FEASIBILITY ASSESSMENT OF DEVELOPING A SEA LEVEL RISE CHECKLIST

AUGUST 2018

Final Report for Resolution R-233-16

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Introduction

Summary

The County has multiple policies that require project designers to consider the implications of sea level rise on their proposed capital improvement projects. In June 2018, the County completed a vulnerability analysis of existing facilities to flooding from sea level rise and future storm surges and determined that the majority of the more than 1,000 county-owned properties evaluated were vulnerable. This study also looked at the vulnerability of planned capital improvement projects and found that of the 28 projects studied, the potential losses from flooding exceeded $24 million. The engineering consultants leading the study estimated that with an additional four percent increase in project budgets for resiliency measures these losses could be largely avoided. The most cost-effective way to systematically protect the County's infrastructure is to integrate resiliency considerations into the design of all new capital improvement projects (CIP) as early as possible.

Protecting facilities from flooding and wind damage typically increases the initial construction costs; however, it can significantly reduce costs over the lifetime of the asset. Failing to fully factor in the risk of flooding and other hazards into project designs may lead to significant costs from storm damage, the disruption of public services, and shorter replacement cycles.

The Water and Sewer Department (WASD) is setting an excellent example by designing improvements to their wastewater treatment plants to anticipate the impact of rising sea levels and higher storm surges. Several other departments are also elevating their structures to reduce flood risks. For example, the Fire Rescue Department recently modified the design of its new Ocean Rescue facility at Crandon Park to be higher to reduce the risk of storm surge. Modifying projects early in the design phase is typically the most cost-effective stage to alter a project.

This report finds that it is feasible and advisable for the County to develop a sea level rise checklist to help ensure that new infrastructure is built to withstand future floods and storms and that there is a consistent approach across departments. A checklist and a clear process will help various departments adopt consistent standards, use consistent information, and adopt best practices for CIP projects. Other major cities have demonstrated that this approach is best practice to coordinate multiple departments. A sea level rise checklist was also recommended by the engineers, Hazen and Sawyer, who completed the vulnerability assessment of the County's critical infrastructure in early 2018.

This report includes a draft checklist that could serve as a template. However, before making the checklist a requirement for the County's own projects, it is recommended that the County convene a working group with key departments responsible for the majority of critical infrastructure projects to test and refine the format. The Office of Resilience is currently working with the Information Technology Department to create an online tool to make the data necessary to complete a checklist accessible and easy to use.

Supporting resolution and context

On March 8, 2016, the Board of County Commissioners (Board) passed Resolution No. R-233-16, which directs the Mayor or Mayor's designee to "explore the feasibility of developing and using sea level rise checklists for Miami-Dade County."

This final report is provided in response to Resolution No. R-233-16. The report provides existing policies in Miami-Dade County and how governments in New York, Boston, San Francisco, and other jurisdictions have integrated sea level rise into their project design and review processes. The report discusses the advantages of adopting a sea level rsie checklist and sets out recommended next steps.

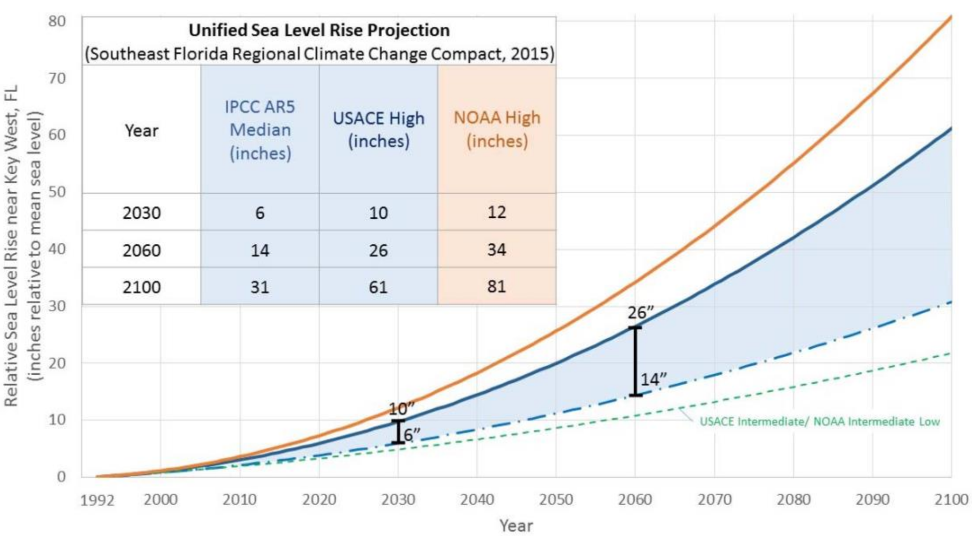
Existing policy

The County currently has multiple policies that require designers and engineers of capital improvement projects to consider the implications of sea level rise on their proposed projects. The Board adopted Resolution No. R-451-14 on May 6, 2014 requiring all County infrastructure projects to consider sea level rise impacts during all project phases. The most pertinent portion of the Resolution specified that,

> "It is the policy of Miami-Dade County that **all County infrastructure projects**, including but not limited to County building elevation projects, County installation of mechanical and electrical systems, County infrastructure modifications, and County infrastructure renovations, initiated from the effective date of this resolution shall **consider sea level rise projections and potential impacts** as best estimated at the time of the project, using the regionally consistent unified sea level rise projections, **during all project phases** including but not limited to planning, design, and construction, in order to ensure that infrastructure projects will function properly for fifty (50) years or the design life of the project, whichever is greater."

This Resolution also directs the Mayor to use the regional unified sea level rise projections (Figure 1) which was updated in the fall of 2015 and will be revised regularly to reflect the best and most current science.

Figure 1: Unified sea level rise projection for Southeast Florida



Source: Southeast Florida Regional Climate Change Compact

Also, in 2014, the Board adopted Ordinance No. 14-79, requiring that all agenda items related to the planning, design, and construction of County infrastructure include a statement that the impact of sea level rise has been considered. This Ordinance modified Section 2-1 of the Code of Miami-Dade County and became effective as of September 13, 2014.

The need to consider sea level rise in capital planning

Vulnerability of existing infrastructure to flooding exacerbated by sea level rise

In June 2018, the County completed a study analyzing the vulnerability of existing County facilities to flooding from sea level rise and future storm surges. The results can be found in a report titled "Rapid Action Plan: Vulnerability of County Assets to Sea Level Rise and Future Storm Surge" available on the Office of Resilience's website.[1] The most important finding, however, was that around 75% of the more than 1,000 county-owned properties evaluated, such as fire stations, airport and seaport facilities and others, were found to be vulnerable. While this study was focused on future flooding risks, many of these same facilities are vulnerable to storms under current conditions.

This study also looked at the vulnerability of planned capital improvement projects (CIP) and found that of the 28 CIP projects studied, the potential losses from flooding exceeded $24 million. The engineering consultants, Hazen and Sawyer, leading the study estimated that with an additional four percent increase in project budgets for resiliency measures, these losses could be largely avoided.

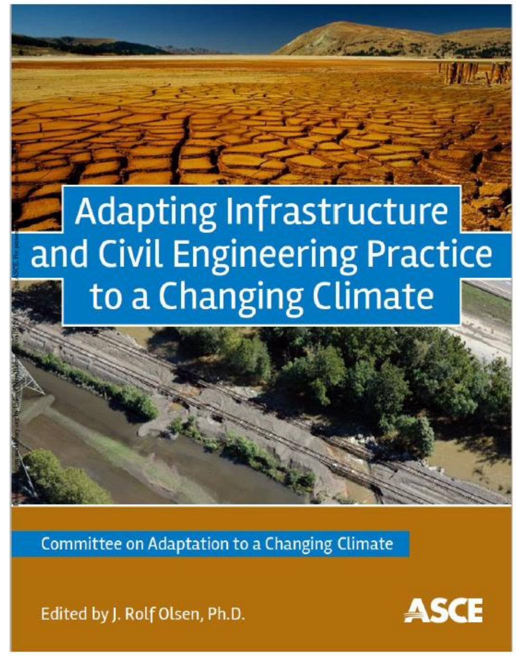
Figure 2: King tide flooding affects access to a City of Miami fire station

[1] This report can be found online at: https://www.miamidade.gov/green/climate-change.asp

Additional costs associated with underdesigned infrastructure

Protecting facilities from flooding and wind damage typically increases the initial construction cost to some degree; however, it can significantly reduce costs over the lifetime of the asset. Failing to fully factor in the risk of flooding and other hazardous events into project designs may lead to significant costs. For example, improperly designed infrastructure may be heavily damaged in the event of a storm. In addition to the direct losses, there is the potential for larger financial impacts if the broader economy is affected by the disruption of public services. Most importantly, the disruption of key public services can also present a safety hazard, such as lack of access to vulnerable populations by emergency services.

Figure 3: Recent publication on adapting to climate change from the American Society of Civil Engineers



Beyond storm damages, one of the most significant costs of failing to account for changing water levels is shorter replacement cycles. As shown in Figure 5 on the next page, many assets such as bridges and wastewater treatment plants are designed to last for more than 50 years. According to current projections, sea levels could be as much as three feet higher in 50 years' time. If an asset cannot be effective for its entire design life due to flooding and needs to be replaced or rebuilt sooner than anticipated, it will drive up capital budgets.

These implications of climate change have been recognized by organizations such as the American Society of Civil Engineers (ASCE) and the Army Corps of Engineers.[2] A recent report from the ASCE[3] (Figure 3) notes that,

> "The long-lived nature of infrastructure and the even longer-term influence of the associated rights-of-way and footprints suggest that the climate of the future should be taken into account when planning and designing new infrastructure. Considering the impacts of climate change in engineering practice is analogous to including forecasts of long-term demands for infrastructure use as a factor in engineering design…Engineers should develop a new paradigm for engineering practice in a world in which climate is changing, but cannot be projected with a high degree of certainty...Engineers should seek alternatives that do well across a range of possible future conditions."

This flooding risk also contributes to many smaller, on-going costs such as higher flood insurance premiums and minor disruptions in services. Additionally, frequent flooding can lead to increased maintenance costs as water damage and corrosion from salt water incrementally damages assets. For example, repeated flooding with salt water degrades the roadbed leading to the need to reconstruct the road sooner than its design life. This flooding also leads to increased corrosion of vehicles, including transit buses, passing through the saltwater.

Figure 4: King tide flooding affects traffic on Biscayne Boulevard

One of the most cost-effective ways to reduce the risk to the County's infrastructure is to ensure that all new projects are built to last.

[2] The Army Corps of Engineers has developed guidance on incorporating sea level rise into project designs which is available on their website https://www.usace.army.mil/corpsclimate/Planning_for_Changing_Sea_Levels.aspx

[3] Adapting Infrastructure and Civil Engineering Practice to a Changing Climate. American Society of Civil Engineers. Available at https://ascelibrary.org/doi/pdf/10.1061/9780784479193

Figure 5: Typical Life expectancy of select infrastructure

Average Life Expectancy of Select Infrastructure Types and Potential Climate-Related Vulnerabilities

Mode	Example of Infrastructure Asset	Design Lifetime	Potential Climate-Related Vulnerabilities
Transportation	Paved Roads	10–20 Years	Softening, deterioration, and buckling caused by heat. Scour (or sediment removal) and erosion caused by flooding and storm surge. Sea level rise inundation. Accelerated corrosion in coastal areas caused by sea level rise. Road closures caused by landslides and washouts during heavy precipitation events. Damage to foundation caused by changes in soil moisture.
	Rail Tracks	50 Years	Buckling and deformation caused by heat. Scour and erosion caused by flooding, storm surges, and extreme precipitation events. Railway subsidence caused by groundwater depletion.
	Bridges	50–100 Years	Erosion and scour caused by flooding, storm surges, and sea level rise inundation. Accelerated corrosion in coastal areas caused by sea level rise and saltwater intrusion. Reduced vertical clearance over major waterways caused by sea level rise. Damage to foundation by changes in soil moisture or higher waterway levels.
Energy	Transmission Lines	50 Years	Lower transmission efficiency caused by increased temperatures; peak demand during highest temperatures compounds vulnerability. Wooden utility poles destroyed and damaged in wildfires. Lines disrupted or shut down by smoke and particulate matter ionizing the air and creating an electrical pathway away from transmission lines.
	High-Voltage Transformers	40 Years	Service disruptions caused by more frequent and severe precipitation events, flooding, and wildfires. Lower transmission efficiency caused by increased temperatures.
	Generating Plants and Substations	35–80 Years 35–45 Years	Inundation of coastal power plants and substations caused by king tides, storm surge, and sea level rise. Service disruptions caused by more frequent and severe extreme heat, precipitation events, flooding, and wildfires.
Water	Reservoirs and Dams	50–80 Years	Lower water availability caused by higher temperatures and droughts in some regions can decrease water supplies and hydropower. More severe precipitation events threaten dam integrity or dam breaching. More frequent and severe wildfires leave ash and eroded sediment in drinking water supplies.
	Treatment Plants and Pumping Stations	60–70 Years	System overwhelmed with storm water resulting from more extreme precipitation events and, in coastal areas, with seawater driven by storm surge. Increased water quality treatment needs during drought periods.
	Drinking Water Distribution and Storm and Sewage Collection Systems	60–100 Years	Storm water management and collection complicated by more extreme precipitation events and changes in water availability caused by higher temperatures.

