University of Hawai‘i Sea Grant College Program

WAIKĪKĪ RESILIENCE & SLR ADAPTATION PROJECT

RESILIENCE AND ADAPTATION PLANNING PRECEDENTS, POLICY AND PRODUCTS

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INTRODUCTION

The University of Hawai'i Sea Grant College Program (Hawai'i Sea Grant) prepared this *Waikīkī Resilience and SLR Adaptation Precedents* report focusing on the Waikīkī Special District. This section examines adaptation pathways, and precedents in other locations as case study adaptation examples with a focus on long-range adaptation planning and implementation as a basis for future state-level adaptation planning for the Waikīkī watershed and special district. This report is a complementary section to the Waikīkī Resilience and Sea Level Rise Adaptation Project (WRAP). The goal of the WRAP is to develop a framework and lay the groundwork for a future Waikīkī adaptation and resilience plan that addresses the projected impacts of climate change and sea level rise in the Waikīkī Special District and beyond.

Climate adaptation is based on adjusting to and compensating for the impacts of climate change. There are a wide variety of strategies for a comprehensive adaptation program of which accommodation strategies serve as important options for adapting in-place. Adaptation can be facilitated by developing conceptual adaptation pathways which serve as planning frameworks that consider the uncertainty of climate change scenarios and provide a prescribed action in response to actual or predicted changes. Accommodation is a critical component of a comprehensive climate adaptation strategy addressing the impacts of climate change and other natural hazards.

Climate change accommodation strategies and design interventions seek to minimize the impacts of coastal hazards and climate change, including flooding and sea-level rise. Accommodation is centered on adapting infrastructure and the built environment to changing environmental conditions place. Accommodation strategies may be utilized for a specific timeframe or based on predicted future conditions and can be a method of phasing in other adaptation options over time based on identified triggers and thresholds. Site-specific design interventions such as flood-proofing and elevation enhance resilience

by addressing the key components of vulnerability and strive to ensure resilience and longevity of coastal communities. Redesigning vulnerable urban areas by retrofitting and upgrading infrastructure along with proactive planning of urban infrastructure can provide an opportunity to build an inclusive process that utilizes local knowledge on social policy, community values and priorities and community-based adaptation strategies.[1]

Accommodation strategies focus on modifying existing systems and infrastructure to withstand new conditions rather than completely transforming or relocating them. Accommodation involves making adjustments to infrastructure, development and societal, economic and environmental practices to live with the changes and challenges posed by climate change. Accommodation works alongside other adaptation strategies, such as resistance/protection, nature-based options and retreat among others (see adaptation strategies below and Figure 1)**.**

Adaptation Strategies

1. ***Resistance: Protection/armoring-*** Hard, engineered, systems designed to defend, armor and stabilize the shoreline and infrastructure in their current location.
2. ***Nature-based and living shorelines-*** Soft "blue-green infrastructure" that relies on ecosystem services, increases the distance between water and development, retains and absorbs inundation, attenuates waves, slows erosion and provides habitat.
3. ***Accommodation: Elevated development-*** Raising the height of land, infrastructure, buildings and other resources for existing or new development over time using fill and/or pilings.

[1] IPCC, (2022). Pörtner, H., et al. *IPCC Sixth Assessment Report. Working Group II –Impacts, Adaptation and Vulnerability*. Summary for Policymakers. *Cambridge University Press*, Cambridge, UK and New York, NY, USA, pp. 20–27, DOI:10.1017/9781009325844.001. Accessed: 5/10/24 https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

4. ***Accommodation: Floodable development-*** Structures and landscapes designed to withstand inundation with habitable space, critical assets and vulnerable infrastructure on upper levels or at higher elevations and can accommodate flooding.
5. ***Accommodation: Floating development-*** Floating buildings, transportation elements and infrastructure designed to accommodate fluctuating water levels.
6. ***Managed Retreat (Relocation)-*** Long-term relocation or removal of existing buildings, infrastructure and resources out of hazard areas to higher elevations and limited construction of new development in vulnerable areas.

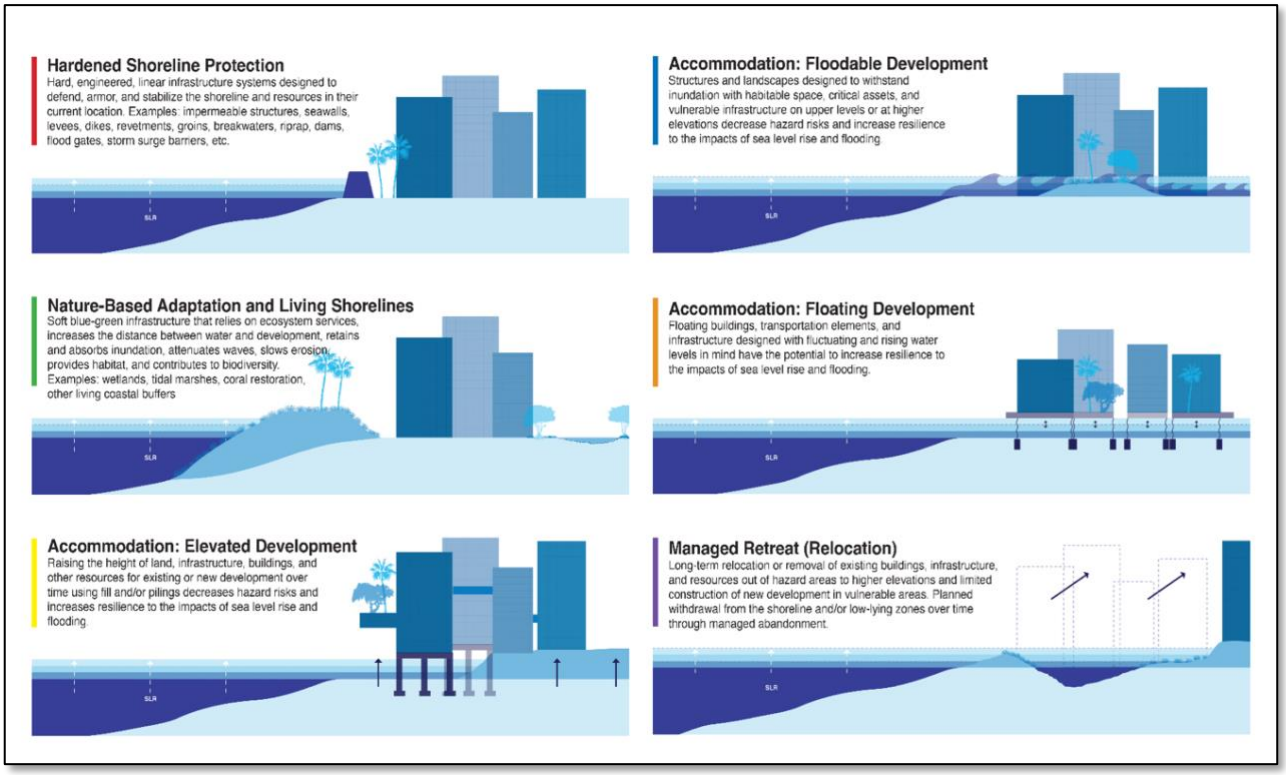
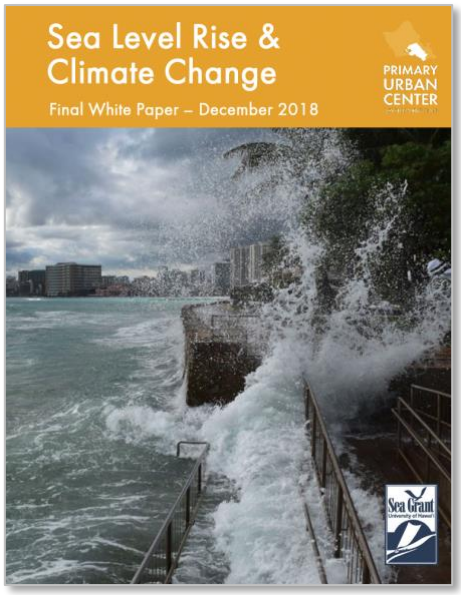


Figure 1. Coastal Adaptation Strategies. Credit: UHCDC.

