

City & County of Honolulu

# Climate Adaptation

# BACKGROUND RESEARCH

## International Best Practices & Local Initiatives

November 2020



## 1. Introduction & Approach

The objective of this project is to develop preliminary climate resilience guidance that can be used by developers and landowners in Honolulu transit-oriented development (TOD) and other urban areas that may be vulnerable to sea level rise (SLR). The guidance is targeted toward providing developers with information and best practices for adapting building sites and structures to climate change-related hazards including SLR, flooding, heat, and groundwater inundation. This project represents an initial step toward developing comprehensive climate resilience design guidelines for the City and County of Honolulu (the City), an effort called for in Action 14 of the City's *O'ahu Resilience Strategy*, which the City intends to undertake in the near future.

The work was conducted by a consulting team from SSFM International and Arup for the City Department of Planning and Permitting (DPP) and the Office of Climate Change, Sustainability, and Resiliency (CCSR). The project was led by DPP TOD Division, and included review of existing plans, guidelines, and projects; interviews with City agencies and stakeholders; and international and local research. The team also developed a companion Climate Adaptation Design Principles for Urban Development document on resilient design principles and best practices, with an emphasis on building scale, urban design solutions, and streetscape transitions (e.g., the area between the building and the curb).

In the initial stage of this project, the consulting team conducted a literature review of local, national, and international references; held a coordination meeting with multiple City agencies; and completed interviews with seven stakeholders to identify best practices and review them against existing City policies, practices, and regulations. This memo summarizes the findings that are most relevant for informing the development of climate adaptation design guidelines for the City. Examples from national and international locations are also included to supplement the findings.

**CITY & COUNTY OF HONOLULU  
"O'AHU RESILIENCE STRATEGY" -  
ACTION 14:  
ESTABLISH FUTURE CONDITIONS  
CLIMATE RESILIENCE DESIGN  
GUIDELINES**

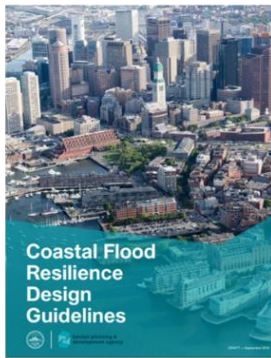
The purpose of the guidelines will be to provide step-by-step instructions on how to supplement historic climate data with specific, regional, forward-looking climate change data in the design of City and private facilities and infrastructure.

**CLIMATE ADAPTATION:  
DESIGN PRINCIPLES FOR URBAN  
DEVELOPMENT**

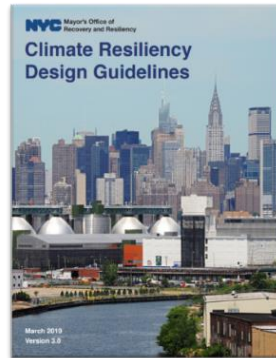
As companion to this Background Research Document, the purpose of the Design Principles for Urban Development document is to provide design principles that can be used by developers, landowners, and design professionals in TOD and other urban areas that may be vulnerable to SLR and other climate change related hazards. This document is available at [www.honolulu.gov/tod](http://www.honolulu.gov/tod).

## 2. Findings: National & International Best Practices

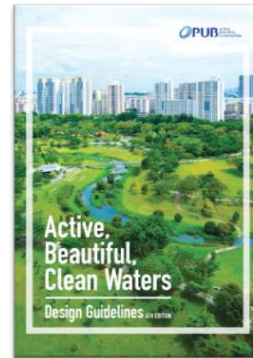
The four national and international references that were identified to be most relevant to urban Honolulu come from Boston, New York City, Singapore, and Hamburg. In each of these places, guidelines have been established for design elements at the building and district scale that enhance climate resilience for people and properties:



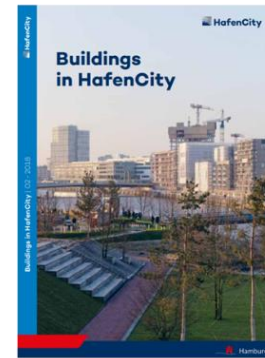
**BOSTON**  
Coastal Resilience  
Design Guidelines



**NEW YORK**  
Climate Resiliency  
Design Guidelines



**SINGAPORE**  
ABC Waters Design  
Guidelines



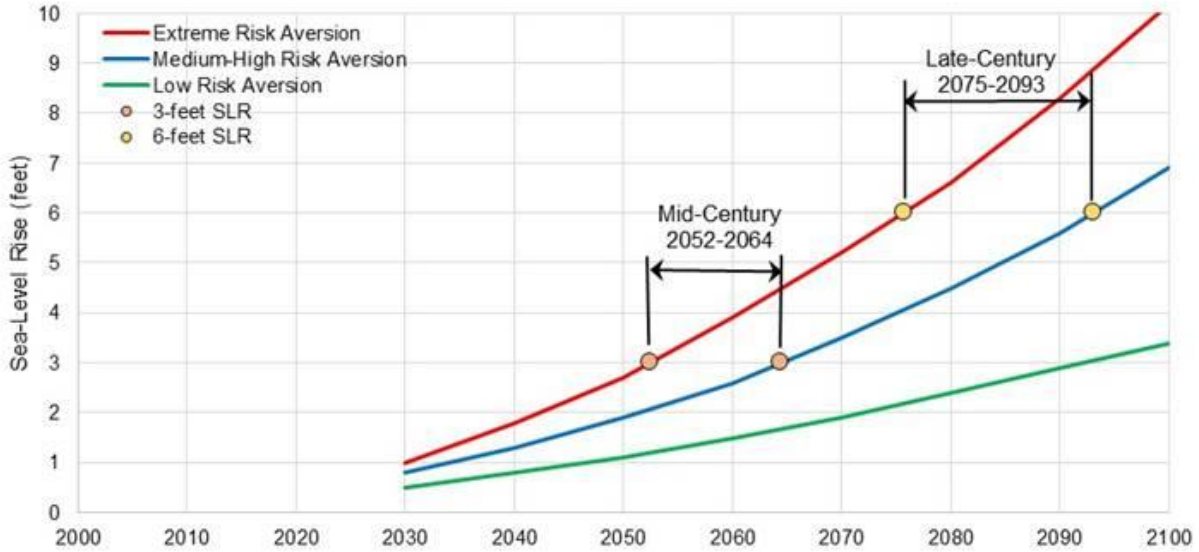
**HAMBURG**  
HafenCity Buildings  
Design Guidelines

In each of these locations, coastal hazards and SLR adaptation have been at the forefront of resilience-focused design guidance. However, some also address climate change-related hazards, including but not limited to, extreme heat, extreme rainfall, pluvial and fluvial flooding, and groundwater flooding. The discussion below highlights key best practices for hazard mitigation and resilient design guidelines pulled from these and other existing references.

