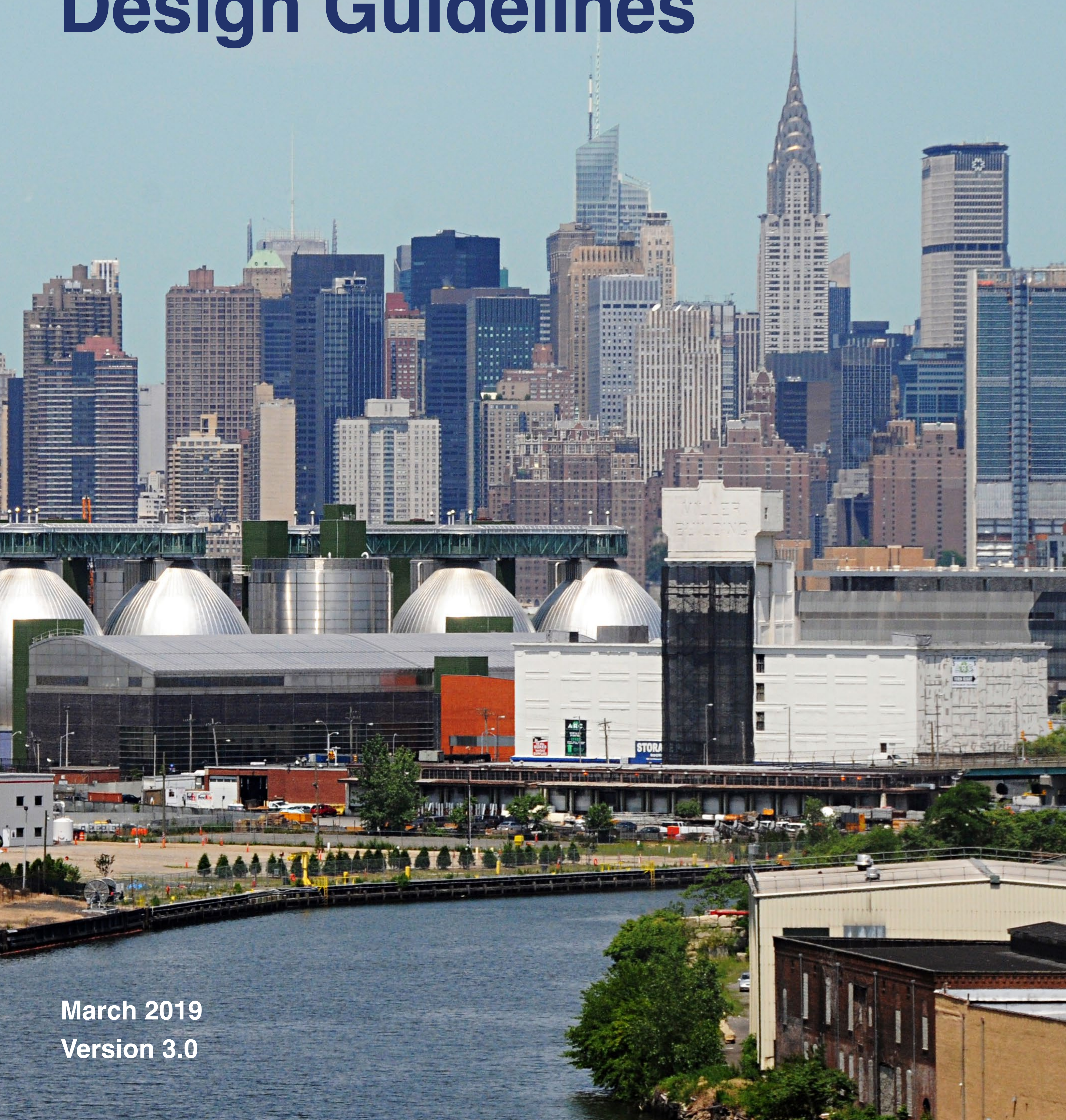
NYC Mayor's Office of Recovery and Resiliency

Climate Resiliency Design Guidelines



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I. Introduction

In the coming years and throughout the 21st century, New York City (NYC) will face new challenges from a rapidly changing climate. Many capital projects, including infrastructure, landscapes, and buildings ("facilities"), will experience extreme flooding, precipitation, and heat events.[1] At the same time, the region's environmental conditions are also projected to change, posing chronic hazards as some coastal areas are regularly inundated by high tide and average annual temperatures rise. In NYC's *Roadmap to 80 x 50*, the City of New York (the City) committed to reducing emissions of greenhouse gases by 80% by 2050.[2] While the City is working toward a low carbon future, the impacts from climate change are already occurring, and these Guidelines establish how the City can increase the resiliency of its facilities to unavoidable climate change hazards through design.

The *Climate Resiliency Design Guidelines* ("the Guidelines") provide step-by-step instructions on how to supplement historic climate data with specific, regional, forward-looking climate change data in the design of City facilities. Resilient design is intended to become an integral part of the project planning process for City agencies and designers. All new projects and substantial improvements should assess risks to climate change hazards in the context of the project's purpose, asset type, site location, and funding, and then determine the appropriate resilient design strategies using the Guidelines. The Guidelines apply to all City capital projects except coastal protection projects (e.g. sea walls, bulkheads, and levees), for which the City is developing separate guidance. Implementing the Guidelines will result in designs that will make City facilities more resilient to climate change and promote the health, safety, and prosperity of New Yorkers.

The Guidelines provide step-by-step instructions on how to supplement historic climate data with specific, regional, forward-looking climate change data in the design of City facilities.

The primary goal of the Guidelines is to incorporate forward-looking climate change data in the design of all City capital projects. Codes and standards that regulate the design of facilities already incorporate historic weather data to determine how to design for today's conditions. However, historic data does not accurately represent the projected severity and frequency of future storms, sea level rise, heat waves, and precipitation. The climate is already changing and will continue to change in significant ways over the full useful life of facilities designed today, threatening to undermine capital investments and impede critical services if they are not designed to future conditions. The Guidelines complement the use of historic data in existing codes and standards by providing a consistent methodology for engineers, architects, landscape architects, and planners to design facilities that are resilient to changing climate conditions (see Figure 1). The Guidelines are to be used throughout the design process—during project planning initiation, as a reference in requests for proposals (RFPs), during a conceptual or study phase, through to final design—for all new construction and substantial improvements of City facilities.

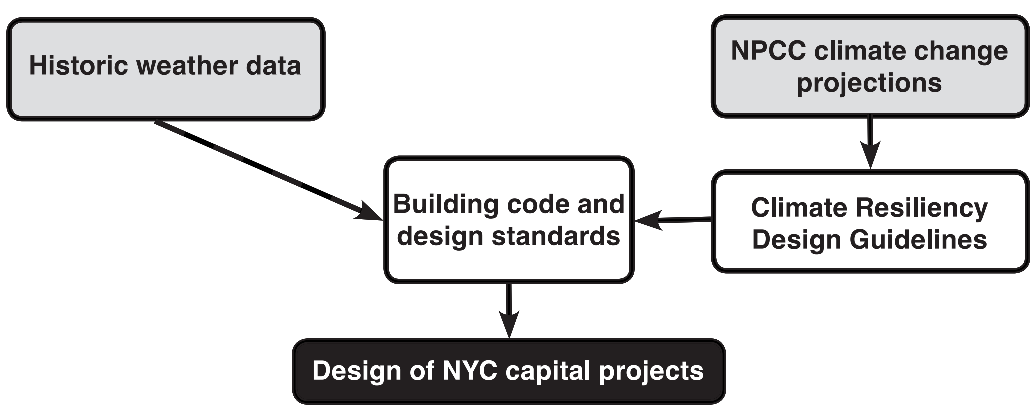

Figure 1 - Both historic weather data and climate change projections inform the design of capital projects in NYC.

[1] Though the intensity and frequency of storms is expected to increase, firm projections on future wind conditions have not yet been developed. NYC s undertaking a study to assess projected changes to extreme wind hazards and identify risks to the city's built environment.
[2] To learn more about 80 x 50, visit: http://www1.nyc.gov/site/sustainability/codes/80x50.page.

A successful resiliency strategy is one that provides co-beneficial outcomes, reduces costs over the life of the asset wherever possible, and avoids negative indirect impacts to other systems. Resilient design should not exist in a silo, but rather be a well-integrated part of existing processes and address other goals of the City. For example, resilient design choices should be made as an integral part of the City's project planning, risk management, and financial planning. Similarly, resilient design choices should be selected to maximize the efficacy and efficiency of investments. Some ways this can be done include: 1) integrating "soft" resiliency strategies (operational measures or investments in green infrastructure) and "hard" resiliency strategies (built or intensive investments); 2) addressing multiple climate hazards with single interventions; and 3) reducing climate change risk in concert with other goals (e.g., energy efficiency or reduction in greenhouse gas emissions).

These Guidelines were developed by the Mayor's Office of Recovery and Resiliency (ORR) in collaboration with City agencies developing and delivering capital projects. The development of the Guidelines has been an iterative, and ongoing, process of testing, vetting, and improving. Important milestones in the development timeline include:

- Fall 2016: the Design Guidelines Working Group, which includes more than 15 City agencies, was convened to collaborate and advise on the development of the Guidelines.[3]
- April 2017: the preliminary version (1.0) of the Guidelines was issued.
- April 2017 - November 2018: the preliminary version of the Guidelines was tested through an extensive review with internal and external climate and design experts, and review of City capital projects.
- April 2018: version 2.0 of the Guidelines was released with various improvements reflecting lessons learned, including the addition of a benefit-cost analysis methodology and projections on Cooling Degree Days and Dry Bulb temperatures.
- March 2019: version 3.0 of the Guidelines was released with refinements, including an Exposure Screening Tool and a Risk Assessment Methodology.

B. Climate Change in New York City

The New York City Panel on Climate Change (NPCC) provides regional climate change projections that inform City resiliency policy. Composed of leading scientists, the NPCC's projections for the metropolitan region show that extreme weather will increase in frequency and severity, and that the climate will become more variable. These projections are divided across future time slices including the 2020s, 2050s, 2080s, and 2100. The 2015 NPCC climate change projections (which were reassessed and validated in 2019) encompass a range of possible outcomes, for example:

- Mean annual temperature is projected to rise by 4.1 to 6.6°F by the 2050s, and by 5.3 to 10.3°F by the 2080s.[4]
- Frequency of heat waves is projected to triple by the 2050s to 5 to 7 heat waves per year and 5 to 8 heat waves per year by the 2080s.[5]
- Mean annual precipitation is projected to increase between 4 to 13% by the 2050s, and by 5 to 19% by the 2080s.[6]
- Sea level is expected to keep rising by 11 to 21 inches by the 2050s, and by 18 to 39 inches by the 2080s.[7]

For more information on climate change projections for the metropolitan region, see Appendix 2. As the NPCC continues to study and refine projections, the Guidelines will be updated as needed to reflect changes in the scientific consensus.

3 Representatives from the following City agencies contributed to the Guidelines: Environmental Protection, Transportation, City Planning, Buildings, Design and Construction, Parks and Recreation, Emergency Management, School Construction Authority, City Administrative Services, Health and Hospitals, Information Technology and Telecommunications, Economic Development Corporation, Housing Authority, Public Design Commission, Mayor's Office of Sustainability, Mayor's Office of the Chief Technology Officer, Housing Preservation and Development, Office of Management and Budget, Sanitation, and Law.
4 Ranges for heat reflect the middle and high range estimates from the NPCC. See Appendix 2 for more information.
5 Ibid.
6 Ranges for precipitation reflect the middle and high range estimates from the NPCC. See Appendix 2 for more information.
7 Ranges for sea level rise reflect the middle range estimates from the NPCC. See Appendix 2 for more information.

C. Useful Life of Capital Projects

A resilient facility is one built to withstand, or recover quickly from, natural hazards, as well as to perform to its design standard throughout its useful life in a changing climate. To meet this goal, facilities should be designed to withstand climate conditions projected for *the end* of the facility's useful life.[8] Full useful life represents the extended service life of a facility (assuming regular maintenance). Some new facilities built today, including some buildings, may have an extended useful life beyond the values listed after undergoing substantial improvements. Therefore, this list is illustrative and not exhaustive. Project teams should utilize professional judgment to determine the useful lives of the facility and components in design.

Climate change projections for NYC, as defined by the NPCC, are broken into decadal projections. In the Guidelines, the following decadal projections are associated with specific time spans:

- 2020s projection = present to 2039
- 2050s projection = 2040 to 2059
- 2080s projection = 2070 to 2099
- 2100 projection = end of century and beyond

Table 1 below provides examples of how to select climate change projections for specific facilities and components.

Table 1 – Facilities and components and associated climate change projections

Climate change projections (time period covered)	**Examples of building, infrastructure, landscape, and components grouped by typical useful life**	
2020s (through to 2039)	*Temporary or rapidly replaced components and finishings*	• Interim and deployable flood protection measures • Asphalt pavement, pavers, and other ROW finishings • Green infrastructure • Street furniture • Temporary building structures • Storage facilities • Developing technology components (e.g., telecommunications equipment, batteries, solar photovoltatics, fuel cells)
2050s (2040-2069)	*Facility improvements, and components on a regular replacement cycle*	• Electrical, HVAC, and mechanical components • Most building retrofits (substantial improvements) • Concrete paving • Infrastructural mechanical components (e.g., compressors, lifts, pumps) • Outdoor recreational facilities • At-site energy equipment (e.g., fuel tanks, conduit, emergency generators) • Stormwater detention systems
2080s (2070-2099)	*Long-lived buildings and infrastructure*	• Most buildings (e.g., public, office, residential) • Piers, wharfs, and bulkheads • Plazas • Retaining walls • Culverts • On-site energy generation/co-generation plants
2100+	*Assets that cannot be relocated*	• Major infrastructure (e.g., tunnels, bridges, wastewater treatment plants) • Monumental buildings • Road reconstruction • Subgrade sewer infrastructure (e.g., sewers, catch basins, outfalls)

[8] NIST, *Community Resilience Planning Guide for Buildings and Infrastructure Systems*, Vol. 1. NIST Special Publication 1190: US Department of Commerce, 2016.

D. Defining "Critical Facilities" and "Major Facilities"

Throughout the Guidelines, particular actions are recommended depending on the criticality and/or the size of a capital project. These two distinctions are summarized below:

Criticality: Some facilities or components are classified as critical either because of the services they provide (e.g., hospitals and key transportation assets) or their importance during an emergency (e.g., designated shelters and back-up energy generators). This classification determines levels of freeboard in the sea level rise-adjustment section. See Table 3 in Section II.C for a full list of critical facilities for the application of the Guidelines.

In complex facilities with multiple components, whether or not the full facility is considered critical, designers should identify critical components. Critical components essential to the facility's functionality should be protected to the higher standard provided even if the facility itself is non-critical. For example, at a non-critical vehicle maintenance yard, some components are critical to the functioning of the site, such as an emergency generator. Critical component protection should also be evaluated if a facility is expected to be fully operational during extreme weather, or if it is expected to quickly resume full operations after an event. Some examples of critical components include:

- boilers,
- chemical feed equipment,
- communications systems,
- electrical distribution and switching areas,
- elevators,
- emergency fuel supplies,
- emergency generators,
- fire alarms and suppression equipment,
- furnaces,
- hazardous material storage,
- HVAC units,
- monitoring and safety equipment, and
- motor-control centers.

Major Projects: Capital projects with a total cost (design and construction) of more than $50 million are defined as "major projects" in these Guidelines. Major projects are recommended to receive additional analysis to ensure that all risks are identified and mitigated in a cost-effective manner. It is recommended that major projects should perform a thorough climate risk assessment and full benefit-cost analysis (see Section III). However, some projects with a total cost over $50 million may not require additional analysis if, for example, the majority of costs relate to restoring natural areas or green space. If using the Guidelines on a major project, please contact ORR at ResilientDesign@cityhall.nyc.gov.

[9] PlaNYC, *A Stronger More Resilient New York*, report of the NYC Special Initiative for Rebuilding and Resiliency. Report. June 11, 2013, page 28. From that report: "Like all projections, the NPCC projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system and limited understanding of some physical processes. The NPCC characterizes levels of uncertainty using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations and recent peer-reviewed literature. Even so, the projections are not true probabilities, and the potential for error should be acknowledged."

[10] To learn more, see Chapter 2 in the NPCC 2010 report, *Climate Change Adaptation in New York City*, available at: http://onlinelibrary.wiley.com/doi/10.1111/nyas.2010.1196.issue-1/issuetoc

E. Managing Uncertainty

Climate change projections from the NPCC are the product of state-of-the-art modeling and analysis. However, as with all projections, there is uncertainty embedded within them.[9] The NPCC continues to develop, review, and synthesize the latest climate data for the metropolitan region, and new findings will be incorporated into future versions of these Guidelines.

Given uncertainty, flexible adaptation pathways provide a useful, iterative approach for managing uncertainty and designing resilient facilities, particularly those with a useful life that extends past 2050 - beyond which the uncertainty of projections increases.[10] Adaptation pathways are particularly useful for expensive, long-lived, and highly complex facilities. They provide a way to balance uncertainty with cost, as well as manage operational and maintenance constraints. A facility can be engineered with an adaptable protection level which reduces risk to acceptable levels for part of its useful life and can be re-evaluated as risk levels change.

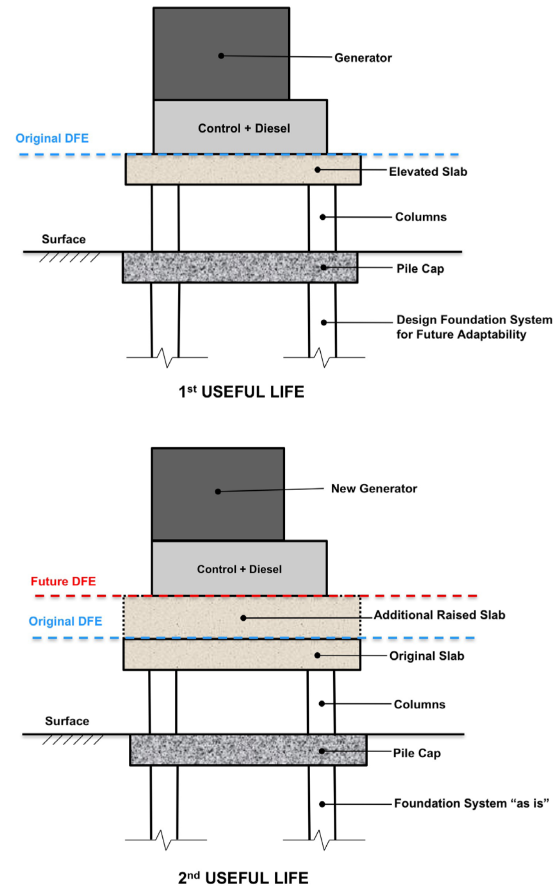

Figure 2 - Example of a flexible adaptation pathway for an outdoor emergency generator and platform

Figure 2 illustrates a flexible adaptation pathway for a critical facility component: an emergency generator with an approximate useful life of 25 years located outside of a non-critical building. The Guidelines recommend that the foundation of the generator structure is designed to match the useful life of the adjacent building, which is built to the 2080s projections. Assuming the generator is at risk from sea level rise and coastal surge, it should be built on an elevated concrete slab that matches the future year design flood elevation (DFE) corresponding to the end of the generator's useful life. The generator must be replaced when it reaches the end of its useful life, which is less than that of the adjacent building. When the replacement generator is installed, the concrete slab is further elevated to accommodate the future DFE. The foundation of the generator and the columns are designed to support the additional future load from the elevated concrete slab. This initial investment allows for future flexibility and avoided costs.