Adaptation Examples in Honolulu

Primary Urban Center Development Plan



The *Proposed Primary Urban Center Development Plan (PUCDP)* is in the process of being formally adopted and has been transmitted by the Planning Commission to the City Council for final decision making and was recently (April, 2024) introduced as Bill 24-24. The chapter on Sea Level Rise + Coastal Hazards Planning includes recommendations for Waikīkī and its context. The Primary Urban Center White Paper Report on Climate Change and Sea level Rise outlines primary adaptation themes in support of the adaptation strategies presented in the report.[2] These adaptation themes are presented as key approaches for the implementation of the adaptation strategies into the PUC General Development Plan, which includes Waikīkī as a way to facilitate consideration of climate impacts into City plans, policies and programs. These strategies are consistent with the recommendations presented in this report and are similar with regional examples shared through this chapter. These and many other adaptation strategies may also play an important role in Waikīkī as resilience and adaptation plans are eventually developed for the area. Selected adaptation takeaways from the PUCDP include:

1. Consider 3.2 feet of sea level rise (3.2 SLR-XA) for all planning decisions
2. Use 6 feet of sea level rise for planning decisions with especially long lifespans or low risk tolerance.
3. Support resilience actions that provide multiple benefits and longer planning horizons.

[2] (PUC, 2018). *Sea Level Rise & Climate Change. Final White Paper. Honolulu Primary Urban Center Development Plan*. City and County of Honolulu. December, 2018. https://www.honolulu.gov/rep/site/dpptod/dpptod_docs2/Sea_Level_Rise_Final_White_Paper.pdf

Adapt Waikīkī 2050

Climate Risk Profiles have been developed as part of the City and County of Honolulu's (City) *Adapt Waikīkī 2050* project. The *Adapt Waikīkī 2050* project strives to develop a shorter-term (~30 year) climate adaptation plan for the Waikīkī Special District with a focus on City plans, policies and infrastructure.[3] Due to the long-term risk uncertainties, the *Adapt Waikīkī 2050* project also includes adaptation strategies for new development as part of long-term climate risk thresholds (years 2050-2100) as detailed in the summary recommendations framework (Courtney, et al, 2024. Table 9. Pg 69).

The long-term adaptation recommendations for Waikīkī include:

- Identify long-term adaptation strategies including protection/elevation, managed retreat, accommodation and ecosystem preservation/restoration.
- Provide general recommendations for an adapt-in-place scenario.
- Consider using Climate Thresholds and the Relative Flood Risk Index to establish long-term planning benchmarks.[4]

The *Adapt Waikīkī 2050* details the natural hazard and climate risk exposure of Waikīkī and provides valuable climate and flood risk thresholds that can be especially helpful for development of triggers and thresholds for accommodation actions. The project is being led by the City and County of Honolulu Department of Planning and Permitting. Together, the *WRAP* and *Adapt Waikīkī* projects form a shared understanding for risks in Waikīkī and provide a foundational component of the Natural Hazards Assessment of the Waikīkī Resilience and Adaptation Project.

[3] Courtney, C., G. Orozco and N. Cole. 2024. *Adapt Waikīkī 2050: Climate Risk Profile for the Waikīkī Special District*. Prepared by Tetra Tech, Inc. and the City and County of Honolulu Department of Planning and Permitting under Contract No. CT-DPP-2300252. https://ssfm.konveio.com/adapt-Waikīkī-factsheet

[4] This approach (using risk thresholds) is consistent with the recommendations from the IPCC, 2022 and Sweet (NOAA), 2017 and 2022 reports (see references above).

ADAPTATION PATHWAYS

Adaptation pathways are conceptual planning approaches that consider the uncertainty of climate change scenarios and provide a prescribed action in response to actual or predicted changes. Adaptation pathways determine when adaptation actions are implemented based on predefined benchmarks or thresholds. Adaptation triggers may include both frequency and/or intensity of: sea level rise and water level thresholds, erosion impacts, beach widths, coastal flooding frequency and infrastructure damage. The development of adaptation pathways and triggers is an important opportunity for stakeholder involvement in providing a shared vision on values and priorities of the community. Phased implementation of specific adaptation strategies over defined timeframes have been suggested as a way to implement adaptive change of the coast over time for the North Shore of Oahu.[5] Incorporating community outreach around adaptation pathways provides an opportunity for community input on the development of a long-term vision of the coast, with a deeper understanding of the tradeoffs of different adaptation approaches and phased implementation priorities which can lead to critically important partnerships for long-term community support.

Adaptation pathways provide coastal stakeholders and managers with a clear understanding of options for addressing complex coastal land use and long-term planning decisions. Adaptation pathways involve the development of flexible, long-term plans that consider multiple potential future scenarios of climate change and their associated impacts, often using a multi-hazard risk framework. Adaptation pathways emphasize integrated approaches that address the complexity and uncertainty of climate change and may provide triggers and thresholds for responsive action. These triggers typically involve a series of iterative steps or phases, allowing for adjustments and refinements over time as new information becomes available or as conditions change (Figure 2).

[5] *North Shore Coastal Resilience Working Group Adaptive Coastal Management Recommendations, Actions and Strategies*. October, 2021. Surfrider Foundation, Surfrider's O'ahu Chapter, Hawai'i Sea Grant and SSFM International. https://20811975.fs1.hubspotusercontent-na1.net/hubfs/20811975/web-North-Shore-Coastal-Erosion-Report_102122_Web.pdf

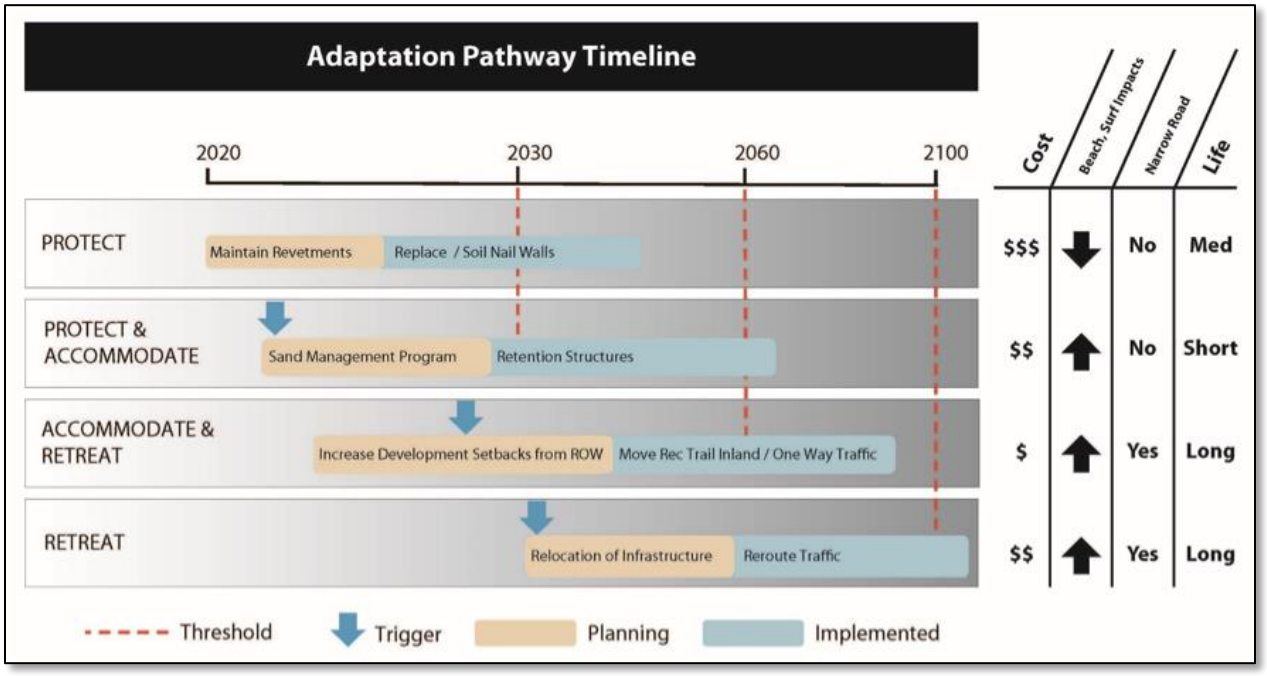


Figure 2. Adaptation pathways and impacts for climate adaptation for Santa Cruz, California. Credit: (David Revell, Integral Corp, 2021).

