Lessons Learned in Climate Adaptation from Miami, Charleston and Boston

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HAWAIʻI
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TABLE OF CONTENTS

INTRODUCTION

Climate change is affecting and will continue to affect us in many ways. Accelerating sea level rise (SLR), storm surge flooding, high winds, heat waves, warming oceans, high tides, land subsiding and coastal erosion brought on by climate change pose significant challenges that will affect nearly every aspect of life in Hawai'i.

Climate change and, specifically SLR, impacts in Hawai'i are compounded by land development and urbanization in flooding zones, tourism economy, aging pipelines and infrastructure vulnerable to sea water corrosion and sea water intrusion, commerce and trade disruptions, food and water security and distribution, public health, lack of policies, laws or regulations (enforcement) to guide the processes involved in sustainable adaptation. We also face increased risk of extinction of native plants and animals and damage to natural resources.

Climate adaptation and management measures can be very expensive and take years to design and fund. Finding sustainable ways to fund aging infrastructure or coastal area planning for impacts of climate change poses tremendous challenges to communities and governments. Climate change exacerbates social problems in vulnerable communities; we found similar social issues here in Hawai'i related to the lack of affordable housing, insufficient transportation systems and poverty.

Therefore, broader exposure to best practices in climate adaptation could help planning for funding and identification of better strategies and avoid repeating costly mistakes that other cities have made preparing for the impacts of climate change. Exposure to how other cities are dealing with the effects of climate change could expand the different options available to decision makers today and decision makers in the future. Preparation and planning for climate change adaptation can strengthen the resilience of our communities and coastal ecosystems. From sharing lessons we all can learn – both in terms of the challenges, as well as the kinds of resources that are needed to carry on adaptation projects.

For this project, three cities were selected because, like Hawai'i, they are already experiencing problems directly related to climate change and specifically to SLR. These cities have a longer trajectory dealing with higher flooding levels and increased SLR. These coastal cities like Hawaii are dealing with particular issues such as aging and vulnerable infrastructure to SLR and they are densely populated.

Miami, Florida, Charleston, South Carolina and Boston, Massachusetts have been addressing issues such as devastating floods, sea level rise, storm surge, saltwater intrusion, heat waves, freshwater availability, commerce, economic loss and, to a certain extent, relocation or managed retreat of native plants, species and people.

We set out for this trip not expecting to find a single solution to solve such complex issues, but to look for best practices, ideas, commonalities and differences that could help us prioritize action, to design and plan more efficiently and effectively develop innovate policies and infrastructure that will better serve Hawaiian communities, environment, economy and increase our resilience. We wanted to observe how others are planning for different flooding scenarios in populated areas and what specific adaptations strategies are needed, to manage floods and buffer their economic impacts.

The complexities that coastal cities have to deal with in their efforts to adapt to the short and long-term impacts of SLR are enormous and daunting; from adapting aging, inadequate or deteriorated infrastructure in interconnected systems, (roads, transportation, water, energy, sewer, communications) and costs related to it; dealings with different authorities at the federal, state, cities and municipalities to distributional effects within and across generations, to communicating in some cases that retreat is the only option because adaptation is no longer feasible.

Regarding social vulnerabilities, we found that here in Hawai'i we share commonalities regarding high cost of living, low wages, and lack of affordable housing, medical care and pockets of extreme poverty. Social vulnerabilities are exacerbated by climate threats and have to be accounted for when designing for adaptation measures.

Policies and laws have not caught up with the emerging issues of adaptation and even less with retreat. The law requires local governments to maintain roads and other infrastructure – but to what extent? Property damage or loss and government interference with property rights are foreseeable effects of the impacts of seal level rise in coastal communities. An increase on inverse condemnation claims is expected as climate change effects increase, like sea level rise, droughts, and flooding. Government adaptation or retreat measures to climate change will be a source of inverse condemnation claims.[1]

This report compiles experiences from our participants, as well as the draft report from Makena Coffman, PhD. Director, Institute for Sustainability and Resilience, Professor of Urban and Regional Planning, Chair of the City and County of Honolulu Climate Change Commission, and Aida Arik, a PhD student who accompanied us on our trip and helped write some of the lessons learned and experiences. It also includes the notes from Makena Coffman, and Aida Arik of the defriending meeting on November 25, 2019. This report also includes the takeaways from the participants at the Focus Conference on October 15, 2019, as well as some written reports, conversations, and interviews. This report also includes my notes from presentations, videos and conversations from presenters and participants of the SLR trip.

[1] Georgetown Law, J.D. 2018; Brandeis University, B.A., Physics and Philosophy 2015. © 2018, Gary Dreyzin. The author appreciates Professor Yvonne Tew, Somin Lee, the Georgetown Environmental Law Review, and especially Georgia Gkoulgkountina for their support and feedback. The author is also thankful to Tom Marshall for the conversation that inspired this article.

During trip we saw specific adaptations currently in use, like stormwater pumps and road-raising to keep streets dry, and how these adaptations are being funded. We learned how these cities developed strategies for building stakeholder involvement and collaboration between government agencies. We observed the importance of building codes and zoning for sea level rise, and talked to community leaders and organizations responsible for creating community awareness and participation through education. We also observed that the capacity to adapt is not evenly distributed across society, making some groups more vulnerable to climate change than others.

Hawai'i delegation/PARTICIPANTS:

1. Charles 'Chip' Fletcher, Associate Dean, School of Ocean, Earth Sciences and Technology, Professor of Earth Sciences, Vice Chair of the City and County of Honolulu Climate Change Commission
2. Barry Usagawa, Program Administrator for the Water Resources Division of the Honolulu Board of Water Supply.
3. Ross Sasamura, Director and Chief Engineer, City and County of Honolulu Department of Facility Maintenance.
4. Michael Fuke, Head of Field Operations, Honolulu Board of Water Supply
5. Sam Lemmo, Administrator, State of Hawaii Department of Land and Natural Resources, Office of Conservation and Coastal Lands
6. Matt Gonser - City and County of Honolulu Office of Climate Change, Sustainability and Resilience Coastal & Water Program Manager
7. Katia Balassiano, Land Use Permits Division, C&C Honolulu Department of Planning & Permitting
8. Sullivan Genevieve, Environmental Planner in State of Hawaii Department of Transportation, Highway Division.
9. Lori Kahikina, Director of Environmental Services
10. Makena Coffman, PhD. Director, Institute for Sustainability and Resilience, Professor of Urban and Regional Planning, Chair of the City and County of Honolulu Climate Change Commission
11. Marta F. Wayne, PhD. CEO Hawai'i Philanthropy Forum
12. Aida Arik, Department of Urban and Regional Planning. PhD Student UH Mānoa. Institute for Sustainability and Resilience, Graduate Assistant.

CITY OF MIAMI AND MIAMI BEACH:

Our trip started in Miami, Florida, on September 30th to October 1st during a King Tide event. Our Hawaii delegation visited sites around Miami-Dade County under the guidance Katherine Hagemann, the Adaptation Program Manager of the County Resilience Office. Katherine, help us set up the meetings and she was instrumental in setting up the agenda for our visit. We visited the Virginia Key Wastewater Treatment Plant led by Doug Yoder of the Miami Dade Water and Sewer Department where we learned about The South Florida Water Management District serving a population of 8.7 million. During our visit to Virginia Key, we learned about the wetlands restoration project which involves removal of Australian pine and Brazilian pepper, invasive plants that have spread copiously negative affecting native habitats.

Our delegation also visited the SUSTAIN laboratory at the University of Miami, which is a wave tank to study hurricane force wind and wave impacts. The group also toured adaptation efforts in Brickell, Riverwalk, Jose Marti Park and around the City of Miami and Miami Beach. We also visited adaptation infrastructure such as pumps and elevated roads.

Like many other sewage and treatment plants in the United States, including Honolulu, Miami-Dade Virginia Key Sewage Treatment Plant built in 1950, is vulnerable to storm surge and hurricanes, as well as sea level rise. In 1950 it was the ideal location because it was cheaper to discharged sewage into the ocean.

Photo of Virginia Key Wastewater Treatment Facility Plant. According to Douglas Yoder, Deputy Director, Miami-Dade Water and Sewer Department, adaptation measures are being undertaken at the plant such as elevating and hardening emergency backup electricity generation and safeguarding water-tight for essential equipment like electrical regulators and control systems.

Hawaii delegation with Katherine Hagemann, Adaptation Program Manager of the Miami-Dade County Resilience Office, at the Virginia Key wetlands restoration project site. The restoration involves removal of Australian pine and Brazilian pepper, invasive plants that have spread copiously, negatively affecting native habitats and replanting native plants.

Dr. Charles 'Chip' Fletcher, Associate Dean, School of Ocean, Earth Sciences and Technology, Professor of Earth Sciences, Vice Chair of the City and County of Honolulu Climate Change Commission, at the University of Miami's SUSTAIN laboratory (SUrge-STructure-Atmosphere Interaction). At this wave tank scientists study hurricane force wind and wave impacts.

Picture of one of many stormwater pump stations fighting flooding conditions and rising sea levels on the streets of Miami and Miami Beach. Before stormwater pumps were installed, the water was carried out into the bay by the force of gravity. Due to sea level rise the water no longer flows by gravity to the bay. Instead the water flows back into the streets resulting in flooding. The existing pump stations redirect the water to the outfalls.

The majority of the components of pump stations are located underground. These components include three different chambers. The first chamber collects floatable trash via a bar rack, the second chamber traps sediments and dirt from site run off through a vortex structure. The third chamber is an aeration chamber, which traps oil and separates and removes it using vacuums. The filtered water after this process is pushed out into the bay.

Jane Gilbert, Chief Resilience Officer, City of Miami at a Pump Station in the City of Miami, explaining how the pumps work.

Elizabeth Wheaton, Director of Environment & Sustainability Department, City of Miami Beach, explaining road elevation.

University of Miami Rosenstiel School of Marine and Atmospheric Science building. The building was established in 1943. Photo shows current sea level rise intrusion.

Key Miami-Dade Counterparts

Katherine Hagemann, Resilience Program Manager, Miami-Dade County

Douglas Yoder, Deputy Director, Miami-Dade Water and Sewer

Josh Mahoney, Environmental Resources Project Supervisor Miami-Dade County

Brian Haus, PhD, Professor and Chair, Department of Ocean Sciences, Director of SUSTAIN, University of Miami

Caroline Lewis, Founder & Senior Climate Advisor CLEO Institute

Jane Gilbert, Chief Resilience Officer, City of Miami

Elizabeth Wheaton, Director of Environment & Sustainability Department, City of Miami Beach

BACKGROUND

Miami-Dade County covers 34 municipalities including Miami and Miami Beach. The City of Miami is the largest municipality, followed by Hialeah, Miami Gardens, Miami Beach, North Miami and Coral Gables. Each municipality has its own government and its own city services. According to the 2015 Census, Miami-Dade County government serves a population of 2.7 million people. In the past decade, the County has been one of the top population gainers in the U.S., mostly due to immigrants. According to census data, between 2010 and 2018, Miami-Dade's population increased by more than 260,000 people, or about 10.5 percent. Due to the increase in population in the last decade and tourism, a big investment in infrastructure has been made; more roads, housing, hotels, bridges, buildings, electrical lines and sewer systems.

This growth has driven real estate, property taxes and other economic drivers. Many believe that dependency on property taxes means the more that they build, the more money they have to run their County. The biggest engines of South Florida's economy are tourism, real estate and agriculture.

Miami-Dade includes more than 2,000 square miles and it is surrounded by major bodies of water such as the Atlantic Ocean, Biscayne Bay and many rivers, lakes and canals.

Miami-Dade is built on the Biscayne Aquifer – 4,000 square miles of unusually shallow and porous limestone. This aquifer is s source of drinking water and it's connected to the ocean. Therefore, as sea level rises, the Biscayne Aquifer's water is constantly threatened by

saltwater intrusion. Its porous limestone allows water to flow through, which means that water will ultimately leak through it.

The area is vulnerable to sea level rise due to its low elevation, unique geology and topography, and the density of coastal development. The average height of Miami Dade County is 1.2 meters or 4 feet above sea level. Its porous limestone foundation is part of the Atlantic Coastal Ridge in southeastern Florida; it runs through Palm Beach, Broward and Miami Dade counties, part of the Everglades and Florida Keys.

Miami and Miami Beach are struggling with serious flooding related to sea-level rise, even on sunny days. "Sunny day flooding," as it is known, is created by high tides, caused by interactions between the sun, moon, earth, and oceans. Our visit was during one of the highest tides of the year, also known as a king tide.

As sea levels rise, the dangers of flooding increases and can contribute directly to higher tides and storm surges causing water to rise over the top of existing sea walls. Higher sea levels also contribute to flooding by affecting groundwater levels and the drainage network. In order to keep up with the demands of growing population and agriculture, some areas were drained, so they are more susceptible to flooding.

The water goes where the water was, a saying that we constantly heard during our trip. Higher groundwater levels can also affect the storage capacity in the soil that generally works as a sponge to absorb excess water and helps alleviate flooding after rain events. When the soil is saturated and cannot absorb water, the water levels on the surface increase for longer periods of time causing flooding. Higher groundwater and sea levels affect and burden the effectiveness of the drainage infrastructure making it more susceptible to malfunctions or failures.

House in a flooded street built in 1920 with the for sale sign. The house sold for $1.3 million according to Zillow, in November 2019. Property values remain high in spite of flooding issues. The house is served by a septic tank. The city doesn't require real estate disclosures for properties sold in hazard areas.

During our visit, a king tide event caused flooding in this neighborhood. This neighborhood is served by septic tanks.

The septic systems were not designed for sea level rise. Malfunctioning of septic tanks can posed serious health and environmental concerns.

Backflow from already full canals exacerbates flooding.

Flooded street near canal during high tide. Katia Balassiano, Land Use Permits Division, C&C Honolulu Department of Planning & Permitting, inspecting the back flowing water coming out of the storm drain during high tide.

Up-scale neighborhood flooding during king tide. Sam Lemmo, Administrator, State of Hawaii Department of Land and Natural Resources, Office of Conservation and Coastal Lands

Flooding in the low income neighborhood in the Upper East Side. Note standing garbage mixed in with tidal flooding.

Tamiami Trail state evacuation road flooded during king tide event on September 30, 2019 during our visit.

The Perez Art Museum Miami opened in 2013. According to Jeff Goodell in his book “the Water Will Come” this is the first building in the city to recognize that Miami is a new Atlantis. The museum was named after the top billionaire developers in Florida. The museum overlooks Biscayne Bay and it was built resembling stilts.

CHALLENGES AND OPPORTUNITIES IN SOUTH FLORIDA

1. They are experiencing fluctuations in precipitation patterns, in sea level rise and in extreme temperatures due to climate change.

2. Sea level rise on low elevation in the South Florida coastal communities has an impact on the tides; king tides are more frequent and they flood streets even on sunny days. The major physical impacts of a rise in sea level include erosion of beaches, inundation of deltas, as well as flooding and loss of many marshes and wetlands.

3. Sea level rise affects the drainage systems. Normally, the water will leave the city by going down the drains and go out the sea walls back into the bay but because the water level has risen so high in the bay, the outfalls or mouth of the drains, are under water so the water reverses course and comes out of the drains in the streets. These events have negative impacts on the economy, agriculture, transportation and tourism.

4. SLR also impacts coastal beach erosion, affecting tourism. South Florida spends a lot of money in beach nourishment, so it's a significant economic impact.

5. They are tackling climate, specifically SLR and storm surge, both at the local and regional levels.

6. Hurricane Andrew was an eye-opener and a game changer for Florida and it helped people realize that they needed to make changes and needed to be proactive.

