Brooklyn Navy Yard
Climate Resilience Strategy

February 2024

BROOKLYN NAVY YARD

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BROOKLYN NAVY YARD

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Sustainable change.

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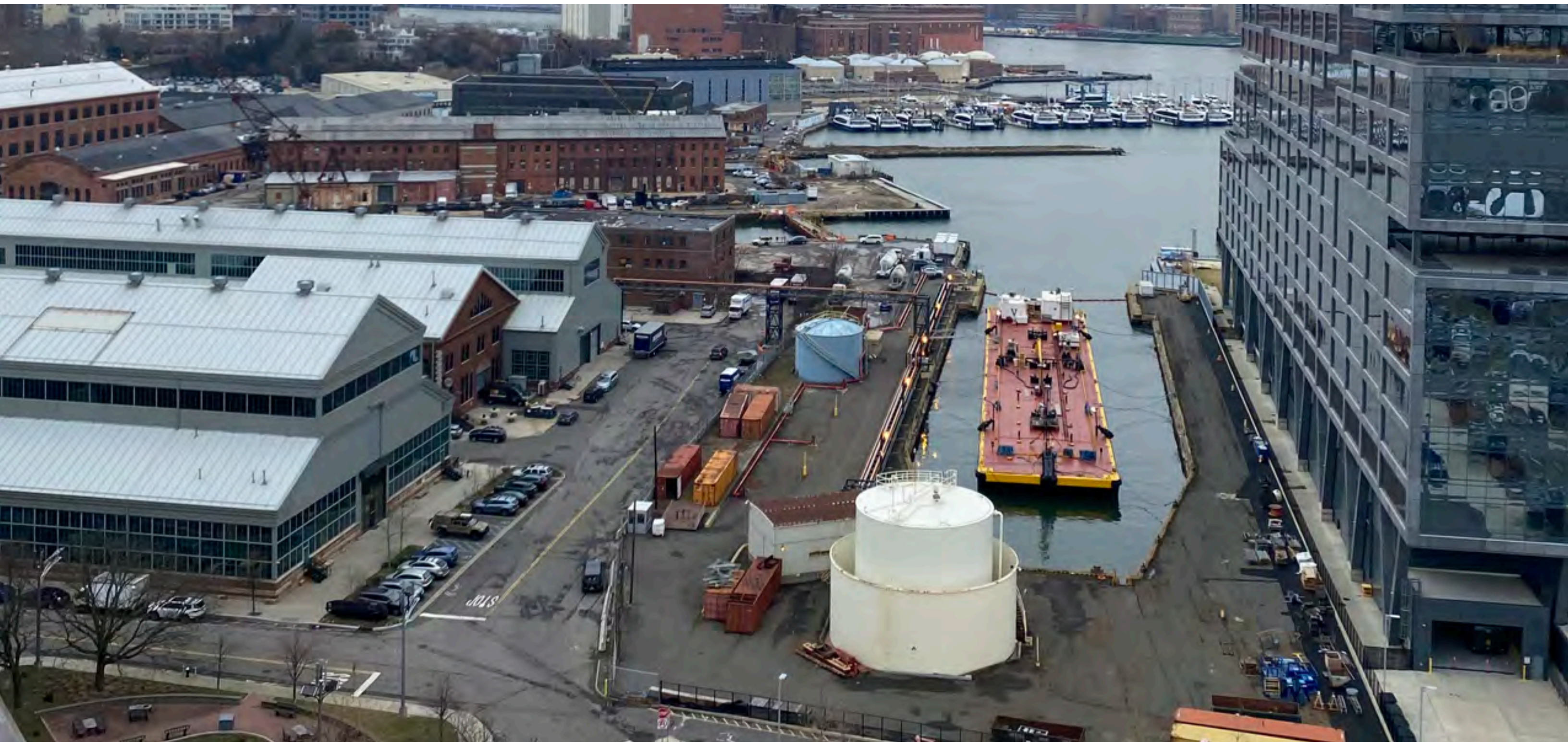


Executive Summary

Executive Summary

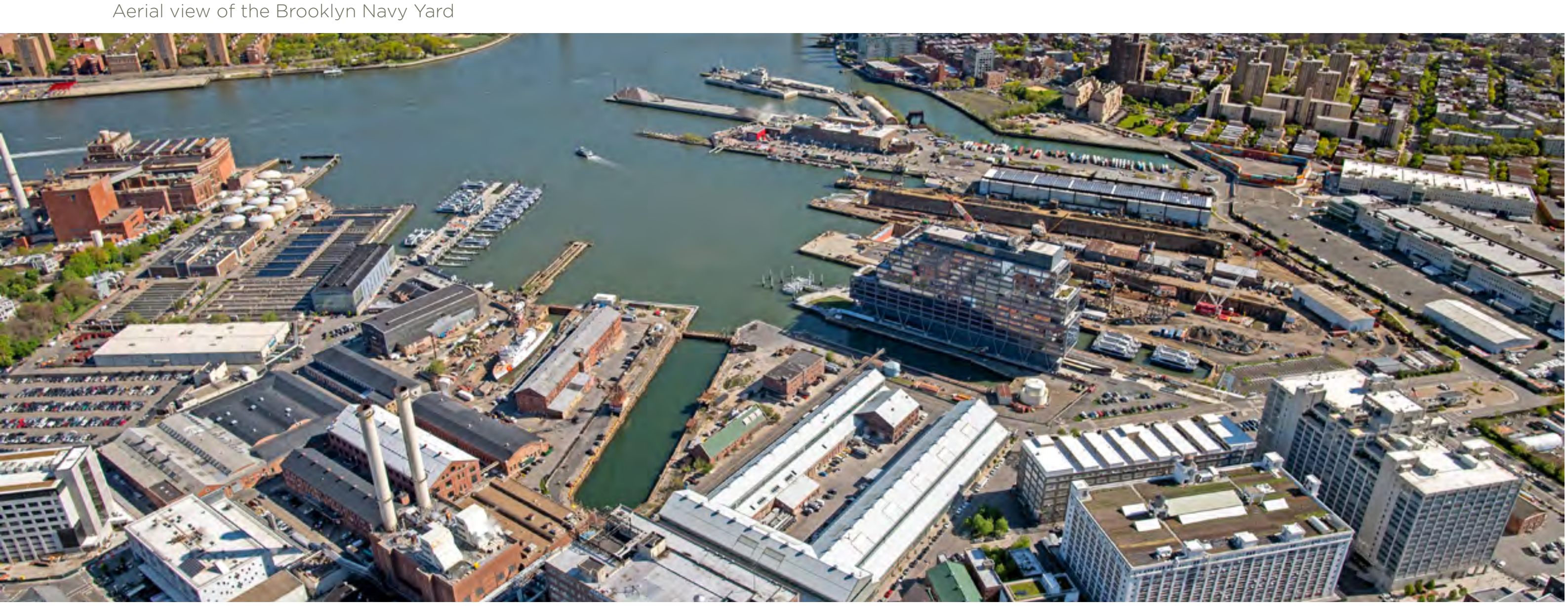
On October 22nd, 2012, Superstorm Sandy took an unexpected curve westward. After first ravaging the Caribbean, the Hurricane made landfall in New Jersey and traveled north to New York City, bringing with it sustained eighty-mile winds and storm surge measuring nearly fourteen feet. The effects of the Hurricane were felt city-wide, and were particularly severe in low-lying, water-front areas. During the Storm, the Brooklyn Navy Yard ("BNY" or "the Yard") was inundated with four to six feet of water that penetrated critical infrastructure; damaged buildings, vehicles, and equipment; caused critical service interruptions; and ultimately resulted in $100 million worth of damages. Though less devastating, other storms in December 1992 and as recently as September 2021 have caused severe flooding at BNY, disrupting the critical infrastructure and services it houses.

These prior storm events highlight the need for climate adaptation to protect all of the Yard's resources—infrastructure, businesses, workers, and jobs—from extreme weather events and climate hazards. Understanding the need for intervention, the Brooklyn Navy Yard Development Corporation (BNYDC) commissioned an assessment of the Yard's risk to current and future climate hazards.

This assessment took the form of the Brooklyn Navy Yard Resilience Strategy ("Resilience Strategy"), which provides a roadmap for BNYDC to implement resilience recommendations and protect the Yard from future climate impacts and extreme weather events.

The Resilience Strategy, which builds upon and is aligned with the Preliminary Resiliency Risk Assessment and Mitigation Strategies Study (2017) and the BNY Master Plan Exercise (2018), is critical for the ongoing success of the Yard as a unique resource for New York City and the region. The renaissance of BNY generates over $2.5 billion in economic impact for the city of New York annually. The Yard houses critical infrastructure and emergency services, in addition to being an innovative industrial campus housing an incredible array of businesses—large and small, makers and marine services, public-facing and private. The Resilience Recommendations put forth in this document are intended to protect the people, businesses, infrastructure, facilities, services, and surrounding communities that call the Brooklyn Navy Yard home.

Aerial view of the Brooklyn Navy Yard



The Resilience Strategy was conducted by an expert consultant team comprised of climate adaptation planners and engineers (Ramboll Engineering), marine and coastal engineers (COWI), and urban designers (WXY). The study occurred between Summer 2023 and January 2024 and demonstrates deep coordination between BNYDC staff members and the consultant team. The scope of work includes:

- **Planning Context –** Regional context, review of prior studies, asset inventory.
- **Climate Hazard and Risk Assessment –** Regional and asset-level analyses of relevant climate hazards.
- **Resilience Recommendations –** Coastal resilience best practices, alternative approaches, selected approach with design elements, proposed small area developments, and cost estimates.
- **Adaptive Resilience Planning –** Recommended framing of priorities, recommended construction phasing, and funding strategies and opportunities.

Work performed during the course of the project is included in this document, with technical analysis included as appendices. A summary of the sections of the document follows.

Planning Context

As a non-profit, anchor economic development institution located on city-owned land, BNYDC's operations and impact extend beyond its 300-acre campus boundary - and even beyond the borough of Brooklyn. The Yard is a regional asset that serves as a central business district for urban manufacturing, home to 500 businesses and approximately 11,000 jobs, and operates as an important link in the regional waterborne transportation system between New York and New Jersey. It is one of only two active shipyards (GMD Shipyard and Bayonne Dry Dock) in the entire New York/New Jersey harbor, offering a truly unique economic development asset and working waterfront.

To accommodate the diversity of activity at the Yard, existing site conditions vary. The 3-mile shoreline includes various working waterfront uses, semi-public areas for tenant access, and public waterfront zones accessible to the broader community. Businesses and other uses within the Yard include light industrial incubator spaces, public safety services and utilities, public transportation, and a historic core that houses predominantly light industrial uses. An asset inventory was prepared for Brooklyn Navy Yard to catalogue the structures and assess their criticality for the site and region.

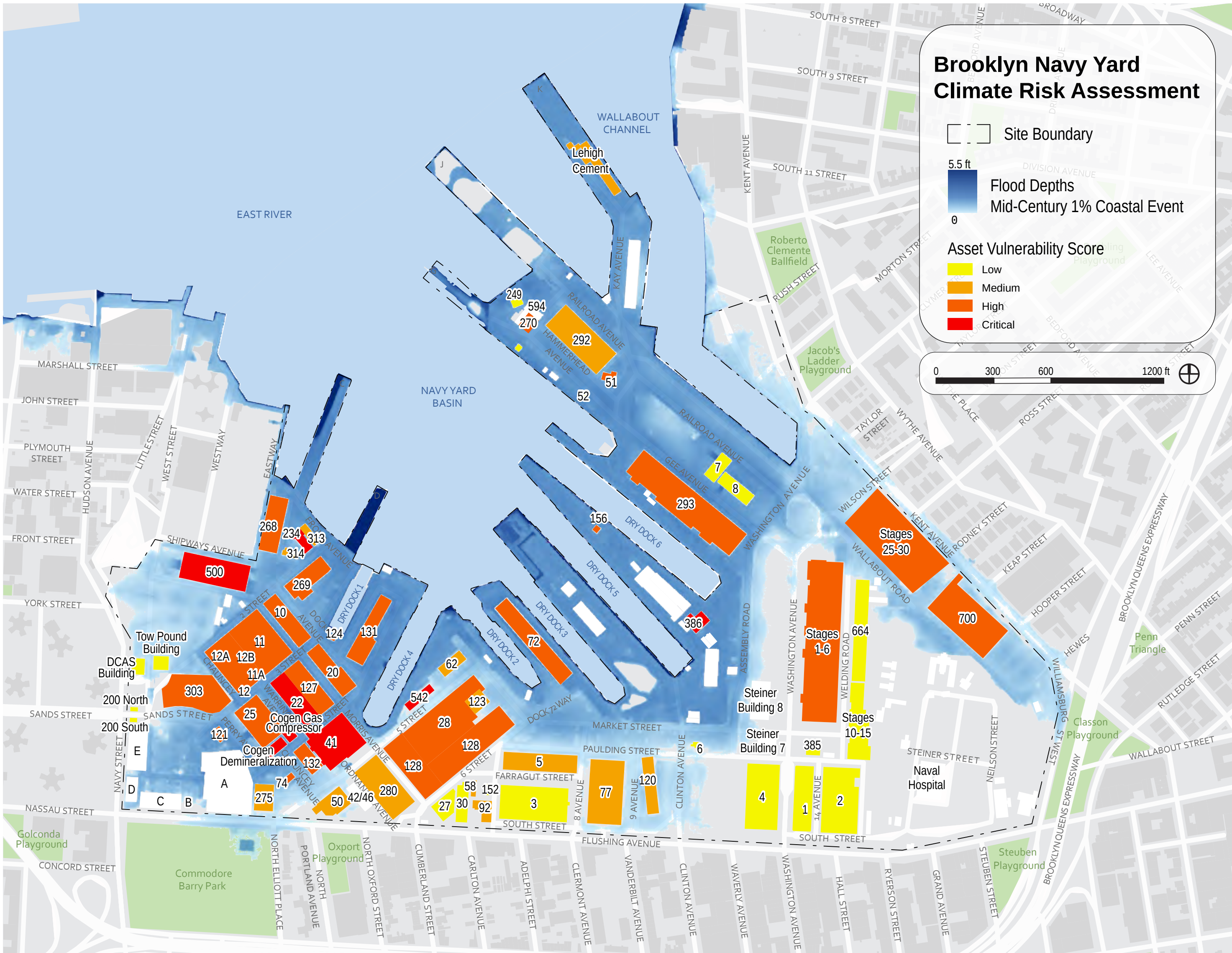
In addition to understanding site conditions and relevant assets, the prior findings of the 2017 Preliminary Resiliency Risk Assessment and Mitigation Strategies and the 2018 Master Plan Exercise were reviewed, both of which act as a foundation for this work. The Preliminary Resiliency Risk Assessment evaluates the 100-year storm alongside sea-level rise, finding severe inundation in the low-lying area on the western and eastern most portions of the site (High Risk Zone), as well as wave action at the waterfront with flooding and wave impacts (Wave Action Zone). The southeast portion of the site and the buildings along Flushing Avenue were found to be less vulnerable (Moderate Risk Zone). The Master Plan Exercise similarly outlines different areas of the Yard; however, these are based on planned development activities and comprise a Campus of Districts with special programming for key sites for future development. The Master Plan Exercise also further reinforces BNYDC's commitment to vertical manufacturing job growth, enhanced industrial operations, and the continuation and expansion of transportation services and mobility amenities, quality public access and open spaces, and the ongoing support and availability of services to the surrounding communities.

The Brooklyn Navy Yard Site Map with building asset labels

Climate Risk Assessment

The Climate Risk Assessment combines site-wide and regional climate hazard assessments with key insights from BNYDC staff to understand the vulnerability of the Yard's assets to current and future climate hazards. Regional climate hazards, including wildfire, drought, and air quality, were assessed using best available data for site-wide impacts in the short- and long-term. To create the asset-level vulnerability assessment, coastal and interior flood exposure was modeled across the site and consequences were estimated using the asset inventory as the basis for the assessment. Each asset was given a score to represent its exposure to both coastal and inland flooding in addition to the asset's criticality and sensitivity, which considers the asset's service and safety impact in conjunction with its adaptive capacity. Taken together, asset's exposure and criticality defined its level of vulnerability.

In most cases, flood exposure of building assets at BNY is of greater consequence under a coastal storm event, than under a precipitation event; however, some buildings outside of the coastal flood zone are at risk of precipitation-based flooding due to depressions in the terrain. Furthermore, the modeling found that by end of century, all buildings will face some risk of coastal flooding due to accelerated sea level rise and corresponding emissions projections. The Vulnerability Assessment concludes with a short list of vulnerable building assets that are recommended for prioritized mitigation and adaptation measures.



The Brooklyn Navy Yard Risk Map

Resilience Recommendations

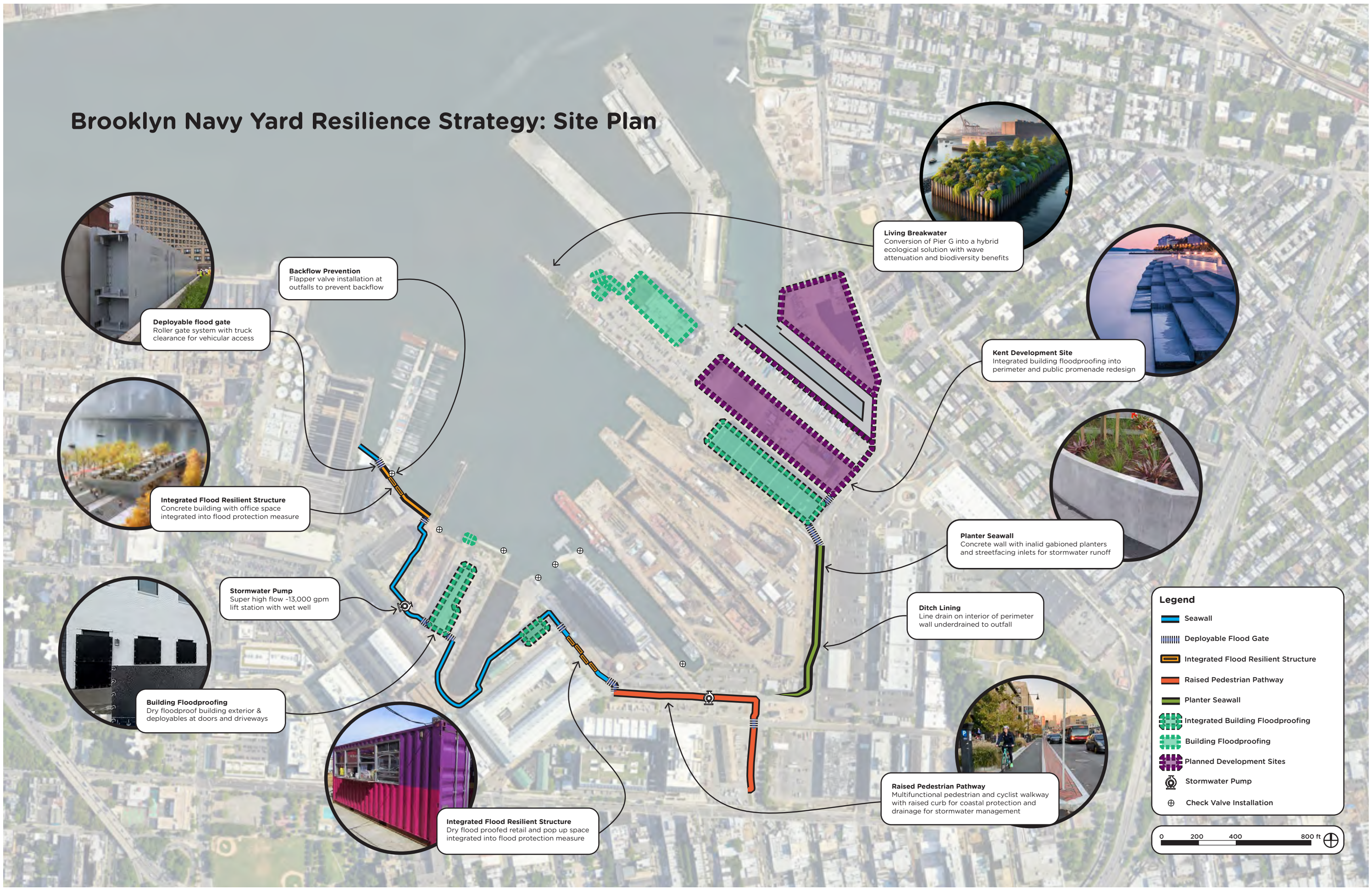
Using the findings of the Climate Risk Assessment as the basis, the Resilience Recommendations for the Brooklyn Navy Yard are uniquely tailored to mitigate flood risk within the site constraints of a working waterfront while creating synergies with development goals. A design elevation of up to 12 to 13 feet (above NAVD88), in accordance with FEMA standards, was chosen after a series of discussions about Vulnerability Tolerance. Furthermore, these recommendations were informed by local and international climate resilience best practices for fortifying flood prone waterfront areas in innovative ways. Precedent projects were selected to reflect the complex landscape and need for varied approaches to resilience in different zones including working waterfronts, public promenades, and in-water solutions.

Inspired by this prior work, the consultant team devised alternative protection measures ranging from marine defense systems, shoreline perimeter measures, onshore floodproof, and drainage plans. Four distinct alternative strategies were developed for how to approach resilience. Each protection alternative presented a different approach of adapting to, mitigating against, or retreating from projected climatic conditions. After careful consideration, a Hybrid Protect Scenario was selected as the basis for Resilience Recommendations that balance the objectives of implementing large scale resilience infrastructure as well as the need for a Resilience Strategy that is adaptable, scalable, and aligned with the overall development vision of the Brooklyn Navy Yard. Additionally, Resilience Recommendations included in the Hybrid Protection Scenario were determined to be the most effective long term resilience planning approach to reduce damages and provide collective benefit for the site and surrounding community.

Resilience Recommendations for the Brooklyn Navy Yard synthesize perimeter and onshore measures with seawalls proposed in the most at-risk low-lying areas of the site and building level floodproofing in working waterfront areas and areas that flood less frequently. A full height seawall (6 – 9 feet above ground level) runs from Pier C along the Historic Core with deployable gates to allow access to working waterfront areas, dry docks, and piers. Instead of a complete shoreline perimeter, the hybrid perimeter gradually slopes down along Clinton Avenue to meet the existing grade at Flushing Avenue. The seawall is intended to be multifunctional and may take many shapes and forms, such as a covered parking area, storage shed, office space, or pop-up retail spaces fortified and sealed to withstand coastal waters.

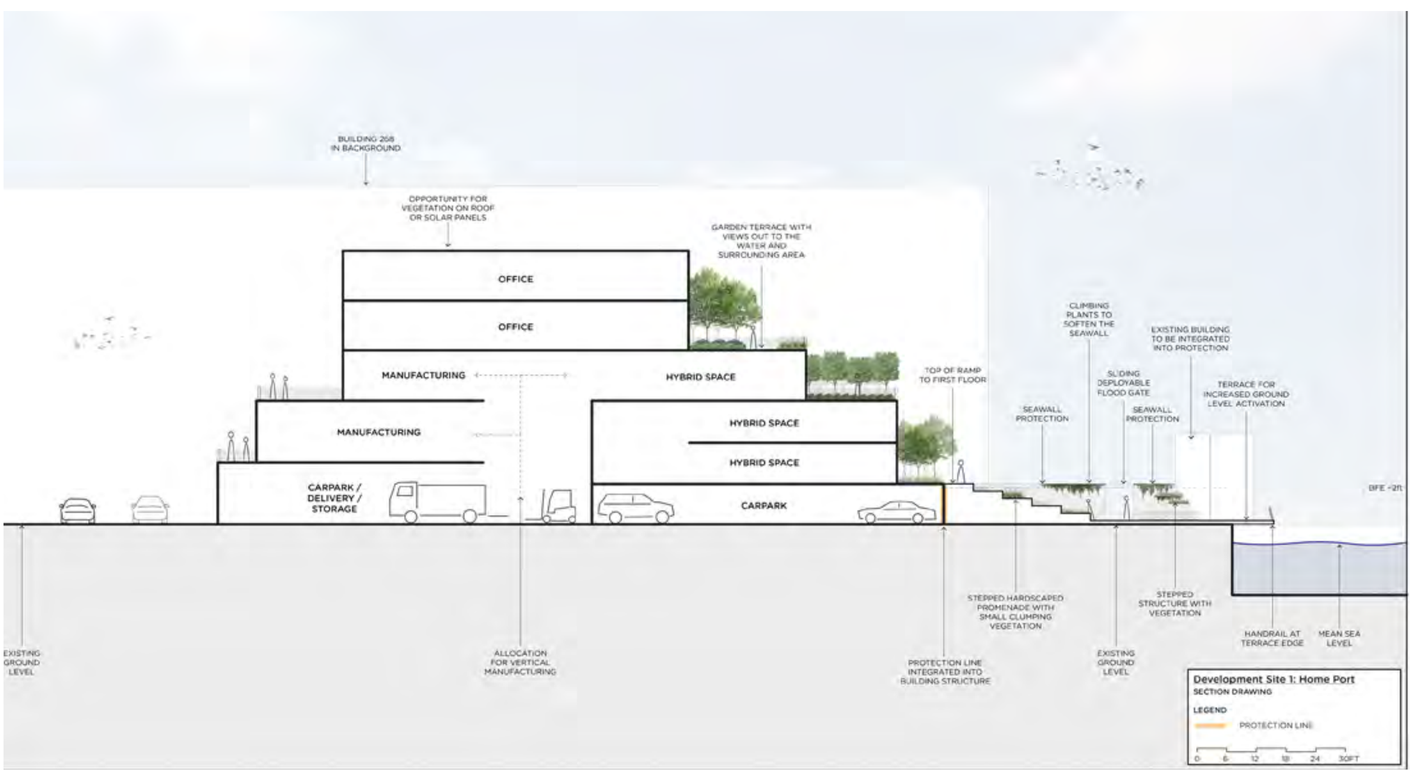
Stormwater management measures will be needed to supplement coastal resilience measures and protect against extreme rain events. Strategies such as increasing pipe capacity, adding catch basins and network infrastructure in low-lying areas of the site, installing backflow preventors at outfalls, and ensuring proper infrastructure maintenance will be utilized to manage the increasingly intense precipitation the Yard is expected to experience in the coming decades. Integrated site solutions like blue-green infrastructure and hybrid shoreline features also provide an opportunity to promote natural habitats while managing flooding and stabilizing existing piers and shorelines.

The sitewide map provides an overall conceptual approach to the Resilience Recommendations. Additionally, three small area plans were developed, providing detailed visualizations of potential strategies to leverage development and align with the Master Plan to create flood mitigation measures. The sites were selected with BNYDC mission development and growth strategies in mind and demonstrate synergies with job creation, transit improvements, and public access objectives. They include Development Site 1: Homeport; Development Site 2: Building 131; and Development Site 3: Market Street. The goal of the small area plans is to inspire how resilience measures may be imagined on new development sites to achieve multifunctional infrastructure at the Yard such that a coastal flood barrier also helps achieve other development, transportation, and open space objectives.

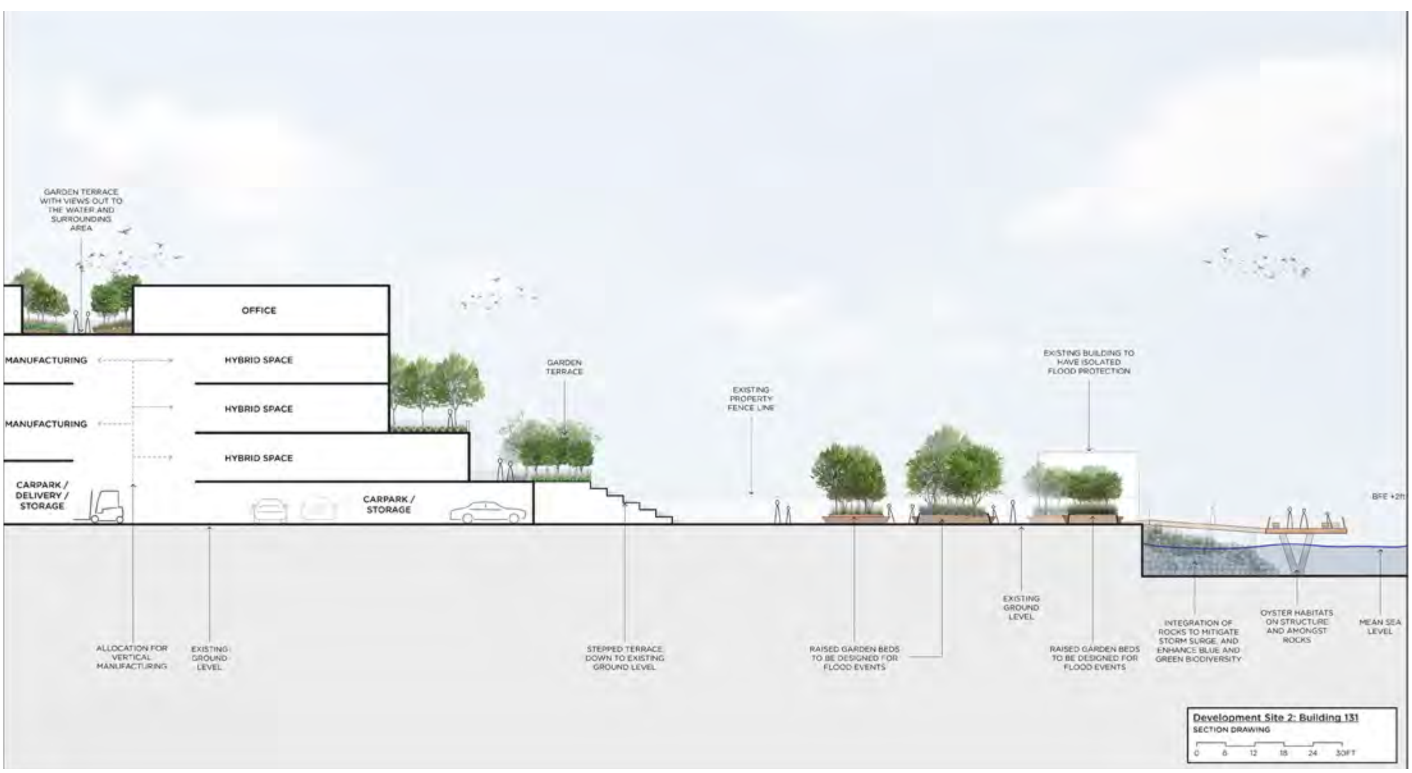


The Brooklyn Navy Yard Resilience Recommendations

DEVELOPMENT SITE 1: HOMEPORT



DEVELOPMENT SITE 2: BUILDING 131



DEVELOPMENT SITE 3: MARKET STREET

Adaptive Resilience Planning

As BNYDC looks towards the funding, phasing, and the eventual implementation of the Resilience Recommendations, a Dynamic Adaptive Planning approach offers key insights into how BNYDC can prepare for and respond to the many uncertainties that are inherent in this type of large-scale resilience implementation. Changes in political administrations, funding availability, institutional decision-making, and many other factors will inevitably affect how and when the resilience measures proposed in this Strategy are realized. As such, Dynamic Adaptive Planning encourages the explicit inclusion of provisions for adaptation as conditions change and knowledge is gained.

With the Dynamic Adaptive Planning approach in mind, the various adaptation pathways that exist for the implementation of the Hybrid Protection Plan can be more broadly envisioned. Elements of this Strategy offer opportunities for alignment with the BNY Master Plan Exercise and other development objectives, which enables linkage between these resilience measures and the various other development activities on the BNY's horizon such that with any new development opportunity BNYDC will ask how this can also advance the Resilience Strategy. This linkage exists in the other direction as well due to the multifunctional nature of the proposed seawall and development sites.

The following Adaptive Resilience Planning approach is offered to provide high-level guidance on recommended priority phasing over time:

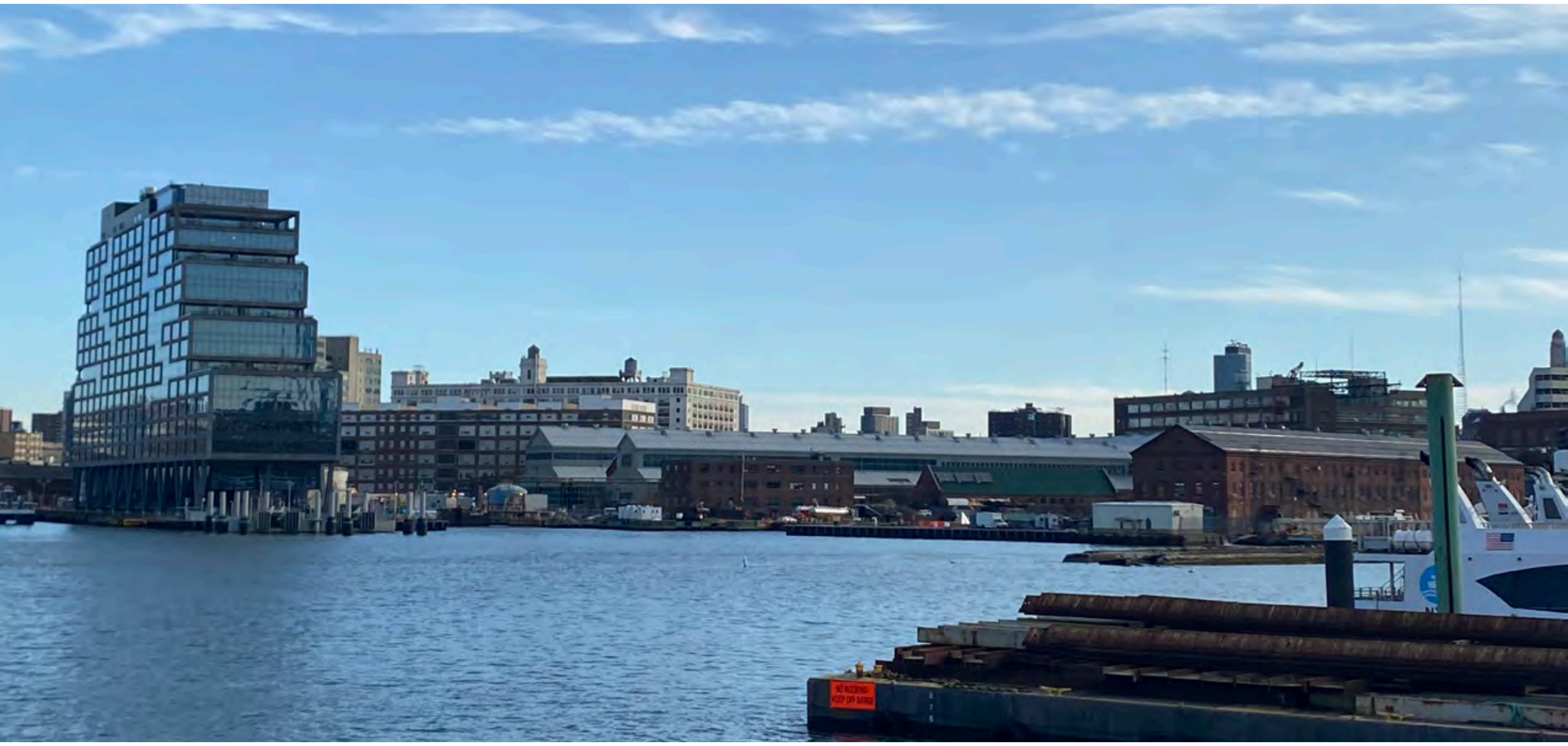
Immediate: BNYDC's focus is on the Capital Project Scope Development (CPSD) work that is currently underway to secure city budget allocations for building-level flood proofing in the wave action zone in addition to the roll-out of the Tenant Resilience Toolkit.

Short-Term (2025 - 2030): BNYDC's focus will be, in part, on implementation as it seeks to utilize the city budget allocations in addition to implementing stormwater management projects. At the same time, it is critical for BNYDC to explore funding avenues and partnerships for larger coastal flood protection projects during this period.

Medium-Term (2030 - 2050): This primary focus is implementation. The coastal elements of the Resilience Strategy will need to be constructed during this twenty-year period to provide protection against the more extreme coastal risks that are expected by mid-century.

Long-Term (Mid-Century and Beyond): In addition to maintaining the constructed resilience measures, ongoing adaptation measures may need to be explored.

In addition to the priority phasing, the Resilience Strategy offers a recommended approach to the phased construction of the perimeter wall, which responds to physical risk such that sections of the site that have lower elevation are given protection first. In addition to reducing risk, this approach minimizes construction costs and allows for a variety of funding mechanisms to be utilized. The estimated cost for the Hybrid Protection Plan is between $81 million and $182 million. A variety of resilience-focused funding opportunities have been provided in this report, though BNYDC will also look to leverage private development and funding, city budget allocations, and federal and local grants for transportation, open space, and economic development to implement these resiliency measures.



1. Introduction

Introduction

The Brooklyn Navy Yard is a critical regional asset for the Borough of Brooklyn, New York City, and the surrounding New York Metropolitan region. As a mission-driven industrial park managed by the Brooklyn Navy Yard Development Corporation (BNYDC) , the non-profit tasked with property management and real estate development, the Yard is home to 500 businesses employing more than 11,000 people and generating over $2.5 billion per year in economic impact. The Yard has a rich history as a regional economic anchor in New York that dates to the 18th century. The site was a military facility until the 1960s which peaked during WWII, with as many as 80,000 workers employed on-site.

Today, the 300-acre waterfront asset is a home for modern manufacturers- including an incubator for innovative new companies, academic institutions, and a center for workforce development that offers a critical pathway to the middle class for many New Yorkers. The City of New York is a key partner, as the owner of the property. The regional impact of the Brooklyn Navy Yard—and the site's vulnerability to climate hazards—creates the need for a comprehensive resilience strategy and adaptation actions to ensure that critical infrastructure and major employers remain operational during and after extreme weather events today and in the years to come.

The Brooklyn Navy Yard has an extensive 3-mile shoreline within Wallabout Bay and sits within flood hazard zones subject to sea level rise, storm surge, and wave action. During Superstorm Sandy in October 2012, portions of the Yard were inundated with four to six feet of water, which penetrated substations, basements, ground floors and lobbies, boilers and boilers housings, and dry docks. The storm surge damaged vehicles and structures in addition to tenant spaces, equipment, and inventory. Flooding in the basement of the Yard's Cogeneration Facility knocked out power to the Yard, delivering a complete power loss for two days after the storm during which generators were relied on from October 31st until December 1st, 2012. The Yard experienced $100 million worth of damage during Superstorm Sandy that heavily impacted the operations of many of the Yard's tenants.

The Brooklyn Navy Yard has also experienced flood damage from other storm events. In 1992, a winter nor'easter storm caused significant damage to the site and region. Record high tides, wind gusts, rain, snow, and severe storm surge inundated assets on site and required evacuation of personnel. In September 2021, the Brooklyn Navy Yard again experienced flood damages, this time from the effects of intense rainfall. Hurricane Ida dropped several inches of rain in one hour on Brooklyn causing flooding in low-lying areas and surcharging sewers. BNYDC staff reported backups and overflows at catch basins onsite.

Given the important economic, historical, and social value of the Brooklyn Navy Yard to New York City and the region, BNYDC has developed this Resilience Strategy to determine the extent of climate hazards and risks to the Yard and its assets over the short and long-term in addition to identifying mitigation strategies to protect the Yard from these climate risks. The Resilience Strategy builds upon the Preliminary Resiliency Risk Assessment (2017) and Mitigation Strategies and Master Plan Exercise (2018) and the completed by BNYDC. The devised strategy includes both resilience measures that mitigate risk at the asset level and sitewide while recognizing site constraints and fostering alignment with development goals. These immediate and long-term actions align with the vision for regional resilience by City, State, and Federal stakeholders and nearby precedent projects established throughout the last decade. It is expected that implementing each of the recommended actions in this Strategy will require an adaptive resilience planning approach that accounts for various grant funding sources, development partnerships, a construction phasing plan based on flood risk, and alignment with the BNY Master Plan Exercise.

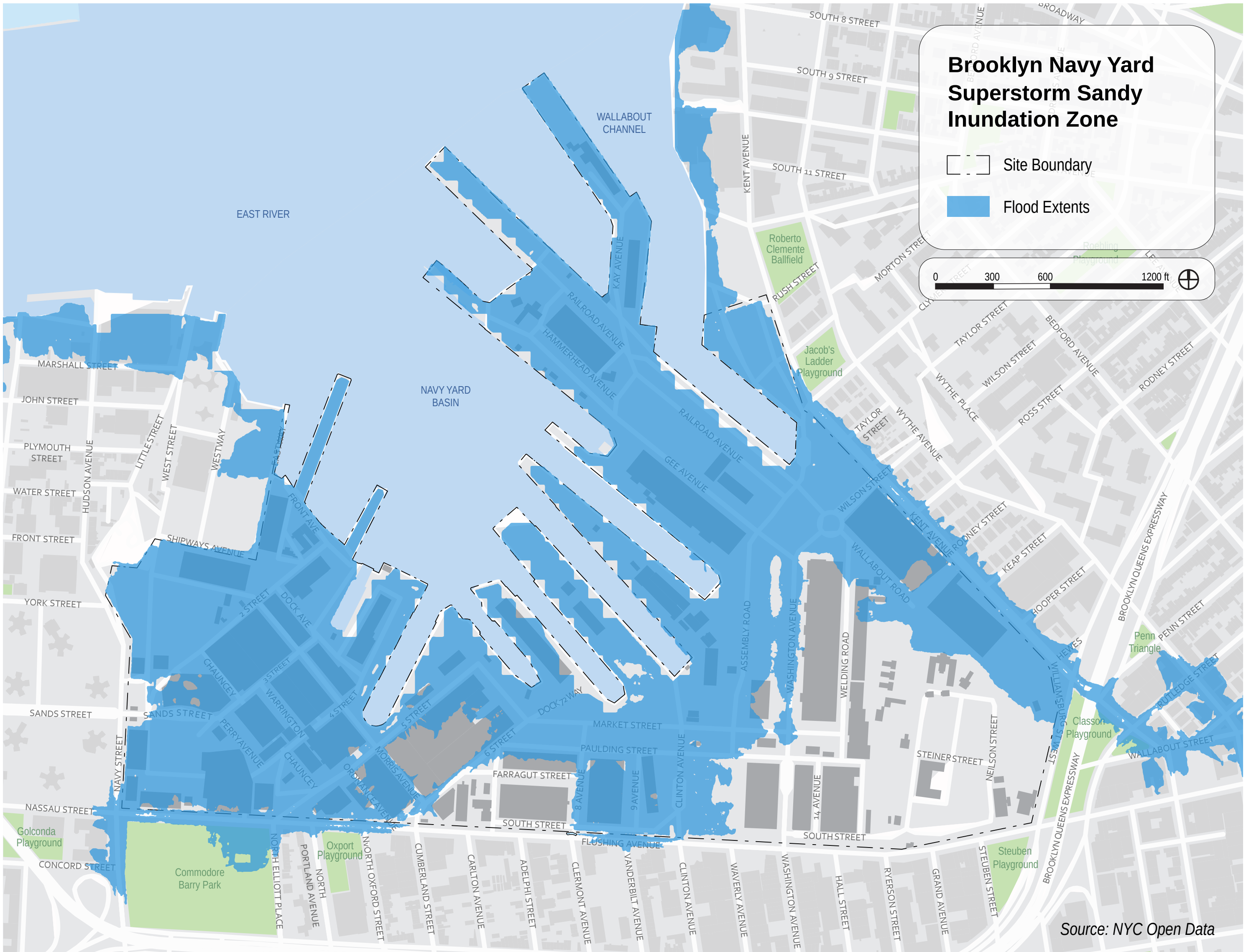
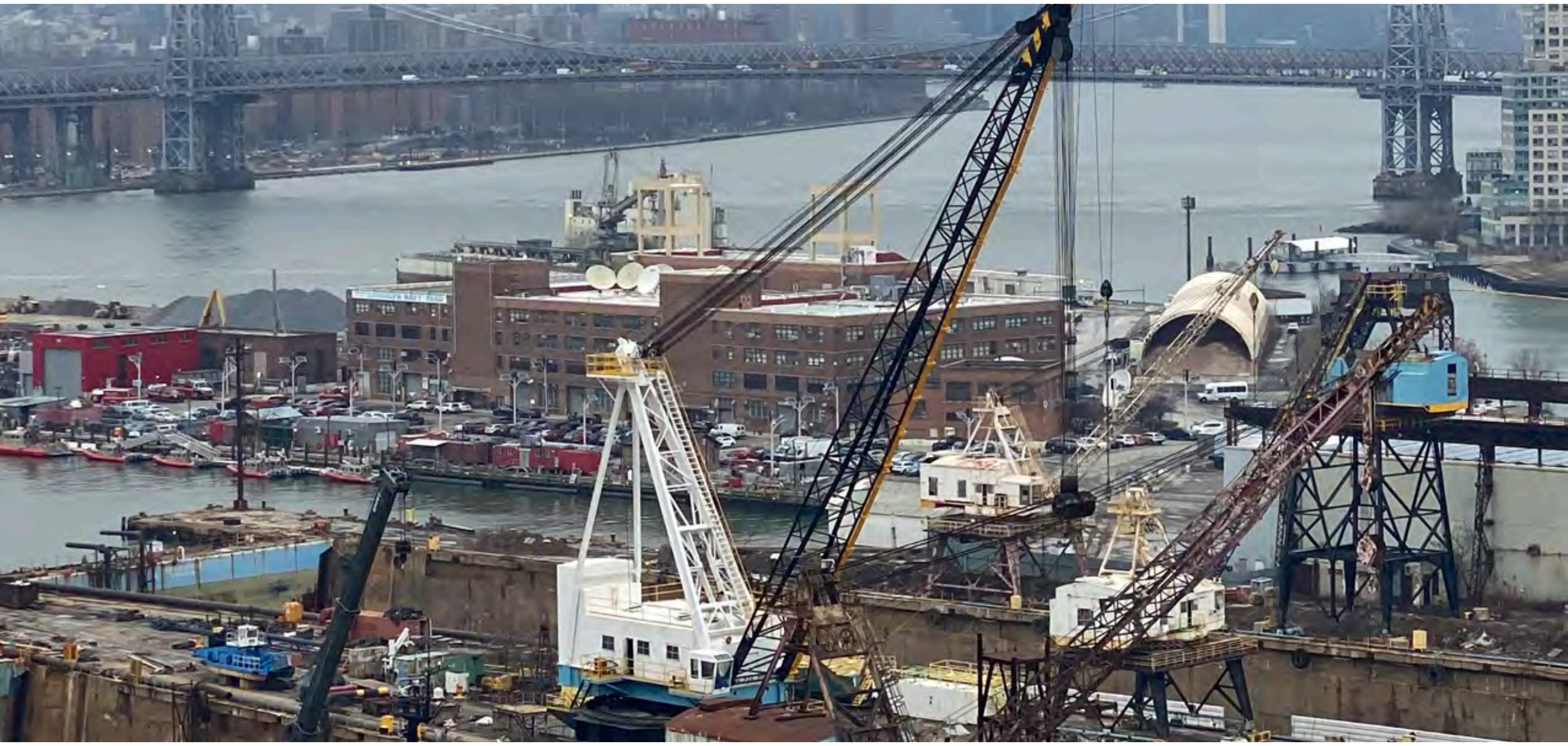


Figure 1. Flooding Extent of Superstorm Sandy at Brooklyn Navy Yard

Sandy flooding at Brooklyn Navy Yard

Flooding at the berths during Superstorm Sandy



2. Planning Context

Regional Resilience Context

Regional resilience has become a top priority for communities and government leaders in the metropolitan region. New York, New Jersey, and other neighboring states have recognized the now common and ever-present threat of climate hazards and the inherent interconnectedness of our critical infrastructure, economies, and growing populations. The Brooklyn Navy Yard Resilience Strategy will align with the overall vision for regional resilience and nearby precedent projects established throughout the last decade, including Rebuild by Design – Meadowlands, Rebuild by Design – Hudson, Rebuild by Design – The Big U, Governor's Office of Storm Recovery – Living Breakwaters, the NYC Special Initiative for Rebuilding and Resiliency, the NYC Mayor's Office New Normal Report, the suite of projects that make up the Lower Manhattan Coastal Resiliency initiative, and countless others.

