SOUTH MAUI COMMUNITY PLAN UPDATE: NATURAL HAZARDS AND CLIMATE CHANGE TECHNICAL RESOURCE PAPER

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List of Acronyms

BCH	Belt Collins Hawaii
CWPP	Countywide Policy Plan
DNLR	Hawai‘i Department of Land and Natural Resources
FEMA	Federal Emergency Management Act
FIRMs	Flood Insurance Rate Maps
HDP	Hawaii Drought Plan 2017 Update

HMP	Maui Hazard Mitigation Plan 2020 Update
HRS	Hawaii Revised Statutes
IPCC	Intergovernmental Panel on Climate Change
LRD	Long Range Planning Division of the Maui County Department of Planning
MIP	Maui Island Plan
NFIP	National Flood Insurance Program
RL	Repetitive Loss property
SLR	Sea level rise
SLR-XA	Sea level rise exposure area
SMCP	South Maui Community Plan
SRL	Severe Repetitive Loss property

Abstract

Natural hazards like storm events, tidal flooding, and coastal erosion are ever present issues for island communities like South Maui, Hawai‘i. A new modern-day challenge facing island communities is the threat of sea level rise and climate change. Recent studies indicate climate change is already impacting South Maui. The studies further anticipate that associated effects will exacerbate existing hazards while contributing to newer hazard types like sea level rise, extreme heat events, and drought. These natural and climate change hazards present serious risks to South Maui residents' health, safety, and welfare. To plan and prepare for existing and new hazards, the Long-Range Planning Division (LRD) of the Maui County Department of Planning is updating the South Maui Community Plan (formerly the 1998 Kihei-Makena Community Plan) to include climate change impacts. The primary objective of this practicum was to recreate and expand a hazards and climate change technical resource paper. The paper will be used as part of the community engagement process for the South Maui Community Plan Update. This was accomplished by conducting an extensive review of climate change impacts on Hawai‘i and the South Maui region, and using a geographic information system (GIS) spatial tools to analyze potential future impacts. Mitigation measures and adaptation opportunities were developed using planning best management strategies based on identified impacts and recommendations from the literature review.

Keywords

Climate Change, Natural Hazards, Community Plans, Long-term Planning, Island Communities, GIS, Hawai‘i, South Maui

Introduction

Climate change is a challenge facing communities around the world. The global society's current release rate of carbon dioxide is ten times faster than of any period in recorded history (Zeebe et al. 2016) and is directly contributing to a warmer global climate. Warmer global atmospheric and oceanic conditions are leading to complex inter-relationships between global, regional, and local climate change impacts.

Impacts created by climate change include sea level rise, food and water shortages, warmer ocean temperatures leading to acidification, pandemics, drought, wildfires, more extreme weather events and human displacement (Arnell et al. 2016). These impacts of climate change that global communities are experiencing are expected to accelerate soon. Studies suggest a global mean temperature rise of 2.7°F (1.5°C) by the end of this decade (Xu et al. 2018), nearly 10 years earlier than projected by the Intergovernmental Panel on Climate Change (IPCC 2018). This means over the next 20 years climate change impacts "could be faster and more furious" than previously anticipated (Xu et al. 2018). As the temperatures rise, more and more people are exposed to broader and more intense climate change impacts.

In 2014, the IPCC reported small island communities, like the Hawaiian Islands, are particularly at risk for impacts associated with sea level rise such as storm surges, coastal erosion, and flooding. The Fourth National Climate Assessment Report (Keener 2018) found that climate change impacts are already being experienced in Hawai'i and the greater Pacific region with rainfall, wind, and wave patterns changing. The report also found sea levels and the ocean heat content surrounding Hawai'i are rising. These changes are resulting in impacts on the Hawaiian Islands such as accelerated coastal erosion and beach loss, extreme heat events, prolonged drought conditions, and coral reef loss.

The Hawaiian Islands are uniquely situated for a variety of hazards. Set atop a volcanic island chain within the North Central Pacific Ocean, the closest continent is approximately 2,500 miles away. Natural hazards like storm events, tidal flooding, volcanic eruptions, earthquakes, and coastal erosion are ever-present issues for Hawai'i's communities. Therefore, planning for natural hazards and disasters has long been a component of community planning. As the population has grown and climate patterns shifted, climate change impacts are being recognized by Hawai'i's communities as a planning priority similar to hazard and disaster planning. In recognition of this new planning priority, Long-Range Planning Division (LRD) of the Maui County Department of Planning is beginning to require a consideration of climate change impacts for each of their community plan updates.

Residents across Maui County have voiced their concerns and support for addressing climate change impacts. During the County of Maui Hazard Mitigation Plan 2020 update, a total of 494 people participated in a Mitigation Planning Survey. The survey found over 50 percent of

respondents were concerned about climate change and other natural hazards climate change exacerbates, like hurricanes and wildfires (County of Maui 2020). In an open-ended question in the survey, respondents cited “drought, temperature increases, fires, erosion, and sea level rise” as climate change effects they themselves had observed occurring in Maui County. This perhaps influenced the strong support from respondents (over 75 percent) to create county policies to address climate change effects.

To reduce the effects of climate change on the natural and built environments, decision makers and stakeholders need to understand the dynamics between global climate change forces, local impacts, and community concerns. Further, they need to establish and document baseline values for areas anticipated to be affected by climate change in the future. These values can then be used to measure the effectiveness of climate change policies over time. Collectively, this can help reduce the effects of climate change on the natural and built environment in ways that have real meaning and value to the community.

Background

History of South Maui

During the Pre-Contact era the Kīhei-Mākena community planning region, referred to in this Practicum as “South Maui,” was largely uninhabited due to the arid climate. Following western contact, the idea of land ownership was introduced to the Hawaiian Islands. In response to pressure by westerners, the Kingdom of Hawai‘i passed the Great Mahele, or land division, in 1848 which resulted in subdivision of the islands for fee simple land ownership. Fee simple land ownership is private land ownership, meaning no person or government entity can legally take the land from the owner without just compensation. Further, the owner has the right to possess, use and dispose of the land in any way they wish (e.g. sell it, give it away, trade it, lease it, etc.). The Great Mahele made land available for private land ownership and the era of the sugar cane and pineapple plantations began on Maui. Plantation-style agricultural development has had long-lasting effects on Maui’s built and cultural landscape which can still be seen today.

Sugar cane and pineapple cultivation continued to be the main forms of commerce in Maui until the end of World War II. With rapid mechanization of industry, the expansion of employment options, unionization of workers, and growth in private land ownership the plantations quickly faded. In the following two decades, from 1950-1970, Maui focused on a new type of industry: tourism. This shift in economic focus led to the development of new towns, resort-destination areas, and community planning laying the foundation for the present-day conditions.

In the 1970s following the success of the new tourist economic model in attracting new residents and visitors, business and county leaders turned their sights to the sparsely populated and primarily agricultural region of Kīhei as the next residential, resort and employment center

(MIP 2012). In 1970, the Maui County planning staff and a hired consultant jointly developed the Kīhei Civic Development Plan, known as the 701 Plan due to the partial funding for its development under Section 701 of the Federal Housing Act of 1954. Plan 701 was to serve as a long-term planning document to guide growth in the region until 1990 and it shaped present day South Maui's built and natural environment.

Prior to the inception of Plan 701, only one hotel existed in the region and the area was characterized by dirt roads and agricultural and grazing lands with plenty of open space. Over the past 50 years, the number of residents and daily visitors to South Maui has grown significantly changing the region. In the years preceding Plan 701, the area's population was estimated to be around 1,600 people (RFP 2019). When the 1998 Kihei-Makena Community Plan was adopted, this number had grown to 15,365 residents and South Maui hosted an average daily visitor rate of over 16,000 people. Since 1998, the population has nearly doubled with approximately 30,000 residents and over 18,000 daily visitors, making South Maui the second most active tourism region in Maui County.

Project Location

South Maui covers a little over 72 square miles of the southwestern coast of the island of Maui. It is a shoreline community located on a low-lying coastal plain bordered by a shallow fringing reef with its northernmost border approximately three miles from Kahului. The region is characterized by the small harbor community in Māʻalaea to the north, shoreline commercial and residential development along its central coastline in Kīhei, and resort and hotel communities to the south in Wailea and Mākena.

The overall shape of South Maui is long and linear, ranging in width from 1 to 10 miles. Because of its distinctive shape, for the community plan update the LRD requested South Maui be subdivided into six subareas instead of just the four communities (Figure 1). This was done to reflect the unique character of the land and residents in each subarea. These subareas are:

- Subarea 1 (Māʻalaea/Keālia),
- Subarea 2 (North Kīhei),
- Subarea 3 (South Kīhei),
- Subarea 4 (Wailea),
- Subarea 5 (Mākena) and,
- Subarea 6 (ʻĀhihi/Kanaio). ʻĀhihi- Kīna'u/Kanaio is largely uninhabited.

Figure 1: South Maui Community Plan Boundary and Subareas. Image courtesy of Maui County.

Community Plan Update

In Maui County the planning period for community plans is 20 years, with a goal of updating the plans every 10 years. Community plans are entitled through Maui County Code 2.80B.070 through 2.80B.110. According to the Maui County Code, community plans "shall be developed after input from State and County agencies and the general public, and shall be based on sound policy and information...with public notification and participation facilitated by the use of tools…and other types of communication and direct consultation with different age, economic and other groups." Each plan must include the requirements set forth in Code 2.80B.070(E), which requires a statement of "the major problems and opportunities concerning the needs and development of the community plan area." The updated Community Plan will provide a vision, goals, policies, and actions to guide County officials, community members, and developers on appropriate growth actions and redevelopment.

Because of South Maui's potential to be impacted by natural hazards and climate change, LRD sought to include a hazards and climate change technical resource paper as part of the South Maui Community Plan update (Community Plan). The previous Community Plan, known as the 1998 Kihei-Makena Community Plan, was adopted before much of Hawai'i's climate change legislation was enacted. Therefore, the existing Plan includes guidance on natural hazards but not climate change.

The hazards and climate change technical resource paper is one of six technical resource papers being prepared as part of the Community Plan update. These papers are intended to describe the existing conditions of South Maui, identify challenges and issues related to each resource paper topic, and provide recommendations on mitigation actions or adaptive strategies LRD can pursue in the Plan update. The natural hazards and climate change technical resource paper is part of the community engagement process to educate community members and provide informational resources about climate change effects in shaping South Maui's future land use.

Initially, the hazard and climate change technical resource paper was drafted by Dr. Fletcher, a leader in climate change science and sea level rise impacts on Hawai'i. Dr. Fletcher's version of the document was extremely informative, but it was crafted at a collegiate reading level. For example, the following is an excerpt from Dr. Fletcher's paper:

"*Anthropogenic pollution has raised the air temperature at Earth's surface about 1.2°C on average above the 19th Century. This increase is expressed in several ways: there are more heat waves on continents, the oceans are hotter, the water cycle is amplified causing more weather disasters, ice is disappearing, the Arctic is warming more than two times faster than the planet average, and global sea level is rising.*

The average concentration of CO_2 in the air has risen from a natural level of about 280 parts per million (ppm) to about 417 ppm (May 2020, Mauna Loa Observatory4) the highest level seen on Earth in millions of years. The rate of CO2 accumulation in the atmosphere is accelerating; it increased from less than 1 ppm/yr in the 1960's to more than 2 ppm/yr averaged over the past

20 years (since 2015, CO2 accumulation has averaged 2.65 ppm/yr). Consequently, from 1900 to 1980 a new global annual temperature record was set every 13.5 years on average; however, since 1981, a new temperature record has been set every 3 years (Appendix F)."

Further, the paper focused on global and regional spatial scales and did not provide planning opportunities. Therefore, the resulting document was deemed too technical for use as part of the LRD's community engagement and Dr. Fletcher did not have time to make the changes LRD requested. It was decided that the document should be recreated and expanded for three primary reasons: it was written too technically for the average reader, it did not include enough South Maui specific impacts, and it did not provide planning opportunities for climate change adaptation.

Technical Reading Levels

The hazards and climate change technical resource paper produced for the Community Plan update is intended to inform and educate *all* community members about these risks as part of the public engagement process. Dr. Fletcher's version of the document was extremely informative, but it was crafted at an advanced, collegiate reading level. An issue with distributing a collegiate-level document to the broader community is that roughly 50% of adults in the United States cannot read at or above an eighth-grade reading level (Literacy Project Foundation 2020). There was thus the potential for up to half of South Maui's adult population being unable to read the document, not to mention many younger community members. Compounding that, currently 45 million American adults cannot read above a fifth-grade level and are considered functionally illiterate (Literacy Project Foundation 2020).

Another issue is that due to Covid-19 restrictions much of the community engagement process will occur remotely or online. According to a study by Weinrich et al. (2008), most users only read about 18-20% of what is written on a page and that written text should be reduced by 50% when posting to an online format. The study went on to state that pages with longer word counts, like academic papers, "people don't give the time of day (Weinreich et al. 2008)." To communicate effectively online, website content is considered clear and effective only if the reader can both find what they need and understand what they read (PlainLanguage.gov).

South Maui Specific Impacts

A second issue with the document was it focused more on regional and global spatial scales of impacts created by climate change, rather than South Maui specifically. While climate change is a global issue, community plans are used to focus on smaller geographic regions to create individualized plans that meet the needs of the community, and thus need to use a smaller spatial scale to analyze effects. This is because the spatial configuration of cities and communities, and how the land is used and developed, has a significant relationship with climate change effects and is central in enacting adaptive responses to the impacts (Hurlimann & March 2012). A baseline knowledge of the existing conditions at the appropriate spatial scale is necessary to develop and monitor future successes or failures of proposed adaptation strategies. Without isolating and discussing South Maui specific impacts in the report, creating

recommendations for mitigation and adaptive management strategies to meet the community's needs would be impractical.

Planning Opportunities for Climate Change Adaptation

Dr. Fletcher is a leader in climate change science and sea level rise impacts on Hawai'i, not a community planner. It was understood from the outset of the project that he would not be responsible for developing opportunities for climate change mitigation and adaptive management strategies in the report. These were always intended to be drafted by a planning staff member at my company, Belt Collins Hawaii (BCH), using the hazard and climate change information found within the document.

Problem Statement

The LRD faced three problems with the initial hazards and climate change paper drafted for the Community Plan update's public engagement:

1. **Readability** – the collegiate level document was too technical for the average American reader limiting its effectiveness in community engagement.
2. **Spatial Scale** – not analyzing impacts at the South Maui specific spatial scale reduces the ability to develop appropriate mitigation and adaptation measures.
3. **Planning Opportunities** – requires planning knowledge and expertise to develop opportunities for mitigation and adaptation measures for climate change.

To solve all three problems, it was determined that the technical resource paper be recreated in a reader-friendly manner and expanded to incorporate South Maui specific climate change impacts and planning opportunities for climate change mitigation and adaptation measures.

Practicum Purpose and Objectives

The purpose of this Practicum was to recreate and expand the hazards and climate change technical resource paper for use in the community engagement process for the South Maui Community Plan update. The Practicum objectives were:

- Use Dr. Fletcher's paper as a literature source for the new paper.
- Write the paper in a reader-friendly manner that includes less text, more graphics, and a simplified vocabulary.
- Survey the current body of knowledge on natural hazards and climate change impacts to determine effects specific to South Maui's built and natural environments.
- Use ArcGIS Pro spatial analysis tools to analyze and visualize the current and future impacts of climate change on local land use planning to make it easier for the public to see where the impacts are occurring.
- Develop planning opportunities for hazard and climate change mitigation and adaptation measures for South Maui.

Literature review

Entitlement History

Vulnerability to climate change impacts led the State of Hawai‘i to become an early adopter of climate change legislation with its 1998 *Hawai‘i Climate Change Action Plan.* The Plan was not intended to set specific goals, but rather to start the discussion with “Hawai‘i's people about their involvement in future efforts to reduce emissions and to adapt to climate change (State of Hawai‘i 1998).” Over the course of the next fifteen years additional climate change legislation was passed that focused on reducing the State’s greenhouse gas emissions, and in 2012 the State Planning Act was amended with Hawai‘i Revised Statutes (HRS) §226-109 to incorporate climate change adaptation priority guidelines. Amending the State Planning Act was intended to encourage cooperation and collaboration among governmental, public, and private stakeholders in mitigating climate change impacts on the life, land, and property of current and future generations of Hawai‘i (State of Hawai‘i 2012).

