Attachment 3

RECOMMENDATIONS FOR AN ENHANCED CAPITAL PLAN

September 2016

Final report for Resolution R-46-15 in support of the Sea Level Risk Task Force final recommendations

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1 Introduction

1.1 History and Context

In January 2015, the Miami-Dade County Board of County Commissioners passed Resolution R-46-15. This resolution directed the Mayor or the Mayor's designee,

"to prepare an action plan and report to accomplish the acceleration of the climate change adaptation planning process by evaluating the engineering and other relevant expertise needed to conduct a comprehensive expert analysis and to develop an enhanced capital plan involving all levels of government to reinvent Miami-Dade County's urban infrastructure in a timely, sequenced manner that includes but is not limited to flood protection, salinity structures, pump stations, and road and bridge designs, and to determine the costs of retaining the experts needed."

This is the final report in support of Resolution R-46-15; however, this report builds on a long history of climate change work and research (Figure 1).

1.2 Process to Develop This Report

To prepare this report, staff within the Office of Resilience (staff) worked with other Miami-Dade County (County) departments, local municipal governments, such as Miami Beach and Fort Lauderdale, major metropolitan areas, and interviewed major engineering and planning firms.

As an initial step, staff spoke with the Water and Sewer Department (WASD) and the City of Miami Beach about their existing contracts to plan for rising sea levels with private firms. To evaluate which components could be useful to support the County's own efforts, staff reviewed the technical products from each project as well as the contracts themselves, where possible. A preliminary "gap analysis" was also conducted with other departments to discuss what information, expertise, and internal capacity exist within the County and which skills and expertise could be best provided by external consultants.

Staff also spoke with peers in Seattle, Boston, New York, and San Francisco to discuss how these metropolitan areas had incorporated climate change risks into their capital planning efforts. These conversations focused on the cities' processes to create comprehensive resiliency or adaptation strategies. Interviewed cities shared information about the time and costs involved in developing their various plans and why they had brought in external consultants for certain components, as opposed to managing the process internally. Additional details from these conversations were included in previous quarterly reports (Appendix 4).

Finally, staff interviewed eight major planning and engineering firms to ascertain the approximate cost, timeline, and scope of work that would be required to develop "an enhanced capital plan involving all levels of government to reinvent Miami-Dade County's urban infrastructure." The intention of these interviews was not to evaluate the firms, but rather to conduct market research, gather order-of-magnitude cost estimates, and understand how an enhanced capital plan could be structured. Firms were asked to provide relevant examples from other cities and details about the approximate time and resources required for each project. They were asked how capital planning could be phased to provide more flexibility based on funding availability, including which components they would include in the first phase. Because Miami-Dade County has such extensive data on projected climate change impacts (e.g. localized sea level rise projections, storm surge, groundwater, and stormwater modeling etc.), firms were asked how they could build upon this strong foundation to maximize project outcomes. The firms also described how they integrated community engagement into prior projects.

Staff also considered how climate change risks are currently being incorporated into the County's capital planning process. The evaluation revealed ways in which the support of external experts could improve upon the existing process. One shortcoming of the current process stems from the fact that it is the responsibility of each department to consider sea level rise during the planning, design and construction of all infrastructure projects following Resolution R-451-14 and Ordinance 14-79 adopted in 2014. However, technical expertise in this area varies across departments and therefore many departments have not yet integrated sea level rise into their capital planning. Another limitation is that no department is explicitly required to construct or maintain infrastructure to protect the community from coastal flooding, despite the fact that it has the potential to cause significant damage. There is also no requirement for departments to coordinate their actions or investments associated with preparation for sea level rise. Closer coordination could reveal opportunities to leverage investments and improve the resiliency of multiple infrastructure networks simultaneously. An enhanced capital plan, for example, could identify opportunities to simultaneously upgrade the stormwater management system, wastewater system and roadways at a lower cost than if those improvements were pursued as three separate projects.

Creating **an enhanced capital plan**, as directed by this resolution, has the potential to address these challenges and improve the existing process. It could also help articulate funding needs to state and federal agencies and engage the community. Ensuring that the right policies are in place for today's capital investments, can create a system where today's incremental investments help build the long-term resiliency of Miami-Dade County.

1.3 Structure of This Report

This report will outline the typical process other governments have taken to improve the resilience of their infrastructure, areas of expertise that exists within the County, areas where external expertise is needed, potential approaches to developing an enhanced capital plan, and finally, a recommended approach.





Typical Planning Process 2

Miami-Dade County can leverage the experience of other cities that have already initiated similar work developing enhanced capital plans to respond to climate change. Many planning processes have followed a generalizable pattern summarized in Figure 2 and described in greater detail below.

Figure 2: Typical Climate Adaptation Planning Process



2.1 Identify Climate Risks

The first step to increasing the resiliency of the County's Figure 3: San Francisco Vulnerability Analysis infrastructure is to understand how key climate variables are expected to change. For example, asking questions like: "How high will water levels be?", "How high could storm surge be during a hurricane?", and "How much rain could fall during the rainy season?". For Miami-Dade County, key climate risks include changing sea levels, groundwater heights, temperatures, as well as precipitation and storm patterns. Fortunately, the County already has very good data on many of these variables and several research efforts are underway to address data gaps. These extensive research efforts are summarized in the final report for Resolution R-48-15 and will be vital inputs to Miami-Dade's capital planning efforts.

There are a number of good examples of this type of work including climate assessments for New York City, ¹ San Francisco,² and The Netherlands.³ To fully understand the risks to critical infrastructure, the best assessments include a range of climate scenarios. For example, it is important to consider whether infrastructure would be vulnerable in the event of increased precipitation or increased drought, because both are potential risks in Miami-Dade County.

This stage requires highly technical expertise in the fields of climatology, hydrology, meteorology, and oceanography.



Source: California Energy Commission- Climate Change Center, 2012

¹ The City of New York. Special Initiative for Rebuilding Resiliency. A Stronger, More Resilient New York: Ch 2 Climate Analysis. By Susan Van Gelde. N.p., n.d. June 11, 2013. Web.

² California Energy Commission. California Climate Change Center. By Julia A. Ekstrom and Ph.d. Susanne C. Moser. N.p., July 2012. Web. <http://www.energy.ca.gov/2012publications/CEC-500-2012-071/CEC-500-2012-071.pdf>.

³ The Netherlands. Netherlands Environmental Assesment Agency. The Effects of Climate Change in the Netherlands: 2012. By Guus De Hollander. N.p., 2013. Web. http://www.pbl.nl/sites/default/files/cms/publicaties/PBL_2013_The...>.

2.2 Vulnerability Analysis

Typically, the second planning step reviews which assets Figure 4: Boston Vulnerability Analysis and Table of Public are vulnerable to the expected changes. For example, if sea levels are expected to be two feet higher, which infrastructure systems will be impacted by those changes? Analysis at this stage is often done using mapping overlays and comparing areas expected to be flooded with other layers containing information about transportation infrastructure, critical facilities or sensitive environmental areas. One example of this type of work from San Francisco (Figure 3) shows critical power infrastructure at risk from a 100-year flood after accounting for sea level rise. A second example from Climate Ready Boston⁴ (Figure 4) shows the vulnerability of Boston's Public Schools and neighborhood emergency shelters. Another very comprehensive example is Los Angeles' sea level rise vulnerability analysis.5

A preliminary analysis of the County's vulnerability to sea level rise was completed in 2012;6 however, that study was not detailed enough to inform infrastructure planning. A more thorough analysis is needed to determine, not only which assets are located in vulnerable areas, but also how those assets will be impacted. For example, a screening analysis may show a portion of a park, a roadway, and substation fall within an area that will be affected by sea level rise. A second step is then required to determine the potential damage and disruption that could result from this exposure. The park may be relatively unharmed by inundation, whereas any inundation at the substation could potentially cause severe disruption like electrical outages. Similarly transportation experts would need to assess the level of disruption caused by the loss of use of affected roadways. Fortunately, future vulnerability analyses can build upon the work recently completed for Miami-Dade's Water and Sewer Department (WASD), which provides many components for future studies.

Schools High-Priority Vulnerabilities



Source: Climate Ready Boston, Climate Preparedness Task

⁴ City of Boston. Office of the Mayor. Climate Preparedness Task Force. Climate Ready Boston. By Carl Spector and Leah Bamberger. Massport, Oct. 2013. Web. < https://www.massport.com/media/266281/2013-October_Climate-Ready-Boston.pdf>. ⁵ Grifman, P. M., J. F. Hart, J. Ladwig, A. G. Newton Mann, M. Schulhof. (2013) Sea Level Rise Vulnerability Study for the City of Los

Angeles. USCSG-TR-05-20. Web.

