



University of Hawai'i Sea Grant College Program
WAIKĪKĪ RESILIENCE & SLR ADAPTATION PROJECT

PRELIMINARY
ADAPTATION IMPLEMENTATION ROADMAP
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Table of Contents

EXECUTIVE SUMMARY	3
KEY MESSAGES	5
BACKGROUND INFORMATION	7
KEY MESSAGES- Science-Informed Policy	8
U.S. National Climate Assessment (USGCRP, 2023)	8
Intergovernmental Panel on Climate Change (IPCC)	11
Hawai'i Sea Level Rise Vulnerability and Adaptation Report (2022)	14
Hawai'i Regional Shoreline Management Study	16
Honolulu Primary Urban Center Development Plan	18
Adapt Waikīkī 2050	20
ADAPTATION PATHWAYS	21
ADAPTATION IMPLEMENTATION	22
KEY MESSAGES- Research Findings	22
Climate Adaptation Effectiveness	24
Adaptive Management-Dynamic Adaptive Policy Pathways (DAPP)	27
PRELIMINARY ADAPTATION ROADMAP	30
KEY MESSAGES - Waikīkī Implementation Roadmap	32
Adaptation Triggers and Thresholds	35
Adaptation Implementation Measure (AIM)	40
CONCLUSIONS	42



EXECUTIVE SUMMARY

This Preliminary Adaptation Implementation Roadmap report provides a summary of climate change adaptation planning and implementation, providing an overview of relevant academic research on adaptation planning strategies and implementation methodologies. This report synthesizes key findings from peer-reviewed studies to create a preliminary roadmap for comprehensive climate adaptation in Waikīkī, Hawai'i. The research highlights the need for a flexible, dynamic and adaptive planning approach, incorporating scientific insights, utilizing case study examples and stakeholder engagement despite significant future conditions uncertainties. A flexible adaptation pathways framework is introduced to support resilient and effective adaptive planning and provides context for adaptation planning and implementation in the context of long-range, 50-100 year, planning timeframes.

This roadmap report serves as a preliminary guidance document to support policymakers, planners, and community leaders in developing robust, equitable, and sustainable adaptation strategies to enhance resilience against the adverse impacts of climate change. The report emphasizes the importance of integrating scientific knowledge with local context to develop robust, flexible, and equitable adaptation plans by providing a review of high-quality academic research related to adaptation planning and implementation. Drawing on global research and examples, this document aims to assist stakeholders in Waikīkī in developing informed, effective, and sustainable adaptation plans and implementation strategies, serving as a model framework for adaptation planning statewide.

This report is not designed to serve as a comprehensive implementation roadmap for climate change adaptation in Waikīkī due to the need for more extensive coordination, community engagement and detailed planning, which should be addressed in a subsequent phase. Instead, this document provides a preliminary assessment of the academic research literature on adaptation planning, highlighting key findings and identifying critical gaps, providing an informed foundation for future planning efforts.



The initial assessment provided here, underscores the need for developing an integrated and collaborative approach involving stakeholders at all levels to ensure the effective implementation of adaptation strategies. The research cited in this report points to the importance of dynamic, inclusive, and multi-sectoral planning processes, which will be essential in the next phase of developing a detailed implementation strategy tailored to Waikīkī's specific needs and vulnerabilities. The analysis highlights the need for integrating political commitment, robust institutional frameworks, and enhanced access to finance and technology as outlined in the academic literature. This initial phase of the implementation roadmap aims to identify critical gaps and opportunities, emphasizing the necessity of continued collaboration and comprehensive planning to develop a robust adaptation framework in the next phase, as supported by the cited research.

Adaptation to climate change is a critical issue for Waikīkī as rising sea levels and extreme weather events increasingly threaten this important coastal community. Successful development and implementation of coastal adaptation strategies requires a comprehensive understanding of the key factors that influence the effectiveness, barriers and acceptance of adaptation plans. Adaptation is founded in the concept of “pathways” which serve as conceptual planning approaches that consider the uncertainty of climate change scenarios and provide a set of prescribed actions in response to actual or predicted changes. Adaptation pathways determine when adaptation actions are implemented based on predefined benchmarks or thresholds. Adaptation pathways provide a conceptual framework for the implementation of place-based adaptation strategies that are developed with community values and priorities as a guiding force. The concept of adaptation pathways plays an important part of a long-term (50-100 year) adaptation plan for Waikīkī.

Adaptation options that are feasible and effective today may become constrained and less effective as climate change progresses. To avoid maladaptation, or developing adaptation strategies that inadvertently increase vulnerability to climate change, it is crucial to engage in flexible, multi-sectoral, inclusive, and long-term planning and



implementation of adaptation actions. Effective climate adaptation strategies often involve dynamic, participatory approaches that foster collective learning and integrate local socio-cultural, geographical, and climatic conditions. Political commitment, well-aligned multilevel governance, robust institutional frameworks, supportive laws and policies, and enhanced access to finance and technology are essential for enabling effective climate action. A comprehensive adaptation framework should encompass information collection and awareness raising, planning and design, implementation, and ongoing monitoring and evaluation. Successful adaptation implementation requires a thorough examination of trade-offs, opportunities, and competing needs while addressing the uncertainties of future climate change.

KEY MESSAGES

- Stakeholder engagement and community support are crucial for the success of climate adaptation strategies. Soft protection and nature-based approaches are gaining interest by local governments, while retreat options are often the most complex in dense urban areas like Waikīkī due to strong place attachment.¹
- Climate adaptation strategies should include interdisciplinary research, adaptive governance, iterative policy monitoring, and community input to be successful.²
- A clear roadmap and proper financing structure are essential for adaptation.³

¹ Mallette, A., Smith, T., Elrick-Barr, C., Blythe, J., & Plummer, R. (2021). *Understanding Preferences for Coastal Climate Change Adaptation: A Systematic Literature Review*. Sustainability. <https://doi.org/10.3390/su13158594>.

² Lebbe, T., Rey-Valette, H., Chaumillon, E., Camus, G., Almar, R., Cazenave, A., Claudet, J., Rocle, N., Meur-Férec, C., Viard, F., Mercier, D., Dupuy, C., Ménard, F., Rossel, B., Mullineaux, L., Sicre, M., Zivian, A., Gaill, F., & Euzen, A. (2021). *Designing Coastal Adaptation Strategies to Tackle Sea Level Rise*. 8. <https://doi.org/10.3389/fmars.2021.740602>.

³ López-Dóriga, U., Jimenez, J., Bisaro, A., & Hinkel, J. (2019). *Financing and implementation of adaptation measures to climate change along the Spanish coast*. The Science of the total environment, 135685 . <https://doi.org/10.1016/j.scitotenv.2019.135685>.



- Risk assessments should integrate community experiences and values to enhance proactive adaptation measures.⁴
- To fully understand the scale of impacts and vulnerabilities, more detailed and localized assessments should provide information about vulnerability, sensitivity, impact, cost and adaptive capacity.⁵
- Many adaptation policies are challenged by a lack of successful implementation. Adaptation planning is relatively recent and concentrated in developed areas.⁶
- Adaptation strategies should enhance the natural resilience of coastal systems and consider both long-term trends and short-term events.⁷
- A self-evaluating process for adaptation planning ensures that adaptation strategies are supported and integrated into existing management practices.⁸

⁴ Koerth, J., Vafeidis, A., Hinkel, J., & Sterr, H. (2013). *What motivates coastal households to adapt pro-actively to sea-level rise and increasing flood risk?* *Regional Environmental Change*, 13, 897-909. <https://doi.org/10.1007/s10113-012-0399-x>.

⁵ Sea Level Rise Adaptation in Hawai'i. *Act 178, SLH 2021 Climate Change and Sea Level Rise Adaptation for State Facilities*. Office of Planning & Sustainable Development - Coastal Zone Management Program. <https://storymaps.arcgis.com/stories/be265cb4250a401699f0d41f6e90054f>

⁶ Olazabal, M., Gopegui, M., Tompkins, E., Venner, K., & Smith, R. (2019). *A cross-scale worldwide analysis of coastal adaptation planning*. *Environmental Research Letters*, 14. <https://doi.org/10.1088/1748-9326/ab5532>.

⁷ Sánchez-Arcilla, A., García-León, M., Gracia, V., Devoy, R., Stanica, A., & Gault, J. (2016). *Managing coastal environments under climate change: Pathways to adaptation*. *The Science of the total environment*, 572, 1336-1352. <https://doi.org/10.1016/j.scitotenv.2016.01.124>.

⁸ Klein, R., Nicholls, R., & Mimura, N. (1999). *Coastal Adaptation to Climate Change: Can the IPCC Technical Guidelines be applied? Mitigation and Adaptation Strategies for Global Change*. 4, 239-252. <https://doi.org/10.1023/A:1009681207419>.