HRS §226-109 is an understanding that even if GHG emissions are reduced to more sustainable levels, the Hawaiian Islands will still be impacted by climate change well into the future. It determined the State’s best response is requiring adaptation priorities in governmental, public, and private actions. In this context, adaptation involved “adjusting our natural and built environments in response to actual or expected climate changes and its effects (OP 2020).” In 2014, Hawai‘i passed Act 83 authorizing an interagency climate adaptation committee and giving authority to the State Department of Planning to coordinate the development of climate adaptation plans and policy recommendations. Because HRS §226-109 was made to the State Planning Act and Act 83 was at the State level, the adaptation priorities they present are intended to guide policy for all major State and County activities, including all County general plans (State of Hawai‘i 2012).

The Maui County General Plan is a long-term comprehensive framework for Maui County’s physical, economic, and environmental development and cultural identity (County of Maui 2010). Maui County includes the islands of Maui, Moloka‘i, Lana‘i, and Kaho‘olawe. Maui County Code 2.80B entitles Maui’s General and Community Plans and is “designed to provide plans that clearly identify provisions that are meant to be policy guidelines and provisions that are intended to have the force and effect of law.” The Countywide Policy Plan (CWPP) is part of the Maui County General Plan.

The CWPP is the broad vision for the County and includes a list of objectives and policies (Figure 2). CWPP is intended to act at a higher, less strategic planning level for land use, the environment, the economy, and housing (Maui County Code 2.80B). Serving as an over-arching framework, the CWPP guides future growth and policy direction by acting as an umbrella document for the Maui Island Plan (MIP) and the MIP's subsequent community plans.

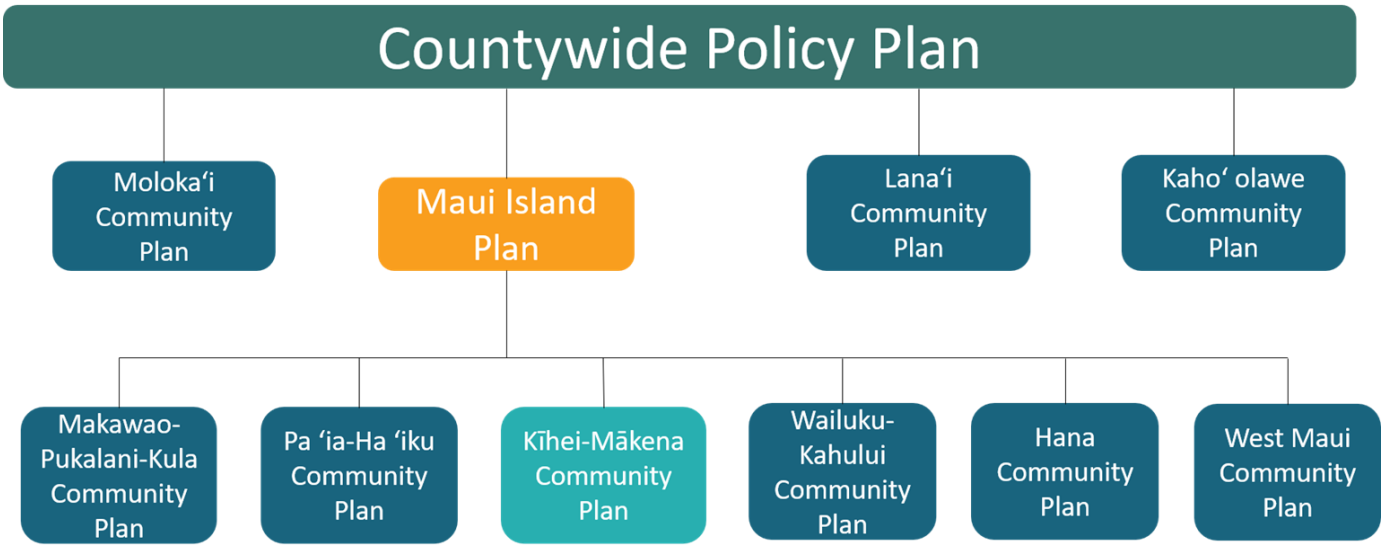

Figure 2: Policy framework umbrella for Maui County; source County of Maui (2010)

The MIP is another part of the Maui County General Plan, but it develops an island-wide strategy on land use specifically for the island of Maui. MIP incorporates the vision, objectives and policies developed in the CWPP and functions in a strategic capacity by managing and directing concepts like future growth areas, water supply and conservation measures, and nearshore coastal resource management (Maui County Code 2.80B). MIP includes capital improvements and financial considerations and requires technical resource papers in developing appropriate objectives and policies. Further, it requires status reports to monitor the Plan's objectives and policies success or failure. The MIP provides over-arching guidance in developing each community plan.

There are six community planning areas on the Island of Maui. Each community plan is developed to address the "major problems and opportunities concerning the needs and development of the community plan area" as well as a discussion on the "social, economic, and environmental effects of such development (Maui County Code 2.80B.070(E))." Community plans discuss the desired density of residents and visitors and dictate specific land use designations and zoning. Like the MIP, community plans also include capital improvements and financial considerations but at a smaller geographic scale. Community plans require technical resource papers to develop objectives and policies, and status reports to monitor the objectives and policies successes or failures.

Climate change considerations were incorporated into the CWPP when it was updated in 2010, even though HRS §226-109 was not enacted until 2012. The MIP was updated in 2012 and it too incorporated goals, policies, objectives, and actions related to climate change. However, many of the community plans, including the South Maui Community Plan, have not been updated since the late 1990's and do not include planning for climate change impacts.

Spatial Scale at Local/Community Level

According to Hurlimann and March (2012), a common theme emerging from adaptation literature is the need to integrate spatial scales in planning decisions to effectively address climate change impacts. In the context of human geography, scale is viewed as a 'form of hierarchy' where each level seems distinct but is in fact interconnected (Penn State 2020). For example, Hawai'i's local, national, and federal governments seem distinct but as discussed in the entitlement section their legislations are all interconnected.

Adaptation strategies for climate change require scale because of the range of time, geographic space, and governance level they are applied to (Hurlimann and March 2012). This mainstream adoption of climate change adaptation scales first appeared at the international level through agreements like the Kyoto Protocol or Paris Accord that provided financing mechanisms to incentivize and fund adaptation strategies. After this, national scale programs were started.

National adaptation programs grew from the international efforts and were intended to be frameworks for prioritizing national adaptation needs, to deliver climate information and projections, and create institutional adaptation strategies and plans (Measham et al. 2011). However, in recent years there has been a perceived collective lack of progress at the international and nation scales to significantly reduce GHG emissions, eroding public confidence in these climate change actors. In response, a widespread acknowledgement and acceptance in the literature and public opinion is that climate change is a global problem that requires local adaptations to solve it (Measham et al. 2011; Hurlimann & March 2012).

Local governments can function as principal agents in adaptation efforts as they often have stronger ties or links to the geographic area and the corresponding geographic variability that influences climate change impacts (Hurlimann & March 2012; Measham et al. 2011). This geographic variability highlights the need for a 'place-based' vulnerability analysis to climate change impacts and adaptation measures (Adger and Kelly 199; Cutter et al. 2000; Turner et al. 2003). Place-based approaches are those that focus on a spatially distinct grouping of globally created social and bio-physical characteristics and the resultant local or regional impacts (Measham et al. 2011; Walker et al. 2002; Turner et al. 2003). An important first step in place-based analysis is downscaling the global level of climate change data projections to the local level (Lowe et al. 2009). This allows communities to see what impacts they are most likely to experience and helps strengthen their resiliency.

More People Living in High-Risk Areas

Managing the broad-reaching impacts of climate change and other human activities on the natural and built environment is a primary challenge for community resilience today and a challenge that is likely to continue. Climate change is one factor contributing to this increase, another is that more Americans are moving into high-risk areas despite the long-term risks and costs (Maciag 2018):

- Number of Americans living in high-risk flood zone areas rose 14% in 2016 compared to numbers in 2000 at the same locations (Maciag 2018).
- Coastal cities across the country have seen a 40% increase in population numbers with roughly 35 million Americans relocating to shoreline communities between 1970 and 2016 (Stein & Van Dam 2019).
- An analysis by Headwaters Economics shows that 60% of new homes built between 1990 and 2017 are within Wildland-Urban Interfaces, areas adjacent to higher wildfire risks (Atkin 2017).

South Maui follows these national trends. South Maui's low coastal plains make it highly enticing as an ideal place to live, while simultaneously making it susceptible to tidal and coastal flooding and erosion. Low rainfall, high temperatures, and non-native grasses make the urban center particularly at-risk for wildfires and drought. Flooding, fires, drought, and extreme heat events are projected to increase in frequency and intensity with climate change. Despite these risks, the population of South Maui has increased roughly 1,600% from 1970 to 2018.

Community Resiliency and Adaptation

According to the American Planning Association (2014), community resiliency is a "three-legged stool comprised of mitigation, adaptation, and response/recovery." With no specific industry definition, resiliency is often described as a community's ability to endure episodic shocks or chronic stressors. Some view resiliency as the capacity to 'bounce back' following a disaster event, while others think of it as an opportunity to 'bounce forward' to create a community that is stronger and better-off following a disaster event (APA 2014; Mattson-Tieg 2015). Whatever the definition, resiliency requires communities mitigate, adapt, and respond to hazards and climate change. Previously, many communities focused on mitigation and response/recovery efforts as the core of their resiliency planning, neglecting to include adaptations (APA 2014).

Lowe et al. (2009) argue that climate change mitigation measures and adaptation strategies are inseparable. Mitigation measures are policies or actions used to reduce the severity of a hazard event (APA 2014). Adaptation strategy is a broad term that refers to the process of change in response to or in anticipation of a hazard (Tompkins 2005; Lowe et al. 2009). Both can be adopted at all spatial scales. Adaptation strategies are approaches to reduce vulnerability created by hazards through protection, accommodation, retreat, or ecosystem-based measures

(Oppenheimer et al. 2019). Many adaptation strategies simultaneously contribute to mitigation benefits, for example green infrastructure mitigates flood risks while also protecting from future extreme heat events.

Adaptive management is an iterative process that takes selected adaptation strategies and implements and modifies them based on observed impacts and predictions of future vulnerabilities (Cortney et al. 2020). Adaptation management strategies like modifying land use zoning to reduce development in high-risk areas, encouraging or incentivizing use of lower-risk spaces, incentivizing multi-modal transportation to reduce GHG emissions, or creating and preserving open spaces can reduce climate change impacts on communities (APA 2014). Cities like New York and Boston have proactively integrated climate change adaptive management. They used tools such as GIS to analyze where the cities were at greatest risk to current and future hazards like sea level rise, coastal flooding, and inland flooding. Their analyses helped them reduce their vulnerability and improve their resiliency by modifying land use policies and developing new building design requirements.

Readability

Climate change is an immensely complex problem given its global nature and local impacts. Compounding the complexity is a 'language gap' present between climate scientists and decision-makers and the public (Lowe et al. 2009). The language gap makes it difficult for non-scientists to understand and apply climate science information. Local governments can help bridge the gap by providing 'actionable science' (Lowe et al. 2009).

Actionable science is scientific information that is readable and actionable at a local level (Lowe et al. 2009). Local governments can further support actionable science by filling in data gaps at the local scale and focusing their information on issues identified as community concerns. Beyond the scientific language gap, when a community consists of many non-native English speakers or illiterate adults it creates another layer to the language gap.

According to Maui Hazard Mitigation Plan 2020 update, estimates for Maui County are that "3.3% of the population (5,198 persons) speaks English 'less than well.'" Compounding the language barrier is approximately 1 in 6 adults across Hawai'i cannot read or write at a basic level (Hawai'i Literacy 2009). Meaning that in 2009 about 155,000 adults across the State were considered functionally illiterate (Hawai'i Literacy 2009). It is worth noting that while many believe illiterate adults are strictly immigrants, roughly 65-70% of Hawaiian illiterate adults are native or fluent English speakers (Hawai'i Literacy 2009). Given Maui's diverse population and potential literacy issues, special attention should be given to the reading level, language use, and graphics used in documents intended to educate all members of the public.

Methods

Maui County and Other Agency Interviews

Prior to the start of the project, interviews were conducted with relevant Maui County departments and outside agencies to identify issues and challenges facing South Maui. LRD notified the departments and agencies beforehand to anticipate our interview requests to speed up the process and encourage participation. Each interview was one hour long and was set up by BCH project leads. Due to time constraints, each interview was a discussion covering all the resource paper topics applicable to that department or agency. For example, during the interview with the Maui Police Department the interview included a discussion on existing traffic patterns and flooding creating road hazards.

To facilitate the interviews, I created two internal team matrixes. The first was to identify the internal team's availability and the second was to identify who the internal team wanted to interview (Figure 3). This was done to align scheduling between the internal team prior to contacting Maui County with prospective interview dates and times. In retrospect, to reduce the amount of time spent organizing the interviews, both internally and externally, I would have used an automated scheduling program like Calendly rather than a static excel file.

A	B	C	D	E	F	G	H	I	J	K	M	N	
BCH Team m	H-Planni	BCH-Civil	F&P	Leland	eensfeldr	Fletche	Interview Date	Comp leted	Follow up Qs?	BCH Staff Attending	Affiliation	Email	Notes
CRYSTAL													
Crystal		X	X		X		6/25 @ 2:00pm-3:00pm	x		CR, LN	Transportation		Deputy Director
Crystal		X	X				6/25 @ 2:00pm-3:00pm	x		CR, LN	Public Works Highways		
Crystal		X	X				6/25 @ 2:00pm-2:30pm - schedule addl call if need	x		CR, LN	Public Works Engineering		
Crystal (Matt	X	X?	X				6/25 @ 1:00pm-2:00pm	x		CR, LN 1:20pm	Police		
Crystal (Matt	X	X?	X			X*	6/23 @ 10:00am-11:00am	x		MK	Fire		
Crystal		X	X				6/24 @ 1:30pm-2:30pm	x		CR, LN	HDOT		Maui District En
Crystal		X	X				6/24 @ 1:30pm-2:30pm	x		CR, LN	HDOT		HDOT Head Pl
Crystal		X	X				6/24 @ 1:30pm-2:30pm	x		CR, LN	HDOT		Planning Brancl
Crystal		X				X*	7/14 @ 9:00-10:00am	x		CR, LN	Water Supply		
Crystal		X				X*	7/14 @ 9:00-10:00am	x		CR, LN	Water Supply		
Crystal	X	?				X*	TBD			CR	Planning Flood (ZAED)		
Crystal	X					X*	Chip			CR	UHSea Grant		issues
Crystal		X				X*	7/16 @ 1:00-2:00pm			CR, LN	Environmental Management		
Crystal	X	X?				X*	PENDING			Crystal	Parks and Recreation		Planner VI in D
Crystal	X					X*	PENDING			Crystal	State Parks		charge of Maui
Crystal						X*				CR	Public Works Development Services		contact
							*Hazards/CC Interviews to be requested after draft tech paper is received; need background information to develo						
MATT													
Matt				X		X*	6/25 @ 1:00pm	x		Matt	Housing and Human Concerns		Deputy Director
Matt				X			06/23 @ 08:30am	x		Matt	Planning Zoning		
Matt				X	X		6/25 @ 10:00 AM	x		Matt	Planning Implementation		
Matt				X	X		6/25 @ 10:00 AM	x		Matt	Planning Current		on particular pro
Matt	X			X	X	X*	7/3 @ 9:00 AM	x		Matt	Economic Development		Director

Figure 3: Maui County interview matrix developed for project.

At this point in the process, Dr. Fletcher was still responsible for producing the paper. Due to his own busy schedule, he was unable to participate in any of the interviews, so the project lead and I attended the interviews in his place. My responsibilities during the interviews were to listen and take notes. See Appendix A: Maui County Interviews for a detailed list of interviews attended and topics covered.

LRD Directive

Following the interviews, two events took place that put me in the position to recreate the hazards and climate change technical resource paper. First, I took over as project lead for the hazards and climate change paper. Second, BCH received directive from LRD to use their recent West Maui Community Plan update as a template for the technical resource papers. The West Maui Community Plan technical resource papers were written in an easy-to-read manner, focused on West Maui specific impacts, and provided planning opportunities for mitigation and adaptation measures. However, this directive was received after Dr. Fletcher had completed drafting most the hazards and climate change paper.

I met with Dr. Fletcher to discuss how to revise his original paper to better meet the input we had received from LRD. Due to his personal time constraints, he acknowledged he would not be able to make the necessary adjustments. He was fully supportive of my revising the document to better suit the needs of LRD and gave me permission to use as much of his paper as I deemed necessary while providing me authorization to change/modify/delete as needed.