Adaptation pathways may not apply equally to all types of projects or climate change projections. Flood defenses, for example, may more easily incorporate an adaptation pathway than heat-vulnerable materials or below-grade drainage systems. For this reason, the Guidelines conservatively use the middle of the 25th to 75th percentile range projections for sea level rise and the high-end 90th percentile projections for heat and precipitation. For precipitation, the Guidelines use existing 50-year storm data as a proxy for the projected high-end 5-year storm (see Section II.B and Figure 5 for more details).

Uncertainty can be further addressed through additional analysis, including a full climate change risk assessment (see Section III for a methodology). This assessment will evaluate protecting the facility to potentially higher levels than recommended in these Guidelines.

F. Project-specific Considerations

Specific characteristics of projects will impact how resiliency design standards and strategies are chosen and employed. Discuss these considerations below as a project team to determine which apply and how to respond:

- **Financing requirements**: if the project is federally-funded, discuss with the funding agency if certain protection standards or benefit-cost analyses are required. For example, FEMA-funded reconstruction projects require specific flood protection standards for critical facilities and non-critical facilities.
- **Interdependencies**: consider how climate hazards impact service or resource interdependencies between the facility in design and other facilities or service utility providers, as well as the risks from coincident events (e.g. extreme precipitation occurring during an extreme surge event) to specific projects.
- **Existing hazard mitigation projects and risk studies**: evaluate if nearby or associated projects have already been assessed for climate change risks. Identify if any studies have been conducted that could inform design (e.g. local flood modeling with sea level rise). This may inform the climate change risk assessment report or provide insights into site specific conditions and design options. A map of NYC climate change hazard mitigation projects is located here: https://maps.nyc.gov/resiliency/
- **Agency-specific resiliency design standards**: refer also to resiliency guidelines provided by various City agencies (one example is Department of Parks and Recreation's *Design and Planning for Flood Resiliency*[11]). Agency guidelines build on the climate data provided in these Guidelines by providing specific design alternatives and insights relevant to those agencies.
- **Limitations**: the Guidelines do not describe or encompass all City resiliency policies. To learn more about how the City plans for a resilient future, see the latest OneNYC plan as well as the 2013 report *A Stronger, More Resilient New York*. Related resiliency issues are being addressed by the City but are out of the scope of these Guidelines, including neighborhood and regional-level climate change risk management and zoning.
- **Further questions?** Contact ORR at ResilientDesign@cityhall.nyc.gov

[11] Available at https://www.nycgovparks.org/planning-and-building/planning/resiliency-plans/flood-resiliency

II. Resilient Design

All City of New York facilities should be designed to withstand increasing heat and precipitation based on the useful life of the asset; design interventions for storm surge and sea level rise depend on the project's proximity to the current and future floodplains, useful life, and criticality.

To support the development and selection of climate-resilient designs, the Guidelines recommend design adjustments or interventions in response to increasing heat, increasing precipitation, and sea level rise.

A. Increasing Heat

Use this section to determine how to adjust a facility's design to account for increasing temperatures and to reduce the facility's contribution to the Urban Heat Island effect. Heat reduction levels will be determined by the function, location, and useful life of the asset.

Background

Every summer, over 100 New Yorkers die from causes exacerbated by extreme heat.[12] The region has seen a steady increase in the number of days at or above 90°F, and temperatures are projected to keep rising, worsening heat-related mortality. By the 2050s, the number of days at or above 90°F is expected to double, and the frequency and length of heat waves will triple to an average of 6 heat waves annually.[13] Certain areas of NYC already experience higher temperatures relative to other parts of the city (see Figure 3 for an example from August 2009), and these hot spots will be exacerbated by climate change. These hot spots correspond with highly developed areas with limited green space, limited shading, and/or a high density of buildings and infrastructure.

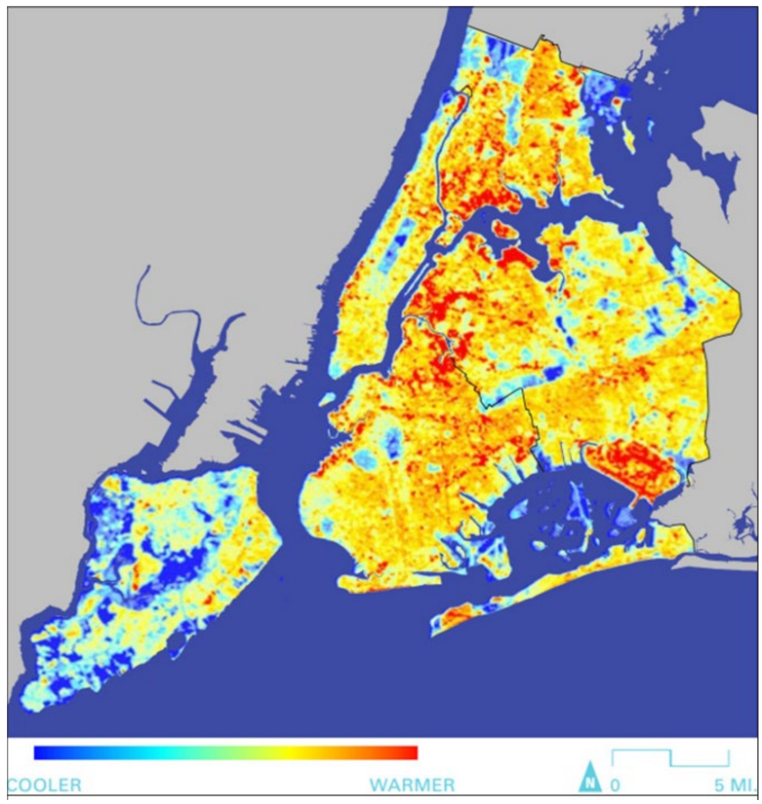

Figure 3 - Thermal imagery of New York City, based on LANDSAT Thermal Data from 8/18/2009[14]

New Yorkers are more or less vulnerable to heat based largely upon socio-economic factors, including age, income, location, tree coverage, and the percentage of dark surfaces in their neighborhoods. In *Cool Neighborhoods NYC*, the City prioritizes strategies to study the Urban Heat Island effect and make targeted investments that benefit communities most vulnerable to heat.[15]

Heat can be lethal for all, but its impact on New Yorkers is not felt equally.

[12] *OneNYC: The Plan for a Strong and Just City*. (The City of New York, 2015) 228. See also: Madrigano J, Ito K, Johnson S, Kinney PL, Matte T. 2015. A case-only study of vulnerability to heat wave–related mortality in New York City (2000–2011). Environmental Health Perspectives 123:672–678; http://www.nyc.gov/html/onenyc/downloads/pdf/publications/OneNYC.pdf

[13] Horton et al. *New York City Panel on Climate Change 2015 Report Chapter 1: Climate Observations and Projections*. Ann. N.Y. Acad. Sci. ISSN 0077-8923: New York, 2015.

[14] LANDSAT Thermal Data from 8/18/2009

[15] *Cool Neighborhoods NYC* is available at https://www1.nyc.gov/assets/orr/pdf/Cool_Neighborhoods_NYC_Report_FINAL.pdf

The NYC Department of Health and Mental Hygiene (DOHMH) developed a Heat Vulnerability Index (HVI) which highlights parts of the city where more residents face an increased risk of heat-related mortality. Their vulnerability is due to exposure to high temperatures, lack of vegetation, and socio-economic conditions that determine sensitivity to heat. Community districts in red and orange in Figure 4 are areas of highest vulnerability. These areas are particularly concentrated in east Brooklyn, the south Bronx, northern Manhattan, and southeast Queens.[17] While all new and substantially improved capital projects should address heat impacts, those sited in moderate to high vulnerable HVI areas should implement multiple strategies to reduce the Urban Heat Island effect and help address the high vulnerability in these neighborhoods.

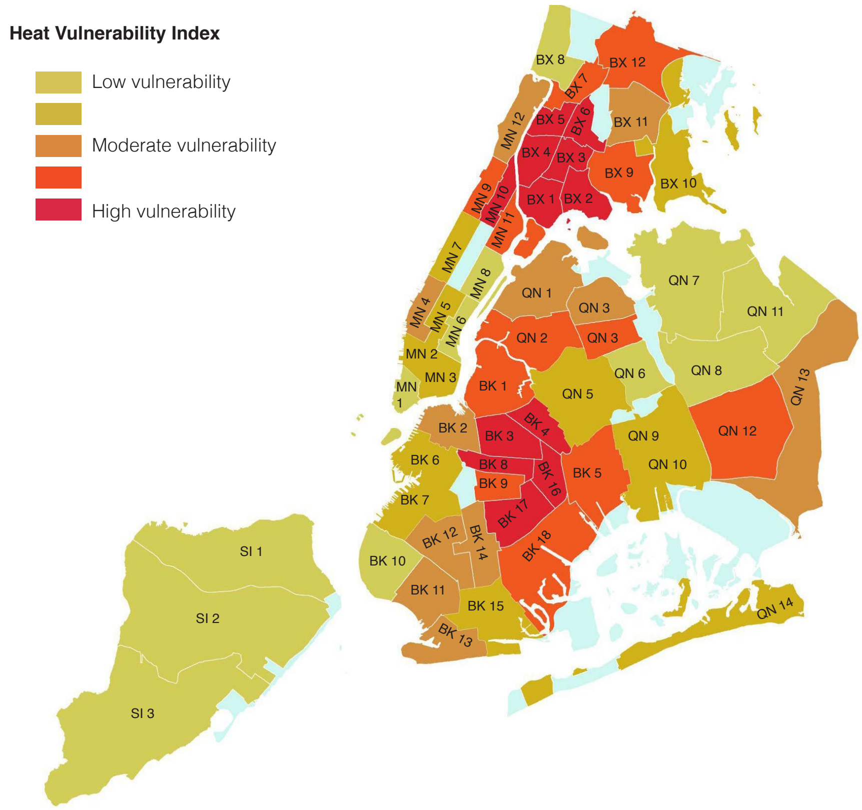

Figure 4 - Heat Vulnerability Index (HVI) for New York City Community Districts (Source: NYC DOHMH 2015). This analysis identifies physical, social, and economic factors associated with increased risk of heat-related morbidity and mortality.[17]

The Guidelines recommend that project designers consider the two aspects of the relationship between their project and increasing heat: the way their project increases or reduces the Urban Heat Island effect as well as the impact that rising average temperatures and increased frequency of extreme heat days will have on the physical components or on the operations of the facility itself:

- **Urban Heat Island effect reduction**: materials in the built environment absorb the sun's heat throughout the day and re-radiate it back into the atmosphere, driving localized temperatures higher and increasing demands on cooling systems. Air conditioning and ventilation equipment also push waste heat into the air, contributing to a feedback loop that increases localized ambient temperatures and impacts the health of heat-vulnerable New Yorkers. This section provides guidance on how capital projects can reduce heat pollution and their contribution to ambient heat in the city.
- **Minimize impact from increasing heat**: increasing heat, or an increasing number of hot days, can physically impact components of buildings, infrastructure, and landscapes by damaging or stressing materials, plantings, electrical systems, and mechanical systems. Rising temperatures will also stress energy and communications networks that buildings and other infrastructure rely upon.[18] Finally, higher average temperatures can increase the energy and operational costs for assets for which it is important to maintain cool temperatures for the thermal comfort of occupants. This section provides climate data to be used to adjust and adapt heat-vulnerable components of facilities.

[16] To learn more about Heat Vulnerability Index, see page 229 of OneNYC at http://www.nyc.gov/html/onenyc/downloads/pdf/publications/OneNYC.pdf
[17] ibid.
[18] Damiano, H. et al. *NYC's Risk Landscape: A Guide to Hazard Mitigation.* (NYC Emergency Management, 2014), 103.

1. Urban Heat Island effect reduction

New capital construction should minimize contribution to the Urban Heat Island effect. The design interventions provided below offer benefits to the community and the facility through reduced heat loading, reduced energy costs, and/or improved occupant health and thermal comfort. The appropriate combination of design interventions will vary dependent on the project scope.

a. **Increase the solar reflectance of surfaces by utilizing light-colored pavement, coatings and materials, in combination with shading, with a minimum target of 50% of the non-structure areas of facility sites.[19]**
Lighter, reflective surfaces help reduce the Urban Heat Island effect, heat loading, and internal building temperatures, thus reducing energy costs and extending the lifespan of rooftops, HVAC equipment, roads, and other paved surfaces. The City has taken steps towards reducing building energy needs and local temperatures, such as implementing the NYC Cool Roofs program.[20] New buildings, as well as existing buildings undergoing a roof membrane replacement, are required by law to utilize materials with high reflectance and emittance factors. The Cool Roofs program expands on the code requirements by offering existing buildings not going through a roof membrane replacement similar energy savings by applying a highly reflective white coating to the normally dark traditional roofing materials, allowing the roof to reflect solar radiation and absorb less heat. Utilizing light colored pavement materials, such as cement concrete, chip seals, stone, etc, which have albedos at least twice as high as standard asphalt concrete, also reduces a facility's contributions to ambient temperatures.

b. **Increase the shading of surfaces by planting trees or other vegetation, in combination with cool pavements, with a minimum target of 50% of the non-structure areas of facility sites.**
Shady areas with heat- and, in coastal areas, salt-tolerant vegetative species can help keep buildings cool and provide energy savings, as well as lower temperatures.

c. **Meet Climate Zone 6 standards for fenestration and insulation (See Section ECC C402 in Chapter C4 of the 2016 NYC Energy Code) to improve efficiency of building envelopes.**
NYC is currently in ASHRAE Climate Zone 4. NYC already requires that small residential building envelopes are designed to meet higher insulation and fenestration requirements to improve energy efficiency.[21] All City capital projects, including non-residential facilities, should meet the Climate Zone 6 standard.

d. **Select green/blue roofs and/or other appropriate landscape elements that maximize cooling with input from landscape architects.**
The City has programs in place to encourage the use of green and blue roofs on buildings to reduce the Urban Heat Island effect, provide stormwater management, and increase the useful life of the roof.[22] Besides replacing dark roof surfaces, green roofs and vegetation also provide shade and keep the air cool through evapotranspiration by releasing moisture into the atmosphere. Blue roofs, coupled with light colored roofing material, can provide stormwater management and rooftop cooling. Some of these designs support the shading and solar reflectance goal in Step a) above. Additionally, City capital projects are subject to Leadership in Energy and Environmental Design (LEED) certification, and green roofs can earn LEED credits.[23] Projects should integrate cooling strategies listed below based on project scope and a balance between costs and benefits:

- Green roofs or blue roofs on a broader range of facilities (including industrial buildings, storage, garages, administration buildings, etc.).
- Vegetated structures, such as shade trees and planters (to reduce heat loading on horizontal or vertical surfaces).
- Bioswales, rain gardens, and bioretention.[24]

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19 Urban Green Council (2010). *Green Codes Task Force*. Proposed code "EF 12: Reduce Summer Heat with Cool, Shady Building Lots".
20 Local Law No. 21 (2011) amended Chapter 12 of the NYC Building Code to update roof coating standards. Also, see *Cool and Green Roofing Manual* (DDC) 2007 for more information on NYC standards for cool and green roofs: http://www.nyc.gov/html/ddc/downloads/pdf/cool_green_roof_man.pdf
21 Read more about the code here https://www1.nyc.gov/site/buildings/codes/2016-energy-conservation-code.page
22 See *Cool and Green Roofing Manual* (DDC) 2007 for more information on NYC standards for cool and green roofs: http://www.nyc.gov html/ddc/downloads/pdf/cool_green_roof_man.pdf
23 See Local Law No. 32 (2016) for more information.
24 When siting bioswales, consider groundwater levels and soil permeability and ensure that the site is not contaminated from past or present land uses. A high water table may prohibit some applications. Refer to NYC Department of Environmental Protection guidelines for standard procedures and details available at https://www1.nyc.gov/html/dep/html/stormwater/green_infrastructure_standards.shtml

- Maximized planted permeable surfaces.
- Other permeable surfaces (used for stormwater management, these retain moisture that evaporates as surface temperatures rise).[25]
- Open-grid pavement system (at least 50% unbound).[26]
- Evaluate site planning and building massing with regard to solar gain.
- Solar panels for shading and generating energy.

2. Minimize impact from increasing heat

This section provides information to support design adjustments that reduce impacts to facility cooling systems, components, structures, landscapes, and materials to manage rising average temperatures and increasing extreme heat events.

a. Design based on forward-looking climate data.
Cooling and other HVAC systems should be provided for all habitable buildings and the design should be based on the useful life of the components and facility (as identified in Table 1 in Section I.B). Table 2 below provides design criteria for future average temperatures, incidents of extreme heat events projected to different time periods across the 21st century, and guidance on future 1% Dry Bulb temperature and Cooling Degree Days for the NYC area. The 1% Dry Bulb Temperature represents the ambient air temperature and is used in the design of HVAC systems.

Table 2 – Current and projected extreme heat events and design criteria[27]

	Extreme heat events			***Design criteria***	
End of useful life	**# of heat waves per year**	**# days at or above 90°F**	**Annual average temperature**	**1% Dry Bulb temperature**	**Cooling Degree Days** *(base = 65°F)*
Current (1971-2000)	**2**	**18**	**54°F**	**91°F**	**1,149**
2020s (through to 2039)	**4**	**33**	**57.2°F**	**--**	**--**
2050s (2040-2069)	**7**	**57**	**60.6°F**	**98°F**	**2,149**
2080s (2070-2099)	**9**	**87**	**64.3°F**	**--**	**--**

Note: Due to HVAC system typical useful life of around 25 years, only design criteria projections for the 2050s are shown. Projections for the 2020s are not shown because it is anticipated that enough of a safety margin is employed already in current systems to withstand the temperature rise expected through the 2020s. The NPCC is developing projections of 1% Wet Bulb temperatures, which are expected to increase. This design criteria will be added in a later version of the Guidelines.

[25] Urban Green Council (2010). *Green Codes Task Force.* Proposed code "SW 1: REDUCE EXCESSIVE PAVING OF SITES"
[26] LEED Neighborhood Development v4 "Heat island reduction" credit.
[27] Projected estimates for average temperatures are based upon 90th percentile change factor added to the baseline average annual temperature from New York City Panel on Climate Change (2015).

b. Evaluate projected heat impacts on systems and materials using climate change projections.
A decrease in the useful life or operational capacity of a facility, or components of a facility, may occur due to rising temperatures. Heat impacts are highly contingent on the facility type and should be reviewed on a case-by-case basis.[28] Interventions also vary depending on whether the project is a new capital investment or a substantial improvement to an existing facility. Factors to evaluate, as applicable to project scope, include, but are not limited to:

- Thermal expansion, warping, softening, or other forms of material change or degradation of structural integrity occurring at an accelerated rate by excessive heat;
- Health and safety impacts on occupants vulnerable to heat;
- Increased failure or reduced efficiency of electrical or mechanical systems;
- Prioritization of critical loads for systems and components at the facility; and
- Moisture control needs for buildings with a higher standard for fenestration and insulation.

