Southwest Maui Watershed Management Plan

Maui County, HI
Final Report 2019

Prepared For:
Hawaii Department of Health
Clean Water Branch and
The U.S. Environmental Protection Agency

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ACKNOWLEDGEMENTS

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Tri-Isle RC&D		Fiscal Sponsor 2017

This project has been funded by the US Environmental Protection Agency under Section 319(h) of the Clean Water Act, the Hawaii State Department of Health Clean Water Branch, and the County of Maui, Office of Economic Development.

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Ka’ono’ulu Ranch
Kihei Community Association
Kula Community Association
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Maui Nui Marine Resource Council
Maui Surfrider Foundation
Thompson Ranch
Ulupalakua Ranch
‘Aha Moku O Kula Makai
Honua'ula Moku
Leeward Haleakala Watershed Restoration Partnership
Whole Foods

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1.0 EXECUTIVE SUMMARY

A watershed is the area of land that contributes water to a lake, river, stream, wetland, estuary, bay, or ocean. The types of activities, management measures, and practices that are conducted on the land in a watershed can impact the quality of the receiving waterbodies. Watershed management plans protect water quality by characterizing watersheds, identifying pollutant sources and impacted natural resources, engaging stakeholders, quantifying pollutant loads, and identifying and implementing management measures and best management practices to reduce nonpoint source pollution.

The Central Maui Soil and Water Conservation District's (SWCD) development of the Southwest Maui Watershed Plan (SMWP) (herein also referred to as the Plan) began in 2010. Since that time, the SWCD has brought stakeholders together to determine how to best manage the watershed in ways that satisfy environmental, human health, and economic interests. This watershed plan has been developed by the SWCD representing diverse interests including local, state, and federal agencies; private landowners and other residents; and nonprofit organizations.

The Plan was originally composed of two volumes submitted in 2013: Volume I: Watershed Characterization, and Volume II: Implementation and Management Strategies. While these reports contained valuable information about the watershed, major deficiencies were identified in those first two documents. In 2016 the SWCD began rewriting the Plan, addressing these deficiencies and additional comments made during the development process. While this document has aimed to retain much of the information produced by the 2013 documents, this Plan has been largely rewritten and should not be confused with the two volumes associated with the 2013 effort.

The SMWP focuses on the 49,688-acre area designated by the State of Hawaii as the Hapapa, Wailea, and Mo‘oloa watersheds. The planning area extends from near the summit of Haleakala down to coastal areas, with 11 major drainage basins discharging to the Kihei-Wailea-Makena coastline. The entire coastline of the planning area is part of the Hawaiian Islands Humpback Whale National Marine Sanctuary. The upcountry areas are primarily forests, farms, and ranch lands, and the coastal areas are developed resort, urban, and residential areas. Long-term rainfall averages range from 10 inches per year near the Kihei coastline to over 40 inches per year at 9,400 feet elevation near the summit of Haleakala. The three watersheds of the planning area encompass diverse habitat types utilized by a significant number of threatened and endangered species, including alpine, dryland forest, scrub and shrub, grasslands, coastal and elevated wetlands, ephemeral streams, estuaries, dune systems, tidal pools, rocky shorelines, and coral reefs.

The three watersheds include some of the nation's fastest growing population areas, increasing an average of 3.3% per year upcountry and 10% per year in the coastal areas. There is a trend of increased impervious surface and habitat loss due to development. The County of Maui Planning Department reported that there is a total of ~11,610 acres of planned development projects within the Southwest Maui planning area, which more than doubles the existing impervious surface area (existing development area totals ~4,194 acres). Some of these projects are already completed or are currently being completed; these projects total 196 acres. Planned/Committed projects total 8,445 acres, Planned/Designated projects total 961 acres, and Planned/Proposed projects total 2,010 acres. Most of the potable water for this area is imported to the coastal areas from the wet

Kahalawai, Iao Watershed, in which water allocations are currently being regulated, and to the upcountry areas from the upper Kula water system at Waikamoi.

The Hawaii Department of Health (DOH) Final 2018 and Final 2016 Integrated Water Quality Reports (IR) submitted to the Environmental Protection Agency (EPA) and Congress pursuant to Clean Water Act Section 303(d) indicate that 20 of the 29 coastal waterbodies sampled are impaired and not meeting state and federal water quality standards for at least one parameter. Of the 29 waterbodies assessed, more than 25 lack adequate data for assessment of at least one water quality standard.

The primary source of water pollutants identified by this Plan is sediment contaminated stormwater runoff. Turbidity measurements in exceedance of State of Hawaii water quality standards were observed at each of the sampled sites within the SMWP. High turbidity conditions can be caused by sediment laden water discharging from freshwater streams and/or from the resuspension of sediment cause by tidal or wave action within coastal waters. Increased sedimentation and nutrient loading on the extensive offshore reef complex threaten the health of the reef ecosystem. Sediments deposited by one storm event can be subsequently re-suspended. Recent studies have demonstrated that increases in sediment discharges from watersheds associated with poor land-use practices can impact reefs over 100 km from shore, and that ecosystem-based management efforts that integrate sustainable activities on land, while maintaining the quality of coastal waters and benthic habitat conditions, are critically needed if coral reefs are to persist (Richmond, et al., 2007).

The goals of the pollution control strategy and various implementation plans are to focus on sediment reduction measures, while also addressing nutrient pollution and other pollutant sources causing impairments to coastal waters as observed through DOH CWB sampling efforts and as reported in the biannual IR reports. Whenever possible, these projects were designed with an emphasis on ecosystem restoration and to reduce flooding and runoff. It should be noted that bacteria levels attained water quality standards in the Hapapa, Wailea, and Mo‘oloa watersheds during both the Final 2016 and Final 2018 Integrated Water Quality Reports. Therefore, this Plan does not consider bacteria a major parameter of concern.

Southwest Maui’s economic engine depends upon water-environment related commercial, recreational, and cultural/traditional gathering opportunities to residents and visitors such as boating, fishing, swimming, snorkeling, diving, hiking, and many other outdoor related activities. The goal of this Watershed Plan is to show the ways to improve water quality to enhance all of these uses, and to establish management practices on the land which will support these uses into the future. All urban/rural, agricultural, and conservation land uses can benefit from improved management measures which reduce nutrient runoff and soil loss caused by erosion during heavy rainfall.

2.0 INTRODUCTION AND PURPOSE

The Southwest Maui Watershed Plan (SMWP) was developed to include the 49,688-acre planning area designated by the State of Hawaii as the Hapapa, Wailea, and Moʻoloa watersheds. The planning area extends from near the summit of Haleakala down to coastal areas, with 11 major drainage basins discharging to the Kihei, Wailea, and Makena coastlines (Figure 1). This Plan is a community-based watershed plan to protect and restore water quality. Pollutants such as nutrients, toxic chemicals, pathogens, and sediments originate from a variety of sources within the watershed and potentially threaten both human and environmental health. These pollutants are transported via surface or groundwater throughout the watershed, reducing the quality of water in groundwater, streams, wetlands, estuaries, coastal, and oceanic waters. Nonpoint source pollution originates from diffuse sources associated with a variety of land uses including urban, agricultural, residential, and conservation. The combined effects of point and nonpoint source pollution can be seen with the decreased water clarity, presence of harmful or nuisance algae blooms, increased nutrients, presence of toxic pollutants and pathogens, and the resulting decline in the health of native ecosystems and aquatic organisms that are subjected to multiple stressors.

In order to meet water quality standards and protect water resources within the planning area, the SWCD employed the EPA planning guidelines for the creation and implementation of watershed-based plans. The development of the SMWP involves stakeholders to determine how to manage the watershed in ways that satisfy environmental, human health, and economic interests. This Plan has been developed by the SWCD to focus on the watershed planning area designated by the State of Hawaii as the Hapapa, Wailea, and Moʻoloa watersheds.

2.1 Building Partnerships

2.1.1 *Community Outreach*

In keeping with the EPA nonpoint source pollutant control (Section 319) grant requirements, the SWCD held a series of meetings (40 in total) during 2010 and 2011 to identify key stakeholders in the community. In addition, four public meetings were held. Since 2016, the SWCD has created a website to disseminate information to the public and to provide a means for the public to ask questions. We have met with and presented at the Kihei Community Association, the Hawaiian Islands Humpback Whale Marine Sanctuary, met with representatives from the ʻAha Moku O Kula Makai, as well as various other stakeholders in the community.

Driving forces for the watershed planning include the impaired water status of the near shore waters within the planning area, drainage and development issues, Maui County Kihei Drainage Master Plan, the Maui County Kihei Drainage Master Plan Alternatives Analysis, Coastal Zone Management, CWA water management, US Army Corps of Engineers (USACE) flood control planning, water conservation/reuse, ecosystem restoration, and recreational and aesthetic issues. A diverse group of stakeholders was invited to participate both at the beginning and throughout the process.

2.1.2 *Partnerships with other Federal Agencies, Non-Government Organizations, Local Government, and Local Land Owners and Businesses*

In addition, a non-profit called the National Fish and Wildlife Foundation (NFWF) is interested in supporting watershed management work in North Kihei due to the significant tracks of coral reefs that exist offshore. As a first step, NFWF has funded a rapid watershed assessment with the United States Geological Survey (USGS), Maui Environmental Consulting, LLC, and the West Maui Ridge 2 Reef Initiative in order to best understand the sediment hot-spots found on the landscape and how they may be addressed. As with all watershed management work, the study could only be undertaken with the community and landowners as partners. Major landowners associated with this proposed study include the Department of Hawaiian Homelands, Kaonoulu, and Haleakala Ranches.

Working together with local partners, NFWF and the USGS propose to answer these questions:

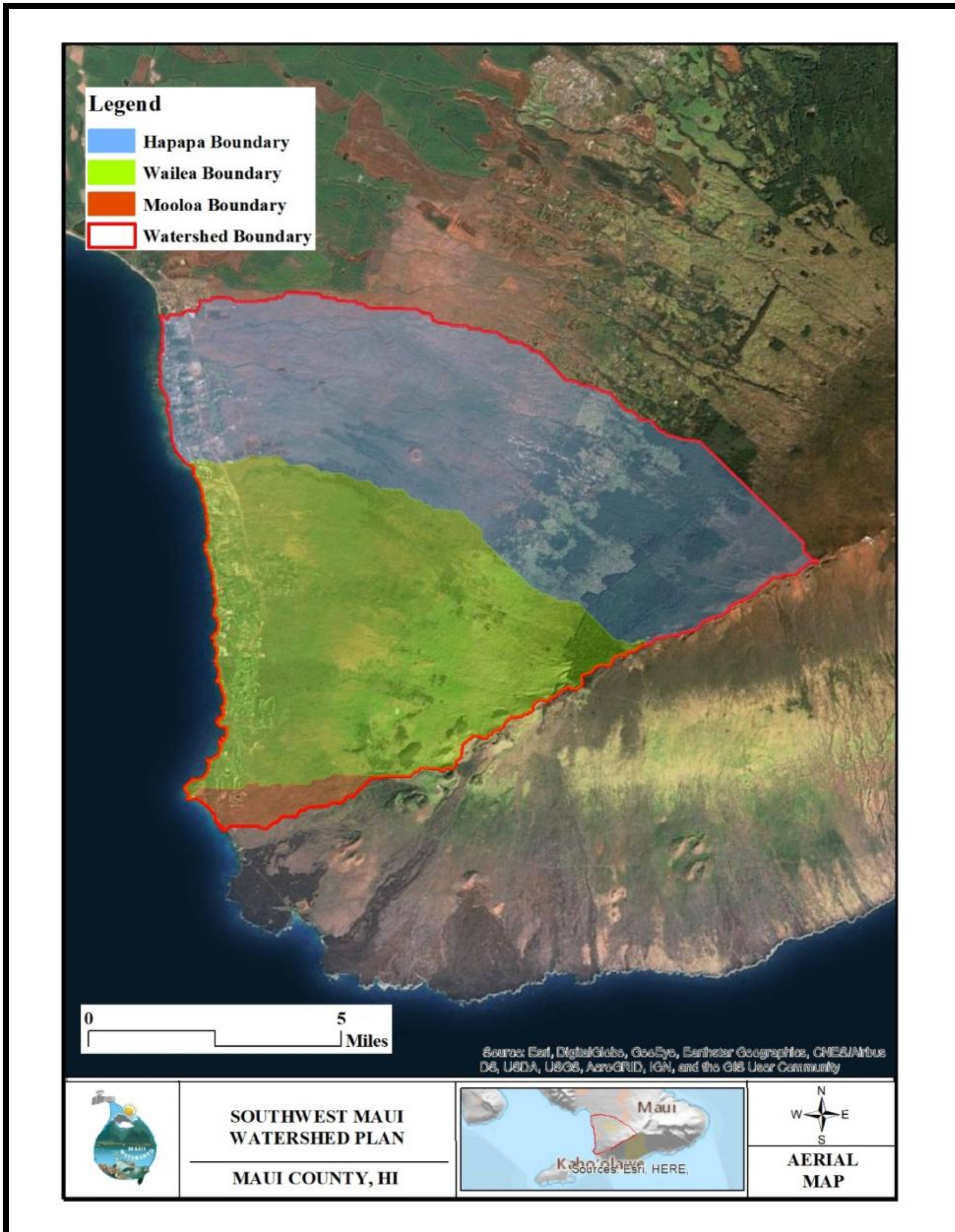
1. What is the major source of fine sediment pollution to Kihei's nearshore?
2. What rainfalls trigger widespread erosion?
3. How often do they happen?
4. How much sediment could come down each year and how could we improve that estimate if needed?
5. What is the ungulate impact and where are the priority areas to mitigate?
6. What are the mitigation projects that can address ungulate impact?
7. What does the data say about reef health and likely impacts from sediment?
8. What is the coastal water quality at stream outlets in this area?
9. What additional monitoring is needed to understand the current dynamics and improvements at the reef over time?

Components of work to complete in the field:

1. Monitoring erosion pins- periodic recording of lowering rates at pins installed along transects
2. Storm sampling: turbidity and nutrient monitoring during and after rain fall events
3. Sediment pods in nearshore waters: deploy, service and evaluation of sediment quantity and origination through time
4. Synthesis of coral reef monitoring: synthesis of information gathered by the State of Hawaii Division of Aquatic Resources (DAR) regular transect monitoring and 2018 TNC reef resilience assessment

As a result of these studies in West Maui, Molokai, and the Big Island, the NFWF partnered with and funded large projects to address sediment issues affecting the reef. These included the installation of fencing, the planting of vegetation, and other projects to help landowners. This project would be focused on the lands associated with Kulanihakoi and Waipuilani stretching from Kula to Kihei as these streams discharge onto large portions of significant coral reef.

Figure 1. Southwest Maui Watershed Plan



2.1.3 *Key Stakeholders*

Key stakeholders in the SMWP include but are not limited to Maui County, Central Maui Soil and Water Conservation District, Olinda-Kula Soil and Water Conservation District, Department of Hawaiian Home Lands, Department of Land and Natural Resources (DLNR) – Division of Forestry and Wildlife, DLNR – Division of Aquatic Resources, DLNR – Division of Boating and Ocean Recreation, Haleakala Ranch, Ka'ono'ulu Ranch, Kihei Community Association, Maui Nui Marine Resource Council, Kula Community Association, Maui Environmental Consulting, LLC, Maui Surfrider Foundation, Thompson Ranch, Ulupalakua Ranch, Aha Moku O Kula Makai, Honua'ula Moku, Leeward Haleakala Watershed Restoration Partnership, United States Coast Guard, USACE, Environmental Protection Agency, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, Hawaii Tourism Authority, Maui County Fire Department, Hawaii Department of Transportation, Maui Visitor's Bureau, Maui Tourism Authority, Boat/Tour Companies, Coral Reef Alliance, Hawaii Wildlife Fund, Maui Cultural Lands, Maui Electric Company, Pacific Whale Foundation, Monsanto, various golf courses and resorts, and the residents and businesses of the Kula, Keokea, Kihei, Wailea, and Makena communities.

While the Central Maui Soil and Water Conservation District is primarily responsible for implementing the Plan, the entire community falling within the watershed boundary is potentially affected by the implementation projects being proposed. Public health, water quality and clarity, flooding of public roads and private property, habitat for listed species and overall ecological health, the fishing and tourist industries, hotels, resorts, small businesses and the community as a whole will be positively affected by implementation of the Plan.

Through meetings with individual entities and organizations, the SWCD has reached out to stakeholders in an effort to provide and receive information on issues and concerns in the watershed. Stakeholders were identified that have knowledge of existing programs and resources that address concerns in the watershed. From forest restoration work being done mauka by the Leeward Haleakala Watershed Restoration Partnership to water quality testing in the coastal waters by the Hui O Ka Wai Ola, to small business owners who rely on healthy and clean coastal waters for their business, the SWCD has identified stakeholders that can provide information on key issues and concerns in the watershed. In addition, stakeholders such as the Hawaii Department of Land and Natural Resources and the Kihei Community association can provide vital resources needed to implement the Plan. Some of these resources include, grants, monetary donations, volunteer work, fundraising, public outreach, educational opportunities, etc. In addition, stakeholders such as the Department of Health Clean Water Branch and Maui County were identified who are able to provide technical and financial assistance with the Plan implementation. The following table was created to note key stakeholders and their role in the SMWP:

Table 1. Stakeholder Capacity in the Southwest Maui Watershed Plan

Stakeholders	Stakeholder Capacity				
	Stakeholders responsible for implementing the Plan	Stakeholders affected by Plan implementation	Stakeholders who can provide information on issues and concerns in the watershed	Stakeholders who have knowledge of existing programs and resources	Stakeholder who can provide technical and financial assistance in implementing the Plan
Central Maui Soil and Water Conservation District	**X**				
Maui County		**X**	**X**	**X**	**X**
Hawaii Department of Health Clean Water Branch			**X**	**X**	**X**
Hawaii Department of Land and Natural Resources			**X**	**X**	**X**
U.S. Environmental Protection Agency			**X**	**X**	**X**
Kihei Community Association		**X**	**X**	**X**	**X**

Stakeholders	Stakeholder Capacity				
	Stakeholders responsible for implementing the Plan	Stakeholders affected by Plan implementation	Stakeholders who can provide information on issues and concerns in the watershed	Stakeholders who have knowledge of existing programs and resources	Stakeholder who can provide technical and financial assistance in implementing the Plan
Kula Community Association		**X**	**X**	**X**	**X**
Maui Nui Marine Resource Council		**X**	**X**	**X**	**X**
Aha Moku O Kula Makai		**X**	**X**	**X**	**X**
Honua'ula Moku		**X**	**X**	**X**	**X**
Rural Land Owners		**X**	**X**		**X**
Urban Land Owners		**X**	**X**		**X**
Hotels, Resorts, and Golf Courses		**X**	**X**	**X**	**X**
Leeward Haleakala Watershed Restoration Partnership		**X**	**X**	**X**	**X**

Stakeholders	Stakeholder Capacity				
	Stakeholders responsible for implementing the Plan	Stakeholders affected by Plan implementation	Stakeholders who can provide information on issues and concerns in the watershed	Stakeholders who have knowledge of existing programs and resources	Stakeholder who can provide technical and financial assistance in implementing the Plan
Department of Hawaiian Homelands		**X**	**X**		**X**
Small Businesses		**X**	**X**		**X**
Hawaii Tourism Authority		**X**	**X**	**X**	**X**

2.1.4 *Education and Outreach*

Stakeholders representing diverse interests including local, state, and federal agencies; private landowners, nonprofit organizations, and community residences were invited to participate in the watershed planning effort. Several public meetings were held to discuss the process and gather input. Early on in the planning process the Southwest Maui Watershed website was developed at www.mauiwatershed.org. Stakeholders were tasked with determining how to best manage the watershed in ways that satisfy environmental, human health, and economic interests.

2.1.5 *Setting Goals and Identifying Stakeholder Concerns*

As a result of reviewing DOH CWB data, it has been determined that the primary source and most problematic pollutant is sediment carried by storm water runoff. Therefore, the major goal of the Plan is to reduce sediment loading throughout the watershed. The Hapapa watershed has been identified as the most troublesome for sediment loading. Specific gulches in the Hapapa watershed, including Kulanihakoi Gulch, Waipuilani Gulch and Keokea Gulch flood and discharge into coastal waters with the most frequency. Storm waters overload coastal wetlands causing flooding in the urban area near the shore. While these three gulches are of major concern, state standards for various water quality parameters are not being met for many sites along the southwest Maui coastline.

Additional water quality parameters such as Total Phosphorus (TP), Total Nitrogen (TN = organic and inorganic nitrogen and ammonia), and Chlorophyll *a* are also of concern. According to DOH CWB data, bacteria is not a concern within the watershed as this parameter has attained water quality standards at every water quality monitoring station where data was collected. Currently, funding does exist allowing for the additional sampling of multiple parameters and their associated laboratory processing costs by SWCD at additional sites not currently being sampled by either DOH CWB staff or by the Hui O Ka Wai Ola citizen scientists.

2.1.6 *Identify Possible Management Strategies*

The Central Maui Soil and Water Conservation District divided the watersheds by land use types and developed possible management strategies based on these distinct areas. The majority of the land in the watershed is rural, with agriculture as the main land use type. For this reason, it was determined that management of sediment in agricultural areas would be most beneficial to the overall watershed and to coastal waters. In addition, management strategies were discussed for the urban and conservation sections of the watershed. Within conservation lands, efforts should focus on ungulate fencing and native forest rehabilitation. Within the urban lands, efforts should focus on nutrients, flooding, and irrigation.

3.0 WATERSHED CHARACTERIZATION

At approximately 48 miles long and 26 miles wide, Maui is the second largest of the main Hawaiian Islands with a total land area of about 725 square miles. The island of Maui was built by two volcanoes, Haleakala (East Maui) (10,025 ft high) and Kahalawai (West Maui) (5,788 ft high). The flat isthmus in between was built by lava flows from Haleakala banking against Kahalawai (Stearns & MacDonald, 1942).

The total area of the Hapapa, Wailea, and Mo‘oloa watersheds is approximately 49,688 acres, extending from near the summit of Haleakala down to coastal areas of Kihei, Wailea, and Makena with major drainage to the Kihei coastline. The upcountry areas are primarily forests, farms, and ranch lands, and the coastal areas are developed resort, urban, and residential areas. Long term rainfall averages range from 10 inches per year near the Kihei coastline to 40 inches per year at 9,400 feet elevation near the summit of Haleakala. Draining these watersheds are numerous large gulch systems that flow seasonally after major rainfall events. Improved drainage systems operated by the County of Maui, Wailea Resort, and Makena Resort also discharge directly to the ocean in the planning area.

The history of this watershed over the last 300 years reflects a decline in native forest cover in favor of farming, ranching, and residential/urban uses, the introduction of grazing animals, and introduction of alien plant and animal species. Since the 1960’s, residential and commercial development in Kihei has contributed to a reduction in the wetland and sand dune acreage along the shoreline. The resulting altered local climate and land use patterns have changed watershed hydrology and the characteristics of stormwater runoff. Excess stormwater causes flooding damage and pollution that are difficult and costly to clean up. This is especially evident in the Hapapa watershed. In Kihei, the Kulanihakoi, Waipuilani, and Keokea gulches are prone to surface water flooding. Both public infrastructure such as roads and bridges and private property are damaged during storm events by sediment laden stormwater.

Currently, Southwest Maui offers a myriad of commercial and recreational opportunities to residents and visitors such as boating, fishing, swimming, snorkeling, diving, hiking, and many other outdoor related activities. Southwest Maui coastal waters have also traditionally been used by Native Hawaiians for canoeing, fishing, limu (seaweed) gathering, and other traditional practices. The people of Maui realize the economic, social, and cultural value of a healthy environment. Many who live, work, recreate, or conduct cultural traditional practices in the area are concerned about the impairment of water quality.

The following sections provide a detailed description of the physical and natural features as they exist within the Southwest Maui Watershed Plan project area. For the purpose of this study we focused on geology, soils, topography, streams, rainfall, climate, terrestrial and benthic habitats, land use, land cover, and population to accurately characterize the watershed.

3.1 Geology

The volcanic rocks of Maui are considered diverse and include basalts, gabbros, picritic basalts, nepheline basanites, basaltic andesites, andesites, and soda trachytes. Haleakala is a broad shield-shaped dome, consisting of thin-bedded lava flows dipping away from vents and rift zones. An east rift, southwest rift, and north rift, ranging in length from 15 to 17 miles, radiate from the location of the former summit at elevation of 10,500 – 11,000 feet above present-day sea level, forming a rounded pyramidal cone. The present-day mountain is 10,025 feet high and 33 miles across. The Haleakala Crater is not believed to be a caldera, but rather the heads of two valleys in which volcanic activity has subsequently occurred, often burying streambeds and erosional features. Craters (defined as orifices at the top of cinder, lava, and spatter cones) on Maui can range from a few feet to one half mile across (Stearns & MacDonald, 1942). The lavas of the Haleakala volcano that are found within the planning area include Hana Volcanics, Kula Volcanics, and Honomanu Basalt (Mink & Lau, 2006) (Stearns & MacDonald, 1942).

The higher elevations of the planning area and the entire Mo‘oloa watershed are Hana Volcanic. In the Hapapa watershed, Kula volcanics are also found at upper and lower elevations, and Hana volcanics are found along the coastline of the Hapapa and Wailea watersheds ((Mink & Lau, 2006), reprinted from Clague 1998). Lava types are Pahoehoe (smooth) flows that can form lava tubes, and A’a (rough), dense basalt that can form beds of clinkers. A major geologic feature of Haleakala Volcano is the southwest rift zone. The ridge that defines the southwest rift zone has a major influence on the hydrology of the area’s watersheds.

3.2 Topography

The topography of the project area ranges in elevation from sea level along the coastal boundaries of the Hapapa, Wailea, and Mo‘oloa watersheds to approximately 9,400 ft. at the top boundary of the Hapapa watershed along Haleakala’s southwest rift zone.

A spatial analysis of the USGS, Digital Elevation Model (DEM) shows that slope ranges from 0 to 85 percent within the planning area (Figure 2). Steeper slopes are associated with higher elevations that border Haleakala’s southwest rift zone on the south side of the project area, along the steep ridges and sides of drainage gulches, and on the side slopes of geologic formations such as Pu`u o Kali, Pu`u Io, and Pu`u Olai cinder cones. The average slope of the project’s watersheds is 14 percent.

The Kihei District is located along the leeward coast of East Maui and the southwest slope of Haleakala. The flat coastal areas are heavily developed with urbanized residential and commercial landscapes. Between South Kihei Road and Pi’ilani Highway, the elevation rises up to 200 feet above mean sea level (msl) at the south part of the district. Mauka (upslope) of the Pi’ilani Highway, the slope becomes steeper and well-defined gulches are seen in the landscape (R.M. Towill, 2009).

Figure 2. Southwest Maui Watershed Plan Topographic Map

3.3 Soils

A diverse group of soils are found in the Hapapa, Wailea, and Mo`oloa watersheds (Soils Map). The project area is comprised mostly of andisols: soils derived from volcanic ash. At elevations higher than 3,000 feet, these andisols have a fairly deep profile in the northeast parts of the watersheds but become shallower towards the southwest. Small areas of histosols (organic soils) are also present at these high elevations. On the lower elevations of Haleakala there are mollisols and aridisols, which are generally fertile soils with higher organic matter in the surface horizons that developed from older ash deposits (Sawdey, 2009). These soils are shallow to moderately deep and contain significant amounts of rocks both on the surface as well as in the soil profile.

There are approximately 40 different soil types within the project watersheds which differ in clay, sand, and silt content and also in texture, slope, and aggregate size. The dominant soils series within the watersheds is Waiakoa extremely stony silty clay (WID2). WID2 soil has a depth of 20 to 40 inches and is well drained. The water movement in the most restrictive layer is moderately high, available water to a depth of 60 inches is low, shrink-swell potential is low, there is no zone of water saturation within a depth of 72 inches, the organic matter content in the surface horizon is about 2 percent, it does not meet hydric criteria, and it can be found on slopes that range from 3 to 25 percent (Soil Conservation Service, 2001).

3.4 Climate

The climate on the island of Maui is influenced by geographic location, creating microclimates. Generally speaking, there is a wet winter season (October to April) and a dry summer season (May to September). On the windward side of Haleakala, northeasterly trade winds generate heavy rainfall while the leeward side remains dry. Orographic rainfall occurs on the windward side as the moisture from the ocean is uplifted and cools to form rain at upper elevations of the mountain, where the highest rainfall occurs. Rainfall decreases gradually toward the coastline as elevations descend. One portion of the watershed area, the traditional ahupua'a of Ka'eo in the Mo'oloa drainage basin, has consistently recorded the highest rainfall data of any of the coastal regions. Cyclonic storms can distribute rainfall across the planning area several times per year (R.M. Towill, 2016).

3.5 Precipitation

Precipitation in Hawaii is highly variable due to the interaction of three controls: the Hadley cell (a thermal cell formed by warm air rising near the equator, forming the northeasterly trade winds), the oceanic position of the Hawaiian Islands, and the high volcanic mountains. Atmospheric disturbances and precipitation can occur in Hawaii on both a synoptic scale (a few thousand meters and days to a week of time) or mesoscale (a few hundred kilometers and hours to days in time). Mechanistically, precipitation can be defined as cyclonic, orographic, or convective. Cyclonic precipitation is the result of low air pressure systems on a synoptic scale. Orographic precipitation results from the blocking action of a mountain range that lifts air flow up the windward slope. Temperature inversion can limit the height of this airflow and alter its path. When the mountain is higher than the inversion, the rain is deposited on the windward slopes. High mountains also provide surface roughness discontinuity that can anchor or enhance cyclonic and convective precipitation. Convective precipitation typically results from cumulus and cumulonimbus clouds

Figure 3. Southwest Maui Watershed Plan Soils Map

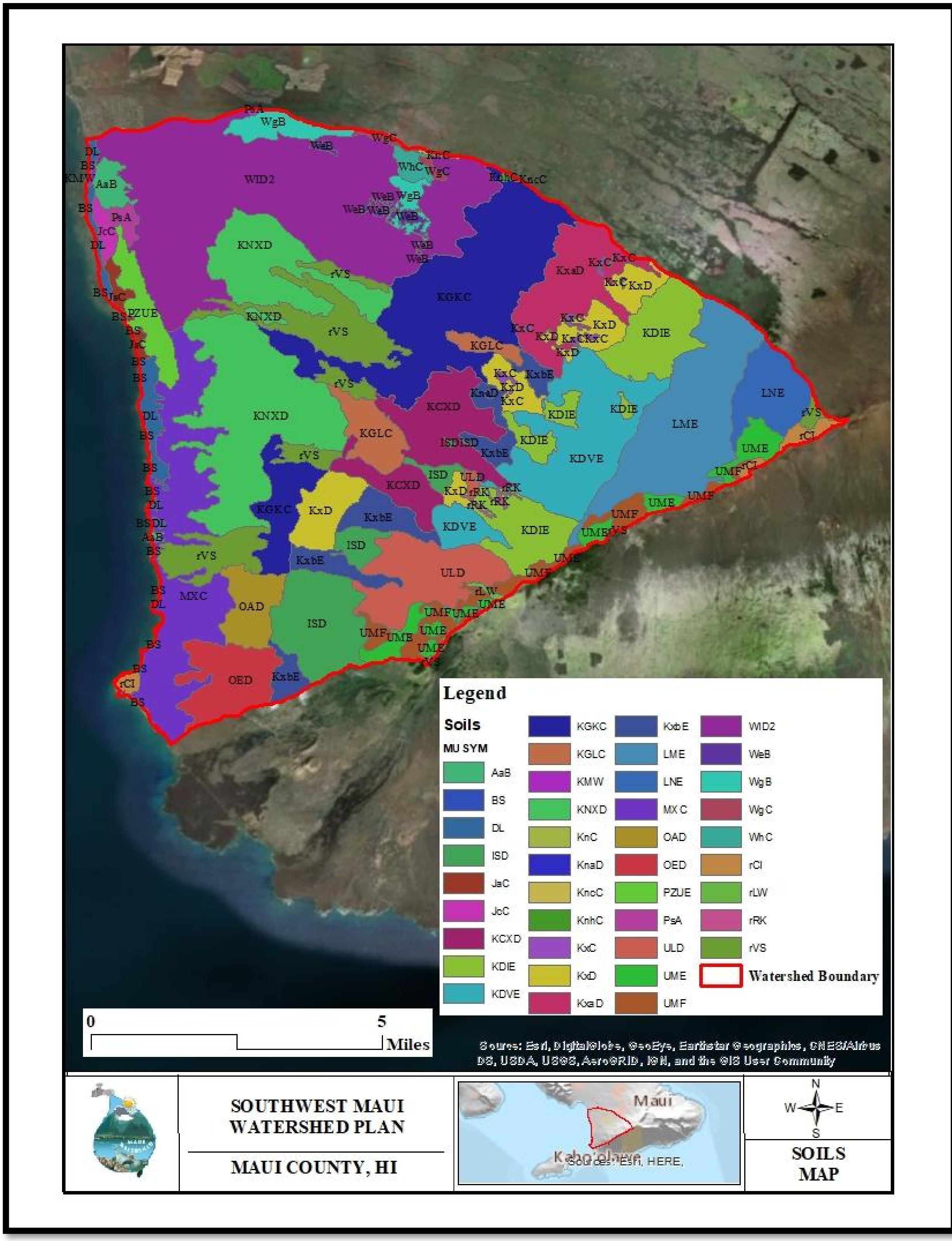
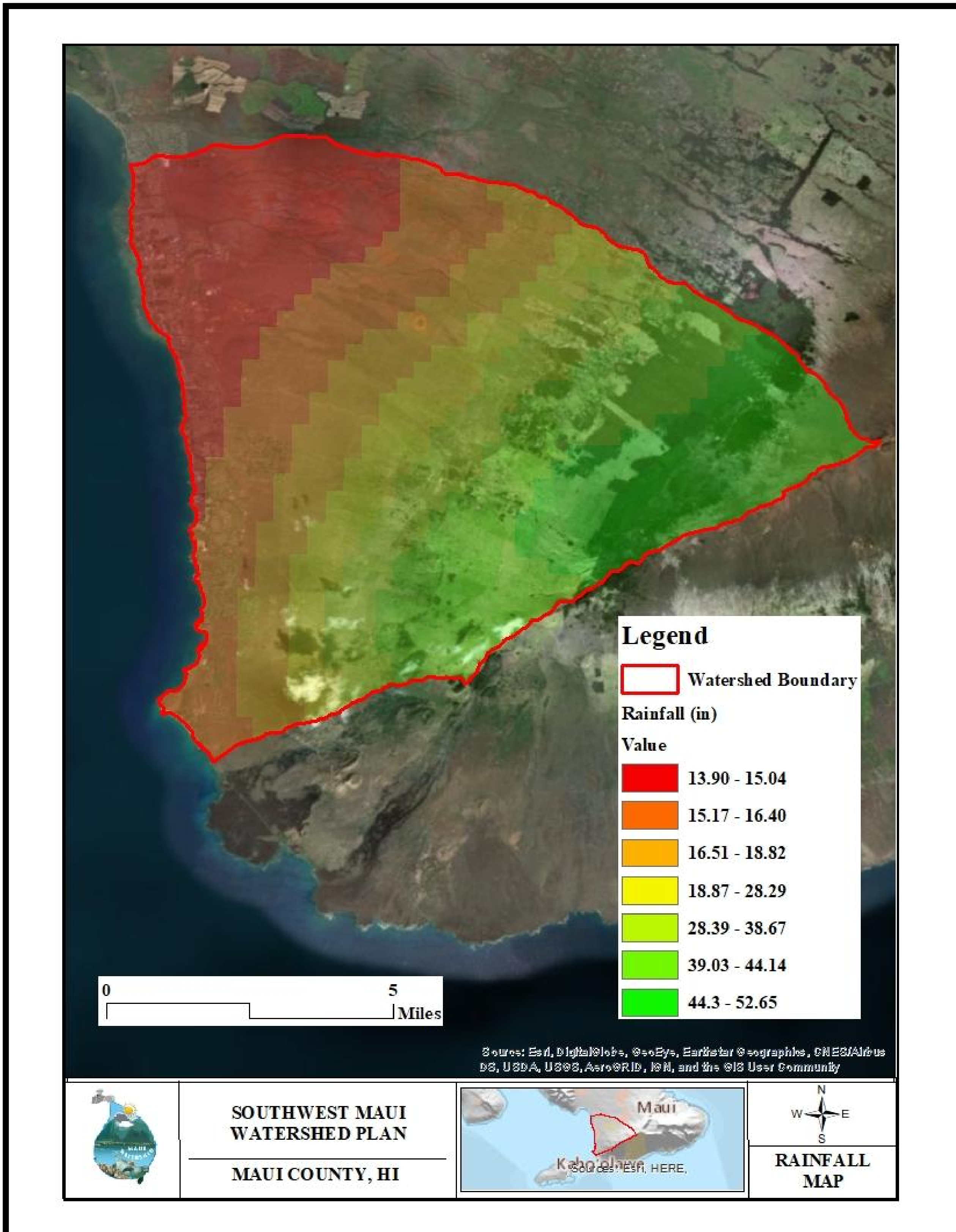


Figure 4. Southwest Maui Watershed Plan Annual Rainfall Map



produced from strong surface heating. Convective rain cells can organize into mesoscale convective systems creating clusters or lines of squalls. Interaction with topography can “lock in” these systems making them nearly stationary for a relatively long duration resulting in heavy downpours and flash flooding. On the island of Maui, during the dry summer season, trade winds predominate, resulting in orographic rain events on the windward side. In the winter, synoptic events, such as Kona and cold-front storms, predominate and bring rain events to the dry leeward side of the island (Mink & Lau, 2006).