Critical infrastructure assets are vulnerable to extreme weather and climate change, with longer-lived assets facing more severe vulnerabilities expected later this century. A particular asset's vulnerability may vary from the general vulnerabilities listed due to its location, age, design, adaptive capacity, etc. The assets listed below are illustrative, not comprehensive. (SOURCES: ASCE 2017; ASCE 2015; TRB 2014; DAVIS AND CLEMMER 2014; DOE 2013; STOMS ET AL. 2013; ASCE 2011; NRC 2008; EPA 2002).

The Water and Sewer Department (WASD) provides an excellent example of how to think proactively about assets and capital projects. WASD is designing improvements to their wastewater treatment plants to anticipate the impact of rising sea levels on flooding frequency and higher storm surges, among other events. As seen in Figure 6, WASD recently constructed their new chlorine building at the Central District Wastewater Treatment Plant higher to withstand future storms. The left portion of the photo shows the floor elevation of the new chlorine building. Note that the doorway is at approximately the same height as the roof of the old facility.

Figure 6: New elevated chlorine building at WASD's wastewater treatment facility on Virginia Key

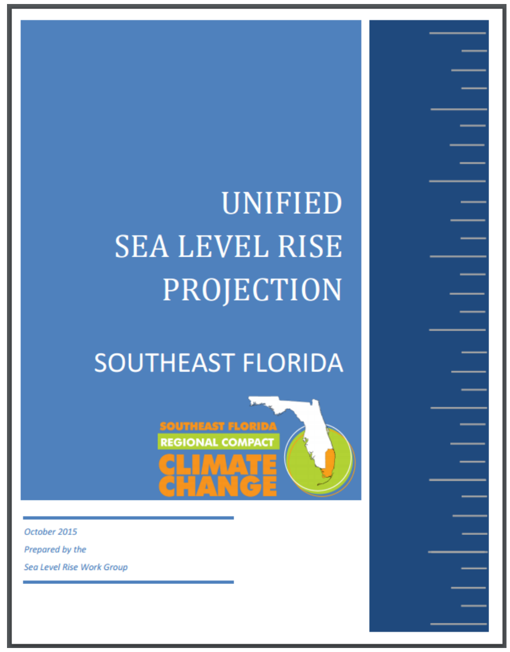
Several other departments are also elevating their structures to reduce flooding risks. For example, the Fire Rescue Department recently modified the design of its new Ocean Rescue facility at Crandon Park to be higher to reduce the risk of storm surge. This decision was informed by the research conducted previously by WASD.

Modifying projects early in the design phase is typically the most cost-effective stage to alter a project. It is important to note that accounting for changing water levels and increased frequency of hazards does not mean designing the infrastructure to be completely unaffected by those hazards. Rather, it means the infrastructure is built with those impacts in mind. The decisions about how to protect a given asset need to be made in the broader context of the assets criticality, design life, desired level of service, and the tolerance for risk. Infrastructure should be designed to perform under a variety of conditions, including the extreme events expected during hurricane season. In some cases, this might mean an asset is built to withstand flooding and quickly recover after. In other cases, it might mean that certain assets will be damaged, but quickly replaced after an event. It may be that only certain sensitive components, such as the electrical equipment, need to be elevated while the remainder of the facility can be left at grade.

Sea level rise projections for Southeast Florida

Miami-Dade benefits from close collaboration with local scientists and world-renowned experts on sea level rise. Through the South Florida Regional Climate Change Compact, this group of technical experts has gone through a rigorous process to develop the *Unified Sea Level Rise Projection for Southeast Florida* that reflects local conditions. The technical working group that developed the original projections collaborates on an on-going basis to revise the projections to reflect the best and most current science. Their revised projection was published in October 2015 and they will provide another revision in five years or sooner if required (Figure 7). As previously mentioned, the Board of County Commissioners has already directed that all infrastructure projects should consider these projections during all project phases.

Figure 7: The Unified Sea Level Rise Projection was recently revised in October 2015 to reflect the most current scientific research and understanding.



Source: Southeast Florida Regional Climate Change

These projections are based on the projections from the Army Corps of Engineers, National Oceanic and Atmospheric Administration (NOAA) and the Intergovernmental Panel on Climate Change and are therefore consistent with all the existing tools and resources provided by these entities. For example, the Army Corps of Engineers has put forward an extensive guidance document and an online tool to help project designers.[4] One online tool allows project designers to calculate the appropriate sea level rise adjustment for each project based on its location and timeline.[5] Similarly, NOAA has developed extensive guidance and a number of online resources to better understand local sea level rise impacts, such as free, online map tools.[6]

The projections allow project engineers and designers flexibility to choose an appropriate level of anticipated sea level rise based on the criticality of an asset and its expected functional life. For example, if an architect was designing a new park gazebo that is intended to last 20 years and presents a low-risk if it floods, they may choose to build it to a lower level of sea level rise. In contrast, if a designer was preparing plans for a new bridge along a critical evacuation corridor that is designed to last 50-100 years, it would be more appropriate to use a higher, and more conservative, estimate of sea level rise.

How other jurisdictions are integrating sea level rise into capital planning

San Francisco, California

Description, process and responsibility

The city of San Francisco requires all departments to complete a "Sea Level Rise Checklist" (Appendix 2) for certain capital projects.[7] The checklist is required for all projects that cost more than five million dollars, are slated for funding in the next 10 years, and are located within a city-designated Vulnerability Zone. This "Vulnerability

[4] These tools are available online at: https://www.usace.army.mil/corpsclimate/Planning_for_Changing_Sea_Levels.aspx.
[5] The most useful tool is the online sea level rise curve calculator which is available at: https://www.usace.army.mil/corpsclimate/Public_Tools_Dev_by_USACE/Comp_Eval_wrt_Sea-Level_Change.aspx
[6] These tools are available online at: https://coast.noaa.gov/digitalcoast/tools/slr.html
[7] San Francisco's Sea Level Rise Checklist can be found here: http://onesanfrancisco.org/node/148

Zone" is the area that will be impacted in 2100 in the event of a 100-year flood combined with a high sea level rise scenario. The vulnerability zone is mapped by the Sea Level Rise Coordinating Committee and is made available to all departments through GIS or static maps.

Each completed "Sea Level Rise Checklist" is submitted for review to San Francisco's Capital Planning Committee and the City Engineer's Office.[8] Project managers who are seeking funding through the budget process must submit the sea level rise checklist to the City Engineer's Office by a given date before their funding request can proceed to the Capital Planning Committee. The City Engineer's Office works directly with each department to work through deficiencies to ensure that adequate protections against sea level rise have been taken.

Figure 8:Updated sea level rise estimates used for planning purposes by the City of San Francisco

Table 2: Recommended Sea Level Rise Estimates for San Francisco Relative to the Year 2000

Year	Projections	Upper End of Range
2030	6 in	12 in
2050	11 in	24 in
2100	36 in	66 in

Source: NRC (2012)

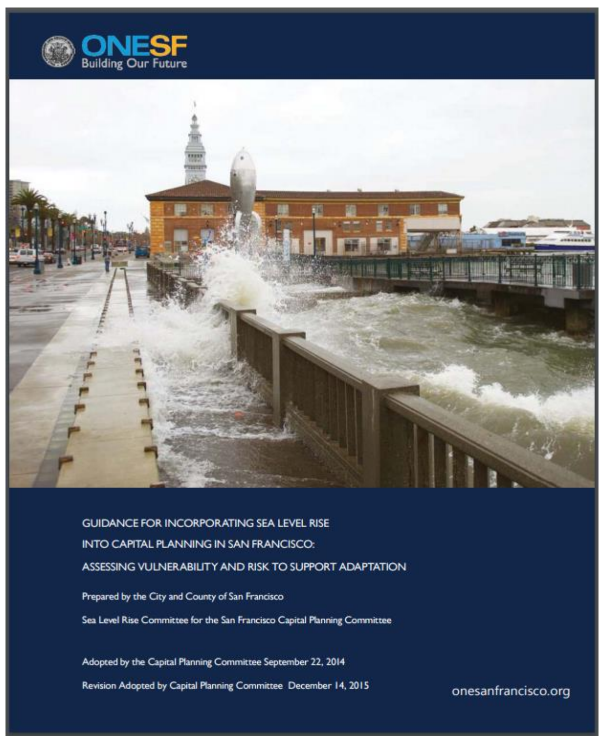
Source: City of San Francisco

The checklist was developed collaboratively over the course of a year with the support of a sea level rise committee composed of representatives from different agencies. This collaborative development process helped build buy-in from key departments. The committee also worked through many of the technical questions such as how to interpret the range in future sea level projections, how to deal with various planning horizons for different project types, and how to provide guidance under uncertainty. The committee was assisted by a series of visiting guest speakers including the director of their capital planning program.

To help disseminate this information, the committee provided training to staff members and developed a guidance document. The guidance document provides direction from the Capital Planning Committee to all departments on how to incorporate sea level rise into new construction, capital improvement, and maintenance projects. The guidance describes four key steps:

1. Sea Level Rise Science Review: What does the science tell us today?
2. Vulnerability Assessment: Which assets are vulnerable to sea level rise?
3. Risk Assessment: Of the vulnerable assets, which are at greatest risk to sea level rise?
4. Adaptation Planning: For those assets at risk, what can we do to increase their resilience to sea level rise?

Figure 9: San Francisco's guidance document for incorporating sea level rise into capital planning



Applicability to Miami-Dade

San Francisco's collaborative development process serves as a good model for the County. The Office of Resilience proposes to lead a similar process to refine the draft checklist provided in this report (Appendix 2). San Francisco's checklist is very thorough and includes several opportunities to allow flexibility in projects, such as its ability to be modified in the future to adjust to changing conditions. The checklist is also focused on the city's own projects and therefore has a strong internal review structure

[8] More information is available about San Francisco's process online at http://onesanfrancisco.org/sea-level-rise-guidance

overseen by their city engineer. At this stage, the Office of Resilience recommends focusing the sea level rise checklist on County-owned assets and using internal review structures to ensure that projects are properly designed and adequately account for the hazards of flooding and sea level rise. Additionally, the guidance document developed by San Francisco is a very good reference for our own staff and consultants working through the process of determining how to adequately design future infrastructure.

