Hanalei Watershed Flood Mitigation Study

October 2023

Hanalei Watershed Hui
5299C Kūhiō Hwy
P. O. Box 1285
Hanalei, Kaua'i, HI 96714
www.hanaleiwatershedhui.org

SUSTAINABLE RESOURCES GROUP INTN'L, INC.
111 Hekili Street, Ste A373
Kailua, HI 96734
www.srgii.com

EXECUTIVE SUMMARY

The *Hanalei Watershed Flood Mitigation Study* evaluated potential flood mitigation strategies to determine their effectiveness at reducing the onset, duration, water depths, and lateral extent of flood waters in the Hanalei Basin. This analysis was conducted within 1,800 acres of the coastal plain area of Hanalei River and Waiʻoli Stream (Figure ES-1). A particular focus of the study was to evaluate strategies that, if implemented, would reduce flooding along Kūhiō Highway between the Hanalei Bridge and Hanalei Town, thereby decreasing the number of times per year the road is closed.

Figure ES-1. Project Area

This publicly available summary report documents the process and findings. It includes technical and community methodology; scenario building; modeling results; prioritization; wetland habitat and bird benefits, mitigation designs with costs and permit requirements; and funding sources for implementation. The results can inform related plans focused on disaster resilience and provide insights into future conditions under climate change and sea level rise (SLR).

This project was spearheaded by the Hanalei Watershed Hui (HWH), a community-based non-profit organization that strives to care for the *ahupuaʻa* of Hanalei, Waiʻoli, Waipā, and Waikoko, guided by Hawaiian and other principles of sustainability and stewardship, integrity and balance, cooperation and *aloha*, cultural equity, and mutual respect. HWH teamed with Sustainable Resources Group Intn'l, Inc., who authored the *Watershed Management Plan for Hanalei Bay Watershed*, to conduct project activities. The project was conducted from March 2021 through October 2023.

Project Objectives

The primary objective of the project was to evaluate potential flood mitigation strategies to determine if they would reduce riverine flooding of Hanalei River and Waiʻoli Stream. The evaluation focused on assessing whether strategies, if implemented, would reduce the number of closings of Kūhiō Highway between Hanalei Bridge and Hanalei Town. A hydraulic model was utilized to calculate hydraulic variables for both rivers, considering existing physiographic conditions and potential future conditions that represent flood mitigation strategies, with the goal of assessing the extent to which flood attenuation can be achieved.

Project Area

Hanalei River

The section of the Hanalei River evaluated and subjected to hydraulic modeling under this study extends 23,150 ft (7,056 m) upstream from the mouth of the river at Black Pot Beach Park. The upstream boundary of the study reach is near the mauka (upstream) boundary of the USFWS Hanalei NWR. The river is tidally controlled from the mouth of the river upstream approximately 18,000 ft (5,486 m). From this point to the upstream boundary at 23,150 ft (7,056 m) the river becomes steeper, with a higher gradient and higher surface water velocities compared to the tidal section. Within the tidally controlled section there are six distinct reaches that differ based on their channel geometry and morphology. Figure ES-2 is a longitude profile that shows the elevation of the riverbed from the mouth of the Hanalei River upstream to the study reach boundary. The profile compares the bed elevation of the river with various tide levels. The elevation of the river bed is lower than all tide levels, which results in backstepping water upstream.

Kūhiō Highway

The 1.2-mile (1.93 km) stretch of Kūhiō Highway between the Hanalei Bridge and The Hanalei Dolphin is prone to flooding due to its low elevation relative to water level during flood events. This stretch of road is a primary focus area of this study and is a key reference location for evaluating the effectiveness of the proposed strategies to mitigate flooding impacts and road closures (Figure ES-3).

Waiʻoli Stream

The section of Waiʻoli Stream evaluated and subjected to hydraulic modeling under this study extends 5,180 ft (1,578 m) upstream from its mouth at Hanalei Bay. The upstream boundary of the study reach is the area where the stream enters onto the coastal plain just mauka of the taro loʻi in the valley. Figure ES-4 is a longitude profile that shows the elevation of the stream bed from the mouth of Waiʻoli Stream upstream to the study reach boundary. Like the Hanalei River, the tide controls the water level for most of the length of Waiʻoli Stream subjected to hydraulic simulations. This is because the bed elevation of the stream is below to slightly higher than tides.

Figure ES-2. Hanalei River Bed Profile with Tides

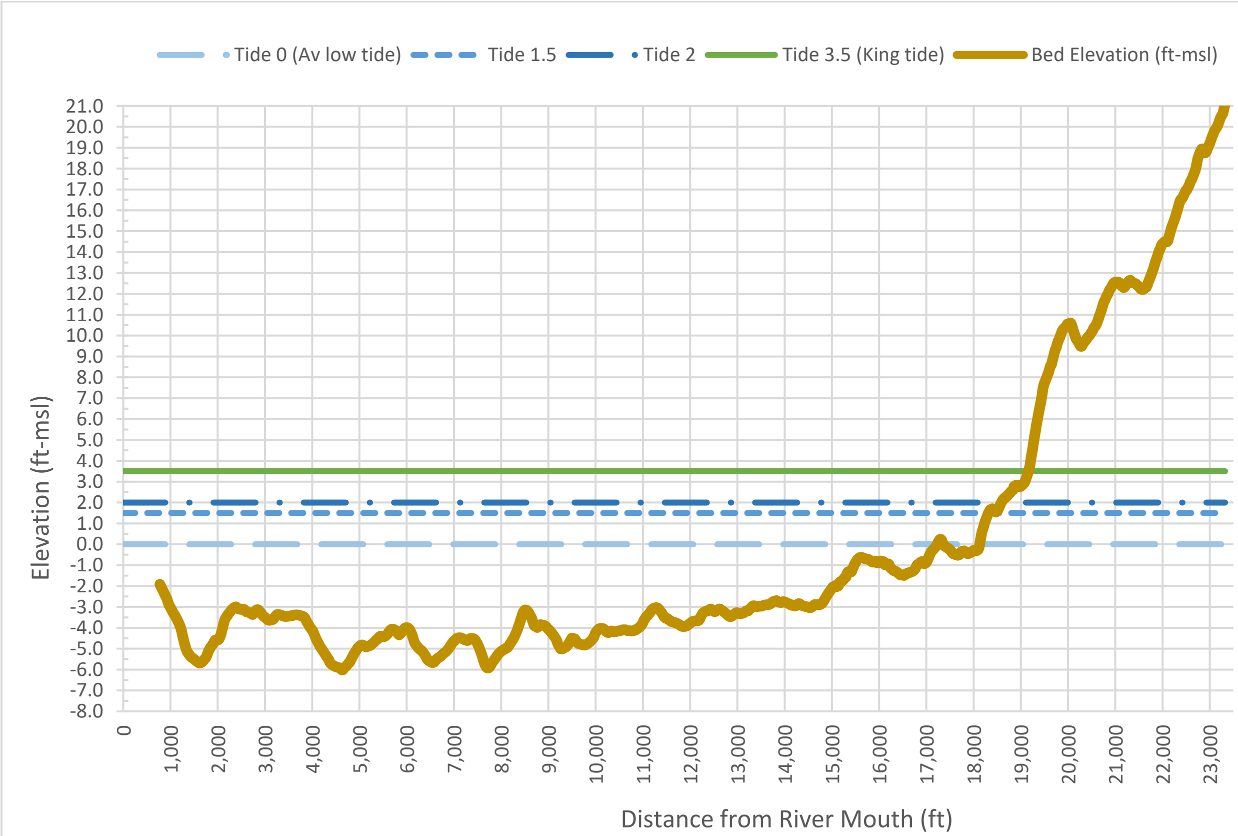


Figure ES-3. Kūhiō Highway Section with Elevations (ft-msl) and Longitudinal Profile

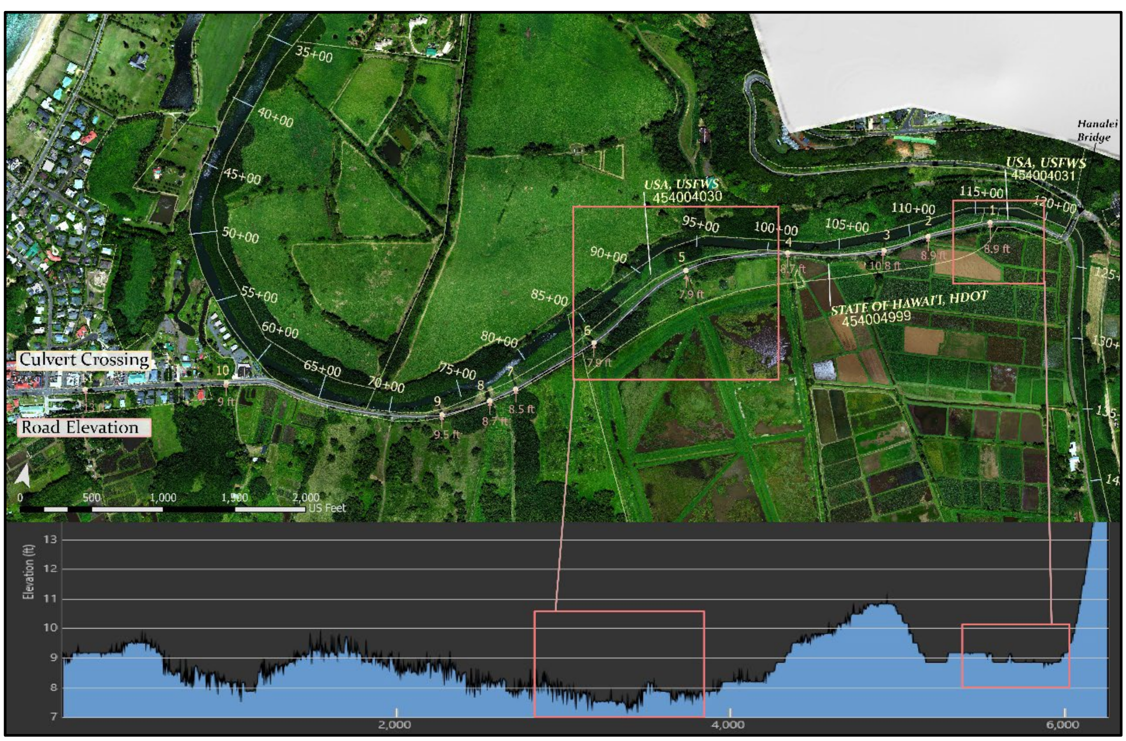
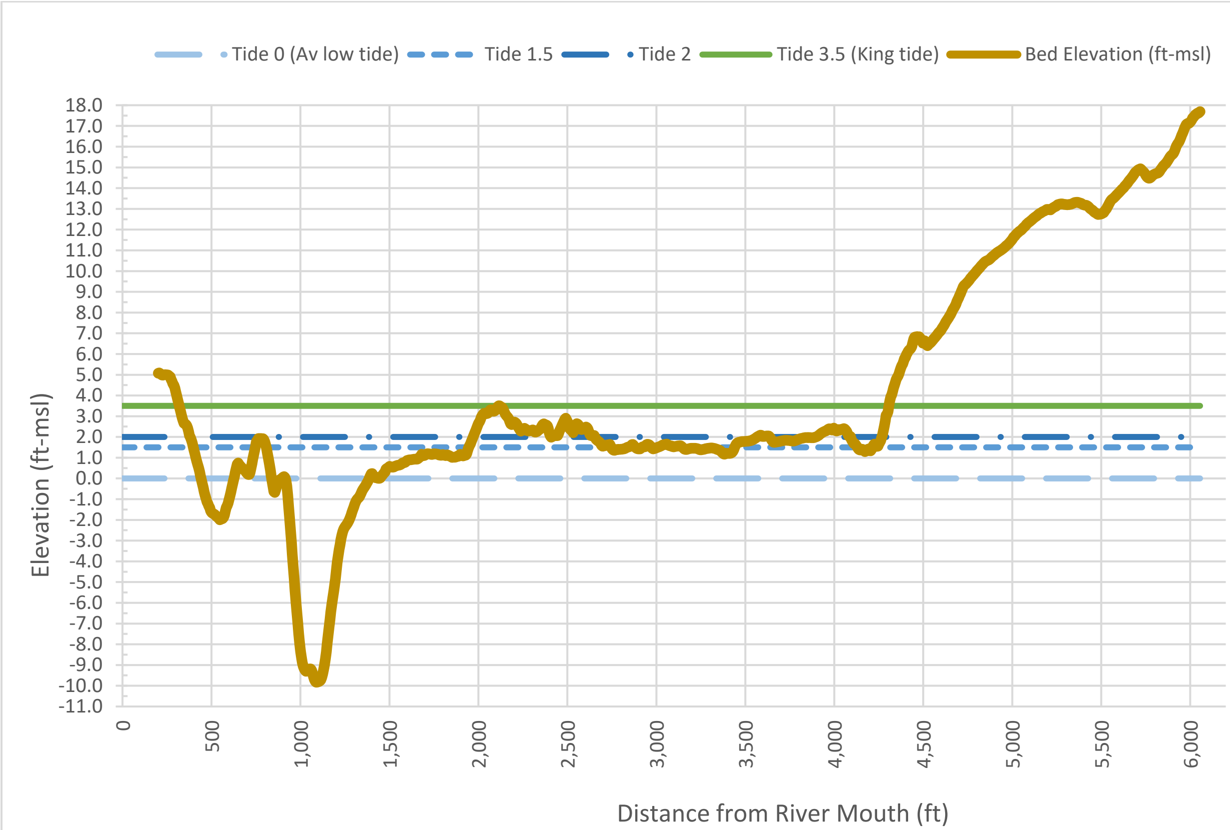


Figure ES-4. Wai'oli Stream Bed Profile with Tides



Tidal Control

Hanalei River and Wai'oli Stream are tidally controlled in their coastal plain reaches. This means that the rivers rarely have continuity, which is when the volume of water flowing into the ocean is equal to the volume of water coming down the rivers. Essentially the tide functions as a weir, and as it goes up, it backs up the rivers.[1] The result is that under tidal control, the rivers are constantly storing water.

The hydraulic model used in this study computes the total volume of water over the duration of model run (simulation) that enters the river at the model's upstream boundary as inflow, and the total volume of water that passes through the river and flows over the downstream boundary and into the ocean as outflow. For every model run, the total volume of the inflow exceeded the total volume of the outflow. The difference in these values is the volume of water stored in the channel.

As sea level rises because of climate change, the rivers will flood more frequently due to the increase in WSEL in the rivers from the backing up of water upstream. Since water levels will be higher, there will be less space to store water in the river channel when high flows come down the river.

Channel bathymetry plays a significant role in how the rivers will respond to future SLR. SLR will not only affect the flood regime during and following storms, but it will also increase the area of land covered by

[1] A weir is a small dam or barrier built across a river, stream, or other watercourse to regulate the flow of water. In this case, the tide is functioning as a non-structural weir.

water during high tides, especially King Tides. The effects are pronounced and planning for strategies to adapt and improve resiliency is needed.

Hydraulic Modeling

Hydraulic model simulations[2] were run to compare existing conditions to future conditions. Existing conditions represent the present bathymetry of the river and topography of the land, and the surface materials (e.g. trees, grasses). Future conditions were either proposed mitigation strategies (e.g. construction of detention basins on the Bison Farm) or under SLR.

Simulations were run using known unsteady state[3] discharges and tide levels for numerous dates, including those of historic flood events that resulted in closure of Kūhiō Highway. The model was run under existing conditions and rerun using the same discharges and tides to evaluate proposed mitigation strategies. The outputs were compared to determine if the proposed strategy (1) mitigated flooding of the highway; (2) reduced the onset of duration or when the flood waters start spilling onto the highway; and/or (3) reduced the duration the flood water covered the highway before receding. The model was also used to compare the wetted surface area over the landscape under existing and proposed conditions. In addition to running the simulations under known tides and discharges, they were also run using tides representing the future condition of +2 ft SLR.

Key Findings

Model Results

Removing Hau Bush. Under existing conditions hau bush removal along the Hanalei River improves flow conveyance of the river, but only provides marginal mitigation of the onset, duration, and lateral extent of flood waters. Under SLR conditions hau bush removal slightly increases the mitigation of flood waters. Hau bush removal will improve recreational uses of the river, decrease instability and erosion of the river channels, enhance endemic waterbird habitat, reduce potential for woody debris jams and river blockage, and improve view planes.

Constructing Detention Basins. Under existing conditions detention basins were estimated to reduce the onset of flooding of Kūhiō Highway by between 10 to 40 minutes and reduce the duration of road flooding by 30 minutes. Under SLR conditions, the onset of flooding would be reduced by approximately one hour if detention basins were constructed. Under SLR conditions, detention basins are not expected to decrease the duration of flooding on Kūhiō Highway.

Dredging the Mouth of the Hanalei River. Under existing conditions and SLR conditions, dredging the mouth of the Hanalei River to elevations approximately three feet lower than present and 500 feet upstream has no impact on the flooding.

Removing Berms on Bison Farm and USFWS Hanalei NWR. Under existing conditions and SLR conditions, the removal of the berms on the Bison Farm and at the USFWS Hanalei NWR has no impact on the onset

[2] Simulation refers to one run of the hydraulic model for one set of input conditions.

[3] Unsteady refers to a variable such as discharge or tide changing over a time step as opposed to remaining constant. Unsteady flow and tides represent actual conditions of the rivers studied.

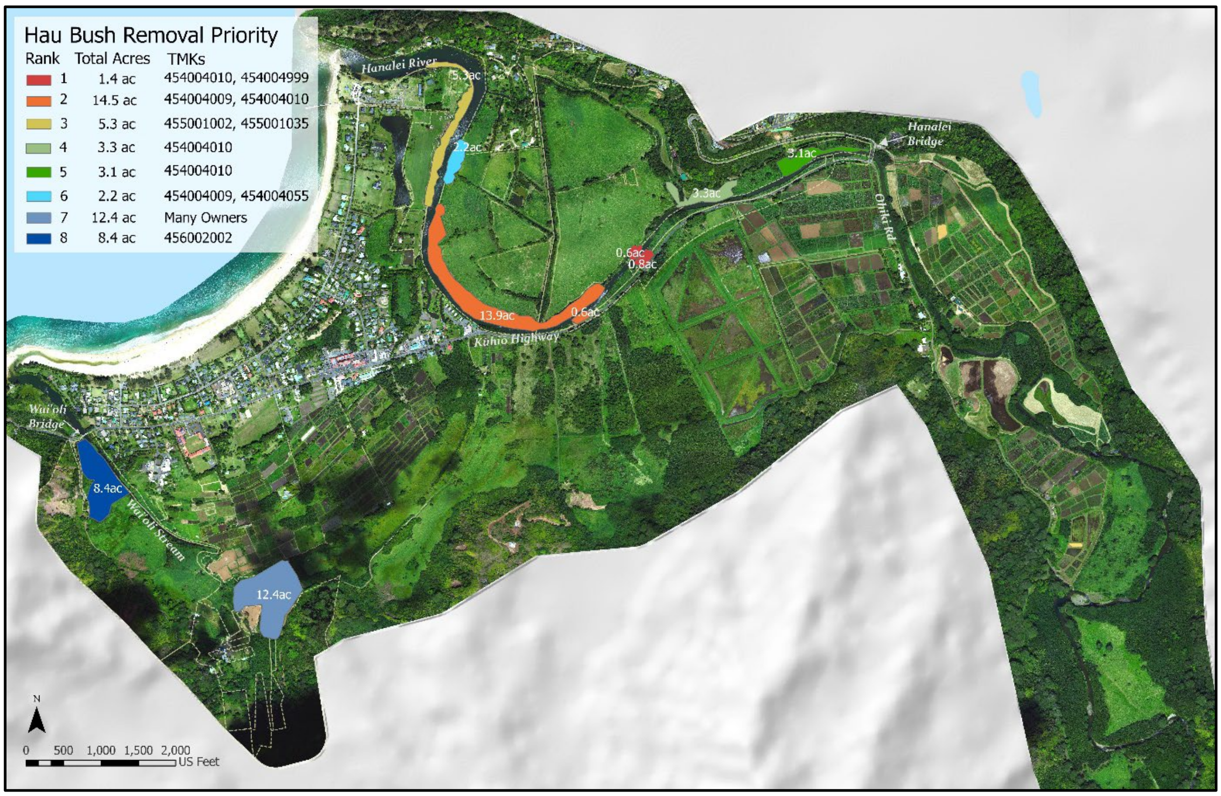
and duration of flooding on Kūhiō Highway. The berms do not redirect water towards Hanalei town, nor do they increase velocity of flood waters over the floodplain.

Prioritizing Action

The study found that none of the potential flood mitigation strategies had a significant effect on mitigating or otherwise attenuating flooding in Hanalei or Waiʻoli. This is primarily due to the strong tidal control of the lower reaches of Hanalei River and Waiʻoli Stream.

Hau Bush Removal. Though none of the strategies evaluated as part of this study have a significant effect on attenuating flooding, hau bush removal is highest priority due to the other ancillary benefits of its removal. Removal of hau bush will improve navigation in the river, reduce instability of riverbanks, reduce the redirection of flood waters, enhance habitat for waterbirds, and open up view planes. The most cost-effective plan for removal of hau bush would be to target several or all the problematic hau bush stands. Figure ES-5 shows the overall ranking and sub-rankings for hau bush removal.

Figure ES-5. Priority Ranking: Hau Bush Removal



The prevalence of hau bush and other invasive trees growing along and into river channels is an island-wide issue. A possible use of funds to facilitate efficient and effective removal of hau bush and other trees would be the acquisition of specialty equipment. An example of such equipment is a tracked feller buncher used in logging operations in many areas of the world. Regardless of how hau bush and other trees are removed, if implementation funds are used to clear vegetation along the rivers, the landowners should assume the financial responsibility for post-clearing maintenance of the areas.

Based on the analysis of the flood mitigation effectiveness and cost, detention basins are not recommended. Detention basins evaluated for this study do not store enough volume of flood waters to mitigate the flood regime either under existing or SLR conditions. Their construction costs are significant, mostly because excavated soil will need to be hauled offsite.

This study recommends adapting to impending SLR and the existing issue of the closure of Kūhiō Highway between the Hanalei Bridge and The Hanalei Dolphin by raising the road to an elevation that will be higher the high water level from future flood events. Funds could be used to take the data from this study to initiate engineering plans, specifications, and cost estimates to raise the road. Other options include providing seed monies for convening strategies to target future buyout of properties that will be vulnerable to impacts from SLR. This might even include addressing potential impacts SLR will have on wastewater systems along the coastline and rivers.

Other Findings and Recommendations

Bank instability due to erosion and mass wasting along the Hanalei River threatens numerous sections of both Kūhiō Highway and Ohiki Road. The failure of the roads would have significant and profound adverse impacts. Presently, the Hawaiʻi Department of Transportation (HDOT) is formulating engineering designs for the installation of a hybrid bio-wall along a section of Kūhiō Highway, aimed at mitigating riverbank erosion that threatens the road. During field work, sections of the bank of the Hanalei River were visually assessed for signs of instability and ongoing erosion and mapped. It is recommended that all vulnerable sections of Kūhiō Highway and Ohiki Road be assessed to determine if stabilization strategies are needed to prevent future road failures due to riverbank erosion.

The impacts of SLR due to climate change will continue for the foreseeable future. The intermediate (mid-range) estimate of SLR for Hawaiʻi is 1 foot (0.3 m) by 2050 and 3 to 4 feet (0.9 to 1.2 m) by 2100. This study used a value of +2 ft (0.61 m) SLR to generate estimates of water surface levels in the rivers during routine discharges and high flow events. Under all scenarios, SLR rise will have significant impacts to the flood regime of Hanalei River and Waiʻoli Stream. The frequency of closure of Kūhiō Highway will increase in the future due to SLR. Floods that currently raise the water level in the river but do not overtop the highway can be expected to reach the road under future SLR water surface elevations. The onset of time that the Hanalei River floods over the road will decrease by one hour or more. As an example, for a given river discharge under existing conditions that covered Kūhiō Highway in two hours after the start of a storm, in the future the coverage can be expected to occur in one hour.

Though not part of the scope of this study, hydraulic modeling was used to estimate what elevation Kūhiō Highway could be raised to in the future to prevent it from over-topping during flood events under +2 ft SLR. Simulations were run using the 100-year return interval discharge of 42,600 cfs estimate by the U.S. Geological Survey. The analysis shows that the roadway surface between the Hanalei Bridge and The Hanalei Dolphin would need to be approximately 15.4 ft-msl. This would require raising the existing road surface by 6 to 8 feet (1.8 to 2.4 m). This analysis is ongoing and will be available as a standalone white paper for the community and HDOT.

CONTENTS

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

3D	three-dimensional
ac	acre
BRIC	Building Resilient Infrastructure and Communities
CAT	Community Advisory Team
cfs	cubic feet per second
cm	centimeters
CWA	Clean Water Act
CWRM	Commission on Water Resource Management
CZM	Coastal Zone Management
DLNR	Department of Land and Natural Resources
DTM	digital terrain model
EA	Environmental Assessment
EC	Existing Condition
EIS	Environmental Impact Assessment
EWP	Emergency Watershed Protection
FC	Future Condition
FEMA	Federal Emergency Management Agency
ft	foot/feet
FMA	Flood Mitigation Assistance
GIS	Geographic Information Systems
GPS	Global Positioning System
HDOT	Hawai‘i Department of Transportation

HGMP	Hazard Mitigation Grant Program
HI-EMA	Hawaiʻi Emergency Management Agency
HRS	Hawaiʻi Revised Statutes
HWH	Hanalei Watershed Hui
LiDAR	Light Image Detection and Ranging
LMSL	local mean sea level
m	meters
mllw	mean lower low water
MOU	Memorandum of Understanding
msl	mean sea level
NCRF	National Coastal Resilience Fund
NFWF	National Fish and Wildlife Foundation
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWP	Nationwide Permit
NWR	National Wildlife Refuge
OPUS	Online Positioning User Service
SCAP	Stream Channel Alteration Permit
SDWP	Stream Diversion Works Permit
SHPD	State Historic Preservation Division
SLR	sea level rise
SMA	Special Management Area
SMS	Surface-water Modeling System
SRGII	Sustainable Resources Group Intn'l, Inc.
SRH-2D	Sedimentation and River Hydraulics – Two Dimensional
TMK	Tax Maps
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UWV	Unmanned Water Vehicle
WFPO	Watershed and Flood Prevention Operations
WSEL	water surface elevation

1 INTRODUCTION

Hanalei River and Waiʻoli Stream are perennial and drain their respective watersheds on the north shore of the island of Kauaʻi (Figure 1). The Hanalei River is 17 miles (27 km) long and is the largest stream system in the State by volume. Waiʻoli Stream drains a smaller watershed to the west. The lower reaches of these two rivers are bounded by a flat, wide floodplain occupied by agricultural plots used for taro cultivation, wetland areas providing habitat for native endangered waterbirds, pasture lands, parklands, commerce, and residential parcels.

The rivers are very prone to flooding in their lower reaches, causing significant impacts to travel in and out of Hanalei and communities to its west; disrupting commerce in Hanalei Town; and threatening property, life, and wetland habitat. Flooding is expected to occur more often due to projected rising sea levels and increases in frequency and magnitude of extreme rainfall events driven by climate change (Section 3.6).