Use results from this evaluation to inform the selection of strategies in the next step.

c. Select strategies to reduce heat impacts.
Review and implement specific changes to the facility design based on assessments above. Develop a strategy based on the specific type of facility and, where relevant, presence of critical components, operational profiles, and the useful life of the facility and its components. A Design Strategies Checklist (Appendix 4) is available to track design approaches. Specific areas of focus are:

- *Electric grid outages:* high temperatures drive demand for air conditioning and can increase the risk of facility equipment failure, potentially broader grid disruptions, or brownouts.[29,30] To manage this risk, design City buildings and infrastructure to withstand periods without electricity using the following approaches, particularly if they provide critical or essential services:
    - Identify and assess how much of the facility's load is critical (e.g., "critical load"), including the necessary duration of the backup power supply. Determining what loads are critical and how long they should be powered for is essential for a facility's operations and what the role of the facility will have in an emergency situation.[31]
    - Depending on the size of the critical load and budget, different backup power supply options could range from backup generators (e.g., diesel, natural gas) to hybrid systems (e.g., solar with battery storage and an appropriately sized generator). Each option has different trade-offs that should be considered in terms of cost, feasibility, and environmental impacts. For shorter duration needs and/or smaller critical loads, buildings with existing solar systems should consider adding storage to provide a resiliency benefit. In some cases, co-generation systems may be most appropriate, especially if there is a significant heating and/or cooling load in addition to electricity demand.[32]
    - Depending on the backup option, assess the need to invest in internal electricity rewiring and building energy management systems. Options include installing switches; reconfiguring distribution infrastructure to isolate critical loads from non-critical loads; installing equipment to make it possible to island system from the broader grid during larger disruption; providing software and hardware to manage the deployment of hybrid systems; setting up external hookups for temporary generators and boilers.[33]

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[28] Sector- and facility-specific impacts vary greatly. For examples of sector-specific impacts and design responses, see *Flooded Bus Barns and Buckled Rails* (FTA 2011) and *Ready to Respond: Strategies for Multifamily Building Resilience* (Enterprise Green Communities 2015).
[29] McGregor et al. (2013) *Two Degrees: The Built Environment and Our Changing Climate*. Routledge Press.
[30] High temperatures also increase energy demand, which can increase fossil fuel based greenhouse gas emissions.
[31] The key roles of the facility that need to be identified are operational hours, number of occupants and electrical loads needed for the desired operations. Electrical equipment and appliances for the desired operations may include - but are not limited to - safety lighting, life-supporting systems, fire protection systems, telecommunications equipment, mechanical systems to mitigate extreme temperatures and computing equipment. Every facility is unique. Operational characteristics and load profiles need to be established prior to sizing the equipment required to keep the facility in operational mode.
[32] To learn more, see the *Building Resiliency Task Force* report from Urban Green Council (2013).
[33] Ibid.

- *Failure in facility ventilation, electrical, and air conditioning systems:* some systems designed to meet the requirements of existing standards may overheat and fail during future extreme events. Some design interventions include:[34]
    - Selecting systems with higher heat tolerance.
    - Adding Energy Recovery Ventilation systems.
    - Providing additional or redundant ventilation systems, either mechanical or natural, to cool electrical equipment.
    - Optimizing building layout by: segregating temperature-sensitive electronics and computer control system from other systems; placing heat-generating equipment like transformers and switchgear outdoors, where permitted; and splitting the facility cooling loads among different HVAC systems in the facility for redundancy and improved zone control.
- *Passive solar cooling and ventilation:* numerous design features provide passive solar cooling for buildings to help maintain lower internal ambient temperatures with less air conditioning. These features also help keep facilities habitable during extended electrical grid failures when generators fail, or must be reserved for critical functions. Some design features include:[35]
    - Appropriate east-west orientation.
    - Passive ventilation design.
    - Vertically stacked double skin facades.
    - Exterior window shades (retractable to not lose beneficial solar heat gain in winter).
    - Light-colored exteriors.
    - Shaded arcades.
    - Thermally massive materials.
    - High performance glazing.
    - Operable windows.

[34] *Flooded Bus Barns and Buckled Rails.* FTA Office of Budget and Policy, 2011.
[35] These and other examples are found in McGregor et al. (2013) *Two Degrees: The Built Environment and Our Changing Climate.* Routledge Press. Also see, *Flooded Bus Barns and Buckled Rails.* FTA Office of Budget and Policy, 2011.

B. Increasing Precipitation

The intensity and frequency of precipitation events are projected to increase with climate change, creating new challenges for stormwater management and impacts to the built environment, such as:

- The potential for stormwater management systems to be overwhelmed with greater frequency;[36]
- More frequent and severe flooding of facilities in areas across the city; and
- Greater variability in rainfall events annually, including the chance of drought.

The goal for this section is to guide on-site stormwater management approaches, particularly increased infiltration and on-site storage volume. Designers should develop and consider design interventions that decrease site contribution to sewer in-flows to a level beyond existing requirements in NYC Building Code and other relevant standards. Increasing on-site infiltration and stormwater retention can reduce flooding overall at sites and in surrounding areas. Given its complexity, the Department of Environmental Protection (DEP) is also evaluating climate impacts to the sewer system on a drainage-wide level.

Background

NYC's drainage systems are designed to handle approximately the current 3-year intensity-duration-frequency (IDF) event in most areas of the city where sewers were built prior to 1970. In locations with sewers built after 1970, they were built to handle the 5-year event. NYC's drainage network can experience flooding above those thresholds during widespread precipitation events or by localized, intense storms (sometimes called "cloudbursts"), causing flooding and backups. Climate change projections indicate that urban flooding is expected to increase in frequency in NYC. This increasing probability is forecast for all types of precipitation events in NYC, although there is greater uncertainty around future short duration events.

The City has several programs and plans in place to augment its existing sewer system in addition to upsizing planned (but not-yet-constructed) sewers. These provide scalable, often above-ground approaches to manage regular precipitation and provide a buffer for extreme rain events (while simultaneously addressing other climate hazards, including reducing ambient temperatures and the Urban Heat Island effect). These practices do not manage stormwater volumes of the same magnitude as the sewer system, but they are sized to fit in the City's dense neighborhoods and collectively contribute to alleviating pressure on the sewer system:

- To manage cloudburst storm events, the City is piloting approaches to control stormwater on the surface. This approach creates networks of open spaces, such as parks and playgrounds, to improve detention and infiltration of excess stormwater.
- Green infrastructure, such as bioswales and rain gardens, are being installed throughout the City to capture and infiltrate stormwater, particularly in combined sewer areas.
- In areas with inadequate space or conditions for trees and other plantings, permeable surfaces and subsurface detention can also be viable alternatives.
- Bluebelt best management practices (BMPs) include engineered streams, ponds, and wetlands designed to convey stormwater volumes of similar magnitudes as the sewer system, and they often provide some retention capacity buffering the volume pulse of heavier storms that can overwhelm downstream parts of the system. Bluebelts require more space than green infrastructure, so they cannot be as broadly implemented throughout the City.

DEP is examining the impact of sea level rise on the sewer system and is working with ORR to identify areas of the City that may be increasingly vulnerable to flooding as a result of the combination of sea level rise and more intense storms. These efforts will integrate forward-looking climate data into the design of these facilities, and the compounding factors of heavier rain storms and sea level rise will likely require greater infiltration and on-site stormwater retention capacity. Agencies and consultants should work directly with DEP to develop strategies on a given site necessary to meet expected increases in rainfall intensities and frequencies.

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[36] NYC is already taking steps to address this problem, which will worsen with climate change. To learn more about how NYC is using green and gray infrastructure to manage stormwater, visit http://www.nyc.gov/html/dep/html/stormwater/index.shtml.

[37] NYC DEP. NYC Green Infrastructure Program.

1. Precipitation design adjustment for on-site stormwater systems

Based upon the design storm required for the City facility in design, follow the steps below and consider recommended design interventions as appropriate to your site and facility.

a. Identify the duration of the design event required.
The current 50-year intensity-duration-frequency (IDF) curve can be used as a proxy for the future 5-year storm (projected for the 2080s). Design on-site detention/retention systems to retain the volume associated with the current 50-year IDF curve (use Equation 1 below and see Figure 5 for the curve). Design the on-site system to release at the maximum rate as specified in 15 Rules of the City of NY Chapter 31.[38]

Equation 1. Equation for sizing on-site retention

$$i = (350/(t+38))$$

Where: i = intensity

t = time of concentration

b. Conduct sensitivity analysis.
Compare the retention/detention required for the current 5-year IDF versus the current 50-year IDF to determine the additional volume and costs associated with complying with these Guidelines. The goal is to maximize retention/detention capacity given site and cost constraints, as well as through an evaluation of the benefit of adding capacity to detain/retain water for larger storm events.[39] Use Section III for guidance on how to identify and assess benefits. Given the results of the benefit-cost analyses, review the added benefit of designing retention/detention using greater magnitude storms (e.g. 100-year) or, as needed, lower magnitude storms (e.g. 25-year).

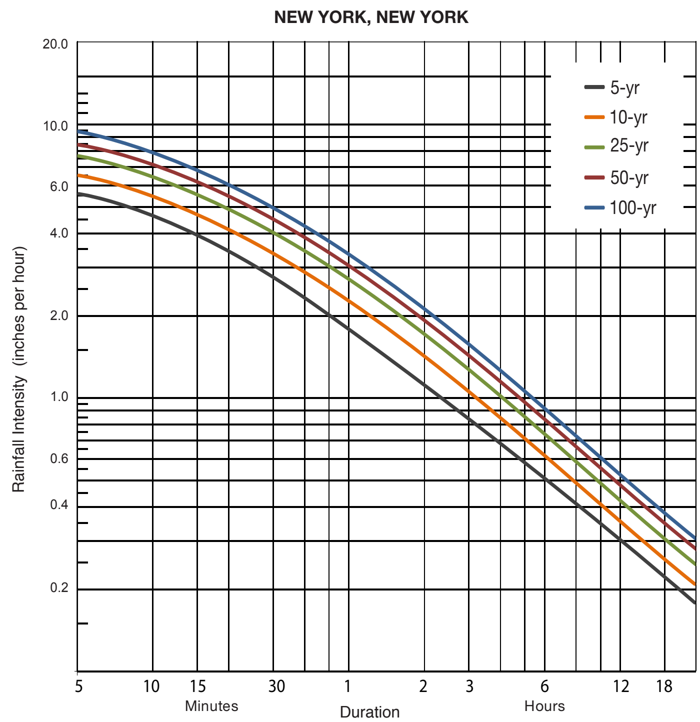

Figure 5 - Current Intensity-Duration-Frequency Precipitation Curve for NYC, adapted from U.S. Department of Commerce Weather Bureau Technical Paper 25.

[38] Refer to existing codes and standards as well when determining the existing required storm, as NYC requires different sizes of design storms for infrastructure and buildings. For example, NYC Plumbing Code Chapter 11, and Title 15 of the Rules of the City of New York Chapter 31.

[39] NYC DEP Standards for Stormwater Release Rates, available at http://www.nyc.gov/html/dep/html/environmental_reviews/stormwater_release_rates.shtml

c. Identify design interventions for managing increased precipitation.[40]
There are different ways to manage stormwater better and avoid urban flooding after intense rain. Choose the right combination of interventions after considering the project type, site location, operational requirements, cost, benefits, and useful life of the intervention. Some examples of design interventions are:

- Minimize increases in impervious surface;
- Utilize strategies that infiltrate, evaporate, or reuse rainwater to achieve stormwater volume reductions. Then choose low impact development strategies that detain (delay drainage) to manage the rate of the stormwater flow into the City's drainage system;
- Install stormwater infiltration, detention, and storage (e.g. bioswales,[41] green roofs, blue roofs, and other blue or green infrastructure; storage basins or tanks). See Figure 6 for an example of a bluebelt under construction;
- Protect areas below grade from flooding;
- Develop operational plan to keep catch basin grates clear;
- When implementing perimeter protections, ensure that interior water management is also accounted for; and
- Explore interventions to protect underground utility and telecommunications infrastructure from water damage.

d. Use appropriate DEP guidelines to perform the above tasks using the higher design storm.
The three currently prescribed DEP guidelines are as follows:

- Guidelines for the Design and Construction of Stormwater Management Systems, July 2012.[42]
- Criteria for Detention Facility Design, November 2012.[43]
- DEP Site Connection Proposal Application and Guidelines.[44]

***Note on stormwater standards**: As DEP updates stormwater standards and develops specific tools to evaluate impacts of increased precipitation and drainage strategies for on-site stormwater management, these changes will be reflected in future versions of these Guidelines. However, until then it is recommended that the designer should develop and consider design interventions that would increase the on-site storage and infiltration beyond the existing requirements. Also, a methodology is under development that will establish a consistent process for addressing legal grade, which will have further implications for how extreme precipitation is managed.*

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[40] Also see: DEP *Guide to Rain Event Preparedness* at: http://www.nyc.gov/html/dep/pdf/brochures/flood-preparedness-flyer.pdf and R*eady to Respond: Strategies for Multifamily Building Resilience* at: http://www.enterprisecommunity.org/resources/ready-respond-strategies-multifamily-building-resilience-13356
[41] When siting bioswales, consider groundwater levels and soil permeability and ensure that the site is not contaminated from past or present land uses. A high water table may prohibit some applications.
[42] Available at http://www.nyc.gov/html/dep/html/stormwater/stormwater_management_construction.shtml
[43] Available at http://www.nyc.gov/html/dep/pdf/water_sewer/30_criteria_for_detention_facility_design_06062012.pdf
[44] Available at http://www.nyc.gov/html/dep/pdf/water_sewer/24.pdf

2. Incorporating climate change projections into DEP drainage planning

The first line of defense for managing intense precipitation events requires changes to site retention and surface management, as described above. For drainage and wastewater infrastructure planning in a changing climate, the sewer network and wastewater infrastructure should be qualitatively evaluated, from the upstream pipes to the regulator chambers, pump stations, interceptors, and ultimately to the downstream outfall, to determine the feasibility of incorporating climate change projections into the system design. For DEP storm sewer projects in FY 2021 or later in separately sewered drainage areas where the design is in the early stages and there is free discharge, the agency is evaluating the feasibility of revising the design to incorporate climate projections into the design. If the project (including the prescribed changes) passes the benefit-cost analysis, then DEP will consider incorporating climate change projections into the sizing. However, changes in one part of the system must be carefully evaluated. For example, any upsizing of the regulator chamber or the high point of the system can negatively impact the design and operation of the wastewater infrastructure and residences/businesses on the system and can lead to a diminished level of service.

DEP is in the process of developing a hydrologic and hydraulic (H&H) model to estimate runoff flow for future climate scenarios and is evaluating rainfall hyetographs for the existing and future rainfall scenarios to be included in the drainage planning process. In addition, DEP currently coordinates with ORR for drainage planning as a part of coastal resiliency projects.

Figure 6 - A DEP bluebelt under construction in Staten Island designed to alleviate chronic flooding. Photo courtesy of JRCRUZ Corp.

C. Sea Level Rise

All City capital projects need to be evaluated for coastal flood risk, even if they are not in the current 100-year floodplain

Use this section to assess if a capital project will experience tidal inundation during its useful life and determine how to incorporate sea level rise into flood protection levels of capital projects located in the current or future floodplains. For projects in the current and future 1% annual chance floodplains, sea level rise-adjusted design flood elevations (DFE) are chosen based on the useful life and criticality.

Background

The Guidelines augment existing requirements to ensure City facilities built today incorporate projected sea level rise that will take place over their useful lives and maintain compliance with NYC Building Code. Current flood protection heights are determined by using the base flood elevation (BFE) established by the FEMA Preliminary Flood Insurance Rate Map (PFIRM) 2015 and the standard of protection for buildings in the floodplain in Appendix G of the NYC Building Code.[46,47] However, NYC has already experienced the devastation of coastal storms, most recently during Hurricane Sandy. Sea level rise is projected to increase the depth, extent, and frequency of flooding from storm surge.[45] Sea level rise will also regularly inundate some low-lying areas as higher high tides overtop coastal edges, impacting sites currently out of the tidal inundation zone.

For facilities with a very long useful life, it is not always cost effective or operationally feasible to design that facility to be resilient to hazards faced at the end of its useful life. In these cases, the most resilient design will be one that provides extra protection against hazards in the initial decades while also leaving open design alternatives for updating resiliency measures as new data is provided or new risk assessments are completed. This flexible adaptation pathways approach builds in options to protect assets later in life, as demonstrated in an example shown in Figure 2 (in Section I.D).

Other considerations include:

- These Guidelines apply to all City capital projects except coastal flood protection systems, which are designed to different standards than those provided here for buildings and other physical infrastructure. Many of NYC's coastal flood protection systems are currently being developed to comply with FEMA accreditation for flood levee systems.[48] The City is developing future guidance for designing coastal protection projects;
- For information on the differences between FEMA FIRM, PFIRM, and the City's forward-looking flood maps, see Appendix 3;
- Coincident stressors from sea level rise should also be considered. For example, bridge scour and coastal erosion may increase as sea levels rise. Similarly, flooding during heavy rainfall events can be worsened due to higher tailwater conditions associated with high sea levels. Be aware of how different risks may interact, and how different interventions can be deployed to address multiple hazards or provide other co-benefits;
- Note that projects that require discretionary approval are required to incorporate sea level rise projections as part of the NYC Waterfront Revitalization Program;[49] and
- A process is under development that will establish a consistent process for addressing challenges around legal grade in a changing climate, which will have further implications for how sea level rise and precipitation are managed.

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45 *New York City Panel on Climate Change Report Chapter 2: Sea Level Rise and Coastal Stor*ms (2015).
46 However, NYC Building code G102.2.2 requires that designers review both the PFIRM and the effective FIRM and use the more restrictive of the two.
47 For information on the differences between FEMA FIRM, PFIRM and the City's forward-looking flood maps, see Appendix 3.
48 For more information, please visit: http://www.fema.gov/fema-levee-resources-library
49 For more information, visit http://www.nyc.gov/wrp

1. Assess tidal inundation due to sea level rise

Tidal flooding already impacts parts of NYC and is projected to worsen as sea levels rise, inundating low-lying coastal sites during high tides. When selecting a site location or establishing a scope of substantial improvements, consider alternative sites outside of zones threatened with regular inundation. Some facilities, such as wastewater treatment plants and harbor facilities, need to be near the coast for operational purposes.

a. Determine tidal inundation risk from sea level rise.
Use the Flood Hazard Mapper (http://www.nyc.gov/floodhazardmapper) to assess if the facility's site will be inundated from high tide with sea level rise within the project's useful life (as determined in Table 1 in Section I.B above).[50] For example, when designing most types of buildings, choose the 2080s High Tide map. Determine risk only from high tide and sea level rise, separate from flood events. Follow the instructions in Figure 7 to review high tide inundation at the end of an asset's useful life.