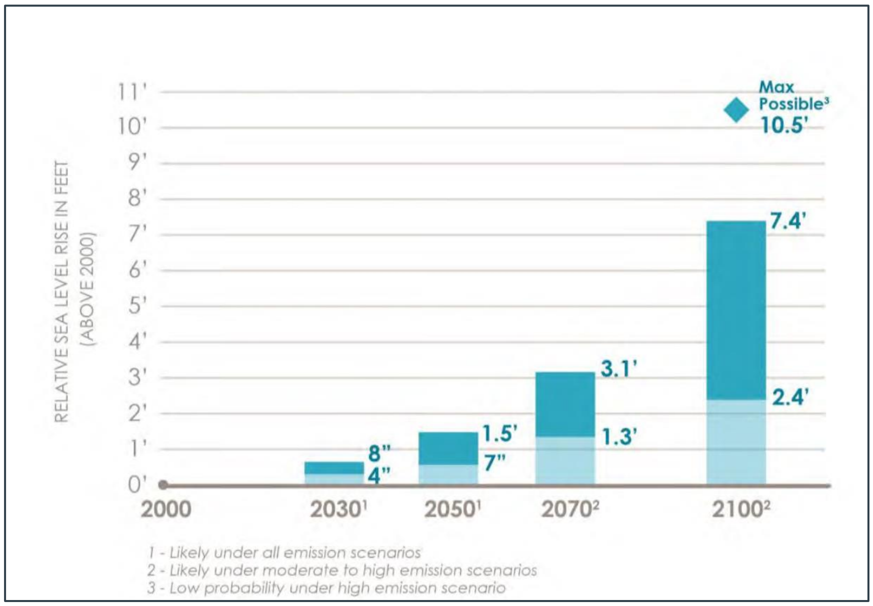
There is one important distinction between San Francisco and Miami-Dade County: due to San Francisco's varied topography only a relatively narrow coastal strip is vulnerable to sea level rise. Consequently, only projects falling within the "Vulnerability Zone" are required to fill out the checklist. Due to the lack of topography and the interconnected nature of the drainage network in Southeast Florida, sea level rise impacts will not be confined to the coastal areas. Therefore, it is more appropriate to require all projects to evaluate the impacts of flooding enhanced by sea level rise.

Boston, Massachusetts

Description, process and responsibility

The City of Boston's zoning code requires that all major building projects are planned, designed, constructed, and managed in a way that is resilient to climate change. To implement this policy, the Boston Planning and Development Agency has developed a checklist (Appendix 3) which requires planned projects to document the expected impacts of sea level rise along with several other sustainability considerations. [9] This checklist differs from the San Francisco example in that it applies to large-scale private developments and is not confined to publicly-funded projects.

Figure 10: Sea level rise planning guidance used by the City of Boston



The checklist grew out of a policy change, *The Resiliency Policy*, enacted in 2013, which required all projects to consider present and future climate conditions. Boston's checklist therefore considers a broader assessment of the project's environmental impacts, including the building's long-term integrity, passive survivability, and the safety for inhabitants. The checklist requires project managers describe the actions they will take to mitigate any adverse impacts from climate hazards. Projects must identify both strategies that will be used during the initial construction to reduce vulnerabilities and future adaptation strategies that will continue to reduce vulnerabilities as climate conditions change.

Once completed, the mandatory checklist is reviewed by an interagency called the *Interagency Green Building Committee*, which draws its members from the planning and environment departments. Compliance reviews happen at three separate points during the project: first during the initial filing, second with the Design/Building Permit Filing, and finally during the Construction/Certificate of Occupancy Filing. The committee's approval is required before building permits or certificates of occupancy can be issued. During the review process the city

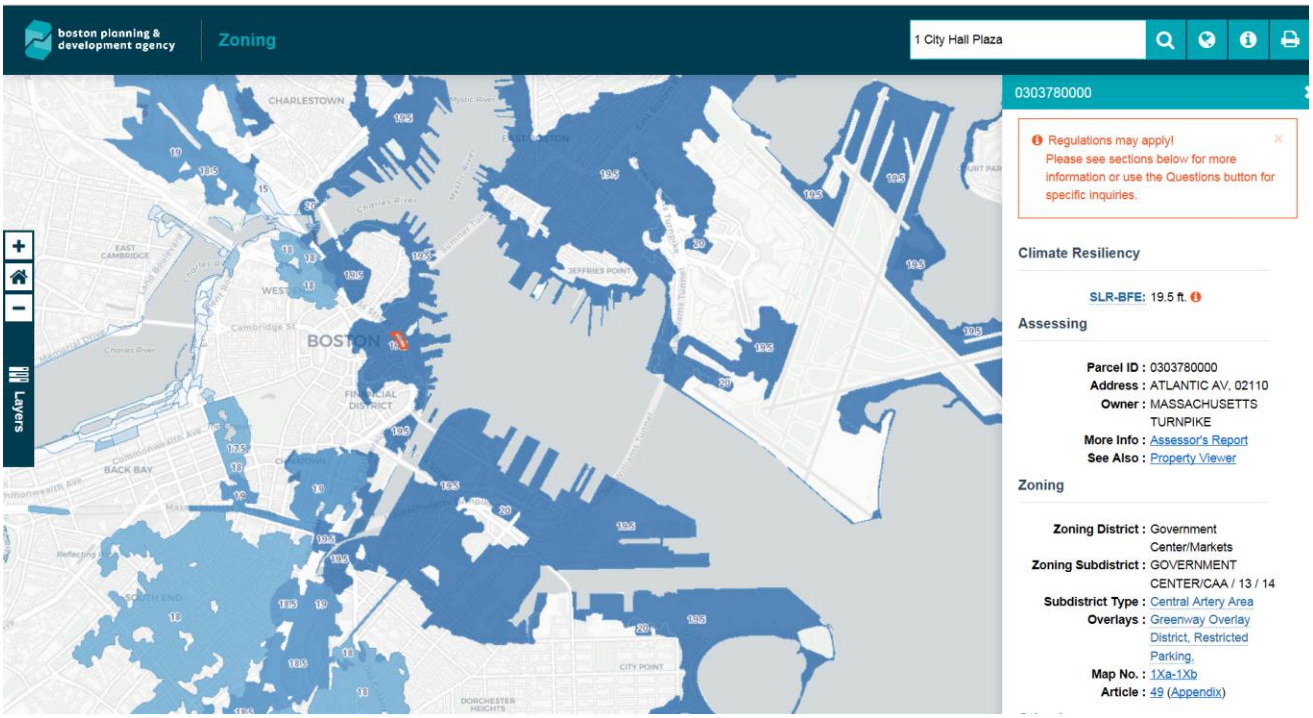
[9] More information about Boston's green building and resiliency checklist and requirements is available online at http://www.bostonplans.org/planning/planning-initiatives/article-37-green-building-guidelines and http://www.bostonplans.org/getattachment/5d668310-ffd1-4104-98fa-eef30424a9b3.

can ask why certain resiliency measures are not being taken in addition to reviewing those measures that are planned.

Boston is now on its second iteration of the Climate Resiliency and Preparedness Checklist. The checklist was updated in the fall of 2017 to reflect the best available science developed during the *Climate Ready Boston* effort. These updated guidelines require project managers to identify how they are adapting to at least 40 inches of sea level rise and detail how they are preparing for other impacts such as increased precipitation and higher temperatures.

To support the implementation of these policies the city also provides an online tool, the *BPDA Sea Level Rise - Flood Hazard Area Map* (Figure 11).[10] This online map shows future citywide flooding conditions at the parcel level with a 1% annual storm event and 40 inches of sea level rise.

Figure 2: Online mapping tool used by Boston to determine design requirements for certain developments



Applicability to Miami-Dade

Boston's checklist effectively directs project managers to reflect on climate impacts and leaves designers with significant latitude as to how to address those impacts. This gives project designers the flexibility to select the measures that are most effective and appropriate for each project and to describe why those measures were chosen. Like the approach taken in South Florida, Boston relied upon a panel of scientists and external experts to develop reliable sea level rise projections for their local planning efforts.

Boston has helped developers simplify their planning process by requiring a minimum future finished floor elevation (or "sea level rise base flood elevation") which includes 40 inches of sea level rise. Providing this information on an easily searchable map (Figure 11) also helps facilitate the planning process and makes these

[10] To access the map online visit http://maps.bostonredevelopmentauthority.org/zoningviewer/?climate=true

requirements easy to access and easy to tailor to each property. It is recommended that Miami-Dade pursue a similar online map to help project designers consistently integrate sea level rise considerations.

While many of the questions included in Boston's checklist could be adopted into the County's checklist, at this time the Office of Resilience recommends limiting the scope of the checklist to County projects and not include private development projects at this time.

New York and New Jersey Port Authority

Description, process and responsibility

In the wake of Hurricane Sandy, the Port Authority of New York and New Jersey suffered $2.2 billion in damages.[11] To protect their assets from similar storms in the future the Port Authority's Engineering Department issued a manual outlining new design guidelines for all projects (Appendix 4).[12] These guidelines discuss temperature change and precipitation change in addition to sea level rise. This guidance prescribes specific changes to certain assets such as adjusting stormwater outfalls, adjustments to the assumptions about the groundwater table, and increases in the design flood elevation. The guidance walks staff through a clear nine step process to establish an appropriate flood protection criterion for every project. These steps include:

- Step 1: Identify flood risks to project scope
- Step 2: Determine the influence of any area or system-wide strategy
- Step 3: Identify if project is part of an Emergency Plan or Enterprise Risk Plan
- Step 4: Review current codes
- Step 5: Determine funding source requirements/guidelines
- Step 6: Identify critical infrastructure
- Step 7: Determine life expectancy
- Step 8: Determine flood protection level (based on the table in Figure 12)
- Step 9: Perform benefit cost analysis
- Step 10: Establish flood resilience criteria

Figure 32: Port Authority of NY & NJ flood resilience design guidelines excerpt

Step 8: Determine Flood Protection Level
Responsible Group: Engineering

The Engineering Department has developed flood protection levels (Table 2 below) which adjust for anticipated sea level rise based on the design life and criticality of the asset. The project team should utilize these elevations unless the project is proven to be cost prohibitive based on the cost benefit analysis (Step 9).

Table 2 – Flood Protection Levels

	Non Critical Assets			Critical Assets		
Asset Design Life	Code Requirement	Sea Level Rise Adjustment	Final Flood Protection Elevation	Code Requirement	Sea Level Rise Adjustment	Final Flood Protection Elevation
Up to 2020	12"	6"	FEMA 1% Elevation + 18"	24"	6"	FEMA 1% Elevation + 30"
2021-2050	12"	16"	FEMA1% Elevation + 28"	24"	16"	FEMA1% Elevation + 40"
2051-2080	12"	28"	FEMA1% Elevation + 40"	24"	28"	FEMA1% Elevation + 52"
2080+	12"	36"	FEMA1% Elevation + 48"	24"	36"	FEMA1% Elevation +60"

As seen in Figure 12, this guidance specifies a height for each project depending upon its criticality and expected design life.

[11] Strunsky, Steve, New Jersey Real-Time News. "Port Authority Puts Sandy damage at $2.2 billion." (2013). Source: http://www.nj.com/news/index.ssf/2013/10/port_authority_sandy_22billion_outlines_recovery_measures.html
[12] This guidance and more information about the Port Authority's resilience efforts can be found online at: https://www.panynj.gov/business-opportunities/pdf/discipline-guidelines/climate-resilience.pdf

Applicability to Miami-Dade

This approach could have many advantages if replicated in Miami-Dade County, including the simplicity and specificity of the process. The guidance is pared down to the essential information, and responsibility for each stage in the decision-making process is clearly prescribed. The method also lays out a very simple approach to modifying designs that could be easily adopted by staff and consultants. This type of prescriptive approach may be advantageous and will be considered for inclusion in the County's own checklist. However, there is a serious downside to consider: given the wide range of facilities that Miami-Dade County is responsible for, it may be more effective to adopt a less prescriptive approach and allow more project-by-project flexibility.

New York City's *Climate Resiliency Design Guidelines*

Description, process and responsibility

Following the publication of the Port Authority's guidelines, New York City adopted new *Climate Resiliency Design Guidelines* to ensure that all infrastructure projects are adequately designed to withstand current and future storms.[13] New York adopted a very similar approach to the Port Authority by specifying how much additional freeboard (or height) needs to be built above the existing code requirements. The foundation of their code requirements is based upon the Federal Emergency Management Agency's Base Flood Elevation (Figure 13). Like the Port Authority, they distinguish between critical and non-critical assets. However, for their largest projects (or those projects costing more than $100 million for design and construction), the City requires the project undergo a full climate risk assessment.