<dornsife.usc.edu/assets/sites/291/docs/pdfs/SeaLevelRiseDocs/City_of_LA_SLR_Vulnerability_Study_FINAL_Online_w_appen_sm.pdf> ⁶ Southeast Florida Regional Climate Change Compact Inundation Mapping and Vulnerability Assessment Work Group. August 2012. Analysis of the Vulnerability of Southeast Florida to Sea Level Rise. p. 103. Web. < http://www.southeastfloridaclimatecompact.org//wpcontent/uploads/2014/09/vulnerability-assessment.pdf>

To complete this component, expertise is needed in the technical understanding of various infrastructure systems, such as stormwater and transportation, as well as expertise in GIS mapping and planning.

2.3 Strategy Development

Once the vulnerabilities are known, the next step frequently involves developing a list of potential strategies to reduce or eliminate the identified vulnerabilities. One of the best examples of this type of work is New York City's Department of City Planning's publication *Urban Waterfront Adaptive Strategies.*⁷ This guide (Figure 5) outlines the potential adaptation measures available and describes where they would be suitable based on the urban coastal typology. This example is focused on adapting to rising sea levels, but similar studies exist for adapting to other hazards.

Several initiatives in the region have outlined potential adaptation strategies to sea level rise, including the Southeast Florida Regional Climate Change Compact's *Resilient Redesign* workshops, however, this information has not been systematically pulled together in one place. More importantly, additional work is needed to gather information about costs, technical effectiveness, suitability, trade-offs, and co-benefits of different adaptation measures. Developing a detailed adaption plan for the County's infrastructure will require creating strategies specific to our unique conditions. Adaptation measures will need to be developed at various spatial scales (facility, block, neighborhood, city, and county). These measures will also need to be tailored to different infrastructure systems including measures specific to roadways, drainage networks, septic systems and existing building stock. There are many advantages to beginning this planning effort at the largest spatial scale.

This type of work requires expertise in engineering, economics, planning, and design.



Figure 5: Strategy Development in New York City

Source: City of New York, Department of City Planning, 2013

2.4 Strategy Prioritization and Phasing

After the potential strategies have been developed, the next stage typically involves assessing the costs, effectiveness, feasibility and desirability of different options. The Greater New Orleans Urban Water Plan is an excellent example of the result of this process. Selections from the plan (Figure 6) show cohesive strategies for

⁷ The City of New York. Department of City Planning. Coastal Climate Resilience. Urban Waterfront Adaptive Strategies. N.p., June 2013. Web. http://www.nyc.gov/html/dcp/pdf/sustainable_communities/urban_waterfront_print.pdf>.

different neighborhoods. The plan also outlines a phasing strategy for implementation. This plan was created with extensive collaboration between technical experts, planners, designers, and the community. The strategy prioritization and phasing stage often involves the most extensive community engagement and a focus on consensus building.

This stage would involve extensive planning and negotiation to prioritize strategies and develop short and long-term phasing. While many strategies will likely focus on building or enhancing infrastructure, ensuring that the County's infrastructure is resilient will also require many strategies that focus on internal processes, codes, policies, and regulations. Accomplishing the Resolution's goal of "involving all levels of government to reinvent Miami-Dade County's urban infrastructure" would also require new levels of coordination between federal, state, regional, and local government agencies.

Successful completion of this component requires technical expertise to assess the validity and feasibility of different adaptation options, as well as expertise in visualization, communication, spatial planning, and consensus building. Many firms with engineering and technical expertise in adaptation have also developed the capacity to clearly communicate the benefits, and trade-offs of different strategies to non-experts and build consensus around the most desirable approaches.



Figure 6: Strategy Development in New Orleans

Source: Greater New Orleans Urban Water Plan

2.5 Project-scale Planning and Design

Once there is agreement on the adaptation strategies and prioritizing and phasing is complete, then projectscale planning and design begins. This stage evaluates selected projects with the intention to determine the specific design of each project. For example, if there were agreement that raising the bulkhead heights along the Miami River was a desirable measure, this stage would involve developing engineering designs for that specific project. This stage would follow the development of an enhanced capital plan and is therefore beyond the scope of this report.

2.6 Project Construction and Monitoring

The final stage would include project construction and monitoring. Monitoring the effectiveness of different measures in partnership with the private sector and academia will also help foster innovation and more effective and efficient technologies. This stage would follow the development of an enhanced capital plan and is therefore beyond the scope of this report.

3 Expertise and Information Needed

3.1 Existing Expertise and Information

The County and regional partners already have significant expertise and data on local climate risks, including localized sea level rise projections, expected changes in groundwater levels, potential storm surge heights (including sea level rise), as well as potential temperature and precipitation scenarios. This depth of knowledge and local expertise can help springboard the County's adaptation efforts. While additional research can always be done to refine and improve local knowledge, existing information is sufficient to begin creating an enhanced capital plan.

Miami-Dade County also has partial information and internal expertise on the vulnerability of County infrastructure to expected climate change impacts. While certain departments such as the Water and Sewer Department and Parks, Recreation and Open Spaces have completed comprehensive assessments, many departments have not begun this process. Some programs, such as the Water Management Division in the Regulatory and Economic Resources Department, have the tools and expertise to thoroughly assess the impact of climate change on the functionality of their systems, whereas, other divisions or departments may not have the required tools or experts in-house. Excellent guidance for conducting vulnerability assessments exists and many guides are tailored to the needs of specific systems, such as transportation.⁸ A complete vulnerability assessment of all systems could likely be completed with the aid of existing guides and cross departmental collaboration. The support of external experts could, however, greatly expedite and add depth to this process.

The County also has internal expertise on capital planning, spatial planning, and community engagement, however, there is less experience using these processes to specifically address climate change risks.

3.2 External Expertise and Information Needed

External expertise could be most useful in evaluating the technical and cost-effectiveness of different adaptation strategies to create a cohesive capital plan. Evaluating the technical effectiveness would involve comparing alternative adaptation measures (e.g. a new bulkhead or new drainage infrastructure) to determine which investment most effectively reduces flooding damage at a given location. The technical evaluation would address questions such as the height a building should be elevated to, or the elevation a

⁸ The Federal Highway Administration has compiled a number of resources to assess the vulnerability of transportation networks available at www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/vulnerability_assessment

sea wall should have, in order to meaningfully reduce flood damage. This requires technical engineering expertise in disciplines such as coastal, geotechnical, and hydraulic engineering.

It is important to pair the technical analysis with Figure 8: Managing Risk with Adaptation an economic analysis to develop feasible adaptation measures. For example, from a technical perspective, nourishing the beach every year and raising the height of dunes to 18 feet may provide the most protection, however, this strategy may not be economically feasible. Completely eliminating risk would likely be prohibitively expensive, therefore, the County needs to systematically determine a reasonable level of risk.⁹ As seen in Figure 7, adaptation measures such as increasing drainage capacity, absorbing more rainfall, or improving drainage maintenance do not completely eliminate the risk of flooding but help gradually manage those risks and



Source: Managing risks and increasing resilience-The Mayor's adaptation strategy, Government of London

lower them to acceptable levels. Many tools exist to help decision makers weigh the relative benefits and costs of additional protection to arrive at some optimum middle ground. These tools can also help assess how spatial distribution of adaptation measures may impact the economy. For example, high dunes along Miami Beach may prevent millions in storm damage, however, similar dunes may have a negligible economic impact if placed in front of a natural park area that would be less affected by a storm. This analysis requires expertise in cost benefit analysis, risk management, economics, and cost engineering. Given that the future sea level rise remains uncertain, the timing of investment in adaptation is critical. Tools exist to help optimize investments and phase them, based on certain flexible adaptation pathways tied to certain physical triggers (such as a given rate of sea level rise or the occurrence of a major hurricane). Economic analysis can also reveal where risks pose the greatest financial threat to economic growth or recovery.

Developing a cohesive plan requires coordinating Figure 7: Interactive spatial planning tools projects so that individual improvements are technically complimentary and not working at cross-purposes. Effective coordination requires both technical and economic assessments so that infrastructure investments are well allocated between different projects. This requires expertise in engineering, economics, cost-benefit analysis, risk modeling, infrastructure prioritization, and spatial planning. Specific tools have been developed to support this type of planning (Figure 8).