The complete vision for the Brooklyn Navy Yard Resilience Strategy is to add to the many ongoing resilience projects already in progress in New York Harbor and the metropolitan region. Several high-value, complex resilience projects are already underway directly across the river from the Yard on the Manhattan side of the East River including the East Side Coastal Resiliency project (NYC Department of Design and Construction) and the Lower Manhattan Coastal Resiliency Project (NYC Economic Development Corporation, NYC Department of Parks & Recreation, Battery Park City Authority) which consists of four capital resiliency projects totaling $900 million in construction value (Brooklyn Bridge Montgomery Coastal Resilience, The Battery Coastal Resilience, the Seaport Coastal Resilience, and the Battery Park City Resilience Projects – North, West, and South). While each of these large-scale coastal resilience projects are designed to protect vulnerable areas of Manhattan, the recommended projects in this Strategy will be one of the first large-scale resilience projects along the East River in Brooklyn since Superstorm Sandy. The proposed project will protect one of the region's few remaining industrial and manufacturing campuses, while not hindering the operations of the Yard's multiple maritime uses and providing co-benefits that serve disadvantaged communities in the neighborhoods surrounding Wallabout Bay.

Benefits to Local Communities

The Brooklyn Navy Yard is steadily becoming a central business district for urban manufacturing, now home to 500 businesses and approximately 11,000 jobs including major employers such as GMD Shipyard, Steiner Studios, New Lab, and Duggal. Businesses at BNY include traditional manufacturers, innovative manufacturers, and producers/makers. Future development plans include projections for about 5.1 million square feet of commercial and industrial space and 10,000 additional jobs on-site. In addition to the regional economic impacts stemming from the Yard's businesses and $2.5B yearly economic output, The Brooklyn Navy Yard is an invaluable asset for the local community. Undertaking resiliency measures could greatly benefit the communities outside of the Yard's boundaries.

Due to climate change, the 100-year storm event by mid-century will cause storm surge flooding in adjacent public housing facilities and industrial neighborhoods. When completed, the recommended actions in this Strategy will also provide flood mitigation benefits to surrounding lower income neighborhoods. Moreover, neighboring communities benefit from amenities located within the Yard, such as a supermarket that serves an area that would otherwise be a food desert.

Involvement of Regional Stakeholders

Because of its status as a non-profit, anchor economic development institution located on city-owned land, BNYDC's operations and impact extend beyond its campus in Brooklyn. BNYDC operations involve coordination with a wide range of regional stakeholders, including:

New York City: The land is owned by the City of New York and BNYDC receives a portion of its capital budget from the city.

New York City Mayor's Office: The majority of BNYDC's Board of Directors are appointed by the Mayor, therefore its leadership has an understanding of and interest in citywide economic development.

City Council Districts: The remaining four Board of Directors represent City Council Districts 33 and 35 that include and/or border the Yard. Therefore, its leadership is a collaborative effort between different council districts and includes representation from the surrounding community.

New York City Agencies: Because of its economic development mission and waterfront location, BNYDC coordinates with several New York City Agencies on a regular basis, including the NYC Department of Small Business Services, NYC Economic Development Corporation, NYC Department of Environmental Protection, and NYC Department of Education. BNYDC also maintains an extensive partnership with NYC Department of City Planning as a special zoning district, and relationships with the New York City Department of Transportation and the Metropolitan Transportation Authority.

State and Federal Agencies and Utilities: For in-water construction, BNYDC coordinates with New York State Department of Environmental Conservation. The Brooklyn Navy Yard Resilience Project is consistent with the flood protection objectives of the US Army Corps of Engineers NY & NJ Harbor & Tributaries Focus Area Feasibility Study. Critical infrastructure within the Yard is operated by, and/or contributes to, energy resources generated by ConEdison and National Grid.

Private Sector: BNYDC partners with larger tenants that employ many workers from around the region, such as GMD Shipyard and Steiner Studios.

BNYDC believes that the manufacturing sector will continue to flourish in New York, employing a diverse cross-section of New Yorkers in jobs that offer real career pathways to the middle-class. BNYDC's vision is a vibrant and dense, modern manufacturing community where businesses are provided the stability needed to invest, grow, and thrive. As more and more businesses lease space at BNY and the economic opportunity at the Yard increases, BNYDC will continue its strong track record of partnering with the local community to ensure residents are able to take part in those opportunities.

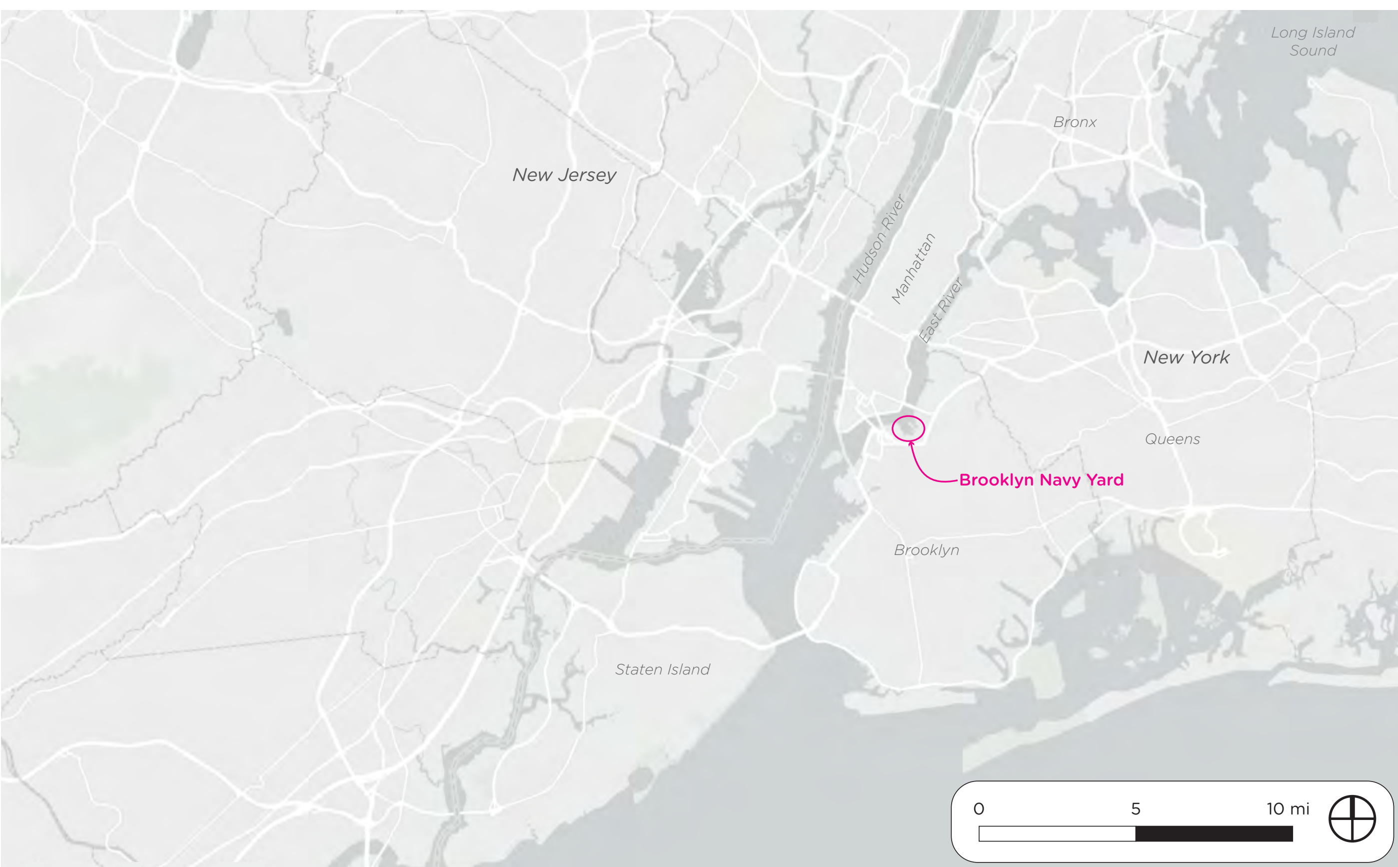


Figure 2. Brooklyn Navy Yard Regional Context

Contextualizing Resilience at the Brooklyn Navy Yard

The Brooklyn Navy Yard is a confluence of economic development drivers for Brooklyn, the five boroughs, and beyond, and its tenants also have a broad regional impact. Assets within the Brooklyn Navy Yard that will benefit from this Strategy include:

Marine and Coastal: The Brooklyn Navy Yard features four of the few remaining graving docks in the Northeastern United States and is one of only two active shipyards (GMD Shipyard and Bayonne Dry Dock) in the entire New York/New Jersey harbor.

Public Safety: The Fire Department of New York (FDNY) Marine 6 station and boat repair facility is located within the Navy Yard.

Utility Infrastructure: A Cogeneration Plant on site provides power for the Yard and Manhattan. The National Grid Gate Station provides service for Downtown Brooklyn.

Regional Construction Materials: Transfer facilities on site import and distribute cement, sand, and gravel for construction projects throughout the metropolitan region.

Transportation: The Yard is the site of the NYC Ferry Homeport, with boats that provide transportation throughout and between the five boroughs. The Navy Yard also operates its own last-mile shuttle service, including fleet storage, which serves many of the Yard's employees. Additionally, the Metropolitan Transportation Authority operates critical bus lines within and directly adjacent to the Yard.

Economic Development: The Brooklyn Navy Yard is steadily becoming a central business district for urban manufacturing, with approximately 4.3 million square feet of space under its roof. It is home to about 500 businesses and approximately 11,000 jobs in sectors including technology, design, and manufacturing. Future development plans include projections for an estimated 5.1 million square feet of commercial and industrial space and 10,000 additional jobs on-site.

Workforce: BNYDC operates an Employment Center, focusing on helping employers build a local workforce which strongly encourages candidates from within the surrounding community. The Employment Center works closely with veterans, individuals who have previously been involved in the justice system, and others seeking employment. The Employment Center also partners with the New York City housing Authority to make job opportunities available to residents.

Historic Preservation: The Yard is home to three locally designated landmarks, including Dry Dock 1 designated by the NYC Landmark Preservation Commission in 1975, and many New York State listed and eligible sites, many of which are especially vulnerable to wave actions and climate hazards. The Brooklyn Navy Yard Historic District is listed on the National Register of Historic Places.

Education: The Yard is home to the STEAM (Science Technology, engineering, arts, and math) Center at Building 77, which provides Career and Technical Education (CTE) to students eight local high schools in Brooklyn. The current Center serves as a model for a new STEAM high school opening in Manhattan.

The Yard houses businesses that receive and stage local construction materials that support the regional construction industry (e. g. concrete aggregate, sand, milled stone, etc.), as well as first responder services (i.e. Fire Department of New York Marine station), and, is also home to the largest film and television production studios outside Hollywood in the United States, Steiner Studios. In addition to these community and regional assets, the Navy Yard is also the Homeport for the NYC East River Citywide Ferry Service. The NYC Ferry Service Homeport provides space for 21 ferries to fuel, pump waste, receive maintenance, and dock overnight – the citywide ferry service provides a new, affordable way to travel between waterfront communities throughout the five Boroughs of New York City and is an important link in the regional waterborne transportation system between New York and New Jersey. The six routes span over 60 nautical miles of waterways and will connect New Yorkers and visitors to the city's waterfront communities – including neighborhoods, job centers, and parks.

Site Conditions at The Yard

To accommodate the diversity of marine, manufacturing, and commercial activity at the Yard, site conditions vary significantly. Characterizing the different zones of the site, building types, and waterfront edge conditions is essential for designing a resilience strategy tailored to preserving the site's function. Waterfront areas at the Yard vary in use and accessibility. The 3-mile shoreline is dotted with dry docks, vessel berths, boat launches, as well as open spaces. The waterfront edge conditions at the Yard are summarized below.

Working Waterfront: These are areas that require regular and direct access from the shoreline to vessels docked on the water. This edge condition encompasses much of the shoreline of BNY and dictates the types of coastal flooding measures that can be considered for much of the site. Examples include:

- Piers J and K: Active barge traffic is needed to transfer construction materials on and offshore.
- GMD Shipyard: Dry docks and caissons require direct access to docked vessels.
- NYC Ferry Home Port: Access to the NYC ferry pier cannot be obstructed.

Semi-Public Waterfront: These are areas that are not currently used for active working waterfront activities but are also not currently accessed by the general public. These sites must be evaluated to determine whether flood protections can be placed directly at the water's edge or must be set back to allow for waterfront access. Examples include:

- Parking area at the base of Pier G and Pier J.
- Dry dock 3, alongside Dock 72.
- Parking area in between Pier C and Pier D.

Public Waterfront: Public waterfront areas may have more flexibility in terms of future edge conditions. Since these portions of the shoreline are not used for working waterfront activities, it may be feasible to construct protective measures up to the shoreline. In these cases, protective measures can be designed so that they are incorporated into broader urban design goals, such as a waterfront promenade or parkland. Examples include:

- The proposed promenade along the Barge Basin.
- The proposed open space north of Building 131, which could be designed as a living shoreline.

GMD Shipyard

Dry Dock 2

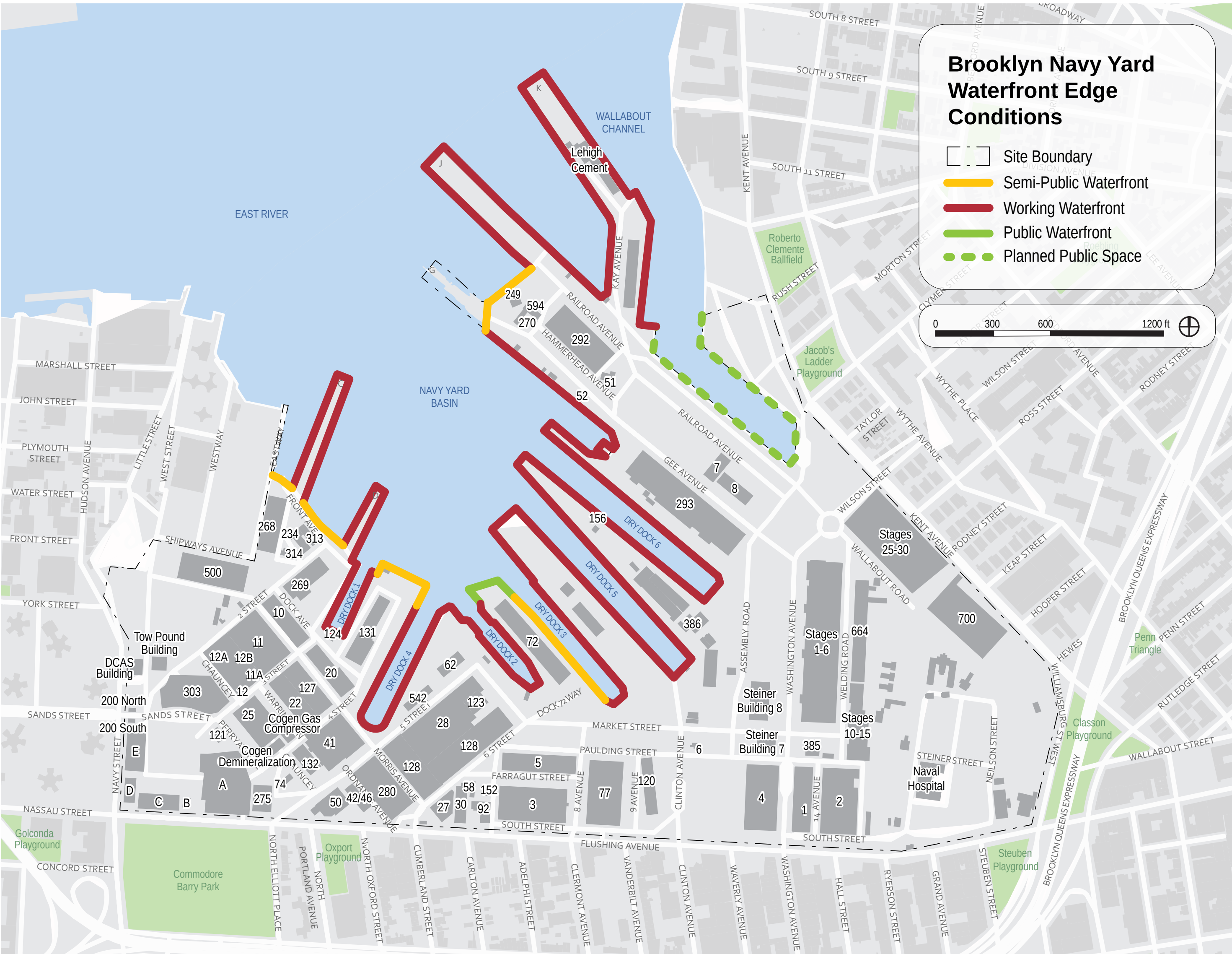
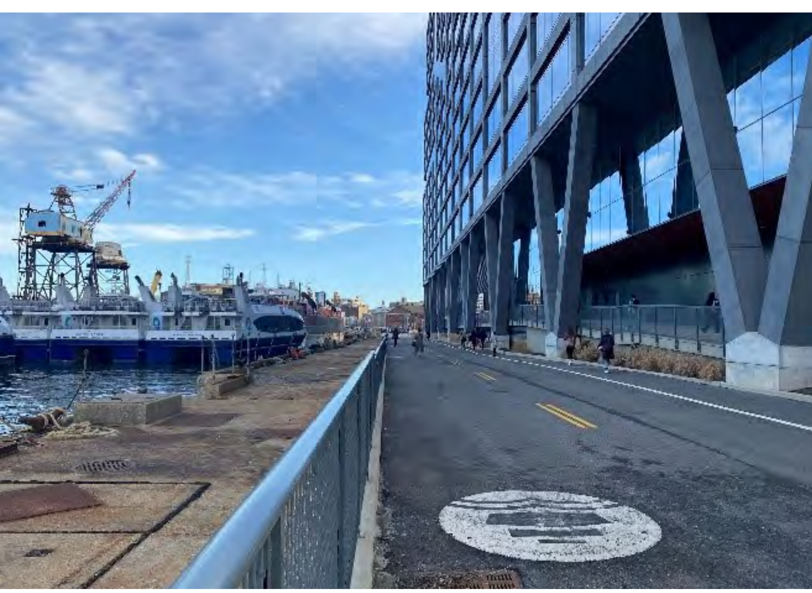


Figure 3. Edge Conditions/Use Types Diagram

Dry Dock 3/Dock 72



Barge Basin

Figure 4. Brooklyn Navy Yard Asset Inventory Map

Asset Inventory

An asset inventory has been prepared for Brooklyn Navy Yard to catalogue the structures onsite and make judgements about their criticality to the safety, public health and welfare, economic activity, and environmental conditions for the site and region. An inventory of building assets in the Brooklyn Navy Yard was prepared in accordance with BNYDC archives and supplemented by staff knowledge. Building data was extracted from the November 26, 2019 Resiliency Data spreadsheet which transcribes design and construction documents, archival information, as well as plans, maps, and drawings. In this data source, assets are described by ownership, occupant(s), year built, last renovation, gross square feet, substation location, and design flood elevation where available. Utility, management systems, and planned construction were not included in this asset inventory. The full building asset inventory for the Yard can be reviewed in Appendix A. Figure 4 maps building footprints of assets included in the inventory.

In subsequent analysis, the asset inventory is used to rank the exposure of assets to climate hazards. Overlaying asset criticality with asset exposure will inform which assets, groups of assets, and areas of the site should be prioritized in recommended resilience actions.

Prior Studies

This Report synthesizes the prior findings of the 2017 Preliminary Resiliency Risk Assessment and Mitigation Strategies and the 2018 Master Plan Exercise as a foundation for the Resilience Strategy.

Preliminary Resiliency Risk Assessment and Mitigation Strategies

The Preliminary Resiliency Risk Assessment evaluates the 1% annual chance storm (100-year storm) with medium to high projection sea-level rise (SLR). Flood elevations at the mid- and end-of-century with SLR projections and 1% chance storm were estimated by New York Department of Environmental Control (DEC) New York Code Rules Part 490 & NYCRR.

Using these projections, models show up to 7.4' of inundation across the BNY site under the 1% annual chance storm and mid-century SLR. The low-lying area on the western portion of the site are vulnerable to between 6.2 and 7.4 ft of inundation. At the waterfront, moderate wave action (waves between 1.5 and 3 feet) is projected to severely impact buildings, resulting in 6.2 to 7.4 feet of flooding and wave impacts. Mid-century floodwater velocities are estimated up to 7.8 mph. The southeast portion of the site and the buildings along Flushing Avenue are less vulnerable to flooding. Based on these projections, the Preliminary Resiliency Risk Assessment divided BNY into three Risk Areas:

- Wave Action Zone
- High Risk Zone
- Moderate Risk Zone

Based on the Risk Zones and vulnerability to critical assets, the Preliminary Resiliency Risk Assessment provided a summary of mitigation concepts that should be considered to protect against flood risk. These mitigation concepts served as a starting point for this Climate Resilience Strategy. The Strategy provides a more detailed climate hazard assessment, complete asset inventory, and vulnerability assessment to further develop recommendations.

BNY Master Plan Exercise

The BNY Master Plan Exercise outlines a Campus of Districts with special programming for key sites planned for development. These areas differ from the High Risk and Low Risk Zones described in the Preliminary Resiliency Risk and Assessment because they are based on planned development activities, rather than vulnerability to flooding and other climate hazards. The following areas and key development sites are identified in the Master Plan.

- **West:** The West development area includes the Historic Core and recently completed development at Admirals Row. In addition, the West area includes potential future

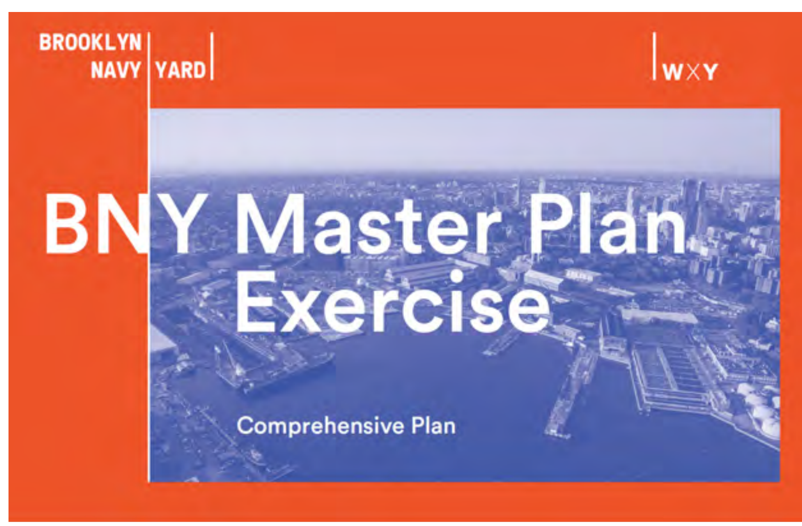


Figure 5. Preliminary Resilience Risk Assessment - Risk Areas

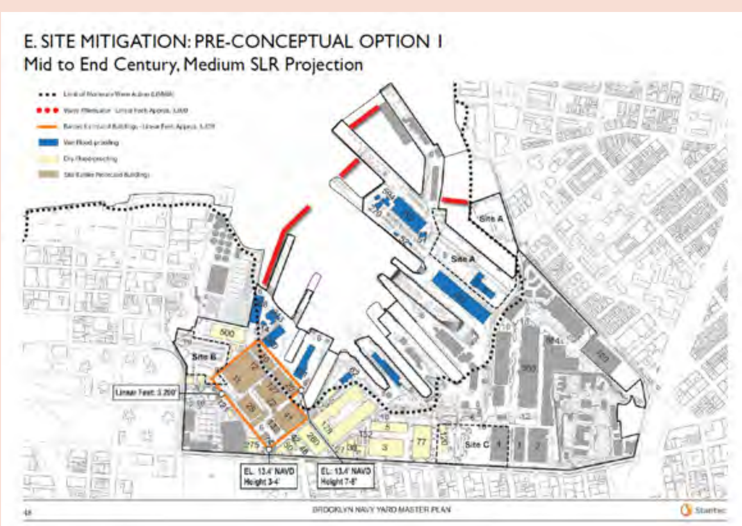


Figure 6. Site Mitigation: Pre-Conceptual Option 1

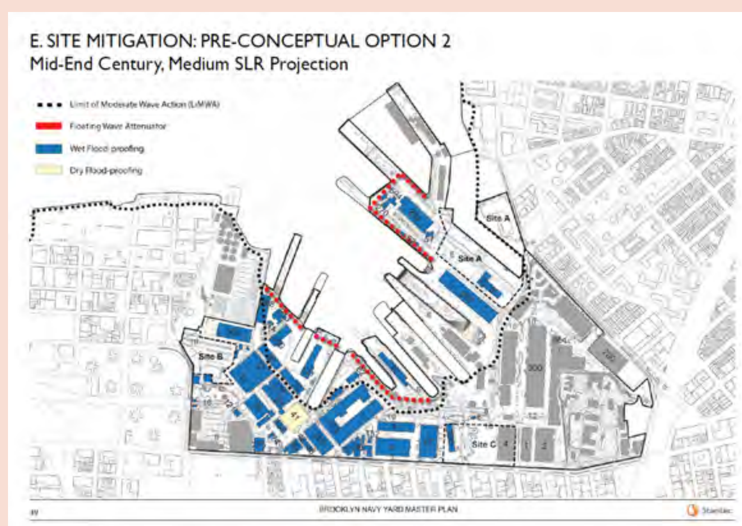


Figure 7. Site Mitigation: Pre-Conceptual Option 2

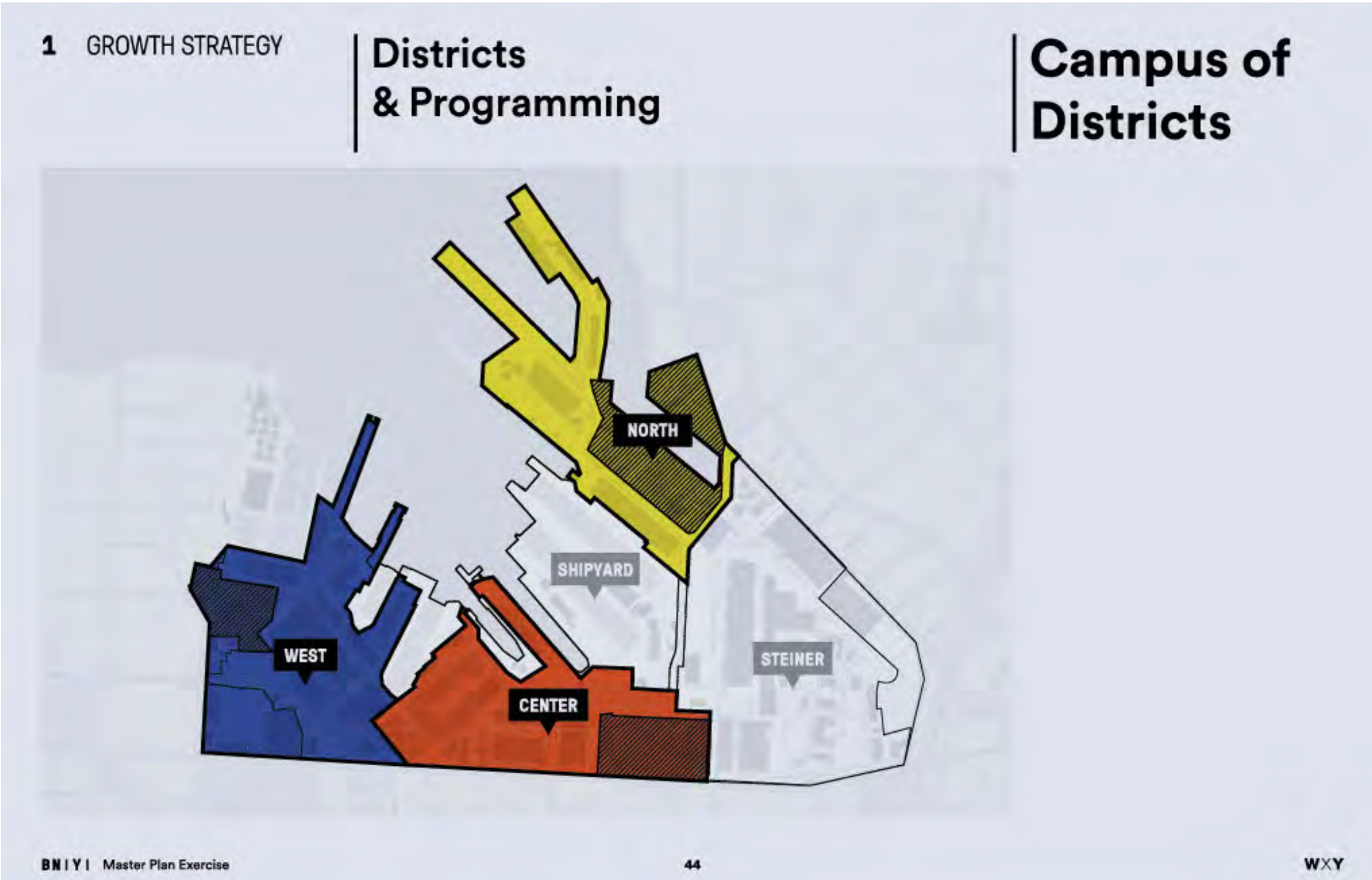


Figure 8. Master Plan Areas

development at the Navy Street site (currently the NYPD Tow Pound).

- **Center:** The Center development area is located along Flushing Avenue and includes Building 77, Dock 72, and New Lab. Potential future development is envisioned at the Flushing Avenue Site (between Building 77 and Washington Avenue).
- **North:** The North development area is located along Kent Avenue, the Barge Basin, and Wallabout Channel. The Kent Avenue sites (on both sides of the Barge Basin) are potential development sites to create a green manufacturing center.
- **GMD Shipyard and Steiner Media Campus:** In addition to the above areas that include future development sites, the GMD Shipyard and Steiner Media Campus are two large areas of the BNY site that each house single anchor tenants.

The above methods for dividing areas of the BNY site are both useful for different purposes. The High Risk and Low Risk Zones (defined in the Risk Assessment) provide an overview of vulnerability to flooding in different parts of the site. The Master Plan Areas help to understand the variations in physical character of different parts of the site, while also highlighting how future development may change uses around BNY.

Figure 9. Ongoing Waterfront Work at Brooklyn Navy Yard

Ongoing Work at the Yard

Surveying, planning, design, and construction projects at Brooklyn Navy Yard present opportunities for coordination and alignment with Resilience work. The work below has projected construction start dates ranging from July 2022 to March 2024. Projects are financed by City Capital, FEMA grants, and BNYDC operating expenses.

- Capital Project Scope Development (CPSD) Study for Office of Management and Budget (OMB)
- Waterfront Work
  - Berth 6 Reconstruction
  - Berth 14A Sinkhole Repairs
  - Berth 9, 10, and 11 Replacements and Small Boat Basin Structural Rehabilitation
  - Pier D Demolition and Bulkhead Replacement
  - Berth 8, 9, 10 Mechanical and Electrical Rehabilitation
  - Dry Dock 5 & 6 caisson replacements, and restoration of Pump Well 156
  - Dry Dock 1 caisson replacement and restoration of Pump Well 124
  - Future project at the Barge Basin

3. Climate Risk Assessment

Introduction

The Brooklyn Navy Yard Climate Vulnerability Assessment combines site-wide and regional climate hazard assessment with key insights from BNYDC staff to understand the vulnerability of the Yard's assets to current and projected climate hazards. As part of the assessment, an inventory of BNYDC building assets was prepared and may be used to guide future resilience investments across the site. Overall, potential flood exposure from coastal storm events and/or intense precipitation events poses the greatest threat to Yard assets. To create this vulnerability assessment, coastal and interior flood exposure was modeled across the site and consequences were estimated on the asset level. Other climate hazards, including wildfire, drought, and air quality, were assessed using best available data for site-wide impacts in the short- and long-term. The Vulnerability Assessment concludes with a short list of vulnerable building assets that are recommended for prioritized mitigation and adaptation measures.

Methodology

To understand BNY's site-wide and asset-specific vulnerabilities to climate related hazards, the project team prepared an asset inventory, assessed hazard exposure across the site, and ranked assets based on their criticality to the site and region in order to draw conclusions on vulnerabilities. The methodology used to rank asset vulnerability includes two parts: exposure and criticality. These terms are defined below as they relate to the Brooklyn Navy Yard assessment.

Exposure to Climate Hazards

Overview of Approach

The consultant team characterized the exposures of the Yard and its assets to physical climate hazards from the present day through approximately 2100. Current conditions and projected changes in climate were characterized using climate models and other hazard data sets for the proposed site location and surrounding region. The climate hazards evaluated were:

- Inland flooding
- Coastal flooding
- Extreme heat and heat stress
- Hurricanes and other tropical cyclones
- Wildfire
- Water stress and drought

Exposure: Evaluation of how much an asset is subject to potential inundation from inland and coastal flood events based on flood modeling.

Criticality: Qualitative composite assessment of the sensitivity, service impact and adaptive capacity.

Vulnerability: a function of exposure and criticality.

A scenario analysis approach was used to account for uncertainty in future changes in greenhouse gas (GHG) emissions. The Shared Socioeconomic Pathway (SSPs) developed for the Coupled Model Intercomparison Project Phase 6 (CMIP6) were used to evaluate changes in temperature, precipitation, and other indicators. These scenarios were developed in support of the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). CMIP5 scenarios, called Representative Concentration Pathways (RCPs), were used for hazard data sets that have not yet been updated to the CMIP6 projections. The

Table 1. Climate Hazard Exposure Rating System for Site-wide Hazards

Score	Hazard Rating	Level of Recommended Action Based on Modeling Results
4	Very High	Imminent hazards for which adaptation strategies should be evaluated and developed as necessary
3	High	Hazards for which adaptation strategies may need to be developed in the near future or for which further information is needed
2	Medium	Hazards for which impacts should be monitored but may not need action at this time
1	Low	Low modeled exposure; may be re-evaluated in the future

Table 2. Brooklyn Navy Yard Projected Climate Hazard Exposure

Hazard	Timeframe	Hazard Rating
Extreme Heat	2030	Medium
	2050	High
	2080	Very High
Wildfire	2030	Low
	2050	Low
	2080	Low
Drought	2030	Medium
	2050	Medium
	2080	Medium

assessment considers two GHG scenarios that span a range of possible futures: a high emissions scenario (SSP5-8.5/RCP 8.5), in which GHG emissions continue to increase with time, and an intermediate scenario (SSP2-4.5/RCP 4.5), in which GHG emissions level off and start to decline by mid-century. High-resolution ("downscaled") climate model projections for each GHG scenario were used to perform a quantitative, screening-level evaluation for the site. Climate models are computer simulations of the earth's climate system, including the atmosphere, ocean, biosphere, and land surface. A climate model is provided with information about how GHG concentrations may change in the future (e.g., the SSP scenarios). The climate model then simulates the response of the earth's climate system to the specified changes in GHGs.

Site-wide Hazard Exposure

Extreme heat, wildfire, and drought hazards were qualified at the site-level based on the findings of the Climate Hazard Exposure Report. The site's exposure to the evaluated climate hazards were rated from low to very high considering the probability that the climate hazard will occur and modeled magnitude of exposure. Each hazard is scored independently. The exposure ratings are intended to represent the need for more detailed vulnerability assessment and development of resilience strategies. The ratings do not account for the specific characteristics of the site including any existing resilience measures and instead represent only the exposure of the location of the site. Each hazard is scored independently. For example, rising temperatures can contribute to increasing wildfire risk, but the heat stress rating only considers the potential impacts of heat on the site (e.g., increased cooling costs). The projected impacts of changing temperatures (and other climate indicators) on wildfire and other hazards are accounted for directly in the rating of those hazards.

The findings of this regional assessment are summarized below. Extreme heat is a significant hazard to the Brooklyn Navy Yard and is expected to worsen as the century progresses. Long-term planning and adaptation strategies are recommended to mitigate the effects of extreme heat. Wildfires pose low risk, though regional effects on air quality should be considered. Drought poses a consistent moderate threat to the region and should be monitored. For the full climate hazard assessment, including projection methodology, forecasts, and maps, please see Appendix B for the Climate Hazard Risk Assessment and Appendix C for the Climate Risk Assessment Tables.

Flood Exposure

Flood exposure is the most imminent and extreme threat to current operations at the Brooklyn Navy Yard. Not only is the Yard responsible for a long and complex shoreline, but it is also a regional topographic low point, downstream of a large urban watershed, and serviced by aging sewer infrastructure. Flood events are projected to increase in probability and intensity by the end of the century. Flood exposure of buildings was assessed as the maximum depth of flooding at a building under the following storm conditions:

Coastal Storm Event:

- 1% extreme water level event in 2018 with Mean Higher High Water (MHHW) tide, storm surge, wave action and present-day water levels.
- 1% extreme water level event in 2050 with Mean Higher High Water (MHHW) tide, storm surge, wave action and intermediate high 2050 SLR projection.
- 1% extreme water level event in 2100 with Mean Higher High Water (MHHW) tide, storm surge, wave action and intermediate high 2100 SLR projection.