Together, adaptation pathways and the associated triggers for climate adaptation provide a framework for proactive planning and decision-making in the face of climate change. By considering climate change impacts and adaptation options holistically, these approaches may help enhance community resilience, sustainability and support long-term adaptation goals. Santa Cruz, California is an example of how city planners are utilizing adaptation pathways to identify and implement coastal management options over phased time frames, with robust community input.[6] See Section 9 *Preliminary Adaptation Implementation Roadmap* for more details on phased implementation and adaptation triggers for Waikīkī.

[6] City of Santa Cruz. 2019, November 6. *City of Santa Cruz Beach Vulnerability and Adaptation Strategy*. https://www.cityofsantacruz. com/home/showpublisheddocument/78991/637165009953900000

ACCOMODATION STRATEGIES

Living Shorelines

A wide range of adaptation and mitigation options are possible based on the site conditions, hazard exposure, community priorities and many other socio-economic, environmental and cultural factors. Adapt-in-place options present a spectrum of options ranging from softer measures such as living shorelines to hard armoring for protection of infrastructure. Living shorelines can be an important tool for managing coastal hazards, enhancing intertidal habitat for fish and marine resources and enhancing the resilience of coastal communities and ecosystems.[7] Figure 3 illustrates the continuum of project techniques along a green (natural materials only) to green/gray (hybrid) to gray (all built materials) scale (NOAA, 2022). For Waikīkī, living shorelines might be best-suited for the creation of back-shore estuary areas such as around the Ala Wai canal, Kapiolani park or other areas where ecosystem restoration is a priority.[8]

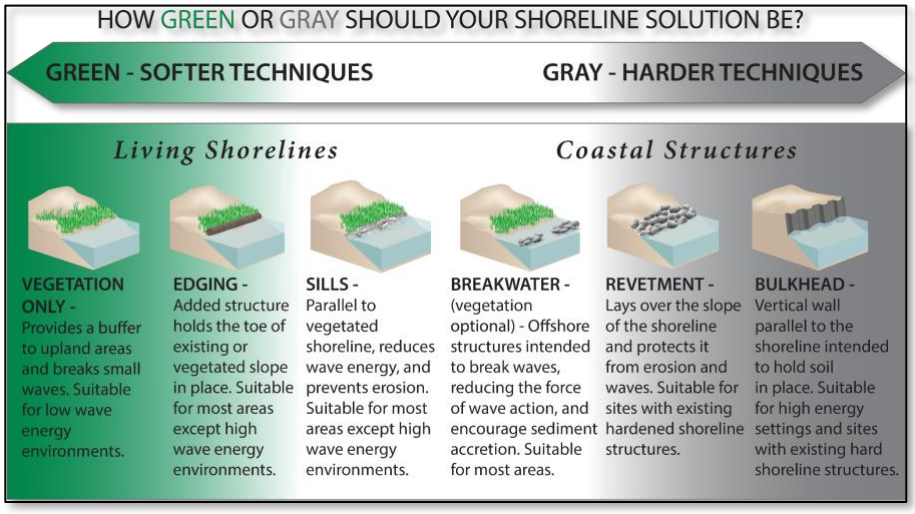


Figure 3. Natural shoreline stabilization options. (Credit: NOAA, 2022).

[7] *Guidance for Considering the Use of Living Shorelines.* 2015. NOAA Habitat Blueprint. https://www.habitatblueprint.noaa.gov/wp-content/uploads/2018/01/NOAA-Guidance-for-Considering-the-Use-of-Living-Shorelines_2015.pdf

[8] *South Shore Promenade and Open Space Network Study: Resilience and Connectivity by Design* (2020). https://www.uhcdc.manoa.hawaii.edu/work/south-shore-promenade

Avoidance

Climate accommodation strategies are, by design proactive, founded in hazard risk management and strive to increase the overall community resilience and sustainability to known or predicted hazard events. Avoidance strategies in the context of climate adaptation involve measures aimed at minimizing the need for accommodating or adjusting to the impacts of climate change by actively avoiding or reducing exposure to those impacts. Unlike traditional adaptation strategies, which often focus on accommodating or adapting to changing conditions, avoidance strategies aim to proactively mitigate risks and vulnerabilities to prevent or minimize adverse impacts. Avoidance strategies seek to proactively reduce exposure to climate risks and vulnerabilities, thereby minimizing the need for costly adaptation measures and enhancing overall resilience to climate change. Avoidance strategies are best-suited for new development and are more challenging to apply to a dense urban environment like Waikīkī.

Accommodation strategies are generally based in a *no regrets* approach and commonly include building-scale design interventions such as flood control, hazard zoning overlays, building codes related to hazards and resistant/resilient designs, elevated structural design, base/design flood elevations and rebuilding requirements.[9,10] Similarly, avoidance techniques are intended to avoid vulnerable development in hazard-prone areas may include coastal construction setbacks, zoning, building codes restrictions, managed retreat through transferable development rights, leasebacks, land swaps and rebuilding or relocation (PUC, 2018).[11] Avoidance strategies may be most applicable to

[9] City & County of Honolulu (C&C). (2020). *Climate Adaptation Design Principles for Urban Development.* SSFM International and Arup for the City Department of Planning and Permitting Transit-Oriented Development Division and the City Office of Climate Change, Sustainability and Resiliency. https://www.honolulu.gov/rep/site/dpptod/climate_docs/Climate_Adaptation_Design_Principles.pdf

[10] *Coastal Flood Resilience Design Guidelines* (CFRDG). (2019). Boston Planning and Development Agency. Accessed 9-10-21. http://www.bostonplans.org/getattachment/d1114318-1b95-487c-bc36-682f8594e8b2

[11] ORS. (2019). *O'ahu Resilience Strategy*. City and County of Honolulu, Office of Climate Change Sustainability and Resiliency. Accessed May, 4, 2024. https://www.honolulu.gov/rep/site/ccsr/Ola_Oahu_Resilience_Strategy.pdf

areas of Waikīkī that include older buildings as they are redeveloped as they reach the end of their design life.

Building-Scale Design Interventions

Urban planning and engineering designs that accommodate existing flood hazards and/or predicted sea-level rise at the parcel scale address coastal inundation and flooding vulnerability resulting in increased resilience for coastal communities. These type of parcel-scale design interventions for development and infrastructure can be distinguished from broader community and regional scale coastal adaptation landscape design techniques. The Federal Emergency Management Agency (FEMA) Coastal Construction Manual (2011),[12] defines the Base Flood and Design Flood Elevation as follows: The Base Flood Elevation (BFE) is the water surface elevation resulting from a flood that has a 1 percent chance of equaling or exceeding that level in any given year. This means a building with a 30-year mortgage has a 26% chance of being flooded during the life of the mortgage.[13] These risk estimates do not account for changes due to sea level rise. The Design Flood Elevation (DFE) is the locally adopted regulatory flood elevation. The DFE is a specified additional elevation (Freeboard) above to the BFE in order to mitigate anticipated impacts from design events like floods or sea level rise (Figure 4). The Design Flood Elevation is exemplified as an additional elevation requirement above the BFE for structural elements of a building. Design flood elevations and associated elevated foundation designs are an increasingly common form of accommodation and can often be administered through existing regulatory authorities for FEMA flood standards without initiating major new adaptation policies or rules at the municipal scale (FEMA, 2011).