BACKGROUND INFORMATION

Implementation of coastal adaptation strategies hinges on several key factors: detailed scientific basis and understanding of impacts, strong public support, integrated and participatory approaches, community-led vision of future pathways, adequate financial and institutional support, robust policy development implementation and monitoring and a flexible adaptation planning framework. The 2018 U.S. National Climate Assessment (4th Assessment) suggested a conceptual five stage adaptation planning process in order to adapt to climate change.⁹ The five stages of adaptation include: awareness, assessment, planning, implementation, and monitoring and evaluation. This stage-oriented process provides a simple and clear process that is generally consistent with most of the adaptation framework approaches including older frameworks by NOAA.¹⁰ More recently, the 2023 U.S. National Climate Assessment (5th Assessment) provides a more detailed analysis of climate adaptation and offers some key messages that may be especially relevant for the development of an implementation strategy for Waikīkī.¹¹

Implementation of adaptation plans will require integrated and cohesive partnerships between government, private-sector, nongovernmental and civil society organizations, which often have different priorities, values and functions. Successful adaptation implementation requires a comprehensive examination of the tradeoffs, opportunities and competing needs, addressing uncertainties regarding future climate change with recognition of the political, social, and technological transformations necessary for

⁹ USGCRP, 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018

¹⁰ National Oceanic and Atmospheric Administration (NOAA). 2010. *Adapting to Climate Change: A Planning Guide for State Coastal Managers*. NOAA Office of Ocean and Coastal Resource Management. <http://coastalmanagement.noaa.gov/climate/adaptation.html>

¹¹ USGCRP, 2023: *Understanding Risks, Impacts, and Responses*. In: Fifth National Climate Assessment. Jay, A.K., A.R. Crimmins, C.W. Avery, T.A. Dahl, R.S. Dodder, B.D. Hamlington, A. Lustig, K. Marvel, P.A. Méndez-Lazaro, M.S. Osler, A. Terando, E.S. Weeks, and A. Zycherman, 2023: Ch. 1. Overview: Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA. <https://doi.org/10.7930/NCA5.2023.CH1>



adaptation to be effective (USGCRP, 2023). A comprehensive adaptation framework should emphasize collaboration, equity, and justice, supporting resilient adaptive strategies, integrating diverse values and knowledge sources through the process. This necessitates working with communities to identify goals, assess vulnerabilities, enhance capacity, and address contextual factors such as values, culture, risk perception, and historical injustices.

KEY MESSAGES- Science-Informed Policy

U.S. National Climate Assessment (USGCRP, 2023)



Effectively and equitably addressing the risks associated with climate change impacts requires inclusive long-term planning, investments in transformative adaptation, and mitigation strategies that prioritize equity and justice and are centered on community vision and values. While adaptation planning and

implementation has advanced in the U.S, most adaptation actions to date have been incremental and small in scale (USGCRP, 2023). In many cases, more transformative adaptation will be necessary to adequately address the risks of current and future climate change. Transformative adaptation requires considering both the physical and social drivers of vulnerability and understanding how they interact to shape local experiences of vulnerability and disparities in risk. Selected findings of the USGCRP (2023) include:

- Adaptation Is Insufficient in Relation to the Pace of Climate Change



Diverse adaptation activities are occurring across the U.S. Adaptation activities are increasingly moving from awareness and assessment toward planning and implementation, with limited advancement progress in monitoring and evaluation. Numerous social, economic, physical, and psychological barriers are preventing more widespread adoption and implementation of adaptation. Current adaptation efforts and investments are insufficient to reduce today's climate-related risks and are unlikely to keep pace with future changes in the climate.

- **Urban Areas Create Opportunities for Climate Mitigation and Adaptation**
Cities across the country are working to reduce greenhouse gas emissions and adapting to adverse climate impacts. Some states and cities are integrating climate considerations into relevant codes, standards, and policies. However, the pace, scale, and scope of action are not yet sufficient to avoid the worst impacts, given the magnitude of observed and projected climate changes.
- **Community Actions Signal a Shift Toward Equitable Climate Governance**
There is varying progress in considering who benefits from, or bears the burden of, local climate actions. The emergence of local and community-led approaches—coupled with increasing collaboration among city, Tribal, state, and federal governments—indicates a movement toward more inclusive planning and implementation of climate actions.
- **Implementation Challenges**
Although there are some documented cases of fully implemented adaptation plans in the U.S, the scarcity of systematic data that enable comparison over time makes it challenging to definitively assess the progress of adaptation implementation. Data suggests that implemented adaptation plans and strategies are being evaluated but face numerous barriers to developing and implementing adaptation. Current adaptation efforts are incremental in nature and are insufficient to address future climate risks that are predicted.



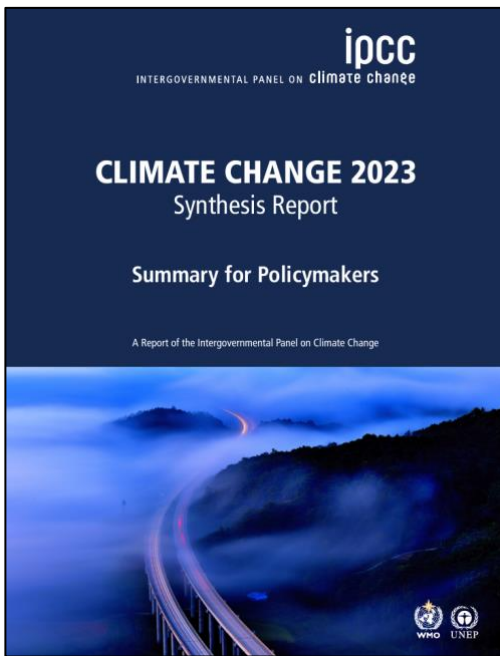
- Transformative Adaptation

Transformative adaptation involves fundamental shifts in systems, values, and practices, including assessing potential trade-offs, intentionally integrating equity into adaptation processes, and making systemic changes to institutions and norms. Transformative adaptation requires new and better-coordinated governance mechanisms and cooperation across all levels of government, the private sector, and society. A coordinated, systems-based approach can support consideration of risks that cut across multiple sectors and scales, as well as the development of context-specific adaptations.

- Resilience

The terms “adaptation” and “resilience” are complementary concepts, however there are distinct and important differences between the meanings of these terms. This can create confusion since they are often used interchangeably in policy and academic discourse. “Adaptation refers to a process or action that changes a living thing so that it is better able to survive in a new environment, whereas resilience describes the capacity or ability to anticipate and cope with shocks, and to recover from their impacts in a timely and efficient manner (USGCRP, 2023).”

Intergovernmental Panel on Climate Change (IPCC)¹²



The IPCC 6th Assessment report recognizes the value of diverse forms of knowledge such as scientific, as well as Indigenous knowledge and local knowledge in understanding and evaluating climate adaptation processes and actions to reduce risks from human-induced climate change. The report describes “effectiveness” in the context of adaptation as the extent to which an action reduces vulnerability and climate-related risk, increases resilience, and avoids maladaptation.¹³ This report has a particular focus on transformation and system transitions in various sectors and

society.¹⁴ The transformations outlined by the IPCC enable the adaptation necessary to achieve high levels of human health and well-being, economic and social resilience, ecosystem vitality, and overall planetary health. These provide a valuable framework for the development of an adaptation plan for Waikīkī.

KEY TAKEAWAYS

- Adaptation options that are feasible and effective today will become constrained and less effective with increasing global warming. Maladaptation can be avoided by flexible, multi-sectoral, inclusive, long-term planning and implementation of adaptation actions, with co-benefits to many sectors.

¹² 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: 6/10/23 https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

¹³ The IPCC (2022) refers to “maladaptation” as actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future.

¹⁴ The IPCC (2022) refers to “transformation” as a change in the fundamental attributes of natural and human systems.

- Effective climate action is enabled by political commitment, well-aligned multilevel governance, institutional frameworks, laws, policies and strategies and enhanced access to finance and technology. Climate resilient development benefits from drawing on diverse knowledge bases.
- Effective multilevel governance for mitigation, adaptation, risk management, and climate resilient development is enabled by inclusive decision processes that prioritize equity and justice in planning and implementation, allocation of appropriate resources, institutional review, and monitoring and evaluation.
- Drawing on diverse knowledge and cultural values, meaningful participation and inclusive engagement processes—including Indigenous, local and scientific knowledge—facilitates climate resilient development, builds capacity and allows locally appropriate and socially acceptable solutions.
- Progress in adaptation planning and implementation globally has been observed across all sectors and regions, generating multiple benefits. Growing public and political awareness of climate impacts and risks has resulted in at least 170 countries and many cities including adaptation in their climate policies and planning processes.¹⁵
- Key barriers to adaptation are limited resources, lack of private sector and citizen engagement, insufficient mobilization of finance (including for research), low climate literacy, lack of political commitment, limited research and/or slow and low uptake of adaptation science, and low sense of urgency.