Subject matter experts could also add value to the County's enhanced capital plan by developing communication and visualization tools that help convey information about the





physical, Source: Deltares

⁹ For example, a recent economic analysis found that "protecting Miami against all possible storms would be extremely expensive, costing several billion US dollars for construction work alone." Source: Elisabeth Genovese and Colin Green "Assessment of storm surge damage to coastal settlements in Southeast Florida" Journal of Risk Research (2015) Vol. 18, No. 4, 407-427.

socioeconomic, and infrastructure systems to a wider audience. Many firms have developed excellent tools that make complex information accessible and manageable to non-experts. These tools (Figure 8) allow users to move beyond reacting to a pre-defined plan and instead allow them to dynamically interact and experiment with different combinations of investments and infrastructure projects. **These visualization and scenario building tools allow planners and community members to explore different views, showing critical infrastructure, relevant landmarks, and other information.**¹⁰ This allows decision makers and the community to understand physical and economic impacts, test alternative outcomes, and identify tradeoffs associated with alternative adaptation solutions.

4 Potential Approaches to Developing an Enhanced Capital Plan

4.1 Top Down: Replicating the Dutch Approach

The Dutch approach to adaptation planning is integrated with spatial planning and begins with a comprehensive assessment of the risks, vulnerabilities, and potential benefits and trade-offs associated with different adaptation options. The Dutch begin with a comprehensive assessment of the appropriate level of protection for each area of the country.¹¹ For example, areas with very low population density have a lower level of protection than densely-settled areas which are national centers of commerce and tourism (Figure 10). In this way, the Dutch integrate adaptation planning with spatial planning and use economic analysis to help determine the appropriate level of investment in adaptation.

The Dutch approach could be considered "top down" in the sense that planning begins at the largest spatial scale by describing the plan for the entire country (Figure 9). Then, through successive steps, it becomes more refined and specific as plans are developed for each province, city, and neighborhood. By beginning with the overarching plan, the process ensures that local adaptation efforts are building blocks that support the larger, country-wide effort.

This approach reduces the risk that a local area would construct something (such as reinforced dunes or a surge barrier) that would increase the vulnerability of a neighboring area. Secondly, this approach reduces the risk that a local area could see its own investment in adaptation undermined by the action of a neighbor. For example, if one city invested in higher sea walls along a river but the neighboring area did not, the investment in the sea walls would be undermined because the water could simply flow over the lower portion of the wall and flood both areas. Effective coordination is one of the primary advantages of a top down approach where local actions support a comprehensive adaptation strategy.

¹⁰ The DELta Analysis and Adaptation Strategy viewer is one example of this type of interactive planning tool. More information is available at: http://www.delta-alliance.org/toolboxoverview/DELTAAS

¹¹ For more information on the Dutch planning approach see the Delta Program available at: deltacommissaris.nl/delta-programme



Project numbering refers to measures scheduled in the Deltaprogramme (Tabel 4 in Chapter 3). An inner colour in the symbol, if any, indicates the plan phase.

2016-2021 Flood Protection Programme



Source: Delta Program Commission. The Netherlands, 2016

A "top down" approach also allows for a comprehensive evaluation of the technical and cost-effectiveness of different adaptation measures at the outset. This helps determine the appropriate level of investment in protective measures for different areas. It also helps to efficiently allocate resources between different areas to both identify "weak links" and create multiple lines of defense. Weak links are vulnerable, under protected areas that may have no protective infrastructure or are totally reliant on a single system for protection. Creating multiple lines of defense means relying on multiple systems for protection. For example, a house in Miami Beach could be protected by the beach, dunes, a waterfront park, drainage infrastructure, and being elevated above the floodplain. **Creating an enhanced capital plan allows decision-makers to allocate investment between multiple lines of defense.** Looking at the economics at a larger spatial scale, it may be most efficient to increase investment in the beach and dunes and reduce the investment needed by residents to protect their individual structures. Using this approach, it is also possible to adjust the level of protection and investment to suit the needs of different areas. For example, additional adaptation measures could be put in place to protect areas with clusters of hospitals, high population density or critical infrastructure.



Figure 10: Example of Incorporating Economics into Adaptation Planning in the Netherlands

Source: Rotterdam Climate Initiative, Climate Proof. Climate Change Adaptation Strategy, 2012

4.2 Bottom Up: Replicating WASD's approach

Developing an enhanced capital plan could alternately begin from the point of identifying the vulnerabilities and needs of each individual infrastructure system. For example, the Water and Sewer Department (WASD) recently completed a very comprehensive assessment of their infrastructure's vulnerability to sea level rise and future storm surges. This assessment, illustrated in Figure 11, compared the elevation of expected storm surge, including sea level rise, to the elevation of their individual assets (e.g. pumping stations). They then assessed which improvements were critical to maintaining key services. Through this process, led by a large engineering firm, **WASD gained a detailed assessment of the vulnerability of each of its assets, a prioritization of infrastructure improvements, and a roadmap for how to design future projects to be resilient to sea level rise and future storms.**

This process could be replicated for each infrastructure system such as

transportation, emergency services, the airport, and the sea port, to name a few. Each entity responsible for the system could replicate WASD's approach to understand where each system is vulnerable and where new infrastructure or enhancements are necessary. These analyses and planning efforts would likely need to supported by external be consultants.

The described process could be considered a "bottom-up" approach in the sense that each individual system would identify and reduce its own vulnerabilities, but would create a more resilient community infrastructure network through these individual improvements. This approach has the benefit of being adaptable to fit the needs and

Figure 11: Analysis for WASD showing recommended design elevations and prioritization of critical facilities



Source: Design Guide for Hardening Wastewater Treatment Facilities against Flooding from Surge, Sea Level Rise, and Extreme Rainfall

unique characteristics of each infrastructure system and its individual capital planning process. The process could also be managed principally by each department with the support of technical experts, where needed. Each department could also take advantage of the existing information on future water levels prepared by WASD and their consultants.

Figure 12: Rendering of the Lafitte Blueway from the New Orleans Urban Water Plan



Source: New Orleans Urban Water Plan

When pursuing a bottom-up approach, the timing would be controlled by each department. approach could This help integrate adaptation needs into on-going capital planning efforts, but could also mean that departments can pursue adaptation measures at different times. Such a method would require very close collaboration between entities to ensure that adaptation measures were coordinated and not working at cross-purposes. It may also be more difficult to coordinate investments across departments complimentary to pursue infrastructure projects. This approach may also rely heavily on implementing known

engineering solutions and may miss opportunities for effective, innovative and creative solutions. Another drawback is the potential to miss vulnerabilities that fall between departments' areas of responsibility. For example, currently there is no department responsible for reducing the risks of coastal flooding due to storm surge. Nevertheless the potential damage from surge is substantial and there are cost-effective ways to reduce this vulnerability. A bottom-up effort may also miss opportunities to engage the community and improve quality of life through multi-purpose infrastructure solutions such as creating new buffers that reduce flooding damage but also serve as new linear parks between storms (Figure 12).

A bottom-up approach would be most effective if the County also developed a more formal process to ensure all capital projects adequately considered their vulnerabilities to climate change. Replicating the City of San Francisco's model could be one way to accomplish this goal. San Francisco's Public Utilities Commission requires each department to identify and map project sites included in the 10 year capital plan and verify whether they fall within a "vulnerability zone". For each project exceeding \$5 million, departments are required to fill out a Sea Level Rise Checklist and submit it for review to the Capital Planning Committee and the City Engineer's Office. Departments are also required to submit specific long-term strategies to address the adaptive capacity of proposed projects. Miami-Dade County could develop a similar mechanism.

4.3 Hybrid Approach: Replicating Boston and New York's Approach

Other major metropolitan areas vulnerable to sea level rise, such as New York and Boston, have pursued a hybrid approach. These cities built upon detailed analysis of individual infrastructure systems (i.e. wastewater treatment) and knit these assessments together into an overarching adaptation strategy. Through this process they identified and filled gaps where necessary.



Figure 13: New York City's Comprehensive Coastal Protection Plan

In the case of New York City, substantial work to assess the vulnerability of different assets had already been completed before Hurricane Sandy hit. After Sandy, however, there was a massive effort, involving more than 40 city staff members and numerous consultants working around the clock for five months, to create a unified adaptation plan: A *Stronger, More Resilient New York*.¹² This comprehensive plan contained actionable recommendations, specific infrastructure projects, and potential funding sources. The plan was structured around key infrastructure systems (transportation, telecommunications, water, and waste water) and neighborhoods (Southern Manhattan and South Queens). The plan outlined over 250 initiatives necessary to protect the city, totaling approximately \$20 billion in required investments. To put this in context, Sandy (which was not a hurricane when it hit the city) caused approximately \$19 billion in damages. The 250 recommended initiatives were a mix of suggested policy changes and discrete infrastructural investments, such as beach nourishment, bulkheads, tide gates, dunes, offshore breakwaters and living shorelines. The final comprehensive coastal protection strategy (Figure 13) was designed on the basis of a number of factors including the likelihood of coastal hazards, the impact of those hazards on the environment and infrastructure, the social

Source: A Stronger, More Resilient New York, 2013

¹² The City of New York. Special Initiative for Rebuilding Resiliency. A Stronger, More Resilient New York. By Susan Van Gelde. N.p., n.d. June 11, 2013. Web.

vulnerability of different areas, and the cost-effectiveness of different strategies. The plan was developed iteratively, testing the effectiveness of different measures together and integrating community feedback. The city held numerous workshops and roundtables engaging more than 1,000 New Yorkers during the plan development.