Literature Review

Upon Dr. Fletcher's permission to modify the document, I began an intensive literature review to establish what issues and impacts related to natural hazards and climate change were specifically affecting South Maui. To begin the process, I first identified overlap between issues and challenges brought up during the interviews, those discussed in Dr. Fletcher's paper, the West Maui Community Plan *Climate Change and Sea Level Rise Technical Resource Paper* (West Maui Technical Paper), and the Aloha + Challenge. These were a combination of sudden 'acute' events and long-term chronic 'stressors.' The following issues and challenges were identified as having the highest potential to affect South Maui:

- Acute Events
    - Tsunamis
    - Wildfires
    - Extreme Weather Events (Tropical Cyclones and Hurricanes)
- Chronic Stressors
    - Coastal Erosion and High Waves (including King Tides)
    - Extreme Heat
    - Sea Level Rise
    - Flooding
    - Drought
    - Food System Insecurity

Literature Selection

Hawai'i's governmental hierarchy and policy framework meant there were multiple resources available to assist my literature review. As the starting point, I looked to Dr. Fletcher's paper

and the West Maui Technical Paper. This helped focus my review on resources relevant to Hawai‘i that provided Maui County and even South Maui specific information. Having information at this spatial scale was crucial for me to evaluate the issues brought up during the County and agency interviews. I spent August through September 2020 researching and writing the preliminary draft, and October through November 2020 on revisions following LRD review and comment. Resources instrumental in my understanding of natural hazards and climate change effects on South Maui and used in developing appropriate mitigation and adaptation measures are included in Appendix B: Literature Review.

GIS Analysis

Esri's ArcGIS Pro analysis tools were used to analyze some of the effects of climate change on South Maui's built and natural environment. This was done to provide support for the adaptation strategies proposed in the paper. Due to budgetary constraints, I had to narrow the focus of the GIS analysis to issues that were identified as major hazards and that had readily available GIS data. As a result, I used GIS to explore or showcase impacts created by sea level rise, wildfire, and inland flooding. For the remaining hazards, (e.g. extreme heat, changing weather patterns, drought) there was limited GIS data available. However, there was sufficient information located during the literature review on these hazards to support the proposed adaptation strategies without further geospatial analysis. As a result, no GIS analysis was conducted for them.

Datasets were provided by LRD or obtained from the Hawai‘i Statewide GIS Program, Geospatial Data Portal (Geospatial Data Portal) in 2D. The Geospatial Data Portal is run by the State of Hawai‘i's Office of Planning and provides free, open-share data as mandated by HRS §225M-2(b)(4). To visualize my findings, I used ArcGIS Pro, Microsoft Excel, and Microsoft PowerPoint to generate graphics using Summary tables from analyses and maps showcasing areas of impact. I also worked closely with Belt Collins Graphic designer to develop infographics based on GIS analyses conducted. A list of datasets used in the analysis are included in Appendix C: Datasets and GIS Analysis.

Due to its coastal nature, coastal erosion and sea level rise are major hazards and concerns for South Maui. To provide a rationale for developing planning opportunities that focused on development outside the sea level rise exposure area (SLR-XA), I calculated the potential economic impacts of 3.2 ft SLR on each of South Maui's subareas. According to the Intergovernmental Panel on Climate Change, under an intermediate greenhouse gas emission scenario it is anticipated that 3.2 ft of sea level rise will occur by the end of this century. As such, this value (3.2 ft) was selected to showcase potential sea level rise impacts. The SLR-XA is a combination of passive flooding (e.g. tidal flooding), annual high wave flooding, and coastal erosion under the 3.2 ft of sea level rise (SLR) scenario. LRD provided a dataset that included the potential economic impacts of 3.2 ft of SLR that had been generated as part of the *Hawai‘i Sea Level Rise Vulnerability and Adaptation Report (2017)* and its companion interactive web map the *Hawai‘i Sea Level Rise Viewer*. For details on the dataset, see Appendix C: Datasets and

GIS Analysis. The *Hawai'i Sea Level Rise Viewer* was also used to create graphics of the 3.2 ft SLR-XA for the paper.

Much of South Maui's directed growth boundaries intersect with the 3.2 ft SLR-XA, so I calculated the total acreage of each subarea and zoning type projected to be affected under a 3.2 ft SLR scenario. A step-by-step description of methods used to calculate economic impacts and acreages affected is provided in Appendix C: Datasets and GIS Analysis.

In addition to SLR, South Maui is at high risk for wildland fires. I created multiple maps for wildfire risk. One map was an overlay map to show the relationship between South Maui's urban centers and wildland fire risk. This was achieved overlaying the Hawai'i Department of Land and Natural Resources (DLNR) wildland-urban interface risk data for South Maui with the area's growth boundaries. The DLNR data had already classified the risk level for South Maui, so no additional analysis was required. I clipped the DLNR data to the South Maui boundary and overlayed the growth boundaries to produce the map.

Another map showing ignition density, the number of fires started in an area over time, in relation to the growth boundaries was created. This was accomplished by overlaying the fire risk data and ignition density data with the growth boundary layer. However, during reviews of the paper it was determined neither map provided enough information about the history of wildfire or exactly where past fire events had occurred in the planning area. Therefore, they were not detailed enough for the report and were removed.

Due to South Maui's high risk for coastal and inland flooding, I calculated the total acreage delineated on the Federal Emergency Management Act's (FEMA) Flood Insurance Rate Maps (FIRMs) using data downloaded on June 22, 2020 from the FEMA Map Service Center (FEMA 2020). FIRMs are official maps of a community where FEMA delineates the severity or type of flooding using zone classifications. South Maui contains FEMA Zones A, AE, V and VE. Zones A and AE represent inland areas with a 1% annual chance of flooding, whereas Zones V and VE represent coastal areas with a 1% annual chance of flooding. A step-by-step description of methods used to calculate the total acreages affected is provided in Appendix C: Datasets and GIS Analysis.

Additionally, I created a map showcasing the general location of FEMA FIRM Repetitive Loss (RL) and Severe Repetitive Loss (SRL) properties. A RL property is any insurable building for which <u>two or more</u> claims exceeding $1,000 were paid by the FEMA National Flood Insurance Program (NFIP) within a rolling ten-year period starting (FEMA 2004). For example, a building floods in 2008 and a NFIP claim over $1,000 is paid. The same building floods again in 2012 and another NFIP claim over $1,000 is paid. This would be a RL property.

A SRL property is a type of RL property. SRL properties are any insurable building that has over <u>four or more separate</u> claims of more than $5,000 each paid, or the building received two or more claim payments that cumulatively exceed the value of the property (FEMA 2004). RL properties generally constitute a small percentage of overall annual claims in an area but are

significant contributors to claims costs. Working with the County of Maui Floodplain Coordinator, I was provided location maps for the RL properties but due to privacy concerns for the homeowners the map I generated showcased generalized locations instead. To generate the map, I used the location maps as a guide and created polygons around the generalized areas of impact. I then selected the "graduated symbol" and symbolized by the number of buildings in the area affected.

Dataset Issues

I encountered four issues that influenced how I analyzed the GIS data for the project. First, South Maui has two zoning maps associated with each parcel. The first is the 1998 Kihei-Makena Community Plan zone map and the second is the island of Maui State Zone map. Currently, there are zoning conflicts between the two zoning maps for some parcels (e.g. community plan zoning is business while state zoning is residential for the same parcel). One objective of the community plan update is to also update and potentially change the community plan zoning map. Therefore, I chose to use the state zoning datasets for my analysis.

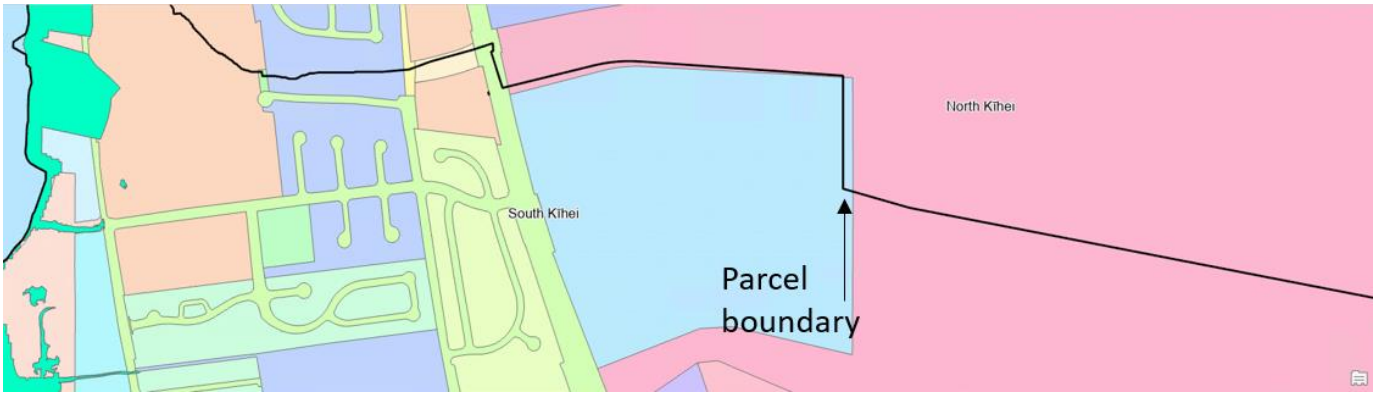

Figure 4: Errors in alignment between data sets. Shown here are offsets between the parcel data and the zoning data.

Second, there were alignment issues between the parcel data and the zoning data (Figure 4). This alignment issue meant that if I tried to perform a spatial join the resulting layer was riddled with sliver polygons, introducing a level of error in the analysis. Issues with parcel alignment is another well-known and established issue. In September 2020, the Hawaii Statewide GIS Program along with a group of stakeholders from the federal, state, county, private, and non-profit sectors began a series of meetings and workshops to address this long-standing issue of GIS layers not overlaying the parcel boundaries and other derivative layers not overlaying each other. The group is working to develop workable solutions to the issues.

Third, the state zoning data (Zoning Island of Maui dataset) itself also contained multiple polygon slivers along the coastline (Figure 5). The Zoning of Maui Island dataset polygon slivers accounted for approximately 55 acres of the entire South Maui area. From aerial imagery, these sliver areas were predominantly sand or beach, which are not developable areas under the existing zoning plan. As a result of these silvers, the beach/park values may have some discrepancy from the SMCP values for these land use types. However, because the slivers did not have a zoning value assigned to them, they were more easily identified and were not included in the analysis of SLR impacts.

Figure 5: An example of the coastal slivers (shown in purple). These areas had no value zoning value assigned to them.

Fourth, I encountered issues with data gaps for some of the hazards analyzed. The largest of these data gaps was the problem with the wildfire datasets as previously discussed. Another was with the FEMA active policy data. Because this dataset was created by an outside, federal agency there were issues with relating the stand-alone tables they provided with the spatially referenced building footprints provided by Maui County.

Practicum Timeline

During the end of June through the middle of July 2020, interviews were conducted with employees of Maui County or other local or state agencies to gather information needed for the technical resource paper. I began recreating the technical resource paper on August 20, 2020, following direction from LRD about the paper's required format and confirmation from Dr. Fletcher to modify the paper as needed. The preliminary draft was submitted to LRD in September 2020. Following comments from LRD on the preliminary draft, a revised draft was submitted to LRD in November of 2020. Following additional comments from LRD on the revised draft, a final draft was submitted in March 2021.

This practicum's proposal, literature review, and methodology were developed during the Fall 2020 semester concurrently with the project (08/21/20-11/30/20). The results, discussion, conclusion, and any additional appendices were developed during the Winter 2020 and Spring

2021 semesters. A timeline of the project and practicum progression to completion is provided in Figure 6.

Results

Practicum Project Phases

The purpose of this Practicum was to recreate and expand the hazards and climate change technical resource paper for use in the community engagement process for the South Maui Community Plan update. There were three overarching phases that occurred during the course of the Practicum project, shown in Figures 7 through 9.

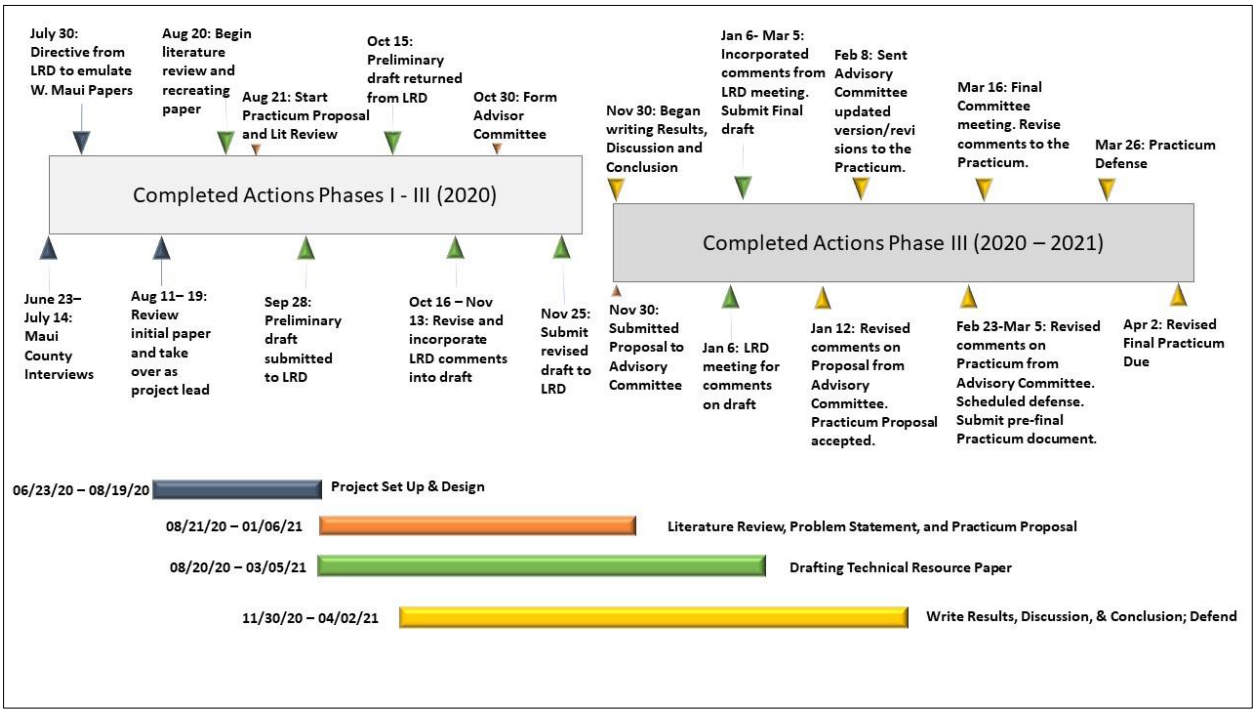

Figure 6: Practicum Timeline

Phases I and II

During Phase I, my primary role was to assist Dr. Fletcher in developing maps if requested, and to review his document before submitting to LRD (Figure 7). This portion of the project was when I participated in Maui County interviews to gain a better understanding of the climate change issues affecting South Maui.

