MANAGED RETREAT AS A STRATEGY TO MITIGATE SEA LEVEL RISE IMPACTS IN HAWAIʻI

A THESIS SUBMITTED FOR PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

GLOBAL ENVIRONMENTAL SCIENCE

DECEMBER 2024

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For my mom, sisters, friends, and family abroad, thank you for your support throughout my college journey. I greatly appreciate all your encouragement while I completed my degree and this thesis, I hope I have made you all proud.

ACKNOWLEDGEMENTS

Thank you to Dr. Charles Fletcher and Dr. Juliette Budge with the Climate Resilience Collaborative for advising me throughout the completion of this thesis. I am grateful they introduced the topic of managed retreat to me as it incorporates my educational interests in environmental science and urban planning. Also, I would like to acknowledge Nancy McPherson with the Planning Office at the Department of Hawaiian Home Lands (DHHL) whom I was partnered with after securing a Keala Internship. My time as Nancy's intern inspired the section of reviewing local climate action plans in this thesis. I am also grateful for the advice and support Nancy has shown me during my consideration of pursuing a master's degree with the Department of Urban and Regional Planning at University of Mānoa. Lastly, I would like to acknowledge Sarah Chang at the Hawai‘i Coastal Zone Management Program (CZM) whom I worked closely with as a GIS intern. My time at CZM showed me how governmental agencies collaborate on environmental issues, something I kept in mind when completing this thesis.

ABSTRACT

Sea levels are projected to rise and remain elevated for centuries to millennia, even with efforts to mitigate carbon emissions. The foremost impacts of rising sea levels are felt by low-lying coastal communities. Coastal erosion, among these impacts, is already significant, particularly affecting Hawaiian beaches. Strategies like protective and accommodative measures are employed to counteract the effects of sea level rise, yet they may prove inadequate and could exacerbate beach loss. Research by Summers et al. (2018) indicated that erosion had claimed 19% of Hawai‘i’s beaches by 2015. In order for a beach to survive, it must be able to migrate landward unimpeded. The State of Hawai‘i bears a constitutional responsibility to preserve its natural resources, including beaches, for current and future generations. However, state and local government policies have placed more effort on asset management rather than beach protection and preservation in response to sea level rise; consequently, failing in their constitutional duty to preserve Hawai‘i’s beaches. Managed retreat is the strategic and purposeful relocation or abandonment of structures to manage the risk of natural hazards and utilize an avoidance strategy to eliminate risk. Successful implementation of managed retreat policies in Hawai‘i could safeguard the public from hazards and facilitate natural beach replenishment through shoreline recession; and allow the State to fulfill their constitutional obligations.

Keywords: Sea level rise, managed retreat, erosion, coastal hazards, mitigation

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1.0 INTRODUCTION

According to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), Working Group I has high confidence that sea level will continue to rise for centuries to millennia due to continuing deep-ocean warming and ice sheet melt and will remain elevated for thousands of years (IPCC, 2021). Sea level rise (SLR) will continue to drive changes in our built and natural environment into the foreseeable future. SLR amplifies coastal hazards such as storm surge, wave impacts, erosion, and other types of flooding related to groundwater and extreme tides as well as rain. Current adaptation approaches that take on protective and accommodating measures against SLR impacts may be inadequate in the long-term. Decision-makers and stakeholders must seek effective solutions that reflect these characteristics.

SLR is a threat to Hawai‘i’s shorelines and beaches as it can intensify coastal erosion. SLR drives shoreline retreat, or land loss, and threatens human communities and infrastructure and other assets. In response, a common practice is to harden the shoreline with walls. However, in order for a beach to survive under SLR, the shoreline needs to migrate landward. Hardening the shoreline with walls leads to beach erosion and eventually beach loss (Fletcher et al., 2010). Under natural conditions shoreline retreat releases sand from deposits located landward of the beach, which nourishes the beach as it adjusts landward with the rising water. Shoreline hardening interrupts this process creating a sand deficiency that drives beach loss.

Stakeholders of coastal communities are conflicted on what actions should be prioritized regarding coastal management as there are multiple assets that require protection from coastal hazards. Along with beaches, SLR threatens other natural

resources, homes, infrastructure above and below ground, and ultimately, the State's economy (Lee, 2020, Habel, 2023). Some of these assets are immediately threatened, driving community reaction without the benefit of long appropriate planning. How should stakeholders proceed? "Protection" is typically achieved by hardening a shoreline with seawalls and revetments (sloping walls). "Accommodation" involves elevating community assets to mitigate flooding and other strategies. "Retreat" employs the avoidance of a hazard as a strategy to mitigate SLR impacts. Protection and accommodation are the most utilized adaptation approaches, but they are insufficient to combat the impacts of long-term SLR and will keep communities at risk. Retreat is often overlooked due to its implications of abandoning property which is not appealing to most stakeholders and the affected communities.

Engineered protective structures, such as seawalls and revetments, have historically been the popular choice to combat coastal erosion. Ironically, these structures inevitably worsen erosion on both neighboring coastal properties and the adjoining beach through a process called flanking. By 2015, protective structures had resulted in a loss of 19% of the length of beach on Kauai, Oahu and Maui (Summers et al., 2018). In addition to worsening erosion, these structures will require frequent maintenance to efficiently combat the intensifying coastal conditions, driving up the costs overtime (Hino et al., 2017). These structures often fail during storms and high surf and are therefore not a long-term solution for protecting the land and assets along the coast. Since sea level will continue to rise and remain elevated past human lifetimes, coastal communities are best served by developing adaptation strategies that will ensure the long-term survivability of public trust lands and other assets. Retreat is the subject of this thesis and will be

examined in more detail in the following sections. Implementing retreat policies successfully in Hawai‘i could ensure natural beach replenishment through shoreline recession and safeguard the public from SLR related hazards.

1.1 INTRODUCTION TO MANAGED RETREAT

Managed Retreat is the permanent relocation of assets after repeated exposure to natural hazards (Doberstein et al., 2019). Both managed and unmanaged retreat are employed in the case of mitigating SLR and flooding impacts. Unmanaged or forced retreat is a reactive form of retreat where affected individuals move away from their damaged property after a natural disaster. Most often this form of retreat does not receive any institutional support unless the disaster had been declared by the U.S. president in that case the Federal Emergency Management Agency (FEMA) will then fund recovery efforts (Siders, 2019). Managed retreat on the other hand is the strategic and purposeful relocation or abandonment of assets to manage natural hazard risks (Mach et al., 2019, Hino et al., 2017). Using a retreat approach to combat coastal hazards may be considered an ideal option in the long term as it permanently removes valuable assets away from risks (Hino et al., 2017).

Managed retreat comes with challenges. Compared to protection and accommodation, managed retreat typically minimizes financial burdens once implemented, but can be the costliest option upfront. According to Setter et al. (2023), an all-at-once retreat approach for Sunset Beach, a neighborhood on the North Shore of O‘ahu, HI that is experiencing extreme coastal erosion, is estimated to cost between $207 and $333 million primarily due to property acquisition (Setter et al., 2023). This high cost

drives the use of more affordable protective structures in the short-term. As pointed out earlier, shoreline hardening, the most common form of protection, causes beach loss and accelerated erosion which are often overlooked in lieu of benefits gained by land protection. That is, the protection of private property becomes an implicit choice that supersedes the public trust right of access to and along the shoreline afforded by beaches. This public trust doctrine is embodied in several legal decisions in Hawaiian law as summarized by Lee (2020). This is discussed in more depth later. A reluctance to abandon coastal lands and funding have emerged as the biggest challenges in implementing managed retreat. Protecting and conserving beaches affects the entire coastal community and ecosystem, potentially leading to a healthier and more protected environment. Other difficulties in retreat implementation include addressing social equity issues, cultural impacts on displaced/relocated communities, and legal obstacles (Mach et al., 2019).