Similarly, Boston has completed a number of detailed climate assessments including Building a Resilient City: Preparing Our Infrastructure for Climate Change, Preparing for the Rising Tide, Climate Adaptation Challenges for Boston's Water and Sewer Systems, and a Regional Climate Change Adaptation Strategy. **Boston is now in the process of knitting together these studies to create a unified plan as part of the comprehensive planning process, Imagine Boston 2030.** In less than a year the City hopes to work with consultants to create an integrated vulnerability assessment, prioritize recommended resiliency initiatives, and develop consensus on climate risk variables to use for planning efforts. This initiative is similar to New York City's as it draws on years of previous work, completed for a variety of purposes and different clients and audiences, and is attempting to create a cohesive strategy that builds upon earlier work without needless replication.

4.4 Recommended Approach

Given the clear value of a large scale systematic plan, but recognizing the relevance of pre-existing efforts, Miami-Dade County would be best served by adopting a hybrid approach similar to Boston or New York. A hybrid approach would incorporate both the best elements of the Dutch holistic planning approach, while taking advantage of the opportunity to move more quickly by leveraging the work done by WASD and other departments. This could be done by simultaneously developing an enhanced capital plan while also developing a rapid action plan to identify and prioritize projects that should be implemented first to address the most immediate vulnerabilities in the County's critical infrastructure.

Rapid Action Plan

This portion would focus on identifying the most urgent vulnerabilities to critical infrastructure. A project team comprised of key County staff from selected departments and the consultants should be created. This project team would help filter up critical needs, compare all proposed projects, quickly prioritize them, and create a phasing strategy to expedite implementation of the most urgently needed projects.

The project team would identify the most urgent vulnerabilities by collaborating with key departments. Each department would be responsible for identifying the most pressing needs in the system they manage. Departments would be asked to focus on elements of the system which would cause an overall system failure if they were compromised. For example, a key vulnerability would be one which causes the loss of electricity at the airport or the loss of the ability to receive new ships at the Port. This vulnerability analysis would rely heavily on the County's internal expertise and knowledge of its own systems and existing climate data including the information developed for WASD's vulnerability analysis. It is helpful to address known vulnerabilities first because many will be exacerbated by climate change. For example, if a key electrical system at the airport is vulnerable to flooding today, that risk will likely increase with time as sea level rises.

A consultant could then help the County review the projects suggested by the departments, prioritize among them, and create a phasing strategy for implementation. The consultant could develop a methodology for comparison of all projects and help screen for urgency, feasibility, and cost-effectiveness. The consultant working with the County could then create a phasing strategy for the "tier 1" projects. This prioritization process would help expedite funding and construction of the most critical projects and immediately address known vulnerabilities. Completion of a rapid action plan could also help departments improve their proposed projects, improve their position for funding, revise their own capital improvement plan to expedite resiliency measures, and help flag overlap in areas multiple departments have identified as vulnerable.

Stakeholder Engagement

Stakeholder engagement should be central to developing an enhanced capital plan. Creating the framework for an **iterative design** process will allow for flexibility and provide a way of integrating community knowledge into the technical design work. An iterative process can facilitate **collective learning**, wherein residents learn more about the technical considerations and technical experts can learn more about the community's preferences, use of and vison for an area. Close collaboration with stakeholders such as local institutions, business leaders, private utilities, community based organizations and others will also help the County prioritize its investments and focus on the most critical infrastructure that supports community resiliency more broadly.



The scope of this portion could be adjusted depending on resources. For example, if resources are limited, the first phase could focus on selected critical infrastructure such as the airport or rely more heavily on County staff to assess and prioritize projects. If additional resources are available, the scope could be expanded to incorporate other systems such as transportation, stormwater management, the Seaport and the Internal Services Department.

Enhanced Capital Plan

Simultaneously, the County could create an enhanced capital plan that addresses medium and long-term risks. This plan would evaluate alternative resiliency strategies on the basis of their technical efficacy, economic impacts, and co-benefits to the community. Evaluation of alternative strategies would require external expertise in the fields of engineering, economics, adaptation planning, and community engagement.

Alternative 1: Three Barriers

One recommended method of developing an enhanced capital plan is to use scenario planning as used in the Netherlands and many other locations. This top down approach looks comprehensively at all infrastructure systems simultaneously to develop potential response plans. For example, before developing the city's comprehensive coastal protection strategy, New York also explored alternative scenarios of creating large storm surge barriers at the entrances to New York harbor (Figure 14). After exploring different alternatives, New York rejected them due to their expense, long time to completion, environmental impacts, and the projected creation of an "insider-outsiders" dynamic where some communities would be protected while others outside the barriers remained vulnerable.

The initial scenarios could be developed cooperatively with technical experts and key stakeholders. One scenario would quantify the costs and implications of inaction and others would explore different combinations of infrastructure investments and land use patterns. The specialized consultants could then evaluate their technical effectiveness and economic implications. Through the iterative development of scenarios the



Figure 14: Alternative adaptation scenarios for New York City

Alternative 2: Two Barriers



Source: A Stronger, More Resilient New York, 2013

County could explore the technical effectiveness of various measures. For example, one suite of infrastructure investments could be compared to alternatives in terms of their ability to provide protection from a 100-year storm, ability to slow or stabilize the loss of wetlands or sandy beaches, and ability to protect critical infrastructure. An economic assessment could be paired with each technical assessment to evaluate scenarios in terms of metrics such as construction, operation, maintenance costs, ability to reduce losses or

economic disruption from hurricanes, or ability to protect property value and other critical, cultural, and environmental assets such as Biscayne Bay.

It would be fruitful to present interim scenarios to key stakeholders and the wider community to gain input and help build consensus around preferred options. Each scenario could be summarized in high-level terms including its key components, potential to prevent damage, benefits, trade-offs, and costs. An illustrative example of this type of scenario planning, from Portsmouth, England, describes three potential responses to sea level rise and their relative merits (Figure 15). Providing accessible summaries and renderings of these scenarios would allow the community and non-experts to contribute and provide feedback.





Source: Facing up to Rising Sea Levels: Retreat? Defend? Attack? Future of Our Coastal and Estuarine Cities. Institution of Civil Engineering.

Following this interim input, the scenarios could be further refined and reanalyzed. The scenarios could then be summarized into an accessible, narrative style report, which might include order of magnitude cost estimates, co-benefits, and potential impacts. If resources allow, the preferred scenario could be developed in much greater detail and include specific projects, detailed cost estimates, detailed descriptions of the benefits and trade-offs, phasing strategies, and funding mechanisms. It is important to include a phasing strategy so that the plan can be flexible and respond to changing environmental conditions. For example, the plan's phased implementation strategy could be structured around certain "triggers" such as a given rate of sea level rise or the occurrence of a tropical storm.¹³ Other cities have proven that very detailed plans can be developed very quickly. However, working in a short period of time requires additional resources to support external experts and requires strong coordination between departments.

Developing these scenarios would provide the County with a full toolbox of potential responses to climate change and an understanding of the order of magnitude costs associated with various responses. It could help clarify the benefits and trade-offs associated with different approaches, helping the County to prioritize and develop consensus around the most promising opportunities. It would also help the County better articulate infrastructure needs and improve its position when applying for funding from federal, state, and private entities. **Creating an enhanced capital plan will also help evaluate the financial feasibility of various solutions and ensure that the proposal is achievable and implementable**. Without a comprehensive evaluation it is possible that a bottom up evaluation would generate a significant number of projects for each infrastructure system, which could grow in magnitude as climate risks increase.

¹³ For more information on the concept of flexible "adaptation pathways" see this video by Deltares http://english.deltacommissaris.nl/delta-programme

4.5 Potential Costs of Retaining External Experts

The cost of retaining external experts to develop an enhanced capital plan depends directly on how comprehensive and detailed the County would like the plan to be. Another important cost driver is how quickly the County would like such a plan to be published. As demonstrated by the costs of other similar projects detailed in Appendix 2, it could cost between \$1.5 and \$5 million to complete a comparable project in Miami-Dade County. As one example, creating A Stronger, More Resilient New York required approximately five months and approximately five million dollars.