7. One of the biggest challenges in south Florida is that the water is highly managed for agriculture, for water supply and for flood control. Douglas Yoder[2] explained during our visit, that the canals were built as a response to a series of hurricanes that crossed over Lake Okeechobee, killing around 3000 people. Berms were built around the lake and canals were constructed to move or redirect water to different parts of the State depending on needs.

   Agriculture exploded with the construction of canals[3]. This highly managed water system uses pumps, gates and canals which eventually drain over Biscayne Bay or to the lower part of Florida because it operates on gravity. The system has its

[2] Douglas Yoder, Deputy Director, Miami-Dade Water and Sewer

[3] Florida rainfall averages nearly 60 inches per year so the canals were built to control seasonal flooding and provided consistent irrigation to farmers. Canals are also use for navigation, recreation and historically add great property value to homes that have access to them.

vulnerabilities, according to Douglas Yoder; the problem is to try to get high water to the West and the East and low water to the middle for agriculture. The South Florida Water Management District operates gates that just go up and down to let the water out. If there is too much water due to precipitation the gates are raised in advance to manage the water, but sometimes because of the high tide and as result SLR, the gates won't always operate in that manner – you have to leave them closed; so in many instances these gates have had to be retrofitted at great expense, to include pumps to operate the standard gates.

8. The Miami-Dade Water and Sewer Department (MDWASD) serves more than 2.3 million residents and thousands of visitors. The MDWASD is the largest water and sewer utility in the southeastern United States. It is divided into 5 water management districts that reflect water basins in Florida. It was created in 1972 as a regional utility by merging the City of Miami and County systems. There operating budget for the 2019-2020 is $870M. Capital is $641M and it has a staff of 2800.

9. The water system supplies 320 million gallons per day (MGD). It has 3 large regional and 5 small water treatment plants. It also has a Reverse Osmosis Plant (RO). The MDWASD (Miami-Dade Water and Sewer Department) supplies 320 million gallons per day and 90% of the County's public water supply. The per capita water use per day is 1369 (gpcpd). It serves 450,000 retail customers and 15 wholesale. There are 100 water supply wells and 7,739 miles of pipes, 120,000 valves and 37,214 fire hydrants.[4]

10. The wastewater system has 3 wastewater regional treatment plants, these plants are located on the coast. There are 2 ocean outfalls and 21 deep injection wells. It collects, treats and disposes of 294 MGD. It has 354,000 retail customers and 12 wholesale customers. It has 6,231 miles of mains and laterals[5]. The wastewater system has 1,047 sewer pump stations and it reuses 13 MGD of wastewater. The reason for not reusing more wastewater is because they always had an abundant supply of water and they had a convenient way to dispose of wastewater before.

[4] Douglas Yoder, Deputy Director, Miami-Dade Water and Sewer Department. Presentation to the Hawaii Delegation. September 30, 2019.

[5] **Sewer lateral** is the pipe that connects indoor plumbing to the **sewer main**
M**ains** are pipelines that convey **wastewater** under pressure from the discharge side of a pump or pneumatic ejector to a discharge point.

11. The main source of drinking water is the shallow Biscayne aquifer. Its replenishment is from the Everglades, so the Everglades are very important. SLR is also impacting the Everglades due to saltwater intrusion in freshwater marshes and estuaries systems impacting the fragile nature of the ecosystem.

12. Since the water resources are highly managed, and hydrologically connected to the ocean, SLR is a constant threat to the water levels of the groundwater table and can negatively impact drinking water wells due to saltwater intrusion.

13. Miami's strategic location as the gateway to the Americas with one of the largest international airports, and one of the largest cruise ports in the U.S., is susceptible to international crime, drug activity, and public health concerns such us vector-borne illnesses like Zika. Tourism, globalization and climate change are increasing public health concerns in South Florida.

14. The storm water infrastructure is designed to work by gravity to let the water flow down and out, so through that infrastructure, particularly on the coast, provides a direct conduit for those high tides to come right into the streets and onto the land.

15. Gentrification, is a process of changing the character of a neighborhood through the influx of more affluent residents and businesses.[6] Gentrification is not new to Miami. Little Haiti is at the forefront of gentrification, known as climate gentrification in Miami. The working class, neighborhood has been experiencing rising housing costs and increases in rent prices forcing many residents to leave. "They are being replaced by whiter, wealthier occupants seeking to move away from Miami's receding shoreline and towards higher ground."[7]

    A 2018 Harvard study[8] found that real estate in high-elevation communities in the Miami-Dade area is appreciating at a faster rate than elsewhere in the county. The study monitored the values of more than 100,000 single-family homes across Miami, going back 45 years. Average rents increased 65% (from $1,505 in 2009 to $2,501 in 2015).[9] It is important to note that this Harvard study did not really have a control

[6] https://en.wikipedia.org/wiki/Gentrification#CITEREFLeesSlaterWyly2010

[7] E.A. Crunden, "Miami residents welcome historic climate gentrification resolution: Neighborhoods on higher ground are becoming more desirable," December 11, 2018: https://thinkprogress.org/miami-to-tackle-climate-gentrification-as-sea-level-rise-pushes-wealthy-further-inland-1c853b81df9a/

[8] **Climate gentrification: from theory to empiricism in Miami-Dade County, Florida**
Jesse M Keenan[1,3], Thomas Hill[1] and Anurag Gumber[2]
Published 23 April 2018 • © 2018 The Author(s). Published by IOP Publishing Ltd
Environmental Research Letters, Volume 13, Number 5

[9] https://www.miamidade.gov/green/library/gmb-preliminary-resilience-assessment-2017.pdf

group. Little Haiti has a three feet higher elevation than the wealthy residents on Miami Beach. According to Jesse Keenan, the lead author of the Harvard study, climate gentrification will put housing pressure in Atlanta from displacement created in Florida. Keenan considers that the impact of climate gentrification is not limited to guiding residential patterns along the coast, it will also impact flora and fauna, guide a new architecture design, change political and cultural geography and guide the capital flows of real estate investment.

We learned that climate gentrification in Miami is occurring in higher elevation areas. According to the CLEO[10] Institute, education is the best way to address equity issues of climate gentrification, so residents in higher elevation areas are not tricked to sell their properties and can make the best decisions regarding their future "with their eyes wide open."

The Fourth National Climate Assessment report found that existing inequalities will only be exacerbated due to climate change posing growing challenges to quality of life, human health and safety and the rate of economic development.

Low income neighborhood in the upper east side of Miami experiencing street flooding near sewer and garbage dumpsters.

[10] **CLEO** is a nonprofit, nonpartisan organization based in Florida that is exclusively dedicated to climate change education and engagement. https://www.cleoinstitute.org/

Climate change affects poor people disproportionally regarding mobility, health and housing.

16. Poverty and inequality in Miami-Dade County. The United Way ALICE Miami-Dade Report [11] (Asset Limited, Income Constrained, Employed) examined financial hardship of households and provides a holistic picture of financial insecurity at the state, county and municipal level.

    The population identified in the ALICE report are hard-working families that earn above the Federal Poverty Level but struggle to keep up with the rising cost of living, such the cost of housing, childcare, transportation, food, health care, technology or other basic needs. According to the ALICE Report, 59% of Miami-Dade households are either in poverty, or one emergency away from poverty and 21% live below the poverty level with incomes less than $16,000.[12] According to this report, the percentage of households below the ALICE threshold has grown over time, and families have not been able to keep up with the increasing cost of living in Miami-Dade County.

17. Southeast temperatures increased again from 1970 to the present by an average of 2°F, with higher average temperatures during summer months. Since 1970, there have been increasing numbers of days above 95°F and nights above 75°F, and decreasing numbers of extremely cold days.[13] According to the US Environmental

[11] http://unitedwaymiami.org/wp-content/uploads/2019/02/18145-EXT-ALICE-One-pager.pdf
[12] https://www.miamidade.gov/business/library/reports/2013-income-poverty.pdf
[13] Kunkel, K. E, L. E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, C.E. Konrad II, C.M. Fuhrman, B.D. Keim, M.C. Kruk, A. Billet, H. Needham, M. Schafer, and J.G. Dobson, 2013: Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part2. Climate of the Southeast U.S. NOAA Technical Report 142-2.

Protection Agency (EPA) temperatures in most of the State of Florida probably would rise above 95°F between 45 and 90 days per year and higher humidity will have impacts on health, especially for vulnerable population including children, the elderly, the poor and the sick. "Warmer air can also increase the formation of ground-level ozone, a key component of smog. Ozone has a variety of health effects, aggravates lung diseases such as asthma, and increases the risk of premature death from heart or lung disease.[14]" Higher temperatures can cause dehydration, heat stroke and affect cardiovascular and nervous systems.

18. Transportation and Mobility. Given its size as the tenth most populous metropolitan area in the U.S.,[15]Miami faces congestion and transportation issues familiar to every city. Flooding exacerbates congestion and mobility issues.

During king tides, flooding is inevitable even on some emergency roads. The transit arm of Miami-Dade County's Department of Transportation and Public Works (DTPW) is the 15th largest public transit system in the country and the largest transit agency in Florida. Its operations include bus, rail, an automated downtown people mover, and paratransit.

The 79thStreet Causeway Bridge malfunctioned, leaving it stuck in the upright position, cars turned around and went against traffic flow.

US 1 BISCAYNE BLVD flooded during king tide.

103pp., National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Washington D.C.

[14] Kunkel, K. E, L. E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, C.E. Konrad II, C.M. Fuhrman, B.D. Keim, M.C. Kruk, A. Billet, H. Needham, M. Schafer, and J.G. Dobson, 2013: Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part2. Climate of the Southeast U.S. NOAA Technical Report 142-2. 103pp., National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Washington D.C.

[15] Rosenberg, Matt. "Most Populous Metropolitan Areas in the United States." ThoughtCo, Jun. 17, 2019, thoughtco.com/largest-metropolitan-areas-1435135.

ADAPTATION AND RESILIENCE MEASURES

1. Adaptation is not new to Miami-Dade County. In the 1970s, they started nourishing the beaches and protecting some environmentally sensitive land. They also started the Division of Environmental Resources Management in the Department of Regulatory and Economic Resources.

   Through this division, they developed some innovative programs such as the Northwest Wellfield Protection Plan to protect the Biscayne Aquifer, the County's primary source of drinking water. They are currently implementing stormwater management plans to eliminate pollution from water bodies: freshwater, estuarine and coastal, and natural areas management; to eliminate the invasion of exotic pest plants that threaten native ecosystems. The "GreenPrint" study by Miami-Dade County stated that they will continue to work towards sustainable development patterns through local and regional partnerships and protect unique natural resources critical to the South Florida economy.[16]

2. In the spring of 2016, Greater Miami & the Beaches, became the first two cities and county to join the 100 Resilient City network as one.

3. They now have stronger building codes from their experience with Andrew in South Florida.

4. They have a very robust stormwater modeling and master plan program that allows them to have a community rating system (CRS) from 1 to 5. They built adaptation from those programs as the fundamentals for climate change adaptation.

5. In 2009, some of the elected officials in the counties of Monroe, Miami Dade, Broward and Palm Beach realized that there were duplications and inconsistences in their SLR efforts, i.e., usage of different measures, projections, approaches and timeframes. They also realized that different communication strategies were being used which created confusion and gaps in tackling climate change and sea level rise. As a solution to this problem, in 2010, the counties decided to collaborate on a regional basis. They also realized that collaboration was also needed to protect their shared natural

[16] http://www.miamidade.gov/GreenPrint/pdf/plan.pdf

resources, their regional transportation and their economies. This collaboration among Counties helped improve regional vulnerability assessments.[17]

According to Nichole Hefty, Deputy Chief Resilience Officer, Regulatory & Economic Resources Dept., Miami-Dade County**,** the four counties represent 30% of the state's population and realized that they had a stronger voice at the state and federal level if they work together.

The four counties adopted the Southeast Florida Regional Climate Change Compact, and signed a formal agreement to work together as a region on climate mitigation and adaptation policies and action. They also agreed to develop resources and inform their communities as a group.

The compact have a steering committee comprised of two representatives from each of the four counties; one representative from a municipality from each of the counties. They have a representative from the south Florida management district and the south border regional planning council and a representative from the nature conservancy. This Compact also has a steering committee and they meet on a regular basis with different groups working on specific projects to develop resources and tools. [18]

One of their most significant actions is the development of a Unified Sea Level Rise Projection for Southeast Florida used for planning and communications purposes. This standard measurement has helped them to see data and specific information about each region and how it affects SLR locally, with guidance from the U.S. Army Corps of Engineers (USACE), and the National Oceanographic and Atmospheric Agency, (NOAA). The information and documents produced help planners design an infrastructure and land use strategy based on urgency and necessity.

The following are the specific actions of the Southeast Florida Compact:

a. Standardize projections of SLR to create a regional vulnerability assessment of inundation and flooding that resulted in a regional map that identified vulnerable infrastructure, including drinking water, and water utilities.

b. The information collected in the assessment helped developed the South Florida Regional Climate Action Plan [19] This Action Plan offers a wide- ranging set of

[17] https://toolkit.climate.gov/case-studies/collaboration-among-counties-improves-regional-vulnerability-assessments

[18] Environmental and Energy Study Institute, "Lessons in Resilience from America's Coastal Communities," citing **Nichole Hefty, Deputy Chief Resilience Officer, Regulatory & Economic Resources Dept., Miami-Dade County, FL** February 22, 2018: https://www.eesi.org/briefings/view/022218coastal

[19] https://southeastfloridaclimatecompact.org/about-us/what-is-the-rcap/

recommendations for local governments on natural resource management, transportation, emergency management, and water management.

c. Municipal and local jurisdictions benefit from all the data and resources developed by the Compact to support and inform their adaptation plans to protect their infrastructure from flooding[20].

d. The South Florida Regional Climate Action Plan also offers guidance regarding implementation on infrastructure position or location and design, measuring reduction in drainage capacity and natural resource degradation in order to minimize vulnerabilities to drinking water supply and wastewater and stormwater management.[21]

e. The Compact created working groups related to sea level rise mitigation such as the Florida Reef Resilience Program, the Sea Level Rise Work Group and the Shoreline Resilience Working Group, which partners with the Nature Conservancy to report on nature-based solutions to sea level rise threats.

   This process has been instrumental in bringing academic resources, representation from the South Florida Water Management District, the Army Corps of Engineers, and the US Geological Survey. The Compact also enables local governments to create pertinent adaptation methods and it is designed to cooperate with state and federal agencies for support and technical assistance.

