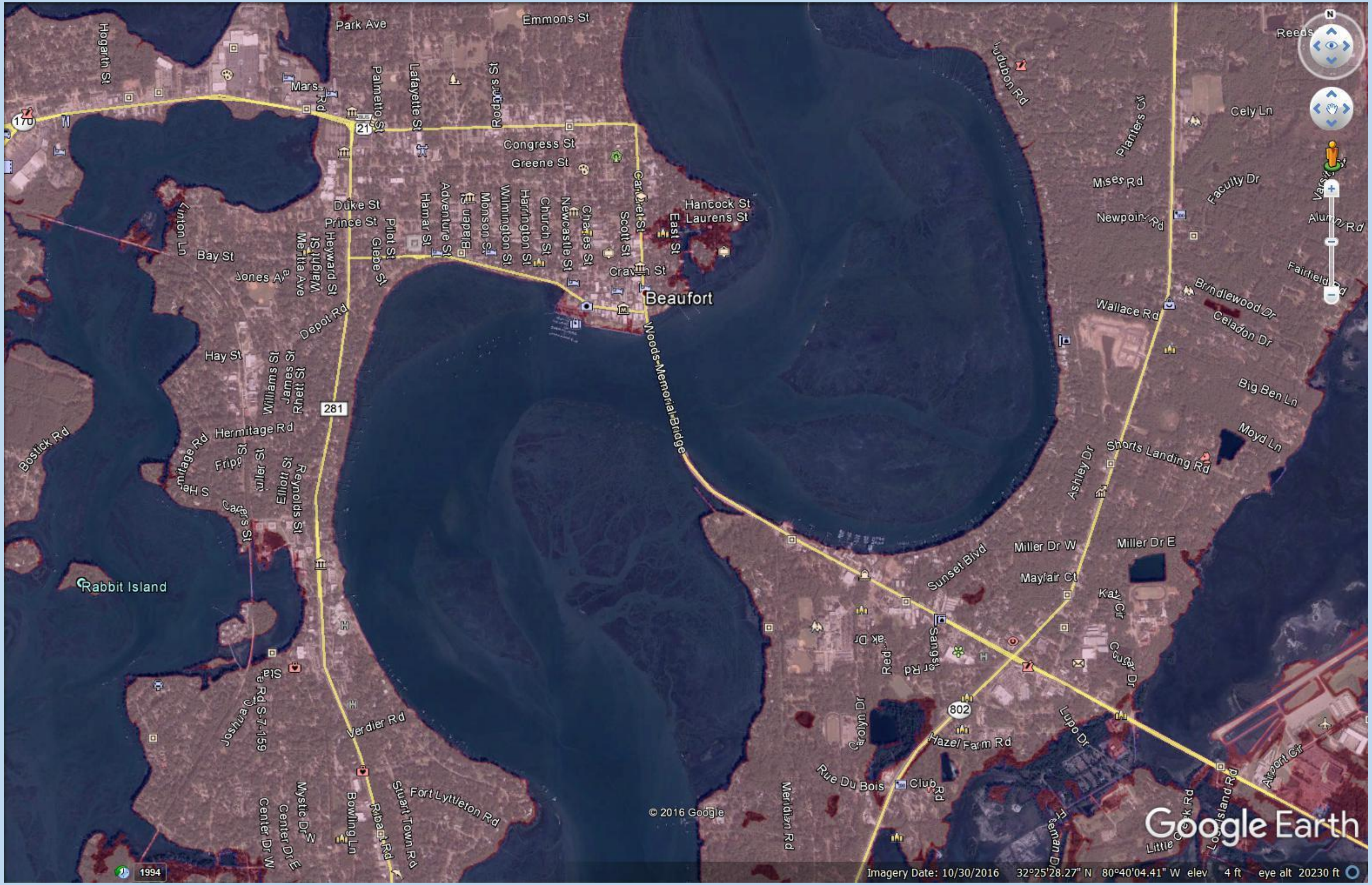
KMZ’s for public use

- 2020
- Blue = Inundation
- Red = Risk
- White = Outside Risk