Climate adaptation is based on adjusting to and compensating for the actual or predicted impacts of climate change. There are a wide variety of strategies for a

¹⁵ IPCC, 2023: *Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

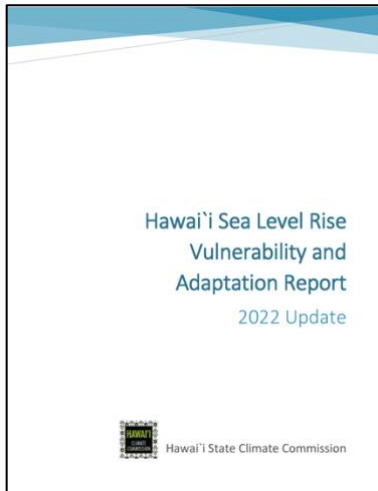


comprehensive adaptation program of which accommodation strategies serve as an important option for adapting in-place. Adaptation can be facilitated by developing conceptual adaptation pathways which serve as planning frameworks that consider the uncertainty of climate change scenarios and provide a prescribed action in response to actual or predicted changes.

Accommodation involves making adjustments to infrastructure, development and societal, economic and environmental practices to live with the changes and challenges posed by climate change. This strategy focuses on modifying existing systems and infrastructure to withstand new conditions rather than completely transforming or relocating them. Accommodation works alongside other adaptation strategies, such as: resistance, nature-based options and retreat among others (see adaptation strategies in Section 7.1.a). Climate accommodation strategies and design interventions seek to minimize the impacts of coastal hazards and climate change, including flooding and sea-level rise, to the built environment through an in-place adaptation approach. Accommodation is centered on adapting infrastructure and the built environment to changing environmental conditions in-place. Accommodation strategies may be utilized for a specific timeframe, based on predicted future conditions and can be a method of phasing in other adaptation options over time based on identified triggers and thresholds. Accommodation is a critical component of a comprehensive climate adaptation strategy addressing the impacts of climate change and other natural hazards.



Hawai'i Sea Level Rise Vulnerability and Adaptation Report (2022)¹⁶

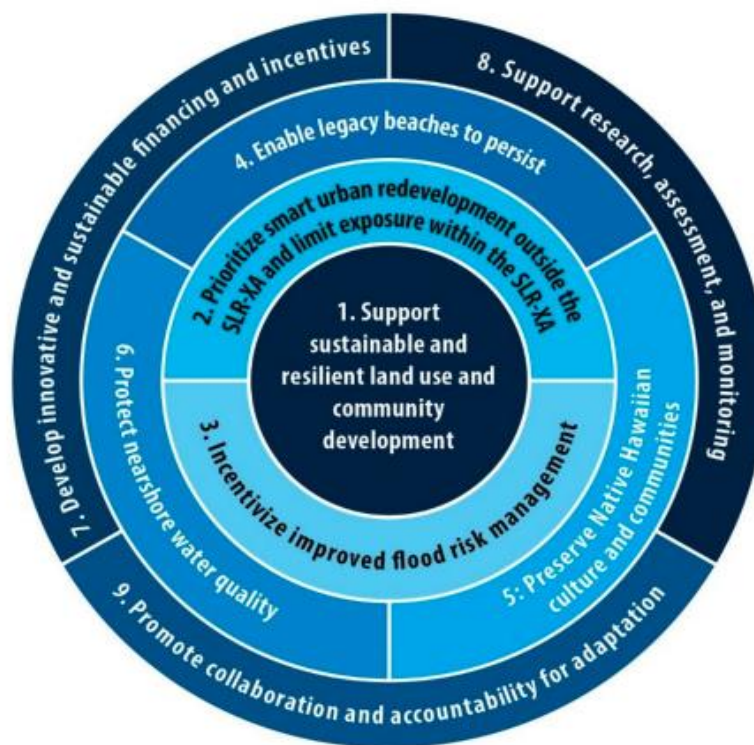


The Hawai'i Sea Level Rise Vulnerability and Adaptation Report serves as a baseline for understanding the most probable impacts of sea level rise. Recommendations to increase capacity to adapt to sea level rise are described, but notably, do not lay out a plan for implementation. Recommendations in this report were developed to provide guidance for State and County agencies, communities, and other stakeholders to adapt to sea level rise. The recommendations are designed to support a multi-sectoral and holistic response to adaptation, building on existing efforts and considering challenges and new opportunities (Figure 1). The Hawai'i Sea Level Rise Vulnerability and Adaptation Report Recommendations include:

- Recommendation 1, support sustainable and resilient land use and community development, focusing on the central role that land use and community development planning play in adapting to sea level rise.
- Recommendations 2 and 3 prioritize smart redevelopment in areas outside the SLR-XA, limiting exposure inside the SLR-XA, and incentivizing improved flood risk management.
- Recommendations 4, 5, and 6 address cultural and environmental vulnerabilities that underpin resilient and sustainable land use and community development.

¹⁶ *Hawai'i Sea Level Rise Vulnerability and Adaptation Report (2022)*. Hawai'i State Climate Change Mitigation and Adaptation Commission, prepared by the State of Hawai'i Department of Land and Natural Resources, Office of Conservation and Coastal Lands. <https://climate.hawaii.gov/wp-content/uploads/2023/01/OCCL23-Sea-Level-Rise-Report-FY22-1.pdf>

- Finally, cross-cutting recommendations include developing funding sources and incentives for adaptation. These cross-cutting recommendations highlight the need to engage diverse stakeholders in making complex decisions about addressing the impacts of sea level rise. Recommendation 7 highlights the very real need to address the cost of adaptation by exploring both funding sources and incentives while Recommendation 8 is fundamental to a learning approach to adaptation which involves conducting research, assessments, and monitoring needed to update the report and other “living” outputs.

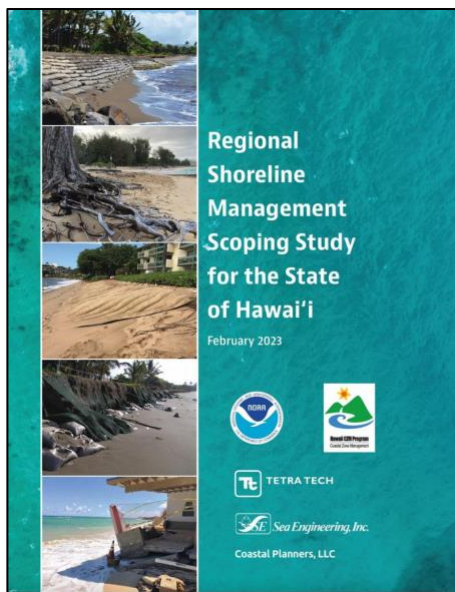


Recommendations to improve Hawaii's capacity to adapt to sea level rise

Figure 1. Adaptation Recommendations. (Credit: Hawai'i SLR Report, 2022).

Hawai'i Regional Shoreline Management Study¹⁷

Hawai'i's current regulatory framework—focusing on individual parcels—is challenged to address the breadth of natural and climate hazard threats. This study evaluates a regional shoreline management approach in order to better address regionally-specific impacts by supporting plans and projects that consider the complex array of shoreline types, ecosystem services, development patterns, and cultural resources. This study establishes a problem statement and Theory of Change that links key issues in shoreline management with potential outputs and outcomes of implementing a regional shoreline management approach.