1.1 Community Concerns

The genesis for this study dates to the early 2000s when the Hanalei Watershed Hui (HWH) Executive Director and members of the north shore community discussed the frequent closures of Kūhiō Highway between the Hanalei Bridge and The Hanalei Dolphin due to flooding from the Hanalei River. Community members conjectured that the frequency of highway closures was increasing over the previous decades from floodplain alterations, hau bush (*Hibiscus tiliceus*) encroachment along the riverbanks, wetland alteration, and sedimentation in the river near its mouth. During that period HWH and Sustainable Resources Group Intn'l, Inc. (SRGII) discussed the community concerns and the type of analysis that could be conducted to assess if the identified issues were exacerbating flooding. As conversations continued, potential strategies to mitigate flooding were identified, including restoring floodplain connectivity to the river and increasing storage of flood waters in open floodable spaces.

Although flooding had been identified as a hazard, no analysis had been done to evaluate community and government concerns that alterations across the floodway of the Hanalei River are adversely impacting the flood regime, flow conveyance, flood water hydrodynamics; and increasing the onset and duration of flood waters onto Kūhiō Highway and the floodplains. Nor had there been a robust and system-wide analysis of the flooding regime of the Hanalei River. There had been insufficient predicative modeling and analysis to evaluate the effectiveness of potential mitigation strategies to reduce flood risk if implemented. This resulted in a piecemeal approach to dealing with problem areas of the river, and a reactionary approach to dealing with the results of flooding on the local community and wetland habitat. As a result, it was challenging for the community and their leaders to make informed decisions about sustainable solutions that offer the best outcomes for people, property, infrastructure, and wildlife habitat in the Hanalei area.

1.2 Planning for Flood Mitigation

The impacts of flooding were pronounced during an episodic flood event that devastated the north shore of Kauaʻi in April 2018. A significant amount of infrastructure was lost or damaged, including homes, roads, and bridges. The Hanalei local economy, heavily dependent on tourism, was crippled. Flooding damaged endangered waterbird habitat and destroyed critical wetland infrastructure (roads, berms, water control structures). These truly catastrophic events resulted in three disaster declarations and two emergency declarations under the Stafford Act. The April 2018 flood was a catalyst for this study.

Following the April 2018 floods, HWH and SRGII developed a proposal to conduct a quantitative study to evaluate potential flood mitigation strategies. The unsolicited proposal was presented to the Hawaiʻi Emergency Management Agency (HI-EMA) in June 2018. HI-EMA personnel reviewed the proposal and determined it had merit. Potential funds were identified through the Federal Emergency Management Agency (FEMA) flooding-related programs administered by HI-EMA. At the time, HI-EMA was focused on recovery efforts following the April 2018 floods that affected both the north shore of Kauaʻi and areas of east Oʻahu. During the summer of 2018 volcanic activity on the island of Hawaiʻi required FEMA and HI-EMA to address emergency needs on Hawaiʻi Island. As a result of the multiple emergency responses that FEMA and HI-EMA were dealing with, they did not have capacity to fund the proposed Hanalei flood study.

After the April 2018 flood a bill authored by State Representative Nadine Nakamura (House District 15) of Kauaʻi became law as Act 12, Session Laws of Hawaiʻi 2018. Act 12 provided appropriations for funding disaster relief for Kauaʻi and other areas of the State. Act 35, Session Laws of Hawaiʻi 2019 was passed to extend the date that funds for disaster relief could be spent and add a provision that funds could be spent to implement mitigation measures to prevent and minimize the impacts of current or future flooding in areas affected by the April 2018 flooding on Kauaʻi.

The State funds were transferred to the County of Kauaʻi for use in helping north shore communities recover from record rainfall and plan to mitigate the effects of future flooding. The Hanalei flood study was included on the list of projects presented to the County of Kauaʻi to address flooding both specifically in the north shore region and other areas of Kauaʻi. In January 2021 the County of Kauaʻi awarded a grant to HWH for the 'Hanalei Watershed Flood Mitigation' project to specifically address flood mitigation design development in the Hanalei Basin. A Notice to Proceed was issued in early February 2021 and the project began after funds were dispersed in March 2021.

Simultaneously, HWH was awarded a grant from the National Fish and Wildlife Foundation (NFWF) under the National Coastal Resilience Fund (NCRF), for a project entitled "Enhancing Community Resilience through Site Flood Assessment and a Flood Mitigation Design (HI)". These funds were used in conjunction with the County funding to complete project activities. Although the intent was similar, in addition to developing resilience in the context of flood mitigation, this funding specifically supported planning for increasing waterbird habitat to support native endangered and threatened waterbirds.

1.3 Project Objectives

The primary objective of the project was to evaluate potential flood mitigation strategies to determine if they would reduce riverine flooding of Hanalei River and Waiʻoli Stream. The evaluation focused on assessing whether strategies, if implemented, would reduce the number of closings of Kūhiō Highway between Hanalei Bridge and Hanalei Town. A hydraulic model was utilized to calculate hydraulic variables for both rivers, considering existing physiographic conditions and potential future conditions that represent flood mitigation strategies, with the goal of assessing the extent to which flood attenuation can be achieved.

This study was not conducted for regulatory reasons, such as updating the FEMA Flood Insurance Rate Maps. This study did not evaluate changes to watershed conditions that affect the rainfall and runoff regime and vegetation management in the forested areas of the watersheds.

Figure 1. Project Area

2 STUDY SITE PHYSIOGRAPHY

The Hanalei Bay Watershed is comprised of four watersheds, which includes Hanalei and Waiʻoli Watersheds (Table 1 and Figure 2). Hanalei Watershed [15,125 ac (6,121 ha)] is drained by the Hanalei River. The Hanalei River is one of Hawaiʻi's largest rivers in terms of length and flow volumes and was designated as an American Heritage River in 1998. It drains into the Hanalei River Estuary, before terminating at Hanalei Bay. Waiʻoli Watershed [3,483 ac (1,410 ha)] is drained by Waiʻoli Stream and also drains into Hanalei Bay.

Table 1. Hanalei Bay Watershed Characteristics

Watershed	Area (acres)	Maximum Elevation (ft)	Percent of Total Area
Hanalei	15,125	5,148	73%
Waiʻoli	3,483	4,409	17%
Waipā	1,592	3,675	8%
Waikoko	458	751	2%
Total	**20,658**		**100%**

A common physical feature of the watersheds is the presence of undeveloped, steeply sloped, forested headwater lands covered predominantly in non-native vegetation that transitions to moderately to gently sloping coastal plains. The coastal plains support agriculture, bird habitat, and residential and commercial uses. A portion of the stream water in each watershed is diverted and used for irrigation of crops, watering animals, and waterbird habitat. This study analyzed the lower elevation sections of Hanalei River (Section 2.1) and Waiʻoli Stream (Section 2.2) (Figure 3).

2.1 Hanalei River

The section of the Hanalei River evaluated and subjected to hydraulic modeling under this study extended 23,150 ft (7,056 m) upstream from the mouth of the river at Black Pot Beach Park (Figure 4). The upstream boundary of the study reach was near the mauka (upstream) boundary of the USFWS Hanalei NWR. The river is tidally control from the mouth of the river upstream a distance of approximately 18,000 ft (5,486 m). From this point to the upstream boundary at 23,150 ft (7,056 m) the river becomes steeper, with a higher gradient and higher surface water velocities compared to the tidal section (Figure 5).

The river was delineated into six reaches to spatially reference and identify areas of interest and issues for this discussion. Figure 4 shows the river from its mouth to the upstream study reach boundary of Hanalei River. Distance is shown as station numbers in 500 ft (152 m) increments (Hanalei River). Table 2 summarizes reach lengths, average riverbed elevation, width, bank height as measured from the bed of the channel to top of the bank, and whether the reach is tidally controlled.

Figure 2. Project Area Watersheds

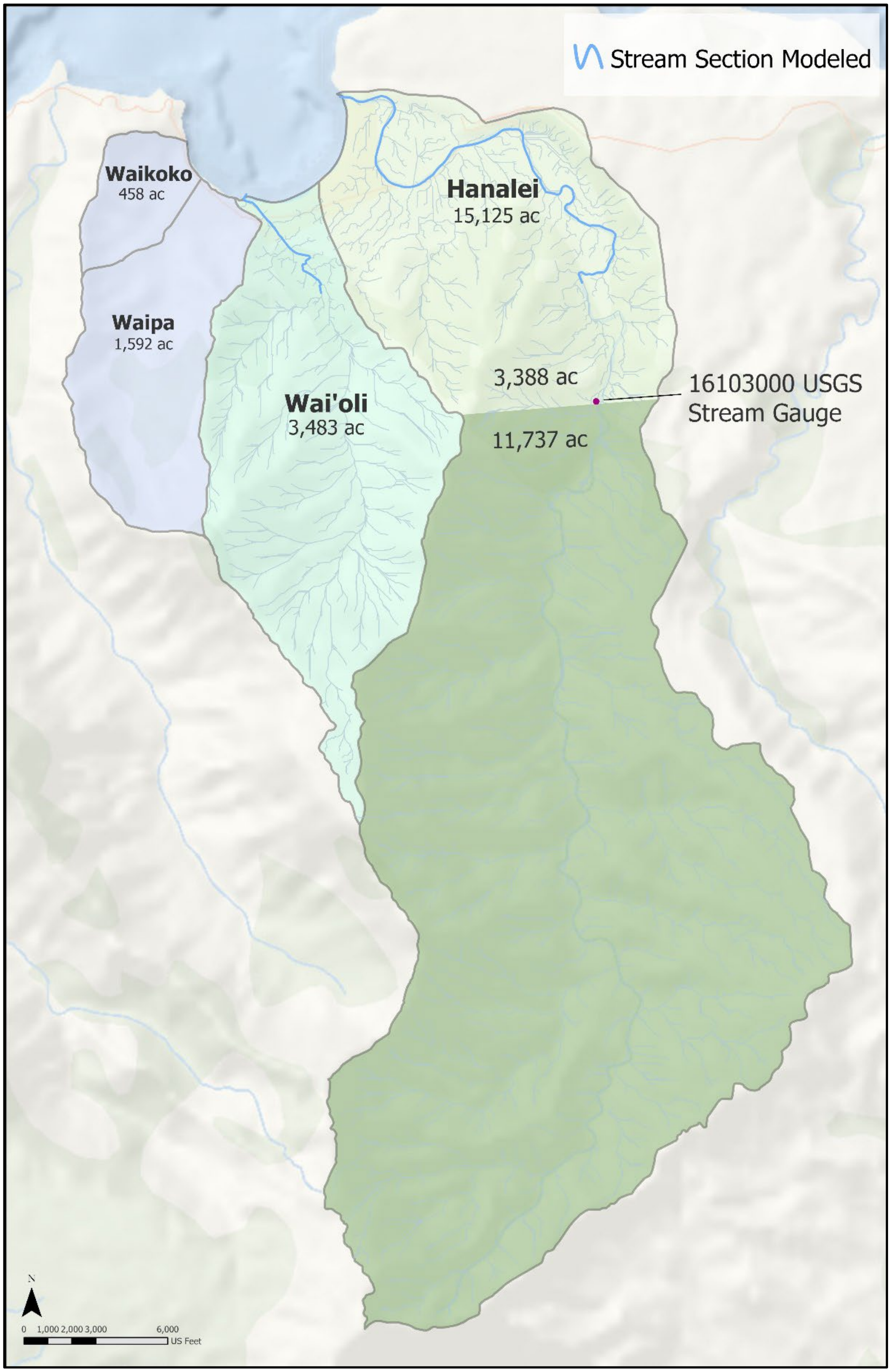


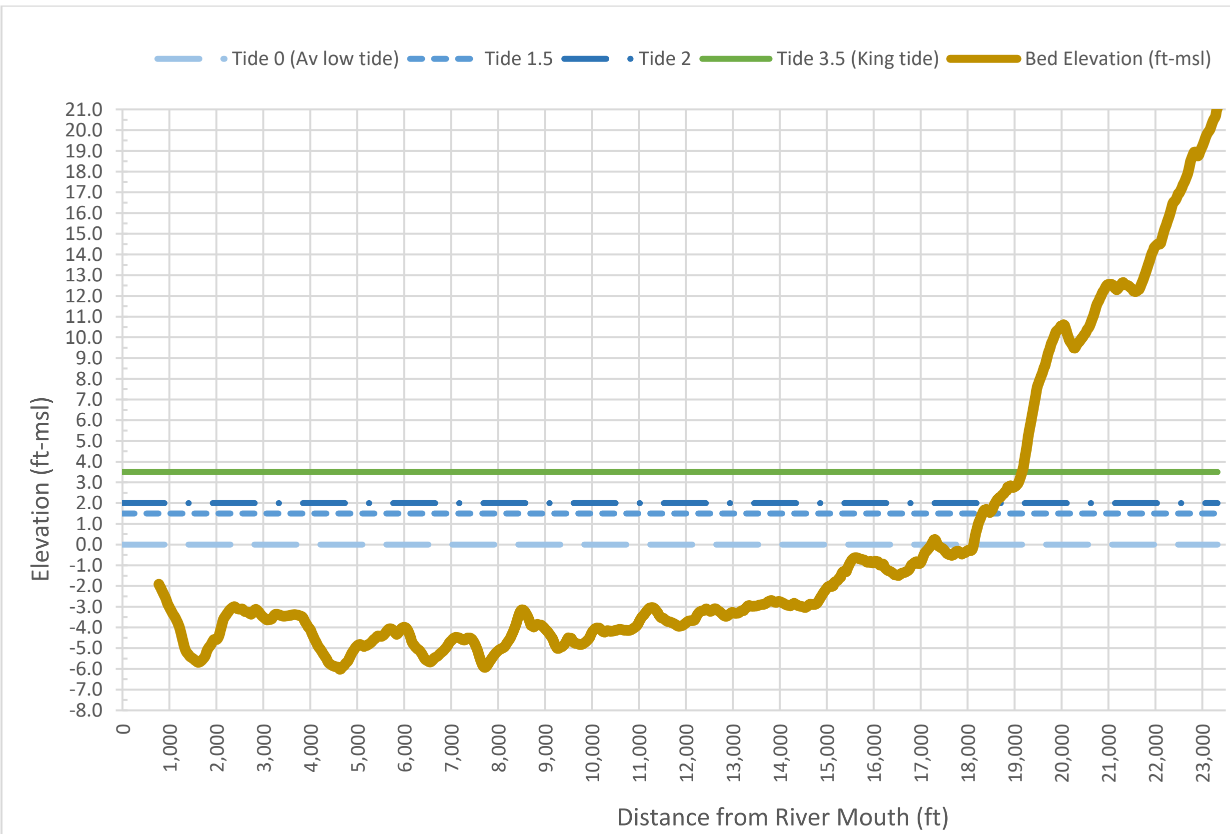
Figure 3. Project Area Waterways

Figure 4. Hanalei River Reaches

Table 2. Hanalei River Reaches

River Reach	Station Start	Station End	Length (ft)	Average Bed Elevation (ft-msl)	Average Width (ft)	Average Bank Height (ft)	Tide Control (Y/N)
1	0	25+00	2,500	-3.8	210	4	Y
2	25+00	125+00	10,000	-4.4	80	11	Y
3	125+00	145+00	2,000	-3.5	71	8.5	Y
4	145+00	180+00	3,500	-2.8	64	9	Y
5	180+00	190+00	1,000	2.2	55	7	N
6	190+00	231+50	4,150	13.8	60	6	N

Figure 5. Hanalei River Bed Profile with Tides



2.1.1 Reach 1 (Station 0+00 – 25+00)

Reach 1 begins at the mouth of the river and goes upstream 2,500 ft (762 m) (Figure 6).[4] In this reach the river has an average width of approximately 210 ft (64 m). Banks are low and bounded by low elevation floodplains with elevations ranging from 1 to 5 feet msl.[5] Because of its proximity to the mouth of the river, the water surface elevation (WSEL) goes up and down with the tide. The bottom of the river is covered in ocean-derived sand near the mouth of stream, which is deposited by ocean wave runup. In the upstream section of this reach the bed is covered in fine sediments carried and deposited by the river.

The mouth of the channel is dynamic and changes seasonally. During winter months large ocean swells generated north of the islands result in frequent wave runup that suspends and transports sand held within Hanalei Bay. The sand is deposited along the shoreline and then redistributed and deposited across the mouth of the river, creating a sand bar that extends from the west bank at the mouth of the river out into the river channel. This sand bar becomes quasi-permanent until river flows of large enough magnitude over top it and erode the sand offshore into the bay. During prolonged periods of low river flow the sand bar will nearly cover the entire width of the river at its mouth. There is no information that the river has ever been completely closed off from the ocean, as a small channel always seems to persist just off the east or right bank of the river that maintains connectivity to the ocean. While this narrow and shallow channel may prevent challenges to passage out of the river for vessels with deep drafts, it does not affect the flood regime. The low ground elevations immediately mauka of Black Pot Beach Park along the river in this reach are prone to frequent flooding.

2.1.2 Reach 2 (Station 25+00 – 125+00)

Reach 2 begins at 2,500 ft (762 m) and extends 10,000 ft (3,048 m) to upstream of the Hanalei Bridge (Figure 6). This reach is bounded by nearly vertical banks that extend from 8 to 14 ft (2.44 to 4.27 m) above the water level depending on the tide and river flows. Its wetted surface width at non-flooding flows is 80 ft (26 m) and it has a fairly uniform bed elevation that averages -4.4 ft-msl. Hau bush extends into and out over the river over long stretches in this reach. In one stretch (between Stations 84+60 and 87+00), growth over the river extending from both banks has resulted in a navigable opening along 240 ft (73 m) that is only 20 ft (6 m) wide. This constriction point has caused several large woody debris jams to form over the past several years, completely blocking the channel and preventing people that use the river for paddling, kayaking, stand-up paddleboarding, and small boats from passing.

Beginning at Station 63+50 and extending upstream a distance of 850 ft (259 m) to Station 72+00 the south or left riverbank is near vertical and unstable. Another stretch along the left bank from Station 95+50 up to the Hanalei Bridge is also unstable and prone to failure. In these two stretches the top of the riverbank is 10 to 20 ft (3 to 6 m) from the edge of Kūhiō Highway. Sections of these vertical banks coincide with the opposite riverbank where hau bush has encroached into the channel and reduced the channel's cross-sectional area. The vertical banks result in part from the cohesive nature of the alluvial soils and are somewhat more resistant to erosion than if they were less cohesive sandy soils. The severity of erosion, and the threat it has on the stability of Kūhiō Highway and communications and electric poles is pronounced. If left unchecked, the erosion will eventually result in damage to infrastructure. The Hawaiʻi

[4] From an ecohydrologic/biologic definition, the Hanalei River estuary encompasses the entire tidally controlled section of the river and has total salinity levels ranging from sea water to slightly brackish.

[5] Elevations throughout the report are reported in feet relative to the mean sea level (msl) datum.

Department of Transportation (HDOT) has initiated a project around Station 100+00 to stabilize approximately 300 ft (91 m) of the most critical section of bank erosion using a hybrid bio-engineer design.

Kūhiō Highway

The 1.2 mile (1.93 km) stretch of Kūhiō Highway between the Hanalei Bridge (Station 120+00) and The Hanalei Dolphin (Station 60+00) is the most prone to flooding. This stretch is a focus of this study and is the reference location for evaluating the effectiveness of the proposed strategies to mitigate flooding impacts and road closures. Figure 7 shows the road elevation of this stretch of Kūhiō Highway along its centerline. The lowest elevation along the road is 7.5 ft-msl, which is just to the west of Culvert 4. This location is where flood waters first reach and cover Kūhiō Highway during flood events. It is a primary reference position in this study's hydraulic analysis as it is used to record onset and duration of when and how long flood waters over-top the road. The profile plot embedded below the image shows road surface elevations from the Hanalei Bridge to The Hanalei Dolphin.

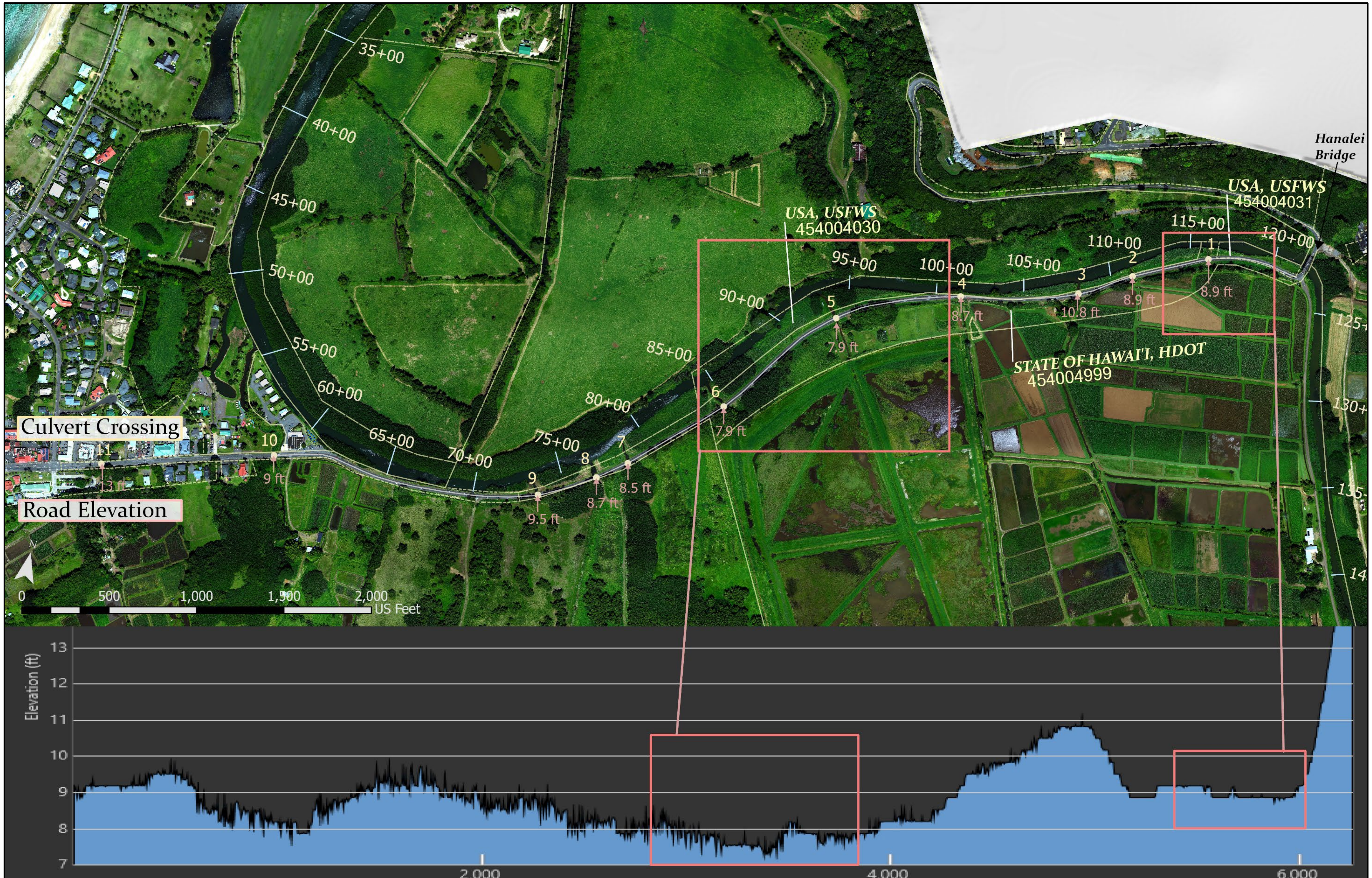
Culverts

There are eleven culverts located between the Hanalei Bridge and Hanalei Town at the ʻauwai that goes under the highway near the Tahiti Nui Restaurant (Figure 7). The culverts are inline with ditches/ʻauwai and are all aligned perpendicular and under the road deck and set on or just below ground (grade). They include a combination of box culverts made of concrete and mortar and corrugated metal culverts. Sizes range from 6 ft (1.8 m) high x 10 ft (3 m) wide for the box culverts to 18-inch (0.46 m) diameter for single barrel round culverts. The culverts were designed to drain rainfall and irrigation runoff from the taro and bird loʻi, pasture lands, and open spaces of the floodplain. Eight of the culverts located between the Hanalei Bridge and The Hanalei Dolphin occur in the stretch of Kūhiō Highway that is most prone to flooding.

The culverts were designed to drain water off the landscape into the river. Water goes through the culverts and into the river only when the WSEL of the river is lower than the WSEL in the ditches. Frequently, when the tide rises and/or the river WSEL goes up due to rise of the river flow, water will backup the ditches towards the culverts, be carried under the highway, and backup the ditches, creating flood conditions. During storms, when rainfall is sufficient to generate overland flow into the ditches and is concurrent to river flooding, the water levels in and along the ditches and floodplain reach their highest WSEL and depths. The culverts allow river water to access the floodplain and dampen water levels upstream. Most over-topping and flooding of the roadway is in proximity to the low elevation culverts and is from river water backing up and rising above the culvert's outlets and onto Kūhiō Highway, and not from the culverts filling up at the inlet side of the culverts and overtopping onto the road deck .

Figure 6. Hanalei River Reaches 1 and 2

Figure 7. Kūhiō Highway between Hanalei Bridge and The Hanalei Dolphin with Elevations (ft-msl), Culverts, and Longitudinal Profile



2.1.3 Reach 3 (Station 125+00 – 145+00)

Reach 3 of the river begins 500 ft (152 m) upstream of the of the Hanalei Bridge and extends upstream for 2,000 ft (607 m) (Figure 8). The average bed elevation is -3.5 ft (-1.07 m) and the channel width averages 71 ft (21.6 m). This reach of the Hanalei River, along with Reaches 4-6, is located in the USFWS Hanalei NWR. The river is nearly straight with uniform geometry through this reach and runs parallel to Ohiki Road. For most of this reach the left bank is steep and nearly vertical, and the top of the bank is about 20 ft (6.1 m) from the edge of Ohiki Road. Both the road and the two utility poles on the river side of the road are vulnerable to failure due to loss of stream bank. The left bank is currently covered by non-native grasses and shrubs that offer some resistance to erosion induced by the river flows. Along the right bank there are several stands of hau bush that protrude into the river. Like other reaches, the banks opposite hau bush show signs of accelerated erosion and bank retreat. There are dense stretches of grasses growing along the right bank that appears moderately stable.

2.1.4 Reach 4 (Station 145+00 – 180+00)

Reach 4 extends 3,500 ft (1,067 m) and is hydraulically[6] controlled by the tide for most of its length (Figure 8). Tidal control is minimal at the upper boundary of this reach at Station 180+00 (5,486 m). The average bed elevation is -2.8 ft (-0.85 m). The banks in this reach are covered with dense stands of mature hau bush, resulting in a water surface width of approximately 64 ft (13 m). The active channel width is wider than the wetted surface width, but hau bush obscures the actual banks of the river for most of the reach. There is a 400 ft (122 m) long stretch of the left riverbank centered around Station 155+00 that is bare and nearly vertical that is actively eroding and contributing sediment into the river. This section of the bank is adjacent to what USFWS refers to as the 'DU Ponds', and the erosion along the river will eventually reach the embankment of the DU Ponds in between the river and the ponds.