### ***Identifying Hazards and Establishing Climate Projections***

In general, there is an established best practice for City or County level governments to identify the most credible hazards that pertain to a certain area and provide relevant climate projection data to utilize in planning. The specificity and granularity of the hazard data and climate projections vary, but in general are to be based on the best available science.

To facilitate ease of use, some localities have taken steps to simplify projected climate data into more usable forms. For example, in California, the Coastal Commission attributes different risk aversion levels, such as medium-high, to SLR projections to assist with project planning. In the figure on the following page, a project planned with a design life extending through mid-century would consider and make design accommodations for three feet of SLR based on the medium-high to extreme risk aversion projections (*State of California Sea Level Rise Policy Guidance, 2018*).



**Sea Level Rise Risk Aversion Levels (provided in the 2018 State of California Sea Level Rise Policy Guidance)**

(Source: [www.opc.ca.gov/webmaster/ftp/pdf/agenda\\_items/20180314/Item3\\_Exhibit-A\\_OPC\\_SLR\\_Guidance-rd3.pdf](http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf))

Some guidelines incorporate factors such as useful life of buildings in determining what climate projections are applicable. Shown below is guidance from New York City’s *Climate Resiliency Design Guidelines* (2019) related to establishing design flood elevations (DFE) for critical facilities that incorporate SLR, useful life, and Federal Emergency Management Agency (FEMA) requirements.

**Table 3 - Determine the sea level rise-adjusted design flood elevation (DFE)<sup>55</sup>**

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

**Design Flood Elevation Guidance for Critical Facilities (provided in the 2019 New York City Climate Resiliency Design Guidelines)**

(Source: [www1.nyc.gov/assets/orr/pdf/NYC\\_Climate\\_Resiliency\\_Design\\_Guidelines\\_v3-0.pdf](http://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v3-0.pdf))

This table from the New York City guidelines highlights another important best practice: the need to establish DFE’s in areas prone to SLR and extreme storms. DFE’s may be tied to hazard zones or zoning overlays, or may be district-specific.

In the case of Hamburg, all new buildings, roads, and open public spaces are required to stand on artificial bases 8 meters (26.2 feet) above sea level. In Singapore, new buildings are required to have a minimum platform level that is 0.6 meters (1.9 feet) above the adjacent road/ground or 0.6 meters (1.9 feet) above the highest recorded flood level. In

each case, the platform levels or DFEs are used to establish a uniform level of flood protection, which is then implemented through raising individual sites as new buildings are constructed. Applying design guidelines on a district-specific level provides the advantage of ensuring consistent building platform height and neighborhood appearance as an area adapts.

### ***Developing Climate Adaptation Strategies***

In the face of rising sea levels and increasingly extreme, unpredictable weather patterns, governments and agencies across the globe are confronted with daunting challenges in planning for future investments in infrastructure. Within a climate of uncertainty and increased risk, investment decisions require developing an awareness of what hazards exist, where and when impacts may occur, what mitigation and adaptation options are feasible, and the relative costs of implementing different options at different timescales and in different phases. There are also questions of if and when it may become infeasible to maintain infrastructure in some locations, and that leads to a need for exploring alternative strategies and timeframes for retreat. The outcomes of these decisions will have great social, financial, and environmental implications. Yet, the price of inaction or failing to at least examine the range of risks and options is far greater.

In order to approach climate adaptation strategically, jurisdictions must be able to evaluate the relative merits, costs, and risks of various adaptation options at both local and regional scales. This requires not only a planning process with input and involvement from key stakeholders and the public but detailed engineering and feasibility study, risk and hazard assessments, and cost-benefit analyses to determine the optimal balance of adaptation options for a particular location or region.

Dynamic or adaptive planning is an approach that has been adopted in jurisdictions worldwide to enable decision makers to take action in the face of uncertainty. Notable examples include the Dutch Delta Works and the Thames Estuary, both of which are using adaptive planning to coordinate future upgrades to major, national-scale flood infrastructure threatened by SLR. The Dutch Delta Program and the Thames Estuary 2100 program are examples of top-down planning initiatives that are attempting to coordinate future infrastructure upgrades in a way that can be flexible to future climate conditions that may be better or worse than currently projected. Ultimately, this approach accepts that adaptation is a dynamic process, not an outcome.

Arup has developed a flexible adaptation pathways approach based on the principles of adaptive planning. This approach allows planners to consider the relative merits of various adaptation options and to develop a pathway of actions and trigger points for decision making. When properly developed, these flexible adaptation pathways form a type of map that shows how infrastructure development might unfold under various future climate regimes.

Implementation of climate adaptation strategies also requires substantial coordination between agencies, landowners, and other stakeholders to execute the strategies in a

way that minimizes disruption. There are a dearth of examples to look to due to the recency of most adaptation planning efforts in the U.S. (see appendix for national and international examples). However, Miami-Dade County has created a SLR task force with the aim of coordinating efforts, and has conducted inter-agency coordination around specific projects. New York City has also created an agency to coordinate funding, projects, and strategies for climate adaptation.

Particularly in dense urban contexts, challenges arise with managing transitions between buildings, lots, and infrastructure that have been raised above existing grade to withstand flooding, and those that have not. This is evident in places such as Miami Beach, where roads have been raised next to existing urban development.

### ***Stormwater Management***

The New York City, Boston, and Singapore guidelines include a number of provisions for stormwater management. The Copenhagen Cloudburst model also provides a case study on this topic (*Cloudburst Management Plan*, 2012). The following from New York City nicely summarizes the core best practices shared by most national and international examples reviewed: “Minimize increases in impervious surface; utilize strategies that infiltrate, evaporate, or reuse rainwater to achieve stormwater volume reductions; choose low-impact development strategies that detain (delay drainage) to manage the rate of the stormwater flow into the utility drainage system; install stormwater

infiltration, detention, and storage.” Specific examples of design features incorporating this guidance include bioswales, rain gardens, greywater recycling systems, green roofs, blue roofs, and detention basins or tanks. The inset shows an example of a green roof implemented in Singapore that provides stormwater management services while enhancing the public realm. Green infrastructure has also been popularized by the “sponge cities” strategy adopted by many major cities in Asia, including Hong Kong and Shanghai. Again, establishing credible hazards and climate projections is key to ensuring that sites and buildings are designed with enough infiltration, detention, and retention to accommodate projected future rainfall and associated runoff.