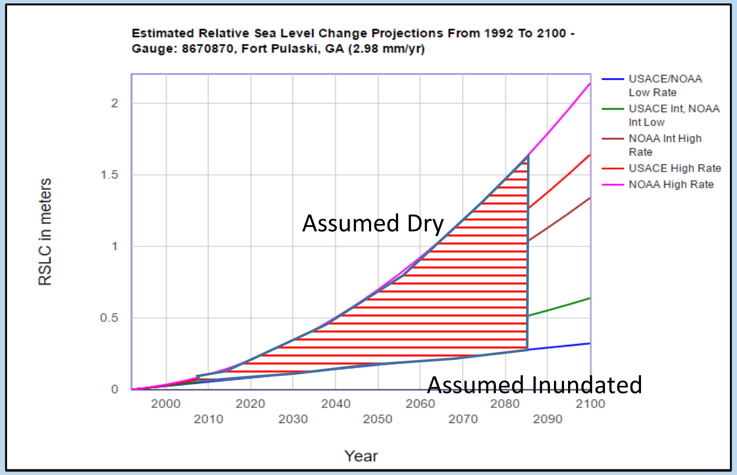
Example – Exposure

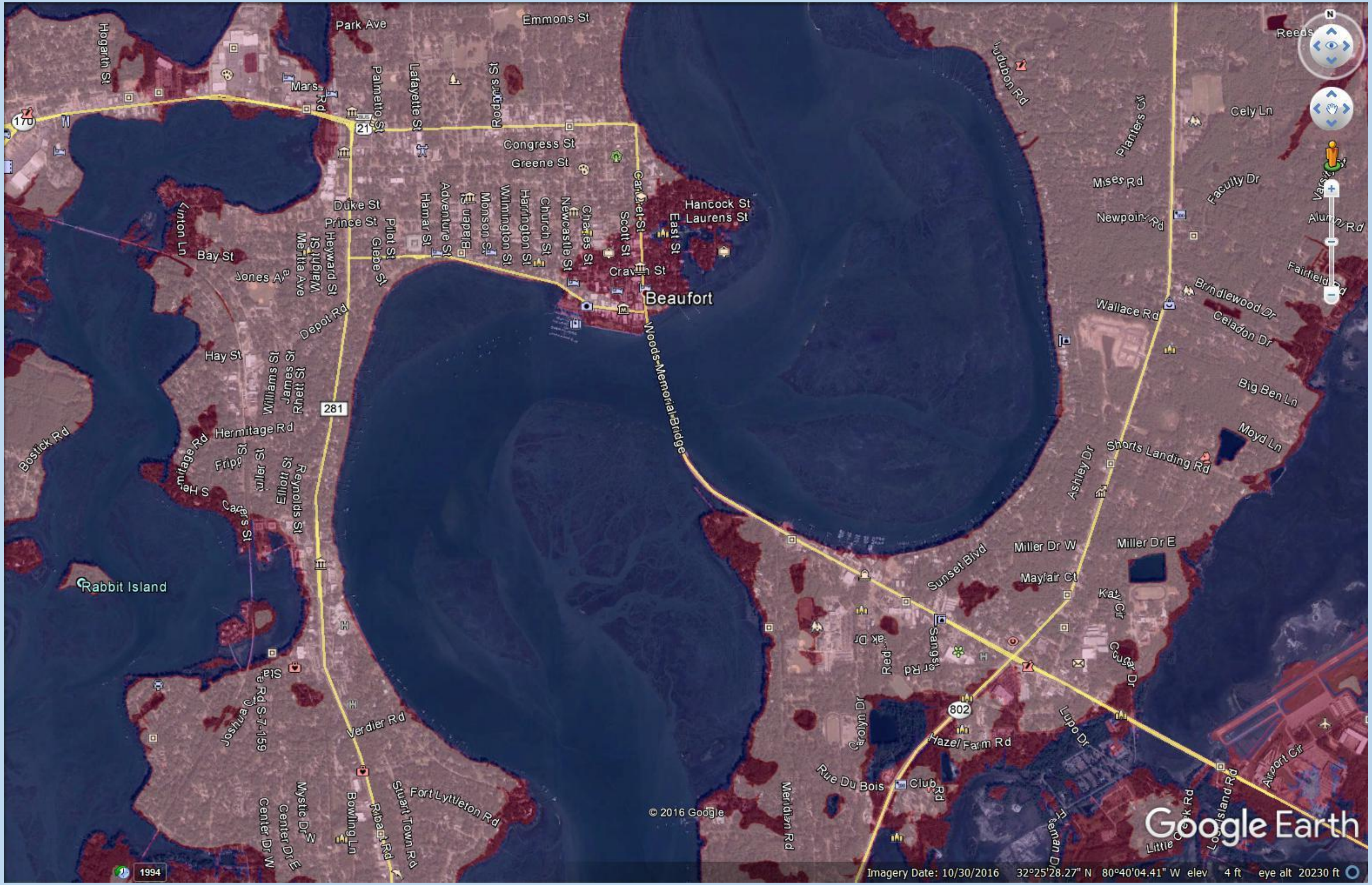
- 2040
- Blue = Inundation
- Red = Risk
- White = Outside Risk