2.1.5 Reach 5 (Station 180+00 – 190+00)

Reach 5 is 1,000 ft (305 m) in length and ends just above where the Kuna Ditch crosses under the river (Figure 9). Kuna Ditch carries water diverted from the Hanalei River upstream and is used to provide irrigation water for taro loʻi on the east side of the river on the USFWS Hanalei NWR. In this reach the river channel has more morphologic variability compared to the low gradient downstream reaches, higher water velocities, and the bed is covered in gravel size sediments. The average bed elevation is 2.2 ft (0.67 m), which means the bed is higher than most of the high tides in Hanalei Bay. This is why tide fluxes do not have significant hydraulic control on water depths and velocities. Within this reach there at least five large albizia (*Falcataria moleccana*) trees growing on top of the riverbank. The mature trees will eventually be undermined, fall into the river, and will likely create a woody debris jam. Debris will be carried downstream, potentially creating navigational issues on the river and damaging the Hanalei Bridge.

2.1.6 Reach 6 (Station 190+00 – 231+50)

Reach 6 is 4,150 ft (1,264 m) long with an average bed elevation of 13.8 ft (4.2 m) (Figure 9). This reach is morphologically different than all the other downstream reaches. The bed is covered with coarse gravels, cobbles, and rubble size rock material. This section was included in the hydraulic model analysis since it is downstream of the multi-branch channels in a stretch where the river water is confined to one channel.

---

[6] Hydraulically controlled and hydraulic control refer to how the variables of water velocity and depth in the river channel are primarily a function of tide water level and the backing up of water and not channel geometry or the material lining the bed and banks of the river channel.

Figure 8. Hanalei River Reaches 3 and 4

Figure 9. Hanalei River Reaches 5 and 6

2.2 Waiʻoli Stream

Waiʻoli Stream was included in this project in part because of concerns with flood damages that happened during previous flood events and because the Waiʻoli and Hanalei floodplains overlap. The section of Waiʻoli Stream evaluated and subjected to hydraulic modeling under this study extended 5,180 ft (1,578 m) upstream from its mouth at Hanalei Bay. The upstream boundary of the study reach is where the stream enters onto the coastal plain just mauka of the taro loʻi in the valley. For the study Waiʻoli Stream was divided into three reaches (Table 3). Figure 10 is a longitude profile that shows the elevation of the stream bed from the mouth of Waiʻoli Stream upstream to the study reach boundary. Figure 11 depicts the length of the stream analyzed under this project, the reach numbers, and the stationing in 300 ft (91 m) increments.

Table 3. Waiʻoli Stream Reaches

River Reach	Station Start	Station End	Length (ft)	Average Bed Elevation (ft-msl)	Average Width (ft)	Average Bank Height (ft)	Tide Control (Y/N)
1	0	15+00	1,500	-5	200	2	Y
2	15+00	45+00	3,000	1	40	3.25	Y
3	45+00	57+00	1,200	5	30	1.5	N

Figure 10. Waiʻoli Stream Bed with Tides

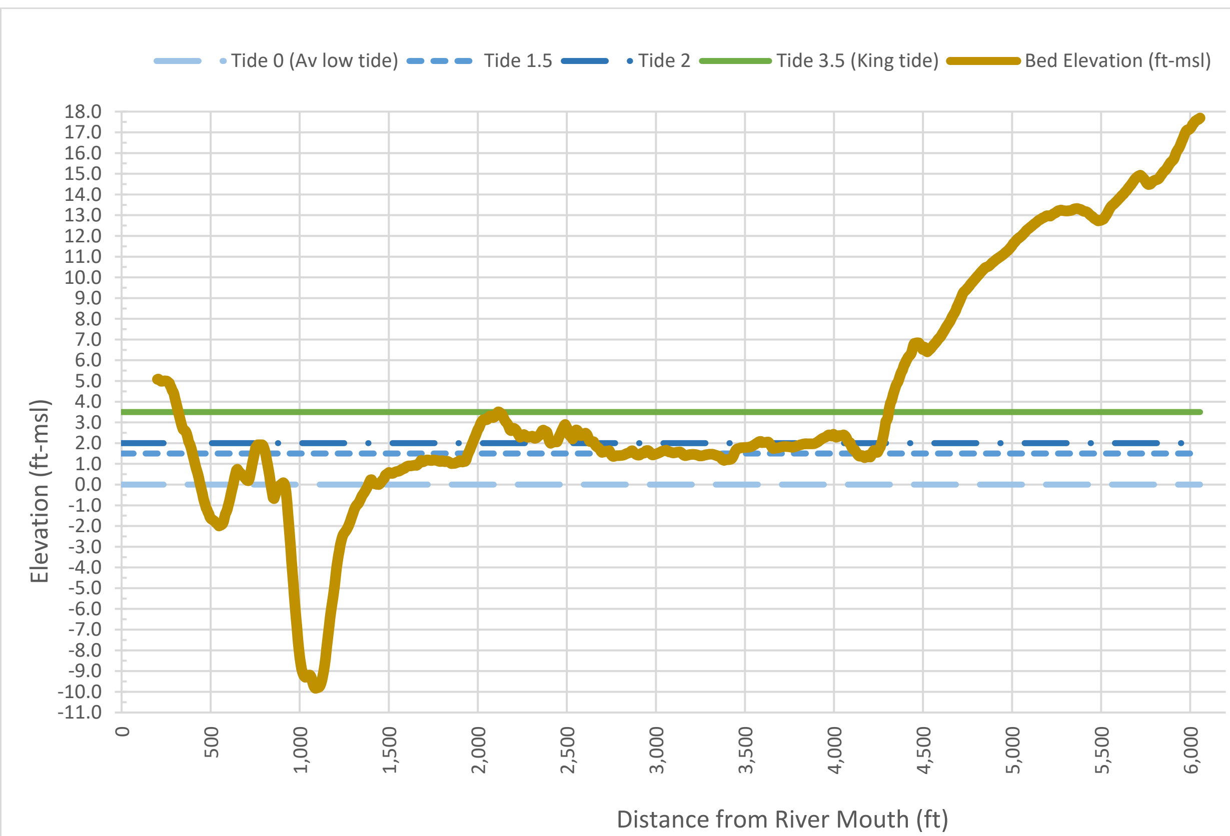


Figure 11. Wai'oli Stream Reaches

2.2.1 Reach 1 (Station 0+00 – 15+00)

The estuary reach extends approximately 1,500 ft (457 m) from the mouth of the stream upstream to just below the Waiʻoli Bridge. Like the Hanalei River, this stretch is tidally controlled since most of its bed elevation is below sea level, with an average elevation of -5 ft (-1.5 m). In this reach there is a deep pool along with high spots along the bed from large, built-up sediment deposits. The lowest or downstream most section of this reach is bounded by a low elevation floodplain and at times the stream can be cut off from the ocean by a sand bar created by wave runup. Connectivity between the stream and channel is restored after flow events of sufficient magnitude and duration erode the sand berm and create an opening between the stream mouth and the ocean. This occurrence is natural and does not have a significant effect on the flood regime.

2.2.2 Reach 2 (Station 15+00 – 45+00)

The second reach is 3,000 ft (914 m) long, nearly straight, has low banks and a fairly uniform width of approximately 40 ft (13 m). Most of the riverbed elevation in this reach is above mean sea level and tidal control is limited to periods when tides are at their highest levels. In this reach the stream is bordered by low lying floodplains that are mostly open and undeveloped. Since the 2018 flood event large patches of hau bush have been removed from portions of the floodplain along the west side of the stream.

2.2.3 Reach 3 (Station 45+00 – 57+00)

The third reach is 1,200 ft (365 m) long. In this reach the stream is steeper, sinuous, and has bed materials comprised of coarse gravels.

2.3 Tidal Control

Hanalei River and Waiʻoli Stream are tidally controlled in their coastal plain reaches. The timing and volume of water that flows into the ocean are controlled by tide level. The depth and velocity of the rivers are controlled by the tide flux for all flow levels for all but the upstream most reaches of the water bodies modeled. This means that the rivers rarely have continuity, which is when the volume of water flowing into the ocean is equal to the volume of water coming down the river. The result is that under tidal control, the river is constantly storing water. This is most pronounced during periods when flows are lowest in the river.

The hydraulic model used in this study computes the total volume of water over the duration of model run (simulation) that enters the river at the model's upstream boundary as inflow, and the total volume of water that passes through the river and flows over the downstream boundary and into the ocean as outflow. For every model run the total volume of the inflow exceeded the total volume of the outflow. For example, on December 2, 2016 over an 8-hour period, the difference between the volume of flow over the upstream model boundary of the Hanalei River and the volume crossing the downstream boundary at the mouth of the river was 14 million gallons or 9.81% more flow coming into the river than leaving it. Most of the 14 million gallons were stored within the banks of the river, which is referred to as in-channel storage. This volumetric difference clearly shows that the tide regulates the channel hydraulics and conveyance. For all flows modeled during this project, inflow exceeded outflow by 14% on average, with values ranging from 8% to 42%.

The maximum daily flow rates from Hanalei River and Waiʻoli Stream into the ocean occur at low low tide when the WSEL at the mouth of the rivers, where the ocean and the river meet, is lowest and the water surface slope upstream to downstream is highest. The lowest flow rates into the ocean occur at high high tides when the WSEL is highest, causing the rivers to backup and raise the WSEL in the rivers. Essentially the tide functions as a weir, and as it goes up, it backs up the rivers.[7]

The extensive and noticeable reach of tidal control upstream is primarily a result of the riverbed elevation being below mean sea level within the coastal plain reaches of the rivers. WSEL generated by the tides, even low tides, are normally higher than the bed elevation, and the water levels in the rivers flux up and down daily with the tides.

As sea level rises because of climate change, the rivers will flood more frequently due to the increase in WSEL in the rivers from the backing up of water upstream. Since water levels will be higher in the tidally controlled sections of the rivers , there will be less space to store water in the river channel when high flows come down the river.

Figure 12 shows the wetted area for a tide of 3.5 ft-msl on July 3, 2023 when discharge in the river was at 114 cfs, and a tide 5.5 ft-msl representing +2 ft SLR and the same discharge. The image shows that SLR will increase the surface area of land that is wetted and back up and raise the WSEL and increase depth in Hanalei River and Waiʻoli Stream. The July 3 tide was a King Tide, and these seasonal high tides events now create what is referred to as dry flooding as the King Tides push water inland causing localized flooding. Inland tidal flooding will become more frequent under SLR.

Channel bathymetry plays a significant role in how the rivers will respond to future SLR. SLR will not only affect the flood regime during and following storms, but it will also increase the area of land covered by water during high tides, especially King Tides. The effects are pronounced and planning for strategies to adapt and improve resiliency is needed.

[7] A weir is a small dam or barrier built across a river, stream, or other watercourse to regulate the flow of water. In this case, the tide is functioning as a non-structural weir.

Figure 12. Comparison of Wetted Surface Area under Existing Condition Tide and Future SLR Tide

3 METHODOLOGY

3.1 Rights of Entry and Land Access Permissions

Rights of entry were sought where required for field work on public (County, State, and Federal) and private properties. Field work included setting control targets for Light Image Detection and Ranging (LiDAR) flights; conducting ground-based surveys to establish control points, ground-truth, and collect elevation data in areas the LiDAR sensor could not penetrate; and accessing the river corridor to conduct bathymetric surveys.

Properties of interest were identified using geographic information systems (GIS) maps. Figure 13 identifies the major landowners along the waterways. Property owners and contact information were identified using publicly available information from tax maps (TMK) and local knowledge. Landowners were contacted by mail, email, and/or phone and provided with an official request, an overview of the project, a land access permission form, and proof of insurance. Additional information shared with participating landowners included maps, description of activities to be conducted, equipment to be deployed, and proposed dates for activities. Private properties were accessed only after signed land access permission forms were received. Most landowners that responded allowed access. One notable exception was the Bison Farm. Access to that property was not obtained until December 2022, after ownership changed hands. Access to the USFWS Hanalei NWR was obtained via a General Activity Special Use Permit.

3.2 Equipment Acquisition and Subcontract Services

Execution of field activities required acquiring specialized equipment and securing subcontractor services.

3.2.1 Equipment Acquisition

Acquiring the necessary equipment was critical to ensuring that the project could progress efficiently and achieve data acquisition objectives. This involved identifying specific equipment that would work in the study environment and procuring equipment (researching suppliers, obtaining quotes, transporting to project site). Survey grade Global Positioning System (GPS) equipment was used for topographic and bathymetric surveys. Survey equipment was rented from Surveyor’s Supply Company on Oʻahu. An Unmanned Water Vehicle (UWV) was used for bathymetric surveys (Section 3.3.2). The Apache 4 UWV was sourced from CHC Navigation.

3.2.2 Subcontractor Services

Subcontractor services were required for air surveys, technical support for equipment and software used for bathymetry mapping, and hydraulic software and modeling. Securing subcontractor services involved identifying subcontractors with the expertise and capacity to fulfill the project’s requirements; developing subcontracts that clearly defined scope, deliverables, timelines, and payment terms; and working with the subcontractors to obtain quality deliverables. The subcontractor used to collect and process aerial imagery was Aerial Surveying from the Big Island. Specific coordination involved:

- Scheduling flight dates and times
- Establishing a network of air targets (Section 3.3.1)
- Setting up GPS receivers and control point network
- Creating flight maps that showed air targets, flight lines, and limits of survey area
- Securing permission to use Princeville Airport
- Preparing outreach announcements to inform the Hanalei community about air operations.

Figure 13. Project Area (Landowners)

Aquaveo, Inc. provided the software used for hydraulic modeling (Surface-water Modeling System (SMS)) along with technical services and support for all phases of the hydraulic model development and execution.

3.3 Survey and Data Acquisition

With the low topographic relief over the project area, high resolution topographic and bathymetric surveys were needed to generate an accurate and precise three-dimensional (3D) map with the resolution required for high confidence hydraulic modeling results.

3.3.1 Topographic Survey

Topographic surveying data was collected by an airborne survey using LiDAR and a ground-based survey using survey grade GPS. The airborne LiDAR survey was primary and provided coverage over the entire 2,377-acre project area. It was carried out using a LiDAR sensor and camera fitted to a helicopter. Ground-based surveying included mapping of terrestrial ground surfaces and manmade water features such as culverts.

Survey Reference Station

All ground-based surveying and bathymetry mapping was conducted using survey grade GPS receivers tied to a base station. The base station was occupied by a base station GPS receiver during ground-based and bathymetric surveying within the project area. The GPS units used for the ground-based and bathymetric surveys are called rovers. The rovers communicate with the base station during the surveys and use its position to improve the accuracy of the points (coordinate positions) they are collecting. This workflow is the most accurate and efficient way to survey using GPS receivers.

A georeferenced base station was established for the project. A base station control point was set at the grass field near the HWH office in Hanalei Town. The control point coordinates were established by setting up a GPS receiver over the point and collecting GPS positions for eight hours. Those GPS points were sent to the National Oceanic and Atmospheric Administration's (NOAA) Online Positioning User Service (OPUS) for processing using Geodetic Model 12B, which was developed by NOAA for processing GPS data in the Pacific Rim. OPUS provided the 3D coordinates for the base station position and a description of the metadata. The 3D coordinates have the highest spatial accuracy possible, including the elevation coordinate commonly referred to as the Zenith or Z of the control point, reported relative to the local mean sea level (LMSL) datum.

All surveys and the maps created from the survey data use a vertical datum of LMSL. A vertical datum is an elevation reference system that is set to zero. Elevations of features surveyed are then reported relative to the datum. Features surveyed and measured as lower than the LMSL datum of zero are reported as minus (-) values, and points surveyed that are higher than zero are reported as plus (+).

Tide levels are reported with a vertical datum based on mean lower low water (MLLW) as their zero reference. The difference between the MLLW and LMSL zero datum values as reported by NOAA is 0.8267 ft (0.252 m), with the LMSL being the higher value. To use one datum for the analysis, tide levels were brought up to the LMSL datum by adding the difference value to MLLW tide values.

Air Targets

An 'air target' in the context of remotely sensed surveys using LiDAR refers to a physical object or feature intentionally placed or used in the survey area to facilitate data collection and calibration. The targets served as reference points to enhance the accuracy and precision of LiDAR measurements.

Air targets were deployed before the LiDAR survey across the entire project area to represent different ground surface elevations. The targets (white 5-gallon bucket lids) were placed on the ground surface and secured by driving a 6-inch spike nail through the center of the target into the ground. All targets were open to the sky so that they would be exposed to the LiDAR laser and visible to the air image. All air targets were surveyed using GPS. Survey points were collected in the center of each target on the head of the spike nail prior to the flight. The air surveyors used this ground-based survey data to validate and fine-tune the LiDAR system's settings to ensure accurate data acquisition by comparing the coordinates recorded by the LiDAR for each air target to the field-surveyed coordinates.

LiDAR

Aerial acquired LiDAR is a remote sensing technology that uses light in the form of pulsed laser to measure the distance from an aircraft containing sensor equipment to the earth's surface. LiDAR systems are used to generate precise, 3D geographic data that depicts terrain, vegetation, and other surface features.

The LiDAR sensor was fitted to the underside of a helicopter. The helicopter flew transects across the 2,337-acre project area. Laser pulses were emitted from the LiDAR sensor and transmitted towards the ground surface. When a laser pulse strikes an object or ground surface, it reflects some of the light back toward the LiDAR sensor. This is known as the 'return'. The LiDAR sensor measures the time it takes for the laser pulse to travel to the target and return to the sensor. By knowing the speed of light, the system calculates the distance from the sensor to the object with high precision. The LiDAR sensor emits thousands of laser pulses per second. The collected distance measurements from these pulses form a dense point cloud, which is a 3D representation of the terrain and objects on the earth's surface.

The point cloud data was processed to remove noise and classify points (e.g., ground or bare earth, vegetation, buildings). Once the data was cleaned and classified, it was used to generate a detailed digital terrain model (DTM) that represents the ground surface ('base map') (Section 3.3.3).

The LiDAR and air photographs were collected on October 1, 2022 between 11:00 a.m. and 3:30 p.m. Winds were light at the time of the flight and visibility was good with limited cloud coverage. Some cloud shadows were cast on the ground, and in some areas such as upper Waiʻoli Stream, the shadows have a masking effect. LiDAR is not affected by cloud coverage.

Prior to the flight, Hanalei and the entire north shore of Kauaʻi was in a minor drought and there had not been any flow events of large enough volume to erode the sand bars in the mouths of either Hanelei River or Waiʻoli Stream. These conditions were favorable for surveying as there were many exposed surfaces in the river channels. This made it possible for the LiDAR to record ground surfaces that normally would be underwater if water levels were higher and not mappable using LiDAR.

At flight time, discharge in the Hanalei River, per the U.S. Geological Survey (USGS) Hanalei River gage, was 68 cubic feet per second (cfs). The discharge in Waiʻoli Stream was estimated to be 12 cfs. The tide in Hanalei Bay was 2.52 ft-msl at 11:00 am and 1.5 ft-msl at 3:30 pm.

Ground-based Surveys

In areas where dense vegetation prevented the LiDAR signal from reaching the ground surface or data was questionable, ground-based surveys with survey grade GPS were conducted to fill in gaps. Ground-based surveys were also used to survey man-made water features, WSEL of the rivers and other water bodies, shallow sections of the rivers, and objects that were visible on the air image to verify elevations and position accuracy.

Aerial Image

A color mosaic image was acquired during airborne surveying. The high-resolution image has pixel size of 0.8 in (2 cm), is orthorectified, and aligns with the DTM grid (Section 3.3.3).

3.3.2 Bathymetric Survey

Bathymetric surveying is mapping of the ground surfaces at the bottom or bed of a water body. The wavelength of light used by LiDAR laser sensors is not able to penetrate through water to reach the bottom (bed) of the rivers and streams. Bathymetric surveying of water bodies was conducted using a UWV. The UWV was a small remote-controlled boat. It was fitted with sonar with frequencies that can be used to measure depths in rivers as shallow as 6 in (15.2 cm) and as deep as 120 ft (36 m). The UWV has a built-in GPS receiver that is coupled to the onboard sonar, which allows 3D coordinates to be collected in real time. The data was used to generate a detailed and accurate bathymetric map of Hanalei River and Waiʻoli Stream along the study reaches.

3.3.3 Digital Terrain Model

A spatially accurate, high-resolution DTM of the 2,337-acre project area (inland water bodies, the floodway along the two rivers, and the land in between them) was developed using LiDAR and ground-based surveys of topography and bathymetry data sets (Figure 14). The DTM provides a highly accurate 3D map of the project area. The DTM developed for this project is comprised of 1 ft^2 (0.09 m^2) grids in the horizontal plane and has a vertical accuracy of 0.8 in (2 cm). The color ramp on the image represents ground surface elevations.

3.4 Hydrology and Hydraulic Methods

SMS is an advanced software system for performing surface water simulations in a 3D environment. The SMS software is comprised of modules and numeric models, each with a specific function. The numeric model, which is the computation engine of the SMS software, carries out calculations and generates solutions for the hydraulic variables for each element in the mesh. The numeric model used in this project is SRH-2D, which stands for *Sedimentation and River Hydraulics – Two Dimensional*. This model was selected as it was designed to be used in riverine system with tidal controls and estuaries.

3.4.1 Hydrology

The hydrologic component of the modeling involves selecting stream and river discharges (flow) and tide levels for input into the hydraulic model. Since discharge and tide data were available for both Hanalei River and Waiʻoli Stream the data sets were used. For the Hanalei River discharge and stage data from the USGS 16103000 Hanalei Stream gage was used. For the un-gaged Waiʻoli Stream, discharges used in the hydraulic model were published values estimated using historic empirical data and statistical method estimates by USGS and CWRM.

Figure 14. Project Area Digital Terrain Model

Tide data was acquired from NOAA for Station 1611683 (Hanalei Bay). This station is referred to by NOAA as a Subordinate Station, meaning that there are no actual tide measurements at the station. Instead the tide values are transposed from Station 16114000 (Nawiliwili).

3.4.2 Hydraulic Modeling

Hydraulic modeling is the routing of water through a river channel to generate estimates of hydraulic variables. The variables that the hydraulic model solved for in this project are water depth, water velocity, WSEL, shear stress, and the dimensionless Froude number. The hydraulic model used for this project is bundled into the SMS software package.

Mesh Module

The mesh module is a model that represents the 3D ground surface of the river and floodplain to be investigated. The mesh is similar to the DTM in that it represents the ground surface of the project area. The mesh is comprised of nodes that have X, Y coordinates with an elevation. The density of mesh nodes helps determine the quality of the solution data and can be important to model stability. Elements, which are formed by joining nodes, are used to describe the area to be modeled. The mesh is created by interpolating the surface of the DTM to generate coordinates for each node in the mesh. Figure 15 depicts the mesh used in the hydraulic model. Color gradient represents elevations from -15 ft-msl to 100 ft-msl.

Materials Coverage

After the mesh is created, each element in the mesh is assigned a roughness number, which becomes the materials coverage layer(Figure 16). A dimensionless roughness number represents the type of material that is on the ground surface or bottom of the river (e.g., grass, gravels). The term roughness is commonly referred to as the Manning’s n coefficient, which represents the level of friction that a material exerts on water as it flows over the material. Roughness values range from 0 to 1. A riverbed with a smooth muddy bottom has a roughness of 0.016 whereas hau bush has roughness value of 0.25.

Boundary Coverage

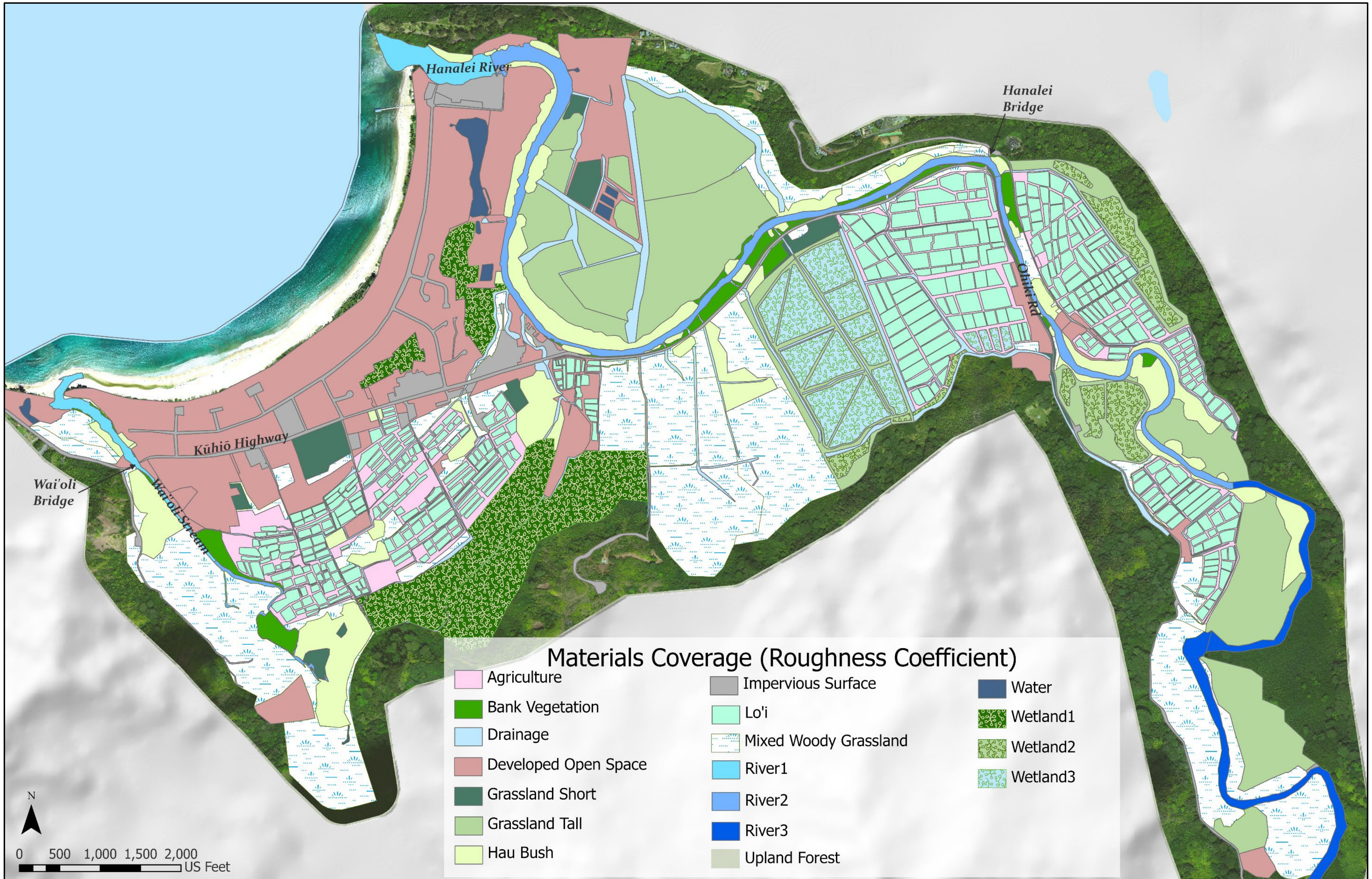
The next step in creating an SRH-2D model is to create the boundary coverage layer by assigning upstream and downstream boundaries on the mesh for the section of the river to be modeled (Table 4).