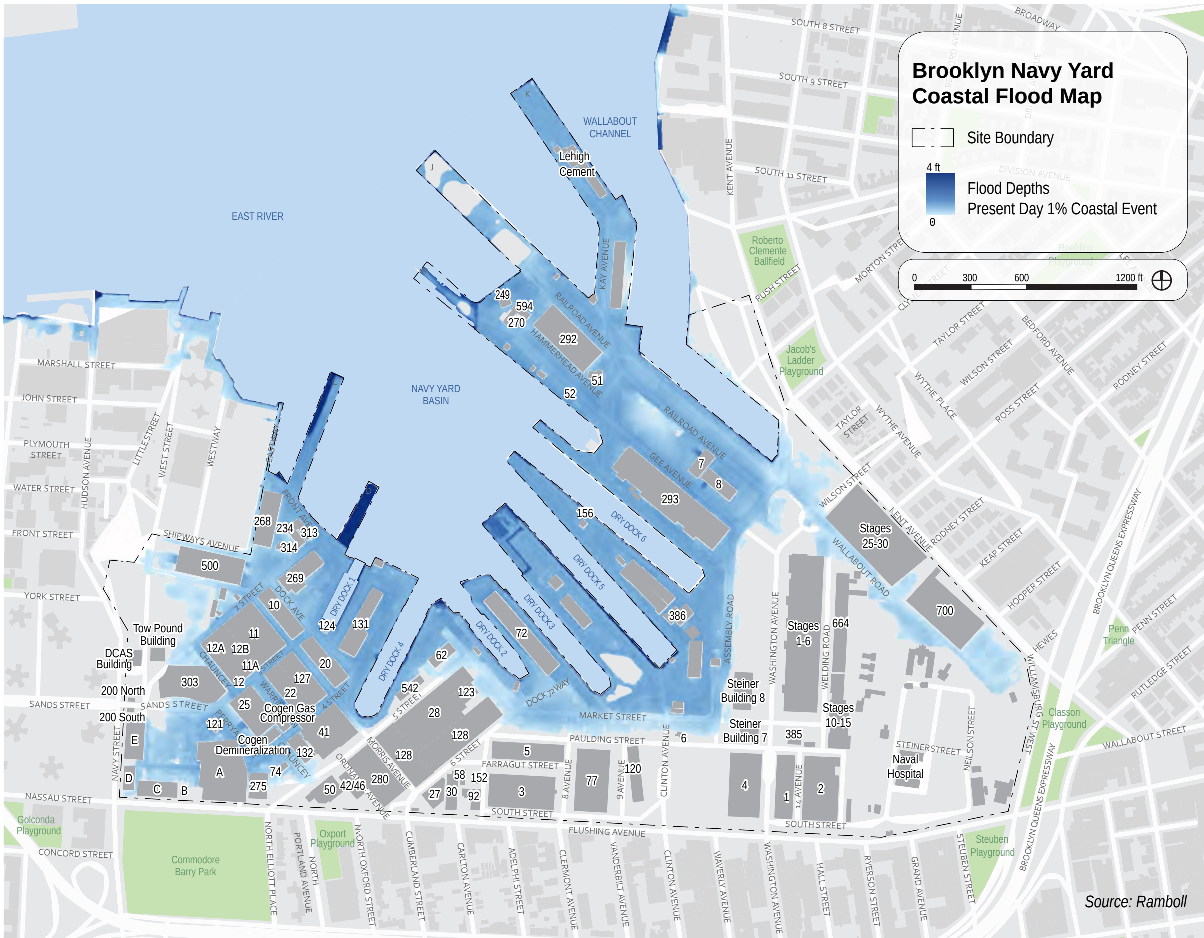
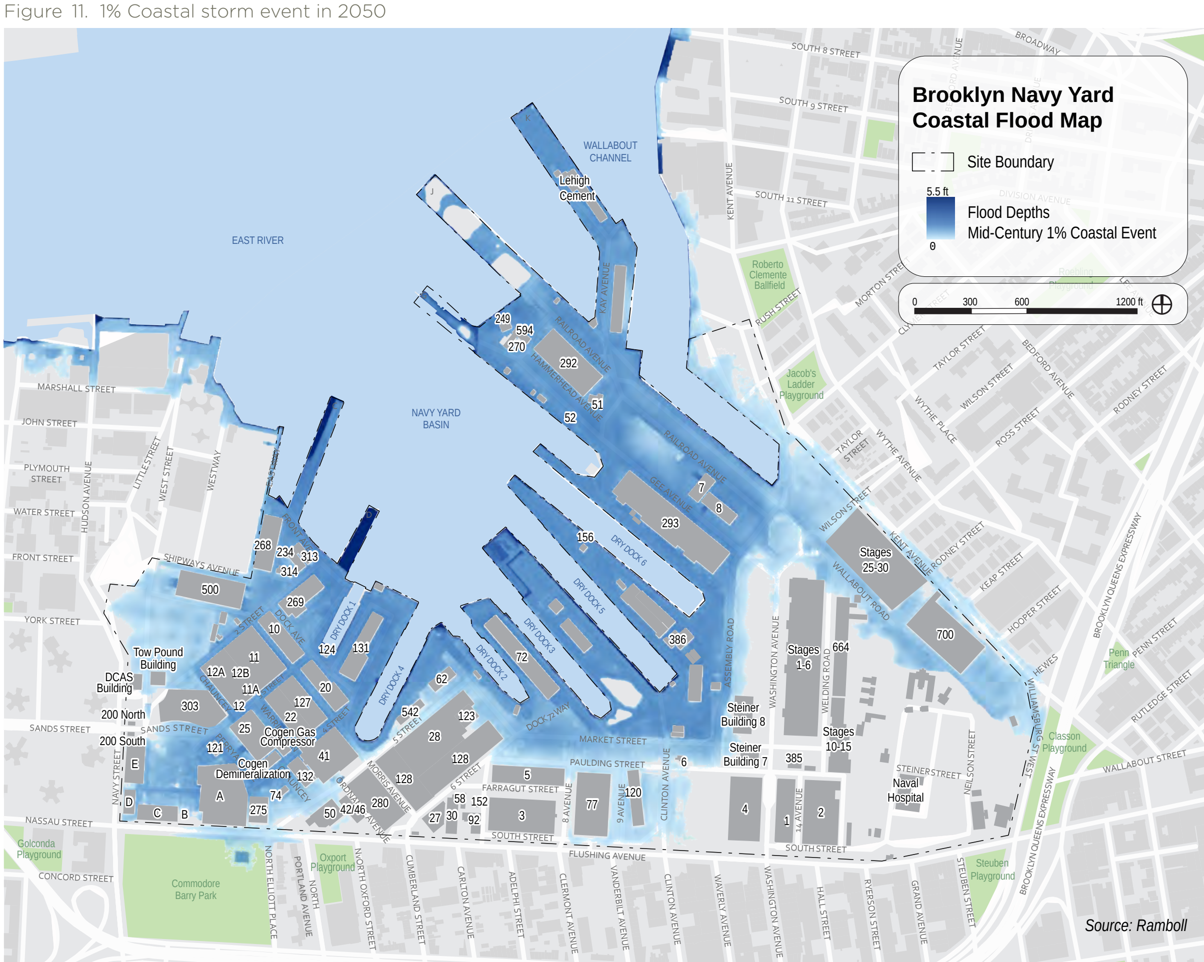


Figure 10. 1% Coastal storm event in Present Day

Figure 11. 1% Coastal storm event in 2050



Inland (Precipitation) Storm Event*:

- 1% return period storm event of 60-minute duration in 2018.
- 1% return period storm event of 60-minute duration in 2050.
- 1% return period storm event of 60-minute duration in 2080.

*All inland storm projections assume a SSP2-8.5 emissions scenario and that sewers relieve 1.65 in/hour of rainfall per NYC DEP operating guidance.

Terrain-based model results for each storm event were exported as raster files and overlayed geospatially with asset base maps. The maximum depth of flooding within 10 linear feet of each asset was extracted for each storm event and the consequence of flooding was scored based on the thresholds in Table 3.

Table 3. Quantitative Thresholds for Flooding

Score	Consequence	Quantitative Threshold Low (feet)
5	Significant	15+'
4	Substantial	6' – 15'
3	Moderate	2' – 6'
2	Minor	0.5' – 2'
1	Insignificant	0' – 0.5'
0	No Impact	0'

During Superstorm Sandy in October 2012, areas of the Yard were inundated with four to six feet of water, which penetrated substations, basements, ground floors and lobbies, boilers and boilers housings, and dry docks.

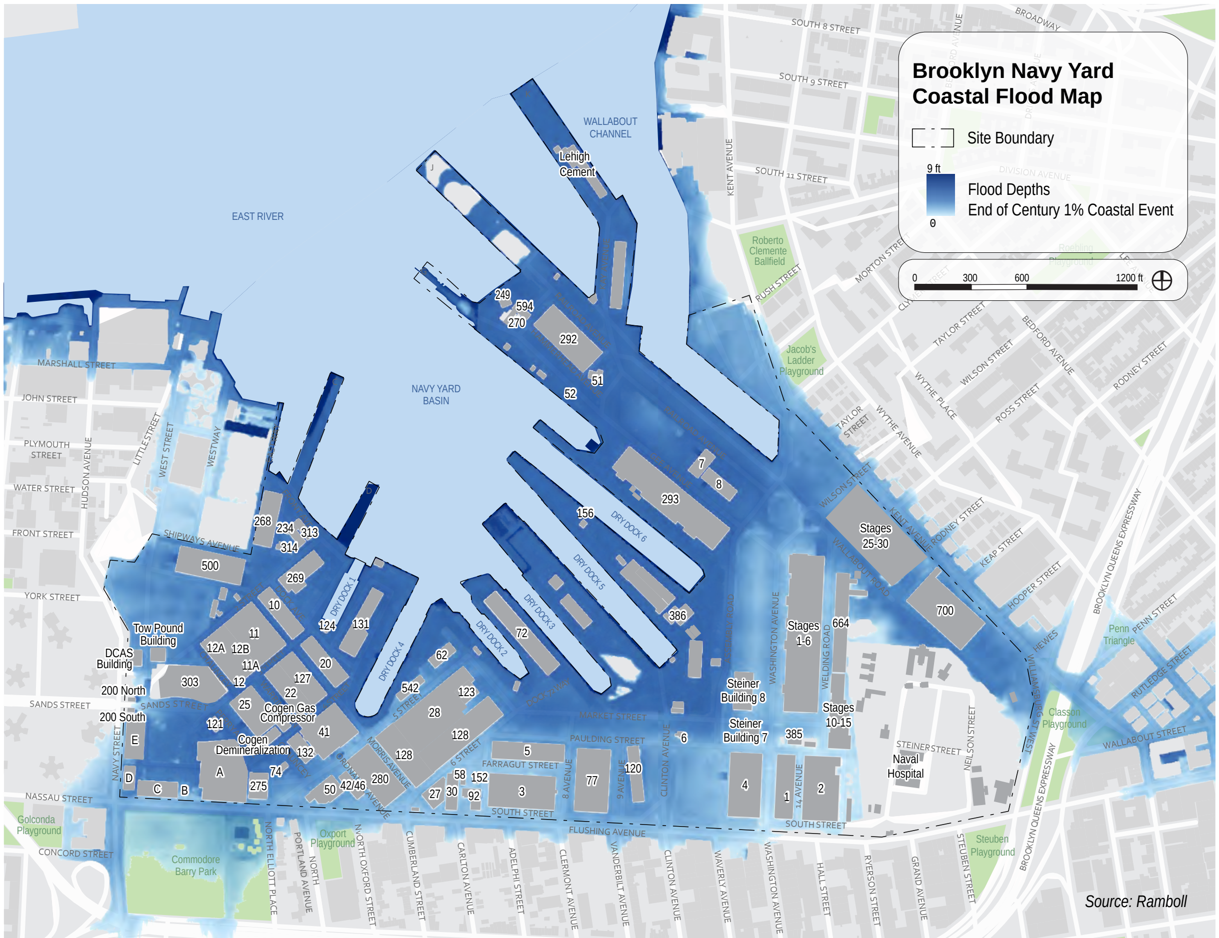


Figure 12. 1% Coastal storm event in 2100

Figure 13. 1% Precipitation event in 2018

Criticality

In a coordinated exercise with BNYDC staff, building assets were ranked by their criticality to the site and the region. Criticality rankings reflect the scale of impact an asset has on health and safety, economic and business operations,

Vulnerability

Vulnerability to climate related hazards was computed as a function of the hazard exposure scoring and asset criticality scoring. The comparative vulnerability score for each asset was

Limitations

This vulnerability assessment is limited to building assets due to data availability. Investigation of nearshore and in-water assets, as well as onshore utilities (underground and structure-housed), management and communication systems, emergency management systems, access routes, and assets planned for construction, is recommended.

The terrain-based modeling approach used to understand flood hazard exposure is a high-level static model not intended for design purposes. Digital elevation models of 1-foot accuracy were used from publicly available 2017 surveying. Future modeling should reflect sewer locations or capacity, and if possible, capture the dynamics of wave action or potential coincidence of a combined coastal-inland storm event.

Refer to the 2023 Capital Project Scope Development Study for a detailed risk assessment of buildings in the wave action zone.

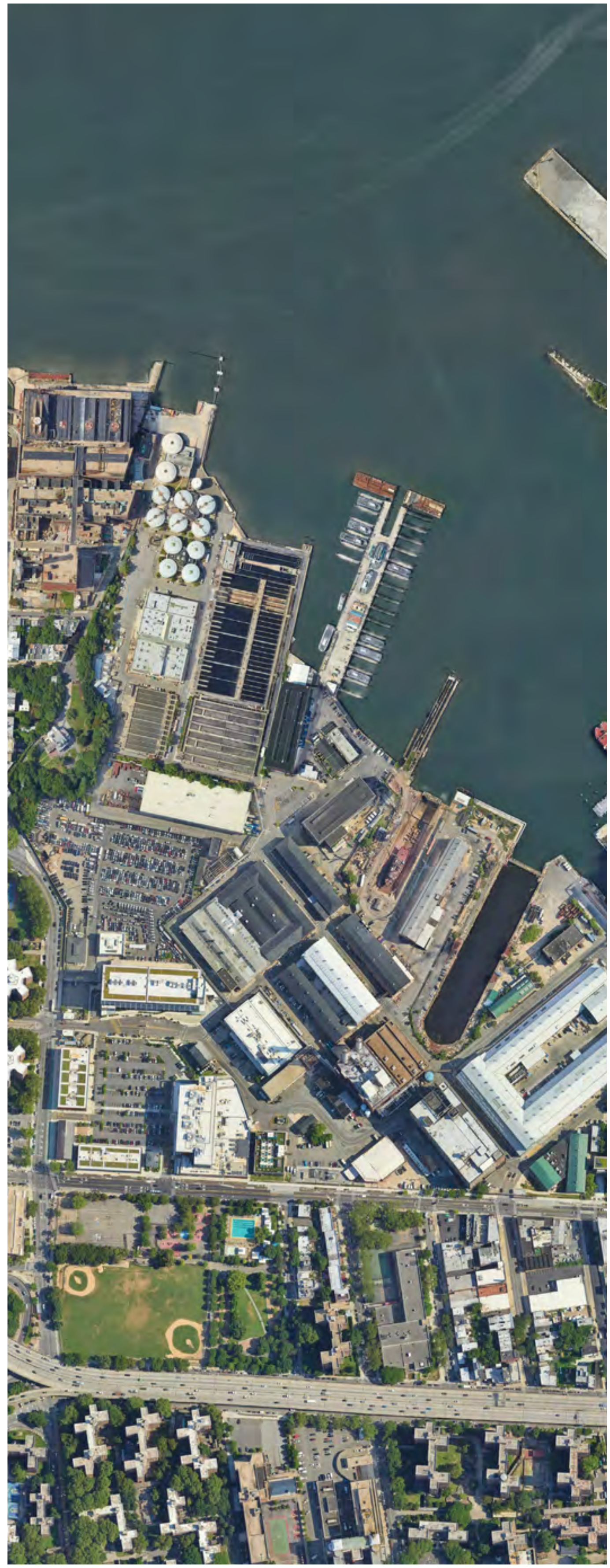


Table 4. Metrics for Ranking Asset Criticality

Score	Scale of Impact	Health/Safety	Economics/Business Operations	Community	Environment
4	Catastrophic	Risk of multiple significant injuries or fatalities or long-term health impacts	Significant building, asset, or infrastructure damages that would prevent continuity of business operations for a period of 6 months or greater and/or requires major reconstruction	Significant portion of Brooklyn/NYC is impacted by the loss of essential services, long-term displacement, and/or intolerable living conditions for a period of 6 months or greater	Irreversible damage to the environment, significant management efforts needed to deal with compliance failure, and/or widespread and significant hazardous waste release with exposure
3	Major	Isolated risk of serious injury or fatality or medium-term health impacts	Extensive building, asset, or infrastructure damage that would prevent continuity of business operations for a period of 1 – 6 months and/or requires major repairs	Some of Brooklyn is impacted by the severe disruption of essential services, temporary displacement, and/or difficult living conditions for a period of 1 – 6 months	Severe and continuing damage to the environment, significant management efforts needed to deal with compliance failure, and/ or substantial hazardous waste release
2	Moderate	Risk of moderate injuries or short-term health impacts	Building cleanup, minor repairs, or replacements of equipment required that would prevent continuity of business operations for a period of 2 – 4 weeks	Entire neighborhood affected by loss or frequent disruption of essential services and/ or challenging living conditions for a period of 2 – 4 weeks	Minor, reversible damage to the environment, action needed to restore compliance, and/or hazardous waste release with limited exposure
1	Minor or Insignificant	Risk of minor injures, near misses, and no residual health impacts	Minor cleanup, repairs, or replacements required that would prevent continuity of business operations for a period of 2 weeks or less	Minor number of people are affected by intermittent disruption of essential services for a period of 2 weeks or less	Negligible damage, minor breaches in compliance, easily resolved

Climate Risk Assessment Findings

Hazard Exposure

In most cases, flood exposure of building assets at BNY is of greater consequence under a coastal storm event, than under a precipitation event; however, some interior buildings outside of the coastal flood zone are at risk of precipitation-based flooding due to depressions in the terrain.

Coastal storm consequence results demonstrate increased hazard exposure over the course of the century due to accelerated sea level rise and corresponding emissions projections. By 2100, it is projected nearly three quarters of all buildings in the Yard will face substantial coastal flood risk (flood depths greater than 6 feet) during a 100-year storm. All buildings will face some risk of coastal flooding by the end of century. Inland storm consequence remains more consistent over the course of the century. Buildings located in low-lying areas will consistently face risk of stormwater flooding if they fail to elevate or floodproof. The consequence of flood exposure of assets is shown in Table 7.

Note that flood exposure rankings are based solely on projected depth of flooding and do not reflect floodproofing measures undertaken by tenants.

Critical Assets

Based on the Asset Criticality exercise, buildings were ranked by the scale of impact from minor (1) to catastrophic (4). Results are tabulated in Table 7. No tenant-occupied building received a criticality score less than 3. Cogen facilities (Building 41, Demineralization Building, and Gas Compressor) received the highest criticality rating due to the sensitivity of the equipment as well as the electrical service implications for BNY and the wider Brooklyn service area.

Prioritizing Assets

The vulnerability ranking accounts for each asset's unique criticality and exposure to flooding. Those buildings with significant exposure to flooding and considerable criticality to the yard and region rank highest. The table below lists the assets from highest vulnerability score, or most vulnerable, to lowest score, or least vulnerable. Note that assets with the same score should be considered equally vulnerable to the impacts of flooding.

Ten Most Vulnerable BNY Buildings:

1. Building 386 (Substation G)
2. Cogen 41
3. Cogen Demineralization
4. Building 22
5. Building 234 (Substation B)
6. Building 542 (Substation C)
7. Cogen Gas Compressor
8. Building 500
9. Building 131
10. Building 270

The top ten most vulnerable building assets should be prioritized for resilience recommendations that both reduce their exposure and promote best practices for safeguarding equipment and operations to improve adaptive capacity and recovery time. Among the most vulnerable assets are Cogen facilities, buildings housing substations, and buildings located along the waterfront or in the low-lying historic core.

Due to recent roadway and drainage improvements, Buildings A, B, C, D, and E were subsequently removed from the analysis as their hazard exposure was reduced through these investments. Similarly, Building 72 was not deemed a vulnerable asset despite its high exposure potential. The building was constructed with proper elevating and floodproofing to protect its structural stability and contents above the 500-yr floodplain. Additional buildings and structures belonging to GMD were removed from the analysis due to limited information on their status.

Vulnerability Tolerance Discussion

In an ideal world, BNYDC would be able to implement adaptation measures that protect against the greatest storm extent (2100 500-year

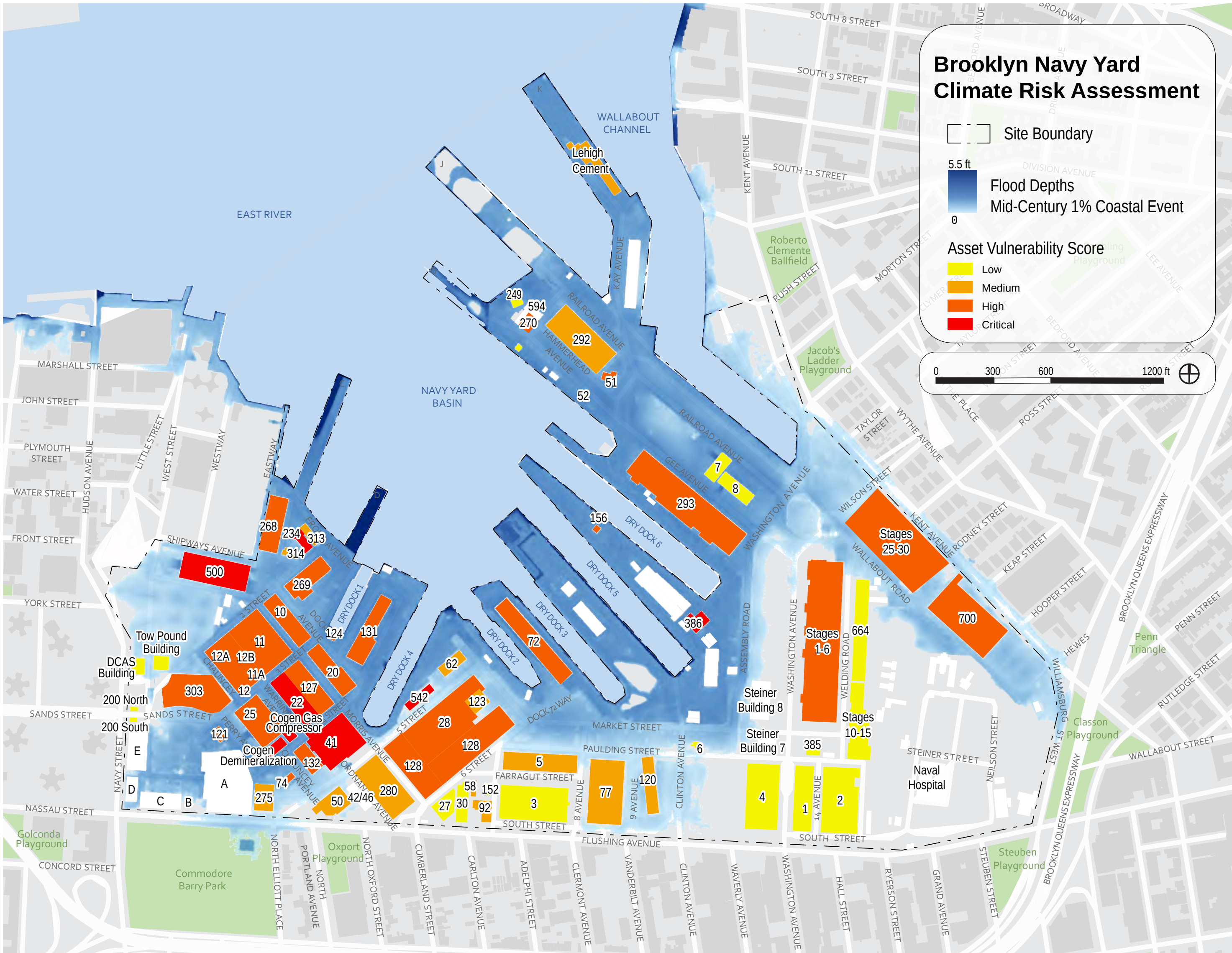


Figure 14. Brooklyn Navy Yard Risk Map

storm). In reality, however, the implementation of flood protection measures bears significant costs which can be prohibitive to construct. The aim of the Resilience Strategy is to provide BNYDC with resilience recommendations that are feasible to enact; therefore, the objective is to determine the level of vulnerability that BNYDC is willing to accept that appropriately balances feasibility and mitigation of flood risk. To this end, BNYDC and the consultant team worked together to determine BNYDC's Vulnerability Tolerance in terms of climate hazard exposure.

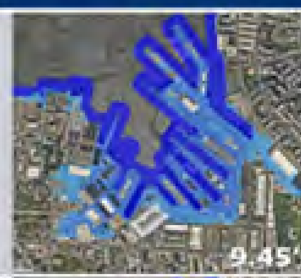
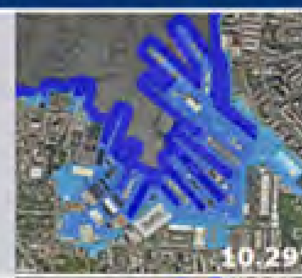
To help inform this discussion, BNYDC examined a range of design storms (10-year, 50-year, and 100-year) based on NOAA historic tidal gauge data and future projections between present day (2018), 2050, and 2100. Table 8 below contains the potential resulting flood levels from these various time horizons and design storms and Table 9 provides an ariel view of how these flood levels would impact the Yard (based on terrain modeling).

Within this assessment, the significance of the historic core district and its low adaptive capacity was considered. Furthermore, the phasing of the site was discussed in terms of which areas of the Yard are expected to be redeveloped over time, as per the Master Plan and the FEMA Project Worksheets (PWs). Site characteristics, such as varying elevation across the site, different building elevations, public access, and site flow, were also considered as an essential component of vulnerability tolerance. The discussion of vulnerability tolerance and level of investment is ongoing within BNYDC and, at this time, may be determined by the requirements of available grant funding. The FEMA Federal Flood Risk Management Standard uses the Freeboard Value Approach for many federal grant funding applications. The Freeboard Value Approach

Table 5. Modeled flood depths for differing storm event severity and time horizons

Time Horizon	10-Year Storm	50-Year Storm	100-Year Storm
2018	6.64 feet	8.24 feet	9.08 feet
2050	7.85 feet	9.45 feet	10.29 feet
2100	11.44 feet	13.05 feet	13.89 feet

Table 6. Modeled flood depths with map visuals for different storm events in 2050 and 2100

Time Horizon	10-Year Storm	50-Year Storm	100-Year Storm
2050			
2100			

Source: Scalgo

determines design elevations and flood hazard areas using the Effective Flood Insurance Rate Map base flood elevation with an additional 2 feet of freeboard for non-critical actions and 3 feet of freeboard for critical actions. Based on the most recent NYC Flood Insurance Rate Maps (2007), a minimum protection height of twelve feet for non-critical assets and thirteen feet for critical assets is required at the Yard. To comply with federal funding requirements the Freeboard Value Approach will drive the Resilience Recommendations.

Protection Level

Based on the findings of the vulnerability assessment and the vulnerability tolerance considerations, the Resilience Strategy identifies areas within the Yard that should be prioritized for federal funding and those that should be prioritized for other funding sources. Building assets in the flood-prone historic core and the waterfront wave action zone will be protected in accordance with the Federal Flood Risk Management Standard. As such, non-critical assets at the Yard will be protected to twelve feet and critical assets (Cogen facilities and FDNY boat launch) to thirteen feet (above NAVD88).

Implications

These findings on asset vulnerability inform the resilience recommendations and Tenant Resilience Toolkit included within this Resilience Strategy. Resilience recommendations will include site-wide solutions, like seawalls, that protect groups of

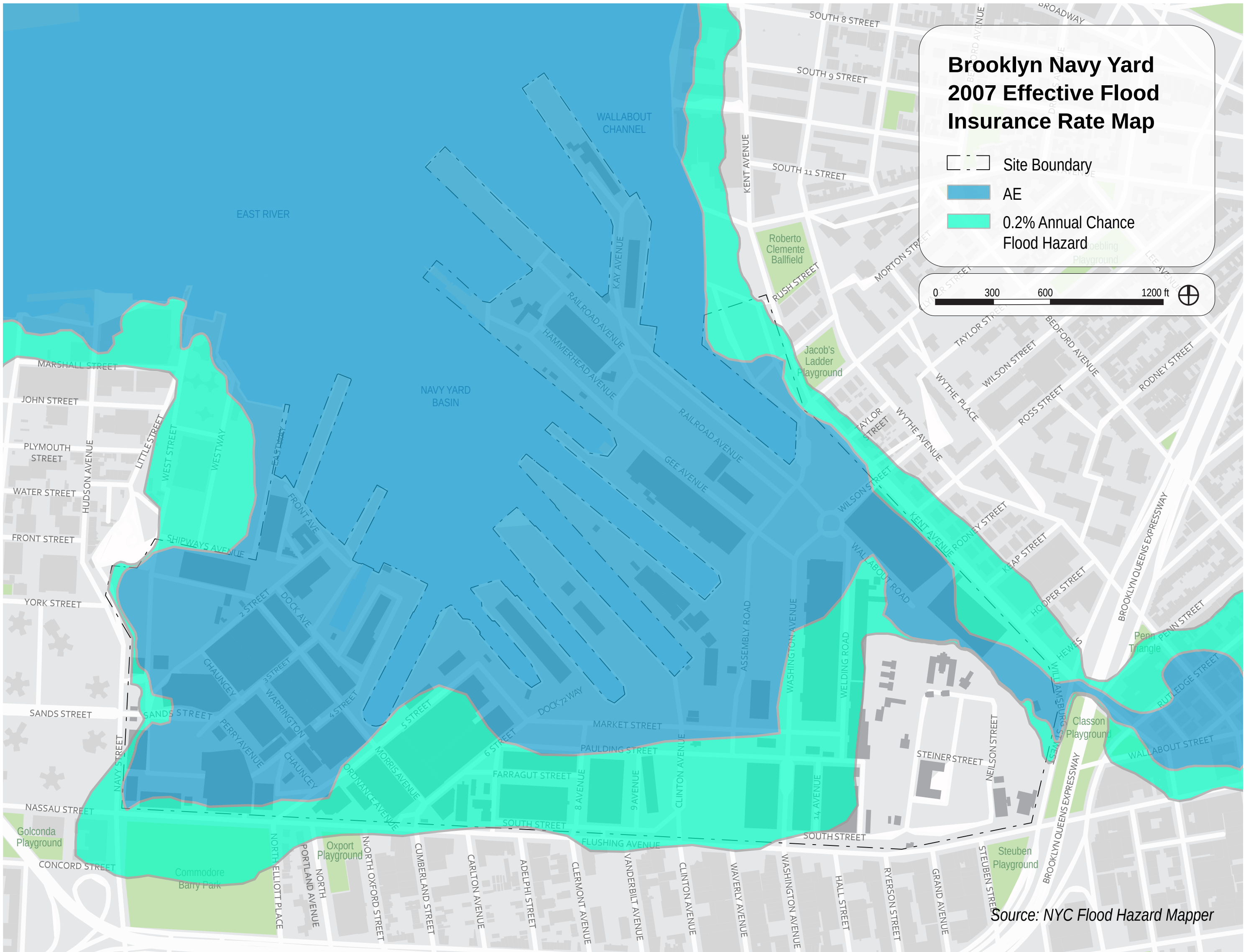


Figure 15. FEMA 2007 NYC Effective Flood Insurance Rate Map

assets, as well as asset-level solutions, like building level floodproofing and critical equipment elevating to reduce vulnerability.

In addition, the hazard exposure analysis illuminates the differing levels of risk in the near, mid, and long term. For certain assets, interim solutions are required to protect against inland flooding and long-term planning is needed to protect against the threat of sea level rise and coastal storm surge. The vulnerability assessment will inform a construction phasing plan to mitigate damage to assets at immediate risk first, with continued roll out. While BNYDC moves to implement sitewide resilience measures, tenants are expected to understand and manage their own climate risk, like floodproofing facilities and elevating critical equipment. For more information tenants can refer to the Tenant Toolkit, included in Section 6.

Table 7. Building assets ranked from most to least vulnerable based on composite score of exposure and criticality

Asset Name	Coastal Flooding Consequence			Inland Flooding Consequence			Criticality Score	Vulnerability Score
	2018	2050	2100	2018	2050	2100		
Building 386 (Substation G)	3	3	4	2	2	2	4	17
Cogen 41	3	3	4	2	2	2	4	17
Cogen Demineralization	3	3	4	2	2	2	4	17
Building 22	4	4	4	3	3	3	3	17
Admirals Row - Building A	3	4	4	3	3	3	3	16
Building 234 (Substation B)	3	3	4	1	1	1	4	15
Building 542 (Substation C)	3	3	4	1	1	1	4	15
Cogen Gas Compressor	3	3	4	1	1	1	4	15
Building 500	3	3	4	3	3	3	3	15
Building 131	3	4	4	2	2	2	3	14
Building 270	3	3	4	0	0	0	4	13
Admirals Row - Building C	3	3	4	2	2	2	3	13
Admirals Row - Building D	3	3	4	2	2	2	3	13
Admirals Row - Building E	3	3	4	2	2	2	3	13
Building 11	3	3	4	2	2	2	3	13
Building 12/12A	3	3	4	2	2	2	3	13
Building 121	3	3	4	2	2	2	3	13
Building 127	3	3	4	2	2	2	3	13
Building 12B	3	3	4	2	2	2	3	13
Building 132	3	3	4	2	2	2	3	13
Building 20	3	3	4	2	2	2	3	13
Building 25	3	3	4	2	2	2	3	13
Building 268	3	3	4	2	2	2	3	13
Building 269	3	3	4	2	2	2	3	13
Building 293	3	3	4	2	2	2	3	13
Dock 72	3	3	4	2	2	2	3	13
Stages 25-30	2	3	4	2	3	3	3	13
Steiner (300) - Stages 1-6	2	3	4	2	2	2	3	12
Building 10	3	3	4	1	1	1	3	12
Building 124 (PW1)	3	3	4	1	1	1	3	12
Building 156 (PW5/6)	3	3	4	1	1	1	3	12
Building 51	3	3	4	1	1	1	3	12
Building 74	3	3	4	1	1	1	3	12
Sands Building (303)	3	3	4	1	1	1	3	12
Brinks 700	2	3	3	2	2	2	3	11
Building 128	2	3	3	2	2	2	3	11
Building 28	2	3	3	2	2	2	3	11
Building 120	0	3	4	2	2	2	3	10
Building 123	2	2	3	2	2	2	3	10
Building 275	3	3	4	0	0	0	3	10
Building 292	3	3	4	0	0	0	3	10

Asset Name	Coastal Flooding Consequence			Inland Flooding Consequence			Criticality Score	Vulnerability Score
	2018	2050	2100	2018	2050	2100		
Building 62	3	3	4	0	0	0	3	10
Building 280	0	0	4	3	3	3	3	9
Building 92	0	0	4	3	3	3	3	9
Building 50	0	2	3	2	2	2	3	8
Building 77	0	2	3	2	2	2	3	8
Building 313	3	3	4	1	1	1	2	8
Lehigh Cement	3	3	4	1	1	1	2	8
Building 58	0	0	3	3	3	3	3	8
ARow - Building B	2	2	3	0	0	0	3	7
Building 314	3	3	4	0	0	0	2	7
Building 5	0	2	3	1	1	1	3	7
Building 1	0	0	3	2	2	2	3	6
Building 27	0	0	3	2	2	2	3	6
Stages 10-15	0	0	3	2	2	2	3	6
Building 30	0	0	3	1	2	2	3	6
Building 8	4	4	4	3	3	3	1	6
Building 664	0	2	3	2	2	2	2	5
Building 200 North	0	0	4	2	3	3	2	5
Building 200 South	0	0	4	2	3	3	2	5
Building 7	4	4	4	2	3	3	1	5
Building 2	0	0	2	2	2	2	3	5
Building 6	2	2	3	0	0	0	2	5
Building 510 (PW4)	3	4	4	2	2	2	1	5
Building 3	0	0	3	1	1	1	3	5
Building 385 (Substation F)	0	0	3	0	0	0	4	4
Building 249	3	3	4	0	0	0	1	3
Building 52	3	3	4	0	0	0	1	3
Building 594	3	3	4	0	0	0	1	3
FDNY Boat Repair Building	3	3	4	0	0	0	1	3
Building 152	0	0	3	1	1	1	2	3
DCAS Building	0	3	3	2	2	2	1	3
Tow Pound Building	1	2	3	1	1	1	1	3
Building 4	0	0	3	2	2	2	1	2

4. Resilience Recommendations

Resilience Recommendations

The resilience recommendations for the Brooklyn Navy Yard are uniquely tailored to mitigate flood risk within the site constraints of a working waterfront while building synergies with development goals. As informed by the Climate Risk Assessment and related vulnerability tolerance discussions, the resilience recommendations proposed herein are designed to protect up to 12 to 13 feet (above NAVD88) in accordance with FEMA standards, which is equivalent to FEMA's design flood elevation (DFE), or base flood elevation (BFE) plus 2 – 3 feet, depending on criticality. These recommendations acknowledge the obstacles to implementing large scale resilience infrastructure as well as the need for a Resilience Strategy that is adaptable, scalable, and aligned with the overall development vision of the Brooklyn Navy Yard. The mid- to end-of-century climate projections used as the basis of design correspond with a realistic implementation horizon, the useful life of constructed materials, and the degree of uncertainty associated with longer term climate projections. Resilience measures are designed as multifunctional infrastructure, such that a coastal flood barrier provides additional benefits and helps to achieve other development, transportation, and open space priorities. Integrated infrastructure projects maximize benefits for resilience, stormwater management, traffic safety, economic activity and job creation, air quality, noise reduction, urban heat, public health, and well-being. With this approach, the Brooklyn Navy Yard Resilience Strategy is aligned with the BNYDC Master Plan Exercise and its development goals.

Resilience recommendations also prioritize protection of the most at-risk assets, those most critical and most exposed, while preserving existing site character, edge conditions, and use types. Taking these elements into consideration, resilience strategies can be conceptualized with areas of protection in mind. These areas have been differentiated as the perimeter zones (Historic Core, Barge Basin, Kent), inland zones (Steiner Studios campus, Commercial Center), and exterior zones outside the perimeter (working waterfront areas). For example, the GMD Shipyard is located within the Wave Action Zone (identified in the Preliminary Resiliency Risk Assessment) and is therefore highly exposed to coastal flooding; however, based on the specific use type of the shipyard, this area cannot simply be protected by a flood wall that obstructs access to the working waterfront.

This blend of climate vulnerability, use type, and edge conditions informed the configuration of flood protection alternatives. Each of the alternatives that were explored as part of this study—whether asset-specific measures (such as building floodproofing) or a site-wide solution (such as a flood wall—are based on an understanding of flood risks and site constraints. In addition, the zonal analysis combined with flood modeling helped to identify phasing of flood protection measures (see Section 5). Phasing will likely be necessary, depending on availability of funding. As such, flood modeling provides a preliminary understanding of segments of flood protection that can operate independent of future phases, as well as tie-backs to ensure that each segment is effective if constructed before future segments are in place.

Conceptualizing the Resilience Strategy for the Yard involved a review of international best practices, an alternatives analysis exercise, alternative selection, and conceptual site planning with small area plans, section diagrams, and construction phasing analysis.

Best Practices in Coastal Flood Resilience

Resilience recommendations for the Brooklyn Navy Yard build on local and international adaptation best practices for fortifying flood prone waterfront areas in innovative ways. Resilience measures are tailored to the varied uses and conditions at the Yard. Precedent projects were selected to reflect the complex landscape and need for varied approaches to resilience in different zones. Precedent projects for working waterfronts, public promenades, and in-water solutions informed the alternatives analysis and, ultimately, the Resilience Strategy. Active dry docks will reflect working waterfront practices, whereas the Master Plan identified development opportunities (e.g., the Barge Basin) which can incorporate a resilient promenade with recreation and accessibility measures featured in the design.

To review the Best Practices local and international project references, refer to Appendix D.

The Financial District & Seaport Climate Resilience Master Plan is part of an extensive flood defense plan to prevent Lower Manhattan from the threat of coastal flooding. Rendering of Pine Street Cove looking north.

Source: NYCEDC

Working Waterfronts

The working waterfront scenario is the primary consideration and design constraint for this Resilience Strategy. These examples were reviewed because they demonstrate strategies to mitigate flooding in thriving harbor areas with a strong maritime heritage. These precedent projects mitigate flood risk while preserving the visual connection to the water, providing direct waterfront access, and maintaining commercial boat access.

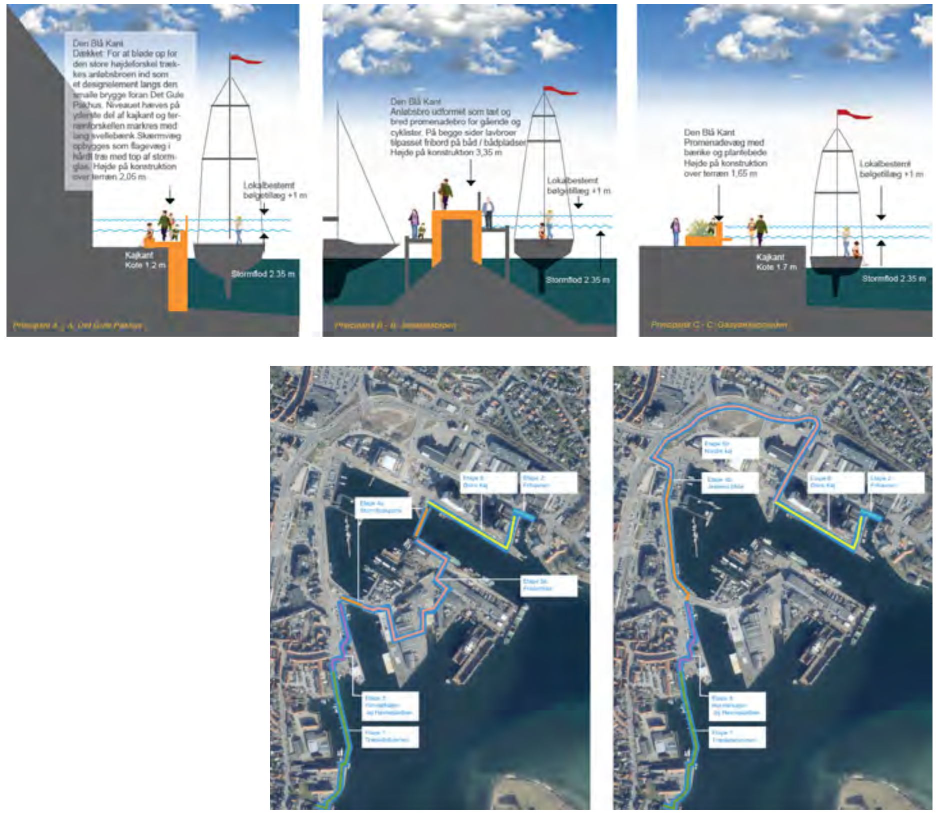


Figure 16. The Blue Edge, Svendborg, Denmark

Public Waterfronts & Promenades

As the Yard expands its job base and gradually becomes more open to the public, there will be more opportunities to provide public waterfront access along the water's edge. Newly developed public waterfronts and promenades should include integral resilience measures, to both protect against flooding while also expanding access to the water. These examples show the ability to create raised boardwalks that facilitate pedestrian access and even opportunities for recreational boating (e.g., kayak launches).

Figure 17. Sea Organs, Zadar, Croatia

Figure 18. MOSE Flood Barrier

The MOSE Flood Barrier, completed in 2020, provides protection to Venice, Italy, by blocking storm surge and reducing wave action in the Venetian Lagoon.

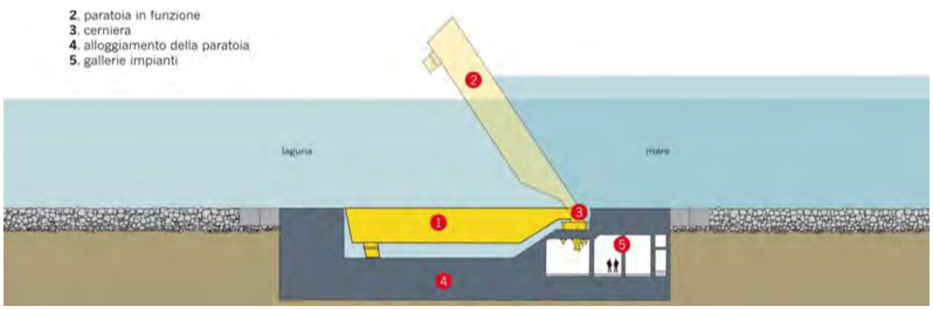


Figure 19. MOSE Flood Barrier Diagram

In-water Solutions

Because the Yard sits inside Wallabout Bay, the potential for a large-scale, in-water solution to block flood waters from entering the bay was considered. Storm surge barriers have been successfully implemented in other sites around the world, but they were viewed as expensive and infeasible in this context—particularly due to the various channels piers that extend out into Wallabout Bay.

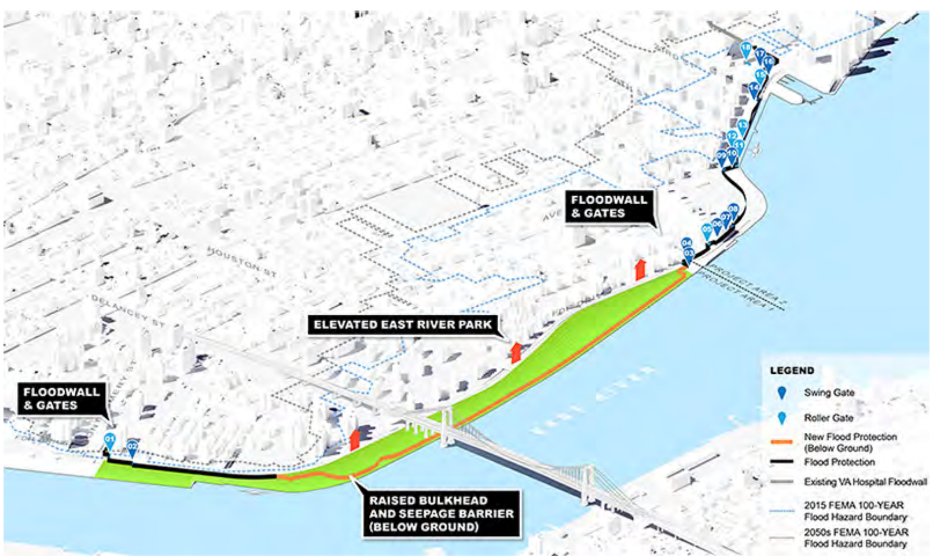


Figure 20. East Side Coastal Resiliency (ESCR) Project

The East Side Coastal Resiliency (ESCR) Project is a coastal protection initiative, jointly funded by the City of New York and the federal government, aims to reduce flood risk due to coastal storms and sea level rise on Manhattan's Lower East Side.