[20] https://www.epa.gov/arc-x/southeast-florida-compact-analyzes-sea-level-rise-risk
[21] https://www.epa.gov/arc-x/southeast-florida-compact-analyzes-sea-level-rise-risk

Unified Sea Level Rise Projection for Southeast Florida updated in 2015 projects the anticipated range of sea level rise for the region from 1992 to 2100

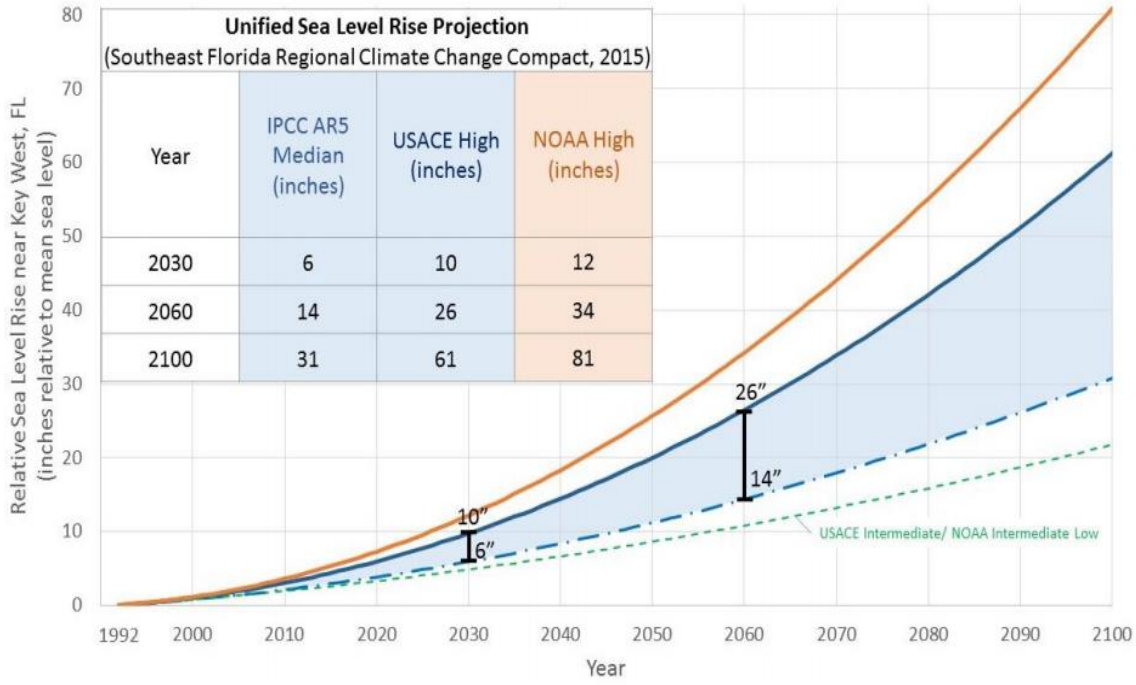

Figure 1: Unified Sea Level Rise Projection. These projections are referenced to mean sea level at the Key West tide gauge. The projection includes three global curves adapted for regional application: the median of the IPCC AR5 RCP8.5 scenario as the lowest boundary (blue dashed curve), the USACE High curve as the upper boundary for the short term for use until 2060 (solid blue line), and the NOAA High curve as the uppermost boundary for medium and long term use (orange solid curve). The incorporated table lists the projection values at years 2030, 2060 and 2100. The USACE Intermediate or NOAA Intermediate Low curve is displayed on the figure for reference (green dashed curve). This scenario would require significant reductions in greenhouse gas emissions in order to be plausible and does not reflect current emissions trends.

The Unified Sea Level Rise Projection for Southeast Florida emphasizes three planning horizons:

i. Short term, by 2030, sea level is projected to rise 6 to 10 inches above 1992 mean sea level.
ii. Medium term, by 2060, sea level is projected to rise 14 to 34 inches above 1992 mean sea level.
iii. Long term, by 2100, sea level is projected to rise 31 to 81 inches above 1992 mean sea level.

6. Miami-Dade is focused on strengthening their infrastructure, building resilient communities and working more with the communities that are impacted on a regular

basis by flooding. They are trying to work on economic resilience in regard to insurance, since that is the driving force in order to move forward.

7. In collaboration with different departments, they look at their infrastructure critically using a matrix to look at the vulnerability to SLR and storm surge.

8. To keep the water out of the cities, specifically out of Miami Beach the city is spending around half a billion dollars to elevate infrastructure, install and retrofit pumps, pipes and drain systems. The city has been upgrading its infrastructure raising all vulnerable roads and installing more than 80 new pumps to readdress floodwaters towards the ocean.

9. The city of Miami Beach is very committed to their infrastructural upgrades, as well as to updates in land use and development codes. The main adaptations for a 10 year plan include: elevating roads and public seawalls, improving drainage systems, installing pumps to replace aging gravity stormwater pipes, replacing much of the utilities such as water, wastewater, expanding seawall height, expanding base flood elevation and creating a freeboard above Federal Emergency Management Agency (FEMA) base flood elevation, introducing other commercial height standards, increasing setbacks and open space for single-family homes and requiring sea-level rise review criteria for land use boards.[22]

10. Regarding water and sewer infrastructure, Miami-Dade started a $13 billion dollar infrastructure improvement program for SLR storm surge. They have been working at changing the design standards to make that infrastructure less vulnerable.

11. Regarding the issue of gentrification, Miami is trying to get ahead of the curve. According to Jane Gilbert, Chief Resilience Officer, City of Miami, the city is planning to gather data on rates of property turnover, building permits, increases in land values, purchases by companies, and opportunity zones to help pinpoint the high-lying neighborhoods experiencing the most development pressure. "The second step is identifying what policies exist (or are needed) to help renters and homeowners stay put if they wish to.

    One move in the right direction is the "Miami Forever" bond, which was approved by voters in the 2017 general election and dedicates $400 million to addressing sea level rise through improving seawalls, roads, and stormwater pumps, in addition to

[22] A ULI Advisory Services Panel Report/2018 by the Urban Land Institute. Miami Beach Florida Stormwater Management and Climate Adaptation Review April 16–19, 2018

creating more affordable housing opportunities. Still, more support is needed."[23] The Miami Forever Bond was designed to build a stronger and more resilient Miami. Around $200 million went to projects to prevent flooding and to mitigate SLR, including a redesigned of Brickell Bay Drive and the installation of 50 new one way valves. This reactive measure happened after Hurricane Irma flooded more than 3 foot the financial district in Brickell on September 10, 2017. According to Alex Harris from The Florida Climate Reporting Network, money generated locally would not last long. The Forever Bond, as Miami Commissioner Ken Russell puts it, "it'll be gone before we know it." Elected officials in South Florida are eager to tap federal funds.[24]

12. As Sasha Forbes notes, there are ways to combat gentrification. "Cities can develop inclusive processes and policies that ensure residents can chart a way forward in their own communities."[25] Forbes is the state and local policy coordinator for SPARCC (Strong, Prosperous, and Resilient Communities Challenge), an initiative to improve the environmental, health, and racial equity of vulnerable communities in six U.S. cities. Community benefits agreements also can help. "Under such agreements, a community group supports an upcoming development project in exchange for the developer providing a community need, such as affordable housing, green space, or jobs for local residents.

    Other strategies include enacting homeowner and tenant protections like rent control, just cause eviction, tax freezes, and community land trusts. Inclusionary zoning, whereby developers dedicate a percentage of new housing units to lower-income residents, can also help. In all, a mix of equitable housing protection, housing preservation, and new housing is needed."[26] "The time to implement protective policies is now," says Forbes. "If we don't move fast enough, we will see historic and institutional inequities repeat themselves, displacing cultures and people who could then suffer the consequences of housing insecurity and vulnerability to climate change."[27]

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[23] Robbyne Boyd, "Has Climate Gentrification Hit Miami? The City Plans to Find Out: As the sea rises, low-income neighborhoods on high land are starting to feel squeezed out," March 11, 2019: https://www.nrdc.org/stories/has-climate-gentrification-hit-miami-city-plans-find-out

[24] Climate change is going to cost Florida a lot of money. Alex Harris By Miami Herald Published Jul. 11, 2019 https://www.tampabay.com/florida-politics/buzz/2019/07/11/

[25] Robbyne Boyd, "Has Climate Gentrification Hit Miami? The City Plans to Find Out: As the sea rises, low-income neighborhoods on high land are starting to feel squeezed out," March 11, 2019: https://www.nrdc.org/stories/has-climate-gentrification-hit-miami-city-plans-find-out

[26] Robbyne Boyd, "Has Climate Gentrification Hit Miami? The City Plans to Find Out: As the sea rises, low-income neighborhoods on high land are starting to feel squeezed out," March 11, 2019: https://www.nrdc.org/stories/has-climate-gentrification-hit-miami-city-plans-find-out

[27] Robbyne Boyd, "Has Climate Gentrification Hit Miami? The City Plans to Find Out: As the sea rises, low-income neighborhoods on high land are starting to feel squeezed out," March 11, 2019: https://www.nrdc.org/stories/has-climate-gentrification-hit-miami-city-plans-find-out

13. There is a relatively long history of law and policy in Florida regarding climate change impacts. In 2006, Governor Jeb Bush signed into law the Renewable Energy Technologies and Energy Efficiency Act. This Act prompted the creation of the new Florida Energy Commission which, in 2007, made a recommendation for the development of a state climate action plan. Since 2007 their focus has shifted to flooding and resilience due to fact that roads and drainage were the first types of infrastructure to deteriorate from sea level rise.

14. The use of ordinances has been instrumental for local governments to implement comprehensive plan policies, specifically, regarding infrastructure.

CHARLESTON, SOUTH CAROLINA

View from the airplane before landing in the Charleston International airport showing how it is surrounded by water. South Carolina is divided into 4 areas: the Sea Islands, Atlantic Coastal Plain, Piedmont Plateau and Blue Ridge Mountains.

Hawaii delegation putting the suitcases into the rental van at the Charleston International airport on October 1, 2019.

Our group visited Charleston from October 1-3, 2019 right at the tail end of a king tide.

Dan Burger, Director of the Charleston Resilience Network (CRN), a collaboration of public, private, and non-profit organizations seeking to enhance the resilience of their region and communities, help us put together the Charleston team and organized our meetings.

Our first meeting was with Dr. Norm Levine at the College of Charleston, Dr. Levine explained the natural hazards and anthropogenic challenges in the Charleston region.

Mark Wilbert, Chief Resilience Officers presented some of the key climate adaptation initiatives in Charleston. Our meetings dealt with their resiliency efforts and strategies for their increasing flooding and sea level rise, Stormwater Management Improvements, the Low Battery Seawall Enhancement, Hazard Vulnerability Assessment, RainProof Charleston, and the "Dutch Dialogues" – a concerted effort for lessons learned from Holland's centuries old efforts battling flooding.

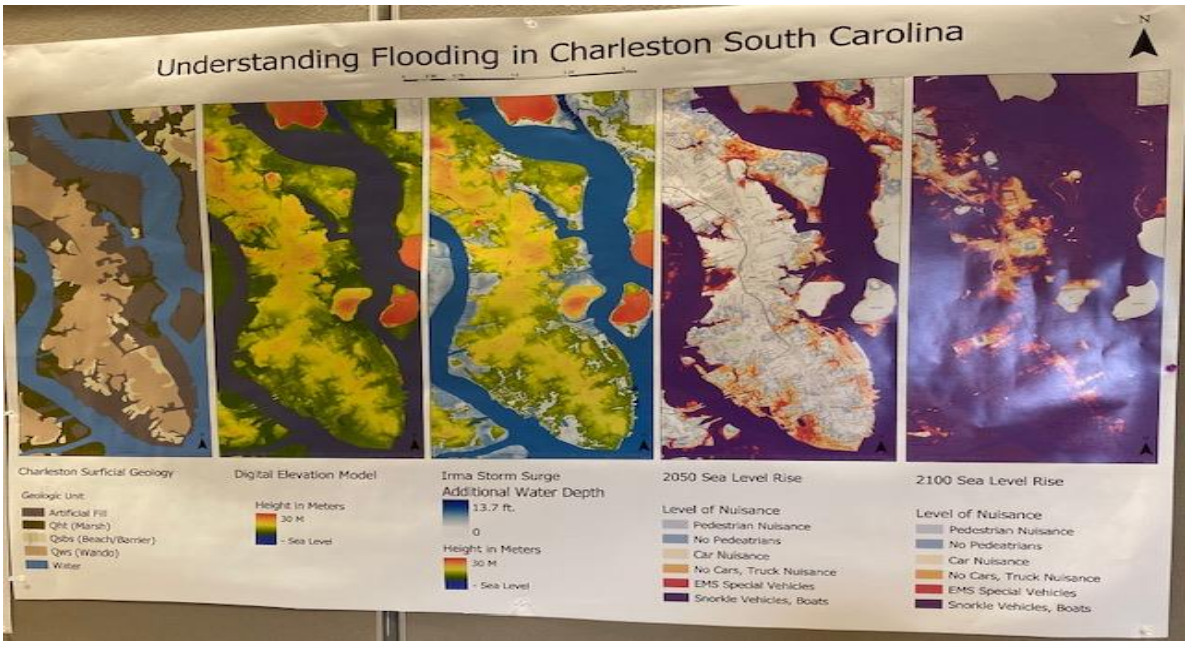
West Wilson gave us an overview of the US Army Corps 3 x 3 Peninsula Flood Risk Management study. This study focuses on surge and storm risks on the peninsula exploring structural and non-structural solutions to mitigate those risks.

We visited the East side neighborhoods where the most vulnerable communities are. This has been a forgotten community over time but Mayor John Tecklenburg, is making an effort to support the people in this community. This community is close, within a mile, to very expensive houses. The Mayor's platform is to address flooding, traffic, public safety and affordable housing.

We also toured key sites of Charleston Peninsula and major stormwater infrastructure projects with Jared Bramblett, a senior civil engineer at Davis and Floyd.

On October 3rd, we visited the Clemson Resilient Urban Design Program with the Director B.D Wortham-Galvin. Rick Devoe, from the South Carolina Sea Grant Consortium, presented details about the resilience communication strategy for South Carolina. Elizabeth Fly from the Nature Conservancy talked about nature based solutions in climate adaptation.

Doug Marcy gave a great demonstration of NOAA Resources and a Tool demo.



Sea level rise impacts communication strategy by level of nuisance.

Dan Burger, Chair of the Charleston Resilience Network talking about the complex history and challenges of South Carolina with water.

Norm Levine, PhD., Director, Lowcountry Hazards Centers, College of Charleston. Dr. Levine explains the multiple hazards that South Carolina faces regarding floods, thunder storms, tornados, earthquakes, mold, coastal erosion, hurricanes, wildfires, and poverty.

Mark Wilbert, Chief Resilience Officer, City of Charleston presenting sea level rise strategies for South Carolina.