1.2 BACKGROUND ON SEA LEVEL RISE

As of July 23, 2024, the global average rate of SLR is 3.6 ± 0.3 mm/year, with an estimated acceleration of 1.2 ± 0.5 mm/year per decade (https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level.html, accessed July 30, 2024). Satellite altimetry missions have monitored global mean sea level (GMSL) since 1993, revealing a consistent and accelerating trend in SLR. The main factors driving this rise, listed in order of their contribution from highest to lowest, are melting ice sheets, thermal expansion, vertical land movement, and groundwater mining (Hamlington et al., 2020).

Melting glaciers and ice sheets are the leading contributors to sea-level change. Increased CO2 emissions have intensified warming, threatening the stability of the world's largest ice sheets and raising the likelihood of higher sea levels throughout the 21st century and beyond (Sweet et al., 2022). Warming in both the atmosphere and ocean drives ice melt and instability in the Greenland Ice Sheet and the West Antarctic Ice Sheet. According to Working Group I of the Sixth Assessment Report, ice loss in the 21st century is virtually certain for the Greenland Ice Sheet and likely for Antarctica's Ice Sheet (IPCC, 2021). The Greenland Ice Sheet is particularly vulnerable to warming conditions, which threaten its stability and lead to significant ice mass loss and runoff into the ocean. Ice melt from this region contributes approximately 20% (0.60 ± 0.04 mm/year) to the sea-level budget (Horwath et al., 2022). This contribution is driven by anthropogenic global warming, Arctic amplification, and changing atmospheric circulation patterns that promote increased melting and instability (Pattyn et al., 2018). Boschow et al. (2023) find that the critical threshold for global mean temperatures affecting the Greenland Ice Sheet lies between 1.7°C and 2.3°C; breaching this threshold could result in SLR contributions exceeding several meters, although complete ice loss could be mitigated by immediate cooling after surpassing the threshold (Armstrong et al., 2022).

For the West Antarctic Ice Sheet, deep-ocean warming poses a significant threat, particularly to the Pine Island and Thwaites Glaciers, which are among the most unstable in the region. Substantial ice loss in the Antarctic Ice Sheet is primarily driven by increasing discharge of grounded ice into the ocean. Warm circumpolar deep water is advancing into ice shelf cavities, thinning these shelves and leading to marine ice sheet

instability and potential disintegration (Pattyn et al., 2018). Outlet glaciers act as critical anchors for the entire ice sheet; if the grounding support for these glaciers fails, it could trigger the collapse of the entire ice shelf into the ocean, contributing to multi-meter SLR. Sediment records indicate that the collapse of the West Antarctic Ice Sheet has occurred in the past, resulting in sea levels that surpassed current levels.

The Pine Island and Thwaites Glaciers are two critical glaciers that scientists are closely monitoring to assess the state of the West Antarctic Ice Sheet. Due to gaps in understanding the relationship between ice sheet processes and long-term ocean dynamics, modeling scenarios for these glaciers remain limited, contributing significant uncertainty to sea-level rise (SLR) projections. Recent studies suggest that even if there is a transition to cooler deep-water circulation in the Antarctic, the ungrounding of ice sheets from warm water circulation may only mark the beginning of further disintegration. This process can trigger ice sheet dynamics that lead to instability in the ice shelf, independent of warm water influences. Consequently, modeling long-term SLR is complicated by this behavior. Some researchers indicate that the outlet glaciers, such as Pine Island and Thwaites, may be approaching a tipping point where their disintegration could accelerate global sea-level rise sooner than previously anticipated (Pattyn et al., 2018; Robel et al., 2019; Rosier et al., 2021); the SLR High scenario of 7.90 ft from the Honolulu tide gauge tool from **Figure** 3 is a representation of this possibility.

Thermal expansion is the next major contributor after melting glaciers and ice sheets, that contribute to global SLR. As a result of warming ocean waters as global average temperatures increase, thermal expansion of the ocean water creates a rise in volume that contributes to higher sea levels. IPCC (2021) estimates that thermal

expansion accounts for about 30% of the observed SLR since 1993. With rising global temperatures, ocean temperatures have also increased, particularly in surface waters, leading to further expansion. A study by Nicholls et al. (2018) emphasizes that thermal expansion is expected to persist as global temperatures continue to rise, intensifying the effects of climate change on coastal areas. This ongoing warming not only raises sea levels but also increases the risks of flooding and coastal erosion, threatening both ecosystems and human infrastructure (Hansen et al., 2016).

Vertical land movement is another factor that contributes to global SLR and is critical to understand regional sea level (RSL) trends. In certain regions, the post-glacial rebound of the Earth's crust results in a decrease in relative sea level of approximately 10 mm per year (Hamlington et al., 2020). As glaciers on land melt, the crust slowly rises, creating an imprint that influences local sea levels. Incorporating this land adjustment into calculations of SLR is essential for accurate assessments. Vertical land movement is highly localized, leading to regional variations in its impact on global SLR. Tide gauges anchored to a fixed land reference can account for both vertical land movement and SLR, providing RSL specific to each location. These gauges reveal diverse RSL trends worldwide; in areas where crustal adjustments are significant, sea-level changes tend to be slower and may even appear to decline. In Hawaii, six tide gauges are maintained by the University of Hawaii Sea Level Center. For instance, the Honolulu tide gauge records a rise of 1.54 mm per year while the Hilo tide gauge records a rise of 3.11 mm per year (https://tidesandcurrents.noaa.gov/sltrends/sltrends, accessed July 30, 2024).

And last, groundwater mining is another contributing factor to sea level change. This human activity extracts aquifers faster than it can be replenished, significantly

depleting the reservoirs and increasing the volume of water entering the ocean by direct runoff or through rivers. According to a study by Wada et al. (2010), groundwater depletion contributes approximately 0.3 mm per year to global sea-level rise. Furthermore, the Intergovernmental Panel on Climate Change (IPCC) emphasizes that groundwater depletion is expected to continue, particularly in areas experiencing significant agricultural and urban development (IPCC, 2021). This trend poses a dual challenge: while groundwater mining meets immediate water needs, it simultaneously accelerates SLR and threatens coastal communities through increased flooding and saltwater intrusion.

1.2.1 PLANNING FOR SEA LEVEL RISE

Several studies have indicated that by 2100, Hawai‘i could experience more frequent flooding, heightened exposure to hazards relating to SLR, and shrinking shorelines (Vitousek et al., 2017; Anderson et al., 2015, Anderson et al., 2018). In earlier responses to SLR and its impacts on coastal properties in the late 20th century, seawalls and revetments were permitted to mitigate coastal erosion. However, studies have suggested that these practices have worsened beach conditions and contributed to beach loss (Summers et al., 2018; Tavares et al., 2020). Recognizing the negative impacts of hardening shorelines, in 2020, the Hawai‘i State Legislators passed Act 16 (SB2060) to reinforce the ban on seawalls, revetments, and other methods aimed at hardening shorelines. Act 16 is a significant progress in terms of coastal management as it reinforces the priority of protecting coastal environments and beaches. In addition, Act 16

can facilitate the implementation of a coastal retreat strategy with the guidance of science-based tools and resources.

Resources generated from scientific findings can guide decision-makers in preparing for and assessing the risks and vulnerabilities of coastal communities and new development. The two resources discussed in this paper are the SLR viewer tool and trend projections, both of which provide valuable insights for planning against SLR impacts. The State of Hawaii SLR Viewer is an interactive mapping tool managed by PacIOOS and is readily available online. The map was created to support the State's Vulnerability and Adaptation Report. The SLR Viewer displays various overlays related to rising sea levels, allowing users to assess the potential hazards and future economic impacts of SLR in Hawaii (Hawaii Climate Change Mitigation and Adaptation Commission, 2021). Exposure maps are particularly useful for determining the risk of SLR and flooding impacts on properties. **Figure 1** shows an exposure map of the Sunset Beach neighborhood, where coastal properties are among those experiencing severe erosion, with homes already falling onto the beach, as shown in **Figure 2**. It is standard for Counties to plan developments under the 3.2ft SLR-XA scenario as shown in **Figure 1**. The 3.2 ft scenario accounts for passive flooding, wave flooding, and coastal erosion hazard areas. Under the 3.2 ft scenario, decision-makers and stakeholders can see if they are vulnerable and at-risk to SLR impacts.