Local Examples

Since Superstorm Sandy, there have been several planning and design efforts to provide coastal flood protection in New York City, some of which have already begun construction. These demonstrate the feasibility and proof of concept for providing flood mitigation against major storm surge events, even in the context of historic maritime areas along the New York City coastline.

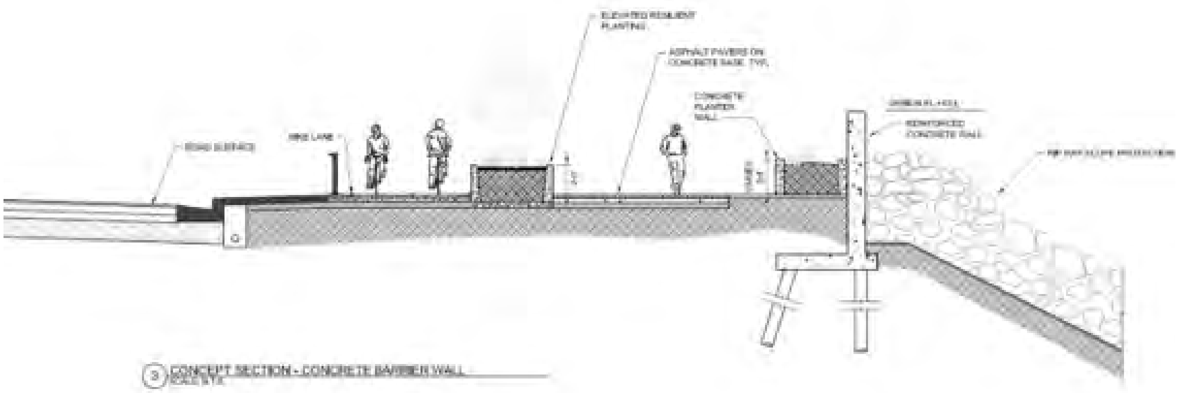
Flood Resilience Protection Measures

Permanent Flood Barriers

Concrete Flood Walls

Steel Sheet Pile

Sliding or Deployable Gates



Concrete Flood Walls

Advantages:

Provides higher level of protection.

Disadvantages:

Require deep foundation to resist flood loads.

Obstructs views.

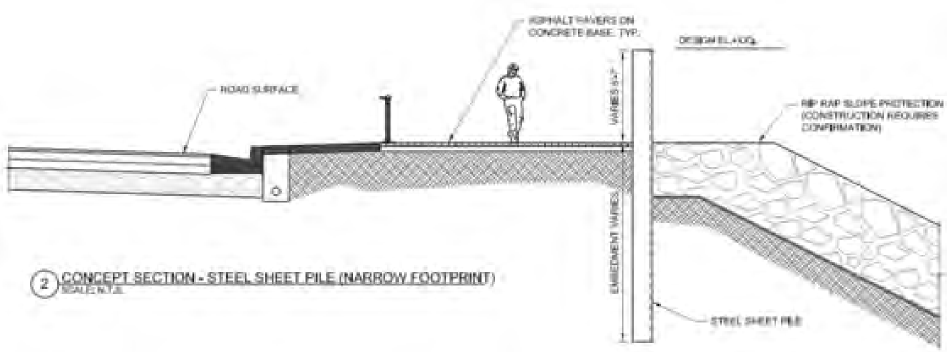
May conflict with underground infrastructure.

Protection Height:

5ft - 7ft +

Vulnerability Zone:

Feasible in Medium to High Zones.



Steel Sheet Pile

Advantages:

Simple design.

Narrow footprint limits impact to overall site.

Utilizes conventional construction techniques.

Cost effective solution for large sites.

Disadvantages:

May conflict with underground infrastructure.

Obstructs views.

Protection Height:

5 - 7ft+

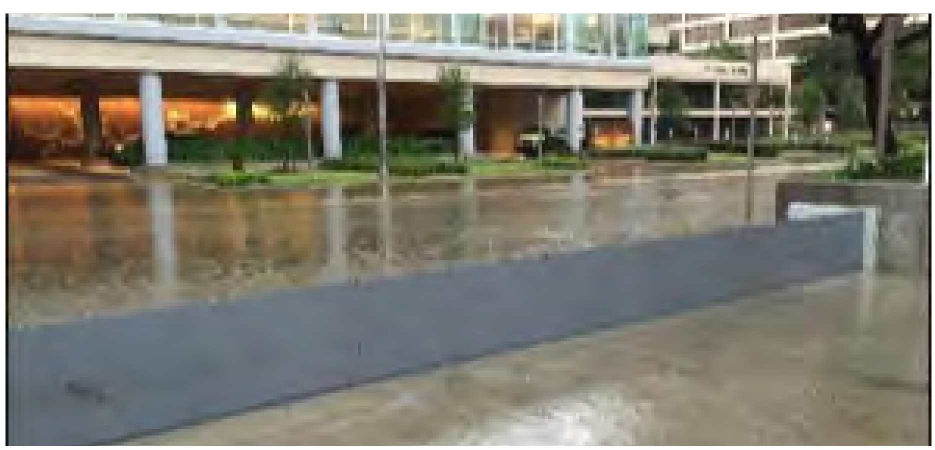
Vulnerability Zone:

Feasible in Medium to High Zones.

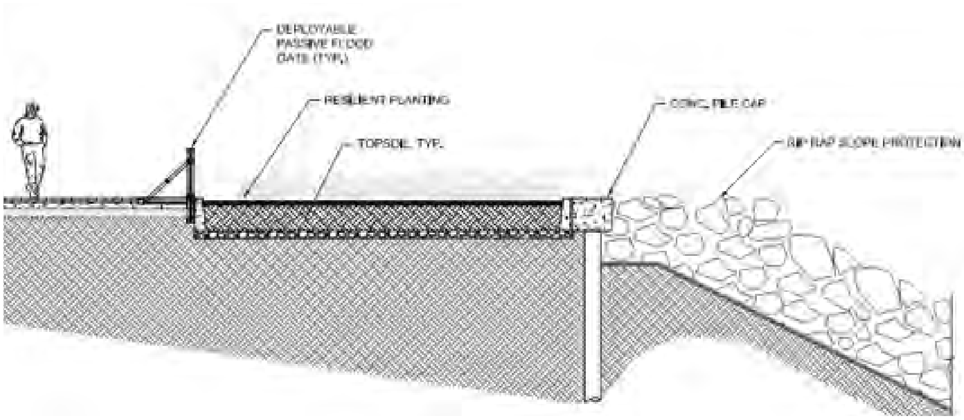
Deployable & Temporary Barriers

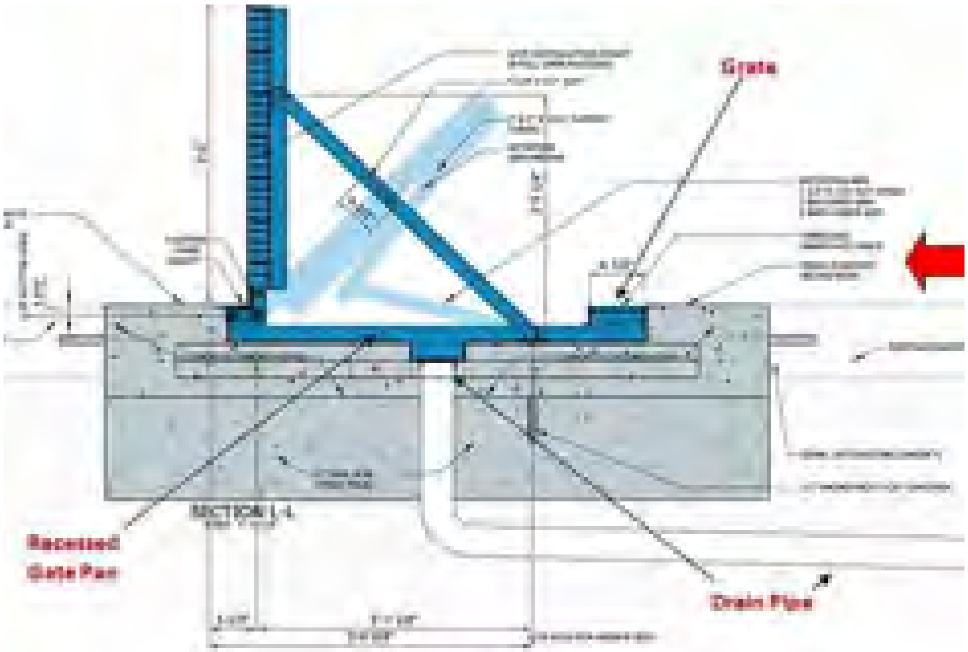
Hesco Barriers

Tiger Dams



Aquafences





Deployable Barrier

Advantages:

Allows for vehicle/pedestrian circulation.
No obstruction of views.

Disadvantages:

Additional considerations for deployment.
Maintenance considerations.

Protection Height:

3 – 5ft

Vulnerability Zone:

Feasible in Low to Medium Zones.

Protected Shorelines

Wharves

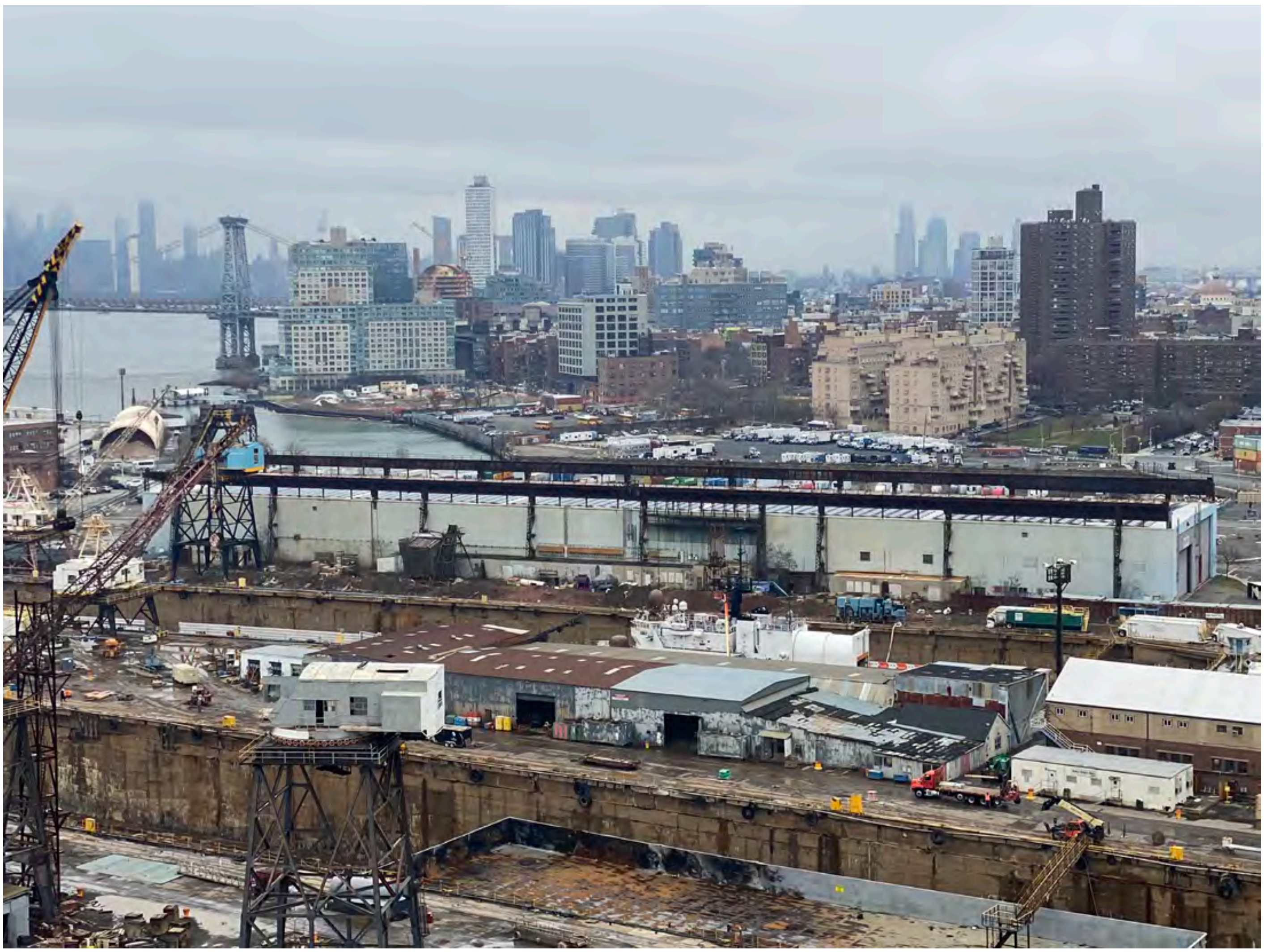
igh Level Platforms

Revetments

Alternative Approaches to Protecting the Yard

The approach to flood resilience at the Yard can take multiple forms. Inspired by the best practices review, the consultant team devised alternative protection measures ranging from marine defense systems to shoreline perimeter measures, to onshore floodproof and drainage plans.

Four distinct strategies were developed for how to approach resilience. Each protection strategy presents a different approach of adapting to, mitigating against, or retreating from projected climatic conditions.



Looking east over Dry Docks 5 & 6 at the Brooklyn Navy Yard.

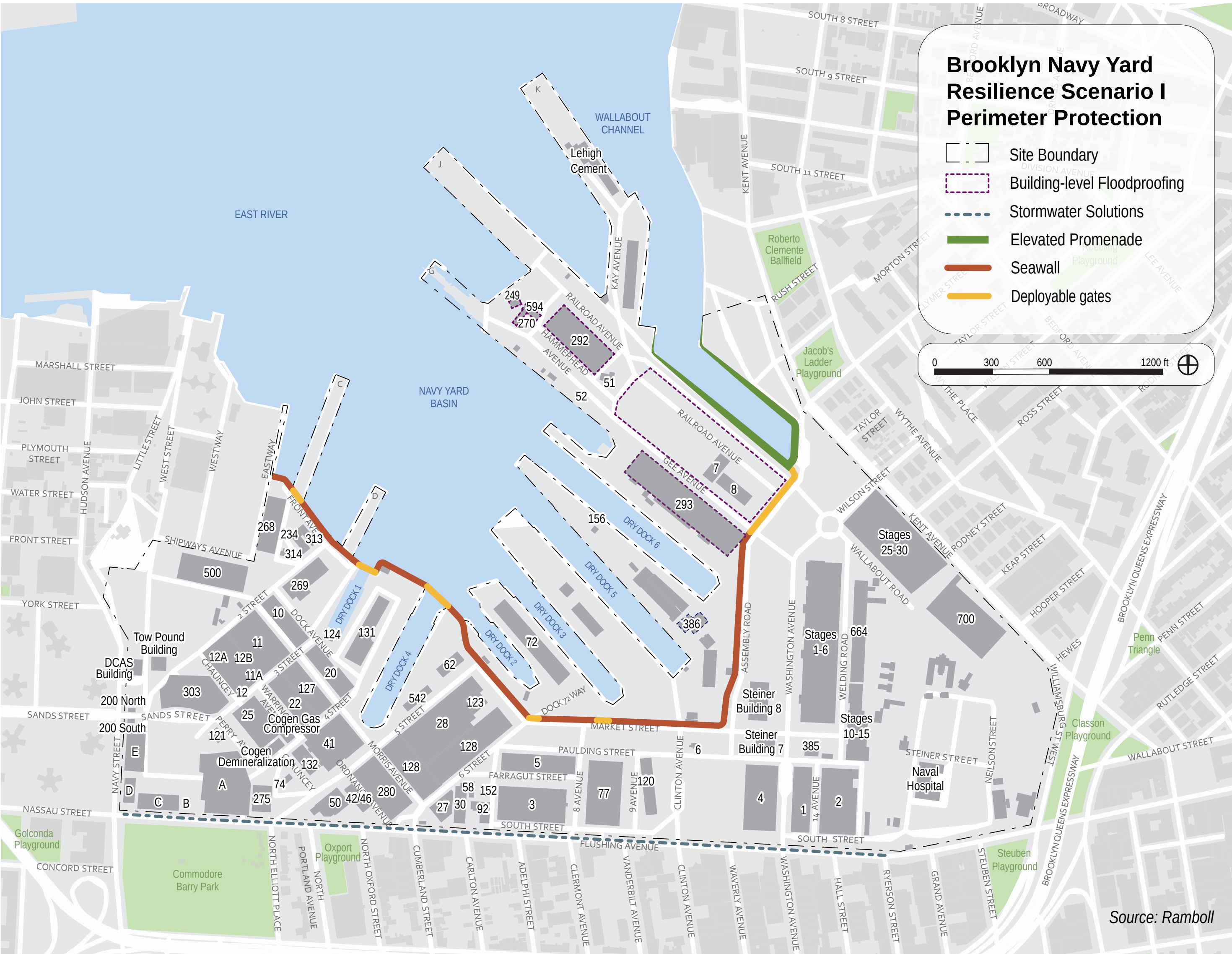


Figure 21. Perimeter Protection Scenario

Perimeter Protection Scenario

The Perimeter Protection Scenario elevates and fortifies the shoreline of the Yard where possible to mitigate coastal flooding at commercial, industrial, and utility buildings on site. Dry docks 2, 3, 5, and 6 as well as Piers G, J, and K are outside of the perimeter and will be adapted to be floodable. Buildings outside of the perimeter (those occupied by GMD, Lehigh Cement, and FDNY) are to be floodproofed to preserve working waterfront operations. Buildings with commercial activity, like Building 72 and the planned Kent development site, are constructed with occupiable spaces built above the design flood elevation. The perimeter protection system itself will consist of a stretch of varied height seawalls, ranging from 6 - 9 feet above ground level, and an elevated development site and elevated promenade on Washington Avenue.

Segments of the perimeter are connected by deployable gates to allow for pedestrian and vehicular access outside of a storm event. Stormwater management solutions on Flushing Avenue and Assembly Road are proposed to convey, detain, and discharge stormwater on the interior of the perimeter. The Perimeter Protection scenario requires cooperation of neighboring property owners (New York City and New York City Department of Environmental Protection) to ensure proper tie in elevation is achieved and adverse effects avoided. If implemented, the Perimeter Protection scenario would allow for continued operation of the working waterfront while providing regional flood protection for adjacent low-lying communities.

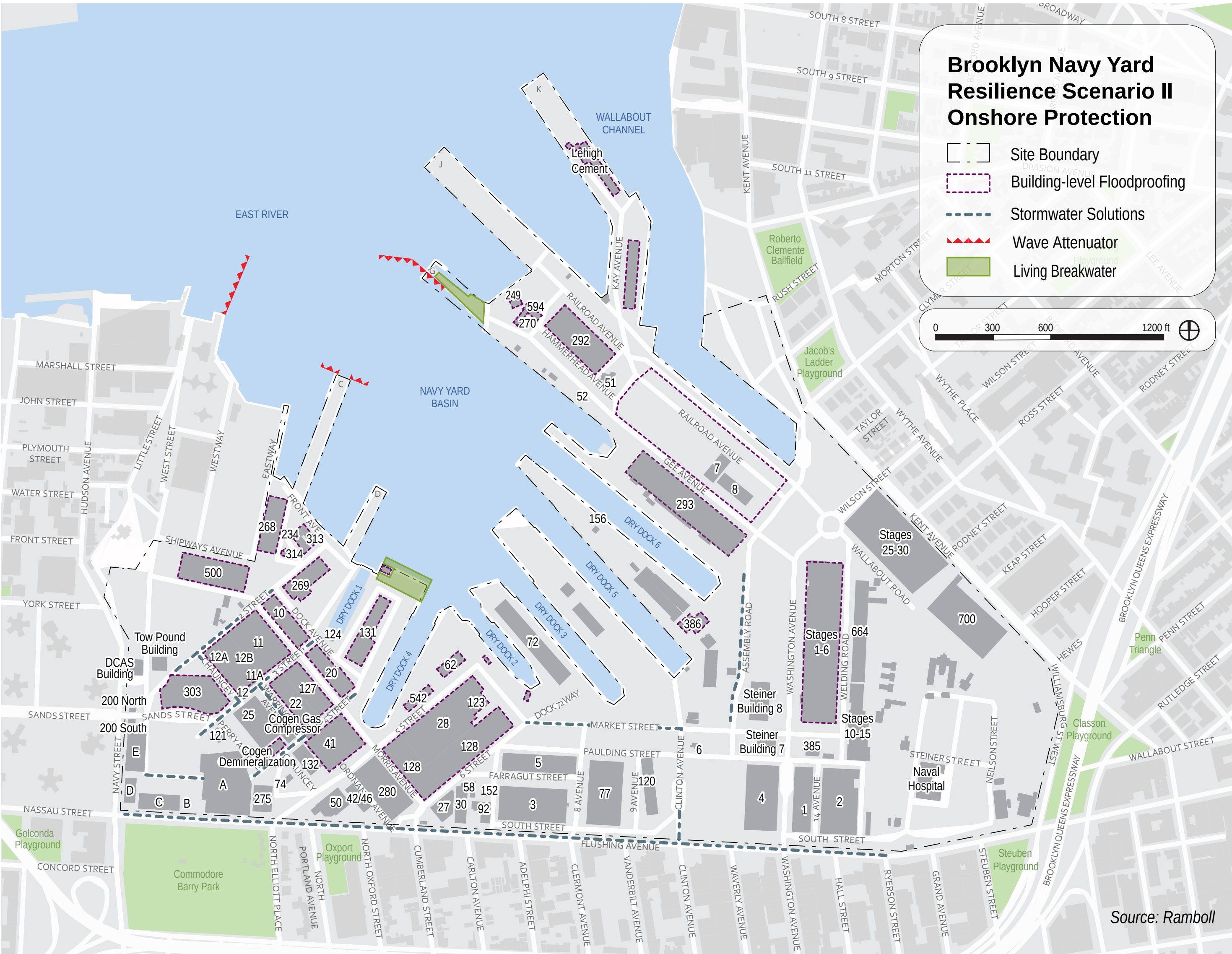


Figure 22. Onshore Protection Scenario

Onshore Protection Scenario

The Onshore Protection Scenario presents a very different opportunity for the Yard to adapt to changing climatic conditions. The Onshore Protection Scenario is a “living with water” approach where buildings and assets are floodproofed, waterfront access and operations are preserved, and areas of the site can expect and withstand persistent flooding during high tides and precipitation events. Building level floodproofing is a readily available and relatively cheaper strategy to protect buildings against flood damages using federal or City funding opportunities. Based on the building activity and contents, wet or dry floodproofing measures could be implemented. Improved communication systems and emergency management operations would be required to notify Yard workers of anticipated flooding and evacuate at-risk areas. During moderate mid-century events, access to the Yard would likely be limited and roadways would be inundated.

Improved drainage infrastructure, especially increased pipe capacity and additional catch basins will support the clearing of floodwaters onsite. Recovery time after a storm event could be expedited with the installation of pumps to clear ponding water from depressed areas and pump out seawater during a high tide. Where possible, wave attenuation structures in the Navy Yard Basin can dissipate wave energy to prevent force-based damages to Yard infrastructure. The Onshore Protection scenario is a conceivable strategy to begin floodproofing assets that are most exposed to coastal flooding immediately using City budget allocations supplemented with federal funding. While the strategy protects assets in the near term it would require a revised strategy or gradual retreat under the climactic conditions projected for 2100. This scenario offers limited benefits for the surrounding community, nor does it advance other goals identified in the BNYDC Master Plan Exercise.

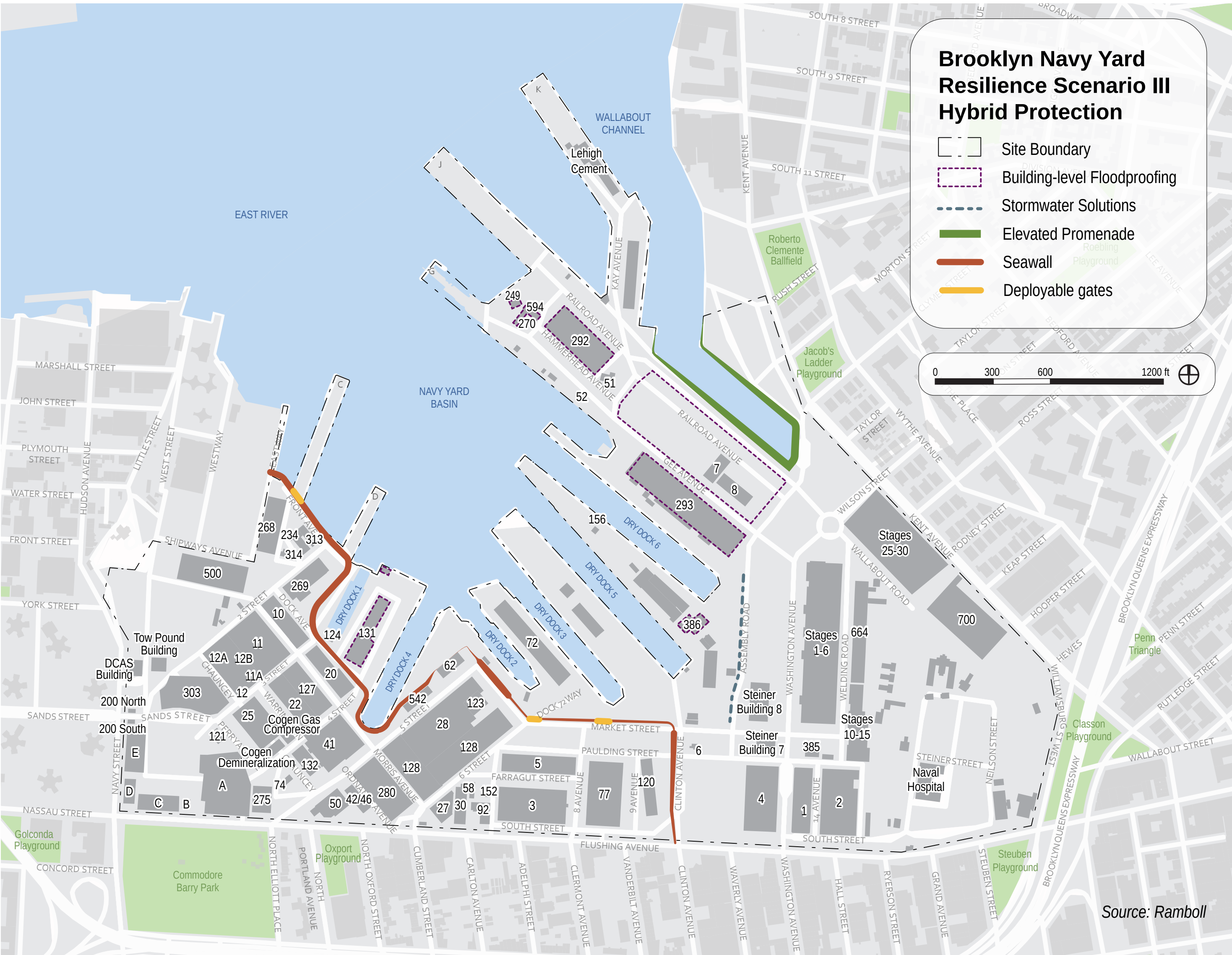


Figure 23.Hybrid Protection Scenario

Hybrid Protection Scenario

The Hybrid Protection Scenario synthesizes perimeter and onshore measures with seawalls proposed in the most at-risk low-lying areas of the site and building level floodproofing in working waterfront areas and areas that flood less frequently. Like the Perimeter Protection Scenario, a full height seawall (6 – 9 feet above ground level) runs from Pier C along the Historic Core with deployable gates to allow access to working waterfront areas, dry docks, and piers. Instead of a complete shoreline perimeter, the hybrid perimeter gradually slopes down along Clinton Avenue to meet the existing grade at Flushing Avenue. The seawall is intended to be multifunctional and may be designed in places as a covered parking area, storage shed, office space, or pop-up retail spaces fortified and sealed to withstand coastal waters.

Like both the Perimeter and Onshore scenarios, stormwater management is needed to supplement coastal resilience measures. Hybrid shoreline features, like living shorelines that integrate plant life and marine habitat into rocky shorelines, are an opportunity to promote natural habitat while stabilizing existing piers and shorelines. Living shorelines are proposed to refurbish the degraded Pier G and as part of an open space plan adjacent to Building 131. The varied resilience measures of the Hybrid Protection scenario provide the most benefit when acting together, while also allowing for phased implementation based on the availability of funding. City budget allocations may be used for building floodproofing and supplemented with grant funding and capital funds to implement multifunctional perimeter protection elements.

Figure 24.Marine Protection Scenario

Marine Protection Scenario

The Marine Protection Scenario is a regional, offshore approach, involving a storm surge barrier closure in Wallabout Bay. As demonstrated by the Maeslant Barrier in Amsterdam and MOSE Barrier in Venice, automatic surge barriers are effective solutions in port environments and active marine passages. Vertical lift gates in Wallabout Bay would optimize space and minimize disruption to vessels in shallow areas. Marine protection features would minimize disruption to Yard activity while alleviating the threat of coastal storm surge. Stormwater management interventions would still be needed to supplement coastal resilience measures. Opportunities to align the Marine Protection scenario with other development goals are limited, as are economic, social, and environmental co-benefits. The Marine Protection Scenario would require approval, if not ownership, by regional stakeholders from governmental entities to federal agencies. This scenario would also be difficult to construct, given the need to connect and tie into various piers that extend into Wallabout Bay.

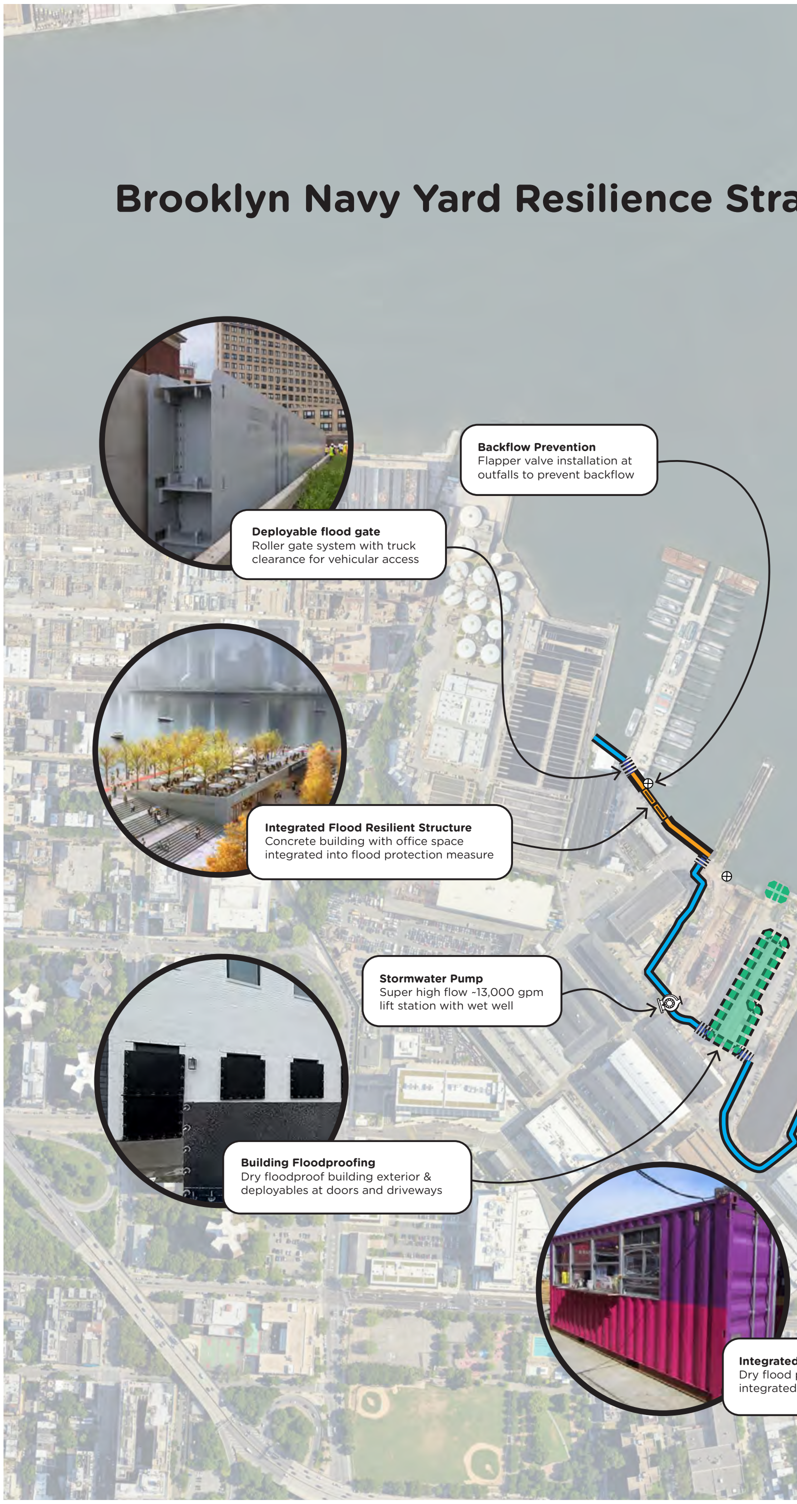
Selected Brooklyn Navy Yard Resilience Approach

The alternatives analysis was an effective tool to help visualize different resilience scenarios for the future of the Yard. The exercise kickstarted a discussion around feasibility, regional collaboration, and potential funding opportunities that indicated that adaptable and phased strategies aligning with the BNY Master Plan Exercise and other related development initiatives.

The Hybrid Protection Scenario was determined to be the most effective long term resilience planning approach to reduce damages and provide collective benefit for the site and surrounding community. A hybrid approach combining waterfront and inland measures addresses varying vulnerabilities across the site and allows for phased adaptation to align with other development goals and funding opportunities.

Benefits and Co-Benefits of the Brooklyn Navy Yard Resilience Strategy

- Coastal flood prevention
- Stormwater management
- Protection of existing assets
- Prevention of new risk for developments inside the perimeter
- Improved traffic flows
- Enhanced open space
- Community connectivity
- Improved air quality and street level heat indices
- Improved runoff water quality
- Avoided damages for tenants



tegy: Site Plan

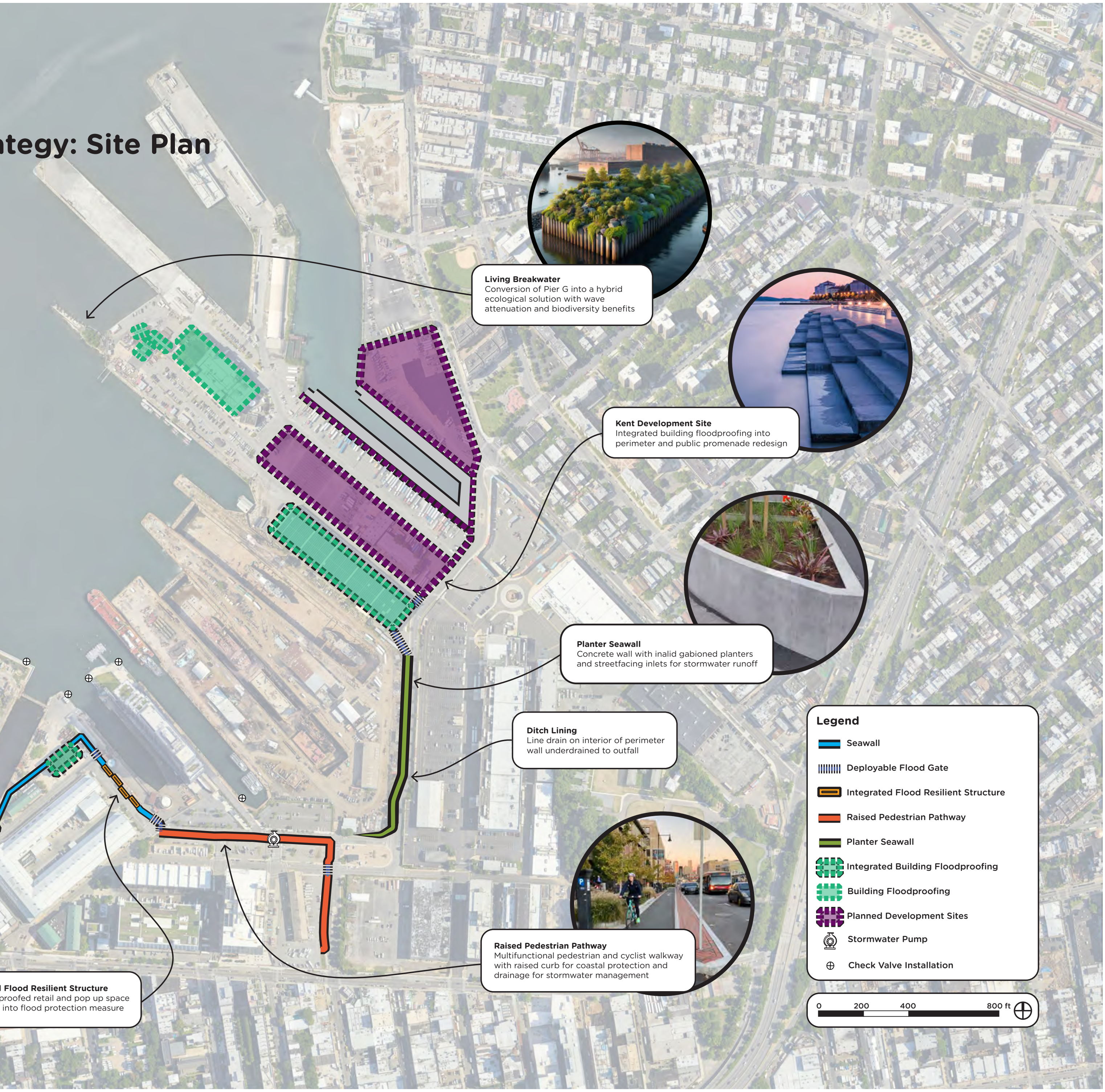
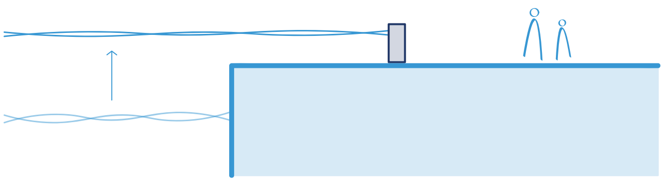


Figure 25.Brooklyn Navy Yard Resilience Strategy: Recommendations

Coastal Flood Resilience Design Elements

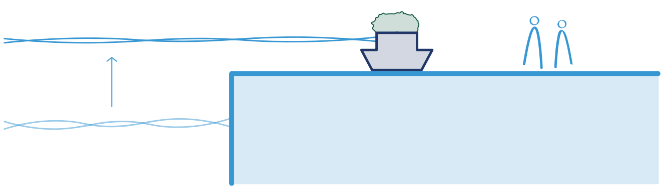
The Brooklyn Navy Yard Resilience Strategy can be simplified into design elements that achieve coastal flood resilience while improving stormwater management, open space, traffic safety, economic activity, and urban design. These elements are described below with varied typologies to show different function, use case, and cost. Design elements include Seawalls, Integrated Structures, Elevated Pathways, and Deployable Floodgates.

Design Elements: Seawall



Typical Seawall

The typical seawall provides protection up to the required height, with limited-to-no multi-functionality. Located offset from the coastal edge, resulting in some coastal flooding on the sea-side of the protection. Suitable typology for navigating with limited space and/or no feasibility for multi-functionality.



Planted Seawall

The multi-functional seawall provides protection to the required height with a core structure, and could have, for example, built-in seating areas on both sides of the wall. The top of the wall can be utilised for planting to enhance local vegetation and biodiversity, and provide a green backdrop for pedestrians.

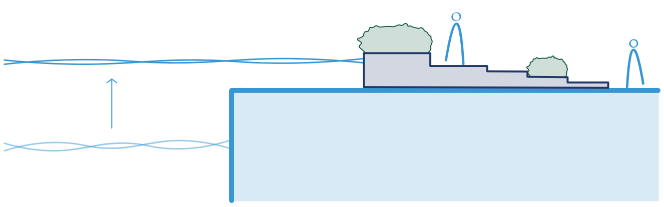
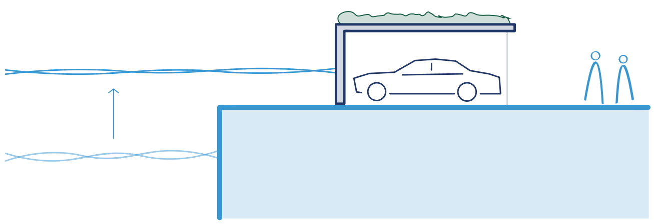


Figure 26.Coastal Flood Resilience Design Elements - Seawalls

Seawall Promenade

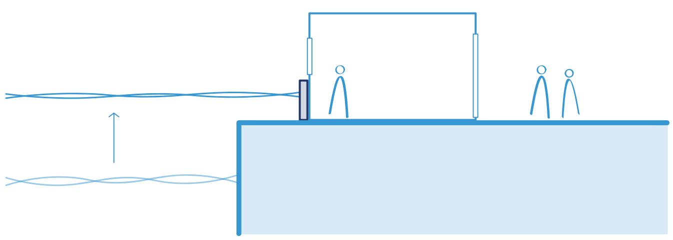
The seawall promenade typology provides both flood protection and attraction of local biodiversity and improvement of vegetation. The promenade allows for public engagement at the coastal edge. Promenade to include ramps to ensure all access.

Design Elements: Integrated Structures



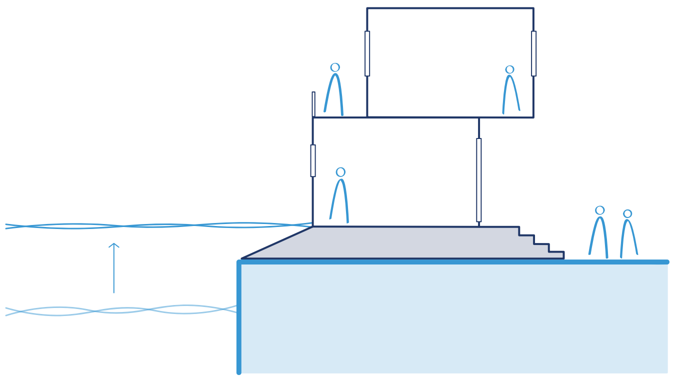
Outdoor Storage

The seawall can be integrated at existing fence and property boundary locations, and can have a multi-functionality of providing space under the wall for car parking, material storage, bike parking etc.. The roof of the structure can be utilised as a green roof, attracting local biodiversity and mitigating urban heat island effect.



Single-Story Office Space

The current solution to flood-proofing existing structures, is the implementation of a solid barrier, built as an extension to the facade of the building. Existing windows and doors can have deployable screens to provide protection against flooding as necessary. The building itself then becomes integrated as the flood protection measure.

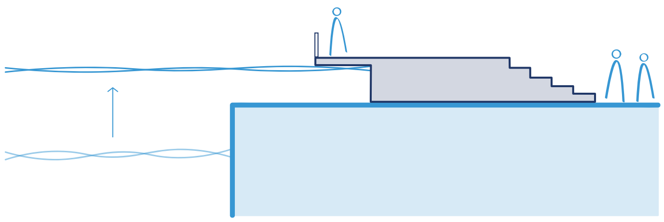


Multi-Level Building

The integrated structures can be developed into larger scale buildings, across multiple levels. From a feasibility perspective, the flood protection is integrated into the development of the local built area, as opposed to an isolated intervention.