Key Charleston Counterparts:

- Dan Burger, Chair of the Charleston Resilience Network
- Mark Wilbert, Chief Resilience Officer, City of Charleston
- Norm Levine, PhD., Director, Lowcountry Hazards Centers, College of Charleston
- Elizabeth Fly, PhD., The Nature Conservancy
- Wes Wilson, U.S. Army Corps of Engineers
- Jared Bramblett, P.E., Davis & Floyd Engineering
- Connie Banegas, Charleston Water System
- Rick Devoe, South Carolina Sea Grant Consortium
- Roberta Kahle, College of Charleston Joseph P. Riley Center for Livable Communities
- B.D. Wortham-Galvin, PhD., Director, Clemson Resilient Urban Design Program
- Doug Marcy, Coastal Hazards Specialist

East side neighborhoods where there the most vulnerable communities are. This area floods because it used to be a wetland before it was filled. "Water goes where waters was"

Charleston is one of the cities on the East Coast that is most vulnerable to catastrophic effects from SLR. As College of Charleston Geology Professor Norman Levine aptly put it, "Charleston is the hazard capital of the East."[28] The city has historically had flooding issues whenever it rains, prompting studies that cite its vulnerability, with subtitles such as "The Challenges of Draining a City that is Low, Flat, and Next to the Ocean."[29] Global sea level has risen eight inches in the past hundred years In Charleston, the Atlantic has risen over a

[28] Tom Cunneff, "Geology Professor's Career is the Gold Standard," December 17, 2019: https://today.cofc.edu/2019/12/17/norman-levine-geology/

[29] Charleston-sc.gov, "Why Does It Seem Like Charleston Always Floods When It Rains?": https://www.charleston-sc.gov/DocumentCenter/View/574/Why-Does-It-Seem-Like-Charleston-Always-Floods-090529?bidId=

foot in that time period.[30] And due to climate change, the pace of SLR has doubled since the early 1990s.[31]

"Compounding the issue is sea level rise, which would make flooding more likely during king tides and hard rains."[32] The Atlantic has risen more than a foot along its shores in the past century and the effects have been devastating to this low, flat, densely populated city. Heavy flooding after a rainfall has become a predictable event. "Every time it, rains, it floods. 'Rain bombs'" overwhelm the city's low-lying areas and drainage systems.[33]

"Across the state, flooding has increased 75% since 2000."[34] Therefore, projections that the Atlantic could rise another five feet by the end of this century have driven planners and politicians to seriously address the issue.[35] "The state is planning over $2 billion in sea level rise solutions, which include beach re-nourishment, seawalls, drainage improvements, and raising roads."[36]

In the last 100 years, the harbor in Charleston has risen 18 inches, 1.5 feet. It is projected that in the next 30 to 40 years it could easily rise another 18 inches. In the last five years, sea level has risen 66% faster than the historical rate, and is now rising by an average of one inch every five years. [37] While it took 60 years for the sea level to rise about 6 inches nationally,[38] scientists now forecast that in just the next 20 years, the sea will have risen by another 6 inches.[39]

The fact that Charleston's future is frightening to scientists should be sounding off alarm bells because they know what they're talking about. Referring to the sea floor, Professor Levine warns: "We're actually seeing sea level rise at a faster rate than other places in the U.S. in part because of our topography and our bathymetry. The effect of how the Earth spins

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[30] Bobby Magill, "The Front Lines of Climate Change: Charleston's Struggle," January 9, 2014, ClimateCentral.org: https://www.climatecentral.org/news/the-front-lines-of-climate-change-charlestons-struggle-16934

[31] Coastal Heritage Magazine, John H. Tibbetts, editor, "Water Cities: Can We Climate-Proof the Coast?," Fall 2014: https://www.scseagrant.org/water-cities-climate-proof-the-coast/

[32] Chloe Johnson, citing Kirsten Dow, University of South Carolina, "5 ways climate change could alter life in SC after 2030," October 27, 2018, *The Post and Courier*: https://www.postandcourier.com/hurricanewire/ways-climate-change-could-alter-life-in-sc-after/article_743edeb4-d879-11e8-ad1f-b7a1ebf4a733.html

[33] Bobby Magill, "The Front Lines of Climate Change: Charleston's Struggle", (quoting College of Charleston biologist, Phil Dustan): lhttps://www.climatecentral.org/news/the-front-lines-of-climate-change-charlestons-struggle-16934

[34] SeaLevelRise.org, "South Carolina's Sea Level Is Rising: And It's Costing Over $2 Billion": https://sealevelrise.org/states/south-carolina/

[35] Bobby Magill, "The Front Lines of Climate Change: Charleston's Struggle", January 9, 2014: https://www.climatecentral.org/news/the-front-lines-of-climate-change-charlestons-struggle-16934

[36] SeaLevelRise.org, "South Carolina's Sea Level Is Rising: And It's Costing Over $2 Billion": https://sealevelrise.org/states/south-carolina/

[37] NOAA Tides and Currents (www.tidesandcurrents.noaa.gov)

[38] John A. Church & Neil J. White, "Sea-Level Rise from the Late 19th to the early 21st Century," March 30, 2011: https://link.springer.com/article/10.1007%2Fs10712-011-9119-1

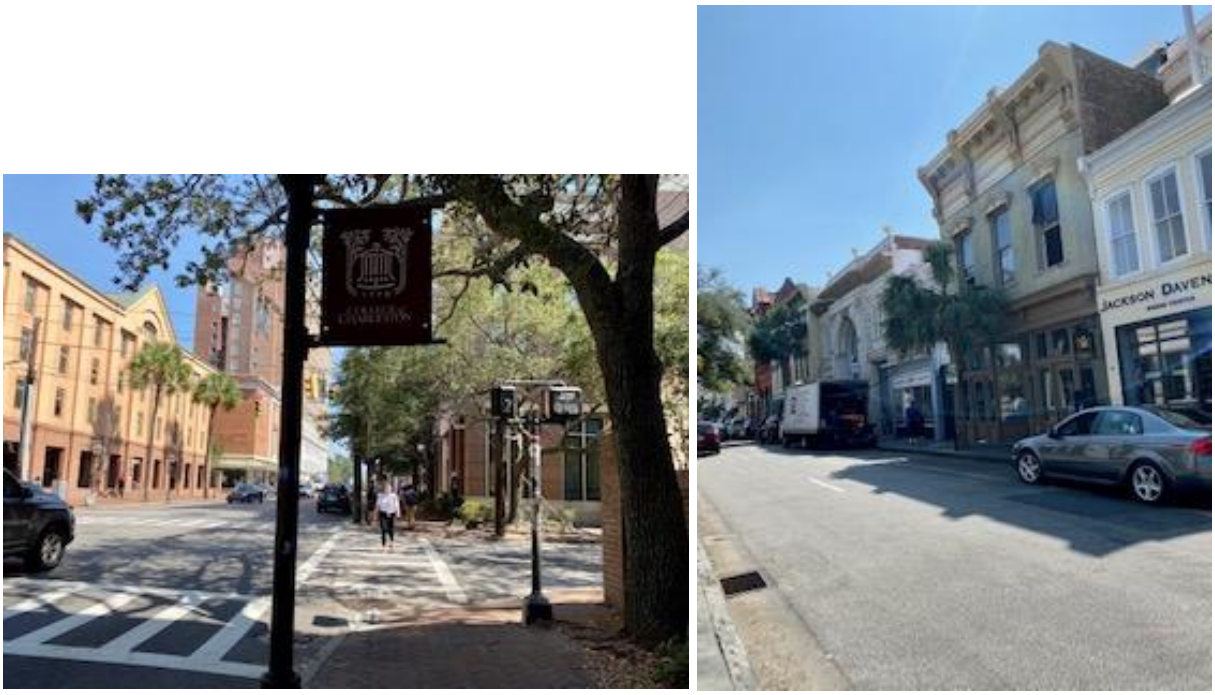
[39] NOAA Intermediate Projection (www.tidesandcurrents.noaa.gov)

combined with the density and salinization changes of the Gulf Stream has caused it to shift its position and move more water upward."[40]

Some say that it is "only" a 10 percent chance to have a sea level rise of 8 feet by 2100. But that would completely inundate the Lowcountry of Charleston and the surrounding area. As Professor Levine responded to that point: "If you were flying in a plane with a 10 percent possibility of crashing, would you take a plane or a car?"[41]

Charleston has installed several floodwater pump stations that drain flooded streets. The stormwater pump stations push the excess water into tunnels 140 feet below ground, the water is sent beneath the Charleston Harbor. But like in Miami-Dade County the system can only do so much as it takes time and energy to drain most of the streets.

CHALLENGES AND OPPORTUNITIES IN CHARLESTON



Charleston, historic downtown.

[40] Tom Cunneff, "Geology Professor's Career is the Gold Standard," December 17, 2019: https://today.cofc.edu/2019/12/17/norman-levine-geology/
[41] Tom Cunneff, "Geology Professor's Career is the Gold Standard," December 17, 2019: https://today.cofc.edu/2019/12/17/norman-levine-geology/

Historic and dynamic area South of Broad known for the 19th-century Rainbow Row, filled with beautiful restored townhouses.

1. Charleston is faced with aging infrastructure in need of replacement, particularly its water systems, which are in a constant process of being updated.[42] "The city is scrambling to update its drainage infrastructure, some of which dates back to the 1800s, to keep up with recent population growth."[43]

2. The city's drainage systems are so challenged that just a light rain causes flooding, especially at high tide. The problem has been increasingly common in recent years, as coastal se levels rise. Referred to as "nuisance flooding" or "sunny-day flooding," because at high tide the streets can get flooded even in good weather, it leads to public inconveniences such as road closures.

   Nuisance flooding not only causes infrastructure damage, sewer blockages and backups, but it's a human health risks cause by bacteria and mold. As Mark Wilbert, the city's Chief Resilience Officer observed, "the city has increased its budget from 8 million dollars to 12 million dollars a year to address so called nuisance flooding

[42] Charleston Water System, "Capital Projects": https://www.charlestonwater.com/158/Capital-Projects
[43] Linda Poon, "In Charleston, the Real Flooding Crisis Is Only Beginning," September 6, 2019: https://www.citylab.com/environment/2019/09/hurricane-dorian-charleston-flood-climate-change-high-tides/597475/

which frequently occurs at high tide whether it's raining or not. "Last year we had 50 of those days," he said. "The projection is we're going to have 180 by 2040."[44]

3. Another effect of SLR is the intrusion of saltwater inland which causes salinization of the soil. When salt accumulates in the soil, it hinders the growth of crops. The presence of salt limits the ability of plant roots to take in sufficient water. Therefore, high levels of salt can actually have a drought-like effect on crops.[45] In Charleston, salinization is already a serious problem. "Salt is inching its way into the groundwater under the coast."[46] The salt threatens the drinking water of the city and surrounding area.[47]

4. Land subsidence is the gradual sinking of land from taking on too much water. Subsidence is worst on infilled lands, SLR causes increasing land subsidence and that exacerbates the issues of flooding.[48] "Along one stretch of the South Carolina coast, from Charleston and farther points south, the land is sinking – or subsiding" and the problem is projected to worsen from the effects of SLR."[49] It doesn't seem that they are tracking subsidence and there is not a lot of baseline information about it in the area. They have a project that they are trying to develop with the State. This project will involve collecting information through aircraft-based type of LIDAR (light detection and raging, an optical remote-sensing technique that uses laser light to densely model the surface of a region) in order to get measures to track subsidence.

5. Meeting the demands of population growth is a constant challenge in Charleston.[50] "Just in the last decade, its population grew by 20 percent, according to the city's own

[44] Victoria Hansen, "Charleston's Chief Resilience Officer Fights Flooding and Sea Level Rise," March 7, 2018: https://www.southcarolinapublicradio.org/post/charlestons-chief-resilience-officer-fights-flooding-and-sea-level-rise

[45] USDA Natural Resources Conservation Service, "Salinization," January 1998: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053151.pdf

[46] Bo Petersen, "Salt creeping into SC coastal groundwater. Keeping track of it is the job of one person," June 10, 2019, *Post and Courier*: https://www.postandcourier.com/news/salt-creeping-into-sc-coastal-groundwater-keeping-track-of-it/article_678e79d8-8c63-11e9-875e-5f954a1f7316.html

[47] Bo Petersen, "Drinking water for Charleston relies on round the clock federal watch to keep saltwater out ," July 8, 2019, *Post and Courier*: https://www.postandcourier.com/hurricanewire/drinking-water-for-charleston-relies-on-round-the-clock-federal/article_24aaf2cc-9131-11e9-81d2-67e2b5e34a23.html

[48] Robert Sanders, "Sinking land will exacerbate flooding from sea level rise in Bay Area," March 7, 2018: https://news.berkeley.edu/2018/03/07/sinking-land-will-exacerbate-flooding-from-sea-level-rise-in-bay-area/

[49] Coastal Heritage Magazine, John H. Tibbetts, editor, "Water Cities: Can We Climate-Proof the Coast?," Fall 2014: https://www.scseagrant.org/water-cities-climate-proof-the-coast/

[50] Charleston Water System, "Capital Projects": https://www.charlestonwater.com/158/Capital-Projects

estimates." [51] That population growth makes the updating of its drainage infrastructure even more challenging.

6. The potential economic impact is severe. As City of Charleston Resilience Officer, Mark Wilbert noted: "Charleston's port brings in $53 billion in economic activity and 200,000 jobs to the city. Resilience is also about protecting people as they carry on with their daily lives."[52]

   A report published in late 2018 concluded that cities like Charleston will face rapidly worsening conditions. "Charlestonians could see far stronger storms and the disappearance of shellfish habitat, according to a new broad-based review of climate change science."[53] The study was conducted by the United Nations' Intergovernmental Panel on Climate Change and concluded that the economic impacts on the entire state will be severe, including higher electric bills, dwindling oyster bed population and higher unemployment. "The region could lose $47 billion annually in wages by 2090" from these effects.[54]

   The impacts will also be further harmful to the environment. For example, the loss of the shellfish population has serious ramifications because they clean the water as they filter-feed. As Kirsten Dow, who studies climate change at the University of South Carolina noted about the United Nations study: "It's not surprising to hear at all that there are going to be serious impacts.[55] The economic impact of SLR could be immense, especially to the city's low-lying historic districts. ""These historic districts are important engines for the local economy."[56] In 2018 the greater Charleston area raked in 7.3 million visitors and record $8 billion in tourism-related economic activity."[57]

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[51] Linda Poon, "In Charleston, the Real Flooding Crisis Is Only Beginning," September 6, 2019: https://www.citylab.com/environment/2019/09/hurricane-dorian-charleston-flood-climate-change-high-tides/597475/

[52] [52] Environmental and Energy Study Institute, "Lessons in Resilience from America's Coastal Communities," citing Mark Wilbert, February 22, 2018: https://www.eesi.org/briefings/view/022218coastal

[53] Chloe Johnson, "5 ways climate change could alter life in SC after 2030," October 27, 2018, *The Post and Courier*: https://www.postandcourier.com/hurricanewire/ways-climate-change-could-alter-life-in-sc-after/article_743edeb4-d879-11e8-ad1f-b7a1ebf4a733.html

[54] Ibid

[55] Ibid

[56] Bo Petersen, "Salt creeping into SC coastal groundwater. Keeping track of it is the job of one person," June 10, 2019, *Post and Courier*: https://www.postandcourier.com/news/salt-creeping-into-sc-coastal-groundwater-keeping-track-of-it/article_678e79d8-8c63-11e9-875e-5f954a1f7316.html

[57] Linda Poon, "In Charleston, the Real Flooding Crisis Is Only Beginning," September 6, 2019, CITYLAB: https://www.citylab.com/environment/2019/09/hurricane-dorian-charleston-flood-climate-change-high-tides/597475/

7. Gentrification is technically defined as "the process of renovating and improving a district so that it conforms to middle-class taste."[58] Charleston has been the fastest-gentrifying city in the entire United States.[59] As a result, the median home price in Charleston rose 77.5% from 2000 to 2015; from $152,100 to $270,000.[60] Wealthier people moving into older neighborhoods raises property values and the cost of living in that area, eventually "pricing out" the less wealthy residents and challenging them economically.[61] They are often forced to move farther away from their jobs and schools.[62]

8. Income inequality is an additional factor. Charleston has historically had a severe gap between wealthy and poor residents and the problem has been worsening. "The gap between rich and poor in Charleston is widening, according to two new analyses of what people earn here, cementing a stubborn pattern of inequality in one of South Carolina's wealthiest and fastest-growing regions."[63] Few cities have experienced the gap between rich and poor residents expand faster than Charleston.[64]

9. Racial disparity widens the gap even further. The disparity is also apparent racially – with gaps in both income and economic opportunity – as reported in a study by the College of Charleston entitled "The State of Racial Disparities in Charleston County."[65] In that landmark report – the first of its kind – it concluded that "there is not a single indicator in which African-Americans' well-being is on par with that of white Charlestonians."[66] The area's gentrification fuels the racial disparity gap even further because then the less wealthy are often forced to move farther away from

[58] Kate Mosso, "Longtime residents speak out about gentrification of downtown Charleston at meeting," March 21, 2019, *ABC News 4*: https://abcnews4.com/news/local/longtime-residents-speak-out-about-gentrification-of-downtown-charleston-at-meeting

[59] Yuqing Pan, "The U.S. Cities That Are Gentrifying the Fastest – You'll Never Guess No. 1," January 23, 2017, realtor.com: https://www.realtor.com/news/trends/10-surprising-cities-that-are-gentrifying-the-fastest/

[60] Yuqing Pan, "The U.S. Cities That Are Gentrifying the Fastest – You'll Never Guess No. 1," January 23, 2017, realtor.com: https://www.realtor.com/news/trends/10-surprising-cities-that-are-gentrifying-the-fastest/

[61] Barbara Eldredge, "Charleston is the 'fastest-gentrifying' city in the U.S., says new report," January 30, 2017, curbed.com: https://www.curbed.com/2017/1/30/14431870/gentrification-cities-charleston

[62] Kate Mosso, "Longtime residents speak out about gentrification of downtown Charleston at meeting," March 21, 2019, *ABC News 4*: https://abcnews4.com/news/local/longtime-residents-speak-out-about-gentrification-of-downtown-charleston-at-meeting

[63] Thad Moore, "Charleston's income inequality gap is growing nearly as fast as Seattle's," April 26, 2018, *The Post and Courier*: https://www.postandcourier.com/business/charleston-s-income-inequality-gap-is-growing-nearly-as-fast/article_05484ea2-48c1-11e8-b5cf-f751b06d8b2a.html

[64] Thad Moore, "Charleston's income inequality gap is growing nearly as fast as Seattle's," April 26, 2018, *The Post and Courier*: https://www.postandcourier.com/business/charleston-s-income-inequality-gap-is-growing-nearly-as-fast/article_05484ea2-48c1-11e8-b5cf-f751b06d8b2a.html

[65] College of Charleston, "The State of Racial Disparities in Charleston County," May 15, 2019: https://www.postandcourier.com/the-state-of-racial-disparities-in-charleston-county/pdf_6966552e-772c-11e9-9735-1b8c23d83b94.html

[66] Ibid

where they work so that they can live more affordably.[67] Therefore, when the city experiences weather events such as "sunny-day flooding," low-income residents are more adversely affected – sometimes they can't get to work because of the road conditions, or get their children to school, making them even more vulnerable economically.