Figure 43: Design standards used by New York City

Table 3 - Determine the sea level rise-adjusted design flood elevation for critical and non-critical facilities[70]				
Critical* facilities				
End of useful life	Base Flood Elevation (BFE)[71]	+ Freeboard[72]	+ Sea Level Rise Adjustment[73]	= Design Flood Elevation (DFE)
Through 2039	FEMA 1% (PFIRMs)	24"	6"	= FEMA 1% + 30"
2040-2069	FEMA 1% (PFIRMs)	24"	16"	= FEMA 1% + 40"
2070-2099	FEMA 1% (PFIRMs)	24"	28"	= FEMA 1% + 52"
2100+	FEMA 1% (PFIRMs)	24"	36"	= FEMA 1% + 60"
Non-critical facilities				
End of useful life	Base Flood Elevation (BFE)	+ Freeboard	+ Sea Level Rise Adjustment	= Design Flood Elevation (DFE)
Through 2039	FEMA 1% (PFIRMs)	12"	6"	= FEMA 1% + 18"
2040-2069	FEMA 1% (PFIRMs)	12"	16"	= FEMA 1% + 28"
2070-2099	FEMA 1% (PFIRMs)	12"	28"	= FEMA 1% + 40"
2100+	FEMA 1% (PFIRMs)	12"	36"	= FEMA 1% + 48"

Coastal flood protection assets, such as storm surge barriers, are also built to another standard. Like San Francisco, the city convened a Design Guidelines Working Group drawn from multiple departments to consult on the standard. Like in South Florida, they rely upon a group of external scientists to develop reliable projections for future climate conditions. New York City is planning for an additional 11 to 21 inches of sea level rise by 2050 and 18 to 39 inches by 2080. The city's guidelines encourage designers to differentiate between critical and non-critical components within larger facilities and to protect the critical components to a higher standard. The guidelines also recognize that for facilities with a very long useful life it may not be cost effective to design to the conditions it will encounter at the end of its useful life, and therefore it may be better to incorporate flexibility into

[13] More information about New York City's design guidelines can be found online at: https://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v2-0.pdf. More information about the City's broader resiliency efforts can be found online at: http://www1.nyc.gov/site/planning/plans/climate-resiliency/climate-resiliency.page

the project design to allow it to be modified over time. Like Boston, New York has developed an online map tool (Figure 14) which allows designers to look up their specific parcel and see future water levels at their site.[14]

Allowing the parcel-by-parcel assessment helps designers adequately design their projects to withstand future conditions and reduce insurance premiums.

Figure 54: New York City walks users through how to identify flood hazards using the online flood hazard map tool

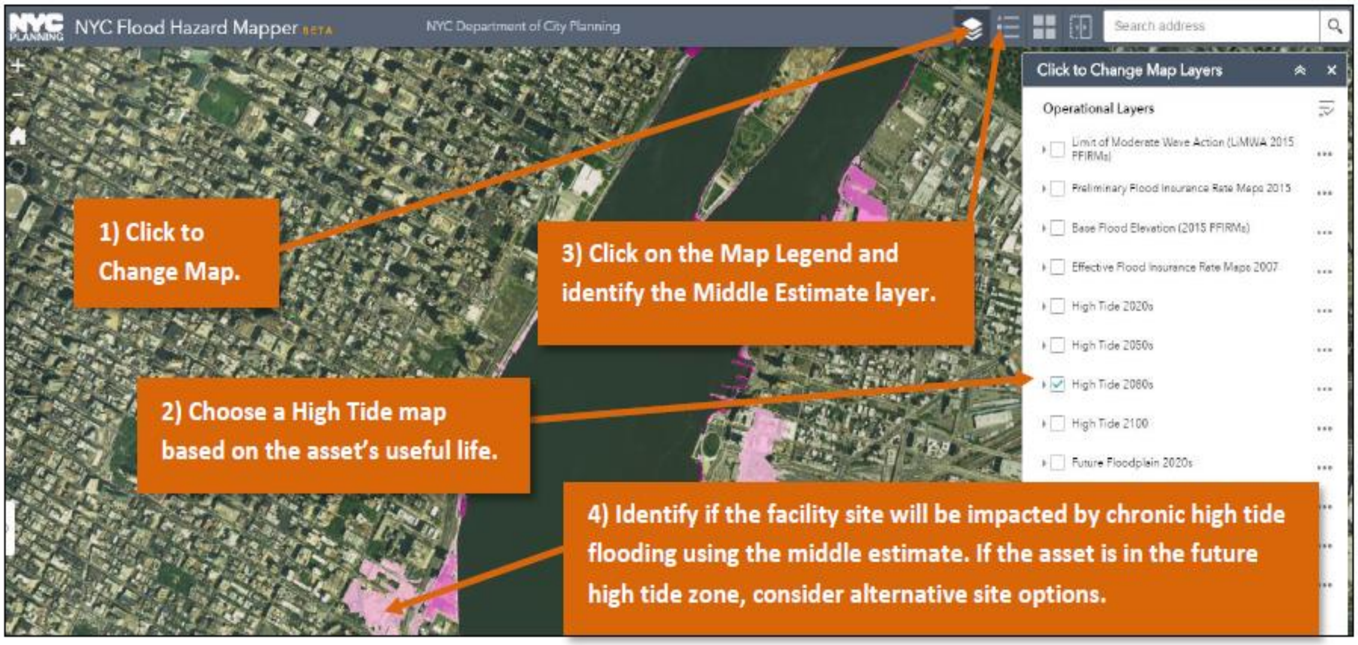


Figure 4 – Flood Hazard Mapper with High Tide + sea level rise at nyc.gov/floodhazardmapper

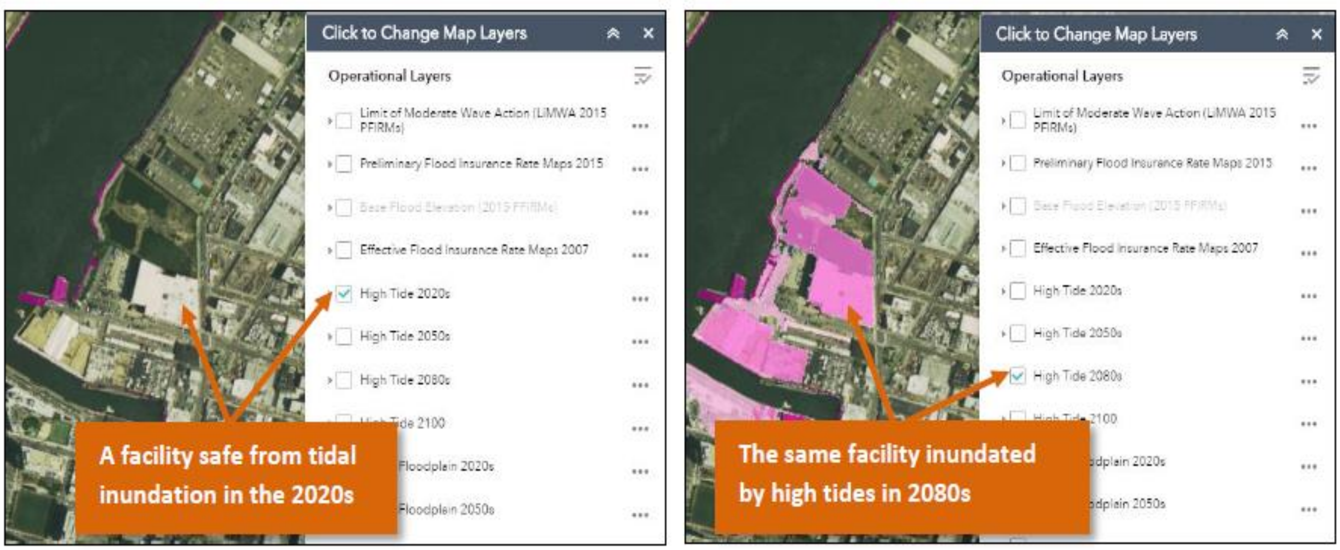


Figure 5 – Flood Hazard Mapper with high tide in the 2020s (left) and in the 2080s (right) at nyc.gov/floodhazardmapper

Applicability to Miami-Dade

This approach is very applicable to the County. The use of an online map tool helps facilitate easy access to pertinent information for project designers and developers. Creating a similar tool locally would be very helpful

[14] This tool can be found online at: http://www1.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page

for both private and public-sector designers. The use of an online platform also allows for frequent updates as new information becomes available. The City's distinction between critical and non-critical buildings (Figure 15) and infrastructure is also useful.

Figure 65: New York City's categorization of "critical" facilities

***Definition of critical buildings and infrastructure**

The criticality definitions below are for use in the application of the Guidelines only. All items identified as critical in NYC Building Code Appendix G are critical in these guidelines; however, this list includes additional facilities that are not listed in Appendix G. If a facility is not listed here, it is considered non-critical for the purposes of determining freeboard.

- Hospitals and health care facilities;
- Fire, rescue, ambulance and police stations and emergency vehicle garages;
- Jails, correctional facilities and detention facilities;
- Facilities used in emergency response, including emergency shelters, emergency preparedness, communication, operation centers, communication towers, electrical substations, back-up generators, fuel or water storage tanks, power generating stations and other public utility facilities;
- Critical aviation facilities such as control towers, air traffic control centers and hangars for aircraft used in emergency response;
- Major food distribution centers (with an annual expected volume of greater than 170,000,000 pounds);[74]
- Buildings and other structures that manufacture, process, handle, store, dispose, or use toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released;[75]
- Infrastructure in transportation, telecommunications, or power networks including bridges, tunnels (vehicular and rail), traffic signals, (and other right of way elements including street lights and utilities), power transmission facilities, substations, circuit breaker houses, city gate stations, arterial roadways, telecommunications central offices, switching facilities, etc.;
- Ventilation buildings and fan plants;
- Operations centers;
- Pumping stations (sanitary and stormwater);
- Train and transit maintenance yards and shops;
- Wastewater treatment plants;
- Fueling stations;
- Waste transfer stations; and
- Facilities where residents have limited mobility or ability, including care facilities and nursing homes.