El Nino (EN) and the Southern Oscillation (SO) are closely associated atmospheric-oceanographic events with global consequences. The hydrology of the Hawaiian Islands is profoundly affected by ENSO events. EN is a large scale, 1 to 4 degree Celsius, warming of surface water in the equatorial eastern Pacific. Every December a warm water current moves eastward and displaces the usually northward currents off Peru and the upwelling of cold water. Every 2-10 years the effects become more extensive and severe, causing profound atmospheric disturbance and hydrologic extremes. The SO is the reversal of usual sea level atmospheric pressure gradient. Normally the gradient goes from low in Indonesia and Northern Australia to high in the eastern South Pacific (Tahiti). During non-ENSO years, the trade winds push ocean surface water westward and offshore from South America causing upwelling of cold water and sea level rise in the South Pacific. During ENSO years, the warm pool of ocean water drifts eastward due to weakened trade winds, shifting the large-scale thermal cell of air circulation (Hadley cell), displacing Kona and cold-front storms that normally bring winter rains to the islands, resulting in dry conditions. (Mink & Lau, 2006)

3.5.1 *Annual Precipitation*

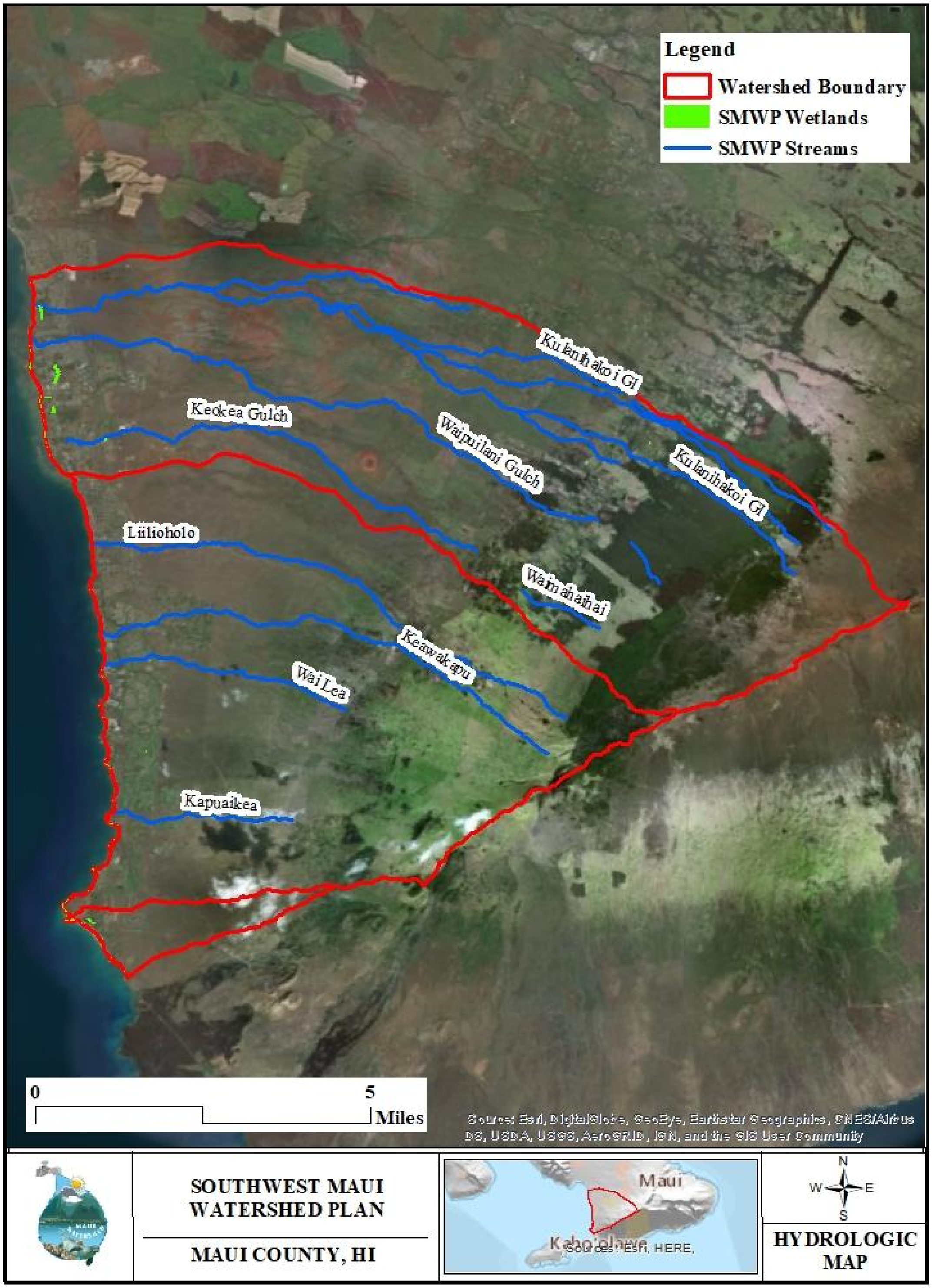
Mean annual precipitation on Maui ranges from 275.6 inches (7,000 mm) at the higher elevations of the windward sides of Haleakala and Kahalawai to 15.8 inches (400 mm) or less on the dry leeward coastlines (Mink & Lau, 2006 adapted from Giambelluca et al. 1986). Rainfall on the western (leeward) slopes of Haleakala increases with elevation, reaching average annual values of 50 inches near the summit (PRISM Group, 2006)(See Figure 4). Rainfall patterns in these watersheds are seasonal in nature. The wettest month typically occurs in January. The months of June through September tend to be the driest months. Dry months generally receive less than one-quarter of the wettest month value (PRISM Group 2006).

This data set contains spatially gridded average monthly and annual precipitation for the climatological period 1971-2000. Distribution of the point measurements to a spatial grid was accomplished using the PRISM model developed by Chris Daly of the PRISM Group, OSU. Display and/or analyses requiring spatially distributed monthly or annual precipitation for the climatological period 1971-2000. Annual grids were created by summing monthly grids for precipitation.

3.6 Hydrology

Maui is considered a high volcanic island. Precipitation varies with altitude, topography, season, and changes with time from wet years to drought years. Precipitation occurs as rainfall, fog, and occasionally as snow or hail at the summit of Haleakala (10,000 feet). Rainfall is greater at upper

Figure 5. Southwest Maui Watershed Plan Hydrologic Map



elevations (greater than 6,000 feet) and falls primarily on the windward side. There is a rain shadow at higher elevation on the leeward side. More rain may fall on the leeward side from one Kona storm than during the rest of the year.

The Kihei District is located along the leeward coast of East Maui and the southwest slope of Haleakala. The flat coastal areas are heavily developed with urbanized residential and commercial landscapes. Between South Kihei Road and Pi'ilani Highway, the elevation rises up to 200 feet above mean sea level (msl) at the south part of the district. Mauka (upslope) of the Pi'ilani Highway, the slope becomes steeper and well-defined gulches are seen in the landscape (R.M. Towill, 2016).

3.6.1 *Groundwater*

Dike complexes in the center of the island are saturated with fresh water and leak into surrounding dry rock. Salt and brackish water underlie a floating freshwater lens (basal water table) that is thicker in the center of the island and thins as it reaches the coastal areas and seeps into the ocean. Rainfall, evaporation and transpiration, runoff, and recharge are significant hydrologic processes on the leeward side. The planning area is underlain by basal water in lavas (Stearns & MacDonald, 1942). The Kamaʻole Aquifer, which lies under most of the project area, has a sustainable yield of 11 MGD. Some brackish water from the aquifer is used for irrigation, and some of the water is treated for private potable use (Waimea Water Services, Inc., June 2004). The aquifer is not used for public potable water supply. According to the Hawaii State Water Use and Development Plan (2008), the sustainable yield of the Kamaʻole aquifer has not been verified through any independent peer reviewed testing. The estimated sustainable yield of 11 MGD is based upon estimates derived from Oahu resources. The WUDP text makes clear that due to the large uncertainty associated with the estimate, it should not be assumed that this amount of water is available or will be of sufficient quality for potable use or will be practical to access.

Approximately 5 MGD of brackish water is pumped from the Kamaʻole aquifer to irrigate golf courses and other landscaping (Commission on Water Resource Management (CWRM) water reporting database). The state has drilled several test wells in this aquifer, which have both proven to produce water with chlorides near the upper limit of acceptable potable water standards. Four wells drilled for a private water system for a proposed development have similar chloride levels of 200 parts per million (ppm) or more. Due to the slope of the land mass from summit to the coast, the predominant direction of groundwater movement is toward the ocean. The groundwater in coastal areas is also subject to tidal influences that can be detected in water wells miles inland.

3.6.2 *Surface Water*

Surface runoff in the planning area collects into a number of major drainage features (gulches) that are considered intermittent streams. There are currently no streams classified as perennial in the planning area. According to the EPA, ephemeral and intermittent streams provide the same ecological and hydrological functions as perennial streams by moving water, nutrients, and sediment throughout the watershed. When functioning properly, these streams provide landscape hydrologic connections; stream energy dissipation during high-water flows to reduce erosion and improve water quality; surface and subsurface water storage and exchange; ground-water recharge and discharge; sediment transport, storage, and deposition to aid in floodplain maintenance and development; nutrient storage and cycling; wildlife habitat and migration corridors; support for vegetation communities to help stabilize stream banks and provide wildlife services; and water supply and water-quality filtering. They provide a wide array of ecological functions including forage, cover, nesting, and movement corridors for wildlife. Because of the relatively higher moisture content in arid and semi-arid region streams, vegetation and wildlife abundance and diversity in and near them is proportionally higher than in the surrounding uplands (USEPA, November 2008).

In the rapidly developing areas, land management decisions must employ a watershed-scale approach that addresses overall watershed function and water quality. Ephemeral and intermittent stream systems comprise a large portion of leeward watersheds and contribute to the hydrological, biogeochemical, and ecological health of the watershed. Given their importance and extent, it is concluded that an individual ephemeral or intermittent stream segment should not be examined in isolation. Consideration of the cumulative impacts from anthropogenic uses on these streams is critical in watershed-based assessments and land management decisions to maintain overall watershed health and water quality (USEPA, November 2006).

As noted above, there are three major watersheds contained within the SMWP watershed-based planning effort. They are (from north to south) the Hapapa (26,493 acres), Wailea (21,985 acres), and Moʻoloa (1,213 acres) watersheds. Generally speaking, in the Moʻoloa watershed the distances from the coastline to the summit are shorter and drainage areas are smaller. The length of the drainages, distance from shore to summit, and elevation of the summit increase moving north, and drainage areas of the watersheds increase (Figure 5). Streams in the Hapapa and Wailea watersheds have steep reaches with deep V-shaped channels, primarily in the upper elevations. In the lower elevations, stream slope decreases and there are wide, shallow stream channels. Prior to development of the coastal zone there were wetland and dune systems along the south Maui coast.

Table 2. SMWP Streams by Watershed

Southwest Maui Watershed Plan	
Watershed	Streams/Gulches
Hapapa	Kulanihakoi
	Waipuilani
	Keokea
	Waimahaihai
Wailea	Liilioholo
	Keawakapu
	Wai Lea
	Kapuaikea
Moʻoloa	None

3.7 Habitat

The three watersheds of the planning area encompass a large number of habitat types; including alpine, dryland forest, scrub and shrub, grasslands, coastal and elevated wetlands, ephemeral (intermittent) streams, estuaries, dune systems, tidal pools, rocky shorelines, and coral reefs.

3.7.1 *Terrestrial Habitat*

The watershed terrestrial habitats include critical and rare species habitat as defined by the Hawaii Natural Heritage Program and US Fish and Wildlife Botanical resources in the project area include a candidate endangered species ‘awikiwiki *(Canavalia pubescens)* (PBR & Associates, Inc. Hawaii, March 2010).

3.7.2 *Benthic Habitat*

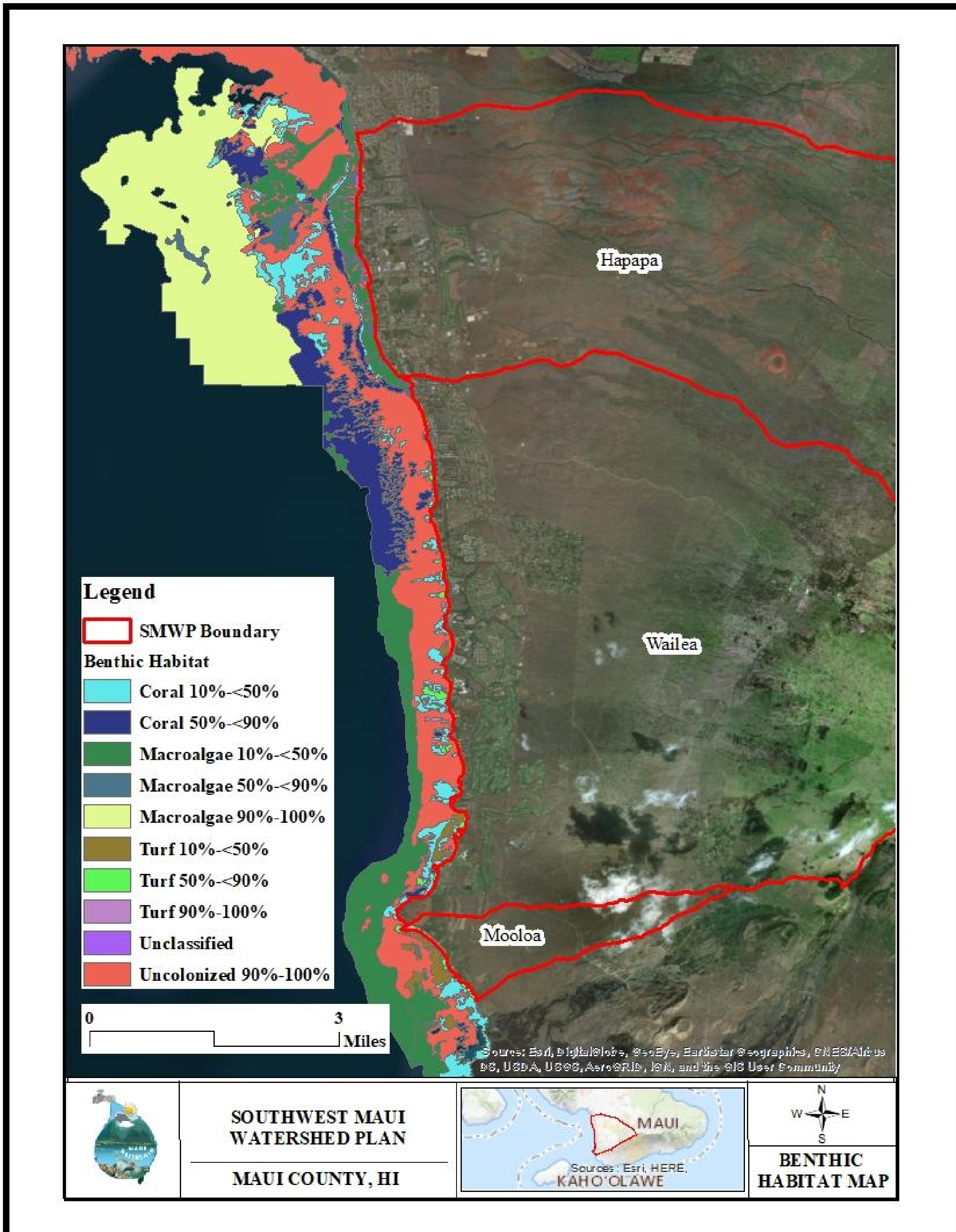
The National Oceanographic and Atmospheric Administration (NOAA) has published benthic habitat data for the planning area (See Figure 6). Vector boundaries of habitat areas were delineated by photo interpreting georeferenced color aerial photography, AURORA hyperspectral, and IKONOS satellite imagery. Overall accuracy of the major habitat classifications in these data is greater than 90%. Habitat boundaries are based on photo-interpretation of imagery of ground condition at the time the imagery was collected. Shore lines are subject to change over time due to natural erosion and vegetation growth processes. Habitat boundaries are subject to change over time due to population dynamics of the dominant biological communities.

The benthic habitat along the shoreline of the Hapapa Watershed is predominately macro algal cover ranging from 10-50%, with areas in the northern most shoreline having algal cover ranging from 50-90% and 90-100%. The areas of high macro algal growth are in the vicinity of both the largest gulch outfalls on the leeward side (Kulanihako’i, Waipu’ilani, and Keokea). Reef habitats, including aggregate coral, scattered coral-rock, colonized pavement, and uncolonized pavement habitat types, are also present, although to a much lesser extent.

The benthic habitat in the Wailea watershed is characterized by large areas of sand bottom, interspersed with reef aggregate coral, colonized volcanic rock and boulder, and colonized pavement. At the northern most boundaries, shared with the Hapapa watershed, there is a small area of macro algal cover near the shore. There is a large area of reef aggregate coral further offshore in the coastal waters off the northern Wailea watershed shoreline.

The Mo‘oloa watershed benthic habitat is characterized by bottom habitats including sand, hardbottom uncolonized pavement, and uncolonized volcanic rock and boulder. Colonized and uncolonized volcanic rock and boulder begin to dominate the shoreline habitat just south of the Mo‘oloa basin.

Figure 6. Southwest Maui Watershed Plan Benthic Habitat Map



3.7.3 *Aquatic Life and Wildlife*

Aquatic life is abundant in the coastal ecosystems that receive inputs from the watershed lands, streams, and groundwater. Hawaiian traditional and customary gathering rights, subsistence fishing, commercial and recreational fishing, and commercial recreational activities, such as snorkeling, diving, and whale-watching, depend on balanced aquatic ecosystems. These systems support aquatic life and wildlife, such as coral, Hawaiian stilts, Hawaiian monk seals, hawksbill turtles, green sea turtles (honu), humpback whales, etc. Monk seals are also known to frequent the coastal waters of the watershed planning areas, especially at Makena. The entire coastline of the planning area is part of the Hawaiian Islands Humpback Whale National Marine Sanctuary.

Evidence was found of the endangered Blackburn's Sphinx Moth (*Manduca blackburni*), and an endangered Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) was sighted within the Wailea Watershed (Wailea 670 or Honua'ula Project area) (PBR & Associates, Inc. Hawaii, March 2010). The watershed lands in Hapapa and Wailea watersheds include the sites of Rare Species Observation, Forest Bird Recovery Area, and areas of Blackburn Sphinx Moth Sightings.

4.0 LAND USE AND POPULATION

4.1 State Land Use Districts

State Land Use District categories include agriculture, conservation, rural and urban areas. Figure 7 depicts the boundaries of these four districts for the Hapapa, Wailea and Mo'oloa watersheds within the Southwest Maui Watershed Plan.

This data was obtained from the March 2014 State Land Use District Boundaries for the 8 main Hawaiian Islands, State Land Use Commission 1:24,000 mylar maps. These District Boundaries were compiled by the State Land Use Commission using the State of Hawaii's Geographic Information System (GIS).

4.1.1 *Hapapa Land Use Districts*

Agricultural lands make up the majority of the Hapapa watershed This district is used for grazing and some crop production. Conservation lands exist near the summit of Haleakala and are primarily forested. An Urban corridor exists along the coastline and is associated with development in north Kihei. Rural districts and small urban areas are located upcountry associated with the town of Kula.

4.1.2 *Wailea Land Use Districts*

Similar to Hapapa, Agriculture is the dominate land use district in the Wailea watershed. Conservation lands in this watershed are associated with the summit of Haleakala and Makena State Park along the coast. Urban and small sections of Rural land exist near the coastline and are associated with the Kihei, Wailea, and Makena communities.

4.1.3 *Mo'oloa Land Use Districts*

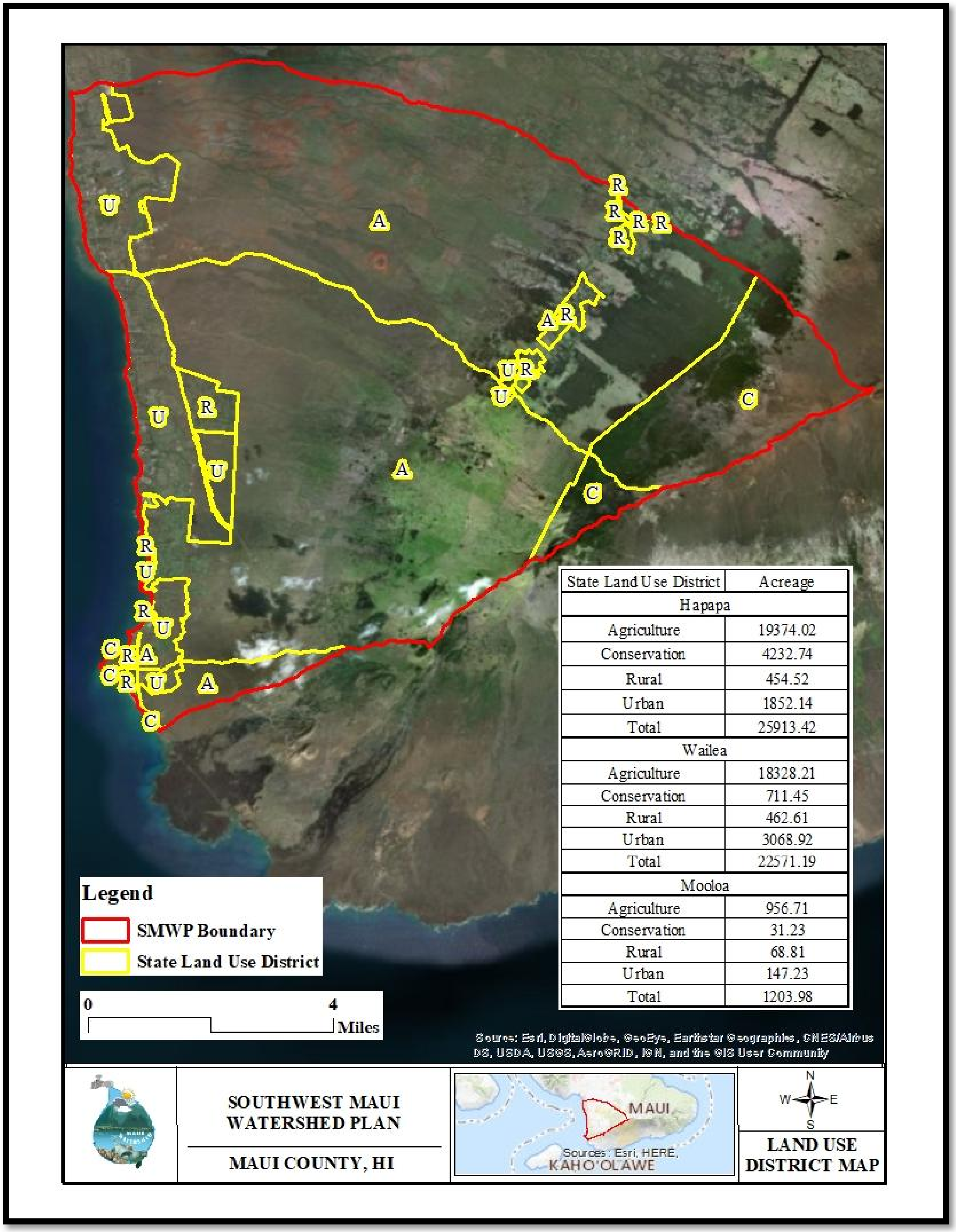
Agriculture is also the dominant land used district in this watershed. Conservation lands associate with Makena State Park also exist along the coastline. The Urban area is primarily a golf course while the Rural area is also associated with Makena State Park.

Table 3 offers a breakdown of the various State Land Use Districts in each watershed.

Table 3. State Land Use Districts by Sub-Watershed

Watershed	State Land Use District								
	Agriculture		Conservation		Rural		Urban		Total
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres
Hapapa	19374	74.76	4232.74	16.33	454.52	1.75	1852.14	7.15	25913.4
Wailea	18328.2	80.9	711.45	3.14	462.61	2.04	3068.92	13.55	22655.2
Mo‘oloa	956.71	79.46	31.23	2.59	68.81	5.72	147.23	12.23	1203.98

Figure 7. State Land Use Districts for the Hapapa, Wailea, and Moʻoloa Watersheds



State Land Use District	Acreage
Hapapa	
Agriculture	19374.02
Conservation	4232.74
Rural	454.52
Urban	1852.14
Total	25913.42
Wailea	
Agriculture	18328.21
Conservation	711.45
Rural	462.61
Urban	3068.92
Total	22571.19
Mooloa	
Agriculture	956.71
Conservation	31.23
Rural	68.81
Urban	147.23
Total	1203.98

4.2 Land Cover Types

There are nine land cover types that exist within the Hapapa, Wailea, and Moʻoloa watersheds. These include Residential, Commercial and Services, Cropland and Pasture Lands, Herbaceous Rangeland, Shrub and Brush Rangeland, Mixed Rangeland, Evergreen Forest Land, Transitional Areas, and Other Urban or Built-up Land. Of these cover types, the majority of the land in all three watersheds is Shrub and Brush Rangeland. Table 4 below breaks down the land cover types by watershed within the Southwest Maui Watershed Plan.

Table 4. Land Cover for the Hapapa, Wailea, and Moʻoloa Watersheds

Landcover	Land Use Description	Acreage
Hapapa		
11	Residential	819.67
12	Commercial and Services	227.45
21	Cropland and Pasture	2925.4
31	Herbaceous Rangeland	90.68
32	Shrub and Brush Rangeland	14718.96
33	Mixed Rangeland	1654.32
42	Evergreen Forest Land	5390.81
76	Transitional Areas	67
Total		25894.28
Wailea		
11	Residential	835.08
12	Commercial and Services	336.85
17	Other Urban or Built-up Land	355.48
21	Cropland and Pasture	7212.75
31	Herbaceous Rangeland	17.94
32	Shrub and Brush Rangeland	11613.16
33	Mixed Rangeland	827.57
42	Evergreen Forest Land	1148.03
76	Transitional Areas	248
Total		22594.86
Moʻoloa		
11	Residential	0.41
21	Cropland and Pasture	157.52
32	Shrub and Brush Rangeland	1041
Total		1198.93

Presently, most of the forested lands in the watershed are used for recreational (hiking, hunting, etc.) and some limited silvicultural (timber production) purposes. The forest reserves in the higher elevations and most of the private forests consist of planted and invasive non-native species. Historically, these forested lands were used for gathering and cultural practices. The land cover was predominantly a native koa/dryland forest complex.

Currently, the Cropland and Pasturelands in the watershed are used for grazing cattle, homesteads, and growing food crops. A large seed corn farm, using R-1 reclaimed water, is located at 300' elevation near Keokea Gulch above Pi'ilani Highway. These farmlands were traditionally used for food crops and foraging, with the protective cover of a native dryland forest.

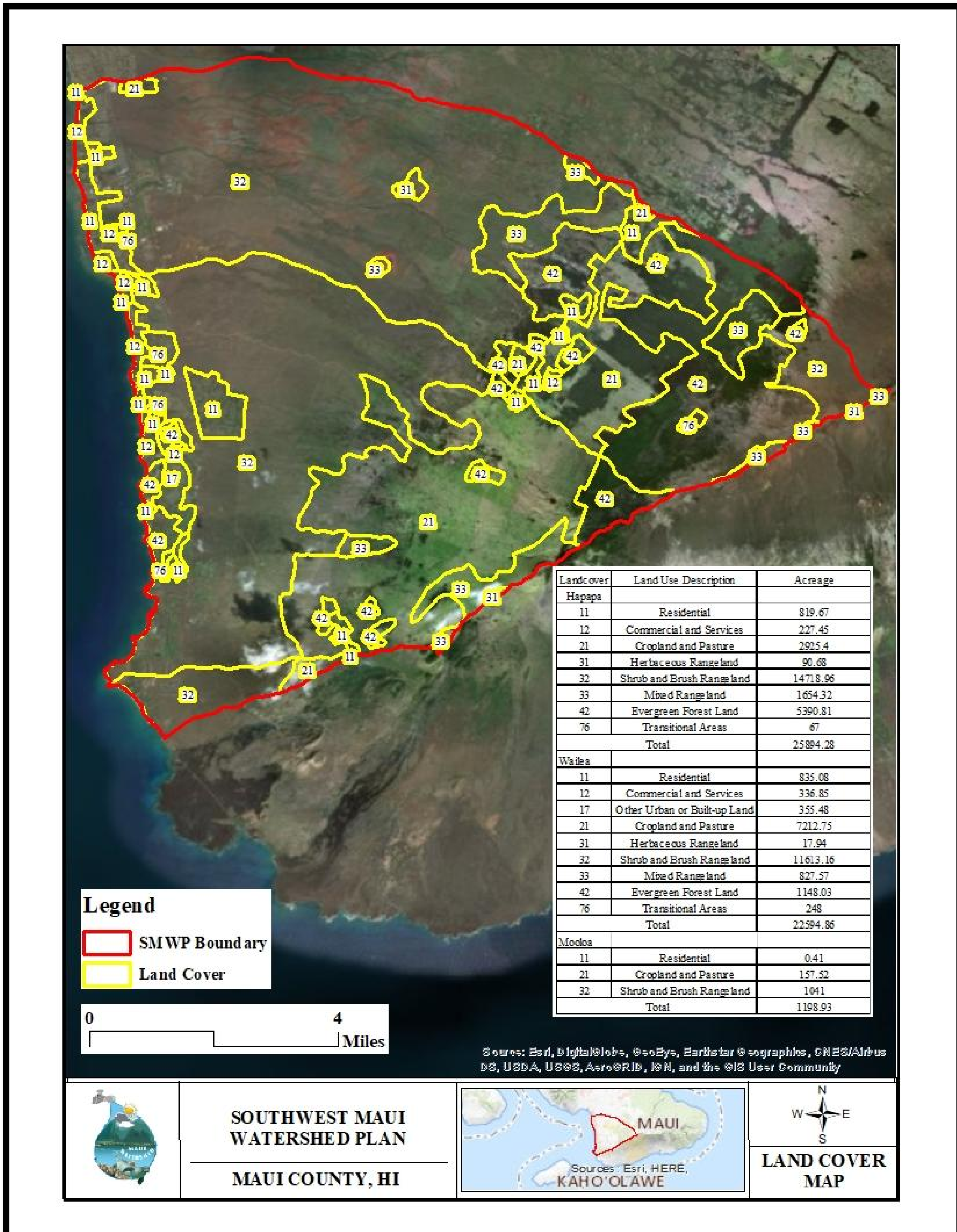
The Kula Stormwater Reclamation Study Existing Conditions report (Mink, & Yuen, 2010) reviewed estimates of cropland acreage in the Kula area. The Upcountry Maui Watershed Plan (NRCS, 1997) estimated that there were nearly 400 acres of cleared cropland irrigated with water supplied by the Upper Kula Water System. Of the 400 acres, about 175 are in cultivation and irrigation at any one time. In 2003, the Maui County Farm Bureau found more than 600 acres of cropland in the Upper Kula area, with reported increases in protea and fruit orchards.

The open grazing lands in the watershed are now mainly used by livestock (cattle, sheep, and goats) and wild game (deer and pigs) and are covered with non-native grasses, trees, shrubs, kiawe, and some native trees and shrubs. In the past, this area was covered with a multi-species native dryland forest (wiliwili, awikiwiki, ilima, etc.).

Residential, Commercial and Other Urban Built-up Land uses in the Kihei, Wailea, and Makena urban/resort areas of the watershed consist of residential, commercial, resort, and public areas. The land cover is mostly irrigated, non-native landscaping, and impervious surfaces. Long ago, native fishing and farming settlements along the shoreline included food gathering on the reef, beach, inland ponds, and coastal fish ponds. There are remnants of fishponds along the south Maui coast and an active fishpond restoration near the outlet of Kulanihako'i Gulch. The land cover in these coastal areas consisted of native dryland forest, dune complexes, and wetlands. Remnants of the dryland forest, dunes, and wetlands remain, despite the existing development.

The Land Cover map (Figure 8) was produced from the Office of Planning, State of Hawaii GIS layer. This data consists of historical land use and land cover classification data that was based primarily on the manual interpretation of 1970's and 1980's aerial photography. Secondary sources included land use maps and surveys. There are 21 possible categories of cover type.

Figure 8. Land Cover for the Hapapa, Wailea, and Mo'oloa Watersheds



Landcover	Land Use Description	Acreage
Hapapa		
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	Total	22594.86
Mooloa		
11	Residential	0.41
21	Cropland and Pasture	157.52
32	Shrub and Brush Rangeland	1041
	Total	1198.93

4.2.1 *Wetland Losses*

According to data presented by Terrell Erickson (Erickson, NRCS 2002), Hawaii has lost tens of thousands of acres of wetlands. USFWS estimated 31% of the coastal wetlands were lost during the 1970's to 1990's. Wetlands in Kihei were determined to have decreased from 199 acres in 1965 to 83 acres in 2001 (including 7.3 acres of mitigation). These wetland losses occur due to development and from aquifer drawdown.

Figure 9. Kihei Wetlands 1991-2000 (Erickson, 2004)

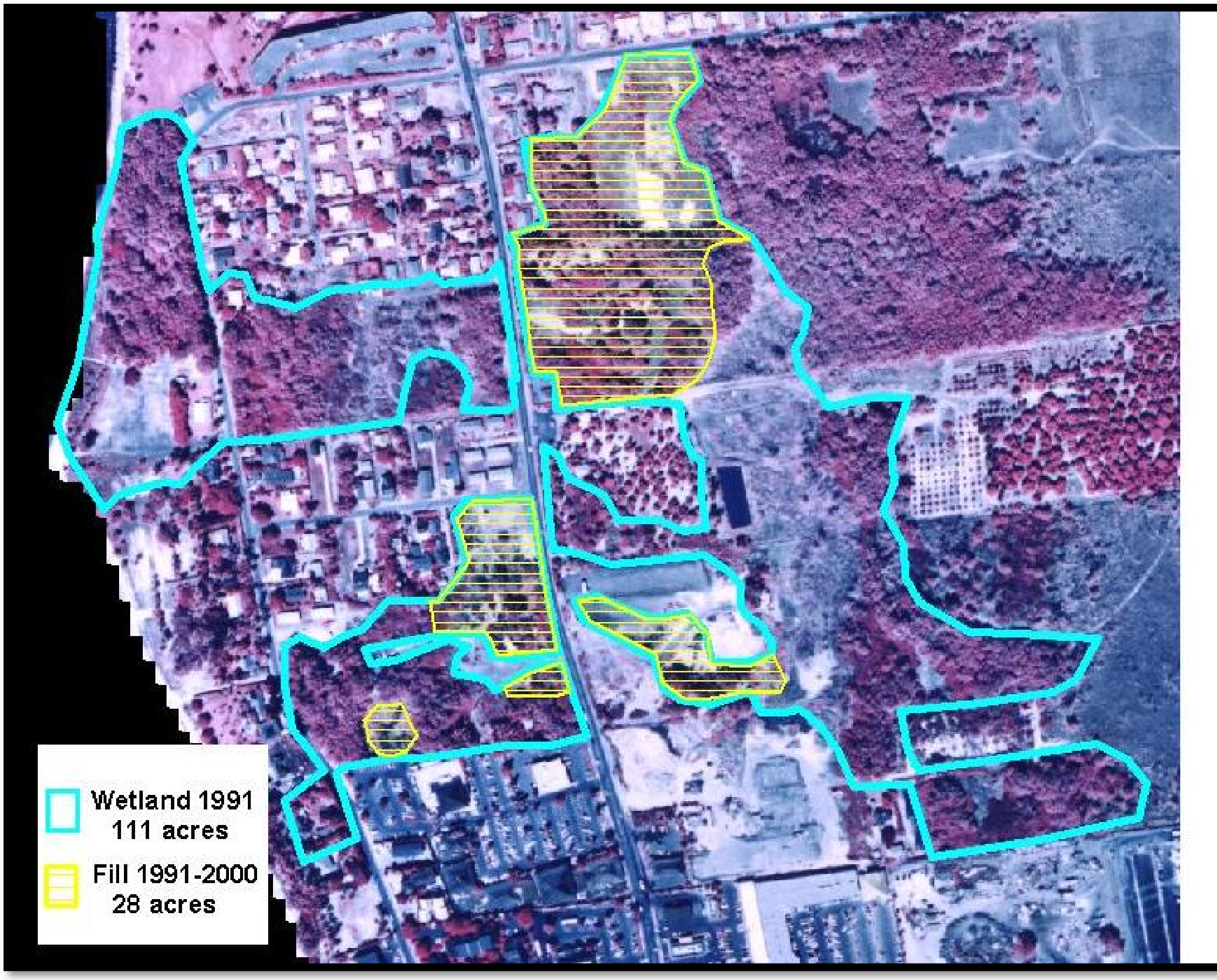


Figure 10. Kihei Wetlands 1965 (Erickson, 2004)

Note: Areas outlined do not represent surveyed lines or wetland USACE regulatory delineation.

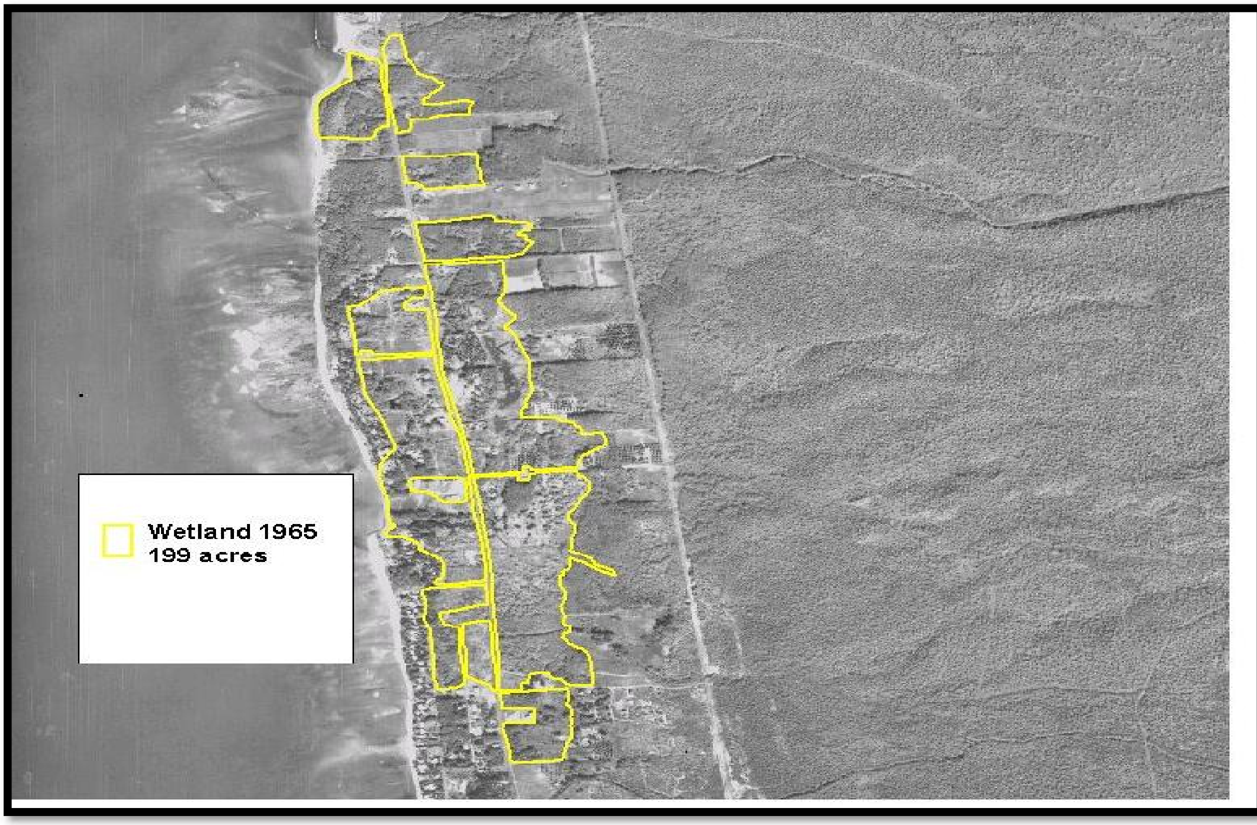
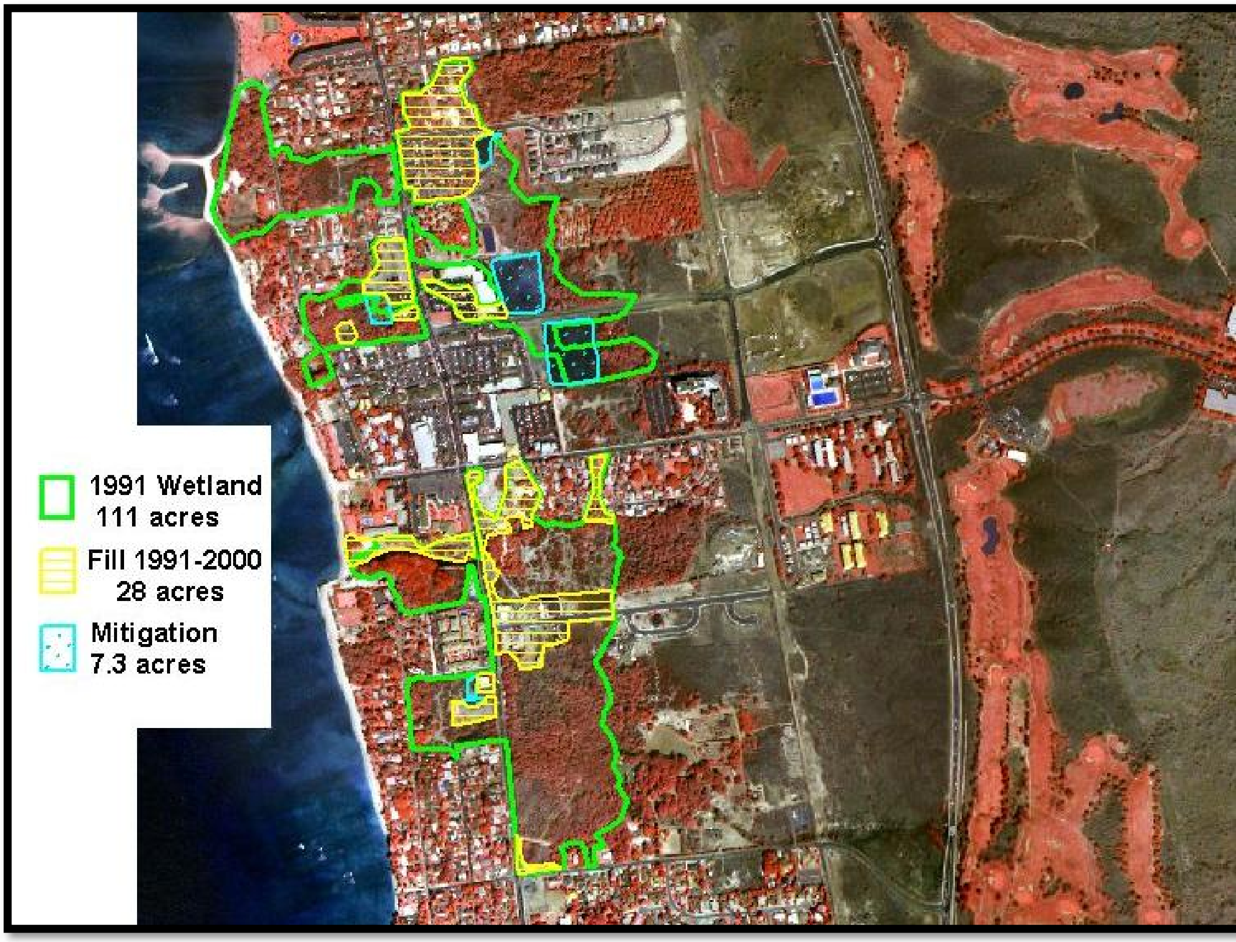


Figure 11. Wetland Losses in Kihei 1991-2000 with mitigation (Erickson, 2004)
Note: Areas outlined do not represent surveyed lines or wetland USACE regulatory delineation.