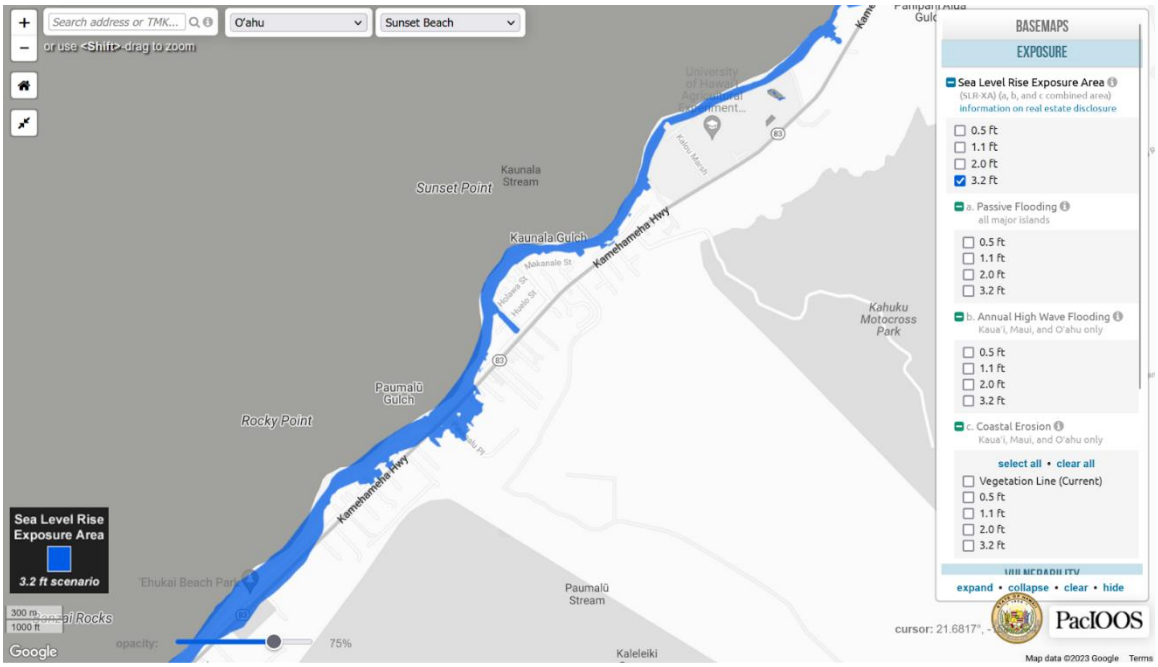

Figure 1*: SLR Exposure Area of Sunset Beach under a 3.2 feet scenario (https://www.pacioos.hawaii.edu/shorline/slr-hawaii/).*

Figure 2*: House on the coastal front of Sunset Beach neighborhood collapses onto the beach (KITV Island News, 2022).*

Sweet et al. (2022) published an updated sea level rise (SLR) technical report that includes five possible scenarios for global sea level rise by 2100: Low (1 foot; 0.3 meters), Intermediate Low (1.6 feet; 0.5 meters), Intermediate (3.3 feet; 1.0 meter),

Intermediate High (4.9 feet; 1.5 meters), and High (6.6 feet; 2.0 meters). However, low and intermediate low scenarios are not utilized as planning tools because they require SLR to slow down by 2100 (Neriem et al., 2018). These SLR scenarios serve as preliminary screening tools for decision-making and planning, helping to consider the potential impacts communities could face under different SLR scenarios. They can guide the development of buildings and other structures. If a community wishes to develop a high-value asset, planners and decision-makers can use these scenarios to identify suitable locations for development that minimize the risk to the asset. SLR scenarios can also be used to assess vulnerable assets, determine design flood elevations, develop mitigation strategies, or consider retreat options. **Figure 3** displays the five SLR projection scenarios based on measurements from the Honolulu Tide Gauge for the year 2100.

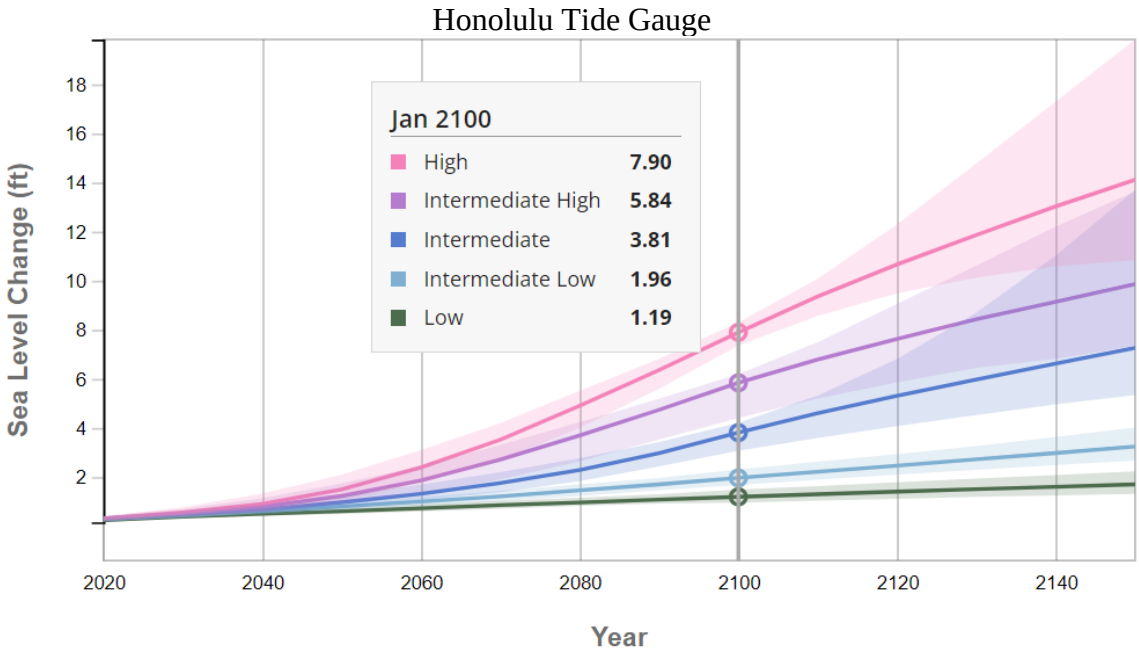

***Figure 3**: NASA interagency SLR Scenario tool for the Honolulu tide gauge (accessed July 30, 2024).*

1.3 MOTIVATION

This paper aims to highlight strategic retreat as a necessary adaptation strategy against SLR to ensure the protection of public trust lands in Hawai‘i. It is not a wake-up call for Hawai‘i lawmakers to address the impacts of SLR and climate change; rather, this thesis emphasizes the necessity of implementing proactive policies to protect and preserve beaches from SLR impacts, fulfilling their duty to the State of Hawai‘i’s constitution. Governmental officials continue to operate in a repeating cycle of reacting to emergencies and pushing aside other issues facing the people of Hawai‘i in the meantime. The implementation of strategic retreat policies is a proactive response to SLR impacts. It can reduce the public’s exposure to risks, hazards, and coastal pollution, and protect beaches at the same time.

Hawai‘i governmental officials at the State and county level have an obligation to ensure the protection and preservation of beaches throughout the State. As stated in Article XI section 1 of the State of Hawai‘i’s constitution:

> For the benefit of present and future generations, the State and its political subdivisions shall conserve and protect Hawaii’s natural beauty and all natural resources, including land, water, air, minerals and energy sources, and shall promote the development and utilization of these resources in a manner consistent with their conservation and in furtherance of the self-sufficiency of the State.