**Elmich Green Roof and Rain Water Harvesting at Singapore Polytechnic**

(Source: Elmich Pte Ltd 23rd, 2012; <https://elmich.com/asia/elmich-green-roof-and-rain-water-harvesting-singapore-polytechnic>)

### ***Sea Level Rise and Flood Protection***

As described above, several guidelines recommend protecting sites against flooding by simply elevating building platform levels, in addition to land use coastal protection measures and managed retreat strategies. The raised building approach has been implemented extensively in Hamburg and Singapore. In addition to elevation-focused mitigation strategies, flood-resilient design for ground floor levels is a current trend in Miami, Boston, New York, Hamburg, and elsewhere. The inset shows the HafenCity example in Hamburg, where ground floor windows are designed to withstand high water pressures and steel bulkheads have been put in place to prevent damage on the glass caused by flooding (*Buildings in HafenCity*, 2018). Residential uses are not permitted on ground floors, and so they are instead used for parking, restaurants, and offices. Additionally, in the event of flooding, buildings have been designed with escape routes on different heights to provide for safe evacuation. Below grade flood protection for utilities is also employed in areas like New Orleans, where the water table is near the ground surface (*Learning to Live with Water*, 2015). Many other examples of floodproofing guidelines exist, with New York and Boston having perhaps the most robust references in the existing literature.

At the campus or district scale, several examples include plazas or public spaces designed to provide both public services and floodwater detention or storage. Perhaps the most prominent example comes from Rotterdam where a “water square” was designed to hold rainwater and to provide a space for recreational use during dry weather. This example, called Benthemplein, can hold up to 1.7 million



**Hamburg: steel bulkheads can be closed to protect the windows of apartment blocks along the Sandtorkai**

(Source: Multi functional flood defenses, Delft University of Technology; [www.flooddefences.org/hamburg](http://www.flooddefences.org/hamburg))



**The Water Square in Benthemplein, Rotterdam**

(Source: De Urbanisten; [www.urbanisten.nl/wp/?portfolio=waterplein-benthemplein](http://www.urbanisten.nl/wp/?portfolio=waterplein-benthemplein))



**The HafenCity district of Hamburg, Germany, with a raised promenade**

(Source: Yale School of the Environment; [https://e360.yale.edu/features/a\\_tale\\_of\\_two\\_northern\\_european\\_cities\\_meeting\\_the\\_challenges\\_of\\_sea\\_level\\_rise](https://e360.yale.edu/features/a_tale_of_two_northern_european_cities_meeting_the_challenges_of_sea_level_rise))

liters of rainwater while also being used for basketball, skateboarding, and performance arts in day-to-day conditions (*Bentemplein Water Plaza: An innovative way to prevent urban flooding in Rotterdam*, 2014). Additional examples include San Diego, where parking structures alongside the San Diego River in the Mission Valley have been modified to accommodate semi-frequent flooding (*San Diego River Context*, 2013). During flood events, the parking structures are closed and operated as temporarily floodable infrastructure. Similarly, in coastal cities in the U.S., including Boston, New York, and San Francisco, waterfront areas are being redesigned to protect central business districts from extreme flood events while also providing waterfront access and beautiful public spaces during normal conditions (e.g., the Big U in lower Manhattan).

Projects in these areas are currently defining new best practices for flood resilient landscape architecture with a core tenet being the ability of the infrastructure to quickly recover from flooding with minimal damage. For a built example of this, Hamburg again provides an excellent case study. The HafenCity's main promenade (pictured in the inset) features abundant public space and waterfront access while also protecting the surrounding area from highwater flood events.

### ***Transitions between Buildings and Rights-of-Way (ROW)***

A gap exists in the existing best practice literature for how to best transition between an elevated platform and the adjacent road, sidewalk, or ground. Most guidance that does exist pertains to preserving the pedestrian/public experience. Although not directly climate related, San Francisco has established a provision for new buildings constructed in the downtown area to build “privately owned public open spaces” that benefit and contribute to the public experience in the district (*San Francisco Planning Code, Section 149*, 1986). At a minimum, different references including those reviewed for Boston and Singapore require transition zones to be highly functional. The inset shows the Wisma Atria property in Singapore where ramps, stairs, and public art were constructed in this transition zone between the sidewalk and the elevated building platform, creating a welcoming environment despite the distance of the building entrance from the pedestrian walkway.



**Wisma Atria transition zone, Singapore**

(Source: *Managing Urban Runoff – Drainage Handbook 1st Edition*: June 2013 © PUB, the national water agency; [www.pub.gov.sg/Documents/managingUrbanRunoff.pdf](http://www.pub.gov.sg/Documents/managingUrbanRunoff.pdf))

### ***Mitigation for Extreme Heat***

Several of the references consulted identified recommendations for mitigation of extreme heat, instances of which are expected to increase with climate change. Design recommendations focused primarily on providing shade through trees, awnings, or canopies; using high solar reflectance building materials and colors for windows, pavements, and coatings; and promoting landscaping on rooftops and around buildings for cooling. New York City's guidelines establish minimum targets of 50 percent of the non-building footprint for the use of landscaping, trees, and cool pavement to mitigate heat. Boston also specifies design of electrical and mechanical systems to accommodate future climate projections for extreme heat (*Climate Ready Boston*, 2019).

### 3. Findings: Local Regulations & Implementation

Climate resilience and adaptation is a relatively new frontier for counties and municipalities worldwide, as evidenced by the recency of most of the available literature and the limited number of implementation examples to point to. The City has been moving toward climate resilience for some time, and its policy direction is quite well established. Integration of resilience considerations into plans, regulations, and projects is also for the most part underway or being actively pursued. The establishment of the City CCSR, as well as Honolulu’s participation in the 100 Resilient Cities initiative, have done much to further this, as have State-led initiatives and legislation.

As this project focuses on providing guidance for private-sector development in urban areas, the literature review of local sources focused on reviewing existing regulations for building and site development against the national and international best practices’ recommendations contained in this memo. Due to the emergent nature of Honolulu’s planning and regulatory frameworks for resilience, the research for this portion of the project was supplemented through a combination of review of existing documents and codes and individual coordination with agency representatives and stakeholders. In-person coordination took place via an initial meeting with representatives from eight City agencies in September 2019, followed by interviews and correspondence with key agency staff and stakeholders engaged in resilience during October and November 2019. They are listed in the table below, followed by a summary of findings for each category of best practices identified in the previous section.