This study describes the Theory of Change framework that outlines the cause-and-effect linkages and outcomes of an initiative in terms of if/then statements (Figure 2). Regional shoreline management when applied to proactive coastal adaptation and when planned and executed at appropriate geographic scales, would align with policy objectives for coastal zone management in Hawai'i and provides a comprehensive framework to support a parcel-by-parcel regulatory approach. The development of a methodology for delineating and characterizing shoreline regions and

subregions is an important achievement that will have significant impact on the implementation of coastal and climate adaptation plans and policies. The study outcomes could play an important part in defining a regional shoreline management framework for Waikīkī as part of a longer-term adaptation strategy. Building on this state-wide sea level rise science, a regional shoreline management approach can be

¹⁷ *Regional Shoreline Management Scoping Study for the State of Hawai'i*. Prepared for: Hawai'i Department of Business, Economic Development & Tourism Office of Planning and Sustainable Development Coastal Zone Management Program Prepared by: Tetra Tech, Inc.; Sea Engineering, Inc.; and Coastal Planners, LLC February, 2023.
<https://storymaps.arcgis.com/stories/e76bd1de3cfb45ccbc7f1eaab196cdeb>

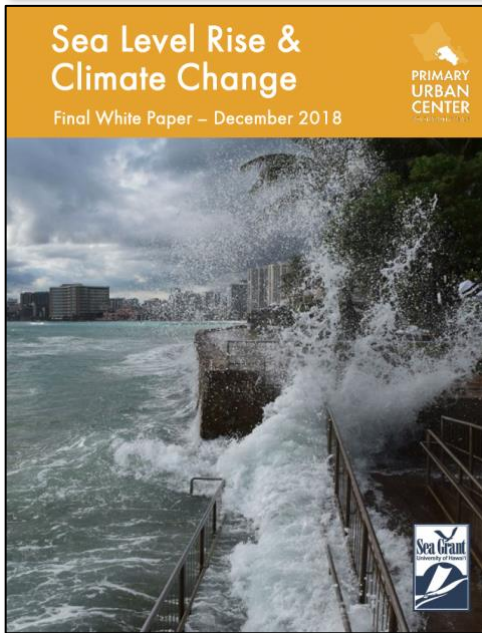
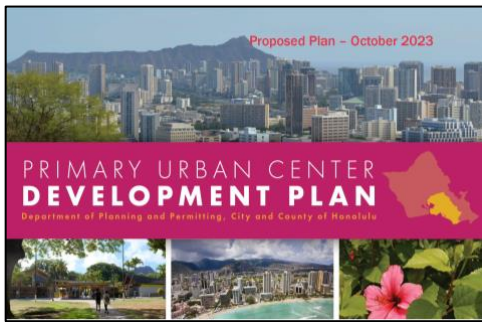
adopted within the existing governance framework for more sustainable and resilient shorelines in what promises to be an increasingly complex future in Hawai'i (Hawai'i Regional Shoreline Management Study, 2023).



Figure 2. Theory of Change Concept. (Credit: OPSD, 2023).

Honolulu Primary Urban Center Development Plan

The Proposed Primary Urban Center Development Plan (PUC DP) 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 white paper addresses a range of climate change impacts and vulnerabilities relevant to the Honolulu Primary Urban Center (PUC). However, the principal focus of the data and recommendations included here is on sea level rise.¹⁸ Recognizing and addressing the impacts of sea level rise in the Primary Urban Center Development Plan, of which Waikīkī lies within, the update is particularly critical because so much of the State's infrastructure, economic activities, and population is concentrated within the PUC boundaries. These and many other

related adaptation strategies will play an important role in Waikīkī as resilience and adaptation plans are eventually developed for the area.

KEY TAKEAWAYS FOR ADAPTATION IN THE PUC DP

- For planning decisions related to critical infrastructure with longer expected lifespans or low risk tolerance, 6 feet of sea level rise should be considered.

¹⁸ (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



- Resilience actions that provide multiple benefits allow for more effective leveraging of resources and acknowledge the connections between climate change vulnerabilities and broader social, economic, and cultural factors.
- Designing and siting of planned development and capital improvement projects should include analysis of sea level rise impacts based on elevation, tolerance for risk, and lifetime of the structure and propose appropriate mitigation steps.
- In-depth assessments of the vulnerability and potential adaptation should be conducted for critical infrastructure in areas exposed to sea level rise impacts.
- Sea level rise should be considered in developing and approving Capital Improvement Projects. This includes retrofitting current infrastructure in the 3.2 SLR-XA for enhanced resilience and prioritizing infrastructure improvements in areas outside of the 3.2 SLR-XA.
- Beaches are important community resources and economic assets for the PUC. Waikīkī Beach alone brings an estimated \$2.22 billion to the local economy.¹⁹ The State Sea Level Rise Report recommends development of public-private partnerships for beach preservation such as the Waikīkī Beach Special Improvement District Association (WBSIDA).
- Effective pre-disaster planning enhances a community's ability to build back stronger and more resilient in the aftermath of a disaster. Pre-disaster planning considers the objectives, resources, and needs of the community and guides post-disaster decisions and investments in a strategic fashion.

¹⁹ Tarui, N., Peng, M., Eversole, D. *Economic Impact Analysis of the Potential Erosion of Waikīkī Beach*. April, 2018. University of Hawai'i Sea Grant College Program. <https://seagrant.soest.hawaii.edu/wp-content/uploads/2018/08/Economic-Impact-Analysis-Waikīkī-Beach-1016-web.pdf>



Adapt Waikīkī 2050



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.²⁰ The project is being led by the

City and County of Honolulu Department of Planning and Permitting. 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 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. 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.

The long-term adaptation recommendations for Waikīkī from this report 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.²¹

²⁰ 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>

²¹ This approach (using risk thresholds) is consistent with the recommendations from the IPCC, 2022 and Sweet (NOAA), 2017 and 2022 reports (see references in Section 7.1.a).



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. 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. 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.

Adaptation pathways are site-specific and consider associated impacts such as cost, environmental impacts, sequencing and design life. 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 one example of how city planners are utilizing adaptation pathways to identify and implement coastal management options over phased time frames, with robust community input.²²

Refer to Section 7.1.a of the Waikīkī Resilience and Sea Level Rise Adaptation Project for more details on adaptation pathways.

²² City of Santa Cruz. 2019, November 6. *City of Santa Cruz Beach Vulnerability and Adaptation Strategy*. <https://www.cityofsantacruz.com/home/showpublisheddocument/78991/637165009953900000>



ADAPTATION IMPLEMENTATION

The development and implementation of adaptation policy is a critical component of climate change adaptation, involving the integration of adaptive measures into various levels of governance, policy and planning. The implementation of adaptation policies is progressing, with a notable increase in initiatives and successful local-level integration in some areas. However, challenges such as voluntary nature, lack of detailed guidance, and insufficient prioritization hinder effectiveness and more widespread implementation. Dense urban areas like Waikīkī face significant barriers related to land use planning priorities and funding challenges. Accelerating adaptation efforts in Waikīkī requires meaningful stakeholder involvement and the use of diverse policy instruments and financial controls and incentives as leverage. This section examines the progress, challenges, and strategies related to the implementation of adaptation policies largely based on recent academic research findings.

KEY MESSAGES- Research Findings

- Increase in adaptation initiatives: There has been a significant rise in adaptation initiatives globally, with an 87% increase since 2010, indicating growing adoption of adaptation practices.²³
- Local-Level Implementation: Adaptation measures at the local government level often remain voluntary and must compete with other non-mandatory issues. Successful implementation is influenced by individual efforts within municipalities, municipal size, and the use of external expertise.²⁴ Local governments can effectively incorporate adaptation measures into long-term planning documents, facilitated by local awareness, existing strategies, and

²³ Lesnikowski, A., Ford, J., Biesbroek, R., Berrang-Ford, L., & Heymann, S. (2016). *National-level progress on adaptation*. *Nature Climate Change*, 6, 261-264. <https://doi.org/10.1038/NCLIMATE2863>.

²⁴ Dannevig, H., Rauken, T., & Hovelsrud, G. (2012). *Implementing adaptation to climate change at the local level*. *Local Environment*, 17, 597 - 611. <https://doi.org/10.1080/13549839.2012.678317>.



flexible planning processes. However, challenges such as lack of priority and limited policy direction persist.²⁵

- **Challenges in Large Cities:** Adaptation planning in large cities is often ineffective due to insufficient financing, regulatory context, monitoring, and evaluation. More effort is needed to improve these areas for long-term sustainability.²⁶
- **Implementation Guidance and Prioritization:** Many local adaptation plans in the U.S. lack detailed implementation processes and fail to prioritize impacts, limiting their effectiveness.²⁷
- **Social Justice in Adaptation:** Implementing socially just adaptation requires the inclusion of vulnerable populations in decision-making, recognition of systemic injustices, and incremental evaluations to ensure justice is advanced over time.²⁸
- **Opportunities and Barriers:** While there are significant opportunities for adaptation, especially in regions like Europe, the process is slow. Accelerating adaptation requires the involvement of all stakeholders and the use of various policy instruments, including economic and legal tools.²⁹

²⁵ Picketts, I., Déry, S., & Curry, J. (2014). *Incorporating climate change adaptation into local plans*. *Journal of Environmental Planning and Management*, 57, 1002 - 984. <https://doi.org/10.1080/09640568.2013.776951>.

²⁶ Olazabal, M., & Gopegui, M. (2021). *Adaptation planning in large cities is unlikely to be effective*. *Landscape and Urban Planning*, 206, 103974. <https://doi.org/10.1016/j.landurbplan.2020.103974>.

²⁷ Woodruff, S., & Stults, M. (2016). Numerous strategies but limited implementation guidance in US local adaptation plans. *Nature Climate Change*, 6, 796-802. <https://doi.org/10.1038/NCLIMATE3012>.