It is possible to phase the development of such a plan to match available resources. The resources currently allocated to the Office of Resilience (\$800,000) will be used to initiate this process. If additional needs arise, they will be addressed in future budgets. Total funding needed for external experts could be reduced by drawing more heavily on internal County resources to manage the project and by limiting the consultant's scope of work to the technical and economic assessments. Following Hurricane Sandy, New York City temporarily pulled together more than 40 staff members from a variety of different agencies to work cooperatively for five months to develop their resiliency plan. Miami-Dade County could consider pursuing a similar strategy.

5 Conclusions

An enhanced capital plan developed with the support of external experts would address many of the County's current challenges with incorporating climate risks into capital planning. It has the potential to create a strong foundation for medium and long-term development. There are many useful precedents to draw upon including the experiences of New York, Boston, and the Netherlands. Similarly there are several different approaches the County can take to develop its own plan. Following a hybrid approach similar to New York or Boston and developing a rapid action plan and enhanced capital plan simultaneously may be the most expedient path forward for the County.

There are also many firms with very specific expertise in the range of disciplines needed to develop an enhanced capital plan, including engineering, economics, planning, community engagement, and communication. There may be benefits to working with several of these firms to take advantage of their individual expertise. There are also advantages to involving local universities and community-based organizations to the greatest extent possible. For example, a technical review board could be created in partnership with local universities to ensure the proposed adaptation measures are in line with known best practices. This review board could also potential help infuse the process with innovative ideas and connect with cutting edge research from the universities.

Most importantly, completing an enhanced capital plan has the potential to help prioritize and develop consensus around preferred adaptation measures. This could be very useful to ensure that short-term investments are not simply reacting to visible, short-term issues, such as nuisance flooding, but are instead proactively contributing to the long-term resilience of the community. Proactive collaboration with the private sector and local academic institutions is recommended to help ensure Miami-Dade County's proposed plan is innovative, multipurpose, and forward looking.

Appendix 1: Conceptual Scope of Work

This conceptual scope of work provides one proposed outline for how the County could proceed with developing an enhanced capital plan that, "reinvents the County's urban infrastructure in a timely, sequenced, and economically efficient manner." The intent is to create a process to develop effective actions that the County can undertake to protect its infrastructure in the face of increasing flood risks and ensure new projects are designed appropriately. The overall project objective is to identify and recommend actions for the short, medium, and long-term that would provide the County with a flexible and adaptable path forward in the face of changing climatic conditions and related risks associated with climate change including sea level rise.

Miami-Dade County: Enhanced Capital Plan

The project would provide the following:

- 1. A baseline vulnerability assessment
- 2. An enhanced capital plan including:
 - a. An assessment of different adaptation pathways in terms of their technical feasibility, economic implications, and impact on natural and urban environments
 - b. A structured stakeholder engagement process to solicit input on the different adaptation pathways and the enhanced capital plan
 - c. Recommendations for implementation and phasing
 - d. Identification of potential funding mechanisms
- 3. A rapid action plan:
 - a. A review and prioritization of tier-1 projects identified by key Miami-Dade County departments in order to accelerate the implementation of the most urgent capital improvement projects
- 4. Development of a methodology for incorporating sea level rise into all capital projects¹⁴

1. Baseline Vulnerability Assessment

Significant investment and staff time has been dedicated to understanding the potential environmental changes associated with climate change and climate variability in Miami-Dade County. The project team will be provided with resources in order to expedite the implementation of adaptation actions. These resources include, but are not limited to, localized sea level rise projections, associated changes in the wet-season groundwater heights, storm surge modeling including sea level rise, areas of repetitive flood losses, areas of concern identified by the Stormwater Master Plan, and potential future precipitation patterns.

This will be a technical, internally-focused phase of work which is intended to build upon existing work already completed by the County.

Task 1.1 Review and confirm vulnerability parameters (month 1)

Review the sea level rise, flooding, and other data provided by the County. The County will provide a climate planning forecast, based on analysis and synthesis of the most recent data on climate impacts for the region. The forecast will be grounded in the extensive work done to date by the Water and Sewer Department, The South Florida Water Management District, Regulatory and Economic Resources, the Southeast Florida Regional Climate Change Compact and the Florida Climate Institute. The consultant will work with the County to confirm the key assumptions and planning horizon that will

¹⁴ This component could be completed by County staff if resources dictate

be used for the development of the enhanced capital plan and the rapid action plan. Data will be provided as shapefiles where possible.

Task 1.2 Review and confirm exposure data (month 1)

The County will provide information on the key infrastructure and critical facilities, property, and population that will be impacted by sea level rise and flooding. The consultant will work with the County to confirm which exposure data can be reasonably assessed during the project timeframe. Data will be provided as shapefiles where possible.

2. Enhanced Capital Plan

The consultant will deliver a spatial plan detailing which adaptation measures are feasible and recommended for different portions of the county. These adaptation measures may include, but should not be limited to, new flood protection infrastructure, enhancing the existing drainage network, elevating key infrastructure, enhancing natural buffers, flood-proofing existing assets, or changing land use patterns. This plan will be based on a review of the technical feasibility of different adaptation measures, their economic benefits, their impacts on the natural and urban environment, and stakeholder input.

This phase of work will be an externally-focused.

Task 2.1 Stakeholder Engagement and Review of Precedent Work (Month 1)

The consultant will work with the County to develop a list of key stakeholders who should be initially consulted. These initial stakeholder discussions will discuss present issues and potential responses to inform the development of different adaptation scenarios.

The County will also provide the consultant with relevant background documents including:

- The Stormwater Master Plan
- The Local Mitigation Strategy
- The Comprehensive Development Masterplan
- GreenPrint (the County's Sustainability Plan)
- SE Florida Regional Climate Change Compact Regional Climate Action Plan
- One Community, One Goal

Task 2.2 Scenario Development

Task 2.2a Technical Assessment (Month 1-4)

The consultant will work the County and key stakeholders to develop a small number of adaptation scenarios that could feasibly be pursued in Miami-Dade County. These spatially-explicit adaptation scenarios will then be assessed to determine their technical feasibility, protective value, and ability to be altered in the future should conditions change. These scenarios should include a range of protection and accommodation strategies and include both structural and non-structural solutions.

Task 2.2b Economic Assessment (Month 2-4)

It is important to consider the economic feasibility and implications of investment in different adaptation measures in the initial planning phase. This assessment will consider the relative return-on-investment of alternative adaption approaches and explicitly consider the costs to protect different portions of the County from climate risks. The purpose of this analysis is to estimate the economic or financial feasibility of protection strategies. These would be initial, order-of-magnitude estimates.

Through the use of scenario planning the consultant will consider the economic implications of different strategies in order of magnitude terms. The exact metrics used to complete this assessment would be developed by the consultant in consultation with the County. These could include, for example, the cumulative costs of adaptation, the replacement costs of lost infrastructure (roadway, sewer, water, electric, and critical public facilities such as police and fire stations), the loss of fiscal generating revenue, and lost economic activity. The analysis would compare the potential costs of alternative solutions and the underlying economic value preserved or enhanced by the adaptation measures. The costs could include the estimated cost of implementation of a strategy, the opportunity cost of lost net fiscal resources, real estate value, infrastructure, jobs, wages, and economic output associated with each scenario. The benefits could include an aggregate estimate of real estate value, infrastructure value, net fiscal revenue, jobs, wages, and economic output protected, and increases in property values attributable to adaptation investments. The consultant will work with the County to develop these high-level scenarios and estimates.

The consultant will work with the County and key stakeholders to present a summary of this information in a way that can be easily understood by the general public. This information will be presented during the stakeholder engagement process.

Given that the future sea level rise remains uncertain the timing of investment in adaptation is critical. The consultant will also work with the County to explore the potential to optimize investments and phase them in over time, based on certain flexible adaptation pathways tied to certain physical triggers (such as a given rate of sea level rise or the occurrence of a major hurricane).

Task 2.3 Scenario Refinement (Month 4-5)

The consultant will work with the County and key stakeholders to refine the adaptation scenarios based on the technical and economic assessments. The consultant will develop three or four potential scenarios, which will be presented in a way that they can readily be understood by the general public. They will be presented in a way designed to illicit feedback and educate the community about tradeoffs and benefits associated with different approaches.

Task 2.4 Mid-way Stakeholder Engagement (Month 4-5)

The consultant will work with the County and key stakeholders to present the high-level adaptation scenarios to the public and solicit their feedback and input. The purpose of this engagement will be to educate the community about the trade-offs and benefits of different adaptation approaches as well as to listen to residents' priorities and concerns. To ensure ample opportunity for dialogue it is suggested that at least a portion of the engagement be structured in an open house or workshop format.

Task 2.5 Scenario Refinement (Month 5-8)

The consultant will use the input from the engagement process to further refine the adaptation scenarios. The consultant will reevaluate their technical or economic benefits to the extent necessary. The consultant will also further refine the presentation and communication of the information.