City Agency Coordination Meeting	Stakeholder Interviews & Correspondence
<p><b>DPP-TOD:</b> Harrison Rue, Andrew Tang, Tim Streitz, Rae Ferraiuolo</p> <p><b>DPP:</b> Tim Hiu, Weston Wataru, Laura Mo, Christina Keller, Katherine Hernandez, Janet Meinke-Lau</p> <p><b>Department of Facility Maintenance (DFM):</b> Ross Sasamura</p> <p><b>Department of Design &amp; Construction:</b> Tim Trang, Walter Billingsley</p> <p><b>CCSR:</b> Matthew Gonser</p> <p><b>Department of Environmental Services:</b> Jack Pobuk, Lisa Kimura</p> <p><b>Board of Water Supply:</b> Barry Usagawa</p> <p><b>Department of Land Management:</b> Sandy Pfund</p>	<p><b>DFM:</b> Randall Wakumoto</p> <p><b>DPP:</b> Tim Hiu, Katia Balassiano, Mario Siu-Li, Dawn Kimura</p> <p><b>U.H. Sea Grant:</b> Wendy Meguro</p> <p><b>Roth Ecological:</b> Lauren Roth Venu</p> <p><b>AIA Resiliency Committee:</b> Hale Takazawa</p>

### ***Identifying Hazards and Establishing Climate Projections***

Several State and City studies have contributed to establishing a shared understanding of the hazards related to climate change. The City Climate Change Commission developed both a *Climate Change Brief* and *Sea Level Rise Guidance* in June of 2018 that identifies local, regional, and global impacts of climate change.

In order to project the location and severity of climate change impacts, the State undertook the *Sea Level Rise Vulnerability and Adaptation Report* (2017) and developed an online interactive viewer to demonstrate where and how SLR impacts may occur. Both the report and viewer utilized modeling of combined impacts from passive flooding due to SLR, annual high wave flooding, and coastal erosion to identify SLR Exposure Area (SLR-XA) across the state. Separate studies of groundwater inundation have added to the overall picture of potential impacts (Rotzoll and Fletcher 2013, Habel 2019). An acknowledged gap remains in understanding how and where overland and riverine flooding will interact with SLR, groundwater inundation, and tidal flooding into the future, and this remains an area for further study.

The City *Multi-Hazard Mitigation Plan* (2019) also identifies hazards that the City may be subject to and establishes goals and priority hazard mitigation projects. The 2019 update for the first time includes a dedicated chapter on the effects of climate change, including SLR and increased frequency and severity of cyclones and other disasters.

These studies have provided the City with a basis to establish policy and move forward with developing plans and guidelines for climate adaptation. In July 2018, Mayor Kirk Caldwell issued a directive instructing all City departments, agencies, and their consultants to consider climate change and SLR in all City plans, programs, and capital improvement projects, and to apply planning benchmarks assuming there will be 3.2 to 6 feet of SLR by the end of this century (Directive 18-2). The Directive also includes guidance to factor SLR into regulations for coastal development, including the Shoreline Setback Ordinance (Revised Ordinances of Honolulu [ROH] Chapter 23) and Special Management Area (ROH Chapter 25).



**Mayor Kirk Caldwell issues Directive 18-2 in 2018.**

(Source: [www.kitv.com/story/38658820/mayor-caldwell-issues-directives-to-take-action-against-climate-change](http://www.kitv.com/story/38658820/mayor-caldwell-issues-directives-to-take-action-against-climate-change))

Additional efforts are underway to provide guidance for utilizing the SLR-XA and SLR viewer in State and City/County planning efforts. There are no known efforts at this stage to move toward risk-based criteria for selecting climate projections; however, the Mayor's Directive provides a range of SLR (3.2 to 6 feet) that can be used to inform risk-

based decision-making for individual projects. Most projects touch multiple agencies and jurisdictions, and inter-agency coordination would benefit from adoption of consistent climate projections and benchmarks.

### ***Developing Climate Adaptation Strategies***

The City CCSR is leading the effort to develop climate adaptation strategies for the City. The *City O'ahu Resilience Strategy* (2019) included an action calling for the preparation of an O'ahu Climate Adaptation Strategy (Action 28). Preparation of the O'ahu Climate Adaptation Strategy is expected to include policy guidance and a recommended framework for approaching adaptation islandwide; however specific regional or neighborhood-scale adaptation actions need to continue to be developed at the area community, special district, and departmental functional plan levels.

Some regional planning and policy development for climate adaptation has taken place on O'ahu and in other counties, such as Maui and Kaua'i, through their regional Community Plan (CP) and Development Plan (DP) processes. The Honolulu Primary Urban Center DP, West Kaua'i CP, and West Maui CP all incorporate policies that will directly impact future coastal development. County General Plans (GP) that have recently been updated (County of Kaua'i) or are underway (the City, County of Hawai'i) are also incorporating policies related to climate adaptation. GPs and CPs can lay important policy groundwork for climate adaptation and have the advantage of extensive stakeholder involvement. However, to fully vet and weigh the costs and benefits of specific adaptation options, such as where to protect, accommodate, or retreat, additional technical studies will need to be funded and commissioned.

Similarly, some neighborhood-level planning efforts have taken place to consider possible alternate scenarios for climate adaptation. This included a workshop by the DPP-TOD with assistance from SSFM and Arcadis in 2018. The workshop resulted in the development of several possible adaptation options for the Iwilei-Kapālama neighborhood at a conceptual level. Additional study will be needed in order to vet these concepts further for cost, feasibility, and other factors.

The adaptive planning approach described earlier in this document has already gained some traction and is a best practice that the City could utilize in the development of a climate adaptation strategy for O'ahu. As part of the State TOD Planning and Implementation project for the island of O'ahu, Arup prepared a demonstration study that applied its flexible adaptation pathways approach to the Iwilei-Kapālama area in a manner that could be reasonably transferrable to other TOD areas on O'ahu and other islands.

## Stormwater Management

Stormwater management regulations and guidelines for private development in the City are found in two primary sources:

- The City *Rules Related to Water Quality* (amended 9/17/18, effective 12/24/18), or Water Quality Rules (WQR) (Administrative Rules Title 20 Chapter 3), establish requirements for regulated projects and activities both during and after construction.
- The City *Storm Water BMP Guide for New and Redevelopment* (2017) provides planning and design guidelines to support implementation of the WQR. It includes minimum design and technical criteria for the analysis and design of storm drainage facilities and water quality, as well as guidance for stormwater quality during the planning phase and operations and maintenance guidance.

With regard to identified national and international best practices, the City is steadily moving in the direction of promoting infiltration, on-site retention, and water reuse. The 2018 update of the WQR specifies that regulated new development and redevelopment projects (including “priority uses” as well as projects >1 acre) include Low Impact Development (LID) Site Design Strategies, Source Control BMPs (best management practices), and Post-Construction Treatment Control BMPs to reduce the pollution associated with stormwater runoff. An internal plan review checklist is under development to assist with permit review for compliance with these guidelines. Green infrastructure and LID is also encouraged in guidance and neighborhood plans for TOD areas (see the *TOD Special District Design Guidelines*, *Greening Iwilei and Kapālama*, and specific Neighborhood TOD Plans for details).