1.3.1 CAPACITY TO RESPOND AND ADAPT TO ENVIRONMENTAL CHALLENGES

Developing and implementing plans to protect both the public and natural resources in a changing climate must be a priority in Hawai‘i. The wildfires that occurred on Maui in August 2023 devastated historic Lahaina town and parts of Kihei and Kula. This tragedy was driven by several factors, including worsening drought conditions. While wildfires are not the primary focus of this thesis, the Maui fires underscored the State and Counties’ challenges in responding to and planning for natural disasters, issues that are directly relevant to this research.

Long-term planning is essential to address the impacts of SLR. To enhance the capacity of the State and Counties to withstand worsening SLR effects, managed retreat must be integrated into mitigation plans. Doberstein et al. (2019) illustrate, through four

geographical case studies, how Canadian communities have employed the PARA (protect, adapt/accommodate, retreat, and avoid) framework to bolster the flood resilience of their vulnerable areas. Each case study assessed a specific element of the PARA framework, evaluating its resilient capabilities based on the Stockholm Resilience Center's seven principles for fostering socio-ecological resilience:

1. Maintain diversity and redundancy
2. Manage connectivity
3. Manage slow variables and feedback
4. Foster complex adaptive systems thinking
5. Encourage learning
6. Broaden participation
7. Promote polycentric governance systems

The elements of the PARA framework are exemplified by various initiatives: Vancouver's dike system represents protection; Winnipeg's flood-proofing and sewer system conversion illustrate accommodation; Toronto's reclamation and rezoning of flood-prone land after Hurricane Hazel demonstrate retreat; and Calgary's policies that prohibit development in flood-prone areas exemplify avoidance. Doberstein et al. (2019) note that the mitigation strategies within the PARA framework are not mutually exclusive; rather, a combination of these strategies must be employed to ensure flood resilience. They strengthen their argument by highlighting the inadequacy of the dike system in protecting communities in a changing climate, revealing that 71% of the dikes could fail under future conditions, potentially resulting in damages estimated between $24 billion and $32 billion if no changes are made to the current system.

In contrast, the City of Winnipeg implemented protective measures alongside its accommodative strategies, significantly reducing both physical and economic impacts during the 2011 Red River Valley flooding. This approach further underscores the Stockholm Resilience Center's first principle of maintaining diversity and redundancy by diversifying mitigation efforts through the integration of other elements in the PARA framework. Doberstein et al. (2019) also emphasize the importance of equity within the PARA framework and resilience planning. Due to systemic underinvestment in First Nations communities outside of Winnipeg, these communities experienced more severe impacts during the 2011 flooding compared to the City, which had robust and diverse flood-reduction strategies. The authors highlight the necessity of diverse flood risk reduction approaches to foster resilience in all communities and stress the importance of understanding the context in which the PARA framework is applied.

In addressing flood resilience and responding to SLR impacts in Hawai‘i, the Counties and the State have primarily focused on the protection and accommodation aspects of the PARA framework. However, recent initiatives, including updated shoreline setback policies, could pave the way for avoidance practices and potentially facilitate managed retreat. To strengthen community resilience against flood-related hazards, Hawai‘i must fully incorporate the PARA framework. To reiterate, implementing a combination of the mitigation strategies within the PARA framework can ensure various assets are safeguarded. However, Hawai‘i currently lacks a retreat plan that can be utilized for coastal communities and threatened beaches.

1.4 LITERATURE REVIEW

Retreat is a globally recognized mitigation strategy against various hazards that repeatedly threaten a community, its assets, and its structures. Flooding is the most common hazard where retreat has been implemented. Depending on the context, managed retreat can target a specific type of threat that stakeholders and decision-makers are addressing or a general risk, such as coastal erosion, coastal hazards, or other natural hazards. Managed retreat can also encompass small actions that contribute to the overall goal of retreat rather than being a singular action, such as a combination of property acquisition or community relocation/redevelopment and prohibited development can achieve some form of managed retreat. There are multiple definitions and terminology that reference retreat strategies globally. Ultimately, managed retreat can be defined as the “strategic relocation of structures or abandonment of land to manage natural hazard risks” (Hino et al., 2017).

Managed retreat has been operational in the continental U.S. through FEMA's voluntary buyout program, which was launched in the late 20th century (Mach et al., 2019). The program provides homeowners with the opportunity to sell their affected property following a Presidential declaration of a natural disaster in their area. This buyout program is a critical source of post-disaster funds that have supported retreat in the U.S. Local city and county governments can apply for these funds from federal agencies like FEMA and then distribute them to their willing constituents. However, if a property had experienced repeated flooding, FEMA would not provide recovery funds unless property owner relocates.

Setter et al. (2023) conducted a study that analyzed the financial cost of coastal development retreat within the Paumalū ahupuaʻa, specifically Sunset Beach, an area experiencing severe erosion on the North Shore of Oahu, Hawaii. The study identifies three types of retreat approaches: all-at-once, threshold, and reactive. All-at-once retreat involves the managed, planned, and proactive removal and potential relocation of communities, buildings, and infrastructure inland. Threshold-based retreat postpones managed retreat until a predetermined trigger is reached, while reactive retreat is an unmanaged approach where affected individuals have no choice but to relocate after a natural disaster (Setter et al., 2023; Siders, 2019). The study concluded that the distribution of costs between public and private actors depends on the retreat approach, with all-at-once being the most expensive up front, for the Sunset Beach neighborhood.

The implementation of managed retreat is a multifaceted effort that requires the involvement of various agencies and stakeholders with diverse backgrounds to ensure

successful execution (Dundon & Abkowitz, 2021). Managed retreat plans must consider socio-economic and environmental impacts, social justice, sources of funding, legal frameworks, and community well-being (Siders & Ajibade, 2021). Without the support of community members, political officials, and legislation, managed retreat can be difficult to implement. And forcing retreat without the consensus of affected communities can result in negative consequences for individuals, communities, and the environment.

Hasnoot et al. (2021) outlines the main pathways or strategies that lead to coastal retreat or managed retreat.

1. Planned Relocation: Which is the organized movement of people, structures and assets away from areas vulnerable to coastal hazards. This strategy is the standard definition of managed retreat used in this thesis. Planned relocation would require comprehensive planning, community engagement and strong support systems that assist the communities that are relocated.
2. Retreat and Redevelopment: This strategy involves abandoning or removing existing structures to develop resilient infrastructure in safer locations.
3. Policy and Regulation Changes: This strategy can be utilized to prohibit or discourage development in areas prone to coastal hazards.
4. Ecosystem-Based Approaches: This pathway involves integrating natural systems into retreat plans to enhance resilience and ecosystem services.
5. Community Engagement and Equity: It is necessary to involve all stakeholders, especially marginalized communities, in the decision-making process.

6. Adaptive Management: This approach emphasizes the need for continuous evaluation and adjustment of retreat strategies to account for new scientific data and changing environmental conditions.

Figure 4 illustrates these pathways and transition phases of a retreat project or program. A retreat project can be divided into three main phases: preparation, active retreat, and cleanup.

1. Preparation Phase: This includes finalizing design plans, modifying land use regulations, implementing temporary measures such as protection or accommodation strategies, and acquiring properties.
2. Active Retreat Phase: During this phase, new community developments are created for those displaced by the retreat, and public infrastructure is bought out and relocated.
3. Cleanup Phase: This final phase involves the displacement and relocation of residents, as well as the removal and repurposing of the land that has been vacated.