10. "Climigration", or climate-induced relocation, may be a new word to many, but in Charleston they know what it means because it is already happening. "What happens when climate change causes extreme events to become chronic, potentially rendering some communities unviable?"[68]

    Flooding issues in recent years have become so common in South Carolina that almost $1 billion dollars has been paid out under the National Flood Insurance Program.[69] That is because, at a certain point, it becomes more feasible for a state to buyout properties instead of replacing them.[70]

    An important consideration regarding climate-induced relocation is that "Climigration, whether managed or unmanaged, tends to favor people with greater financial means because moving is costly and often involves changes to employment, schools, medical services, child and elder care options."[71]

11. If SLR and increases in storm surge continue – as is predicted – Charleston will face enormous challenges.[72] "That prediction spells big trouble for many coastal cities, but especially ones like Charleston, whose stock of 18th-century homes and buildings are located in a vulnerable low-lying downtown."[73] Nowadays, it is not an uncommon sight

[67] Yuqing Pan, "The U.S. Cities That Are Gentrifying the Fastest – You'll Never Guess No. 1," January 23, 2017, realtor.com: https://www.realtor.com/news/trends/10-surprising-cities-that-are-gentrifying-the-fastest/
[68] Jeff Inglis, "'Climigration': when communities must move because of climate change," *The Conversation*, accessed December 20, 2019: https://theconversation.com/climigration-when-communities-must-move-because-of-climate-change-122529
[69] Chloe Johnson & Stephen Hobbs, "Charleston failed to properly identify flood damages, leaving homes and buyers unprotected," June 29, 2019, *The Post and Courier*: https://www.postandcourier.com/hurricanewire/charleston-failed-to-properly-identify-flood-damages-leaving-homes-and/article_8384ac3e-9771-11e9-a51e-bb617e99cc9b.html
[70] Jeff Inglis, "'Climigration': when communities must move because of climate change," *The Conversation*, accessed December 20, 2019: https://theconversation.com/climigration-when-communities-must-move-because-of-climate-change-122529
[71] A.R. Siders and Carri Hulet,"Climigration and the private sector" Federal Reserve Bank of San Francisco: Community Development Innovation Review. October 2019
[72] Global Climate Change, "Future of Charleston, South Carolina," accessed December 21, 2019: https://sites.google.com/site/gccclimatechange/the-future-of-charleston-south-carolina
[73] Linda Poon, "In Charleston, the Real Flooding Crisis Is Only Beginning," September 6, 2019, CITYLAB: https://www.citylab.com/environment/2019/09/hurricane-dorian-charleston-flood-climate-change-high-tides/597475/

during major surges to see kayakers paddling their way through the heart of the city's water-drenched historic district.[74] Recent history is a clear warning: "the onslaught of water that began with historic rainfall in October 15, colloquially called the '1000-year flood,' caught many off guard when it dropped more than 20 inches in some areas over four days. The next year, Hurricane Matthew brought more rain and surge before it landed as a Category 1 farther north on the coast. In 2017, Tropical Storm Irma set the third-highest record at Charleston Harbor's tidal gauge."[75]

[74] Coastal Heritage Magazine, John H. Tibbetts, editor, "Water Cities: Can We Climate-Proof the Coast?," Fall 2014: https://www.scseagrant.org/water-cities-climate-proof-the-coast/

[75] Chloe Johnson & Stephen Hobbs, "Charleston failed to properly identify flood damages, leaving homes and buyers unprotected," June 29, 2019, *The Post and Courier*: https://www.postandcourier.com/hurricanewire/charleston-failed-to-properly-identify-flood-damages-leaving-homes-and/article_8384ac3e-9771-11e9-a51e-bb617e99cc9b.html

ADAPTATION AND RESILIENCE MEASURES

People in Charleston are elevating their homes to avoid flooding and the City is dealing with elevation guidelines and permits.

1. In 2018, the city instituted a new Office of Resilience and Emergency Management. As Chief Resilience Officer for the City of Charleston (prior to that he was the city's Emergency Manager for four years), Mark Wilbert is well aware of its flooding problems. "In 2014, Charleston released a sea level rise strategy, which defined and explained the problems and laid out guiding principles."[76] "Be Ready, Respond, and Reinvest. "[77] Since the initial framework to meet the challenges of planning for sea level rise, the City has made more progress on its way to resilience.

   Their initiatives to promote readiness involve partnerships with other entities "because flooding does not recognize jurisdictional or political boundaries. In other words, Charleston realizes it is necessary to engage with local, regional and federal partners.

   Sharing knowledge and resources achieves the best results - promoting readiness, including prevention and preparedness, through continued planning, monitoring and identification of changing vulnerabilities and risks; Improvements in our ability to respond to flooding and related events, to minimize service disruptions and threats to

[76] Environmental and Energy Study Institute, "Lessons in Resilience from America's Coastal Communities," (citing Mark Wilbert), February 22, 2018: https://www.eesi.org/briefings/view/022218coastal
[77] Ibid.

public health and safety. Reinvestment in infrastructure and other physical assets to promote long-term public health, safety, and quality of life."[78]

2. Resilience measures in Charleston must preserve the cultural and historical environment and architecture that makes the city a historical icon that attracts millions of visitors a year.

3. According to Dan Burger, The Charleston Resilience Network (CRN) was established in 2014 from the Climate Vulnerability Assessment that came after Hurricane Hugo. CRN is a voluntary network of public and private organizations throughout Berkeley, Charleston, and Dorchester counties with a commitment to increasing resilience of communities, critical infrastructure, and socioeconomic continuity to episodic natural disasters and chronic coastal hazards. CRN is a combined effort to build community resilience by sharing information connecting partners and creating a unified strategy.[79]

4. As Dan Burger, founder and chair of the Charleston Resilience Network observed, the Dutch Dialogues taught us that a "living with water" approach implies risk assessment, prioritized intervention and continuous management for improvement. It also requires us to think beyond infrastructure and work towards a whole community approach, social, economic, physical and environmental. It implies looking at short, medium and long-term solutions. It entitles education, engagement, and action. It requires continuous learning and self-assessment across sector, organizations and partnerships.

5. The city has installed several large floodwater pumping stations that can handle a lot of water. But it takes a long time to drain the excess from the streets. As Charleston's Public Service Director, Laura Cabinnes, put it: "It'll handle a 10-year storm event – 6.8 inches of rain in a 24-hour period."[80] However, that statement was made back in 2014 – the problem has continued to worsen. So they have been working hard on expanding that drainage system.

6. FEMA funds are being used to build three large underground stormwater tunnels to capture and store water from flooded land. Also there is repurposing 10 mile tunnels built around 1850s to remove infected waste from the yellow fever epidemic in Charleston. Since these tunnels were not maintained, they are blamed for sinkholes in the downtown area. The city engineers are looking at the potential of these

[78] https://www.charleston-sc.gov/DocumentCenter/View/20299/Flooding-and-Sea-Level-Rise-Strategy-2019-web-viewing?bidId=
[79] http://www.charlestonresilience.net/
[80] Bobby Magill, "The Front Lines of Climate Change: Charleston's Struggle", January 9, 2014: https://www.climatecentral.org/news/the-front-lines-of-climate-change-charlestons-struggle-16934

historical archways to help lessen the heavy flooding events that are becoming more pervasive.

Using these tunnels as assets city engineers will work on one section as a test program. The plan involves: "Contractors will line and repair the tunnel, and tie it to the surface drainage. City officials say it should act like a huge pipe that drains stormwater from the road surface and sends it out into the marsh." [81] The repair costs are estimated from $1 million to $3 million.

7. In "Pathways to Resilience," Chief Resilience Officer Mark Wilbert laid out five major lessons about climate resilience:

   i. The first was land use. "Land use is crucial. It's critical to get the land use strategy right and make sure one only builds buildings where it makes sense to build buildings."
   ii. The next was Regulations. "One must get together with smart engineers and scientists and look at where the regulations really need to be."
   iii. Resources. "Charleston has committed $8 to $12 million a year to flooding and drainage issues, which is a large amount of money for Charleston. It is looking at the use of hospitality taxes/tourism to help fund flood protection. "
   iv. Outreach. "If you don't tell people what you're doing, you will be answering questions all the way. You need to get down to the personal level and meet with people; learn about their concerns and experiences."
   v. Wilbert's fifth major lesson about climate resilience was infrastructure. "Infrastructure is hard and expensive. How we get that money really matters and how we apply it and put it to work really matters."[82]

8. Experts have begun working with other cities and even other nations to study lessons learned; for example, looking at the Netherlands and how they have dealt with the challenges of catastrophic flooding for hundreds of years. In Holland, the construction of massive surge barriers – gigantic engineering marvels – is one of the things that have helped to "protect the nation's flood-prone estuaries from North Sea storms."[83] However, planners in Holland have realized that hard infrastructure spending will not hold off SLR forever. Therefore, they have embarked on a new strategy – they have begun complementing their "hard systems" for flood-control and storm-drainage with softer and greener infrastructures which some have called a "living with

[81] Historic underground archways beneath downtown Charleston repurposed to address flooding. Anne Emerson Friday, May 31st 2019 https://abcnews4.com/news/local/historic-underground-archways-beneath-downtown-charleston-repurposed-to-address-flooding

[82] Environmental and Energy Study Institute, "Lessons in Resilience from America's Coastal Communities," citing Mark Wilbert, February 22, 2018: https://www.eesi.org/briefings/view/022218coastal

[83] Coastal Heritage Magazine, John H. Tibbetts, editor, "Water Cities: Can We Climate-Proof the Coast?," Fall 2014: https://www.scseagrant.org/water-cities-climate-proof-the-coast/

engineered nature" plan. [84] "The Dutch have built extensive 'soft' or 'green' infrastructure as a way to make up for past damage. For instance, they have created or restored barrier islands and beachfronts to buffer high waves and winds. Behind those soft storm barriers, they have restored oyster reefs, wetlands, and forests for multiple functions: filtering and storing water, buffering storm energy, and offering wildlife habitat."[85]

9. South Carolina has learned a lot from the Dutch Dialogues, a program started in the United States after Hurricane Katrina hit and flooded New Orleans in 2005. This program focuses on research and design to create an all-inclusive strategy on how to deal with rising seas and flooding by embracing water instead of trying to build against.

10. In South Carolina the Dutch Dialogues guidelines recommended to the city of Charleston "to slow water, store it and then drain it; develop a master plan; update the city's comprehensive plan; reduce fill; engage private-sector leaders; improve coordination with regional governments; and offer stormwater credits" [86]

11. Officials throughout the City of Charleston and State of South Carolina are certainly cognizant of the coming problems and are in the planning process to meet future challenges. As Charleston Public Service Director Laura Cabiness observed, "Charleston is making smart choices, and officials are thinking about how the climate will affect the city 50 years from now and what's reasonable to act on now."[87]

12. The cost of implementing these adaptation and resilience measures keeps getting higher, so the City is looking for alternative finance means such as storm water fees and changing tax increment financing districts, a tool used to make public improvements and widely used in Charleston.

    Mayor John Tecklenburg "called flooding and drainage a challenge that's "nothing less than existential" and wants the state Legislature to create a way for Charleston to collect new fees from tourists — "including cruise ship passengers," he said — to help

[84] Ibid
[85] Ibid
[86] **Charleston Dutch Dialogues findings include pilot programs on East Side, limited development on Johns Island Mikaela Porter, The Post and Courier,** Sep 26, 2019.
https://www.postandcourier.com/business/real_estate/charleston-dutch-dialogues-findings-include-pilot-programs-on-east-side/article_dbf51bf2-df00-11e9-8808-e77bbbc7f040.html

[87] Bobby Magill, "The Front Lines of Climate Change: Charleston's Struggle," January 9, 2014, ClimateCentral.org: https://www.climatecentral.org/news/the-front-lines-of-climate-change-charlestons-struggle-16934

fund a solution. “To truly begin solving this problem, we simply must ask our city’s 8 million-plus annual visitors ... to help save the city they love,” [88]

South of Broad known for the 19th-century Rainbow Row, a hot tourist spot. Tour business offers to tour historic downtown on a horse-drawn carriage.

[88] Charleston mayor’s cruise ship ‘head tax’ gets pushback from SC Ports Authority.
By David Wren https://www.postandcourier.com/business/charleston-mayor-s-cruise-ship-head-tax-gets-pushback-from/article_95994622-3d67-11ea-b74d-03b1b82bf12d.html

BOSTON, MASSACHUSETTS

Our group next visited Boston and met with key city employees and community organizations on October 4 and 5. The Barr Foundation hosted our meeting. We learned about various government, community and private resilience efforts taking place, including Climate Ready Boston, the Boston Green Ribbon Commission, climate mitigation and resiliency efforts by the Massachusetts Port Authority, The Harborkeepers organization, the coordinated watershed efforts by Mystic River, coastal flood modeling, climate and water management by the Massachusetts Water Resources Authority and Boston Water and Sewer Commission.

Kalila Barnett, Program Officer, of Climate Resilience, and Jill Valdés Horwood, Director of the Boston Waterfront Initiative at the Barr Foundation were instrumental in helping us set up our meetings at theirs offices and helping us to connect with key leaders in climate resilience in Boston and Cambridge. They also connected us with Boston Harbor, a nonprofit dedicated to reaching Boston Harbor's potential to benefit their city and region through partnering with community leaders, public agencies, businesses and other non-profits.

The Boston Harbor Now organized a 7-mile Harbor walk from Neponset River Park through the South Boston Waterfront and Dorchester, ending in Moakley Park. Our group participated in the walk; we were very fortunate to meet and talk to some of the Barr Foundation grantees and learn about their community efforts on climate, social, economic and educational resiliency.