Table 4. Mesh Boundaries for SRH-2D Model

Boundary	Station
Hanalei River Upstream	231+50
Hanalei River Downstream	0+00 at the mouth of the river at Hanalei Bay
Wai‘oli Stream Upstream	51+50
Wai‘oli Stream Downstream	0+00 at the mouth of the stream at Hanalei Bay

Figure 15. Project Area Mesh with Existing Conditions

Figure 16. Project Area Materials Coverage



Simulation
A simulation can represent an actual flow event that has occurred or a hypothetical flow event. A model run is referred to as a simulation. Once the mesh, materials coverage, and boundary coverage are complete, they are loaded into the SRH-2D model and a simulation is built.

The hydrology data inputs are added to the boundary coverage. The upstream boundary, known as the Q inlet, is where the hydrograph discharge data is entered. The downstream boundary, known as the H exit, is where the tide data is entered. The hydrograph and tide can be set to run in steady state or unsteady state. Steady state is when a variable does not change with time, and unsteady state is where the variables change with time. This project used unsteady state for Q inlet and H exit boundaries for all simulations as it more accurately represents actual conditions.

Within the SRH-2D is a model control interface where the initial WSEL in the river was assigned before the simulation is run. It is also where the duration of the simulation was set, which is equal to the duration of the flow event being modeled. The model control is also used to set the computational time step to an average time step of three seconds for the model to solve solutions for the hydraulic variables for each wet mesh element. The output time step was set to show solutions of the hydraulic variables for each mesh element. The output time step varied, but for most simulations it was 15 minutes.

After setup, the simulation is started and the model runs. Duration of simulation was equal to the length of the hydrograph used to input discharge into the model. In other words, the model ran for the same length of time that an actual runoff event lasted. The simulations took an average of 30-50 minutes per hour of simulation duration. This was in part due to the large number of elements in the mesh (421,000) and that two rivers were being modeled at the same time. The simulation runs ranged from 4 to 48 hours.

Calibration
The model was calibrated and verified by comparing computed WSEL outputs at monitoring points along the river for six simulations, each corresponding to different flow event dates, with field-measured values and visually observed water surface levels on those same dates. Differences between modeled WSEL and measured values ranged from 0.1 ft (0.03 m) to 1.25 ft (0.38 m). The model was adjusted and the process repeated by re-running the simulations until all differences between modeled and measured values were equal to or less than 0.1 ft (0.03 m).

Simulation Dates
Simulation dates were selected by mining data and reviewing articles and reports that documented dates back to 1991 that Kūhiō Highway closed due to flooding. For the Hanalei River, for selected dates when the highway was reported as closed, hydrology discharge data was downloaded from the USGS gage and tide data was retrieved from NOAA. For Waiʻoli Stream, estimates of discharge derived by USGS and Department of Land and Natural Resources (DLNR) Commission on Water Resource Management (CWRM) were used to create synthetic hydrographs using the same duration as the Hanalei data. No sources were found that documented all closure dates, and none that stated the time the highway closed or for how long.

A subset of the dates that the highway closed was chosen for analysis (Table 5) to represent a range of peak discharges, flow event duration, and tide levels. Five dates where the highway was not reported as closed were simulated using known hydrology data to calibrate the model, evaluate strategies, and use in SLR analysis. Fourteen additional simulations were run using hypothetical hydrology inputs to conduct sensitivity analysis on the serial correlation between tide levels, discharges, and channel storage. Numeric results in Section 4 and Section 5 are presented for a representative flow event on December 2, 2016.

Table 5. Kūhiō Highway Closure Dates

Date	Flow Duration[8] (hr)	Peak Discharge Hanalei River (cfs)
2/20/2023	47	8,810
3/27/2020	24	30,500
2/4/2023	8	7,040
12/2/2016	11	18,100
4/15/2018	40	31,300
12/5/2016	16	13,800
11/3/1995	38	41,000
12/29/2018	16	24,000

Existing Conditions: Setting a Reference Point for Simulation Analysis

For each simulation the model was run using Existing Conditions (EC), which refers to existing topography as represented by the mesh and materials and boundary condition coverages loaded into the model. The outputs of the hydraulic variables and wetted surface area over the mesh were recorded. The model outputs for each simulation were reviewed at monitoring points, which are locations (elements) within the mesh that record the hydraulic variable values for each model output time step.

Of particular interest were monitoring points located along Kūhiō Highway between Stations 65+00 and 120+00 because this stretch of highway is prone to inundation from flood waters resulting in closure of the highway. The model outputs of depth and WSEL for EC for all simulations showed that this 5, 500 ft (1,676 m) section of road was the first section that flood waters cover during flood flow events. Monitoring Point 10 near Culvert 4 was used as the primary reference location for analysis.

For each model run, the onset time represents the simulation time when water from the Hanalei River started to cover the highway at Monitoring Point 10. The time of recession is the simulation time when water receded and was no longer covering the road. The difference between onset and recession times is the time of duration, or length of time the road was covered with water. For almost all simulations, this area around Monitoring Point 10 was the first and last stretch of highway to be covered with water from flood flows.

The onset time and duration varies for each simulation (flow event) modeled. This is because hydrologic conditions of tide and discharge vary by flow event, and some flow events last for only a few hours and others for a few days.

Future Conditions: Setting Parameters

A Future Condition (FC) represents a specific flood mitigation strategy such as removal of hau bush along the river, construction of a detention basin on the floodplain, or removal of a berm on the floodplain. A FC is derived by changing an EC simulation mesh and/or materials coverage roughness value. For example,

[8] Duration refers to the length of the flow event and not the duration of peak discharge.

to evaluate hau bush removal the roughness values for each element with hau bush coverage was changed from 0.25 to 0.01 on the materials coverage layer. The changes made to represent a FC were input into the EC simulation and the simulation was rerun under the new conditions.

3.5 Scenario Analysis

A scenario-based comparative analysis was conducted to evaluate potential flood mitigation strategies. Model hydraulic output variables (Section 3.4.2) derived for each EC simulation were compared to a FC for the same flow event. Boundary conditions (hydrology) remained the same for both simulations.

Together, the EC and FC simulations comprise a scenario. The outputs from the EC and FC simulations were compared for each monitoring point and across the mesh to quantify differences and evaluate effectiveness of the flood mitigation strategies. Comparisons were made to see if the onset and duration times changed at Monitoring Point 10. Model outputs were assessed to determine how effective the FC strategies were for mitigating floods individually, paired, or cumulatively.

3.6 Sea Level Rise Analysis

The uncertainty regarding future rates of SLR stems from the unpredictability of future carbon emission rates, shifts in climate patterns, and how the oceans will respond to these changes. SLR is expected to alter the location of the shoreline and impact infrastructure layout (i.e. buildings, roads). It will also impact the water table of aquifers currently in contact with the ocean, and in some locations may increase the salinity level of the ground water, reducing availability for fresh water uses. SLR may cause saltwater intrusion into low-land agriculture (e.g. taro loʻi) or inundate freshwater and brackish coastal wetlands needed by waterbirds. Most of the dwellings and other built areas are in the low elevation coastal plains, and in some of the lowest lying areas properties and structures may be threatened by higher sea levels. In addition, the rise in the ground water table will likely adversely impact disposal of effluent from individual wastewater systems that are located throughout the watershed.

Peer-reviewed scientific literature as well as government and multinational reports increasingly point to an intermediate (mid-range) estimate of a rise of 1 foot (0.3 m) by 2050 and a 3 to 4 foot (0.9 to 1.2 m) rise by 2100 for Hawaiʻi.[9] SLR conditions modeled as part of this study used a 2 ft (0.61 m) rise.

Scenario analysis included assessing EC and FC for flood mitigation strategies under SLR conditions. Simulations were also run under +2 ft SLR for EC and FC to quantify the effects of SLR on the flood regime and on over topping and flooding of Kūhiō Highway. For each EC and FC simulation the boundary condition tide levels at the H exit location at the mouth of Hanalei River and Waiʻoli Stream were raised 2 ft (0.61m).

3.7 Flood Mitigation Strategies

Strategies evaluated for reducing the impact of riverine flooding were divided into two categories: Flow Conveyance and Flood Water Storage. Both aim to reduce the impact of riverine flooding on properties and human health and safety. Flow Conveyance strategies include dredging, hau bush removal, maintenance of ditches and ʻauwai, groin rock removal, and berm removal. Flood Water Storage strategies include construction of detention basins. Some of the simulations were run as cumulative scenarios, including the installation of detention basins and the removal of hau bush; detentions basins and berm removal; hau bush removal and berm removal; and hau bush, berm removals and detention basins.

[9] https://www.pacioos.hawaii.edu/shoreline/slr-hawaii/

Figure 17. Monitoring Points

4 FLOOD MITIGATION STRATEGIES: FLOW CONVEYANCE

Flow conveyance strategies are normally implemented to improve the river channel's ability to carry water so that water is not slowed down, impounded, redirected, or otherwise prevented from flowing freely down the river channel to the ocean. In Hanalei River and Waiʻoli Stream, strategies to improve conveyance do not increase the rate or the volume of water moving through the channels because the waterways are tidally controlled.

4.1 Dredging

4.1.1 Description

Dredging is the process of removing sediment and debris from within the active channel and lowering the bed elevation. This is done to maintain or increase the depth of the channel, which can improve navigation, reduce the risk of flooding, and protect coastal infrastructure.

The mouths of Hanalei River and Waiʻoli Stream are routinely built up with sand from ocean wave runup and nearshore currents and sediment deposits carried by river water. Dredging the mouth of the rivers was evaluated to address concerns suggested by community members that this buildup exacerbates flooding by backing up the rivers when freshets and high flows occur.[10] On the Hanalei River an additional concern is that the sand deposits narrow the channel between the river and the ocean and make it too shallow for boat traffic, especially boats with moderate to deep drafts, to pass through the river mouth.

Evaluation of this strategy was limited to the mouth or muliwai sections of Hanalei River and Waiʻoli Stream (Figure 18). To evaluate if dredging would reduce flood impacts in the Hanalei River, the SMS model mesh was altered to represent two different future conditions.

For the FC dredging simulation the mesh elements bounded between the riverbanks and extending from the mouth upstream 500 ft (152 m) were lowered by 3 ft (0.9 m) on Hanalei River and Waiʻoli Stream. Upstream areas were not considered for dredging.

The mesh was also altered on Hanalei River and Waiʻoli Stream for a future condition that built up the elevation of the riverbed in the mouth of the channel to create a large sandbar, to represent the worst-case scenario of blocking the river mouth.[11] For the FC sandbar simulation, the topography of the sandbar in the mesh remained constant during the simulation. This skewed the analysis slightly as under actual high flow conditions the sandbar would be eroded from the mouth of the Hanalei River.

Six simulations were run: EC, FC with dredging, and FC with sandbar, under measured tides and under +2 ft SLR.

---

[10] A freshet is a sudden rise in the level of a stream, or a flood, caused by heavy rains.

[11] The air image and LiDAR were flown on October 1, 2022 and the topography and bathymetry of the Hanalei River mouth area on that date reflects a worst case scenario used in both analyses (Section 3.3.1).

4.1.2 Findings

Under the FC dredging scenario, the WSEL upstream near the Hanalei River boat ramp was less than 0.1 ft (0.03 m) less than under existing conditions and SLR conditions. Dredging has no impact on reducing flood WSEL or the extent of floodplain inundation. Dredging does make the river deeper and will make passage easier for larger vessels with deep drafts. A dredging scenario was conducted on Waiʻoli Stream and there was no difference in WSEL and wetted area between the EC and FC simulations.

With a sandbar across the channel at the mouth of the Hanalei River, the WSEL in the river at Black Pot Beach Park for FC is 0.2 ft (0.061 m) higher than EC. The buildup of sandbar does not affect the flooding regime in the river. Graphical representations of the model outputs at Monitoring Point 10 for EC and FC conditions, with and without SLR, are shown for dredging (Figure 19)and sandbar removal (Figure 20).

The same analysis was carried out on Waiʻoli Stream and the results were the same. Dredging had little to no effect on flow conveyance or changing the flood regime upstream of the stream mouth.

Figure 18. Dredging Analysis

Figure 19. Analysis of Dredging, with and without SLR, Hanalei River along Kūhiō Highway

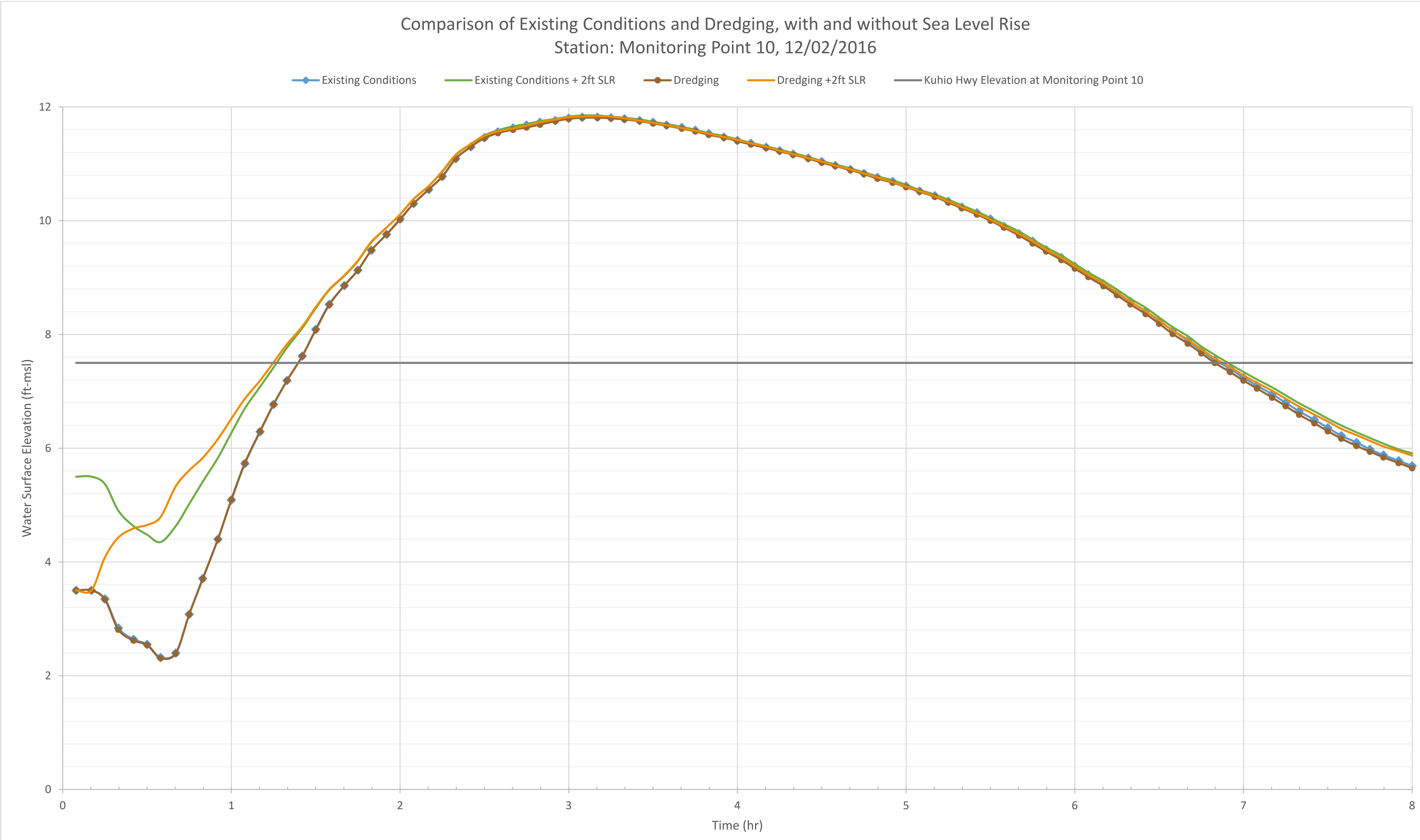
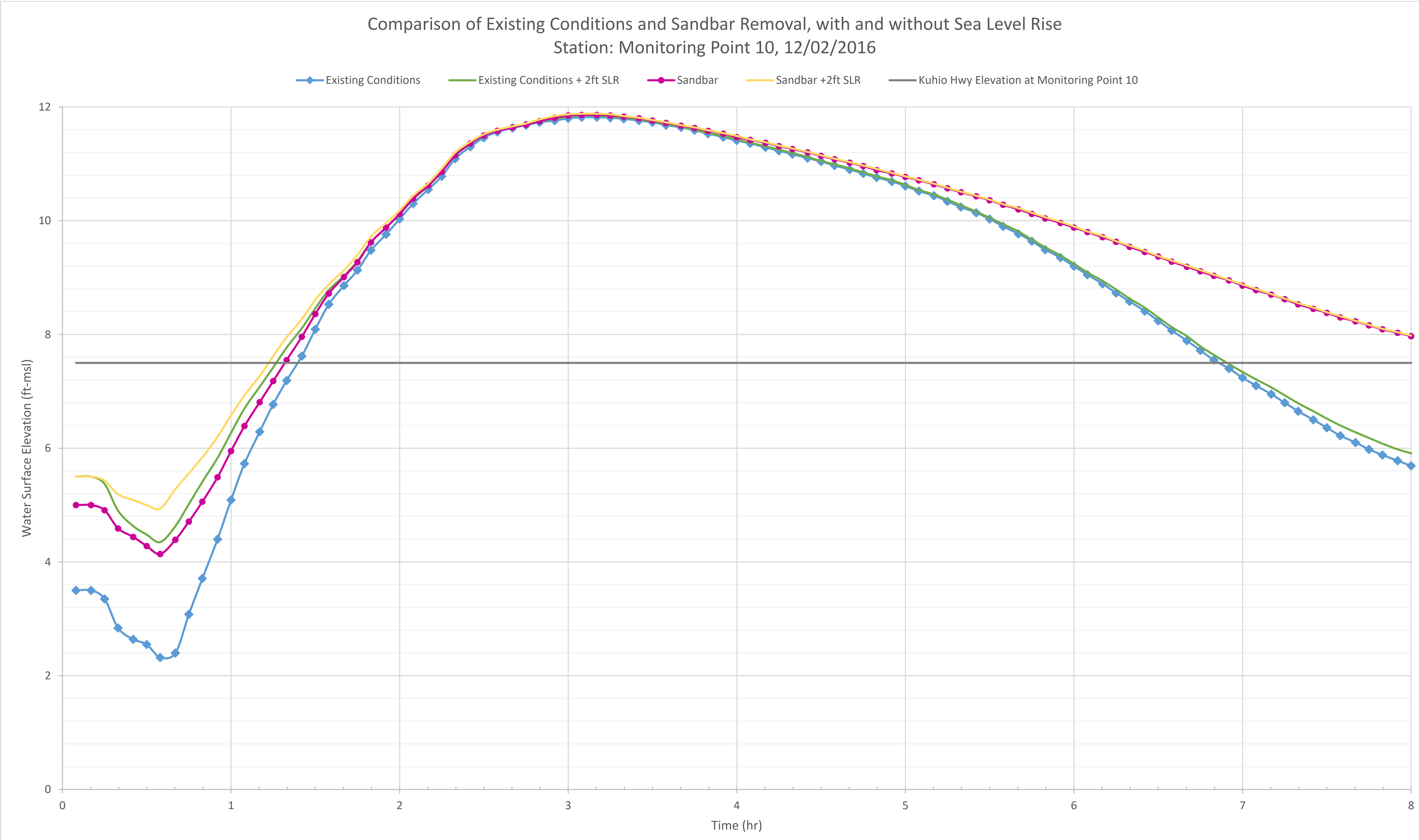


Figure 20. Analysis of Sandbar Removal, with and without SLR, Hanalei River along Kūhiō Highway



4.2 Vegetation Removal

4.2.1 Description

The study evaluated whether removing vegetation encroaching on water bodies would be an effective strategy to attenuate flooding. The water bodies included rivers, streams, ʻauwai, and ditches, with the focus on the mainstems of Hanalei River and Waiʻoli Stream. The primary vegetation evaluated was hau bush. Dense mats of California grass, elephant grass, and giant king grass along the waterways were also evaluated.

Hau Bush

Hau bush grows in large, dense stands along Hanalei River and Waiʻoli Stream. Hau bush has been identified as a significant impediment to passage by paddlers, boaters, and all watercraft that use the Hanalei River. In many sections of the Hanalei River hau bush growth has significantly narrowed the river channel, limiting passage to one vessel at a time. This is most pronounced between Stations 84+00 and 87+00. Many people believe that removing hau bush will increase the velocity of river flows and increase the area of the channel, allowing more water to flow out into the ocean.

Hau bush impacts the transport of suspended sediments carried by the river, causing deposition of fine materials along the riverbanks where the trees protrude. The trees increase the roughness or friction in the water column which in turn reduces the river's ability to carry fine sediments. The buildup of fine sediments along the banks decreases the channel's cross-sectional area in many parts of the river, further narrowing the channel and creating new surfaces for hau bush to sprout from. In some sections hau bush forms a partial flow barrier between the active river channel and its terrestrial floodplain.

In many sections where hau bush grows into the river, the opposite banks are eroding at accelerated rates. This causes sedimentation in the channel, water quality issues, impacts to infrastructure, and reduction in channel stability. The dense stands of hau bush can also trap woody debris carried by the river, which can block passage completely, and induce local scouring of the riverbed. The sedimentation induced by hau bush likely covers more coarse riverbed gravel and cobbles, resulting in a softening of the bed. This likely has an adverse impact on foraging by native and endemic fish that feed on insect and plant matter growing on the gravel and cobble banks.

To evaluate if hau bush removal would attenuate flooding, a FC was developed representing removal of all hau bush polygons depicted on Figure 21. The FC simulation was created by editing the materials and coverage layer and changing the roughness value from 0.25 to 0.1 for all mesh elements with hau bush. To account for changes in channel geometry that may occur after hau bush is removed, the mesh was altered to pull back the banks of the river. This had the effect of widening the channel in areas where the hau bush was located. Multiple simulations for FC of hau bush removal were run since there are numerous hau bush patches along the river. This allowed for an iterative approach to remove patch by patch and compare FC to EC.

Albizia Trees

There are several locations on the Hanalei River where large albizia trees grow on top of the bank. These fast-growing alien trees are becoming more prevalent in the riparian corridors. They are easily uprooted and knocked over by the wind, often falling into the river channel and impeding water flow and boat passage.

California, Elephant, and Giant King Grasses

Grasses grow in thick, dense stands long numerous waterways within the larger project area. Along ditches and ʻauwai they can reduce flow conveyance and block flow if left to grow unchecked without treatments such as herbicide application or mechanical removal via cutting. Along the rivers and streams grasses can grow in thick stands, but usually do not block the entire channel width. Like hau bush analysis, simulations were run under EC with roughness coefficients representing existing grass coverage. To see if the removal of grass would change the flood regime along Hanalei River and Waiʻoli Stream, the roughness coefficients were lowered to reflect removal and the simulations run again.

4.2.2 Findings

Hau bush removal reduces the duration Kūhiō Highway is submerged by eight minutes. It also reduces the maximum WSEL and depth of water over the highway surface by 0.70 ft (0.21 m). Hau bush removal will lessen riverbank erosion by reducing the redirection of flow towards the opposite bank of the river. Graphical representations of the model outputs at Monitoring Point 10 for EC and FC conditions, with and without SLR, are shown for hau bush removal (Figure 22).

Figure 23 shows prioritized locations for hau bush removal. Prioritization for removal was based on stands that impair navigation, stands that constrict flow and induce woody debris jams, and stands that reduce channel cross section area.

While not evaluated using the models, it is recommended that albizia trees growing on the banks that are likely to fall into waterways and partially or fully block the river be removed (Figure 24).

There was little to no change in flow conveyance for removal of the grasses for flood flows along Hanalei River and Waiʻoli Stream. Grasses growing along ditches, ʻauwai, and the Hanalei River and Waiʻoli Stream should be maintained. While they do not have a significant effect on the conveyance of flood flows, they do affect the ecohydrology of the system by creating stagnant conditions that become breeding habitat for mosquitoes, impairing view plains, and encroaching into waterways. The removal of the grasses is warranted in ditches as the blockage of a ditch can cause backing up and redirecting of water.

Figure 21. Project Area Hau Bush Locations

Figure 22. Analysis of Hau Bush Removal, with and without SLR, Hanalei River along Kūhiō Highway

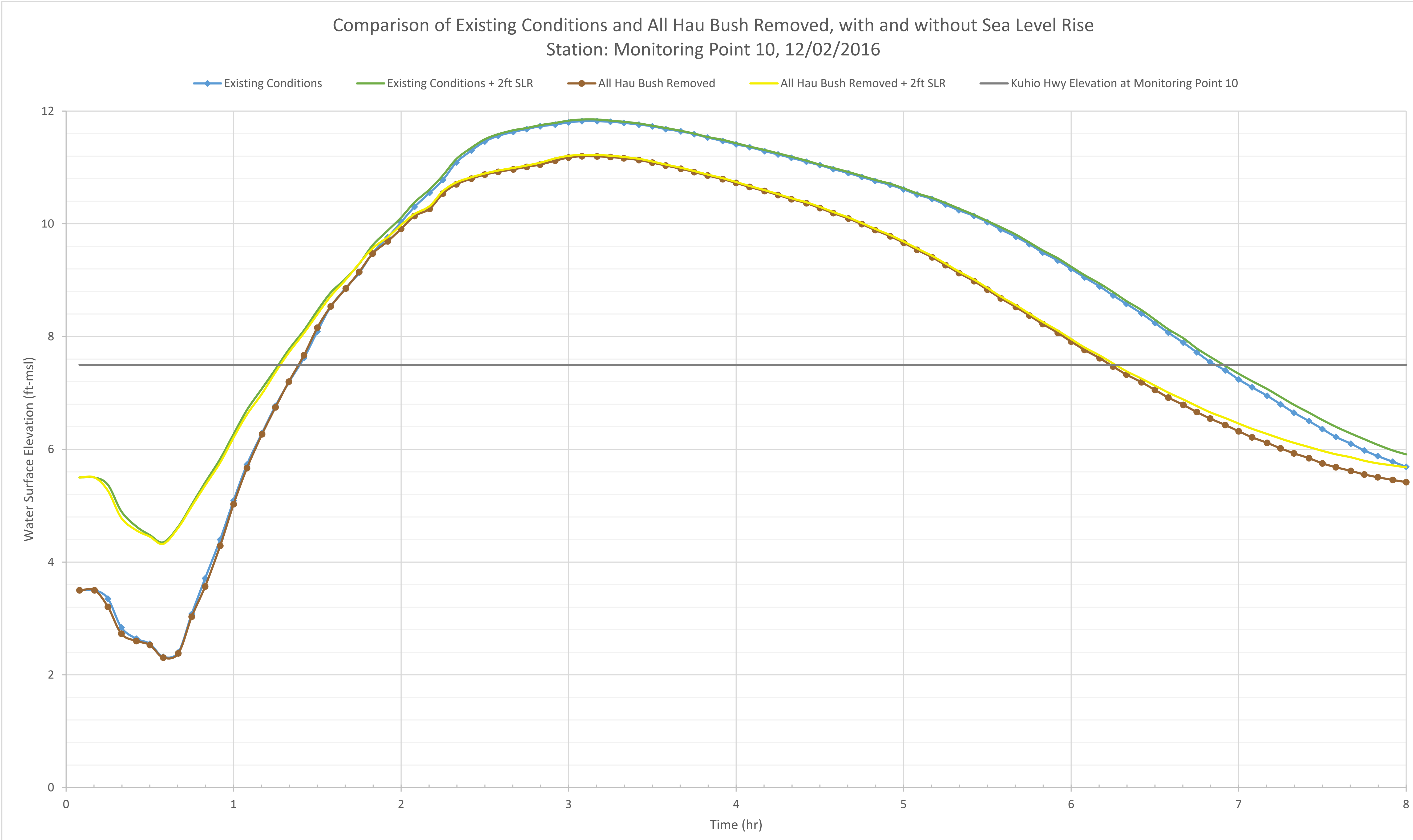


Figure 23. Priority Ranking: Hau Bush Removal

Figure 24. Recommended Locations for Albizia Removal and Bank Stabilization

4.3 Maintenance of Ditches and ʻAuwai

4.3.1 Description

General maintenance of ditches and ʻauwai is important for keeping water flowing freely without impairments. Maintenance involves keeping these features free of vegetation to ensure hydraulic capacity. The ditches that drain taro and bird loʻi along Kūhiō Highway between Hanalei Bridge and Hanalei Town are routed through culverts under the highway. These ditches function as two-way flow paths. During floods, river water is routed up the ditches. After floods, during dry periods when the river water level is lower, the ditches drain agricultural runoff into the river. The hydraulic model was used to determine if reducing vegetation growing in and along the ditches has an impact on flood drainage.