²⁸ Malloy, J., & Ashcraft, C. (2020). *A framework for implementing socially just climate adaptation*. *Climatic Change*, 160, 1-14. <https://doi.org/10.1007/s10584-020-02705-6>.

²⁹ Verschuuren, Jonathan, *Adaptation to Climate Change: Opportunities and Barriers*. (May 2007). *Proceedings of the International Colloquium on Global Warming*, Rio de Janeiro, May 21st, 2007, Available at SSRN: <https://ssrn.com/abstract=1291183> or <http://dx.doi.org/10.2139/ssrn.1291183>



Climate adaptation initiatives traditionally focus on the concept of vulnerability, but rarely frame problems and solutions in terms of the underlying causes of vulnerability. Malloy & Ashcraft, (2020) identify the conditions that must occur to implement socially just adaptation. First, just adaptation requires the inclusion of socially vulnerable populations as full participants with agency to shape the decisions that affect them. Second, just adaptation requires that adaptation framings explicitly recognize the causes of systemic injustice. Third, just adaptation requires a focus on incremental evaluations of implementation to avoid timeframes inconsistent with advancing justice. This research framework aims to position justice at the center of climate adaptation implementation and to better understand how vulnerable populations develop and exert agency over climate adaptation decisions. These social justice conditions could be important adaptation planning features for Waikīkī.

Effective implementation of climate change adaptation measures is influenced by a combination of local efforts, multi-level governance, integrated solutions, and inclusive policies. Overcoming barriers and ensuring systematic planning and evaluation are essential for advancing adaptation initiatives. Adaptation plans in the United States often fail to prioritize climate impacts or provide detailed implementation processes, highlighting a gap between planning and action (Woodruff & Stults, 2016). This study also found that adaptation plans authored by planning departments and those that engaged elected officials in the planning process were of higher quality and implemented at a higher rate. The research results provide important insights for practitioners, policymakers and scientists wanting to improve local climate adaptation planning and action and the direct application to Waikīkī adaptation planning efforts.

Climate Adaptation Effectiveness

The effectiveness of climate adaptation refers to the extent to which adaptation actions achieve desired and/or stated outcomes in reducing vulnerability and increasing resilience to climate change impacts. The effectiveness of climate adaptation is often multifaceted, involving the successful reduction of vulnerabilities, enhancement of



resilience, ensuring sustainability, promoting equity, and achieving economic efficiency. Continuous monitoring, flexible strategies, and inclusive planning are crucial for effective adaptation to climate change. The implementation of climate change adaptation strategies can be considered effective when it reduces risk, develops resilient social systems, improves the environment, increases economic resources, and enhances governance and institutions.³⁰ It can be difficult to distinguish climate adaptation from related activities, such as reducing risk to environmental disasters or alleviating poverty, which complicates attribution of successful adaptation efforts. The IPCC (2023), states incorporating climate adaptation into sustainable development strategies will result in win-win solutions.

While many adaptation responses are designed to reduce the impacts of climate change, the implementation of adaptation strategies should be consistent with typical coastal hazard mitigation strategies, as well as with wider societal and development objectives; hence, an integrated coastal management philosophy is required.³¹ The research suggests there is little consensus on what counts as effective adaptation in practice. One reason is that adaptation initiatives are often proposed and planned but rarely implemented on an effective timescale.³² Barriers that routinely impede adaptation efforts include insufficient resources, prohibitive policies, competing or conflicting priorities for action, and uncertainty about future changes.³³ This type of evaluative policy framework helps identify and address potential barriers to climate change adaptation, providing a systematic approach for decision-making support.

³⁰ Owen, G. (2020). *What makes climate change adaptation effective? A systematic review of the literature*. Global Environmental Change-human and Policy Dimensions, 62, 102071. <https://doi.org/10.1016/j.gloenvcha.2020.102071>.

³¹ Nicholls, R. (2011). *Planning for the impacts of sea level rise*. Oceanography, 24, 144-157. <https://doi.org/10.5670/OCEANOLOG.2011.34>.

³² Mimura, Nobuo, et al. *Adaptation planning and implementation*. Climate change 2014 impacts, adaptation and vulnerability: Part A: Global and sectoral aspects. Cambridge University Press, 2015. 869-898.

³³ Moser, S., & Ekstrom, J. (2010). *A framework to diagnose barriers to climate change adaptation*. Proceedings of the National Academy of Sciences, 107, 22026 - 22031. <https://doi.org/10.1073/pnas.1007887107>.



Barriers to climate change adaptation are often institutional and social, but their definition and assessment are limited.³⁴

Assessing the effectiveness of climate adaptation involves evaluating how well adaptation actions achieve their intended goals. This type of assessment requires a comprehensive approach, combining quantitative and qualitative methods, and considering various dimensions such as environmental, social, and economic outcomes. By systematically applying an evaluation and monitoring process, policymakers, practitioners, and researchers can effectively assess the outcomes of climate adaptation initiatives, identify areas for improvement, and enhance the overall resilience of communities and ecosystems to climate change.³⁵ A necessary, but often missing, component of adaptation planning and implementation involves the strategic assessment of plan outcomes and impacts.

The evaluation of climate adaptation effectiveness relies on a broader strategy that integrates technology, human and economic development, and acknowledges uncertainty.³⁶ A common perspective on climate change adaptation assumes the local government is responsible for implementing technological adaptation measures, chosen based on specific predictions of future climate conditions. This view has been widely challenged but is still prevalent within sectors dominated by engineering, such as water and coastal management. Technology has an important part to play in climate adaptation, however the value of technology relies on it being part of a broader strategy that acknowledges uncertainty and addresses the underlying drivers of people's current and future vulnerability (Klein, 2020). The heavy reliance on technology requires the balanced integration of adaptation with human and economic development

³⁴ Biesbroek, G., Klostermann, J., Termeer, C., Kabat, P., & Kabat, P. (2013). *On the nature of barriers to climate change adaptation*. *Regional Environmental Change*, 13, 1119-1129.

<https://doi.org/10.1007/s10113-013-0421-y>.

³⁵ Lebbe, T., Rey-Valette, H., Chaumillon, E., Camus, G., Almar, R., Cazenave, A., Claudet, J., Rocle, N., Meur-Férec, C., Viard, F., Mercier, D., Dupuy, C., Ménard, F., Rossel, B., Mullineaux, L., Sicre, M., Zivian, A., Gaill, F., & Euzen, A. (2021). *Designing Coastal Adaptation Strategies to Tackle Sea Level Rise*. *Frontiers in Marine Science*. Vol. 8. DOI=10.3389/fmars.2021.740602. ISSN=2296-7745

<https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2021.740602>

³⁶ Klein, R. (2020). *Adaptation to climate change*. ECLAC Books. https://doi.org/10.1007/978-94-007-1770-1_9.



efforts that result in multi-sectoral benefits to a broad swath of the economy and community.

Climate change adaptation indicators and metrics are valuable tools that should incorporate best practices from evaluation and science-practice interaction for effective evaluation and informed decision-making. Indicators and metrics (I&M) can be used to evaluate the success of climate change adaptation implementation. Cities are among the leading experimenters developing I&M as a tool for providing clarity and accountability about the goals and progress of adaptation.³⁷ Numerous definitions of indicators and metrics exist in the literature on monitoring and evaluation. Arnott, et al (2016), define an indicator as quality or trait that suggests (“indicates”) effectiveness, progress, or success and a metric as a variable that can be measured (if quantifiable) or tracked (if qualitative) that represents the indicator. These definitions are useful in the development of policy evaluation frameworks and programs.

Adaptive Management-Dynamic Adaptive Policy Pathways (DAPP)

Effective climate adaptation could benefit from developing and implementing dynamic adaptation strategies to sea level rise over time in order to plan for uncertainty. By testing different pathways against different scenarios, dynamic management approaches support the development of signals and decision triggers for taking anticipatory action and articulate temporal scales to move toward desirable futures.³⁸ Despite advances in long-range climate modeling projections, it will be difficult to anticipate societal advances and changes to norms, especially beyond the year 2050 timeframes. Therefore, it will be necessary to adapt under large uncertainty and over time frames beyond 2050, thus calling into question planning and decision-making

³⁷James C. Arnott, Susanne C. Moser, Kristen A. Goodrich, *Evaluation that counts: A review of climate change adaptation indicators & metrics using lessons from effective evaluation and science-practice interaction*. Environmental Science & Policy, Volume 66, 2016, Pages 383-392, ISSN 1462-9011, <https://doi.org/10.1016/j.envsci.2016.06.017>.