[12] *FEMA Coastal Construction Manual.* (FEMA, 2011) Coastal Construction Manual Principles and Practices of Planning, Siting, Designing, Constructing and Maintaining Residential Buildings in Coastal Areas (Fourth Edition) FEMA P-55 / Volume I / August 2011.https://www.fema.gov/sites/default/files/2020-08/fema55_voli_combined.pdf

[13] https://emilms.fema.gov/is_0727/groups/33.html

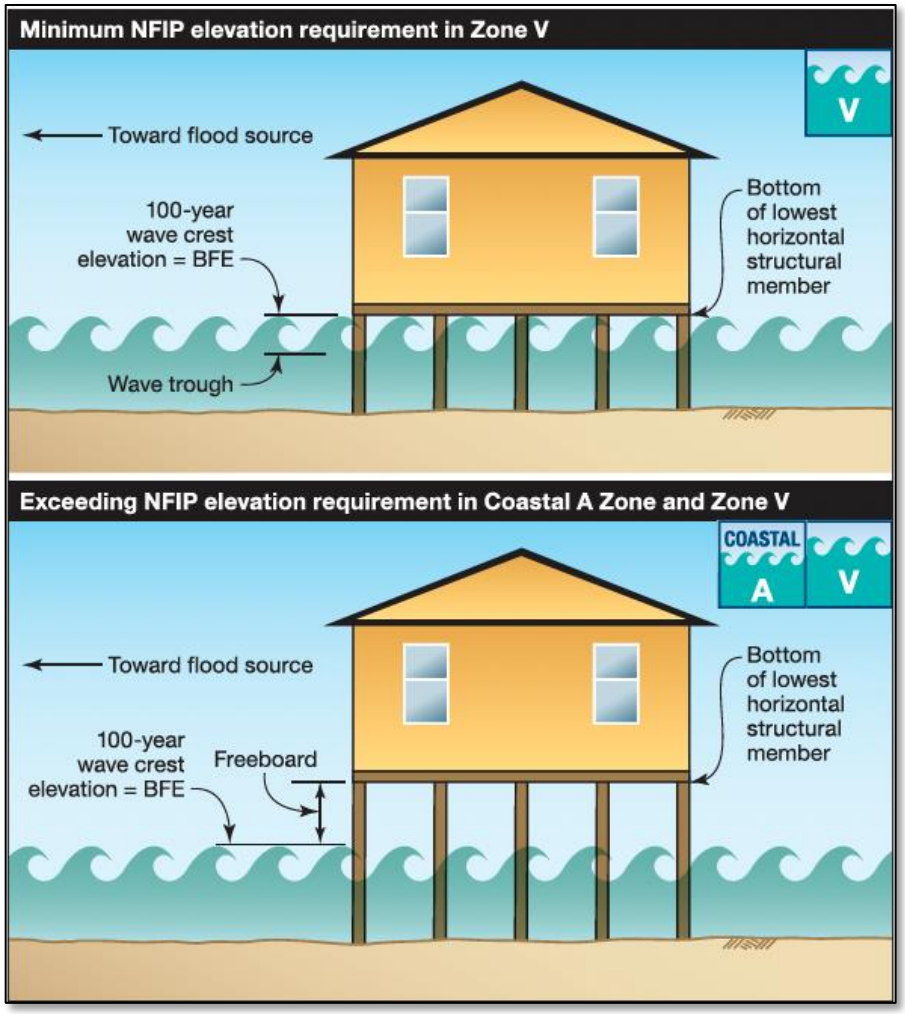


Figure 4. Conceptual illustration of the FEMA, BFE, elevation requirements for the V zone (above) and the additional buffer elevation (Freeboard-DFE) (below). Credit: FEMA, 2011

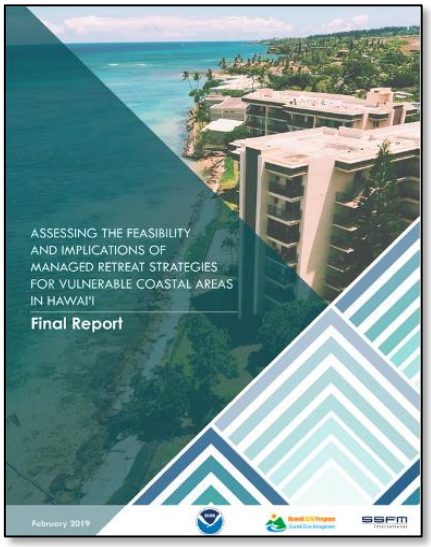
DFEs are but one suite of tools and techniques that can be utilized in order to achieve increased community resilience and as one form of climate adaptation. DFEs are commonly associated with the engineering and architectural fields having originated in the flood mitigation sector associated with the FEMA flood hazard elevations and flood insurance rate (FIRM) maps. DFEs may also incorporate other hazard avoidance principles such as the development design lifetime, risk tolerance and criticality in addition to the more traditional flood risk history and forecast future conditions. Incorporating freeboard into new construction is extremely cost effective. FEMA, (2008) evaluated the

total benefits for each additional foot of freeboard. This is represented in the total cost of damages avoided and the reduction in flood insurance premiums. In some cases, the total benefit to cost ratio can be as high as 18 times for the first foot of freeboard in the V-flood zone (FEMA, 2008).

The utilization of design lifetime is a common civil engineering protocol but is a relatively new urban planning tool that integrates emerging planning recommendations from government agencies to incorporate the risk tolerance of a development into the designs, specifically the DFE.[14,15] Many DFE standards and guidelines serve to provide exemplary adaptation strategies and are relatively easy to implement through existing flood ordinance and codes. Ultimately DFEs play an important role in serving to establish site-specific design criteria to anticipated future coastal inundation and flooding resulting in an early form of coastal adaptation to climate change. The DFE for a new or redeveloped building in Waikīkī could potentially have an expected design life of 50 or 70 years (putting the design lifetime roughly out to the year 2100). This could present design lifetime challenges for reconciling the design lifetime against anticipated future conditions such as sea level rise. Under these conditions, even if sea level rise is sufficiently accounted for in the DFE, there may be regional infrastructure challenges related to transportation and critical infrastructure for the continued operation of the development. These challenges require a comprehensive regional approach for accommodation so there is consistent, predictable and efficient adaptation of the community.

[14] Sweet, W.V., et al. (2017). *Global and regional sea level rise scenarios for the United States*, NOAA Technical Report NOS COOPS 083.
[15] FEMA. (2012). *Quick Reference Guide: Comparison of Select NFIP and Building Code Requirements for Special Flood Hazard Areas*. March 2012. https://www.fema.gov/media-library-data/20130726-1828-25045-8178/fema_quick_ref_guide_flood_areas_022713_508.pdf

MANAGED RETREAT



In 2019, the State of Hawai'i Coastal Zone Management Program conducted a study assessing the feasibility and implications of managed retreat strategies for vulnerable coastal areas in Hawai'i.[16] This document is the first report focused on research, planning and policies around adaptation and managed retreat. The CZM (2019) report recommended convening a "multi-prong statewide leadership committee" to "devise a comprehensive, cohesive managed retreat plan with identified implementable pilot projects at the end of its limited term." Key findings of the study include:

- Retreat is a complex problem that requires a combination of planning, policy, regulatory and financing tools, political will and community acceptance.
- The community must have some level of agreement, understanding and support for retreat. Retreat programs are more successful when they are voluntary.
- Retreat should be considered in context with other approaches and following a careful analysis of benefits and costs that address the stated program objectives.
- The area to be retreated to and from, should be determined locally.
- New laws will need to be adopted to implement and facilitate retreat. This may include increased shoreline setbacks, prohibitions and rebuilding restrictions and other land use and transfer incentives.