4.3.2 Findings

Analysis of ditches in Hanalei and Waiʻoli Watersheds found that maintaining the ditches improves conveyance under non-flooding periods. During high floods maintenance reduces the chance of debris jams that redirect water causing channel erosion, and localized flooding.

4.4 Removal of Berms

4.4.1 Description

This study evaluated two existing berms to determine if they alter flood water depths, velocities, and area of inundation on the Hanalei River floodplain. One built-up berm is on the parcel commonly referred to as the Bison Farm (named after the North American Bison (*Bos bison*) that pasture on the parcel) and the other berm is on the USFWS Hanalei NWR (Figure 25). Within the mesh the two berms were removed to create a FC with no berms. Eight simulations were run: EC, FC with Bison Farm berm removed, FC with USFWS berm removed, and FC with both berms removed, under measured tides and under +2 ft SLR.

4.4.2 Findings

Under existing conditions and SLR conditions, removal of the berms, either separately or together, had no impact on the onset and duration of flooding on Kūhiō Highway (Figure 26).

4.5 Removal of Rock Groin Structures on East Bank of the Hanalei River at its Mouth

4.5.1 Description

There are three rock groin structures on the east bank at the mouth of the Hanalei River. Review of historic photographs shows that the structures were present in the 1960s (actual dates of install unknown). The structures were likely installed to protect the east bank from erosion and to maintain a deep-water channel between the river and the ocean. The hydraulic model was used to evaluate the impacts these structures have on sediment transport and sedimentation at the river mouth. The analysis was directed at trying to figure out if the structures are accelerating sedimentation, which is a concern raised by the community. The analysis was conducted by altering the mesh to reflect removal of the rock groins.

4.5.2 Findings

The results of this analysis were inconclusive due in part to the complex hydrodynamics of the area where the groins are located. The deposition and scour of sand at the groins is affected by hydraulics of the river and the ocean, and setting the model up to simulate the removal of the groins was challenging. Preliminary analysis indicated that the removal will likely result in loss of the sand along the east bank of the river mouth where the groins are located and increasing the channel width by approximately 15 ft (4.6 m).

Figure 25. Existing Berms with Ground Surface Profiles

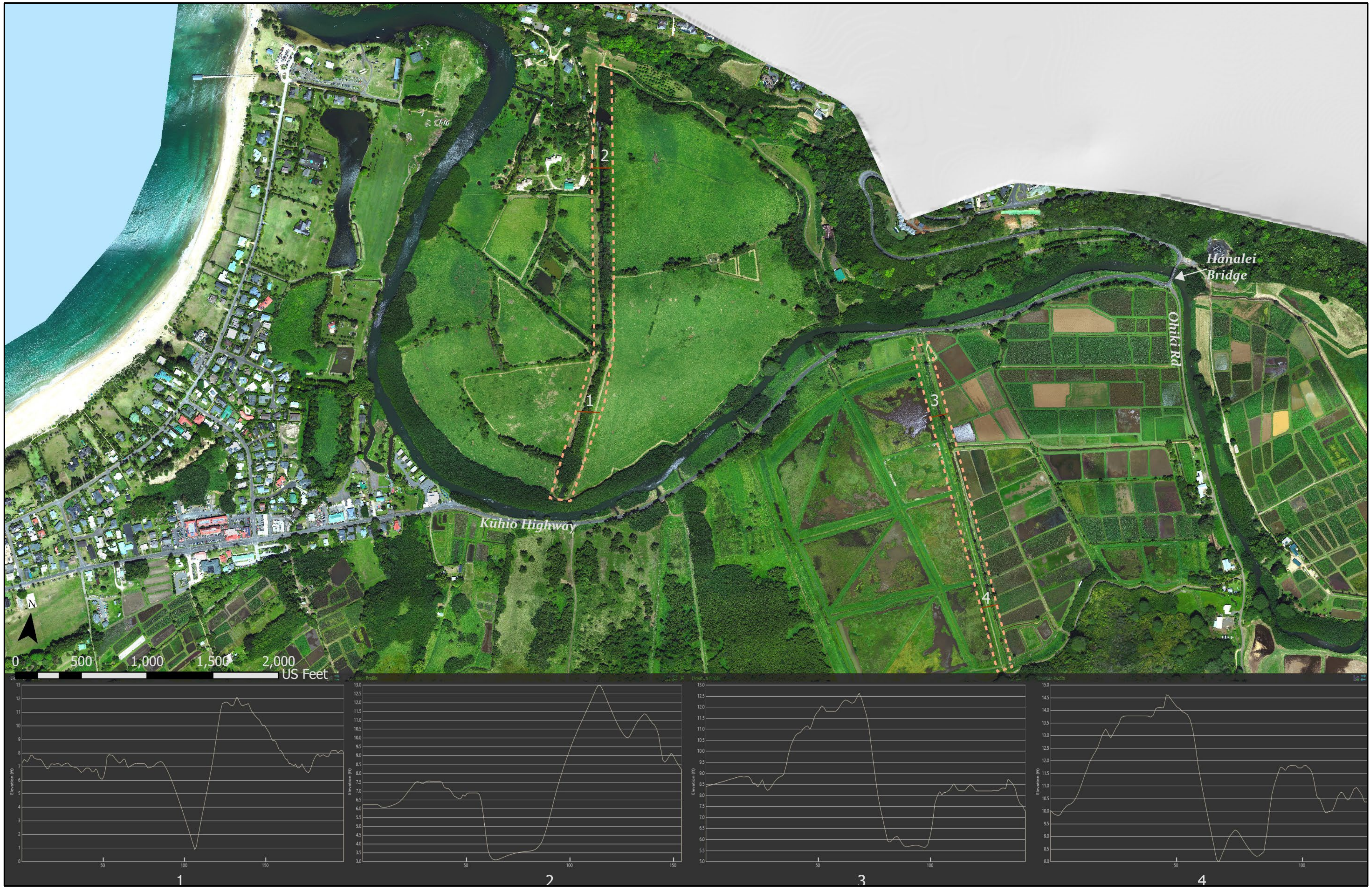
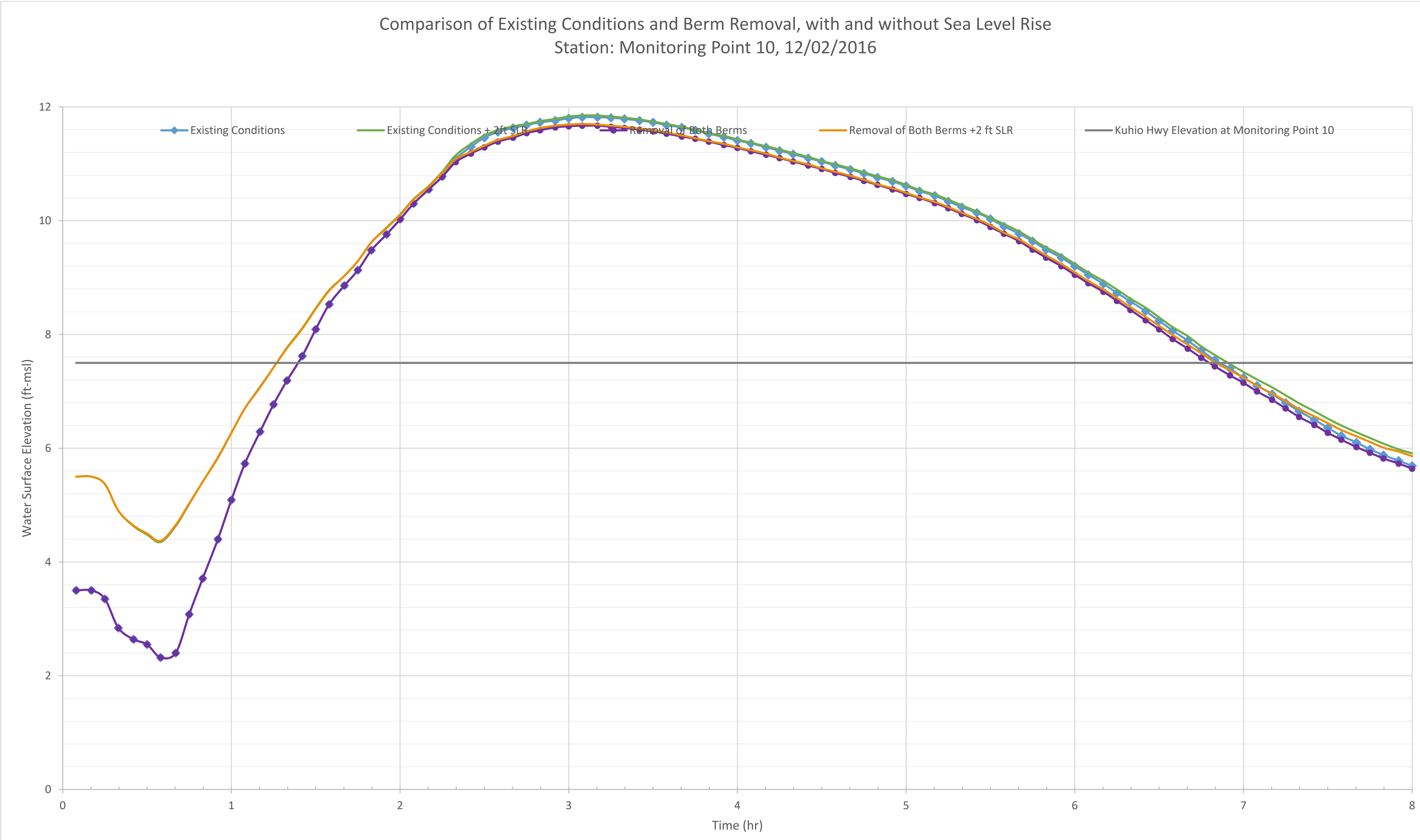


Figure 26. Analysis of Berm Removal, with and without SLR, Hanalei River along Kūhiō Highway



5 FLOOD MITIGATION STRATEGIES: FLOOD WATER STORAGE

Flood water storage strategies allow flood waters to be stored in areas where they do not pose a threat to property or human health and safety or disrupt land uses. These areas are generally referred to as open floodable space. This project evaluated areas prone to flooding and in the active floodplain. Flood water storage strategies can help reduce the risk of flooding by capturing runoff and storing it temporarily. By increasing the volume of storage on open floodable spaces, it may be possible to offset the volume of water that reaches areas where flooding is problematic. Flood water storage is used in many river systems in the U.S. and across the globe.

5.1 Construction of Flood Water Detention Basins in Open Floodable Spaces

5.1.1 Description

Flood water detention basins can be created on floodplains to increase the volume of flood water storage. Site specific analysis using the hydraulic model was conducted to determine if storage of flood waters from the Hanalei River in detention basins would offset the volume of water in the river to prevent overtopping of Kūhiō Highway.

For evaluation purposes, several potential locations for detention basins were identified in the Hanalei Watershed and their surface areas delineated (Figure 27). Detention basins were not considered in Waiʻoli due to limited space available. In addition, detention basins in Waiʻoli would not alter the flood regime in the flood prone area of Kūhiō Highway.

Two parcels situated in the Hanalei River floodplain were evaluated. The selection criteria included location within the floodplain, that they routinely flood, sufficient parcel size to accommodate detention basins with substantial storage capacities, and willingness of owners to explore the possibility of constructing detention basins on their land.

The first parcel is locally known as the Bison Farm. The conceptual design for detention basins on this parcel included six basins ranging in size from 4 to 23 acres, with a total surface area of 73 acres (Table 6). The ponds would be excavated to five feet below the existing ground surface level. The elevation of the invert or lowest point of the basins would vary since the existing ground surface elevations over the site range from 6 to 10 ft-msl. The estimated total volume of water storage for the six basins is 17 million cubic feet. The detention basins would be filled by flood waters routed into shallow channels connecting the basins to the top of the riverbank. The channel elevations would be set just below the top of the riverbank and excavated below grade so that their invert elevation at the top of the riverbank would be 2 to 4 ft (0.61 to 1.22 m) lower than the natural grade. This would allow water to flow inland towards the basins before the river overtopped the banks. This will allow the ponds to fill up before the river over tops its banks on the left or south side of the river along Kūhiō Highway.

The second parcel where detention basins were evaluated is on the west side of the Hanalei River. There are two existing six-acre ponds/wetlands that could be repurposed as flood storage basins. These ponds have old channels that connect to the river and could be used to fill the ponds at the onset of flooding. Excavation would be six feet below grade, creating invert elevations of approximately 0 ft-msl. The total storage capacity for the two basins is approximately 3.1 million cubic feet.

Several other parcels were considered for detention basins, including land owned by Princeville Agriculture and land in the USFWS Hanalei NWR. Princeville Agriculture declined to explore the possibility of constructing detention basins on their land. USFWS was interested and several potential sites on the Hanalei NWR where detention basins could be created were evaluated. However, because of their topography and elevation, the sites would not provide much storage. USFWS also stated detention basins were not compatible with habitat requirements of the native waterbirds managed at the refuge.

FC simulations were created by altering the mesh with the proposed basin geometry. Simulations were run under EC and FC representing all basins on both parcels with both measured tide and SLR.

5.1.2 Findings

Detention basins were estimated to reduce the onset of flooding by between 10 to 40 minutes and reduce the duration of road flooding by 4 to 30 minutes for all simulations with measured tides (Figure 28). Under SLR conditions, there is no difference between EC with SLR and FC with SLR. The detention basins were ranked based on volume of storage and landowner approval (Table 6).

Table 6. Priority Ranking: Detention Basins

TMK	Acres
Priority Rank 1: Hanalei Bison Ranch Land Holdings LLC	**73**
454004010	23, 12, 9
454004009	10, 9, 6, 4
Priority Rank 2: Halele‘a Investment Company LLC	**12**
455010081	6, 6
Priority Rank 3: USFWS Hanalei NWR	**16**
453001007	14, 2
Priority Rank 4: USFWS Hanalei NWR	**68**
454003007	32, 25, 7, 3, 1

5.2 Enhancement of Existing or Historic Wetlands and Taro Lo‘i

5.2.1 Description

Wetlands function similarly to detention basins, with the difference being that these locations historically were ponds. Restoring wetlands to receive flood water can increase flood storage capacity, while slowing water to reduce the height of floods and erosion rates. Wetlands act as natural sponges, soaking up and holding water until it can infiltrate into the ground. Whatever water does not infiltrate into the groundwater is slowly released into nearby rivers and streams. This slow release helps prevent flooding during storm events. Wetland vegetation also helps reduce the speed of water as it flows over the landscape. Wetlands were not evaluated as a solution since it was determined that detention basins provided a better option for achieving wetland function and maximizing flood water storage capacity.

Taro lo‘i function as detention basins. Lowering the bed elevation of lo‘i to increase the potential volume of flood water storage was not considered or evaluated because the depth is directly related to the productive capacity for growing taro.

Figure 27. Priority Ranking: Detention Basins

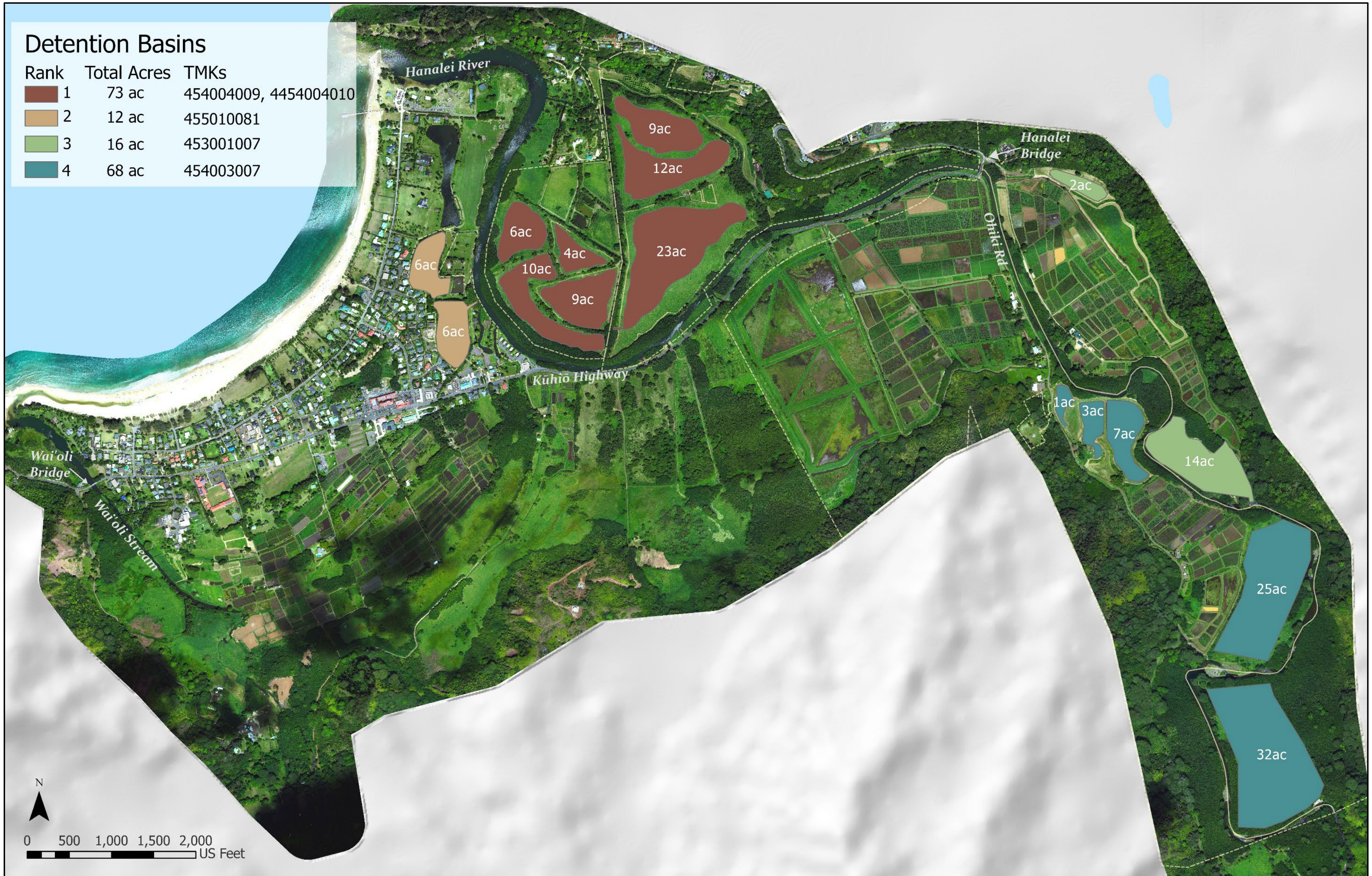
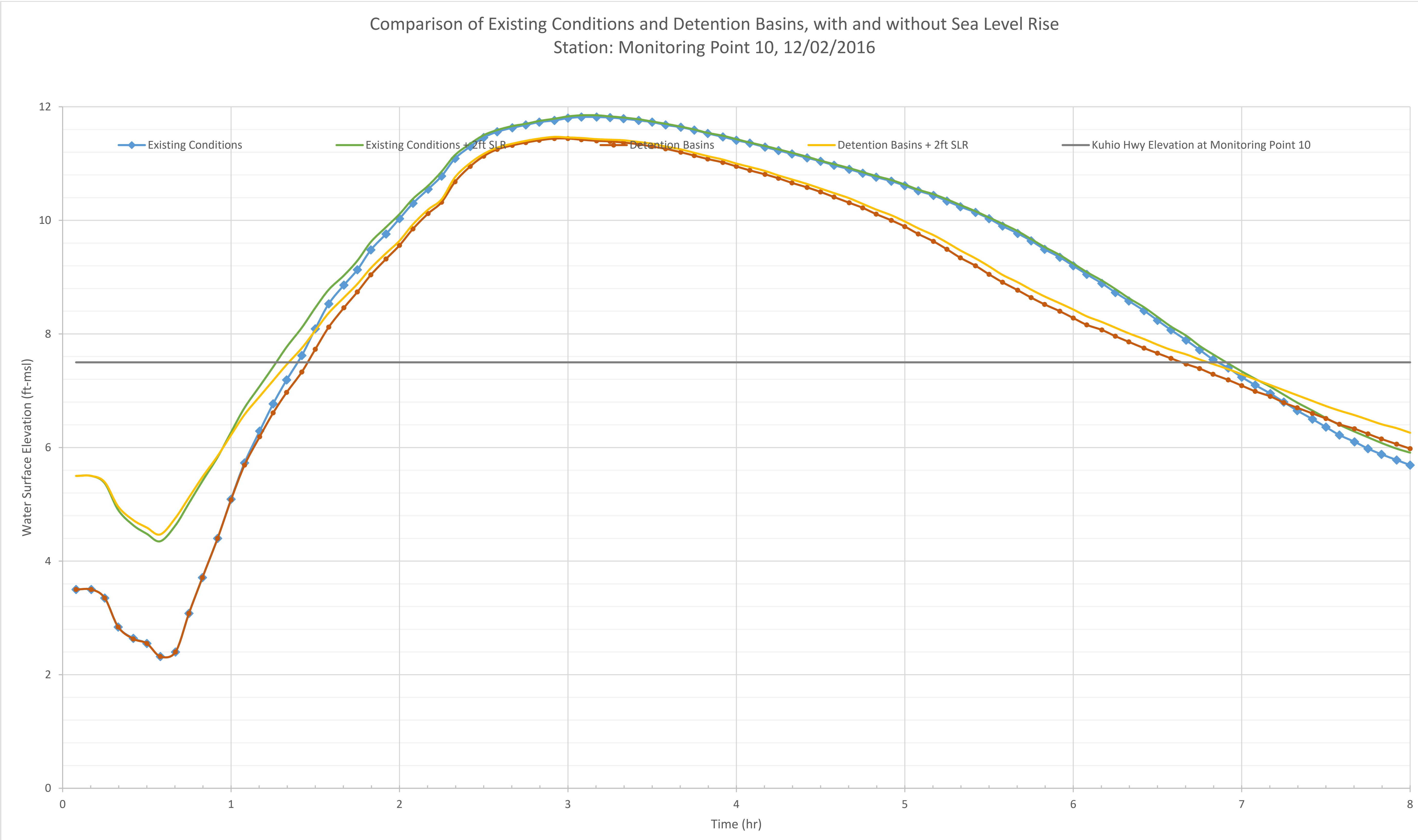


Figure 28. Analysis of Detention Basins, with and without SLR, Hanalei River along Kūhiō Highway



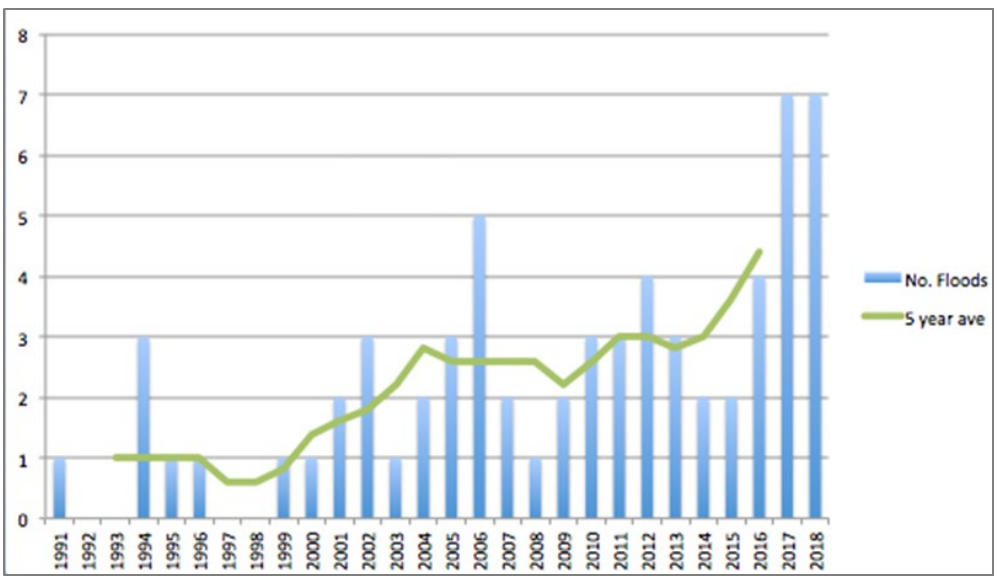
6 OTHER ISSUES

6.1 Flooding of Kūhiō Highway between Hanalei Bridge and Hanalei Town

6.1.1 Description

Kūhiō Highway between Hanalei Bridge and Hanalei Town is prone to inundation by flood waters at a fairly high frequency, which results in road closures (Figure 29). Closures are not limited to extreme river flows and floods, but also occur during moderate river flow events when the tide is rising or the river is at a high-water level at the onset of the flow event. The elevation of the road in this section varies from approximately 14 ft-msl near the Hanalei River bridge to 7.1 ft-msl near Culvert 4, with at least three locations regularly prone to flooding, and one location near Monitoring Point 10 where flood waters first cover the road surface (Figure 17). Site specific analysis using the hydraulic model was conducted to estimate an elevation of the road surface that would be above flood waters for moderate to extreme floods under present tide conditions. The height the road would need to be raised to in the future was also evaluated under SLR conditions. Hypothetical simulations were run using tide levels for SLR at the H exit downstream boundary conditions. Discharge hydrographs used the USGS Hanalei data for the highest flow on record, 41,000 cfs.