We also joined the Historic Harbor Cruise and learned about how Boston Harbor was transformed from being one of the most polluted, with raw sewage discharges, loads of pesticides, and heavy metals, into one of the cleanest harbors in the country.

Hawai'I Delegation and Boston counterparts at the Barr Foundation. Peter DeBruin & Kathy Ledoux – presentation on Climate Mitigation & Resiliency, Massachusetts Port Authority.

Julie Wormser, Mystic River Watershed Association, Katia Balassiano, Land Use Permits Division, C&C Honolulu Department of Planning & Permitting and Magdalena Ayed, Harborkeepers community organization

The Hawaii delegation participated in the 7-mile Harbor walk from Neponset River Park through the South Boston Waterfront and Dorchester, ending in Moakley Park. This event was organized by The Boston Harbor Now organization and supported by the Barr foundation.

Key Boston Counterparts:

- Bud Ris, Boston Green Ribbon Commission, Climate Ready Boston
- Peter DeBruin, Climate Migration & Resiliency Manager, Massachusetts Port Authority
- Kathy Ledoux, Massachusetts Port Authority
- Julie Wormser, moderator, Mystic River Watershed Association

- John Bolduc, Cambridge Community Development Department
- Olivia Sellers-Garcia, Somerville Office of Sustainability and Environment
- Austin Faison, Winthrop Town Manager
- Rebecca Herst, UMass Boston Sustainable Solutions Lab
- Magdalena Ayed, Harborkeepers
- Kirk Bosma, Woods Hole Group

BACKGROUND

Boston Harbor and Aquarium underground station with water leaks. The Station has many entry points for water and fixing it will cost millions of dollars.

Deer Island Wastewater Treatment Plant. The plant is operated by the Massachusetts Water Resources Authority (MWRA). It is the second largest treatment plant in the United States. The plant removes all kinds of household and business pollutants in 43 greater Boston communities.

New elevated developments around the Boston harbor. Boston is especially vulnerable to rising sea levels and extreme storms known as nor'easters. Regardless of increasing hazard of storm surge and chronic flooding, the city is experience new coastal development.

The sea level off the coast of Massachusetts is 8 inches higher than it was in 1950.[89] SLR continues to deliver increasing storm surges into coastal cities. "In Boston, the most persistent reminder comes in the form of regular "nuisance" flooding — when seawater spills onto roads and sidewalks during high tides. Those nuisance events are harbingers of a wetter future, when extreme high tides are predicted to become a daily occurrence."[90]

In order to reduce climate risks, way back in 2007, Thomas Menino, Boston's Mayor issued an Executive Order directing each city department to assess their risks from climate change. Each city department conducted a vulnerability assessment and the city used those assessments to inform community planners and integrate climate change vulnerabilities in their Natural Hazard Mitigation Plan.[91]

[89] SeaLevelRise.org, "Massachusetts Sea Level Is Rising: And It's Costing over $1 Billion, accessed December 31, 2019: https://sealevelrise.org/states/massachusetts/

[90] Science News, "With nowhere to hide from rising seas, Boston prepares for a wetter future," August 17, 2019: https://www.sciencenews.org/article/boston-adapting-rising-sea-level-coastal-flooding

[91] City of Boston, "Climate Ready Boston: Final Report," December 2016: https://www.boston.gov/sites/default/files/embed/2/20161207_climate_ready_boston_digital2.pdf

CHALLENGES AND OPPORTUNITIES IN BOSTON

Bud Ris presenting an overview and Introduction of Boston Green Ribbon Commission and Climate Ready Boston. "WE'VE TACKLED SOME BIG PROBLEMS BEFORE…"

1. Since 1950, the sea level off the Massachusetts coast has risen 8 inches. Sea level has risen 28 centimeters (11 inches) in the past 100 years.

2. SLR is increasing rapidly. "I'ts speed of rise has accelerated over the last ten years and it's now rising by about 1 inch every 8 years."[92] "Around Boston, it took 36 years for the sea level to rise around 6 inches. Scientists now forecast that in the next 15 years, the sea will rise by another 6 inches."[93]

3. Flooding already occurs even without the presence of rain. "Flooding during extreme high tides, when there's no storm in sight, already happens in East Boston, Charlestown and the downtown waterfront."[94]

[92] SeaLevelRise.org, "Massachusetts Sea Level Is Rising: And It's Costing over $1 Billion, accessed December 31, 2019: https://sealevelrise.org/states/massachusetts/
[93] SeaLevelRise.org, "Massachusetts Sea Level Is Rising: And It's Costing over $1 Billion, accessed December 31, 2019: https://sealevelrise.org/states/massachusetts/
[94] Science News, "With nowhere to hide from rising seas, Boston prepares for a wetter future," August 17, 2019: https://www.sciencenews.org/article/boston-adapting-rising-sea-level-coastal-flooding

4. While Boston's official elevation is 14 meters above sea level, many of its lowest areas sit directly at sea level, making them very vulnerable.[95]

5. The shallow topography of the Boston area makes it additionally vulnerable. "New England and the eastern shore of Canada have a unique combination of geographic factors that push water farther inland in response to high tides: The region's shallow seafloor topography tends to funnel water higher inland, and its proximity to the Gulf Stream — a major ocean current that runs from the Gulf of Mexico up along the East Coast — also helps magnify tides."[96]

6. Much of the city was built on landfill, also making it more susceptible to high tide flooding. Established in the 1600s, Boston was built 2 feet above high tide. But sea level has risen 11 inches in just the past 100 years and is forecast at 40 inches by 2070.[97]

7. Landfill further complicates the issue of land subsidence in the Boston area as the taking on of water under the surface further increases the weakening of structures above.

8. As Julie Wormser of Mystic River Watershed Association has observed, parts of Boston – particularly it's transportation tunnels and other below-grade infrastructure – are at serious risk of damage from the increasing saltwater intrusion.[98]

9. Those huge "Big Dig" tunnels are a key vulnerability because they are the city's main transportation arteries but were not designed to tolerate flooding. As noted by Ellen Douglas – a hydrologist at the University of Massachusetts Boston and member of BRAG (Boston Research Advisory Group): "Perhaps the biggest challenge is to keep the Big Dig highways open for traffic while protecting the tunnels from flooding. You can't just close off the tunnels. They are important evacuation routes during emergencies, but they were not built to tolerate any amount of flooding."[99]

10. Hurricane Sandy in 2012 was true "wake-up call." Across the board, city and state officials, scientists and planners realized that they were very lucky in not being hit

[95] Science News, "With nowhere to hide from rising seas, Boston prepares for a wetter future," August 17, 2019: https://www.sciencenews.org/article/boston-adapting-rising-sea-level-coastal-flooding
[96] Science News, "With nowhere to hide from rising seas, Boston prepares for a wetter future," August 17, 2019: https://www.sciencenews.org/article/boston-adapting-rising-sea-level-coastal-flooding
[97] Barry Usagawa, "Sea Level Rise Tour Report," September 30-October 5, 2019
[98] Julie Wormser, "Preparing for a shrinking Boston: Resilience should be goal, resistance is futile," March 26, 2017, CommonWealth Magazine: https://commonwealthmagazine.org/environment/preparing-for-a-shrinking-boston/
[99] Science News, "With nowhere to hide from rising seas, Boston prepares for a wetter future," August 17, 2019: https://www.sciencenews.org/article/boston-adapting-rising-sea-level-coastal-flooding

directly by the hurricane and that if they had, the effects would have been catastrophic.

11. Boston sits directly in the path of coastal winter hurricanes and storms, which are increasing in both intensity and in frequency. It also encounters many superstorms, known colloquially as "nor'easters," which are technically "extratropical cyclones" that can cause as much storm surge and flooding as a hurricane. "There are around three strong nor'easters every winter, 15 times as frequent as hurricanes — plenty of opportunity for repeat flooding disasters."[100]

12. The potential economic impact is extreme. "Boston is ranked eighth worldwide for expected economic losses due to coastal flooding, estimated at $237 million per year in 2005 and $741 million annually by 2050, according to a 2013 study in Nature Climate Change*."*[101]

13. Gentrification and displacement are important issues in Boston. For example, in the predominantly black neighborhood of Roxbury, real estate prices are rising and traditional residents are being economically forced out. Record-breaking real estate prices and racialized gentrification are displacing people rapidly. "Ask anyone in Boston, 'what's going on in Roxbury?' and the word you're most likely to hear is gentrification. Ask that same question in the predominantly Black neighborhood of Roxbury, and the word you're probably going to hear is displacement.

    These two responses both say something important about what's happening in Boston as well as in other cities across the nation."[102] MIT graduate Isabelle Anguelovski, who co-directs the Barcelona Lab for Urban Environmental Justice and Sustainability, argues that "while [Boston] seems committed to inclusive planning ... we have not heard much about climate gentrification or the risk of mid- to long-term displacement of socially vulnerable residents. In an interview, Anguelovski warned the city's efforts could result in a 'climate resilience crisis' that leads to large-scale displacement of poor residents. "Boston has to radically change the way it's doing urban greening, together with affordable housing, to be able to avoid this."[103]

14. Moakley Park is one of the largest and most-used green spaces in the Boston area. It has 60 acres of South Boston waterfront and boasts an impressive array of athletic

[100] Eric Holthaus, "Nor'easters are now just as dangerous as hurricanes," March 2, 2018: https://grist.org/article/boston-noreaster-hurricane-like-winter-bomb-cyclone/
[101] Science News, "With nowhere to hide from rising seas, Boston prepares for a wetter future," August 17, 2019: https://www.sciencenews.org/article/boston-adapting-rising-sea-level-coastal-flooding
[102] Zebulon Miletsky & Tomas Gonzalez, "How Gentrification and Displacement are Remaking Boston," November 28, 2017: https://www.aaihs.org/how-gentrification-and-displacement-are-remaking-boston/
[103] https://www.wbur.org/earthwhile/2019/05/02/moakley-park-east-boston-climate-resiliency

facilities – making it a very popular place. Its problem is that it is very prone to stormwater flooding. But that problem is being addressed. "Instead of just trying to fight stormwater and tidal flooding, the design seeks to manage the water with a series of berms, structural elevations and underground basins designed to keep water from overcoming the park's boundaries."[104] "The redesign will change all that, turning Moakley Park into what the city describes as 'a world-class, climate-resilient waterfront park for all.'"[105] Researchers at the Autonomous University of Barcelona say they've produced the first analysis of "green gentrification" underway in the city. In still-unpublished data shared with WBUR, the researchers show a correlation between new green spaces on one hand and, on the other, neighborhoods becoming wealthier, more educated and whiter.

ADAPTATION AND RESILIENCE MEASURES

1. To their credit, before many other cities, the City of Boston embarked on a serious strategic plan to deal with the inevitable effects of SLR. Ever since they escaped the potentially catastrophic effects of 2012's Hurricane Sandy, they have been acknowledging, addressing and planning for what they now know is necessary. Boston has adopted a strategy of "living with water" which includes adapting in-place structures to potential flooding.

2. Funding the necessary improvements is something that Bostonians and the entire State of Massachusetts have not shied away from. "The cost of adaptation is daunting; estimates range into the billions of dollars over the next 50 years. In April, Boston Mayor Martin Walsh pledged 10 percent of the city's $3.49 billion capital budget in 2020 to fund resiliency projects, such as raising major roadways and replacing existing concrete structures and pavement along coastlines with floodable green spaces."[106]

3. Boston has been adapting its wastewater treatment facilities to sea level – raising them to avoid inundation. That raising has been expensive but, as in the case of the Deer Island Wastewater Treatment Plant, it has "avoided extensive costs associated

[104] Simón Ríos, "As Boston Pursues Climate Resilience, Some Warn Efforts Could Make Inequality Worse," May 2, 2019: https://www.wbur.org/earthwhile/2019/05/02/moakley-park-east-boston-climate-resiliency

[105] Simón Ríos, "As Boston Pursues Climate Resilience, Some Warn Efforts Could Make Inequality Worse," May 2, 2019: https://www.wbur.org/earthwhile/2019/05/02/moakley-park-east-boston-climate-resiliency

[106] Science News, "With nowhere to hide from rising seas, Boston prepares for a wetter future," August 17, 2019: https://www.sciencenews.org/article/boston-adapting-rising-sea-level-coastal-flooding

with building a seawall and covered the projected vulnerability over the planned life of the facility (through 2050)."[107]

4. Protecting wetlands has become an established priority. Wetlands serve the public interest in many ways: protection from flooding, prevention of storm damage, pollution, protection of public and private water supplies, groundwater supply, fisheries, land containing shellfish and the protection of wildlife habitat.[108]

   The city and state have been cognizant of wetlands protection for many years and strictly regulate what can and cannot be constructed near them through the Wetlands Protection Program. "Massachusetts has one of the most restrictive wetlands and environmental codes in the U.S. Simply put you cannot do *anything* — not clear, cut, fill, dump (not even leaves, grass clippings or dirt), alter, grade, landscape or build upon — any wetland resource area without a permit from your local town Conservation Commission."[109]

   Although a booming real estate market in Boston has made it difficult to fight development, the city has stood its ground and has made efforts to even strengthen existing wetlands protection regulations. "At the urging of groups like the Boston Conservation Commission, the rules would be another tool in the city's growing arsenal against the effects of climate change."[110]

5. MassDOT (Massachusetts Department of Transportation), in conjunction with the Woodshole Group, created a dynamic high resolution probabilistic hydrodynamic climate models that details probabilistic flooding and represent the various scenarios for SLR and storm surge from a nor'easter.[111]

   According to Kirk Bosma, their model shows probabilities of flooding, duration, how long the flooding lasts and in what areas, depths, waves, flood paths, volumes, currents and even dam operations and other information that can help prioritize and design of resilience options. The high- resolution models allows us to see at the street level for specific types of assessments of where the water goes, the water level, waves,

[107] EPA Climate Change Adaptation Resource Center, "Boston Raises Wastewater Facility to Avoid Inundation," 2013: https://www.epa.gov/arc-x/boston-raises-wastewater-facility-avoid-inundation
[108] Mass.gov, "Protecting Wetlands in Massachusetts," accessed January 2, 2020: https://www.mass.gov/guides/protecting-wetlands-in-massachusetts
[109] Rich Vetstein, "Wetlands, Swamps and Buffer Zones: A Primer on Massachusetts Wetlands Protection," May 20, 2011: https://massrealestatelawblog.com/2011/05/20/wetlands-swamps-and-buffer-zones-a-primer-on-massachusetts-wetlands-protection-law/
[110] Andrew Morrell, "Development restrictions proposed to protect Boston wetlands," February 11, 2019: https://bostonagentmagazine.com/2019/02/11/development-restrictions-proposed-protect-boston-wetlands/
[111] MassDOT, "Pilot Project Report: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options for the Central Artery, June 2015: https://www.mass.gov/files/documents/2018/08/09/MassDOT_FHWA_Climate_Change_Vulnerability_1.pdf

currents, winds, etc. In order to run all these simulations, they need 3 to 4 supercomputers. These models could provide accurate baseline information to provide key factors for developing cost effective designs and climate adaptations.

Mapping out the best possible use of resources to respond to increasing SLR, computer-modelling offers a valuable tool for planners, city and state officials and scientists. The result from probabilistic models are used to calculate risk for properties throughout the City of Boston. These models also provide adaption options to diminish vulnerabilities and to establish an emergency response plan for tunnel protection and/or shutdown. The model include climate scenarios coupled with storm surge and sea level rise for present-day, as well as 2070 and 2100.