At this stage the consultant will also be asked to provide additional detail on project feasibility including: identifying potential funding sources, potential partners, potential financial or regulatory

incentives, regulatory or legal changes required, and critical coordination between public, private, and non-profit entities needed for implementation.

Task 2.6 Final Stakeholder Engagement (Month 8)

The consultant will work with the County and key stakeholders to present the second iteration of the adaptation scenarios to solicit final feedback. At this stage the consultant will also present information about feasibility including details on resources required, funding sources, and potential project phasing.

Task 2.7 Scenario Refinement and Feasibility Assessment

The consultant will work within the County to complete a final refinement of the scenarios based on feedback received.

Task 2.8 Final Report

Based on the analysis and stakeholder engagement the consultant will prepare a final report summarizing the refined adaptation scenarios as well as providing a recommendation on the preferred approach. In addition to containing the outputs of the technical and economic analysis the report should also summarize the feedback received and include examples of how the plans were refined to incorporate this feedback. The final report should also include a chapter on potential feasibility including potential funding sources, incentives, regulatory or governance changes necessary for implementation, community engagement needs, and a potential phasing strategy.

The final report should also include a short, high-level summary of adaptation scenarios which includes, to the extent possible, graphical representations of these scenarios. This summary should be aimed at the general public and should be easily understood by non-experts.

A draft of the final report will be provided to the County for review and comment before being finalized.

3. Rapid Action Plan

For this portion of the project the consultant will work closely with the County's infrastructure advisory group, which will be created and composed of key staff from selected departments responsible for critical infrastructure. The consultant will work with this group to review each department's list of improvements needed to address critical vulnerabilities. The consultant will then assess and prioritize these needs and develop a Rapid Action Plan, which will outline a phasing strategy for these more urgent projects.

This will be a technical, internally-focused portion of the project.

Task 3.1 Kick-Off Meeting (month 1)

Hold an in-person kick-off meeting with the Infrastructure Advisory Group. This meeting will finalize project goals and schedule. Infrastructure Advisory Group members will be asked to provide information on past vulnerability assessments and review infrastructure resiliency efforts already underway. Advisory group members will be asked to discuss potential data sources and/or other contributions from their agencies. This group may include, would not be limited to:¹⁵

- Internal Services Department
- Transportation and Public Works
- Water and Sewer
- Aviation

¹⁵ The size of this group could be adjusted to match available resources. If funding is limited this group could be limited to just the most critical systems.

- Seaport
- Regulatory and Economic Resources
- Parks, Recreation and Open Spaces
- Police
- Fire Rescue

The County will support the logistics and invitations for this meeting.

Task 3.2 Identify Key Infrastructure Needs and Vulnerability (month 1-3)

The consultant will meet with department liaisons individually, or in groups as appropriate, to review the projects each department has identified as important to address critical vulnerabilities. This phase will focus on urgently needed improvements, such as where a major roadway is compromised at high tide, where access to a fire station is limited due to flooding, or where key electrical equipment is located at the ground level.

Each department will be responsible for providing the consultant with details about each needed improvement. Characteristics relevant to the vulnerability including location, elevation, flood-sensitivity, age, current condition, and planned service life will be described and cataloged and provided as shapefiles where possible.

Task 3.3 Assess and Prioritize Potential Projects (month 4-6)

Following the interviews with the Infrastructure Advisory Group the consultant will work with the County to develop a method to assess and prioritize the projects in terms of their cost-benefit and criticality. This could build on existing methods used by Emergency Management to prioritize mitigation projects. Factors may include, but are not limited to: life safety needs, criticality to ongoing operations for an infrastructure system, time sensitivity to gaining protection, lack of current or planned hazard protection projects, and high vulnerability to flooding. The exact method of prioritization would be developed in close cooperation with the members of the Infrastructure Advisory Group.

The goal of this prioritization process is to identify projects that should be implemented immediately to begin reducing the County's vulnerability.

Task 3.4 Final Report – Rapid Action Plan (months 6-8)

The consultant will develop a list of prioritized projects and recommend project phasing.

4. Develop a methodology for incorporating sea level rise into all capital planning

Moving forward all capital projects should incorporate future sea levels and flooding risks into the project design. Some departments, such as Water and Sewer, have already systematically evaluated their infrastructure and have a plan in place to incorporate climate change risks into new project designs. Other departments have not yet taken those steps. This portion of the project would develop a standard method and review process for incorporating climate risks into the design of all capital projects.¹⁶

¹⁶ This portion of the project could be developed by County staff, building on precedents from other areas such as San Francisco. Alternatively this portion could be developed by a consultant.

Appendix 2: Potential Costs & Completion Times

The following projects are a selection of relevant examples that can help inform Miami-Dade County's own adaptation planning efforts. Below are both examples of other projects from other areas as well as professional estimates provided by the interviewed firms. The examples are organized based on their completion time. Many of the project descriptions and cost estimates were provided by the engineering and planning firms that developed them.

Project and Location	Description	Time	Approximate Cost
New York City	A Stronger More Resilient New York was developed in a highly expedited manner in the immediate aftermath of Hurricane Sandy. Developing this plan relied on approximately 40 full time city staff and numerous consultants. This plan drew upon years of detailed and thorough assessments of climate risk, vulnerability of sub-systems (such as wastewater), and urban waterfront planning	5-6 months	Approximately \$5 million
Norfolk, Virginia	Norfolk is in the process of developing a comprehensive resiliency strategy. They are developing a multi-layered strategy and phasing in different protective components over time. Developed quickly (less than a year) under time constraints imposed by an external competition. Developed with several consultants estimated to be approximately equivalent to 10-12 full time employees.	6-12 months	\$600,000 - \$800,000
WASD Ocean Outfall Program	Under Ocean Outfall program developed up-to-date climate scenarios for sea level rise (SLR), storm surge, extreme rainfall, and wind to incorporate climate risks and vulnerability assessments to build resilience into the \$13.5B capital wastewater program. Focused on assessing WASD wastewater facility vulnerability and risk to projected changes in precipitation intensity, duration, and frequency (IDF), sea level rise (SLR), and storm surge. Climate scenarios were selected and were used to estimate coastal surge conditions. Those surge elevations were then coupled with rainfall to estimate inundation depths at each of 3 of WASDs critical treatment plants and 140 critical pump stations (140 out of over 1000). Flood hardening options were evaluated for different levels of risk. This data was used for flood risk evaluation and facility hardening evaluation and design guidance.	9 months	\$600,000
Hoboken	This project, <i>Resist, Delay, Discharge,</i> was developed through the Rebuild by Design Competition. The plan is a comprehensive urban water strategy that addresses the risks of storm surge, sea level rise, and intense rainfall. Because of the competition timeline the project was developed in a very short time span.	9 months (initial design phase), implementation is ongoing	(design phase unknown; \$230 million was awarded to support implementation)
Wilmington, North Carolina	A pilot project developed guidance on potential strategies to adapt to future SLR and extreme storm events on water and wastewater infrastructure for the Wilmington, N.C. area. It is built on a previous NC SLR Risk Management Study as well as an asset management study for the Cape Fear Municipal Utilities Authority.	9 months	\$75,000
Engineering firm #1 estimate	For many local coastal resiliency plan projects, this company completes a thorough gap-analysis of all development, infrastructure planning and building to recommend across the board changes. For state level mitigation plans, they have looked across all agencies and programs with policies, programs or regulations that impact resilience and completed gap-analysis with recommendations for improvements. Many times changes to codes, policies, regulations and capital spending are very effective resiliency strategies that can come at low costs. Depending on the scope, such a study could be completed for Miami-Dade County in 6 months to a year for \$40,000 to \$100,000.	6 months – 1 year	\$40,000 - \$100,000
Engineering firm #2 estimate	Studies in other areas range in scope, detail and length and the cost and timeline also vary accordingly. Other studies have ranged from	1 year (initial planning) to 5-8	\$100,000 - \$25 million