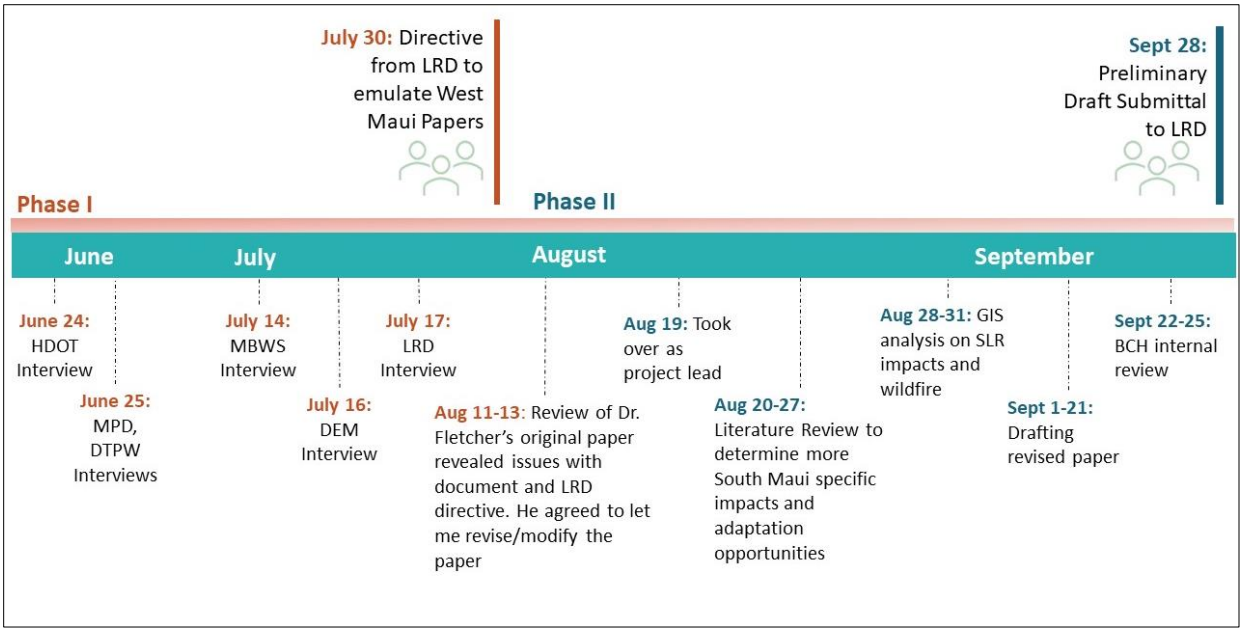

Figure 7: Timeline for Phases I & II

Phase II started after LRD gave the directive to emulate the West Maui papers. This was when I took over the project and redrafted Dr. Fletcher's original paper. During Phase II, I conducted an extensive Literature Review as detailed in Appendix B: Literature Review. I revised the paper's overall structure and expanded the scope of discussion on South Maui specific impacts for wildfire, tsunamis, food insecurity, inland flooding, and drought. However, I kept the key messages from Dr. Fletcher's paper.

At this stage in the project, the paper's content was re-written at closer to an 8^{th}-12^{th} grade reading level. It was updated to include more South Maui specific impacts, but it still contained information on global issues including information on greenhouse gas emissions. This was when sections on Maui County's policy framework and proposed adaptation strategies were added.

During Phase II, I performed the GIS analyses for SLR economic impacts, and the number of parcels and acreage affected by SLR. I also created the wildfire risk and ignition density maps. Most of the other graphics used in the document were taken from Dr. Fletcher's original paper. While I was able to trim down the paper's length to 36 pages from 43 pages, it was still quite long for the average reader. This version of the document was submitted to LRD as the Preliminary Draft.

Phase III (A)

The third phase began after receiving LRD's first round of comments on the preliminary draft submittal (Figure 8). Phase III resulted in having to overhaul the paper for a third time to better meet the reading level and content styling LRD wanted. It was also during this phase that LRD determined to reclassify all of the papers from "technical resource papers" to simply "resource papers." For consistency, this Practicum will continue to refer to the document as a technical resource paper. The document and graphics developed during Phase III would serve as the foundation of the final paper.

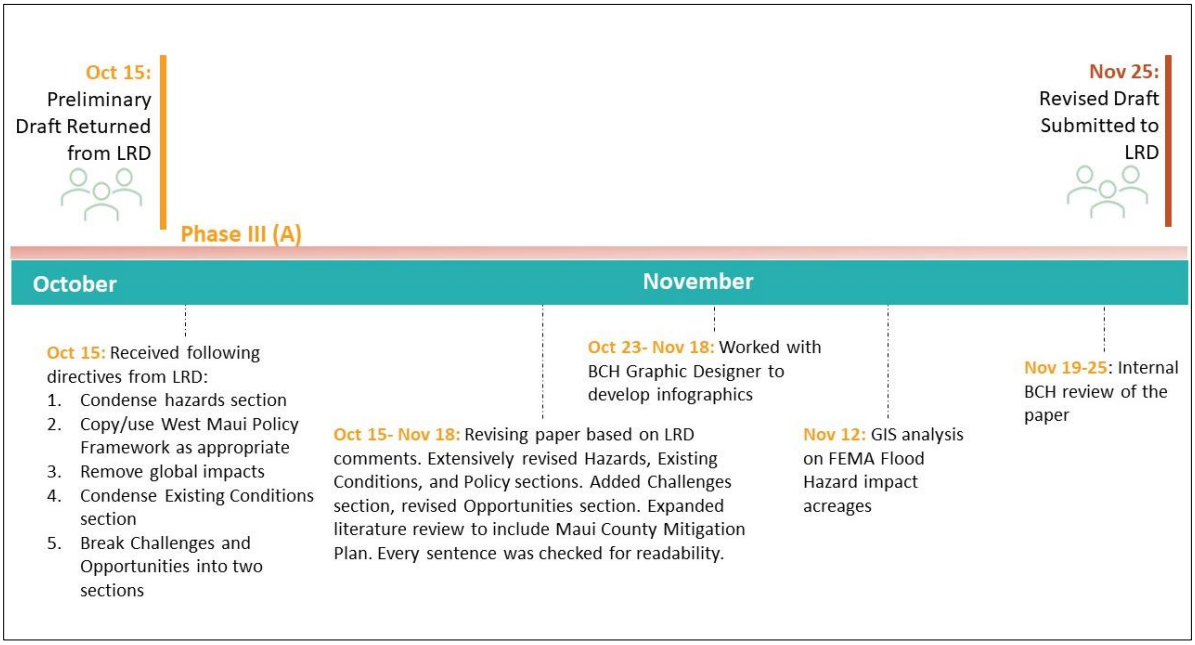

Figure 8: Timeline for Phase III (A)

In Phase III (A), LRD provided more definitive comments on the style and content they wanted. As a result, during this round of revisions I relied heavily on the corresponding West Maui paper and the County of Maui Hazard Mitigation Plan (2020) for more detailed South Maui specific impacts. Information from these papers was used to supplement the Hazards and Existing Conditions sections to better meet the request of LRD. This included providing a definition of each hazard for clarity and describing actions currently being used to address hazard impacts in South Maui.

I retained the paper's overall structure but created or removed sections to simplify the document. Splitting the Challenges and Opportunities into two sections removed the restriction of having to tie challenges to specific hazards, thus removing repetition of the same challenge posed by multiple hazard types. I removed all the global or regional impacts that were not specifically linked to South Maui and created infographics to help simplify complex concepts. Many of the graphics used in Phase II were removed or replaced by those developed in Phase III.

During Phase III (A), I used GIS to calculate the acreage that could be flooded based on FEMA Special Flood Hazard data. I used the SLR zoning data developed in Phase II to calculate the length of road that would be impacted by the 3.2 ft SLR-XA.

I simplified the language and sentence structure again in Phase III. Using the Hemingwayapp.com website, each sentence was checked and revised to be between a 5th and 8th grade reading level. The final version of the paper was 29 pages, and it was submitted to LRD as the Draft submission. LRD returned the draft on December 7, 2020 with additional comments and revisions. However, at this point in the paper's progression their comments were comparatively minor to Phases I and II. As such, these revisions were considered part of Phase III (B).

Phase III (B)

This round of comments included removing the introductory hazards section and instead combining the information provided there with the appropriate Existing Conditions discussion (Figure 9). The comments also requested removing or revising some of the infographics and maps produced, incorporating more information about the FEMA flood hazards, and modifying or removing some of the adaptation strategies proposed related to food insecurity as it was determined to be a broader, county level issue. It was also during this round of revisions when the Opportunities section where adaptation measures were discussed was renamed the "Strategies" section.

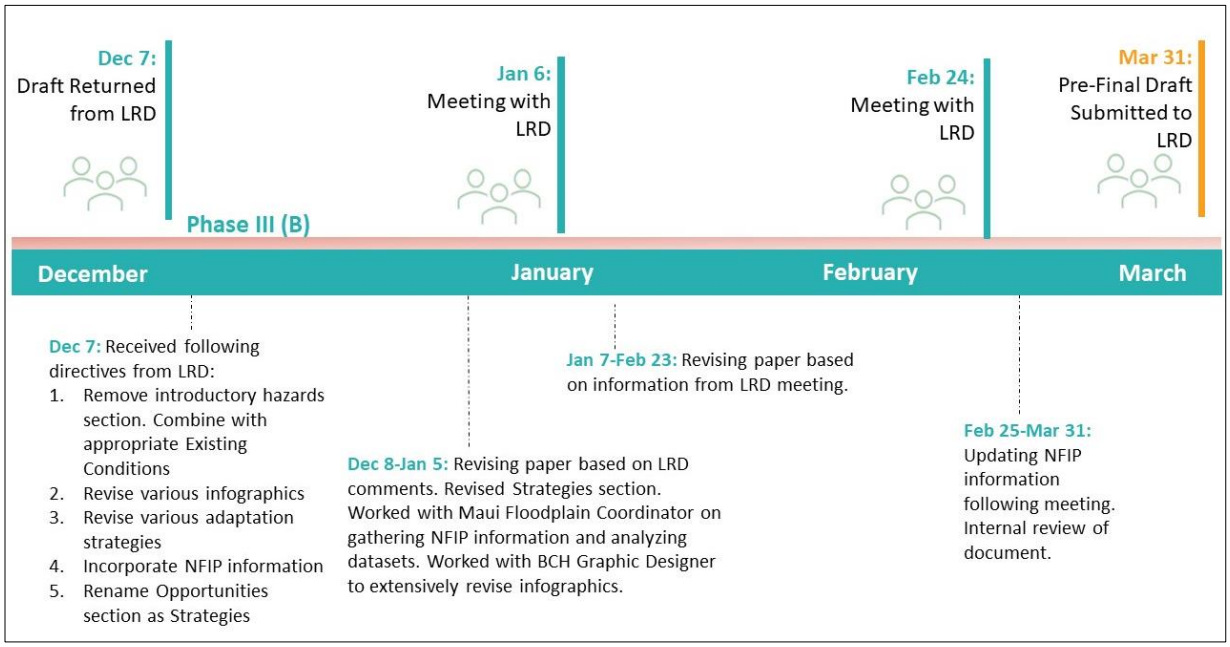

Figure 9: Phase III B Timeline

The only major additional content required was the inclusion of NFIP information and a RL map. Working with the Maui County Floodplain Manager, I was provided a variety of datasets relating to active policies, insurance claims and values, and hard copy maps showing the

general locations of RL and SRL properties. This information was used to calculate the value of claims paid out by the County and FEMA over the past 20-years for RL and SRL properties, as well as determine the general causes of flooding at these locations. This caused the length of the paper to increase to 35 pages to accommodate the new information and graphics.

Two follow-up meetings with LRD were conducted during this phase. One on Jan 6, 2021 to provide additional clarification regarding their most recent round of comments; and one on February 24, 2021 to discuss outstanding comments relating to the NFIP. Based on the guidance and dialog during the two meetings the document was revised, and a pre-final draft was submitted to LRD on March 31, 2021. To view the Pre-Final Draft submission, see Appendix F.

Key Findings

Below are the "Key Challenges" described in the hazards and climate change technical resource paper. These are a summary of the paper's findings based on the existing conditions, literature review, and GIS analyses performed for the Practicum project. They were used to support the adaptation strategies proposed in the Strategies section of the technical resource paper.

The following information is pulled directly from the Draft Pre-Final South Maui Hazards and Climate Change Resource Paper prepared for LRD with only minor paraphrasing or revisions for clarity in this context. The graphics produced in this section were a collaboration between me and BCH's Graphic Designer Amy Yamakawa. I developed a mock-up of the graphics which she would then improve. Because the paper is still a draft version, at this stage it is not intended for use in public planning or policy making decisions. See Appendix F for the full context and the source of these key challenges. This information is provided courtesy of Maui County.

Key Challenges

Many of the current hazards affecting South Maui will be compounded and their affects worsened by climate change and sea level rise (Figure 10).

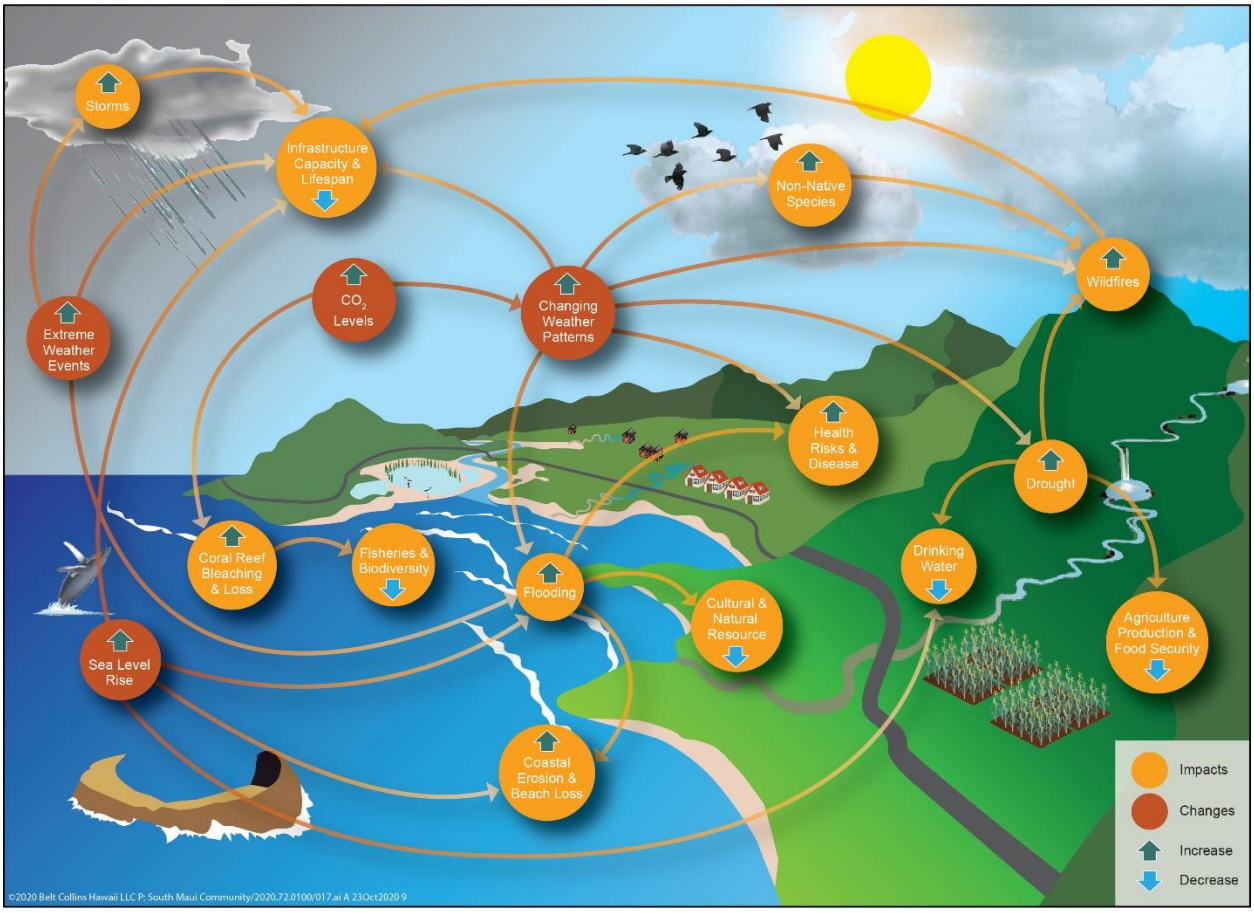

Figure 10: Overview of climate change and impacts affecting South Maui. Image courtesy of Maui County.

Chronic Flooding

Flooding is the most common hazard to affect South Maui. Over the past 20 years, 105 flood insurance claims have been made to the NFIP totalling almost $3 million dollars in damage and loss. Of these payouts, a total of almost $1.4 million dollars has been spent on claims for RL and SLR properties. This equates to 45% of all the money spent on flood insurance claims going to RL and SRL properties.

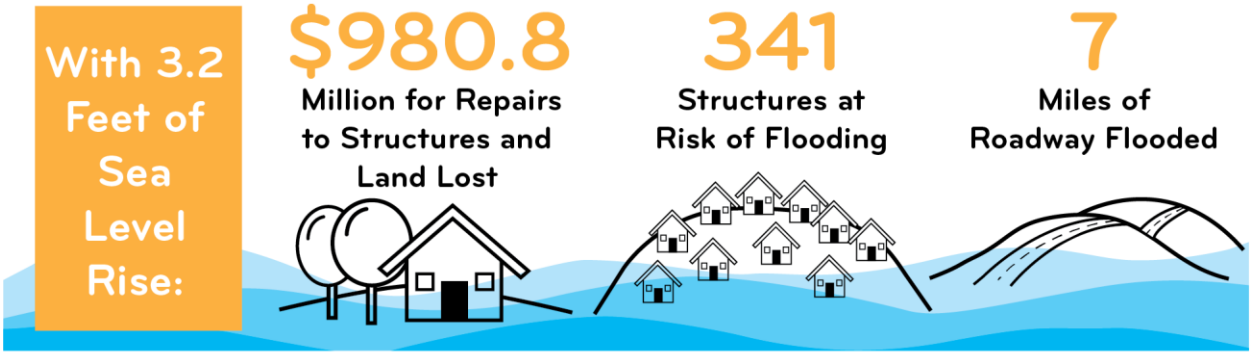

Figure 11: Potential impacts from 3.2 ft SLR. Image courtesy of Maui County.