Example – Exposure

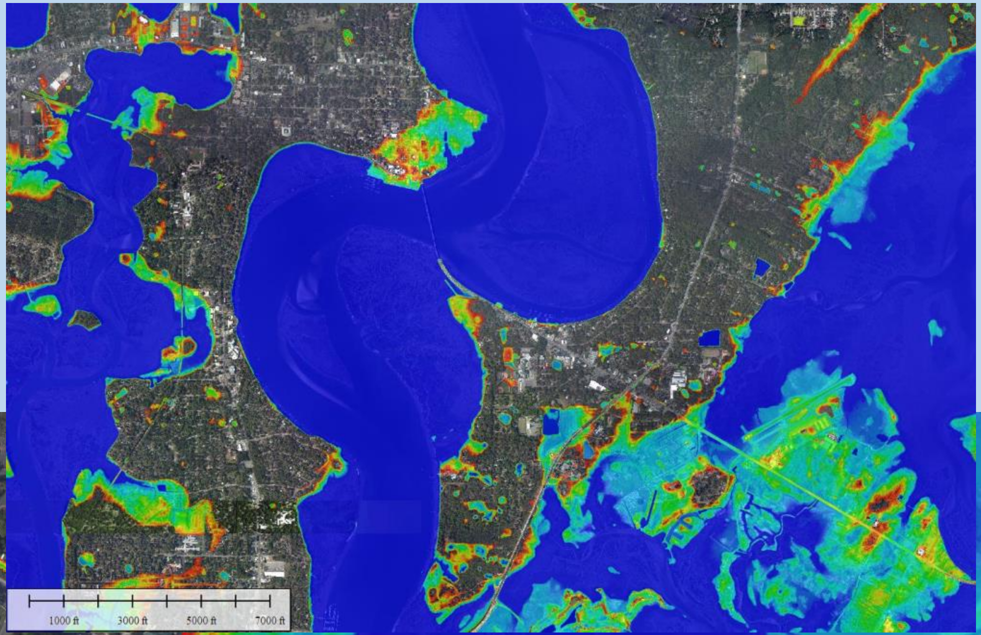
- 2085
- Blue = Inundation
- Red = Risk
- White = Outside Risk
- Change in blue is minimal through time; Baseline trend
- Big difference is Risk zone