The State of California

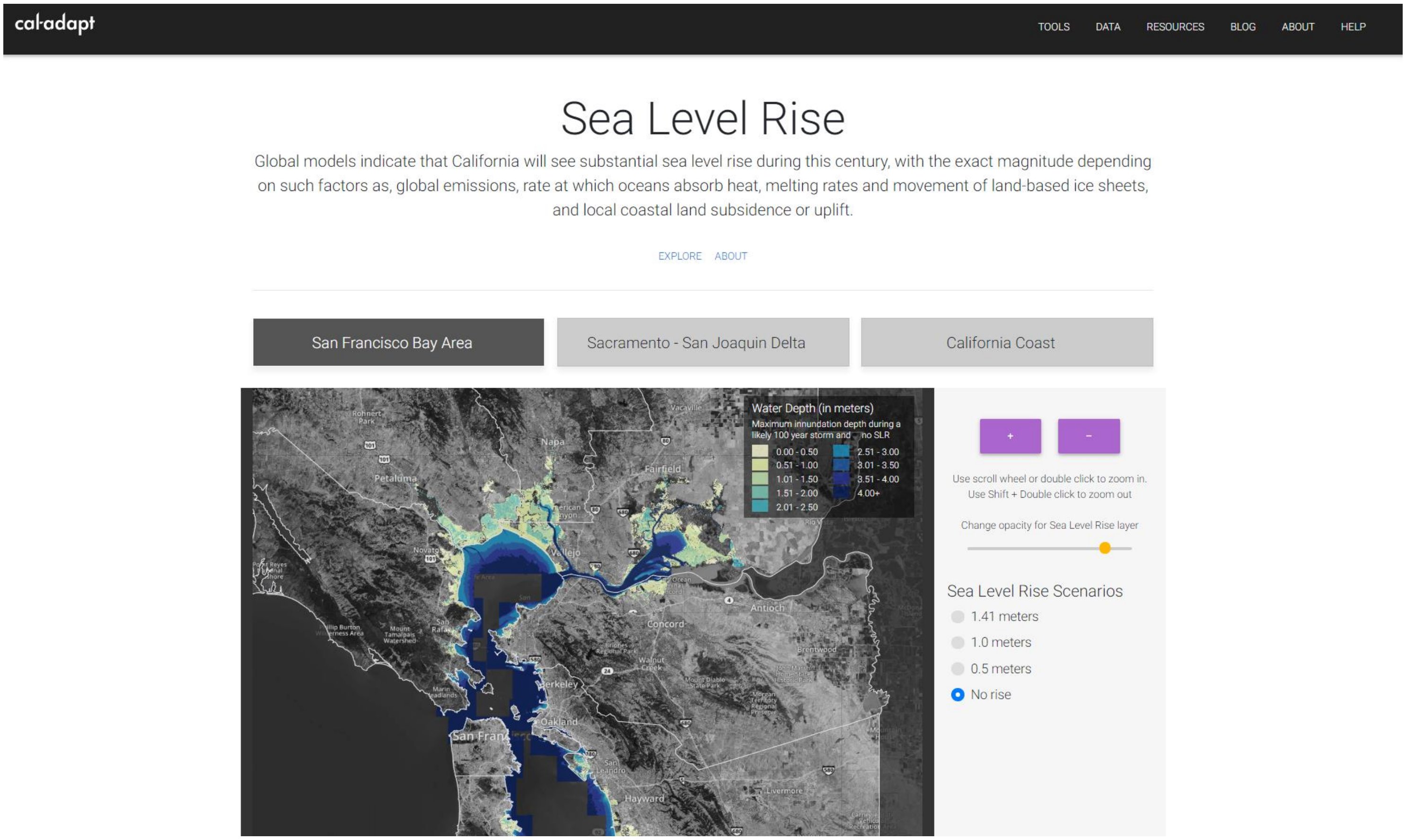
Description, process and responsibility

The State of California has an existing Executive Order (S-13-108) passed by Governor Schwarzenegger requiring all planning decisions concerning vulnerable coastal areas to consider sea level rise.[15] While the state does not use a checklist to help project managers comply with that requirement, the state has issued several guidance documents which serve as excellent resources. The state also provides information to public and private sectors

[15] This order can be found online at https://www.gov.ca.gov/news.php?id=11036

alike through an online platform called, "Cal-Adapt" (Figure 16). This site publishes the state's regularly-updated climate assessments which synthesize the best-available science.

Figure 76: A screenshot of the Cal-Adapt webpage on sea level rise impacts



Applicability to Miami-Dade

The state's existing policy to consider sea level rise in all planning decisions provides valuable precedent for the County to emulate. Furthermore, the online map resources hosted by Cal-Adapt continue to provide consistent and transparent information to the public and private sector, which the County could consider replicating.

Florida examples

Other governments in Florida are preparing for sea level rise and are implementing checklists or scorecards to insure capital projects are planned with sea level rise in mind. For example, Pinellas County conducted an extensive vulnerability assessment of their assets and capital projects.[16] They released a guidance report with a checklist to incorporate sea level rise into capital project planning. If a critical asset or capital project must function in a storm, Pinellas County uses the higher-end of sea level rise and storm surge scenarios in their planning.

St. Augustine is also creating a resilience plan which includes a scorecard that will aid the city in prioritizing capital improvements based on their vulnerabilities to shocks and stresses such as sea level rise and storm surge, among

[16] For an overview of the work done in Pinellas County, refer to the County's presentation on their efforts: http://www.tbrpc.org/onebay/obwg/020218/KLevy_PinellasCounty_IncorporatingSLRintoCapitalPlanning_020218.pdf/ ("Incorporating Sea Level Rise into Capital Planning." 2018.)

others.[17] The city looks to incorporate a variety of topics in their resilience plan, including the identification of critical assets, various adaptation strategies from the asset-level to the landscape-level, and both project-based and policy-based solutions to increase the city's resilience, including the scorecard for capital improvement prioritization.

Feasibility of developing a sea level rise checklist

It is feasible for the County to develop a sea level rise checklist as one tool to help ensure that new infrastructure is built to withstand future floods and storms. Other major cities have demonstrated that this approach is straightforward, a helpful way to coordinate multiple departments, and a way to ensure project designers are using the most current science. This approach was also recommended by the engineers, Hazen and Sawyer, who completed the vulnerability assessment of the County's critical infrastructure in 2018. This report includes a draft of what such a checklist could look like (Appendix 1). However, before making the checklist a requirement for the County's own projects, it is recommended that the County first convene a working group with key departments responsible for the majority of critical infrastructure projects to test and refine the format. It will also be necessary to create an online tool to make the necessary data more accessible. At this stage, it is recommended that the County first use the checklist for its own projects.

Conclusion and next steps

The vulnerability analysis completed in June 2018 showed that around 75% of the County's properties are vulnerable to some degree of impact from permanent inundation from sea level rise or flooding during future higher storm surges. In some cases, it will be possible and cost effective to retrofit these existing structures to better protect them. However, the most cost-effective way to systematically protect the County's infrastructure is to integrate resiliency considerations into the design of all new capital improvement projects as early as possible. If these considerations are not integrated into the design, key infrastructure may not last its entire design life and additional funds will be required to rebuild or modify the asset.

The marginal cost of altering a project in the design phase is typically much smaller than the cost to retrofit an existing structure and significantly less than the loss and damage costs after a storm. A recent study showed that every $1 spent on mitigation prevents $6 in flood damage losses.[18] **According to the engineering consultants, Hazen and Sawyer, that completed a recent study of the vulnerability of projects in the CIP, the consultants estimated that approximately $6 million in additional protective measures would prevent approximately $24 million in losses and protect assets worth more than $150 million.** Building this way will also save flood insurance costs over the lifetime of the building. Most importantly it will reduce the risk of infrastructure failure and disruption of public services.

While working with multiple departments to complete the vulnerability analysis (named the "Rapid Action Plan"), it became clear that many departments were unaware of the requirement to integrate sea level rise considerations into their capital planning. Of the departments that were fulfilling this requirement, there was a lack of consistent methods and data. Creating a checklist will help improve consistent compliance and make it

[17] For more information on efforts in St. Augustine, refer to the city's presentation from a resilience strategy workshop: http://www.citystaug.com/document_center/Publicworks/Resiliency/05.08.18ResiliencyStrategyWorkshop.pdf ("City of St. Augustine Resiliency Strategy Workshop." 2018.)

[18] Multihazard Mitigation Council (2017) Natural Hazard Mitigation Saves 2017 Interim Report: An Independent Study. Principal Investigator Porter, K.; co-Principal Investigators Scawthorn, C.; Dash, N.; Santos, J.; Investigators: Eguchi, M., Ghosh., S., Huyck, C., Isteita, M., Mickey, K., Rashed, T.;P. Schneider, Director, MMC. National Institute of Building Sciences, Washington. The full report can be accessed here: http://www.wbdg.org/files/pdfs/MS2_2017Interim%20Report.pdf

easier for departments to access the most current data. **A checklist and a clear process will help various departments adopt consistent standards, use consistent information, and adopt best practices for CIP projects.**

The checklist approach will also allow project managers to determine the most effective method of protecting their project. Many projects will not need to be modified and in some cases, it may be more cost effective to replace an asset quickly after a storm rather than making it stormproof. Using a checklist will help departments weigh the tradeoffs between avoiding loss or damage and investing in protective measures. The approach used in the vulnerability assessment completed in 2018 provides one method of systematically assessing these risks and evaluating potential costs. However, to make these kinds of decisions, all departments need ready access to reliable information. Therefore, the Office of Resilience is partnering with the GIS team within the Information Technology Department to develop an online platform like the ones used in New York City and Boston to provide this information.

The following are proposed next steps:

- The Office of Resilience will work with the Information Technology Department to create an online map where information about sea level rise, storm surge risks, elevation, and other pertinent data can be easily searched at the parcel level.
- The Office of Resilience will work with the County Engineer and key departments to test and refine the draft checklist.
- The Office of Resilience will continue to provide technical assistance to other County departments in the form of training, project-specific guidance, and assistance with interpreting and accessing existing tools and data related to sea level rise.

Appendix 1: Draft Sea Level Rise Checklist

The following is a draft of a potential sea level rise checklist. This format will be tested with multiple departments and refined over time. The checklist will also be accompanied by guidance and an online map providing the necessary information. The following questions are meant to help guide the project designers to adequately account for sea level rise risks and modify their project designs accordingly.

Questions about the project:

1. Is this project related to a critical facility needed during or after an emergency?	☐ N	☐ Y
2. Is this project related to providing a key public service to the community or serving a particularly vulnerable population immediately before, during, or after an emergency?	☐ N	☐ Y
3. Would this project be significantly damaged if it flooded? a. If yes, could the damages from flooding be expected to exceed $100,000 dollars? b. If yes, what is the expected damage? ______________________________ (in dollars)	☐ N ☐ N	☐ Y ☐ Y
4. If it was damaged by a flood, would it take more than three months to be replaced or repaired?	☐ N	☐ Y
5. Is damage from corrosion from salt water a concern for this project?	☐ N	☐ Y

Questions about the site:

1. Is this site in the Coastal High Hazard Area?	☐ N	☐ Y
2. Is this site within the Special Flood Hazard Area? a. If yes, is it in the V or Coastal A zone? __________ b. What is the base flood elevation? ____________ (feet in _____ vertical datum)	☐ N ☐ N	☐ Y ☐ Y
3. Has this site historically flooded?	☐ N	☐ Y
4. Is this site in an area expected to be permanently inundated by sea level rise?	☐ N	☐ Y
5. Is this site in a storm surge planning zone? a. Zone: ____________ b. What is the expected storm surge height from a Category 5 storm? _____ (feet in _____ vertical datum)	☐ N	☐ Y
6. Is the depth to the average wet season groundwater level on the site less than three feet?	☐ N	☐ Y
7. Does any of the site have an elevation that is less than 3 feet above sea level?	☐ N	☐ Y
8. Are any of the primary access roads to the site vulnerable to flooding?	☐ N	☐ Y

Questions about the asset or building:

1. Is this project designed to last for more than 20 years? ☐ N ☐ Y
    a. If yes, what is the design life of the asset? ________________ (in years)
2. Over the design life of the asset how much are sea levels expected to rise? __________ (inches)
3. Has the project elevation been elevated to be above expected flood levels? ☐ N ☐ Y
    a. If yes, how high has the project been elevated? _________ (in inches) ☐ N ☐ Y
    b. If no, has the project been wet or dry flood-proofed to minimize flood damages? (Y/N)
4. How high above the expected storm surge levels are the key mechanical and electrical systems?
    a. HVAC system: ______________ (feet above storm surge elevation of _________ feet NAVD88)
    b. Electrical systems: _________________ (feet above storm surge elevation)
    c. Emergency/back up power: _________________ (feet above storm surge elevation)
    d. Potentially hazardous materials storage: _________________ (feet above storm surge elevation)
5. Has the drainage plan been modified to account for higher groundwater levels? ☐ N ☐ Y

Appendix 2: San Francisco's sea level rise checklist

Below is a copy of the checklist used by the San Francisco.

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ONESF
Building Our Future
CAPITAL PLANNING PROGRAM

EDWIN M. LEE
Mayor

NAOMI M. KELLY
City Administrator

BRIAN STRONG
Director of Capital Planning

Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco
Sea Level Rise Checklist (Version 2.0)

This checklist should be used in conjunction with the SLR Guidance document ("Guidance") for use by City departments to guide the evaluation of capital planning projects in light of sea level rise.

Pre-Checklist check:

The checklist is only required if the following 3 conditions are ALL met. If the answer is 'No' to ANY of these questions, do not complete the SLR checklist. The pre-checklist should be retained for your records.

1. ***Project has a location identified*** *(some projects are so early in planning that they do not yet have a specific location within CCSF)* Yes[ ] No[ ]
2. ***Project is within the SLR Vulnerability Zone*** Yes[ ] No[ ]
   (see the Supplementary Document "SLR Vulnerability Zone Map" at: http://onesanfrancisco.org/staff-resources/sea-level-rise-guidance/; contact Hemiar Alburati (hemiar.alburati@sfgov.org) to request a Geodatabase (GIS file) of the SLR Vulnerability Zone Map (overlaid on San Francisco base layers).
3. ***Anticipated total project costs[1] equal or exceed 5 million dollars*** Yes[ ] No[ ]

Department Name:	
Project Name:	
Project ID:	
Name of Project Mgr:	
Name of Preparer:	
Date prepared:	

Only projects answering 'Yes' for questions 1, 2 AND 3 must complete the following checklist.
As noted above, if the answer to questions 1, 2 OR 3 is 'No', the SLR checklist does not need to be submitted. *However, it is recommended that the project manager* ***retain this document in their project records.***

[1] Project costs include planning, design, and construction costs.