However, the frequency of flooding and the number of RL properties will likely increase with sea level rise. Under a 3.2 ft sea level rise scenario, chronic flooding of 1,179 acres, or roughly 893 football fields, may impact nearshore properties of South Maui. Twenty-two percent of this acreage is expected to be within the Maui Island Plan growth boundaries, including 85 acres of residentially zoned land.

Assuming no adaptation measures are used, up to 553 parcels will be affected by chronic flooding under a 3.2 ft sea level rise scenario (Figure 11). Within the parcels, 341 buildings and seven miles of roadway could be regularly affected. Impacts on each area of South Maui vary, but South Kīhei is projected to be the most affected with approximately 130 acres impacted (Figure 12). Areas like Mākena and Wailea are projected to have a combined total of 72 acres impacted. While this may not seem like a large area, it could amount to $462 million dollars in economic impacts. The Maui Island Plan identifies lands in North Kīhei that could provide opportunities for redevelopment or expansion away from the shoreline.

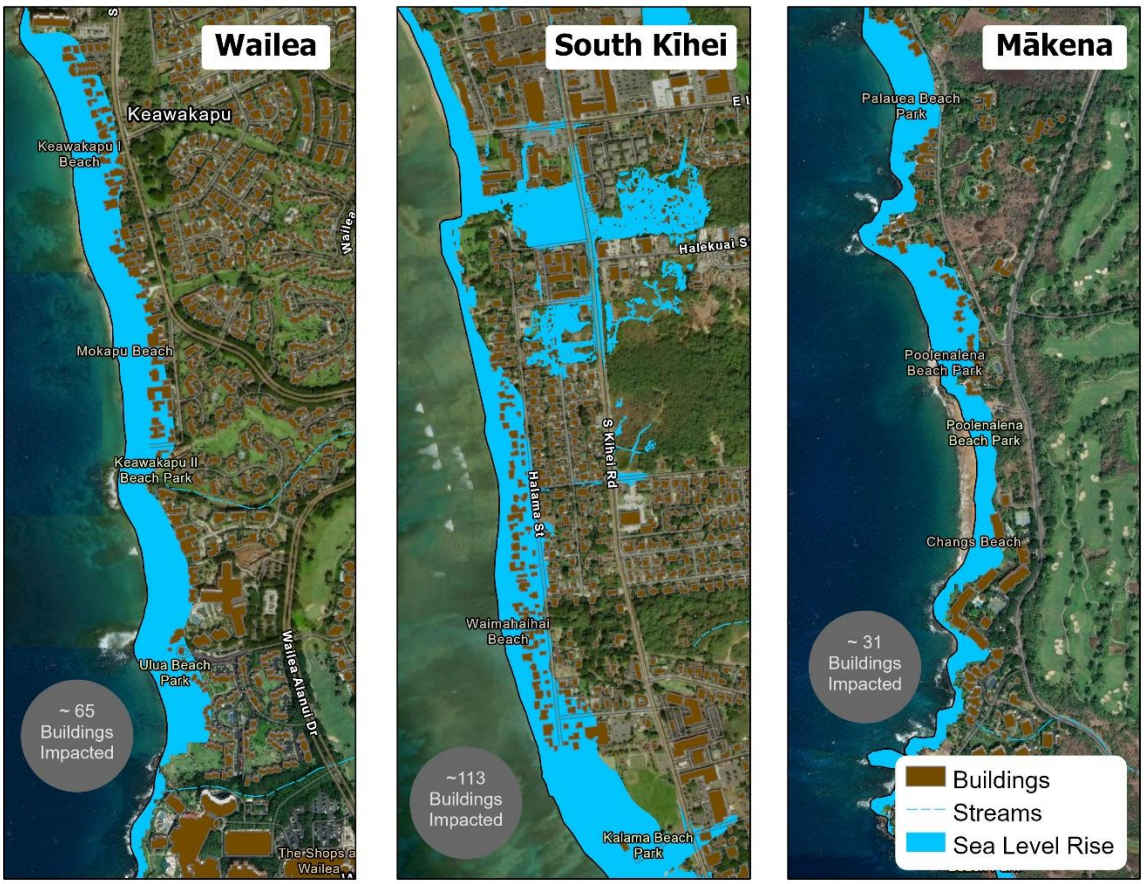

Figure 12: shows portions of South Maui and the approximate number of buildings impacted by 3.2ft SLR. Image courtesy of Maui County.

Erosion and Overwash on Roadways

Erosion and overwash threaten major roads in South Maui. Of the 7 miles affected by sea level rise, 1.96 miles are major roads including North and South Kīhei Road and Honoapi‘ilani Highway. North and South Kīhei Road are one of two roads in/out of South Maui. The road was built along low-lying coastal beaches that are prone to erosion and wave overwash during seasonal high tide flooding or storm surges. Seasonal flooding and storm surges are already causing traffic disruptions and safety concerns. These events will become common and widespread as conditions from sea level rise become permanent.

Economic Impacts

Climate change brings with it a potential for $980.8 million of economic impacts from sea level rise alone (Figure 13).

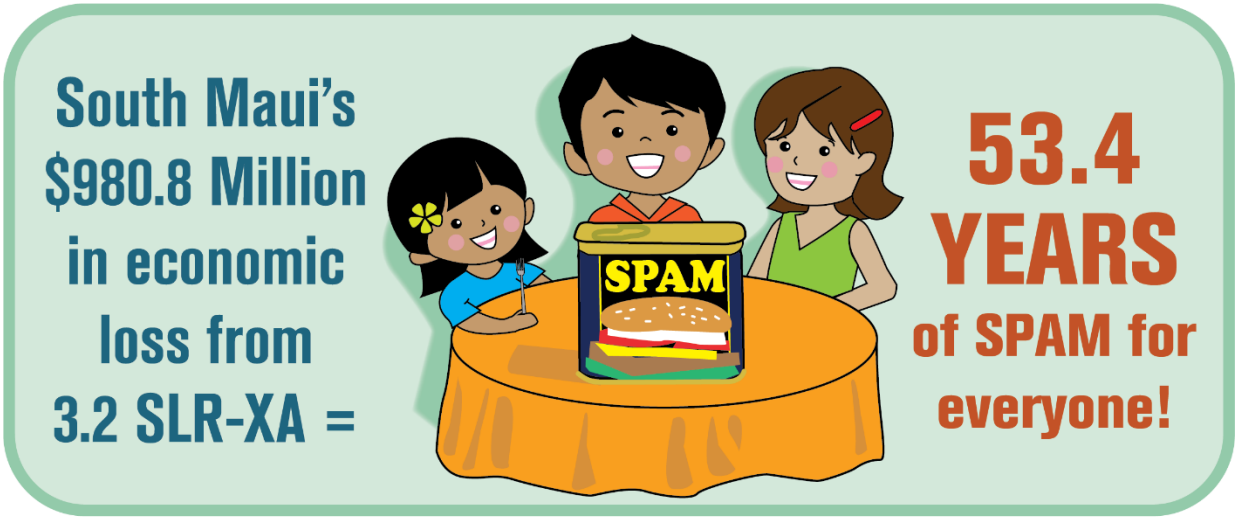

Figure 13: this is based on the State of Hawai'i's annual Spam consumption (7 million cans) at a cost of $2.62/can. Graphic courtesy of Maui County.

Development along the shoreline means some areas of South Maui are at greater risk for economic impacts than others (Figure 14). South Kīhei and Mākena have the greatest potential losses and combined total of nearly $500 million dollars. Potential economic loss is based on the County's tax parcel values of the land and structures permanently lost to 3.2 ft sea level

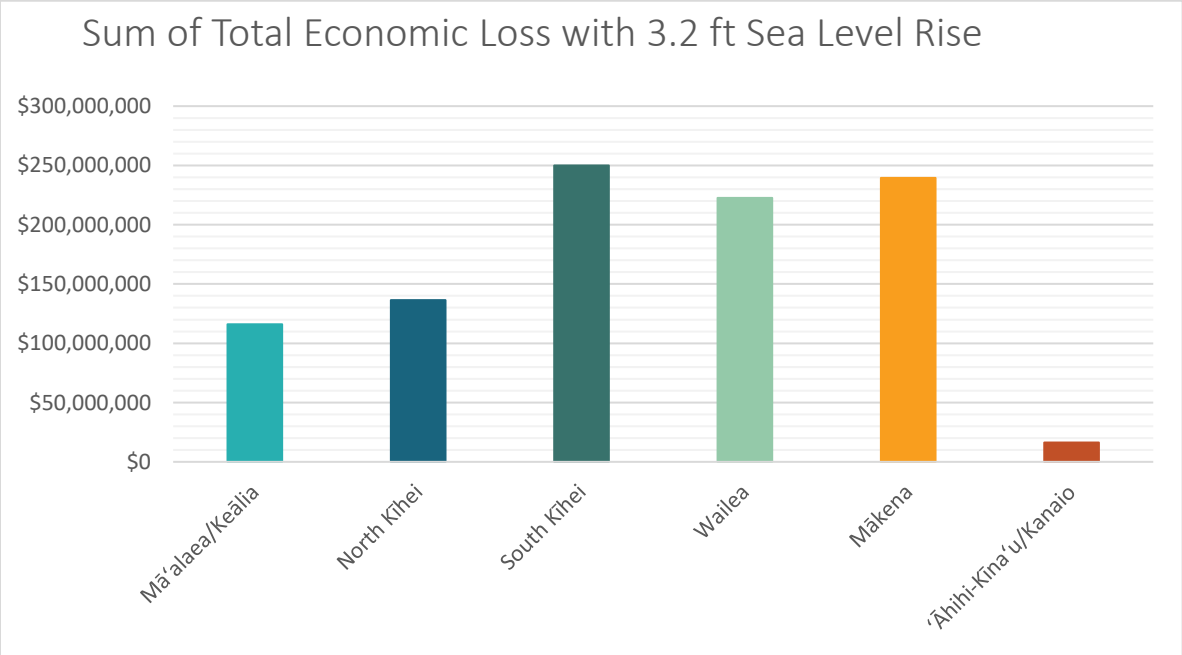

Figure 14: Sum of total economic loss caused by 3.2 ft of SLR per subarea of South Maui. Graphic courtesy of Maui County

rise. This amount does not include critical infrastructure like roads, bridges, fresh water or wastewater treatment facilities and lines, harbor facilities, electrical systems, or emergency services.

The monetary impacts to critical infrastructure that could be impacted by sea level rise are presently unknown. This value is likely to be even greater than the potential loss of structures and properties, not including other secondary social and economic impacts of infrastructure loss. A more detailed economic loss analysis is needed for Maui's critical infrastructure.

Ongoing Coastal Erosion

Continued and increasing permanent coastal erosion is highly likely in the future (Figure 15). A total of 304 buildings are at-risk to coastal erosion by the mid-21st century to late-21st century. Erosion also threatens critical infrastructure. As beaches continue to shrink and dunes are lost, their natural capacity to buffer and protect adjacent areas is substantially reduced or even eliminated. This threatens the resorts and development along South Maui's highly developed coastline. Further, beach loss can negatively impact tourism and resident quality of life. The Grand Wailea-Waldorf Astoria resort is Maui County's largest employer (Data.Hawaii.Gov 2019), but it is projected to lose much of its beach to coastal erosion and sea level rise.

Figure 15: Current coastal erosion along South Maui using Hawaii Sea Level Rise Viewer. Image shows shoreline armoring near Halama Street. Graphic courtesy of Maui County

South Maui has been heavily impacted by coastal erosion, with 11% of its total beach length lost between 1900 and 2007. Halama Street/ Kalama Park area has lost the most with 34 percent of its beach width gone due to shoreline armoring. Many more miles of beach could be lost if widespread armoring is allowed. Identifying alternative interim and long-term adaptive

strategies that are feasible for each beach cell will require proactive planning. They could include relocation or retreat and adaptation measures like elevating buildings, dune restoration and/or beach nourishment.

Changing Weather Patterns

Changing weather patterns could bring more extreme weather events compounding existing flooding and other climate change problems (Figure 16). Climate models predict tropical storms and hurricanes will occur more often near Hawai‘i in the future. They also predict the intensity and amount of rainfall from the storms will increase while their speed decreases, resulting in greater impacts and damage costs from storms. Sea level rise combined with these storms will cause greater flooding from storm surges, high waves, or seasonal tidal flooding in low-lying coastal areas like South Maui.

Figure 16: Graphic courtesy of Maui County.

Average temperatures in Maui County are projected to increase 2-3°F by the mid-21st century and 5-6°F by the late-21st century under a high greenhouse gas emissions scenario. Impacts of extreme heat events can include loss of life and economic costs imposed by property, crop, coral reef, and infrastructure loss. Extreme heat events also lower air quality by creating more smog and lower water quality by drying out water sources.

Extreme heat events impact certain demographics more than others. Demographics at greater risk are kupuna, keiki, outdoor workers, and households without air conditioning. Currently, more than 17 percent South Maui residents are over 65 years old and nearly 20 percent of the population is under 18. The population of South Maui is expected to increase over the next 20 years. Therefore, increased populations of at-risk demographics could be living in the area as the temperatures rise increasing the risk for loss of life and economic costs associated with heat illness.

Wildfire

Wildfire events will continue to be an ongoing threat to South Maui. A total of 31,030 acres were burned within or nearby South Maui over the past 13 years. In 2019, Maui’s largest wildfire on record impacted portions of South Maui. That same year another large scale fire

prompted the evacuation of several thousand residents and tourists from Mā‘alaea and North Kīhei (Figure 17).

Figure 17: Wildfire burning upslope of Mā‘alaea threatening the community and Honoapi‘ilani Highway. Photo courtesy of MEMA and Maui County.

Wildfire potential increases with drought and hot, windy conditions, meaning fires could become more common and intense in the future due to climate change. Climate change conditions also make native plant species more vulnerable to competition from non-native species. More land cover of fire-prone, non-native plants increases wildfire frequency and intensity. Drought also increases wildfire vulnerability as water is needed to fight fires, which are more frequent in dry conditions.

Food Systems Vulnerability

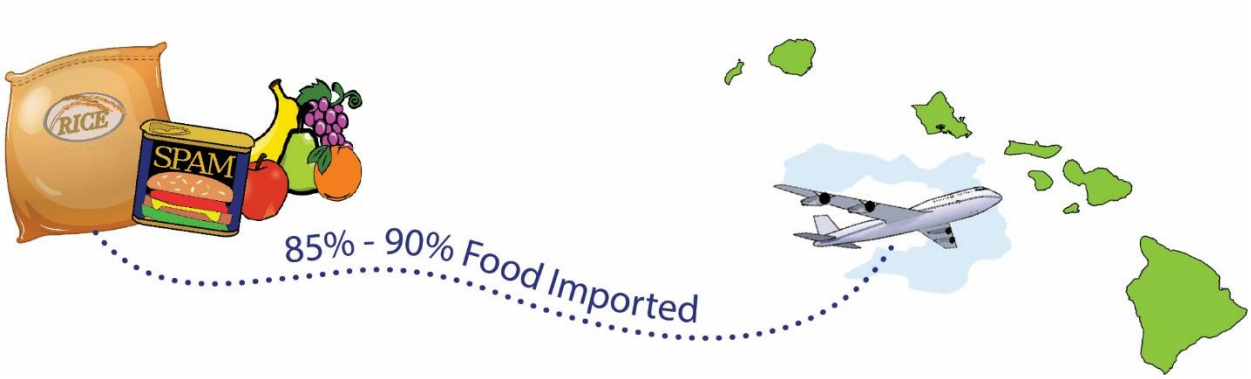

Figure 18: graphic courtesy of Maui County

Hawai'i is uniquely vulnerable to food insecurity (Figure 18). Climate change may affect food security in South Maui in many ways. It could disrupt the global food system the region relies on or it could help the spread of vector borne diseases resulting in pandemics that create social disruptions, impacting access and affordability of food. Areas with higher poverty rates are at greater risk to food insecurity, as residents often do not have the financial resources to deal with social disruptions like the Covid-19 pandemic. South Maui had the 4th highest poverty rate on Maui before the start of the pandemic and over 8% of the population received food assistance. Many more residents may now be at risk of food insecurity.