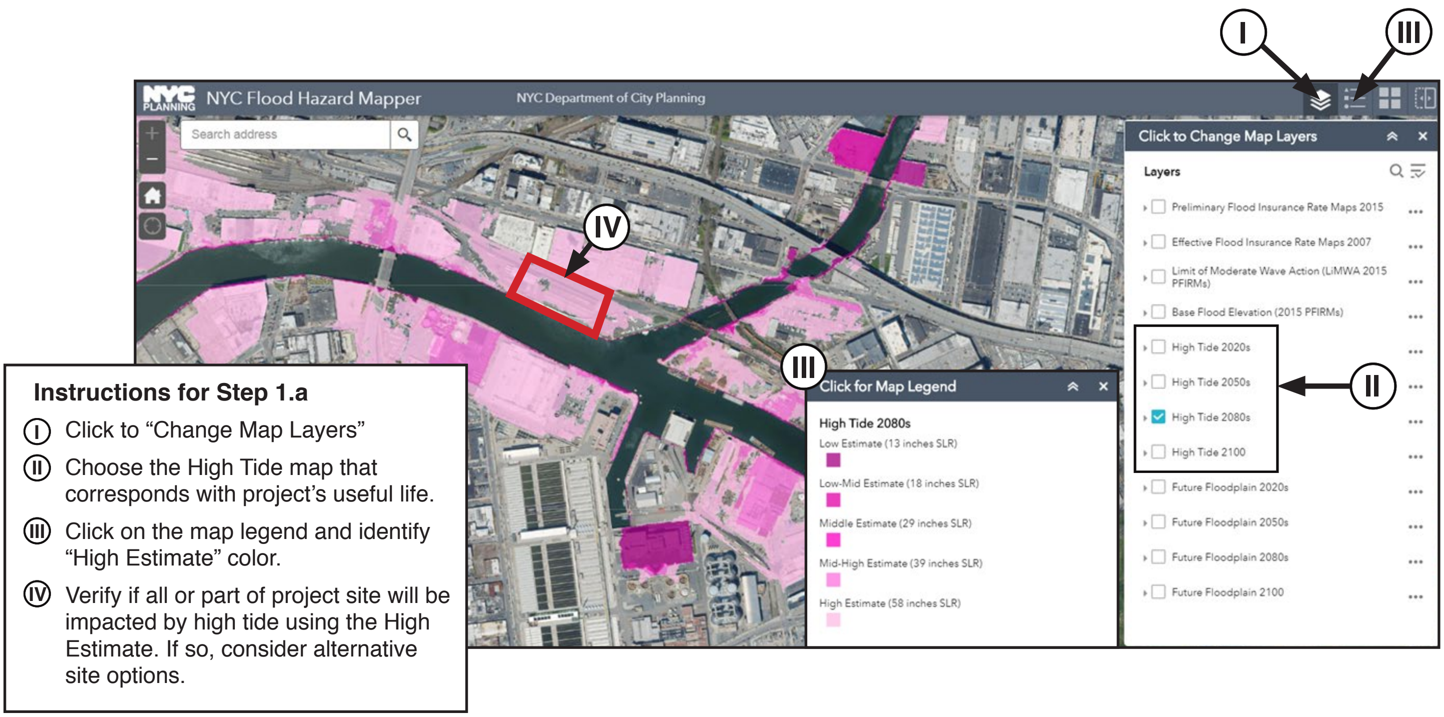

Figure 7 - Flood Hazard Mapper high tide plus sea level rise at http://www.nyc.gov/floodhazardmapper. Project site illustrative only.

b. Address tidal inundation risk.
If the Flood Hazard Mapper shows that the facility is inundated by high tides within its useful life or if primary access roads are at risk of inundation, consider alternative site options.

- OR -

If the site is not expected to be regularly inundated by tides, proceed to *2. Address risks in the current floodplain*.

Note on calculating tidal inundation depths with sea level rise: *if a project team is interested in understanding the depth of tidal inundation given climate change projections, follow these steps. First, determine the Mean Higher High Water (MHHW) elevation in feet-NAVD 88 datum nearest to the site.[51] If the MHHW data is unavailable from a site specific survey, refer to http://www.nyc.gov/wrp for a list of MHHW elevations (NAVD88) at tide stations across the city.[52] Second, add the high estimate (90th percentile) of expected sea level rise (see Table 7 in Appendix 2) for the year corresponding to the facility's useful life to the MHHW to determine the projected depth of tidal inundation with sea level rise.*

50 The Flood Hazard Mapper relies on publicly available data to present these map resources. Users should also refer to FEMA and the NPCC for official information.
51 North American Vertical Datum of 1988 (NAVD 88) is the vertical control datum of orthometric height established for vertical control surveying in the U.S. based upon the General Adjustment of the North American Datum of 1988. https://www.ngs.noaa.gov/datums/vertical/
52 SLR elevations at http://www.nyc.gov/wrp are adjusted to account for sea level rise since the last tidal epoch. If no other resource is available to determine MHHW, use the NOAA Online Vertical Datum Transformation tool to calculate the MHHW in feet-NAVD 88.

2. Address risks in the current floodplain[53]

A facility located in the current 1% annual chance floodplain (PFIRM 2015) will face increasing risk and/or depth of flooding during its useful life due to sea level rise.[54]

a. Determine the flood inundation risk from current coastal storms
Use the Flood Hazard Mapper (http://www.nyc.gov/floodhazardmapper) to assess if the facility's site is in the current floodplain and, if so, what the BFE is. Follow the instructions in Figure 8.

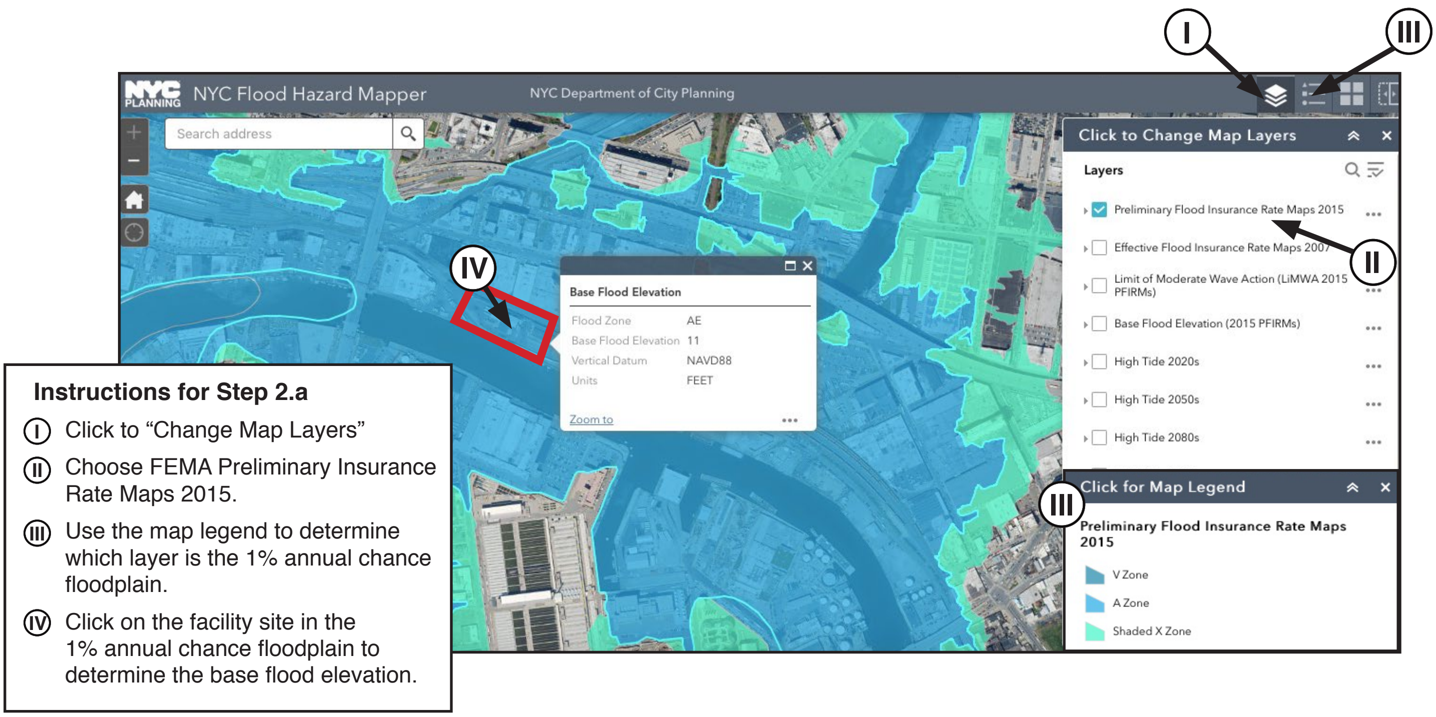

Figure 8 - Flood Hazard Mapper with FEMA PFIRM (2015) at www.nyc.gov/floodhazardmapper. Project site illustrative only.

b. If the facility is <u>not in the current</u> 1% annual chance floodplain (PFIRM 2015), proceed to *3. Address risks in the future floodplain*.

- OR -

If the facility is <u>in the current</u> 1% annual chance floodplain (PFIRM 2015), note the BFE and proceed to c) below. If a facility has multiple BFEs, or if the site is partially in the 1% annual chance floodplain, use the highest BFE as the current BFE for the entire site.

c. Establish a sea level rise-adjusted DFE.
Use the current BFE at your site and the facility's useful life to determine the DFE using Table 3 (on the next page) as a basis of design. Then proceed to *4. Identify appropriate design interventions*.

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[53] This process for adjusting the design flood elevation to account for sea level rise satisfies the criteria of the "climate-informed science approach" described at the state and federal level.

[54] FEMA updates its flood maps periodically. As of April 2018, the most recent maps are the Preliminary Flood Insurance Rate Maps (PFIRM) available at DCP's Flood Hazard Mapper (http://www.nyc.gov/floodhazardmapper). Also note that NYC Building Code requires developers to use the PFIRM (2015) or the FIRM (2007), whichever is more restrictive. For more information on these requirements, please refer to Appendix G of the NYC Building Code. Please note that the DCP maps are not official and all site locations should be confirmed with the official FEMA PFIRM. NYC will provide information on the latest flood maps as they are updated.

Table 3 - Determine the sea level rise-adjusted design flood elevation (DFE)[55]

End of Useful Life	Base Flood Elevation (BFE)[56] in NAVD 88	+ Freeboard[57]	+ Sea Level Rise Adjustment[58]	= Design Flood Elevation (DFE) in NAVD 88
Critical* Facilities				
2020s (through to 2039)	FEMA 1% (PFIRM)	24"	6"	= FEMA 1% + 30"
2050s (2040-2069)	FEMA 1% (PFIRM)	24"	16"	= FEMA 1% + 40"
2080s (2070-2099)	FEMA 1% (PFIRM)	24"	28"	= FEMA 1% + 52"
2100+	FEMA 1% (PFIRM)	24"	36"	= FEMA 1% + 60"
Non-critical Facilities				
2020s (through to 2039)	FEMA 1% (PFIRM)	12"	6"	= FEMA 1% + 18"
2050s (2040-2069)	FEMA 1% (PFIRM)	12"	16"	= FEMA 1% + 28"
2080s (2070-2099)	FEMA 1% (PFIRM)	12"	28"	= FEMA 1% + 40"
2100+	FEMA 1% (PFIRM)	12"	36"	= FEMA 1% + 48"

Additional analysis should be conducted to incorporate wave action and wave run-up in DFE calculations especially in areas that are located within the FEMA's 1% annual chance Limit of Moderate Wave Action (LiMWA) zone. Wave run-up is the maximum vertical extent of wave uprush above surge.

***Facilities defined as critical**

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.[59] If a facility is not listed here, it is considered non-critical for the purposes of these Guidelines.

- Hospitals and health care facilities;
- Fire, rescue, ambulance, and police stations, as well as 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);[60]
- 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;[61]
- 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;
- Water supply infrastructure;
- Combined-sewer overflow (CSO) retention tanks;
- Fueling stations;
- Waste transfer stations; and
- Facilities where residents have limited mobility or ability, including care facilities and nursing homes.

55 If an industry design standard does not include freeboard in its flood protection standards for particular infrastructure assets, then only consider the sea level rise adjustment when determining flood protection levels.

56 Note that NYC Building Code requires developers to use the PFIRM (2015) or the FIRM (2007), whichever is more restrictive. Where the NYC Building Code differs from the Guidelines, use whichever requires the higher DFE. Refer to the latest version of Appendix G of the NYC Building Code.

57 These freeboard values reflect NYC Building Code Appendix G Table 2-1, which establishes the minimum elevation of the top of lowest floor. Appendix G requires other freeboard values for other parts of structures and in different parts of the floodplain. Refer to Appendix G for the appropriate freeboard and use that value in Table 3 above.

58 The sea level rise figures provided are for the middle of the 25th-75th percentile range projections from the NPCC. These values do not necessarily indicate the average of all models.

59 The structural occupancy categories outlined in Appendix G of the NYC Building Code are the same as in ASCE 7 used for structural design. For critical buildings, structural design should comply with ASCE 7 and 24 for design class IV.

60 This threshold represents the median volume of main food distributors in NYC according to statistics collected as part of the Five Borough Food Flow study in 2016, available at: https://www.nycedc.com/system/files/files/resource/2016_food_supply-resiliency_study_results.pdf .

61 The threshold quantity for hazardous materials is established by Chapter 7 of Title 24 of the NYC Administrative Code.

EXAMPLE: How to determine a sea level rise-adjusted DFE

This example illustrates how to calculate a sea level rise-adjusted DFE based on the useful life of a hypothetical critical services building and its primary components.

1. Organize the site by various primary components and their years of construction. Using Table 1 in Section I.B, determine the climate change projections that corresponds to useful life. In this example, the building structure and the external emergency generator are the most at-risk components from combined sea level rise and coastal storm surge.

2. Using the Flood Hazard Mapper, identify the site footprint area on the effective current floodplain map and the BFE. In this example, it was determined that the critical facility site has a 1% annual chance of flooding with a BFE of 13' NAVD.

3. Evaluate the criticality of each primary component of the facility based on the Guidelines' definition for critical infrastructure. This building and its emergency generator are both critical.

4. Table 4 demonstrates how to calculate freeboard requirements and the sea level rise adjustment for each component and calculate the sea level rise-adjusted DFE for each that corresponds to their useful lives.

5. Use the Guidelines' adjusted DFE for each component in the design of the facility.

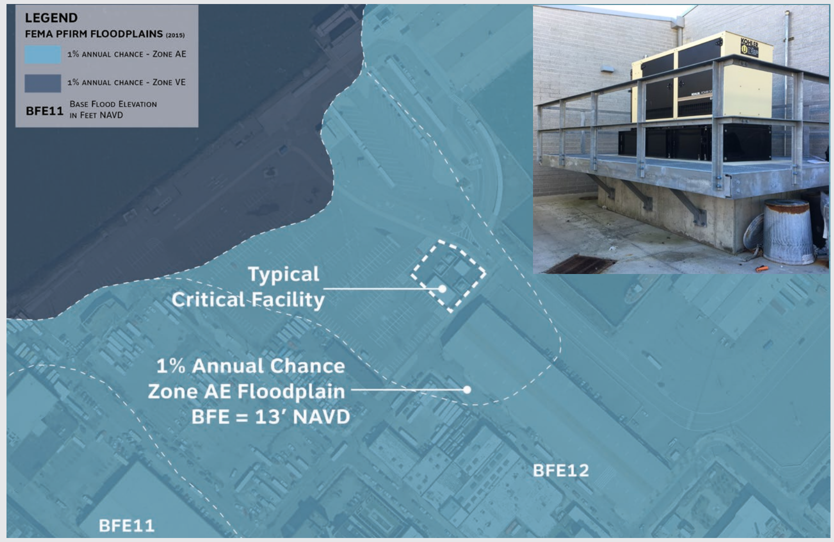

Figure 9 - Example of how to locate a facility within the current floodplain and determine the BFE. Inset: outdoor elevated emergency generator at the facility elevated to a sea level rise-adjusted DFE specific to its useful life.

Table 4 – Example of a sea level rise-adjusted DFE for a new critical facility

Construction year	Components	Useful Life	Future Year Scenario [Useful Life + Const. Year]	BFE in NAVD 88 (feet)	Freeboard + Sea Level Rise Adjustment (feet)	Adjusted DFE in NAVD 88 (feet)
2010	Building Structure	70 years	2080s	13.0'	2' + 2'4"	17'4"
2010	Outdoor Emergency Generator	25 years	2020s	13.0'	2' + 6"	15'6"

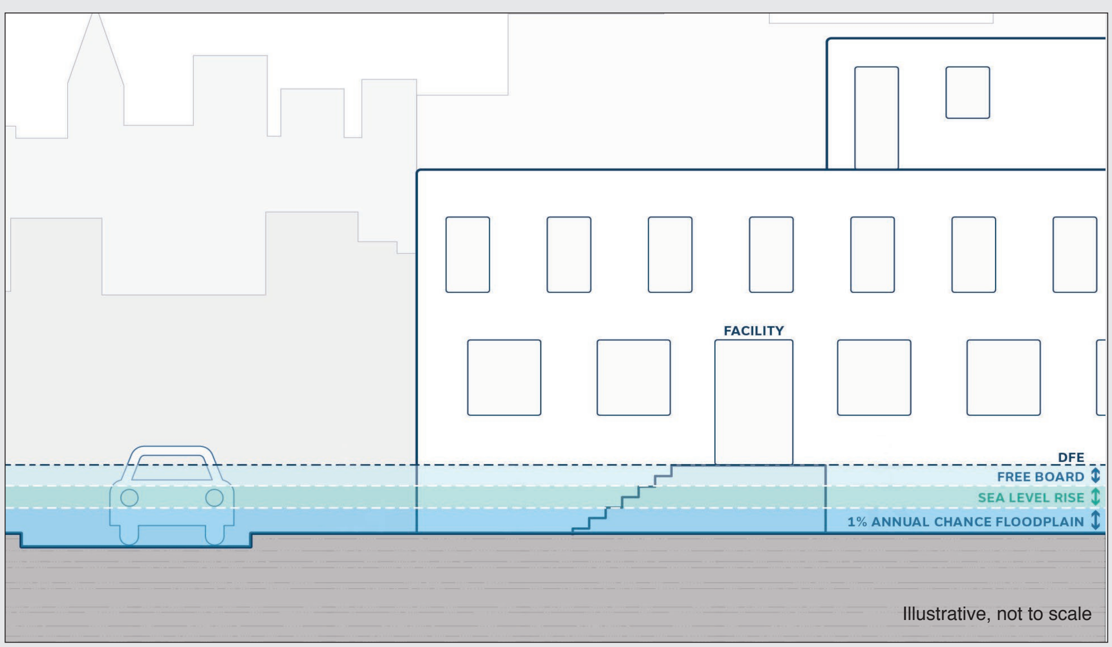

Figure 10 - This schematic shows how to determine the DFE of a facility within the current 1% floodplain.

3. Address risks in the future floodplain

If the facility is not in the current 1% annual chance floodplain (PFIRM 2015), it may still be at risk in the future from flooding as sea level rise increases the horizontal extent of the floodplain. Follow the steps below to determine if your facility is located in the future floodplain and, if so, what sea level rise-adjusted DFE to use.

a. Determine if the facility site will be in the future floodplain.
Use the Flood Hazard Mapper (http://www.nyc.gov/floodhazardmapper) to assess if all or part of the facility's site will be located in the future 1% floodplain within the project's useful life (as determined in Table 1 in Section I.B). Follow the instructions in Figure 11 below.

Figure 11 - Flood Hazard Mapper with future floodplain map (the projected 1% annual chance floodplain adjusted for sea level rise at http://www.nyc.gov/floodhazardmapper. Project site illustrative only.

b. If the site is not in the future floodplain, no flood protection is required for this facility.

- OR -

If the site is in the future floodplain, identify the nearest adjacent BFE at the project site in the current 1% annual chance floodplain (PFIRM 2015) using the Flood Hazard Mapper.[62]

c. Use Table 3 to determine the sea level rise-adjusted DFE.
Add freeboard and the sea level rise-adjustment to the nearest adjacent BFE on the current 1% annual chance floodplain (PFIRM 2015) to determine the sea level rise-adjusted DFE. See Figures 12 and 13 for an illustration of how to calculate the BFE and DFE. Then proceed to *4. Identify appropriate design interventions*.

[62] Maps of future floodplains show the impacts of sea level rise alone, and do not consider how changes in storms' climatology might also affect wave action and the full extent of the floodplain.