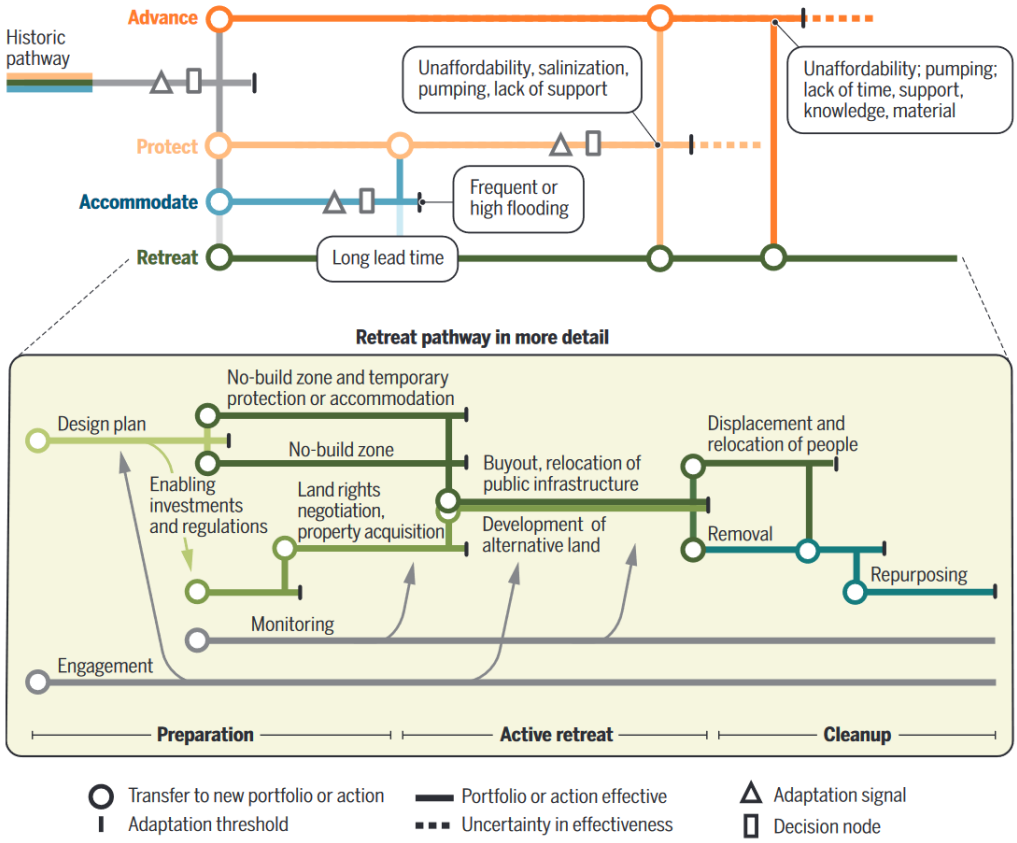

***Figure 4**: Diagram of Retreat Pathways in three phases: preparation, active retreat, and cleanup (Hasnoot et al., 2021)*

Planning for retreat involves multiple agencies and stakeholders from various disciplines and backgrounds to be successful (Dundon & Abkowitz, 2021; OPSD-CZM, 2019). Managed retreat plans are tailored to the specific location and region for which they are intended and may not be readily applicable elsewhere without careful consideration. Assessing the level of involvement of various stakeholders and agencies in managed retreat plans can guide decision-makers in Hawai‘i on where to begin their managed retreat planning. **Table 1** lists government agencies that can be involved in managed retreat planning and projects. These agencies can serve as primary participants, supporting entities, and sources of funding for a managed retreat project.

Municipal Agencies	State Agencies	Federal Agencies
City & County of Honolulu	Dept. of Health	Dept. of Agriculture
Kauaʻi County DP	Dept. of Land & Natural Resources	Dept. of Health & Human Services
Maui County DP	Office of Conservation & Coastal Lands	Dept. of Housing & Urban Development
Hawaiʻi County DP	Dept. of Transportation	Dept. of Interior
	NDPTC	Dept. of Transportation
	OPSD-CZM	Economic Development Administration
		EPA
		FEMA
		NOAA
		NSF
		Small Business Administration
		U.S. Army Corps of Engineers

Table 1*: Lists of municipal, state, and federal agencies that are typically involved in managed retreat planning and implementation.*

2.0 METHODS

2.1 RESEARCH PROCESS

The purpose of this thesis is to review managed retreat policies and projects that can be utilized to mitigate SLR impacting public beaches in Hawai‘i. Managed retreat as an adaptation strategy is primarily used to address repetitive flooding hazards but can be applied to other threatening hazards. In the U.S., the longest-running retreat program uses funds from FEMA to buy-out properties that have experienced repeated riverine flooding disasters (Mach et al., 2019). This voluntary buy-out program operated through FEMA is an example of post-disaster managed retreat.

Table 2 is a template that was used to assess the two retreat projects that have been applied in Hawai‘i: Project Kaiko‘o for Hilo, Hawai‘i in 1960 and the voluntary housing buyout program for Puna, Hawai‘i in 2018. These two cases are the only projects in Hawai‘i that have applied some form of retreat strategy or approach. Evaluating the development and outcome of these projects could provide useful insights for future retreat projects. The parameters in the left column of **Table 2** are used to gather key details of the managed retreat projects and whether those details can be useful or inspire retreat plans in the context of mitigating SLR impacts. The evaluation of these parameters regarding the retreat projects in Hawai‘i are provided in **Table 3.**

Parameters	Hilo, Hawai‘i 1960	Puna, Hawai‘i 2018
Was there a governance structure in which managed retreat policies and programs were implemented?		
How involved were community members, municipal(s), and other stakeholders in the planning and implementation process?		
Where was the financial support for managed retreat projects coming from?		
What considerable actions were taken to ensure the implementation of managed retreat policies?		
How much support did implementing managed retreat get from the community, political officials, and legislation?		
Was the managed retreat project/policy reactive or proactive?		

***Table 2**: Template of parameters involved in retreat implementation under the two cases: Hilo, Hawai‘i 1960 and Puna, Hawai‘i 2018.*

The concept of retreat has existed in Hawai‘i but has not been applied in major projects since Project Kaiko‘o. To determine the consideration of retreat policies and planning in Hawai‘i communities, a review of State, County, and regional climate action plans was conducted as a part of this thesis. Produced by the State’s CZM Program, the Ocean Resources Management Plan and Feasibility Report on Managed Retreat in Hawai‘i were reviewed for this thesis. Four climate action plans from each county were also reviewed: Kaua‘i County’s Multi-Hazard Mitigation and Resilience Plan (2021), Climate Ready O‘ahu (2024), the Integrated Climate Action Plan for the Island of

Hawai‘i (2023), and the Maui County Climate Action & Resiliency Plan (2022). These plans highlight the hazards impacting their communities locally and the actions each county plans to take to mitigate and combat these hazards. Adaptation strategies and policies targeting coastal hazards and flooding mitigation within the counties' plans were identified for this thesis. In addition to the CZM reports and local climate action plans, mentions of managed retreat in local news were also explored for updates in any current or existing managed retreat projects or programs.

The results will discuss the evaluation of coastal planning, climate action plans, and retreat programs that have been implemented in Hawai‘i. The Coastal Zone Management Program (CZM) is an important governmental agency that has produced documents critical to coastal planning and development. The summarization of CZM documents on Ocean Resource Management and Feasibility of Managed Retreat strategies in Hawai‘i are included in the following section. **Table 3** summarizes the key details of the retreat projects in Hilo and Puna, Hawai‘i based on the parameters established in **Table 2**. And lastly, the review of retreat strategies and language found in local climate actions are produced in **Table 4**.

3.0 RESULTS

3.1 HAWAIʻI COASTAL ZONE MANAGEMENT PROGRAM

In 1972, the U.S. Congress passed the Coastal Zone Management Act (CZMA) to address development demands in the Nation's coastal zone. The National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management oversees the implementation of CZMA and maintains a relationship with the local entities that had volunteered for the program (Coastal Zone Management Act, 1972). CZMA provides a managing entity that has a voluntary relationship with NOAA that aims "to preserve, protect, develop, and where possible, to restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations," (Coastal Zone Management Act, 1972). In 1973, the Office of Planning (OP) was designated as the lead agency responsible for the CZM program in Hawaiʻi. In 1976, OP presented a CZM Policy Plan to the Hawaiʻi State Legislature, outlining the state's major coastal issues. This led to the legislature enacting CZM law into Hawaiʻi Revised Statutes (HRS) Chapter 205A in 1977 with the purpose of providing effective management, beneficial use, protection, and development of the coastal zone (HRS 205A, 1977). With the CZM Program incorporated into OP, OP is responsible for:

1. Providing central direction and cohesion in the allocation of resources and effectuation of state activities and programs, and
2. Effectively addressing current or emerging issues and opportunities, (Ocean Resource Management Plan, 2020).