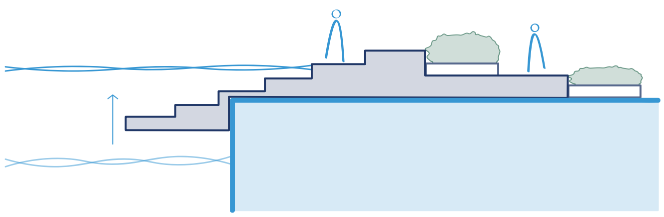
Figure 27. Coastal Flood Resilience Design Elements - Integrated Structures

Design Elements: Elevated Pathways



Shared-Use Path

The elevated pathway provides flood protection from its core structure up to the required height, and can be accessible by stairs and ramp. The pathway is designed for pedestrians and cyclists.

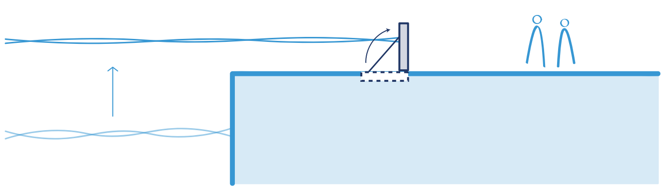


Stepped Promenade

A stepped promenade (with all access ramps) can provide protection up to the required height, as well as serving as a recreational space and engagement with the water. Vegetation in the flood risk area should be resilient species, designed for erosion mitigation.

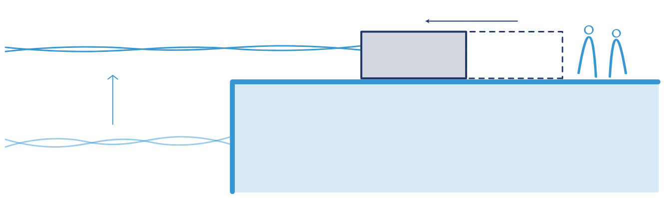
Figure 28.Coastal Flood Resilience Design Elements - Elevated Pathways

Design Elements: Deployable Flood Protection



Deployable Floodgate

The typical deployable flood gate - it is mobilised as necessary in the case of an event and provides protection to the required height. The gate offers no multi-functionality but is the current best solution for protection alignment that crosses over roads.



Sliding Floodgate

The sliding deployable flood gate can be utilised only when there is sufficient space to allow for the gate to be stored, for example, at ground level of a raised building. The gate can be deployed as necessary and is a feasbile solution for crossing roads.

Figure 29.Coastal Flood Resilience Design Elements - Deployables

Stormwater Resilience Design Elements

Stormwater management is critical to mitigating interior flood risk within the Yard. Stormwater ponding and catch basin overflows during recent storm events indicate infrastructure challenges that will only be exacerbated by the changing intensity in precipitation patterns. At a high level, increasing pipe capacity, adding catch basins and network infrastructure in low-lying disconnected areas of the site, installing backflow preventors at outfalls, and ensuring proper infrastructure maintenance will support improved drainage at the yard. Blue-green infrastructure solutions like bioswales, tree pits, and floodable recreation areas can also improve detention and conveyance of stormwater while lessening the burden on traditional sewer infrastructure.

A stormwater management investigation, including up to date mapping of the sewer network, assessment of pipe conditions with video inspection, and comprehensive modeling are recommended as a priority next step for the Yard to inform stormwater resilience recommendations and formulate a comprehensive stormwater management plan.

Figure 30. Blue-Green Infrastructure (BGI) Hardscape Plaza in Ringsted Torv, Denmark

Hardscape plazas in Ringsted Torv Denmark detain stormwater during extreme events and operate as recreation spaces during dry weather

Small Area Plans and Master Plan Synergies

To help conceptualize the resilience recommendations and corresponding implications for the Yard, a series of small area plans for potential development sites were created. Sites were selected with BNYDC mission development and growth strategies in mind and demonstrate synergies with job creation, transit improvements, and public access objectives. The goal of the small area plans is to inspire how resilience measures may be imagined on new development sites and how to achieve multifunctional infrastructure at the Yard.

Development Site 1: Homeport

Site Location:

Located on Front Avenue between Pier C (NYC Ferry Homeport) and Pier D (GMD)

Existing Development:

Buildings 234, 313, 314, and the temporary Homeport trailer offices

Co-benefits:

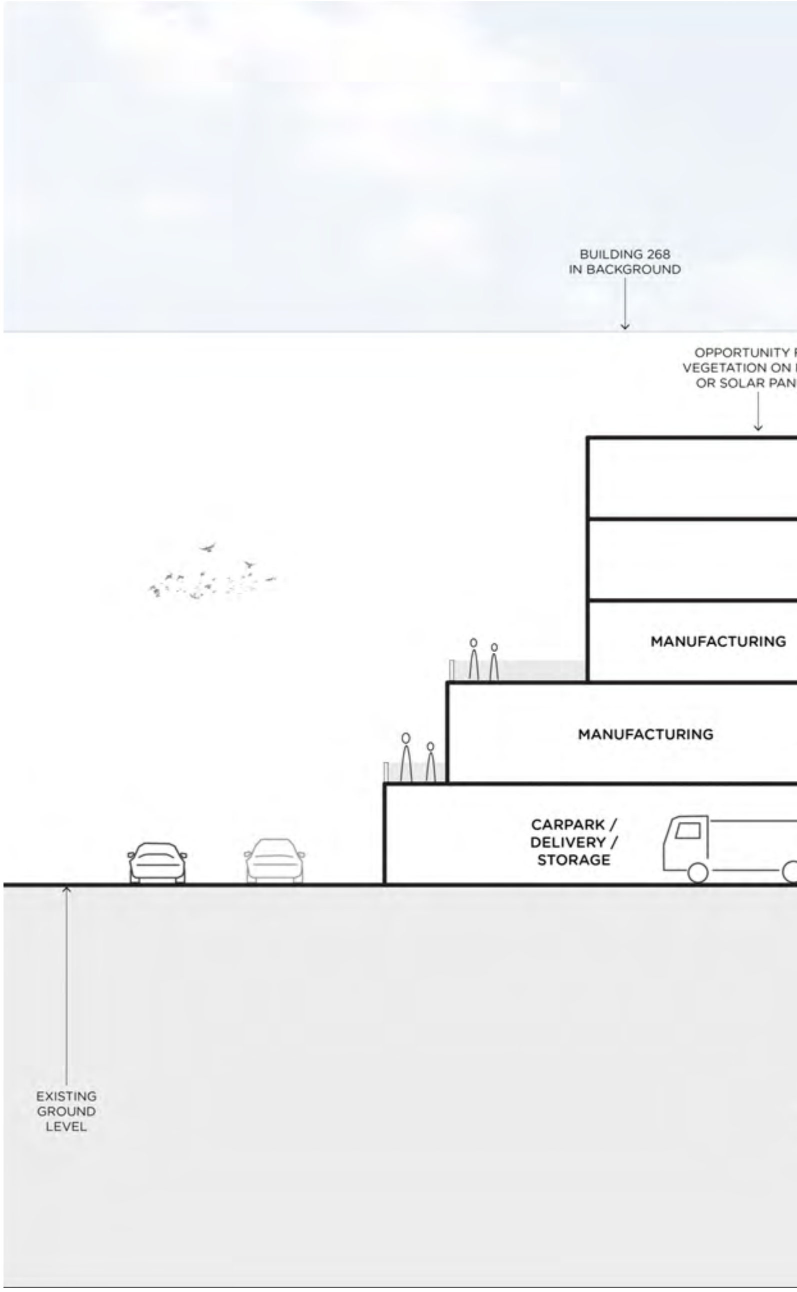
Optimized loading and circulation, accessible waterfront space, enhanced green spaces, leasable office space, job creation, multimodal transit options, shared amenities, oversized floors for urban manufacturing, parking below design flood elevation, loading, servicing and staging areas, public programming showcasing the yard.

Figure 31. Development Site 1: Homeport - Site Plan

Proposed Development and Resilience Measures:

Development Site 1 is situated between Piers C and D and reimagines the waterfront area and building opportunity integrated into the perimeter protection line. An improved mixed-use building structure has been designed in the footprint of Buildings 234, 313, and 314 with a terrace space for increased ground level activation and a seawall integrated into the proposed landscape. The imagined building will offer top floor office spaces with garden terraces and views of the Manhattan skyline, hybrid manufacturing spaces on lower floors, and ground level parking with storage, delivery, and truck access provisions. The ground level parking and terrace area will be floodable under extreme coastal storm conditions (as per the FEMA Freeboard Value Approach described in Section 4). Interior office spaces will be above the DFE and the building exterior will be resistant to water damage. Traffic circulation is maintained for passenger vehicles and trucks accessing Piers C and D. Deployable gates will remain open for daily function and electronically closed by BNYDC staff in preparation for a coastal storm event.

Development Site 1 offers not only a critical resilience solution to coastal flooding in the perimeter zone, but also an opportunity to activate an area of the site to create new tenant space, foster job creation, and enhance experience on the site with inviting open spaces. The small area plan presents one possibility of an integrated resilience development scheme.



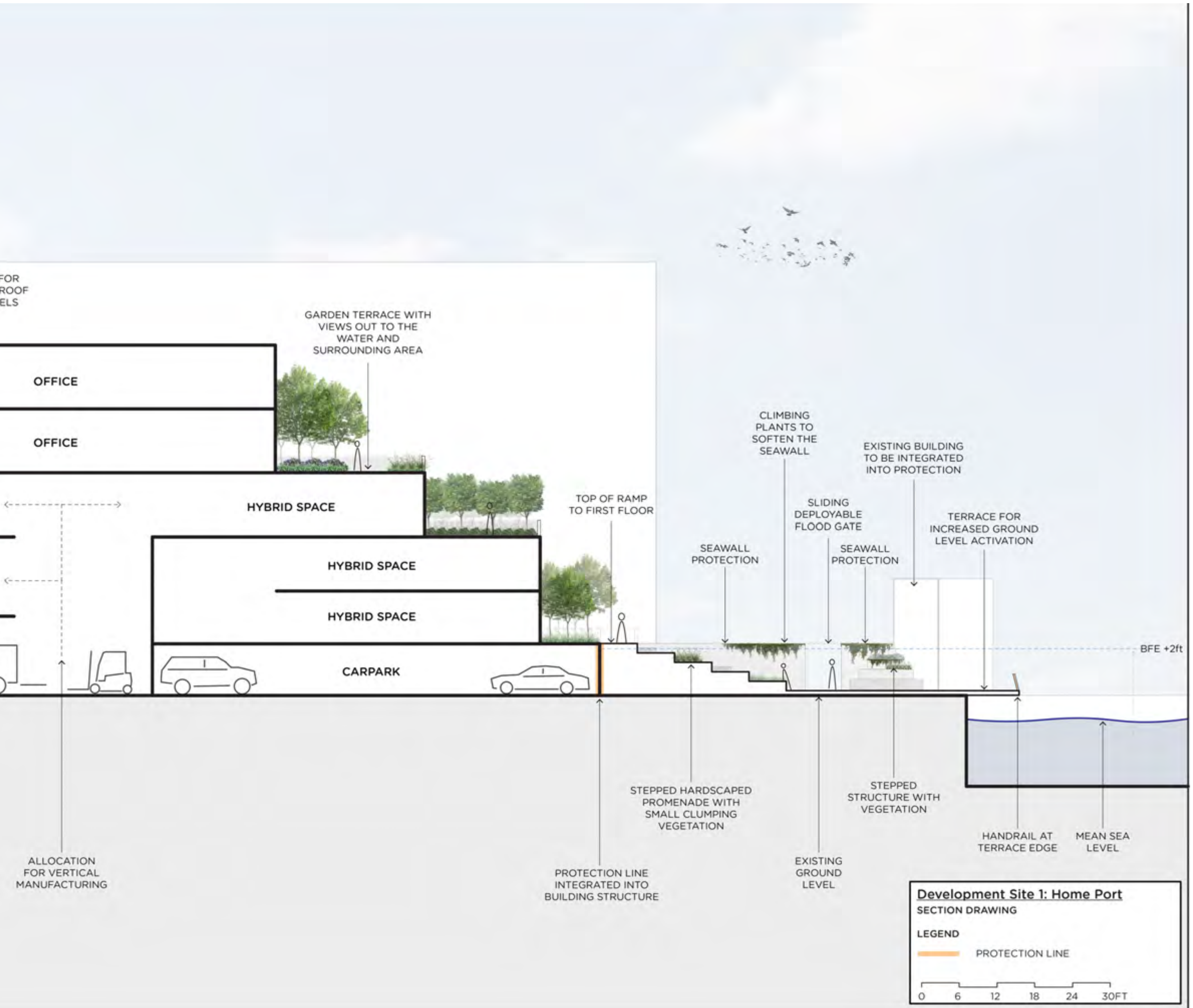


Figure 32. Development Site 1: Homeport - Site Section

Development Site 2: Building 131

Site Location:

Building 131, located between Dry Docks 1 and 4.

Existing Development:

Building 131, CoGen Steam Building

Co-benefits:

Leasable office space, optimized loading and circulation, pedestrian pathway with accessible waterfront space, shoreline stabilization, micro-habitat creation for marine and plant life, water quality improvements, job creation, multimodal transit options, shared amenities, oversized floors for urban manufacturing, parking below design flood elevation, loading, servicing and staging areas, public programming showcasing the yard, heat moderation.

Proposed Development and Resilience Measures:

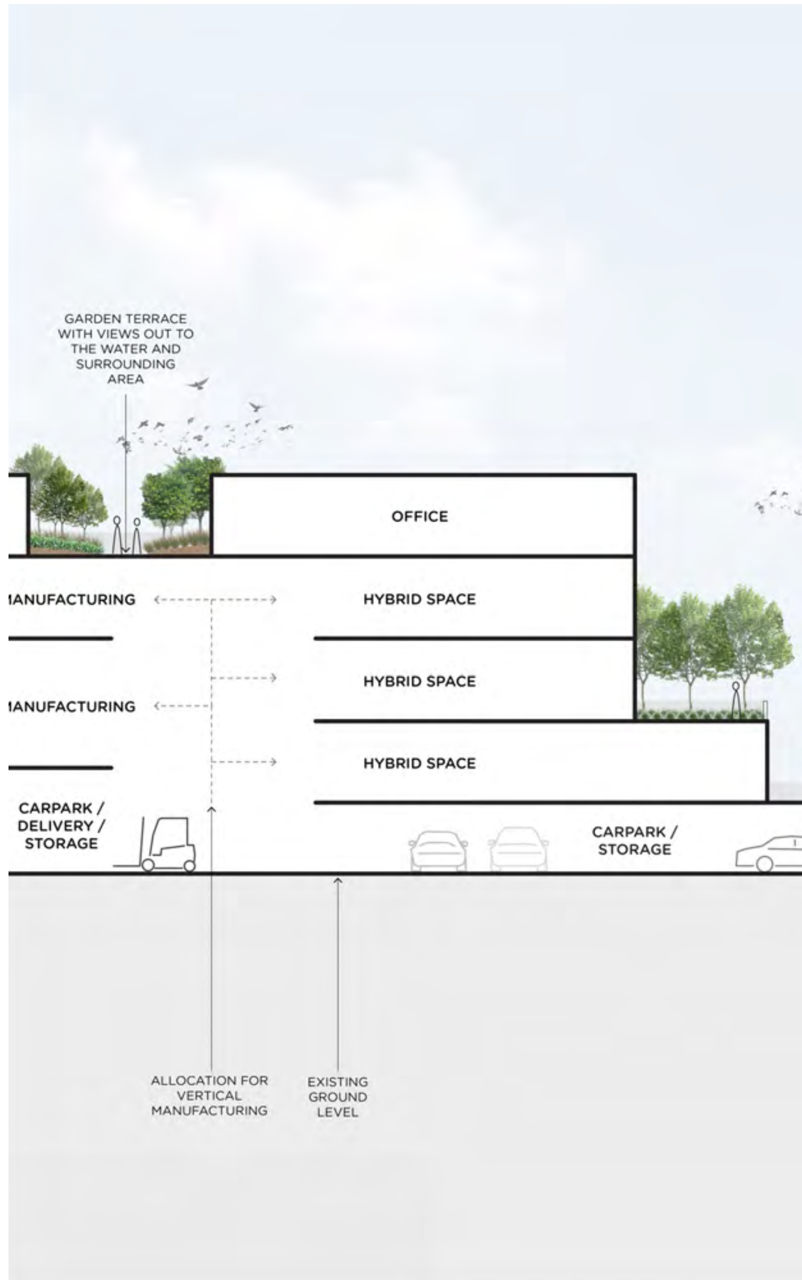
Since Superstorm Sandy, Building 131 has not been fully repaired. The ground level is largely unoccupied due to needed improvements. Although the second floor is occupied, the building remains underutilized and underoccupied. The site remains one of the most vulnerable areas of the Yard to repeat coastal flood risk. Its location is at risk of present-day tidal flooding and acts as a gateway for coastal waters flowing into the Historic Core during extreme events. Dock 72

Figure 33.Development Site 2: Building 131 - Site Plan

provides a compelling case study for elevated waterfront developments at the Yard. The proposed redevelopment of Building 131 aims for a similar top-of-the-line tenant facility, with integration into a greater perimeter line of defense to provide resilience benefits not only for the site itself but also for the vulnerable Historic Core beyond.

Development Site 2 envisions an improved campus with shared amenity features to attract new commercial, light industrial, and vertical manufacturing tenants. Tenant spaces, beginning on the first floor, will be elevated and dry floodproofed above the DFE. Waterfront open space is made available for Yard tenants with a protected pedestrian pathway on the eastern side of the building. Raised garden areas with seating provide an enhanced outdoor experience and potential event space. From the terrace, an elevated boardwalk and seating area reaches out over the basin for a protected connection to the waterfront. Below the boardwalk, shoreline measures like rocky rip rap dissipate wave energy and a protected zone fosters plant and marine life and enhance biodiversity in the basin.

Shifting the existing building footprint to the northeast allows for a consistent seawall protection line along Dock Avenue as well as improved truck loading docks and vehicle circulation for both Building 20 and Building 131. The site plan provides additional parking adjacent to the building and on the ground floor below DFE. Under warning of coastal storm threat, it is expected that the site would be evacuated, deployable gates closed, and tenants, vehicles, and ground floor equipment relocated to behind the protection wall. External grounds of the development site will be wet floodproofed with damage resistant materials and terrace planters installed with gabions and secured to prevent washout. The Cogen Steam facility is recommended for dry floodproofing and watertight seal.



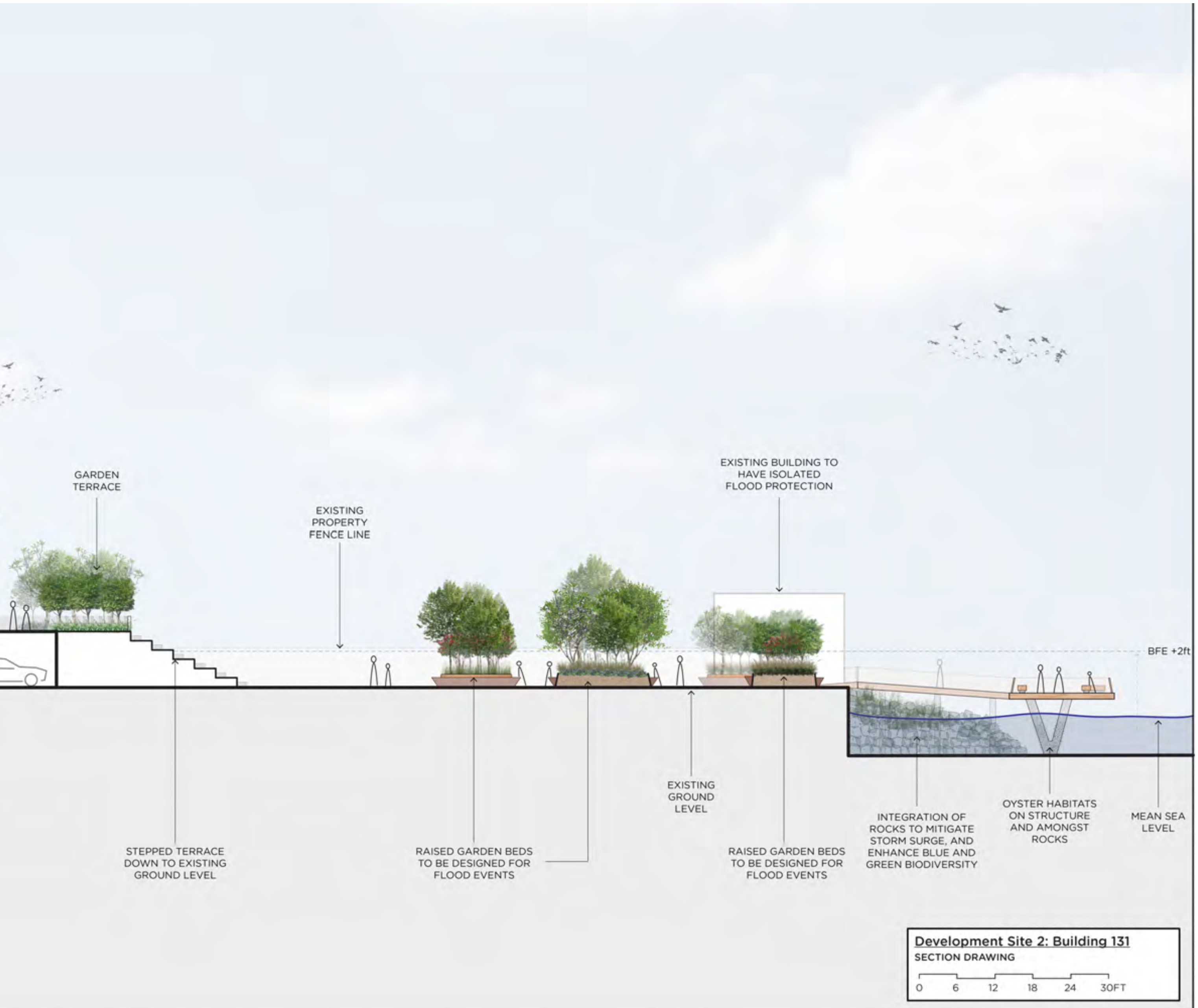


Figure 34. Development Site 2: Building 131 - Site Section

Development Site 3: Market Street

Site Location:

Between Market Street and Paulding Street from 6th Street to Clinton Avenue

Existing Development:

Parking Lots between Market Street and Paulding Street

Co-benefits:

Improved safety and accessibility, multi-modal hub, enhanced green spaces, improved connectivity to mass transit, more bikeable & walkable, open space amenities, heat moderation, air quality improvements.

Proposed Development and Resilience Measures:

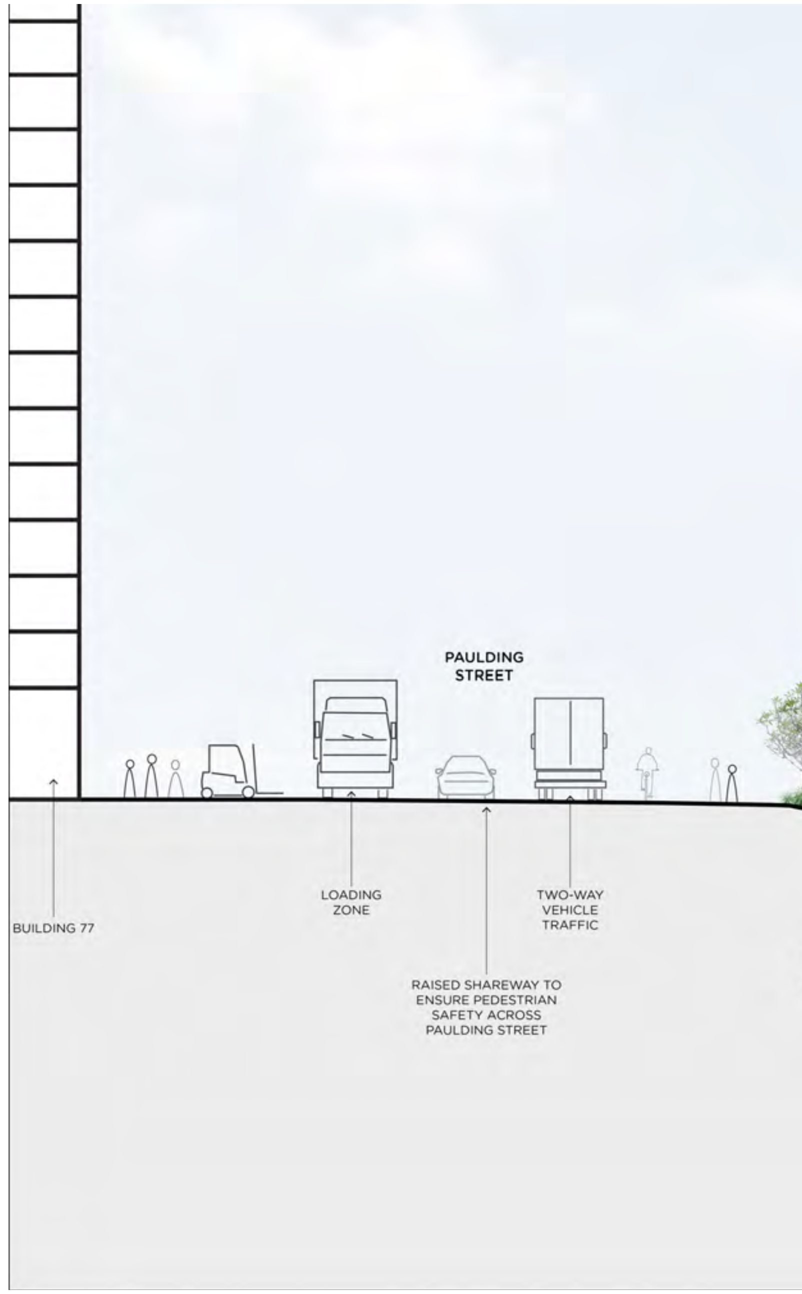
BNYDC is committed to improving transport and mobility around the Yard. Development Site 3 re-envisions bicycle, pedestrian, transit, and open space areas along Market Street, creating a central hub for the Yard with integrated resilience measures. While this site is not at the highest risk from flooding, it demonstrates the synergies between resilience initiatives and transportation objectives and the need for coordinated planning. Development Site 3 also centralizes the benefits of multifunctional infrastructure for improved stormwater management, ground level temperature

Figure 35. Development Site 3: Market Street - Site Plan

moderation, air quality, accessibility, and transit safety.

Market Street currently serves as the primary east-west corridor for vehicular and cyclist traffic in the Yard. Directly south, Paulding Street is a primary truck route with access to loading docks for Buildings 5 and 77. Building 77 is a primary entryway into the Yard for many tenants, many of whom travel to Building 72 and/or to the NYC Ferry. This creates a major pedestrian thoroughfare perpendicular to Market Street and Paulding Street. The current roadways, parking lots, and sidewalks do little to create safe access routes, encourage multimodal transit, or enhance open spaces.

The proposed redevelopment of Market Street creates a central green space at the Yard for congregating and hosting events. It introduces a curved, elevated pathway parallel to Market Street for cyclists and pedestrians to travel safely through the site. Simultaneously, the path acts as a coastal flood barrier preventing water from impacting Building 77, Building 5, and adjacent properties. The elevated pathway ties back to the perimeter protection line on Market Street with deployable flip-up gates that may be activated during an extreme storm event. Multimodal transit options, including the Navy Yard shuttle, bikeshare, MTA bus stops, ferry access and parking lots, are centralized at the Market Street hub to support BNYDC's mobility objectives. Shared streets designate safe crossing areas from Building 77 to Dock 72 and favor pedestrian right of way while improving visibility to vehicle traffic. In the hardscape plaza, depressed areas can detain stormwater runoff during periods of intense precipitation to relieve burden on the sewer network (including conveyance of stormwater from the south side of Building 77 to avoid flooding during extreme rain events). These areas will remain dry most of the time and can provide additional seating, recreation areas, or be used as event spaces. Underdrain connections will discharge the collected rainwater to the sewers and eventually outfall into the basin.



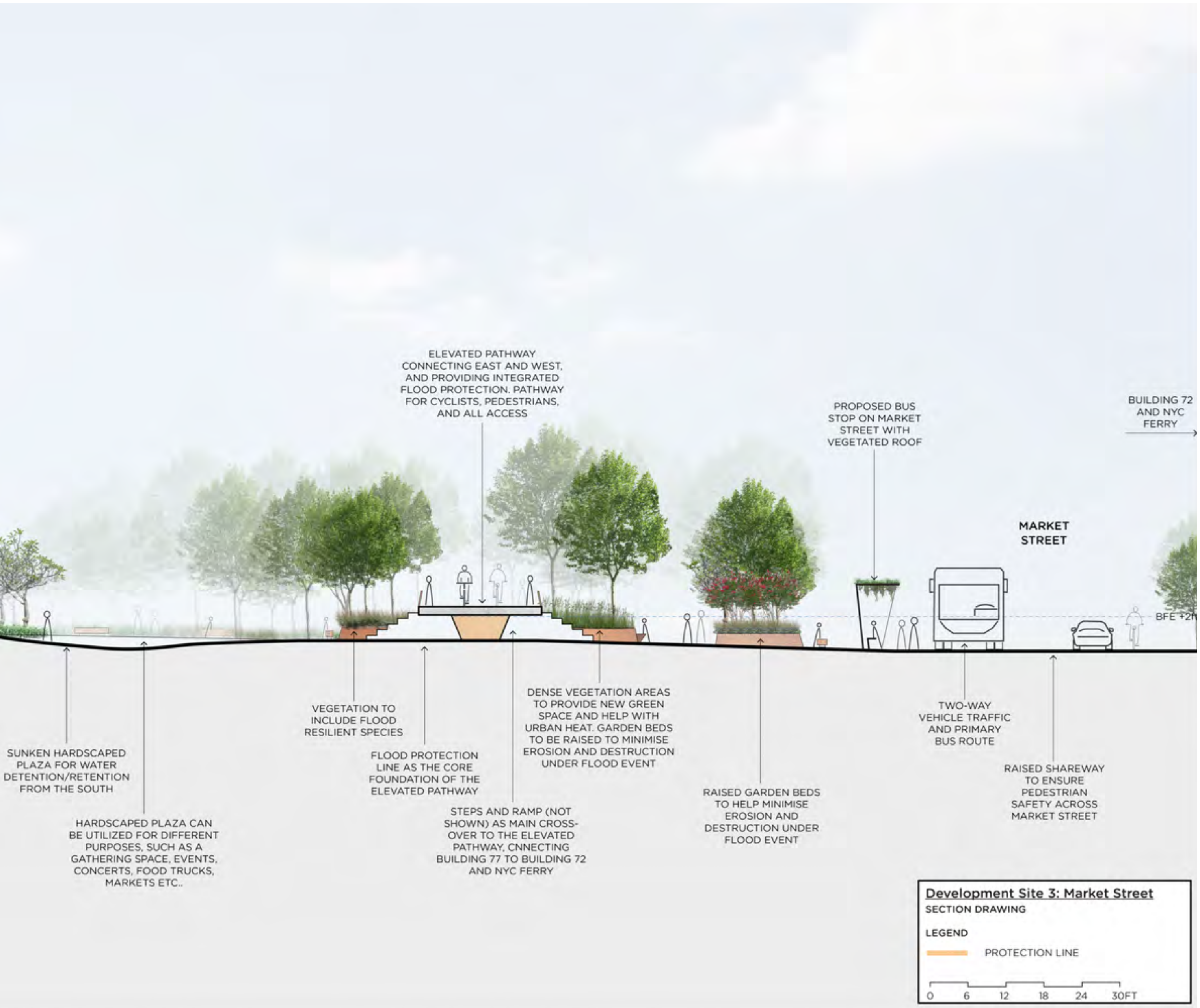


Figure 36.Development Site 3: Market Street - Site Section

Cost Estimates

To better understand the feasibility of implementing the Resilience Recommendations, construction cost estimates were developed in coordination with the recommended construction phasing plan (described in more detail in Section 5). At a high-level, the implementation of these resilience measures is estimated to cost between $81 million and $182 million.

For additional information of the cost estimate assumptions and a more detailed cost breakdown by recommended construction phase, see Appendix E.

These cost estimates include:

- A contingency range
- Percentages for soft costs, including construction management, engineering design, and permitting
- Contractor's general conditions, overhead, and profit
- Utilities (It should be noted that detailed review of as-built conditions and coordination with utility stakeholders will be required to accurately scope the design, permitting, and construction costs for this work, which could constitute a significant portion of the project cost.)

The following items have been excluded from cost estimates and will require further analysis:

- Engineering and construction costs for hazardous materials and other contaminants
- Mitigation for environmental impacts
- Operations equipment
- Architectural and landscape features

Below is a summary of the various physical components that were priced, along with a high-level description of related assumptions:

Building 131: Exterior protections consist of a simply supported concrete barrier wall and will require a protective coating. This assumes the height of the exterior wall is three feet tall and is built directly alongside existing exterior perimeter. Small and large openings (i.e., doors and garages) are included as steel rollup floodproof doors.

Steel Sheet Pile Bulkhead with Concrete Cap: The steel sheet pile wall will require four and a half feet of revetment (i.e., rip-rap) with a slope of 1:2 when adjacent to the shoreline. Additional structural fill beyond the wall along the inshore side extends nine feet to provide structural stability for the freestanding wall.

Pile Supported Reinforced Concrete Barrier Wall: The reinforced concrete barrier wall is assumed to be 6 feet tall with four and a half feet of rip-rap and a 1:2 slope. Micropiles assume ten feet spacing for the entire length of the constructed wall with sixty feet of embedment. Structural fill is assumed above the heel along with twelve inches of compacted gravel beneath footing. No drains are included in this estimate.

Reinforced Concrete Barrier Wall: The reinforced concrete barrier wall is assumed to be three feet tall with four and a half feet of rip-rap and a 1:2 slope. Precast concrete sections are assumed. Two feet of structural fill beneath the wall is assumed due to unknown geotechnical conditions and structural fill above the heel is assumed along with twelve inches of compacted gravel beneath footing.

Carbon Sliding Floodgate Wall: Assumed to be six feet tall and fifty feet long with automated direct drive motor. Installation costs are included in labor contingency.

Powered Flip Up Barrier Wall: Assumed to be three feet tall and twenty feet long with localized activation. Technical crew installation included in labor contingency.

Market Street Pedestrian Walkway: The costing for the pedestrian walkway included in the Market Street development assumes an elevated platform, supported by structural fill, with an 8-foot-wide and reinforced T-shaped walls on either side. Concrete curb and drainage inlets are included in the cost, but landscaping features have been excluded.

Utility Relocation: Additional utilities are calculated as 10% of the raw construction labor costs.

5. Adaptive Resilience Planning

Dynamic Adaptive Planning

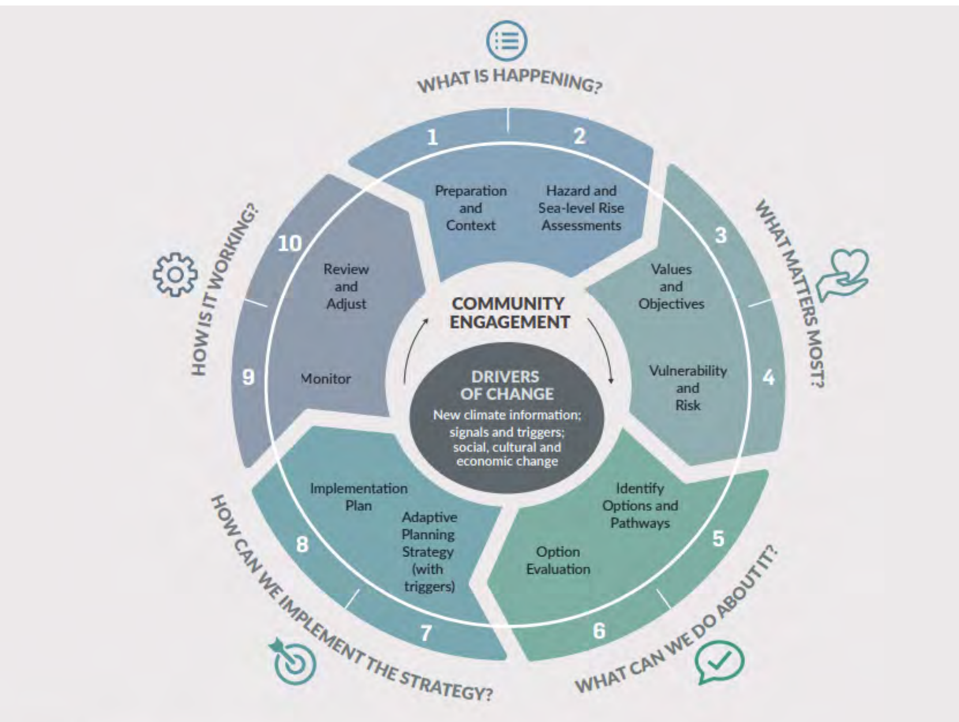
Bridging the gap between planning and implementation is no simple feat. This truism is particularly evident when applied to resiliency planning, which by nature deals in uncertainties as it sits between the nexus of now and what's to come. Mid- and end-of-century projections, while based on the best available data and modeling, have inherent temporal limitations. As the coming decades unfold, the rate at which greenhouse gases are emitted will invariably shape the realities of the climate, and our world, in ways that are both anticipated and unforeseen. Furthermore, changes in political administrations, funding availability, institutional decision-making, and many other factors will inevitably affect how and when the resilience measures proposed in this Resilience Strategy are realized.

Consequently, a dynamic planning approach that acknowledges these uncertainties and makes explicit consideration of decision making through time is a critical component of this Strategy. The theoretical approach of Dynamic Adaptive Planning offers key insights into how BNYDC can prepare for and respond to these uncertainties as it looks to implementation.

Central to Dynamic Adaptive Planning is the inclusion of provisions for adaptation as conditions change and knowledge is gained[1]. This relatively new planning paradigm urges the identification of short-term actions, long-term options, and adaptation pathways – recognizing that decisionmakers need to adapt plans and policies in a rapidly changing world[2]. The graphic below offers a conceptualization of how this theory translates to process.

Returning to the Brooklyn Navy Yard Resilience Strategy with the Dynamic Adaptive Planning approach in mind, the various adaptation pathways that exist for the implementation of the Hybrid Protection Plan can be more broadly envisioned. Elements of this Strategy offer opportunities for

1. Kwakkel, Jan & Walker, Warren & Marchau, V.. (2012).
2. Kwakkel, Jan & Walker, Warren & Marchau, Vincent. (2010).



Source: Adapted from Max Oulton (University of Waikato), and UN-Habitat (2014)

Figure 37. Dynamic Adaptive Planning Approach Process

alignment with the BNY Master Plan Exercise and other development objectives. This enables linkage between the implementation of resilience measures and the various other development activities that will arise over time such that, with any new development opportunity, BNYDC will ask how this can also advance the Resilience Strategy. This linkage exists in the other direction as well, such that funding can be secured for resilient infrastructure implementations that also advances other BNYDC objectives such as economic development, urban manufacturing, and improved open space and public access due to the multifunctional nature of the proposed seawall and development sites.

While this alignment and synergy diversifies the number of opportunities wherein resilience measures can be implemented as components of other development activities, and vice versa, it also necessitates a clear understanding of adaptation pathway-dependencies. Central to this is the identification of adaptation signals, implying opportunities for implementation, as well as tipping points, indicating a changing pathway and the potential need to pivot. An example of an adaptation signal for BNYDC would be if transportation-related sitework is needed near Market Street, that may signal an implementation opportunity as components of the Market Street small area development proposed in the Resilience Strategy could be integrated into the redevelopment. An example of a tipping point would be if city-led or regional resilience measures are implemented, changing BNY's risk level.

Essential to the Dynamic Adaptive Planning approach is laying a solid foundation for short-term actions and understanding long-term priorities so that, regardless of how its achieved, BNYDC can ensure that these measures are in place in time to respond to the hazards they are designed to protect against. Below offers high-level guidance on recommended priority phasing, which can act as the basis to guide implementation:

Immediate:

In the immediate term, BNYDC's focus is on the CPSD work that is currently underway to secure city budget allocations for building-level flood proofing in the wave action zone. Additionally, the roll-out of the Tenant Resilience Toolkit and further coordination between the Resilience Strategy and the Master Plan Exercise will be key considerations for the coming year.

Short-Term (2025 - 2030):

In the next five or so years, BNYDC's focus will be, in part, on implementation as it seeks to utilize the OMB budget allocations for building-level measures in addition to implementing stormwater management projects, such as acquiring and installing pumps and backflow preventors and implementing smaller-scale stormwater site work. This will provide protection from heavy rainfall events, which are expected to occur more frequently and require protection measures sooner than coastal flooding events. At the same time, it is critical for BNYDC to explore funding avenues, submit grant applications, and form partnerships for larger coastal flood protection projects during this period .

Medium-Term (2030 - 2050):

This period's primary focus is implementation. The coastal elements of the Resilience Strategy, including the construction of the multifunctional seawall and the integration of new developments into the perimeter, will need to be constructed during this twenty-year period to provide protection against the more extreme coastal risks that are expected by mid-century. Additional detail on the recommended approach for construction phasing of the perimeter protection is provided below.

Long-Term (Mid-Century and Beyond):

Looking to 2050 and beyond introduces more uncertainties as climate hazards continue to evolve. In addition to maintaining the constructed resilience measures, ongoing adaptation measures may be required to respond to the rising sea level and other exacerbated climate hazards. Other factors, such as the long-term intent and use of the BNY site will need to be considered, and additional adaptation measures will need to be coordinated with wider NYC and regional resilience efforts.

Construction Phasing

While the short-, medium-, and long-term phasing delineated above provides guidance to BNYDC on how to approach implementation at a higher-level based on changing priorities over time, the recommended construction phasing provides more detail into how the Resilience Strategy can be implemented incrementally during the medium-term phase.

This construction phasing approach is based on flood modeling and therefore responds to physical risk, such that sections of the site that have lower elevation are given protection first. It is important to note that the perimeter wall will only effectively protect against the DFE when fully constructed, but initial segments will provide interim protection against smaller coastal flood events that are more likely to occur in the near future.

In addition to reducing risk, this approach minimizes construction costs and allows for a variety of funding mechanisms to be utilized, which will be discussed further in the Funding Strategies and Opportunities section below. Based on that rational, phased construction of the perimeter wall in conjunction with provisional protection measures, such as building level floodproofing and stormwater management, offers a more attainable implementation pathway.

The map below demonstrates how the multi-functional seawall can be constructed in segments, each providing interim protection against smaller storms while working to develop the site-wide perimeter protection that is needed by mid-century.

As noted, this phasing plan responds to physical factors such as elevation and modelled flood risk. In coordination with the Dynamic Adaptive Planning approach, however, opportunities may arise through other avenues to implement certain segments of this Resilience Strategy that do not align with recommended phasing. **If and when funding becomes available for implementation that allows for the construction of recommended segments, they should be leveraged regardless of the phasing approach.**

Furthermore, this phasing approach suggests the incremental construction of protection measures across the site linearly from west to east.

Construction Phasing Sequence

1. Based on flood modeling, Development Site 1: Building 131 should be constructed first as it has the lowest elevation and is most at risk of inundation (Phase 1).
2. Construction of the seawall should then extend westward along Dock Ave and wrap up 3rd Street to provide protection to the historic core (Phase 2).
3. The next phase should include the implementation of Development Site 2: Homeport and the extension of the seawall to East Way (Phase 3).
4. Protection measures can then begin to move eastward, first addressing the area to the immediate east of Building 131 along Dock Ave, 4th Street, and extending to the intersection of Morris Ave and 5th Street (Phase 4).
5. The next phase would be the extension of the perimeter protection on the east side of Dry Dock 4 to provide critical protection to the substation in Building 542. Deployable gates in the protection wall allow truck access to the adjacent lot (Phase 5).
6. Based on elevation and flood risk, the perimeter wall should continue at the intersection of Market Street and 6th Street, which includes the implementation of Development Site 3: Market Street. At its eastern end, the perimeter will turn onto Clinton Avenue and gradually slope to grade at Flushing Avenue ensuring wrapped protection of all the buildings to the east. (Phase 6).
7. The next segment would then return west, closing the gap between Market and 5th Street to the northeast of Building 128 (Phase 7)
8. The final phase would include protection measures for the remaining easternmost portion of the site. A low planter seawall would replace the existing GMD fence line on Assembly Road and act as worksite boundary, a coastal seawall, and as a raingarden to detain stormwater runoff from Assembly Road. The seawall should tie into the proposed Kent Development Site buildings and Barge Basin promenade to provide a consistent perimeter protection system (Phase 8).