EXAMPLE: How to determine a BFE and an adjusted DFE for a facility in the future floodplain

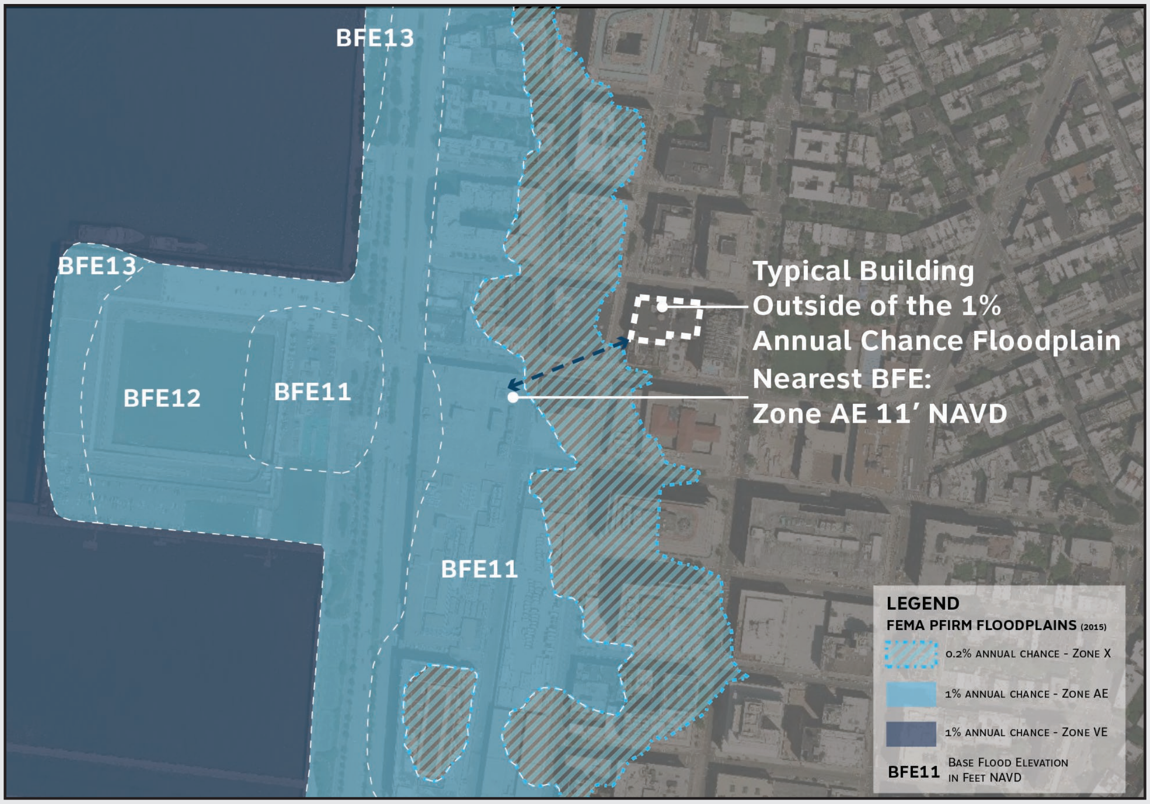

Figure 12 - This schematic map shows how to locate the nearest adjacent 1% floodplain elevation from a given project site.

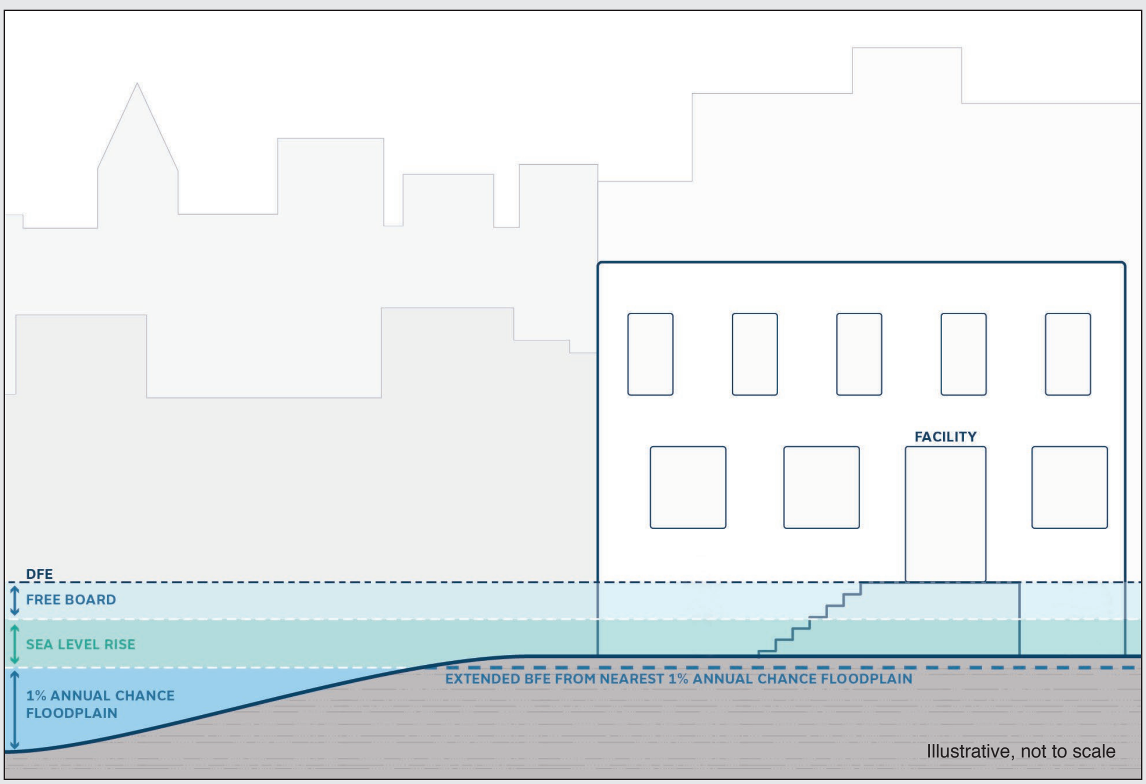

Figure 13 -This schematic shows how to use a base flood elevation in the current floodplain, with sea level rise and freeboard, added, to determine a design flood elevation for a facility located in the future floodplain.

4. *Identify appropriate design interventions*

For all projects at risk of current or future flooding, select design interventions that meet the project's sea level rise-adjusted DFE. Consider project-specific factors, including the site location, criticality, operational requirements, existing continuity planning, and cost.[63] A Design Strategies Checklist in Appendix 4 is available for use as a resource to track possible design approaches. Some examples of design alternatives are:

- For site relocations, conduct alternative site analysis where feasible.
- Permanent barriers at a site (e.g., flood walls).
- Deployable flood barriers (e.g., stop logs, flood doors/gates, inflatable barriers).
- Natural systems-based approaches (e.g. living shorelines, restored wetlands).[64]
- Prioritized protection of electrical, mechanical, and other critical or costly-to-replace equipment above the DFE (e.g., motors and controller, boilers and furnaces, fuel storage tanks, duct work, alarm systems, suppression equipment, electrical panels, electrical distribution, switching areas, gas and electric meters, telecommunications equipment, chemical feed equipment, HVAC units, and emergency generators).[65]
- For dry floodproofing, design a facility to prevent water from entering.
- For wet floodproofing, design a facility to permit floodwaters to flow in and out of the structure without causing significant damage (e.g., elevate or protect critical equipment, use water-resistant building materials below the design flood elevation, include flood vents and pumps).
- Design redundant telecommunications conduit entrances for multiple carrier entry. Telecom conduit should run to diverse manholes when possible.
- Install backup power for telecom equipment with resilient design considerations (e.g., installation above the DFE).
- Install outdoor-rated disconnect switch for telecommunications equipment on the roof.
- Explore interventions to protect underground utilities and other telecommunications facilities from water damage.
- Install backflow preventers, backwater valves, and sump pumps for all buildings and infrastructure in the floodplain, as well as behind flood barriers.
- Shoreline improvements that reduce the height of waves or attenuate waves where feasible.

Operational requirements and continuity plans can inform the selection of appropriate design interventions, particularly in terms of how quickly a site needs to be up and running after a flood event. Some examples of how functional uses can pair with interventions include:

- A facility that needs to be operating during or immediately after a flood event may need to be dry floodproofed using permanent barriers or designed for passive survivability (such as a police or fire station).
- A facility that needs to recover quickly after an event could elevate prioritized equipment and have deployable barriers.
- A site that can recover over a longer duration of time (such as parks or plazas) could be designed to be temporarily inundated during an event. The use of resilient materials and strategies can reduce costly damage caused by temporary inundation.

Different design interventions should be chosen based on the specific operational requirements of the project; however these must meet the ASCE 24 design requirements.

[63] Additional resources for identifying adaptive strategies: *Urban Waterfront Adaptive Strategies* (NYC Department of City Planning) available at https://www1.nyc.gov/assets/planning/download/pdf/plans-studies/sustainable-communities/climate-resilience/urban_waterfront.pdf and *Floodproofing Non-Residential Buildings* (FEMA) at: https://www.fema.gov/media-library/assets/documents/34270 and *Ready to Respond: Strategies for Multifamily Building Resilience* (Enterprise Green Community) at: http://www.enterprisecommunity.org/resources/ready-respond-strategies-multifamily-building-resilience-13356

[64] While natural systems-based approaches ameliorate flooding, their use for storm surge or wave mitigation would need to be quantified before contributing towards the design flood elevation.

[65] For more information, see FEMA's *Floodproofing Non-Residential Buildings* at: https://www.fema.gov/media-library/assets/documents/34270

III. Toolkit

The following section provides tools and resources to be used during the planning and design process to develop scientifically-supported, cost-effective resilient design strategies. Below is an overview of the process showing how exposure to climate risk can be identified, benefits and costs can be determined, and, for larger projects, the steps for performing an in-depth risk assessment. Examples of tools to support these steps can be found on the following pages.

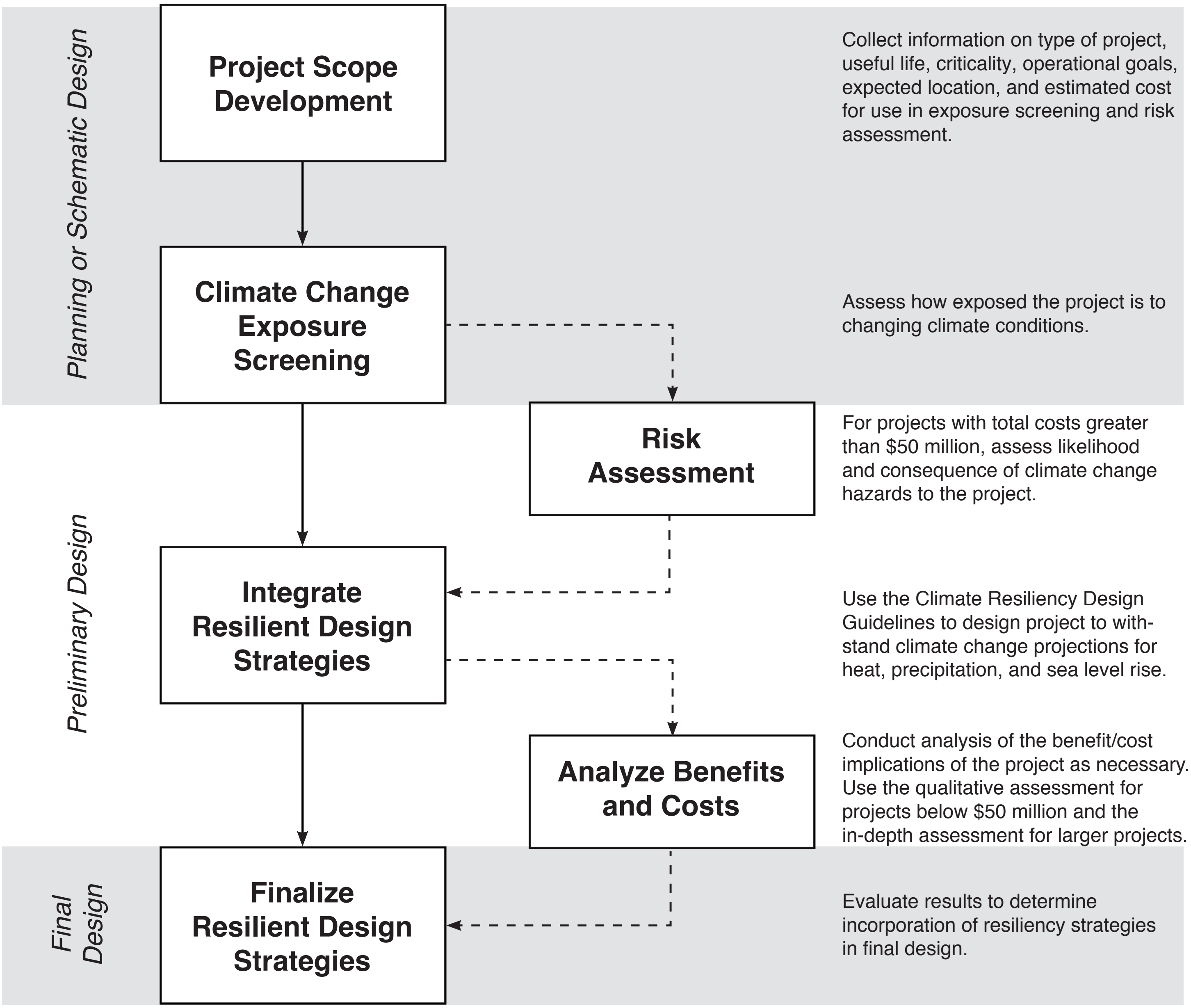

Figure 14 - Example of how resilient design fits into a capital project development process

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B. Exposure Screening Tool

Use the Exposure Screening Tool to identify and assess climate change-related hazards and risks. A capital project's exposure can be determined based on preliminary project information available at the earliest stages of project planning and/or design. Results from the screening tool can inform if to include the Guidelines in the project scope. This screening tool can be completed in under an hour by a project manager, before finalizing the scope of work and/or procuring a consultant.

Exposure Screening Tool

Hazard	Risk Screening Question	Directions	Answers and Score	Total Score and Next Steps
Heat	Does the facility include new construction of, or substantial improvements to, the landscape, hardscape, roof, HVAC, building envelope, ventilation system, or façade?	All parts of NYC are exposed to extreme heat. New construction projects or substantial improvements that include changes to the landscape, hardscape, roof, HVAC, building envelope, ventilation system, or façade could affect the material performance of a project, thermal comfort of occupants, and/or increase ambient temperatures. If the project includes any of those components, answer 'yes.'	Yes=1 or No=0	Total Score 2-5: Exposure Rating Low Total Score 6-8: Exposure Rating Medium Total Score 9-10: Exposure Rating High *If project budget is less than $50 million:* ...and scores "Medium" or "High" **consult Section II.A in the Guidelines.** ...and scores "Low" using the Guidelines is not required. *If project budget is more than $50 million:* ...and scores "Medium" or "High" **complete a detailed Risk Assessment (see Section III) and then consult Section II.A in the Guidelines.** ...and scores "Low" using the Guidelines is not required.
Heat	Is the facility in community district with high heat vulnerability?	Identify the community district your facility is located in. Locate that community district on the Heat Vulnerability Index map located in Section II.A of the Guidelines and note the area's vulnerability. Select the corresponding answer.	*Heat Vulnerability Score* Low=1 Low-moderate=2 Moderate=3 Moderate-high=4 High=5	
Heat	How many annual heat waves are projected to occur during the facility's useful life?	See Section II.A of the Guidelines and note the annual heat wave projection according to the useful life of the facility. Select the corresponding answer.	*# of heat waves* 2 days = 1 4 days = 2 7 days = 3 9 days = 4	
Precipitation	Does the facility require a new DEP site connection proposal, or a modification to the existing site connection plan?	The intensity and frequency of precipitation events are projected to increase across all parts of NYC, creating new challenges for stormwater management and impacts to the built environment. New construction projects provide opportunities to accommodate increased precipitation flow volumes, and typically require submitting a new site drainage connection proposal to DEP for review and approval. If a project is a substantial improvement, the scope of work of the substantial improvement would dictate if the previously approved DEP site connection plan will require modifications. If a new site connection proposal or modifications are required, answer 'yes.'	Yes=1 or No=0	Total Score 1: Exposure Rating Low Total Score 2: Exposure Rating Medium Total Score 3: Exposure Rating High *If project budget is less than $50 million:* ...and scores "Medium" or "High" **consult Section II.B in the Guidelines.** ...and scores "Low" using the Guidelines is not required. *If project budget is more than $50 million:* ...and scores "Medium" or "High" **complete a detailed Risk Assessment (see Section III) and then consult Section II.B in the Guidelines.** ...and scores "Low" using the Guidelines is not required.
Precipitation	Does the site have a history of flooding during precipitation events?	Consult institutional knowledge (for example, if this site flooded during Hurricane Irene) and 311 service requests for flooding at or near this site (see hyperlink below) and select "yes" if there is a history of flooding at the site. https://data.cityofnewyork.us/Social-Services/Street-Flooding/wymi-u6i8	Yes=1 or No=0	
Precipitation	Will there be a net increase in impervious area on the site as a result of the project?	Refer to preliminary site plans (if they are part of the project scope) or consult with Capital Project Initiation team. Choose 'yes' if a net increase in impervious area is anticipated.	Yes=1 or No=0	

Exposure Screening Tool

	Risk Screening Question	Directions	Answers and Score
Sea level rise	*Current Flood Risk* Is the facility in the current 1% annual chance floodplain (100-year)?	Visit NYC Flood Hazard Mapper.* Click on the Map Legend and select the 'Preliminary Flood Insurance Rate Maps 2015'. Search for or navigate to the site to see if it is located within the current effective floodplain. If the site is shown to be all or partly in the current floodplain, answer 'yes.' http://www.nyc.gov/floodhazardmapper	Yes=1 or No=0
	Future Flood Risk Is the facility in the future 1% annual chance floodplain (100-year) at any point during its useful life?	Visit NYC Flood Hazard Mapper.* Click on the Map Legend and select the 'Future Floodplain' that corresponds to the project useful life. Search for or navigate to the property to see if it is located within the future floodplain. If the site is shown to be all or partly in the future floodplain, answer 'yes.' http://www.nyc.gov/floodhazardmapper	Yes=2 or No=0
	Current Tidal Inundation Does this site have a history of flooding from high tide events?	Potential sources to answer this question include institutional knowledge (for example, if this site floods during regular high tides) or history of 311 service requests (see hyperlink below). If the site is shown to have a history of tidal flooding, answer 'yes.' https://data.cityofnewyork.us/Social-Services/Street-Flooding/wymi-u6i8	Yes=1 or No=0
	Future Tidal Inundation Are there any critical access roads to the site that will be inundated by future high tides?	Visit the NYC Flood Hazard Mapper.* Click on the Map Legend and select the "High Tide" scenario that corresponds to the project useful life. Identify if any primary access roads are inundated from high tide plus sea level rise. If the site is shown to have roads at risk of tidal inundation, answer 'yes.' http://www.nyc.gov/floodhazardmapper	Yes=1 or No=0

Total Score and Next Steps

Total Score	Exposure Rating
0	Not Exposed
1	Low
2	Medium
>3	High

If project budget is less than $50 million:
...and scores "**Medium**" or "**High**" **consult Section II.C in the Guidelines.**
...and scores "**Low**" using the Guidelines is not required.