	\$100,000 to \$25 million. A project could be designed for Miami-Dade County which is structured to complete the initial planning in the first	years (long- term planning)	
	year and longer-term planning over a period of 5-8 years.		
Engineering firm #3 estimate	Most of this company's resilience planning efforts range in duration from one to two years and have budgets from \$100,000 to \$3,000,000.	1-2 years	\$100,000- \$3 million
Engineering firm #4 estimate	Conducted a regional study program which resulted in a stakeholder supported, implementable, staged plan backed up by a quantitative basis of costs and benefits could be completed in 1.5 to 2 years for \$1-1.5 million. This plan would not contain all design details needed for implementation of the different elements. The cost would depend on the division of work between consultants and the government and the availability of good system models.	1.5-2 years	\$1- \$1.5 million
Engineering firm #5 estimate	To complete a first phase, utilizing existing baseline information (surge modeling etc.) and focusing on outlining certain strategies at a high level could be done for \$100,000 to \$300,000. To develop a capital plan, it will require \$1-2 million dollars; however funding for a first round of \$100-200,000 could provide an adequate start.	1-3 years	\$100,000 - \$300,000 (phase 1) \$1 - \$2 million (full plan development)
New Orleans Urban Water Plan	This plan outlines a long-term vision for remaking the water management system of New Orleans.	+2 years	~\$2.5 million
NYCDEP Wastewater Resiliency Plan	Comprehensive flood protection plans for all of NYC's wastewater infrastructure, including climate vulnerability assessments, development of a citywide framework for future adaptation actions that may be vulnerable under current and future conditions.	2.5 years	\$3 million
City of Virginia Beach	Developing a Comprehensive Sea Level Rise and Recurrent Flooding Analysis and Planning Study. This study provides an integrated approach starting with a hazard/risk assessment that will inform adaptation planning, initial conceptual designs and implementation.	3-4 years	\$3 million
California Statewide Flood Management Planning Program	"California's Flood Future: Recommendations for Managing the State's Flood Risk" provides information for developing California's flood management policies and investments in the coming decades. More than 7 million people and \$580 billion in assets (crops, buildings, and public infrastructure) are exposed to the hazards of flooding in California. The program identified the immediate need for more than \$50 billion to complete flood management improvements and projects. Stakeholder engagement included information from more than 140 local agencies located in all 58 counties and State and Federal agencies. The report recommended flood management using an Integrated Water Management approach to promote system flexibility and resiliency to accommodate changing conditions such as ecosystem needs, climate change, flood events, and financing capabilities.	4 years	\$12 million
Los Angeles	Through a Department of commerce grant they are beginning the adaptation planning for some components with a preliminary vulnerability assessment, which will be the foundation for the longer term study	5+ years	\$4 million
Alexandria Virginia Storm Sewer Capacity Analysis	Consultants prepared a stormwater master plan, including assessments of capacity limitations based on projections of increased rainfall and sea level rise, and prioritization of problem areas and alternatives based on assessment of critical infrastructure	6 years	\$3.5 million
Central Valley Flood Protection Plan, California	Consultants updated flood risk mapping in the Central Valley of California and provided public education, communications, and outreach. Developed state-of-the art data management tools to support California Department of Water's flood risk management program. Other uses include land-use planning, levee maintenance prioritization, programming of infrastructure investment, and preparations for emergency response plans.	7+ years	\$25 million
Thames Estuary 2100	Consultants completed a comprehensive flood risk management for lower Thames River in London, including SLR and riverine and coastal surge risk to all infrastructure assets	10 years	14 million pounds (~\$21 million)

Appendix 3: Examples from Other Cities

New York City



This comprehensive plan contains actionable recommendations for increasing the resilience of the city's infrastructure and buildings. The plan is organized by infrastructure systems such as telecommunications, transportation, water and wastewater and by communities such as South Queens and Southern Brooklyn. The plan covers all five boroughs and includes a comprehensive coastal protection plan. The plan's recommendations cover both infrastructure improvements and policy changes.

Available at: http://www.nyc.gov/html/sirr/html/report/report.shtml

London



This plan outlines the Mayor's adaptation strategy for managing flooding, drought, and heat. The plan outlines tangible short-term benefits, such as improving parks and public spaces, that will help the city adapt to long-term challenges. Chapter 9 focuses on the city's infrastructure as one component in a larger system. This plan is more focused on identifying vulnerabilities and policy recommendations than on specific infrastructure improvements.

Available at: <u>https://www.london.gov.uk/what-we-</u> <u>do/environment/environment-publications/managing-risks-</u> increasina-resilience-mavors

Rotterdam



This very comprehensive plan frames the city's adaptation efforts in terms of the protective system (inner and outer dike systems) and in terms of different urban typologies (port, suburban, urban). This differentiation of strategies by typology could be very relevant to development of Miami-Dade's own plan. This plan developed in partnerships with external research centers.

Available at:

http://www.rotterdamclimateinitiative.nl/documents/Documenten /20121210 RAS EN Ir versie 4.pdf

Appendix 4: Quarterly Reports

First Quarter Update (January 3, 2015 – April 30, 2015)

On January 21, 2015, the Board of County Commissioners (Board) approved Resolution No. R-49-15, which requested quarterly status reports and a final report within one year of adoption regarding the initiation of discussions related to climate change by the Mayor, in conjunction with the Office of Intergovernmental Affairs, with private insurance and reinsurance professional organizations, member local governments in the Southeast Florida Climate Change Compact, the Florida Office of Insurance Regulation's Department of Finance Services, and other key stakeholders to develop long-term risk management solutions. This is the first Quarterly Status Report submitted for your review. In accordance with Ordinance 14-65, this memorandum and report will be placed on the next available Board of County Commissioners meeting agenda.

<u>Background</u>

In July 2013, the Board created the Miami-Dade Sea Level Rise Task Force (SLRTF) for the purpose of reviewing current and relevant data, science and reports, and to assess the likely and potential impacts of sea level rise and storm surge to Miami-Dade County over time. On July 1st, 2014, the Task Force presented a report to the Board entitled, "Miami-Dade Sea Level Rise Task Force Report and Recommendations," providing the requested assessment along with recommendations of how Miami-Dade County may more specifically begin planning and preparing for projected sea level rise impacts. In addition, Resolution R-451-14 and Ordinance 14-79 were adopted in 2014, requiring that planning, design and construction of County infrastructure consider potential sea level rise impacts. On January 21st, 2015, the Board passed seven separate resolutions, each supporting the implementation of one of the seven recommendations related to climate change with the insurance sector and other key stakeholders to develop long term risk management solutions.

On September 29, 2014, the Mayor and the Beacon Council co-hosted a meeting with the UK Ambassador, the UK Consul General, and key leaders in the business and insurance sectors of Miami-Dade to discuss issues and opportunities associated with climate change and sea level rise in Southeast Florida. In addition, the Mayor announced in his opening remarks at the Sixth Annual Southeast Florida Climate Leadership Summit on October 1st, 2014, that he will convene a group of business, financial and insurance leaders to begin a dialogue around these critical business and financial issues.

Quarter 1 Progress (January 31, 2015 – April 30, 2015)

The following steps have been taken during the first quarter towards implementation of this Resolution:

The Nature Conservancy contacted Miami-Dade County in March 2015 with information regarding their collaborative work with Swiss Re to demonstrate the cost effectiveness of coastal ecosystems in adaptation and risk reduction. They have developed "a set of tools and approaches for quantifying risks from coastal hazards and climate change," and provided a Project Note (see attached), summarizing the methodologies used and tools and models developed. They are proposing consideration of parametric insurance policy based on their existing model. Staff from the Regulatory and Economic Resources Department and Internal Services Department's Risk Management Division are currently evaluating the information provided for applicability and use by Miami-Dade County.

In addition, RER staff are working with the Office of Intergovernmental Affairs to identify appropriate stakeholders and candidates to include in an initial meeting, which will occur during the next Quarter.

If you have questions concerning the above, please contact Mark R. Woerner, AICP, Assistant Director for Planning, Department of Regulatory and Economic Resources, at (305) 375-2835 or <u>mwoerner@miamidade.gov</u>.

Second Quarter Update (May 1, 2015- July 30, 2015)

R-46-15: Prepare Action Plan and Report to Accelerate the Climate Change Adaptation Planning Process by Evaluating the Engineering and Other Relevant Expertise Needed to Develop an Enhanced Capital Plan

This resolution directs the Mayor or the Mayor's designee to prepare an action plan and report to accelerate the climate change adaptation planning process by evaluating the engineering and other relevant expertise needed to develop an enhanced capital plan that includes but is not limited to flood protection, salinity structures, pump stations, and road and bridge designs, and to determine the costs of retaining the experts needed.