Figure 29. Hanalei Bridge Closures by Year



6.1.2 Findings

The frequency of closure of Kūhiō Highway will increase in the future. Historically there have been high flow events with water levels that have come close to overtopping the highway. Floods that currently raise the water level in the river but do not overtop onto the highway can be expected to reach the road under +2 ft SLR

Though not part of the scope of this study, hydraulic modeling was used to estimate what elevation Kūhiō Highway could be raised to in the future to prevent it from over-topping during flood events under +2 ft SLR. Simulations were run using the 100-year return interval discharge of 42,600 cfs estimate by USGS. The analysis shows that the roadway surface between the Hanalei Bridge and The Hanalei Dolphin would need to be approximately 15.4 ft-msl. This would require raising the existing road surface by 6 to 8 feet (1.8 to 2.4 m). This analysis is ongoing and will be available as a standalone white paper for the community and HDOT. Design of the highway improvements is beyond the scope of this study, but the findings could be useful to HDOT.

6.2 Bank Stability

Riverbank instability along numerous stretches of the Hanalei River was mapped during field work. While assessing the condition of the river channel was not part of the project scope, it became evident during field work that mapping unstable sections would provide valuable information. Bank failure along the unstable sections of the river occurs primarily during high flow flood events. Bank instability due to erosion and mass wasting along the river threatens sections of both Kūhiō Highway and Ohiki Road. The failure of the roads would have significant and profound adverse impacts. Presently, HDOT is formulating engineering designs for the installation of a hybrid bio-wall along a section of Kūhiō Highway near Station 100+00, aimed at mitigating riverbank erosion that threatens the road. It is recommended that all vulnerable sections of Kūhiō Highway and Ohiki Road be assessed to determine if stabilization strategies are needed to prevent future road failures due to riverbank erosion. Figure 24 shows sections of the Hanalei Riverbank where bank stabilization is recommended based on the unstable nature of the banks and the threat to the road network infrastructure.

7 IMPLEMENTATION

7.1 Landowner Responsibilities

7.1.1 Waterway Maintenance

Basic river/stream channel maintenance is important for mitigating the effects of future floods on the Hanalei and Waiʻoli communities. Maintenance is often challenging or neglected in part because ownership boundaries and responsibilities are unclear, or owners do not know that they are responsible for maintenance. The State, the County, and private landowners disagree over who is responsible for the maintenance of channels, streambeds, streambanks, drainageways, and river mouths. Hawaiʻi Revised Statutes (HRS) Chapter 46, Section 11.5 [1986] *Maintenance of channels, streambeds, streambanks, and drainageways* states:

> Notwithstanding any law to the contrary, *each county shall provide for the maintenance of channels, streambeds, streambanks, and drainageways, whether natural or artificial, including their exits to the ocean, in suitable condition to carry off storm waters*; and for the removal from the channels, streambeds, streambanks, and drainageways and from the shores and beaches any debris which is likely to create an unsanitary condition or otherwise become a public nuisance; provided that to the extent any of the foregoing work is a private responsibility the responsibility may be enforced by the county in lieu of the work being done at county expense, and any private entity or person refusing to comply with any final order issued by the county shall be in violation of this chapter and be liable for a civil penalty not to exceed $500 for each day the violation continues; provided further that it shall be the responsibility of the county to maintain all channels, streambeds, streambanks, and drainageways unless such channels, streambeds, streambanks, and drainageways are privately owned or owned by the State, in which event such channels, streambeds, streambanks, and drainageways shall be maintained by their respective owners.

DLNR previously had a stream maintenance plan for Kauaʻi and staff and resources to maintain streams and rivers. In addition, Hanalei community leaders would inform DLNR Division of Boating and Recreation of debris accumulation in the river and their staff would collect, cut, and offer debris for public use. DLNR changed their policy and is no longer undertaking this critical work. DLNR is taking a narrow interpretation of HRS §46-11.5 which states that "each county shall provide for the maintenance of channels, streambeds, streambanks, and drainageways, whether natural or artificial, including their exits to the ocean, in suitable condition to carry off storm waters…" However, channels, streambeds, streambanks, and drainageways that are privately owned or owned by the State are to be maintained by their respective owners. The interpretation and implementation of this law has been a matter of contention and legal dispute between Kauai County and DLNR for the past several years.

Much of the land and floodplain area along the lower reaches of Hanalei River and Waiʻoli Stream is privately owned. While private landowners have responsibility for maintenance, maintenance can be expensive, especially if banks are overgrown with dense stands of vegetation including, but not limited to, hau bush. Opportunities for funding maintenance with the help of outside sources are limited (Appendix B). In the short term, access to funding secured as part of Act 12 and Act 35 must involve a non-profit partnership for work on most privately held land. Over the longer term DLNR and the County could work to educate landowners along the waterways on their maintenance responsibilities. A resolution to the interpretation of HRS §46-11.5 may help guide this education.

This study recommends hau bush removal from the riverbanks on private and State-owned properties. Pursuant to HRS §46-11.5 the landowner is responsible for maintenance. It would be an equitable arrangement that if State funds were used to clear hau bush, which in many areas has been left to grow unchecked for decades, and out-plant native plants, that the landowner who benefited from State funds would fund ongoing maintenance.

7.1.2 Implementing Strategies

Pre-Installation Approvals

Landowners or partnering entities implementing flood mitigation strategies will, at a minimum, need to identify funding sources (if not self-funded) (Section 7.2) and determine if permits are required for conducting work (Section 7.3).

Certain outside funding sources require non-profits to be the entity receiving funds (Section 7.2). Entities seeking to implement a strategy for this type of work on land they do not own will be responsible for securing landowner cooperation and approvals. The non-profit organization should enter into a written agreement with the landowner to facilitate implementation and maintenance of flood mitigation strategies (Appendix C). The agreement should detail the scope of work including implementation and maintenance requirements, funding sources and commitments, entities responsible for implementation and maintenance, and access and liability requirements. Such agreements may be negotiated at the proposal stage and finalized after funding is awarded.

Post-Installation Responsibilities

Most flood mitigation strategies will require ongoing post-implementation maintenance and monitoring to ensure success. Maintenance requirements should be identified and planned for as part of the project design, and funding should be budgeted for at least five years of regular maintenance (Section 7.4). Landowners will need to understand and support the requirements for ongoing maintenance through memorandums of understanding or similar agreements. Agreements with the landowner should consider requesting the landowner assume fiscal responsibility for post-implementation maintenance.

7.2 Funding

Funding for flood mitigation implementation can come from a variety of sources, both public and private, to support projects aimed at reducing the risks and impacts of flooding (Appendix B). If not self-funded, there is usually an application process, which may be competitive, for grant funding. To secure funding for flood mitigation, it is essential for communities and organizations to understand the eligibility criteria, application processes, and reporting requirements associated with each funding source and to develop comprehensive proposals that demonstrate the potential impact and benefits of their projects. Collaboration between multiple funding sources is often necessary to cover the substantial costs associated with effective flood mitigation measures.

A significant portion of the funding secured under Act 12, Session Laws of Hawaiʻi 2018 and Act 35, Session Laws of Hawaiʻi 2019 for disaster relief and mitigation needs is being managed by Hale Halawai ʻOhana O Hanalei, a 501(c)(3) organization based in Hanalei. The County of Kauaʻi selected Hale Halawai to manage the implementation and financial distribution of $7,285,000 for North Shore Watershed Flood Mitigation Sub-grants. The sub-grants will be directed to other non-profit organizations so they can conduct mitigation projects that reduce harm from future flooding events. The results of this *Hanalei Watershed Flood Mitigation Study* are helping to inform which mitigation strategies will be identified and prioritized.

Entities that want to implement strategies may need to secure additional funding. Since the Act 12 and Act 35 funding is classified as State funds, it may be used as match for Federal funding programs, potentially increasing the possibility of award and impact of funding dollars.

7.3 Permits and Approvals

Federal, State, and County of Kauaʻi permits and approvals may be needed for implementation of some of the flood mitigation strategies. Regulatory requirements ensure compliance with all Federal, State, and County laws designed to protect natural and cultural resources. The sequence of securing permits and a specific timeline for permit completion, submission, and review will be based on dialogue with each agency. In general, the permits can be prepared concurrently and much of the required information is similar. Potential permits that may be required depending on the methods of implementation of strategies, the cost and funding source, and ownership where work will occur, are summarized in Table 7. Additional information is included in Appendix D. Proposers will need to determine which permits and approvals are necessary for planned actions.

Table 7. Permits and Approvals for Implementing Flood Mitigation Strategies

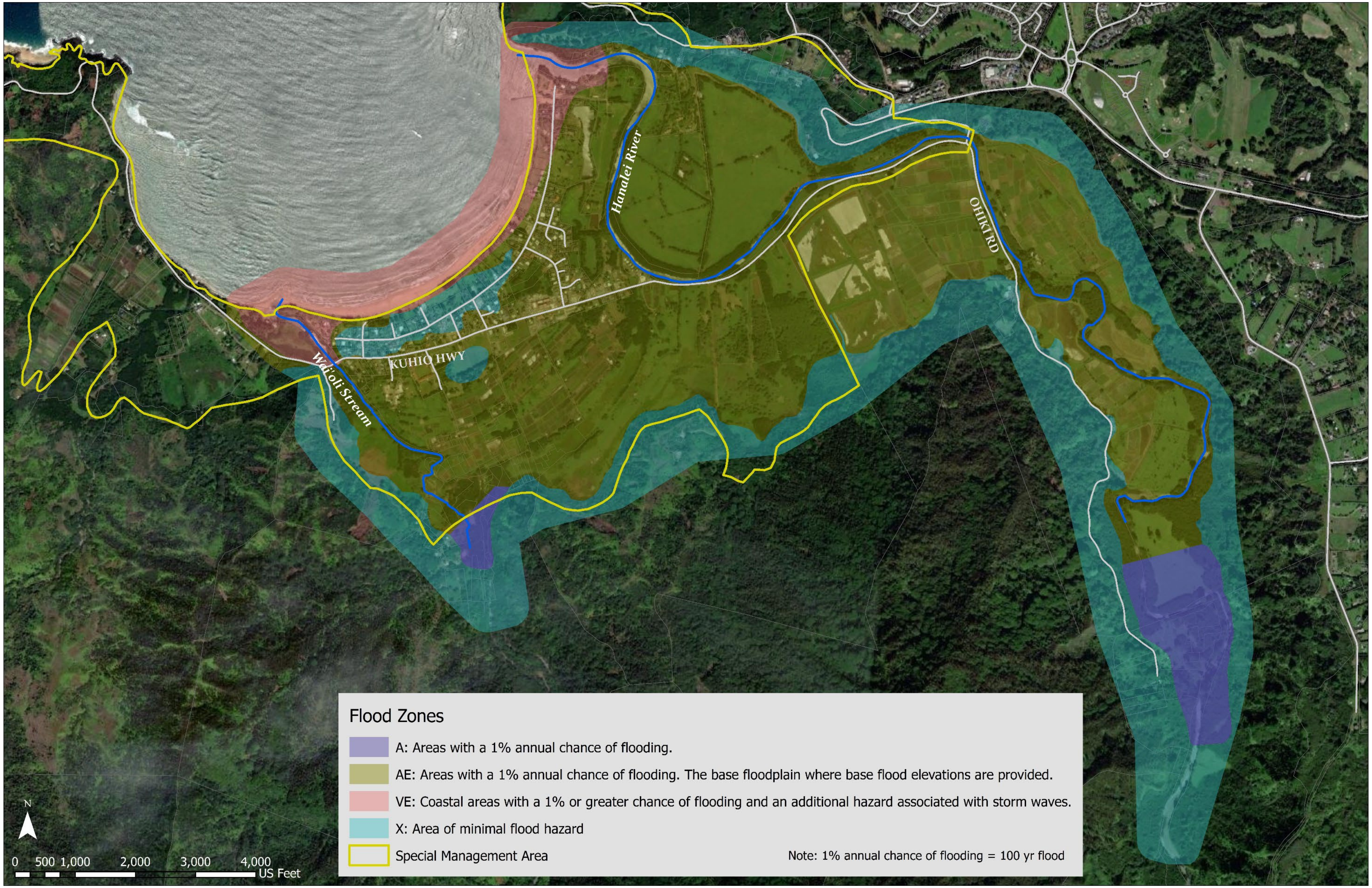
Act/Statute/Ordinance	Administering Agency	Permit or Approval
Federal		
Clean Water Act Section 404	U.S. Army Corps of Engineers (USACE)	Individual (Standard or Letter of Permission), Nationwide, or General [and/or Rivers & Harbors Act Section 10]
Rivers and Harbors Act Section 10	USACE	[or CWA Section 404]
National Environmental Policy Act	Federal Petitioner	EIS or EA
Endangered Species Act	USFWS	Federal Salvage Permit
Endangered Species Act Section 7	USFWS / NOAA Fisheries	Consultation and Approval
Migratory Bird Treaty Act	USFWS	Consultation
State		
Clean Water Act Section 402	Hawaiʻi Department of Health	National Pollution Discharge Elimination System Permit
Coastal Zone Management Act Section 307/ CZM Consistency	Hawaiʻi Office of Planning	Approval
Hawaiʻi Revised Statute Chapter 343	Hawaiʻi DLNR	EIS or EA
Stream Channel Alteration Permit	Hawaiʻi DLNR CWRM	Permit

Act/Statute/Ordinance	Administering Agency	Permit or Approval
Stream Diversion Works Permit	Hawaiʻi DLNR CWRM	Permit
County		
Special Management Area Hawaiʻi Revised Statutes 205A	Kauaʻi County Planning Department	Permit (Major or Minor)
Grading/Grubbing/Stockpiling Soil Erosion and Sedimentation Control (County of Kauaʻi Ordinance No. 808)	Kauaʻi County Department of Public Works	Permits
No Rise Certification	Kauaʻi County Department of Public Works	Approval / Certification
Other		
Right of Entry	Landowner	Permit

7.4 Maintenance

Once flood mitigation strategies have been implemented, it is important to regularly maintain them to ensure that they remain effective. While these strategies play a crucial role in reducing the immediate risks associated with flooding, their long-term effectiveness relies heavily on diligent and proactive maintenance. Without proper maintenance, these strategies may not be able to perform as intended, which could lead to increased flood risk. Appendix E provides considerations for stream bank restoration activites, including vegetation clearing and out-planting, maintaining ditches and ʻauwai, and maintaining flood water detention basins and bird loʻi. Specifics, including frequency of maintenance, level of effort, and costs, depend on type and extent of implementation.

Figure 30. Project Area Flood Zones and SMA Boundary



8 COST ESTIMATES

Having cost estimates is important for guiding the implementation of flood mitigation strategies. These estimates serve as a financial roadmap, guiding decision-makers in allocating resources effectively and ensuring that the chosen strategies are both viable and sustainable. This section provides costing information on implementing hau bush removal and constructing detention basins, the two primary strategies evaluated.

Costs estimates include planning, permitting, and implementation. Cost estimates derived for implementation actions that will take place makai of the Special Management Area (SMA) boundary (Figure 30) and that are estimated equal to or greater than $500,000 will trigger an SMA Major permit. If an SMA Major permit is required, other permits are also triggered (Section 7.3).

Cost estimates should be considered provisional and were derived to conduct cost benefit analysis and provide guidance to those considering implementation, including those proposing and reviewing proposals that involve these activities. Proposers should derive their own cost estimates.

8.1 Hau Bush Removal

Cost estimates for hau bush removal were obtained from contractor quotes, actuals based on a completed project, and pricing provided to the County of Kauaʻi (Table 8). Cost for hau bush removal was calculated by landowner and the acres of hau bush on their parcel (Table 9). Through the economy of scale, there may be a reduced unit cost to remove hau bush if one entity conducts the removal across some or all properties. Ongoing maintenance would be the responsibility of the landowner (Section 7.1.1.)

Table 8. Cost Estimates for Hau Bush Removal

Cost per Acre	Notes	
Based on contractor quotes		
$250K	Includes: - Planning and coordination - Permitting (SMA Major with Environmental Assessment) - Vegetation removal - Disposal of chipped waste - Revegetation with native plants	Excludes: - Maintenance
Extrapolated from actuals (in-house) (0.66 acres)		
$150K	Includes: - Vegetation removal - Revegetation - No permitting required	
R.M. Towill estimate to County (2020) (17 acres in Hanalei, 2.35 acre in Waiʻoli)		
$280K	Includes: - Vegetation removal - Disposal of chipped waste	Excludes: - Permitting - Maintenance

Table 9. Cost Estimates for Hau Bush Removal by TMK

TMK	Acres	Cost: No permitting ($150K/acre)	Cost: Permitting ($250K/acre)[12]
Priority Rank 1	**1.4**		
454004999: State of Hawaiʻi, Department of Transportation	0.8	$120,000	$200,000
454004010: Hanalei Bison Ranch Land Holdings LLC	0.6	$90,000	$150,000
Priority Rank 2	**14.5**		
454004009 / 454004010: Hanalei Bison Ranch Land Holdings LLC	13.9	$2,085,000	$3,475,000
454004010: Hanalei Bison Ranch Land Holdings LLC	0.6	$90,000	$150,000
Priority Rank 3	**5.3**		
455001002: Sheehan, Patricia W. Trust 455001035: Sheehan, Michael G.	5.3	$795,000	$1,325,000
Priority Rank 4	**3.3**		
454004010: Hanalei Bison Ranch Land Holdings LLC	3.3	$495,000	$825,000
Priority Rank 5	**3.1**		
454004010: Hanalei Bison Ranch Land Holdings LLC	3.1	$315,000	$775,000
Priority Rank 6	**2.2**		
454004009: Hanalei Bison Ranch Land Holdings LLC	1.8	$270,000	$450,000
454004055: M Ben-Dor Diamonds Inc Trust	0.4	$60,000	$100,000
Priority Rank 7	**12.4**		
Many owners	12.4	$1,860,000	$3,100,000
Priority Rank 8	**8.4**		
456002002: Kobayashi, Glenn I.	8.4	$1,260,000	$2,100,000

Entities proposing to remove hau bush are encouraged to consult with the County of Kauaʻi Department of Planning to request an exemption from the SMA requirement on the basis that the removal is maintenance activity. This could bring project costs down significantly by reducing costs to secure permits. The permitting costs do not include Clean Water Act or Section 10 River and Harbor permits since it assumed all removal will be done from the land side of the hau bush and there will be no in water work, placement of fill into the rivers, or dredging or grading below the normal water line.

The prevalence of hau bush and other invasive trees growing along and into river channels is an island wide issue. A possible use of funds to facilitate efficient and effective removal of hau bush and other trees

[12] If cost is greater than $500,000, an SMA Major permit may be required.

would be the acquisition of specialty equipment. An example of such equipment is a tracked feller buncher used in logging operations in many areas of the world.[13] Cost estimates for this piece of equipment range from $780K - $925K.

8.2 Construction of Detention Basins

Based on the analysis of the effectiveness of detention basins and their cost, they are not recommended as a flood mitigation strategy. Detention basins evaluated for this project do not store enough volume of flood water to mitigate flooding. Their construction costs are significant, mostly because excavated soil will need to be hauled offsite (Table 10 and Table 11). For example, the total volume, for both storage of water and the amount of fill to remove, for the Priority Rank 1 site was 17 million cubic feet. Alternative designs for detention basins may be considered as bird loʻi to provide habitat for endangered and threatened waterbirds (Section 10.4). Costs for bird loʻi would be lower since less material would need to be excavated.

Table 10. Cost Estimates for Construction of Detention Basins

Cost per Acre	Notes
Based on quotes	
$325K	Includes - Planning and coordination - Permitting - Hauling of material off-site and disposal - Revegetation with native plants Excludes - Maintenance

Table 11. Cost Estimates for Construction of Detention Basins by Property Owner

TMK	Acres	Total Cost
Priority Rank 1: Hanalei Bison Ranch Land Holdings LLC	**73**	**$23,725,000**
454004010	23, 12, 9	
454004009	10, 9, 6, 4	
Priority Rank 2: Haleleʻa Investment Company LLC	**12**	**$3,900,000**
455010081	6, 6	

[13] https://www.deere.com/en/tracked-feller-bunchers/

9 COMMUNITY AND STAKEHOLDER ENGAGEMENT

Hanalei, Hawaiʻi is a community known for its civic engagement and sense of place, while also acutely aware of the need to maintain resilience in the face of climate change and projected SLR. Recent and recurring flooding has given the Hanalei community a sense of urgency. This project engaged the community in the decision-making process and is providing it with sound and actionable information to reduce the impacts of flooding.[14] Interested parties had opportunities for meaningful engagement with project partners and their observations and opinions were considered in the planning and evaluation process. The community was engaged to provide input on concerns related to existing and hypothetical conditions that can affect flooding. Community input was gathered to assist with identifying and assessing specific sites either affected by or contributing to flooding. Community engagement is also necessary for developing collective capacity for future implementation.

9.1 Community Advisory Team

A Community Advisory Team (CAT) was formed to advise on efforts to address flooding in Hanalei. Meetings were held to provide background information, share the proposed process, gather information on observations of flooding events, and understand community concerns related to causes of flooding. The CAT members represent local business interests, major landowners, elected officials, agency partners and community leaders.

9.2 Landowner Discussions

Most of the floodplain area adjacent to the Hanalei River and Waʻioli Stream within the project area is privately owned. Landowners were engaged throughout the project to provide access to their land for fieldwork. HWH assisted with individual outreach regarding the flood survey work and coordinated with specific landowners to facilitate access. Landowners shared observations on how their property is affected by flooding and suggestions they had regarding mitigation. Discussions with landowners also included whether mitigation strategies could potentially be sited on their property.

9.3 Community Outreach

Outreach was conducted to build awareness of the project; solicit engagement; explain the process; and identify why, when, and how community input is needed. Throughout the course of the project, HWH engaged in opportunistic community contacts and conversations. Meetings and other outreach events were held, including community-wide gatherings and smaller ‘talk story’ sessions with target community members, to provide opportunities to work collaboratively and share information throughout the process. HWH has a centrally located office in Hanalei and maintained an “open door” policy encouraging drop in conversations and spontaneous feedback. Numerous community members have availed themselves of the opportunity to drop in and talk about the planned project. Hosted tables were set up at local community events (e.g. Waipa Taro Festival, Waipa Summer Festival) to inform the community on progress of the flood mitigation study.

[14] The ‘community’ includes local government representatives, federal and state officials, representatives from Native Hawaiian groups, non-profits, local community members, landowners, farmers, wildlife advocates, and any other interested parties that engaged.

HWH participated in monthly meetings with all recipients of the Act 35 funds and shared project updates and opportunities for collaboration. HWH provided project updates to County, State, and Federal partners and interested parties regarding progress of the flood study. HWH attended and participated in the HDOT community meeting on flood mitigation projects.

HWH provided project updates to the leadership of the Hanalei to Haena Community Association. HWH provided project updates and supports information queries at regular meetings with NOAA Sanctuaries and the Hawaiʻi State Environmental Advisory Council. HWH also communicated directly with Hale Halawai ʻOhana O Hanalei regarding project updates and specifics of their proposed Request for Proposal for flood mitigation projects. HWH and SRGII presented the project at the 2023 Hawaiʻi Conservation Conference to an audience of approximately 80, sharing additional information with numerous attendees during the conference general sessions over three days.

HWH produces monthly broadcasts on Hawaiʻi public radio station, KKCR, designed to provide community information on various projects. Listeners are encouraged to call in with questions and comments. SRGII provided information on the flood mitigation study and HWH provided information on opportunities for citizen participation. The one-hour show reaches all of Kauaʻi, the north shore of Oʻahu by signal, and transmits internationally via live streaming. The programs are archived for 60 days on the kkcr.org website.

HWH facilitated continued community education and outreach via specific conversations on a critical piece of property in the Hanalei Watershed that has the potential to provide flood water storage and native waterbird habitat. HWH provided this information to the County of Kauaʻi currently conducting a countywide *Climate Adaptation Plan*. In addition, HWH continued to participate and contribute to the *County of Kauaʻi Multi-Hazard and Resilience Plan* and to the *Kauaʻi Climate Adaptation Plan* discussions, which may use information from this project in future updates (Section 10.1).

Opportunities for outreach will continue after the study is released (e.g. community events, Hanalei to Ha'ena Community Association, Hanalei Bay Rotary).

9.4 Directed Outreach

Directed presentations were developed and offered to government agencies and local businesses. The agency presentation highlighted the need for access across public property for field work and the need for expertise and cooperation with Federal, State, and County agencies for successful implementation of mitigation strategies (Table 12).

Table 12. Agency Contributions to Flood Mitigation Implementation

Agency	Contribution
Federal Agencies	
U.S. Army Corps of Engineers	- Expertise (floodplains) - Regulatory role (Clean Water Act Section 404 – regulating dredging and fill in waters of the US)
U.S. Fish and Wildlife Service	- Hanalei National Wildlife Refuge: Participation in flood study and implementation - Regulatory role (Endangered Species Act) - Expertise (freshwater species, birds, vegetation)

Agency	Contribution
NOAA Fisheries	- Regulatory role (Endangered Species Act) - Expertise (marine species)
NOAA National Weather Service	- Meteorologic information and expertise
U.S. Geological Service	- Stream gages
Natural Resources Conservation Service	- Conservation planning with farmers
State Agencies	
State Department of Transportation	- Highway and Hanalei Bridge considerations
State Department of Health	- Regulatory role (CWA Section 401 Water Quality Certification, CWA Section 402 NPDES)
Department of Land and Natural Resources: Land Division, Commission on Water Resource Management, Division of Aquatic Resources, Division of Forestry and Wildlife	- Regulatory roles (CWRM: Stream Channel Alteration Permit) - Expertise (State land management, hydrology, in-stream flow, aquatic resources, wildlife)
Department of Land and Natural Resources: State Historic Preservation Division	- Expertise (cultural and historic properties, archaeology) - Regulatory role (National Historic Preservation Act Section 106)
Department of Business, Economic Development & Tourism	- Expertise (businesses, tourism) - Regulatory role (Coastal Zone Management Program)
Office of Hawaiian Affairs	- Supporting Native Hawaiian communities
County Agencies	
Kauaʻi Emergency Management Agency (HI-EMA / FEMA)	- Expertise (hazard mitigation and resilience) - Potential funding
Department of Planning	- Long-range planning - Regulatory role (construction permits, CZM Program / SMA)
Department of Public Works, Engineering Division	- Feasibility of implementation projects - Flood review
Board of Water Supply	- Regulatory role

9.5 Community Input

Throughout this project conversations with community members were routine. Community members expressed their opinions and related their experiences and observations of the river systems, flood events, and understanding of hydrodynamics. Community members offered valuable insights into the problems associated with flooding and suggested potential strategies for mitigation. Their manaʻo was appreciated and served as a valuable reality check.

10 TRANSFERABILITY

This project took a more comprehensive approach to addressing flooding in Hanalei and Waiʻoli than any previous efforts, identifying problem areas system-wide, looking at individual and cumulative issues, and proposing location-specific and general recommendations. In addition to providing input for the distribution of the North Shore Watershed Flood Mitigation Sub-grants, the findings are being shared with others that have or are currently preparing studies, plans, or other works that may benefit from the information.