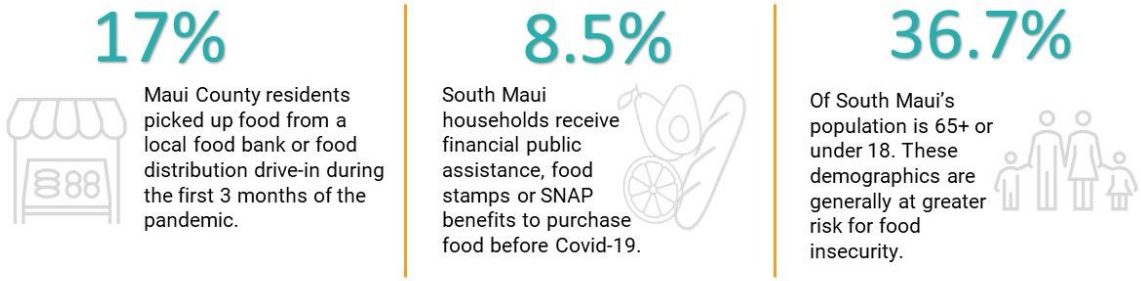

Figure 19: Graphic courtesy of Maui County

Vulnerable populations, such as kupuna and keiki, are at a greater risk for food insecurity. These groups make up about 36 percent of South Maui's population. Identifying ways to produce more food locally has been an ongoing goal and challenge of the State and County that will require a dedicated collaborative effort by government, farmers, and the community. This effort will involve proactive planning and reimagining of local food systems.

Adaptation Strategies

An abbreviated version of the adaptation strategies developed for the technical resource paper are provided below. For a full description of the strategies see Appendix F. Adaptation strategies were developed to consider not only short-term impacts, but long-term effects of climate change. While the community plan update is intended to guide development for the next 20-years, the focus of the technical resource paper was to consider impacts on South Maui through the end of the century. This timeframe was selected because of South Maui's risks to sea level rise as well as other climate change impacts like drought, wildfire and changing weather patterns.

The following information is pulled directly from the Draft Pre-Final South Maui Hazards and Climate Change Resource Paper prepared for LRD with only minor paraphrasing or revisions for clarity in this context. Because the paper is still a draft version, at this stage it is not intended for use in public planning or policy making decisions. See Appendix F for the full context and the source of these adaptation strategies. This information is provided courtesy of Maui County.

Consider the 3.2 SLR-XA as a vulnerability zone for planning at the community level.

Planning decisions made today will have impacts into the future when sea level rise becomes increasingly likely. Considering the 3.2 SLR-XA throughout the South Maui Community Plan is a critical first step in preparing for, adapting to, and avoiding sea level rise impacts.

Limit future development or redevelopment inside the 3.2 SLR-XA.

Sea level rise will exacerbate existing coastal hazards like erosion and flooding. This puts structures within the exposure area at greater risk for damage. Rebuilding in the exposure area should incorporate design elements to enhance community safety and resiliency.

Consider sea level rise and other hazards facing South Maui in designing and siting development.

Incorporate sea level rise in the design and siting of future developments or capital improvement projects. Include an analysis of sea level rise impacts based on the project's elevation, tolerance for risk, and the life span of the structure.

- Develop design standards as best management practices within the 3.2 SLR-XA. Design standard should increase flood resiliency for structures that cannot be relocated outside the exposure area.
- Special consideration should be given to public housing and affordable housing projects. In addition to coastal hazards, design standards could include considerations for other hazards affecting vulnerable populations. These standards could include design measures for extreme heat, like improved air circulation within and between buildings, shade structures or cooling systems. They could also include water and energy efficient design or appliances.
- Integrate recommendations from the Hawai‘i Drought Plan to promote water conservation into the design and redevelopment of future projects.

Support design standards and adaptation strategies that provide multiple benefits.

For example, design standards for high wave and coastal erosion could require the use of fire-resistant materials where appropriate. Other crossover designs include strategic expansion of parklands and open space to create buffers around wetlands, beaches, and floodplains. Buffers create space allowing for natural expansion of these protective features to minimize sea level rise and flooding impacts. When managed, these spaces can also serve as fire breaks and recreation areas for the community.

Prioritize smart growth and redevelopment in urban lands outside the 3.2 SLR-XA.

Relocation and inland retreat from sea level rise will be essential to the long-term safety and economic viability of South Maui's communities. Urban lands outside the 3.2 SLR-XA that are suitable for smart growth should be identified. These lands would be used for future development and re-development of structures threatened by sea level rise.

Develop new funding sources and engage stakeholders (i.e. decision-makers, government officials, community members, and organizations) in adapting to sea level rise.

Options for financing are available at the international and national levels. They integrate both public and private capital. It will be important here in Hawai'i to take steps to understand, document and link financing with local coastal adaptation actions. This is because the price tag connected to reducing vulnerability will be high. Further, local conditions shape the choices for both the best adaptation strategies and financing sources.

Conduct a detailed vulnerability assessment for existing critical infrastructure (e.g. roads, wastewater facilities, electrical supply, etc.).

In-depth assessments of vulnerability and adaptation strategies (e.g. relocate, retrofit, or protect) should be conducted for critical infrastructure within the sea level rise exposure area. Critical infrastructure's long lifespan and low risk tolerance make it especially vulnerable to sea level rise. The potential variability in future sea level rise supports a more detailed economic loss analysis for South Maui's critical infrastructure.

Explore options for beach, wetland, and coral reef preservation.

Beaches, wetlands, and reefs are important community resources and economic assets for South Maui. They form the first line of natural defense against high waves caused by many hazards like storms and tsunamis. Coastal wetlands, and possibly even coral reefs, can serve as carbon sinks known as "blue carbon" systems. Blue carbon sinks can help reduce the amount of greenhouse gases in the atmosphere associated with climate change. Strategies to protect and preserve these resources should be proactively explored before their important ecosystem services are lost.

Conduct an inventory of natural and cultural resources and develop preservation plans.

Include place-based cultural practices and shoreline access locations in the inventory. Shoreline access locations and place-based cultural practice areas may become inaccessible due to sea level rise. They may also be impacted by wildfires or landslides following heavy rains. Baseline

databases should be developed to plan for and monitor changes over time. The County of Maui released the updated shoreline access survey in June 2020. That survey could be used as a starting point to inventory these resources.

Encourage measures to reduce flood damage to existing and future developments.

Changing weather patterns and sea level rise may expand where coastal, inland, and flash flooding occurs in South Maui. Areas not previously located in a flood risk zone may now be at-risk and flooding impacts to current RL and SRL properties may be exacerbated. Maui County has participated in the NFIP since 1996 and is a CRS Class 7, entitling Maui County participants for discounts on flood insurance premiums.

Incorporate green infrastructure or low impact development into the design requirements of future and re-development projects.

Green infrastructure and low impact development reduce stormwater runoff and help prevent erosion and flooding. This is accomplished using trees, shrubs, plants, soils, and other natural design elements. These design elements absorb or slow the flow of stormwater runoff at its source. This would help reduce flooding along roadways and in urban areas of South Maui.

Green infrastructure can also deliver added environmental, social, and economic benefits. For example, green infrastructure can function as parks or open space. This creates recreational space for residents and reduces the urban heat island effect. It can also help improve water quality and reduce some drought impacts.

Integrate actions proposed in the Community Wildfire Protection Plan South Maui into the Community Plan.

This will allow South Maui to become a fire-adapted community. Actions outlined in the Plan will foster building resilient landscapes and establishing safe and effective wildfire responses.

Encourage development of additional roadways in and out of South Maui to create additional hazard escape routes.

In 2019, the limited access in and out of South Maui created a health and safety hazard when residents were trapped following a wildfire near Mā'alaea and North Kīhei. Additional roads in and out of South Maui are needed to protect residents.

Encourage local food production and land use by preserving important or prime agricultural zoned lands existing within South Maui.

This may require developing conservation easements or transfer of development rights programs. To increase production for local consumption, collaboration with local farmers and distributors would be required.

Agricultural water rights would be need protection in the Community Plan update. Encourage the incorporation of traditional Native Hawaiian agricultural practices where possible.

Local food production and food insecurity are regional, county-wide issues. In addition to the recommendations to preserve agricultural lands, addressing them will require further planning processes, more research and collaboration, and/or supportive funding on a broader county-wide scale.

Incorporate sea level rise and other climate change impacts into disaster pre-plans.

Communities that plan for disaster recovery achieve greater success in accessing funding and improving resilience through the recovery process. This allows a community to build back smarter and more resilient following a disaster by allowing a community to decide their priorities and explore alternative development patterns.

Discussion and Conclusion

Discussion

This Practicum started with the intent to produce a technical resource paper on natural and climate change hazards as part of the community engagement process for the South Maui Community Plan update. Throughout the process, however, the scope of the paper changed from a truly 'technical' document into a scaled back, reader friendly resource paper. The Practicum project was started in late June 2020 and was completed in March 2021.

Throughout the course of this Practicum, the Covid-19 pandemic was creating massive social disruptions across the world and Hawai'i which directly impacted some aspects of the project. For example, during the entire project and Practicum timeframes the State of Hawai'i was under varying degrees of government ordered lockdown limiting any inter-island travel or interpersonal interaction. This had some expected impacts on the project, like no site visits were conducted, and some unexpected impacts like relying entirely on LRD for descriptions of "on the ground" problems and photos of affected areas.

The Covid-19 pandemic also resulted in having to reconsider the community engagement process and the materials produced for it. Because public gatherings across the State were restricted to either the same household or less than 5 people, traditional "open house" meetings were no longer viable. This meant that community engagement would now have to be entirely digital. To facilitate this, a greater consideration was required on how to incorporate elements like infographics, photos, maps, and charts into the technical resource papers that translated more easily to a digital medium.

GIS was particularly useful in addressing this consideration. Many of the issues covered in the paper were easily displayed on maps of the project area, or through converting the findings from my analyses into infographics and tables (see Key Findings). This was an aspect of the project that involved a lot of trial and error. Each map and graphic included in the pre-final submission underwent multiple rounds of internal and external review and was improved upon during each draft submission. By Phase III of the project, I began submitting the maps and

graphics to LRD for their review independent of the paper because these were so tricky to perfect.

Adding to this difficulty of perfecting maps and infographics were limitations or errors in the GIS datasets. The alignment error between the parcels layer and other land use datasets made it very difficult to use this layer without encountering polygon slivers and other issues. Other limitations included having to integrate information from multiple data sources and authors. For example, I was asked by LRD to determine the number of properties located within the FEMA SFHA that had flood insurance. The active insurance policy dataset was provided as a standalone table from FEMA and unsurprisingly it did not share corresponding fields in the buildings layer provided by the County. Since there were over 900 structures and over 1,000 active policies it was outside the budgetary constraints of the project to try and georeference the active policy dataset. Therefore, I was unable to perform this analysis and answer this question in the paper.

Another limitation was the lack of recent countywide records of wildfire events and acres burned within the State. This is due to multiple departments and agencies being responsible for fighting fires, a lack of standardized method of recording fires across the organizations, and limited budget to gather and map the wildfire data (HWMO 2013). There are a few existing datasets and map products that record one or the other, and one resource that records both variables but its most recent records are from 2011. The 10-year gap in data meant this resource was not recent enough for the paper because during that time there have been multiple large-scale fires in South Maui alone.

This limitation meant I were unable to map or analyze the history of wildfire in the region. To me this was the biggest let down in data because South Maui is already ranked as a high-risk community for wildfire, and with climate change the risk of wildfire is expected to increase. While it is a known and recognized issue in the area, having maps to illustrate the size and frequency of recent wildfire events would have been an extremely effective way to support the adaptation strategies recommended in the technical resource paper.

Throughout all this, the project was developed in three overarching phases. Phase I consisted of interviews with various Maui County departments and agencies, and Dr. Fletcher drafting the original paper. The directive from LRD in late July 2020 to use the West Maui papers as a guideline can be considered the turning point for my involvement in the project. This was when I became lead on the paper for BCH and when I received permission from Dr. Fletcher to revise the paper as needed.

Phase II involved conducting an extensive literature review, performing GIS analyses for SLR and mapping wildfire impacts, and revising Dr. Fletcher's paper. This phase moved the paper closer to the format LRD wanted, but still missed the mark in terms of spatial scale, reading level and the paper's overall length. The version developed during this phase was submitted to LRD as the preliminary draft.

Phase III (A) involved a substantial number of revisions based on LRD's comments of the preliminary draft. During this phase I removed all discussion on global or regional impacts, revised the paper's structure, developed more infographics, and re-wrote the paper at a 5th to 8th grade reading level. Following these changes, this version of the paper was submitted to LRD as the draft submittal. While LRD did have additional comments upon the draft submittal, they were comparatively minor to those received during Phases I and II. At this point the project moved into Phase III (B) where I updated some of the infographics and incorporated the NFIP information into the paper.

As such, the Practicum was concluded during Phase III (B) upon the submission to LRD of the pre-final draft of the paper. However, the project is still ongoing. The paper has been submitted to LRD for further review and will likely require some additional, minor edits before being shared with the public as part of the community engagement process.

Throughout the three overarching phases of this Practicum there were a few substantial issues encountered. In the following section, I will discuss a few of the issues and what I learned from them to help others who may perform similar projects in the future.

Lessons Learned

Throughout the process of this Practicum there were a few substantial issues encountered. The first issue was unclear expectations at the start of the project pertaining to the level of technical detail required. By not initially specifying the level of detail desired in the paper, it resulted in three separate versions of the document being prepared. This was extremely costly from both budgetary and time standpoints.

My suggestion would be to establish a clear understanding at the start of the project with the client on the level of technical detail required. This could be accomplished by providing writing samples or sharing previous reports with the client for feedback before diving into reporting. This would allow the client to see the caliber and level of technical detail you are planning to provide, and they could offer input on if it is what they are looking for before anything is written.

The second issue was related to the paper's scope and scale of issues being analyzed. In the instance, this could have been prevented by providing a detailed project outline prior to drafting the paper and including descriptive placeholders for graphics. For this project, providing LRD with a detailed outline was a submittal requirement. However, this occurred during part of the project timeline when Dr. Fletcher was still responsible for drafting the paper.

In retrospect, instead of trying to rework Dr. Fletcher's paper straight away I would have developed a detailed project outline highlighting the proposed sections and graphics and submitted that to LRD for review. This would have afforded LRD the opportunity to provide feedback on things like removing global impacts, isolating the discussion to specifically South

Maui issues, re-structuring the sections, and revising the graphics before they were drafted. This could have saved time on both writing and revising the paper.

The third issue was not considering the audience and their reading capacity more consciously at the start of the project. This was the biggest learning lesson for me during the Practicum. When writing for academic or more professional audiences, the assumption is the reader has a basic understanding of the topic and reading abilities to comprehend the discussion. Since this paper was for *every* member of the public, the writing style required was very different than what I was used to.

Upon learning that 1 in 6 Hawaii residents cannot read or write at a basic level, I had to rethink the way I was writing resulting in having to re-write much of the paper. I would suggest taking the time to do a little background research on the audience's reading level and abilities before drafting a paper to avoid this mistake. One tool I found invaluable for simplifying vocabulary and sentence structure was the Hemingwayapp (2020). Using infographics to tell the story or explain more complicated processes was another tool I used in writing for a broader audience.

Finally, do not be hesitant to ask for help or seek outside input. On this project I learned a tremendous amount about employing GIS to answer questions about the project area and was able to use many of the GIS skills I learned during my master's program. However, I also needed a lot of additional help. This included guidance and input from other members of the project team, personal friends with GIS knowledge, and internet searches. Without these resources I would not have been able to figure out how to analyze many of the spatial questions I was asked to answer. This experience reinforced the value of collaboration and seeking additional help when you need it.

To share some of the key lessons I learned throughout process, I developed an Effective Communication Checklist (see Appendix D). I shared this document within my department to help facilitate a broad-level, standard operating procedure when undertaking new projects. My hope is by sharing, my department and I can avoid similar pitfalls and mistakes on our future projects.