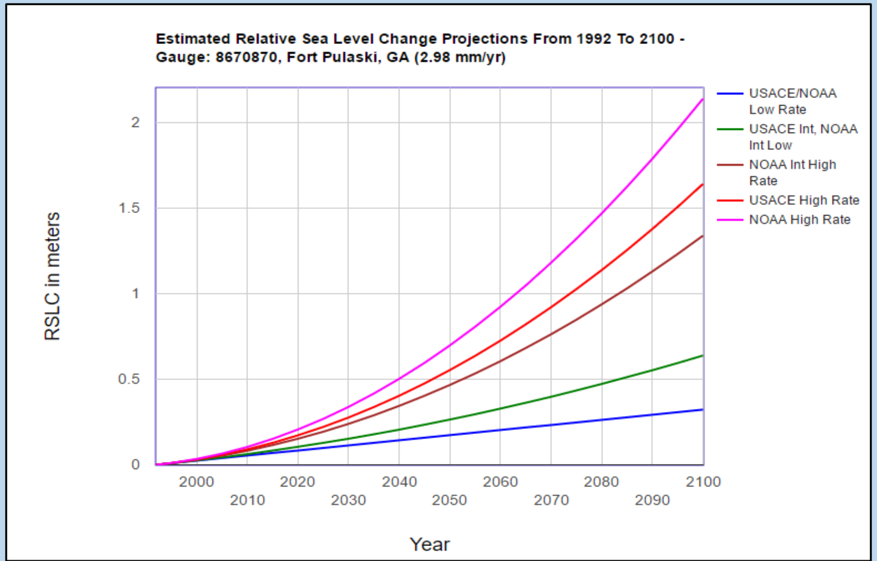


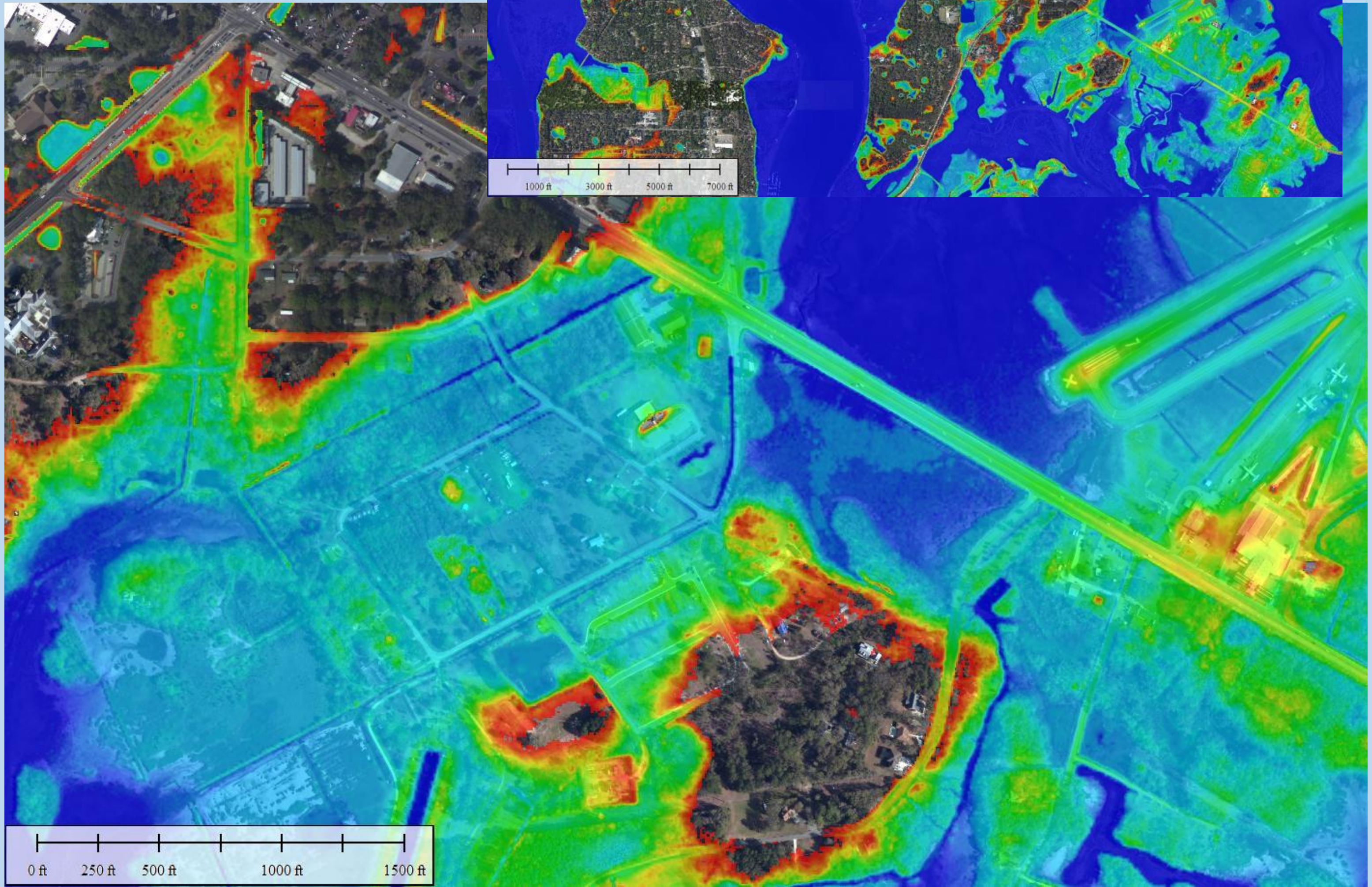
Example – Exposure

- Exposing the ‘operational values’
- Relative risk values used to define exposure of infrastructure



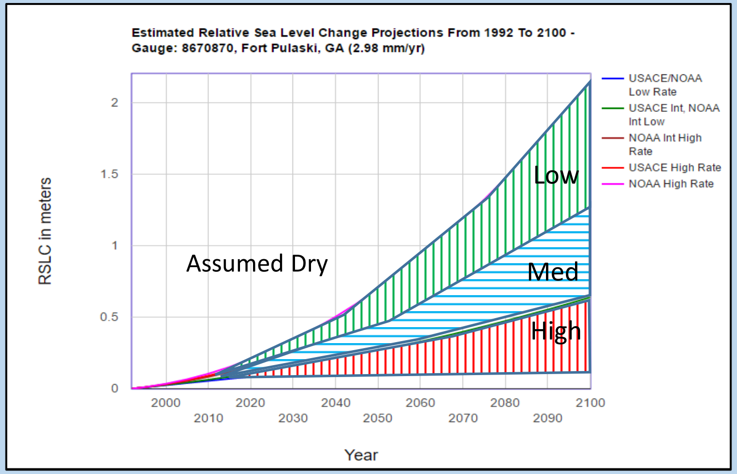
Roads (Highways); Roads (Local);
Sewer Drains;
Water Lines;
Sewer Lines;
Lift stations;
Fire hydrants





Example – Application of SLR Mapping to Infrastructure – 2040: Exposure Screen

Medium & Highly Exposed Infrastructure



- Yellow dots represent sewer drains.
- Yellow lines represent sanitary sewer pipes
- Example Infrastructure with exposure risk (entire study area)
  200,000 ft. of sewer pipes
  236 storm drains

Sensitivity – 2nd Screen

Transportation- High Sensitivity

- Roadway overtopping Standing water – hydroplaning, stalling vehicles
- Undermining and erosion leading to washout of embankments
- Settling and road deterioration
- Accelerated deterioration of bridge superstructures

Storm Water- High Sensitivity

- Surcharging of pipes and overflowing of grate inlets and catch basins
- Full pipe flow condition causing pressure and failure of joints between concrete pipe
- Saturation of supporting soils leading to collapse and joint separation
- Scour and undermining of outfall structures, headwalls, etc.