10.1 Informing Resilience Planning

The study results provide important input to inform hazard mitigation planning efforts, including the *Hanalei to Haena Community Disaster Resilience, Climate Adaptation & Justice Plan* and the *County's Multi-Hazard Mitigation and Resilience Plan* (Appendix A). Climate-related predictions of SLR are forecast to increase flooding, making these challenges even more difficult to overcome. The impacts of SLR due to climate change will continue to occur for the foreseeable future. Under all scenarios SLR rise will have significant impacts on the flood regime of Hanalei River and Waiʻoli Stream. The model analysis shows potential hydrologically vulnerable areas under SLR estimates. Data and analysis can be used when updating these plans. Maps that depict inundation zones from the rivers will be shared so that strategies and plans to enhance community resiliency in the face of climate change impacts can utilize the findings.

10.2 Sharing Data

The DTM maps, air imagery, and coordinates for established survey control points are publicly available by request from HWH and will be shared with interested Federal, State, and County agencies.

10.3 Application to Other Locations

Hydraulic models can be used in areas conducting feasibility assessments and design of flood mitigation strategies. The methodology for acquisition of survey data and specific technical approaches for analysis will be shared with those that are interested, including lessons learned and how things could be done differently.

10.4 Meeting Priority Conservation Needs for Waterbirds

The Hanalei Basin is vitally important for the recovery of five highly endangered and threatened endemic species: the endangered koloa maoli (Hawaiian duck, *Anas wyvilliana*) - estimated world population 931 birds; ʻalae keʻokeʻo (Hawaiian coot, *Fulica alai*) – 1,815 birds; ʻalae ʻula (Hawaiian common gallinule, *Gallinula galeata sandvicensis*) – 927 birds; and aeʻo (Hawaiian stilt, *Himantopus mexicanus knudseni*) – 1,932 birds; and the threatened nēnē (Hawaiian goose, *Branta sandvicensis*).[15] Kauaʻi is one of the last places in the Hawaiian Islands where pure koloa may be found, and the Hanalei Basin is critical for the conservation and recovery of the species statewide, as well as for the ʻalaeʻula, which have been extirpated from all other islands except Oʻahu, with the USFWS Hanalei NWR the key stronghold in Kauaʻi.

Wildlife habitat for these protected birds is at serious risk from flooding in the Hanalei basin. Nests are lost on an almost annual basis to flooding and the damage to conservation infrastructure severely hinders

---

[15] Paxton, E.H., Brinck, K., Henry, A., Siddiqi, A., Rounds, R., and Chutz, J. 2021. Distribution and Trends of Endemic Hawaiian Waterbirds. Waterbirds 44(4): 425-437. https://doi.org/10.1675/063.044.0404

recovery efforts. Endangered waterbirds are further threatened by loss of suitable wetland habitat due to SLR. While large-scale flood mitigation efforts are cost-prohibitive, understanding the flooding regime may help localized efforts to reduce flooding effect on waterbird habitat.

Community understanding of flood mitigation strategies, and their value to both people and wildlife, is essential to ensure support for solutions that strive to include wetland restoration as a nature-based option, while reducing flooding to existing wetland habitat. Endangered wetland birds should be considered within implementation of mitigation strategies to reduce the impacts of flooding in Hanalei.

Hau bush removal will likely benefit waterbirds by removing perches for introduced avian predators (cattle egret) and providing better riverine habitat, especially when combined with out-planting of suitable native species.

While the study results indicate that detention basins will not solve flooding issues with respect to Kūhiō Highway, shallower bird loʻi would provide additional high-quality habitat for endangered and threatened waterbirds and migratory birds. These bird loʻi would involve less excavation and would not be as expensive to create compared to detention basins designed to maximize flood storage. Creating shallow bird loʻi may increase resilience by providing some level of flood mitigation to areas of bird habitat. Ongoing discussions with the landowner of the Bison Farm indicate a willingness to consider this conservation use of the land. A group of interested parties, including conservation groups, are exploring ways to make this happen. With the refuge itself at risk from climate impacts, the provision of additional habitat that will also provide ecosystem services including flood control, is vitally important to reduce the likelihood of extinction of these species and promote their recovery.

10.5 Infrastructure: On-site Disposal Systems

The Hanalei and Waiʻoli Watersheds do not have centralized sanitary sewer systems. Properties throughout the area use onsite wastewater systems (i.e., cesspools, septic tanks, and small batch wastewater treatment systems) to treat and dispose of wastewater. All treated effluent from these systems is discharged into the ground. Almost all the septic tanks and cesspools are located below ground, and in some areas rest at or just above the ground water surface. Based on the hydraulic modeling of a + 2 ft SLR, surface water elevations will increase inland along the rivers, streams, and manmade waterways. This increase in surface water elevation will also increase ground water elevations, which will impact onsite wastewater system performance. It is likely that higher ground water elevations will reduce efficacy of the systems, increase pollutants loads into the ground water, and in some areas make disposal of effluent not possible.

10.6 Early Warning Notification System

Another possible option more directly related to flooding is to establish a Flood Forecast and Early Warning Notification System for the Hanalei River. At present there is no robust forecast and early warning system to warn and trigger evacuation of the north shore region. The main objective of such a system is to provide information that can protect property and save lives. The system would also mitigate impacts to the resources of the region in terms of putting strain on the community, civil defense personnel, and first responders, who are often tasked with both rescuing and provided aid to residents and visitors who become stranded by flood waters. The system would use real-time, localized data to provide real-time, actionable information. It would involve operation of a real-time coupled hydrologic-hydraulic model used to generate stage and discharge estimates in the Hanalei River and an Early Warning Notification System linked to the model and used to issue advanced warnings of flooding along the Hanalei River.

The model would utilize hydro-meteorological data streamed via telemetry from autonomous sensors and equipment distributed throughout the Hanalei Watershed. Hydro-meteorological data will be used as real-time input into a rainfall runoff model to construct hydrographs along nodes on the main-stem of the Hanalei River. Hydrograph data will then be used in a hydraulic model to generate estimates of water surface elevations along nodes of the Hanalei River, which will be cross correlated to elevations along Kūhiō Highway and other vulnerable low elevations in the Hanalei Town/Watershed.

The model would also use existing National Weather Service (NWS) data from ground-based stations and remotely sensed data via satellite and radar stations. The combination of hydro-hydraulic models coupled with forecasting data provided by NWS data sources is expected to result in an output that would accurately forecast river water levels and provide notification with sufficient lead to the community to evacuate the area or seek high ground.

The Early Warning Notification System would be incorporated in the NWS warning system. In addition, a local warning system would be developed utilizing social media, local radio stations, and a community activated phone tree system. This effort would be coordinated with ongoing efforts related to the *Hanalei to Hāʻena Community Disaster Resilience, Climate Adaptation, and Justice Plan.*

11 ADAPTATION: LOOKING AHEAD

This study used innovative, scenario-based hydrologic and hydraulic modeling to assess concerns and evaluate the effects of potential mitigation strategies on reducing the impacts of floods in the Hanalei Basin. It quantitatively evaluated strategies to protect life, property, and habitat, and reduce disruption to commerce, the larger community, and endangered waterbirds. Although it used the low point of Kūhiō Highway as a benchmark for assessing effects of flooding, the study provides broader insights on tidal control of the waterways, flooding, and predictions for conditions under future SLR. The study found that none of the potential flood mitigation strategies, either alone or in combination, had a significant effect on mitigating or otherwise attenuating flooding in Hanalei or Waiʻoli.

In addition to modeling potential mitigation strategies, the models were also used to evaluate actions to adapt to climate change. Given the physiography of the study area, with its steep watersheds and high rainfall rates, it can be expected that the frequency of both riverine and coastal floods will increase in the future with SLR. Adaptive management strategies should be considered to address the inevitable climate-driven changes.

While there is general agreement that extreme rain and steep mountains sloping into the coastal plain will result in annual flooding, and that there is no mitigation that will prevent this from occurring, there is a strong case that management of hau bush and albizia along the river, stream bank stabilization and restoration, and floodplain modifications are needed to mitigate the effects of future floods on the Hanalei and Waiʻoli communities.

Hau bush and other invasive trees growing along and into river channels is an island-wide issue. Removal of this vegetation is recommended to improve navigation in the river, reduce instability of riverbanks, reduce the redirection of flood waters, prevent downstream debris jams, enhance habitat for waterbirds, and open view planes. Under HRS §46-11.5, on-going maintenance of the riverbanks, including clearing non-native vegetation and maintaining stable banks, is the responsibility of the landowner. As a region-wide strategy, using State funds (through the North Shore Watershed Flood Mitigation Sub-grants) to clear hau bush, which in many areas has been left to grow unchecked for decades, and out-plant native plants, would provide a new baseline for landowners who benefit from State funds to begin funding ongoing maintenance. A coordinated effort to address multiple stretches of hau bush and other vegetation would streamline the permitting process and contracting cost as removal and out-planting would best be conducted by a landscaping/construction entity. One possible use of the sub-grant funds to facilitate efficient and effective removal of hau bush and other trees would be the acquisition of specialty equipment such as a tracked feller buncher.

Detention basins evaluated in this study would not store enough flood water volume to mitigate the flood regime along critical sections of Kūhiō Highway, whether considering existing or SLR conditions. Furthermore, their construction costs are substantial. Although the study results indicate that detention basins will not solve flooding issues, creating shallower bird loʻi would provide additional high-quality habitat to support the area's endangered and threatened waterbirds and migratory birds. These bird loʻi would involve less excavation and would not be as expensive to create. Creating shallow bird loʻi may increase resiliency by providing some level of mitigation to areas of bird habitat.

Planning should begin now for adapting to SLR and addressing the issue of the repeated closure of Kūhiō Highway between the Hanalei Bridge and The Hanalei Dolphin during flooding. Modeling demonstrated that under future SLR conditions, the elevation of Kūhiō Highway would need to be raised by 6 to 8 feet (1.8 to 2.4 m) in the lowest stretch to be at an elevation that will be higher the high water level from future flood events. Sub-grant funds could be used to take the data from this study to initiate engineering plans, specifications, and cost estimates to raise the road. In the interim, a Flood Forecast and Early Warning Notification System for the Hanalei River would provide valuable and time sensitive advanced warnings of flooding along the Hanalei River. Other options for the sub-grant funds could focus on adaptation measures, including providing seed monies for convening strategies to target future buyout of properties that will be vulnerable to impacts from SLR. This might include addressing potential impacts SLR will have on wastewater systems along the coastline and rivers.

APPENDIX A. RELATED PLANS

Several existing plans laid important foundational work for this project by identifying flooding as a major hazard in the Hanalei basin and indicating that this area is a top priority for the County of Kauaʻi and its citizens. The plans recognize the potential for the community to increase resilience, through a variety of different means, and to play a significant role in flood risk reduction and impact mitigation.

USACE Flood Plain Analysis of Hanalei River

In 1998 the USACE conducted a hydraulic study of the Bison Farm and USFWS berms to determine if they changed the base flood elevation, also known as the 100-year flood water depths.[16] According to the results, the berm on the Bison Farm increased the base flood elevation by a maximum of 0.74 ft (0.225 m) and the berms around the USFWS ponds increased the maximum base flood elevation by 2.11 ft (0.64 m). The increases were reported for lands upstream from each of the features relative to the Hanalei River and were found to dissipate over several thousand feet. The report did not discuss the alterations to flood water depths or changes to flow direction during floods on lands near Hanalei Town proper. The report also did not make recommendations to mitigate the effects of the berms or evaluate other strategies to mitigate or attenuate flood waters.

Watershed Management Plan for Hanalei Bay Watershed

The *Watershed Management Plan for Hanalei Bay Watershed* (2014) is a two-volume document. *Volume 1: Watershed Characterization* summarizes the current environmental conditions of Hanalei Bay Watershed, with an emphasis on identifying water quality pollutant sources and types. *Volume 2: Strategies and Implementation* recommends pollution control strategies, outlines implementation strategies, provides evaluation and monitoring protocols, and describes education and outreach approaches.

Hanalei to Haena Community Disaster Resilience, Climate Adaptation & Justice Plan

HWH spearheaded the development of the *Hanalei to Hāʻena Community Disaster Resilience Plan* (2014), which has been updated and expanded over time to become the *Hanalei to Hāʻena Community Disaster Resilience, Climate Adaptation & Justice Plan* (2023 Update). The original driver for development of this plan, beginning in 2008, was to understand current demographics and dynamics of community and what they mean for local resilience to disasters, including identifying vulnerable and resilient populations and areas, and developing an Action Plan and Community Maps to promote local resilience. This plan represents years of research and planning efforts grounded in identifying gaps in preparedness community risks and vulnerabilities, resources, knowledge, and visions for improving resilience for the communities of Hanalei to Hāʻena. The plan was an important resource for guiding the Hanalei community response to flood events in April and August 2018. Lessons learned from these floods were used to develop the most recent update.

The plan addresses current challenges, resources, and opportunities relevant to community resilience. In addition, the plan lays out principles, actions and policy recommendations for community members, government, non-government organizations, faith-based groups, private sectors, and others to improve resilient recovery, and how to collaborate on ongoing community preparedness, response, relief, and

---

[16] USACE. 1999. *Flood Plain Re-Analysis of Hanalei River, Island of Kauaʻi*. Honolulu, HI: U.S. Army Corps of Engineers, Honolulu District, Civil Works Technical Branch for Federal Emergency Management Agency and County of Kauaʻi.

recovery efforts for future emergencies in ways that do not undermine community, the environment, the economy, and future resilience.

The main components of the plan include a community resilience assessment and a resilient recovery recommendations report, and 'living' plan tools that can be taken out as a packet for community zone captains and first responders to utilize and update as needed. These tools include communications tools and lists; community resource lists and contact information; disaster supply go kit lists; guidance on mass care and spontaneous volunteer management; action plan checklists for zone captains and local responders to use for preparedness, response, relief and recovery; and community risk and resource maps for hurricanes/floods and tsunamis.

County of Kauaʻi Multi-Hazard Mitigation and Resilience Plan

The *County of Kauaʻi Multi-Hazard Mitigation and Resilience Plan* (2021 Update), is a local hazard mitigation plan developed in part to insure eligibility for FEMA mitigation and disaster recovery funding and is updated every five years. The plan outlines the County's commitment to a long-term strategy for reducing the risks of natural hazards using a disaster risk reduction framework.

Hawaiian Waterbird Conservation

Efforts to protect waterbirds and their habitat are outlined in two related plans. The USFWS designates waterbird habitat in the Hanalei area as "Core (Hanalei National Wildlife Refuge), Supporting & Other (Hanalei Valley)." This project recognized multiple habitat objectives in the Hanalei area as outlined in the *USFWS Recovery Plan for Hawaiian Waterbirds*, including to "Protect and manage all core and supporting wetlands"; "encourage landowners and private citizens to protect and preserve waterbirds and their habitats through cooperative agreements, and funding for habitat restoration and creation"; "increase the population size of each species throughout its range"; and "protect and manage, including habitat restoration, core and supporting wetland habitats in order to maximize productivity and survival of endangered waterbirds". The *USFWS Recovery Plan* also notes the likely impacts of climate change on waterbirds and the requirement to plan for that, which was considered by this project (Section 10.4).

The *Pacific Coast Joint Venture Strategic Plan for Wetland Conservation* sets out habitat restoration objectives in Hanalei for waterbird recovery. This project recognized the need to consider waterbird habitat when evaluating mitigation strategies to help achieve those objectives. An update, *A Strategic Plan for Hawaiʻi Wetlands*, will be published in early 2024 by Pacific Birds Habitat Joint Venture, www.pacificbirds.org.

APPENDIX B. FUNDING

Flood mitigation is an increasingly critical aspect of disaster management and environmental protection as climate change continues to exacerbate the frequency and intensity of flooding events worldwide. To effectively address this pressing issue, adequate funding is paramount. Whether it's for the construction of resilient infrastructure, the implementation of advanced early warning systems, or the development of sustainable land-use practices, securing the necessary financial resources is essential to safeguarding communities, preserving ecosystems, and reducing the devastating impacts of floods. Funding for governments, organizations, and communities to implement flood mitigation strategies can come from a variety of sources.

Government Grants and Appropriations: National, state, and local governments often allocate funds specifically for flood mitigation projects (Appendix B2, B3, B4). These grants can cover a wide range of activities, from building levees and floodwalls to conducting floodplain mapping and updating building codes. Governments may also set aside funds for disaster preparedness and response, which can indirectly contribute to flood mitigation efforts.

Federal Disaster Relief Funds: Federal disaster relief programs provide financial assistance after a flood event. While this funding primarily focuses on recovery and rebuilding, some of it may be channeled into mitigation measures to prevent future floods. https://www.disasterassistance.gov/

Insurance Programs: Flood insurance, typically offered through government-backed programs, such as the National Flood Insurance Program, can provide funds to homeowners, businesses, and communities affected by floods. Insurance payouts can help cover losses and facilitate post-flood recovery, encouraging property owners to invest in mitigation measures to reduce future risks. https://www.floodsmart.gov/

Public-Private Partnerships: Collaborations between governments and private sector entities can yield funding for flood mitigation initiatives. Public-Private Partnerships can take various forms, such as joint ventures for infrastructure construction or innovative financing models involving private investment in flood risk reduction projects.

Environmental Funds and Grants: Some environmental organizations and foundations offer grants and funding opportunities for projects that promote sustainable floodplain management, wetland restoration, and other nature-based solutions for flood mitigation (Appendix B5).

Community Contributions: Local communities often play a crucial role in flood mitigation by contributing their resources and labor to protect their homes and neighborhoods. Community-driven initiatives, such as volunteer efforts and fundraising, can complement government and external funding sources.

Bond Financing: Municipal bonds and special assessments can be used to raise funds for flood mitigation infrastructure. Communities issue bonds to secure upfront funding for projects and repay the debt over time using dedicated revenue streams.

Resilience and Adaptation Funds: Some regions establish dedicated funds for climate resilience and adaptation, which can encompass flood mitigation efforts. These funds may draw from various sources, including carbon pricing mechanisms or taxes on industries contributing to climate change.

Research Grants and Innovation Funding: Academic institutions and research organizations may offer grants and funding opportunities for innovative research and technologies aimed at improving flood prediction, early warning systems, and sustainable flood management practices.

The availability and accessibility of these funding sources can vary significantly depending on the geographic location, government policies, and the severity of flood risks. Effective flood mitigation often requires a combination of these funding streams and a strategic approach that aligns financial resources with identified flood-prone areas and vulnerable communities.

B.1. Act 35 Implementation Funds

A significant portion of the funding secured under Act 12, Session Laws of Hawaiʻi 2018 and Act 35, Session Laws of Hawaiʻi 2019 for disaster relief and mitigation needs is being managed by Hale Halawai ʻOhana O Hanalei, a 501(c)(3) organization based in Hanalei. The County of Kauaʻi selected Hale Halawai to manage the implementation and financial distribution of $7,285,000 for North Shore Watershed Flood Mitigation Sub-grants. The sub-grants will be directed to other non-profit organizations so they can conduct mitigation projects that reduce harm from future flooding events. The results of this project are helping to inform which mitigation strategies will be identified and prioritized.

Since Act 12 and Act 35 funding is classified as State funds, it may be used as match for Federal funding programs, potentially increasing the possibility of award and impact of funding dollars.

B.2. Federal Emergency Management Agency and Hawaiʻi Emergency Management Agency

HI-EMA administers three FEMA grant programs that are focused on Hazard Mitigation:

1. Building Resilient Infrastructure and Communities (BRIC)
2. Hazard Mitigation Grant Program (HMGP)
3. Flood Mitigation Assistance (FMA)

For more information, including eligibility, visit the website or contact the State Hazard Mitigation Officer at 808-733-4300 ext. 812.

https://www.fema.gov/grants
https://dod.hawaii.gov/hiema/non-disaster-grants/

Building Resilient Infrastructure and Communities (BRIC)

Funding (typical): Variable; typically up to $2 million per applicant
Application due (typical): Open: September, Closes: January
Eligible entities: State, Local and Territorial governments, Federally recognized tribes.
Match requirement: Required. Generally, the cost share is 75% federal and 25% non-federal. Non-federal contributions can be cash, third-party in-kind services, materials, or any combination thereof.
Website: https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities

Description: The FEMA Building Resilient Infrastructure and Communities (BRIC) funding opportunity is a program aimed at supporting projects that enhance community resilience by reducing the impact of natural disasters and hazards on infrastructure and public safety. Eligible flood mitigation projects include elevation of flood-prone structures, acquisition of flood-prone properties for demolition, retrofit of flood-prone structures, construction of floodwalls and levees, improvement of drainage systems, restoration of wetlands and other natural features that reduce flood risk, and hurricane-resistant construction. In addition to mitigation activities, BRIC funding can also be used to support planning and capacity-building activities. The BRIC program places an emphasis on projects that incorporate climate resilience strategies, such as addressing the impacts of climate change, sea-level rise, and extreme weather events. Grantees are often required to monitor and evaluate the effectiveness of their mitigation projects to ensure they achieve the desired hazard reduction and resilience goals. Homeowners, businesses, and non-profit organizations cannot apply directly for a grant, however eligible entities can apply on their behalf.

Hazard Mitigation Grant Program (HGMP)

Funding (typical): Variable
Application due: Within 12 months of the date of the presidential declaration of a disaster.
Eligible entities: State, Local and Territorial governments, Local communities, Federally recognized tribes, and certain private non-profit organizations.
Match requirement: Required. Generally, the cost share is 75% federal and 25% non-federal. Non-federal contributions can be cash, third-party in-kind services, materials, or any combination thereof.
Website: https://www.fema.gov/grants/mitigation/hazard-mitigation

Description: The FEMA Hazard Mitigation Grant Program (HMGP) provides funding to reduce or eliminate the risk of long-term loss of life, property, infrastructure, natural, cultural, and environmental resources from natural hazards. This grant is available when a natural disaster or emergency is declared by the President of the United States. Eligible flood mitigation projects include elevation of flood-prone structures, acquisition of flood-prone properties for demolition, retrofit of flood-prone structures, construction of floodwalls and levees, improvement of drainage systems, restoration of wetlands and other natural features that reduce flood risk, and hurricane-resistant construction. HMGP funding may also cover non-structural measures such as hazard mapping, land-use planning, and public education campaigns. FEMA often places a priority on funding projects that address repetitive loss properties, severe repetitive loss properties, and projects that provide a cost-effective solution to mitigate hazard risks. Grantees are often required to monitor and evaluate the effectiveness of their mitigation projects to ensure they achieve the desired hazard reduction goals. Homeowners and businesses cannot apply directly for a grant, however eligible entities can apply on their behalf.

Flood Mitigation Assistance (FMA) Grant Program

Funding (typical): Variable
Application due (typical): Open: September, Closes: January
Eligible entities: State, Local and Territorial governments, Local communities, Federally recognized tribes, and certain private non-profit organizations.
Match requirement: Required. Generally, the cost share is 75% federal and 25% non-federal. Non-federal contributions can be cash, third-party in-kind services, materials, or any combination thereof.
Website: https://www.fema.gov/grants/mitigation/flood-mitigation-assistance

Description: The FEMA Flood Mitigation Assistance (FMA) Grant Program provides funding to reduce or eliminate the risk of repetitive flood damage to buildings insured under the National Flood Insurance Program. Eligible projects include elevation of flood-prone structures, acquisition of flood-prone properties for demolition, retrofit of flood-prone structures, construction of floodwalls and levees, improvement of drainage systems, and restoration of wetlands and other natural features that reduce flood risk. The FMA program may also support flood mitigation planning and other activities that help communities become more resilient to flooding events. FEMA often places a priority on funding projects that address repetitive flood loss properties, severe repetitive loss properties, and projects that provide a cost-effective solution to mitigate flood risks. Grantees are often required to monitor and evaluate the effectiveness of their mitigation projects to ensure they achieve the desired flood reduction goals.

B.3. USDA Natural Resources Conservation Service

Emergency Watershed Protection (EWP) Program

Funding (typical): Variable
Application due: Should be submitted within 60 days of the disaster occurence.
Eligible entities: State and local governments, Federally recognized tribes, Watershed districts, Irrigation districts, Resource conservation and development districts, Other local and state agencies.
Match requirement: Funding not to exceed 75% of the construction/installation cost; 90% in limited resource areas as identified by U.S. Census data.
Website: https://www.nrcs.usda.gov/programs-initiatives/ewp-emergency-watershed-protection

Description: The Emergency Watershed Protection (EWP) Program is a federal program that provides technical and financial assistance to local communities to help relieve imminent threats to life and property caused by floods, fires, windstorms, and other natural disasters that impair a watershed. Its main objective is to assist with the recovery and restoration of watersheds and natural resources after emergencies and natural disasters.

To be eligible for funding, a project must be located in a watershed that has been damaged by a recent natural disaster; must address an imminent threat to life and property; must be technically feasible and cost-effective; and must have the support of a local sponsor that is willing to assume responsibility for the project's operation and maintenance after it is completed. Interested public and private landowners must work through an eligible entity sponsor.

EWP Program funding can be used to cover a variety of costs associated with planning and implementing emergency watershed protection projects, including: technical assistance, engineering and design, construction, land acquisition, easements, and operation and maintenance. EWP funds can be used for a variety of emergency recovery projects, such as debris removal, streambank stabilization, erosion control, flood control structures, and the restoration of damaged lands and infrastructure. The EWP Program emphasizes the need for rapid action to implement emergency measures promptly, reducing the risk of further damage and protecting communities in the aftermath of a disaster. While the program focuses on emergency response, it also considers environmental impacts and strives to implement measures that are environmentally sound and sustainable. EWP funds become available when a natural disaster or emergency is declared by the President of the United States, triggering the need for immediate response and recovery efforts.

Watershed and Flood Prevention Operations (WFPO) Program

Funding (typical): Variable; $500 million available annually for the program
Application due (typical): Open: October/November, Closes: August
Eligible entities: State and local governments, Federally recognized tribes, Watershed districts, Irrigation districts, Resource conservation and development districts, Other local and state agencies
Match requirement: Required. Cost share rates depend on the type of measure and the purpose to which the cost is allocated but are typically 1:1.
Website: https://www.nrcs.usda.gov/programs-initiatives/watershed-and-flood-prevention-operations-wfpo-program

Description: The Watershed and Flood Prevention Operations (WFPO) Program is a federal program that provides technical and financial assistance to help plan and implement authorized watershed projects. The primary goal of this program is to enhance watershed resilience and reduce the risk of flooding and erosion. It also emphasizes the importance of improving water quality in affected areas. To be eligible for funding, a project must be located in a watershed that has been authorized for assistance under the Watershed Protection and Flood Prevention Act (Public Law 83-566). The project must address at least one of the following resource concerns: flood prevention, watershed protection, public recreation, public fish and wildlife, agricultural water management, municipal and industrial water supply, and water quality management. It must be supported by a local sponsor that can act as the fiscal agent and provide project oversight and management throughout the different phases of implementation and throughout the project lifespan. Upon approval, project sponsors help landowners carry out the authorized watershed conservation measures. It must be cost-effective and provide a net benefit to the public. It must result in agricultural benefits that are ≥20% of the total benefits for the project. WFPO Program funding can be used to cover a variety of costs associated with planning and implementing watershed projects, including: technical assistance, engineering and design, construction, land acquisition, easements, and operation and maintenance. By investing in watershed and flood prevention projects, the program seeks to provide long-term benefits to communities by reducing the economic and environmental costs associated with flooding and erosion.