These wetland losses negatively affect the watershed twofold. First, wetlands act as natural flood retention basins during stormwater events. As streams discharge into the wetlands that exist along the coastline, stormwater fans out and is distributed throughout these wetlands before continuing on to the ocean. As stormwater enters these wetlands, it slows allowing for sediment to drop out of suspension. In addition, wetland vegetation absorbs nutrients and traps sediment in the water.

Wetlands also have a direct subsurface connection to the aquifer. As wetlands receive stormwater, they are able to recharge aquifer levels as this water slowly percolates downwards. A 2004 review of the Kamaʻole Aquifer Unit reported that approximately 4.5 million gallons of groundwater are pumped out of the aquifer every day through various wells serving golf courses and resorts. Additional smaller wells are located throughout the urban corridor (Waimea Water Services, Inc., June 2004).

4.2.2 *Fire Risks*

Extremely windy conditions and aging infrastructure make powerline corridors vulnerable ignition sources for wildfires. While a wildfire prevention and mitigation strategy is not included in this document, the loss of vegetation and subsequent erosion resulting from wildfires is well documented in this area, and every effort should be made to prevent their occurrence in collaboration with Maui Electric Company.

The Hawaii Wildfire Management Organization (HWMO) is a 501(c)(3) non-profit working in Hawaii to protect the environment from wildfire damage. Its goals are to prevent wildfires, mitigate for their impacts, aid in post-fire recovery, and to provide for a collaborative environment. In 2016, HWMO made the following movie discussing the recent Maʻalaea wildfires and their effects on water quality in the watershed:
(https://www.youtube.com/watch?time_continue=18&v=ZtsG5fP-Z9Y)

After fires are extinguished, restoration activities should be coordinated and targeted to quickly stabilize newly burned areas with appropriate planting. Techniques such as hydro mulching with native plants, which have been piloted in West Maui by the Puʻu Kukui Watershed Preserve (https://www.puukukui.org/) have potential application in this regard, but further refining of the methods is needed within dry land contexts as well as further study of the overall ecological response of plant communities and vegetation regrowth following fires in this particular area.

4.2.3 *Government and Large Land Ownership*

This dataset was created using the TMK Parcel shapefiles from the counties of Honolulu, Kauai, Maui, and Hawaii. The "MajorOwner" field was queried for all private landowners owning a cumulative land area of at least 1,000 acres *per island*, as well as those parcels owned by government agencies (public lands). All land owners with "MajorOwner" = "other" were excluded. The largest landowners in the planning area are ʻUlupalakua Ranch, Haleakala Ranch, Ka'ono'ulu Ranch, the State of Hawaii, and Department of Hawaiian Homelands (DHHL) (See Figure 12. Large Land Ownership).

4.2.4 *Impervious vs. Pervious Surface*

This is a final impervious surface layer ready for distribution through NOAA CSC. The data set is an inventory of impervious surfaces for the island of Maui for the year 2007. Impervious surfaces prevent infiltration of precipitation into the soil, disrupting the water cycle, and affecting both the quantity and quality of water resources. Impervious surfaces include manmade features such as building rooftops, parking lots, and roads consisting of asphalt, concrete, and/or compacted dirt. This data set utilized 52 full or partial Quickbird multispectral scenes, which were processed to detect impervious features on the island of Maui (Impervious Surfaces Map).

Impervious surfaces, such as those listed above, convey more runoff than pervious surfaces such as lawns, fields, shrub lands, or woods. Areas that become developed and are converted from pervious to impervious surfaces increase surface runoff. Correspondingly, increased impervious surfaces and the channelization of streams due to development convey runoff without infiltration and frequently at high speeds. The transport of water in this manner allows pollutants to be carried and deposited quickly, in large pulses, into receiving water bodies with no opportunity for filtration. The amount of infiltration into groundwater resources is reduced as impervious surfaces are increased.

The historic and recent urbanization of Southwest Maui watersheds has had an impact on the runoff and pollutant loads of the area. Prior to urbanization the coastal lowlands were covered by coastal vegetation, wetlands, sand dunes, and varying low impact agriculture lands, and were able to act as flood plain filters. Now, most of the coastal zone is urbanized and its surfaces are highly impervious and the amount of surface water runoff generated under storm events has increased when compared to historic land cover.

Figure 12. Large Land Ownership

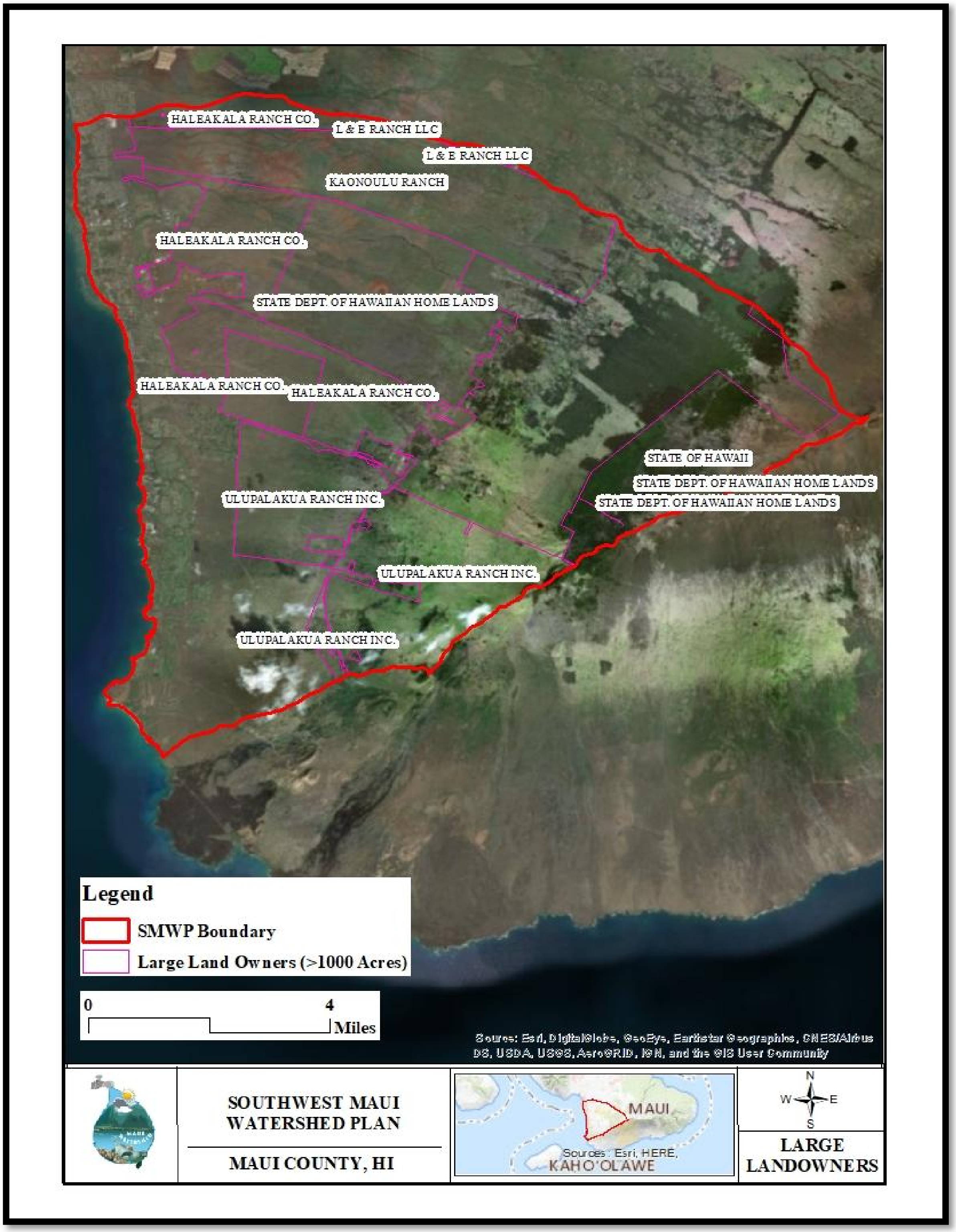
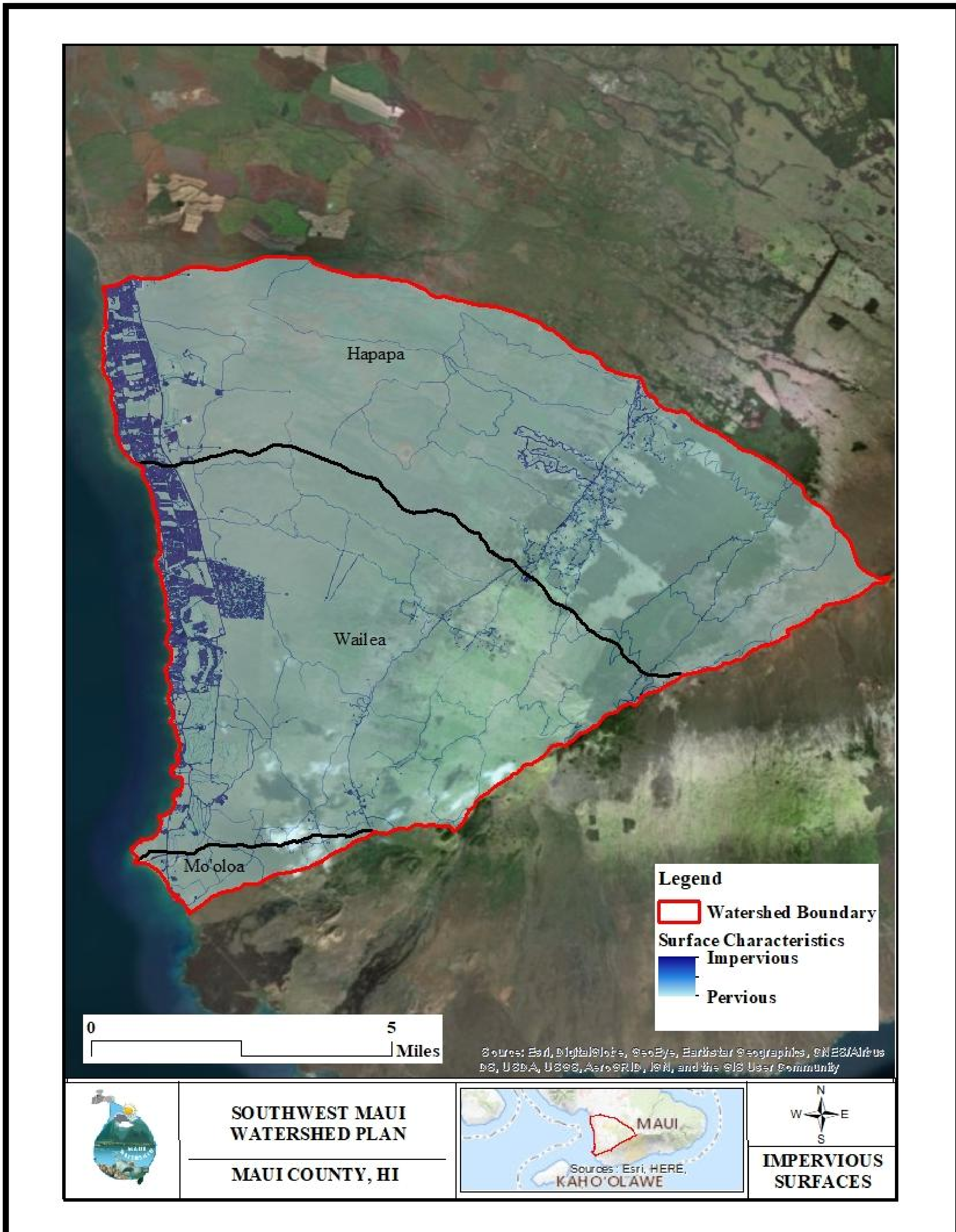


Figure 13. Impervious Surface Map

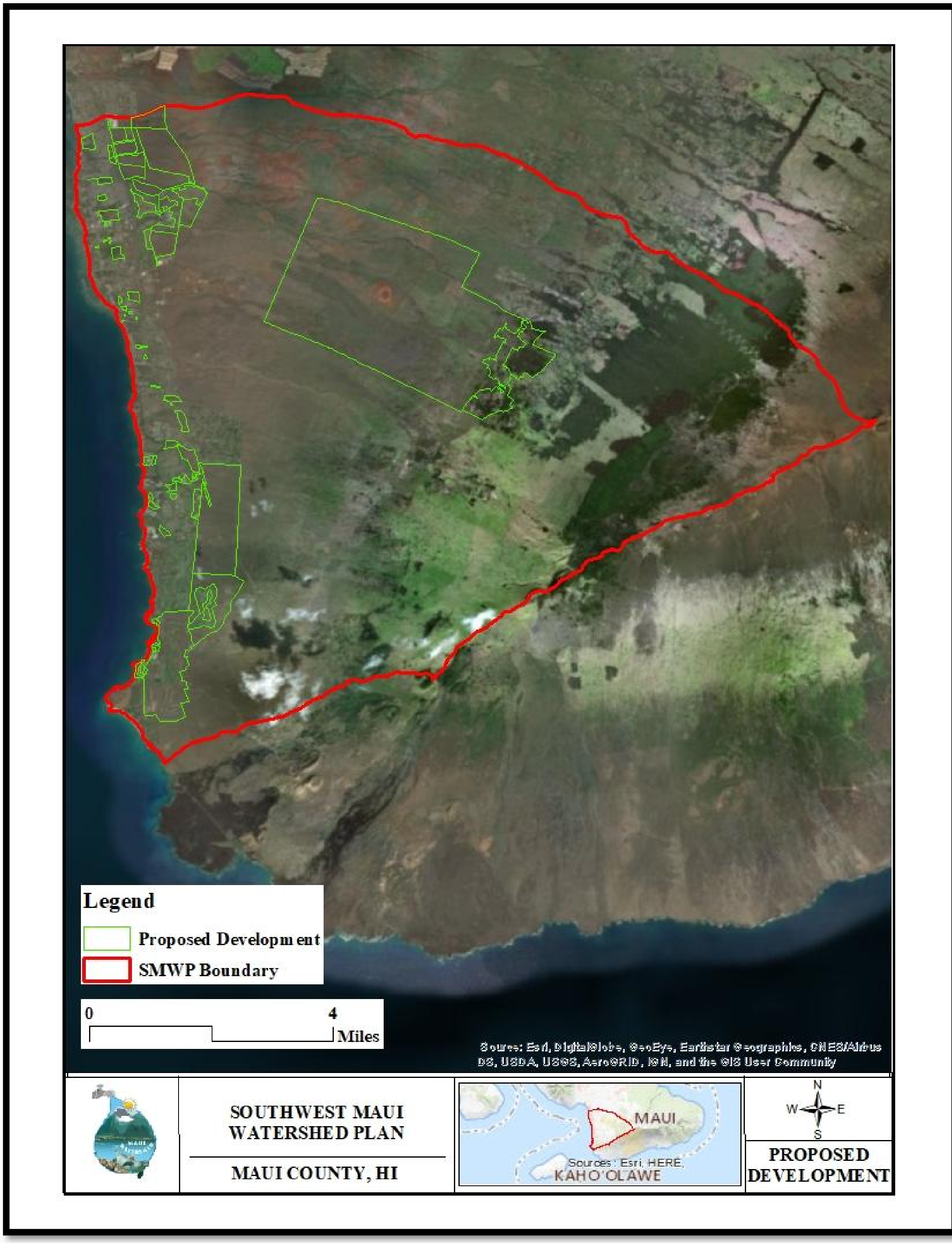


4.2.5 *Planned Development*

Future land use projects for the project area are notable because development increases the amounts of impervious surfaces within the watersheds. As stated earlier, these planned developments may affect the hydrology of the planning area and will likely increase the amount and velocity of surface runoff. It is recommended that all of these planned developments employ Low Impact Design (LID) technologies.

The County of Maui Planning Department (COM planning) reported that there are at total of 11,161 acres of planned development projects within the Southwest Maui planning area alone. This accounts for roughly 22% of the entire planning area. Some of these projects are already completed or are currently being completed, these projects total 196 acres. Projects identified as "Planned/Committed" total 8,445 acres and have the appropriate conforming Community Plan and zoning entitlements, are approved agricultural subdivisions, are approved 201G/H projects, or are Department of Hawaiian Homeland projects (6138 ac.). Projects identified as "Planned/Designated" total 961 acres and have urban or rural Community Plan designations but not the conforming zoning entitlements to proceed. Projects identified as "Planned/Proposed" total 2,010 acres and are currently lacking urban or rural Community Plan designations.

Figure 14. Planned or Proposed Development in the SMWP



4.2.6 *Historic Population Trends*

Maui Island has experienced steep population increases since 1970. In 2000, Maui Island had a population of 117,644, the third-most populous of the Hawaiian Islands, after Oahu and Hawaii (http://en.wikipedia.org/wiki/Maui). By 2010 Maui's population had risen to 144,444. The Southwest Maui watersheds have two distinct population centers: upcountry rural and coastal urban/resort. The population of residents and visitors on Maui, on any given day (*defacto population*), is projected to increase from 159,462 in 2000 to 235,582 in 2030, a gain of more than 47%. The island's resident population is expected to grow at nearly an identical rate as the de facto population, with the resident population of Maui reaching 176,687 by 2030. (Draft Maui Island Plan; Volume II- Recommendations, 2009).

In the rural uplands, most of the ranchers, farmers, and other residents live between 2,000 and 4,000 ft. elevation along the Kula Highway corridor, where water and utilities are available. The population of the Kula-Keokea area has grown from about 4,000 in 1980, to about 8,013 in 2010 (Mayer, 2010). This is a 100% increase in 30 years, or an average of 3.3% per year.

In the urban/resort areas along the ocean in Kihei, growth has been much more rapid. Kihei-Wailea-Makena had a population of 6,755 in 1980, and 26,918 in 2010. This represents close to a 300% increase in 30 years, or an average of 10% per year (Mayer, 2010). Most of the water for this area is imported from the wet Kahalawai, Iao Aquifer. This water is supplemented by a few fresh water wells, some wastewater reclamation and reuse, and many brackish irrigation wells within the watershed boundaries.

Maui Island is divided into six community plan districts. The Kihei-Makena Community Plan area has one of the fastest growing populations. Population projections from 2000-2030 for community plan areas within the watershed planning area are given in
Table 5. Community Plan Area Population Projections. It should be noted that not all of the Makawao-Pukalani-Kula Community plan area is within the watershed planning area.

Table 5. Community Plan Area Population Projections

Area	2000	2005	2010	2015	2020	2025	2030
Kihei-Makena	22,870	25,609	27,222	29,731	32,208	34,528	36,767
Makawao-Pukalani-Kula	21,571	23,176	23,862	25,360	26,792	28,077	29,294

5.0 WATERBODY CONDITIONS

5.1 Applicable Water Quality Standards

Water Quality Standards (WQS) for the State of Hawaii, including designated uses, water quality criteria, and the anti-degradation policy, are found in the Hawaii Administrative Rule (HAR) Chapter 11-54. In the Hawaii regulations, waters are first classified by waterbody type as inland waters, marine waters, or marine bottom ecosystem, and are then further categorized into classes based on ecological characteristics and other criteria. To access (HAR) Chapter 11-54: Water Quality Standards go to:
http://health.hawaii.gov/cwb/files/2013/04/Clean_Water_Branch_HAR_11-54_20141115.pdf

5.1.1 *Waterbody Types and Classes*

The three main waterbody types are inland waters, marine waters, and marine bottom ecosystems. Inland waterbody types found within the planning area include intermittent freshwater flowing streams, low wetlands, brackish or saline standing waters, coastal wetlands, and estuaries. Marine waterbody types found within the planning area include embayments, open coastal waters, and oceanic waters. Marine bottom ecosystems receiving drainage from planning area watersheds include sand beaches, lava rock shoreline, marine pools, protected coves, reef flats, and soft bottom.

These waterbody types encompass diverse aquatic ecosystems. The uses of these waters will vary along with the type of aquatic organisms each supports. These waterbody types are grouped into classes, and beneficial uses are designated for each waterbody class.

5.1.2 *Designation of Water Class and Beneficial Uses in Hawaii*

Specific waterbodies are assigned to classes based on both waterbody characteristics (e.g. marine or saline, standing or flowing) and other considerations described in the state's anti-degradation policy, such as outstanding natural resource, or important economic or social development. Class determinations are made in accordance with provisions of the water quality law, HAR §11-54. Some waterbodies are specifically named and assigned a class, while for most waterbodies the determination is made based on the class description.

Table 6. Waterbody Classes and Designated Uses

Designated Uses	**Inland Waters**			**Marine Waters**		**Marine Bottom Ecosystem**	
	Class 1a	Class 1b	Class 2	Class AA	Class A	Class I	Class II
Natural Waters							
Native Aquatic Life							
Aquatic Life							
Recreation							
Aesthetics							
Wildlife							
Drinking Water							
Food Processing							
Agricultural Water Source							
Industrial Water Source							

Designated Uses	Inland Waters			Marine Waters		Marine Bottom Ecosystem	
	Class 1a	Class 1b	Class 2	Class AA	Class A	Class I	Class II
Shipping	Not designated	Not designated	Designated	Not designated	Not designated	Not designated	Not designated

Legend:	
Use is designated for class	(shaded)
Use is not designated for class	(hatched)

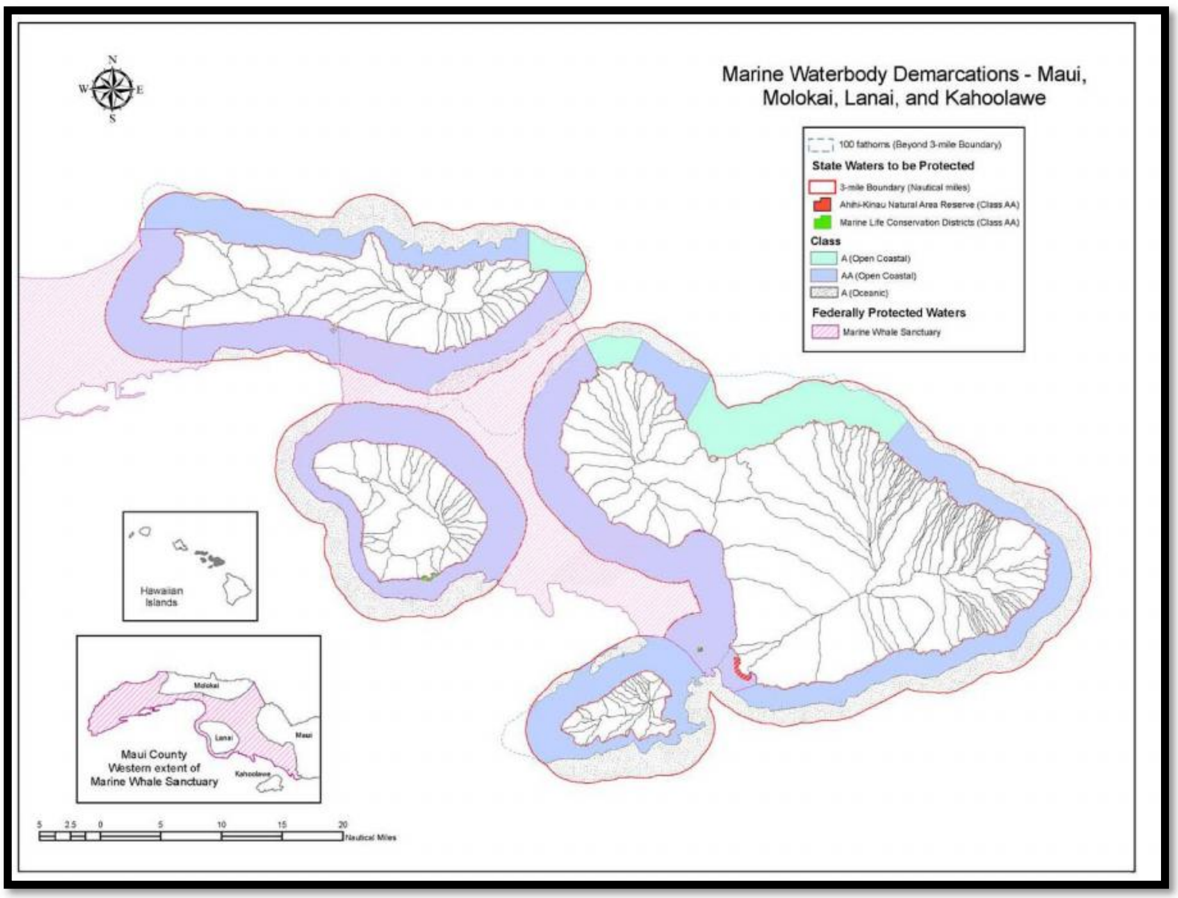
Inland Water Classes

Inland waters within the SMWP area include numerous intermittent flowing streams and stream systems, Ka’ono’ulu Estuary, and coastal wetlands.

Marine Water Classes

The open coastal waters of the Mo‘oloa watershed at Makena are included as named Class AA waters. The receiving waters for drainages from the remainder of the watershed planning area include open coastal and oceanic marine waters within the Hawaiian Islands Humpback Whale National Marine Sanctuary. These waters may be considered Class AA by virtue of being in a Federal Marine Sanctuary.

Figure 15. Marine Waterbody Demarcations for Maui County



HAR §11-54-3(c) (1) states: “It is the objective of class AA waters that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions. To the extent practicable, the wilderness character of these areas shall be protected." The uses to be protected in Class AA waters are:

- Oceanographic research
- The support and propagation of shellfish and other marine life
- Conservation of coral reefs
- Wilderness areas
- Compatible recreation
- Aesthetic enjoyment

The classification of any water area as Class AA shall not preclude other uses of the waters which are compatible with these uses, objectives, and in conformance with the criteria applicable to them.

Marine Bottom Ecosystem Classes

HAR §11-54-7 describes the classes of marine bottom types. For sandy beaches, the Northwest Hawaiian Islands are Class I; all other beaches in the state are Class II.

5.1.3 *Water Quality Criteria*

Basic criteria are applied to all classes of waters, and specific criteria are assigned to some, but not all classes. Within a class, the specific criteria may not apply to all waterbody types. The regulations do not provide specific criteria for uses for all waterbody types. Therefore, the regulations provide a nexus between waterbody class and use, but not between use and criteria. An exception is that recreational waters are defined and recreational uses are tied to bacterial criteria in the water quality standards.

Basic Criteria

The basic criteria apply to all waters (HAR §11-54-4). These criteria include narrative statements for controlling substances, including materials that settle or float, or that can have toxic or other undesirable effects. The narrative criteria include that all waters should be free of "deleterious substances sufficient to be toxic or harmful to human, animal, plant, or aquatic life, or in amounts to interfere with any beneficial use of the water." A translator for these narrative criteria is contained within the regulation in the requirement that waters be free from pollutants in concentrations exceeding acute and chronic toxicity and human health standards (expressed as average criteria concentrations at specified durations). There are also provisions translating the narrative criteria in terms of toxicity testing (bioassay) results.

Specific Criteria

For some waterbody types, there are specific narrative or numeric criteria. There are specific criteria for inland waters (HAR §11-54-5), marine waters (HAR §11-54-6), marine bottom types (HAR §11-54-7), and recreational areas (HAR §11-54-8).

5.1.4 *Numeric Criteria for Water Column Chemistry*

Numeric criteria for water column chemistry for marine waters are expressed for wet and dry conditions and as values not to be exceeded by the geometric mean, more than ten percent of the time and more than two percent of the time. The Kaonoulu Estuary sampling location is designated as an inland waterbody and does not have separate wet and dry water quality criteria. Table through 11 provide the applicable numeric criteria for water column chemistry in inland waters (streams and estuaries) and marine waters (open coastal and oceanic) within the SMWP area (Source HAR§11-54, 2014)

Table 7. Inland Waters - Specific Water Quality Criteria for Streams

Parameter	Hawaii State Water Quality Standards HAR §11-54-5.2(b)					
	Geometric Mean (Not to Exceed)		Not to Exceed > 10% of time		Not to Exceed > 2% of time	
	wet	dry	wet	dry	wet	dry
Nitrate+Nitrite (as N) (µg/L)	70.0	30.0	180.0	90.0	300.0	170.0
Nitrogen, Total (µg/L)	250.0	180.0	520.0	380.0	800.0	600.0
Phosphorus, Total (µg/L)	50.0	30.0	100.0	60.0	150.0	80.0
Total Suspended Solids (mg/L)	20.0	10.0	50.0	30.0	80.0	55.0
Turbidity (NTU)	5.0	2.0	15.0	5.5	25.0	10.0

Notes: Wet Season = November 1 through April 30; Dry Season = May 1 through October 31;

Table 8. Specific Water Quality Criteria for Estuaries (except Pearl Harbor)

Parameter	Hawaii State Water Quality Standards HAR §11-54-5.2(d)(1)		
	Geometric Mean (Not to Exceed)	Not to Exceed > 10% of time	Not to Exceed > 2% of time
Nitrogen, Total (µg/L)	200.00	350.00	500.00
Ammonia (as N) (µg/L)	6.00	10.00	20.00
Nitrate+Nitrite (as N) (µg/L)	8.00	25.00	35.00
Phosphorous, Total (µg/L)	25.00	50.00	75.00
Chlorophyll a (µg/L)	2.00	5.00	10.00
Turbidity (NTU)	1.5	3.00	5.00

Table 9. Specific Marine Water Quality Criteria for Open Coastal Waters

Parameter	Hawaii State Water Quality Standards HAR §11-54-6(b)					
	Geometric Mean (Not to Exceed)		Not to Exceed > 10% of time		Not to Exceed > 2% of time	
	wet	dry	wet	dry	wet	dry
Nitrogen, Total (as N) (µg/L)	150.00	110.00	250.00	180.00	350.00	250.00
Ammonia (as N) (µg/L)	3.50	2.00	8.50	5.00	15.00	9.00
Nitrate+Nitrite (as N) (µg/L)	5.00	3.50	14.00	10.00	25.00	20.00
Phosphorus, Total (µg/L)	20.00	16.00	40.00	30.00	60.00	45.00
Chlorophyll a (µg/L)	0.30	0.15	0.90	0.50	1.75	1.00
Light Extinction Coef (k units)	0.20	0.10	0.50	0.30	0.85	0.55

Parameter	Hawaii State Water Quality Standards HAR §11-54-6(b)					
	Geometric Mean (Not to Exceed)		Not to Exceed > 10% of time		Not to Exceed > 2% of time	
Turbidity (NTU)	0.50	0.20	1.25	0.50	2.00	1.00

Notes: Wet Season When open coastal waters receive **more** than three million gallons per day of fresh water discharge per shoreline mile; Dry Season = When open coastal waters receive **less** than three million gallons per day of fresh water discharge per shoreline mile

Table 10. Marine Water Quality Criteria for Oceanic Waters

Parameter	Hawaii State Water Quality Standards HAR §11-54-6(c)		
	Geometric Mean (Not to Exceed)	Not to Exceed > 10% of time	Not to Exceed > 2% of time
Nitrogen, Total (µg/L)	50.00	80.00	100.00
Ammonia (as N) (µg/L)	1.00	1.75	2.50
Nitrate+Nitrite (as N) (µg/L)	1.50	2.50	3.50
Phosphorus, Total (µg/L)	10.00	18.00	25.00
Chlorophyll a (µg/L)	0.06	0.12	0.20
Turbidity (NTU)	0.03	0.10	0.20

Table 11. Recreational Criteria for all Sate Waters

Parameter	Hawaii State Water Quality Standards HAR §11-54-8		
	Geometric Mean (Not to Exceed)	Statistical Threshold Value Not to Exceed > 10% of time	Not to Exceed > 2% of time
Enterococcus (cfu's/100ml)	35	130	NA

Notes: Enterococcus content shall not exceed a geometric mean of 35 colony forming units (cfu's) per 100 milliliters over any 30-day interval. A statistical threshold value (STV) of 130 colony forming units shall be used for enterococcus. The STV value shall not be exceeded by more than ten percent of samples taken within the same 30-day interval in which the geometric mean is calculated.

5.1.5 *Criteria for Marine Bottom Ecosystems*

The criteria for Marine Bottom Ecosystems are found at HAR §11-54-7. There are no named Class I reefs or reef communities, or any named Class II harbors within the SMWP area. The marine bottoms of the Hawaiian Islands Humpback Whale National Marine Sanctuary may be considered Class I depending on the interpretation of the language, "in preserves, reserves, sanctuaries, and refuges established by the department of land and natural resources under chapter 195 or chapter 190, HRS, or similar reserves for the protection of marine life established under chapter 190, HRS, as amended; or in refuges or sanctuaries established by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service."

It is the objective of Class I Marine Bottom Ecosystems that they remain as nearly as possible in their natural pristine state, with an absolute minimum of pollution from any human-induced source. Uses of marine bottom ecosystems in this class are passive human uses, without intervention or alteration, allowing the perpetuation and preservation of the marine bottom in a most natural state, such as for non-consumptive scientific research (demonstration, observation, or monitoring only), non-consumptive education, aesthetic enjoyment, passive activities, and preservation.

5.2 Clean Water Act Sections 303(d) and 305(b)

The Hawaii State Department of Health (DOH) is obligated by the Clean Water Act (CWA) Sections (§) 303(d) and 305(b) to report on the State's water quality on a two-year cycle. The CWA §305(b) requires states to describe the overall status of water quality statewide, and the extent to which water quality provides for the protection and propagation of a balanced population of shellfish, fish, and wildlife, and allows recreational activities in and on the water. The CWA §303(d) requires states to submit a list of waters that do not attain applicable water quality standards, plus a priority ranking of impaired waters for Total Maximum Daily Loads (TMDL) development based on the severity of pollution and the uses of the waters. As noted earlier, on the island of Maui, the Hui O Ka Wai Ola assists the DOH with the collection of water quality data.

The IR informs the public on the status of marine and inland (streams and estuaries) water bodies and serves as a planning document to guide other CWA programs. The 2018 IR incorporates data collected from November 1, 2015 to October 31, 2017 to provide an updated snapshot of water body conditions throughout the state and carries over the assessment results from previous IRs. Impaired waters—waters that do not meet the State's water quality standards (WQS)— in the IR may be targeted for further monitoring activities to develop TMDLs, to plan and evaluate CWA §319 nonpoint source (NPS) pollution control projects and set requirements for National Pollutant Discharge Elimination System (NPDES) permits and §401 Water Quality Certifications (WQCs). The IR not only identifies areas in need of restoration but serves as a baseline to validate the State's efforts to improve water quality and eventually delist impaired waters that have been rehabilitated.

5.2.1 *2018 State of Hawaii Integrated Water Quality Report - Clean Water Act §305(b) Assessments and §303 (d) List of Impairments*

In the most recent Integrated Water Quality Report (IR) (Hawaii Department of Health, 2018), assessment results for each waterbody were assigned one of five categories based on water quality standards attainment decisions, made in accordance with Hawaii's 2004 Priority Ranking and Listing/Delisting Criteria and 2006 Rules of Logic:

Category 1 - all designated uses attained.

Category 2 - one or more designated use attainments.

Category 3 - insufficient data for determining designated use attainment and water quality impairment.

Category 4 - one or more designated use non-attainments or water quality impairments; but no TMDL needed:

4a = A TMDL to address a specific segment/pollutant combination has been approved or established by EPA.

4b = A use impairment caused by a pollutant is being addressed by the state through other pollution control requirements.

4c = A use is impaired, but the impairment is not caused by a pollutant.

Category 5 - one or more designated use non-attainments or water quality impairments.

Chapter 3 of the IR includes the Water Body Assessment Decisions table that contains the assessment results for all waters, inland and marine (see Table 12 below for the Hapapa, Wailea, and Mo'oloa watersheds). Waterbodies entered in the table are not necessarily reflective of all waters of the state; rather, they indicate areas where sampling has taken place, and areas of higher incidence of human contact. Areas not shown in the table do not have any sampling data available and are considered to be in category “3”, more information needed to make a decision. Future reporting cycles may add waterbodies as necessary. Tools utilized for the assessment in the 2018 reporting cycle included chemical analyses, bacteriological analyses, and Hawaii Stream Bioassessment Protocol scores (for native aquatic life - Class 1 streams).

5.2.2 *Impaired Waterbodies within the SMWP Area*

There are 29 coastal water quality monitoring sites and one estuary site within the SMWP area that were included in the 2018 IR Report (See Figures 16-19 and Table 12). Of these, only three sites where prior data had been confirmed were sampled with enough frequency during the two-year timeframe used to generate the report (11/1/2015 to 10/31/2017) to update the report from 2016 findings. The rest of the sites were either not sampled, or sampled with a frequency less than required to update the 2018 IR report.

The estuary site is located at the Kaonoulu Estuary and is associated with the outfall of Kulanihakoi Gulch where it meets coastal waters. This site has been assessed for TN, Nitrate+Nitrite (inorganic nitrogen as NO^3+NO^2), and turbidity. During past assessments, this site did not attain water quality standards for any of these parameters. Insufficient data points for ammonia and Chlorophyll *a* were available at this site to adequately assess their attainment status.

Of the 20 coastal water quality sites that have been assessed for enterococcus within the SMWP boundary, all attained State water quality standards for bacteria. Thirteen of the 29 sites were sampled for nutrients and of these, all sites failed to attain water quality standards for either TP, TN, Nitrate+Nitrite, or Ammonia (NH_4). Of the 18 sites sampled for turbidity, none attained State water quality standards. Of the 18 sites tested for Chlorophyll *a*, none attained State water quality standards. Twenty waterbodies and 65 individual water quality parameters require TMDL studies. In addition, 25 waterbodies lack adequate data for assessment of 115 different parameters. All of the 20 impaired waterbodies requiring a TMDL for one or more pollutants in the SMWP area are listed as Low Priority for TMDL development. (Hawaii Department of Health, 2018) (See Figures 16-19 and Table 12).

Recreational health is assessed by measuring enterococci, the recommended EPA fecal indicator bacteria for coastal recreational waters. It has been proposed that enterococcus makes its way into the watershed through various means including through the Kihei wastewater treatment plant injection wells, from ungulate feces, and faulty/overflowing cesspools. Data reviewed from the Hawaii Department of Health Clean Water Branch IR s from 2018, 2016 and 2014 show that all sites where enterococcus was measured, the locations attained water quality standards for the fecal indicator.

Ecosystem health is assessed by comparing nutrients and other parameters to the applicable water quality criteria. The nutrient parameters assessed in the SMWP include total nitrogen (TN), nitrate + nitrite (NO_3+NO_2), ammonium-nitrogen (NH_4), and total phosphorus (TP).

Total nitrogen is equal to the sum of organic nitrogen, ammonia, and inorganic nitrogen. It should be noted that the term ammonia refers to two chemical species which are in equilibrium in water (NH3, un-ionized and NH4+, ionized). Ammonia and ammonium forms of N are usually only elevated near sources of human or animal waste discharges. Nitrate + nitrite nitrogen is also known as inorganic nitrogen. Inorganic nitrogen is typically associated with the use of fertilizers for agricultural operations, golf courses, and residential lawn maintenance. Organic nitrogen can originate from various sources including organic fertilizers, detritus, human and animal waste, and algae in the water column (Wall, 2013). When too much nitrogen is present in water, algae blooms can occur. These blooms reduce dissolved oxygen that fish and other aquatic and marine organism need to survive. Some types of algae are toxic and can cause respiratory issues, rashes, neurological impairments, and stomach or liver illness. In addition, high levels of nitrates in drinking water can cause illnesses such as blue baby syndrome in infants and can even result in death (Beaudet, et al., 2014).