³⁸ Bongarts Lebbe T, et al. (2021). *Designing Coastal Adaptation Strategies to Tackle Sea Level Rise*. Front. Mar. Sci. 8:740602. doi: 10.3389/fmars.2021.740602



practices as they are conceived today.³⁹ Academic research on adaptation pathways suggests adaptation pathways can meet short and long-term needs, promote collaborative learning, and account for complexity and long-term change, but their utility in different decision contexts remains untested and unclear.⁴⁰

One method of adaptation planning includes Dynamic Adaptive Policy Pathways (DAPP). DAPP is a decision-making framework designed to manage uncertainties in long-term planning helping overcome policy paralysis due to deep uncertainty. It emphasizes the need for flexible, adaptive strategies that can evolve over time in response to changing conditions and new information. Haasnoot, et al, (2013) based the DAPP framework on two complementary approaches for designing adaptive plans: ‘Adaptive Policymaking’ and ‘Adaptation Pathways’. Adaptive Policy making is a theoretical approach describing a planning process with different types of actions and signposts to monitor to see if adaptation is needed. In contrast, Adaptation Pathways provide an analytical approach for exploring and sequencing a set of possible actions based on alternative external developments over time. Dynamic adaptive policy pathways are strategies that can be changed over time to deal with uncertainties in a changing environment, such as climate change, land use, and policy efficacy. Given the pathways and signposts, decision-makers can make an informed decision on a dynamic adaptive plan in a changing environment that is able to achieve their intended objectives despite the myriad of uncertainties.⁴¹ The DAPP approach is particularly useful in contexts such as climate change adaptation, where future conditions are highly uncertain and traditional static planning methods may fall short.

A key component of DAPP is to monitor indicators and thresholds of change such as flooding and storm events, which can trigger timely adaptive actions (change

³⁹ Haasnoot, M., Kwakkel, J. H., Walker, W. E., and ter Maat, J. (2013). *Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world*. *Glob. Environ. Change* 23, 485–498. doi: 10.1016/j.gloenvcha.2012.12.006

⁴⁰ Werners, S., Wise, R., Butler, J., Totin, E., & Vincent, K. (2021). *Adaptation pathways: A review of approaches and a learning framework*. *Environmental Science & Policy*. <https://doi.org/10.1016/j.envsci.2020.11.003>.

⁴¹ Kwakkel, J., Haasnoot, M., & Walker, W. (2015). *Developing dynamic adaptive policy pathways: a computer-assisted approach for developing adaptive strategies for a deeply uncertain world*. *Climatic Change*, 132, 373-386. <https://doi.org/10.1007/s10584-014-1210-4>.



pathway/behavior) ahead of these thresholds. Signals and triggers are needed to support DAPP—the signal provides early warning of the emergence of the trigger (decision-point), and the trigger initiates the process to change pathway before a harmful adaptation-threshold is reached.⁴² By integrating with other decision-making methods and involving stakeholders, DAPP provides a flexible and effective approach to addressing complex, uncertain challenges such as climate change adaptation. By considering a wide range of future scenarios and maintaining flexibility in decision-making, DAPP helps ensure that adaptation strategies remain effective and responsive to changing conditions.

Pathway analysis is a low-cost tool to define long-term adaptation responses that provide a positive approach to reduce coastal risks and minimize ineffective investments and social inequities. It enables adaptation to SLR over time and allows for alternative pathways.⁴³ This approach aims at defining the triggers and benchmarks or “solution space” to accelerate climate change adaptation, defined by Haasnoot et al. (2020) as “the space within which opportunities and constraints determine why, how, when, and who adapts to climate risks.” The solution space is shaped in an integrative approach, taking into account biophysical, cultural, socio-economic, and political-institutional dimensions at a given moment in time. Haasnoot et al. (2021) show that the space for available solutions is shrinking and that managed retreat is often emerging as the main remaining response.⁴⁴

⁴² Stephens, S., Bell, R., & Lawrence, J. (2018). *Developing signals to trigger adaptation to sea-level rise*. Environmental Research Letters, 13. <https://doi.org/10.1088/1748-9326/aadf96>.

⁴³ Haasnoot, M., Biesbroek, R., Lawrence, J., Muccione, V., Lempert, R., and Glavovic, B. (2020). *Defining the solution space to accelerate climate change adaptation*. Regional Environ. Change 20:37. doi: 10.1007/s10113-020-01623-8

⁴⁴ Haasnoot, M., Lawrence, J., and Magnan, A. K. (2021). *Pathways to coastal retreat*. Science 372:1287. doi: 10.1126/science.abi6594



PRELIMINARY ADAPTATION ROADMAP

This adaptation roadmap serves as preliminary guidance to support policymakers, planners, local government and community leaders in developing robust, equitable, cost effective and sustainable climate change adaptation strategies for Waikīkī. Adaptation planning requires a flexible approach and emphasizes the importance of integrating scientific knowledge with local context to develop comprehensive adaptation plans. This roadmap is not intended to serve as an authoritative implementation strategy for climate change adaptation in Waikīkī but instead introduces potential conceptual strategies and pathways to be developed further with local stakeholders prior to implementing adaptation in Waikīkī. A comprehensive adaptation strategy for Waikīkī requires more extensive interagency coordination, community engagement and detailed planning and design, which should be implemented in a subsequent phase.

This preliminary roadmap provides a conceptual framework for adaptation planning and implementation based on a review of academic research and adaptation planning literature and case studies. This information provides a foundation for future adaptation planning and implementation efforts in Waikīkī. The initial adaptation framework provided here, underscores the need for developing an integrated, interdisciplinary and collaborative approach involving stakeholders at all levels to ensure the effective implementation of adaptation strategies. Effective adaptation in Waikīkī will require dynamic, inclusive, and multi-sectoral planning processes, which will be essential in the next phase of developing detailed implementation strategies tailored to Waikīkī's specific needs, vulnerability and risk tolerance. This initial phase of the implementation roadmap aims to identify potential adaptation pathways, timelines, triggers, critical gaps and opportunities, emphasizing the necessity of continued collaboration and comprehensive planning to develop a robust adaptation framework in the next phase, as supported by the research cited in this document.