If project budget is more than $50 million:
...and scores "**Medium**" or "**High**" **complete a detailed Risk Assessment (see Section III) and then consult Section II.C in the Guidelines.**
...and scores "**Low**" using the Guidelines is not required.

**For more information on how to use the Flood Hazard Mapper, see Section II.C*

C. Risk Assessment Methodology

In the following methodology, a project's overall level of climate change risk is determined through evaluating the likelihood that a climate-related impact will occur over the project's lifetime and assessing the consequence of such an impact.

This methodology should be used for major projects with a total cost greater than $50 million and that scored medium or high using the Exposure Screening Tool. This will enable project managers to identify the climate change-related risks most relevant to their project and prioritize areas of concern. The methodology can be used iteratively to provide information about project-specific climate risks in the early stages of project development and throughout the design process.

This risk assessment should be completed during planning and/or preliminary design by the project manager or consultant. When conducting a risk assessment, please contact ORR at ResilientDesign@cityhall.nyc.gov.

Step 1: Identify Hazards
Determine the extent to which the project site may have been previously affected by climate-related extreme heat, heavy precipitation, or coastal flooding events, and note any risk mitigation actions taken in response. In order to evaluate potential climate risks, it can be beneficial to establish an understanding of historic climate-related impacts, consequences on the project or site, and risk mitigation strategies now in place. Though not all future risks have historic analogues, determining the extent to which the project site may have been previously affected by hazards can assist in the identification of a future risk profile. Potential sources for finding this information include institutional knowledge (for example, if the site flooded from precipitation during Hurricane Irene or storm surge during Hurricane Sandy), 311 service request data, social media, operations and maintenance manuals, or site managers.

Step 2: Define Impact Thresholds
Define the magnitude and type of impact for each relevant climate hazard that would need to occur to significantly hinder site operations, and the type of disruptions or damages one would expect. Before reviewing specific impacts to the project it is important to understand the types of conditions that can have a detrimental effect on the project. This can range from catastrophic events (e.g., hurricanes) to 'nuisance' events (daily flooding from high tide, heat amplification every afternoon in summer, etc.). Both types of events should be examined. These events or conditions will be used in Step 4 in the evaluation of various types of consequences and will allow the design team to coordinate with any appropriate agencies and reviews consistently.

Step 3: Evaluate Likelihood
Evaluate a project's physical hazard exposure and useful life to determine probability of climate-related impacts occurring over the project's lifetime and account for the way extreme heat, precipitation, and sea level rise manifest over the project useful life. Exposure is a factor of the project's physical location, taking into account the area's geographic susceptibility to extreme events or environmental change. Likelihood is the probability of hazardous climate-related impacts occurring over the project's lifetime, and increases with the length of a project's useful life. A likelihood rating is based on the project's physical hazard exposure and useful life, and will help agencies understand how the threat posed by each climate hazard changes over time. For example, a project with a useful life ending in 2100 is more likely to experience extreme events or conditions, such as a 1% annual chance storm, than a project that has a useful life ending in 2030, and would therefore receive a higher likelihood rating. Likelihood is rated on a tiered qualitative scale of nearly certain to rare.

Step 4: Estimate Consequences
Consequences come in many forms and are a product of the value and sensitivity of the exposed asset. Estimate the potential damage, disruption, or strain to project assets and components, as well as to dependent sectors and the surrounding community, that would result if a climate impact were to occur. Assess conse-

quence regardless of the likelihood of occurrence. For example, if the first floor of a building were inundated for several days due to a coastal storm, the consequence of this flooding would be the same irrespective of its likelihood. Consequence ratings rely on user's technical and institutional knowledge of the sensitivity of the project's internal and external systems to climate impacts, and of the potential severity of the hazard occurring.

Step 5: Summarize Risk

Assess a project's risk to all climate hazards using the likelihood and consequence rating scores generated in Steps 3 and 4. Summarize the results and identify notable trends. The results of Steps 3 and 4 can be summarized and compared using a risk matrix, like the example below.

Risk Rating Matrix					
	Likelihood Rating				
Consequence Rating	Rare	Possible	Probable	Expected	Nearly Certain
Severe	Low	Medium	High	High	High
Moderate	Low	Low	Medium	Medium	High
Minor	Low	Low	Low	Medium	Medium

Figure 15 - Example of a risk matrix

Step 6: Treat Risk

Use the Guidelines to identify appropriate design interventions for mitigating climate change risks rated medium and high, and apply resiliency strategies to the project design, operations, and management. If there are specific risks identified in this review process that are not addressed in the Guidelines, it is highly recommended to consult outside resources and identify resilient design strategies that could be implemented to lower the project's risk rating.

Step 7: Reassess Risk as Needed

After risk-mitigating treatments are identified, repeat Steps 3 and 5 to evaluate the risk reductions associated with the chosen resilient design alternatives.

D. Benefit-cost Analysis

Designing resilient facilities to handle future climate risks, and associated loads, provides quantitative and qualitative benefits that often outweigh the upfront costs. This section provides benefit-cost analysis (BCA) methodologies and tools to calculate and compare the incremental costs of using the Guidelines with the incremental benefits. These resources will aid in making decisions when selecting between various resilient design strategies.

The main guiding principle in the development of the BCA methodologies included here was to balance simplicity with accuracy. However, types of benefits can vary by climate hazard and by the type of facility; benefit categories identified here may not cover all the potential benefits provided by every facility type within New York City. In particular, the benefits of planning for increased precipitation are difficult to quantify and the project design team should incorporate additional data as new inputs become available.

For projects with construction costs below $50 million, the project team is recommended to perform a qualitative benefits assessment on the interventions that meet the Guidelines’ recommendations for all applicable climate hazards. For projects with construction costs over $50 million, or projects that are highly complex and critical, the project design team is recommended to perform an in-depth quantitative benefit calculations to identify the optimal interventions that meet Guidelines’ recommended design criteria.

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1. Categories of Project Benefits

There are three types of project benefit categories: direct benefits, indirect benefits, and other benefits. Assessed together, these can be used to perform qualitative assessments and develop quantitative estimates of monetary benefits for interventions that meet the Guidelines’ recommendations. These project benefit categories can be used to perform a high-level benefit-cost analysis that balances accuracy with an appropriate level of effort.

- **Direct benefits** include reduced or avoided physical damages to facilities and contents, reduced or avoided displacements for residential structures, and reduced life cycle or O&M costs that can be quantified as a primary result of implementing a specific hazard mitigation measure. Table 12 in Appendix 5 provides a list of direct benefits and basic guidance on estimating and documenting values for sea level rise and increased precipitation-related flood hazards. Note that given the current state of practice, it is not possible to quantify reduced or avoided physical damages or residential displacements that result from specific extreme heat mitigation measures. Therefore, direct benefits applicable to extreme heat hazards are limited to reduced life cycle costs applicable to certain measures, such as green roofs (refer to Table 15 for more details).
- **Indirect benefits** include reduced or avoided service losses for non-residential buildings, public facilities, and/or infrastructure (e.g., utilities, roads, and bridges) based on the value of service continuity and/or emergency services to New Yorkers that can be quantified as a secondary result of implementing a specific hazard mitigation measure. Table 13 in Appendix 5 provides a list of indirect benefits and basic guidance on estimating and documenting values for sea level rise and increased precipitation-related flood hazards. Note that given the current state of practice on extreme heat, it is not possible to quantify reduced or avoided service losses that result from specific extreme heat mitigation measures. Therefore, indirect benefits applicable to extreme heat hazards are limited to reduced energy costs such as cool roofs, green roofs, shade trees, and so on (refer to Table 15 in Appendix 5 for more).
- **Other benefits** can include social benefits for residents such as avoided stress and anxiety, avoided lost productivity, environmental/ecosystem service benefits, avoided need for emergency services, and other potential benefits. These can be estimated as after implementing a specific hazard mitigation measure. Table 14 in Appendix 5 provides a list of other potential benefits and basic guidance on estimating and documenting values for sea level rise and increased precipitation-related flood hazards.

Note on the ecosystem service benefit category: *in Table 14, the stormwater management benefits of green infrastructure should be distributed between the extreme heat and increased precipitation hazards since these measures both provide significant reductions in rainfall runoff as well as Urban Heat Island mitigation through evapotranspiration. However, there is currently limited data available to quantify the actual distribution of stormwater management benefits between the two hazards. In this methodology, the stormwater management benefits of green infrastructure are applied to the increased precipitation hazard in order to avoid a duplication of benefits.*

Note on real estate and quality of life benefits: *additionally, it is important to note that two potential benefit categories shown in Table 14 - real estate and quality of life/health/avoided casualties - were not included in the current BCA methodology for sea level rise or increased precipitation hazards. Although these categories could increase project benefits for both hazards, they were only applied to measures that address extreme heat hazards such as green roofs, trees, and other plantings. Refer to Table 15 for a detailed summary of other benefit categories quantified as unit benefits for extreme heat hazards.*

2. BCA methodology for projects less than $50 million

For smaller City capital projects that cost less than $50 million, a rapid, qualitative benefits assessment is recommended. As the project design team is developing design alternatives to meet the Guidelines' criteria, it is important to compare the added costs and benefits of those alternatives when in excess of NYC code and standards requirements (baseline conditions). It is assumed that the project design team will develop alternatives to address each of the following applicable climate hazards - sea level rise/coastal storm surge, increased precipitation and extreme heat - separately.

This assessment allows agencies to screen the qualitative benefits for various alternatives that would then lead to development of final project components to match the available budget and goals of the project. Use Table 5 as a template to evaluate resilient design alternatives using a set of general evaluation criteria and metrics. Develop appropriate evaluation criteria and metrics for each of the project benefit categories applicable to the capital project being assessed. Tables 12-15 in Appendix 5 provides a list of typical direct, indirect, and other benefits provided by various intervention typologies to reduce impacts from climate hazards. See Table 6 for an example of how to complete the template. The template can be customized to meet project goals and objectives.

During the qualitative assessment, the project design team should assess how intervention strategies will have varying levels of reliability, effectiveness, benefits, and cost implications. For each alternative, the project design team could use either a scoring, weighting, ranking, or other type of qualitative assessment framework to assess each applicable project benefit category with the developed evaluation criteria and metrics.

Table 5 – Evaluation matrix for comparison of mitigation alternatives across the useful life of a project

Project title:____

Evaluation Criteria	Baseline Condition (Designed to NYC Building Code and Standards)	Resilient Design Alternatives for Managing__________________		
		Alternative 1 ________________ ________________ ________________	Alternative 2 ________________ ________________ ________________	Alternative 3 ________________ ________________ ________________
First Costs				
Constructability/Ease of Implementation				
Environmental Impacts/Co-Benefits/Permitting				
Operation and Maintenance (O&M)				
Reliability and Durability				
Risk Reduction Benefits				
Quality of Life Benefits/Visual Aesthetics				

Qualitative Color Scale: Green=Least resource intensive alternative; Purple=most resource intensive; yellow=medium level of resource intensity.

Qualitative Evaluation Factors	Description	Relative Color Rating System
First Costs	Additional construction costs needed to incorporate Guidelines' recommended resilient design over the baseline project costs	Highest cost ($$$) rated as Purple, whereas lowest cost ($) rated as Green
Constructability/Ease of Implementation	Construction techniques and site conditions such as presence of major utilities conflicts and other conditions which dictate the level of constructability required for each alternative	Difficulty to construct rated as Purple, whereas easiest to construct rated as Green
Environmental Impacts/ Co-Benefits/Permitting	Impacts to the built and natural environment such as circulation, noise and hazardous waste plus the level of effort required for permitting (e.g. interventions in water require highest level of permitting requirement) from each alternative in addition to the baseline project condition	Highest environmental impacts and highest level of effort required for permitting rated as Purple, whereas the least impact and level of effort rated as Green
Operation and Maintenance (O&M)	Level of effort of additional manpower and cost of O&M for the alternatives over the baseline project O&M requirements	Highest level of effort and cost for O&M rated as Purple, whereas the lowest is rated as Green
Reliability and Durability	Interventions that do not require human involvement or a facility's ability to withstand all the forces during a storm event (e.g. permanent solutions with higher reliability than deployable solution)	Interventions requiring human involvement (active measures) rated as Purple, whereas interventions with minimal or no human involvement (passive measures) rated as Green
Risk Reduction Benefits	Monetary benefits provided by each intervention alternative in avoided damages over the baseline condition	Lowest potential monetary benefit rated as Purple, whereas as highest potential monetary benefit rated as Green
Quality of Life Benefits/ Visual Aesthetics	Benefits either to the community, such as recreation or safety, or serve the community during emergency situations	Lowest potential quality of life benefits rated as Purple, whereas as highest potential benefits rated as Green

EXAMPLE: How to conduct a qualitative benefit-cost analysis for projects below $50 million

A new, non-critical facility with a building structure is proposed on a site that is currently in the 2015 Preliminary FEMA 1% annual chance floodplain with a base flood elevation of 10' (NAVD 88). The baseline design flood elevation (DFE) to meet existing NYC codes and standards is 11' (NAVD 88). Using the Guidelines recommended design criteria, the facility's DFE is 13.3' (NAVD 88) and existing grade is around 6' (NAVD 88). The project design team develops three alternatives to meet the Guidelines' recommended DFE design for the facility. Table 7 offers an example of how a qualitative assessment can be used to compare three resilient design alternatives to meet that DFE using the evaluation criteria and metrics.

Table 6 – Evaluation matrix for comparison of mitigation alternatives across the useful life of a project - COMPLETED EXAMPLE

Evaluation Criteria	Baseline Condition (Designed to NYC Building Code and Standards)	Resilient Design Alternatives for Managing *Coastal Surge/SLR*		
		Alternative 1 *Floodproof building built on grade to Guidelines DFE*	**Alternative 2** *Elevate building structure above Guidelines' DFE on columns*	**Alternative 3** *Raise site grade by filing the building site footprint to Guidelines' DFE*
First Costs	*Baseline cost for building structure is $15 million*	*Incremental costs are within 5% over the baseline costs*	*Incremental costs are between 5-10% over baseline costs*	*Incremental costs are 20% and more over baseline costs*
Constructability/Ease of Implementation	*Relatively easy to construct within site constraints*	*Similar to baseline conditions since construction requires additional flood proofing only*	*Moderate challenges to construct foundation structure for columns within site constraints*	*Extremely challenging to construct within the site constraints. May conflict with zoning. Potentially fatal flaw.*
Environmental Impacts/ Co-Benefits/Permitting	*No major impacts but may require additional effort to obtain DOB permits with flood proofing and deployable systems*	*No major impacts but may require additional effort to obtain DOB permits with flood proofing and deployable systems*	*No major impacts and relatively easy to permit*	*Potential drainage, circulation impacts and challenges to obtain clean fill material for the site*
Operation and Maintenance (O&M)	*Major O&M costs associated with deployable systems*	*Major O&M costs associated with deployable systems*	*Moderate O&M costs associated with proposed elevator for access*	*Minimal O&M costs since deployable and elevators not required*
Reliability and Durability	*Least reliability with highest potential risk from flooding during to failure of deployable systems*	*Least reliability with highest potential risk from flooding during to failure of deployable systems*	*Moderate reliability with potential risk from flooding limited to elevator shaft only*	*Highest reliability since deployable are not required to protect building from flooding*
Risk Reduction Benefits	*Maximum flood risk reduction benefits assuming deployable and flood proofing is effective*	*Maximum flood risk reduction benefits assuming deployable and flood proofing is effective*	*Maximum flood risk reduction benefits*	*Maximum flood risk reduction benefits*
Quality of Life Benefits/ Visual Aesthetics	*Facility may not be operational during the storm event*	*Facility may not be operational during the storm event*	*Facility can be potentially operational during the storm event*	*Facility can be potentially operational during the storm event*

Qualitative Color Scale:
Green=Least resource intensive alternative; Yellow=medium level of resource intensity; Purple=most resource intensive;.

3. *In-depth BCA methodology for projects more than $50 million*

For larger City capital projects that cost more than $50 million, a detailed, quantitative assessment is recommended. In order for a project to be considered cost-effective, the benefits of a project must outweigh the costs in a benefit-cost analysis (BCA) (as illustrated in Equation 2), or in other words, the benefit-cost ratio (BCR) is greater than 1.0.

Equation 2. Benefit-Cost Ratio Formula

$$\mathbf{BCR} = \frac{\mathbf{BENEFITS}}{\mathbf{COSTS}}$$

Where: BCR = Benefit-Cost Ratio

BENEFITS = Total project benefits

COSTS = Total project costs

However, a BCR of greater than 0.75, if supported by additional qualitative benefits, can be accepted as a positive BCR. Give consideration to non-monetary benefits such as quality of life and social resiliency to justify the need for additional resiliency investment costs. This approach aligns with FEMA’s approach of using social and environmental benefit categories when calculating benefits and costs.

In this analysis, estimated project benefits are combined with the project costs, which are defined as the differential construction and long-term operation and maintenance costs associated with designing and constructing a proposed project to the Guidelines’ recommended design level. It is assumed that the baseline project will be designed to the most prevalent NYC codes and standards. This benefit methodology should be used to determine the additional project benefit that the Guidelines’ recommended design would provide over the baseline project benefit. It is assumed that the project design team will develop alternatives to address each of the following applicable climate hazards separately: sea level rise/coastal storm surge, increased precipitation, and extreme heat.

The project design team should use the following steps as a methodology to conduct a climate change-informed BCA:

a. Determine project useful life for design interventions.
Determining the useful life (see Section I.B) of the project in design is an important first step in the detailed BCA assessment methodologies for two reasons. First, the project useful life determines what values must be used from the Guidelines to establish the future climate design conditions. The various climate change hazard tables in the Guidelines establish design requirements based on useful life ranges: through 2039, 2040-2069, 2070-2099 and 2100+ (2100+ projections are only available for sea level rise). A review of these tables show that the design requirements needed to meet the projected climate hazards increase as the end of useful life range increases. Second, the useful life determines how long the project will need to be operated and maintained in order to remain technically sound and effective at reducing future damages and losses.

b. Determine discount rate for project benefits calculation.
The cost-effectiveness of projects assessed using the BCR must be done on a net present value basis, meaning the present value of the benefits is compared to the present value of the costs. Most project costs are computed for present value based on current cost estimates, bids or cost guidance. However, project benefits, as well as project costs for operation and maintenance, accrue over time into the future and are computed on an annualized basis. To address this issue, the Present Value Coefficient (PVC) is used to

bring these annualized project benefits and O&M costs into the present value. As indicated by the formula in Equation 3, the PVC is a function of the Project Useful Life (PUL) and the Discount Rate (DR).

Equation 3. Present Value Coefficient (PVC) Formula

$$PVC = \frac{[1 - (1 + DR)^{-(PUL)}]}{DR}$$

Where: PVC = Present Value Coefficient

PUL = BCA Project Useful Life based on project type

DR = Discount Rate

The project design team should coordinate with agencies and NYC OMB if needed to determine appropriate discount rates based on funding source, project type and other factors. This coordination should take place during project initiation phase when total project costs (design and construction) are over $50 million.[66]

c. Develop input data to perform benefit calculations.
Tables 16 and 17 in Appendix 5 provide a list of typical input data by each climate hazard needed to perform benefit analysis quantitatively on variety of facilities.[67] The project design team should use these tables as a reference to identify appropriate input data categories and/or additional input data needed to perform benefit analysis on the project.

d. Identify applicable project benefit categories to estimate benefits.
Tables 16 and 17 in Appendix 5 provide a list of typical project benefits for each climate hazard needed to perform benefit analysis quantitatively on various types of projects. The project design team should use these tables as a reference to identify appropriate project benefit categories for each climate hazard to perform benefit analysis on the project.

e. Calculate benefits of recommended design interventions for each climate hazard.
The input data and applicable project benefits can be assembled along with incremental project cost data to analyze cost-effectiveness using the FEMA BCA Tool Damage-Frequency Assessment module or similar software. This analysis will provide a BCR for each alternative, which can then be used to compare the alternatives that were developed to mitigate effects from applicable climate hazards. The project design team can then use the results from this analysis to identify optimal interventions which provide a design solution that balances resiliency benefits with the available project budget.