Total phosphorus is found in agricultural fertilizers, manure, and organic wastes in sewage and industrial wastewater. An abundance of phosphorus in surface waters can lead to an abundance of plankton and algae that consume large amounts of dissolved oxygen and may ultimately lead to eutrophication within the system. Too much phosphorus can also be detrimental to human health, causing kidney damage and osteoporosis. Phosphorus and orthophosphates are not typically very mobile in stormwater. Phosphorus fertilizers typically enter streams with sediment transport and increase as TSS increases (Oram, 2014).

Testing for algal growth in coastal waters is conducted by measuring chlorophyll *a* concentration in the water. Chlorophyll *a* is the most abundant type of chlorophyll within photosynthetic organisms and gives plants their green color. Higher concentrations generally indicate poor water quality. Abundance of algal growth is maintained by high nutrient concentrations.

Turbidity is caused by particles suspended or dissolved in water that scatter light making the water appear cloudy or murky. Particulate matter can include sediment - especially clay and silt, fine organic and inorganic matter, soluble colored organic compounds, algae, and other microscopic organisms. High turbidity can negatively affect the aesthetic quality of coastal waters. It can also disrupt gill function in fish and particulate matter can smother reefs.

A review of data presented in recent IR reports shows that for those sites where data was collected, turbidity, total nitrogen, inorganic nitrogen, ammonia, total phosphorus, and Chlorophyll *a* are major parameters of concern in the Hapapa watershed.

In the Wailea watershed, inorganic nitrogen, turbidity and Chlorophyll *a* are of equal concern. While less data exists on total nitrogen, ammonia, and total phosphorus, the data that exists on Chlorophyll *a* suggests that these nutrients may be high in this watershed as well.

Similarly, within the Moʻoloa watershed, turbidity and Chlorophyll *a* are parameters of concern, suggesting suspended solid runoff from erosion during storm events and high nutrient loading causing algal blooms in near-shore coastal waters. It should be noted that wherever sampled, enterococcus levels attained State water quality standards throughout the SMWP boundary.

The locations where water quality sampling has taken place in the Hapapa, Wailea and Moʻoloa watersheds are depicted in Figures 16-19.

Table 12. 2018 IR Assessments for the Hapapa, Wailea, and Moʻoloa Watersheds in the SMWP

Site Name	Waterbody Type	Enterococcus	TN	NO^3+NO^2	NH_4	TP	Turbidity	Chl *a*	Category	TMDL Priority
HAPAPA WATERSHED									2,3,5	LOW
Kihei Coast - Kaonoulu Estuary	Estuary	**	N	N	**	**	N	**	3,5	LOW
Kalama Beach Co. Park (Beach)	Coastal	A	N	N	N	N	N	N	2,5	LOW
Kalama Beach Co. Park (Cove)	Coastal	A	N	N	N	N	N	N	2,5	LOW
Kalepolepo Beach	Coastal	A	**	**	**	**	**	**	2,3	**
Kalepolepo (Waimahaihai)	Coastal	A	A	N	N	N	N	N	2,5	LOW
Kihei Coast - Kalepolepo	Coastal	**	N	N	**	**	N	N	3,5	LOW
Kihei Coast - Kulanihakoi	Coastal	**	N	N	N	**	N	N	3,5	LOW
Kihei Coast - Lipoa-South	Coastal	**	**	**	**	**	N	N	3,5	LOW
Kihei Coast - Luana Kai	Coastal	**	N	N	N	**	N	N	3,5	LOW
Mai Poina Oe Iau Beach Co. Park (Kihei North Station)	Coastal	A	**	**	**	N	N	N	2,3,5	LOW
Waipuilani	Coastal	A	**	**	**	**	**	**	2,3	**
WAILEA WATERSHED									2,3,5	LOW
Kamaole Beach #1	Coastal	A	A	N	N	A	N	N	2,5	LOW
Kamaole Beach #2	Coastal	A	**	**	**	**	N	N	2,3,5	LOW
Kamaole Beach #3	Coastal	A	**	**	**	**	N	N	2,3,5	LOW
Keawakapu Beach	Coastal	A	**	**	**	**	N	N	2,3,5	LOW
Kihei Coast-Cove Park	Coastal	**	N	N	**	**	N	N	3,5	LOW
Kihei Boat Ramp	Coastal	**	N	N	**	**	N	**	3,5	LOW
Keawakapu (2)	Coastal	**	**	N	**	**	**	N	3,5	LOW
Maui Coast	Coastal	**	**	N	**	**	N	N	3,5	LOW
South Kamaole II	Coastal	**	**	N	**	**	N	N	3,5	LOW
Makena Landing	Coastal	A	**	**	**	**	**	**	2,3	**
Maluaka	Coastal	A	**	**	**	**	**	**	2,3	**
Mokapu	Coastal	A	**	**	**	**	**	**	2,3	**

Site Name	Waterbody Type	Enterococcus	TN	NO³+NO²	NH_4	TP	Turbidity	Chl *a*	Category	TMDL Priority
Palauea	Coastal	A	**	**	**	**	**	**	2,3	**
Polo Beach	Coastal	A	**	**	**	**	**	**	2,3	**
Poolenalena	Coastal	A	**	**	**	**	**	**	2,3	**
Puu Olai (Small Beach)	Coastal	A	**	**	**	**	**	**	2,3	**
Ulua Beach	Coastal	A	**	**	**	**	N	N	2,3,5	**
Wailea Beach	Coastal	A	**	**	**	**	N	**	2,3,5	LOW
MO‘OLOA WATERSHED									3	**
Oneloa Beach (Big Beach-Makena Beach Station)	Coastal	A	**	**	**	**	N	N	2,3,5	LOW

** Insufficient Data

A=Attained/N=Not Attained

Category 2=Some Use Attained; Category 3= Not Enough Data to Evaluate; Category 5=At Least One Use Not Attained, TMDL Needed

Figure 16. Hapapa Watershed DOH CWB Water Quality Sampling Locations with Impairments

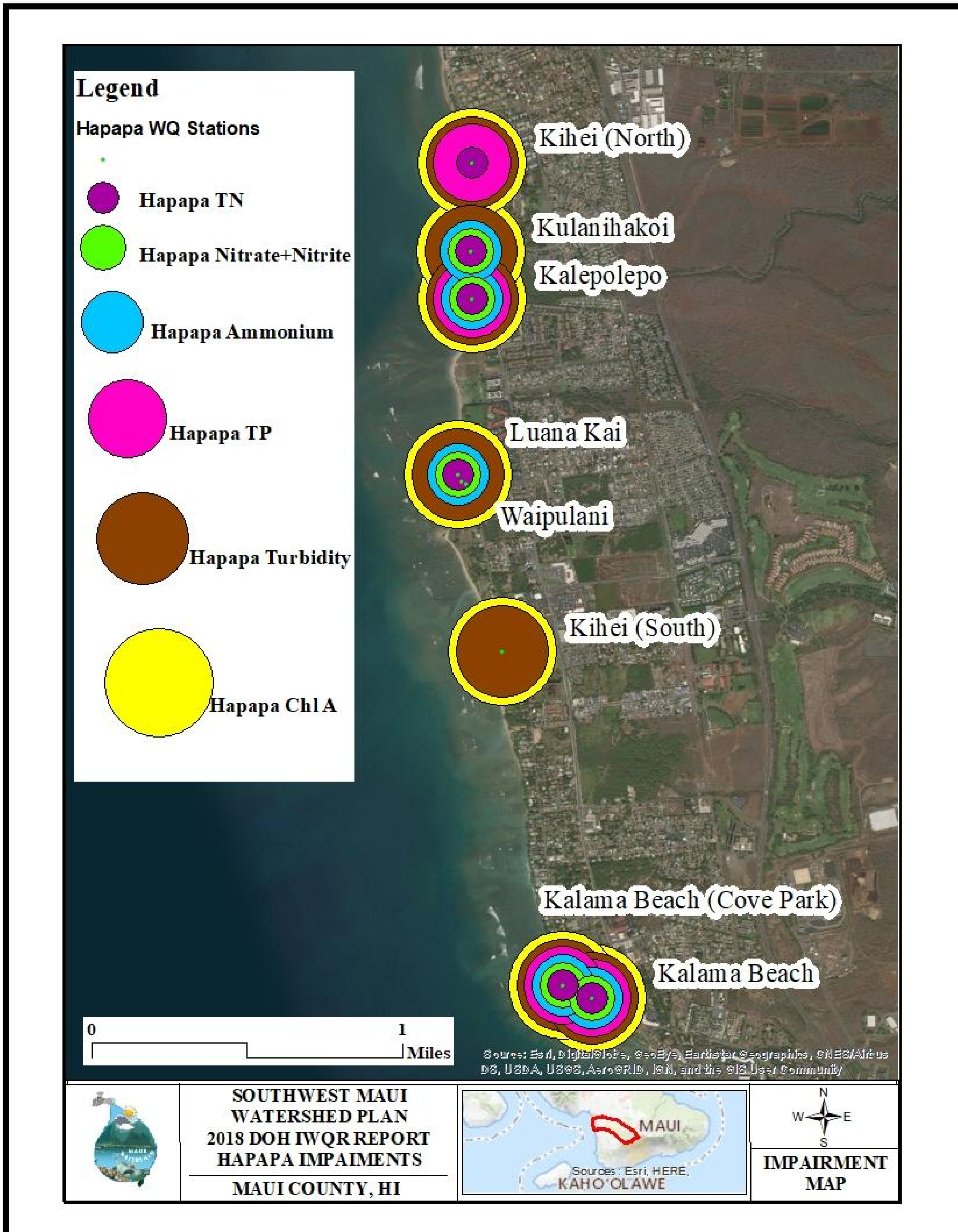


Figure 17. Wailea Watershed DOH CWB WQ Sampling Stations with Impairments (Map 1 of 2)

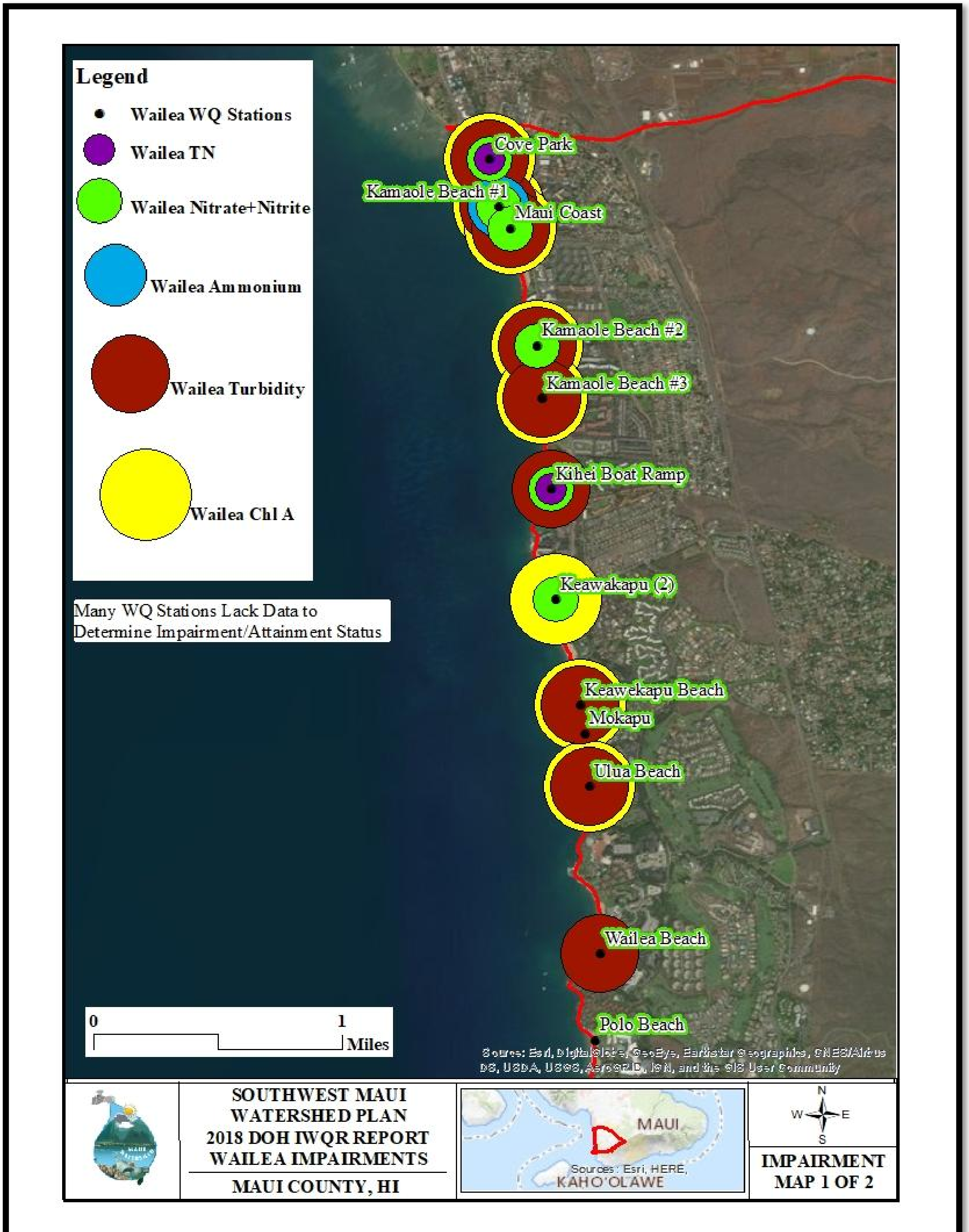


Figure 18. Wailea Watershed DOH CWB WQ Sampling Stations with Impairments (Map 2 of 2)

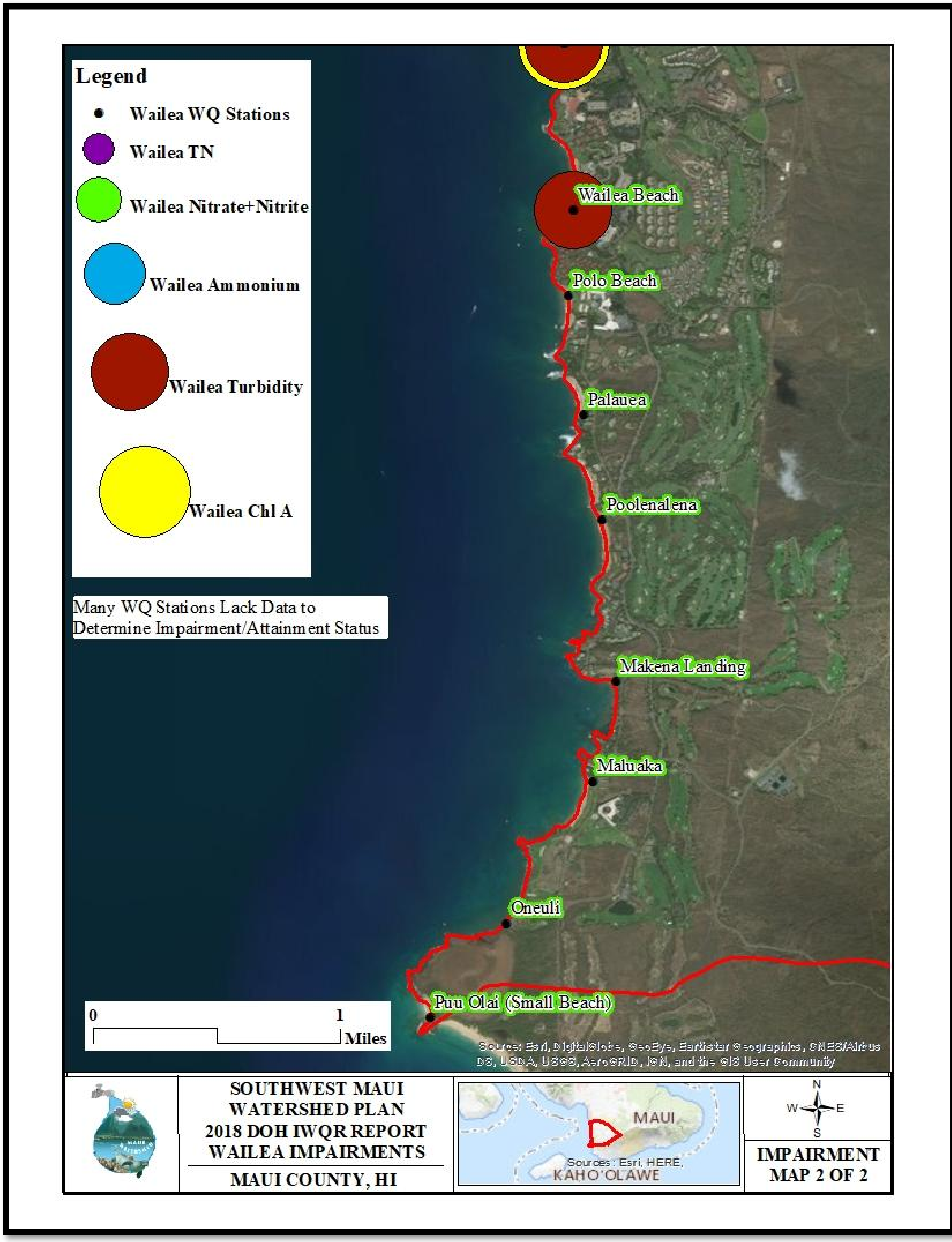
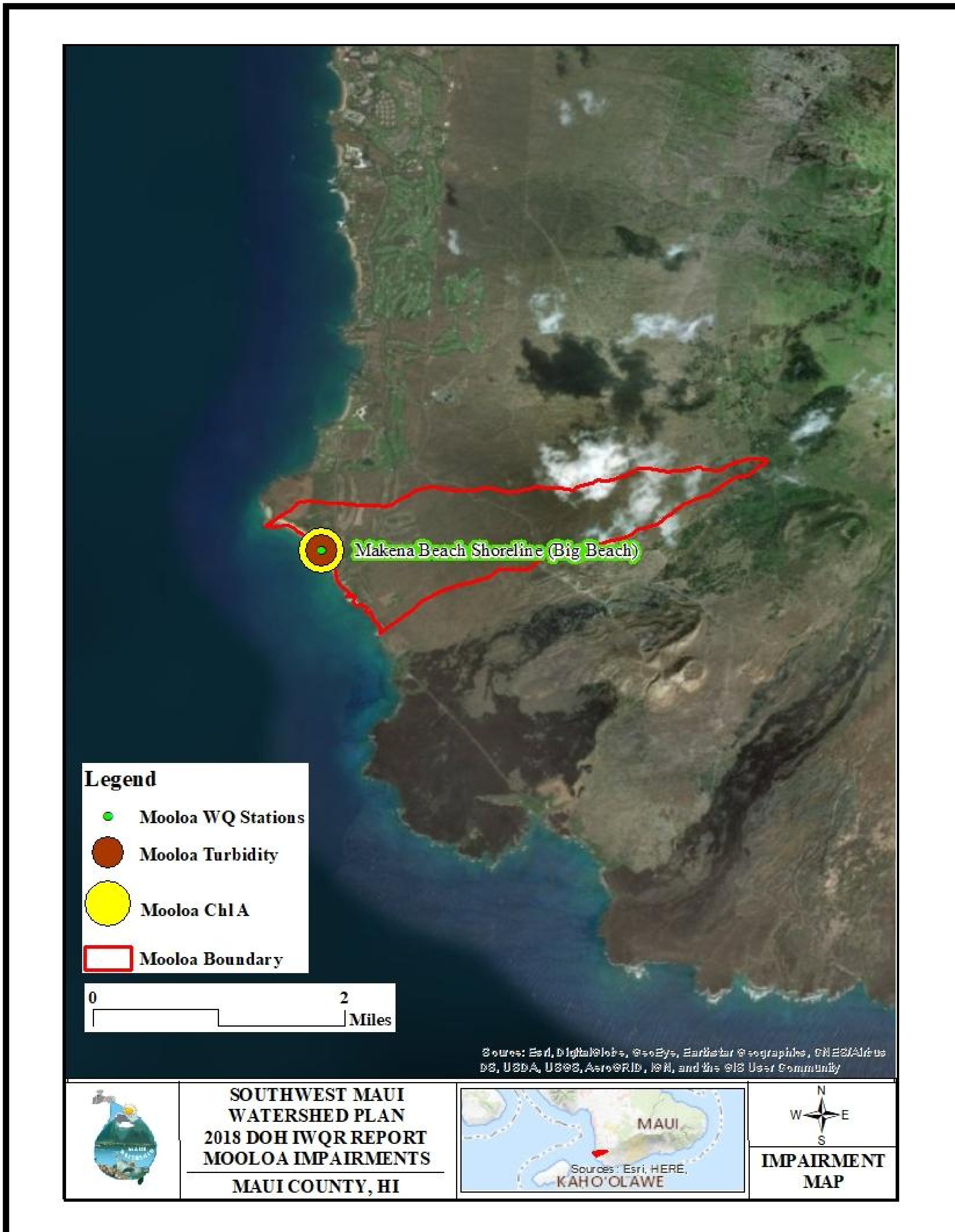


Figure 19. Mo'oloa Watershed DOH CWB Water Quality Sampling Stations



In an effort to identify trends in water quality, the 2018 IR data was compared with the 2016 and 2014 IR reports. Relative water quality trends persisted throughout the SMWP boundary. Enterococcus measurements were within water quality standards while nutrients, turbidity, and chlorophyll a continue to be a problem.

None of the intermittent streams in the SMWP area were assessed in the 2018 Integrated Water Quality Report; therefore, status of standards attainment for these streams is unknown. Opportunistic sampling of gulches within the Hapapa watershed were performed by the SWCD during flood events to capture flow and TSS concentrations within these systems. Specifically, Kulanihakoi, Waipu'ilani and Keokea gulches were sampled due to these systems high frequency of flooding and because they are known to deposit large amounts of sediment into coastal waters after storm events.

While turbidity values were observed to be high throughout coastal waters in Wailea and Moʻoloa watersheds as well, streams and gulches discharge with less regularity and were more difficult to sample in response to storm events. Data compiled from these efforts are meant to supplement data collected by the DOH CWB on TSS loading and are presented in Table 13. High TSS concentrations in stormwater runoff directly affects turbidity levels in coastal waters. As discussed earlier, all sites sampled for sediment had measurements that were well above water quality standards for TSS with the exception of Laʻie wetland which receives water from Keokea Gulch through a series of marginal wetlands that retain and filter this water.

The method used to determine sediment load during opportunistic sampling of intermittent streams was calculated within the watersheds during heavy rain events using the equation outlined by J.R. Gray and F. Simões in their 2008 USGS contribution entitled: *Estimating Sediment Discharge*. The calculation is as follows:

$$Qs = Qw*Cs*k$$

where Qs = suspended-sediment discharge, in tons per day; Qw = water discharge, in cubic feet per second; Cs = mean concentration of suspended sediment in the cross-section in milligrams/liter; and k = a coefficient based on the unit of measurement of water discharge that assumes a specific weight of 2.65 for sediment, and equals 0.0027 in inch-pound units, or 0.0864 in SI units (https://water.usgs.gov/osw/techniques/Gray_Simoes.pdf).

Water discharge for each gulch was measured using a Price AA current meter. Relative stream area was measured assuming a uniform depth and width observed at the time and location where the flow measurement was recorded.

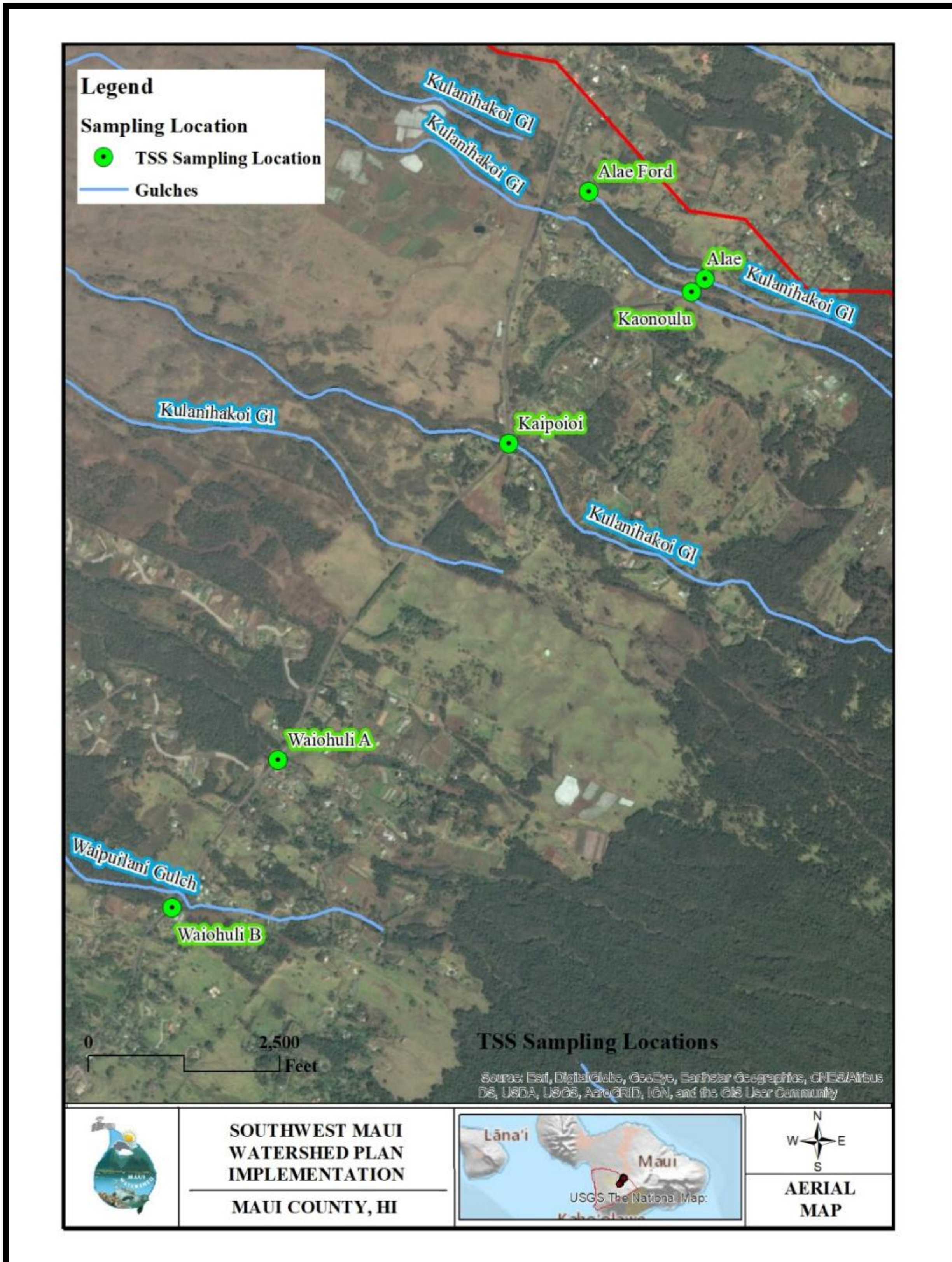
On April 30th 2017, October 23rd 2017, and February 15th 2018 rainfall was sufficient to cause flow at major gulches near the shoreline in the SMWP. Sampling was conducted at defined locations depicted in Figures 20 and 21. In addition, several gulches upcountry were also sampled. Sediment loads were calculated for these flow events using the method described above. Table 13 depicts sediment load measured at these locations during the two flow events.

Table 13. Sediment Load During April 30th 2017, October 23rd 2017, and February 15th 2018 Rainfall Events

Sample Location	Qw	Cs	K	Qs	tons per hour
	ft³/sec	TSS in mg/L	0.0027	tons per day	
April 30th, 2017					
Kulanihakoi at S Kihei	124.33	1215.58	0.0027	408.07	17.00
Kulanihakoi at Pi‘ilani	102.62	1802.64	0.0027	499.48	20.81
High Intensity Zone Downstream	1.08	45.69	0.0027	0.13	0.01
High Intensity Zone Upstream	6.17	28.21	0.0027	0.47	0.02
Keokea Downstream	2.06	393.90	0.0027	2.19	0.09
Keokea Upstream	2.59	405.79	0.0027	2.84	0.12
Alae	19.29	93.66	0.0027	4.88	0.20
Ka’ono’ulu	No flow data	55.91	0.0027	NA	NA
Kaipoioi	No flow data	443.97	0.0027	NA	NA
Waiohuli A	15.06	75.25	0.0027	3.06	0.13
October 23rd, 2017					
Kulanihakoi at S Kihei (Barely Flowing)	5.83	1966.09	0.0027	30.95	1.29
Kulanihakoi at Pi‘ilani	38.57	10870.48	0.0027	1132.04	47.17
High Intensity Zone Downstream	NA	NA	0.0027	NA	NA
High Intensity Zone Upstream	NA	NA	0.0027	NA	NA
Keokea Downstream	NA	NA	0.0027	NA	NA
Keokea Upstream	NA	NA	0.0027	NA	NA
Alae	15.32	1324.95	0.0027	54.81	2.28
Ka’ono’ulu	10.14	896.16	0.0027	24.54	1.02
Kaipoioi	12.20	5913.23	0.0027	194.78	8.12
Waiohuli A	17.63	1567.84	0.0027	74.63	3.11
February 15th, 2018					
Kulanihakoi at S Kihei	80.17	404.71	0.0027	87.61	3.65
La'ie Wetland at S. Kihei	NA	2.67	0.0027	NA	NA
Keokea at Pi‘ilani	3.25	176.97	0.0027	1.55	0.06
Waipuilani at Pi‘ilani	5.14	536.04	0.0027	7.44	0.31
Kulanihakoi at Pi‘ilani	32.65	1138.51	0.0027	100.35	4.18
High Intensity Zone Downstream	5.58	280.48	0.0027	4.23	0.18
High Intensity Zone Upstream	0.73	275.09	0.0027	0.54	0.02
Keokea Upstream	2.20	1174.15	0.0027	6.98	0.29
Keokea Downstream	2.94	946.26	0.0027	7.50	0.31

Figure 20. Hapapa Intermittent Stream TSS Sampling Locations

Figure 21. Upcountry Intermittent Stream TSS Sampling Locations



6.0 ELEMENT A – SOURCES AND CAUSES OF POLLUTANTS

The two primary sources of water pollutants in the planning area watersheds are nutrients and sediment. Nutrients may enter coastal waters through various mechanisms including shallow waste water injection wells, malfunctioning septic systems, cesspools, and the improper use of fertilizers on agricultural lands, golf courses, residential lawns and resort landscapes. An injection well can be considered a point source, whereas discharges from cesspools and septic systems are usually accounted for as nonpoint sources of pollution. Stormwater runoff from conservation lands; agricultural or industrial land uses; and urban, resort, and rural development can transport nonpoint source pollution to the ocean.

Uncontrolled stormwater runoff has many cumulative impacts on humans and the environment including:

- Flooding - Damage to public and private property
- Eroded Streambanks - Sediment clogs waterways and drainage systems, enters the ocean, kills fish and other aquatic life, and causes property loss and degradation
- Widened Stream Channels – Damage and loss of valuable property
- Sediment Filled Channels and Basins - Reduces volume for managing stormwater runoff and increases pollutant loading
- Aesthetics - Dirty water, trash and debris, foul odors, mud deposits, etc.
- Fish and Aquatic Life – Mortality, impaired health and reproduction, and tissue contamination
- Impaired Recreational Uses - Swimming, fishing, boating, diving, snorkeling, surfing, windsurfing, kite surfing, etc.
- Threats to Public Health – Contamination of drinking water, recreational waters, and fish/shellfish, and waterborne diseases
- Threats to Public Safety - Drowning or injuries occur in flood waters; debris increases hazards
- Economic Impacts – Impairments to fisheries, shellfish, ecosystems, real estate values, tourism, and recreation related businesses
- Increased Cost of Water and Wastewater Treatment - Stormwater pollution increases raw water treatment costs, reduces the assimilative capacity of water bodies (requiring greater level of wastewater treatment), and increases wastewater

treatment costs and pollutant discharge loads due to stormwater inflow and infiltration into sewage collection systems

6.1 Point Sources

6.1.1 *National Pollutant Discharge Elimination System*

The discharge of pollutants from point sources is generally regulated through the National Pollutant Discharge Elimination System (NPDES). The Clean Water Act prohibits discharge of pollutants to Waters of the US except in compliance with an NPDES permit. The Hawaii Department of Health, Clean Water Branch is delegated authority for issuance of general and individual NPDES permits. The NPDES program requires permits for the discharge of "pollutants" from any "point source" into "waters of the United States." The terms "pollutant", "point source", and "waters of the US" are found at Code of Federal Regulations (CFR) Chapter 40 Part 122.2. Point source means any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural storm water runoff (See §122.3).

There are no individual NPDES permits authorizing direct discharges of wastewater or stormwater to surface waters within the SMWP area. Given the large number of planned developments, there presumably are, or will be, a large number of construction sites permitted under either the General Permit for Stormwater Associated with Construction Activity, or individually issued NPDES permits. Although the COM Kihei Wastewater Reclamation facility (WWRF) has been assigned an NPDES permit number (HIU000102), no NPDES permit has been issued for the facility.

Stormwater runoff from construction sites greater than one acre discharging to Class A waters are regulated point sources under the State's General NPDES Permit for stormwater associated with construction activity. Discharges of stormwater associated with industrial activity to Class AA waters require an individual NPDES permit. Table 14 below lists the NPDES permits that exist within the Southwest Maui Watershed Plan boundary.

Table 14. NPDES Permits within the Southwest Maui Watershed Plan

Name	Permit Number	Owner	Permit	Type	Issued:	Expires:
Kaonoulu Market Place	HIR10D273	Pi'ilani Promenade South LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018
Maui Bay Villas	HIR10E789	Kupono Partners, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 9/28/2015	Expires on: 12/5/2018

Name	Permit Number	Owner	Permit	Type	Issued:	Expires:
Kihei Seventh-day Adventist Church and Pre-school	HIR10D024	Hawaiian Association of Seventh-day Adventist	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018
Tamura's Plaza	HIR10E704	GKT at Lipoa LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 5/6/2015	Expires on: 12/5/2018
Hokulani Golf Villas	HIR10B971	Signature Development of Hawaii LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018
Maui Research & Technology Park - Phase I/Increment I	HIR10D125	Maui R&T Partners, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018
Nu'u Aina	HIR10E554	Nu'u Aina Properties, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 11/10/2014	Expires on: 12/5/2018
Paradise Ridge Estates	HIR10C486	Paradise Ridge Limited Partnership	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018
Andaz Resort & Residences	HIR10C693	Wailea Hotel and Beach Resort, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2014	Expires on: 12/5/2019
Wailea Beach Marriott	HIR10E729	Sunstone Hawaii 3-0, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 6/24/2015	Expires on: 12/5/2018
Keala o Wailea	HIR10E638	Armstrong Development Ltd.	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 2/27/2015	Expires on: 12/5/2019

Name	Permit Number	Owner	Permit	Type	Issued:	Expires:
Makena Golf & Beach Club	HIR10E723	ATC Makena Hotel LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 6/2/2015	Expires on: 12/5/2020
Makena Farm Lots Subdivision	HIR10E685	Samuel M Garcia Jr. Trust, Ellen Frenette Garcia, and Jon E. Garcia	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 5/5/2015	Expires on: 12/5/2018
Makena South Golf Course (17th Renovations)	HIR10D187	ATC Makena S Golf, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018
Makena South Golf Course (10th-14th Renovations)	HIR10D245	ATC Makena S Golf, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018
Makena South Golf Course	HIR10D242	ATC Makena S Golf, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018
Makena Bay Club (Parcel H-1)	HIR10B787	Keaka, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018
The Hill House	HIR10E654	Yellow Brick Road, LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 3/13/2015	Expires on: 12/5/2018
Hoku O Wailea	HIR10C980	Wailea MF-7 LLC	Notice of General Permit Coverage	Form C: Storm water associated with construction activities	Issued on: 12/9/2013	Expires on: 12/5/2018

As shown in the table above, all of the active NPDES permits associated with the Southwest Maui Watershed Plan were obtained as required for construction activities. Due to the dry climate and few rainfall days in Kihei, Wailea, and Makena, sediment runoff from these construction activities is highly unlikely and is not a major contributor to sediment reaching coastal waters.

6.1.2 *Injection Wells*

An injection well (IW) is a bored, drilled or driven shaft, or a dug hole, whose depth is greater than its largest surface dimension; an improved sinkhole; or a subsurface fluid distribution system used to discharge fluids underground (40 CFR Part 144.3). Injection wells and cesspools are regulated by the USEPA under the authority of the Underground Injection Control (UIC) program, as provided by Part C of the Public Law 92-523, the Safe Drinking Water Act (SDWA) of 1974. DOH administers a separate UIC permitting program under state authority.

Twenty injection wells with UIC permits exist within the SMWP boundary. Of these, ten are used for sewage, six are used for stormwater, and four are used for other substances ranging from brine to condensate. Table 15 below lists these wells and provides information on their permit number, operator and location within the SMWP boundary.

Table 15. UIC Wells within the SMWP Boundary

Facility	Operator	TMK	Discharge Type	Well Classification	Location
6-4627.04	Ilima House lots	2-3-9-028-039	Storm Runoff	Class V, Subclass C	Not Listed
Not Listed	Lucien Charbonnier Residence	Not Listed	Other	Class V, Subclass E	Pi‘ilani Hwy. & Ohukai Rd., Kihei, Maui
6-4627.02	Kihei Commercial Center	2-3-9-001-033	Sewage	Class V, Subclass AB	Not Listed
Not Listed	Hale Kai O Kihei Association of Apartment Owners	2-3-9-008-003, 2-3-9-008-004	Sewage	Class V, Subclass AB	1310 Ulunui Road, Kihei, Maui
6-4527.01	Haggai Institute - Mid Pacific Center	2-3-9-002-084	Sewage	Class V, Subclass AB	Not Listed
6-4426.01	Kihei Wastewater Reclamation Facility	2-2-2-002-040	Sewage	Class V, Subclass AB	480 Welakahao Road, Kihei, Makawao, Maui, HI 95753

Facility	Operator	TMK	Discharge Type	Well Classification	Location
Not Listed	Ke Alii Villas Drainage Injection Well	2-3-9-020-020, 2-3-9-020-027	Storm Runoff	Class V, Subclass C	Not Listed
Not Listed	Ke Alii Kai II Subdivision Drainage Injection Well	2-3-9-019-004	Storm Runoff	Class V, Subclass C	Not Listed
Not Listed	Maui Oceanfront Days Inn	Not Listed	Other	Class V, Subclass E	Not Listed
6-4226.	The Palms at Wailea	Not Listed	Sewage	Class V, Subclass AB	3200 Wailea Alanui Dr., Kihei, Maui
6-4126.03	Wailea Beach Villas	Not Listed	Storm Runoff	Class V, Subclass C	Not Listed
6-4126.01	Grand Wailea Resort	2-2-1-008-109	Sewage	Class V, Subclass AB	3850 Wailea Alanui Rd., Wailea, Maui
6-4126.02	Kea Lani Hotel Drainage Wells	2-2-1-023-003	Storm Runoff	Class V, Subclass C	4100 Wailea Ala Nui Drive, Kihei, Maui
6-4026.01	Wailea Golf Clubhouse	2-2-1-008-092	Sewage	Class V, Subclass AB	120 Kaukahi St., Wailea, Maui
6-4026.02	Diamond Resort Wastewater Treatment Plant	2-2-1-008-042	Sewage	Class V, Subclass AB	Kalai Waa St. & Kaukahi St., Wailea, Maui
6-3826.01	Maui Prince Hotel (Drainage Wells)	2-2-1-005-086	Storm Runoff	Class V, Subclass C	5400 Makena Alanui Road, Makena, Kihei, Maui, HI 96753
Not Listed	Bak North	Not Listed	Other	Class V, Subclass E	Not Listed

Facility	Operator	TMK	Discharge Type	Well Classification	Location
Not Listed	Evans Holding Water System	Not Listed	Other	Class V, Subclass E	Not Listed
Not Listed	Ulupalakua Ranch Restrooms at Tedeschi Winery	Not Listed	Sewage	Class V, Subclass E	Not Listed
6-4221.01	Kula Hospital	2-2-2-004-077	Sewage	Class V, Subclass A	100 Keokea Place, Kula, Makawao, Maui, HI 967909

Currently, all DOH CWB monitoring sites are attaining water quality standards for enterococcus, meaning sewage from UIC injection wells is not currently a water quality issue. Stormwater wells may affect turbidity but only four wells exist and stormwater runoff through surface water conveyances would have a much larger effect on turbidity in coastal waters than the injection wells.