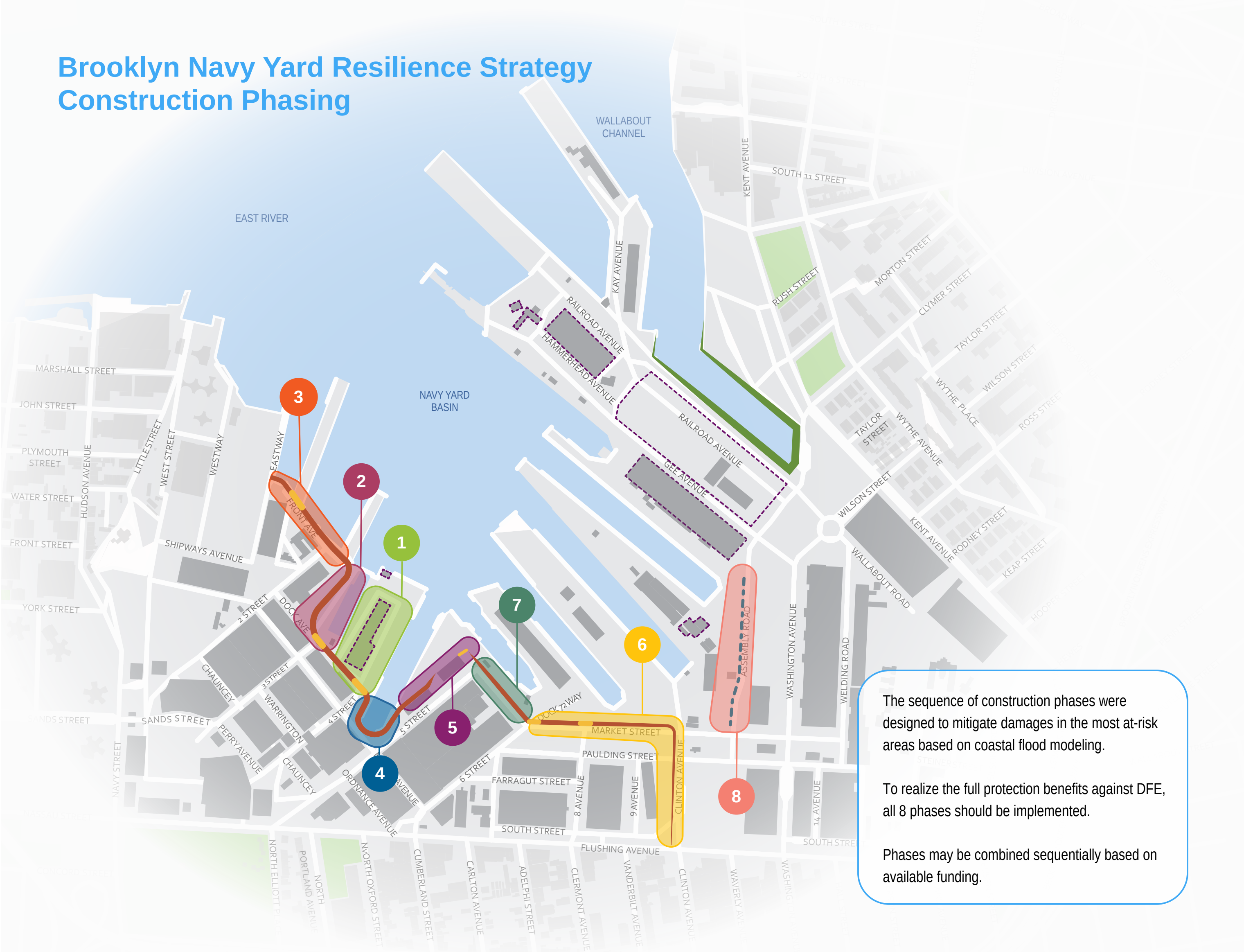


Figure 38.Resilience Recommendations: Construction Phasing Plan

Depending on funding and other factors, there may also be opportunities to construct protection measures that are incremental vertically. In other words, if there is an opportunity to build part of the seawall but funding constraints limit the height of the wall such that it does not provide design level protection, this incremental measure should still be taken as it provides a higher-level of interim protection.

Master Plan Exercise Coordination

Regardless of phasing, a high degree of coordination between the Master Plan Exercise and the Resilience Strategy is an essential component of BNYDC's Dynamic Adaptive Planning approach. The two plans should not be viewed as separate entities, but rather linked approaches to achieve shared objectives.

To that end, the Master Plan Exercise and the Resilience Strategy are deeply aligned and should be implemented in concert. The multifunctionality of this infrastructure acts as the linkage between the Resilience Strategy and the Master Plan Exercise since both can achieve BNYDC's development goals. For instance, the seawall proposed in the multifunctional Resilience Strategy can take different shapes and forms, such as fortified pop-up retail spaces, a storage shed, and office space which meet the Master Plan Exercise's stated development objectives of job creation and economic development. Similarly, Development Site 3: Market Street not only provides improved open spaces and public access, but also eliminates parking spaces which supports the Master Plan Exercise's objective of reducing single-occupant vehicle use on-site.

These synergistic overlaps again highlight the need for the Dynamic Adaptive Planning approach and the identification of adaptation signals. By understanding the ways in which the Resilience Recommendations can achieve the Master Plan Exercise's development objectives, and vice versa, the opportunities to implement both are multiplied.

Funding Strategies and Opportunities

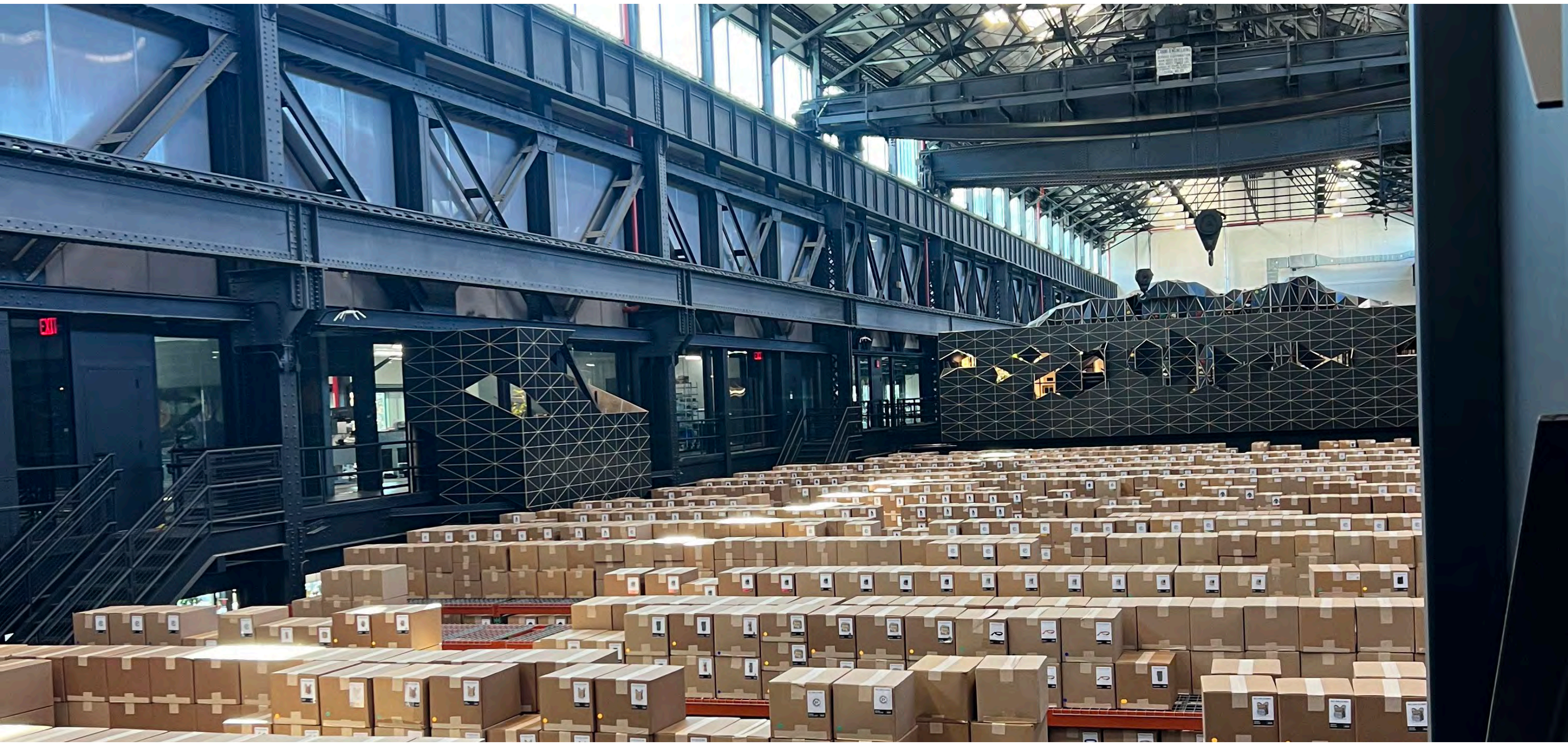
As the climate continues to warm, resulting in extreme weather events such as hurricanes, extreme precipitation, and other natural disasters, funding for climate resilience projects has become increasingly available at the federal, state, and local levels. Beyond just resilience-focused funding, city budget allocations and federal and local grants for multifunctional infrastructure that also provides transportation, open space, and economic development co-benefits can be explored as possible resources to implement these resiliency measures, in addition to developer-led and private funding sources.

As such, one aspect of the funding strategy is to maximizes available funding resources while lending flexibility to the resilient design of the Yard. As the FEMA standard requires a minimum protection height of twelve to thirteen feet, depending on criticality, any resilience measures that are to be positioned for FEMA funding should be designed to meet that height. However, pursuing a uniform design protection height across the entire site can be limiting from a design perspective, as it does not account for building-level protection measures, and may result in higher construction costs than are required to provide necessary levels of protection. Furthermore, given the amount of new development that is expected to occur at BNY over the next few decades, as per the Master Plan Exercise, there will be many opportunities for adaptation measures to be incorporated.

The recommended approach, therefore, is to not use a uniform protection height across the site and instead identify areas within the Navy Yard that should be prioritized for federal funding and those that should be prioritized for other funding sources and are not require to meet the twelve- to thirteen-foot protection height standard. From a phasing perspective, BNYDC may consider timing resilience improvements on future development sites so that they are aligned with the actual development and can be funded either as part of the private development and/or leveraging private funding to secure grant funds.

This approach lends flexibility to the Navy Yard's resilience approach that allows for building-level protection measures (such as floodproofing) to occur in conjunction with new development while targeting federal funding for the more substantial infrastructure installments, such as the seawall, that are intended to protect larger swaths of the site where it is difficult to retrofit with building or roadway resilience measures. This funding strategy is well aligned with the DAP approach as it provides further linkage between the resilience recommendations and the Master Plan, ultimately creating new adaptation pathways that facilitate implementation.

Appendix E includes pertinent resilience grant opportunities, as well as potential public sector low-interest funding sources and foundation funding sources. Each funding source is accompanied by a description of the program, eligibility requirements and activities, information regarding the application cycles, funding/cost-share considerations, and additional resources.



6. Tenant Resilience Toolkit

Tenant Resilience Toolkit

In addition to the actions undertaken by BNYDC to plan for future climatic conditions and mitigate risk on site, tenants at the Yard have a responsibility to protect their facilities, equipment, and staff. The Resilience Tenant Toolkit will serve as a guide to help tenants understand their risk and their adaptation options to protect against precipitation and coastal flooding. The adaptation strategies included therein provide guidance on elevating assets, sealing building openings and building perimeters, using flood damage resistant materials, and protecting critical systems. These strategies will work in concert with the sitewide protection plan and mitigate short term flood risk until the BNY Resilience Strategy Recommendations are implemented.

To review the Tenant Toolkit, refer to Appendix G.

7. Conclusions and Next Steps

Conclusions and Next Steps

The Brooklyn Navy Yard is a vital economic asset and employment hub for the New York metropolitan area that must evolve in the face of a changing climate. The Brooklyn Navy Yard Resilience Strategy outlines recommendations for protecting commercial and manufacturing infrastructure at the Yard while preserving operations of the working waterfront. The multifunctional infrastructure recommendations improve the Yard's resilience to climate impacts and mitigate risk at the asset level and sitewide while fostering alignment with BNYDC's Master Plan Exercise and economic development goals.

Essential to the Dynamic Adaptive Planning approach is a solid foundation for short-term actions and a shared vision for long-term priorities. In the immediate future, BNYDC will continue to utilize funding from local and federal sources (e.g., NYC capital budget allocations and FEMA recovery grants) to make repairs from Superstorm Sandy and floodproof at-risk facilities in the wave action zone. Waterfront construction work for structural repairs, mechanical rehabilitation, and caisson replacements will continue at the Yard's berths, piers, and dry docks. These ongoing efforts support Superstorm Sandy recovery and near-term resilience, and couple with the resilience recommendations herein. Repairs and floodproofing bolster existing infrastructure and protect waterfront assets and equipment from present-day climate hazards. These protections are essential while BNYDC seeks additional funding to finance the Resilience Strategy for more enduring, sitewide measures. Implementation of the resilience recommendations are targeted for the mid-century scenario. The perimeter protection system is designed to mitigate damages of projected coastal storm events, construction of the system itself may be phased based on varying risk levels across the site.

BNYDC will also continuing expanding upon concepts outlined in the Master Plan Exercise, including plans for building development, mobility improvements, expanded open space, and continued growth of the light industrial and innovation sectors. As BNYDC pursues development goals, they may consider pathways that emphasize multi-functional infrastructure solutions to simultaneously achieve resilience goals. BNYDC is currently in the process of initiating a mobility and transport study at the Yard with potential overlap with stormwater management, heat moderation, and open space objectives. The study may allow for further investigation into Development Site 3: Market Street and the perimeter protection system. The synergy between potential mobility improvements on Market Street and the recommended resilience measures in the Strategy highlights the potential for multi-functional infrastructure solutions. These integrated infrastructure solutions can achieve the goals of this Resilience Strategy, while also supporting other critical BNYDC objectives and demonstrating co-benefits that can help make a strong case for receiving local, state, and federal funds.

BNYDC may use this Strategy and the funding opportunities outlined in Appendix E to seek additional financing. It is recommended that these pursuits prioritize projects that protect the vulnerable Historic Core district, as is described in the Construction Phasing Plan. The multifunctionality of the resilience recommendations in the Strategy should be used to identify additional funding pathways and strengthen the case for the investment. In addition to the funding sources identified in Appendix F, BNYDC should also continually monitor additional funding sources that have not yet announced, including potential upcoming funding sources made available by the federal Infrastructure Investment and Jobs Act (IIJA), Inflation Reduction Act (IRA), and the New York State Environmental Bond Act.

Aside from the coastal flood resilience recommendations, stormwater management remains a need at the Yard. Short duration, intense rainfall continues to challenge the aging and overburdened sewer network on site. To diagnose infrastructure problems and mitigate damages from interior flooding, a Stormwater Management Investigation is recommended. The investigation should include up to date mapping of the sewer network, conditions assessments for existing infrastructure, and comprehensive modeling of stormwater runoff and high tides. This will help diagnose interior flooding occurring at the Yard and determine the need for additional pipe capacity, new catch basins, backflow prevention, improved maintenance, or other solutions to prevent future flooding.

Building resilience to uncertain and changing climactic conditions will require an adaptive planning mindset, regional cooperation, and a multifunctional approach to development at the Yard. In the long term, end of century and beyond, the uncertainty of projected climate hazard increases. In addition to maintaining the constructed resilience measures, ongoing adaptation measures may be required to respond to the rising sea level and other exacerbated climate hazards. The long-term intent and use of the Yard will need to be considered in the context of the changed climate, and additional adaptation measures will need to be coordinated with wider NYC and regional resilience efforts. Furthermore, changes in political administrations, funding availability, institutional decision-making, and many other factors will inevitably affect how and when the resilience measures proposed in this Resilience Strategy are realized. The Brooklyn Navy Yard Resilience Strategy serves to kickstart the effort and act as an ever-evolving guide for sustainable development.

Appendix

Appendix A: Asset Inventory

The complete Asset Inventory was delivered as a spreadsheet to BNYDC.

Appendix B: Exposure of Brooklyn Navy Yard to Physical Climate Hazards

Overview of Approach

The consultant team characterized the exposures of Brooklyn Navy Yard (the "Yard" or "site") and its assets to physical climate hazards from the present day through approximately 2100. Current conditions and projected changes in climate were characterized using climate model and other hazard data sets for the proposed site location and surrounding region. The climate hazards evaluated were:

- Inland flooding
- Coastal flooding
- Extreme heat and heat stress
- Hurricanes and other tropical cyclones
- Wildfire
- Water stress and drought

A scenario analysis approach was used to account for uncertainty in future changes in greenhouse gas (GHG) emissions. The Shared Socioeconomic Pathway (SSPs) developed for the Coupled Model Intercomparison Project Phase 6 (CMIP6) were used to evaluate changes in temperature, precipitation, and other indicators. These scenarios were developed in support of the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). CMIP5 scenarios, called Representative Concentration Pathways (RCPs), were used for hazard data sets that have not yet been updated to the CMIP6 projections. The assessment considers two GHG scenarios that span a range of possible futures: a high emissions scenario (SSP5-8.5/RCP 8.5) in which GHG emissions continue to increase with time and an intermediate scenario (SSP2-4.5/RCP 4.5) in which GHG emissions level off and start to decline by mid-century.

High-resolution ("downscaled") climate model projections for each GHG scenario were used to perform a quantitative, screening-level evaluation for the site. Climate models are computer simulations of the earth's climate system, including the atmosphere, ocean, biosphere, and land surface. A climate model is provided with information about how GHG concentrations may change in the future (e.g., the SSP scenarios). The climate model then simulates the response of the earth's climate system to the specified changes in GHGs. The NASA Earth Exchange CMIP6 Global Daily Downscaled Projections ([NEX-GDDP]; Thrasher et al., 2022) were used to assess future changes in temperature, precipitation, and related indicators. The NEX-GDDP data set includes downscaled projections from thirty-five CMIP6 global climate models for a historical period (1950-2014) and a future period (2015 to 2100) at a resolution of 0.25 degrees x 0.25 degrees. In this study, indicators were calculated for a baseline period (1995-2014) and three future time horizons: 2030s (2015-2044), 2050s (2035-2064), and 2080s (2065-2094). Indicators were calculated for each model and year and then averaged across the baseline and future time horizons. Then, the delta between each future time horizon and the baseline period was calculated for each model in the ensemble. Finally, the median (50th percentile) delta value across models was determined along with the 10th and 90th percentiles. Statistics are calculated for a 20-year period to address the natural variability of the climate system.

The site's exposure to the evaluated climate hazards were rated from low to very high considering the probability that the climate hazard will occur and modeled magnitude of exposure. It should be noted that these ratings are meant to be interpreted site-wide. Inland and coastal flooding, the impacts of which are expected to vary across the site, will be further assessed at higher resolution. The exposure ratings are intended to represent the need for more detailed vulnerability assessment and development of resilience strategies. The ratings do not account for the specific characteristics of the site including any existing resilience measures and instead represent only the exposure of the location of the site. Each hazard is scored independently. For example, rising temperatures can contribute to increasing wildfire risk, but the heat stress rating only considers the potential impacts of heat on the site (e.g., increased cooling costs). The projected impacts of changing temperatures (and other climate indicators) on wildfire and other hazards are accounted for directly in the rating of those hazards. The climate

Table 8. Climate Hazard Exposure Rating System

Hazard Rating	Level of Recommended Action Based on Modeling Results
Very High	Imminent hazards for which adaptation strategies should be evaluated and developed as necessary
High	Hazards for which adaptation strategies may need to be developed in the near future or for which further information is needed
Medium	Hazards for which impacts should be monitored but may not need action at this time
Low	Low modeled exposure; may be re-evaluated in the future

hazard exposure rating system is summarized in Table 8.v

Hazard Exposure Evaluation

Inland Flooding

Inland flooding is defined here to be comprised primarily of flooding due to precipitation events. NYC Stormwater Flood Maps were identified as a potential resource, as they model flooding due to moderate and extreme rainfall intensities and incorporate modeling of the city's sewer system (Department of Environmental Protection, 2022). However, the Brooklyn Navy Yard was not modeled within these maps because it is classified as a "Non-Commercial PLUTO [Property Land Use Tax Lot Output] lot greater than or equal to 250,0000 square feet", one of several types of areas omitted due to insufficient information about their drainage infrastructure (New York City Mayor's Office of Resiliency, 2021).

For this reason, present-day and future exposure to inland flooding was estimated using NEX-GDDP data and modeled across the site using SCALGO. SCALGO allows for terrain-based analysis of surface runoff and informs on inland flow paths and surface accumulation independent of sewer drainage.

Projected changes in the frequency and intensity of extreme rainfall from NEX-GDDP were then used, with context from historical baseline values from the New York City Panel on Climate Change (NPCC3) 2019 Report (González et al., 2019), to evaluate the site's future exposure to inland flooding.

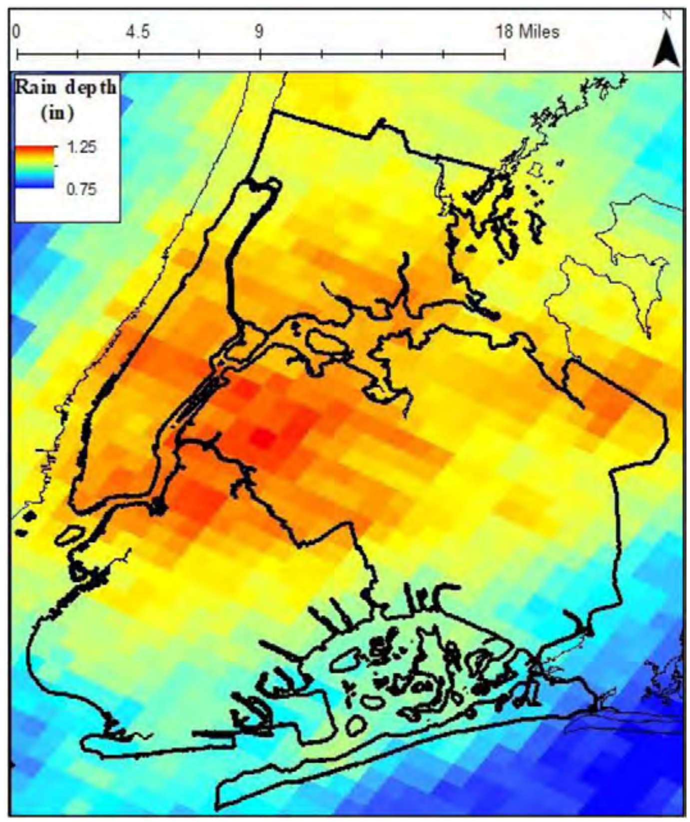


Figure 39.Daily average rainfall for days of known flooding during 2001-2015

Source: NYC Office of Emergency Management and National Climatic Data Center [NCDC]). Image from NPCC3 (González et al., 2019).

Present and Future Exposure

Extreme precipitation indicators from the NEX-GDDP data set are presented in Tables 2 and 3. To determine the levels of extreme rainfall that are relevant to the site and may cause flooding, daily rainfall amounts on 72 days of known flooding from 2001-2015 (reported by the NYC Office of Emergency Management and the National Climatic

Table 9. NEX-GDDP SSP2-4.5 projections for precipitation

	Modeled Baseline	Absolute Change from Baseline Median (10th, 90th percentile)			Percent Change (%) from Baseline Median (10th, 90th percentile)		
Indicator Variable	1995-2014	2030s	2050s	2080s	2030s	2050s	2080s
Days with daily precipitation at or above 1 inch/day	6.84	0.95 [-0.33, 2.02]	1.51 [0.49, 2.40]	1.96 [1.16, 2.98]	13.88 [-4.78, 29.53]	22.10 [7.10, 35.13]	28.71 [16.90, 43.59]
Maximum 1-day total precipitation (in.)	2.05	-0.01 [-0.18, 0.29]	0.13 [-0.16, 0.32]	0.14 [-0.09, 0.34]	-0.33 [-8.97, 13.87]	6.13 [-7.55, 15.76]	7.01 [-4.42, 16.66]
Maximum 5-day total precipitation (in.)	3.32	0.04 [-0.15, 0.44]	0.26 [0.08, 0.59]	0.31 [-0.02, 0.63]	1.14 [-4.39, 13.18]	7.69 [2.43, 17.73]	9.26 [-0.54, 18.94]

Table 10. NEX-GDDP SSP5-8.5 projections for precipitation

	Modeled Baseline	Absolute Change from Baseline Median (10th, 90th percentile)			Percent Change (%) from Baseline Median (10th, 90th percentile)		
Indicator Variable	1995-2014	2030s	2050s	2080s	2030s	2050s	2080s
Days with daily precipitation at or above 1 inch/day	6.84	1.08 [0.04, 2.61]	2.36 [0.23, 2.91]	2.97 [1.82, 5.02]	15.83 [0.60, 38.10]	34.53 [3.38, 42.50]	43.46 [26.58, 73.42]
Maximum 1-day total precipitation (in.)	2.05	0.06 [-0.16, 0.19]	0.20 [-0.13, 0.41]	0.32 [0.08, 0.57]	2.97 [-8.00, 9.33]	9.84 [-6.27, 19.73]	15.58 [3.96, 27.57]
Maximum 5-day total precipitation (in.)	3.32	0.11 [-0.16, 0.57]	0.33 [-0.05, 0.68]	0.59 [0.22, 0.90]	3.39 [-4.69, 17.17]	10.01 [-1.43, 20.43]	17.88 [6.59, 27.12]

Data Center [NCDC]) were reviewed(taken from NPCC3). In northwestern Brooklyn where the Yard is located, daily rainfall reached amounts of approximately 1 inch on flooding days. Thus, in Tables 2 and 3, the number of days with daily precipitation at or above 1 inch is included as a precipitation-based indicator from the NEX-GDDP downscaled simulations. The baseline (1995-2014) modeled value is approximately 7 days per year, with projected increases of 14%, 22%, and 29% under SSP2-4.5 and 16%, 35%, and 43% under SSP5-8.5 by the 2030s, 2050s, and 2080s, respectively. We note that the observed baseline value provided by the NPCC2 and NPCC3 reports for the Central Park weather station over 1971-2000 is 13 days per year, nearly double the modeled baseline value. This is because, within climate models, precipitation is averaged over each grid cell, thus making direct comparisons to weather station data inappropriate. However, the aforementioned percentage increases can be used in conjunction with the observed baseline to estimate the number of days in the future that exceed 1 inch of precipitation. In the SSP2-4.5 scenario, this would be approximately 15, 16, and 17 days exceeding 1 inch of precipitation per year for the 2030s, 2050s, and 2080s, and in the SSP5-8.5 scenario, this would be approximately 15, 18, and 19 days per year, respectively.

Two other metrics relevant for flooding are the annual maximum 1-day and 5-day total precipitation, the modeled baseline values of which are 2.05 in. and 3.32 in., respectively (Tables 2 and 3). Future projected changes in the SSP2-4.5 scenario are approximately 6-8% for the 2050s and 7-10% for the 2080s; the corresponding ranges for the SSP5-8.5 scenario are 9-10% for the 2050s and 15-18% for the 2080s. These values are largely in

Table 11. 24-hour precipitation (inches) for SSP2-4.5 and SSP2-8.5

	Observed (1970 - 1999)	2030	2050	2080
SSP2-4.5	9.6	9.6	10.2	10.3
SSP5-8.5	9.6	9.9	10.5	11.1

Note: 24-hour precipitation (inches) using the intensity duration frequency curve (100-year return period) for the Central Park weather station and scaling factors from NEX-GDDP simulations.

Table 12. 24-hour precipitation (inches) for 10-Year, 50-Year, and 100-Year Return Periods

		SSP 2-4.5	SSP 5-8.5
10-Year Return Period	Observed (1970-1999)	5.5	
	2030	5.5	5.7
	2050	5.9	6.1
	2080	5.9	6.4
50-Year Return Period	Observed (1970-1999)	8.2	
	2030	8.1	8.4
	2050	8.7	9.0
	2080	8.7	9.4
100-Year Return Period	Observed (1970-1999)	9.6	
	2030	9.6	9.9
	2050	10.2	10.5
	2080	10.3	11.1

Note: 24-hour precipitation (inches) using the intensity duration frequency curve for the Central Park weather station and scaling factors from NEX-GDDP simulations.

line with those provided online by the Northeast Regional Climate Center, despite the latter being derived from CMIP5 simulations and different downscaling methodologies (DeGaetano and Castellano, 2017).

Due to the very high present-day exposure and projected increases in the intensity and frequency of extreme precipitation, BNY has a very high inland exposure rating for all future time horizons and scenarios.

Data used for modeling inland flooding

To perform a simple model of the inland flooding the software Scalgo was used to model the inland flooding to account for future climate change impact on precipitation patterns a Climate Factor (CF) is applied to the rainfall data. The CF is developed using climate projections from Cornell University. (Northeast Regional Climate Center, 2015). These projections are based on a downscaling of a global climate model output for the four Representative Concentration Pathway (RCP) scenarios by the Intergovernmental Panel on Climate Change (IPCC). Projections are available for three future projection periods: 2010-2039, 2040-2069, 2070-2099. The high emission RCP 8.5 scenario in 2040-2069 (referred to as "2050") from Cornell University is chosen as a conservative climate scenario for a medium future (2050) planning horizon. This methodology has been chosen because it is consistent with the methodology that has previously been applied in cloudburst projects with NYC Department of Environmental Protection (DEP).

Secondly, a box rain is used to calculate the overall amount of stormwater within a catchment and the spatial flood exposure. A duration of 60 minutes is chosen for each return period, based on an analysis of estimated catchment sizes and corresponding time of concentration. The capacity of the existing drainage system is estimated to a 5-year storm in current climate based on the NYC DEP Drainage Plan. The amount the existing drainage system can manage is subtracted from the calculated rain depths to estimate the remaining volume.

Table 13. 60 minutes rain depth in inches (volume of flooding) for 10-, 50- and 100-year return periods

Future Projections (SSP2-8.5) -NYC DEP Drainage Plan 5- year event[Inches/hour]	Return Period (Years)		
	10	**50**	**100**
Present-Day	0.25	0.89	1.17
2030	0.58	1.58	2.22
2050	0.71	1.79	2.49
2080	0.83	2.00	2.77

Coastal Flooding

Coastal flooding includes both chronic flooding from high tides and acute flooding from storm surge. The present-day exposures of the site to acute and chronic coastal flood hazards were evaluated separately. Exposure to storm surge flooding was assessed using hurricane inundation modeling prepared by the National Oceanic and Atmospheric Administration (NOAA), the National Hurricane Center (NHC), and the National Weather Service (NWS). Exposure to chronic flooding was evaluated through review of present-day high tide flood mapping and frequency data from NOAA. NOAA provides event frequencies (alternatively, return periods) for various high tide flooding (HTF) levels for tide gauges across the U.S. (Sweet et al. 2022). The data for the tide gauge at The Battery were used as it is the closest to the site.

The present-day exposure of the site to coastal flooding was supplemented with a review of flood mapping from the FEMA National Flood Hazard Layer (NFHL). As the effective Flood Insurance Rate Maps (FIRMs) that comprise the NFHL were last updated for New York City (NYC) in 2007, Preliminary Flood Insurance Rate Maps (PFIRMs) released for NYC in 2015 were also reviewed.

Future coastal flooding exposure was evaluated through review of NOAA sea level rise projections (Sweet et al. 2022) and NOAA sea level rise layers[1]. These data sets were supplemented with maps from the New York City Flood Hazard Mapper[2].

Present-Day Exposure

Figure 39 shows the FEMA NFHL map for the area surrounding the Yard, which is almost entirely within either a Zone AE 100-year (1% annual chance) or the 500-year (0.2% annual chance) flood zone, with much of the site in the former category. The PFIRMs published in 2015 (not shown) indicate increases in both the extent and base flood elevations of the 100-year flood zone. Some of the hazard areas in the eastern portion of the site were also reclassified as Zone VE which reflects additional hazard due to storm waves (Zone VE).

Acute Exposure

The NOAA/NHC/NWS storm surge inundation maps were developed using the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model to simulate storm surge from tropical cyclones. Maximum Envelopes of Water (MEOWs) were created by computing the maximum storm surge resulting from up to 100,000 simulated hypothetical storms. Maximum of MEOWs (MOMs) were created for each hurricane category (1 through 4) by retaining the maximum storm surge value across all the MEOWs for that category. Thus, no single hurricane will produce the regional flooding depicted in the MEOWs / MOMs; instead, the maps are estimate of the near-worst case extent of inundation from each hurricane category. Maps of storm surge for Category 5 hurricanes are not available for New York.

Figure 40 shows the near-worst case storm surge depths from the SLOSH-MOM data set for Category 1 hurricanes. Virtually the entire site is modeled to experience inundation, with most of the Yard modeled to be inundated by 3 to 6 feet of storm surge and a significant portion facing more than 6 feet. The SLOSH-MOM results for Category 2, 3, and 4 hurricanes show increasing storm surge heights with most of the site and surrounding area modeled to be inundated to depths of greater than 9 feet with the Category 3 storm.

Chronic Exposure

The event frequency of a given water height at a tide gauge was determined via a regional frequency analysis (RFA), which uses information from other nearby tide gauges under the “assumption that similar physical forcing across a region will produce a similar frequency of events…up to…a local scaling factor that captures response peculiarities” (Sweet et al., 2022). This RFA defined extreme water levels (EWLs) for each tide gauge as water heights higher than the 98th percentile of daily highest water levels, which for The Battery is coincidentally the same as the NOAA threshold for minor HTF: 0.55 meters above mean higher high water (MHHW). The authors noted, however, that tide gauges are generally unable to measure higher-frequency wave effects “due to their general placement (e.g., in harbors), protective housings that dampen wave effects, and their multi-minute sampling rates”, and

1. https://coast.noaa.gov/digitalcoast/tools/slr.html

2. https://www.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page

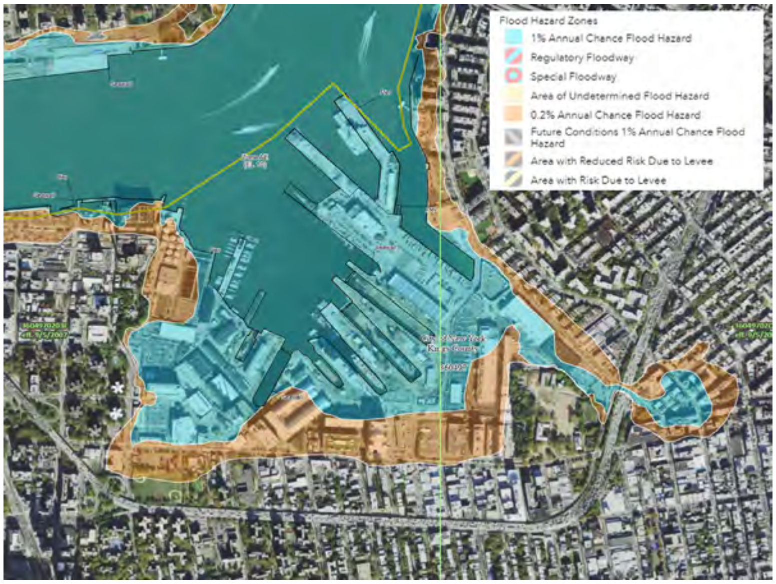


Figure 40. FEMA National Flood Hazard Layer

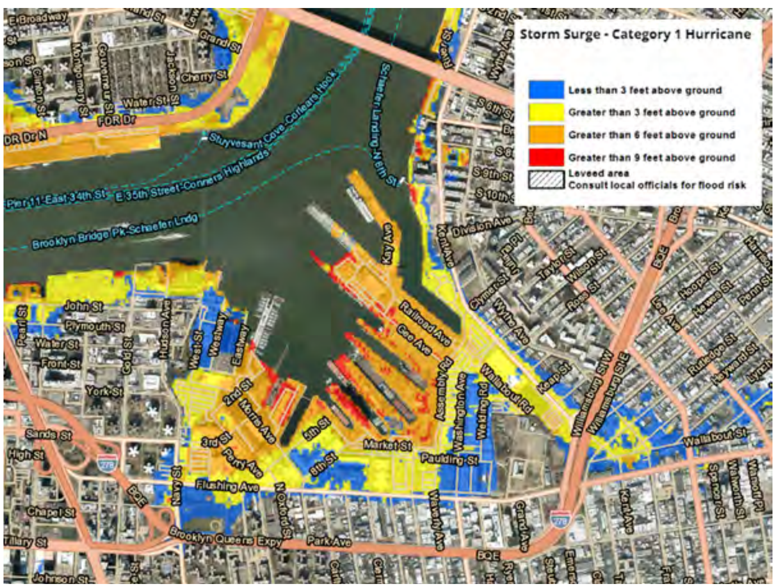


Figure 41. Estimated near-worse case storm surge flood depths, present-day Category 1 hurricane

Estimated near-worse case storm surge flood depths from the present-day Category 1 hurricane as modeled by NOAA SLOSH-MOM.

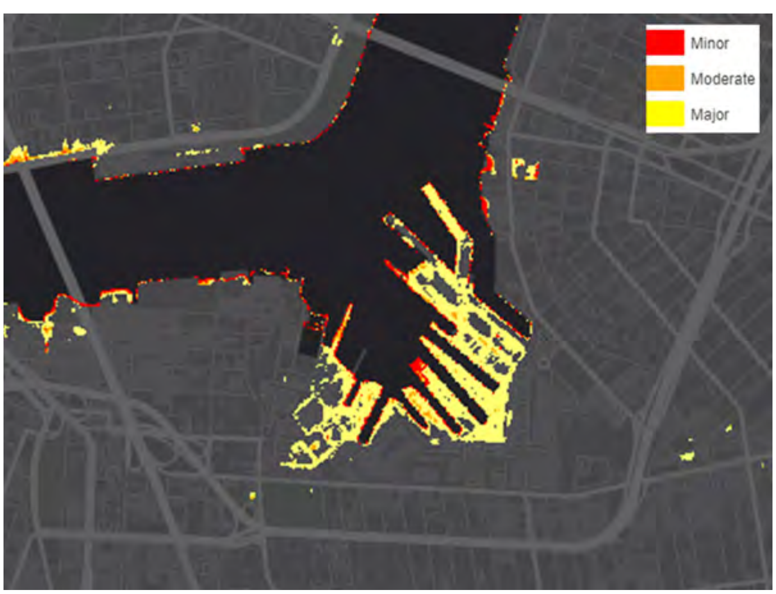


Figure 42.NOAA High Tide Flooding Map

Depicting exposure to NOAA's three levels of high tide flooding: Minor (0.55 meters above mean higher high water [MHHW]), Moderate (0.85 meters above MHHW), and Major (1.20 meters above MHHW).

so these EWLs may underestimate the actual water height reached for a given event frequency.

Figure 41depicts the present-day exposure of the Yard to high tide flooding, and Figure 42plots the height of the daily highest water level at The Battery tide gauge as a function of event frequency (alternatively, return period). Small pockets of the site on the bank of the East River and the edge of the Navy Yard Basin are susceptible to minor or moderate HTF. At the tide gauge at The Battery, minor HTF occurs during 4-5 events per year (Figure 42), with each event spanning approximately 2 days (Sweet et al., 2022). Moderate HTF, defined by NOAA as water levels reaching 0.85 meters above MHHW, has an average event frequency of 0.8-0.9 events per year. Lastly, Figure 41shows that major HTF, defined by NOAA as water levels reaching 1.20 meters above MHHW, would inundate much of the site. These events occur less frequently, with an average event frequency of approximately 0.1/year (equivalently, a 10% annual chance) in the present day.

Thus, we characterize the site as having a very high present-day exposure to coastal flooding, on account of the high exposure to both acute storm surge flooding and chronic, high tide flooding.

Future Exposure

To evaluate the potential future exposure of the Yard to coastal flooding, we first review NOAA sea level rise (SLR) projections for The Battery tide gauge. Projections are provided for five scenarios defined by target values of global mean sea level rise in 2100: Low (0.3 m), Intermediate Low (0.5 m), Intermediate (1 m), Intermediate High (1.5 m), and High (2 m). The projections originate from a technical report produced by the Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force (Sweet et al., 2022). This report updates the previous version (Sweet et al., 2017) by drawing upon new science from IPCC AR6, including a longer observational record, improved understanding of ice-sheet dynamical processes, and better-constrained models.

Figure 43 presents the NOAA projections under these scenarios. The median projected values for 2050 range from 1.08 feet for the Low scenario to 1.65 feet for the High scenario; the corresponding values for 2080 range from 1.54 feet to 4.30 feet, for 2100 from 1.80 to 6.58 feet.

Given this result, we can put the NOAA sea level rise layers, which depict MHHW inundation with 0 to 10 feet of SLR in 1-foot increments, into context. With 1 or 2 feet of SLR, there is very little modeled inundation, with small portions of the piers being flooded. At 3 feet of SLR, there is more noticeable inundation, but it is still contained to the piers. At

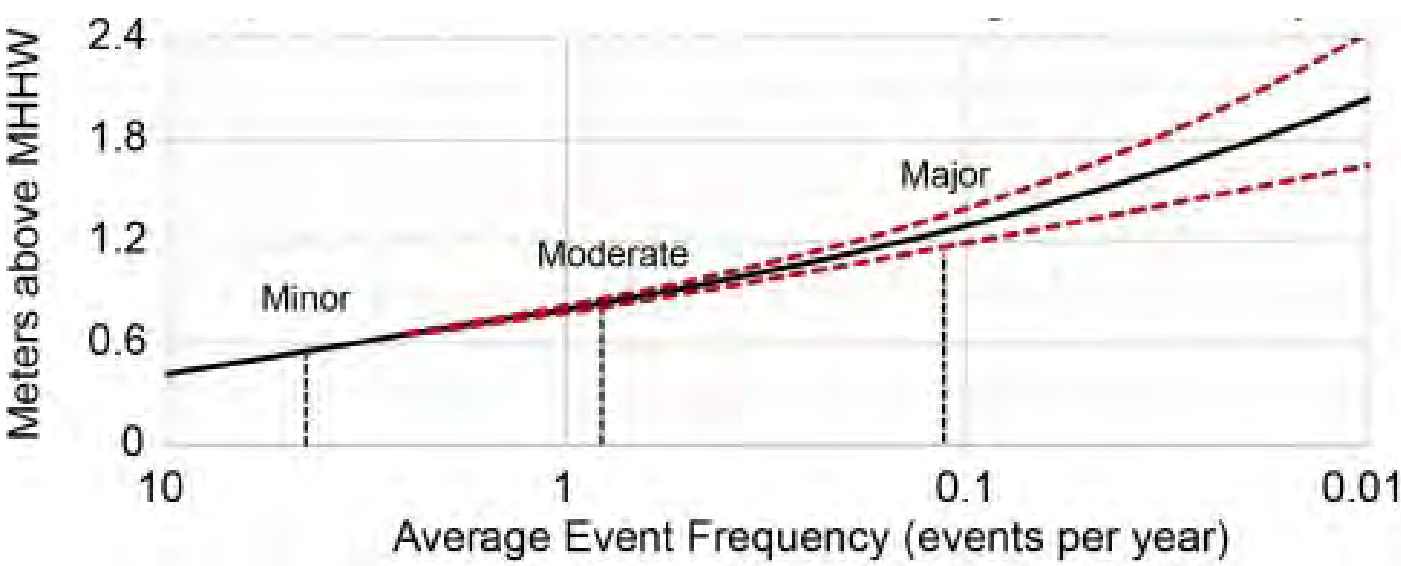


Figure 43. Return interval curve for daily highest water levels

Return interval curve for daily highest water levels (normalized to year-2020 relative sea levels) at the NOAA tide gauge at The Battery (New York City). The black curve denotes the median, and the red dashed curves denote the 95% confidence interval (2.5% and 97.5% levels). Image from Sweet et al. (2022).