[16] (CZM, 2019). Hawai'i State Office of Planning, Coastal Zone Management Program. 2019, February. *Assessing the Feasibility and Implications of Managed Retreat Strategies for Vulnerable Coastal Areas in Hawai'i: Final Report*. https://files.hawaii.gov/dbedt/op/czm/ormp/assessing_the_feasibility_and_implications_of_managed_retreat_strategies_for_vulnerable_coastal_areas_inhawaii.pdf

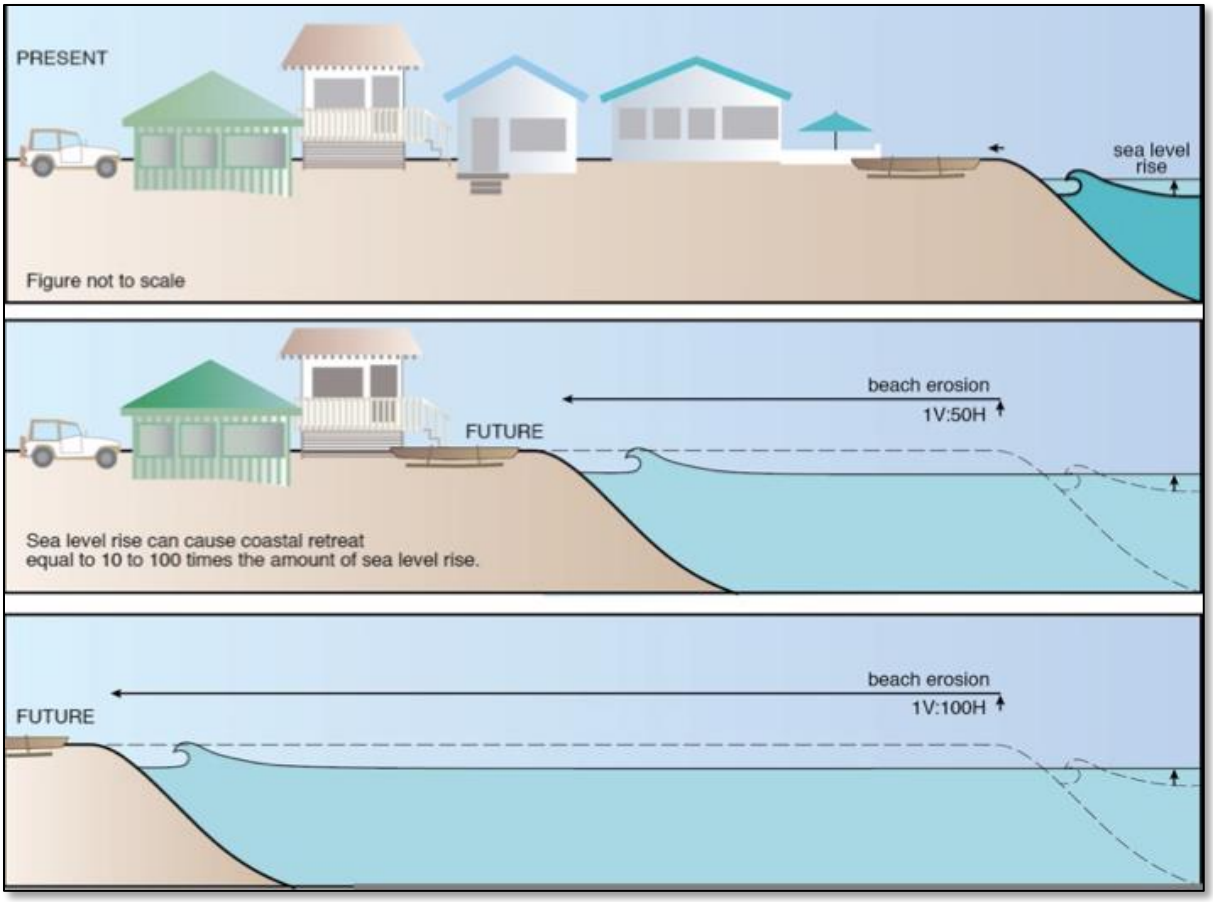


Figure 5. Conceptual illustration of planned (phased) retreat from the coast as sea-level rise progresses landward over time. Credit: Dr. Chip Fletcher, UH CRC.

Adaptation strategies are not mutually exclusive and instead offer a spectrum of options that are available and can be implemented over time by specific triggers and thresholds for action. Adaptation pathways can be considered in a phased or sequenced manner with predetermined actionable thresholds that result in implementation of the next adaptation measure. Reframing retreat from a reactive and temporary measure to a proactive and long-term strategy that encompasses broader societal transformations may facilitate long-term adaptation strategies (Figure 5).[17] Recent academic research on long-term adaptation emphasizes the need for integrating equity considerations, engaging communities and incorporating multiple dimensions of well-being in retreat planning.

[17] Mach, K. and Siders, A. R. (2021). *Reframing strategic, managed retreat for transformative climate adaptation*. *Science.* 372, 1294-1299. DOI: 10.1126/science.abh1894.

Mach, et al, (2021) propose a framework that combines climate science, policy and social dimensions to guide decision-making and implementation of strategic retreat. Serious consideration of retreat, even if subsequently rejected, can help communities articulate why remaining in place is a core value, what costs they are able to endure or what opportunities they can forgo to remain in place and what responses sustainably support individual and community priorities.[18]

Long-term adaptation planning often includes managed retreat as an later-stage option for adapting at-risk development. Practical modern application suggests retreat and relocation are more often a result of major disasters, as a form of "forced retreat" instead of a planned relocation due to pre-determined triggers. Refusing to consider managed retreat as an eventual possibility limits the options available and the range of possible outcomes (Mach et al, 2021). Academic research highlights the importance of transformative adaptation in the face of climate change and offers insights into how retreat can be reimagined as a tool for resilience and sustainability rather than a reactive response to natural disasters. There is an active and evolving discourse on climate adaptation strategies and the role of managed retreat, thus providing a roadmap for rethinking the role of retreat in addressing the challenges and uncertainties of a changing climate.

Adaptive planning for climate change is a proactive planning option that is being utilized in jurisdictions worldwide as a way to take action in the face of uncertainty. Most adaptation however is fragmented, small-scale and sector-specific, designed to respond to current impacts or near-term risks and focused more on planning rather than implementation.[19] Planning initiatives such as the Dutch Delta Works, 2019[20] and the

[18] M. Oppenheimer, et al. *Sea level rise and implications for low-lying islands, coasts and communities* in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, H.-O. Pörtner, et al. (Intergovernmental Panel on Climate Change, 2019), pp. 321–446; www.ipcc.ch/site/assets/uploads/sites/3/2019/11/08_SROCC_Ch04_FINAL.pdf.
[19] City & County of Honolulu (C&C, 2020). *Climate Adaptation Design Principles for Urban Development*. December, 2020. City and County of Honolulu Transit Oriented Development. https://www.honolulu.gov/rep/site/dpptod/climate_docs/Climate_Adaptation_Design_Principles.pdf
[20] https://www.water-technology.net/projects/delta-works-flood-netherlands/

Thames Estuary, 2012[21] are examples of high-level, top-down planning approaches being applied to address predicted sea level rise and associated flood hazards that rely on technical engineering approaches (C&C, 2020).

A combination of urban design interventions and landscape strategies, fine-tuned to the unique characteristics of each community is a type of accommodation strategy that may provide for hazard mitigation and result in short and mid-term resilience benefits.[22] The selected adaptation examples below illustrate the diversity of accommodation strategies available and may offer insight into the opportunities and challenges associated with adaptation in Waikīkī. Adapting a dense, urban resort district like Waikīkī presents unique challenges for sequencing projects, financing and integration into broader community plans and social equity considerations. Implementing in-place accommodation strategies such as the following design interventions combined with longer-term adaptation strategies like avoidance, managed retreat and ecosystem-based approaches will provide an opportunity to couple long-term coastal adaptation, community resilience and sustainability through site-specific adaptation efforts.

[21]https://engageenvironmentagency.uk.engagementhq.com/thames-estuary-2100-adaptation-pathway-project

[22] City & County of Honolulu Climate Change Commission (HCCC, 2022). *Updated Sea Level Rise Guidance* (July, 2022). https://static1.squarespace.com/static/5e3885654a153a6ef84e6c9c/t/62f46b3fff589f651af14410/1660185409937/HonoluluClimateChangeCommission-SeaLevelRiseGuidance_Updated-July2022.pdf