6.2 Estimating Nonpoint Source Pollutant Loads

6.2.1 NSPECT Modeling

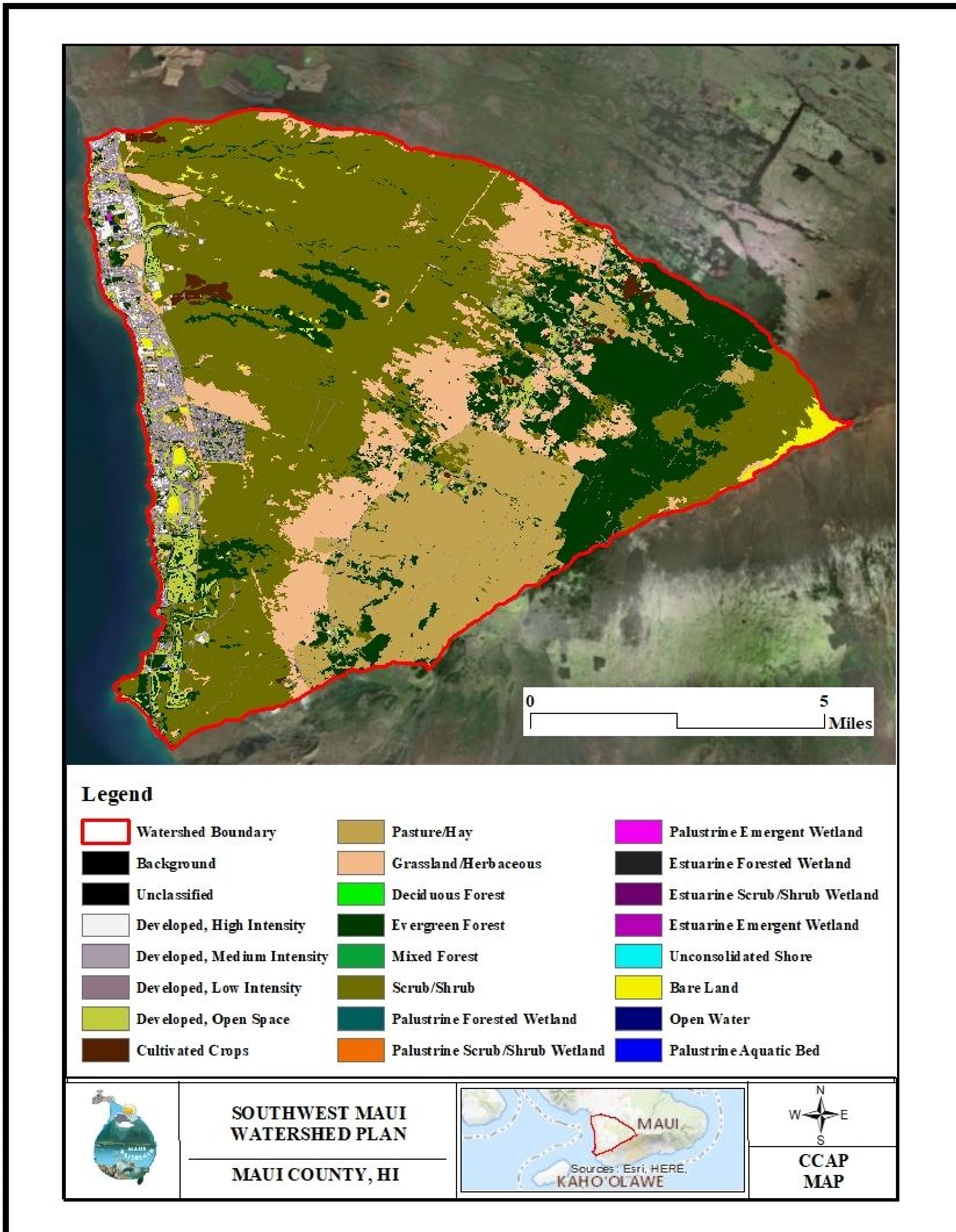
NSPECT is an informative spatial tool developed by the National Oceanic Atmospheric Administration (NOAA) Coastal Services Center (CSC) for watershed managers and planners (Eslinger, 2012). It is a GIS-based application that models potential water-quality impacts from non-point source pollution and erosion. The model inputs include soil maps from U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Soil Survey Geographic Database, 30m Digital Elevation Maps (DEMs) from the United States Geological Survey (USGS), annual precipitation from the Parameter- elevation Regressions on Independent Slopes Model (PRISM) group, and Coastal Change Analysis Program (CCAP) land cover. Each land cover type has an associated impervious surface co-efficient.

The SWCD ran the NSPECT model for sediment, nitrogen and phosphorus delivery throughout the Southwest Maui Watershed. The model provides estimates of both accumulated sediment and nutrients in the gullies and gulches making their way towards the ocean and localized sediment and nutrient contributions based on the model inputs listed above.

It should be noted that NSPECT has known limitations with accuracy and precision when modeling for erosion in wet, steep slopes like those in the upper reaches of the Southwest Maui Watershed. This is due, in part, to a lack of available data collection from inaccessible mountainous areas. Inputs to NSPECT, such as rainfall days and soil erosion factors, are often very different throughout the landscape being modeled and may not be accurately represented by the input data.

In addition, general CCAP designations can skew data. As an example, CCAP data used in this effort designates the golf courses as “Developed Open Space” and does not consider that these lands may contribute additional nutrients to the watershed. SWCD recognizes that there are other models available, namely InVEST, and that there are trade-offs between cost-efficiency and higher accuracy (more robust modeling methods and procedures can be costly and time-intensive).

Figure 22. SMWP Coastal Change analysis Program (CCAP) Land Use Map



The CCAP produces a standardized dataset of land cover and land change information for the coastal regions of the US. Land cover and land change maps provide an inventory of coastal intertidal areas, wetlands, and adjacent upland areas. These data are updated every 5 years, which allows end users to monitor changes in land cover over time.

Table 16 lists the quantitative data resulting from the NSPECT modeling effort. In addition, the results of the NSPECT modeling exercises for localized sediment, nitrogen and phosphorus are included as figures (Figures 23-25). These figures are offered as qualitative data serving as visual representations of the various sediment and nutrient sources as water flows toward coastal waters. When compared with the CCAP data depicted in Figure 22, the relationship between pollutant sources and land use become evident.

The Localized Sediment Map (Figure 23) depicts several areas within the watershed where sediment transport is particularly high. The NSPECT model predicts heavy amounts of localized sediment for both Bare Land and Pasture/Hay land uses at higher elevations where mountain slopes are fairly steep. In the lower reaches of the watershed, where the slope of Haleakala changes from being extremely steep into the various gulches and gullies ultimately leading to the coastline, localized sediment availability is also relatively high on lands classified as Bare Land. In addition, the Grassland/Herbaceous land use associated with mid-level agricultural lands are listed as elevated areas of localized sediment. NSPECT values for sediment ranged from a high of 2, 330 metric tons in areas such as upcountry pasturelands to virtually no localized sediment throughout the majority of the watershed.

The Localized Nitrogen and Phosphorus Maps (Figures 24 and 25) depict high amounts of these nutrients (highest amount being 2.68mg/l and 0.48mg/l respectively) in upcountry pasturelands and cultivated crops associated with agricultural lands mauka of Pi‘ilani Highway. In addition, elevated nutrient concentrations were calculated for the highly developed land associated with the urban corridor of Kihei, Wailea, and Makena.

Table 16. NSPECT Localized Pollution Values

NSPECT Localized Pollution			
Non-Point Source Pollution	Nitrogen (mg/l)	Phosphorus (mg/l)	Sediment (Mg)
Minimum Value	0.96	0.049	0
Maximum Value	2.68	0.48	2,330

Figure 23. Localized Sediment in the SMWP Based on NSPECT Modeling

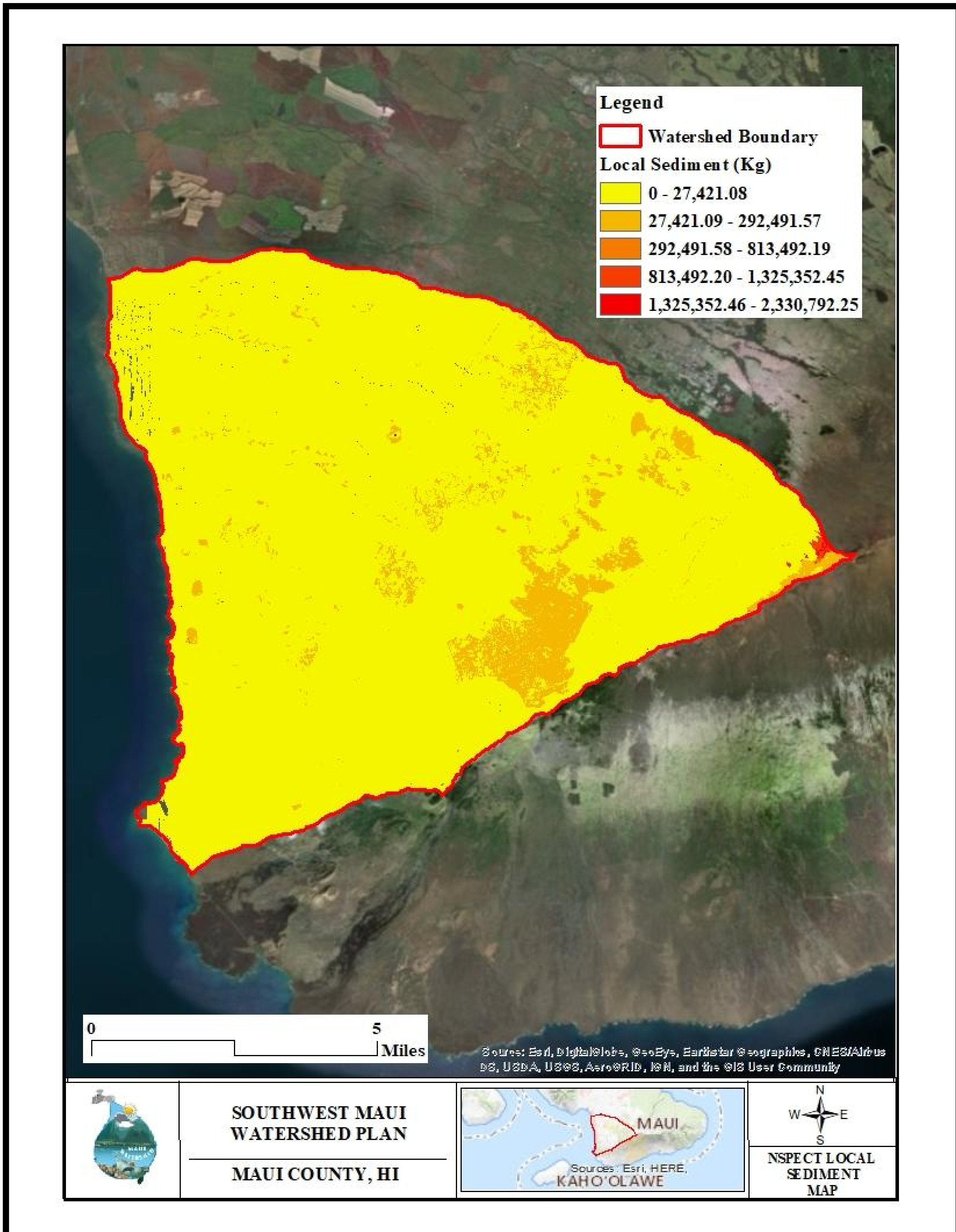


Figure 24. Localized Nitrogen in the SMWP Based on NSPECT Modeling

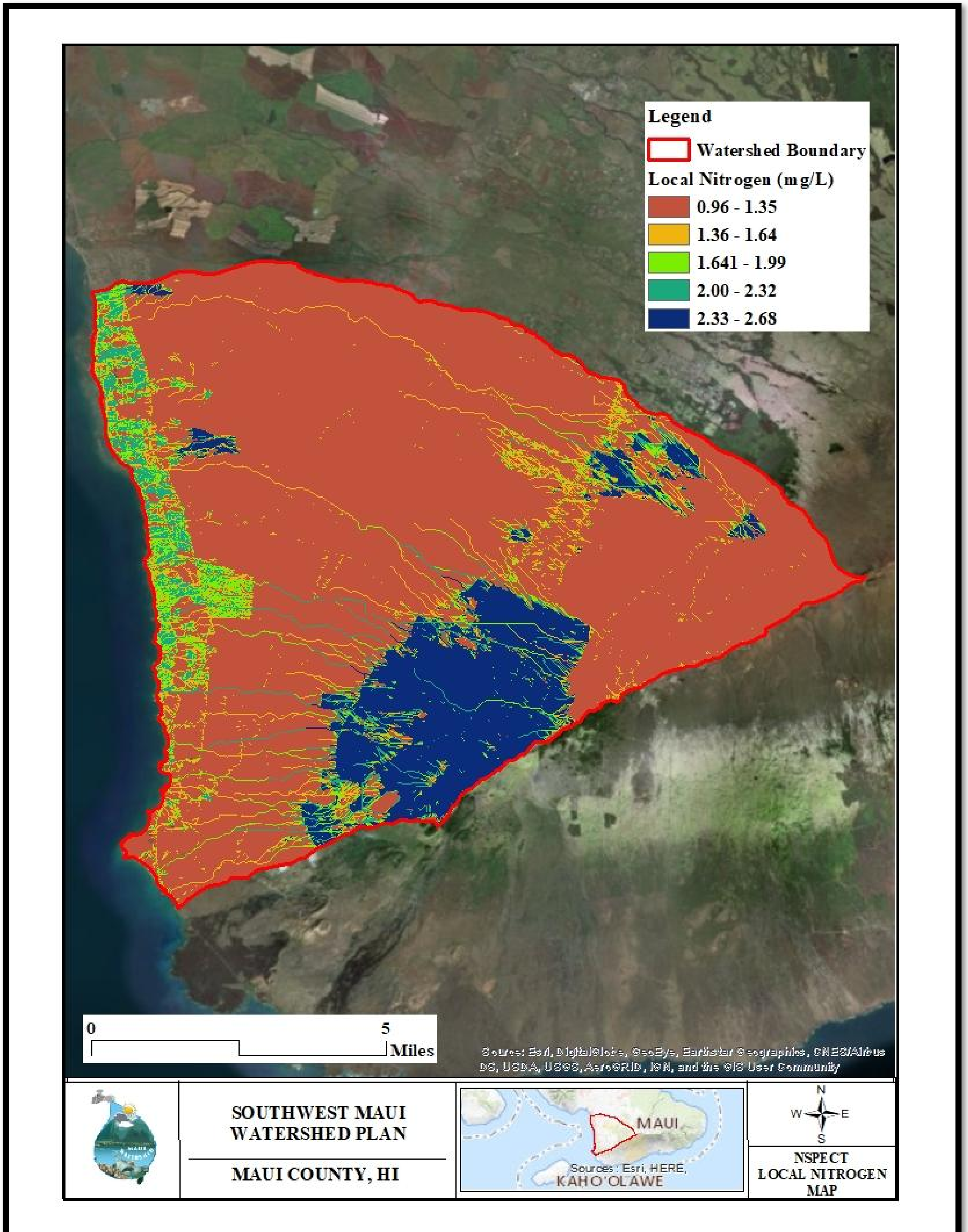
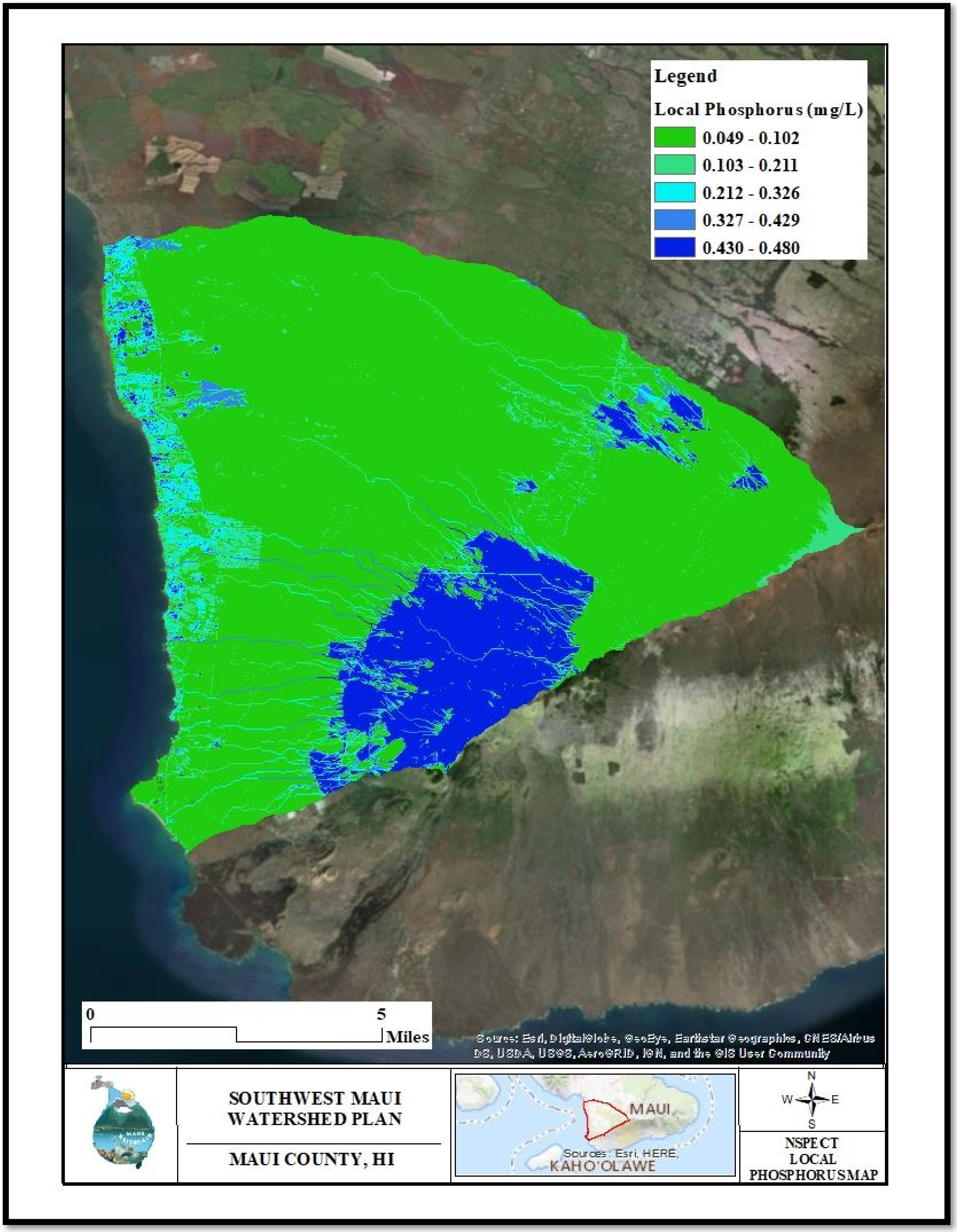


Figure 25. Localized Phosphorus in the SMWP Based on NSPECT Modeling



6.2.2 STEPL

The EPA has developed the Spreadsheet Tool for Estimating Pollutant Load (STEPL) which employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various BMPs. STEPL provides a user-friendly Visual Basic (VB) interface to create a customized spreadsheet-based model in Microsoft (MS) Excel. It computes watershed surface runoff; nutrient loads, including nitrogen, phosphorus, and 5-day biological oxygen demand (BOD5); and sediment delivery based on various land uses and management practices. For each watershed, the annual nutrient loading is calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by factors such as the land use distribution and management practices. The annual sediment load (sheet and rill erosion only) is calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. The sediment and pollutant load reductions that result from the implementation of BMPs are computed using the known BMP efficiencies (http://it.tetratech-ffx.com/steplweb/).

Region 5 Model is an Excel workbook that provides a gross estimate of sediment and nutrient load reductions from the implementation of agricultural and urban BMPs. The algorithms for non-urban BMPs are based on the "Pollutants controlled: Calculation and documentation for Section 319 watersheds training manual" (Michigan Department of Environmental Quality, June 1999). The algorithms for urban BMPs are based on the data and calculations developed by Illinois EPA. Region 5 Model does not estimate pollutant load reductions for dissolved constituents.

The SWCD ran STEPL for the SMWP to include the Hapapa, Wailea, and Moʻoloa sub-watersheds. The model calculates pollutant loads for the known land uses occurring in the watershed. These include urban, cropland, pastureland, forest, cesspools, and also considers groundwater load contributions.

To account for ungulate contributions, approximate cattle, hog, deer and goat populations were also entered into the model. Cattle herd and domestic goat numbers were acquired from Kaonoulu, Haleakala, Ulupalakua, and the various other small ranches that occur within the SMWP boundary. In addition, data from contracted hunter take reports and estimates in the field were used to estimate feral deer, pig and goat populations.

Cesspool contributions were also accounted for. There are 1655 known cesspools in the SMWP boundary. The national average of 2.43 persons per household was used as the number of persons serviced by each cesspool.

Table 17 presents the STEPL total load estimates by land use type for Nitrogen, Phosphorus, and Sediment within the Southwest Maui Watershed Boundary.

Table 17. STEPL Pollutant Loads by Land Use within the SMWP

Total Load by Land Use			
Sources	N Load (lb/yr)	P Load (lb/yr)	Sediment Load (t/yr)
Urban	30798.60	4843.05	723.26
Cropland	5246.89	1398.93	924.37
Pastureland	203956.02	38523.69	23414.30
Forest	1687.73	735.05	295.69
Cesspools	51451.00	20151.64	0.00
Groundwater	300616.58	13260.01	0.00
Total	593756.81	78912.37	25357.62

6.3 Nonpoint Sources

Several nonpoint sources of pollution have been identified within the SMWP boundary. While not as easy to quantify as point sources, the cumulative effect of these diverse, dispersed pollutants can be substantial. A list of some of the important nonpoint sources of pollutants within the Hapapa, Wailea, and Moʻoloa watersheds include:

- Cesspools
- Excess fertilizers, herbicides, and pesticides from agricultural lands, resorts, and residential areas
- Oil, grease, and toxic chemicals from commercial, light industrial, and urban runoff
- Sediment from improperly managed construction sites, ranch, crop, and forest lands, and eroding streambanks
- Salt (nitrates) from irrigation practices
- Bacteria and nutrients from wildlife, feral animals, livestock, pet wastes, cesspools, and faulty septic systems

6.3.1 *Cesspools*

Cesspools are of particular concern throughout Maui County. These underground regions are used for the disposal of human waste, where untreated sewage is discharged directly into the ground, leakage from which can contaminate oceans, streams, and ground water by releasing disease-causing pathogens and nitrates.

Maui Meadows, upcountry residential areas, and a few residences in the Makena area are served by onsite waste disposal systems, including individual residential cesspools or septic tanks. DOH and USEPA databases indicate that the island of Maui has >12,000 individual small septic or small cesspool wastewater systems (including those in the areas of Waiehu, Wahikuli, and Maui Meadows). Figure 26 depicts the locations of cesspools within the SMWP boundary.

While DOH CWB water sampling has shown no issue with pathogens exists within the coastal waters of Kihei, Wailea, and Makena, leaching from these cesspools may be contributing to the high levels of nutrients observed in these waters. Once in the water, nutrients such as nitrogen and phosphorus can cause algae blooms as well. High Chlorophyll *a* values act as evidence of these algae blooms.

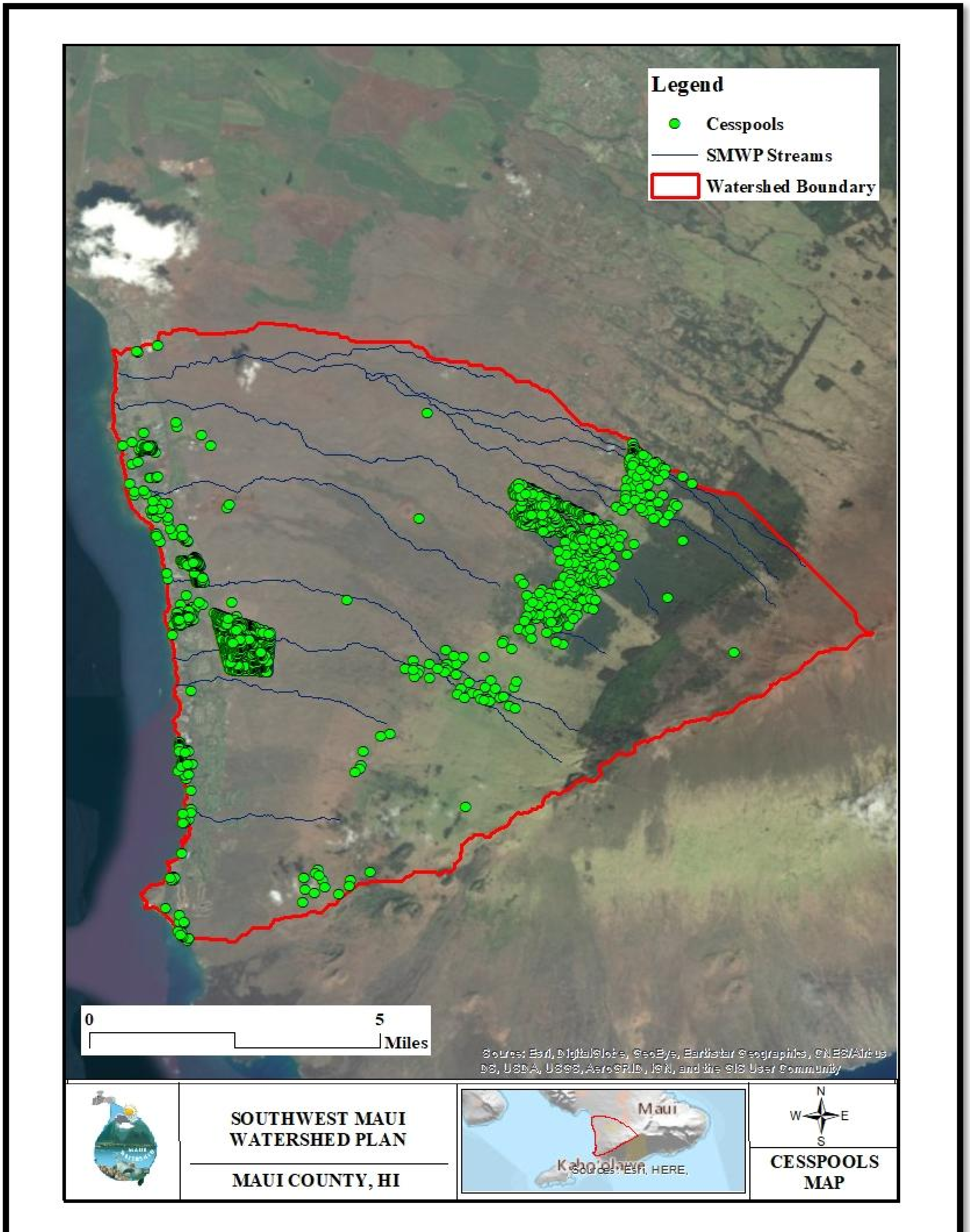
6.3.2 *Agricultural Lands*

Agricultural lands may provide a nonpoint source for sediment, pathogens, and nutrient pollution. Agricultural plots within the SMWP are situated on gently sloping ridges at the base of Haleakala and above Kihei. These plots are flanked on either side by gulches that begin at the upper reaches of the watershed, near the summit and flow downhill before discharging into coastal waters. Sediment from agricultural fields, feeding areas, and unimproved roads can make its way into these gulches during stormwater events, ultimately making its way to the ocean. Nutrients used for fertilizer such as nitrogen and phosphorus can be transmitted to coastal waters along with sediment. Likewise, bacteria associated with domestic and feral ungulates can be swept off the landscape by stormwater sheet flow.

6.3.3 *Landscaped Golf Courses, Resorts and Residential Communities*

Many landscapes throughout Kihei, Wailea, and Makena are unnatural, requiring irrigation and fertilizer to exist. Golf courses, resorts, and individual residences with manicured grassed lawns are examples of these unnatural landscapes. When fertilizers are placed in the soil, they can be transferred to the ocean by both surface water and ground water. During heavy rainfall, stormwater can carry these nutrients from their source to the ocean through gullies, gulches, stormwater drains and other surface water conveyances. In addition, nutrients can be absorbed into the aquifer and make its way to coastal waters through groundwater flow.

Figure 26. Cesspools within the SMWP Area



7.0 GOALS AND MANAGEMENT RECOMMENDATIONS

The main goals of the Southwest Maui Watershed Plan are to ensure fishable and swimmable waters by promoting watershed health and by taking action to improve water quality throughout Southwest Maui. By improving water quality and managing the watershed correctly, we will increase safety and reduce flood related property damage in coastal communities. These goals will mainly be met by implementing various projects throughout the watershed that will reduce sediment and nutrient loads in gulches and gullies that discharge into the coastal waters of Kihei, Wailea, and Makena.

The SWCD intends to serve the community through public outreach to educate stakeholders about the efforts underway to protect coastal reef environments and reduce sediment and nutrient loads in the watershed. The following overarching goals will be met by performing individual implementation projects throughout the Hapapa, Wailea, and Mo‘oloa watersheds. Individual projects designed to meet these goals are listed in Chapter 8.0 with detailed descriptions.

7.1 Improve Water Quality by Reducing Existing Sediment, Nutrient, and Pathogen Loads

The Southwest Maui Watershed Plan is designed to specifically address marine water quality criteria for open coastal waters. Currently both the DOH CWB and the Hui O Ka Wai Ola test these coastal waters for various parameters as discussed in Section 5.

Through the SMWP, the SWCD has identified and will implement various land management efforts to reduce sediment and nutrient loads within the watershed, ultimately ensuring water quality standards are being met for these and other parameters within the Southwest Maui Watershed boundary. The goals of the pollution control strategy and various implementation plans are to focus on sediment reduction measures, while also addressing nutrient pollution and other pollutant sources causing impairments to coastal waters as observed through DOH CWB sampling efforts and as reported in the biannual IR reports. Whenever possible, these projects were also designed with an emphasis on ecosystem restoration and to reduce flooding and runoff. In addition, implementation projects that are designed to slow water before it reaches the coastline will allow time for aquifer recharge and can augment surface waters in wetlands that are presently dry most of the year due to historic land use changes. Individual implementation projects are detailed in Chapter 8.0 and the technical and financial assistance needed to complete these projects is explained in Section 9.

7.2 Promote Aquifer Recharge

One of the main goals of the watershed plan is to promote aquifer recharge. Water quality in coastal waters becomes degraded when stormwater is discharged from surface water conveyances directly after storm events. By capturing stormwater on the landscape and allowing it to percolate into the aquifer, pollutants are removed prior to this water entering the ocean.

Due to the flashy nature of the gulches in the Southwest Maui Watershed, surface water flows mauka to makai and ultimately discharges into coastal waters with little time for aquifer recharge. Historically, freshwater and brackish wetlands occurring near the coastline would have slowed this water, functioning as both a filter and as a means for aquifer recharge. Unfortunately, today many of the wetlands in Kihei, Wailea, and Makena have been impacted by urban development and aquifer drawdown. Continued protection and restoration of existing wetlands will ensure they continue to provide these important ecological functions.

Detention basins in series have been proposed to function in much the same way as historic wetlands, by slowing water before it reaches highly populated areas along the coastline. These detention basins would assist in flood prevention by retaining water upstream. These detention basins will also allow flowing water to rest, so that sediment can drop out of suspension. Lastly, because of the porous nature of soils within the watershed, these detention basins will act as aquifer recharge locations.

Aquifer recharge can be promoted in several other ways including regulations on well withdrawals, installing LID into the urban landscape, protecting riparian buffers and conducting stream restorations.

7.3 Manage Rural and Agricultural Lands

As much of the SMWP boundary encompasses rural and agricultural lands, many of the implementation projects included in Chapter 9 are located mauka of Pi'ilani Highway in these areas. These are projects designed to control pollutant delivery to the ocean by detaining stormwater, trapping sediment, and facilitating infiltration. Focus has been placed on well-established BMPs. Feral ungulate fencing, elevated cattle crossings at gulches and gullies, grade and slope stabilization with vegetation and geotextiles, High Impact Zone Mitigation Sites (HIZMS), vegetated riparian buffers, unpaved road stabilization and other methods will be employed.

As mentioned earlier, a non-profit called the National Fish and Wildlife Foundation (NFWF) is interested in supporting watershed management work in areas such as North Kihei that include significant tracks of coral reefs. FWF recently funded a rapid watershed assessment with USGS, Maui Environmental Consulting, LLC and the West Maui Ridge 2 Reef Initiative in order to best understand the sediment hot-spots that exist on rural lands and how they may be addressed.

While this study is currently on-going, observations made in the field clearly identified feral ungulates as a major issue in rural lands. As a result of these studies in West Maui, Molokai, and the Big Island, the NFWF partnered with and funded large projects to address sediment issues affecting the reef. These included the installation of feral ungulate fencing, the planting of vegetation, and other projects to help landowners.

7.4 Manage Urban Areas

The urban areas of Kihei Wailea, and Makena can be actively managed to ensure high water quality in nearshore coastal waters. The Southwest Maui Watershed Plan aims to properly manage these critical areas by working with stakeholders in the community to address non-point sources of pollution, install illegal dumping controls and identify homeless encampments, protect the few remaining wetland areas, and incorporate Low Impact Design into existing infrastructure.

7.4.1 *Protect and Manage Existing Wetlands*

Existing wetlands along the coast of Kihei, Wailea, and Makena should be delineated, protected and restored wherever possible. Like the detention basins discussed above, wetlands have the ability to filter stormwater for sediment, nutrients and pathogens. They are habitat for native flora and fauna. They serve as flood prevention and aquifer recharge locations. Lastly, wetlands represent greenspace within urban communities, offering recreational space and improve the community's relationship with the natural environment.

7.4.2 *Promote and Manage Stormwater Runoff Programs for Existing Development - LID*

The development of urban areas within Kihei, Wailea, and Makena have resulted in impervious structures and surfaces throughout the coastal areas of the watershed. Many of the existing wetlands have been filled in and paved over to make room for this development. Stormwater is unable to filter through the soil and instead, flows over these impervious surfaces directly into the ocean, transporting sediment, oil and hazardous waste, nutrients and pathogens directly into the ocean. LID techniques can be used for future development as well as being well suited for retrofitting existing development. These design features account for impervious surfaces associated with urban development by ensuring stormwater is retained on-site instead of being directed towards storm drains leading to coastal waters. LID improves aquifer recharge while minimizing polluted stormwater from reaching the ocean. Examples of design techniques that promote and support the use of urban LID and BMPs include the use of porous pavement, grassed swales, rain gardens, retention/infiltration basins, street cleaning, above ground tank spill control, and illegal dumping controls.

7.5 Protect and Manage Riparian Corridors (Mauka to Makai Connections)

Riparian buffers along gulches and gullies prevent sediment laden sheet flow from entering flow ways and ultimately discharging into coastal waters. They also offer important habitat for native flora and fauna to inhabit from mauka to makai throughout the watershed. Operation TAKO POKE, a 319(h), R-1 irrigated riparian buffer project completed in 2005 on Keokea Gulch shows the viability and effectiveness of riparian buffer projects.

7.6 Resiliency – Fire and Flooding Control Measures and Water Quality

7.6.1 *Work with Maui County to meet Goals of the Kihei Drainage Master Plan*

Maui County recently released the Kihei Drainage Master Plan in November of 2016. This plan addresses drainage and future development in Kihei, from Waiakoa Gulch to Kilohana Drive. Many of the proposed actions in this plan are consistent with implementation projects proposed by the Southwest Maui Watershed Plan. For example, several detention basins are proposed in the

County plan that lend themselves well to the efforts and goals described in this document and have therefore been included as proposed implementation projects in Chapter 8.0.

7.6.2 *Fire Prevention and Mitigation*

While a wildfire prevention and mitigation strategy is not included in this document, the loss of vegetation and subsequent erosion resulting from wildfires is well documented in this area, and every effort should be made to prevent their occurrence in collaboration with Maui Electric Company, Kaonoulu, Haleakala, and Ulupalakua Ranches, Maui County, the Hawaii DLNR, the Hawaii Wildfire Management Organization, and Maui Nui Marine Resource Council.

7.7 Watershed Coordination and Public Education on Watershed management

7.7.1 *Watershed Coordinator*

A permanent watershed coordinator position is needed to oversee implementation projects. In addition, this individual will act as the liaison between the Environmental Protection Agency, Hawaii Department of Health, Clean Water Branch, the SWCD, Maui County, land owners, and other stakeholders in the community.

7.7.2 *Public Education and Outreach*

As implementation projects are undertaken, the watershed coordinator will disseminate information to the community on the progress being made. In addition, input from stakeholders and the community at large will be directed back to the SWCD so that issues and concerns can be addressed. Information on stormwater programs, best management practices and the state of water quality in the watershed will also be made available to the community. Both the SWCD website and mauiwatershed.org will be updated to provide information. Volunteer opportunities related to implementation projects will assure community involvement in projects designed to improve water quality in the SMWP. A detailed description of the education and outreach program can be found in Section 10 of this Plan.

8.0 ELEMENTS B AND C – ESTIMATED LOAD REDUCTIONS FROM NON-POINT SOURCE POLLUTION IMPLEMENTATION PROJECTS

Due to the ephemeral nature of the streams associated with the Hapapa, Wailea, and Mooloa watersheds, all water quality data is currently collected along the coastline. Therefore, any pollutants discharged from the landscape via surface water or groundwater are diluted in the nearshore coastal waters. This makes quantifying the actual load reduction from any given implementation project extremely difficult. As an example, STEPL may estimate a certain nitrogen load reduction for creating a floating treatment wetland in a golf course along Keokea Gulch. Once implemented, water quality testing in coastal waters may not reflect this reduction due to multiple cesspools, a condominium’s recent landscaping activity, or some other source of nitrogen in close proximity to the gulch. Also, due to ocean currents, water quality data may be representative of pollution entering the ocean some distance away from where it is sampled. For these reasons, we have designed the Plan to incorporate a wide array of implementation projects across the landscape, focusing on those pollutants that show impairment at multiple locations along the coastline.

The implementation projects proposed in this Plan are outlined below. They include excavated detention basins in series, riparian buffers, terracing, stream diversions, grade and slope stabilization with vegetation and/or geotextiles, fenced and/or vegetated riparian buffers, unpaved road stabilization, installation of porous pavement, grassed swales and wetland restorations. In addition, more generalized projects mentioned under the general goals and management recommendations listed in Section 7 are also discussed. These include the creation of a full-time watershed coordinator, implementation of a water quality monitoring plan, and a grazing management plan as examples. Below we discuss practices that have been deemed the most appropriate for implementation in the near future. Other implementation projects may also be incorporated into the Plan in the future as needs and resources dictate.

In addition to modeling for current pollutant loads within the SMWP, STEPL is able to estimate load reduction values for individual and combined BMPs implemented within each land use type. The list of BMPs provided in the STEPL model is quite extensive, with over 70 different practices to reduce pollutant loading. We have included load reduction estimates for each of the proposed implementation projects listed below as modeled using the STEPL program.

8.1 Excavated Basins / Excavated Basins in Series

Excavated basins in series, connected by berms or channels for sedimentation and infiltration purposes, have been identified as having a high priority as a management measure to improve water quality in the watersheds. “Excavated basins are often constructed in sequences adjacent to streams, so that excess stormwater flows, from the stream or stormwater channel, can be diverted under gravity to the first basin, then overflows from each basin to the next under gravity, and back to the stream or stormwater channel at the end” (A Handbook for Stormwater Reclamation and Reuse Best Management Practices in Hawaii, December 2008, Commission on Water Reclamation Management).