4 feet of SLR, a significant fraction of the Yard was modeled to be chronically inundated (Figure 44). These results agree very well with those shown in the NYC Flood Hazard Mapper, specifically the layer depicting high tide flooding with various projected estimates of 2080s sea level rise (Figure 45). Here again, inundation is constrained to the piers and one of the dry docks with 3 feet of SLR or less. However, with 4 to 5 feet of SLR, high tide flooding is modeled to chronically inundate a large fraction of the site.

Due to the very high present-day exposure, which will be exacerbated by sea level rise, a very high coastal flooding exposure rating was assigned for all future time horizons and scenarios.

As an aside we note that Stantec previously performed a Preliminary Resiliency Risk Assessment for the Yard (Stantec 2017), employing sea level rise projections prepared for the New York State Energy Research and Development Authority's ClimAID report (Horton et al., 2014a) and that were adopted by the Department of Environmental Conservation (DEC) for Part 490 of Title 6 of the New York Codes, Rules, and Regulations. Specifically, CMIP5 projections for the RCP 4.5 and 8.5 scenarios, downscaled to New York State, were used to create 10th, 25th, 75th, and 90th percentiles of sea level rise, which then became the DEC's low, low-medium, high-medium, and high projections, respectively. As the Community Risk and Resilience Act requires Part 490 to be revised every five years, the DEC recently requested comments on its proposed methodology to update these projections. Briefly, the DEC proposed employing three scenarios, SSP2-4.5; the default, medium-confidence SSP5-8.5; and the low-confidence SSP5-8.5, and performing a similar percentile calculation to define the low, low-medium, medium, high-medium, and high projections as before. The update would also include a new time period (2150) and replace the 2020s time frame with the 2030s.

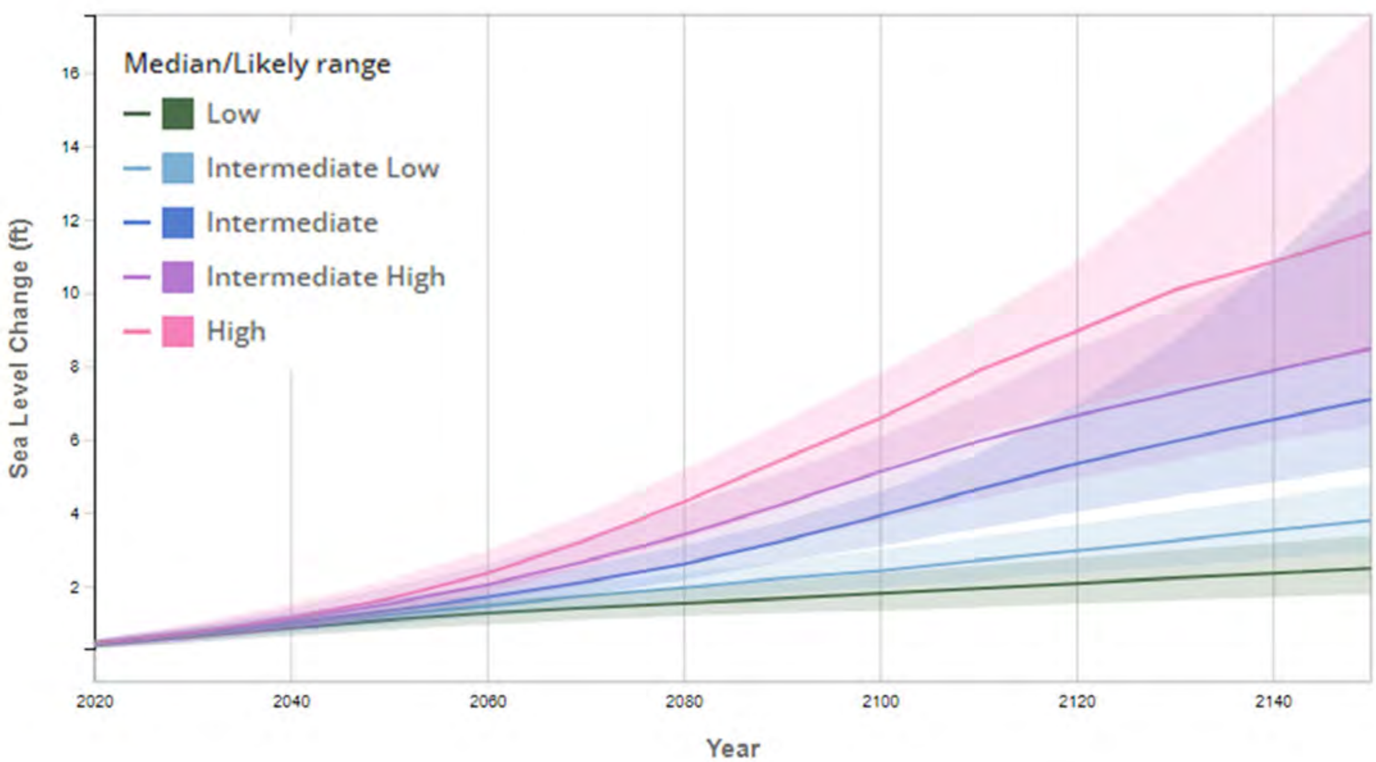


Figure 44. NOAA Interagency Sea Level Rise Scenario Tool

NOAA Interagency Sea Level Rise Scenario Tool projections from the closest tide gauge to Brooklyn Navy Yard: The Battery (New York City). Median values are provided for each scenario, along with likely ranges represented by shaded regions showing the 17th-83rd percentile ranges. projections from the closest tide gauge to Brooklyn Navy Yard: The Battery (New York City). Median values are provided for each scenario, along with likely ranges represented by shaded regions showing the 17th-83rd percentile ranges.

With this methodology, the range in future projections would narrow, with low and low-medium SLR projections increasing and high-medium and high projections decreasing relative to those currently in the 2017 projections. The Sweet et al. (2022) projections also make use of CMIP6 scenarios—including the low-confidence scenarios that include unknown-likelihood but high-impact outcomes, such as earlier-than-projected ice-shelf disintegration in Antarctica—in different proportions. For example, low emissions scenarios comprise over 80% of the Low projection from Sweet et al. (2022), while low-confidence high emissions scenarios comprise approximately 80% of the High projection. Over the longer time horizons, i.e., from the 2080s onward, this results in the DEC's proposed projections having a narrower range than those from Sweet et al. (2022), with higher projections at the low end and lower projections at the high end in the former.

Low, Intermediate, Intermediate High, and High projections for extreme water levels under mean higher high water tidal conditions, sea level rise, and extreme return period events (1-yr, 2-yr, 5-yr, 10-yr, 50-yr, 100-yr, 200-yr) are tabulated below. Projections include present day water levels (2018), mid-century (2050), and end of century (2100). The mean higher high water elevation observed between 1983 and 2001 by NOAA is used to represent highest tide.

Table 14. Mean higher high water (MHHW) tidal water levels (NOAA)

1983-2001 MHHW (relative to NAVD88)	0.695

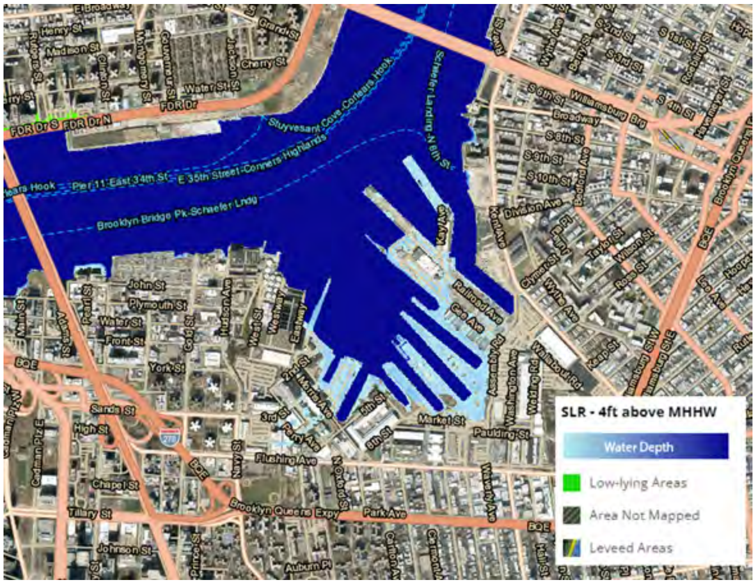


Figure 45. NOAA Sea Level Rise Viewer

NOAA Sea Level Rise Viewer depicting inundation from 4 feet of sea level rise above the average of the highest high tides (mean higher high water [MHHW]).

Figure 46. NYC Flood Hazard Mapper

NYC Flood Hazard Mapper depicting high tide flooding with estimates of sea level rise in the 2080s.

Table 15. Relative* Sea Level Rise Low Projections (Sweet et al.)

Year	Relative* Sea Level (relative to 1983-2001)
2018	0.1162
2050	0.3516
2100	0.5706

* "Relative" here means vertical land motion is included.

Table 16. Extreme Water Level Static Low Projections

	Return Period Event (Years)	1	2	5	10	50	100	200
2018	Return Level (Feet above NAVD88)	5.02	5.44	6.08	6.64	8.24	9.08	10.04
2050		5.79	6.21	6.85	7.41	9.01	9.85	10.81
2100		6.51	6.93	7.57	8.13	9.73	10.57	11.53

Table 17. Relative* Sea Level Rise Intermediate Projections (Sweet et al.)

Year	Relative* Sea Level (relative to 1983-2001)
2018	0.1162
2050	0.4276
2100	1.2156

* "Relative" here means vertical land motion is included.

Table 18. Extreme Water Level Static Intermediate Projections

	Return Period Event (Years)	1	2	5	10	50	100	200
2018	Return Level (Feet above NAVD88)	5.02	5.44	6.08	6.64	8.24	9.08	10.04
2050		6.04	6.46	7.10	7.66	9.26	10.10	11.06
2100		8.62	9.04	9.68	10.24	11.84	12.69	13.65

Table 19. Relative* Sea Level Rise Intermediate-High Projections (Sweet et al.)

Year	Relative* Sea Level (relative to 1983-2001)
2018	0.1162
2050	0.4846
2100	1.5816

* "Relative" here means vertical land motion is included.

Table 20. Extreme Water Level Static Intermediate-High Projections

	Return Period Event (Years)	1	2	5	10	50	100	200
2018	Return Level (Feet above NAVD88)	5.02	5.44	6.08	6.64	8.24	9.08	10.04
2050		6.23	6.64	7.29	7.85	9.45	10.29	11.25
2100		9.82	10.24	10.88	11.44	13.05	13.89	14.85

Table 21. Relative* Sea Level Rise High Projections (Sweet et al.)

Year	Relative* Sea Level (relative to 1983-2001)
2018	0.1162
2050	0.5236
2100	2.0256

* "Relative" here means vertical land motion is included.

Table 22. Extreme Water Level Static Intermediate-High Projections

	Return Period Event (Years)	1	2	5	10	50	100	200
2018	Return Level (Feet above NAVD88)	5.02	5.44	6.08	6.64	8.24	9.08	10.04
2050		6.35	6.77	7.41	7.97	9.57	10.42	11.38
2100		11.28	11.70	12.34	12.90	14.50	15.35	16.30

Extreme Heat

The present-day and future exposure of the site to extreme heat was evaluated using NEX-GDDP projections for the site (presented in Tables 4 and 5). These projections were supplemented with information from the New York City Panel on Climate Change 2019 Report.

Present-Day Exposure

Currently, the region of the site is not highly exposed to heatwaves (defined as the daily maximum temperature exceeding 95°F for at least three consecutive days), with NEX-GDDP simulations modeling approximately 0.11 heatwaves per year on average in the historical period of 1995-2014 (Tables 4 and 5). Temperatures were modeled to exceed 95°F approximately one day per year during the same period.

Future Exposure

Under the SSP2-4.5 scenario, the site is still projected to experience less than one heatwave per year on average until the 2080s, and approximately one extra week's worth of days with temperature exceeding 95°F on average (Table 4). Under the SSP5-8.5 scenario, the site was modeled to experience one heatwave per year by the 2050s and over three per year on average by the 2080s (Table 5). Under this scenario, daily temperatures would exceed 95°F an additional 24 days every year.

The NPCC3 2019 report defines heatwaves slightly differently: daily maximum temperature exceeding 90°F for at least three consecutive days (González et al., 2019). Under this lower threshold, New York City experiences an average of 1.1 heatwaves per year in the present day, according to three weather stations located within the city. CMIP5 simulations bias-corrected against these observational records show the number of heatwaves increasing to four or five per year by the 2050s in both the RCP 4.5 and the RCP 8.5 scenarios. After midcentury, the growth in number of annual heatwaves levels out, which the authors describe as a consequence of meeting the 90°F threshold more consistently as mean temperatures increase.

Considering both sets of results, we assign the following exposure ratings for heat stress:

- SSP2-4.5/RCP4.5: medium for the 2030s and 2050s and high for the 2080s
- SSP5-8.5/RCP8.5: medium for the 2030s, high for the 2050s, and very high for the 2080s

Table 23. NEX-GDDP SSP2-4.5 projections for temperature

	Modeled Baseline	Absolute Change from Baseline Median (10th, 90th percentile)		
Indicator Variable	1995-2014	2030s	2050s	2080s
Annual Maximum Temperature (°F)	95.16	1.67 [0.41, 3.37]	2.70 [1.03,5.08]	4.21 [2.83,6.64]
Number of Days with Temperature Exceeding 95°F	1.37	1.69 [0.46, 4.28]	3.72 [1.30, 9.11]	7.81 [3.48, 16.41]
Number of Heatwaves per Year	0.11	0.21 [0.02, 0.60]	0.56 [0.12, 1.17]	1.09 [0.42, 2.36]

Table 24. NEX-GDDP SSP5-8.5 projections for temperature

	Modeled Baseline	Absolute Change from Baseline Median (10th, 90th percentile)		
Indicator Variable	1995-2014	2030s	2050s	2080s
Annual Maximum Temperature (°F)	95.16	2.00 [0.02, 3.69]	3.42 [1.69, 5.87]	7.81 [4.81, 11.61]
Number of Days with Temperature Exceeding 95°F	1.37	1.89 [-0.09, 4.51]	6.81 [1.88, 13.94]	24.00 [12.02, 49.59]
Number of Heatwaves per Year	0.11	0.27 [-0.01, 0.69]	0.85 [0.16, 1.94]	3.14 [1.72, 5.59]

Hurricanes / Tropical Cyclones

Both the present-day and future exposure of the site to hurricanes and other tropical cyclones (TCs) were evaluated using the historical record of storms passing within 60 nautical miles of the site, as there is low confidence in climate model projections regarding long-term trends in TC frequency. While there is low confidence in the projected change in the frequency of these events, it is expected that the average intensity of tropical cyclones and the proportion of strong tropical cyclones will increase across the globe (IPCC, 2019). The International Best Track Archive for Climate Stewardship (IBTrACS) project is the most complete global collection of TCs available (Knapp et al., 2018). It merges TC data from agencies around the world to create a unified, publicly available, best-track data set.

While tropical storms pass through the region relatively frequently, hurricane-status storms are much rarer, with only three passing within 60 nautical miles since 1950 (Figure 46). Also, none of these storms were considered major hurricanes (Category 3 or higher). Thus, we classify the site as having medium exposure to tropical cyclones over all time horizons. We note, however, that even storms that are not classified as hurricanes at landfall can generate severe storm surges, high winds, and flooding, as Hurricane Sandy showed in 2012.

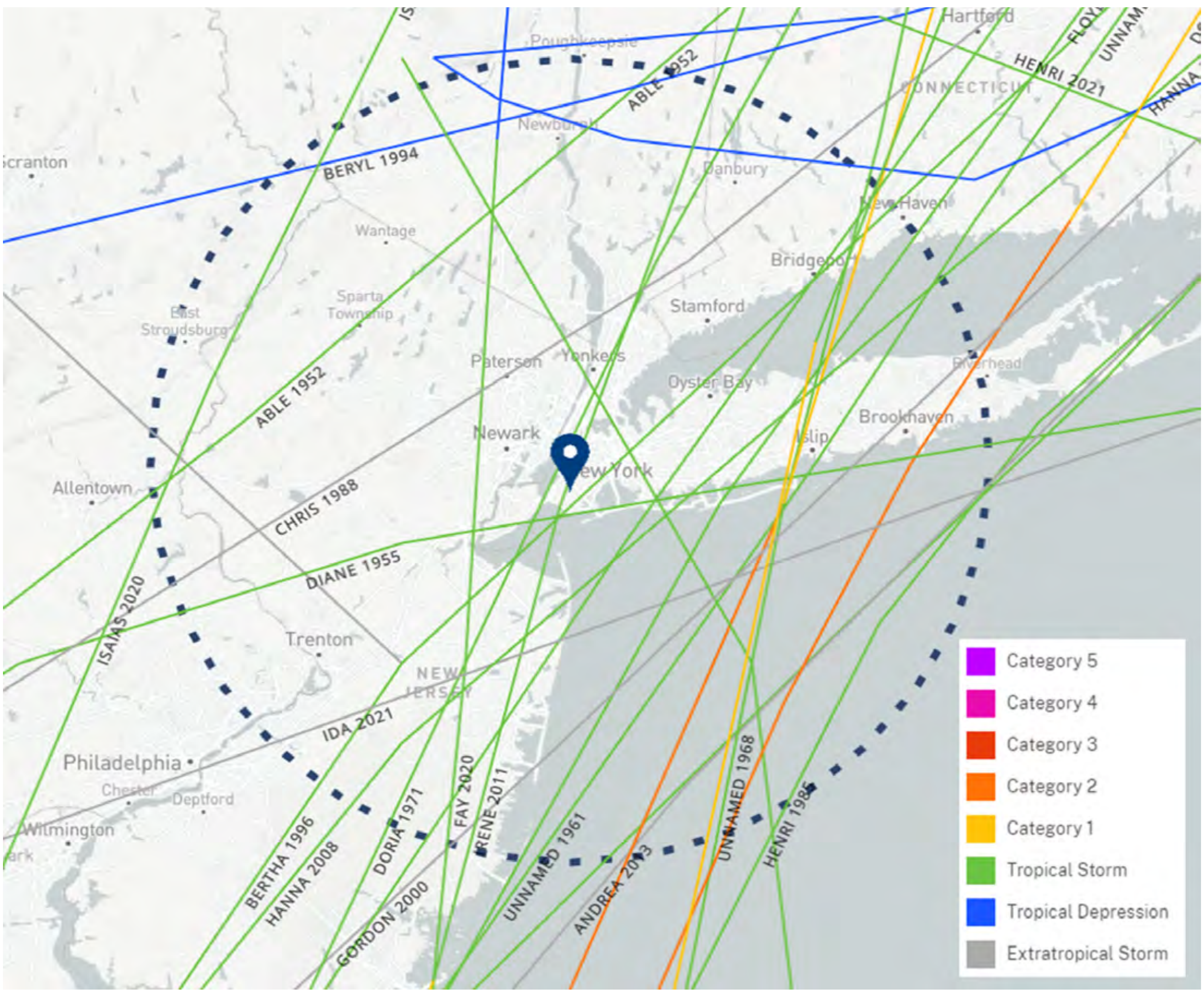


Figure 47. Historical hurricane tracks from 1950-2023 within 60 nautical miles of Brooklyn Navy Yard

Wildfire

Direct present-day exposure of the site to wildfire was evaluated through review of the United States Forest Service (USFS) Wildfire Hazard Potential data set. Projections of future fire probability by Gao et al. (2021) were then used in conjunction to assess how wildfire exposure may evolve in the future. Indirect exposure of the site to wildfire (for example, through smoke and air quality impacts) was assessed qualitatively using regional projections of the change in wildfire frequency (Gao et al., 2021).

Present-Day Exposure

Figure 47 depicts the USFS Wildfire Hazard Potential (WHP) in the region of the Yard. The primary objective of the WHP map was to depict the relative potential for wildfire that would be difficult for suppression resources to contain (Dillon and Gilbertson-Day, 2020). The data reflect landscape conditions as of the end of 2014 and thus could overestimate exposure in recently developed areas.

As expected, most of the Yard and the surrounding land is classified as non-burnable due to the developed nature of the area. A small fraction of the site is classified as having high WHP due to the presence of tidal marshland, which the Yard was originally built on. However, given the highly developed nature of the site and its distance from forested areas, the exposure of the site to the direct impacts of wildfire is minimal, and thus we assign a low rating across all time horizons. With that said, the site is exposed to the indirect impacts of fires on air quality, as the recent Canadian wildfires have shown: the Air Quality Index (AQI) reached over 400 on June 7th, leaving New York City with the worst air quality in the world among major metropolitan centers (Favetta, 2023).

Future Exposure

Figure 48 depicts the projected percentage change in annual fire probability using downscaled CMIP5 climate model output in conjunction with a fire frequency model from Gao et al. (2021). Wildfire frequency is expected to increase in all 128 USFS pyromes (areas of relatively homogeneous historical fire regimes) under the RCP 4.5 scenario and in almost all pyromes under the RCP 8.5 scenario, with some of the largest increases in the northeast US near the site. While the developed nature of the site and its distance from vegetated areas will continue to protect it from the direct impacts of wildfire, exposure to smoke and other indirect impacts is likely to increase with climate change.

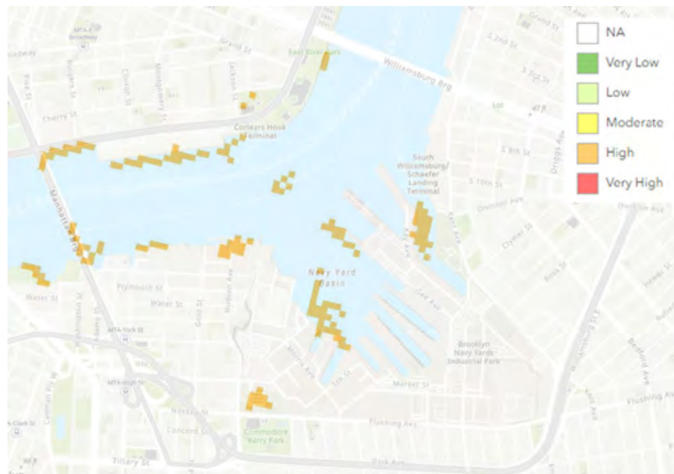


Figure 48. Map of USFS Wildfire Hazard Potential centered on Brooklyn Navy Yard

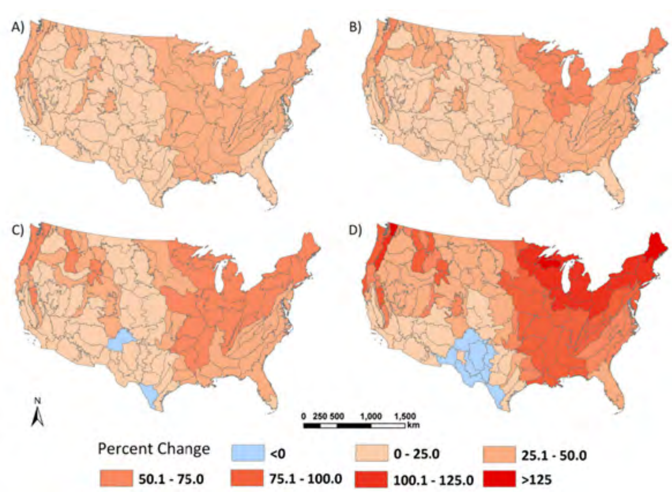


Figure 49. Projected percentage change in annual fire probability

Projected percentage change in annual fire probability across time periods and emission scenarios. A) RCP 4.5 mid-century (2040-2069), B) RCP 4.5 late century (2070-2099), C) RCP 8.5 mid-century (2040-2069), and D) RCP 8.5 late century (2070-2099). Image from Gao et al. (2021).

Water Stress

The present-day and future exposure of the site to water stress was evaluated through review of the World Resources Institute's (WRI) Aqueduct Water Risk Atlas (Luck et al., 2015). These data were supplemented with information from the New York City Panel on Climate Change 2019 Report and the Department of Environmental Protection.

The WRI projections provide a regional-scale estimate of the effects of development and climate change on water stress, defined as the ratio of water use to supply. WRI modeling indicates that the present-day water stress of the region is high at 74% and that drought risk is low to medium. The modeling also suggests that water stress, water supply, and water demand will remain near present-day levels through the 2040s under both business-as-usual and optimistic greenhouse gas emissions scenarios.

The NYC Department of Environmental Protection (DEP) launched the Climate Change Integrated Modeling Project (CCIMP) in 2008 to evaluate the effects of climate change on the quantity and quality of water in the New York City water supply (Lloyd and Licata, 2015). The CCIMP Phase 1, which concluded in 2013, used a combination of climate models and DEP's watershed, reservoir, and system operation models to form an initial estimate of climate change impacts. Matonse et al. (2013) projected increasing annual streamflow through the 2090s, with most of the increase occurring during winter and early spring due to increased rainfall and earlier snowmelt. This finding suggests that the increasing trend in streamflow observed since 1951 will continue into the future (Burns et al. 2007, NASEM 2018). Matonse et al. (2013) also project a decrease in the number of days under watch, warning, and emergency drought conditions in the Catskill and Delaware subsystems, due in large part to the increased streamflow. They note, however, the wide variability in model projections, and other studies have suggested that drought will become more likely in the future, including Major and Goldberg (2001), Horton et al. (2011), and the Third National Climate Assessment (Horton et al., 2014b).

The NPCC3 2019 report developed a drought index for the city's major reservoir system with explicit consideration of water demand. The index was developed using instrumental streamflow data and paleoclimate tree-ring data. The reconstruction showed that there have been less severe but longer droughts compared to the notable drought that impacted the New York metropolitan region in the 1960s. Thus, while the city's water demand has decreased since the 1990s despite population growth, Pederson et al. (2013) caution that the city's water supply systems should be viewed as vulnerable to severe and potentially frequent drought.

The One Water NYC plan[3] developed by NYC Department of Environmental Protection (DEP) indicates that the water supply is also vulnerable to extreme weather and other climate hazards. Past impacts include damage to low-lying infrastructure during Hurricane Sandy and extensive flooding of upstate reservoirs from tropical storms in 2011. DEP has been implementing measures to make the system more resilient to climate change. This includes the development of the third water tunnel that will provide increased redundancy in the connections to upstate water supplies (expected to be complete in 2032) and upgrades to the city's water and wastewater systems such as the Water for the Future program to address leakage in the Delaware Aqueduct (final phase currently planned to begin in October 2024[4]).

Given the conflicting nature of findings in the literature on impacts of climate change on water supplies and significant work by DEP to improve the resilience of the city's supplies and distribution, we assign a medium exposure rating for water stress for all time horizons. Impacts should be monitored along with the implementation of DEP's water resilience projects and other measures.

3. https://www.nyc.gov/assets/dep/downloads/pdf/climate-resiliency/one-nyc-one-water.pdf

4. https://www.nyc.gov/site/dep/news/23-030/schedule-up-date-last-phase-repairs-delaware-aqueduct-start-2024#/0

Appendix C: Climate Risk Assessment Tables

Table 25. Flood exposure consequence (scored 1-4) for building assets

Asset	Coastal Flooding Consequence			Inland Flooding Consequence		
	2018	2050	2100	2018	2050	2100
Building 22	4	4	4	3	3	3
Building 8	4	4	4	3	3	3
Building 7	4	4	4	2	3	3
ARow - Building A	3	4	4	3	3	3
Building 131	3	4	4	2	2	2
Building 510 (PW4)	3	4	4	2	2	2
Cogen 41	3	3	4	2	2	2
Building 386 (Substation G)	3	3	4	2	2	2
Cogen Demineralization	3	3	4	2	2	2
Building 234 (Substation B)	3	3	4	1	1	1
Building 542 (Substation C)	3	3	4	1	1	1
Cogen Gas Compressor	3	3	4	1	1	1
Building 500	3	3	4	3	3	3
Building 270	3	3	4	0	0	0
Building 20	3	3	4	2	2	2
Building 11	3	3	4	2	2	2
Building 127	3	3	4	2	2	2
Building 121	3	3	4	2	2	2
Building 132	3	3	4	2	2	2
Building 268	3	3	4	2	2	2
Building 293	3	3	4	2	2	2
Building 12/12A	3	3	4	2	2	2
Building 25	3	3	4	2	2	2
Building 269	3	3	4	2	2	2
ARow - Building E	3	3	4	2	2	2
ARow - Building D	3	3	4	2	2	2
ARow - Building C	3	3	4	2	2	2
Dock 72	3	3	4	2	2	2
Building 12B	3	3	4	2	2	2
Building 10	3	3	4	1	1	1
Building 74	3	3	4	1	1	1
Building 51	3	3	4	1	1	1
Sands Building (303)	3	3	4	1	1	1
Building 124 (PW1)	3	3	4	1	1	1
Building 156 (PW5/6)	3	3	4	1	1	1
Building 62	3	3	4	0	0	0
Building 292	3	3	4	0	0	0
Building 275	3	3	4	0	0	0
Lehigh Cement	3	3	4	1	1	1
Building 313	3	3	4	1	1	1

Asset	Coastal Flooding Consequence			Inland Flooding Consequence		
	2018	2050	2100	2018	2050	2100
Building 314	3	3	4	0	0	0
Building 249	3	3	4	0	0	0
Building 594	3	3	4	0	0	0
Building 52	3	3	4	0	0	0
FDNY Boat Repair Building	3	3	4	0	0	0
Stages 25-30	2	3	4	2	3	3
Steiner (300) - Stages 1-6	2	3	4	2	2	2
Building 120	0	3	4	2	2	2
Building 280	0	0	4	3	3	3
Building 92	0	0	4	3	3	3
Building 200 North	0	0	4	2	3	3
Building 200 South	0	0	4	2	3	3
Brinks 700	2	3	3	2	2	2
Building 28	2	3	3	2	2	2
Building 128	2	3	3	2	2	2
DCAS Building	0	3	3	2	2	2
Building 123	2	2	3	2	2	2
ARow - Building B	2	2	3	0	0	0
Building 6	2	2	3	0	0	0
Tow Pound Building	1	2	3	1	1	1
Building 77	0	2	3	2	2	2
Building 50	0	2	3	2	2	2
Building 5	0	2	3	1	1	1
Building 664	0	2	3	2	2	2
Building 58	0	0	3	3	3	3
Building 1	0	0	3	2	2	2
Building 27	0	0	3	2	2	2
Stages 10-15	0	0	3	2	2	2
Building 30	0	0	3	1	2	2
Building 3	0	0	3	1	1	1
Building 385 (Substation F)	0	0	3	0	0	0
Building 152	0	0	3	1	1	1
Building 4	0	0	3	2	2	2
Building 2	0	0	2	2	2	2

Table 26. Criticality (scored 1-4) of building assets

Asset	Criticality Score
Cogen 41	4
Building 386 (Substation G)	4
Cogen Demineralization	4
Building 234 (Substation B)	4
Building 542 (Substation C)	4
Cogen Gas Compressor	4
Building 270	4
Building 385 (Substation F)	4
Building 22	3
ARow - Building A	3
Building 500	3
Building 131	3
Building 20	3
Building 11	3
Building 127	3
Building 121	3
Building 132	3
Building 268	3
Building 293	3
Building 12/12A	3
Building 25	3
Building 269	3
ARow - Building E	3
ARow - Building D	3
ARow - Building C	3
Dock 72	3
Building 12B	3
Stages 25-30	3
Steiner (300) - Stages 1-6	3
Building 10	3
Building 74	3
Building 51	3
Sands Building (303)	3
Building 124 (PW1)	3
Building 156 (PW5/6)	3
Brinks 700	3
Building 28	3
Building 128	3
Building 62	3
Building 120	3
Building 292	3
Building 275	3
Building 123	3
Building 280	3
Building 92	3
Building 77	3
Building 50	3
Building 58	3
ARow - Building B	3
Building 5	3
Building 1	3
Building 27	3
Stages 10-15	3
Building 30	3
Building 2	3
Building 3	3
Lehigh Cement	2
Building 313	2
Building 314	2
Building 664	2
Building 200 North	2
Building 200 South	2
Building 6	2
Building 152	2
Building 8	1
Building 7	1
Building 510 (PW4)	1
Building 249	1
Building 594	1
Building 52	1
FDNY Boat Repair Building	1
DCAS Building	1
Tow Pound Building	1
Building 4	1

Appendix D: Coastal Resilience Best Practices

Table of Contents

Working Waterfronts

- *The Blue Edge, Svendbord, Denmark*
- *Fort Point Resilient Channel Infrastructure, Boston, MA*

Public Waterfronts & Promenades

- *Chicago Riverwalk, Chicago, IL*
- *Sea Organs, Zadar, Croatia*

Local Examples

- *The Battery Coastal Resilience, New York, NY*
- *Seaport Coastal Resilience (SPCR), New York, NY*
- *East Side Coastal Resilience (ESCR), New York, NY*

In-Water Solutions

- *Maeslant Barrier, Amsterdam*
- *MOSE Flood Barrier, Venice, Italy*

Ramboll

Site Description

- Thriving harbor with surrounding commercial, residential, and maritime heritage

Project Description

- Mitigate flood risk while preserving the visual connection to the water and provide direct access to the water surface on most days of the year, even during high water or storm surge.
- Area needs to maintain commercial boat access

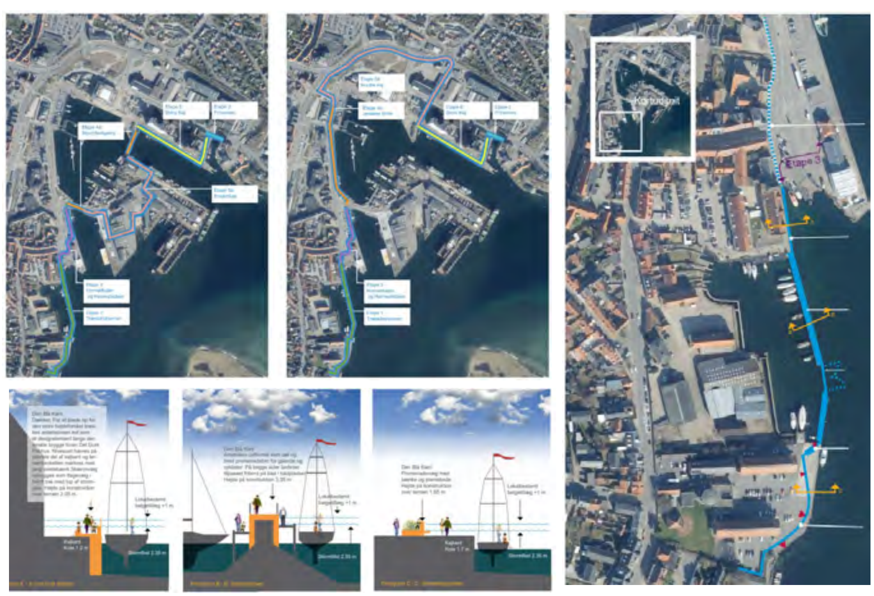
Mitigation Strategies

- Varying sea wall sections
- Movable flood gates are integrated into the seawalls to ensure transportation for ferries and yachts.

Ramboll

Working Waterfronts

The Blue Edge, Svendborg, Denmark



Source: Ramboll

4

Site Description

- Active channel with surrounding commercial, industrial, and residential uses

Project Description

- Perimeter plan protecting a 2,300 linear foot stretch along the eastern edge of Fort Point Channel
- Includes 600 linear feet of interim flood protection solutions

Mitigation Strategies

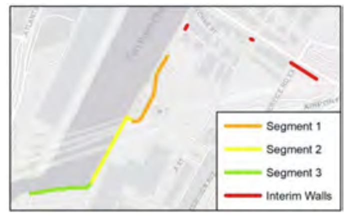
- Mix of earthen berms and mitigation of existing floodwalls (sea walls and retaining walls)
  - Phase 1: Vegetated berm (730')
  - Phase 2: Double retaining wall built on existing seawall (816')
  - Phase 3: Vegetated berm (546')

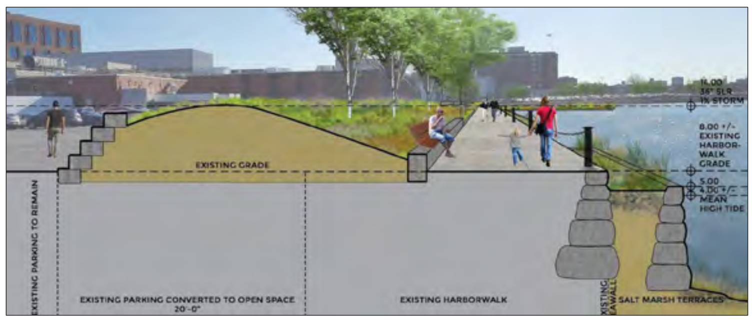
Ramboll

Working Waterfronts

Fort Point Resilient Channel Infrastructure, Boston, MA

Source: Boston Planning & Development Agency and Arcadis





5

Public Waterfronts & Promenades

Site Description

- 3.5 acres multi-purpose public space located on the south bank of the Chicago River

Project Description

- Completed 2016
- Flood-resilient six-block pedestrian promenade

Mitigation Strategies

- Raised boardwalk providing flood protection while facilitating pedestrian, biking, and boating recreation
- Durable materials that are resilient to periodic flooding events

Ramboll

Public Waterfronts

Chicago Riverwalk, Chicago, IL

Source: Sasaki and Landscape Architecture Foundation

7

Site Description

- Located on a peninsula in coastal Zadar
- Surrounded by mixed residential and commercial development

Project Description

- In addition to this project's protection measures, the sea wall contains a series of pipes and cavities within the wall that act as an architectural instrument or "sea organ"

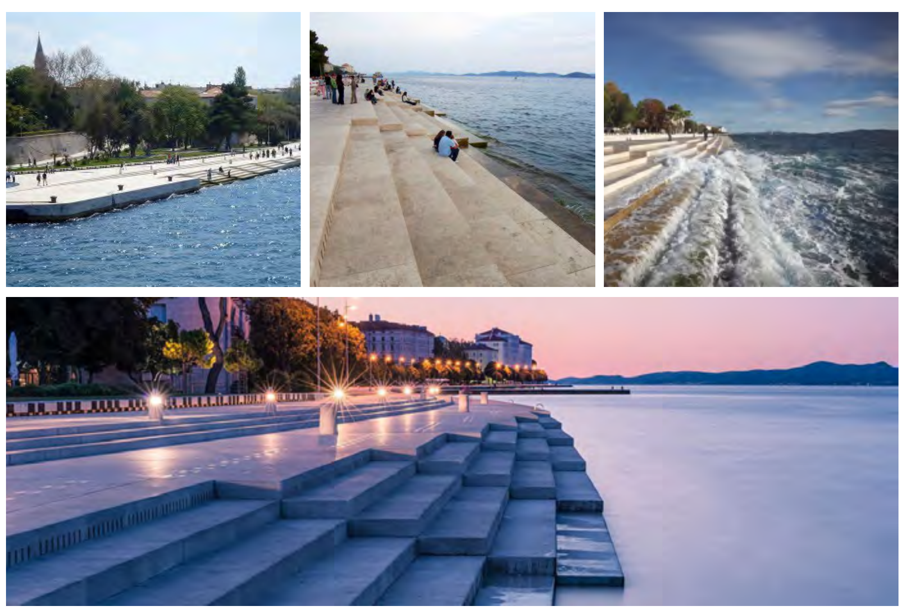
Mitigation Strategies

- "Stepped" seawall provides waterfront access to both protect and invite
- 35 pipes embedded in the stone staircase to

Ramboll

Public Waterfronts

Sea Organs, Zadar, Croatia



Source: Landezine, Architectuul, and Archdaily

8

Site Description

- Located along the water's edge in the Battery

Project Description

- Undertaking by NYCEDC in partnership with NYC Parks, part of LMCR Project
- Will provide protection from rising seas through 2100
- To be completed in 2025

Mitigation Strategies

- Elevated waterfront edge to mitigate sea level rise and provide storm surge protection while providing waterfront access
- Salt-tolerant trees and planting
- Enhanced drainage system
- Permeable paving

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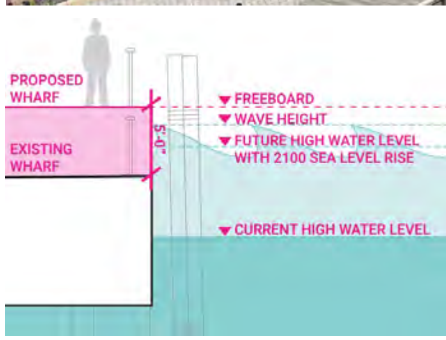
Local Examples

The Battery Coastal Resilience, New York, NY



10

Source: NYC Lower Manhattan Coastal Resiliency

Site Description

- Contains a mix of maritime operations, historic landmarks, multimodal transportation networks, open space, and residential and commercial uses

Project Description

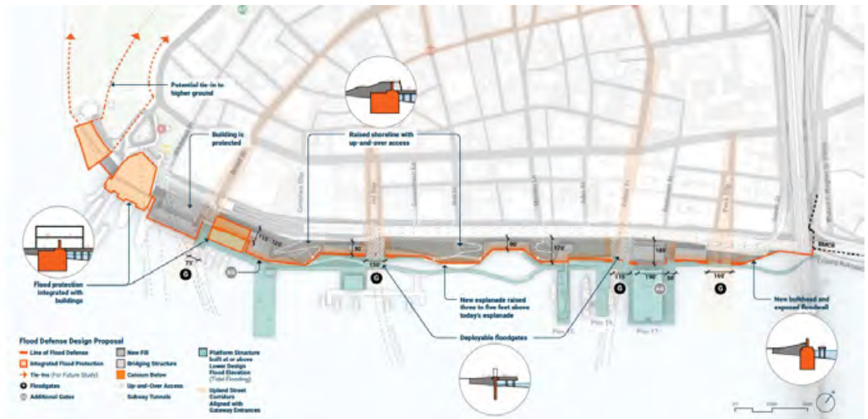
- Undertaking by NYCEDC and MOCR, part of LMCR Project
- Will provide protection from rising seas through 2100
- To be completed in 2025

Mitigation Strategies

- Raised shoreline and esplanade (+11 feet) to protect against SLR
- Floodwalls buried in the landscape to create elevated ridge (+23 – 26 feet) to protect against coastal storms
- New pump station
- Deployable floodgates
- Green infrastructure

Local Examples

Seaport Coastal Resilience (SPCR), New York, NY



Source: *NYC Lower Manhattan Coastal Resiliency*

Site Description

- Manhattan's East Side from East 25th Street to Montgomery Street

Project Description

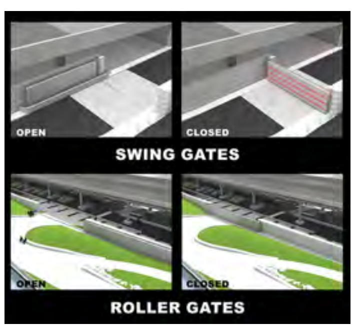
- The East Side Coastal Resiliency (ESCR) Project is a coastal protection initiative, jointly funded by the City of New York and the federal government, aimed at reducing flood risk due to coastal storms and sea level rise

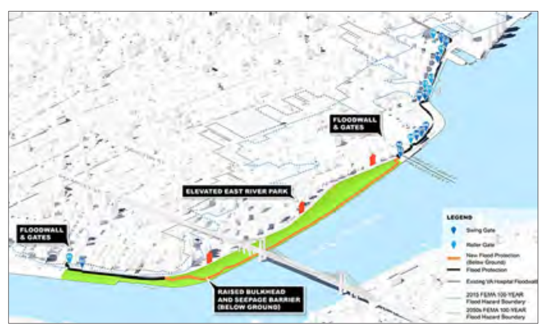
Mitigation Strategies

- Floodwall and swing and roller gates
- Elevated East River Park
- Raised bulkhead and seepage barrier
- New parallel conveyance system
- Height of the flood protection ranges from 8-9 feet above existing grade, 100-yr useful life, 2050s 100-yr storm

Local Examples

East Side Coastal Resilience (ESCR), New York, NY





Source: *NYC East Side Coastal Resiliency*

Site Description

- Located in an active ship canal "Nieuwe Waterweg"