Department Name: [ ] *Project ID (if available):* [ ]
Date prepared: [ ]

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SLR checklist – only for projects meeting all 3 pre-checklist conditions above:

Project Information

1. **What is the project location?** (Please provide the street address or GIS coordinates):
2. **What type of asset or project is being proposed?** (e.g., new construction, rehabilitation or modification of existing structure, building(s), roadway structure, utility structure, park, etc.):
3. **What is the remaining or potential future functional lifespan of the project?** *The functional lifespan is the period for which a structure can still meet the purposes for which it was constructed. It refers to the time the asset may realistically be in use at this location, including through one or more repair and maintenance cycles. (See Guidance for more information).*
   Remaining or Potential functional lifespan in years: ______
   Please provide a brief explanation of how this number was arrived at:
4. **What is the planning horizon?** (The construction completion year + functional life span = planning horizon year; e.g., (2017 construction completion year + 60 years of functional life span = 2077.)
   Planning horizon year: ______

SECTION I - Vulnerability Assessment for Potential Projects in the SLR Inundation Zone

A. Exposure (see SLR Guidance for additional information):
Using the steps below and SFPUC inundation zone maps or site-specific modeling, please assess if the project site or asset is subject to inundation or temporary flooding during one of the future flood events.

Site Information

Past/Current

5. **Has the site historically been flooded due to high tides/and or storms?** If yes, please describe conditions: (e.g., King tide, storm surge, rainstorm event)	[ ] Yes [ ] No
6. **What is the lowest ground elevation at your project location (in feet)?** Please select the elevation data used for all calculations (NAVD88 or City Datum): [ ] NAVD88: [ ] City Datum:	(feet) Elevation ______ft

Future Flooding Calculation

7. **Calculate the sea level rise amounts at the end of the planning horizon year ____ (enter from question 4.)**
   Use the equations in Appendix 3 of the Guidance to derive the applicable sea level rise: (e.g. for year 2077, upper range SLR in 2077 = 111.79 cm; 44.01 inches; 3.67 ft)
   a) 10,488 in inches and 874.0 in feet -- most likely
   b) 13,985 in inches and 1,165.4 in feet -- upper range

Department Name: [ ] *Project ID (if available):* [ ]
Date prepared: [ ]

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8. **What map/ modeling is used for this assessment?**
   - [ ] SFPUC 2014 Maps and the Supplementary Document "Sea Level Rise Scenario Selection and Design Tide Calculation" found at http://onesanfrancisco.org/staff-resources/sea-level-rise-guidance/
   - [ ] Site Specific Modeling (*please provide date and source of information*):
9. **What is the Mean Higher High Water (MHHW) elevation closest to your project location?** Use the data source in question 8 (e.g., from Figure 1 in Supplementary Document cited in Question 8, which includes maps of the City with tidal data at various points along the shoreline) or site specific modeling).
   MHHW Elevation (year 2000): ______ft [ ] NAVD88 [ ] CITY DATUM

Assess Project Vulnerability to Permanent Inundation from SLR

10. **Subtract MHHW (9) from the Project Elevation (6)**
    a) **Difference in feet:** 0.0 ft
    A negative number indicates that the project is below MHHW today and is at risk. If the number is positive, this is the amount of sea level rise needed to result in permanent inundation at your project location.
    b) Is the Project vulnerable to permanent inundation during the functional lifespan using the most likely SLR scenario? (Yes if the value of question 7a is greater than the value of question 10a).
    ☒ Yes: The project is at risk and requires design considerations that address most likely sea level rise.
    ☐ No: Not at risk. Go to 10c.
    The Project is vulnerable to permanent inundation during the functional lifespan if SLR raises MHHW above the Project Elevation.
    c) Is the Project vulnerable to permanent inundation during the functional lifespan using the upper range SLR scenario? (Yes if the value of 7b is greater than the value of 10a)
    ☒ Yes: The project may be at risk at upper range SLR. This requires either a finding of adaptive capacity OR identification of adaptation strategies that address upper range SLR.
    ☐ No: Assess temporary flooding risk below.

Assess Project Vulnerability to Temporary Flooding from 100-year Coastal Flood

11. **What is the 100-year storm surge elevation (in feet) closest to your project location?** Use the Supplementary Document cited in Question 8 or site specific modeling. If the project is located directly along the shoreline, the 100-year total water level (which includes wave runup along the shoreline) should also be evaluated.
    a) **100-year storm surge elevation (in feet):** ______ft [ ] NAVD88 [ ] CITY DATUM
    Only for projects directly adjacent to the shoreline:
    b) **100-year total water level elevation (in feet):** ______ft [ ] NAVD88 [ ] CITY DATUM

Department Name: [ ] *Project ID (if available):* [ ]
Date prepared: [ ]

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12. Subtract the 100-year storm surge elevation (11a) from the Project Elevation (6).

a) Difference in feet: 0.00 ft

If the answer is negative, the project is at risk of temporary flooding today by the 100-year storm surge event under existing conditions.

b) Is the answer to Question 12a less than the answer to Question 7a (most likely sea level rise)?

- [x] Yes: project will be at risk of temporary flooding and requires design considerations that address temporary flooding or an acknowledgement that temporary flooding doesn't result in any impacts
- [ ] No: Not at risk. Go to 12 c.

c) Is the answer to Question 12a less than the answer to Question 7b (upper range sea level rise)?

- [x] Yes: The project may be at risk of temporary flooding and requires design adaptation strategies that can reduce potential future risk and/ or the project has inherent adaptive capacity.
- [ ] No: The project is not vulnerable to SLR/ temporary flooding. Please proceed to Section 3.

13. Only for projects directly adjacent to the shoreline. If project is not adjacent to the shoreline, Go to 14. **Subtract the 100-year total water elevation (11b) from the Project Elevation (6).**

a) Difference in feet: 0.00 ft

If the answer is negative, the project is at risk of temporary flooding today by the 100-year total water level event under existing conditions.

b) Is the answer to Question 13a less than the answer to Question 7a (most likely sea level rise)?

- [x] Yes: project will be at risk of temporary flooding due to wave hazards and requires design considerations that address wave hazards or an acknowledgement that wave hazards don't result in any impacts
- [ ] No: Not at risk. Go to 13c.

c) Is the answer to Question 13a less than the answer to Question 7b (upper range sea level rise)?

- [x] Yes: The project may be at risk of temporary flooding due to wave hazards and requires design adaptation strategies that can reduce potential future risk and/ or the project has inherent adaptive capacity.
- [ ] No: The project is not vulnerable to existing or future wave hazards. Please proceed to Section 3.

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B. Sensitivity (see SLR Guidance for definition):
14. What is the proposed overall sensitivity to flooding and other sea level rise impacts?

- [ ] **Low Sensitivity**: flooding would cause minimal impact; project/ asset(s)/ surrounding infrastructure are able to function during and/or after temporary flooding event
- [ ] **Medium Sensitivity**: flooding would cause medium impact; project/ asset(s)/ surrounding infrastructure would be impacted, but are able to maintain most functions during and/or after temporary flooding event, though repairs may be needed
- [ ] **High Sensitivity**: flooding would result in complete loss of project/asset/surrounding infrastructure or shut-down of operation with high cost and potential impact to health and safety

Please explain briefly*:

*(If more space is required, please provide on separate page).

C. Adaptive Capacity (see SLR Guidance for definition):
15. What is the inherent adaptive capacity to tolerate flooding and other sea level rise impacts or to relatively easily be subsequently adapted to higher levels of SLR should they occur (see Guidance text for explanation)?

- [ ] **High Adaptive Capacity**: ability of the project/asset(s)/surrounding infrastructure to tolerate flooding, moderate potential damages, and cope with the consequences without the need for significant intervention or modification (e.g. alternate infrastructure routes available, elevated structure/site, etc...)
- [ ] **Medium Adaptive Capacity**: ability of the project asset(s)/surrounding infrastructure to tolerate flooding, moderate potential damages, and cope with the consequences with some significant intervention or modification (e.g. modifications, repairs and replacements are possible to restore the function, etc...)
- [ ] **Low Adaptive Capacity**: the project/asset(s)/surrounding infrastructure have limited or no ability to tolerate flooding and/ or inundation, moderate potential damages, and cope with the consequences without significant modification (e.g. no alternate infrastructure routes available, elevation of site not feasible, function can't be restored in that location without replacement, etc...)

Please explain briefly*:

*(If more space is required, please provide on separate page).

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SECTION 2 – Risk Assessment for Projects vulnerable to SLR per the above

16. What is the anticipated level of **DAMAGE** to the project/ asset(s)?
- [ ] **Low Damage**: Asset(s) could be repaired/ partially replaced
- [ ] **Medium Damage**: Asset(s) would require complete replacement or very costly repairs
- [ ] **High Damage**: Asset(s) would not repairable or replaceable in the existing location
- [ ] Unknown

Please explain briefly*:

17. What is the level of **DISRUPTION**?
- [ ] **Low**: no or little disruption in service or function
- [ ] **Medium**: disruption in service or function that doesn't threaten public health & safety (non-critical)
- [ ] **High**: disruption of service and/or function that threatens public health & safety (critical)
- [ ] Unknown

Please explain briefly*:

18. What are the **COSTS** (to replace/repair or for health & safety)?
- [ ] **Low**: no or little cost to return asset(s) or minor secondary service disruption costs
- [ ] **Medium**: moderate costs to repair/ replace asset(s)
- [ ] **High**: high costs to fully replace asset(s) in new location and/ or high secondary costs attributed to asset being out of service
- [ ] Unknown

Please explain briefly*:

If all answers to Section 2, 15, 16, and 17 are Low, proceed to adaptation planning. If answers are Low and/ or Medium, additional information may be needed to justify certification. If any answers are High, alternatives sh be considered.

Please briefly summarize sea level rise adaptation measures associated with this project or program*:

Additional Comments*:

*(If more space is required, please provide on separate page).

Appendix 3: Boston's Climate Resiliency Checklist

Below is a copy of the climate resiliency checklist used by Boston.

NOTE: Project filings should be prepared and submitted using the online Climate Resiliency Checklist.

A.1 - Project Information

Project Name:				
Project Address:				
Project Address Additional:				
Filing Type (*select*)	*Initial (PNF, EPNF, NPC or other substantial filing)* *Design / Building Permit (prior to final design approval), or* *Construction / Certificate of Occupancy (post construction completion)*			
Filing Contact	*Name*	*Company*	*Email*	*Phone*
Is MEPA approval required	*Yes/no*		*Date*	

A.3 - Project Team

Owner / Developer:	
Architect:	
Engineer:	
Sustainability / LEED:	
Permitting:	

Construction Management:	

A.3 - Project Description and Design Conditions

List the principal Building Uses:	
List the First Floor Uses:	
List any Critical Site Infrastructure and or Building Uses:	

Site and Building:

Site Area:	*SF*	Building Area:	*SF*
Building Height:	*Ft*	Building Height:	*Stories*
Existing Site Elevation – Low:	*Ft BCB*	Existing Site Elevation – High:	*Ft BCB*
Proposed Site Elevation – Low:	*Ft BCB*	Proposed Site Elevation – High:	*Ft BCB*
Proposed First Floor Elevation:	*Ft BCB*	Below grade levels:	*Stories*

Article 37 Green Building:

LEED Version - Rating System :		LEED Certification:	*Yes / No*
Proposed LEED rating:	*Certified/Silver/ Gold/Platinum*	Proposed LEED point score:	*Pts.*

Building Envelope

When reporting R values, differentiate between R discontinuous and R continuous. For example, use "R13" to show R13 discontinuous and use R10c.i. to show R10 continuous. When reporting U value, report total assembly U value including supports and structural elements.