Water Utilities- Moderate Sensitivity

- Potential Increase of salinity in water source
- Undermining of buried pipe lines
- Saturation of soils and corrosion of pipe lines
- Infiltration of Gravity Sewers
- Flooding of wet wells
- Damage to Lift Station Pumps

Example – Application of SLR Mapping to Infrastructure – 2040: Exposure & Sensitivity Screen = Vulnerability

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- Highly Vulnerable Infrastructure

- Vulnerability = Exposure + Sensitivity
- Sensitivity based on infrastructure specifics
- Infrastructure with **Vulnerability** of 5 or more (out of 6) shown

- Orange dots represent sewer drains.
- Red lines represent sanitary sewer pipes
- 50,000 ft. of sewer pipes (**25% of exposed**)
  199 storm drains (**85% of exposed**)

An Appropriate Catalog of Infrastructure to Judge Level of Effort

Criticality – 3rd Screen (optional)

- The last screen is the “criticality screen”. Criticality factors developed from existing resiliency studies and the projects preliminary focus on MCAS Beaufort and MCRD Parris Island.
- Stakeholder Screen
- Most difficult (!!)
- Can also be first screen

- Socio-Economic Factors
  - Proximity to schools
  - Census weighting – Social Vulnerability Index (SOVI)
- Use and Operation
  - Proximity to DoD bases
  - Use statistics (e.g., number of vehicles using a road, population served by sewer lines, etc.)
  - Ownership (e.g., private, local, state, federal)
  - Watershed size
  - Land cover type (e.g., high development, low development, forest or location relative to coastline)
- Health and Safety
  - On an evacuation route
  - Proximity to hospitals or Critical Facilities

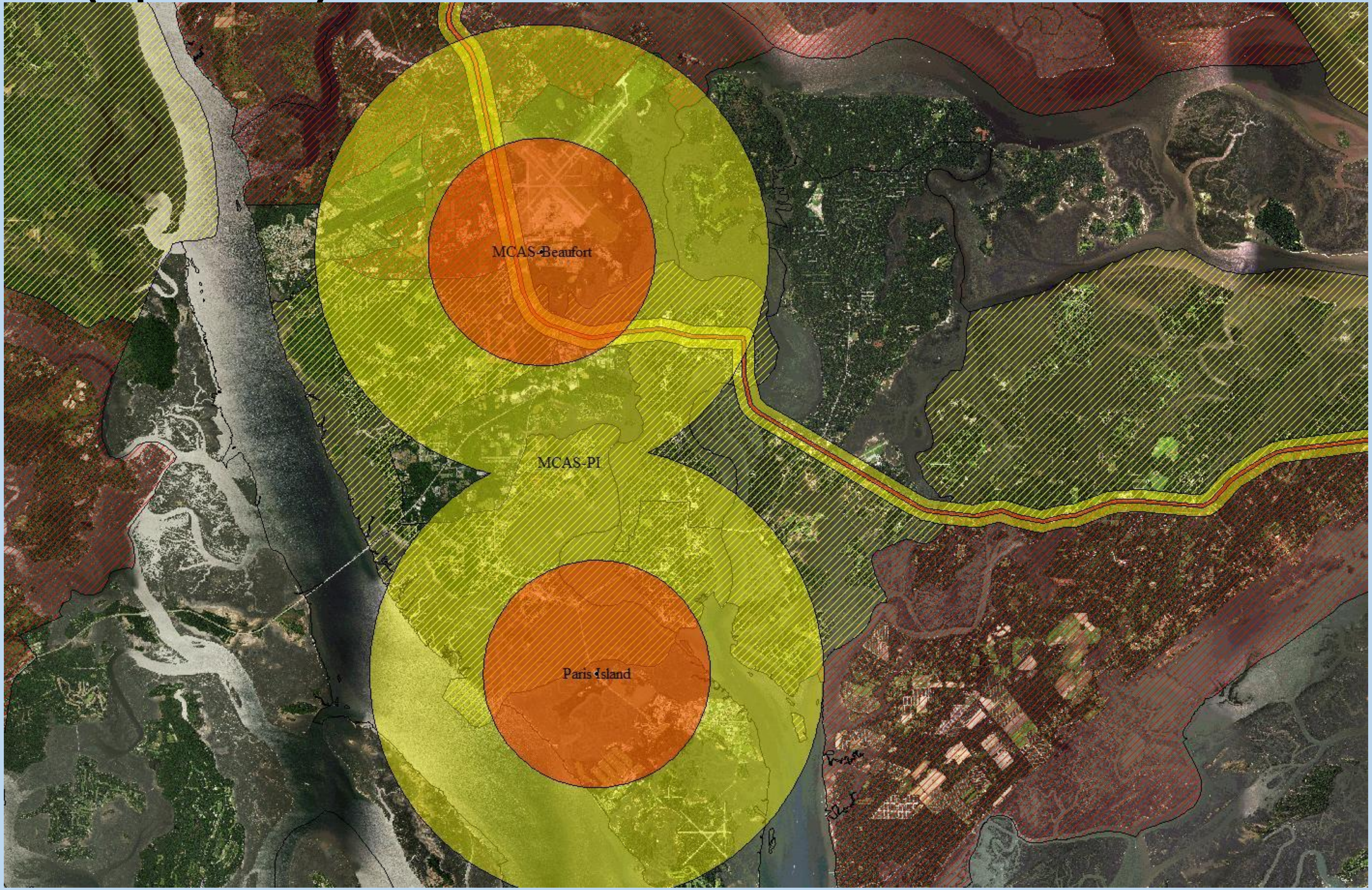
Example – Application of SLR Mapping to Infrastructure – 2040: Criticality Screen (optional)