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[66] For example, a NYC OMB March 2015 memorandum recommends using an annually updated DR as published each year in Appendix C of OMB Circular A-94. The current OMB-recommended discount rates from OMB A-94 Appendix C vary by project useful life and are as follows: 2.1% DR for useful lives of 10 to 19 years, 2.5% DR for useful lives of 20 to 29 years, and 2.8% DR for useful lives of 30 years or greater. By contrast, FEMA hazard mitigation grants use a DR of 7.0% for all projects based on the Federal OMB A-94 rate for federally-funded mitigation measures. Since these DRs will impact the PVC and the project benefits, the project team must ensure that BCA results prepared using an OMB-recommended DR (2.1% to 2.8%) be updated to reflect the Federal DR (7.0%) when applying for FEMA mitigation grant funds.

[67] Note the data requirements for the sea level rise and increased precipitation hazards in Table 16 are more detailed than the requirements for the extreme heat hazards, due to the less detailed level of analysis available for extreme heat.

Appendices

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Appendix 1 - Key Terms[68]

100-year flood (1% annual chance flood)	A flood that has a 1% probability of occurring in any given year. The 100-year floodplain is the extent of the area of a flood that has a 1% chance of occurring or being exceeded in any given year.
500-year flood (0.2% annual chance flood)	A flood that has a 0.2% probability of occurring in any given year. The 500-year floodplain is the extent of the area of a flood that has a 0.2% chance of occurring or being exceeded in any given year.
Adaptation	Adjustment in natural or human systems to a new or changing environment that seeks to maximize beneficial opportunities or moderate negative effects. Successful adaptations contribute to resiliency.
Base flood elevation (BFE)	The elevation of surface water resulting from a flood that has a 1% annual chance of occurring or being exceeded in any given year. The BFE is shown on the Flood Insurance Rate Map (FIRM).[69]
Bioswale	See "rain garden."
Bluebelt	Reference to the Department of Environmental Protection's Bluebelt program to preserve natural drainage corridors, including streams, ponds and other wetland areas. Preservation of these wetland systems allows them to perform their functions of conveying, storing and filtering stormwater.
Climate	The average weather (or, more rigorously, a statistical description of the average in terms of the mean and variability) over a period of time, usually 30 years, in a given place. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.[70]
Climate change	Changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events, and changes to other variables of the climate system. Future periods, defined by the NPCC, for when climate change projections are available are broken into decadal projections. In this document, the following decadal projections are associated with specific time spans: 2020s projection = present to 2039 2050s projection = 2040 to 2059 2080s projection = 2070 to 2099 2100 projection = end of century and beyond
Climate change risk	The chance that investments (such as capital projects) can be affected by the physical impacts of climate change.[71] Risks are evaluated as a product of the probability of occurrence and the magnitude of damages or impacts, including socioeconomic factors that would result if they did occur (consequences).
Climate change risk assessment	An assessment of the consequence and likelihood of a given climate change hazard.
Climate vulnerability	The degree to which systems and populations are affected by adverse impacts. It is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity.[72]
Cloudburst	An extreme amount of rain in a short period of time, often over a small geographic area.[73]
Cooling Degree Day (CDD)	A form of degree-day used to estimate the energy requirements for air conditioning or refrigeration when the daily mean temperature is above 65°F.

68 All terms are from the U.S. Global Change Research Program (USGCRP) glossary unless otherwise noted. The USGCRP glossary is available at: http://www.globalchange.gov/climate-change/glossary
69 "Definitions," FEMA, last modified March 1, 2017. https://www.fema.gov/national-flood-insurance-program/definitions
70 UKCIP Glossary http://www.ukcip.org.uk/glossary/
71 *Account for Climate Risk*, International Finance Corporation
72 UKCIP Glossary http://www.ukcip.org.uk/glossary/
73 New York City Environmental Protection "Cloudburst Resiliency Planning Study," 2017. Available at: http://www.nyc.gov/html/dep/pdf/climate/nyc-cloudburst-study.pdf

Design Flood Elevation (DFE)	An elevation above the base flood elevation that incorporates freeboard or other adjustments to provide increased protection and minimize damage, as specified in Appendix G of the Building Code. The Guidelines recommend a sea level rise-adjusted DFE that goes beyond the Building Code elevation.
Design life	The life expectancy of an asset or product as determined during design.[74] As opposed to "project useful life" (see below).
Dry Bulb temperature	The ambient air temperature measured by a thermometer.
Extreme event	Unexpected, unusual, or unpredictable weather or flooding compared to historical or future projected distribution. Extreme events include, for example, heat waves, cold waves, heavy rains, periods of drought and flooding, and severe storms.
Facilities	For the purposes of this document, "facilities" refers to all types of buildings, housing, infrastructure, structures, and landscape features designed by or for the City of New York.
Flexible adaptation pathway	Resilience-building strategies that can evolve or be adapted over time as climate change risk assessments and evaluations and monitoring of adaptation strategies continue.[75]
Flood Insurance Rate Maps (FIRM)	Official flood map of a community on which FEMA has delineated the 1% annual chance floodplain and the base flood elevations applicable to the community.[76] The FIRM also includes the 0.2% floodplain annual chance floodplain and differentiates between special flood hazard areas (V, A Coast A zones) and floodways. The official FIRM is from the year 2007, while the 2015 PFIRM is currently required by NYC Building Code to calculate design flood elevations; NYC DOB references the more restrictive of the two maps in both base flood elevation and flood hazard area. Refer to Appendix 3 for more information.
Freeboard	An additional amount of height above the base flood elevation used as a factor of safety (e.g., two feet above the base flood) in determining the level at which a facility's lowest floor must be elevated or floodproofed to be in accordance with state or community floodplain management regulations.[77]
Green infrastructure	An array of practices that use or mimic natural systems to manage urban stormwater runoff. Water is either directed to engineered systems for infiltration or detained for longer periods before it enters the sewer system.
Heat pollution	Excessive heat released into the environment often generated from industrial practices, infrastructure, or transportation.
Heat Vulnerability Index (HVI)	Summarizes relative risk of adverse health effects from heat due to social and environmental factors. Used to identify neighborhoods at higher risk during and after extreme heat events.
Heat wave	A period of three consecutive days where temperatures rise above 90°F, or two consecutive days over 95 degrees.[78]
New York City Panel on Climate Change (NPCC)	The body of leading climate and social scientists charged with making climate change projections for the metropolitan region.[79]

[74] Sustainable Infrastructure Management Program Learning Environment. http://simple.werf.org/
[75] Rosenzweig, C. Et al. *Climate Change Adaptation in New York City: Building a Risk Management Response.*
[76] "Definitions," FEMA.
[77] Ibid.
[78] Horton, R. et al. *New York City Panel on Climate Change 2015 Report: Chapter 1: Climate Observations and Projections.* Ann. N.Y. Acad. Sci. ISSN 0077-8923. (New York, 2015) 25.
[79] For more information on the NPCC, visit www1.nyc.gov/site/MOR/challenges/nyc-panel-on-climate-change.page

Nuisance flooding	Refers to low levels of inundation that do not typically pose significant threats to public safety or cause catastrophic property damage, but can disrupt routine day-to-day activities, put added strain on or damage infrastructure systems, such as roadways and sewers, and cause minor property damage. Typically describes flood depths between 1" and 4".[80]
Open-grid pavement system	Pavements that consist of loose substrates supported by a grid of a more structurally sound grid or webbing. Unbounded, loose substrates in these systems transfer and store less heat than bound and compacted pavements and aid permeability. Pavement that is 50% pervious and contains vegetation in the open cells designed to allow percolation or infiltration of stormwater through the surface into the soil below.[81]
Preliminary Flood Insurance Rate Map (PFIRM)	Preliminary flood map developed by FEMA in 2015 for New York City that provides projected risks for flood hazards.[82] Refer to Appendix 3 for more information.
Project useful life (PUL)	The period over which an asset or component is expected to be available for use by an entity. This depends on regular and adequate maintenance. This period of time typically exceeds the design life (see above). The combined effect of operational requirements and useful life is practical in assessing an investment in improving resilience.[83]
Rain garden	Planted areas designed to collect and manage stormwater that runs off streets, sidewalks, commercial and residential rooftops and other sources when it rains. Also called "bioswale."
Resiliency	The ability to bounce back after change or adversity. The capability of preparing for, responding to and recovering from difficult conditions.[84]
Sea level rise-adjusted design flood elevation	As defined in these Guidelines, the increased height of the base flood elevation due to sea level rise plus freeboard. The sea level rise adjustment depends on the project useful life.
Storm surge	An abnormal rise of water generated by a storm, over and above predicted astronomical tides.[85]
Substantial improvement	Any repair, reconstruction, rehabilitation, addition, or improvement of a building or structure, the cost which equals or exceeds 50% of the market value of the structure before the improvement or repairs started. For more information, see Appendix G of the NYC Building Code and 1 Rules of the City of New York (RCNY) §3606-01.[86]
Tidal inundation	Flooding which occurs at high tides due to climate-related sea level rise, land subsidence and/or the loss of natural barriers.[87]
Urban Heat Island (UHI) effect	The tendency for higher air temperatures to persist in urban areas as a result of heat absorbed and emitted by buildings and asphalt, tending to make cities warmer than the surrounding suburban and rural areas.
Weather	The state of the atmosphere at a given time with regard to temperature, cloudiness, precipitation, wind and other meteorological conditions.[88]
Wet Bulb temperature	The temperature indicated when a thermometer bulb is covered with a water-saturated wick over which air is caused to flow at approximately 4.5 m/s (900 ft/min) to reach the equilibrium temperature of water evaporating into the air when the heat of vaporization is supplied by the sensible heat of the air.[89]

80 Moftakhari, H. R. et al. "What is Nuisance Flooding? Defining and Monitoring an Emerging Challenge." (2018) Available at: https://doi.org/10.1029/2018WR022828
81 "Glossary," US Green Building Council (2017). Available at: http://www.usgbc.org/glossary/term/5525
82 "Preliminary FEMA Map Products," FEMA Map Service Center. Available at: https://hazards.fema.gov/femaportal/prelimdownload/
83 "Glossary," International Infrastructure Management Manual (2011).
84 *A Stronger, More Resilient New York* (2013), 1.
85 "Storm Surge Overview," National Hurricane Center. NOAA. Available at: https://www.nhc.noaa.gov/surge/
86 "Flood Resistant Construction," Appendix G, New York City Building Code (2008), and 1 RCNY §3606-01 available at: https://www1.nyc.gov/assets/buildings/rules/1_RCNY_3606-01.pdf
87 "Ocean Facts," National Ocean Service. NOAA. Available at: http://oceanservice.noaa.gov/facts/nuisance-flooding.html.
88 UKCIP Glossary http://www.ukcip.org.uk/glossary/
89 "ASHRAE Terminology," ASHRAE. Available at: https://www.ashrae.org/technical-resources/authoring-tools/terminology

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Appendix 2 - Climate Change Projections

Climate change projections are provided by the New York City Panel on Climate Change (NPCC). The full NPCC report is available from the New York Academy of Sciences.[90] Tables 7-9 (below) were reproduced directly from the NPCC report, while Table 2 (see Section II.A) was developed using the data underlying the NPCC report to inform the design of HVAC systems under warmer conditions.

Table 7 – NYC sea level rise projections[91]

Baseline (2000-2004) 0 in	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
2020s	2 in	4-8 in	10 in
2050s	8 in	11-21 in	30 in
2080s	13 in	18-39 in	58 in
2100	15 in	22-50 in	75 in

Note: Projections are based on six-component approach that incorporates both local and global factors. The model-based components are from 24 global climate models and two representative concentration pathways. Projections are relative to the 2000-2004 base period.

Table 8 – Projected mean annual changes[92]

a. Temperature Baseline (1971-2000) 54°F	**Low estimate (10th percentile)**	**Middle range (25th to 75th percentile)**	**High estimate (90th percentile)**
2020s	+ 1.5°F	+2.0-2.9°F	+3.2°F
2050s	+3.1°F	+4.1-5.7°F	+6.6°F
2080s	+3.8°F	+5.3-8.8°F	+10.3°F
2100	+4.2°F	+5.8-10.4°F	+12.1F
b. Precipitation Baseline (1971-2000) 50.1 in	**Low estimate (10th percentile)**	**Middle range (25th to 75th percentile)**	**High estimate (90th percentile)**
2020s	-1 percent	+1-8%	+10%
2050s	+1 percent	+4-11%	+13%
2080s	+2 percent	+5-13%	+19%
2100	-6 percent	-1% to +19%	+25%

Note: Based on 35 global climate models (GCMs) and two RCPs. Baseline data cover the 1971–2000 base period and are from the NOAA National Climatic Data Center (NCDC). Shown are the low estimate (10th percentile), middle range (25th percentile to 75th percentile), and high estimate (90th percentile). These estimates are based on a ranking (from most to least) of the 70 (35 GCMs times 2 RCPs) projections. The 90th percentile is defined as the value that 90 percent of the outcomes (or 63 of the 70 values) are the same or lower than. Like all projections, the NPCC climate change projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system and limited understanding of some physical processes. The NPCC characterizes levels of uncertainty using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations and recent peer-reviewed literature. Even so, the projections are not true probabilities and the potential for error should be acknowledged.

90 The NPCC 2015 report is available at: http://onlinelibrary.wiley.com/doi/10.1111/nyas.2015.1336.issue-1/issuetoc.
91 From *New York City Panel on Climate Change 2015 Report, Chapter 1: Climate Observations and Projections*, page 41.
92 From *New York City Panel on Climate Change 2015 Report, Chapter 1: Climate Observations and Projections*, page 30.

Table 9 – Projections of extreme events[93]

2020s	Baseline (1971-2000)	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
Numbers of heat waves per year	2	3	3-4	4
Average heat wave duration (days)	4	5	5	5
Number of days per year with:				
Maximum temperature at or above 90°F	18	24	26-31	33
Maximum temperature at or above 100°F	0.4	0.7	1-2	2
Minimum temperature at or below 32°F	71	50	52-58	60
Rainfall at or above 1 inch	13	13	14-15	16
Rainfall at or above 2 inches	3	3	3-4	5
Rainfall at or above 4 inches	0.3	0.2	0.3–0.4	0.5
2050s				
Numbers of heat waves per year	2	4	5-7	7
Average heat wave duration (days)	4	5	5-6	6
Number of days per year with:				
Maximum temperature at or above 90°F	18	32	39-52	57
Maximum temperature at or above 100°F	0.4	2	3-5	7
Minimum temperature at or below 32°F	71	37	42-48	52
Rainfall at or above 1 inch	13	13	14-16	17
Rainfall at or above 2 inches	3	3	4-4	5
Rainfall at or above 4 inches	0.3	0.3	0.3-0.4	0.5
2080s				
Numbers of heat waves per year	2	5	6-9	9
Average heat wave duration (days)	4	5	5-7	8
Number of days per year with:				
Maximum temperature at or above 90°F	18	38	44-76	87
Maximum temperature at or above 100°F	0.4	2	4-14	20
Minimum temperature at or below 32°F	71	25	30-42	49
Rainfall at or above 1 inch	13	14	15-17	18
Rainfall at or above 2 inches	3	3	4-5	5
Rainfall at or above 4 inches	0.3	0.2	0.3-0.5	0.7

Note: Projections for temperature and precipitation are based on 35 GCMs and 2 RCPs. Baseline data are for the 1971 to 2000 base period and are from the NOAA National Climatic Data Center (NCDC). Shown are the low estimate (10th percentile), middle range (25th to 75th percentile) and high estimate (90th percentile) 30-year mean values from model-based outcomes. Decimal places are shown for values less than one, although this does not indicate higher precision/certainty. Heat waves are defined as three or more consecutive days with maximum temperatures at or above 90°F. Like all projections, the NPCC climate change projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system and limited understanding of some physical processes. The NPCC characterizes levels of uncertainty using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations and recent peer-reviewed literature. Even so, the projections are not true probabilities and the potential for error should be acknowledged.

93 From *New York City Panel on Climate Change 2015 Report, Chapter 1: Climate Observations and Projections*, page 31.

Appendix 3 - Differentiation of Flood Maps

These Guidelines reference several different kinds of flood maps and sources of design flood elevations. These maps are described and differentiated below.

Table 10 - Differentiation of flood maps used in NYC

Reference Title	Data Source	Information Provided	Referenced By	Link
2007 FIRM	FEMA	Based on historical data from before 1983, identifies the current base flood (extent and elevation) as the flood that has a 1% chance of occurring in any given year, also known as a 100-year flood. The NYC Building Code requires that either the 2007 FIRM or 2015 PFIRM elevation be used, whichever is more restrictive or higher elevation.	2014 NYC Building Code Appendix G Climate Resiliency Design Guidelines	https://msc.fema.gov/portal
2015 PFIRM	FEMA	Based on historical data, identifies the current base flood (extents and elevation) as the flood that has a 1% chance of occurring in any given year, also known as a 100-year flood. The NYC Building Code requires that either the 2007 FIRM or 2015 PFIRM elevation be used, whichever is more restrictive or higher elevation. The 2015 PFIRM is currently being reassessed by FEMA.	2014 NYC Building Code Appendix G Climate Resiliency Design Guidelines	https://hazards.fema.gov/femaportal/prelimdownload/ http://www.region2coastal.com/view-flood-maps-data/view-preliminary-flood-map-data/
NYC Flood Hazard Mapper	NYC Department of City Planning	Maps current and future flood hazards in NYC including the following data layers: 2007 FIRM and 2015 PFIRM, high tide with sea level rise and PFIRM with sea level rise through 2100.	Climate Resiliency Design Guidelines Waterfront Revitalization Plan	http://www1.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page
"Table 4 – Determine the sea level rise-adjusted design flood elevation for critical and non-critical facilities"	ORR & NPCC	Provides data to use when adding sea level rise to a given 2015 PFIRM or 2007 FIRM base flood elevation to calculate a design flood elevation. Based on the criticality and expected useful life of a facility.	Climate Resiliency Design Guidelines	See Section II.C on "Sea Level Rise"

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Appendix 4 - Design Strategies Checklist

This appendix provides a template for identifying possible design strategies to address climate change hazards, as described throughout the Guidelines.

Project Title:

Design Strategies Checklist (not exhaustive)								
	Extreme Heat	**Comments**		**Extreme Precipitation**	**Comments**		**Sea Level Rise & Storm Surge**	**Comments**
	Select Site in Low Heat Vulnerability Index area			Select High Elevation Site			Select High Elevation Site	
	Building Cooling System			Green Roof			Raise Building Floor Elevation	
	Minimize East-West Building Orientation			Protect Below Grade Areas from Flooding			Waterproof Building Envelope	
	Passive Solar Cooling and Ventilation Systems			On-site Stormwater Management (gray)			Elevate Critical Building Functions	
	Cool Roof (SRI appropriate)			Reduce Impervious Areas			Elevate Critical Equipment	
	Green Roof (extensive)			Permeable Pavement			Perimeter Floodwall[94]/ Levee (passive or active)	
	Vegetative Structures			Increase Green Spaces and Planted Areas			Dry/Wet Floodproofing	
	Enhanced HVAC System, including space layout optimization and system scalability			Blue Roof			Utility Redundancy Design[95]	
	More Efficient Building Envelope			Bioswale			Resilient Materials & Landscape Treatments	
	Parking Lot Shading			Other:			Design for Storm Surge Outflow	
	Light Colored Pavements (appropriate SRI)						Install Backwater Flow Prevention	
	Increase Planted Areas						Design for Scour	
	Permeable Surfaces and Open-grid Pavement						Raise Road Elevation	
	Other:						Other:	

[94] Permanent perimeter flood walls are not permitted to meet floodproofing requirements in buildings with substantial improvements and/or damages.
[95] Utility redundancy design should be pursued for critical systems, not all building systems.