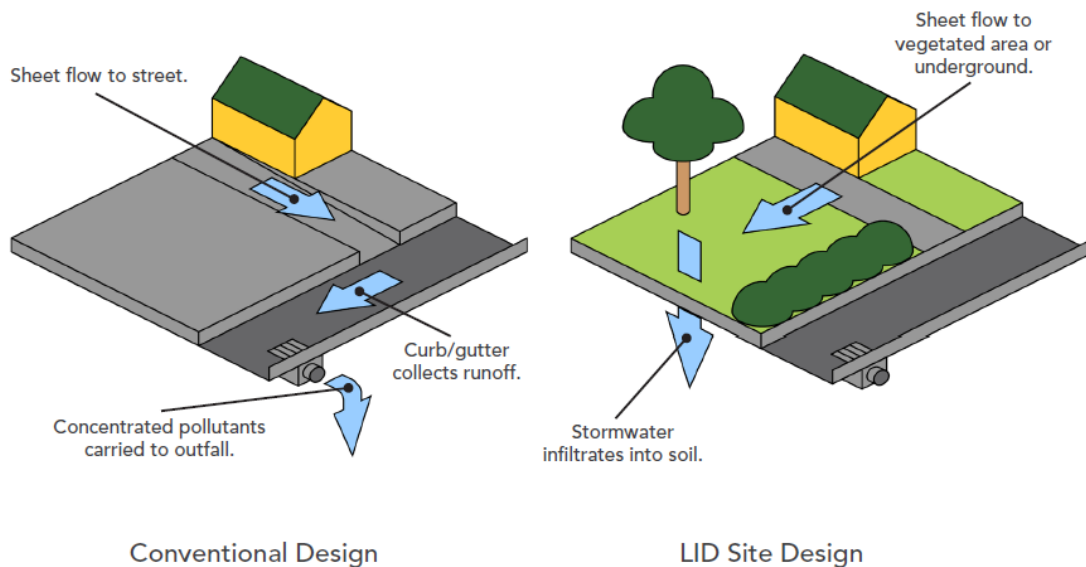


Green infrastructure concepts from *Greening Iwilei and Kapālama* (2018).

(Source: [www.honolulu.gov/rep/site/dfm/Post\\_Construction\\_WQR\\_July\\_2019\\_booklet.pdf](http://www.honolulu.gov/rep/site/dfm/Post_Construction_WQR_July_2019_booklet.pdf))

Updates are also currently underway for the *Storm Water BMP Guide for New and Redevelopment* to provide an appendix with more detailed specifications and guidelines for LID features, including infiltration basins and trenches, vegetated bioretention basins, permeable pavement and pavers, and vegetated swales, biofilters, and buffer

strips. In addition, currently proposed updates to the Plumbing Code would allow more applications for water reuse in residential and commercial properties.



**Low impact development guidance from the City's Post-Construction Water Quality Requirements (2019).**

(Source: [www.honolulu.gov/rep/site/dfm/Post\\_Construction\\_WQR\\_July\\_2019\\_booklet.pdf](http://www.honolulu.gov/rep/site/dfm/Post_Construction_WQR_July_2019_booklet.pdf))

The primary limitation to existing stormwater regulations is that they only require developments to provide infiltration/retention for one inch of rainfall (85 percent rainfall event). This may not be adequate to accommodate future climate projections for rainfall and runoff. In addition, there are no regulations that require on-site retention/detention for flooding or larger rainfall events, and there is no guidance or specifications for elements such as floodable parks, plazas, and parking areas. The City can encourage such features as part of the review and approval of discretionary permits (e.g., Planned Development, Special District, or Special Management Area), but they are not represented in the regulations.

While there are landscaping requirements in the Land Use Ordinance (LUO) for almost all new development projects (e.g., for required yards or surface parking lots), there are few regulations that limit or disincentivize the use of impervious surfaces. However, as of 2018, the LUO now requires large detached dwellings to have landscaped side and rear yards, not impervious or paved surfaces. As part of the 2012 International Building Code (IBC) update, impervious surface area is capped at 75 percent of the total zoning lot area for construction of a one- or two-family detached dwelling or duplex. In addition, the City is actively pursuing the formation of a stormwater utility, which would impose fees for impervious area and further incentivize the use of green infrastructure and LID solutions in new and redevelopment.

### ***Sea Level Rise and Flood Protection***

The City's Flood Hazard Ordinance (ROH Chapter 21A) regulates development in flood hazard zones. The designation of flood hazard zones and base flood elevation (BFE) is based on FEMA's Flood Insurance Rate Maps (FIRM). Currently, the FIRM does not account for projected SLR in determining flood hazards and associated flood insurance rates. Additionally, large portions of O'ahu are mapped as Zone D, "area of undetermined risk," where no studies have been conducted. This further challenges risk comprehension and regulating for enhanced flood resilience.

The Flood Hazard Ordinance requires that the minimum platform level for all structures in the flood hazard zones and fringe areas (including basements) be situated at or above BFE. Anything below BFE (doors, equipment, elevators, etc.) is required to be flood-proofed and designed to structurally accommodate the base flood. See ROH Chapter 21A for specific details on the minimum requirements. While these requirements are consistent with the types of recommendations included in national and international best practices, they are based on a BFE that does not incorporate SLR or other climate change projections.

Several of the national and international best practices referenced herein refer to establishing a DFE that incorporates future SLR and flooding projections. The recently updated *Multi-Hazard Mitigation Plan* also recommends establishing DFEs that incorporate SLR, as well as adoption of a 500-year flood zone.

While there are no current plans to depart from the use of FIRM as the basis for establishing City's flood zones and BFE, there are changes to the Building Code that may effectively establish a DFE. The City recently adopted the 2012 IBC (Ordinance 20-7), which will require one foot of freeboard above current BFE in certain identified flood areas. While the current BFE is based on FIRM, and does not account for projected SLR, requiring additional freeboard is a step toward designing for rising sea levels and increased flooding. As the FIRM is updated, the Flood Hazard Ordinance will also need to be amended.

### ***Transitions between Buildings and ROW***

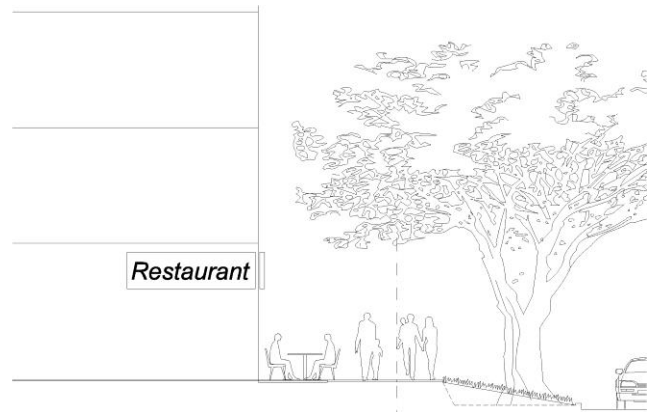
As buildings and/or adjacent streets are elevated to adapt to flooding and SLR, the design of the transition between buildings and the public ROW remains critical to maintaining a walkable, inviting urban environment and active streetscape. Most codes and regulations in Honolulu are silent on what this transition zone should look like, with or without the elevation of buildings. ROH Chapter 14 provides standard details for

public works construction and the design of anything that touches the ROW (e.g., curbs, sidewalks, driveways, etc.), but does not speak directly to the design of a transition zone.