Project Description

- Completed in 1997
- Part of the Deltaworks mitigation project in the Netherlands which includes a series of dams, sluices and storm surge barriers aimed to protect the Port of Rotterdam

Mitigation Strategies

- Automatic forward flood surge barrier (360 meter wide)
- When closed, the two doors fill with water and sink to the surface within a couple of hours

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In-Water Solutions

Maeslant Barrier, Amsterdam

Sources: Rijkswaterstaat, Ministry of Infrastructure and Water Management and GCaptain

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Site Description

- Flood barrier is located at the tip of the Lido di Venezia, a barrier island located between Venice and the Adriatic Sea

Project Description

- Completed in 2020
- Provides protection to Venice by blocking storm surge and reducing wave action in the Venetian Lagoon

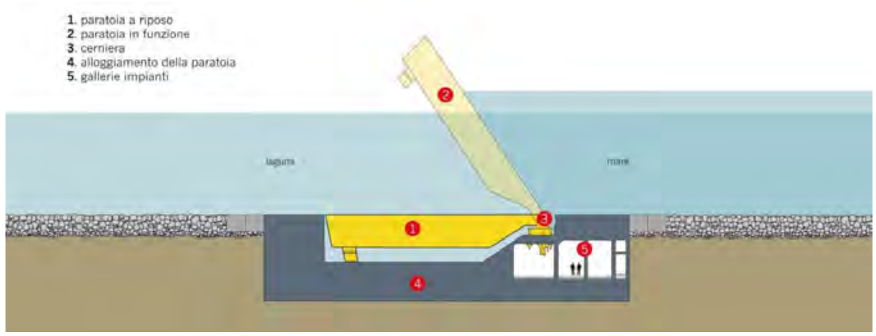
Mitigation Strategies

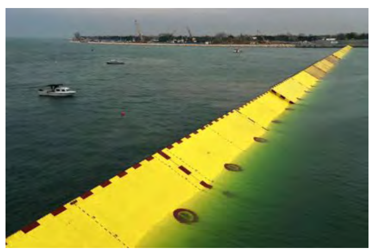
- Automatic forward flood surge barrier

Ramboll

In-Water Solutions

MOSE Flood Barrier, Venice, Italy





Source: CNN, 2022

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Appendix E: Cost Estimate Worksheets

BROOKLYN NAVY YARD RESILIENCY PROGRAM - HYBRID SCENARIO - OPINION OF PROBABLE COST

COWI

NEW YORK - BROOKLYN NAVY YARD

PROJECT NO: A252262
PROJECT NAME: BNY Resiliency
VERSION: 1.0
CLIENT: Ramboll
SITE LOCATION: Brooklyn Navy Yard

PREPARED BY: GSVR
DATE: 01.23.2024
CHECKED BY: MKWZ
DATE: 01.23.2024

CONSTRUCTION PHEASE[5]	PHASED CONSTRUCTION - CLASS 5 OPC					
		CLASS 5 ELEMENTS[1]				
	ACTIVITY DESCRIPTION	UNITS	UNIT PRICE[2]	QUANTITY	EXTENDED PRICE	SUBTOTAL[3]
PHASE 1 - 2025	Contractor Mobilization & Demobilization (10% Building Floodproofing)	PCT	10%	1	$238,000	
	West Building - Integrated Flood Resiliency	LS	$2,378,000.00	1	$2,378,000	$2,616,000
PHASE 2 - 2026	Contractor Mobilization & Demobilization (10% Building Floodproofing)	PCT	10%	1	$1,799,000	
	Steel Sheet Pile Bulkhead with Concrete Cap	LF	$5,700.00	2,030	$11,571,000	
	Pile Supported Reinforced Concrete Barrier Wall - 6ft (Design Elev.)	LF	$8,500.00	450	$3,825,000	
	Carbon Sliding Floodgate Wall (6 Ft Tall)	8500	$10,800.00	240	$2,592,000	$20,302,000
PHASE 3 - 2027	Contractor Mobilization & Demobilization (10% Building Floodproofing)	PCT	10%	1	$809,000	
	Carbon Sliding Floodgate Wall (6 Ft Tall)	LF	$10,800.00	135	$1,458,000	
	Pile Supported Reinforced Concrete Barrier Wall - 6ft (Design Elev.)	LF	$8,500.00	670	$5,695,000	
	Reinforced Concrete Barrier Wall - 3ft (Design Elev.) - Integrated Flood Structure	LF	$2,700.00	345	$932,000	$9,363,000
PHASE 4 - 2028	Contractor Mobilization & Demobilization (10% Building Floodproofing)	PCT	10%	1	$905,000	
	Carbon Sliding Floodgate Wall (6 Ft Tall)	LF	$10,800.00	175	$1,890,000	
	Steel Sheet Pile Bulkhead with Concrete Cap	LF	$5,700.00	1,255	$7,154,000	$10,746,000
PHASE 5 - 2029	Contractor Mobilization & Demobilization (10% Building Floodproofing)	PCT	10%	1	$1,229,000	
	Steel Sheet Pile Bulkhead with Concrete Cap	LF	$5,700.00	2,155	$12,284,000	$14,975,000
PHASE 6 - 2030	Contractor Mobilization & Demobilization (10% Building Floodproofing)	PCT	10%	1	$1,245,000	
	Carbon Sliding Floodgate Wall (6 Ft Tall)	LF	$10,800.00	275	$2,970,000	
	Pedestrian Walkway	LF	$2,000.00	3,780	$7,560,000	
	Pile Supported Reinforced Concrete Barrier Wall - 6ft (Design Elev.)	LF	$8,500.00	225	$1,913,000	$15,563,000
PHASE 7 - 2031	Contractor Mobilization & Demobilization (10% Building Floodproofing)	PCT	10%	1	$617,000	
	Pile Supported Reinforced Concrete Barrier Wall - 6ft (Design Elev.)	LF	$8,500.00	135	$1,148,000	
	Carbon Sliding Floodgate Wall (6 Ft Tall)	LF	$10,800.00	150	$1,620,000	
	Steel Sheet Pile Bulkhead with Concrete Cap	LF	$5,700.00	260	$1,482,000	
	Reinforced Concrete Barrier Wall - 3ft (Design Elev.) - Integrated Flood Structure	LF	$2,700.00	710	$1,917,000	$7,914,000
PHASE 8 - 2032	Contractor Mobilization & Demobilization (10% Building Floodproofing)	PCT	10%	1	$1,426,000	
	Powered Flip Up Barrier Wall (3 Ft Tall)	LF	$8,200.00	800	$6,560,000	
	Reinforced Concrete Barrier Wall - 3ft (Design Elev.) - Integrated Flood Structure	LF	$2,700.00	2,850	$7,695,000	$18,768,000
CONTINGENCY[6]	Utility Relocation - Steel Sheet Pile (10%)	LS	$540,800.00	1	$541,000	$541,000
	Utility Relocation - Concrete Wall 3 ft (10%)	LS	$327,200.00	1	$328,000	$328,000
	Utility Relocation - Concrete Wall - 6 ft(10%)	LS	$179,100.00	1	$180,000	$180,000
		CONSTRUCTION PHASES - HYBRID DIAGRAM SUBTOTAL[3,4]				$101,296,000

BROOKLYN NAVY YARD RESILIENCY PROGRAM - HYBRID SCENARIO - OPINION OF PROBABLE COST

Escalation - Engineering Design Services		
Construction Management Services (+10%)	$	10,130,000
Engineering Design Services (+15%)	$	15,195,000
Permitting Services (+5%)[9]	$	5,065,000
CONSTRUCTION PHASES & ESCELATION - HYBRID DIAGRAM SUBTOTAL[3,4,8,10]		**$131,686,000**
Contingency and AACE Confidence Ranges		
Contingency: Class 5 High (+50%)	$	50,648,000
Contingency: Class 5 Low (-50%)	$	50,648,000
TOTAL (High)	**$**	**182,334,000**
TOTAL (Low)	**$**	**81,038,000**

NOTES:

[0]GENERAL - COWI HAS NO CONTROL OVER THE COST OF LABOR, MATERIALS, EQUIPMENT, OR SERVICES FURNISHED BY OTHERS, OR OVER THE CONTRACTOR'S METHODS OF DETERMINING PRICES, OR OVER COMPETITIVE BIDDING OR MARKET CONDITIONS. COWI'S OPINIONS OF PROBABLE PROJECT COST AND CONSTRUCTION COST PROVIDED FOR HEREIN, ARE MADE ON THE BASIS OF COWI'S BEST JUDGEMENT AS EXPERIENCED AND QUALIFIED PROFESSIONAL ENGINEERS, FAMILIAR WITH THE CONSTRUCTION INDUSTRY; BUT COWI CANNOT AND DOES NOT GUARANTEE THAT PROPOSALS, BIDS OR ACTUAL PROJECT OR CONSTRUCTION COSTS WILL NOT VARY FROM OPINIONS OF PROBABLE COST PREPARED BY COWI. OPC ESCELATED TO FY **2025** UTILIZING US ARMY CORPS OF ENGINEERS CIVIL WORKS CONSTRUCTION COST INDEX SYSTEM, EM 1110-2-1304. ASSUMED YEAR FOR EACH PHASE IS LISTED IN THE TABLE, BUT FURTHER PLANNING REQUIRED TO DEVELOP PHASING SCHEDULE. LABOR RATES ARE BASED ON CURRRENT DAVIS-BACON RATES FOR NY (BRONX, KINGS, NEW YORK, QUEENS, AND RICHMOND COUNTIES).

[1]CLASS 5 ELEMENTS BASED ON HYBRID DIAGRAM PROVIDED BY CLIENT FOR PROPOSED BNY RESILIENCY PROJECT.

[2]UNIT PRICES INCLUDE MARKUPS FOR CONTRACTOR'S GENERAL CONDITIONS, OVERHEAD, AND PROFIT. WHERE APPLICABLE, UNIT PRICES FROM PAST SIMILAR CONSTRUCTION PROJECTS WERE USED WHICH ARE INCLUSINVE OF THESE MARKUPS. IN CERTAIN CASES WHERE HISTORICAL UNIT PRICES WERE NOT AVAILABLE, UNIT PRICES WERE DEVELOPED BASED ON COWI'S EXPERIENCE WITH SIMILAR CONSTRUCTION. IN SUCH CASES, FACTORS OF 5% FOR GENERAL CONDITIONS, 10% FOR OVERHEAD, AND 10% FOR PROFIT WERE TYPICALLY APPLIED.

[3]CONSTRUCTION COSTS HAVE EXPERIENCED HISTORIC PRICE VOLATILITY IN RECENT TIMES. ESCALATION FACTORS AND CONTINGENCIES HAVE BEEN INCLUDED IN THE OPINION OF PROBABLE COST TO HELP ACCOUNT FOR POTENTIAL FUTURE PRICE INCREASES. IT MUST BE UNDERSTOOD, HOWEVER, THAT THIS VOLATILITY IS NEARLY IMPOSSIBLE TO PREDICT, ESPECIALLY FOR WORK PLANNED SEVERAL YEARS OUT, SO THESE CONTINGENCIES AND ESCALATION FACTORS SHOULD NOT BE CONSIDERED DEFINITIVE.

[4]SUBTOTAL OF PHASED CONSTRUCTION VARIES FROM OVERALL APPROACH DUE TO MOBILIZATION/DEMOBILIZATION REQUIRED FOR EACH PHASE AND ROUNDING OF SIGNIFICANG FIGURES.

[5]CONSTRUCTION PHASES ARE ESCELATED BEGININNING IN YEAR 2025 (PHASE I) USING THE ARMY CORPS OF ENGINEERS CIVIL WORKS CONSTRUCTION COST INDEX SYSTEM UP TO THE YEAR 2032.

[6]UTILITIES ARE CALCULATED AS AN ADDITIONAL 10% OF THE RAW CONSTRUCTION COSTS FOR EACH LINE ITEM SPECIFIED. DETAILED REVIEW/ANALYSIS OF AS-BUILT CONDITIONS AND UTILITY STAKEHOLDERS WILL BE REQUIRED TO ACCURATE SCOPE THE DESIGN, PERMITTING, AND CONSTRUCTION COSTS FOR THIS WORK, WHICH COULD CONSTITUTE A SIGNIFICANT PORTION OF THE PROJECT COST.

[7]FURTHER STUDY IS REQUIRED TO DETERMINE THE POTENTIAL COST IMPACTS OF HAZMATS/CONTAMINANTS ON THE SITE.

[8]ADDITIONAL OVERHEAD INCLUDED INCLUDES, BUT NOT LIMITED TO; CONSTRUCTION MANAGEMENT SERVICES, PERMITTING SERVICES, AND ENGINEERING DESIGN SERVICES.

[9]PERMITTING SERVICES MAY VARY BASED ON STAKEHOLDER AGENCIES, ENGINEERING AND CONSTRUCTION SCOPE, ENVIORNMENTAL MORATORIUM, ETC.

[10]THE FOLLOWING ITEMS ARE EXCLUDED: 1) ENGINEERING AND CONSTRUCTION COSTS FOR HAZARDOUS MATERIALS AND OTHER CONTAMINANTS; 2) PERMITTING FEES; 3) MITIGATION FOR ENVIRONMENTAL IMPACTS; 4) OPERATIONS EQUIPMENT; 5) ARCHITECTURAL AND LANDSCAPE FEATURES.

ADDITIONAL ASSUMPTIONS ARE INCLUDED ON PG 2.

BROOKLYN NAVY YARD RESILIENCY PROGRAM - HYBRID SCENARIO - OPINION OF PROBABLE COST

NEW YORK - BROOKLYN NAVY YARD

PROJECT NO:	A252262	PREPARED BY:	GSVR
PROJECT NAME:	BNY Resiliency	DATE:	01.23.2024
VERSION:	1.0	CHECKED BY:	MKWZ
CLIENT:	Ramboll	DATE:	01.23.2024
SITE LOCATION:	Brooklyn Navy Yard		

Assumptions

LINE ITEMS:

1. Assumptions below represent general assumptions used when preparing the Opinion of Propbable Costs.

BNY RESILIENCY - HYBRID DIAGRAM	
Line Item:	**General Assumption(s):**
West Building - Integrated Flood Resiliency	1. Exterior protections consist of a simply supported concrete barrier wall will require a protective coating. Assume the height of the exterior wall is 3 ft. tall and is build directly alongside existing exterior perimeter. 2. Small and large openings (i.e., doors and garages) identified via Google Earth are included in the OPC as steel rollup floodproof doors.
Steel Sheet Pile Bulkhead with Concrete Cap	1. Steel Sheet Pile Wall will required some revetment (i.e., Rip-Rap) when adjacent to the shoreline. 2. Rip-Rap placement extends 4.5 ft. high against the Steel Sheet Pile Wall with a slope of 1:2. 3. Additional structural fill beyond the wall along the inshore side extends 9 ft. to provide structural stability for the freestanding wall.
Pile Supported Reinforced Concrete Barrier Wall - 6ft (Design Elev.)	1. Rip-Rap placement extends 4.5 ft. high against the Concrete Barrie Wall with a slope of 1:2. 2. Assume micropyle bent spacing is consistently 10 ft. for entire length of the constructed wall. 3. Assume micropiles require 60 ft. of embedment to support the 6ft. tall wall and avoid overturning. 4. No drains are included in the OPC. 5. Assume #6 Rebar is used at 200 lb. / cy. in wall and footing sections. 6. Assume wall geometry based on *Engineering Principles and Practices for Retrofitting Flood-Prone Structures* and USACE Guidelines [FEMA 2012]. 7. Assume structural fill required above the heel, and 12 inches of compacted gravel beneath footing.
Reinforced Concrete Barrier Wall - 3ft (Design Elev.) - Integrated Flood Structure	1. Rip-Rap placement extends 4.5 ft. high against the Concrete Barrie Wall with a slope of 1:2. 2. Assume concrete sections are precast. 3. Assume #6 Rebar is used at 200 lb. / cy. In wall and footing sections. 4. Assume 2ft of structural fill required beneath wall due to unknown geotechnical conditions. 5. Assume wall geometry based on *Engineering Principles and Practices for Retrofitting Flood-Prone Structures* and USACE Guidelines [FEMA 2012]. 6. Assume structural fill required above the heel, and 12 inches of compacted gravel beneath footing.
Carbon Sliding Floodgate Wall (6 Ft Tall)	1. Pricing based on a 50 ft. long x 6 ft. tall design provided in 2023 Quote provided by others. 2. Assume sliding gate utilized an added push button and automated direct drive motor. 3. Assume technical crew required for installation included in labor cost.
Powered Flip Up Barrier Wall (3 Ft Tall)	1. Pricing based on a 20 ft. long x 3 ft. tall design provided in 2023 Quote provided by others. 2. Assume sliding gate requires localized activation. 3. Assume technical crew required for installation in labor costs.
Pedestrian Walkway	1. Assume 3 ft. T-Shaped Walls on either side of walkway are simply reinforced. 2. Assume elevated platform is supported with structural fill for entire height of the wall. 3. Assume a walkway width of 8 ft. 4. Assume general pavers and 6 inch. of compacted and for walkway topping. 5. Other ancillary landscape features not included. 6. Assume simple concrete curb and drainage inlet included.
Utility Relocations	1. Assume additional utilies calculated as 10% of the raw construction labor costs.

Appendix F: Funding Strategies and Opportunities

Coastal Resilience & Climate Adaptation Funding Opportunities

Federal

NOAA Climate Resilience Regional Challenge (CRRC)

Agency/Entity: National Oceanic and Atmospheric Administration (NOAA)

Program/Funding Source: Inflation Reduction Act (IRA)

Description: NOAA's CRRC grant is a new competitive funding opportunity made possible through the IRA. The program will provide approximately $575 million to projects that build the resilience of coastal communities to extreme weather and other impacts of climate change (NOAA, n.d.). The program offers funding under two tracks and is focused on collaborative approaches to achieving resilience in coastal regions by strengthening partnerships, capacity building, and implementing coordinated adaptation measures.

Eligibility Requirements: Eligible applicants include coastal states, territories, tribes, cities, municipalities, and non-profit associations.

Eligible Activities: There are two tracks under which NOAA awards grants:

Track One: Regional Collaborative Building and Strategy Development, such as:

- Build and expand regional collaboratives; and
- Engage and partner with marginalized and/or underrepresented communities; and
- Assess risk and vulnerability; and
- Plan resilience strategies and adaptation actions; and
- Build community and workforce capacity for climate adaptation efforts.

Track Two: Implementation of Resilience and Adaptation Actions, such as:

- Acquisition of vulnerable land; and
- Building natural infrastructure; and
- Hybrid green and gray construction activities; and
- Building regional capacity for ongoing actions that increase resilience; and
- Planning and preparing for community-led relocation; and
- Updating state and local codes and policies.

Funding and Cost-share: There are no cost-share requirements for this grant. Funding availability varies per track according to the following:

- Track One: Funding is available between $500,000 and $2 million for approximately 20 to 25 applicants, to be spent over three to five years. A total of $25 million is available under track one.
- Track Two: Funding is available between $15 million and $75 million for approximately 15 applicants, to be spent over five years. A total of $550 million is available under track two.

Additional Considerations: This grant program places emphasis on the scale of impacts, favoring projects that will deliver resiliency benefits regionally. As such, BNYDC should highlight how the BNY provides jobs for a wide-ranging extent of the metropolitan workforce.

Timeframe: The letter of intent (LOI) for FY23 was due on August 28th, 2023 and the full application is due Tuesday, February 13th, 2024.

Additional Resources:

- Program Overview: https://coast.noaa.gov/funding/ira/resilience-challenge/
- Notice of Funding Opportunity: https://www.grants.gov/web/grants/view-opportunity.html?oppId=348810

FEMA Building Resilient Infrastructure and Communities (BRIC) Grant

Agency/Entity: Federal Emergency Management Agency (FEMA)

Program/Funding Source: Hazard Mitigation Assistance (HMA)

Description: The BRIC program aims to increase community resilience by providing funding for a wide range of climate hazards, including extreme heat, wildfires, drought, hurricanes, and flooding (FEMA, 2023). BRIC will support hazard mitigation projects that are cost-effective and designed to reduce the loss of life and damage and destruction of property and minimize the impacts on the Disaster Relief Fund (DRF).

Eligibility Requirements: The BRIC program will support states, municipalities, local communities, tribes, and territories, as such, BNYDC should submit any BRIC applications in conjunction with the City. Additionally, all applicants and sub-applicants must have a FEMA-approved mitigation plan that has been adopted by the jurisdiction by the application deadline. Submitted projects must demonstrate cost-effectiveness through a Benefit-Cost Analysis (BCA).

Eligible Activities: Under BRIC, FEMA may provide financial assistance under four different activity categories:

Mitigation Projects

- Competitively awarded financial assistance to implement cost-effective mitigation projects that are designed to reduce loss of life, injuries, and damage to property or infrastructure.

Capability and Capacity Building

- Expand or improve the administration of mitigation assistance; and
- Mitigate risk by creating and supporting partnerships; and
- Develop or update mitigation priorities and plans; and
- Pursue project-scoping activities; and
- Establish, adopt, and enforce codes and standards consistent with applicable law; and
- Reduce vulnerability by identifying and implementing other hazard-mitigation activities, enhancing public safety, and improving the resilience of communities and critical infrastructure to natural hazards.

Non-Financial Direct Technical Assistance

- Identification of potential mitigation projects; and
- Develop and review mitigation plans; and
- Provide training on grant mitigation.

Management Costs

- Reimbursement for eligible indirect costs related to mitigation measures (up to 15 percent of the total amount of the grant award).

Funding and Cost-share: FEMA made $3 billion in funding available via BRIC in FY22. FEMA may provide up to 75 percent of the cost of eligible mitigation activities under BRIC.

Additional Considerations: The BRIC program awards projects that support communities through capability- and capacity-building; encourage and enable innovation; promote partnerships; and facilitate the installation of large projects (FEMA, 2023). BRIC also focuses on projects that benefit disadvantaged populations of larger communities. As such, BNYDC should highlight its presence as a regional job producer and describe the benefits BNY provides to underserved populations in the area. Additionally, this grant has a performance period of four years, during which the awarded funding must be utilized.

Timeframe: While the FY23 funding cycle has not yet been announced, the FY22 funding period opened on September 30th, 2022, and closed on January 28th, 2023. Therefore, a Notice of Funding Opportunity (NOFO) announcement is expected this fall.

Additional Resources:

- Program Overview: https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities
- HMA Policy Guide: https://www.fema.gov/sites/default/files/documents/fema_hma-program-policy-guide_032023.pdf
- FEMA BCA Toolkit: https://www.fema.gov/grants/tools/benefit-cost-analysis

FEMA Flood Mitigation Assistance (FMA) Grant

Agency/Entity: FEMA

Program/Funding Source: HMA

Description: FMA is a competitive program that provides funding for projects that reduce or eliminate the risk of flood damage to structures insured by the National Flood Insurance Program (NFIP). FEMA chooses recipients based on the applicant's ranking of the project and the eligibility and cost-effectiveness of the project (FEMA, n.d.).

Eligibility Requirements: Funding is available to states, local communities, federally recognized tribes and territories. As such, BNYDC should submit any FEMA FMA applications in conjunction with the City. All applicants and sub-applicants must have a FEMA-approved mitigation plan that has been adopted by the jurisdiction and applicable mitigation planning policies by the application deadline. Additionally, submitted projects must demonstrate cost-effectiveness through a BCA.

Eligible Activities: FMA provides funding for the following project types:

- Elevation; and
- Flood Control; and
- Acquisitions; and
- Mitigation reconstruction; and
- Project scoping (engineering, environmental, feasibility, and/or BCA).

Funding and Cost-share: FEMA may provide technical assistance to contribute up to 100 percent federal cost share for severe repetitive loss structures and up to 90 percent federal cost share for repetitive loss structures. In the case of all other activities, FEMA may contribute to an amount up to 75 percent.

Additional Considerations: This grant has a performance period of four years, during which the awarded funding must be utilized.

Timeframe: The FY23 funding cycle opened on March 1st, 2023, and closed on April 14th, 2023. As such, the next cycle's NOFO is expected in Spring 2024.

Additional Resources:

- Program Overview: https://www.fema.gov/grants/mitigation/floods
- HMA Policy Guide: https://www.fema.gov/sites/default/files/documents/fema_hma-program-policy-guide_032023.pdf
- FEMA BCA Toolkit: https://www.fema.gov/grants/tools/benefit-cost-analysis

EPA Clean Water State Revolving Fund (CWSRF)

Agency/Entity: Environmental Protection Agency (EPA) / Environmental Facilities Corporation (EFC)

Program/Funding Source: Clean Water Act (CWA), Amended in 2014 by the Water Resources reform and Development Act

Description: The CWSRF program is a federal-state partnership that provides low-cost financing for a wide range of wastewater infrastructure and water quality projects. The state-administered programs operate like banks with federal and state contributions used to capitalize the programs. These funds are used to make low-interest loans to local communities for water quality projects and are then repaid to the CWSRFs over terms as long as 30 years or the useful life of the project, whichever is less. Repayments are then recycled back into the fund to finance additional projects (EPA, n.d.).

Eligibility Requirements: Publicly or privately owned projects are eligible to apply, in addition to Publicly Owned Treatment Works (POTWs).

Eligible Activities: CWSFs fund a wide variety of water infrastructure projects under eleven different project types. Project types that are relevant to BNYDC include :

- Nonpoint Source
    - Implementation of a NPS pollution management program.
- Stormwater Management
    - Green infrastructure projects that manage stormwater, such as constructed wetlands, bioretention, porous pavement, and green roofs; and
    - Environmentally innovative projects that demonstrate new and/or innovative approaches to delivering services or managing water resources; and
    - Practices that manage, reduce, treat, or recapture stormwater or subsurface drainage water.
- Water Reuse
    - Reuse or recycle wastewater, stormwater, or subsurface drainage water.

Funding and Cost-share: According to the EPA, the CWSRF has provided $163 billion in low-cost financing to communities over the past 35 years. There is no specific cap amount.

Application Considerations: In the state of New York, the CWSRF is administered through the NYS EFC.

Timeframe: CWSRF applications are accepted on a rolling basis, but new projects had to have been submitted by June 16, 2023, to be listed in the 2024 Intended Use Plan (IUP). Project listings received after that date will be postponed to the next IUP year.

Sources/Additional Resources:

- EPA Program Overview: https://www.epa.gov/cwsrf
- EFC Program Overview: https://efc.ny.gov/cwsrf
- Program Brochure: https://www.epa.gov/sites/default/files/2021-01/documents/funding_resilient_infrastructure_and_communities_with_the_cwsrf.pdf
- Overview of Clean Water State Revolving Fund Eligibilities: https://www.epa.gov/sites/default/files/2016-07/documents/overview_of_cwsrf_eligibilities_may_2016.pdf

EPA Environmental Justice Government-to-Government Program (EJG2G)

Agency/Entity: EPA

Program/Funding Source: EPA

Description: The Environmental Justice Government-to-Government (EJG2G) program provides funding to support government activities that lead to measurable environmental or public health impacts in communities disproportionately burdened by environmental harms (EPA, n.d.). Approximately $70 million in funding is provided through annual appropriations and the IRA under the EJG2G program, with $20 million being allocated to state applicants and $20 million being allocated to local government applicants.

Eligibility Requirements: Eligible applicants include states, local governments, and tribes in partnership with a community-based nonprofit organization. As such, BNYDC would need to submit in conjunction with the City or State.

Eligible Activities: Projects must address one of the following broad categories:

- Community-led air and other pollution monitoring, prevention, remediation; and
- Investments in low- and zero-emission and resilient technologies and related infrastructure and workforce development that help reduce greenhouse gas emissions and other air pollutants; and
- Mitigating climate and health risks from urban heat islands, extreme heat, wood heater emissions, and wildfire events; and
- Climate resiliency and adaptation; and
- Reducing indoor toxins and indoor air pollution; and
- Facilitating engagement of marginalized communities in local, state, and federal public processes, such as advisory groups, workshops, and rulemakings.

Funding and Cost-share: There is a $1 million funding cap associated with the EJG2G program and no cost-share requirement.

Additional Considerations: As the name suggests, the primary focus of this program is to provide meaningful and measurable environmental and/or public health benefits for disadvantaged communities. If/when applying, BNYDC should highlight the benefits that the adaptation measures for which funding is being sought provide to local and regional underserved communities such as job continuity and public/worker safety.

Timeframe: While FY24 funding has not yet been announced, the application for the FY23 funding cycle closed on April 14, 2023, so a NOFO is expected in early 2024.

Additional Resources:

- Program Overview: https://www.epa.gov/environmentaljustice/environmental-justice-government-government-program#:~:text=The%20Environmental%20Justice%20Government%2Dto%2DGovernment%20(EJG2G)%20program,disproportionately%20burdened%20by%20environmental%20harms

NFWF National Coastal Resilience Fund (NCRF)

Agency/Entity: National Fish and Wildlife Foundation (NFWF)

Program/Funding Source: NOAA, BIL

Description: Established in 2018, the National Coastal Resilience Fund supports nature-based solutions that enhance the resilience of coastal communities and habitats to address increasing threats from storms, sea and lake level changes, flooding, erosion and other coastal hazards (NFWF, n.d.). The NCRF invests in nature-based projects – such as installing living shorelines – to protect communities from coastal hazards and enhance habitats for fish and wildlife. In 2022 with increased funding provided by the Bipartisan Infrastructure Law, the NCRF awarded approximately $144 million in competitive grants to support planning, design, and implementation of nature-based resilience projects (NFWF, n.d.). The NCRF is primarily funded by, and coordinated with, the NOAA.

Eligibility Requirements: Non-profits, states, tribal governments, local governments, educational institutions, and for-profit organizations are eligible. BNYDC could therefore apply directly or be a sub-applicant to the City.

Eligible Activities: NFWF funds activities in four categories designed to advance a project through the project pipeline from planning to implementation. As such, the four categories include:

- Community capacity building and planning; and
- Site assessment and preliminary design; and
- Final design and permitting; and
- Restoration implementation.

While projects that have been previously funded under earlier pipeline categories are not guaranteed funding and each proposal will be reevaluated for competitiveness at subsequent stages of the pipeline, NFWF prioritizes proposals that seek to advance previously funded NCRF projects to the next stage in the project pipeline (NFWF, n.d.). As such, to maximize funding through the NCRF program, BNYDC should aim to submit projects earlier in the pipeline (at the planning and preliminary design stages) for the best chance of receiving funding for the implementation and construction of the project.

Funding and Cost-share: Typical awards are between $100,000 and $1 million for planning and up to $10 million for implementation. A funding match is encouraged, but not required.

Application Considerations: Program priorities include nature-based solutions (NBS), community resilience benefits, fish and wildlife benefits, community engagement, and innovation and sustainability. To be well-positioned, BNYDC should submit green infrastructure or NBS projects for funding under this opportunity and highlight community resilience benefits.

Timeframe: FY23 preproposals were due on April 12, 2023. Requests for FY24 applications will be announced in early 2024.

Additional Resources:

- Program Overview: https://www.nfwf.org/programs/national-coastal-resilience-fund?activeTab=tab-1
- 2023 Request for NCRF Proposals: https://www.nfwf.org/programs/national-coastal-resilience-fund/national-coastal-resilience-fund-2023-request-proposals
- Program Fact Sheet: https://www.nfwf.org/sites/default/files/2022-12/NFWF-NCRF-20221129-Nov-FS.pdf

State

NYS EFC Green Innovation Grant Program (GIGP)

Agency/Entity: NYS Environmental Facilities Corporation (EFC)

Program/Funding Source: Consolidated Funding Application (CFA)

Description: Through the Governor's Consolidated Funding Application (CFA) process, the GIGP supports projects across New York State that utilize unique EPA-designated green stormwater infrastructure design and create cutting-edge green technologies (NYS EFC, n.d.). Competitive grants are awarded annually to projects that improve water quality and mitigate the effects of climate change through the implementation of one or more of the following green practices: Green Stormwater Infrastructure, Energy Efficiency, Water Efficiency and Environmental Innovation.

Eligibility Requirements: Eligible applicants vary per project type but generally include municipalities, private entities, state agencies, and soil and water conservation districts.

Eligible Activities: BNYDC is eligible to apply for the below project types:

- Green stormwater infrastructure (municipalities, private entities, state agencies, and soil and water conservation districts)
    - Bioretention; and
    - Downspout disconnection; and
    - Establishment or restoration of floodplains, riparian buffers, streams, or wetlands; and
    - Green roof or green walls; and
    - Permeable paving; and
    - Stormwater harvesting and reuse; and
    - Stormwater street tree/urban forestry.
- Water efficiency (municipalities only)
    - Water meter installation; and
    - Water meter replacement; and
    - Water meter retrofit; and
    - Water reuse.
- Environmental innovation (municipalities only)
    - Treatment technologies that significantly reduce residuals; and
    - Adaptation projects that prepare for long-term effects of climate change (such as relocation of a facility); and
    - Implementation of asset management plans that meet DEC guidelines.

Funding and Cost-share: The GIGP has a maximum funding allocation of $3 million per project and will provide a total of $15 million in funding in FY23. Further, the GIGP cost-share varies based on municipal median household income (MHI). Since Brooklyn has a MHI of less than $100,000, BNY would qualify for 90 percent cost-share for green stormwater infrastructure and environmental innovation projects and up to 75 percent cost-share for energy efficiency and water efficiency projects.

Application Considerations: In addition to water quality improvements, projects that provide benefits to disadvantaged communities, advance downtown revitalization, and/or align with the Regional Economic Development Council's (REDC) Strategic Plan are given priority. As such, BNYDC should highlight how BNY provides job opportunities and promotes strategic growth if/when applying.

Timeframe: FY23 CFA applications were due on July 28th, 2023. FY24 applications will likely follow a similar application cycle.

Additional Resources:

- Program Overview: https://efc.ny.gov/gigp
- Required documentation guidance: https://nysefc.app.box.com/s/u1lz5pw7ej7nndrcsz25mgcj1xja8s5h

NYS EFC Water Quality Improvement Project (WQIP) Program

Agency/Entity: NYS EFC

Program/Funding Source: Consolidated Funding Application (CFA)

Description: The Water Quality Improvement Project (WQIP) program is a competitive, reimbursement grant program that funds projects that directly improve water quality or aquatic habitat, promote flood risk reduction, restoration, and enhanced flood and climate resiliency, or protect a drinking water source (EFC, n.d.).

Eligibility Requirements: Eligible applicants include municipalities, soil and water conservation districts, and non-for-profits (for Aquatic Connectivity Restoration, Marine District Habitat Restoration, and Land Acquisition for Source Water Protection only). As such, BNYDC would need to apply as a sub-applicant to the City if pursuing funding under the nonagricultural nonpoint source abatement and control project type. Additionally, the project must be within a 100 year or 500 year FEMA floodplain.

Eligible Activities: The following project types could be relevant for BNYDC :

- Wastewater Treatment Improvement; and
- Nonagricultural Nonpoint Source Abatement and Control including:
    - Green infrastructure,
    - Stormwater retrofits,
    - Streambank/shoreline stabilization
- Aquatic Connectivity Restoration; and
- Marine District Habitat Restoration.

Funding and Cost-share: A total of $75 million is available under this program with a required cost-share of 25 percent. Funding caps vary per project type, according to the following:

- Wastewater Treatment Improvement: $1 million - $15 million
- Nonagricultural Nonpoint Source Abatement and Control: $100,000 - $10 million
- Aquatic Connectivity Restoration: $250,000
- Marine District Habitat Restoration: $750,000

Application Considerations: This funding is for construction/implementation projects only, not projects that are exclusively for planning. Additionally, projects that promote climate change resilience and adaptation, or both, will receive additional points in the evaluation of an application (EFC, 2023).

Timeframe: FY23 CFA applications were due on July 28th, 2023. FY24 applications will likely follow a similar application cycle.

Additional Resources:

- Program Overview: https://www.dec.ny.gov/pubs/4774.html
- Program Brochure: https://www.dec.ny.gov/docs/water_pdf/wqiprfa2023.pdf

Regional/Local

HEP Building Community Capacity for Climate Resiliency

Agency/Entity: EPA / Governors Offices of New York and New Jersey

Program/Funding Source: New York-New Jersey Harbor & Estuary Program (HEP)/Infrastructure Investment and Jobs Act (IIJA)

Description: This grant program supports disadvantaged communities seeking to advance research, planning and/or infrastructure projects that will help build climate resiliency while addressing water quality and related management issues in those communities (HEP, 2023). A total of $400,000 is available in FY 2023, as allocated from the IIJA.

Eligibility Requirements: Grant recipients must be a local government or non-profit organizations located in and/or serving disadvantaged communities as defined by HEP using criteria set by the EPA.

Eligible Activities: Specific eligible activities are not prescribed, but may include:

- Community engagement activities; and
- Technical assistance to understand climate risks or measure benefits of proposed climate adaptation measures; and
- Monitoring, data collection, and analysis; and
- Planning activities including site assessment, conceptual plans, and initial (10 – 30 percent) engineering/design drawings.

Funding and Cost-share: The HEP plans to award between four and eight recipients between $50,000 - $100,000 in grant funding in FY 2023. While no cost-share is required, the contribution of outside funds or other matches is viewed favorably.

Application Considerations: N/A

Timeframe: The 2023 LOI was due on June 1st and the full proposal was due on August 15th. Grants awards are expected to be announced in mid-September 2023. FY24 applications will likely follow a similar application cycle.

Additional Resources:

- Program RFP (2023): https://www.hudsonriver.org/wp-content/uploads/2023/04/HEP-RFP_Building-Community-Capacity-for-Climate-Resiliency.pdf?utm_source=HRF+Master+Email+List&utm_campaign=e2675565f1-EMAIL_CAMPAIGN_2018_11_27_03_42_COPY_01&utm_medium=email&utm_term=0_85a8e175d3-e2675565f1-421164577

NYC DEP Resilient NYC Partners Program

Agency/Entity: NYC Department of Environmental Protection (NYC DEP)

Program: Resilient NYC Partners Program

Description: Through the Resilient NYC Partners Program, both private and publicly-owned properties can receive funding to install green infrastructure (GI) to manage stormwater on-site.

Eligibility Requirements: Private- and City-owned properties that have long-term leases and are at least 50,000 square feet with large impervious surfaces that drain into the City's combined or separate sewers are eligible applicants for this program.

Eligible Activities: Funding is available for the following activities:

- Installation of rain gardens, bioretention, or other blue-green infrastructure (BGI); and
- Fixing drainage issues and reducing ponding; and
- Resurfacing or replacing pavement; and
- Installation of sub-surface stormwater storage.

Funding and Cost-share: While no specific project cap is provided, the program offers $53 million in available funding, as of its launch in 2021.

Application Considerations: The Resilient NYC Partners Program provides the assessment, planning and review, scheduling and approvals, and construction of GI projects such that the City is highly involved in the implementation of the project, as opposed to just providing funding.

Timeframe: Ongoing

Additional Resources:

- Program Overview: https://www.nyc.gov/site/dep/whats-new/resilient-nyc-partners.page
- Program Brochure: https://www.nyc.gov/assets/dep/downloads/pdf/whats-new/programs-initiatives/resilient-nyc-partners-about.pdf

Emergent Legislative Funding Sources

While the previous section details multiple existing opportunities for BNYDC to further investigate to fund the implementation of the Resilience Plan, there are several other key programs that are on the horizon that should also be considered but have not yet been fully released. Namely, the roll-out of the Clean Water, Clean Air, and Green Jobs Environmental Bond Act (NYS Bond Act) at the state-level, the continued roll-out of both the IIJA (also known as the Bipartisan Infrastructure Act) and the IRA at the federal-level are substantial, and even unprecedented, funding opportunities that should be kept in mind.

New York State Clean Water, Clean Air, and Green Jobs Environmental Bond Act

The NYS Environmental Bond Act was approved by a ballot proposition in November of 2022 and represents a $4.2 billion investment to fund environmental and community projects throughout the state. The legislation allocates funding in four categories:

- Climate Change Mitigation
- Restoration & Flood Risk Reduction
- Water Quality Improvement & Resilient Infrastructure
- Open Space Land Conservation and Recreation

The allocation and distribution of the funding is still being formally determined but includes up to $1.5 billion for climate change mitigation projects; at least $1.1 billion for restoration and flood-risk reduction projects; and at least $650 million for water quality improvement and resilient infrastructure projects (NYS Environmental Bond Act Overview, n.d.). This significant new funding source will provide support to state agencies, local governments, and partners to fund resiliency projects and will offer new funding opportunities for BNYDC to consider in 2024 and 2025.

During the summer of 2023, New York State agencies have been leading a Listening Tour about the Environmental Bond Act. In the meantime, agencies are in the process of developing eligibility guidelines for the various grant programs that are being developed. Draft eligibility guidelines are expected to be released for public review in the fall of 2023. BNYDC should watch for this release so that they are able to review and comment on the draft eligibility guidelines—and help to ensure that climate adaptation projects at BNYDC will fit within the guidelines. Following the public comment period, NYS agencies will finalize the eligibility guidelines. Grant applications are expected to open in 2024. It is likely that some of the funds will be distributed through the existing Consolidated Funding Application (which typically is due in July). However, programs established by the Environmental Bond Act that do not fit within existing grant programs will require new programs—these new programs may or may not follow the same submission deadlines as CFA. More information and program updates are available at: www.ny.gov/bondact.

Infrastructure Investments and Jobs Act

In terms of upcoming federal opportunities, the IIJA was signed into law in November of 2021, marking the most significant action congress has taken to fund clean energy infrastructure and combat climate change in the nation's history. While some of the funding from these pieces of legislation has already become available, details on specific allocations and funding roll-out to states is still being defined. The IIJA will allocate roughly $1.2 trillion over the next ten years, including at least $50 billion for climate resiliency efforts (White House Briefing, 2023). Below is a list of open and/or recently closed NOFOs that were the result of this legislation, to provide BNYDC guidance for FY24:

Open/Ongoing:

- Clean Water State Revolving Fund (rolling basis): https://www.epa.gov/cwsrf
- Reconnecting Communities and Neighborhoods Program (FY23 applications are due 9/28/23): https://www.transportation.gov/grants/rcnprogram/reconnecting-communities-how-apply

Closed, but returning in 2024:

- Port Infrastructure Development Program (FY23 applications were due 4/28/23): https://www.maritime.dot.gov/PIDPgrants

- National Coastal Zone Management Program (FY23 LOI was due 8/14/23): https://coast.noaa.gov/czm/

Inflation Reduction Act

The IRA, which was approved in August of 2022, will direct nearly $2.6 billion to invest in improving resilience in coastal communities with an emphasis on environmental justice (NOAA, 2023). Below is a list of open and/or recently closed NOFOs that were the result of this legislation, to provide BNYDC guidance for FY24:

Open/Ongoing:

- Greenhouse Gas Reduction Fund: Clean Communities Investment Accelerator (FY23 applications are due 10/12/23): https://www.epa.gov/greenhouse-gas-reduction-fund/clean-communities-investment-accelerator
- Transformational Habitat Restoration and Coastal Resilience (FY23 applications are due 11/17/23): https://www.fisheries.noaa.gov/grant/transformational-habitat-restoration-and-coastal-resilience-grants

Closed, but returning in 2024:

- National Coastal Resilience Fund (FY23 preproposals were due on 4/12/23): https://www.nfwf.org/programs/national-coastal-resilience-fund?activeTab=tab-1

Transportation Funding Considerations

Additionally, while the focus of this memo is to identify sources of funding for resiliency measures resulting from the BNY Climate Resilience Plan, other funding opportunities should also be considered for public transit and access improvements, as these are intended co-benefits of various resiliency measures and are in alignment with the BNY Master Plan (2022). Programs such as the US Department of Transportation's (DOT) Transportation Enhancement Activities and the Rebuilding American Infrastructure through the Sustainability and Equity Program (RAISE) offer BNYDC additional funding streams to consider when implementing transit- or access-oriented resilience measures.

Conclusion

In summary, undertaking site-wide resiliency improvements at the BNY will be a considerable effort and will require external funding sources to support these ambitious initiatives. Thankfully, there is currently an unprecedented amount of funding available in the United States to implement resilience and adaptation measures, and even more so within the New York City context due to additional state and local action.

Appendix G: Tenant Resilience Toolkit

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