- Criticality – Example Factors

SOVI Scores

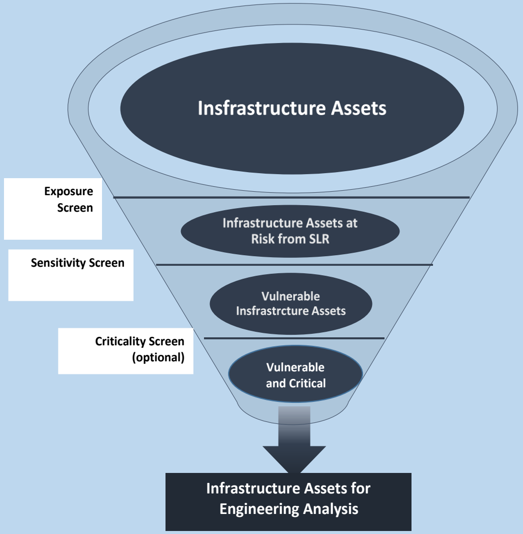
Base Proximity

Evacuation Route



Example – Application of SLR Mapping to Infrastructure – 2040: Highly Vulnerable Critical Infrastructure

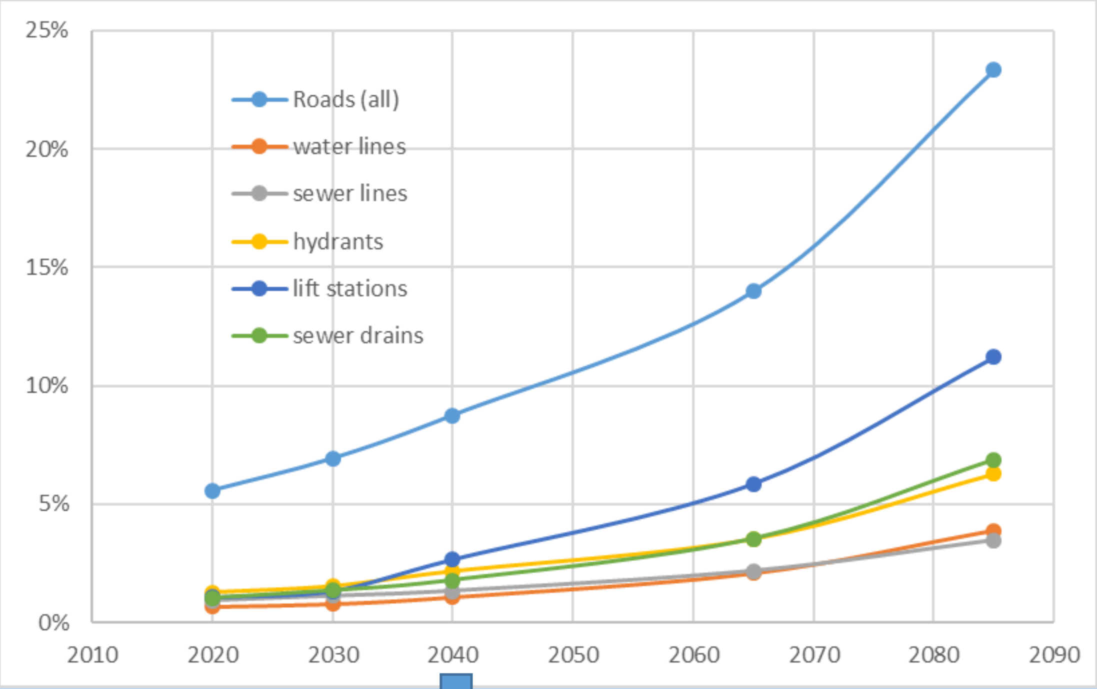
- Infrastructure Passing All Screens

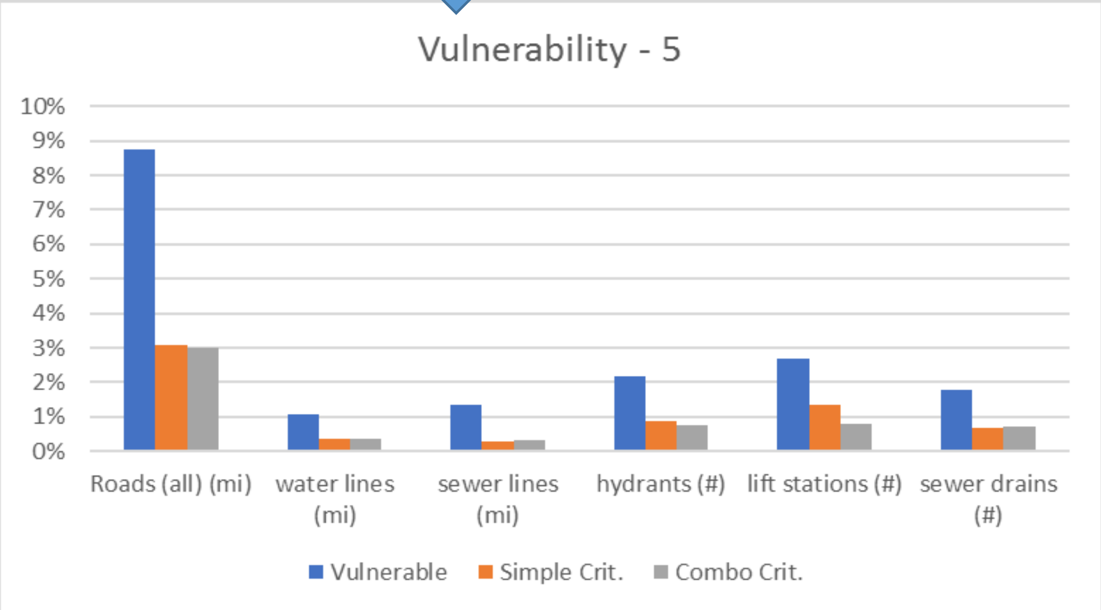


- White dots represent sewer drains.
- Purple lines represent sanitary sewer pipes
- 10,000 ft. of sewer pipes (**5% of exposed**)
  75 storm drains (**30% of exposed**)

Vulnerable and Critical Infrastructure

- Infrastructure with Vulnerability of 5 or more (out of 6)
- 2040 Criticality of 5 out of 9
- Two different Criticality scenarios
- Vulnerable and Critical Infrastructure are about 1 to 3% of total in 2040
- A significant portion of transportation system could be vulnerable by 2085





Adaptive Measures: Storm Water Examples

- Limit of Development-Promote Low Impact Development
- Raising drainage inlet structures in conjunction with roadways
- Enlarge Detention Ponds and Drainage Swales
- Installation of check valves and tide gates
- Install bulkheads and berms
- Promote living shorelines and dune growth at Ocean front
- Build Pump stations

Adaptive Measures: Water Utilities Examples

- Ensuring a good water source and protecting it from potential salinity increase
- Raising rim elevations of manhole and other potential infiltration locations
- Installation of rubber gaskets on manhole cover to inhibit infiltration when overtopped
- Raising lift stations
- Protect in place with sheet pile

Adaptive Measures: Transportation Examples

- Raising vulnerable roadways in areas ½ -1 ft in elevation
- Protecting roadways in place with bulkheads, riprap, and other shore protection devices
- Implement improvements to storm drainage serving roadways
- Re-routing /horizontal re-alignment of future routes to minimize effects from risk

Engineering Assessment and Costs for Resiliency

- Infrastructure asset types taken from GIS information
- 30,000 ft. view of costs
- Each asset assigned one Adaptive Measure
- Costs for adaptive measure generated from local sources where possible, standard costs (e.g., RS Means) where not.
- Does not account for existing actions or designed resiliency