Some plans and guidance documents, such as the *TOD Special Design District Guidelines*, Neighborhood TOD Plans, and the *Honolulu Complete Streets Design Manual*, provide examples and best practices for how to create the desired human-scale environment between buildings and the ROW. These guidelines can be used to review projects that require discretionary permit review (e.g., Planned Development, Special District, and Special Management Area). However, most do not include guidance for addressing significant differences in building and street elevations, which will become an increasing reality in the future.

In general, the direction that the City promotes in O'ahu's urban areas is consistent with the national and international literature in emphasizing active transition zones that provide public amenities as well as green infrastructure like trees, landscaping, and rain gardens. The U.S. Environmental Protection Agency study on *Greening Iwilei and Kapālama*, as well as a recent U.H. Sea Grant College Program study around the Waipahu rail station, provide location-specific examples to reference.

Changes to current codes and policies will need to be made to facilitate much of the design elements discussed here. If developers are asked to put landscaping in the ROW, and elevate the sidewalks to hug the building façade, they currently have to get a permit to do so. In addition, some of the LID and green infrastructure features that the City is promoting involve curbless transitions, which are not compatible with ROH Chapter 14.



**Diagram of desired streetscape transition along Kapiolani Boulevard (DPP-TOD, 2019)**

(Source: [www.honolulu.gov/rep/site/dfm/Post\\_Construction\\_WQR\\_July\\_2019\\_booklet.pdf](http://www.honolulu.gov/rep/site/dfm/Post_Construction_WQR_July_2019_booklet.pdf))



**Volunteer Citizen Foresters collect critical data on Honolulu's park and street trees and help build the City's urban forestry inventory for improved asset management.**

(Source: photo by Abbey Seitz)

### ***Mitigation for Extreme Heat***

Mitigating extreme heat from climate change is a concern that is notably absent from current codes and regulations in Honolulu. While many practices that mitigate heat and provide cooling are required or encouraged, they are mostly viewed through other lenses (e.g., cool roofs for energy efficiency, shade trees to promote a pleasant pedestrian environment, or for historic preservation of certain legacy trees and districts).

The City's adopted Energy Code includes standards for roof insulation and identifies options and specifications for cool roofs as part of building cooling systems. The City Energy Code also includes guidance on reflective glazing for windows. However, there are no codes that promote or require the use of lighter or more reflective materials for paving or other building coatings – or that discourage the use of black top for surface parking areas. Existing codes likewise do not require designing cooling systems for critical loads that reflect future extreme climate projections for heat.

With regard to providing shade and cooling through trees, landscaping, and other means, the *TOD Special District Design Guidelines* (per TOD Special District LUO Regulations) require trees where Street Tree Plans exist, and stipulate a variety of species that will create shade, or awnings where trees are not feasible. The *Honolulu Complete Streets Design Manual* likewise provides recommendations for street trees and landscaping.

Mayor Caldwell and the Honolulu City Council have committed to increasing urban tree canopy coverage to 35 percent by 2035. The City is currently preparing Street Tree Plans for the TOD neighborhoods to further this goal. However, none of the existing codes, including the LUO, presently require a minimum number or percent coverage of trees and landscaping in private development projects. Some of the special district guidelines have requirements for tree species selection and removal/replacement, although primarily for the purposes of maintaining the character of their district.

## 4. Conclusions

The literature review and agency/stakeholder interviews yielded a number of observations regarding the extent to which the City is implementing or moving toward adopting current best practices in resilient design:

- Climate projections are still evolving, but are established enough to provide a basis for setting policy and initiating integration of climate adaptation into planning and design.
- There is a need for State-City coordination on many projects; however, the State lacks an established planning benchmark or directive for SLR and resilience planning.
- Regional and neighborhood-level climate adaptation strategies are needed to inform where to protect and develop, where to accommodate, and where to retreat. These strategies will need to be developed through planning processes as well as engineering and feasibility studies and cost-benefit analyses, guided by an adaptive planning approach.
- Further analysis is needed to determine how to apply specific climate projections and risks to neighborhoods and districts in order to inform district-specific hazard zones, associated design guidelines, and comprehensive adaptive measures that each project (public and private) can contribute to.
- The baseline data and hazard designations that underpin current City stormwater management and flood hazard regulations should incorporate future projections of SLR and other climate-related hazards.
- The City is moving toward widespread adoption of resilient design features, such as green infrastructure, LID, water reuse, and cool roofs. These requirements may need to be expanded to require additional capacity for retention/detention during major rainfall and flood events, and to provide developers with a toolbox for innovative on-site detention and retention.
- Extreme heat is not currently recognized as a driver of building and site design, although there are many requirements that support the need for cooling.
- Requirements for trees, landscaping, and transition zones between the building and sidewalks need to be better formalized and reconciled with potentially conflicting codes.