Roof:	*(R)*	Exposed Floor:	*(R)*
Foundation Wall:	*(R)*	Slab Edge (at or below grade):	*(R)*

Vertical Above-grade Assemblies (%’s are of total vertical area and together should total 100%):

Area of Opaque Curtain Wall & Spandrel Assembly:	*(%)*	Wall & Spandrel Assembly Value:	*(U)*
Area of Framed & Insulated / Standard Wall:	*(%)*	Wall Value	*(R)*
Area of Vision Window:	%	Window Glazing Assembly Value:	*(U)*
		Window Glazing SHGC:	*(SHGC)*
Area of Doors:	%	Door Assembly Value:	*(U)*

Energy Loads and Performance

For this filing – describe how energy loads & performance were determined			
Annual Electric:	*(kWh)*	Peak Electric:	*(kW)*
Annual Heating:	*(MMbtu/hr)*	Peak Heating:	*(MMbtu)*
Annual Cooling:	*(Tons/hr)*	Peak Cooling:	*(Tons)*
Energy Use - Below ASHRAE 90.1 - 2013:	%	Have the local utilities reviewed the building energy performance?:	*Yes / no*
Energy Use - Below Mass. Code:	%	Energy Use Intensity:	*(kBtu/SF)*

Back-up / Emergency Power System

Electrical Generation Output:	*(kW)*	Number of Power Units:	
System Type:	*(kW)*	Fuel Source:	

Emergency and Critical System Loads (in the event of a service interruption)

Electric:	*(kW)*	Heating:	*(MMbtu/hr)*
		Cooling:	*(Tons/hr)*

B – Greenhouse Gas Reduction and Net Zero / Net Positive Carbon Building Performance

Reducing GHG emissions is critical to avoiding more extreme climate change conditions. To achieve the City's goal of carbon neutrality by 2050 new buildings performance will need to progressively improve to net carbon zero and positive.

B.1 – GHG Emissions - Design Conditions

For this Filing - Annual Building GHG Emissions: *(Tons)*

For this filing - describe how building energy performance has been integrated into project planning, design, and engineering and any supporting analysis or modeling:

Describe building specific passive energy efficiency measures including orientation, massing, envelop, and systems:

Describe building specific active energy efficiency measures including equipment, controls, fixtures, and systems:

Describe building specific load reduction strategies including on-site renewable, clean, and energy storage systems:

Describe any area or district scale emission reduction strategies including renewable energy, central energy plants, distributed energy systems, and smart grid infrastructure:

Describe any energy efficiency assistance or support provided or to be provided to the project:

B.2 - GHG Reduction - Adaptation Strategies

Describe how the building and its systems will evolve to further reduce GHG emissions and achieve annual carbon net zero and net positive performance (e.g. added efficiency measures, renewable energy, energy storage, etc.) and the timeline for meeting that goal (by 2050):

C - Extreme Heat Events

Annual average temperature in Boston increased by about 2˚F in the past hundred years and will continue to rise due to climate change. By the end of the century, the average annual temperature could be 56° (compared to 46° now) and the number of days above 90° (currently about 10 a year) could rise to 90.

C.1 – Extreme Heat - Design Conditions

Temperature Range - Low:	*Deg.*	Temperature Range - High:	*Deg.*
Annual Heating Degree Days:		Annual Cooling Degree Days	

What Extreme Heat Event characteristics will be / have been used for project planning

Days - Above 90°:	#	Days – Above 100°:	#
Number of Heatwaves / Year:	#	Average Duration of Heatwave (Days):	#

Describe all building and site measures to reduce heat-island effect at the site and in the surrounding area:

C.2 - Extreme Heat – Adaptation Strategies

Describe how the building and its systems will be adapted to efficiently manage future higher average temperatures, higher extreme temperatures, additional annual heatwaves, and longer heatwaves:

Describe all mechanical and non-mechanical strategies that will support building functionality and use during extended interruptions of utility services and infrastructure including proposed and future adaptations:

D - Extreme Precipitation Events

From 1958 to 2010, there was a 70 percent increase in the amount of precipitation that fell on the days with the heaviest precipitation. Currently, the 10-Year, 24-Hour Design Storm precipitation level is 5.25”. There is a significant probability that this will increase to at least 6” by the end of the century. Additionally, fewer, larger storms are likely to be accompanied by more frequent droughts.

D.1 – Extreme Precipitation - Design Conditions

10 Year, 24 Hour Design Storm: *In.*

Describe all building and site measures for reducing storm water run-off:

D.2 - Extreme Precipitation - Adaptation Strategies

Describe how site and building systems will be adapted to efficiently accommodate future more significant rain events (e.g. rainwater harvesting, on-site storm water retention, bio swales, green roofs):

E – Sea Level Rise and Storms

Under any plausible greenhouse gas emissions scenario, sea levels in Boston will continue to rise throughout the century. This will increase the number of buildings in Boston susceptible to coastal flooding and the likely frequency of flooding for those already in the floodplain.

Is any portion of the site in a FEMA SFHA?	*Yes / No*	What Zone:	A, AE, AH, AO, AR, A99, V, VE
		Current FEMA SFHA Zone Base Flood Elevation:	*Ft BCB*

Is any portion of the site in a BPDA Sea Level Rise - Flood Hazard Area? Use the online BPDA SLR-FHA Mapping Tool to assess the susceptibility of the project site.	*Yes / No*

If you answered YES to either of the above questions, please complete the following questions.

Otherwise you have completed the questionnaire; thank you!

E.1 – Sea Level Rise and Storms – Design Conditions

Proposed projects should identify immediate and future adaptation strategies for managing the flooding scenario represented on the BPDA Sea Level Rise - Flood Hazard Area (SLR-FHA) map, which depicts a modeled 1% annual chance coastal flood event with 40 inches of sea level rise (SLR). Use the online [BPDA SLR-FHA Mapping Tool] to identify the highest Sea Level Rise - Base Flood Elevation for the site. The Sea Level Rise - Design Flood Elevation is determined by adding either 24” of freeboard for critical facilities and infrastructure and any ground floor residential units OR 12” of freeboard for other buildings and uses.

Sea Level Rise - Base Flood Elevation:	*Ft BCB*		
Sea Level Rise - Design Flood Elevation:	*Ft BCB*	First Floor Elevation:	*Ft BCB*
Site Elevations at Building:	*Ft BCB*	Accessible Route Elevation:	*Ft BCB*

Describe site design strategies for adapting to sea level rise including building access during flood events, elevated site areas, hard and soft barriers, wave / velocity breaks, storm water systems, utility services, etc.:

Describe how the proposed Building Design Flood Elevation will be achieved including dry / wet flood proofing, critical systems protection, utility service protection, temporary flood barriers, waste and drain water back flow prevention, etc.:

Describe how occupants might shelter in place during a flooding event including any emergency power, water, and waste water provisions and the expected availability of any such measures:

Describe any strategies that would support rapid recovery after a weather event:

E.2 – Sea Level Rise and Storms – Adaptation Strategies

Describe future site design and or infrastructure adaptation strategies for responding to sea level rise including future elevating of site areas and access routes, barriers, wave / velocity breaks, storm water systems, utility services, etc.:

Describe future building adaptation strategies for raising the Sea Level Rise Design Flood Elevation and further protecting critical systems, including permanent and temporary measures:

A pdf and word version of the Climate Resiliency Checklist is provided for informational use and off-line preparation of a project submission. NOTE: Project filings should be prepared and submitted using the online Climate Resiliency Checklist.

For questions or comments about this checklist or Climate Change best practices, please contact: John.Dalzell@boston.gov

Appendix 4: NY/NJ Port Authority's sea level rise checklist

Below is a copy of the design guidelines for climate resilience used by The Port Authority of New York and New Jersey. The full design guidelines can be found here: https://www.panynj.gov/business-opportunities/pdf/discipline-guidelines/climate-resilience.pdf

2.0 Stressor: Sea Level Rise and Coastal Inundation

2.1 Codes and Standards

The Port Authority takes a code-plus approach to designing for future sea level rise, meaning that the Climate Resilience Guidelines supplement, but do not supersede, applicable codes and standards[6].

The American Society of Civil Engineers (ASCE) standard *Flood Resistant Design and Construction* (ASCE 24) is fully incorporated into New Jersey Building Code and serves as the basis for New York City Building Code Appendix G (*Flood-Resistant Construction*). ASCE 24 dictates that construction in the FEMA 1% ("100-year") annual chance floodplain is subject to specific, safety-driven requirements, most notably the establishment of a Design Flood Elevation (DFE) comprising:

- **Base Flood Elevation.** The project-specific FEMA Base Flood Elevation (BFE)[7]—the elevation of the 100-year flood including waves—is derived from the FEMA Flood Insurance Rate Map(s); *and*
- **Freeboard**. Freeboard is a factor of safety usually expressed in feet above the BFE, as dictated by the requirements of ASCE 24 or the applicable code.

The Climate Resilience Guidelines supplement ASCE 24 and applicable local codes in two primary ways:

- **Adjustment of the BFE for Sea Level Rise:** The Guidelines augment the applicable FEMA BFE by adding the relative increase in future sea levels (based on the NPCC projections) over the project's expected service life[8].
- **Consideration of future floodplain expansion:** Rising sea levels may also lead to expansion of the 100-year tidal floodplain over time, depending on local conditions. Therefore, the Guidelines apply to projects sited in or proximate to today's 0.2% annual chance ("500-year") floodplain or in the projected future tidal 100-year floodplain, in addition to the current FEMA 100-year floodplain.

2.2 Grant Funding

Projects receiving federal, state or local funding may be required to adhere to specific design criteria. In such instances, the design lead (LE/A or Principal) should contact the Line Department Project Manager early in the process to identify any design requirements stipulated in the grant agreement. If the project is receiving funding from FEMA, FTA, or other entities, the design lead should additionally contact the Climate Resilience Specialist (resilience@panynj.gov) and the Engineering Program Management group during proposal development.

[6] In the unlikely instance that these Guidelines are found to be less stringent than code in a particular application, code prevails.
[7] FEMA Region 2 defines Base Flood Elevation (BFE) as the elevation shown on the Flood Insurance Rate Map (FIRM) for Zones AE, AH, A1-30, or VE that indicates the water surface elevation resulting from a flood that has a 1% chance of occurring in any given year.
[8] Where it is necessary or useful to differentiate between code-required design flood elevations and the DFEs derived from these Guidelines, use "SLR DFE" in drawings, notes, and narratives to indicate that the DFE has been adjusted for projected future sea level rise.

2.3 Design Criteria

There are five principal steps for developing the sea-level rise adjusted project DFE (SLR DFE). For questions about this process, please contact the Climate Resilience Specialist at resilience@panynj.gov.

Step 1: Determine CRG Applicability

These Guidelines apply to Port Authority projects where at least one of the following criteria is true:

1) The project is located in or is potentially hydrologically or hydraulically connected[9] to a federally delineated tidal floodplain (Effective or Preliminary);
2) (Advisory) The project is located in a projected future tidal floodplain, as defined by the Future Flood Risk Mapper[10], an application created by the City of New York and adapted for portions of northern New Jersey[11] by the Port Authority.

Please contact the Climate Resilience Specialist with questions concerning the applicability of the CRG to your project, or email resilience@panynj.gov.

Step 2: Include Climate Resilience in Project Documents

Early integration of the CRG criteria into the project delivery process is essential to ensuring an effective and cost-conscious outcome. Consequently, the CRG must be referenced in the following documents, if applicable:

- The project Proposal;
- The Attachment A for consultant services;
- Design Criteria/Performance Criteria/Basis of Design documents;
- Requirements and Provisions for Work;

Further, invite the Climate Resilience Specialist to the kick-off meeting.

Interdependent Risks

As part of Step 2, consider whether there may be an opportunity to address critical interdependencies (for example, shared risks to essential electrical, telecommunications, fueling, or surface access infrastructure) within the project scope.