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Appendix 5 - Project Benefit Categories

This appendix provides guidance on how to identify and assess benefits as a supplement to Section III Benefit-cost Analysis. Table 11 lists typical direct benefits for reducing impacts from climate hazards and basic guidance for how to estimate them. See Section III for more information.

Table 11– Direct benefits for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Direct Benefit	Basic Guidance for Estimating Values
Physical Damages (Structure, Contents)	• For flood-damaged buildings, use depth damage functions developed by FEMA and USACE for structures and contents. • Use depth damage functions in conjunction with Building Replacement Values (BRVs) and not market values; BRVs typically range between $100 to $325/SF for residential buildings and $120 to $450/SF for commercial/ public buildings. • For more complex structures or facilities, use engineering estimates of flood damages; or review historic flood damages documented from insurance claims, repair records, or FEMA Public Assistance claims from recent flood disasters.
Residential Displacements	• For flood-damaged buildings, use depth damage functions developed by FEMA and USACE for residential displacements.
Reduced Life Cycle/ Operation and Maintenance (O&M) Costs[96]	• Applicable only to projects that reduce overall life cycle costs or net annual O&M costs from baseline conditions. • Input reduced annual O&M costs as a project benefit at a 1-year recurrence interval. • Reduced overall life cycle costs can be input as a longer project useful life.

Table 12 lists typical indirect benefits for reducing impacts from climate hazards, and basic guidance for how to estimate them. See Section III for more information.

Table 12 – Indirect benefits for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Indirect Benefit	Basic Guidance for Estimating Values
Non-Residential Building Service Losses	• Estimate service loss values and durations for non-residential buildings, public buildings, critical facilities and parks/natural features based on FEMA BCA guidance and standard values based on building use.
Utility Service Losses[97]	• Estimate utility service losses for water, wastewater and electrical facilities based on the number of impacted customers, FEMA per capita standard values for utility service ($105/person/day for potable water; $49/person/day for wastewater; $148/person/day for electrical).[98] • Estimate utility service loss durations based on engineering estimates, or review historic flood damages losses documented from utility company records. • This benefit can also apply to measures that increase energy efficiency.
Road/Bridge Service Losses	• Estimate road/bridge service losses based on the average daily traffic (ADT), detour time, additional travel distance, and FEMA and GSA standard values for road service ($33.44/vehicle/ hour of delay; $0.545/mile).[99] • Estimate road/bridge service loss durations or review historic flood damages losses.
Emergency Service Losses	• Applicable only to projects that reduce or eliminate documented emergency service costs from baseline conditions. • Examples of avoided emergency services costs include NYPD staffing to monitor barricades for flooded roads or FDNY staffing for water rescues of residents from flooded buildings or streets.

96 Reduced life cycle costs may be applicable to some measures that provide extreme heat benefits such as green roofs that can last longer than a standard roof if properly maintained.
97 Reduced utility service costs may be applicable to some measures that provide extreme heat benefits such as cool roofs, green roofs and shade trees.
98 FEMA per capita standard values taken from FEMA BCA Toolkit Version 5.3.0 (Build Date 12/22/2016) and developed in FEMA's *Baseline Standard Economic Value Methodology Report* (July 28, 2016). Consider updating FEMA standard per capita values to reflect current New York City utility rates.
99 Consider updating FEMA and GSA standard values to reflect current New York City area labor rates and fuel costs.

Table 13 lists other typical benefits for reducing impacts from climate hazards, and basic guidance for how to estimate them. See Section III for more information.

Table 13 – Other potential benefits for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Other Benefit	Basic Guidance for Estimating Values
Avoided Stress and Anxiety	• Applicable only for projects that directly benefit occupants of residential structures. • Use FEMA standard value for avoided mental stress and anxiety treatment costs of $2,443/person to estimate benefit for all impacted residents.
Avoided Lost Productivity	• Applicable only for projects that directly benefit occupants of residential structures. • Use FEMA standard value for avoided lost worker productivity costs of $8,736/household to estimate benefit for all impacted workers (conservatively assuming one worker per household).
Environmental Open Space	• Applicable only for projects that create or acquire open space areas by acquisition. • Use FEMA standard value for environmental open space based on the type of land acquired ($8,308/Acre/year for Green open space; $39,545/Acre/year for Riparian; $6,010/Acre/year for Wetlands; $554/Acre/year for Forests; $1,799/Year for Marine and estuary).[100]
CSO Volume Reduction	• Applicable only for projects that provide Combined Sewer Overflow (CSO) abatement by reducing the volume of rainfall runoff. • Use CSO abatement cost of $0.015/gallons/year applied to increased precipitation hazard runoff volume for 5-year design storm.[101]
Ecosystem Service[102]	• Add stormwater management benefits of green infrastructure projects to increased precipitation hazards where avoided damages and service losses are not quantified. • Unit benefits applicable to increased precipitation hazard include: o Green roofs: $0.133/SF/year (PUL 40 years) o Bioswale/Rain Garden/Meadow Mix: $0.020/SF/year (PUL 30 years) o Permeable Grass Pavers: $0.020/SF/year (PUL 30 years) o Tree Plantings: $303/Tree/year (PUL 30 years) o Planter Box Trees: $101/Tree/year (PUL 15 years)
Real Estate[102]	• Potential real estate benefits from increased resilience of residential and/or commercial properties/streetscapes/neighborhoods included within the project scope. • Benefit applied to extreme heat hazard for green infrastructure projects directly impacting residential or commercial properties.
Quality of Life/ Health Benefits[102]	• Potential quality of life benefits related to improved public health from the resilience measures included within the project scope. • Benefit applied to extreme heat hazard for green infrastructure projects directly impacting residential or commercial properties.

[100] FEMA standard values for avoided mental stress and anxiety and environmental open space values taken from FEMA BCA Toolkit Version 5.3.0 (Build Date 12/22/2016)

[101] CSO abatement cost taken from APG1 Report for NYC *Technical Approaches for Benefit-Cost Analysis of Hazard Mitigation Projects in Urban and Coastal Environments* (April 2016)

[102] Ecosystem Services, Real Estate and Quality of Life/Health benefits tend to be more applicable to green infrastructure measures that provide extreme heat benefits such as green roofs, trees and other plantings.

Table 14 lists potential benefits for reducing impacts from heat, and basic guidance for how to estimate them. See Section III for more information.

Table 14 – Potential benefits for extreme heat and Urban Heat Island reduction measures

Category	Benefit	Basic Guidance for Estimating Values
Direct Benefit	**Reduced Life Cycle Cost**	• Applicable only to measures such as green roofs that are expected to last longer than standard roofs. • Compute total cost savings including annual O&M costs.
Indirect Benefit	**Energy Savings**	• Applicable to measures that reduce energy costs by providing cooling through increased shading and/or evapotranspiration. • Use New York Power Authority rates of $0.148/kWh for electricity and $0.810/Therm for natural gas.
Other Potential Benefits	**Air Quality**	• Applicable to measures that absorb pollutants and/or reduce carbon dioxide emissions.
	Acoustics	• Applicable to measures such as green roof or walls that reduce noise transfer.
	Quality of Life/Health	• Potential quality of life benefits and related to improved public health.
	Real Estate	• Applicable to measures that provide residential real estate benefits from increased resilience of properties/streetscapes/neighborhoods.
	Retail Sales/ Marketing	• Applicable to measures that provide commercial property benefits from increased aesthetics resulting in increased marketing and sales for streetscapes/neighborhoods.
	Social Cost of Carbon[103]	• Based on reduced energy outputs in kWh of electricity or Therms of natural gas. This is an area of ongoing research and associated values vary greatly.
	Tax Credits/ Incentives	• Applicable to resilience or green infrastructure measures such as green roofs that have accompanying Federal, State or City tax credits or other incentives.

[103] The social cost of carbon values used in this benefit-cost analysis are based on a review of scholarly and government sources, and in line with 2016 EPA memo *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (May 2013, Revised July 2015) available at: https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf

Table 15 provides general guidance on how to quantitatively calculate benefits from efforts to address from climate hazards. See Section III for more information.

Table 15 – Guidance on quantitative calculations for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Data Input	General Guidance – Basic Description	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
First Floor Elevation (FFE)	• The elevation of the first finished floor of the structure, excluding basements. • FFE measured from top of lowest floor (riverine/non-coastal high hazard areas) or bottom of lowest horizontal structural member (coastal high hazard areas).	Y			Y	Y	Y	
Building Replacement Value (BRV)	• The unit cost to rebuild a structure of the same quality of construction. • Not the same as market value.	Y			Y	Y	Y	
Building Size	• The total floor area of the building in square feet. • Total Building Value = BRV x Building Size • Typical BRVs for NYC range between $100 to $325/SF for residential buildings and $120 to $450/SF for commercial/public buildings.	Y			Y	Y	Y	
Structure Description	• The type of building, number of stories and foundation type (full basement, partial basement, no basement). • Collect more detailed foundation data for coastal flood zones.	Y			Y	Y	Y	
Building Use	• Details related to residential housing, commercial business and public use.	Y	Y		Y	Y	Y	
Building Type	• The primary use of building – residential, commercial, public and others.	Y	Y		Y	Y	Y	
Depth Damage Function (DDF)	• Curves used to estimate structure damage, contents damage and displacement of residential buildings based on flood depth. • DDFs selection based on Structure Description, Building Type, Building Use. • Structure DDFs based on percentage of Total Building Value. • Contents DDFs based on percentage of Total Contents Value. • Displacement DDFs based on number of displacement days x Displacement Cost.	Y	Y		Y	Y	Y	
Contents Value	• The cost to replace structure contents (furnishings, equipment). • Residential building Contents Values typically 50% BRV (FEMA DDFs) or 100% BRV (USACE DDFs). • Non-residential building Contents Values between 18% to over 100% depending on building use (USACE DDFs). • Total Contents Value = %BRV x Building Size.	Y	Y		Y	Y	Y	

Table 15 – Guidance on quantitative calculations for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Data Input	General Guidance – Basic Description	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Number of Residents (Residential)	• Total number of occupants in a residential building. • Typically estimated based on number of residential units x average number of individuals per household (based on current US Census data or use 2.5 individuals per household as a default).	Y		Y	Y	Y	Y	
Displacement Cost (Residential)	• The unit cost to lodge and feed displaced residents while flood damage is repaired. • Average unit displacement cost of $415/ residential unit/day recommended based on current FY2018 GSA Per Diem rates for New York City.	Y		Y	Y	Y	Y	
Value of Service (Non-Residential and Public)	• The unit cost of service disruption and rental of temporary facilities while flood damage is repaired. • Disruption costs for non-residential buildings typically range from $0.95 to $1.36/SF/month and rental costs range from $0.20 to $1.36/ SF/month depending on building use. • Value of service for public buildings ($/day) is typically based on the annual operating budget for the City agency using the building prorated based on building size or population served by the building, then divided by 365 days/year.		Y		Y		Y	Y
Value of Service (Critical Facilities)	• The unit cost of critical facilities (police, fire, emergency medical services) lost or delayed while flood damage is repaired.		Y		Y		Y	
Value of Service Duration	• The duration of service disruption and rental of temporary facilities for non-residential buildings and critical facilities while flood damage is repaired. • For non-residential buildings: o Value of Service Durations vary from 4 months to over 30 months based on building use and the depth of flooding. o Total Value of Service Loss = (Disruption Cost x Building Area) = (Rental Cost x Building Area x Value of Service Duration) • For public buildings and critical facilities: o Value of Service Durations vary from 0 days to 720 months based on building use and the depth of flooding from FEMA, Federal Insurance Administration, or US Army Corps of Engineers DDFs o Total Value of Service Loss = (Value of Service) x (Service Loss Duration)		Y		Y		Y	

Table 15 – Guidance on quantitative calculations for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Data Input	General Guidance – Basic Description	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Engineering Estimates for Damages	• Engineered estimate models of physical damages and service losses at the project site based on the Guidelines event recurrence interval(s) and flood depth(s).	Y	Y		Y	Y	Y	Y
Historic Damages and Service Losses	• Historic physical damages and service losses at the project site documented from previous flood events. • Do <u>not</u> use routine maintenance. • The historic damage event recurrence interval and/or flood depths must be determined, updated for inflation to the present value, and adjusted to match the Guidelines event recurrence intervals/flood depths.	Y	Y		Y	Y	Y	Y
Facility Replacement Value	• The unit cost to rebuild the facility.							
Impacted Area	• The geographic area impacted by the facility in the event of failure in acres.		Y	Y		Y	Y	
Facility Capacity	• The design capacity of the facility. • For example - facility capacity expressed in millions of gallons per day for water and wastewater facilities or megawatts for electrical facilities.		Y	Y		Y	Y	
Service Population	• The number of <u>impacted</u> residents served by the facility. • Typically estimated based on number of impacted residential customers x average number of individuals per household (based on current US Census data or use 2.5 individuals per household as a default). • Facilities serving mostly non-residential/ public buildings and/or critical facilities should focus on service losses rather than service population.		Y			Y	Y	

Table 15 – Guidance on quantitative calculations for (1) sea level rise with coastal storm surge and (2) increased precipitation measures

Data Input	General Guidance – Basic Description	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Value of Service	• Unit value of service provided by the facility. • Example of FEMA standard values for complete loss of utility service: $105/person/day for potable water $49/person/day for wastewater $148/person/day for electrical • Consider updating FEMA standard per capita values to reflect current The New York City utility rates.		Y			Y		
Roadway Elevations	• Roadway Elevations.	Y					Y	
Roadway Replacement Value	• Roadway Replacement Value.	Y					Y	
Inundation Area Map	• Inundation Area Map developed by FEMA or through modeling by project design team.	Y	Y				Y	
Building Inventory of Inundation Area	• The number and type of buildings within the streetscape and neighborhood inundated by the Guideline’s flood events.	Y	Y				Y	
Average Daily Traffic (ADT)	• The average number of one-way traffic trips per day along the roadway(s) within the streetscape/neighborhood inundated by the Guidelines’ flood events.		Y				Y	
Additional Travel Time	• The additional travel time needed to detour around a flooded roadway expressed in minutes. • In the unlikely event there is no detour available, use a 12-hour travel time per one-way trip, but provide a detailed area street map as supporting documentation.		Y				Y	
Value of Traffic Delay	• The value of service associated with lost time in traffic. • For example - FEMA standard average value of $33.44/vehicle/hour of delay. • Consider updating FEMA and GSA standard values to reflect current New York City area labor rates and fuel costs.		Y				Y	

Table 16 provides general guidance on how to quantitatively calculate benefits from efforts to address extreme heat hazards. See Section III for more information.

Table 16 – Guidance on quantitative unit benefit calculations for extreme heat hazard measures

Measure	General Guidance – Unit Benefit Information and Data Requirements	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Green Roof	• Unit benefit range over PUL = $4.70/SF to $373/SF of green roof area ($7.19/SF standard value). • Assumed PUL = 40 years • Apply standard value unit benefit to green roof area to estimate measure benefit. • Higher range values more applicable to residential and commercial building streetscape projects.	Y	Y	Y	Y	Y	Y	
Bioswale/ Rain Garden/ Meadow Mix	• Unit benefit range over PUL = $3.96/SF to $211/SF of area ($7.30/SF standard value). • Assumed PUL = 30 years • Apply standard value unit benefit to bioswale/ rain garden/meadow mix area to estimate total measure benefit.		Y	Y	Y	Y	Y	Y
Cool Roof	• Unit benefit range over PUL = $1.17 to $31.51/SF of material area ($1.44/SF standard value). • Assumed PUL = 20 years • Apply standard value unit benefit to cool roof area to estimate total measure benefit. • Higher range values more applicable to residential building streetscape projects.		Y	Y	Y	Y	Y	
Light-Colored Pavers/ Light-Colored Materials	• Unit benefit range over PUL = $0.774 to $2.04/SF of material area ($0.866/SF standard value). • Assumed PUL = 30 years • Apply standard value unit benefit to material area to estimate total measure benefit.			Y	Y	Y	Y	
HVAC Improvements (High-Efficiency Chillers, Energy Recovery Systems)	• Unit benefit over PUL = $4.97/kWh and $3.87/ Therm • Assumed PUL = 25 years, based on current NYC electric rate of $0.27/kWh and gas rate of $0.21/Therm • Apply standard value across energy savings to estimate benefit.	Y	Y	Y	Y	Y		
Building Envelope Improvements (Windows, Insulation)	• Unit benefit over PUL = $7.22/kWh and $5.62/ Therm • Assumed PUL = 50 years, based on current NYC electric rate of $0.27/kWh and gas rate of $0.21/Therm • Apply standard value across energy savings to estimate benefit.	Y	Y	Y	Y	Y		

Table 16 – Guidance on quantitative unit benefit calculations for extreme heat hazard measures

Measure	General Guidance – Unit Benefit Information and Data Requirements	Applicable Benefit Category			Applicable Typical Facility Typology*			
		Direct Benefits	Indirect Benefits	Other Potential Benefits	Building Structures	Complex Facilities	Transportation/ Streetscapes/ Plazas	Park Features
Tree Planting	• Unit benefit range over PUL = $1,005 to $77,154/Tree ($1.855/Tree standard value). • Assumed PUL = 30 years • Apply standard value unit benefit to number of trees to estimate total measure benefit. • Higher range values more applicable to residential and commercial building streetscape projects.		Y	Y	Y	Y	Y	Y
Planter Box Tree	• Unit benefit range over PUL = $212 to 16,304/ Tree ($392/Tree standard value). • Assumed PUL = 15 years • Apply standard value unit benefit to number of trees to estimate total measure benefit. • Higher range values more applicable to residential and commercial building streetscape projects.		Y	Y	Y	Y	Y	
Shade Canopy	• Unit benefit range over PUL = $0.363 to $3.96/SF ($0.458/SF standard value) • Assumed PUL = 15 years • Apply standard value unit benefit to area of shade canopy estimate total measure benefit. • Higher range values more applicable to residential and commercial building streetscape projects.	Y	Y		Y	Y	Y	
Permeable Grass Pavers	• Unit benefit range over PUL = $0.258/SF to $0.521/SF of pavers ($0.363/SF standard value). • Assumed PUL = 30 years • Apply standard value unit benefit to paver area to estimate total measure benefit.		Y	Y	Y	Y	Y	

** For the purposes of the BCA, refer to the following facility typologies:*

- *"Building Structures" include critical small building sites such as EMS or FDNY stations, and non-critical small building sites such as libraries or comfort stations.*
- *"Complex Facilities" include critical infrastructure such as wastewater treatment sites, pump stations, water filtration plants and similar large or complex facilities.*
- *"Transportation/Streetscape/Plazas" include roadway reconstruction, streetscape improvements, street raising, plazas and other transportation-related infrastructure.*
- *"Park Features" include parks and similar public recreational facility with natural landscape features.*

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