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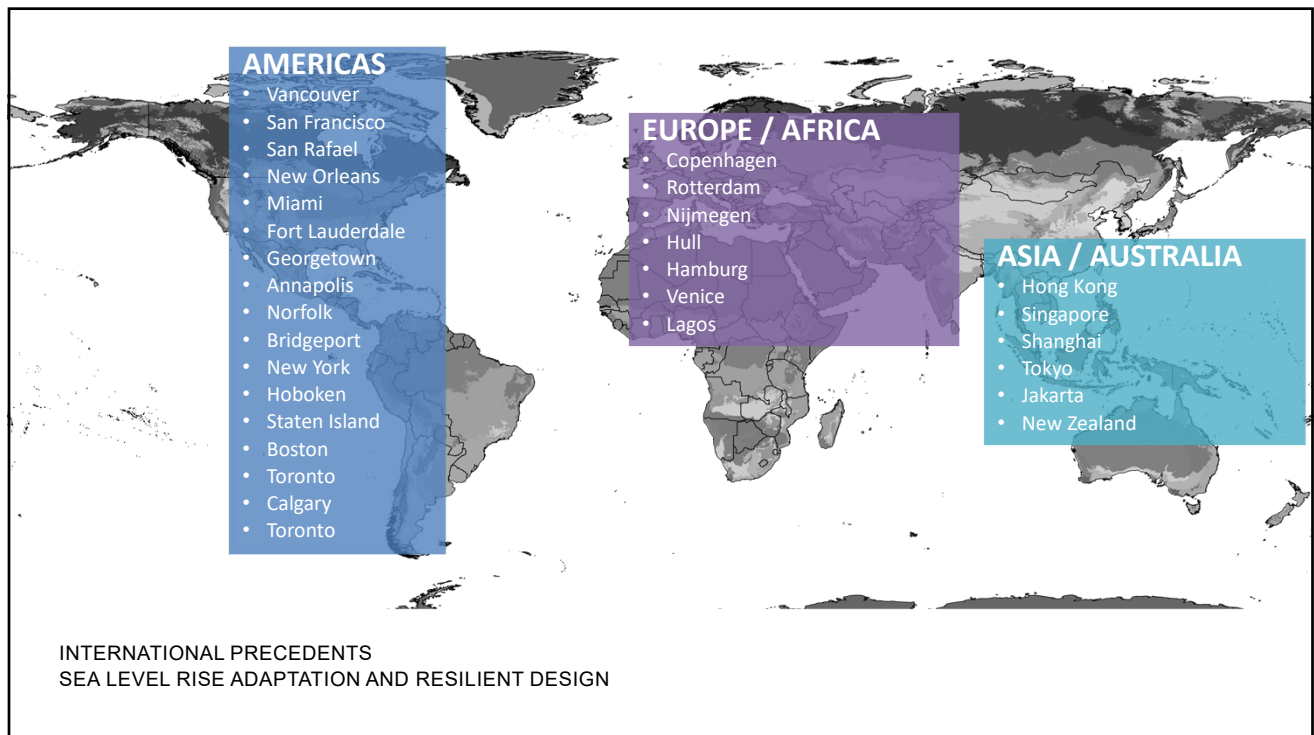
[www.abettercity.org/assets/images/Voluntary\\_Resilience\\_Standards.pdf](http://www.abettercity.org/assets/images/Voluntary_Resilience_Standards.pdf)

Waipahu Neighborhood TOD Plan. (2014). Available from:

[www.honolulu.gov/tod/neighborhood-tod-plans/dpp-tod-waipahu](http://www.honolulu.gov/tod/neighborhood-tod-plans/dpp-tod-waipahu)

West Kauai Community Plan: Departmental Draft. (2020). Available from:  
<https://westkauaiplan.konveio.com/west-kaua%CA%BBi-community-plan-departmental-draft>

West Maui Community Plan Update. (2019). Available from:  
<https://wearemaui.konveio.com/draft-west-maui-community-plan>

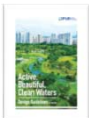


ASIA  
SINGAPORE  
SHANGHAI  
HONG KONG  
JINHUA CITY

SINGAPORE



[Code of Practice on  
Surface Water Drainage](#)



[ABC Waters Design  
Guidelines](#)



[Managing Urban Runoff  
Drainage Handbook](#)

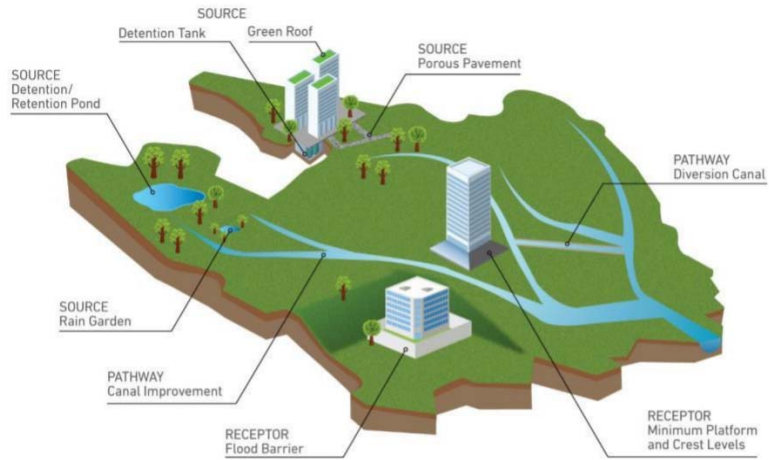


## SINGAPORE “SOURCE-PATHWAY-RECEPTOR”

Using a system-wide source-pathway-receptor approach, Singapore developed and implemented new drainage standards to decrease flood risk.

Measures are taken from the source where runoff is generated (e.g., through on-site detention), to the pathways through which runoff is conveyed (e.g., through widening and deepening drains and canals), as well as in areas where floodwaters may end up (e.g., through specifying platform levels to protect developments from floods).

This builds flexibility and adaptability into the drainage system to cope with increasing weather uncertainties and future climate change impacts.



## SINGAPORE “SOURCE”

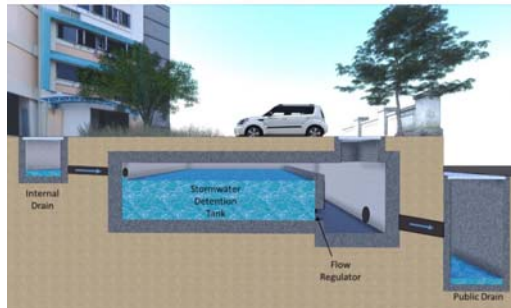
### Runoff Controls

Developments greater than 0.5 acres are required to control the peak runoff discharged from their sites.

The maximum allowable peak runoff to be discharged to the public drains is limited by codes of practice.

On-site storage is required for many new developments

- Raingardens
- Bioretention basins / swales
- Detention tanks



**SINGAPORE  
"RECEPTOR"**

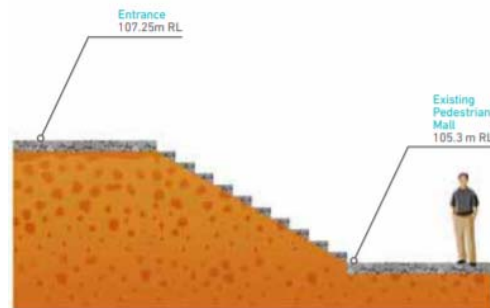
**Minimum Platform Level**  
(new developments)

- +0.6 m above adjacent road/ground
- or

- +0.6 m above the highest recorded flood level

**Minimum Crest Level**  
(entrances, exits, basements)

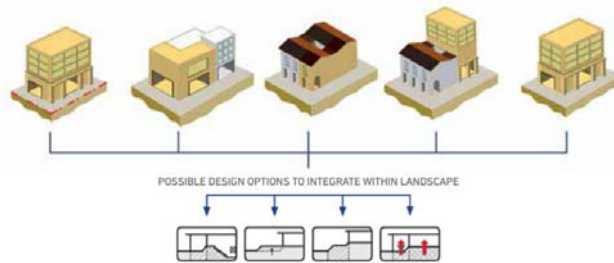
- +0.3 m above platform level



**SINGAPORE  
"RECEPTOR"**

Design options for different building types to meet minimum platform and crest levels

- Sloped urban parks
- Staircases and ramps
- Flood barriers



## HONG KONG SPONGE CITY

In addition to building code updates, Hong Kong has adopted the concept of the "Sponge City"

Sponge City is a modern stormwater management approach which allows the city to collect rainwater and use the stored rainwater when needed.