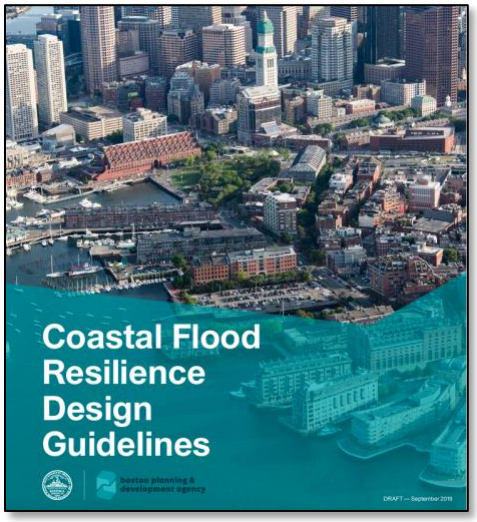
ADAPTATION PRECEDENTS

The most common design intervention strategy is to elevate the site or structure to protect against flooding (C&C, 2020; FEMA, 2011).[23,24,25,26] This strategy is extensively used around the world and in examples from Hamburg[27], Rotterdam[28] and Singapore.[29] There are also a wide variety of complementary flood mitigation design intervention techniques applied to the ground floor spaces with relevant examples from Hamburg and Singapore, Miami, Boston, New York and elsewhere (C&C, 2020). Ground-floor flood mitigation options can be generally categorized into two main types; dry flood-proofing and wet flood-proofing (Watersquare, 2018; Hawai'i Sea Grant, 2022). Elevation-based approaches are foundational as part of a comprehensive adaptation and accommodation plan for the built environment. Evaluation of building-level adaptation using a cost-benefit approach reveals an exponential increase in the estimated cost to mitigate SLR hazards by traditional adaptation techniques alone which may make traditional mitigation/protection strategies not cost effective in the long-term (CFRDG, 2019).[30]
Coastal adaptation design interventions and guidelines may be applied at the building-scale and in some cases, can required for new or major renovation projects that are

[23] *Coastal Flood Resilience Design Guidelines* (CFRDG). (2019) Boston Planning and Development Agency. Accessed 9-10-21. http://www.bostonplans.org/getattachment/d1114318-1b95-487c-bc36-682f8594e8b2
[24] New York City Mayor's Office of Recovery and Resiliency (NYORR). (September, 2020). *Climate Resiliency Design Guidelines, Version 4.0*
https://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v4-0.pdf
[25] (Miami, 2021). February, 2021. *Miami Dade County Sea-level Rise Strategy*. Miami Dade County.
https://miami-dade-county-sea-level-rise-strategy-draft-mdc.hub.arcgis.com/
[26] (Hawai'i Sea Grant, 2022). *Envisioning In Situ Sea Level Rise Adaptation Strategies for an Urban Coastal Community, Waikīkī, Hawai'i*. Potential flood adaptation strategies for two residential developments. University of Hawai'i, Mānoa Architecture Environmental Research and Design Lab. Hawai'i Sea Grant Center of Excellence for Smart Building and Community Design. School of Ocean and Earth Science and Technology March, 2022. https://seagrant.soest.hawaii.edu/meguro-adapting-Waikīkī/
[27] (HafenCity, 2018). *Urban Spaces in HafenCity*.
https://www.hafencity.com/stadtentwicklung/stadtraeume
[28] (Watersquare, 2018). Publicspace.org. (2018). *Public Space: "Water Square" in Benthemple in Rotterdam* (Netherlands). [online] Available at: http://www.publicspace.org/en/works/h034-water-square
[29] (ABC Waters, 2018) *Design Guidelines. Singapore water Design Guidelines*. Available from: www.pub.gov.sg/Documents/ABC_Waters_Design_Guidelines.pdf
[30] Han, Yu., Mozumder, P. 2021. *Building-level adaptation analysis under uncertain sea-level rise.* Climate Risk Management, Volume 32, 100305, ISSN 2212-0963,
https://doi.org/10.1016/j.crm.2021.100305.

identified in a special flood hazard overlay zone. Some municipalities have taken the planning initiative to develop adaptation implementation roadmaps which are further detailed by short-term (2025) and long-term strategies (2050) (Courtney, et al, 2024; CFRDG, 2019; Hawai'i Sea Grant, 2022). Site-specific design lifetime and risk tolerance are critical considerations for localized implementation strategies, adaptation pathways and timelines. There are building-scale adaptive designs that accommodate predicted sea level changes and utilize risk assessment decision-support tools (Han et al, 2021). Some of the most robust and highly referenced adaptation guidelines are found in the Boston Coastal Flood Resilience Design Guidelines, (CFRDG, 2019) and the New York Climate Resiliency Design Guidelines, (NYORR, 2020). These serve as relevant examples of the type of accommodation practices that could be applied to a dense urban environment like Waikīkī.

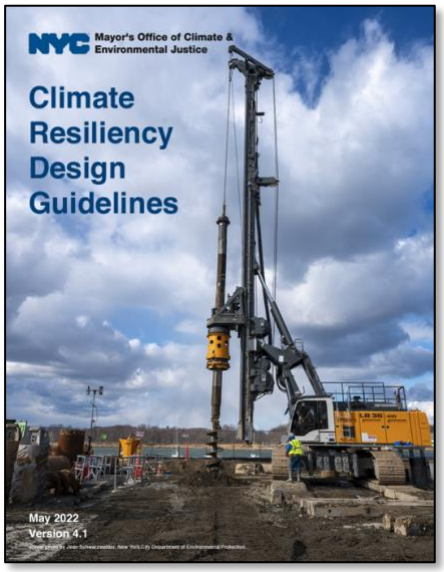
Boston, Massachusetts



Boston's adaptation efforts build on *Climate Ready Boston's* initiatives on coastal flood resilience utilizing the designation of a special zoning overlay district for coastal adaptation. Zoning and building type-specific resilient design guidelines are provided to support adoption of adaptation techniques as part of a broader municipal resilience initiative and serve as a model for implementation of coastal adaptation accommodations and design interventions for an urbanized setting like Waikīkī. The application of zoning overlay and design principles are part of a multi-layered strategy that emphasizes resilience at a variety of scales from regional zoning to site-specific design examples. The Boston guidelines offer building-scale resilience strategies and can be categorized into three types; building form, building envelope and access and building systems (CFRDG, 2019). While storm-induced coastal flooding and sea-level rise are the main drivers for these adaptation guidelines there are

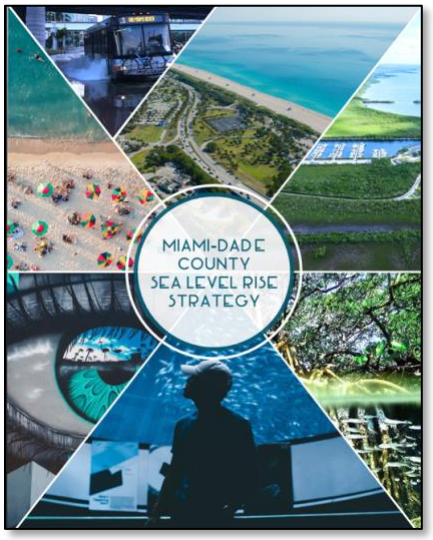
a number of overlapping benefits to implement adaptation for other climate-related impacts and efficiency standards such as those that address heat exposure, energy and water efficiency in addition to resilience improvements.

New York



The New York Climate Resiliency Design Guidelines (NYORR, 2020) provide site-specific adaptation guidelines and instructions for utilizing in-place accommodation standards and design flood elevations. The New York guidelines are by design, forward-looking, though informed by historical climate data and are intentionally adaptive to evolving projections of climate change including sea level, precipitation and heat. The guidelines are meant to be used at all stages of the design process from initial project concept and scoping to the site-specific design. The guidelines are intended to support integration with the City's other project, risk management and financial planning efforts. A distinguishing element of the New York guidelines includes defining criticality of development, or how important the service that is provided and the design lifetime specific to the type of land use and what is considered a major project (>$50 million in cost). These considerations are factored into the design flood elevation calculations and play a role in how uncertainty is dealt with for critical or major projects (NYORR, 2020). The New York design guidelines serve as an important case study for Waikīkī, as an example of developing design flood elevation standards for sea-level rise based on quantitative parameters that are incorporated into the guidelines.

Miami, Florida



Miami and Waikīkī share some similarities in their geologic and urban characteristics, despite being located in different geographic regions. Geologically, both Miami and Waikīkī are situated in low-elevation, coastal areas with a porous limestone bedrock that is susceptible to sea level rise, groundwater inundation and coastal erosion. The low topography setting makes Miami and Waikīkī vulnerable to flooding from both heavy rainfall events and rising sea levels with compound flooding a frequent hazard. For coastal adaptation, Miami-Dade County applies an elevation-focused mitigation and accommodation strategy to managing development in areas vulnerable to sea level rise and tidal flooding. The Miami-Dade Sea Level Rise Strategy (2021), includes five elevation and design-oriented adaptation approaches which are used to adapt to higher water levels (Miami, 2021). Miami has also developed design principles and planning strategies specifically for elevating municipal roads. These principles include an engineering target for keeping road surfaces above king tide elevations to avoid increasing non-storm tidal flooding (Figure 6). These strategies have been used successfully in Miami but there is growing recognition for the need to scale up and expand these type of efforts as completed projects have been prioritized for only the most critical areas first.