B.4. National Oceanic and Atmospheric Administration

Transformational Habitat Restoration and Coastal Resilience Grants

Funding (typical): Ranges from $1 million to $25 million over the award period.
Award period: Approximately three years
Application due (typical): November
Eligible entities: State and local governments, Federally recognized tribes, Non-profit organizations, Academic institutions, Private companies
Match requirement: No
Website: https://www.fisheries.noaa.gov/grant/transformational-habitat-restoration-and-coastal-resilience-grants

Description: The NOAA Transformational Habitat Restoration and Coastal Resilience Grants provide funding for transformational projects that restore coastal habitat and strengthen community resilience. The funding is available through the Biden-Harris Administration's Bipartisan Infrastructure Law and Inflation Reduction Act. Funding supports efforts such as: restoring coastal ecosystems such as wetlands and seagrass beds; protecting and restoring coral reefs; building living shorelines and other coastal infrastructure to protect communities from erosion and SLR; reconnecting rivers to their historic floodplains; improving water quality; and creating jobs and supporting economic development in coastal communities. For this grant, NOAA prioritizes projects that demonstrate a broad base of stakeholder and community support, address climate change impacts, benefit threatened and endangered species, and are innovative and sustainable. Projects should demonstrate innovation and have a transformative impact on coastal communities and ecosystems. Grantees are typically required to monitor and evaluate the progress and outcomes of their projects to assess their effectiveness in achieving habitat restoration and coastal resilience goals. The grants aim to provide long-term benefits by improving the health of coastal ecosystems, reducing the vulnerability of communities to natural disasters, and enhancing overall coastal sustainability.

B.5. National Fish and Wildlife Foundation

National Coastal Resilience Fund

Funding (typical): $100,000 to $1 million for projects that complete the preliminary stages required for restoration. For restoration implementation, averages $1 million to $10 million.
Application due (typical): April
Qualified applicants: State and local governments, Federally recognized tribes, Non-profit organizations, Academic institutions, Private companies
Match requirement: Non-federal match not required but is encouraged to demonstrate support.
Website: https://www.nfwf.org/programs/national-coastal-resilience-fund

Description: The NFWF NCRF is a funding opportunity aimed at supporting projects that enhance the resilience of coastal communities and ecosystems to the impacts of climate change and extreme weather events. NCRF grants support projects that create, restore, or enhance natural features to protect coastal communities from coastal hazards and to improve habitats for fish and wildlife. The NCRF invests in nature-based solutions, such as restoring coastal marshes and wetlands, dune and beach systems, oyster and coral reefs, forests, coastal rivers and floodplains, and barrier islands.

To be eligible for funding, a project must be located in a coastal watershed in the United States or its territories; must use nature-based solutions to protect coastal communities from coastal hazards or to improve habitats for fish and wildlife; must have a measurable impact on coastal resilience; and must be supported by a local sponsor that is willing to assume responsibility for the project's operation and maintenance after it is completed.

Funding can be used for a variety of projects, including coastal habitat restoration, living shorelines, beach and dune restoration, and other efforts that bolster the ability of coastal ecosystems to absorb the impacts of storms and sea-level rise. The fund places a strong emphasis on projects that incorporate climate resilience strategies and help communities adapt to the effects of climate change, such as rising sea levels, increased storm intensity, and coastal erosion. NFWF encourages collaborative partnerships among organizations, agencies, and local stakeholders to leverage resources, expertise, and community involvement for the success of the projects. Grantees are typically required to monitor and evaluate the progress and outcomes of their projects to assess their effectiveness in achieving habitat restoration and coastal resilience goals. NCRF grants aim to provide long-term benefits by improving the health of coastal ecosystems, reducing the vulnerability of communities to natural disasters, and enhancing overall coastal sustainability.

B.6. Private Landowners

Private landowners funding flood mitigation strategies can play a crucial role in bolstering a community's resilience to flooding events. Flooding can have devastating consequences, not only for individuals and their homes and properties, but also for the broader community and its infrastructure. When private landowners actively engage in flood mitigation efforts, they contribute to a more comprehensive and effective approach to managing this natural disaster. Their funding contributions can be directed towards initiatives that are most effective for their particular circumstances.

Investing in flood mitigation measures can have significant economic benefits for private landowners. By protecting their properties from flood damage, they can maintain property values and reduce insurance premiums, ultimately saving money in the long run. Private landowners who actively engage in flood mitigation initiatives often foster a sense of community resilience. When neighbors collaborate to protect against flooding, it can strengthen social bonds and create a shared sense of responsibility for community well-being.

Governments and private landowners can collaborate through public-private partnerships to fund and implement flood mitigation strategies. These partnerships can leverage the resources, expertise, and funding from both sectors to develop comprehensive flood management plans. Private landowners who invest in flood mitigation measures may be eligible for incentives including tax breaks, grants, or low-interest loans, encouraging more individuals to participate in flood resilience efforts.

APPENDIX C. MEMORANDUM OF UNDERSTANDING

A Memorandum of Understanding (MOU) for implementing flood mitigation strategies on private property is a formal document that outlines the terms and conditions under which the project will be carried out on private land. It should provide a clear understanding of the responsibilities and expectations of all parties involved in the project. Here are some key elements that should be included in such an MOU:

Title and Date: Begin with the title "Memorandum of Understanding" followed by the date of the agreement.

Parties: Identify the parties involved in the agreement. This typically includes:

- The private property owner(s)
- The organization or entity responsible for the project
- Any other relevant stakeholders or partners (e.g., government agencies, non-profit organizations, community groups)

Purpose: Clearly state the purpose and objectives of the MOU, including the project goals and the specific property or area involved.

Scope of Work: Describe in detail the project activities to be undertaken on the private property. This may include:

- Permit acquisition
- Ecological assessments
- Invasive species removal
- Habitat restoration
- Planting native vegetation
- Flood mitigation measures
- Erosion control measures
- Monitoring and maintenance plans

Responsibilities: Clearly define the roles and responsibilities of each party involved in the project. This should cover:

- Property owner’s responsibilities (e.g., granting access)
- Organization’s responsibilities (e.g., conducting assessments)
- Any third-party roles (if applicable)

Timeline: Specify the timeline for the project, including start and end dates for various phases of the effort.

Resources: Outline the resources required for the project, such as funding, equipment, materials, and labor. Clarify how these resources will be provided and managed.

Permits and Regulations: Address any permits, licenses, or regulatory requirements necessary for the project and specify who will be responsible for obtaining them.

Monitoring and Reporting: Describe the methods for monitoring and evaluating the success of the project and the frequency of progress reporting.

Termination and Dispute Resolution: Include provisions for termination of the MOU if necessary and outline procedures for dispute resolution.

Insurance and Liability: Clarify insurance and liability issues, including who will be responsible for any damages or injuries that may occur during the project. To include proof of insurance.

Confidentiality: If applicable, include clauses related to the confidentiality of sensitive information or data.

Access and Property Rights: Address access to the property, easements, and property rights, ensuring that the property owner's rights are respected. Include right of entry agreement if necessary.

Indemnification: Define the terms of indemnification, outlining how parties will be protected against legal claims or liabilities arising from the project.

Signatures: Have authorized representatives from each party sign and date the MOU to indicate their agreement to the terms and conditions.

Amendments: Include a provision allowing for amendments to the MOU if necessary, and specify the process for making amendments.

Governing Law: Specify the governing law that will apply in case of legal disputes.

Attachments: Include any necessary appendices or attachments, such as maps, project plans, or budget details.

Entities should consult with legal counsel and relevant experts when drafting MOUs to ensure compliance with local laws, regulations, and best practices. MOUs should reflect the unique circumstances and needs of the specific project and property in question.

APPENDIX D. PERMITS AND APPROVALS

D.1. Department of the Army Permits

A Department of the Army permit is issued by the USACE and is required for any impact to a navigable water or wetland that is connected to navigable waters, including filling, draining, or excavating. Projects may require a Clean Water Act (CWA) Section 404 permit, a Rivers and Harbors Act Section 10 permit, or both. Permits for activities regulated under CWA Section 404 and Section 10 are commonly processed simultaneously.

http://www.poh.usace.army.mil/Missions/Regulatory/Permits/

CWA Section 404 Permit

CWA Section 404 requires approval to perform any activities involving the placement of dredged and fill material into a water of the U.S. Activities requiring permits include: deposition (placement) of fill or dredged material in waters of the U.S. or adjacent wetlands; site-development fill for residential, commercial, or recreational developments; construction of revetments, groins, breakwaters, levees, dams, dikes, and weirs; and placement of riprap and road fills. There are no prerequisite permits for the Section 404 permit application, although a jurisdictional wetland delineation will likely be required.

Section 10 of the Rivers and Harbors Act

Section 10 of the Rivers and Harbors Act requires authorization from USACE for the construction of any structure in or over any navigable waters of the U.S.; the excavation, dredging, or deposition of material in these waters; or any obstruction or alteration in a navigable water. Structures or work outside the limits of defined for navigable waters of the U.S. require a Section 10 permit if the structure or work affects the course, location, condition, or capacity of the waterbody.

Any actions that involve alteration of topography would require a CWA Section 404 permit and/or a Section 10 of the Rivers and Harbors Act permit.

Nationwide Permit

Under Section 404(e) of the CWA, USACE can issue general permits to authorize activities that have only minimal individual and cumulative adverse environmental effects on the aquatic environment. A nationwide permit (NWP) is a general permit that authorizes projects under 59 specific categories of activities (i.e. NWP 13: Bank Stabilization, NWP 37: Emergency Watershed Protection and Rehabilitation). Issuance of NWPs helps streamline the approval process for qualifying projects. To qualify for a NWP, the project must be able to meet the general conditions for that category of activity and meet the requirement of minimal adverse effects.

https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/20099

CWA Section 401 - Water Quality Certification Permit

CWA Section 401 Water Quality Certification is required and is triggered when a Section CWA Section 404 or Section 10 permit is required. CWA Section 401 is administered by the Hawaiʻi Department of Health Clean Water Branch.

In most cases in Hawaiʻi, the issuance of an NWP covers the requirements of the CWA Section 401 (termed blanket water quality certification), and an individual water quality certification is not required. One exception for Hawaiʻi is for the construction of U.S. Coast Guard approved bridges. The USACE will inform the applicant of the general conditions that must be followed under blanket water quality certification.

https://health.hawaii.gov/cwb/section-401-wqc/

National Historic Preservation Act: Section 106

Section 106 of the National Historic Preservation Act requires Federal Agencies to consider the effects of their undertakings on historic properties. An undertaking is a project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a Federal agency, including those carried out by or on behalf of a federal agency; those carried out with Federal financial assistance; and those requiring a federal permit, license, or approval. Under Section 106, a historic property is any property that is included in, or eligible for inclusion in, the National Register of Historic Places. For proposed strategies that require any of the CWA permits, Section 106 would be triggered and required.

D.2. State of Hawaiʻi Permits and Approvals

National Pollutant Discharge Elimination System (NPDES)

HRS Chapter 149A regulates the use of pesticides in the State of Hawaiʻi. Application of pesticides to, over, or near waters of the state requires a National Pollutant Discharge Elimination System (NPDES) permit. This includes all inundation areas (even if dry at the time of application), and the surrounding banks. The Hawaiʻi Department of Health Clean Water Branch is responsible for the implementation of the NPDES pesticides permit program. Application of pesticides without an NPDES permit would be in violation of the CWA.

http://health.hawaii.gov/cwb/site-map/clean-water-branch-home-page/forms/

Coastal Zone Consistency Statement (CZM)

Section 307 of the Coastal Zone Management Act of 1972, as amended (16 U.S.C. 1458(c)), requires the applicant certify that the project is in compliance with an approved State Coastal Zone Management (CZM) Program. The Office of Planning, attached for administrative purposes to the Department of Business, Economic Development, and Tourism, is the lead agency for the Hawaiʻi CZM Program. CZM review is required for all projects in the State due to the proximity of all lands to the ocean. CZM review requires completing an application and demonstrating conformance and compliance with other permits and regulations.

A CZM Consistency Statement would be required in conjunction with any NPDES permit (for application of pesticides) or for any activities that require a CWA Section 404 permit (for discharge of dredge and fill). State concurrence with the applicant's certification is required prior to the issuance of permits from USACE. If a NWP is issued, separate CZM review is not required.

http://planning.hawaii.gov/czm/federal-consistency/

Stream Channel Alteration Permit (SCAP)

A Stream Channel Alteration Permit (SCAP) is required for any temporary or permanent activity within the stream bed or banks that may: 1) obstruct, diminish, destroy, modify, or relocate a stream channel; 2) change the direction of flow of water in a stream channel; 3) place any materials or structures in a stream channel; or 4) remove any material or structure from a stream channel. Routine streambed and drainageway maintenance activities and the repair of existing facilities are exempt from SCAP requirements.

https://dlnr.hawaii.gov/cwrm/surfacewater/permits/

Stream Diversion Works Permit (SDWP)

A Stream Diversion Works Permit (SDWP) is required for the removal of water from a stream into a channel, ditch, tunnel, pipeline, or other conduit for off-stream purposes including, but not limited to, domestic, agricultural, and industrial uses. Construction of a new stream diversion structure or alteration of an existing structure requires an SDWP. Routine maintenance activities are exempt from SDWP requirements.

https://dlnr.hawaii.gov/cwrm/surfacewater/permits/

Hawaiʻi State Historic Preservation Division Review

HRS Chapter 6E requires the Hawaiʻi State Historic Preservation Division (SHPD) to be informed of and review the potential effect of proposed projects on historic properties. Historic property is any building, structure, object, district, area, or site including heiau or underwater site, which is over fifty years old. Burials that are 50 years are also characterized as historic property. Any privately-owned single-family houses that are 50 years old but not listed or nominated for listing in the state or federal Register of Historic Places are exempt from Chapter 6E review.

HRS §6E-8 requires any project carried out by or funded by State and County agencies to consult with SHPD prior to project initiation if the project has the potential to affect historic properties. HRS §6E-10 requires landowners to consult with SHPD before initiating any construction, alteration, disposition, or improvement on private land that may affect a historic property.

https://dlnr.hawaii.gov/shpd/state-review-compliance/

D.3. County of Kauaʻi Permits and Approvals

Special Management Area (SMA) Permit

The purpose of HRS Chapter 205A, the CZM law, is to "provide for the effective management, beneficial use, protection, and development of the Coastal Zone." The County of Kauaʻi Department of Planning assesses and regulates proposed activities in the SMA for compliance with the CZM objectives and policies and SMA guidelines. A major permit is required for any project valued at over $500,000. A minor permit is required for projects under this amount. When an SMA Major permit is required, an Environmental Assessment (EA) or an Environmental Impact Statement (EIS) must be prepared. The County of Kauaʻi Department of Planning assesses proposed projects and determines what type of permit is required or if the project is exempt from the SMA permitting process.

http://planning.hawaii.gov/czm/special-management-area-permits/

https://www.kauai.gov/Government/Departments-Agencies/Planning/Zoning-Land-Use-Permits

Grading / Grubbing / Stockpiling Permits

Grading, grubbing, and stockpiling activities require permits from the County of Kauaʻi Department of Public Works. Grading (cutting into the earth) permits are required for most excavations and/or backfills of more than 100 cubic yards. Permits are required for grubbing (mechanical clearing of the surface without cutting into the ground) activities greater than one acre or if general drainage patterns will be altered. A separate grubbing permit is not required when grubbing activities are performed in conjunction with and as part of activities conducted pursuant to a validly issued grading permit. Projects that are small in scope and involve certain conservation activities may be exempt from the required permit, however, all projects involving any type grading, grubbing, or stockpiling activities require that Best Management Practices be employed to the maximum extent possible to avoid sedimentation to streams, watercourses, natural areas, and the property of others.

https://www.kauai.gov/Government/Departments-Agencies/Public-Works/Engineering/Regulatory-Review

No Rise Certification

Projects that include changes to topography and/or include a structure within the regulatory 100-year floodplain require a No Rise Certification administered by the County of Kauaʻi Department of Public Works. The purpose of the certification is to ensure that the proposed actions will not impact the 100-year flood elevations, floodway elevations, or floodway widths of the stream of communities where the action will occur.

https://www.kauai.gov/Government/Departments-Agencies/Public-Works/Engineering/Floodplain-Management

D.4. Other Permits

Right of Entry Permit

A right of entry permit is a legal document that grants permission to enter and use another entity's property for a specific purpose and for a specific period of time. Right of entry permits are often required for construction and maintenance work, as well as for other activities that may impact the property owner's rights. Right of entry permits are typically issued by the property owner or their representative, and they may include specific conditions that the permittee must follow, such as: the scope of work that is permitted; the dates and times that the permittee is allowed to access the property; any safety or environmental precautions that the permittee must take; and any insurance requirements that the permittee must meet. Failure to comply with the terms of a right of entry permit may result in the permit being revoked and the permittee being held liable for any damages to the property. Right of entry permits may be necessary for implementation of mitigation strategies on public and private lands.

https://dlnr.hawaii.gov/dobor/files/2023/03/230317-Request-for-State-Lands-Application-Fillable.pdf

APPENDIX E. MAINTENANCE AND MONITORING

E.1. Streambank Restoration – Vegetation Clearing

Maintenance needs for streambank restoration sites can vary depending on the specific project, location, and the techniques used in the restoration. Clearing hau bush stands or albiza trees is an initial step in streambank restoration. The most important tasks after vegetation removal are treating the cut stumps with approved herbicide to prevent regrowth and weeding the area, otherwise the undesirable vegetation will regrow and invasive grasses will overrun the area.

Here are some common maintenance needs for streambank restoration sites:

Vegetation Management: Regularly monitor and manage plant growth to ensure that native vegetation is thriving and invasive species are controlled. Prune and trim plants as necessary to maintain a healthy and stable bank.

Erosion Control: Inspect and maintain erosion control structures, such as silt fences, erosion control blankets, and sediment basins. Repair any damage to erosion control measures caused by storms or heavy runoff.

Structural Maintenance: Check and repair any structural components of the restoration, such as retaining walls, rock revetments, or bioengineered structures. Replace any damaged or deteriorating materials.

Monitoring: Continuously monitor the site to assess the effectiveness of the restoration in terms of stabilizing the streambank and improving water quality. Collect data on bank stability, vegetation health, and wildlife habitat.

Riparian Zone Management: Implement riparian zone management practices to protect the buffer area around the stream, including controlling grazing, mowing, and recreational activities. Replant native vegetation as needed.

Public Education: Educate local communities and stakeholders about the importance of streambank restoration and the need to protect the restored areas from damage.

Stormwater Management: Ensure that stormwater runoff from adjacent areas is managed to prevent excess sediment and pollutants from entering the stream.

Collaboration: Collaborate with local environmental agencies, organizations, and volunteers for ongoing maintenance efforts and community engagement.

Adaptation to Changing Conditions: Continually assess the restoration's resilience to changing environmental conditions, such as climate change, and adapt maintenance practices accordingly.

A well-defined maintenance plan is important to have in place from the outset of a streambank restoration project to ensure the long-term success and sustainability of the restoration efforts. Regular inspections and proactive maintenance can help prevent issues from escalating and maintain the ecological and hydrological benefits of the restored site.

E.2. Streambank Restoration - Out-planting

Hau bush removal will be immediately followed by out-planting of native species across the cleared area. Biowalls can be considered to protect the banks that are excessively steep or unstable from erosion. Planting native plants after removing invasive species is a crucial step in ecological restoration because it helps restore ecological balance, conserve biodiversity, support native wildlife, and enhance ecosystem functions. It promotes the overall health and resilience of the ecosystem, ultimately benefiting both the environment and human communities. Native plants are often better adapted to local environmental conditions, which can make them more resilient to future invasion attempts by non-native species. Native sedges and grasses provide forage and habitat cover for endemic waterbirds and should be the first choice for revegetation. Native sedges have extensive fibrous roots systems that can stabilize banks and prevent surficial erosion. Native plants have high modulus of elasticity, meaning that during flow events they can lay down and do not block or slow flow. A diverse community of native plants can act as a barrier to prevent invasive species from reestablishing themselves.

Streambank restoration with native plants is an important conservation practice to stabilize eroding streambanks, improve water quality, and enhance habitat for wildlife. Here are the general steps for streambank restoration using native plants:

Assessment and Planning: Conduct a site assessment to understand the extent of erosion, soil composition, water flow, and the types of native plants suitable for the area. Create a restoration plan that includes goals, objectives, and a timeline.

Obtain Necessary Permits: Check with local, state, and federal authorities to determine if any permits are required for streambank restoration projects.

Site Preparation: Remove invasive species, debris, and any non-native plants that may be contributing to erosion. Grade the streambank to create a stable slope. Install erosion control measures such as silt fences or erosion control blankets to prevent sediment runoff during construction.

Plant Selection: Choose native plant species that are well-suited to the specific site conditions, such as soil type, sunlight, and moisture levels. Consider a diverse mix of plants to enhance biodiversity and resilience. Plants recommended for out-planting along Hanalei River and Waiʻoli Stream include native sedges and shrubs (Table E-1).

Planting: Plant native trees, shrubs, grasses, and herbaceous plants at appropriate spacings and densities. Pay attention to proper planting depth and technique to ensure the plants establish well.

Mulching: Apply a layer of mulch (e.g., wood chips, straw, or native plant material) to reduce erosion, retain moisture, and suppress weeds.

Irrigation: Water newly planted native plants as needed, especially during dry periods, to promote establishment.

Maintenance: Regularly monitor the site for weed competition and invasive species. Prune and maintain native plants to encourage healthy growth. Repair erosion control measures if necessary.

Monitoring: Set up a monitoring program to assess the success of the restoration project over time. Measure parameters such as plant survival rates and erosion rates.

Adaptive Management: Based on monitoring results, adjust the management plan as needed to ensure the long-term success of the streambank restoration project.

Education and Outreach: Engage with the community and stakeholders to raise awareness about the importance of streambank restoration and native plant conservation. Provide information and resources on how others can undertake similar projects.

Documentation: Keep detailed records of all activities, including plant species used, planting dates, maintenance actions, and monitoring results.

Long-Term Management: Continue to manage and maintain the restored streambank to ensure its sustainability and continued ecological benefits.

Streambank restoration with native plants is a long-term commitment, and success may take several years to become evident.

Table E-1. Native Plants for Streambank Restoration

Hawaiian / Common Name	Scientific Name
Lower Bank (0-2 ft above low water line)	
uki	*Cladium jamaicense*
ʻahuʻawa	*Cyperus javanicus*
Makaloa	*Cyperus polystachyos*
Middle Bank (2-4 ft and 4-7 ft above low water line)	
	Carex wahuensis
nanea	*Vigna marina*
ilieʻe	*Plumbago zeylanica*
Top of Bank	
aʻaliʻi	*Dodonaea viscosa*
ilima ku kahakai	*Sida fallax*
kokiʻo kea (Kauai white hibiscus)	*Hibiscus waimeae* subsp. *hannerae*

E.3. Maintaining Ditches and ʻAuwai

Ditches and ʻauwai require regular maintenance to ensure proper water flow, prevent erosion, and maintain their functionality. Here are some maintenance needs for ditches and ʻauwai:

Clearing Debris: Regularly remove debris such as leaves, branches, and sediment from the channel to prevent blockages and maintain proper water flow.

Weed and Vegetation Control: Control the growth of invasive plants and weeds within and around the ditch or ʻauwai to prevent them from obstructing the flow of water.

Erosion Prevention: Implement erosion control measures such as vegetation cover, rocks, or erosion control blankets to prevent soil erosion along the banks of the channel.

Structural Repairs: Inspect the ditch or ʻauwai for structural damage, including cracks or leaks, and repair them promptly to prevent water loss and maintain efficient water delivery.

Silt Removal: Periodically remove accumulated silt and sediment from the channel to maintain its depth and capacity for water conveyance.

Bank Stabilization: Stabilize the banks of the ditch or ʻauwai with appropriate materials such as rocks or vegetative cover to prevent bank erosion.

Maintenance of Inlets and Outlets: Ensure that inlet and outlet structures are clear of debris, functioning properly, and free from blockages.

Regular Inspections: Conduct routine inspections to identify and address maintenance needs promptly. Inspections should occur before planting seasons and at regular intervals throughout the year.

Emergency Preparedness: Have an emergency response plan in place to address unexpected issues such as breaches or excessive water flow during heavy rains.

Historical and Cultural Considerations: If the ditch or ʻauwai has cultural or historical significance, ensure that maintenance activities respect and preserve these aspects.

Community Involvement: Engage with the local community and stakeholders to foster a sense of responsibility for the maintenance and preservation of these traditional irrigation systems.

Documentation: Maintain records of maintenance activities, inspections, and any repairs made. Documentation can be essential for historical, cultural, or regulatory purposes.

The specific maintenance needs may vary depending on the size, location, and historical significance of the ditch or ʻauwai. It is advisable to work closely with local experts, community organizations, or cultural authorities to ensure that maintenance activities are conducted in a culturally sensitive and ecologically responsible manner.

E.4. Maintaining Flood Water Detention Basins and/or Bird Loʻi

Detention basins used for flood control require regular maintenance to ensure their effectiveness and maintain maximum water storage capacity. Bird loʻi require similar maintenance, more focused on ensuring high-quality habitat with native plants, clean water, and predator control. Here are some key maintenance needs for detention basins and/or bird loʻi:

Sediment Removal: Over time, sediment and debris can accumulate in the detention basin, reducing its storage capacity. Regular removal of sediment is essential to maintain the basin's functionality.

Vegetation Management: Vegetation in and around the basin should be managed to prevent overgrowth, which can impede water flow and reduce the basin's capacity. Controlling invasive species and maintaining mainly native vegetation will provide higher quality habitat.

Erosion Control: Inspect and maintain erosion control measures such as grass cover, riprap, or erosion control blankets to prevent soil erosion within the basin.

Inlet and Outlet Maintenance: Ensure that inlet and outlet structures are clear of debris and properly functioning. This includes checking for blockages, erosion, and damage to pipes or culverts.

Trash and Debris Removal: Regularly remove trash and debris from the basin to prevent clogging and maintain proper drainage.

Inspect and Repair Infrastructure: Regularly inspect the infrastructure, including berms, spillways, and control structures, for signs of damage or deterioration. Repair any issues promptly.

Safety Measures: Ensure that safety features such as fences, warning signs, and access control are in place and functional to prevent unauthorized access and ensure public safety.

Water Level Management: During heavy rainfall events, monitor and manage water levels to prevent overflows and ensure that the basin is ready to receive additional runoff.

Water Quality Monitoring: Conduct regular water quality monitoring to maintain environment that supports high-quality habitat.

Regular Inspections: Conduct routine inspections to identify and address maintenance needs promptly. Inspections should occur after significant rainfall events and at regular intervals throughout the year.

Predator Control: If needed, implement predator control (e.g. fencing, trapping) to protect native waterbird populations.

Documentation: Maintain records of maintenance activities, inspections, and any repairs made. This documentation can be important for compliance and reporting purposes.

Regular and proactive maintenance of detention basins and bird loʻi is crucial to their ability to effectively control flood waters and protect downstream areas from flooding, provide high-quality habitat, and ensure long-term sustainability and compliance with regulations.