[https://www.dsd.gov.hk/Documents/SustainabilityReports/1617/en/sponge\\_city.html](https://www.dsd.gov.hk/Documents/SustainabilityReports/1617/en/sponge_city.html)

## SHANGHAI SPONGE CITY

Sponge City is a modern stormwater management approach which allows the city to collect rainwater and use the stored rainwater when needed. The Sponge City initiative was launched in 2015 with 16 "model sponge cities", before being extended to 30, including Shanghai.

Replacing concrete pavement with wetlands, green rooftops and rain gardens means stormwater is absorbed back into the land, making water work for the city instead of against it.

In the Lingang district, pavements are lined with trees, gardens and public squares full of plant beds. Between cranes and construction sites, plans display new buildings enveloped in the green and blue of parks, streams, and water features.



Shanghai's "Sponge City" ecosystem in the Lingang District opened in Summer 2019

## EUROPE COPENHAGEN ROTTERDAM HAMBURG

### COPENHAGEN CLOUDBURST

Copenhagen has deployed its "Cloudburst Formula", focused on integrating Blue-Green stormwater management approaches which also strengthen placemaking and the urban experience. An integrated planning approach is applied to ensure the connection to planning and urban development is maintained.

Extreme rainfall more than 15mm in 30 minutes

Target water levels exceeding ground level by 10 cm once every 100 years

Storage and separation (sewer and stormwater)



[https://en.klimatilpasning.dk/media/665626/cph - cloudburst management plan.pdf](https://en.klimatilpasning.dk/media/665626/cph_-_cloudburst_management_plan.pdf)

## BENTHEMPLEIN WATER PLAZA, ROTTERDAM

A water square retains rainwater and serves as a repository for rainfall-runoff.

A water square also doubles as an urban public space – the lowered areas can be repurposed for sports and recreational use during dry weather.

The Bentheemplein example offers room for basketball, skateboarding and performance arts

The Bentheemplein holds up to 1.7 million litres of water during rainfall. The water is infiltrated into the soil beneath the pavement or pumped out to canals elsewhere in the city.



## HAMBURG ELEVATED PROMENADES

HafenCity is partially protected against storm surges and rising seas.

Old buildings have been raised; new buildings adhere to flood-resilient design standards.

The city built the roads and open public spaces on terraces more than 25 feet above normal high tide.

Developers were permitted to build at this level, but were required to waterproof the structures all the way up to, and have entrances at, the higher street level.



<https://www.smartcitiesdive.com/ex/sustainablecitiescollective/hamburgs-ambitious-green-network-addresses-nature-climate-resilience-sustainable/213946/>

## HAMBURG PROMENADE + PLINTH

A promenade in the HafenCity district is designed to withstand flooding.

All new buildings stand on artificial bases eight meters above sea level - safe for the most extreme flooding.

Ground floor windows designed to withstand high water pressures and steel bulkheads have to prevent eventual damage on the glass.

Residential uses are not allowed on ground floors, so they are used for car parks, restaurants and offices.

Blocks have different access levels.

There are also escape routes on different heights for evacuation.

[https://e360.yale.edu/features/a\\_tale\\_of\\_two\\_northern\\_european\\_cities\\_meeting\\_the\\_challenge\\_of\\_sea\\_level\\_rise](https://e360.yale.edu/features/a_tale_of_two_northern_european_cities_meeting_the_challenge_of_sea_level_rise)

<https://www.smartcitiesdive.com/ex/sustainablecitiescollective/hamburgs-ambitious-green-network-addresses-nature-climate-resilience-sustainable/213946/>



UNITED STATES  
NEW YORK CITY  
BOSTON  
MIAMI BEACH  
SAN FRANCISCO

## NEW YORK THE BIG U

The "BIG U" is a proposal by BIG Architects in NYC through Rebuild by Design to protect lower Manhattan from floodwater, storms, and other impacts from climate change

New York City agencies are working to implement sections of the BIG U, including sections along the East River and Battery Park City



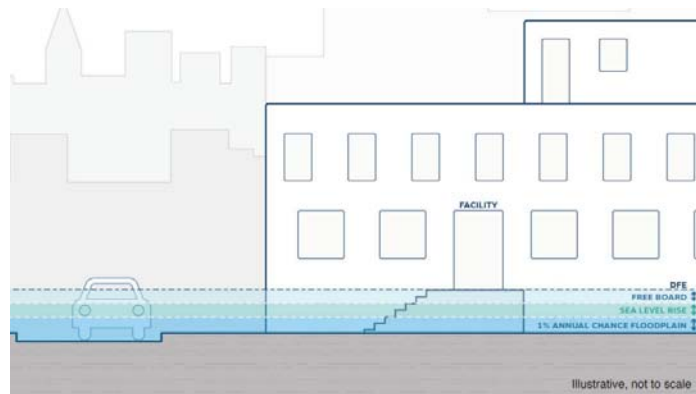
The BIG U – Bjarke Ingels Group

## NEW YORK RETROFITS & FREEBOARD

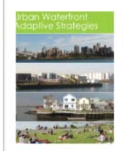
Multi-family and commercial buildings require 100-year + 12"

Critical facilities require 100-year + 24" + (6" to 36") depends on lifecycle

Non-critical facilities require 100-year + 12" + (6" to 36") depends on lifecycle



[Urban Waterfront Adaptive Strategies](#)



[Retrofitting Buildings for Flood Risk](#)



[Street Design Manual](#)



[Climate Resiliency Design Guidelines](#)



[Shaping the Sidewalk Experience](#)



## MIAMI BEACH STREET & BUILDING RAISING

The City of Miami Beach is currently exploring ways to make existing buildings and adjacent infrastructure more resilient

Many properties fall within an historic district

Working on resilient building design guidelines and updates to zoning code to allow for raising of buildings

Raising buildings provides challenges related to transitions from street to sidewalk to building

### Sunset Harbour elevated

Purdy Avenue is raised about 2 1/2 feet at 18th and 20th streets. The higher roadway means people have to take steps down to the sidewalk and front doors of businesses.

Water main Sanitary sewer Power and telecom

Soil

Sidewalk Elevated street Lower sidewalk

Area detailed  
Miami Beach  
1/2 mile

Biscayne Bay

Source: City of Miami Beach

200 ft.

20th St.  
Purdy Ave.  
Bay Rd.  
Publix  
West Ave.  
Miami Beach  
20th St.  
Alton Rd.  
Michigan Ave.  
Miami Beach Golf Club  
Dade Blvd.

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<https://www.miamiherald.com/news/local/community/miami-dade/miami-beach/article115264938.html>