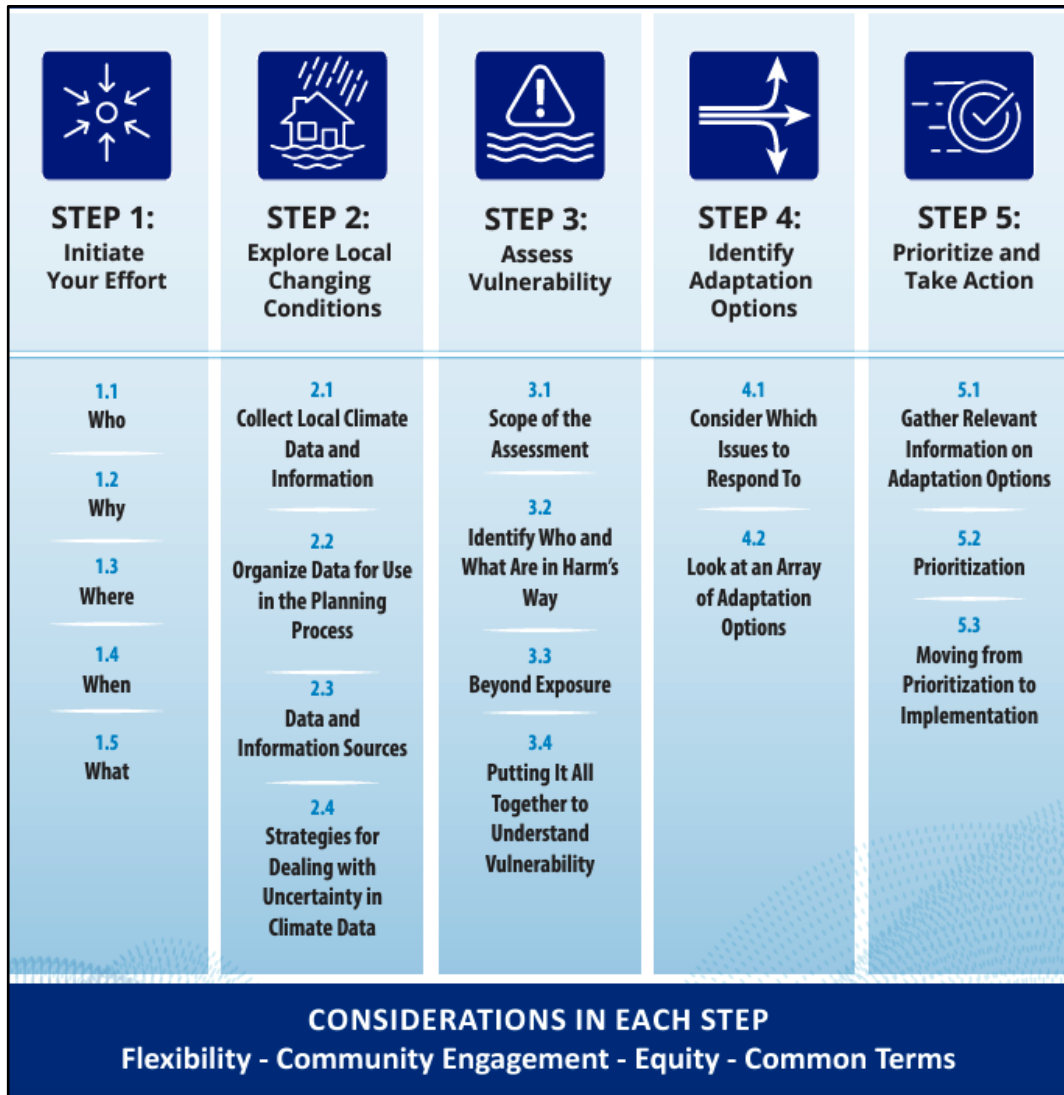


Figure 1. Five Step Adaptation Planning Process. Credit: NOAA, 2023

The National Oceanic and Atmospheric Administration (NOAA), developed a five-step coastal adaptation planning guide to support local communities in adapting to climate change which includes tips and ideas to consider along the way and a collection of informational resources and references (Figure 1).⁴⁵ This document is part of a suite of reference material that can support adaptation planning in Waikīkī using recognized and established frameworks and approaches with demonstrated success. This

⁴⁵ National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management. *Coastal Adaptation Planning Guide: Five Steps for Beginners*. May 2023. Charleston, SC: NOAA.

reference document reinforces several of the key highlights for the Waikīkī adaptation roadmap below and serves as a conceptual example for the adaptation planning process. The Waikīkī adaptation planning process may already be somewhere around step 4 of this conceptual framework, having largely completed the vulnerability assessment for natural hazards for Waikīkī and well into the identification of adaptation options.

KEY MESSAGES - Waikīkī Implementation Roadmap

Adaptive and Flexible Approach:

- This adaptation framework emphasizes a flexible, adaptive management approach to accommodate the evolving nature of climate impacts. This involves regularly updating plans and strategies based on new data, scientific advancements, and stakeholder feedback.
- Develop multiple adaptation pathways and overlapping implementation timeframes that can be adjusted as conditions change, and identify adaptation tipping points, triggers and thresholds where current measures may need to be re-evaluated. These triggers should be founded on community priorities and values.
- Robust monitoring and evaluation ensures that adaptation measures remain relevant and effective under various future climate scenarios, enhancing Waikīkī's resilience to unexpected changes and maximizing the return on investment for innovative or new technologies.
- The framework allows for proactive adaptation, allowing for long-term cost savings through a focus on co-benefits to the community and reducing the risk of missed opportunities for adaptation, or even maladaptation where poorly planned and uncoordinated actions can result in increased vulnerability.



- Post-disaster recovery is an often-cited example of a major adaptation trigger in many coastal communities. Having a well-developed disaster recovery plan in place before a major disaster is crucial for implementing resilient and sustainable post-disaster recovery.
- Waikīkī has a pilot Pre-Disaster Recovery planning initiative conducted through a partnership between the Waikīkī Business Improvement District Association (WBIDA) and the National Disaster Preparedness Training Center (NDPTC) at the University of Hawaii at Manoa⁴⁶. The Project aims to increase the understanding of recovery needs in Waikīkī and build momentum for planning prior to a disaster. but this plan has not yet been promulgated into law with enacting rules.
- Having a robust adaptation planning framework in place can allow landowners, other stakeholders, and agencies to consider expected lifespans of buildings and infrastructure to time adaptation actions with intended upgrades and redevelopment (i.e., “dig once”).

Integration of Local Context and Scientific Knowledge:

- The Waikīkī adaptation plan should integrate progressive and regularly updated scientific data with local socio-cultural/ecological knowledge and application to geographical contexts that tailor adaptation strategies to Waikīkī’s unique conditions, risk tolerances, economic considerations and long-range development priorities and timeframes.
- This integrated approach ensures that adaptation measures are culturally appropriate, locally relevant, economically viable and supported by the community, leading to more effective and sustainable outcomes.

⁴⁶ <https://sites.google.com/site/waikikirecoveryplanning/>

Multi-Sectoral Collaboration and Inclusive Planning:

- Effective adaptation planning for Waikīkī requires collaboration across multiple sectors, including government agencies, local businesses, community groups, non-profit groups and researchers.
- Establish cross-sector partnerships to coordinate efforts, share resources, and align policies and strategies. Ensure inclusive planning that addresses the needs of a broad swath of the community as well as the integration of long-range economic and development plans.
- Coordinate adaptation efforts to maximize resilience, sustainability and economic benefits and leverage funding opportunities and infrastructure maintenance funds to enhance resilience efforts.

Comprehensive Monitoring, Evaluation, and Feedback Mechanisms:

- Continuous monitoring and evaluation are essential for assessing the effectiveness of adaptation measures and making necessary adjustments to changing conditions, policies and economy.
- Establish indicators and metrics to track progress, acknowledge, prioritize and inform adaptation triggers and thresholds and implement feedback mechanisms that allow for real-time adjustments based on monitoring results. This enables adaptive management, ensuring that strategies remain effective over time and can be modified in response to new challenges and opportunities.

The adaptation planning framework for Waikīkī requires a flexible approach to accommodate the uncertainties and evolving nature of climate change impacts. Integrating scientific knowledge of climate impacts with the unique local socio-cultural and geographical context can facilitate robust, adaptive strategies which support community goals and values. This approach ensures that adaptation measures are



relevant, effective, and equitable, addressing both immediate vulnerabilities to coastal hazards and emerging long-term resilience and sustainability needs. By incorporating monitoring and feedback mechanisms with adaptive management principles, the framework allows for continuous learning and adjustment, enhancing Waikīkī's capacity to respond to growing challenges posed by climate change and sea level rise.

Adaptation Triggers and Thresholds

Adaptation triggers and thresholds are specific conditions or events that prompt the need for adjusting or implementing new adaptation measures in response to climate change. Adaptation triggers are critical components in dynamic adaptation planning as they signal when current strategies will likely become ineffective or when additional actions are necessary to address emerging climate risks. Triggers should be developed in partnership with the communities they impact and should be specific, measurable observations founded in robust data and quantitative methods. It is important to recognize the advantages of proactive implementation of adaptation strategies well before the onset of drastic triggers. Conceptualizing a “window of opportunity” for adaptation is important to incorporate into the triggers and thresholds concept. Specific adaptation pathways for Waikīkī should include clear thresholds for action based on established triggers and highlight the precursors to the final thresholds while acknowledging a necessary degree of indeterminacy (Figure 2).



Waikīkī Resilience & Sea-Level Rise Adaptation Project (WRAP)

Preliminary Conceptual Adaptation Roadmap

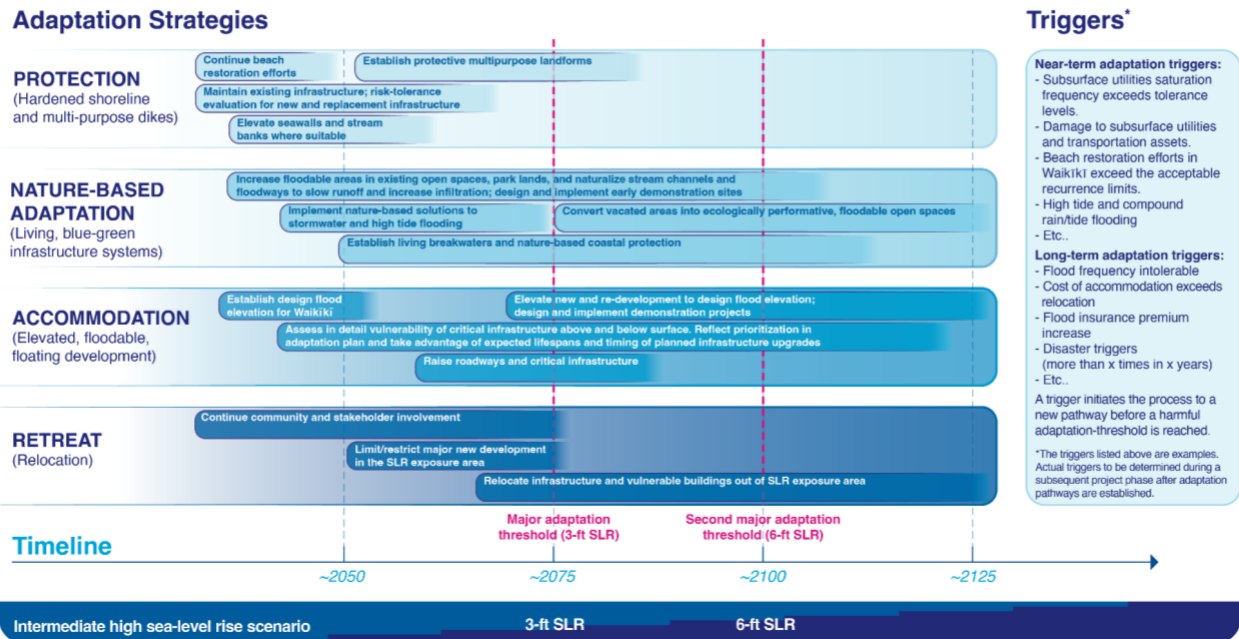


Figure 2. Preliminary Conceptual Adaptation Roadmap for Waikīkī

The goal of the WRAP is to provide the conceptual framework and context for the next phase of adaptation and resilience planning and design for Waikīkī. As part of the subsequent comprehensive planning process, it is envisioned there will be a continuation and refinement of the implementation roadmap that is presented in Figure 2. Subsequent iterations of these types of timelines should include more detailed assessment and development of the specific triggers for phased adaptation strategies including implementation solutions, techniques, and practices for Waikīkī, estimated costs, complexity and implementation and design lifetime horizons as some examples of future adaptation planning research needs.