6. The City of Boston's first climate resilience plan in 2016- "Coastal Resilience Solutions for East Boston and Charleston"- outlined "near and long-term strategies to protect vulnerable neighborhoods from flooding. It's the first neighborhood-specific application of the Climate Ready Boston framework, the City of Boston's ongoing initiative to adapt to climate change."[112]

7. Another major study – "Governance for a Changing Climate: Adapting Boston's Built Environment for Increased Flooding" – was released by the University of Massachusetts Boston in September 2018. It made several important recommendations - among them are:

    a. Reform existing tools; adapt existing buildings to improve their resilience. Ensure that new buildings are built to be resilient to the future flood conditions predicted. Construct new coastal flood protection measures. Create co-benefits related to stormwater management and sustainability.
    b. Establish an Infrastructure Coordination Committee
    c. Convene a Climate Research Advisory Organization
    d. Establish Governance for District-Scale Coastal Flood Protection
    e. Regarding the question of whether we have to do something new or reinforce what we already have, the study reached the conclusion that Boston needs to do both; that "an acceptable level of resilience can be achieved only if Boston is able to do both – renovate and innovate."[113]

[112] Stoss Landscape Urbanism, ""Coastal Resilience Solutions for East Boston and Charleston," 2016: https://architizer.com/projects/coastal-resilience-solutions-for-east-boston-and-charlestown/

[113] Sustainable Solutions Lab, University of Massachusetts Boston, "Governance for a Changing Climate: Adapting Boston's Built Environment for Increased Flooding," September 2018: https://www.greenribboncommission.org/wp-content/uploads/2018/09/Governance-for-a-Changing-Climate-Full-Report-UMB-SSL-1.pdf

8. In October 2018, Boston's second climate resilience plan was released: "Coastal Resilience Solutions for South Boston." It's 21-page Executive Summary details a wide range of concerted efforts being made to mitigate the effects of SLR and climate change and to protect the city's waterfront.[114] "To protect the South Boston community, jobs, and infrastructure, coastal resilience solutions across South Boston combine existing green spaces and built water management systems with new open space intended to be expanded over time. These measures include elevated waterfront open spaces and HarborWalk, reinforced structures and piers, flood walls, dunes, and a living shoreline that will grow and change over time."[115]

9. Instead of relying on massive infrastructure programs like gigantic sea walls that will not hold off SLR forever, scientists and city and state planners have concluded that a more productive use of resources is a broader and "greener" approach. "Shore-based solutions that buffer against high tides and storm surges make more sense, the analysis found. Nature-based coastal adaptations such as parks and wetlands that can absorb the flooding are not only effective but also bring added benefits such as native habitat restoration, tourism and recreational opportunities."[116]

10. When combined with reforming existing tools to make the existing infrastructure more resilient, "greener" planning will also allow for flexibility in the future. The ability to adjust; "As much as possible, we're using nature-based solutions that are flexible and can be adjusted over time to conditions depending on what happens with sea level rise."[117]

[114] Boston.gov, "COASTAL RESILIENCE SOLUTIONS FOR SOUTH BOSTON," October 2018: https://www.boston.gov/sites/default/files/imce-uploads/2018-09/climatereadysouthboston_execsum_v9.1s_web.pdf

[115] PreventionWeb, "Coastal Resilience Solutions for South Boston," October 2018: https://www.preventionweb.net/publications/view/62431

[116] Science News, "With nowhere to hide from rising seas, Boston prepares for a wetter future," August 17, 2019: https://www.sciencenews.org/article/boston-adapting-rising-sea-level-coastal-flooding

[117] Science News, "With nowhere to hide from rising seas, Boston prepares for a wetter future," August 17, 2019: https://www.sciencenews.org/article/boston-adapting-rising-sea-level-coastal-flooding

LESSONS LEARNED

Trip participants had many valuable and concrete takeaways from their experiences. Below are listed some of the learning outcomes from the delegates. This information was gathered from the takeaways at the Focus Conference on October 15, 2019 (video tape available), interviews, notes, conversations and reports, and also from a debriefing meeting on November 25th.

COLLABORATION, EDUCATION, AND OUTREACH:

1. The trip helped me understand how important collaboration among government agencies, private sectors, philanthropic organizations and communities are for climate resilience and adaptation.

2. Collaboration among stakeholders is critical. There is not a single agency or organization or person that has all the answers regarding adaptation to climate change. Input from the community is key. That is why it's important to create public awareness and find more opportunities to engage the public with a consistent message.

3. We learned that local non-profit organizations and Foundations such as Barr Foundation, the Charleston Resilience Network, Climate Ready Boston, Harbor Keepers and the Cleo Institute are helping catalyze action, advance solutions and increase leadership, awareness and equity issues related to climate change and resilience.

4. I was impressed with the cities' commitment to climate education and the outreach programs they have. They really simplified it into a few sayings. They showed maps of old Charleston and old Boston and explained that water wants to go where water was. Large parts of those cities were actually filled in and those are the areas that are flooding. I was very impressed with how they described it, through charts at different levels at different ranges, the walk-through water, the walk around water, the drive through water, in terms of how they inform people of different levels.

5. Community organizations and foundations should be invited to and involved in the conversations regarding adaptation.

SOCIAL EQUITY AND GENTRIFICATION:

1. Social inequities, such as lack of affordable housing, transportation, and poverty are exacerbated by climate change. Policies in climate adaptation should be guided by all stakeholders, particularly by the most vulnerable.

2. We learned that climate gentrification is latent in the cities visited. In Miami is occurring in higher elevation areas. Education is the best way to address equity issues of climate gentrification, so residents in higher elevation areas are not tricked to sell their properties and can make the best decisions regarding their future "with their eyes wide open."

3. We learned that the city of Charleston is developing an app to help residents and business owners know where and when nuisance flooding is occurring and the mobility impacts they may have.

4. Financially disadvantaged communities may be affected by SLR-induced flooding due to limitations to relocate, elevate, or harden personal property without some form of assistance from government or philanthropic organizations.

5. Visiting the cities, I learned an important part about social impacts: those at a disadvantage are impacted the greatest. Those at a disadvantage have a more difficult time addressing the issues and actually being more adaptive and resilient to that situation.

6. We visited some areas that represented not the highest level of financial means. Having some of those people talk to us and make some comments about them, waiting for the city of Miami to do something about the problem. I think it is very reflective of how the public views these issues, regardless of whose fault it is or what people can do to address it. I think it will always fall upon the government, whether it will be at the city level, state or federal.
7. I learned that social challenges present opportunities. Right now in the city of Honolulu we have many different measures to complete streets to make sure there is equity and mobility so people who want to walk or bike can have that opportunity; we are not favoring cars.
8. While coastal erosion and wave run-up are serious effects of SLR, tidal inflows impacting storm drain systems may affect more people by unexpected flooding of streets and neighborhoods.

INFRASTRUCTURE ADAPTATION AND HOW TO PAY FOR IT, STORMWATER FEES AND FEMA:

1. Now I am not as intimidated at thinking about SLR and how it affects our infrastructure. Before, I wanted to turn a blind eye because it is daunting to think about how our facilities will be impacted and how do we possibly protect them with the given system in place and limited amount of funds?

2. We learned that having a stormwater management plan is essential. Infrastructure vulnerability assessments and functional plans that drive capital improvement plan (CIP) and annual budget action is essential to address climate and SLR impacts.

3. Stormwater fees (flat fee, no credits for reduced impervious surface, works well in affluent communities) pay for raising streets, but not raising utilities. Underground utilities required in watertight lines underground in new neighborhoods.

4. We learned how streets were lifted and how that was funded. Streets were lifted because of existing flooding, not necessarily before. I was interested as far as infrastructure, especially in how they go about lifting streets. We found out that Miami is very similar to Honolulu – very flat, the geology is very porous – a lot of the flooding actually comes up from the ground, as well as from the drains.

5. Their maintenance crews appeared to have put thought into "hardening" their facilities focusing on the pump stations and base yards. Although the tidal change is huge for Boston on a daily basis, Florida seems heavily impacted by dry weather flooding. I was impressed that they're actually raising the roads and putting in pump systems to drain the area.

6. We learned from our SLR trip that everyone is resource constrained. We also learned that various projects seek funds from the Federal Emergency Management Agency (FEMA), the Department of Homeland Security (DHLS), State, City & private funding and do a few adaptation plans & projects every year rather than wait until it becomes critical.

7. I was very impressed with how they did their cost benefit analysis of what it would cost to have no action, as well as different adaptation strategies.

8. Miami-Dade County Resiliency Plan outcomes included: Design Guide for Coastal Water Waste Treatment Plants, Design Guide for Water Waste Pump Stations, saltwater intrusion timeline for water supply planning, storm surge/event flooding model for other facilities, commitment to incorporate SLR in all infrastructure, and

plan for a marginal capital cost of 5% of project cost for adaptation measures Benefit Cost Analysis (BCA).

9. We learned that stormwater fees are used to raise revenue to address stormwater and tidal flooding issues. The definition of "stormwater" is broadly applied to include ocean water because of tidal flooding. This supports a "one water" approach to the idea of stormwater fee. The city of Miami Beach for example, is using revenue raised from water fees to pay for raising roadways and installing pump stations. Charleston has similarly use revenues from its stormwater fee to strategically install stormwater pump stations that address both tidal flooding and rainfall.

10. We learned about the importance of stormwater fees. Major flood mitigation projects are being funded in-part by existing and increased stormwater fees. The development of a stormwater fee is very timely for Honolulu but needs to consider more than just water quality permit compliance. Charleston created both a Stormwater Department and a Floodplain Manager position in late 2018 in recognition of the need for new, focused, and dedicated work. Miami Beach is conducting its road raising and pump projects via its stormwater fee and bonds.

11. The trip helped refine the actions for SLR in Hawaii; the cities that we visited have more experience dealing with floods and SLR and they are a few steps ahead. The trip helped give perspective to a daunting task, such as adaptation of the Water Waste Treatment Plant.

12. There was discussion on our trip regarding budget evaluation. We already spend a lot of money on a lot of things, but what is our system for evaluating budgets and projects for consistency with and toward implementation of climate resilience goals? Utility fees are great for investments, operations, and maintenance of those systems, but shared resources across departments for capital projects are good/needed. Multiple water utilities stated they "don't have to have a Climate Change budget"; they have an operating budget for maintenance and short-term actions, and a capital budget for major rehab of facilities with new parameters based on Resilience Design Guidelines and working with the best available science and projects. We need to pursue budget ideas in the "Implementation" section of the Resilience Strategy.

13. Utilities have a role as leaders in technical and technology analyses for resiliency. Adaptation strategies may be very capital and energy intensive with long lead times. However, utilities cannot plan for climate change in isolation – forecasting future habitability on a metropolitan or regional scale is uncharted territory.

14. Multiple water utilities stated they "don't have to have a Climate Change budget," they have an operating budget for maintenance and short-term actions, and a capital

budget for major rehab of facilities with new parameters based on Resilience Design Guidelines and working with the best available science and projects.

15. Many of the agencies in Miami and Charleston didn't take into account the effects of the underground utilities, except Boston.

16. Miami and Miami Beach - The City is paying for raising streets in certain areas, but then the first floor of a building becomes the basement and this creates insurance issues, so the City still needs to change building/zoning so that property owners aren't penalized.

17. Raised streets require that sidewalks are at least 8 to 10 feet wide, with each section (raised and sunken) at least 4 feet wide, so that the sections don't feel too narrow and there's room for pedestrian safety (like fences to prevent falling or landscaping). As the sidewalk width increases, the vehicle path in the row.

18. I want to learn more from Miami, i.e. who will pay for maintenance, fencing, landscaping, etc.? If the storm exceeds stormwater system capacity or the drain is clogged, the building may flood because it's lower than the street.

19. Miami is creating an extensive stormwater pump system. Pumps are designed for lifespans of 15-20 years. Above the earth, these systems are relatively large, smelly, and need extensive security and landscaping. They are located in odd (sometimes not so good) places – wherever the City owns land. Stormwater fees (flat fee, no credits for reduced impervious surface, works well in affluent communities) pay for raising streets, but not raising utilities; underground utilities required in watertight lines underground in new neighborhoods. Stormwater projects/priorities chosen based on where flooding occurs regularly on streets. Streets raised to correspond with 3.7 feet of SLR. Department of Transportation funds created extensive dune system along Miami Beach. Dunes now naturally grow and shrink. They are roped off to prevent pedestrian traffic.

20. Concessions on beaches must meet standards (everything removed at night). Sand was initially pumped onto beach from offshore, but now it's trucked in from central Florida. Miami's Form-based Code is about 10 years old. It still requires that all other codes be in use for nonconformities. The Code needs to be revisited because it doesn't account for SLR. The City wants to change how height is measured: raising buildings for FEMA, plus SLR, plus freeboard, should not count against zoning height.

21. Shoreline regulations require a 50-foot setback plus 25 feet for public access. Very concerned about mangrove preservation as a way of reducing winds and storm surge.

22. In Boston, the city prefers berms and buffers instead of sea walls, but "wharfing out" (creating fill land) for new buildings still appears popular, and seawalls appear prevalent

23. The Water Waste Treatment Plan in Miami is under EPA consent decree to upgrade its treatment components. I learned that the three treatment plants in Florida are all on the coast. Being raised/hardened, no retreat planned. While raised plants may be okay, issues remain regarding access; how staff will reach plants if roads are under water. Is anticipating SLR with storm surge to total 25 feet.

24. Building resilience is an ongoing process but a lot of the infrastructure maintenance requires knowing what to do now.

PROACTIVE VERSUS REACTIVE MEASURES:

1. My main takeaway is that Honolulu is trying to be proactive – most of the lessons learned were following an event, or repeated extreme events (all), and/or regular disruption from high tide flooding (Miami Beach and Charleston).

While we've had extreme localized flooding events and are disrupted from high tide flooding in Mapunapuna, these severe events and stresses are not well-understood island-wide and have not yet directly affected a majority of individuals, businesses, etc. We have the information and can project the issues that we'll face and should take actions. Such interventions have long lead times for planning and design and must be acted upon now. There will be an inflection point where the flooding curve slope moves too fast for our planning, design, and construction, to be able to address the problem in an intentional manner, or a large shock will occur that could have been mitigated.

DATA, COMPUTER MODELS AND MESSAGING:

1. I learned about how important it is to have consistency of data, messaging, web maps – the cities have established policies that set the standard for public projects and private projects, along with guidelines and zoning informed by the data; this is very important.

2. I was very impressed with Boston's computer model. It was very impressive. I would like to take a look at implementing something like that for Honolulu. If we can partner with Dr. Fletcher and the modeling he's already done as a basis, Department of Environmental Services (ENV) could help fund such an effort.

3. I learned from the trip the importance of developing common vernacular across departments, with training and support, and are using the same information and data. There is concerted emphasis on messaging. However, it is insufficient to just present the issue; we must connect solutions with the information extended. Fear is not a good motivator; information alone won't lead to action.

4. In Charleston, "Trauma aware risk communication" - SLR heightens anxiety. Storms and flooding already have people on edge. They are considering partnering regularly with mental health workers at public events.

5. The enhanced "coastal data" map viewer being developed by the City and County of Honolulu Office of Climate Change, Sustainability and Resiliency (CCSR) and The Honolulu Land Information System (HoLIS) consolidates disparate data sets and web viewers in one inclusive web tool for City staff to use and to serve as a public facing resource and private applicants' use (e.g., Climate Ready Boston Map Explorer and Boston Redevelopment Authority Zoning Viewer Climate Resiliency Layer).

VALIDATION FROM OTHER LOCATIONS OF OUR LOCAL EFFORTS:

1. The trip helped validate what we are trying to do here in Hawaii. It also reassures us that we are not alone in our adaptation efforts.

2. It was good to learn that other agencies are a few steps ahead of us, so I don't have to feel so alone in having to tackle our problems.