Conclusion

The Practicum demonstrated the need to prepare community planning documents at an appropriate spatial scale and readability level, while also providing climate change adaptations for communities. By using the appropriate spatial scale, impacts directly affecting the South Maui community were analyzed. These analyses were used to develop and support the climate change adaptations provided in the technical resource paper. Without this spatial link, it would have been difficult to show to the public why these adaptation measures were necessary. Further, by understanding the reading level of most members of the public the document was written in a manner that promoted public inclusion and feedback. As the planning profession works to promote greater inclusion in the decision-making process for greater social equity, preparing documents in a way that the public can read and understand will be critical.

Final Thoughts

I owe special thanks to Allen Kam for giving me the opportunity to take this project and run with it, and to Matt Kodama for all his help in drafting and revising the paper throughout the project's phases. This Practicum experience was a very interesting and I learned so much throughout the process. I also want to give a special thanks to Jared Taylor for all his help, support, and encouragement throughout my entire master's program. Thank you for everything Jared.

Throughout the project, I gained a greater working knowledge of Hawai'i's planning and community development processes. Different tasks performed as part of the project such as GIS analyses, researching climate change adaptation strategies, and researching how the existing policy framework supported those strategies were directly related to classes I took during the degree program. Additionally, I gained a deeper knowledge and interest in climate change science and how communities can better prepare for climate change impacts. Perhaps most importantly, I gained a better appreciation and understanding of the significance in *how* information is relayed.

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Appendix A: County Interviews

The following agencies and departments were interviewed as part of the South Maui Community Plan update. During the interviews, my primary role was to listen and take notes.

1. Hawai‘i Department of Transportation (06/24/20)
    a. Focus of the interview was traffic related issues.
    b. Concerns about current and future flooding created by SLR were discussed. Primarily concerned with areas along N. and S. Kīhei Road.
2. Maui Police Department (06/25/20)
    a. Focus of the interview was on safety issues in South Maui. Upland flooding near Pi’ilani Highway and Kanakanui currently create flooding issues and the department routinely has to direct traffic around these areas.
    b. Other safety hazards identified were the lack of roads in and out of South Maui in case of emergencies. For example, a recent wildland fire near Kīhei effectively blocked off all access in/out of South Maui. Had to request use of a private road near ‘Āhihi- Kīna'u/Kanaio to get access to the community.
3. Maui County Department of Transportation and Public Works (06/25/20)
    a. Focus of the interview was on safe mobility around South Maui. Flooding on S. Kīhei Road creates impacts on pedestrian and bike mobility, as well as bus lines and traffic. Want more N/S connectors to detour around flooding and increase connectivity in community.
    b. Significant flooding issues in South Kīhei. Major concern with SLR is that DTPW is currently maintaining sand plugs near Kīhei, worried this will be worse in future. Flooding in the regions is worse in rainy season, following named storm events, and upcountry rain.
    c. Tidal surges creating erosion on both sides of coastal roads.
    d. Mā‘alaea debris basin in old cane fields near condos and drainage ditches having erosion issues near mouth of basin at coastline.
4. Maui County Board of Water Supply (07/14/20)
    a. Focus of the interview was on water availability and long-term planning for future development. Constantly looking for water sources. Priority of focus is on first finding groundwater sources, then surface water sources, then desalinization.
    b. Reclaimed water for non-potable uses. Suggested extending existing lines to portions of the area that do not currently have piping (e.g. Wailea) and offering dual systems/meters in residential areas for reclaimed and potable water.
    c. Major issue is running out of source drinking water because South Maui is at the end of the Central Maui Distribution line and the water source is located well outside the Community Plan area.
    d. Encourage changes in landscaping to xeriscape gardening to reduce water needs.
5. Maui County Department of Environmental Management (07/16/20)

a. Focus of the interview was on reclaimed water and working with public/private partnerships to fund extending the lines to large, reclaimed water users (e.g. Bayer, formerly Monsanto).
b. Discussed a departmental desire for more legislation pushing and mandating 100% reclaimed water use for landscaping and watering outdoor areas.
c. Working on a SLR strategic retreat plan now due to location of existing sewer pipes and facilities along N. and S. Kīhei Road and projected SLR inundation.
d. Concerns with wildland fires near infrastructure and lack of access in/out of South Maui.

6. Long Range Planning Division of the Maui County Department of Planning (07/17/20)
    a. Focus of the interview was on all the resource paper topics. Regarding climate change, the following issues were brought up as major concerns.
    b. Wildland fires and the climate change connections/implications, for example the lack of roads in/out of South Maui.
    c. Long-term water availability in the area and drought.
    d. SLR. Community is very concerned about N. and S. Kīhei Road. High risk for flooding and coastal erosion now and in the future from SLR, hurricanes, tidal flooding. One suggestion is to make southern portion a pedestrian path.
    e. Greater wetland and coastal dune restoration efforts.
    f. Heat stress. Could tie into complete street efforts with shade trees or construct shade as part of public infrastructure projects.

Appendix B: Literature Review

The following resources were instrumental in my understanding of natural hazards and climate change effects on South Maui and used in developing appropriate mitigation and adaptation measures.

Dr. Fletcher's Original Paper

Dr. Fletcher's paper was the starting point of my literature review. It provided a wealth of best available science on global and regional climate change, greenhouse gas emissions, and sea level rise. I learned a tremendous amount about the inter-connectivity between climate change and its direct and indirect effects. It also was the starting point in determining which issues to analyze in my version of the paper. Dr. Fletcher's paper made me think more deeply about how land use planning at a community scale could deal with global issues to make South Maui more resilient.

Initially, I incorporated an extremely condensed explanation on how global climate change and greenhouse gas emissions effect South Maui. However, following the preliminary draft review LRD requested that this information be removed. Based on their experience with community engagement process for the West Maui Community Plan update they believed that a global level perspective was not needed. So, I used this as an opportunity to create a graphic. With the

help of my company's graphic designer, Amy Yamakawa, we developed a comprehensive climate change graphic that incorporated South Maui specific changes and impacts. She also assisted in producing many of the final infographics for the paper.

West Maui Community Plan Climate Change and Sea Level Rise Technical Resource Paper

The West Maui Technical Paper, prepared for the West Maui Community Plan update, is the counterpart to South Maui's hazards and climate change paper (County of Maui 2018). This paper was prepared in part by Maui County Department of Planning. LRD requested its format, some of its content, its overall writing style and length be used in drafting the South Maui paper. However, the West Maui Technical Paper only addresses coastal hazards that result in flooding such as coastal erosion, tsunamis, high waves, and sea level rise. Because hazards vary between communities and the South Maui paper includes more, it proved difficult to closely match the overall writing style and length requirements. However, I did use the West Maui Technical Paper as a framework as much as possible and incorporated its adaptation recommendations into the South Maui paper as appropriate.

County of Maui Hazard Mitigation Plan 2020 Update

The *County of Maui Hazard Mitigation Plan 2020 Update* (HMP) was one of the resources recommended by LRD in their preliminary draft comments. As part of Maui County's sustainability and resiliency planning efforts, HMP is a master plan used to identify resources, information, and strategies to reduce direct and indirect risks posed by natural hazards and technological disasters. It is intended to identify and guide hazard mitigation actions to reduce life, economic, environmental, and property losses. The Maui County Planning Department played a key role in developing the HMP and has committed to incorporating elements into their updated community plans.

An important update in the 2020 HMP was the focus on stakeholder engagement and risk assessments at the community planning level. To assess physical and economic impacts, the 2020 update included a priority risk index (PRI) tool to score and rank hazards quantitatively for each community planning area. In addition to the PRI tool, the update included an assessment of impacts on socially vulnerable populations using a social vulnerability index (SVI).

I relied heavily on this report following LRD's comments. HMP is the only document I could find that provided a hazards assessment, covering an extensive range of hazards, at the community plan spatial scale. I used the HMP's hazard descriptions, PRI, and SVI rankings to explain how South Maui may be impacted in the future by climate change and other natural hazards.

Hawai‘i Sea Level Rise Vulnerability and Adaptation Report

The 2017 *Hawai‘i Sea Level Rise Vulnerability and Adaptation Report* (Adaptation Report) is the first state-wide assessment of Hawai‘i's vulnerability to sea level rise (SLR) (HCCMAC 2017). It relies on the best available science to model the vulnerability of Hawai‘i's shorelines at four potential SLR scenarios. The report's peer reviewed models and information are considered sufficiently validated for use in land management decisions, such as long-term planning. The

Adaptation Report is intended to be a living document updated as new information becomes available and provides mitigation measures to reduce the State's exposure to SLR and increase its adaptation capacity.

Information from this report was cited in Dr. Fletcher's paper, and I used it as the basis for my consideration of SLR. Initially, I briefly incorporated the four potential SLR scenarios in the paper and focused on the two scenarios (1.1 ft and 3.2 ft) highlighted in the West Maui Paper. Following LRD's preliminary draft comments, I removed much of the background information about SLR and only included a brief discussion on the 1.1 ft and 3.2 ft SLR-XAs in the paper.

Hawai'i Sea Level Rise Viewer

Corresponding to the report is the Pacific Islands Ocean Observing System (PacIOOS 2020) Sea Level Rise Viewer (Viewer). The Viewer is an interactive web map created to showcase impacts of the four SLR scenarios discussed in the Adaptation Report. The user can select which SLR scenario they want to view, and apply a layer for passive flooding, annual high-wave flooding, coastal erosion, or a combination of the three known as the sea level rise exposure area (SLR-XA). In addition to the SLR scenarios, the user can view estimates for potential economic impacts from flooding, roadways projected to be flooded, and how these interact with the community plan areas.

Because the Viewer is a free, publicly available GIS resource I wanted to showcase it in the paper. I included screenshots to visualize how future SLR scenarios would impact South Maui specifically and provided a link to the website.

Atlas of Natural Hazards in the Hawaiian Coastal Zone

The 2002 *Atlas of Natural Hazards in the Hawaiian Coastal Zone* (Fletcher et. al 2002) is a report that describes the history and relative intensity of coastal hazards across the State to assist with smart coastal land and resource management. It is combines into a single comprehensive document previous studies on Hawaiian coastal hazards by various researchers and county, state, and federal agencies. The report assigns a relative overall hazard ranking to Hawai'i's coastal areas based on their risk from tsunamis, stream flooding, high waves, storms, erosion, sea level and volcanic/seismic activity.

I used this report to determine the overall hazard ranking for each subarea in South Maui. After submitting the preliminary paper to LRD, they suggested I rely more heavily on the HMP to relay hazard vulnerability as it was a more recent assessment. However, the Atlas remained a relevant source that I used in confirming or supplementing information from the HMP.

Hawaii Drought Plan 2017 Update

To research the effects of drought, I relied heavily on The *Hawaii Drought Plan 2017 Update* (HDP) to establish drought adaptation strategies (State of Hawai'i 2017). Originally published in 2000, the HDP was updated in 2017 to improve coordination and implementation of drought mitigation strategies across the State. The updated plan is intended to serve as a loose framework to assist State and local entities to proactively work together in developing and

implementing mitigation measures to reduce drought effects and improve response strategies during extended drought periods. Drought mitigation are the emphasis of this plan, although it does include recommendations on adaptation actions.

Aloha + Challenge Dashboard

The Aloha + Challenge is a "statewide commitment to achieve Hawai'i's sustainability goals, and locally driven framework to implement the United Nations Sustainable Development Goals (Hawai'i Green Growth 2020)." One of the goals is to increase local food production 20-30% by 2030. The challenge is to look at State and local food systems, and how changes in land use or zoning can be used to achieve food production increase. I used this mainly as a cornerstone in my rational for including food system insecurity as a hazard facing South Maui. Food insecurity is an issue across the State, and I felt it needed to be included in the paper as climate change and natural hazards can severely increase that insecurity.

Local News

Local news sources were a surprisingly good resource on hazards effecting South Maui. Because they were local sources, they were spatially appropriate and gave a good temporal perspective to the hazards. I used these to find information about a variety of hazards like flooding, drought, wildfires, extreme heat events, and storms.

Appendix C: Datasets and GIS Analysis

Datasets

The following datasets were used to analyze various hazards affecting South Maui.

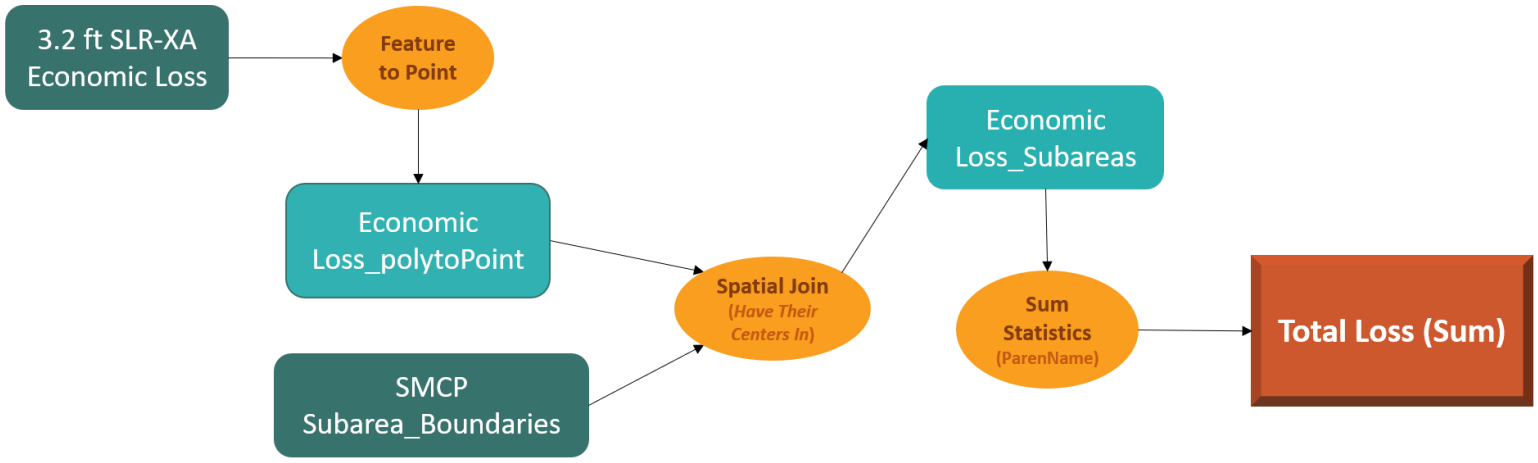
Layer/Shapefile	Source	Description
GrowthBoundaries	Maui Long Range Planning	Directed growth boundaries established by the MIP
CommunityPlanBoundary	Maui Long Range Planning	Boundary of South Maui Community Plan area
Wetlands	Maui Long Range Planning	Wetlands within South Maui
Sub-areas	Maui Long Range Planning	Boundary lines of Subareas 1 to 6
Parcels_08_2019	Maui Long Range Planning	Property parcel boundaries from 2019 updated
ProtectedAreas	Maui Long Range Planning	Areas determined by Maui Planning to be sensitive lands (e.g. parks, open space)
Zoning_Island_of_Maui	Maui County Dept. of Planning; Hawai'i Statewide GIS Program	Zoning based on MIP zone maps
Simplified_Zoning	Created by Matthew Kodama using Zoning_Island_Of Maui data	Excel dataset created by co-worker using MIP zones
CommunityPlan (1998 zoning)	Maui Long Range Planning	Zoning based on 1998 Kīhei-Mākena Community Plan zone maps
slr_potent_econ_loss_3_pt_2_ft	Maui Long Range Planning	Potential economic loss based on County's tax parcel values for land and structures permanently lost
slr_high_wave_fld_3_pt_2_ft	Maui Long Range Planning	Potential inundation extent from high wave surges under 3.2 ft SLR scenario
slr_exposure_area_fld_3_pt_2_ft	Maui Long Range Planning	Potential impacted area from combination of high waves, passive flooding, and coastal erosion under 3.2 ft of SLR
Parks_Open_Space	Maui Long Range Planning	Lands zoned in 1998 Community Plan zone maps as parks or open space

Layer/Shapefile	Source	Description
slr_cstl_erosn_3_pt_2_ft	Maui Long Range Planning	Potential extent of coastal erosion inland under 3.2 ft of SLR
slr_passive_fld_3_pt_2_ft	Maui Long Range Planning	Potential inundation extent from passive coastal flooding (e.g. tidal flooding) under 3.2ft of SLR
FireRisk	Department of Land and Natural Resource, Division of Forestry and Wildlife, Fire Management Program 2007	Analysis and ranking of wildland-urban interface areas potential risk for wildfires
SpecialManagementArea	Maui Long Range Planning	Coastal areas usually within 40' of the shoreline that are specially managed by Maui Dept. of Planning
buildings	Maui Long Range Planning	Footprints of buildings located within South Maui
S_FLD_HAZ_AR	FEMA 100-year floodplain map	FEMA Flood Insurance Rate Maps Special Hazard Flood Areas.
Streams	Maui Long Range Planning	Streams present in South Maui
Maui_Co_Ign_Density	University of Hawai'i at Manoa, College of Tropical Ag and Human Resources	Wildland fire ignition density maps for Hawai'i
gaplandcov_hi	United State Geological Survey, EROS Data Center, National GAP Analysis Program	Statewide vegetation land cover maps