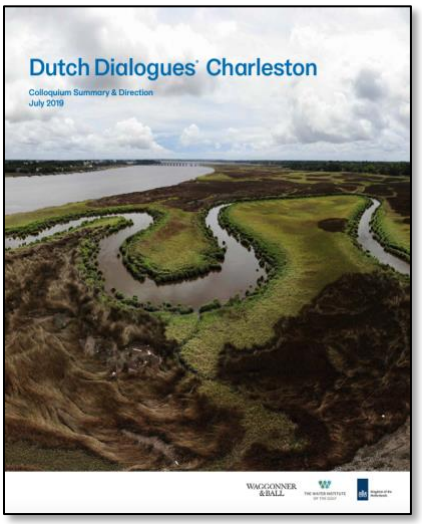
Figure 6. Conceptual illustration of the Miami-Dade Sea Level Rise Strategy showing elevated development, raised transportation corridors and green/blue infrastructure. Image credit: (Miami, 2021).

The Florida Resilient Coastlines Program, administered by the Florida Department of Environmental Protection (FDEP) Office of Resilience and Coastal Protection, produced an Adaptation Planning Guidebook and a grant program to facilitate adaptation.[31] Communities and regional entities have utilized this process to undertake various types of adaptation planning, examining vulnerabilities and risks associated with flooding from storms, tides and combinations thereof (Figure 7). The goal of this guidebook is to assist Florida communities in preparing for and dealing with the effects of sea level rise. This guidebook is scalable and intended to be used by local government planners in cities and counties of any size, providing a framework to develop an initial or update an existing Adaptation Plan.

Figure 7. Example of Florida's Resilient Coastlines Program conceptual adaptation four-step planning process. Image Credit: FDEP, 2018.

[31] Florida Department of Environmental Protection (FDEP). June, 2018. *Florida Adaptation Planning Guidebook*. Florida Resilient Coastlines Program, Tallahassee, FL. https://floridadep.gov/sites/default/files/AdaptationPlanningGuidebook.pdf

Charleston, South Carolina



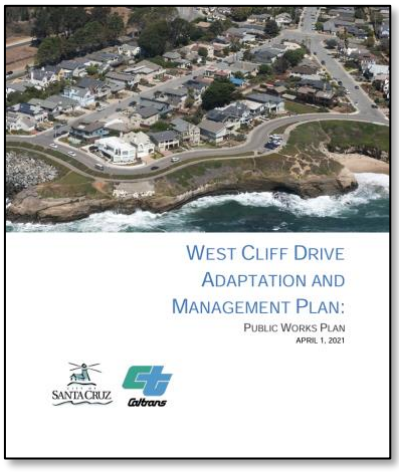
In 2019, the city of Charleston, South Carolina recognized the urgency to develop climate adaptation plans due to the vulnerable, low-lying elevation of the city. The "Dutch Dialogues" as this effort has become known as, is a collaborative, multi-disciplinary effort by local experts, government and community members to develop an integrated flood and stormwater management plan that incorporates key concepts of resiliency and economic vitality. The dialogues were centered on a key Dutch concept that the flooding cannot be "fixed" but instead can be reduced and mitigated through resilience planning and integrated urban design.[32] The concept is founded in the conceptual planning framework of "living with water," an increasingly common sentiment in the climate adaptation planning fields.

The Dutch Dialogues did not produce engineering plans or specific designs to mitigate flooding but instead led to the development of community-oriented planning principles and pathways based on community values and priorities. The recommendations and priorities developed through this process were grounded in science, driven by a community engagement process and based in practical design elements. These dialogues serve as an important reminder of the value of community engagement that is aligned with expertise and experience that provides informed decision-making and planning for long-term resilience. This alignment ensures community trust in government and reinforces the value systems of each community and can illuminate solutions to the vexing socio-economic problems associated with specific projects and planning decisions.

[32] Waggoner and Ball, 2019. *The Dutch Dialogues, Charleston*. City of Charleston. https://www.historiccharleston.org/dutch-dialogues/

Santa Cruz, California

Resilient Coast Santa Cruz, an initiative of the City of Santa Cruz, developed an adaptation and management plan addressing coastal flooding and erosion at four zones along West Cliff Drive by developing site specific adaptation strategies (Figure 8).[33] The plan details site-specific, adaptation options to address coastal flooding and bluff erosion considering future hazards like sea level rise. The Resilient Coast Santa Cruz takes a multi-hazard approach through the development of a collaborative initiative led by the City of Santa Cruz to develop a vision for coastal management to address climate-induced coastal hazards like coastal erosion and flooding.[34] The proposed policies and plans are being implemented through the West Cliff Drive Adaptation and Management Plan. The Resilient Coast initiative continues with dialog and preparation for coastal climate impacts and conducting targeted engagement, developing a Coastal Change Monitoring Program to implement the City's adaptation pathways approach to coastal management.



The West Cliff Drive Adaptation and Management Plan (Plan) is centered on a set of scientifically-informed, community-informed coastal management projects to be implemented in the near-term (10 to 15 year time horizon), to address coastal erosion and adopt them in a Public Works Plan format. The list of projects represents a proactive approach to managing the changing geography and increased hazard risk of West Cliff Drive under City jurisdiction and sets forth a process for prioritizing projects

[33] (Santa Cruz, 2021). *West Cliff Drive Adaptation and Management Plan. City of Santa Cruz*. April 1, 2021. https://www.cityofsantacruz.com/home/showpublisheddocument/83938/637552831003230000
[34]https://www.cityofsantacruz.com/government/city-departments/city-manager/climate-action-program/resilient-coast-santa-cruz

including phased implementation of managed retreat of major public infrastructure. The Plan is presented in the context of various coastal resources – recreation, access, transportation, parking habitat, facilities, open space, protection structures, amenities and utilities and how these projects can be designed to protect, enhance or adapt those resources.