The OP-CZM Program works with a network of state agencies and local governments to administer enforceable laws, regulations, and policies that protect the

coastal zone. Through this collaboration of governmental agencies and local organizations the State's CZM program had published two documents relevant to this thesis: the Ocean Resource Management Plan (2020) and Assessing the Feasibility and Implications of Managed Retreat Strategies for Vulnerable Coastal Areas in Hawai‘i (2019).

3.1.1 The Hawai‘i Ocean Resources Management Plan (ORMP) (2020)

In 2020, OP-CZM published the fifth version of their ORMP: Collaborative Coastal Zone Management from Mauka to Makai. Instead of having several entities attempting to address the same issues separately, the State aims to utilize the ORMP to address Hawai‘i's environmental challenges through a collaborative governance structure (Ocean Resources Management Plan, 2020).

Building on the previous versions of the ORMP, the fifth version narrows down Hawai‘i's environmental challenges to three focus areas where resources should be prioritized. These focus areas are:

1. Development and Coastal Hazards,
2. Land-Based Pollution, and
3. Marine Ecosystems.

Development and coastal hazards have been integrated into a single focus area because addressing one inherently involves considering the other; they cannot be treated in isolation. The aim of this combined focus area is to "develop a statewide integrated shoreline management strategy to address the compounding impacts on Hawai‘i's shorelines resulting from coastal development, climate change, sea level rise, erosion,

and other chronic coastal hazards" (Ocean Resource Management Plan, 2020). In order to meet this goal, the ORMP proposed the following tasks:

- Vulnerability assessment of assets and critical infrastructure along the shoreline and assess options for protection, accommodation, and retreat of public infrastructure.
- Identify suitable geographic scale for shoreline adaptation planning based on coastal processes.
- Determine barriers to beach nourishment, including impacts to coastal habitats, cost, and regulatory requirements.
- Study the feasibility of utilizing ‘nature-based solutions’ on Hawai‘i’s high-energy shorelines to manage and mitigate erosion.
- Study the impacts of SLR projections on cultural and archeological resources, such as gathering sites, loko i‘a, heiau, and ki‘i pohaku.
- Incorporate a managed retreat analysis in all action team projects/studies to help develop criteria for this adaptation strategy.

3.1.2 Assessing the Feasibility and Implications of Managed Retreat Strategies for Vulnerable Coastal Areas in Hawai‘i (2019)

In compliance with the 2013 version of the ORMP, OP-CZM prepared a Managed Retreat Implementation report with support from a consultant team from SSFM International. Initially, CZM’s Managed Retreat report was intended to create a step-by-step plan to implement managed retreat in Hawai’i, but at the time the report was drafted OP-CZM found the objective was “unrealistic and unachievable.” Instead, the CZM

report focused on discussing the applicability of several managed retreat case studies to Hawai‘i and how the common themes of implementing retreat strategies are addressed in four scenario profiles in Hawai‘i. OP-CZM (2019) found the following key themes to consider when discussing managed retreat programs and the impacts of implementing retreat strategies:

1. Social/Cultural/Historic/Education
2. Planning
3. Resiliency
4. Regulatory/Legal
5. Economic
6. Shoreline Management/Public Access

There are some overlap between the themes OP-CZM (2019) are considering and the pathways Hasnoot et al. (2021) had established. Implemtenting retreat strategies with the themes and pathways in mind are important to ensure a well developed managed retreat plan. OP-CZM further explores these six themes in the four scenario profiles that addresses the implementation of managed retreat on different development types on different islands. The scenario profiles are:

1. Maui: Scenario for resorts, hotels, and condominiums.
2. Kaua‘i: Scenario for urban areas.
3. Hawai‘i: Scenario for single-family homes.
4. O‘ahu: Scenario for critical infrastructure.

OP-CZM (2019) noted that although the scenarios profiles are modeled on different development types that are affiliated with a specific island, the findings from

these model scenarios are transferable to any of the islands that have the development type that is addressed in the scenario. So findings from the critical infrastructure scenario on Oʻahu can be considered for Kauaʻi's critical infrastructure.

3.2 MANAGED RETREAT APPLIED IN HAWAIʻI

There have only been two instances in which managed retreat had been applied in Hawaiʻi: the first case was in 1960 at Hilo, Hawaiʻi after a tsunami struck downtown Hilo, and the second case in 2018 at Puna, Hawaiʻi after the eruption of Kīlauea volcano damaged several hundreds of properties (OPSD-CZM, 2019; Star Advertiser, 2022). In both cases, the regulatory agencies determined that the affected areas were unsuitable for current and future development and should be converted into open space, resulting in the permanent relocation of individuals who lived in these zones (OPSD-CZM, 2019). Property owners affected in these two instances were compensated for the pre-disaster market value of their homes, supported by post-disaster federal funds.

Hilo was affected by two destructive tsunami events, the first in 1946 and the second in 1960. After the tsunami in 1946, Hilo created a buffer zone at the bayfront and prohibited any development for businesses in this area, in addition the highway along the waterfront was raised to act as a barrier for future tsunami events. The destruction after the 1960 tsunami prompted authorities to consider a more elaborate approach to tackle flooding and inundation hazards in the area, so Project Kaikoʻo was initiated and completed in 1965 (McDaniel, 2020). Project Kaikoʻo was considered an Urban Renewal or Redevelopment Plan for the area in Hilo affected by the 1960 tsunami (Amended Urban Renewal Plan for the Kaikoʻo Project, 1965). The objective of the plan was to

designate lands within the project area that will minimize the danger or loss of life or damage to property in areas subject to possible inundation and flooding from future seismic waves. To accomplish the objectives of this renewal plan, the leading agency, Hawaii Redevelopment Agency, is tasked with:

1. Property acquisition
2. Assist relocation of individuals, families, and businesses whose lands or premises had been acquired by the Agency
3. Management of the acquired property until occupants are relocated
4. Demolition and removal of buildings
5. Designate lands within the project area for either “Elevated Areas” or “Open Areas”
6. Disposition of all acquired project lands by sale or lease to private, public, or quasi-public developers at its fair value for development or redevelopment in accordance with the Renewal Plan.

The other parties involved in Project Kaikoʻo were the State of Hawaii through Department of Land and Natural Resources (DLNR) and the County of Hawaiʻi. For Project Kaikoʻo, DLNR acquired lands that were designated for State Parks, recreational, agricultural, and other related uses and was responsible for the installation of necessary improvements and facilities. As for the County of Hawaiʻi they were responsible for financing Project Kaikoʻo with funds from local grants and financial assistance from the federal government. In addition, the County had also acquired lands for County Parks, recreational, and other related uses and was also responsible for installing improvements and facilities. The County’s Department of Public Works, Board of Water Supply,

County Planning Commission, and the Department of Parks and Recreations had assisted in:

1. Approving designs and plans for street improvements
2. Provide inspection services for the construction or installation of site improvements
3. Rezoning project lands

Project Kaikoʻo created a larger buffer zone that consists of lagoons, gardens, and recreational facilities that were designed to absorb the impact of future tsunamis and inundation. This area is now known as the Wailoa River State Recreation Area. Project Kaikoʻo was not labeled as a Retreat Plan, but the foundational tasks that supported the success of the project are retreat strategies.