An adaptation threshold is a specific point or condition beyond which impacts or risks to people, buildings, and infrastructure, including any previous climate adaptation measures, become intolerably high or unsafe. Adaptation thresholds mark the limits of existing adaptation measures, indicating when they need to be revised or replaced due



to changing climate impacts. Approaching or crossing an adaptation threshold typically triggers the need for new or adjusted strategies to manage the increased risks or changes in conditions. Adaptation thresholds for Waikīkī should be regionally specific and locally supported and identified based on the capacity of current systems to cope with stressors and are based in an established risk tolerance framework. Common adaptation triggers for application in Waikīkī may include, but are not limited to the following categories of triggers.

Environmental Triggers

- **Sea-Level Rise:** Specific thresholds of sea-level rise, such as a 3-foot and 6-foot above mean sea level thresholds or other similar predefined elevations. The science for predicting future water levels continues to improve and may trigger the need for shifts in adaptation pathway implementation timeframes for increased coastal restoration, protection, accommodation or relocation in vulnerable areas.
- **Flood Frequency Thresholds:** Exceeding specific flood frequency thresholds, like an average annual flood event with a defined statistical probability (e.g. 1% annual probability). These need to be location-specific to apply to different areas of Waikīkī. Establishing a design flood elevation is a common way to apply the flood frequency to an elevation and should consider compounding effects of sea level rise and rainfall flooding⁴⁷.
- **Relative Flood Risk:** This is described in the *Adapt Waikīkī 2050* Climate Risk Profiles.⁴⁸ Climate risk thresholds for Waikīkī are estimated using regional and

⁴⁷ Meguro, W.; Briones, J.; Failano, G.; Fletcher, C.H. 2024. *A Science and Community-Driven Approach to Illustrating Urban Adaptation to Coastal Flooding to Inform Management Plans*. Sustainability, 16, 2849. <https://doi.org/10.3390/su16072849>

⁴⁸ 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



local projections for key climate hazards. A climate risk threshold is defined as the decade that separates a period of relatively stable and minimal risk from one of rapidly increasing risk (Courtney et al. 2024).

- For episodic and chronic flooding, the estimated threshold decade is based on the sea level rise projection in which the area flooded is three times that of the preceding decade.
 - For annual high wave-driven flooding and groundwater inundation, the risk threshold is 3 feet of sea level rise beginning in 2070.
 - For passive flooding and storm drain backflow, the risk threshold is 4 feet of sea level rise beginning in 2080.
 - Groundwater inundation poses the greatest risk in terms of flood extent and flood depth by compounding other flood risks, including rainfall flooding.
- **Precipitation Changes:** Significant deviations in precipitation patterns and trends, such as a significant increase in annual rainfall, could shift timing of triggers to improve stormwater management systems, enhance flood resilience, or adjust design flood elevation policies.

Socio-Economic Triggers

- **Economic Losses:** When economic damages from climate impacts (e.g., from storms or flooding) reach a certain financial threshold, it may prompt the implementation of new financial protection measures, such as insurance programs or disaster funds.⁴⁹

Planning and Permitting under Contract No. CT-DPP-2300252. <https://ssfm.konveio.com/adapt-Waikīkī-factsheet>

⁴⁹ Lawyer, C.; An, L.; Goharian, E. A Review of Climate Adaptation Impacts and Strategies in Coastal Communities: From Agent-Based Modeling towards a System of Systems Approach. *Water* **2023**, *15*, 2635. <https://doi.org/10.3390/w15142635>



- **Public Health Indicators:** Increases in climate-related health issues, such as a rise in heat-related illnesses or vector-borne diseases, can trigger public health interventions or modifications to storm-water infrastructure.

Infrastructure and Systemic Triggers

- **Infrastructure Performance:** Deterioration in the performance of critical infrastructure (e.g., roads, bridges, or water supply systems) due to climate impacts can trigger the need for retrofitting or redesigning to enhance resilience or eventually relocating (Lawyer and Goharian, 2024).
- **Service Interruptions:** Repeated or prolonged interruptions in essential services (e.g., power, wastewater, transportation, or communication) can necessitate the protecting, accommodating or upgrading these systems to improve reliability and resilience.
- **Post-disaster Recovery:** Disaster recovery is an often-cited example of a major adaptation trigger in many coastal communities, particularly when a federal disaster is declared which tends to bring more recovery resources that expedite recovery.

Ecosystem Health Triggers

- **Biodiversity Loss:** Biologically diverse communities are more ecologically resilient. Significant declines in biodiversity or the health of key ecosystems, such as coral reefs, beaches, and wetlands, can trigger conservation and restoration efforts to maintain ecosystem services (Lebbe. et al, 2021).
- **Groundwater Contamination:** Increased severity of groundwater contamination and subsurface infrastructure damage due to increased saturation and salinity with sea level rise.

Policy and Governance Triggers

- **Regulatory Changes:** New regulations related to climate change can trigger updates to local adaptation policies or the introduction of new compliance measures (Lawyer and Goharian, 2024).
- **Funding Structure and Availability:** Access to new funding sources or changes in financial support for adaptation projects can trigger the initiation of planned adaptation actions or the scaling up of existing measures.
- **Insurance Availability:** Updated insurance policies, costs, and availability may limit coverage for some policy-holders due to increased risk. This might serve as a trigger for different accommodation/retreat strategies or a shorter timeline for adaptation measures.

Adaptation Implementation Measure (AIM)

Adapting to climate change before reaching critical triggers and thresholds is essential for mitigating severe impacts and avoiding the substantial costs of emergency disaster responses in Waikīkī. Utilizing proactive *Adaptation Implementation Measures (AIMs)* to address the impacts of climate change emphasizing early and proactive efforts to enhance resilience well in advance of the onset of the trigger. Proactive AIMs are typically more cost-effective than reactive responses, can enhance community resilience, safeguard vital infrastructure, and protect ecosystems from long-term degradation. Proactively adapting to climate change before critical triggers and thresholds occur is consistent with the land use planning precautionary principle and allows for the implementation of flexible, multi-sectoral strategies that enhance resilience. Anticipating and adapting to climate change before critical thresholds and triggers are reached allows for more strategic, cost-effective, and flexible responses,



ultimately leading to better long-term outcomes for communities and ecosystems (Lebbe. et al, 2021).

Adaptation triggers and thresholds serve as key signals for when to adjust current strategies or implement new ones in response to evolving climate conditions. By monitoring environmental, socio-economic, infrastructure, ecosystem, and policy indicators, decision-makers can proactively manage risks and ensure that adaptation measures remain effective and responsive to changing circumstances using pre-established metrics for action. Having built-in evaluation metrics and monitoring systems for the triggers is crucial for the successful implementation of adaptation plans and the associated thresholds and triggers.



CONCLUSIONS

A flexible adaptation pathways framework is introduced to support resilient and effective adaptive planning for Waikīkī. Adaptation pathways are one planning framework, providing 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 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. 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. Adaptation pathways involve the development of flexible, long-term plans that consider multiple potential future scenarios of climate change and their associated impacts.

The implementation of adaptation strategies should be consistent with typical coastal hazard mitigation strategies, as well as with wider societal and development objectives utilizing an integrated adaptation management framework. Barriers that routinely impede adaptation efforts include insufficient resources, prohibitive policies, competing or conflicting priorities for action, and uncertainty about future changes. Continuous monitoring, flexible strategies, and inclusive planning are crucial for effective adaptation to climate change. 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.