Infrastructure Asset	Cost	Unit	Adaptive Measure	Potential Actions
			(Protect in lace/Relocate/Raise)	
STORM WATER				
Culvert	$25,000	each	Protect in Place/ Replacement	Rip rap/sheet pile- scour
Flap Gate	$15,000	each	Protect in Place/ Replacement	Block tail water during high tide
Flume	$5,000	each	Protect in Place/ Replacement	Rip rap-scour protection
Headwall	$25,000	each	Protect in Place/ Replacement	Rip rap/sheet pile-scour protection
Inlet	$5,000	each	Raise	Regrade/ raise area and add riser
Manhole	$5,000	each	Raise	Add precast riser section
Outlet Drain	$15,000	each	Protect in Place	Add tide gate /check valve
Storm Drain	$5,000	each	Relocate	Relocate/Replace
Swale	$25	LF	Protect in Place	Excavate/Clean
Weir	$10,000	each	Protect in Place	Rip rap/sheet pile
Access Gate	$5,000	each	Protect in Place	Rip rap/sheet pile
Catch basin	$10,000	each	Replace/raise	Install larger pre cast box
Concrete Junction box	$10,000	each	Protect in Place	Install larger pre cast box
Drainage Box	$10,000	each	Protect in Place	Install larger pre cast box
Detention Pond	$50,000	each	Protect in Place	Excavate/Clean
WATER SUPPLY				
4"-6" Lines DIP	$100	LF	Relocate (replace)	Replace w/ corrosion resistant mat.
Fire Hydrants	$7,500	each	Relocate (replace)	Replace with corrosion resistant mat.
Supply Intake Source	$30,000,000	each	Relocate	Construct new supply network

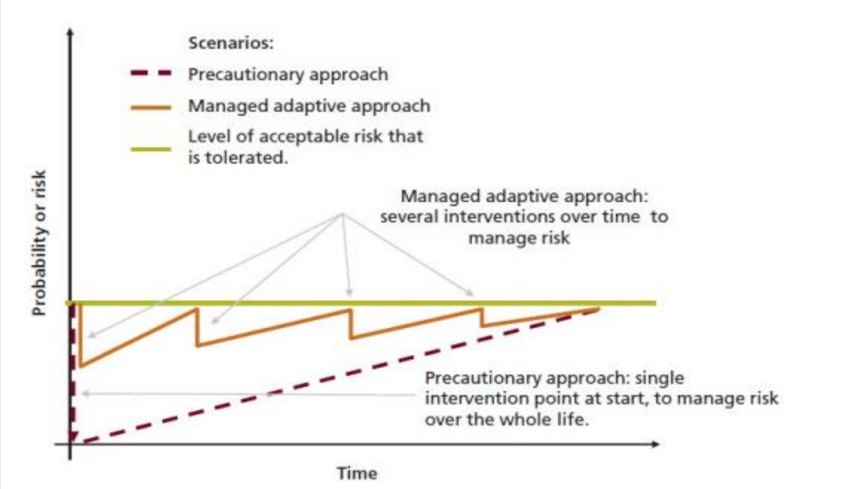
A “Generic” Cost for Adaptive Measures

Engineering Assessment and Costs for Resiliency

“Generic” Costs for Adaptive Measures

Year	Scenario (screen thresholds)	Total Cost	Transportation	Water & Sewer	Storm Water
2030	vul,5; crit 5	$ 196,942,054.00	$ 193,250,346.00	$ 3,016,708.00	$ 675,000.00
2040	vul,5; crit 5	$ 257,377,025.00	$ 251,812,545.00	$ 4,759,480.00	$ 805,000.00
2060	vul,5; crit 5	$ 467,192,639.00	$ 456,426,316.00	$ 9,281,323.00	$ 1,485,000.00

- Costs reflect the generic handling of retrofits (widgets).
- Does not reflect systematic gains or existing resiliency measures – higher level engineering required
- Costs highlight the impetuous to perform strategic cyclical maintenance (managed adaptive approach) during normal course of business



Some Suggested Next Steps

- Continued Stakeholder Involvement
- Leverage Risk Maps for Planning (will help with Stakeholder Involvement)
- Develop Consensus on Vulnerability Thresholds – What level of risk is acceptable (based on stakeholder involvement)
- Define a Criticality Scenario(s)
- Develop Planning Horizons – e.g., 2025 vision or 2040 vision
- Develop an Understanding of Potential Systematic Gains – Start with a Pilot Project that leverages a logical/inclusive approach and older infrastructure

Recommendations for Follow-on Work

- Include Other Utilities (energy and communications)
- Incorporate Structures/Residences – and the associated infrastructure with them (gravity sewer lines, leach fields, ponding and mosquitoes)
- Incorporate Green Infrastructure/Nature-Based Techniques
- Improved Base Information – Water Levels, GIS Databases

Take Away

- Systematic Efficiencies Are Key To Keeping Costs Below 1 Billion!
- Look to Informed Cyclical Maintenance to Lower Costs of Adaptive Measures
- Adopting a Vulnerability Threshold Will Help Unify Groups/Agencies
- Hurricane Matthew and Future SLR
  - Comparison of a single event vs. a periodic tidal-influenced inundation
  - Highly affected infrastructure (2 ft. inundation) during Mathew are similar to those projected in 2040 – 2060 to be at moderate risk of being inundated by monthly high tides
- All Reviewed Deliverables Available at:
  http://www.geosciconsultants.com/low-country-cog
  or contact Keil Schmid; keil@geosciconsultants.com