In the 2018 Kīlauea case, the buyout of affected properties and assets was supported by approximately $107 million in HUD funds (Kīlauea Eruption Recovery, Hawaii County). The buyout process was implemented in three phases: the first two phases prioritized applicants with primary and secondary homes and provided up to $230,000 for their properties, while the third phase was dedicated to undeveloped property, with awards of up to $22,000 (Kīlauea Eruption Recovery, Hawaii County). Recipients of the grant money were free to move wherever they chose but also had the option to stay near their hometown. State Senator Russell Ruderman proposed a land swap, offering Puna residents development rights to a newly developed land parcel near Pāhoa (Hawaiʻi Public Radio, 2018). There are no reports indicating that Puna residents affected by the 2018 Kīlauea eruption took the land swap option for Pāhoa parcels, but the Kīlauea Eruption Recovery site provides resources for the Pāhoa Village Master Plan

(Hawaii County Gov). The Pāhoa Village Master Plan was created by the Disaster Recovery Division of the Hawai‘i County DP to guide decision-making processes aimed at shaping Pāhoa village’s future while preserving its heritage and identity (Kīlauea Eruption Recovery Hawaii County Gov).

Parameters	Hilo, Hawai‘i 1960	Puna, Hawai‘i 2018
Was there a governance structure in which managed retreat policies and programs were implemented?	Hawai‘i Redevelopment Agency is the leading agency to carry out the tasks that led to the retreat of the area. The Urban Renewal Plan for Project Kaiko‘o outlines the purpose, plan, and roles of the Hawai‘i Redevelopement agency, State of Hawai‘i, and County of Hawai‘i for the project area.	Community Development Block Grant Disaster Recovery Voluntary Housing Buyout Program (VHBP) divided into three phases that dispersed the funds from HUD. County of Hawai‘i responsible for handling the applications for the VHBP.
How involved were community members, municipal(s), and other stakeholders in the planning and implementation process?	Primary involvement came from the Hawai‘i Redevelopment Agency, State of Hawai‘i DLNR, and County of Hawai‘i.	Voluntary buy-out program necessitates the involvement of the community and individuals affected by the lava destruction.
Where was the financial support for managed retreat projects coming from?	Local grants and financial assistance from Federal Government.	HUD funds provided $107 million to pay out property owners during the voluntary buy out process.
What considerable actions were taken to ensure the implementation of managed retreat policies?	Cooperation Agreement between Hawaii Redevelopment Agency, State of Hawaii, and County of Hawai‘i.	Declaration of disaster from the U.S. president at the time for the State and County to receive necessary funds and disaster relief assistance.
How much support did implementing managed retreat get from the community, political officials, and legislation?		Pāhoa Village Master Plan. Retreat necessary, voluntary buyout of properties to ensure compensation to those affected.
Was the managed retreat project/policy reactive or proactive?	Reactionary to Tsunami and inundation hazards, but proactive approach in implementation.	Reactive but working through Pāhoa Village Master Plan.

Table 3*: Key details from Project Kaiko‘o (1960-1965) and the Voluntary Housing Buyout Program for Kīlauea Recovery (2018).*

The OPSD-CZM report (2019) found that consensus for retreat implementation is more likely to occur following a disaster, as many view retreat as a last-resort strategy.

However, retreat policies come in various forms. The implementation of retreat in the case of the 2018 Kīlauea eruption exemplifies a reactive approach (Setter et al., 2023). Retreat policies can include smaller-scale actions that contribute to larger-scale retreat efforts. Examples of these smaller-scale retreat policies can be found in the climate action and hazard mitigation plans of the four counties: Kaua‘i, Hawai‘i, Maui, and the City & County of Honolulu.

3.3 RETREAT POLICIES IN LOCAL COUNTY PLANS

The four counties in the State of Hawai‘i have released new and updated climate action plans that highlight their strategies to combat the climate hazards impacting their communities. **Table 4** gathered retreat stratgies found in the four counties’s climate action plans. Strategies including the terms: “relocate” and “acquisition” most likely imply a retreat policy. Out of the four counties, only Maui county explicitly states managed retreat in their Climate Action Plan.

Kaua‘i Multi-Hazard Resilience Plan (2021)	Climate Ready O‘ahu Plan (2024)	Hawai‘i County Integrated Climate Action Plan (2023)	Maui County Climate Action and Resiliency Plan (2022)
Reduce repetitive property losses through acquisition, retrofitting, design, and updated construction and land use regulations	Safeguard buildings, homes, and infrastructure against climate hazards.	Upgrade/relocate parks, infrastructure (e.g., roads, wastewater) and facilities exposed to hazards.	Plan for managed retreat and infrastructure relocation.
Incorporate mitigation measures into repairs, major alterations, new development, and redevelopment, especially in areas with substantial hazard risk and those known to have repetitive loss.	Reduce flood risk and coastal erosion by directing development to safer and higher ground.	Set aside shoreline areas as open space to benefit natural resources and public access and reduce risk to structures from SLR.	
		Reduce repetitive flood loss to structures and properties.	

Table 4*: Retreat strategies found in Kaua‘i Muti Hazard Resilience Plan (2021), Climate Ready O‘ahu (2024), Hawai‘i County Integrated Climate Action Plan (2023), and Maui County Climate Action and Resiliency Plan (2022).*

3.3.1 MAUI COUNTY MANAGED RETREAT REVOLVING FUND

In 2022, Bill 68, CD1 was introduced to create a revolving fund for Maui County to support managed retreat projects along its shores. The revolving fund would contain deposits from:

1. 20% of the Maui County Transient Accommodations Tax;
2. Revenue from any applicable fees set in the annual budget ordinance; and
3. supplemental transfers set in the annual budget ordinance.

The transient accommodation tax requires any person that provides transient accommodation or short-term rentals to pay 3% on all gross rental proceeds to the county. Maui County generated a revenue of about $57 million for the fiscal year 2022.

The funds will be administered by the department of management for managed retreat projects that meet the following criteria. The criteria are listed in **Table 5**, the left column lists the required objectives managed retreat projects are required then the second column ranks the order of preference for proposed managed retreat projects.

Required Project Objectives	Projects of Priority in order of preference
Shoreline safety improvements that include mitigation or removal of hazardous conditions due to shoreline erosion	Removal or relocation of County-owned structures or infrastructure that pose an imminent threat to public health or safety or the environment
Removal or relocation of structures or infrastructure that pose a threat to public health or safety or the environment	Removal of structurally compromised abandoned structures that pose and imminent threat to public health or safety or the environment
Programs and permitting, inclusive of environmental assessments	Removal, relocation, or safety improvements to County-owned structures
Leveraging funds provided by federal, state, nonprofit or for-profit organizations, and other non-County entities to further the purpose of managed retreat	Assist in the facilitation of permitting to remove privately-owned structures
Equivalent personnel and administrative costs	Other County or privately-owned projects related to managed retreat.

Table 5*: Maui County's criteria for funding managed retreat projects.*

The revolving fund had $12 million for the 2024 fiscal year and was expected to receive another $12 million in the following fiscal year. However, in June 2024, a unanimous vote suspended new payments to the managed retreat revolving fund. Bill 78 was then introduced to reallocate the managed retreat funds to support the construction of permanent, affordable housing and wildfire recovery following the deadly fires that impacted Maui in August 2023.

4.0 DISCUSSION

It is within the State of Hawai‘i’s responsibility to conserve and protect beaches in accordance with the State’s constitution. Tide gauges across the world have shown an increasing trend in sea level. The Honolulu tide gauge records a rise of 1.54 mm per year. Key contributors to this rise include melting ice sheets, thermal expansion, vertical land movement, and groundwater mining. In response to the hazards brought on by SLR, the State of Hawai‘i and Counties employed various protective and adaptive measures along the coast. Measures such as shoreline hardening have intensified beach erosion and contribute to beach loss. Retreat strategies are necessary to ensure the survival of Hawai‘i beaches as the strategies can result in their ultimate protection. Recognizing the importance of retreat strategies against coastal hazards for Hawai‘i, the State and Counties have discussed its potential in current and updated climate action and mitigation plans.