As mentioned earlier in this document, Maui County released the Pre-Final Report for the Kihei Drainage Master Plan (KDMP) in November of 2016. Several detention basins are proposed in the County plan. The locations of these basins and proposed suitable locations for the installation of these basins in series are depicted in Figure 27. While the locations of the basins proposed in the KDMP are subject to change, and the depiction of the basins in series in Figure 27 are meant as an example, appropriate sites can be found in the watershed gulch systems, in locations based on the following:

- Where sufficient undeveloped land exists on the sides of the gulches for the infiltration drain fieldAfter the convergence of tributaries to maximize efficiency
- Preferably in shallow segments where earth-moving to extract the water can be minimized
- In locations where stormwater intakes can be feasibly installed
- On soils which have adequate permeability

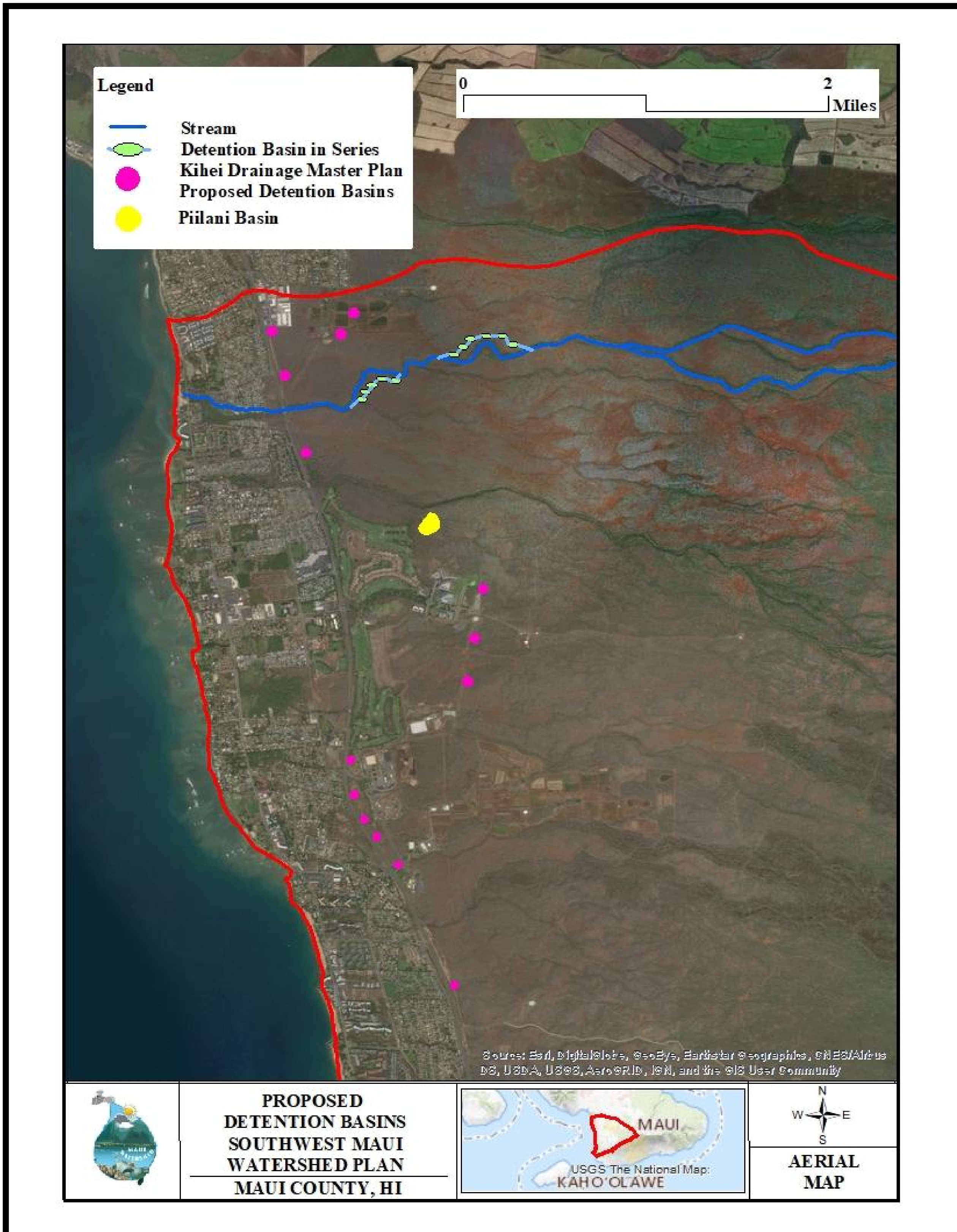
Of the fourteen detention basins proposed in the KDMP, 12 are located within the Hapapa watershed while the other two are located in the Wailea watershed. Their sizes range from eight to 50 acres in size. Load reduction estimates were calculated for each of these basins and are presented in Table 18 below.

Table 18. Load Reduction Estimates for the 14 Proposed KDMP Detention Basins

Basin Number	Sub-Watershed	Land Use	Acreage	N Reduction (lbs/yr)	P Reduction (lbs/yr)	BOD Reduction (lbs/yr)	Sediment Reduction (tons/yr)
1	Hapapa	Residential	15	11.00	1.73	44.99	958.04
2	Hapapa	Residential	43	31.52	4.97	128.96	2746.37
3	Hapapa	Residential	16	11.73	1.85	47.99	1021.90
4	Hapapa	Residential	43	31.52	4.97	128.96	2746.37
5	Hapapa	Residential	18	13.20	2.08	53.98	1149.64
6	Hapapa	Residential	26	19.06	3.00	77.98	1660.59
7	Hapapa	Residential	26	19.06	3.00	77.98	1660.59
8	Hapapa	Residential	34	24.93	3.93	101.97	2171.55
9	Hapapa	Residential	8	5.86	0.92	23.99	510.95
10	Hapapa	Residential	21	15.40	2.43	62.98	1341.25
11	Hapapa	Residential	12	8.80	1.39	35.99	766.43
12	Hapapa	Residential	50	36.66	5.78	149.95	3193.45
13	Wailea	Residential	17	12.46	1.96	50.98	1085.77
14	Wailea	Residential	33	24.19	3.81	98.97	2107.68

STEPL BMP = Dry Detention

Figure 27. Excavated Detention Basins in Series



In addition, the Pi‘ilani Detention basin has already been excavated. It is five acres is size. The connection of this basin to Waipuilani Gulch is offered as a separate implementation project later in this section.

8.2 Pi’ilani Basin Utilization Strategy

The Pi’ilani Mauka Detention Basin No.1, located mauka of Maui Nui Golf Course in central Kihei, intercepts and captures a portion of the offsite surface runoff from a tributary to Waipu’ilani Gulch (Figure 28). The spillway from this detention basin continues downstream and enters Waipu’ilani Gulch just east of Pi’ilani Highway. The detention basin is approximately 50 acre-ft. in volume occupying approximately 5 acres of surface area. Overflow drains associated with this detention basin consist of 48” and 60” diameter grated drain inlet risers. The captured stormwater begins to exit the basin through 60” drain inlet no. 1, when it reaches a depth of approximately 8 feet. All water below that level remains in the basin and infiltrates down into the aquifer. Sediment remains in the basin to be cleaned out as needed.

This huge unlined detention basin has the potential to capture much more sediment laden stormwater within the Waipu’ilani drainage basin than is currently being detained. If engineering studies would accommodate it, a portion of the flow from Waipu’ilani could be diverted through this basin to allow stormwater sediments to be settled out before continuing downstream. The design would place the stormwater intake at approximately 200 ft. elevation in Waipu’ilani Gulch, and channel the water into the basin, which is located 150 to 200 ft. to the south of the gulch. This project was also proposed in the KDMP as a flood mitigation measure. Using this method, some of the sediment being carried by the stormwater could fall out of suspension before the water returns to the gulch and the eight feet of water remaining in the basin would infiltrate into the aquifer. This would change the nature of the floodwaters in Kihei by reducing their volume and sediment load. An engineering study is recommended to determine the feasibility of this project.

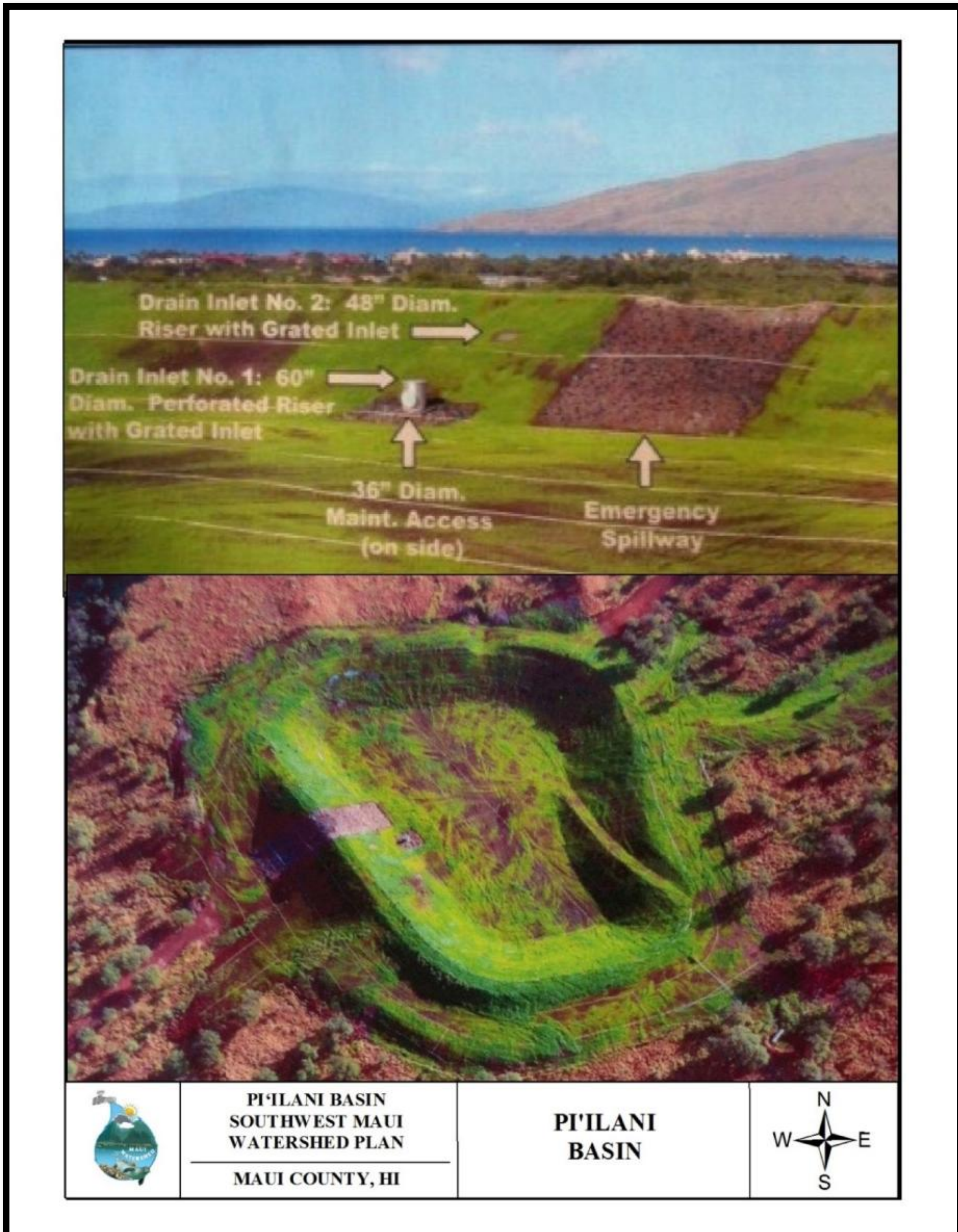
To estimate the pollutant load reductions that would be achieved by diverting stormwater from Waipu’ilani Gulch to Pi‘ilani Basin in this manner, we entered the area of the structure as an infiltration basin in STEPL. Table 19 below details the pollutant reductions calculated.

Table 19. STEPL Generated Pollutant Load Reduction Estimated from Diversion of Storm Water from Waipu’ilani Gulch to Pi‘ilani Basin

Basin Number	Sub-Watershed	Land Use	Acreage	N Reduction (lbs/yr)	P Reduction (lbs/yr)	Sediment Reduction (tons/yr)
Pi‘ilani Basin	Hapapa	Pastureland	50	37.26	4.04	2173.57

STEPL BMP = Dry Detention Basin

Figure 28. Pi'ilani Basin



8.3 Stream Diversions to Contoured Terrace Ditches

Contoured terrace ditches will be used to capture, store, and divert water from gulches to detention basins. Diversion of sediment laden water during peak flow into these ditches and ultimately into detention basins in series provides multiple functions. The infiltrated water would sub-irrigate grass for cattle feed, recharge aquifers, and water left in the ponds would be used by livestock and wildlife. The terrace ditches would run perpendicular to the slope and capture overland flow runoff.

On any given gulch, several of these intake/drain field systems, capturing stormwater runoff after a big rain event, could remove a significant portion of the sediment load and return cleaner water to the stream. There would be several advantages to this approach, including increased productivity in the pasturelands, aquifer recharge, flood mitigation, and water quality improvements through the reduction of storm water generated sediment loss.

The cost advantage of using this method, rather than large detention basins lower in the landscape, and the relative ease of installation make this approach more feasible. According to Unemori Engineering the general cost of constructing a large detention basin is approximately $20 per cubic foot. This would mean that a 50-acre-foot basin, like the Pi'ilani Mauka detention basin discussed later in this document, cost approximately $1.6 million to install. The comparable price of smaller excavated basins would be considerably less. Costs would depend on terrain, accessibility, and geologic conditions, among other things. Stream diversions would require several permits including a State of Hawaii, Department of Land and Natural Resources Commission on Water Resources Management Stream Channel Alteration Permit (SCAP).

While STEPL does not calculate load reduction estimates specific to this implementation project, it does calculate efficiencies for combined BMPs. When contour farming, terracing, controlled drainage and detention BMPs are combined, STEPL calculates the following reduction for sediment and nutrients per each acre where these BMPs are implemented.

Table 20. Contoured Terrace Load Reduction per Acre*

BMP	Size of Implementation Project (Acres)	Pollutant		
		N (lbs/yr)	P (lbs/yr)	Sediment (tons/yr)
Contoured Terrace	1	0.343	0.264	0.185

*BMPs are specific to Cropland and load reduction estimates will be different in other land use types where STEPL provides different BMPs.

Figure 29. Examples of Shallow, Flatter Sections of Gulches Suitable for Detention Basins in Series

Figure 30. Examples of Stream Diversions

8.4 High Impact Zone Mitigation Sites

Intensive land use activities that reduce the vegetative cover and loosen soil can produce conditions promoting erosion. These sites are called high impact zones. Figure 31 is an example of a high impact zone on grazing lands, where a single water trough serves hundreds of acres of dry pastureland. High impact zones, related to activities such as construction, agriculture, ranching, and forestry, could benefit from a suite of management measures designed to protect water quality. They will collectively be termed High Impact Zone Mitigation Sites (HIZMS). The interception of sediment laden runoff and other pollutants caused by high impact zones is the primary objective of HIZMS.

County ordinances control the impact of construction through grading and grubbing permits and agricultural activities through conservation plans developed by the SWCDs and NRCS. For instance, the County requires silt fences to catch eroding sediments from construction sites; conservation plans require the control of runoff through vegetative methods, diversions, and sediment basins. Unfortunately, many high impact zones in the watershed exist without mitigation measures.

Mitigating practices that can be adopted to capture sediment from stormwater runoff in HIZMS include but are not limited to vegetated buffers, fabric roll runoff interceptors, berms and terraces, small detention basins, and fenced riparian corridors. These relatively low-cost mitigation measures have the potential to reduce impacts to water quality from these high intensity land uses.

Figure 32 depicts some of the mitigation measures that can be implemented as part of a HIZMS. A vegetated buffer is placed downslope of the impacted area. To prevent cattle and wildlife from grazing on the vegetation, an exclusionary fence will surround the vegetation. In addition, seeded fabric rolls can be used to further slow sheet flow. The fabric rolls can be seeded with a combination of native shrubs and grasses to enhance native habitat and create a living filter. A small berm can be used to detain water flowing down slope towards gullies and gulches and keep sediment laden water within the vegetated buffer. Sediment buildup can be monitored to demonstrate the effectiveness of this technique. It has proven successful in other similar locations (see Kohala Watershed Partnership's Pelekane Bay Watershed Restoration Project-Final Report, May 31, 2011).

Currently, two locations have been identified as priority sites for HIZM implementation as shown in Figure 33. Both of these locations are located within the Hapapa watershed on Haleakala Ranch land. These sites are meant to act as pilot projects to show their effectiveness on ranch lands. Additional HIZM site locations will be identified on ranch lands associated the Wailea and Moʻoloa watersheds in the future as appropriate. Using ArcGIS software, the areas downslope of the HIZM locations that will be affected by the project were calculated and entered in the STEPL program. Table 21 provides the estimated load reduction for sediment and nutrients from the implementation of HIZM at these two sites

Table 21. STEPL Estimated Load Reductions from HIZM Implementation

HIZM Site	Land Use	Acreage	N Reduction (lbs/yr)	P Reduction (lbs/yr)	Sediment Reduction (tons/yr)
1	Pasture	46.79	60.05	14.22	9.68
2	Pasture	27.79	36.03	8.53	5.81

STEPL BMP = Critical Area Planting

Figure 31. Watering Trough Depicting Intensive Land Use Promoting Erosion

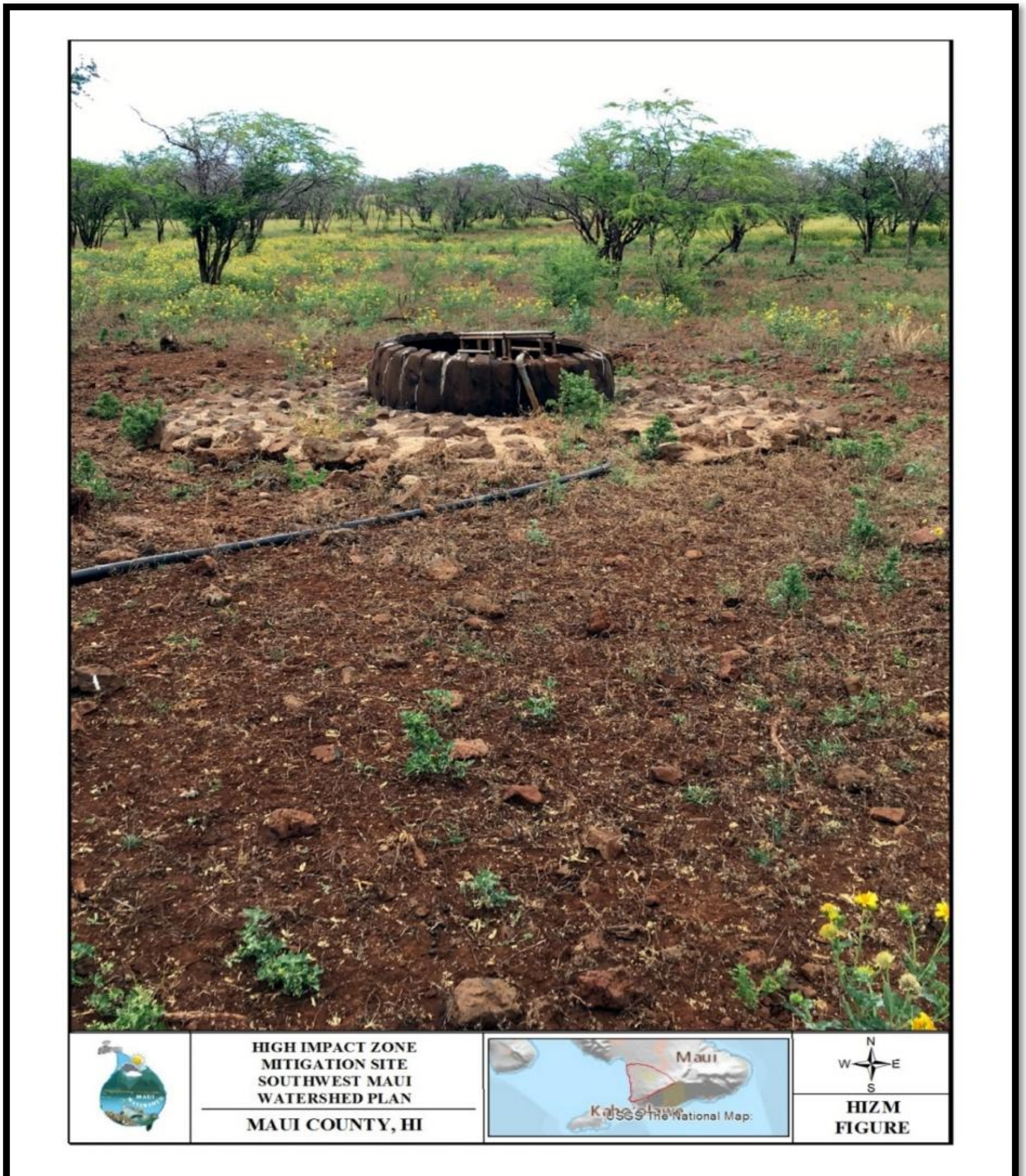


Figure 32. High Impact Mitigation Site Depicting Various Mitigation Measures

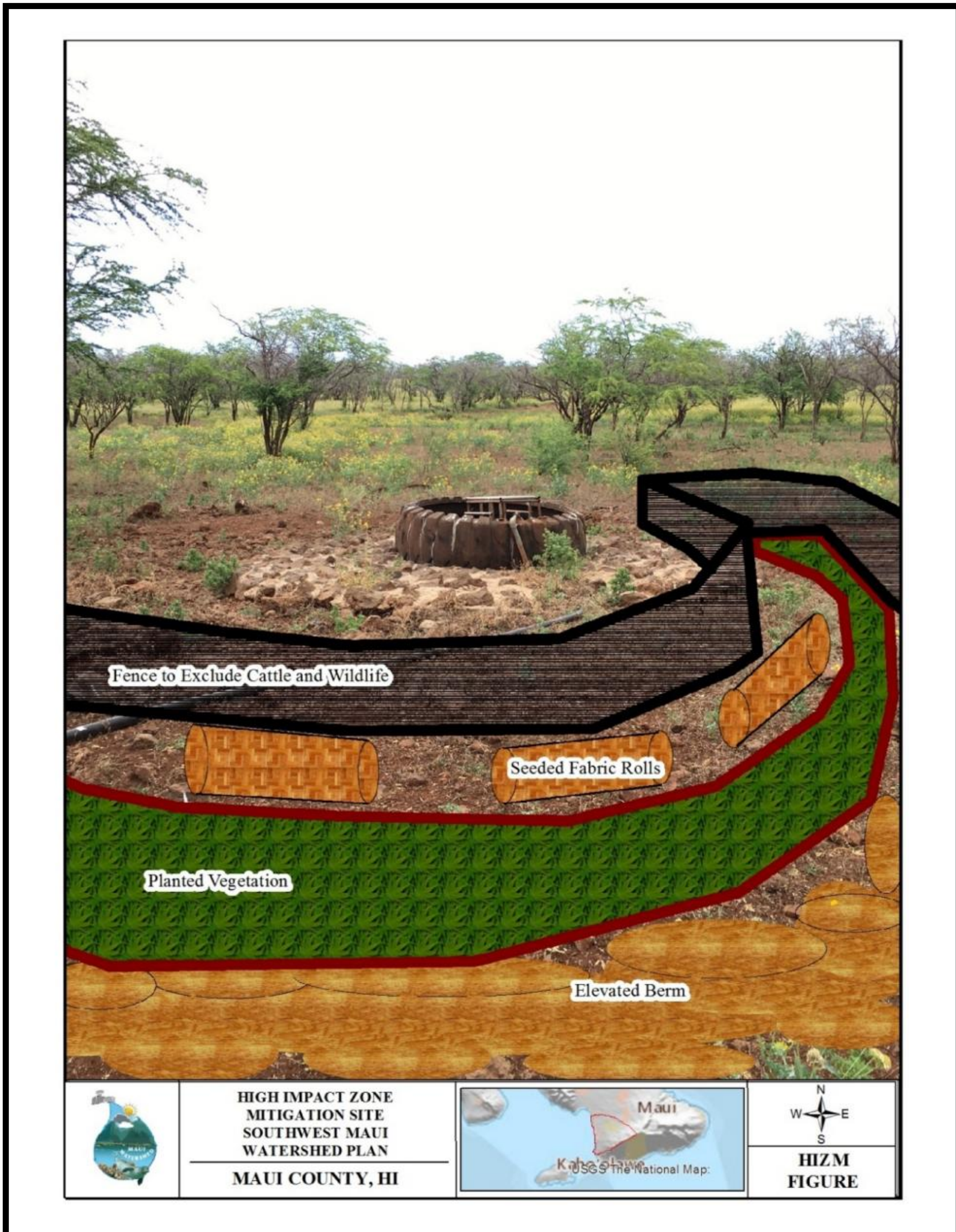
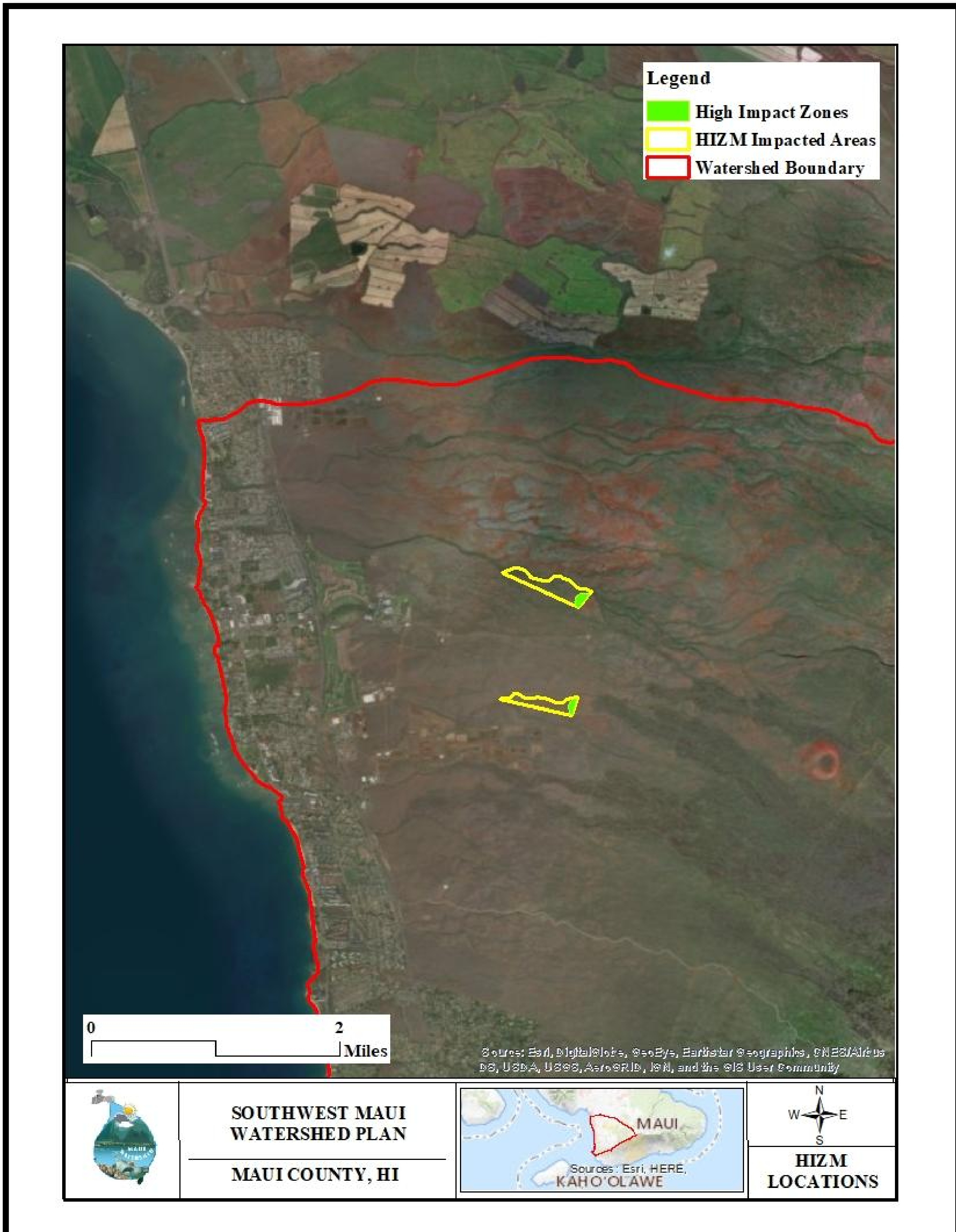


Figure 33. Proposed HIZM Implementation Site Locations



8.5 Grazing Management

In addition to the high impact zones associated with cattle grazing discussed above, additional management of grazing lands will benefit water quality within the SMWP. More than half of the lands in the SMWP are grazed by a combination of domestic and feral animals, including cattle, deer, pigs, goats, sheep, and elk. Much of the grazing acreage is rough and prone to drought, and grazing management is necessary in order to maintain the health of the watershed. NRCS promotes what is called “Prescribed Grazing”. The NRCS defines prescribed grazing as the controlled harvest of vegetation with grazing animals, managed with the intent to achieve a specific objective. This practice may be applied on all lands where grazing and/or browsing animals are managed. Removal of herbage by the grazing animals is in accordance with production limitations, plant sensitivities and management goals. Frequency of defoliations and season of grazing is based on the rate of growth and physiological condition of the plants. Duration and intensity of grazing is based on desired plant health and expected productivity of the forage species to meet management objectives. In all cases enough vegetation is left to prevent accelerated soil erosion. Application of this practice will manipulate the intensity, frequency, duration, and season of grazing to:

- Improve water infiltration
- Maintain or improve riparian and upland area vegetation
- Protect stream banks from erosion
- Manage for deposition of fecal material away from water bodies
- Promote ecological and economically stable plant communities which meet landowner objectives

While some of the ranchers have adopted managed grazing practices, much of the acreage could benefit from improved management. As an example, watering troughs in paddocks not currently in use should be turned off and emptied so feral ungulates don’t have access to this water. During the recent USGS sediment study conducted in North Kihei, large herds of deer in excess of 100 individuals were routinely observed. Small groups of goats and hogs were also seen. While ranchers are able to effectively employ traditional grazing management strategies for their cattle, feral ungulates are much more difficult to manage. Taller fences are needed to manage feral ungulates. Due to the high costs associated with these fences, feral ungulate grazing management in extremely difficult.

ArcGIS was utilized to determine the portion of the SMWP containing pasturelands. This acreage was then plugged into STEPL to determine the load reduction for nutrients and sediment within the project area. STEPL does not take into account sediment reduction from grazing management. Table 22 depicts the estimated nutrient load reductions calculating using the STEPL model for grazing management assuming the BMP is implemented on all existing pasturelands. While this acreage may seem like an overestimation, only a small number of ranching entities exist in the SMWP and grazing management implementation is believed to be widely accepted amongst these stakeholders.

Table 22. STEPL Estimated Load Reduction from Grazing Management

Project	Land Use	Acreage	N Reduction (lbs/yr)	P Reduction (lbs/yr)	Sediment Reduction (tons/yr)
Grazing Management	Pasture	38963.53	55483.01	2545.12	NA

STEPL BMP = Grazing Land Management (Rotational Grazing with Fencing)

8.6 Riparian Protection and Rehabilitation

All of the gulches in the Southwest Maui Watershed project area can benefit from protection and rehabilitation management measures. Various site-specific measures can be utilized depending on the resources available. Unfenced riparian zones are grazed by livestock and provide hidden trails used by deer and other feral ungulates. As a result, vegetation is grazed and trampled and soil is loosened; this contributes to unstable stream banks and causes erosion and sediment laden stormwater during runoff events. Fencing is the primary means of protection, preventing access by hoofed animals. The effectiveness of the removal of sediments and nutrients from stormwater runoff increases with buffer width (see Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness, EPA/600/R-05/118, October 2005). Access crossings through the gulches are incorporated into the fence design, and stream curtains are installed to prevent animals from entering the buffers while crossing. These curtains allow stormwater to pass under without destroying the fence.

Fabric rolls impregnated with native seeds can be utilized to both intercept sediment and provide a living filter. They can be staked as check dams in the stream flow and serve as streambank stabilizers.

The expense of fencing prevents landowners from committing riparian areas for protection and rehabilitation. It is therefore recommended that riparian fencing be one of the major funded implementation strategies in the watershed and that it be provided to any willing landowner.

Riparian fencing higher up in the landscape in association with conservation lands can prevent the need for bigger, more expensive solutions downslope by reducing sediment laden sheet flow from reaching gullies and gulches. Fencing is a core goal of the Leeward Haleakala Watershed Restoration Partnership as well as the SMWP. However, riparian buffer fencing in the lower elevations is also important to prevent sediment from entering the stream corridors where there is more surface area and higher potential for erosion between waterways.

A fenced, re-vegetated corridor can also provide a sediment filter for the sheet flow from adjacent lands, as demonstrated by Operation TAKO POKE, a 319(h), R-1 irrigated riparian buffer project completed in 2005 on Keokea Gulch (Figure 34). Even un-irrigated buffers will revegetate after fencing, given time. Options include allowing existing vegetation to reestablish itself, or actively seeding and out planting native grasses, shrubs, and trees to further enhance native habitat (see list of native species in Table 23).

Because much of the infrastructure associated with the portion of Keokea Gulch where TAKO POKE was implemented still exists, an approximately 5200-ft length of this stream has been proposed for riparian protection. In addition, an approximately 5400-ft length of Liilioholo Gulch further south in the Wailea watershed of the SMWP has also been proposed. No streams exist within the Mo'oloa watershed. STEPL estimates for pollutant load reductions based on a 35-ft wide riparian corridor protection area for both of these streams is provided in Table 23 below. Figure 35 depicts their relative locations within the SMWP boundary.

Table 23. STEPL Estimated Load Reduction from Riparian Protection and Rehabilitation

All Streams protected without fencing	Watershed	Length of Proposed Riparian Protection (ft)	Percent of Total Length of all Streams	N Reduction (lbs/yr)	P Reduction (lbs/yr)	Sediment Reduction (tons/yr)
	Entire SMWP	388822.00	100.00	62436.85	18715.69	13463.22
Keokea	Hapapa	5200.00	2.00	3059.34	577.86	351.21
Liilioholo	Wailea	5400.00	5.00	7648.35	1444.64	878.04
No Mo'oloa	NA	NA	NA	NA	NA	NA

STEPL BMP = Streambank Stabilization and Fencing

Figure 34. TACO POKE Riparian Buffer with Exclusionary Fence in 2005

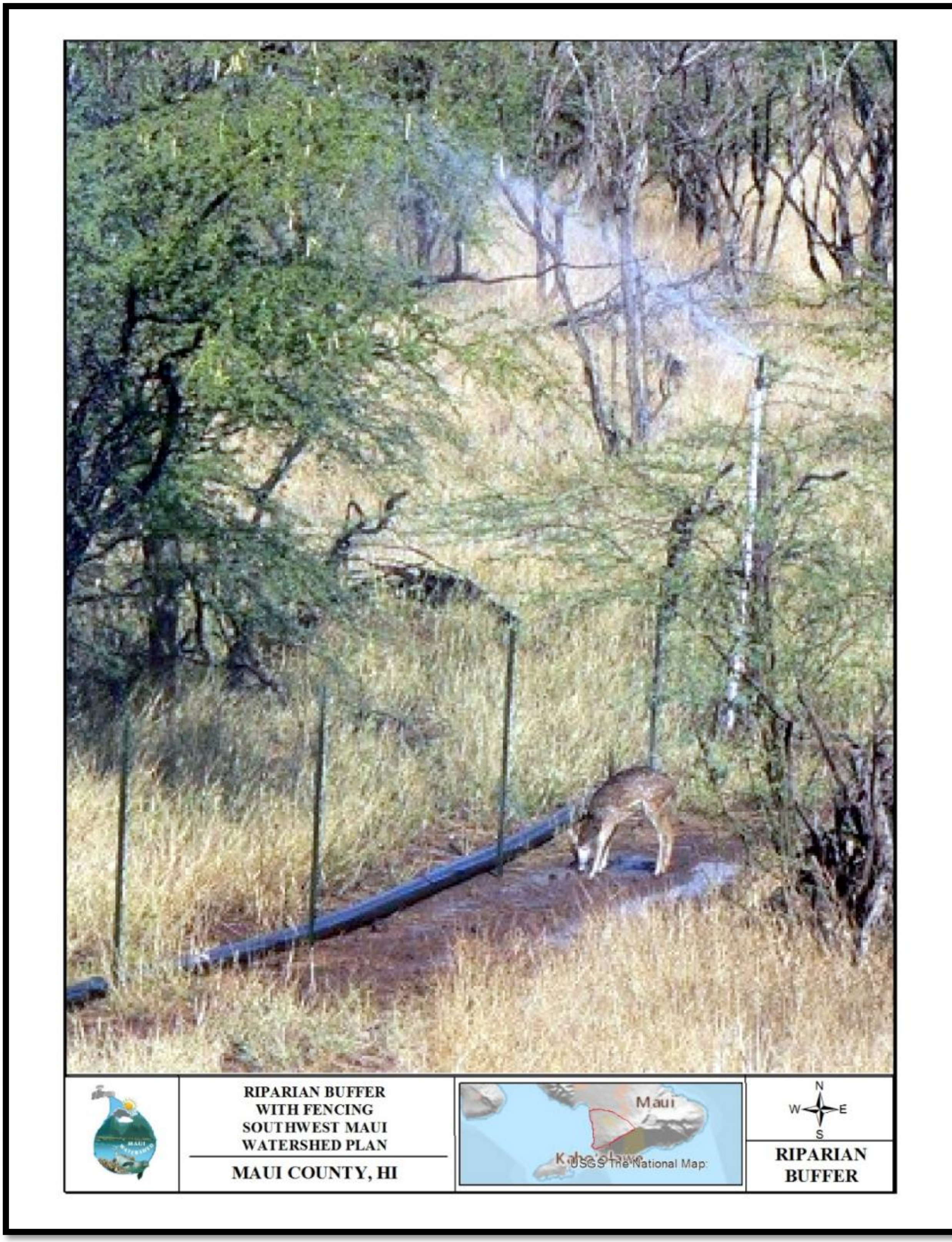


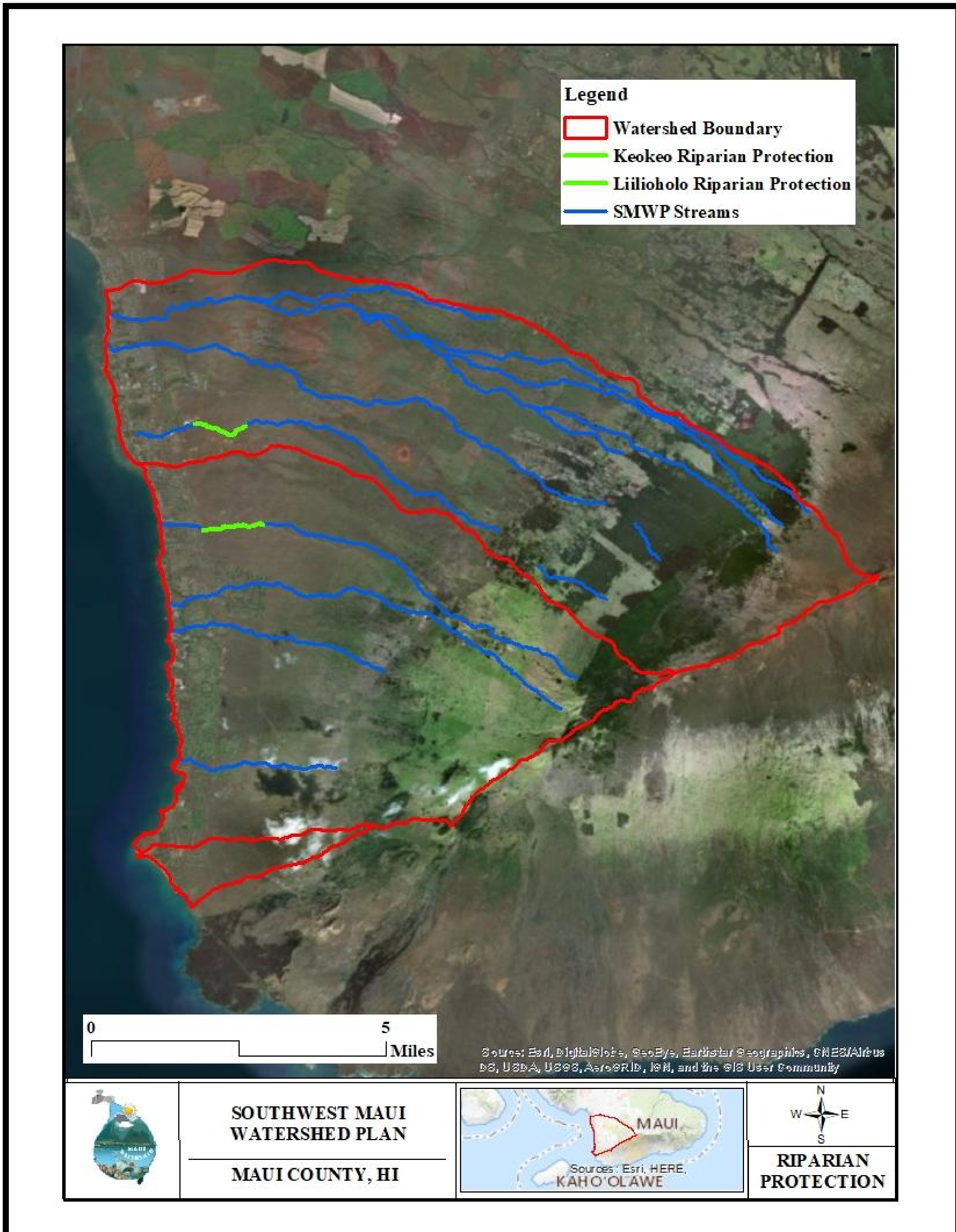
Table 24. List of Native Plants Potentially Used to Restore Riparian Buffers

Hawaiian Name	Scientific Name	Core Plant?	Notes
ʻAʻaliʻi	*Dodonaea viscosa*	Y	Easy to collect, germinate and grow.
ʻĀkia	*Wikstroemia pulcherrima*	Y	Variable fruit output. Few fruit in 2010.
Alaheʻe	*Psydrax odorata*	N	Very slow to germinate. No longer common on Kohala.
ʻĀlaʻa	*Pouteria sandwicensis*	N	No longer common on Kohala.
ʻĀweoweo	*Chenopodium oahuense*	Y	Abundant seed, fast growing and hardy.
ʻĀwikiwiki	*Canavalia hawaiiensis*	N	Low success rate from cuttings.
Hala pepe	*Pleomele hawaiiensis*	N	* Endangered - passed on seed to STN.
Hōʻawa	*Pittosporum hosmeri*	Y	Easy to grow.
Huehue	*Cocculus orbiculatus*	N	Low success from cuttings. No fruit.
ʻIliahi	*Santalum ellipticum x. Santalum paniculatum*	Y	Common tree on our watershed; abundant flowers and fruit. Slow to germinate.
ʻIlima	*Sida fallax*	Y	Variable forms; abundant seeds.
Koiaʻa	*Acacia koaia*	Y	Low seed production in 2010.
Koali ʻawa	*Ipomea indica*	Y	Easy to grow from cuttings and seed.
Kuluʻī	*Nototrichium sandwincense*	Y	Abundant seed; easy to grow.
Lama	*Diospyros sandwicensis*	N	Very slow growing.