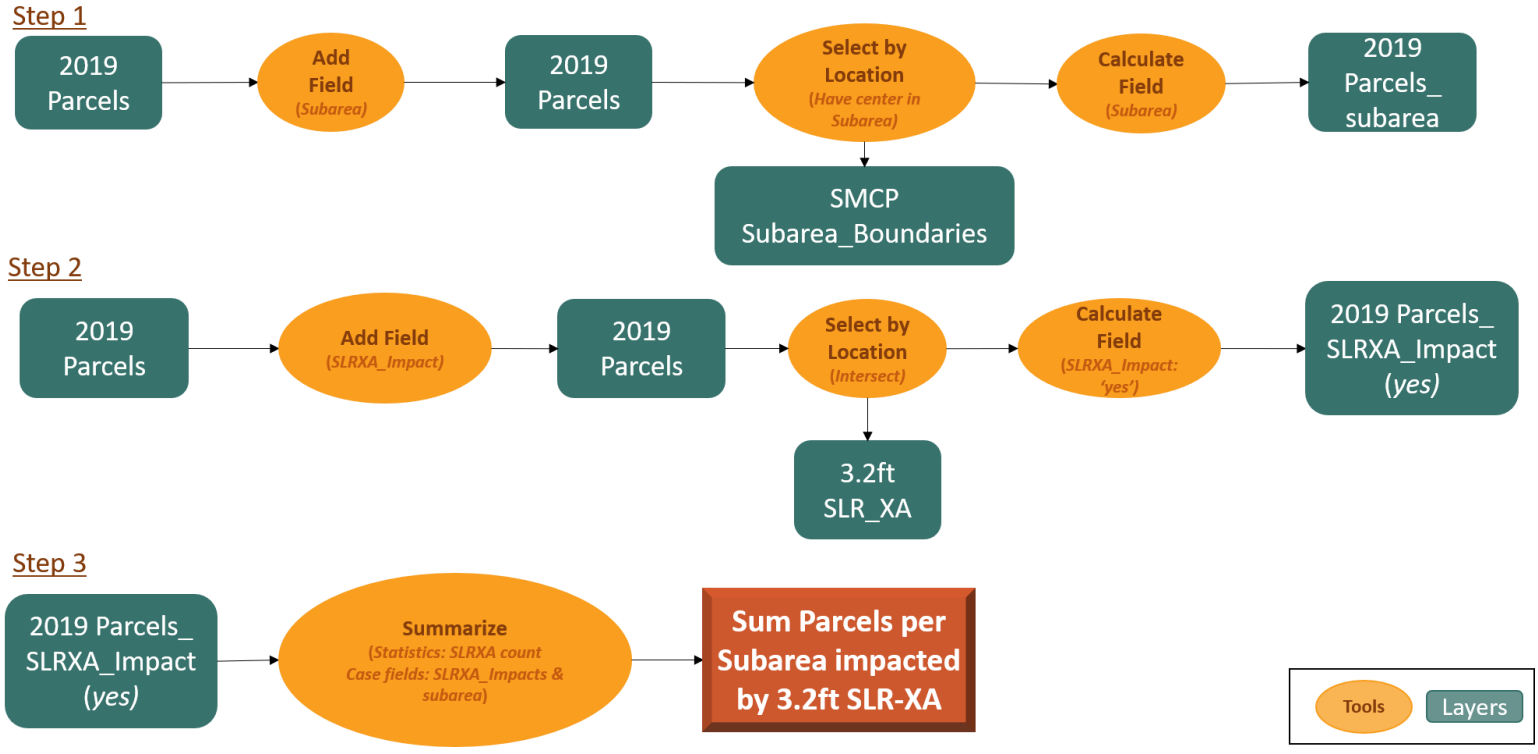
GIS Analysis Methods

The following methods were used to perform GIS analysis to develop key challenges facing South Maui.

Calculating 3.2 ft SLR-XA Economic Loss

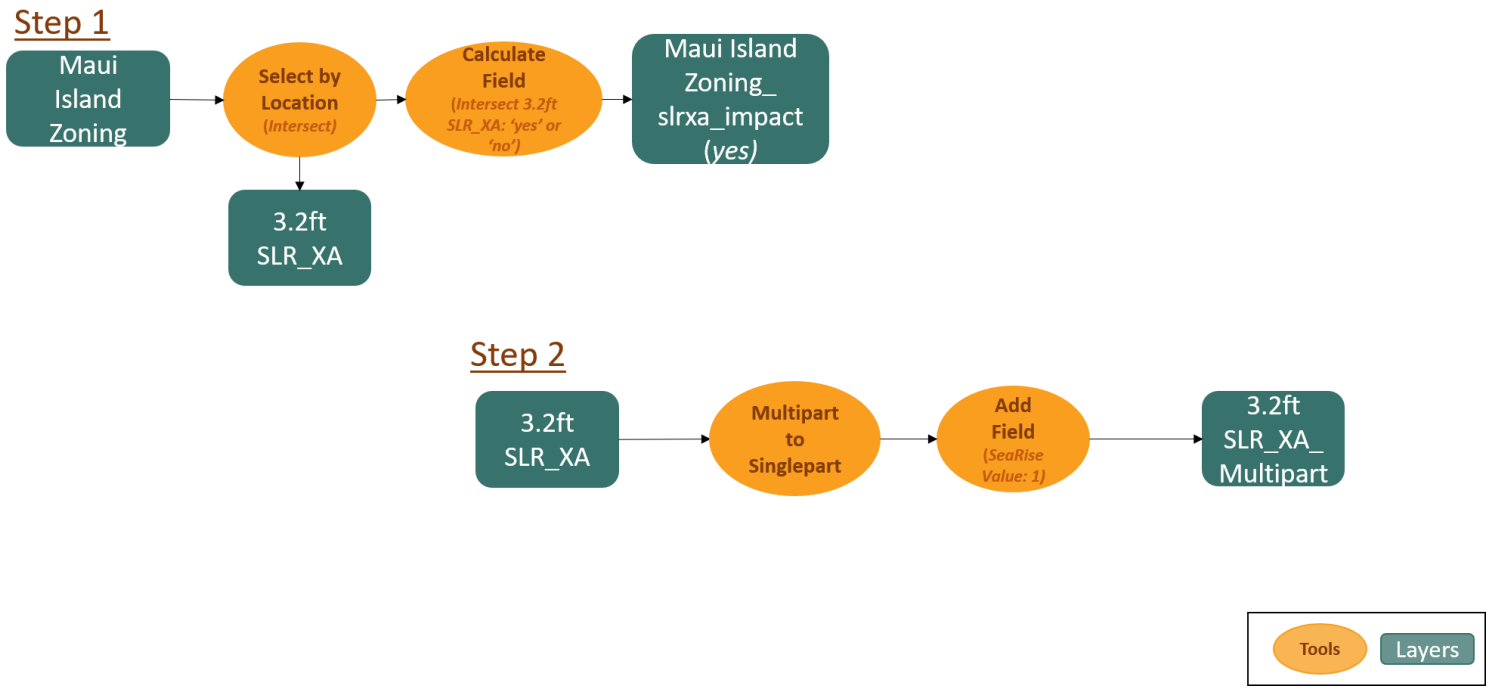


Determining Number of Parcels Impacted by Sea Level Rise

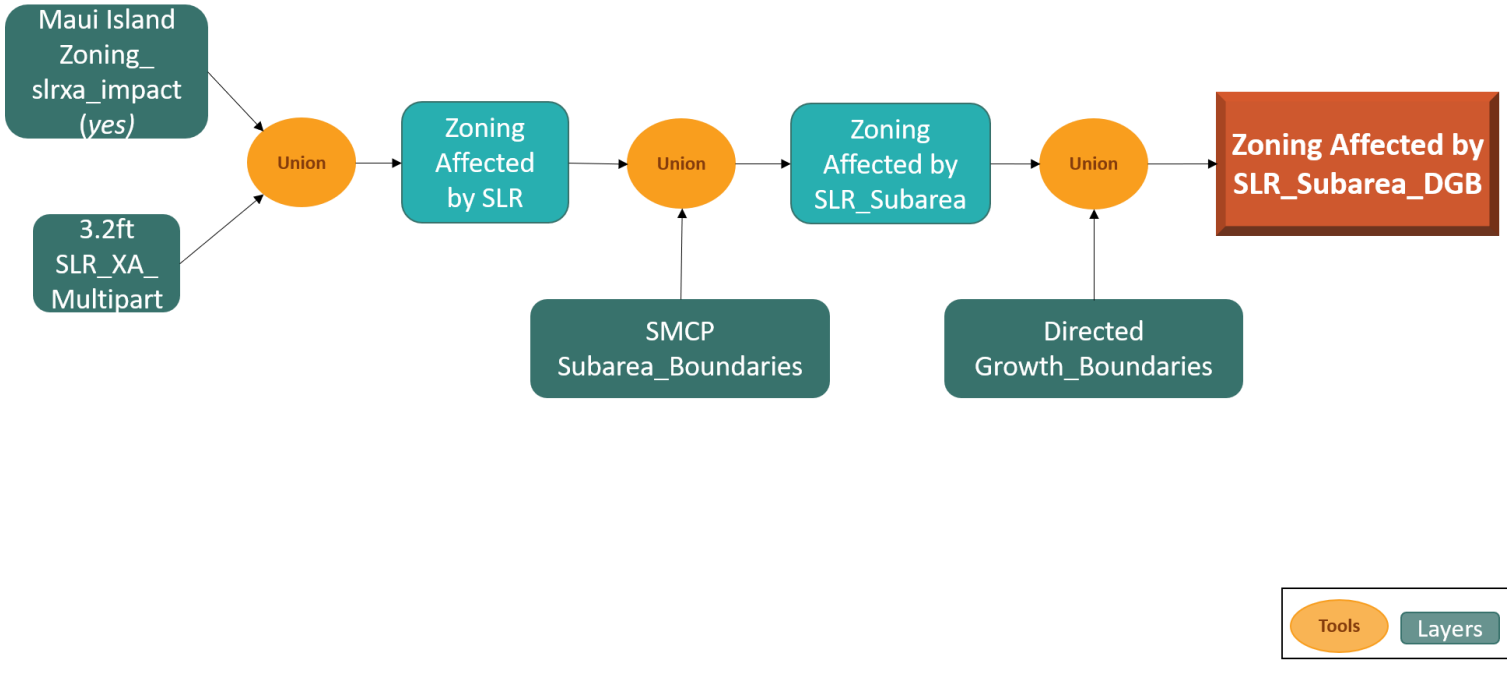


Calculating SLR Impacted Acreage per Zone within each Subarea and the Growth Boundaries

Part 1: Preparing Data to Calculate Acreage Impacted by 3.2 ft SLR-XA



Part 2: Creating Layer to Calculate Acreage Impacted by 3.2ft SLR-XA



Part 3: Calculating Acreage Impacted by 3.2 ft SLR-XA

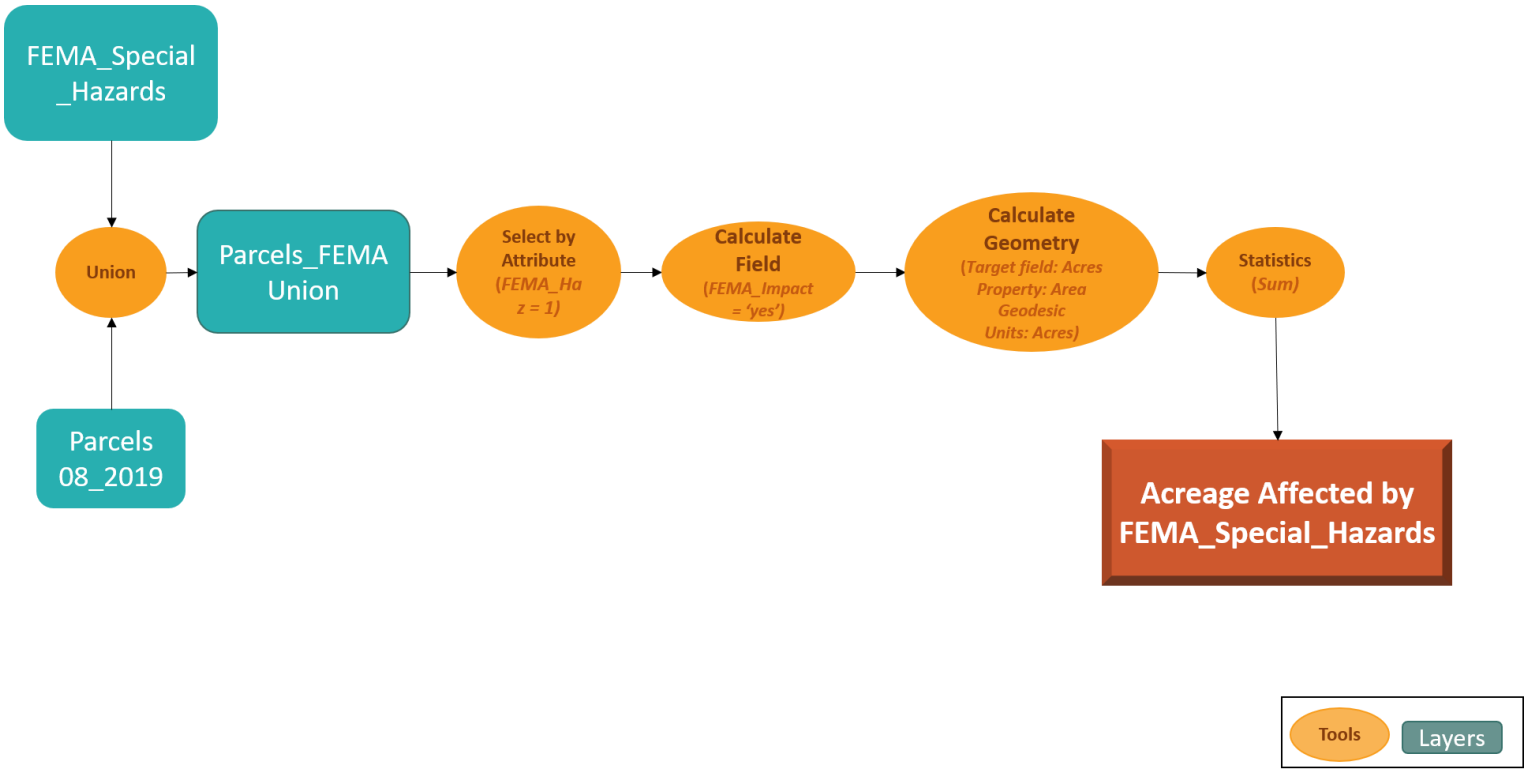
Calculating FEMA Flood Hazard Impacted Acreage

Part 1: Preparing Data to Calculate Acreage Impacted by FEMA Flood Hazards

Step 1

Step 2

Part 2: Calculating Acreage Impacted by FEMA Flood Hazards



Appendix D: Effective Communication Checklist

Effective Communication Checklist

- ❑ Determine the intended audience
  - Ask who is reading and using the information

- ❑ Determine and agree upon level of technical detail required
  - Provide writing samples from previous projects or reference documents
  - Examples of infographics, charts, tables, and photos

- ❑ Determine and agree upon scope and scale of content
  - Provide a detailed project outline

Appendix E: Time Log of Practicum Project

Phase	Date	Hours
I		
	June 2020	5
	July 2020	5
	August 2020	10
II		
	August 2020	20
	September 2020	50
III (A)		
	October 2020	30
	November 2020	30
III (B)		
	December 2020	30
	January 2021	15
	February 2021	10
	March 2021	30
Total		**235**

Appendix F: Pre-Final Draft Submission of Climate Change and Natural Hazards Technical Resource Paper

The attached document is a Pre-final draft version of the paper that was submitted to LRD. It is not intended for public use to guide policy or planning. The final version of the paper is forthcoming based on any additional comments or revisions as requested by LRD following their review of this version of the document.