Step 3: Establish Project DFE (SLR DFE)

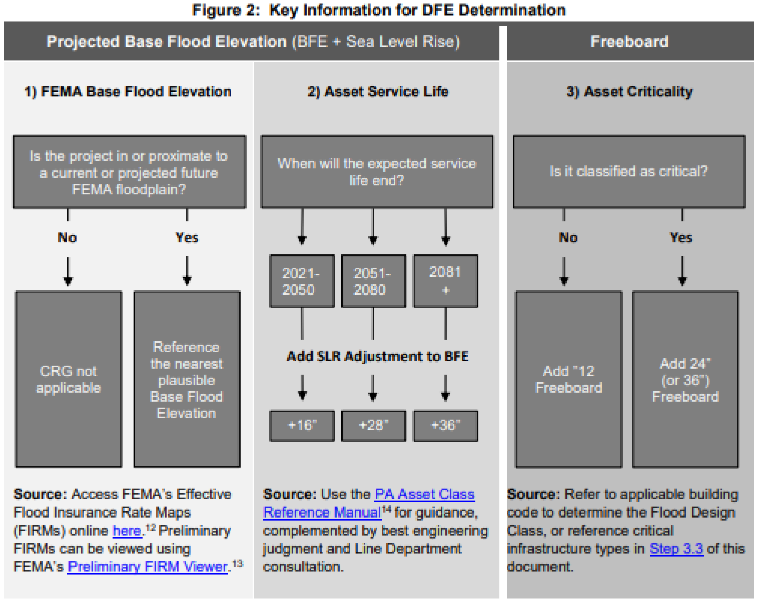
The design team must assemble three sources of information to compute the project's sea level rise adjusted Design Flood Elevation:

1. FEMA Base Flood Elevation (BFE)
2. Asset Service Life
3. Asset Criticality

The key informational requirements for determining the project DFE are summarized in Figure 2, below, followed by detailed guidance.

[9] Via storm drain, channel, or ditch, for example.
[10] http://www1.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page
[11] PA staff may access this resource from the RSD SharePoint site. Consultants may request access through the project Lead Engineer/Architect.

Figure 2: Key Information for DFE Determination



3.1 FEMA Base Flood Elevation (BFE)

Overlay the project footprint on the applicable Preliminary and Effective FEMA Flood Insurance Rate Maps (FIRM) and, consistent with local building codes, select the *more conservative* (higher) Base Flood Elevation among the two. Convert the BFE into the North American Vertical Datum of 1988 (NAVD88), if necessary[15].

For CRG-applicable projects outside of the current 1% annual chance floodplain (e.g., in the 0.2% annual chance floodplain or in a projected future 1% annual chance floodplain, per the applicability criteria in Step 1), select the nearest plausible Base Flood Elevation, accounting for subsurface (e.g., drainage and/or seepage) connectivities and/or structurally-sound obstructions to overland flows.

FEMA FIRMs are available online (as of May 2018):

- Effective FIRMs (2007): https://msc.fema.gov/portal/advanceSearch
- Preliminary FIRMs (2013/2015): www.region2coastal.com/view-flood-maps-data/view-preliminary-flood-map-data/

[12] https://msc.fema.gov/portal/advanceSearch
[13] http://www.region2coastal.com/view-flood-maps-data/view-preliminary-flood-map-data/
[14] \\patcdsrv2\data\GTWYD\SHARED\Eng Design Guidelines\Updates for Climate Resiliency\120814_SD Changes\ASSET MANUAL Rev Dec 2011.pdf
[15] Note that the Effective FIRM references the outdated NGVD29 datum, whereas the Preliminary FIRM references the required NAVD88 datum. For guidance on conversion, consult Central Survey or visit: www.region2coastal.com/view-flood-maps-data/understanding-vertical-datums

Contact the Climate Resilience Specialist (resilience@panynj.gov) for information on pending FEMA flood map appeals, revisions, or amendments, if applicable.

In instances where higher resolution or more up-to-date flood risk information is available, as validated by the Climate Resilience Specialist, these additional sources should be factored into determination of the project DFE (unless the alternative information results in an DFE less stringent than applicable codes and standards). Such sources may include:

- NOAA's Hurricane SLOSH maps;
- Hurricane Sandy inundation maps;
- USACE's North Atlantic Coast Comprehensive Study maps;
- Site-specific flood hazard analyses.

3.2 Asset Service Life

Sea level rise is already impacting the Port District, with over 14 inches of increase in mean sea level observed at the Battery since the year 1900[16], an average rise of 1.2 inches per decade. The rate of increase is projected to accelerate as the 21st century progresses, likely leading to a significant rise in both the frequency and magnitude of coastal flooding. To help mitigate these risks, the Authority supplements the applicable FEMA Base Flood Elevation with projected sea level rise, commensurate with the expected service life of the asset(s) being designed.

For guidance on determining an asset's expected service life, refer to the Port Authority Asset Class Reference Manual. This reference should be complemented by the engineering judgment of the design team, in consultation with the appropriate Line Department or facility. A conservative estimate is recommended, as the *service* life of a given asset may vastly exceed its original *design* life.

Based on the anticipated end year of a given asset's expected service life, use Table 1, below, to determine the appropriate sea level rise adjustment factor to be added to the Base Flood Elevation established in Step 3.1. No SLR adjustment is required if a given project's service life will terminate prior to January 1, 2021.

Table 1. Sea Level Rise Adjustment Factors

End of Anticipated Asset Service Life	Sea Level Rise Adjustment
2021-2050	+16"
2051-2080	+28"
2081+	+36"

[16] https://www1.nyc.gov/assets/planning/download/pdf/applicants/wrp/wrp-2016/nyc-wrp-appendixd.pdf

3.3 Asset Criticality

An asset's classification as *Critical* or *Non-Critical* determines the level of code-required freeboard, a safety factor added to the BFE. Freeboard typically adds 1 foot (non-critical) or 2 feet (critical) to the BFE, but can be as high as 3 feet in certain circumstances.

The determination of asset criticality is driven primarily by the following local codes and national standards, depending on the host jurisdiction:

- New Jersey: New Jersey Building Code (IBC), which points to ASCE-24, *Table 1-1 Flood Design Class of Buildings and Structures*; or
- New York City: New York City Building Code, which points to Appendix G, *Table 1-1 Classification of Structures for Flood-Resistant Design and Construction*.

Under both building codes, Flood Design Classes 1 and 2 are considered "Non-critical," while Classes 3 and 4 are considered "Critical."

Calculation of Flood Loads

Flood load calculations must incorporate projected future sea level rise for all applicable projects. To calculate flood loads, augment the Base Flood Elevation by the appropriate SLR adjustment factor (see Steps 3.1 and 3.2). Where SLR is likely to result in landward migration of the VE Zone, factor in breaking wave loads as appropriate.

Consistent with ASCE 7, *Minimum Design Loads for Buildings and Other Structures*, freeboard should be omitted from flood load calculations.

In addition, the following Port Authority infrastructure types follow ASCE-24 freeboard requirements for Category 4 structures:

- PATH Tunnels (e.g., entrances, penetrations, vent buildings);
- Vehicular Tunnels (e.g., entrances, penetrations, vent buildings);
- Power distribution facilities (e.g., electrical substations, switch houses, transformers);
- Emergency generators;
- Fire Protection Systems; and
- Aircraft Fueling Systems.

Additions or subtractions of assets to the list above require agreement between the respective Line Department Director and the Chief Engineer.

3.4 Sea Level Rise Adjusted DFE

Based on the information collected in Steps 3.1 through 3.3, calculate the sea level rise-adjusted DFE (SLR DFE) for the project. Refer to Table 2 for *non-critical* assets and Table 3 for *critical* assets.

Table 2. SLR DFE for *Non-Critical* Assets

1) FEMA Base Flood Elevation (BFE)	2) Sea Level Rise Adjustment based on Asset Design Life		3) Freeboard (code-required)	DESIGN FLOOD ELEVATION (SLR DFE)
Project specific (see Step 3.1 for guidance)	2021-2050	+16"	+12"	= FEMA BFE + 28"
	2051-2080	+28"	+12"	= FEMA BFE + 40"
	2081+	+36"	+12"	= FEMA BFE + 48"

Table 3. SLR DFE for *Critical* Assets

1) FEMA Base Flood Elevation (BFE)	2) Sea Level Rise Adjustment based on Asset Design Life		3) Freeboard[17] (code-required)	DESIGN FLOOD ELEVATION (SLR DFE)
Project specific (see Step 3.1 for guidance)	2021-2050	+16"	+24"	= FEMA BFE + 40"
	2051-2080	+28"	+24"	= FEMA BFE + 52"
	2081+	+36"	+24"	= FEMA BFE + 60"

Step 4: Develop Resilient Design Strategies

This Guideline sets out the methodology for incorporating projected sea level rise into project design criteria, but preserves the flexibility of project teams to develop packages of flood mitigation solutions that best satisfy broader design objectives in a cost-effective and co-beneficial manner[18].

Approaches to increasing the resilience of an asset to flood damage and/or operational disruption generally fall into the basic categories of a) elevate, b) relocate, c) protect, or d) accommodate. These approaches include, but are not limited to:

- Coastal protection, including wave attenuation (placement of levees, berms, or living shorelines)[19];
- Site selection and relocation (placement of structures on higher ground or within flood protected areas);
- Perimeter protection (placement of flood walls and/or deployable protection measures to limit flood risk within a defined perimeter);
- Elevation (raising an entire structure above the DFE);
- Elevation of utilities and critical equipment such as controls, outlets, generators, etc.;
- Wet floodproofing (allowing floodwaters to enter and exit certain non-critical, generally unoccupied portions of a structure to equalize flood loads, subject to code restrictions);
- Dry floodproofing (placement of permanent, deployable, and/or temporary mitigation measures to prevent intrusion of flood waters into a structure);
- Pumps (to prevent build-up of incidental leakage in a dry floodproofed structure or perimeter protected site);
- Backflow prevention (the installation of devices to prevent surge intrusion through storm or sanitary sewers).

[17] See New York City Building Code, Appendix G for circumstances in which 3 feet of freeboard are required, which must be reflected in the SLR DFE.
[18] Subject to the restrictions of applicable codes, standards, and PANYNJ Engineering Guidelines.
[19] In certain instances, the elevation of coastal/perimeter protection structures may be lower than the SLR DFE as long as all applicable landward/perimeter-enclosed assets are designed in accordance with these Guidelines, subject to the restrictions of codes, standards, and other PANYNJ Guidelines.

Flood Mitigation Product Library

To support design teams in identifying potential flood mitigation products and systems, the Port Authority Resilience & Sustainable Design unit offers an extensive product library of flood mitigation products (for informational use only). PA staff may access this resource from the RSD SharePoint site. Consultants may request access through the project Lead Engineer/Architect.

A viable flood protection system may incorporate several of the preceding strategies. For the most critical assets—for which loss of operation for any period of time would be unacceptable—multiple layers of redundant protection may be preferable.

The PANYNJ Climate Resilience Specialist is available to meet with project teams to discuss flood mitigation approaches and product options.

Step 5: (If Applicable) Conduct A Climate Risk-Enhanced Benefit-Cost Analysis (BCA)

At the request of the Line Department or if required for a given funding source, Benefit-Cost Analysis (BCA) can be employed to inform design decision-making. Climate risk-enhanced BCA considers the incremental capital and/or operating costs of designing for resilience (i.e., only the portion of Total Project Cost attributed directly to the additional consideration of sea level rise) in balance with projected avoided losses over time due to flood-related failures.

Climate risk-enhanced BCA has at least two potential applications in the context of climate resilient design:

- Typically, to support selection of the most cost-effective flood mitigation alternative during Stage I design services;
- Selectively, to determine whether a Stage III flood mitigation design to the required DFE is appropriately cost effective. If the BCA definitively demonstrates that design to the full DFE is not cost beneficial, the design team may pursue a flexible adaptation pathway[20] approach, in consultation with the Climate Resilience Specialist.

The Resilience & Sustainable Design unit and the Economics unit of the PANYNJ Office of Planning and Regional Development collaborate to perform the climate-risk enhanced BCA, on request. This service should be specified in the project Proposal and Attachment A, if applicable. Contact the Climate Resilience Specialist with questions pertaining to the BCA process at resilience@panynj.gov.

[20] A Flexible Adaptation Pathway is one or more "[r]esilience-building strategies that can evolve or be adapted over time …" as better information becomes available. *NYC Climate Resiliency Design Guidelines, Version 2.0* (April 2018). http://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v2-0.pdf