Staff conducted the following research and interviews during the Second Quarter to address the preparation of the action plan required by this resolution:

- In September 2014, San Francisco's Capital Planning Committee adopted a new policy "Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco." RER staff have consulted with the Climate Program Director from the San Francisco Public Utilities Commission who helped create a consistent and comprehensive review, planning and implementation process to carry out that policy. San Francisco has addressed this challenge by requiring each department with responsibility for implementing capital projects to identify and map project sites included in the 10 year capital plan and verify whether they fall within a "Vulnerability Zone" as defined and mapped by San Francisco's sea level rise committee. For each project exceeding \$5 million, departments are required to complete a Sea Level Rise Checklist and submit it for review to the Capital Planning Committee and the City Engineer's Office. Departments are also required to submit specific long-term strategies to specifically address the adaptive capacity of the project. The San Francisco Public Utilities Commission makes its consulting firm (AECOM) available for training and assistance to individual departments who are unsure of how to comply with the requirements. Aspects of the approach adopted in San Francisco may have direct applicability to addressing some of the needs of Miami-Dade County. In particular, this approach may be useful to evaluating routine capital projects across departments.
- RER staff have reviewed the U.S. Department of Transportation Federal Highway Administration's training series "Building a Climate Resilient Transportation System". While it is focused on transportation infrastructure, the methods and tools available for assessing a system's criticality and sensitivity to climate and extreme weather, and therefore its vulnerability, would be applicable across other systems. At a minimum, these tools, as well as tools available from the Florida Department of Transportation, could be immediately useful for informing the capital planning process for future transportation projects.
- The City of Miami Beach has commissioned the engineering firm AECOM to conduct a study focused on performing modelling of the existing stormwater infrastructure to support collection system and conveyance improvements along with stormwater pump stations to mitigate flooding potential for low lying areas. The study also involves elevating roadways, sidewalks, and other public infrastructure. While this study is being conducted at a smaller scale than that needed to assess the vulnerabilities of Miami-Dade County, it serves as a useful precedent and benchmark to estimate the potential resources required for a larger scale study. The City of Miami Beach is also conducting a study to evaluate stormwater utility rates. The study is exploring what changes may be needed to support the necessary major capital improvements required to mitigate flooding. The results of this study will also provide useful information on a potential financing mechanism for future infrastructure investments.
- RER staff are continuing to consult with other county departments Water and Sewer Department, WASD); Public Works and Waste Management (PWWM); and Parks, Recreation and Open Spaces (PROS) - which all have various levels of experience integrating flood risks into capital planning and prioritization. This work is being reviewed in consideration of developing a broader process for all County departments.
- RER staff also consulted with City of Fort Lauderdale staff about their approach to incorporating sea level rise considerations into their capital planning process. These considerations have been incorporated through the use of Adaptation Action Areas. They shared their prioritization process with RER staff, but the

approach adopted by the City of Fort Lauderdale is not directly applicable to the capital planning and prioritization process employed at Miami-Dade County's scale.

 The Compact's Sea Level Rise Consensus Workgroup has finalized a revised Sea Level Rise Projection for Southeast Florida. This projection differs to some degree from the original sea level rise projection developed in 2011, and will be utilized for planning purposes by Miami-Dade County and the other partners of the Compact. This revised projection and accompanying document are expected to be publicly released in the fall of 2015, and are currently available for internal review.

Third Quarter Update (July 31, 2015- October 31, 2015)

R-46-15: Prepare Action Plan and Report to Accelerate the Climate Change Adaptation Planning Process by Evaluating the Engineering and Other Relevant Expertise Needed to Develop an Enhanced Capital Plan

This resolution directs the Mayor or the Mayor's designee to prepare an action plan and report to accelerate the climate change adaptation planning process by evaluating the engineering and other relevant expertise needed to develop an enhanced capital plan that includes but is not limited to flood protection, salinity structures, pump stations, and road and bridge designs, and to determine the costs of retaining the experts needed. This resolution requires a status report within 90 days and a final report within 180 days of the effective date. A resolution authorizing an extension to provide the final report is pending final Board approval.

Staff conducted the following research and interviews during the third quarter to address the preparation of the action plan required by this resolution:

- RER staff continued many tasks initiated in previous quarters including working with the Water and Sewer Department (WASD), the Stormwater Utility Planning Division (formerly in the PWWM department) at RER, and the City of Miami Beach, to evaluate the applicability of their existing contracts with various firms to plan for adaptation to rising sea levels. Each of these existing contracts provide very useful information which can serve as a springboard for the County's own efforts. The technical products from these projects are also being collected by RER staff to inform the final reports for this resolution and Resolution R-48-15.
- On August 31, 2015, RER had a conference call with the city of Seattle staff to discuss how the city has incorporated sea level rise into its capital project planning process. The City staff explained how consideration of sea level rise implications were integrated into their Public Works department's "stage gates" process, which is designed to rationalize investments and ensure that capital improvement projects make sense from a triple bottom line perspective. Before creating this review process Seattle had two rounds of studies developing localized sea level rise projections which were then mapped in GIS and used for a vulnerability analysis. Project managers and have adopted the sea level rise projection and have experienced a relatively low marginal cost to elevate projects to be resilient to sea level rise. City staff are beginning conversations with other agencies to ensure that these resilient projects do not become islands, but are instead supported by the surrounding infrastructure. The City has yet to encounter significant pushback against these new requirements and has generally found good buy-in. Seattle is considering strengthening their floodplain regulations in the future to better incorporate sea level rise, but have not determined the timing for this yet.
- On September 2, 2015, RER staff spoke with New York City to discuss how the City developed the comprehensive coastal protection strategy outlined in A Stronger More Resilient New York. This comprehensive strategy drew heavily upon the Urban Waterfront Adaptive Strategies guide (discussed later in this report) and previous supporting research such as that done by the New York City Panel on Climate Change. Building on this foundational research and working with an urgency provided by Hurricane Sandy, the New York City team developed a comprehensive strategy for coastal protection in a period of five months. Typically, an effort of this scale would take one to two years, at a minimum. With an internal team of over 40 people pulled from various departments, and with the support of external consultants and academics, the plan was published in June 2013. Even though the plan was prepared

over a short time period the team garnered significant community engagement and feedback that was incorporated into the final plan. This comprehensive plan serves as an excellent model that Miami-Dade County should consider drawing from as the County prepares its own strategy.

- On September 3, 2015, RER staff spoke with staff at the City of San Francisco about how the city has incorporated sea level rise into its capital planning process and to discuss the city's process to develop the sea level rise checklist summarized in the Second Quarter report. To support the development of the checklist and the accompanying comprehensive guidance document framing vulnerability and adaptive capacity, City staff worked with liaisons from key government departments for over a year. Through frequent meetings they were able to develop a process that had wide buy-in from other departments. Through that process they were also able to integrate additional training on climate change and sea level rise to bolster their internal capacity to respond to these changes. During this process the city was able to draw upon existing contracts with consulting firms with the relevant technical expertise. For example, the city was able to draw upon the engineering firm that was under contract to develop a comprehensive capital improvement plan for the city's sewer system. One of the many strengths of the approach adopted by San Francisco is that it provides considerable flexibility to account for the type of project, the project lifespan, and the marginal cost of future adaptations, as well as other considerations. This allows project managers to select the appropriate adaption scenario based on their project. For example, a fire station that is intended to function in place for 75 years, will be built to a much higher elevation than a new park gazebo with a lifespan of only 20 years. San Francisco has shared the materials they used to develop the guidance, their sea level rise project checklist, and their training materials. This process is also an excellent example of how Miami-Dade County can begin to systematically integrate considerations of sea level rise into its own capital planning process.
- During the week of September 21, 2015, RER staff interviewed eight major planning and engineering firms to ascertain the approximate cost, timeline, and scope of work that would be required to develop an enhanced capital plan involving all levels of government to reinvent Miami-Dade County's urban infrastructure. The intention of these interviews was not to evaluate any of the firms, but rather to conduct market research and gather order of magnitude estimates of the approximate costs to fulfil this resolution and better understand how this work could be structured. During these interviews, the firms were asked to discuss precedent projects where their firms had developed a comprehensive capital plan, flood protection plan, or resiliency plan that would be relevant to Miami-Dade County. For each example, the approximate time and resources required to develop it were discussed. Firms were also asked how this work could be phased and subdivided to provide more flexibility based on future funding availability. Specifically they were asked to detail which subcomponents (i.e. economic assessments of adaptation strategies) they would recommend including in phase one of the process. All firms were asked how they could build upon the extensive data and analysis the County has previously developed (i.e. localized sea level rise projections, surge, groundwater, and stormwater modeling etc.) to maximize project outcomes. All firms were asked how they would adapt their work to reflect the unique hydrology and geology in Southeast Florida, which precludes a number of typical flood defenses such as levees. All firms were asked if they have experience evaluating existing codes/regulations/procedures to understand how they could better encourage resilient investments in other capital projects. Finally, all firms were asked how they integrated community engagement into prior planning projects.
- On September 23, 2015, RER staff spoke with a senior climate scientist and coastal engineer from the Army Corps of Engineer's (USACE) Institute for Water Resources in Portland, Oregon. Both individuals are experts in how to incorporate sea level rise into capital project planning. During the conference call, the discussion focused on how Miami-Dade County could potentially implement the USACE's Engineering Technical Letter on sea level rise, which is already partially incorporated through the SE Florida Regional Climate Change Compact's (Compact) Unified Sea Level Rise projection.