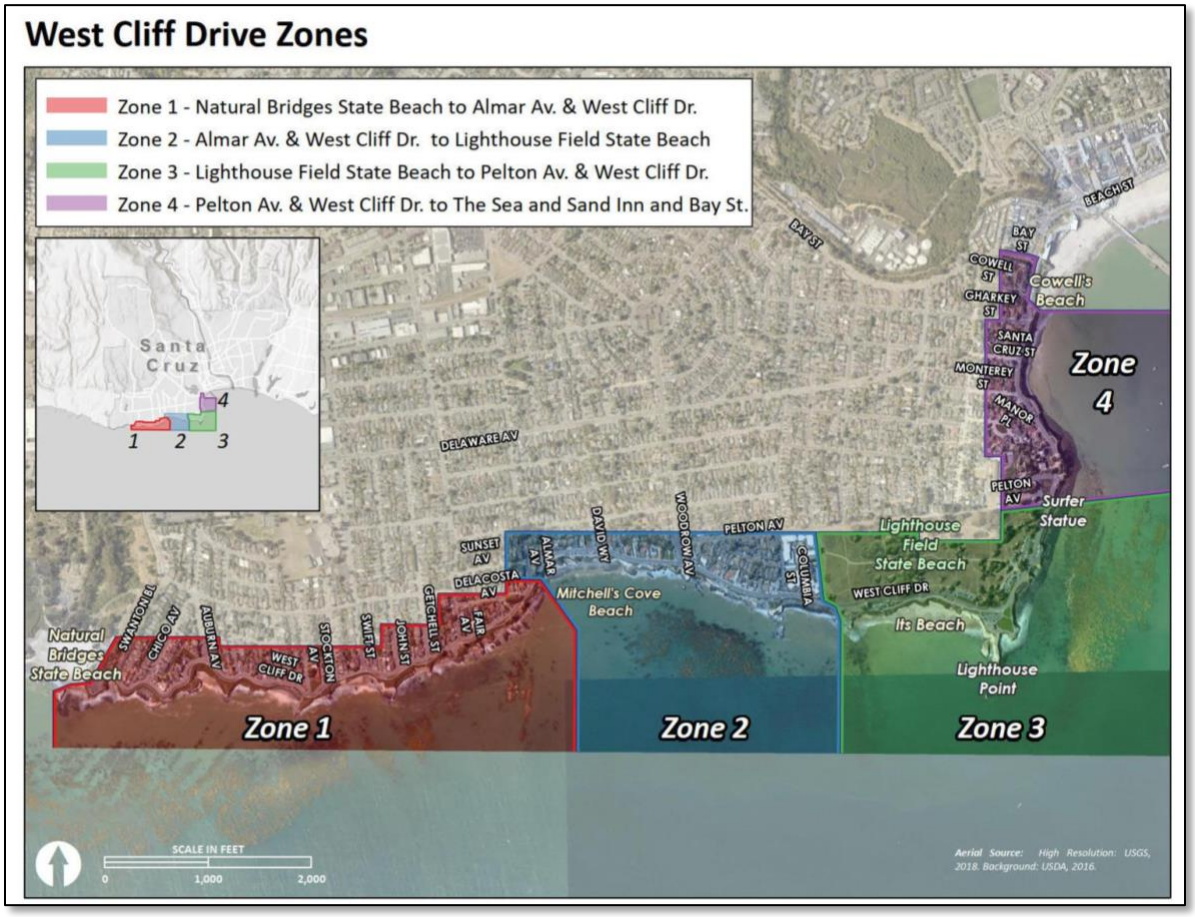
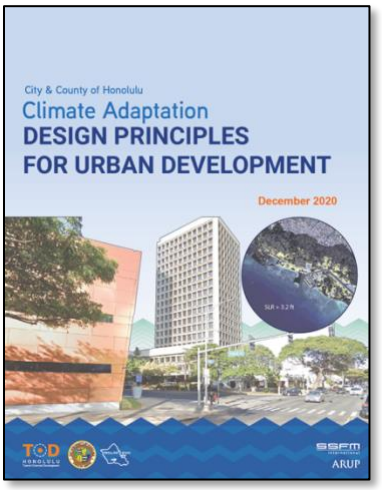


Figure 8. Santa Cruz, California, West Cliff Drive project zones. (Image Credit: Santa Cruz, 2021)

Honolulu, Hawaii



The City and County of Honolulu is developing adaptive urban design recommendations that are consistent with national and international standards and frameworks. Honolulu offers a four-step approach for urban design resilience: 1) assessing the hazard risk, 2) managing stormwater, 3) designing for flood water and sea level rise and 4) managing heat exposure (C&C, 2020). These design guidelines consist of a variety of site-specific recommendation for green infrastructure and low impact development for managing stormwater such as green/blue roofs and walls that retain captured stormwater, rain gardens, detention tanks and permeable concrete as examples of ways to manage stormwater onsite (Hawai'i Sea Grant, 2022; C&C, 2020; ABC Waters, 2018; CFRDG, 2019).[35] These measures are intended to simultaneously address resilience, sustainability and urban design considerations but need to be backed up with regulatory triggers that require their application.

Hazard and climate risk-based adaptive planning approaches that incorporate design lifetime concepts and risk tolerance have been developed elsewhere (CFRDG, 2019; NYORR, 2020).[36,37,38] Design lifetime plays a critical part in determining acceptable levels

[35] USGBC. (2021). V2.0. U.S. Green Building Council. *Resilient Design and Construction*. v4 - LEED v4 Design for Enhanced Resilience. https://www.gbci.org/sites/default/files/RELi%20mandatory%20users%20guide.pdf

[36] Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger and J. Weiss. (2012). *Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Technical Memo OAR CPO-1*. Pg 37.

[37] Collini, R.C., J. Carter, L. Auermuller, L. Engeman, K. Hintzen, J. Gambill, R.E. Johnson, I. Miller, C. Schafer and H. Stiller. (2022). *Application Guide for the 2022 Sea Level Rise Technical Report*. National Oceanic and Atmospheric Administration Office for Coastal Management, Mississippi–Alabama Sea Grant Consortium *(MASGP-22-028) and Florida Sea Grant (SGEB 88)*. https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt02-global-regional-SLR-scenarios-US-application-guide.pdf

[38] National Oceanic and Atmospheric Administration ("NOAA"). Ocean and Coastal Resource Management (2007). *Managed Retreat Strategies.* Accessed on 5/12/24.

of risk to predicted climate change impacts. Attempts have been made to estimate the vulnerability and relative costs associated with sea level rise adaptation and costs based on a range of greenhouse gas emission scenarios (IPCC, 2021; IPCC, 2022).[39] Further research on the costs associated with various sea level rise adaptation for Waikīkī are underway and will positively contribute to the adaptation pathways discussion. As the economic impacts of climate change become more pronounced, broader recognition is being made for the need to evaluate where and how communities are established and the level of acceptable risk associated with these communities (Mach, 2021). It is important to evaluate adaptation strategies holistically to ensure they do not displace flood hazards to neighboring properties. Design interventions and building-scale accommodation strategies are one way to adapt-in-place for new and renovated development in high-risk coastal areas.

https://web.archive.org/web/20150905055350/http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_retreat.html

[39] Ware, Daniel et al. Using Historical Responses to Shoreline Change on Australia's Gold Coast to Estimate Costs of Coastal Adaptation to Sea Level Rise. Journal of marine science and engineering 8.6 (2020): 380. https://www.mdpi.com/2077-1312/8/6/380

CONCLUSIONS

Developing a risk-based adaptation planning approach for Waikīkī will result in more effective and efficient adaptation plans and policies. Significant tradeoffs exist between various sea-level rise adaptation strategies which broadly range from in-place adaptation such as protect/armor and accommodation to strategies that involve planned relocation and retreat. Climate accommodation strategies are, by design proactive, founded in hazard risk management and strive to increase overall community resilience to known or predicted hazard events. Adaptation pathways are conceptual planning approaches that consider the uncertainty in a range of climate change scenarios and provide a prescribed action in response to actual or predicted changes.

Adaptation of the built environment through accommodation and design intervention is centered on adapting infrastructure and the built environment to changing environmental conditions. The strategies of the adaptation planning and policy precedents report provided here, are consistent with and support a number of state and county-level resilience strategies, guidelines and policies. Adaptation strategies are not mutually exclusive and instead present a spectrum of options that are available and can be implemented over time by specific triggers and thresholds for action. Adaptation pathways can be considered in a phased or sequenced manner with predetermined actionable thresholds that result in implementation of the next adaptation measure.

A wide variety of research related to economic cost to benefit analysis reveals significant socio-economic and environmental benefits from increased elevation of new development. Utilizing adaptive designs such as DFEs that factor in sea-level rise projections, result in a more resilient and sustainable community that is able to resist and ultimately recover quicker after a major natural hazard as well as be better prepared for long-term impacts related to climate change. While coastal flooding and sea-level rise are the main drivers for these types of adaptation guidelines, there are a number of overlapping co-benefits and opportunities to implement adaptation for resilience and sustainability. Adaptation plans need to consider community values and priorities in local

land use decision-making, acknowledging economic limitations, uncertainty, timing and sequencing issues, cost-benefit of responses in addition to the anticipated socio-economic and environmental trade-offs of various adaptation strategies.

Adaptation planning efforts in Waikīkī benefit from the precedents in other coastal communities that have implemented innovative and holistic adaptation strategies. The precautionary principle emphasizes taking proactive measures to mitigate potential harm, even in the absence of full scientific certainty. This is a form of a "no regrets" planning principle which refers to strategies and measures that offer co-benefits regardless of future climate conditions. Building-scale adaptation strategies can be broadly categorized by building typology and use with site-specific design interventions such as elevation of critical features, flood resistance and floodwater management as signature examples. Elevation-based approaches such as design flood elevations, are foundational as part of a comprehensive adaptation and accommodation plan for the built environment. There are many innovative adaptation plans, policies and guidelines emerging from around the world, these serve as important examples and case studies for comprehensive adaptation approaches. Some of the more relevant examples of adaptation in-place through accommodation for Waikīkī being from Boston and New York.