The State of Hawai‘i and four Counties have mentioned and discussed retreat strategies in their climate action and hazard mitigation plans and have already implemented some strategies and policies. However, the State and the Counties currently lack a comprehensive plan to implement managed retreat proactively to mitigate SLR impacts to the public and beaches. Each County has released climate action plans that proposes retreat strategies to mitigate coastal hazards and flooding but have not published any implementation plans. Understandably, developing a proactive and comprehensive managed retreat implementation plan is a lengthy process that requires collaboration of multiple disciplines and incorporation of various factors. Based on **Figure 4** (Hasnoot et al., 2021), Hawai‘i can be considered somewhat in the preparation and planning phase of

coastal retreat in which governmental agencies and other authoritative agencies are currently engaging with communities, gathering research, and feedback.

The State of Hawai‘i has been able to address most of the retreat pathways outlined in Hasnoot et al. (2021) in OP-CZM’s feasibility report (2019), but pathway six, adaptive management, may be the most crucial pathway to be addressed. Managed Retreat plans are highly specific to its intended location and can be difficult to replicate for other communities. Based on current plans, the justification for implementing managed retreat proactively in Hawai‘i is not leveraged enough. Project Kaiko‘o and the Kīlauea Eruption Recovery program were examples of an all-at-once and reactive approach respectively. These retreat approaches are not the most ideal form of retreat at present: an all-at-once approach is unfavorable financially and socially and a reactive approach lacks long-term planning (Setter et al., 2023, OP-CZM, 2019).

The ideal approach to managed retreat for Hawai‘i is through a threshold-based model, where retreat is triggered when a predetermined threshold is reached (Setter et al., 2023). To effectively implement managed retreat using this approach, it is recommended the State of Hawai‘i and its Counties need to develop a tool to monitor beach health. The development of this tool could be contracted out to University of Hawai‘i at Mānoa coastal research groups that already have the most up-to-date data on SLR available. This tool, similar to those used for tracking coral reefs and other ecosystems in Hawai‘i, can provide decision-makers with the necessary data to determine when retreat should be enacted in coastal communities. Integrating a beach health monitoring tool into Hawai‘i’s SLR resources would strengthen the state’s ability to implement retreat strategies based on the most up-to-date data available.

Suggested metrics for a beach health monitoring tool include:

- Erosion rates
- Sea-level exposure area
- Beach width and length
- Projections of beach narrowing
- Presence of sand dunes

These metrics could be used to create a notification system that signals when managed retreat strategies should be implemented to conserve beaches. The tool could also help identify when resources, such as labor and financial support, should be allocated to beach conservation. Moreover, retreat strategies can aid in beach conservation by supporting sediment replenishment and providing space for beach width to increase as areas are transformed into natural open spaces.

In addition to the need for a new data tool, the State and Counties currently lack a sustainable, locally funded source dedicated specifically to retreat implementation. Most federal funding is only available after a presidential disaster declaration, which does not align with the proactive nature of managed retreat, which is intended to be implemented before significant disasters occur. Maui County had previously developed a local funding source, but this was redirected for disaster relief following the 2023 Lahaina fires.

On November 5, 2024, 51.6% of Honolulu voters supported the establishment of a Climate Resiliency Fund (Hawai‘i Elections). One of its intended uses is to finance programs and projects aimed at protecting people from flooding and hurricane damage (Angarone, 2024). However, critics argue that creating a separate fund was unnecessary and that such projects could be financed through existing budget processes. The Climate

Resiliency Fund will receive 0.5% of the property tax revenue, amounting to about $8 million, similar to the Affordable Housing Fund and the Clean Water and Natural Lands Fund (Angarone, 2024). Despite this, the resolution establishing the fund does not explicitly mention its use for retreat projects, leaving it unclear whether the fund could be allocated for this purpose (Resolution 23-162, CD1).

There are still key factors related to managed retreat that the State and counties have not fully addressed and should consider. Coastal hazards affect communities across different demographics, with marginalized communities often being the most vulnerable. The term "stakeholders" can be too broad when discussing those most at risk from coastal hazards and affected by managed retreat projects, leading to the exclusion of some critical voices. Specifically, non-property owners and rental tenants could be overlooked in managed retreat planning. How will these groups be incorporated into retreat strategies?

5.0 CONCLUSION

The AR6 from the IPCC warns that SLR will continue for centuries to millennia due to ongoing deep-ocean warming and ice sheet melt, significantly affecting coastal environments. This will exacerbate hazards like storm surges, flooding, erosion, and extreme tides. In Hawai‘i, SLR threatens shorelines, beaches, and infrastructure. Common responses like hardening the coastline with seawalls worsen erosion and lead to beach loss, as they prevent natural shoreline migration and sand replenishment. Current adaptation strategies based on protective and adaptive actions may be insufficient for long-term resilience in a 100-year time frame, and decision-makers need to consider both short- and long-term solutions in order to protect Hawai‘i beaches. Managed retreat, a strategy involving the relocation of assets away from coastal hazards, offers a long-term solution but faces challenges due to high upfront costs, cultural impacts, legal obstacles, and negative consensus from the public.

This paper advocates for managed retreat as a necessary adaptation strategy for Hawai‘i to protect public trust lands and beaches from SLR impacts. It highlights the constitutional obligation of the state to conserve and protect its natural resources, including beaches. Although protection and accommodation are more common, they are insufficient for long-term sustainability. Instead, managed retreat offers the opportunity to move assets away from risks, but it requires proactive policies, significant planning, and appropriation of funds.

Drawing on the PARA framework (Doberstein et al., 2019), this framework advocates for a diverse and integrated approach to managing climate risks. While Hawai‘i has primarily focused on protection and accommodation, adding managed retreat

to these strategies could enhance the resilience of the State's coastal communities to SLR and flooding impacts. Currently, a comprehensive, all-at-once retreat approach is impractical due to high costs and the absence of a detailed plan for coastal communities (Setter et al., 2023). However, smaller, more achievable retreat strategies, as outlined in Hasnoot et al.'s (2021) six pathways, could help facilitate coastal retreat. These actions could include changes to zoning and development policies. A current example in Hawai‘i is the shoreline setback policies implemented by each county, which restrict the construction of structures within a certain distance from the shoreline. These shoreline setback policies serve as an avoidance strategy within the PARA framework and could initiate a pathway to coastal retreat.

While retreat strategies, which offer long-term protection for beaches, are discussed in climate action and mitigation plans, Hawai‘i currently lacks a comprehensive proactive plan for managed retreat. A case study by Setter et al. (2023) on the Sunset Beach neighborhood found that the threshold-based retreat approach was the most favorable within their retreat framework. However, there are no existing resources to support the implementation of this approach. To enable a threshold-based retreat in Hawai‘i, it is recommended to develop a tool for monitoring beach health. This tool could help establish a threshold that would inform lawmakers and decision-makers when retreat strategies should be enacted. In addition to developing this tool, securing a local and sustainable funding source for retreat projects is essential for successful implementation. While Honolulu voters approved the creation of a Climate Resiliency Fund set to begin in 2025, it remains unclear whether this fund will be used to support retreat strategies.

Existing retreat projects, like Project Kaikoʻo and the Kīlauea Eruption Recovery program, have been successful in achieving their objectives. However, Project Kaikoʻo was carried out under different socio-economic conditions, making its direct applicability to the current setting in Hawai'i unlikely. Meanwhile, the Kīlauea Eruption Recovery program employed a reactive retreat approach that is unfavorable in comparison to proactive retreat planning. A strategically planned retreat, which carefully considers the challenges faced by individuals, communities, and the environment, is the most ideal form of retreat. Phasing retreat strategies would allow stakeholders, decision-makers, and regulatory agencies to assess the effectiveness of the policies and where improvements may be needed. Without establishing foundational retreat pathways soon, it may be difficult for at-risk coastal communities to transition from a reactive to a proactive retreat approach. Therefore, recommending the development of a beach health monitoring tool and locally sourcing a retreat fund could provide the essential foundation to kickstart coastal retreat efforts in Hawai'i.

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