Table 25. List of Native Plants Potentially Used to Restore Riparian Buffers Continued

Māmaki	*Pipturus albidus*	N	Field conditions too dry for this species.
Māmane	*Sophora crysophylla*	Y	Abundant seed available, esp. Mauna Kea.
Ma'o hau hele	*Hibiscus brachenridgei*	N	*Endangered - passed on seed to STN.
Naio	*Myoporum sandwicense*	N	Culled plants due to naio thrips infestation.
Olopua	*Nestigis sandwicensis*	N	Slow to germinate and grow.
Pā'ū o Hi'iaka	*Jacquemontia ovalifolia*	N	Easy to grow from cuttings.
Pili	*Heteropogon contortus*	Y	Common in lower watershed.
Pilo	*Coprosma spp.*	N	Field conditions too dry for outplanting.
Pōhinahina	*Vitex rotundifolia*	Y	Easy to grow from cuttings.
Pāpala kepau	*Pisonia sandwicensis*	N	Very hard to soak and grow sticky seeds.
Pua kala	*Argemone glauca*	Y	Easy to grow. Used seeds for direct sow.
'Ūlei	*Osteomeles anthyllidifolia*	Y	Powdery mildew reduced viability.
Wiliwili	*Erythrina sandwicensis*	Y	Abundant seed. Easy to grow.

Figure 35. Proposed Locations for Riparian Protection in the SMWP

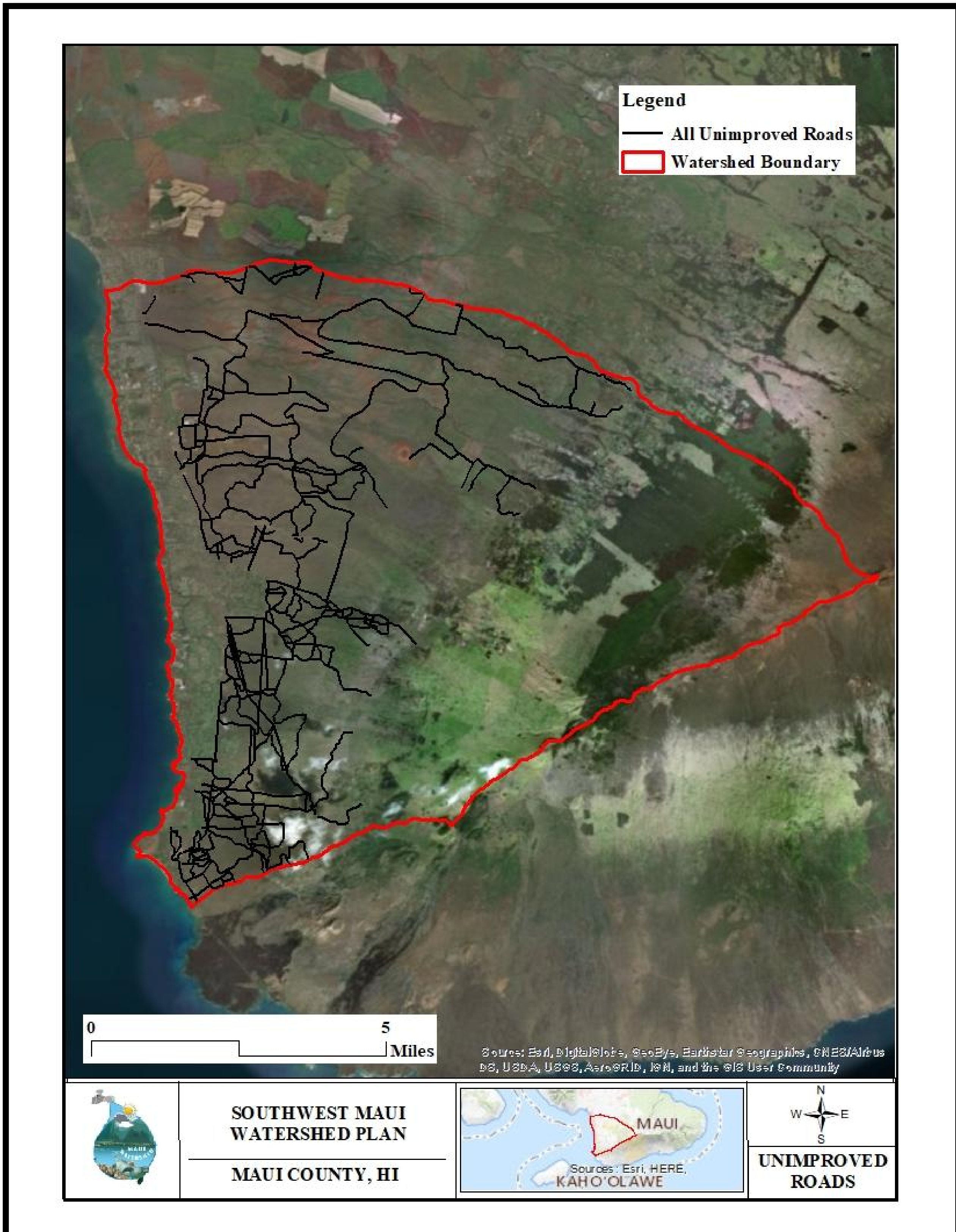


8.7 Unpaved Roads

Many of the unpaved roads in the SMWP are on slopes and much of the landscape is dry throughout much of the year. Figure 36 depicts the unimproved roads within the SMWP. Occasional storms, especially Kona storms, lead to runoff, which often turn these roads into conveyances for stormwater. The miles of poorly maintained and disused ranching roads have the potential to be major sources of sediment transfer and pathways for channeling stormwater runoff into stream gulches.

A comprehensive inventory of the SMWP unimproved roads should be conducted to determine stakeholder access needs and roads that are candidates for decommissioning or repair. Closing roads using structural methods (barriers) such rocks, logs, or vetiver plantings can capture sediment and attenuate runoff. Many roads are severely compacted, and the soils have lost most, if not all, of their stormwater infiltration capabilities. In coordination with landowners and potential road users, disused, and unnecessary or redundant roadways should be identified for decommissioning, and roads likely to stay in use should be improved using water bars, sediment traps and other BMPs to minimize downslope transport of eroded sediments. Example BMPs can be found in the document entitled: Unpaved Road Standards for Caribbean and Pacific Islands.
See: https://dcrm.gov.mp/wp-content/uploads/crm/2017IslandUnpavedRoadStandards.pdf

Figure 36. Unimproved Roads within the SMWP



Roads for stabilization and closure should be prioritized based on 1) stakeholder use and needs, 2) slope, 3) percentage of sand, silt, clay, and stone, 4) erosion and infiltration rates, and 5) likelihood of transport to streams/gulches based on models developed by Ramos-Scharron in 2009. Other agricultural roads on Maui have been decommissioned based on the following criteria:

1. Roads with high levels of erosion and deep ruts that render them dysfunctional as a road.
2. Those roads which have clearly not been used for at least two years.
3. Mauka roadways in SMWP that are directly contributing sediment and stormwater into gulches.

Lines of vetiver can be planted on contours across disused roads. These lines serve to interrupt and spread stormwater flows, capture sediment, and infiltrate water safely into the ground. As plants mature, and especially if coupled with stones or other physical barriers, they effectively delineate a road as decommissioned. It is important to conduct stakeholder engagement with any potential road users such as fire crews, rangers, illicit dirt bikers, hunters, hikers, etc. to help select sites and ensure potential users understand the purpose of the road closure barriers and plants so they are left intact. Signage can also be useful to convey this information.

To estimate loads reductions from the repair or decommissioning of unimproved roads, we aerially digitized their locations throughout the SMWP. We then calculated their length and assumed a uniform width of 20 feet wide. We then entered these numbers into STEPL to generate load reduction estimates for sediment throughout the entire watershed as shown in Table 26 below.

Table 26. STEPL Estimates of Sediment Load Reduction from Unimproved Road Repair

Sub-Watershed	Acres	Length (ft)	Land Use	Percent of Total Sub-Watershed	Sediment Reduction (tons/yr)
Hapapa	282.51	283735.13	Pastureland	0.88	368.86
Wailea	480.31	459107.38	Pastureland	1.50	596.84
Moʻoloa	93.31	47144.10	Pastureland	0.29	61.29

Combined STEPL BMPs = Use Exclusion, Critical Area Planting, and Grass Buffers

Based on initial monitoring results from similar projects, the above project can capture and retain approximately10-15 tons of sediment in one year (CORAL unpublished data). Projects should be coordinated with existing restoration activities being conducted in the area. Potential partners include Leeward Haleakala Watershed Partnership, large land owners, and DLNR.

8.8 Illegal Dumping Controls

Illegal dumping occurs throughout the natural areas within the urban portion of the Southwest Maui Watershed Plan. Homeless encampments are a major source of rubbish and dumping. Of particular concern is the dumping of yard debris and waste into wetlands, gullies and gulches within the watershed. Wetlands provide habitat for important wildlife species. This habitat is severely degraded by the addition of pollutants from outside sources. Gullies and gulches that become clogged with debris can eventually flood. Decaying natural material such as lawn clippings and landscaping debris decay and can cause nutrient loading within the watershed.

Wetlands and other natural areas where illegal dumping is taking place should be identified. These areas should be cleaned up and preventative measures should be installed (signs, bollards, etc.) to ensure future dumping does not occur. Community outreach programs can accompany this effort to ensure stakeholders are informed about and empowered to act against illegal dumping.

8.9 Stream Restorations

The portions of Kulanihakoi, Waipuilani, and Keokea located makai of Pi'ilani Highway within the urban corridor of Kihei are good candidates for stream channel restoration. Kulanihakoi in particular, has had so much sediment deposited into its flood plain that this section of the stream is no longer able to rise above its flood banks and access this area of the stream during smaller storm events. Dredging to remove this sediment has been proposed for this stream to restore proper function to the coastal flood plain. Coupled with appropriate infiltration and detention BMPs, restoration of these stream sections would have the added benefit of reducing flow volumes through the urban corridor and retain water instead of having it discharge directly into nearshore coastal waters.

Table 27. STEPL Pollutant Load Reduction Estimates for Stream Restorations in North Kihei

Wetland	Sub-Watershed	Land Use	Acreage	N Reduction (lbs/yr)	P Reduction (lbs/yr)	Sediment Reduction (tons/yr)
Kulanihakoi	Hapapa	Residential	16.88	27.09	4.27	2360.32
Waipuilani	Hapapa	Residential	17.70	23.79	5.39	1690.81
Keokea	Hapapa	Industrial	101.40	14.06	328.53	4421.89

STEPL BMP = Dry Detention

Figure 37. Example of a Restored Stream Reach

Example of a restored stream reach that is incorporating course woody debris, native plants (both which increases nutrient uptake), and stepped pools constructed with boulders (that slow down the erosive forces of the water).

Figure 38. Example of a Stream Channel Restoration

Stream channel restoration and stabilization projects usually include step pools and rip rap, both of which reduce erosive action and increase infiltration.

8.10 Low Impact Design (LID)

As stated earlier, the three watersheds within the SMWP include some of the nation's fastest growing population areas. There is a trend of increased impervious surface and habitat loss due to this development. These impervious surfaces cause stormwater that would otherwise be drawn up by vegetation and soil to instead pond on impervious surfaces and runoff into coastal waters. LID systems mimic natural conditions within developed environments, allowing stormwater to access the permeable surfaces and ultimately sink into the ground instead of becoming runoff. LID examples include systems such as curb cuts, vegetated bioswales, rain gardens, and pervious paving options.

8.10.1 *LID Stormwater Treatment in Parking Lots*

Retrofits such as curb cuts and biofiltration gardens could easily be incorporated into parking lots within the urban corridor of Kihei, Wailea, and Makena. Other projects include the installation of pervious pavement.

Figure 39. Examples of Low Impact Design Stormwater Treatment in Parking Lots

8.10.2 *Stormwater Wells*

The underlying geology in the Southwest Maui Watershed consists of layers of volcanic deposits; some containing rapidly cooled lava that is brittle and highly porous, while other deposits are denser as a result of having cooled more slowly. Dense layers do not allow water to rapidly percolate, while the less dense, porous layers promote surface water infiltration into the aquifer. This latter geology has the potential to infiltrate significant amounts of water provided engineered wells and trenches are suitably high enough above underlying groundwater tables and the bottoms of wells and trenches can access enough porous (less dense) strata to allow water to permeate through the soil. Infiltration wells, trenches, or French drains are all designed to convert surface water into groundwater by sinking excess stream flows safely into the ground. Acting like a ‘reverse well’, this approach has the added benefit of effectively recharging freshwater aquifers.

8.10.3 *Stormwater Infiltration (Dry) Wells*

These wells are similar in construction to a cesspool. This open-bottomed well structure is installed surrounded by gravel and wrapped in a geotextile cloth to prevent fine sediment from clogging the well, which would reduce infiltration performance over time. Stormwater is directed into the well where it drains effectively into the ground. Infiltration wells can be as simple as a pit filled with rubble or as complex as a prefabricated concrete structure. UIC permits are typically required for the installation of infiltration wells.

Figure 40. Stormwater Infiltration Well

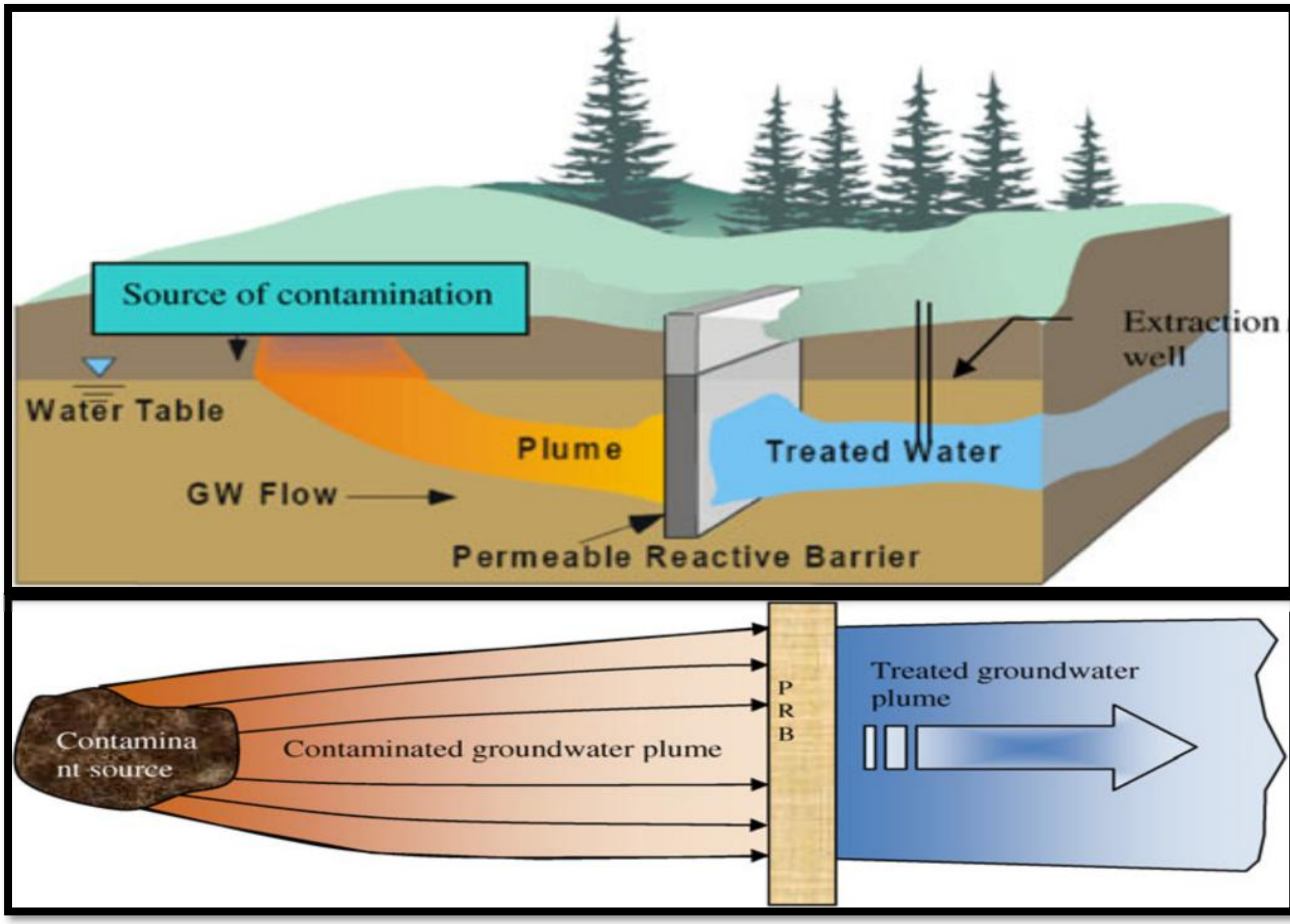
8.10.4 *Infiltration Trench or French Drain*

This structure is similar to a well except that it is configured as a long trench filled with gravel or a perforated pipe which spreads water over a larger area. Excess stream water could be directed into a trench, provided the water did not contain significant fine sediment particles which might eventually clog the system.

8.10.5 *Nutrient Curtain*

The Permeable Reactive Barrier (a.k.a. 'nutrient curtain') is constructed by excavating a trench approximately three feet wide, and four feet deep and long enough to bisect the groundwater moving through the area. It consists of a mix of hardwood chips, sand, sawdust, and activated charcoal (a.k.a. 'biochar'). This precise mixture converts nitrogen pollution contained in the groundwater into atmospheric nitrogen effectively filtering pollutants from groundwater passing through. This process requires no maintenance once installed and has a long effective lifespan because charcoal lasts for hundreds of years when buried in the soil (charcoal makes up a substantial portion of ancient archaeological sites in the Amazon Basin as well as Pacific Islands). There may be a slight loss in nutrient removal efficiency when the woodchips eventually break down (10-15 years), but the system will still function well beyond this time horizon.

Figure 41. Nutrient Curtain (Permeable Reactive Barrier) Example



8.10.6 *Floating Treatment Wetland (FTW)*

A floating treatment wetland (FTW) can improve the pollution treatment effectiveness of a wet retention pond. An FTW consists of a floating raft of buoyant material that is deployed on the surface of the pond, on which aquatic plants are grown hydroponically. Plant roots take up nutrients to support plant growth. The roots hanging down in the water column provide an ideal habitat for denitrifying bacteria. These bacteria remove nitrogen from the water and convert it into nitrogen gas which bubbles out of the water and is released into the atmosphere.

Figure 42. Floating Treatment Wetland Examples

Golf course ponds are ideal locations for the implementation of FTWs. Fourteen ponds have been identified on the three golf courses throughout the Hapapa, Wailea, and Moʻoloa watersheds. The locations of these ponds are depicted in Figure 43 below. STEPL modeling was conducted to calculate pollutant load reductions from the installation of floating treatment wetlands throughout the SMWP.

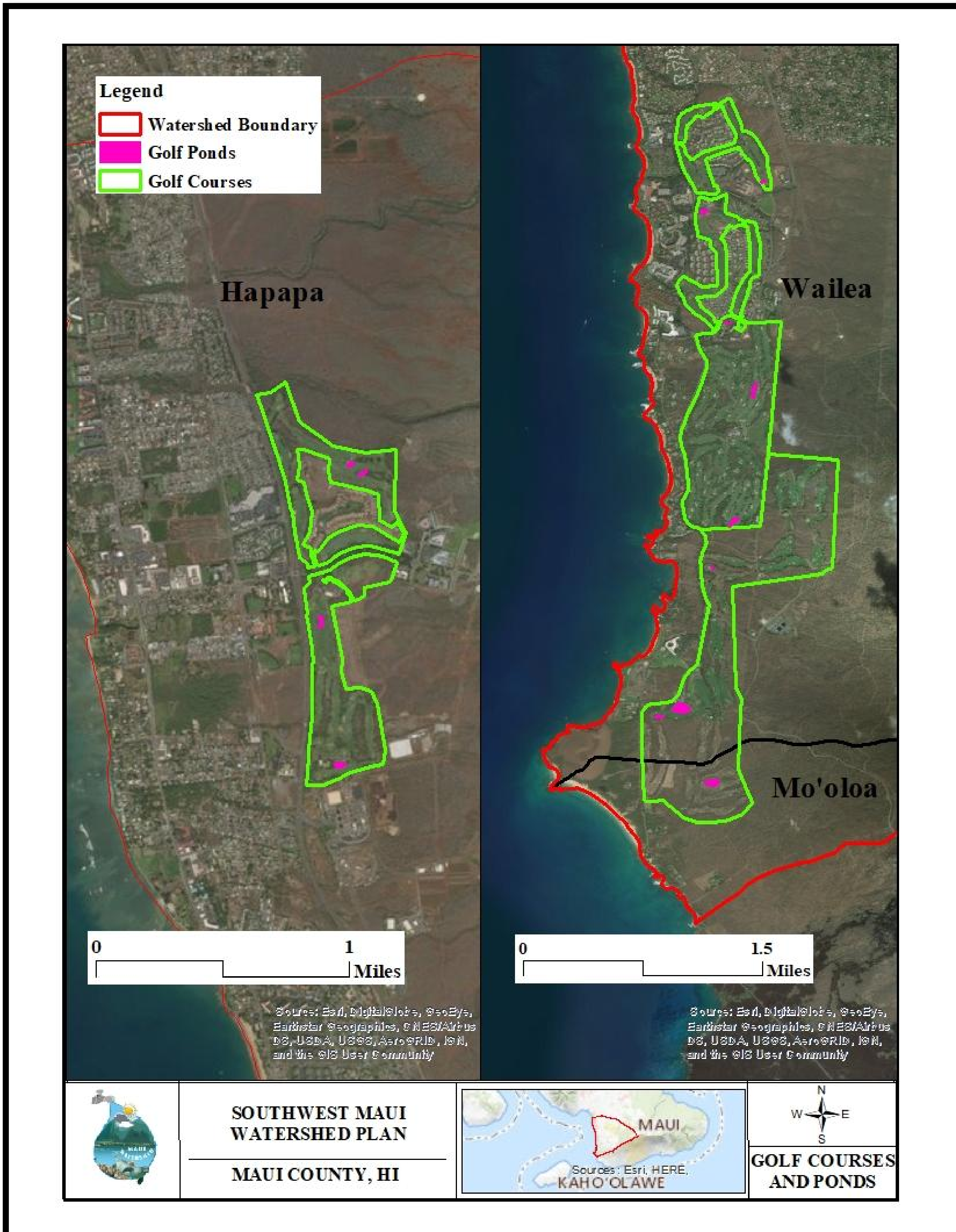
Table 28. STEPL Pollutant Load Reductions for Floating Treatment Wetlands on Golf Courses within the Southwest Maui Water Plan

Pond Number	Golf Course	Acres	Sub Watershed	N Reduction (lbs/yr)	P Reduction (lbs/yr)	Sediment Reduction (tons/yr)
1	Maui Nui Golf Course	0.48	Hapapa	0.29	0.10	90.11
2	Maui Nui Golf Course	0.39	Hapapa	0.24	0.08	73.21
3	Maui Nui Golf Course	0.26	Hapapa	0.16	0.06	48.81
4	Maui Nui Golf Course	0.25	Hapapa	0.15	0.05	46.93
5	Wailea Golf Course	0.18	Wailea	0.11	0.04	33.79
6	Wailea Golf Course	0.08	Wailea	0.05	0.02	15.02

Pond Number	Golf Course	Acres	Sub Watershed	N Reduction (lbs/yr)	P Reduction (lbs/yr)	Sediment Reduction (tons/yr)
7	Wailea Golf Course	0.55	Wailea	0.34	0.12	103.25
8	Wailea Golf Course	0.35	Wailea	0.21	0.07	65.70
9	Wailea Golf Course	1.24	Wailea	0.76	0.26	232.78
10	Wailea Golf Course	1.03	Wailea	0.63	0.22	193.36
11	Wailea Golf Course	0.18	Wailea	0.11	0.04	33.79
12	Makena Golf Course	3.07	Wailea	1.88	0.65	576.32
13	Makena Golf Course	0.52	Wailea	0.32	0.11	97.62
14	Makena Golf Course	1.76	Moʻoloa	1.08	0.38	330.40

STEPL BMP = Wetland Detention

Figure 43. SMWP Golf Course and Golf Pond Locations



Numerous other LID projects exist within the STEPL load reduction model. For each of these projects, we calculated load reduction estimates based on a drainage acreage of one acre for consistency. While we have not currently proposed specific locations for each of these projects, we wanted to include them in the Plan to inform stakeholders of their relative ability to reduce pollutant loads within the SMWP. We will continue to reach out to hotels, resorts, condominiums, and other entities where LID projects can be successfully implemented. Table 29 below lists some of the various LID projects available to stakeholders and their STEPL generated pollutant load reductions per one acre of drainage.

Table 29. STEPL Generated Pollutant Load Reductions for LID Projects Per One Acre of Drainage

LID Project (As Listed in STEPL)	Drainage Acreage	N Reduction (lbs/yr)	P Reduction (lbs/yr)	Sediment Reduction (tons/yr)
Dry Well	1.00	4.48	0.45	302.31
Filter/Buffer Strip	1.00	2.69	0.27	201.54
Infiltration Swale	1.00	4.48	0.58	302.31
Infiltration Trench	1.00	4.48	0.45	302.31
Vegetated Swale	1.00	0.67	0.16	159.55
Wet Swale	1.00	3.58	0.18	268.72
Oil/Grit Separator	1.00	0.45	0.04	50.38
Porous Pavement	1.00	7.61	0.58	302.31
Settling Basin	1.00	0.00	0.46	273.76
Vegetated Filter Strips	1.00	3.58	0.41	245.21
Weekly Street Sweeping	1.00	0.00	0.05	53.74

8.11 Expansion of R-1 Reuse Area

Most of the wastewater from the Kihei urban area is collected and treated at the Kihei Wastewater Reclamation Facility (WWTF). Presently, the Kihei WWTF reclaims and reuses roughly 40 to 50 percent of the wastewater it treats. This amounts to approximately 1.6 to two million gallons per day (mgd). The remaining treated effluent is discharged through injection wells where it percolates into the ground. At present, the reclaimed water, also known as treated R-1 recycled water, is being reused for irrigation purposes by golf course, park, residential, commercial, and agricultural entities. Figures 44 and 45 below depict the current and proposed reclaimed water systems. These figures were provided by Maui County.

Figure 44. Current Reclaimed Water Infrastructure

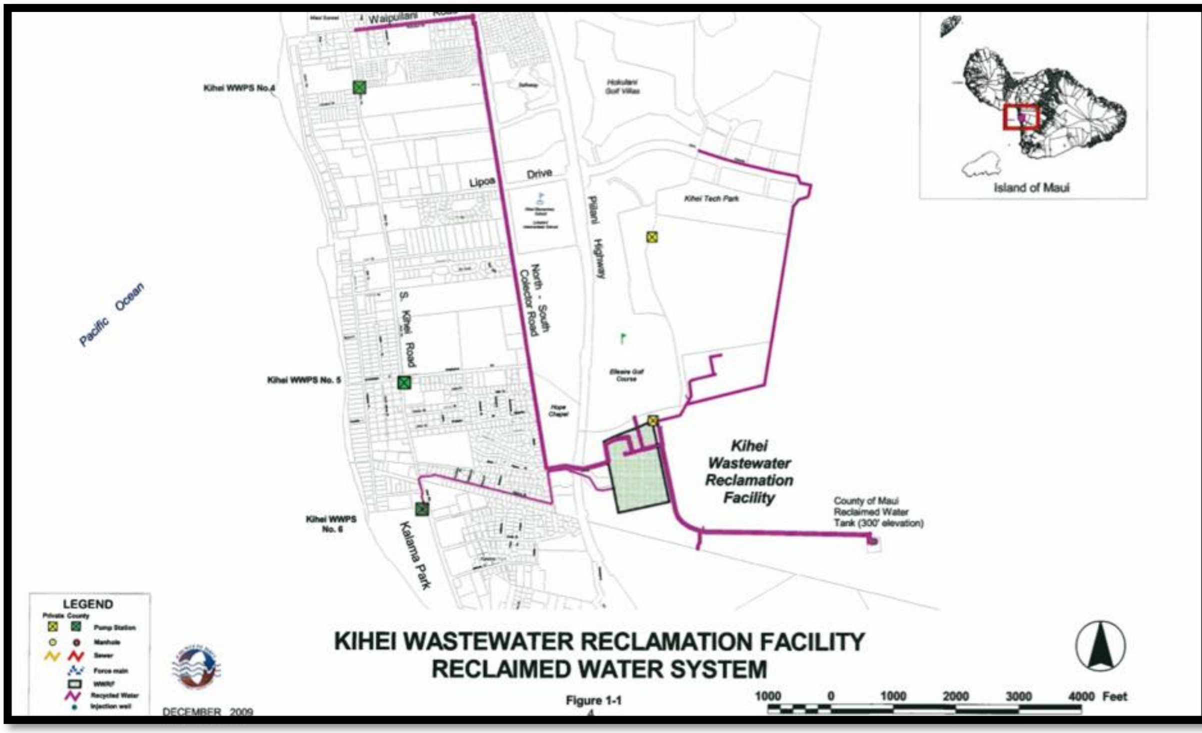


Figure 45. Proposed Reclaimed Water Infrastructure

As part of its fiscal 2020 budget deliberations, the Maui County Council is currently reviewing the following Victorino administration recycled water project proposals:

West Maui recycled water reuse expansion, $13.5 million in construction costs in fiscal 2020. This project would design and create a pressurized recycled water distribution system, including a new tank/reservoir, force main and other distribution system upgrades.

Wailuku-Kahului recycled water pump station, $600,000 for design in fiscal 2020 and $6 million for construction in fiscal 2022. This project would design and construct a station to pump recycled water to potential agricultural and other users in the Central Valley.

Wailuku-Kahului recycled water force main, $600,000 for design in fiscal 2018, $500,000 for land acquisition in fiscal 2020 and $13.5 million for construction in fiscal 2021. This project would design and construct a recycled water force main to convey water from the Wailuku-Kahului Wastewater Reclamation Facility to the Central Maui/Waikapu area for agricultural or landscape irrigation use or deposit in soil aquifer treatment basins to eliminate injection well usage at the Kahului reclamation facility.

Kihei in-plant pump station upgrades, $750,000 for construction. This project would upgrade both the Kihei in-plant lift station No. 2 and the recycled water pump station. The project includes replacing pumps, piping and the access hatch of the left station; replacing pumps and control equipment for the recycled water distribution system; and renovation of various in-plant valve vaults.

8.12 Cesspool Upgrade or Closure

With 1655 cesspools known to exist within the SMWP, they are of particular concern throughout the watershed. Maui Meadows, upcountry residential areas, and a few residences in the Makena area are served by cesspools or septic tanks. Figure 26 depicts the locations of cesspools within the SMWP boundary.

As stated earlier, while DOH CWB water sampling has shown no issues with pathogens exist within the coastal waters of Kihei, Wailea, and Makena, leaching from these cesspools may be contributing to the high levels of nutrients observed in these waters.

Generally, options for upgrade or closure include:

1. Closure and connection to an existing nearby sewer system with available capacity.
2. Closure and connection to a new private or public sewer system.
3. Closure and connection to a community-scale package wastewater treatment system.
4. Upgrade to an onsite septic tank and/or aerobic treatment unit system.

Signed into law in July of 2017, Act 125 requires all cesspools to be upgraded, converted to a septic system, or connected to a sewer system by Jan. 1, 2050. It directs the Hawaii DOH to evaluate residential cesspools in the state, develop a Report to the Legislature that includes a prioritization method for cesspool upgrades, and work with the Department of Taxation on possible funding options to reduce the financial burden on homeowners.

In addition, Act 120 provides a temporary income tax credit for the cost of upgrading or converting a qualified cesspool to a septic tank system or an aerobic treatment unit system, or connecting to a sewer system. A taxpayer may apply for a tax credit of up to $10,000 for each qualified cesspool. The tax credit started in tax year 2016 and ends in tax year 2020. There is a $5,000,000 cap that is available for each tax year. Any taxpayer who is not eligible to claim the credit in a taxable year shall be eligible to claim the credit in the subsequent taxable years up to 2020.

It should be noted that only cesspools located within 500 feet of a shoreline, perennial stream, wetland, or within a source water assessment program area (two-year time of travel from a cesspool to a public drinking water source) are eligible for the tax credit.

Through the watershed coordinator and as an outreach and education component of this Plan, the SWCD will engage with the community within the SMWP known to be using cesspools to inform them of the environmental impacts associated with cesspools and the laws and programs in place to assist in their conversion to one of the options listed above. To estimate pollutant load reductions from the conversion of cesspools to septic systems or aerobic treatment unit, we referenced the EPA Onsite Wastewater Treatment Systems Manual. Table 3-17 provides percent removal rates for systems utilizing leach fields for various wastewater quality parameters. Total Nitrogen is reduced by 10-40% and Total Phosphorous is reduced by 85-95%. Fecal Coliforms are reduced by 99.9%. Table 30 below shows the calculated nutrient estimates for the 1655 cesspools in the SMWP using a 25% conversion rate to show relative pollution reductions within the watershed using an average of the reduction rates supplied by the EPA Onsite Wastewater Treatment Systems Manual.

Table 30. Pollutant Load Reduction Estimates for SMWP Cesspool Mitigation

Number of Active Use Cesspools within the SMWP	Percent Conversion of Known Cesspools within the SMWP	Total Load		
		N Load* (lb/yr)	P Load± (lb/yr)	Sediment Load (t/yr)
1655	0	51451.00	20151.64	0
1241	25%	48234.96	15620.46	0
828	50%	45028.16	11093.98	0
414	75%	41811.38	6556.54	0
0	100%	38594.60	2019.10	0

*Assuming Conversion Results in Nitrogen Loads Being Reduced by 25%
±Assuming Conversion Results in Phosphorus Loads Being Reduced by 90%
Replacement of each existing cesspool with an improved treatment method could cost $20,000 or more per system.

8.13 Oyster Seeding

As filter feeders, oysters are capable of pumping large volumes of water through their gills every day. This process removes nutrients like nitrogen and phosphorus from the water while improving water clarity, removing algae and promoting other life in the harbor.

While STEPL does not provide pollution load reduction estimates from the use of oysters, MNMRC is currently pursuing an oyster project in Maalaea Harbor. Data from this pilot project will be used to determine the efficacy of using oysters to remove pollutants from coastal waters. Similar projects could be implemented at the Kihei Boat Ramp or off shore at floating barges.

8.14 Existing Management Practices

The forested conservation lands and private forests in the watershed are mainly used for recreational purposes. A major native re-vegetation project in the burned portion of the Kula Forest Reserve at 6,000 ft. el., is striving to re-stabilize the area. It is managed by the Hawaii State Department of Fish and Wildlife (DOFAW) for both conservation and recreational uses. Ungulate populations are maintained for a sustainable yield of game for hunters. The Leeward Haleakala Watershed Restoration Partnership recommends upland reforestation in the cloud belt in order to enhance fog drip.

Many of the farms in the watershed have conservation plans for resource protection that were developed with the help of NRCS and Olinda-Kula and Central Maui SWCDs. Rotational cropping and organic matter (OM) management are being practiced by some farms for biologically sustainable soil health and productivity. However, many of the conventional farms are relying on imported chemical inputs. Some farms using permaculture design principles use water catchment and storage systems to augment county water supplies. In this dry region, crop irrigation is a necessity.

Most of the grazing lands in this dry watershed utilize some form of rotational grazing. There is a growing trend toward holistic grazing practices, which use smaller paddock sizes to intensify grazing impact, more frequent rotations, and longer-term recovery. This improves the diversity of the forage and the productivity of the pasture land. Holistic grazing can also reduce erosion and improve water infiltration.

In the urban zone, there are wetland recovery projects, some channelized stream beds designed to mitigate flooding, and dune protection sites along the shoreline. Some of the public parks, a golf course, a corn seed farm, a shopping center, an apartment complex, the MRTP, and others are using R-1 reclaimed water for irrigation, reducing imported potable water use.

In the developing areas of the South Maui urban corridor, Wailea and Makena Resorts, and upcountry rural/residential areas, construction site Best Management Practices (BMPs) are mandated for sites over 1 acre by CWA National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges. There are currently no post construction requirements for stormwater pollution prevention or BMPs, except as may be specified for a particular project as a special condition.

In the coastal zone, special management areas are established under the Coastal Zone Management Act. Water reuse, irrigation, and fertilization/pesticide/herbicide use conditions, as well as marine monitoring, are often required by the SMA special permits (See Figure 46).