3. There is a lot of information available on the web that relates to coastal flooding and sea level rise. But the value of the trip came down to hearing comments and being able to ask questions. I had face-to-face conversations with officials and people that have studied this problem and have addressed it for quite some time.

4. I learned that it is very important "to study the past when planning for the future."

5. The trip helped elevate the level of the conversation among the key agencies participating here in Hawai'i.

FLOODING AND SEA LEVEL RISE:

1. I learned that the extent of the flooding there was pretty dramatic. In Charleston in January there were like 19 days that the streets are flooded more than a foot. By 2050, the streets will be flooded with more than a foot of water. This is a huge problem.

2. The flooding is extensive in Charleston, Certain streets are closed 50-70 days per year because of sunny day flooding, e.g., king tides, etc. pour up through the storm drains, canals overflow. This adversely impacts access to schools, businesses, hospitals – so a variety of resulting economic impacts.

3. Community and business impacts of nuisance flooding from sea level rise are much broader in some East Coast cities than in Honolulu.

4. "Nuisance flooding" causes damage to infrastructure. They recommend to construct improvements now because once flooding is more regular, construction will take longer and cost more. Charleston has a Stormwater Department that is separate from DPW, with a position dedicated solely to floodplain management whose role it is to promote natural floodplain functions and reduce and mitigate flood loss. Charleston has a population of 150,000. Updates their Comprehensive Plan every five years. Has 30 staff in Planning Department. Has urban growth boundaries and maximum heights that reflect City's history. Property is more valuable because of boundaries and height limits. Conducts design review for almost every project. Has guidelines for elevating homes. Retrofits must honor existing architectural character. Will not raise streets because of historic preservation issues. Wants to create TDR (Transfer of Development Rights) based on Manhattan model, but is not confident it will work. Knows that TDR doesn't work anywhere. Strong property rights for State, little support from State for SLR/climate change issues.

5. Certain streets are closed 50-70 days per year because of sunny day flooding, e.g., king tides, etc. pour up through the storm drains, canals overflow. This adversely impacts access to schools, businesses, hospitals – so a variety of resulting economic impacts.

6. They cannot "pump and pipe" all the water out – there's too much of it. Need to buy out "a couple of hundred" homes to make room for stormwater systems (detention, etc.) within neighborhoods. Wants to acquire properties, remove infrastructure, provide no services to these areas and increase flood storage capacity. Is paying fair market at pre-damage value. Installing inline valves (like duck bills) to keep river water out of stormwater system. Very concerned about marsh preservation. Has a stormwater utility (approx. $120/hr annually) tied to water bill? Uses Equivalent Residential Unit and offers credits for certain uses and impervious area. Uses also TIFs. "Trauma aware risk communication" – SLR heightens anxiety. Storms and flooding already have people on edge. They are considering partnering regularly with mental health workers at public events.

7. Boston anticipates 7" to 1.5' SLR by 2050; 1.3' to 3.1' by 2070; 2.4 to 7.4' by 2100. Two inches SLR projected per decade. Will revisit projections every 5 years. Expects

regulations to be revised accordingly. Department of Environment drafts neighborhood-scale functional plans that include plans for all infrastructure. Recently created a waterfront zoning overlay district that requires new buildings and major redevelopment to be raised 40 inches. Property owners are not penalized for this "excess" height. They're not sure how to deal with small projects or existing buildings. The City prefers berms and buffers instead of sea walls, but "wharfing out" (creating fill land) for new buildings still appears popular, and seawalls appear prevalent. 12-foot wide harbor walks for public access are required of all buildings on the waterfront. Shoreline solutions include: elevating spine (roads), using open space to collect stormwater and create buffers, and outboard elements which involve building seawalls. Waste Water Treatment Plan is under consent decree for leaking laterals and phosphorous. Boston will not be raising its streets because it doesn't want to change its gravity driven sewer system; but water lines could be raised. Massport (airport/harbor authority): their resiliency plan will not keep everything dry. Facilities are not retreating. Currently using temporary floor barriers and fencing to protect certain facilities. Requires raising new buildings to Base Flood Elevation (BFE) with 3-foot freeboard. Cambridge: Climate change is a social problem. Cambridge was built for past climates not future climates. Requiring developers to build to 2070 Woods Hole projections (not just FEMA). Requiring stormwater storage under parking lots.

8. Charleston anticipates a 1-foot SLR by 2050, 2-3 feet by 2070 and 5 feet by 2100. Much of Charleston (peninsula surrounded by the Cooper and Ashley Rivers) is built on non-engineered fill, so they have problems with subsidence, flooding and contamination of waterways with dirty fill oozing into rivers and streams.

POLITICAL WILL AND LEADERSHIP:

9. I was also interested in Miami Beach for what they were able to do, to raise the roads. And how they got to that. My take on that was that there was a lot of political will. They had a mayor that ran on that political campaign promise of how to raise the streets and they didn't necessarily raise all the infrastructure, but they did install a pretty fancy stormwater pump system.

10. In Charleston Mayor John Tecklenburg ran a platform on alleviating flooding and traffic.

11. Charleston has a Stormwater Department that is separate from the Public Works Department Has a position dedicated solely to floodplain management whose role it is to promote natural floodplain functions and reduce and mitigate flood loss.

NEW DEVELOPMENTS, ZONING AND REAL ESTATE DISCLOSURES:

1. We learned that many new developments in Miami are done with no adaptation measures built into the building designed. This underscores the importance of incorporating ground floor height regulations into building codes and adjusting zoning laws to reduce hazards.

2. We learned about the importance of building codes and zoning (based on maps and data). Cities are updating flood maps and creating new hazard overlay zones and zoning designations.

3. In addition to a variety of design guidelines for utilities, public projects, and private projects, the cities are using the traditional tools of city-wide and/or community plans, along with zoning and a heavy reliance on their codes and standards, which set the minimums and provide certainty of expectations for design and construction. Miami and Boston are areas with very active development markets where new and redevelopment is driving adaptation, in addition to municipal investments.

4. We learned that none of the cities visited require real estate disclosures for properties sold in hazard areas.

5. New development guidelines should be defined, reinforced and very clear for all the stakeholders to avoid possible litigation.

CROSS-JURISDICTIONAL COORDINATION:

1. We learned the importance of cross-jurisdictional coordination. In the cities visited, different political motivation across jurisdictions can affect changes in infrastructure or policies. Honolulu has the advantage of having O'ahu as a well-defined boundary for the City and County jurisdiction.

INFILLED LAND:

1. We learned that areas that were initially infilled are experiencing flooding. This was the case in Charleston. They had a saying: "Water goes where water was." There are parallels with O'ahu in areas like Mapunapuna, Kakaako, Waikiki and Iwilei.

2. It is important to have simple messaging for decision-making, e.g., what will people tolerate? "Walk through water, walk around water, drive through water, get car stuck in water."

3. Experiences shared by the cities visited in the SLR study tour showed us that these areas of fill can be expected to subside and flood.

4. Much of Charleston (peninsula surrounded by the Cooper and Ashley Rivers) is built on non-engineered fill, so they have problems with subsidence, flooding, and contamination of waterways with dirty fill oozing into rivers and streams.

RETREAT AND REPETITIVE LOSS:

1. The methods and processes to address "retreat" from areas experiencing flooding or identified as inundation areas in future years have yet to be developed in the cities visited.

2. There are not a lot of retreat efforts in Miami, Charleston or Boston. There were some isolated instances of buybacks related to emergency declarations and obtaining FEMA funds.

3. 70% of the State's FEMA-determined "repetitive loss properties" are in Charleston.

PRIVATE SECTOR INVOLVEMENT:

1. Involvement of the private sector doesn't seem to have caught on. Insurance companies, banks and builders should take a more proactive approach in guiding communities and property owners to find different locations for their homes. It seems that the expectation of the private sector is to have the government deal with it. The private sector should be accountable for disclosure regarding sales of properties that are at risk by climate change and sea level rise.

OTHER OUTCOMES:

1. We developed and reinforced collegial working relationships, which, while not an expressed purpose of the trip, is an important outcome of such an experience.

2. Level of climate change and SLR conversation is at a whole new level because of this trip.

3. My takeaway is a little bit different. I feel that I come to these conferences and we talk about the science talk, about the education component, talk about the training, teaching people how to mitigate natural disasters, teaching people how to do better planning and getting educational materials into K-12, so on and so forth and that's wonderful and I'm more on the far side of that. What people are saying, you know, you

were facing an existential crisis! I take it a little bit further. So I'm going to talk about what I found in South Carolina. It's more than an existential crisis – the whole climate change problem is challenging our basic values and everything we need, everything we do – everything underscores and dictates the decisions that we make as consumers and how we live in this world. We need to look at our core values and think about how we can look at it differently.

HAWAII PARTICIPANTS SUGGESTIONS FOR IMPLEMENTING SOME OF THE TAKEAWAYS IN HAWAI'I

1. Initiate work to implement measures under the authority we each have in our roles at work.

2. Participate in the establishment of ordinance based requirements to incorporate SLR considerations in all City capital projects similar to processes already established for Complete Streets.

3. One thing in Charleston and Boston is how everyone collaborated. If it could get into an ordinance, that would be optimal. Directive could be forgotten and ignored.

4. Begin internal discussion of means to identify parcels anticipated to be impacted by SLR for the purpose of notifying owners of record of potential future events.

5. Participate in active discussion of options for property owners that are anticipated to be impacted by retreat policies to develop practical alternatives that may be offered.

6. Using existing sea level rise models and information available on storm drain system elevations, identify areas that will likely experience nuisance flooding of streets similar to Mapunapuna.

7. Prioritize areas identified as potentially impacted by nuisance SLR induced flooding to develop potential measures to minimize effects until longer term measures may be implemented.

8. Establish pilot project to isolate a storm drain system from tidal influence while preserving design discharge rate during storm events to minimize impacts from weather related flooding.

9. There are also way different solutions. For example: Mapunapuna. Move it, retreat. Build it up. Mapunapuna Is the best example that we have right now, but it's not enough to garner action.

10. Our plans must appropriately address the anticipated increase in SLR induced flooding due to rising ground water and tidal inflows to the area storm drain along with weather induced storm water to be successful.

11. It is critical that adaptation requirements/standards be established for new development in SLR areas (like the SLR Zoning Overlay Districts). We are missing huge opportunities as these buildings may last 100 years. Roads can be lifted later when the nuisance flooding trigger is reached in mid-century.

12. Can Mapunapuna be a candidate demonstration project, since its flooding now? There is a lawsuit. A 3rd duckbill drain backflow preventer is in the works according to the Department of Design and Construction (DDC). Some streets are subsiding. Should the City elevate or retreat and when? What is the Long Term Plan?

13. Board Water Supply (BWS) and Honolulu Department of Planning and Permitting (DPP) and consultants are developing the Primary Urban Center Development Plan and Watershed Management Plans, expanding climate change & SLR adaptation plans, adding policies, strategies and catalyst and demonstration projects.

14. Working on the One Water Collaboration Framework for Climate Resilience, with a draft SLR and Stormwater check list and 5 demonstration projects.

15. Assisting Honolulu Office of Climate Change, Sustainability and Resiliency (OCCSR) with the O'ahu Resilience Strategy OLA Climate Adaptation Strategy Effort.
16. Assisting The Department of Facility Maintenance (DFM) in the Stormwater Utility/Fee project on the stakeholder advisory group.

17. Those cities are worse off than Honolulu. We got some time, but we need forward momentum to reach critical mass, a plan, elected official leadership and community support.

18. Storm surge is not being addressed here. Should it be?

PERCEIVED OBSTACLES TO IMPLEMENTING SOME OF THE LESSONS LEARNED IN HAWAI'I

1. Funding and planning for funding. Funding limitations due to projects that have funds committed over a period of years with more immediate benefits to the community and/or government services.

2. Streets are not flooding yet, except for Mapunapuna

3. We need to focus on today's problems first.

4. Board of Water Supply (BWS) should maybe stay in its own lane… but we have to wait for low tide to repair coastal main breaks now and it will only get worse…

5. The perception that SLR impacts are still too far into the future to prepare for them now.

6. Possibly our problem is that we don't experience the extent of the flooding that we are seeing in the urbanized areas. How do we keep the message alive? We are going to be there soon.

7. We don't experience the extent of flooding that presents urgency: 10 to 20 years from major problems, which will be too late to take action.

8. Rows here in Hawai'i aren't wide enough, raising roads requires space.

9. Right of ways aren't wide enough. For the situation where we have split sidewalks, need that area to be relatively wide so in the short term have the width for people walking at two different levels. Need to think about how wide that barrier needs to be for safety purposes. If building isn't going to move, need sidewalk to be as wide as possible for ADA accessibility, streetscape quality, etc., and therefore it makes the vehicle travel lanes narrower. But that will result in congestion in places, problematic from a political perspective.

10. There is a need for grassroots organizations to coordinate climate change action and outreach

11. With all of the stakeholders, insurance, mortgage, etc. How do we work together? City, State, Feds, Private Sector. Insurance, regional perspective.

12. If we are going to ask professionals to make major infrastructure investment, need to see that the science is solid. Tools that we are going to be able to zero in on this area.

13. Sustaining through administration changes is a challenge

14. There is a need to build sustainability of the processes related to climate change.

15. Mayor's directives or executive orders can be reversed or ignored.

16. There is not a "golden benchmark" to be achieved, it will take a lot of small things.

17. We have inadequate private drain system that not only lacks capacity but has not been maintained over the years.

18. There are a lot of things that can happen to build momentum up to the trigger point- there are still things that required knowing what to do now. Building in resilience is an ongoing process but much of the infrastructure maintenance requires knowing what to do now.

19. Political will and leadership in climate change can be better

20. Public awareness about climate change and sea level rise needs to increase.

21. No redevelopment guidelines

22. Homeless issues trump environmental issues as a social good.

SPECIFIC OBSERVATIONS AND POSSIBLE NEXT STEPS

- There is very little discussion about managed retreat. If we are not thinking about managed retreat, then is adaptation the only option?

- There are not a lot of retreat efforts in Miami, Charleston or Boston. There were some isolated instances of buybacks related to emergency declarations and obtaining FEMA funds.

- How can developers, businesses and real estate companies help communities deal with climate change and drive action on creating climate safe communities?

- Wealth drives adaptation efforts in the cities visited. What type of governance structures need to be put in place to address the adaptation needs of vulnerable populations?

- The cost of adaptation is high; who is going to pay for it? Adaptation is also energy intensive (storm water pumps require electricity).

- More and more states are relying on FEMA funds for adaptation. What are the long-term implications? Are we relying too much on federal funds for climate adaptation?

- Utilities cannot plan for climate adaptation in isolation. How do we create incentives to encourage collaboration and collaborative planning among different departments and agencies?

- Building political will is as challenging as addressing climate change. How do we develop political will in places where denial to climate change is lacking?

- Coastal communities and coastal utilities are most vulnerable but all communities will have impacts.

- How do vulnerable states and countries prepare for climate adaptation with little or no capital and lack of know-how?

- What kinds of key information is necessary to facilitate scenario/location planning, early warning systems, disaster risk preparedness, and management/emergency response for climate adaptation or retreat strategies for vulnerable states and countries with limited capital and resources?

- What resources are out there that can help vulnerable communities or countries to take their first steps into climate adaptation or retreat?

- Low-income communities in both urban and rural areas will be disproportionately impacted by climate change and SLR. What type of information or checklist would they need to prepare for flooding events or other disaster? What type of information would be needed to bounce back from an extreme event?

- How can we make sure that education, outreach and communication strategies for climate impacts, extend to all communities not just the affluent ones?