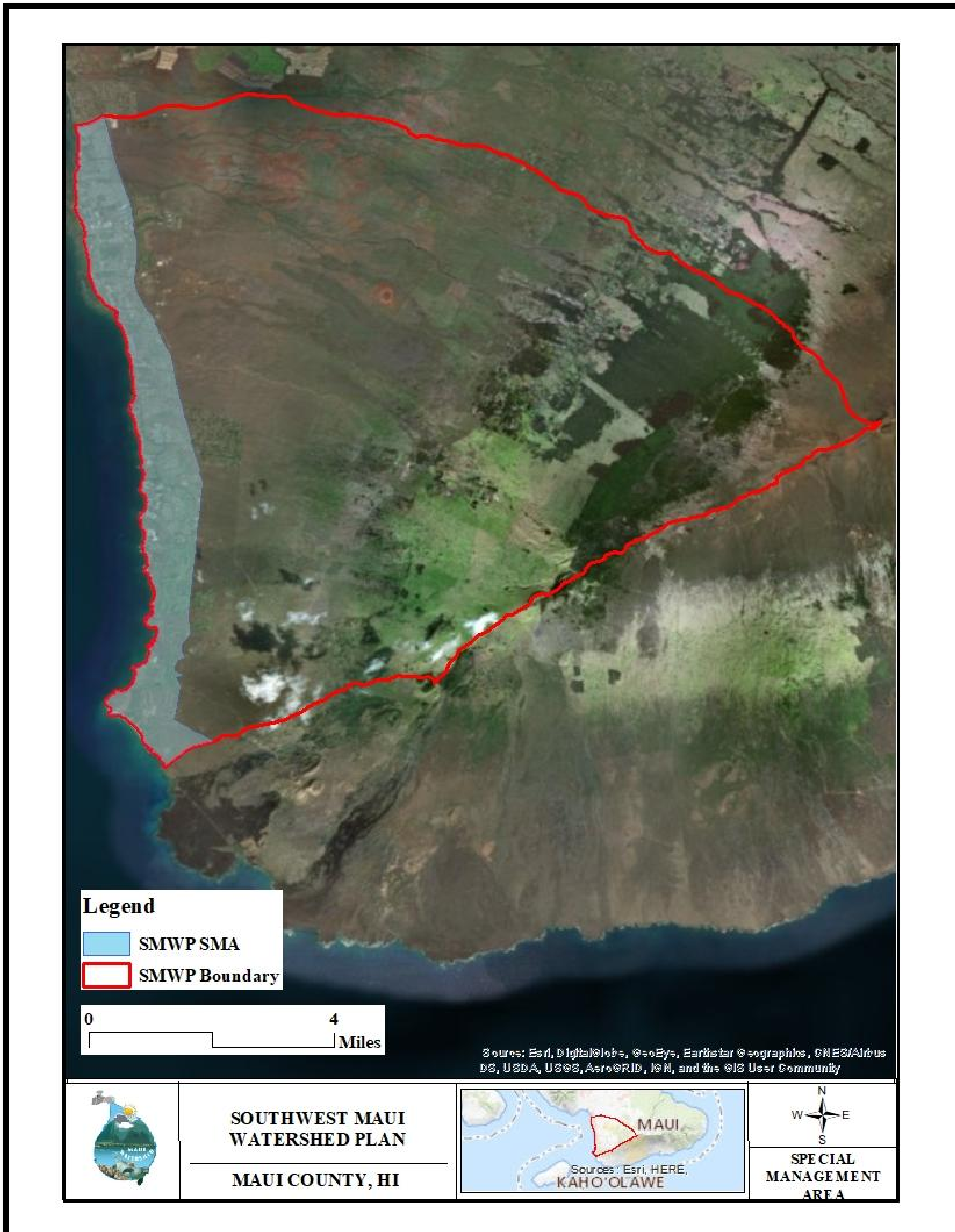
Small craft are offered a sewage pumping station in nearby Ma'alaea Harbor by a cooperative agreement between the County of Maui and the grassroots "Pump Don't Dump" group.

The Maui Soil and Water Conservation Districts and NRCS review individual proposed County grading permits and make specific recommendations for BMPs to control soil erosion and prevent water pollution. The County of Maui drainage systems receive agricultural, urban, and light industrial/commercial stormwater runoff. The County submitted a stormwater quality management program plan to the DOH in 2014. The plan was revised in 2015 to reflect information gained during initial implementation of the program. The purpose of their plan is to control polluted storm water runoff from the County's regulated Municipal Separate Storm Sewer System (MS4).

The Hawaii Department of Land and Natural Resources Division of Aquatic Resources is working with Maui Environmental Consulting, LLC to build the technical capacity of Maui County stakeholders to implement LID and align incentives to encourage widespread adoption of LID BMPs across public and private landscapes. This is being done with the end goal of improving water quality in nearshore waters by focusing on projects in the SMA and within the urban corridors of Maui.

This is accomplished by training County employees in LID through their participation in training exercises, by designing incentives to integrate LID methodologies into County ordinances and watershed management planning efforts, and by working with private landowners, developers, and engineers on Maui to plan LID on their properties.

Figure 46. Special Management Area within the SMWP



9.0 ELEMENT D – TECHNICAL AND FINANCIAL ASSISTANCE NEEDED TO MEET GOALS AND CONDUCT IMPLEMENTATION PROJECTS

9.1 Technical Assistance and Permits

In addition to the key stakeholders listed in Section 2.1.3, implementation projects proposed in this Plan will often require technical assistance from engineers, architects, land surveyors, environmental consultants, and other professionals. The following chart lists the major permits, some of which may be required for the implementation of the various recommended management measures. Whenever a project will fall within the Special Management Area (SMA), which is makai of Pi‘ilani Highway within the urban cooridor, impacts a stream, wetland, or other surface water feature, is within 150 feet of the shoreline, is in a flood zone, involves clearing of vegetation or earth moving activities, or will have a significant environmental impact, various permits will likely be required.

Table 31. Potential Permits needed for Excavated Basins in Series and Stream Diversions

Permit Name	Issuer	Trigger	Application Requirements	Project Improvements
Grading and Grubbing Permit	Maui County Department of Public Works	Required for removal of vegetation and earthmoving activities associated with construction	Application will require construction plans to be submitted	Any activity that bares or grades the ground surface, such as structural installation, access roads, and equipment and material staging areas
Special Management Area (SMA) Permit	Maui County	Required for any work being conducted in the Special Management Area	Application will require plots/drawings of work being conducted	Any use, activity, or operation qualifying as "development", and has a total cost fair market value of $500,000 or more; or

Permit Name	Issuer	Trigger	Application Requirements	Project Improvements
				has significant adverse environmental or ecological effect within the Special Management Area.
Perform Work on County Highway Permit	Maui County Department of Public Works	Required when a County roadway is disturbed by installation of pipelines	Application will require construction plans for the affected area	Any activities affecting County-owned roadways or structures, such as pipeline installation, use of bridges, and traffic control
Stream Channel Alteration Permit	State of Hawaii Commission on Water Resources Management	Any activity which will affect the stream course within the channel of a perennial or intermittent stream. The regulated channel extends to the top of the streambank.	Application will include design drawings, effects on and mitigation for aquatic organisms and communities, water pollution prevention plan	Intakes, stream crossings of pipelines, construction and maintenance roads
Stream Water Diversion Permit	Commission on Water Resources Management	Any new or modified diversion of water from streams for beneficial use	Application will include amount of water to be taken, assessment of other instream and non-instream water uses, design of intake	New stream intakes and change in diversion amount at existing intakes

Permit Name	Issuer	Trigger	Application Requirements	Project Improvements
Department of Army Permit	U.S. Army Corps of Engineers	Any activity resulting in filling of water bodies in the U.S., including flowing streams and wetlands. Fill includes sediment and structures.	Application will require site plan, design, construction methodology, CWA Section 401 Water Quality Certification by Hawaii Department of Health	New stream intakes, road and pipeline crossings of streams and wetlands
Clean Water Act Section 401 Water Quality Certification	Clean Water Branch, State of Hawaii, Department of Health	Required for any Federal permit that will involve discharge into bodies of water including streams and wetlands	Application will require items submitted for Department of Army Permit, environmental and chemical evaluation of receiving water, and Hawaii Water Quality Standards compliance plan	Applies to locations requiring Department of Army Permit
Conservation District Use Application (CDUA)	State of Hawaii, Department of Land and Natural Resources	Any development actions in Conservation Districts as designated by the State Land Use Commission	Application will require a Hawaii Chapter 343 EA/EIS	Pipeline or reservoir installation in the Conservation District

Permit Name	Issuer	Trigger	Application Requirements	Project Improvements
National Pollution Discharge Elimination System (NPDES) Permit	Clean Water Branch, State of Hawaii, Department of Health	Required for construction site runoff management when construction area exceeds one acre and if the operation of the improvement results in discharge into water bodies	Application will require sediment and runoff management designs and a water quality monitoring plan	Applies to all construction sites with potential of erosion and runoff
Use and Occupancy Permit/Construction within a State Highway Permit	Division of Highways, State of Hawaii, Department of Transportation	Required for surveying, materials testing, and construction affecting State-owned roadways	Permit will depend on phase of work with full plans required for construction activities	Any activities that affect State-owned roadways or structures, such as pipeline installation, use of bridges, and traffic control

9.2 Implementation Project Cost Estimates

In addition to modeling pollutant load reductions from the various implementation projects outlined in this watershed plan, we have prepared project cost estimates to facilitate stakeholders in obtaining financial assistance and in the decision-making process. These cost estimates were generated using the best information available at the time this report was written. Stakeholders are encouraged to use these cost estimates when designing projects and applying for grants. It should be noted that certain costs are specific to the type of work being conducted, their location in the watershed, community support, etc. While we attempted to formulate these costs using the best information available, many of these cost estimates were generated over the several years it took to compose this watershed plan. Therefore, these costs are meant as estimates and stakeholders should always budget for projects using quotes and information obtained at the time of implementation.

Potential sources of financial assistance include but are not limited to the Department of Health Clean Water Branch, the National Fish and Wildlife Foundation, Maui County Office of Economic Development, the Hawaii Tourism Authority, the Kihei Community Association, the Central Maui Soil and Water Conservation District, home owners associations, and large landowners. The watershed coordinator will assist any stakeholder in the Plan to identify possible financial assistance for a proposed implementation project.

9.2.1 *Excavated Detention Basins:*

Costs for the detention basins proposed in the Kihei Drainage Master Plan are provided in Table 32 below. Components of each detention basin included excavation costs, hydro-mulching, Glass-fiber Reinforced Plastic (GRP) slope protection at spillways, inlet and outlet concrete headwalls, perimeter six-foot-high chain link fencing, and 18-inch reinforced concrete piping.

Table 32. KDMP Estimated Financial Costs for Proposed Detention Basins

Proposed Basin	Estimated Financial Cost
Proposed Detention Basin at Pi‘ilani Basin 6U	$1,266,000
Proposed Detention Basin at Pi’ilani Basin 6D	$1,342,000
Proposed Detention Basin at Pi‘ilani Basin 7, mauka of future Kaonoulu Affordable Apartments	$3,111,000
Proposed Detention Basin at Pi‘ilani Basin 7, mauka of Pi‘ilani Highway	$3,111,000
Proposed Detention Basin at Pi‘ilani Basin 9	$1,583,000
Proposed Detention Basin at Pi‘ilani Basin 13U	$2,261,000
Proposed Detention Basin at Pi‘ilani Basin 14U	$2,068,000
Proposed Detention Basin at Pi‘ilani Basin 16U	$2,595,000
Proposed Detention Basin at Pi‘ilani Basin 17A	$682,000
Proposed Detention Basin at Pi‘ilani Basin 19A1	$1,622,000

Proposed Basin	Estimated Financial Cost
Proposed Detention Basin at Piʻilani Basin 19A2	$985,000
Proposed Detention Basin at Piʻilani Basin 19	$3,500,000
Proposed Detention Basin at Piʻilani Basin 20	$1,366,000
Proposed Detention Basin at Piʻilani Basin 23	$2,550,000

9.2.2 *Piʻilani Basin Utilization via Stream Diversion Strategy*

As mention in Section 8.2, the existing Piʻilani basin is quite large relative to the amount of stormwater it receives. To better utilize this detention basin, and to better control flooding in Waipuilani Gulch, The KDMP proposed the construction of a small channel that would run from the stream to the basin. Costs for the proposed channel were estimated at $127,000 and included excavation and hydromulch for the grassed channel. Additional costs associated with permitting were not included in this amount.

9.2.3 *High Impact Zone Mitigation Sites*

To determine costs for the two proposed HIZM sites, we considered their size, costs for ungulate fencing, fabric rolls, irrigation, vetiver and native plants. Planting costs were based on the length of the perimeter fencing as opposed to the square foot acreage of the two projects. This was done as a cost savings measure. It is believed that once ungulates are removed, vegetation will naturally recruit in these areas and will be further assisted by the vetiver and native species planted at the HIZM perimeters. If the HIZMs are planted throughout, costs will be significantly higher.

Table 33. High Impact Mitigation Site Costs

HIZM Component	Cost Per Foot
Fencing	$15.00
Fabric rolls*	$150.00
Irrigation*	$500.00
vetiver	$5.00
natives	$5.00
Total Cost Per Foot	$25.00
HIZM 1	$54,848.36
HIZM 2	$50,776.61
*Total Cost per HIZM Site	

9.2.4 *Grazing Management*

While ranchers currently employ traditional grazing management practices, including rotational grazing and forage surveys to determine current conditions of grasses, additional management can be employed. Some of these practices include smart collars that contain cattle in virtual paddocks, lowering or even eliminating the cost of fence installation and maintenance. While these collars can be as much as $150 per cow, they are able to track cattle location and utilize audio signals and mild electric shocks to direct movement. By tracking individual cows and being able to move herds electronically, ranches can rotate cattle more efficiently.

Due to the large numbers of feral ungulates on the property, feral ungulate fencing would be the most effective type of grazing management employed. Once ungulate fencing is in place, these areas can be hunted to remove the large herds presently in place on the landscape. Unfortunately, this fencing is quite expensive and can range in price from $15 to $20 per foot. Several miles of this fencing would be required. As an example, the lower portion of Haleakala Ranch mauka of Pi'ilani Highway and makai of DHHL lands would require over 77, 000 feet of fencing to cover its perimeter. At $15 a linear foot, the cost to fence the perimeter would be over 1.1 million dollars. All of the ranches currently have active hunting programs in place on their properties. In addition, Haleakala Ranch has partnered with a company to harvest this meat for use as pet food. Hunting is regulated with both bow and rifle hunting activities available. Take permits should be increased and hunting of feral deer should be promoted.

To further assist in the removal of feral ungulates, the ranches should cut water off to paddocks where cattle are not grazing. This is a fairly easy management practice that is not currently being employed.

Lastly, the watering troughs may offer a delivery system for feral ungulate contraception. By placing hormonal contraception in these watering troughs after the cattle have been removed, deer would consume these contraceptives when drinking water and become sterile or significantly less fertile.

9.2.5 *Riparian Protection and Rehabilitation*

As mentioned earlier, much of the infrastructure associated with the portion of Keokea Gulch where TAKO POKE was implemented still exists. An approximately 5200-ft length of this stream has been proposed for riparian protection. In addition, an approximately 5400-ft length of Liilioholo Gulch further south in the Wailea watershed of the SMWP has also been proposed. No streams exist within the Mo'oloa watershed.

On Maui, deer populations have increased dramatically, and higher fences will be required to protect riparian buffers. Recent installed fencing costs, on Maui, for 6-foot game fencing, range from $15 per foot in the open and accessible grazing lands, to $20 per foot in inaccessible, remote upland areas at 6,000 to 8,000-foot elevation.

Fabric rolls impregnated with native seeds can be utilized to both intercept sediment and provide a living filter. They can be staked as check dams in the stream flow and serve as streambank stabilizers. We included costs for these fabric rolls every 200 feet along the perimeter of each gulch. The cost for a 9-foot wide, 50-foot long roll is approximately $150 installed.

While TAKO POKE utilized R-1 water, riparian protection and rehabilitation does not necessarily require additional water. In addition, R-1 water is not allowed to discharge in gulches but must remain in the riparian zone so as not to be considered a wastewater discharge. Ideally, plants placed in a protected corridor are able to survive utilizing only the natural conditions found in these gulches. Plant costs will depend on plant selection and quantity. General prices for nursery grown plants range from $4 dibbles, $12 for 1-gallon pots, $12-$18 for 5-gallon pots, $45-$85 for 7-gallon pots, $125 for 15-gallon pots, $50-$225 for 20-gallon tubs with larger trees for $200 or more. Depending on the type and extent of the rehabilitation effort, plant costs will vary widely. Keep in mind fabric rolls are also impregnated with native seeds so plant costs may be offset by use of these rolls.

Table 34. Costs associated with Riparian Protection and Rehabilitation

Streams	Watershed	Length of Proposed Riparian Protection (ft)	Six-Foot-Tall Fencing at $15 per foot	Fabric Rolls (Every 200 feet)	Plants
Keokea	Hapapa	5200	$156,000	$7,800	Variable
Liilioholo	Wailea	5400	$162,000	$8,100	Variable
No Moʻoloa	NA	NA	NA	NA	NA

9.2.6 *Illegal Dumping Controls*

Illegal dumping is rampant throughout the urban corridor of the Southwest Maui Watershed Boundary. Many of the illegal dumping grounds are associated with wetlands. Homeless encampments also contribute large amounts of rubbish to undeveloped parcels. Dumping controls include public outreach, piling large rocks or installing fence posts or bollards to prevent trucks from off-loading in undeveloped areas, using signage to dissuade would-be polluters, and perimeter fencing to deny access to would-be polluters.

Table 35. Prices for Illegal Dumping Controls

Dumping Control	Price per Unit
Fence Posts	$8
Signage	$25
Bollards	$100
Perimeter Fencing	$20/Foot

9.2.7 *Stream Restorations*

Costs vary widely with stream restoration projects, and are most dependent upon site access, proximity and cost of aggregate materials (sand, boulders, etc.), and quantities needed to fill the incised stream channel. A study in North Carolina (an early adopter of stream restoration methods) found an average cost of $242.12 per linear foot of stream restored (Templeton, 2008).

While the costs are likely significantly higher on Maui, this figure is included for illustrative purposes. In many cases, the largest proportion of the costs of stream channel restoration is associated with temporarily diverting stream flow around the area being restored to allow access by heavy equipment. In the case of the SMWP, these streams are ephemeral and rarely flow except during heavy rain events, essentially eliminating this expense. Using the costs cited above, an estimate to restore the entire 2,850 feet of Kulanihakoi makai of the highway would be approximately $690,000. It may be that these costs would be substantially lower than this figure due to the fact that the most of the silt and sediment deposition within the channel exists nearest South Kihei Road and is not observed to occur throughout the entire section of stream makai of the highway.

Table 36. Estimated Stream Restoration Costs Makai of Piʻilani Highway

Kulanihakoi Stream Restoration (2850 feet)	$690,000
Waipuilani Stream Restoration (3100 feet)	$750,572
Keokea Stream Restoration (5750 feet)	$1,392,190

9.2.8 *Low Impact Design*

Costs vary widely for the various Low Impact Design BMPs. For new construction, many of these costs can be included in the overall design and buildout of the project. We have provided costs for retrofitting existing urban land use with LID BMPs, including retrofitting parking lots, installing nutrient curtains and floating treatment wetlands.

Table 37. Parking Lot Low Impact Design Implementation Cost Estimates

Technical design/ infiltration test, plan and oversight:	$500
Volunteer coordination:	$500
Cement work:	$750
Native plants:	$300
Soil and compost:	$300
Transportation/hauling	$300
TOTAL (per site):	**$2,650**

* If multiple sites were done at once, there would likely be cost savings associated with economies of scale.

A sample budget for a nutrient curtain 40’ long x 4’ wide x 4’ deep is included for illustrative purposes (depth is dependent upon depth to groundwater and may be more or less):

Table 38. Sample Budget for Nutrient Curtain Installation

Item	**Cost**
Site planning and design	$4,000
Excavation	$3,000
Materials (biochar, woodchips, sand, and sawdust)	$5,000
Construction management and oversight	$3,000
TOTAL	**$15,000**

Costs vary widely depending upon the overall size and complexity of the floating treatment wetland. Assuming volunteer labor is used to assemble the wetland, a small (8' x 8') version of a floating treatment wetland can be constructed for less than $1000. Golf Course greens managers should be partnered with to implement this nutrient reduction strategy. Detailed instructions for creating an FTW can be found at the link below.

https://coral.org/wordpress/wp-content/uploads/2017/11/2017_Maui_CaseStudies_FloatingTreatmentWetlands_Final.pdf

9.2.9 *Expansion of R-1 Reuse Area*

As mentioned earlier, Kihei in-plant pump station upgrades will cost approximately $750,000 for construction. This project would upgrade both the Kihei in-plant lift station No. 2 and the recycled water pump station. The project includes replacing pumps, piping and the access hatch of the left station; replacing pumps and control equipment for the recycled water distribution system; and renovation of various in-plant valve vaults.

9.2.10 *Unpaved Roads*

Table 39 below provides a sample budget for decommissioning roads based on similar projects in West Maui. Note that this sample budget is for the decommissioning of 1,000 feet of roadway with the use of vetiver and native plants and assumes an average of one vetiver row per 100 feet. In addition, it assumes volunteers will be used for digging and planting, that no ungulate fencing will be installed and that site access via 4x4 truck is available.

Table 39. Sample Budget for Decommissioning Dirt Roads Using Vegetation

Item	Cost $
Installation Supplies:	
Plants, equipment, and irrigation supplies	7,500
Surveying and site prep	2,000
Transportation and fuel	1,200
Total:	10,700
Maintenance:	
Initial watering and establishment (first 2 months)	3,200
Adaptive management/maintenance	800
Total:	4,000
Monitoring:	
Supplies (tape measures, erosion posts)	500
Soil lab tests	500
Monitoring transportation and fuel	2,400
Total:	3,400
Staff:	
Project management; volunteer coordination, and outreach	8,000
Technical/design consulting	4,000
Monitoring overall effectiveness	2,400
Total:	14,400
Contingency costs (15%)	4,875
Project TOTAL	**$37,375**

10.0 ELEMENT E – INFORMATION AND EDUCATION OUTREACH PROGRAM

10.1 Education and Outreach Program Goals

The main goal of the Information and Education Outreach Program is to build public understanding of the Southwest Maui Watershed Plan, Hawaii water quality standards, and the projects proposed by the Plan to remove and reduce pollutants entering our coastal waters through stormwater runoff. Efforts will be focused on discussing non-point sources of pollution and how these pollutants make their way into our streams and coastal waters and harm our coral reefs. In addition, land-based issues relating to flooding and erosion from stormwater, nutrient runoff, oil and hazardous materials, and wastewater reclamation will all be addressed.

10.2 Education and Outreach Objectives

The CMSWCD intends to establish and maintain a Watershed Coordinator position to direct, organize, and coordinate efforts related to the Southwest Maui Watershed Plan. This individual will be the primary contact between the conservation district, the community, government entities, and other organizations involved in improving water quality within the watershed. They will be responsible for spearheading all education and outreach objectives listed below.

10.2.1 *Build Public Awareness and Support*

Lack of understanding of non-point sources of pollution is a major factor affecting water quality. All of the implementation projects outlined in the SMWP will require some level of stakeholder awareness and involvement. The community will be educated about current DOH CWB and Hui O Ka Wai Ola water quality monitoring locations and about data trends arising from these water quality monitoring efforts. Links to both organization's data portals will be made available on the www.mauiwatershed.org website.

Many stakeholders who implement projects proposed in this watershed Plan will want their efforts to address pollution known the wider public. In addition, many individuals will want to know about volunteer opportunities where they are able to help in the community. This public awareness can be expected to improve and/or support water quality and coral reef health.

Public awareness can also assist in enforcement of laws and reporting of activities that cause pollution. The community can also provide its technical expertise to solve pollution problems within the watershed.

10.2.2 *Focused Outreach to Engage Businesses and Decision Makers*

In conjunction with the project implementation schedule offered in Section 11 of this watershed plan, the CMSWCD and the watershed coordinator will conduct focused outreach to natural resource managers, large landowners, and businesses. Examples of focused outreach include:

- Meetings with ranchers to discuss grazing management, ungulate control, HIZMs, dirt roads, and riparian zones

- Hotels with major landscaping operations and golf courses will be educated on the use of fertilizers, LID BMPs, etc.
- Business handling and storing oils and hazardous materials will be identified. These businesses should be engaged with CMSWCD personnel to ensure they are incorporating best management practices related to their industries. Examples of these businesses include auto mechanics, oil changing facilities, and industrial facilities.
- Meetings with community associations to discuss cesspools, illegal dumping controls, etc.

10.2.3 *Advertise Implementation Projects*

Implementation projects will be advertised on the www.mauiwatershed.org website operated by the CMSWCD as well as on social media. The main purpose of advertising these projects is to inform the community about projects occurring within the watershed to improve water quality. Advertising will also inform the public about project successes, failures, and data gaps. These advertising events will also serve as public relations opportunities for businesses and large land owners who would like the community to know about the implementation projects they have conducted to improve water quality. Advertising will also serve to inform the public about upcoming volunteer opportunities to assist in the various implementation projects. The use of volunteers not only allows the community to work directly on various projects, but can make projects more feasible by lowering costs.

The Conservation District will establish mailings, pamphlets, brochures and other materials specific to projects being implemented and design persuasive materials and presentations to provide to potential project partners such as resorts and golf courses.

10.2.4 *Participation with Government Agencies, Community Groups, Small Group Meetings, and Trainings*

Implementation projects listed in this Plan are all meant to improve water quality by reducing pollutant loads entering coastal waters. Depending on the proposed project, meetings will have to be conducted between the CMSWCD, the watershed coordinator, and government agencies, community groups, and businesses. Government agencies at the Federal, State, and local levels will have to be engaged on several fronts. These agencies can act in their regulatory capacity to force action be taken for some types of pollution or to provide a permit. They can also serve as a source of funding for implementation projects. These agencies can also provide technical expertise, training and prior knowledge about the best way to reduce pollution and improve water quality.

The Watershed Coordinator will attend Kihei Community Association Meetings and Aha Moku O Kula Makai Council meetings to disseminate information about the Southwest Maui Watershed Plan. The Kula Makai council currently takes an active role in Hawaiian culture and land stewardship throughout the Southwest Maui Watershed. In addition, the CMSWCD will invite stakeholders in the community to attend their meetings at the Kahului NRCS office in Kahului.

10.3 Education and Outreach Structure and Support

Table 40 provides the basic components making up the structure of the Education and Outreach Program. This table includes tasks associated with the objectives listed above, cost per unit, and a five-year budget for enacting the program.

Table 40. SMWP Education and Outreach with Costs

Southwest Maui Watershed Plan Education and Outreach Program							
Objectives	Cost per Unit	Year 1	Year 2	Year 3	Year 4	Year 5	Total 5 Year Cost
Build Public Awareness and Support							
Establish and maintain a Watershed Coordinator position to direct, organize, and coordinate all efforts related to the Southwest Maui Watershed Plan - including education and outreach.	$55,000 increasing annually by $1,000	$ 55,000	$ 56,000	$ 57,000	$ 58,000	$ 59,000	$285,000
Maintain Central Maui Soil and Water Conservation District website dedicated to watershed information - www.mauiwatershed.org	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$10,000
Maintain Central Maui Soil and Water Conservation District administrative staff (Maggie Kramp) support of outreach and education efforts	$8,000	$8,000	$8,000	$8,000	$8,000	$8,000	$40,000
List illegal dumping areas and known locations of pollution on websites	Included in Website Costs	NA	NA	NA	NA	NA	NA
Focused Outreach to Engage Businesses and Decision Makers							
Meetings with ranchers to discuss grazing management, ungulate control, HIZMs, dirt roads, and riparian zones	Included in Watershed Coordinator position costs	NA	NA	NA	NA	NA	NA
Hotels with major landscaping operations and golf courses will be educated on the use of fertilizers, LID BMPs, etc.	Included in Watershed Coordinator position costs	NA	NA	NA	NA	NA	NA

Southwest Maui Watershed Plan Education and Outreach Program							
Objectives	Cost per Unit	Year 1	Year 2	Year 3	Year 4	Year 5	Total 5 Year Cost
Business handling and storing oils and hazardous materials will be identified. These businesses should be engaged with CMSWCD personnel to ensure they are incorporating best management practices related to their industries. Examples of these businesses include auto mechanics, oil changing facilities, and industrial facilities.	Included in Watershed Coordinator position costs	NA	NA	NA	NA	NA	NA
Meetings with community associations to discuss cesspools, illegal dumping controls, etc.	Included in Watershed Coordinator position costs	NA	NA	NA	NA	NA	NA
Advertise Implementation Projects							
List upcoming implementation projects and volunteer opportunities in local papers and various websites	Included in administrative and website costs	NA	NA	NA	NA	NA	NA
Establish mailings, pamphlets, brochures and other materials specific to projects being implemented and design persuasive materials and presentations to provide to potential project partners such as resorts and golf courses.	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$10,000
Participation with Government Agencies, Community Groups, Small Group Meetings, and Trainings							
Meetings between the CMSWCD, the watershed coordinator, and government agencies, community groups, and businesses	Included in Watershed Coordinator position costs	NA	NA	NA	NA	NA	NA
Obtaining necessary permits	Included in Watershed Coordinator position costs	NA	NA	NA	NA	NA	NA

Southwest Maui Watershed Plan Education and Outreach Program							
Objectives	Cost per Unit	Year 1	Year 2	Year 3	Year 4	Year 5	Total 5 Year Cost
Meetings with large land owners and land managers	Included in Watershed Coordinator position costs	NA	NA	NA	NA	NA	NA
Attendance at Kihei Community Association and Aha Moku O Kula Makai Council meetings	Included in Watershed Coordinator position costs	NA	NA	NA	NA	NA	NA
Total for Outreach and Education							$ 335,000

11.0 ELEMENT F - IMPLEMENTATION SCHEDULE

When developing the implementation schedule for the Southwest Maui Watershed Plan, water quality data from the State of Hawaii Integrated Water Quality Report Assessments, 303d list of impaired waters, and Hui O Ka Wai Ola water quality data was compared with non-point sources of pollution on the landscape. This comparison assisted in identifying which projects should be given priority status. Besides observed water quality impairments, project costs and complexity were taken into account when assigning priority status.

When estimating when water quality standards would be achieved as a result of the implementation projects, factors such as the severity of the pollution based on current water quality data, the expected efficacy of individual projects, and whether the non-point source of pollution is related to stormwater or groundwater were considered. Timelines for individual project completion generally range from six months to five years. Estimates of when water quality standards will be achieved were based on the extent of the non-point pollution sources and the load reduction estimates for associated implementation projects. As an example, chlorophyll *a* standards may be require several different projects addressing nutrients originating from cesspools, wastewater injection wells, farming BMPs, ranching BMPs, and other non-point sources before water quality standards are met. Estimated timelines for water quality standard attainment generally range from 15 to 20 years. Timelines specific to individual water quality parameters being attained are discussed in detail in Section 13. Element H. While many of the projects listed below would immediately improve water quality, it may be years before they are implemented. As an example, many of the basins proposed in both this Plan and in the Kihei Drainage Master Plan are very expensive. These basins would immediately begin removing sediment from stormwater, but it may require large funding sources or future development before these basins are a reality.

Table 41. Implementation Project Priority Status and Approximate Timeline

Implementation Project	Location (Gulch)	Description	Approximate Timeline to Completion	Organization(s) Responsible for Implementation	Priority
Excavated Basins/Basins in Series	Kulanihakoi, Waipuilani, and Keokea	Basins capturing sheet flow prior to stormwater entering gulches would have precedent over basins connecting directly to gulches	6 Months - 4 Years	Central Maui Soil and Water Conservation District, Hawaii Department of Transportation, Maui County Department of Public Works	Medium

Implementation Project	Location (Gulch)	Description	Approximate Timeline to Completion	Organization(s) Responsible for Implementation	Priority
Pi'ilani Basin Utilization Strategy	Waipuilani	Utilize Pi'ilani basin to capture water from Waipuilani gulch	Unknown	Central Maui Soil and Water Conservation District, Pi'ilani Homeowners Association	Low
Contoured Terrace Ditches	Kulanihakoi, Waipuilani, and Keokea	Water bars and drainageways leading to detention basins	1 Year	Central Maui Soil and Water Conservation District, Kaonoulu, Haleakala, and Ulupalakua Ranches	Low
High Impact Zone Mitigation Sites	Waipuilani and Keokea	Swales and berms downslope from watering troughs	6 Months	Central Maui Soil and Water Conservation District, Kaonoulu, Haleakala, and Ulupalakua Ranches	Medium
Grazing Management Measures	Throughout Watershed	Ensures rural lands are being managed to account for erosion	Ongoing	Central Maui Soil and Water Conservation District, Kaonoulu, Haleakala, DHHL, and Ulupalakua Ranches	High
Riparian Protection and Rehabilitation	Keokea And Liilioholo	Area surrounding Keokea gulch already has fencing and water to assist in riparian rehabilitation/protection	6 Months	Central Maui Soil and Water Conservation District, Kaonoulu, Haleakala, and Ulupalakua Ranches	Medium
Illegal Dumping Controls	Throughout Watershed	Public outreach to educate about pollutants and the environment	6 Months	Central Maui Soil and Water Conservation District, Various Land Owners	Medium

Implementation Project	Location (Gulch)	Description	Approximate Timeline to Completion	Organization(s) Responsible for Implementation	Priority
Stream Restorations	Hapapa	Remove sediment buildup from streams	5 years	Central Maui Soil and Water Conservation District, Kaonoulu, Haleakala, and Ulupalakua Ranches	Medium
Low Impact Design	Throughout Watershed	Parking lots, Stormwater Wells, Nutrient Curtains, Floating Wetlands, etc.	6 months per project	Central Maui Soil and Water Conservation District, Resorts, Hotels, Golf Courses, and Various Owners	High
Expansion of R-1 Reuse Area	Kulanihakoi, Waipuilani, and Keokea	Use of R-1 to augment existing wetlands and gulches	Ongoing	Central Maui Soil and Water Conservation District, Hawaii Department of Transportation, Maui County Department of Public Works	High
Unpaved Roads	Throughout Watershed	Stabilization of roads to prevent erosion	1-4 Years	Central Maui Soil and Water Conservation District, Kaonoulu, Haleakala, and Ulupalakua Ranches	Low
Cesspool Upgrade	Throughout Watershed	Cesspool upgrade to septic tanks	6 months	Various Owners	Medium
Water Quality Monitoring	Throughout Watershed	Captures current and future water quality data	Ongoing	Hawaii DOH CWB, Hui o Ka Wai Ola	High
Watershed Coordinator	Throughout Watershed	Watershed representative	Ongoing	Central Maui Soil and Water Conservation District	High

Implementation Project	Location (Gulch)	Description	Approximate Timeline to Completion	Organization(s) Responsible for Implementation	Priority
Education and Outreach	Throughout Watershed	Conducted by Watershed Coordinator, ensures informed community participation	Ongoing	Central Maui Soil and Water Conservation District	High

12.0 ELEMENT G – INTERIM MILESTONES

The following section provides interim milestones for the various implementation projects proposed in the watershed plan. We attempted to provide appropriate timescales for each project, within a total time of twenty years. While watershed planning and implementation projects will be needed for much longer, the scope of this Plan was kept to two decades in total. Milestones listed in this section are meant to be both measurable and attainable, with clearly described benchmarks for measuring progress as it is made. Table 42 summarizes the information presented in this section.

12.1 Excavated Detention Basins

These basins have been given medium priority status. While detention basins are regarded as highly effective in the capturing of stormwater and in the removal of sediment, they are quite expensive to construct and often require extensive permitting, especially if connected to an existing stream.

Fourteen basins have been proposed in the Kihei Drainage Master Plan. The total estimated cost to construct all of these basins would be roughly 28 million dollars. For this reason, we believe a realistic milestone would be to construct at least one large detention basin as described in the KDMP once every five years. We would therefore have four large detention basins functioning within the watershed by 2040.

12.2 Piʻilani Basin Utilization

The Piʻilani Basin Utilization project was given low priority status due to both the permitting requirements and liability associated with the project. The basin is currently owned by Piʻilani Gardens, LLC and they would have to be willing to allow their detention basin to be connected to Waipuilani Gulch prior to the project progressing. That being said, the basin is ideally situated on the landscape and has been built on a large enough scale to accommodate stormwater from Waipuilani Stream during stormwater events. The stream diversion should be incorporated into the detention basin within the next ten years.

12.3 Stream Diversions to Contoured Terraces

Water bars and terraced ditches leading to detention basins were given low priority status due to feasibility and permitting constraints. Because these projects are associated with detention basins, we assigned them the same timeline and milestones as the basins above. Therefore, any stream diversions leading to contoured terraces and detention basins should occur slowly over the next 20 years, with individual projects happening every five years in conjunction with a large detention basin project.

12.4 High Impact Zone Mitigation Sites

Two high impact zone mitigation sites have already been identified on Haleakala Ranch in association with heavily used watering troughs. While these projects have been assigned a medium priority status, they both can be completed fairly quickly and should therefore be completed by 2025. Using this same benchmark, two HIZM projects should be completed every five years through 2040.

12.5 Grazing Management

While expensive, feral ungulate fencing has been determined to be the most effective implementation project for controlling sediment loading in the watershed. This observation is supported by the USGS rapid watershed assessment conducted in the summer of 2019. Feral ungulates have also deposited large amounts of feces in the stream beds mauka of Pi’ilani Highway, which contribute to nutrient and pathogen loads when these streams flow during storm events. For these reasons, feral ungulate fencing has been assigned high priority. Fencing should begin on ranchlands directly mauka of the Kihei-Wailea-Makena urban corridor in 2020 and continue throughout the next twenty years as needed until feral ungulate populations are under control.

As a benchmark, the Plan proposes to fence off 40 square acres per year which is equivalent to one linear mile of fencing per year. At $20 a foot, annual cost for ungulate fencing would be $105, 600. Therefore, by 2025, 200 square acres of ungulate fencing would be installed at a cost of approximately $528,000. By 2040, 800 square acres of ungulate fencing will be installed.

12.6 Riparian Protection

The Plan calls for riparian protection to both Keokea Stream in the Hapapa watershed and Liilioholo Stream in the Wailea watershed. We propose fencing off 5200 feet of Keokea Stream by 2025 and 5400 feet of Liilioholo Stream by 2030. Additional riparian corridors may be protected based on these two projects between 2030 and 2040.

12.7 Illegal Dumping Controls

Illegal dumping controls will be established in 2020 and maintained throughout the duration of the Plan implementation at sites where rubbish is known to accumulate.

12.8 Stream Restorations

The Plan proposes to restore sections of Kulanihakoi, Waipuilani, and Keokea streams makai of Pi‘ilani Highway. Due to the high expense associated with these restorations, we propose to complete one of these restorations every five years. Beginning with Kulanihakoi in 2020, restoration of Waipuilani would be slated for 2025 and restoration work in Keokea Stream would be slated to begin in 2030.

12.9 Low Impact Design Projects

Numerous LID projects are outlined in the watershed Plan. To affect the greatest increase to water quality, we propose conducting at least one large scale LID project per year. These would include LID projects associated with parking lots, golf courses, resorts, condominiums, or other locations that have large swaths of impervious cover ideal for LID improvements.

12.10 Expansion of R-1 Reuse Area

Maui County Mayor Victorino has called for Kihei Wastewater Treatment Plant pump station upgrades. This project would upgrade both the Kihei in-plant lift station No. 2 and the recycled water pump station. The Plan supports this work and will lobby for future County administrations to continue expansion of the R-1 reuse infrastructure. Ideally, infrastructure providing access to

R-1 will be installed as far north as Ohukai Road in North Kihei by 2030, throughout Wailea along Pi‘ilani Highway by 2035, and throughout Makena along the highway by 2040.

12.11 Unpaved Roads

Repair or decommissioning of unpaved roads was assigned low priority status due to large data gaps associated with the current condition of these roads. The Plan proposes completing a comprehensive inventory of these roads by 2025 to fully understand their relative status and functionality. Based on this assessment, repairs or decommissioning would occur as needed from 2025 through 2040.

12.12 Cesspool Upgrade or Closure

The vast majority of the cesspools that exist in the Southwest Maui Watershed Plan are privately owned. As part of the education and outreach program, the Watershed Coordinator acting on behalf of the Central Maui Soil and Water Conservation District will conduct an annual cesspool workshop to educate the public on the environmental consequences of this infrastructure as well as the programs and opportunities that can assist them in upgrading to septic or municipal wastewater systems.

12.13 Promotion of Existing Management Practices

12.13.1 *Water Quality Monitoring*

Water quality monitoring is currently being conducted by both DOH CWB staff and by the Hui O Ka Wai Ola citizen scientist organization. Unfortunately, several monitoring sites are currently not being monitored for any water quality parameters and other sites are only sampled for a few parameters. Kihei North, Kulanihakoi, Luana Kai, Maui Coast, Kihei Boat Ramp, Mokapu, Polo Beach, and Puu Olai - Little Beach sampling sites should be added to the current water quality monitoring program within the next five years. In addition, all sites should be tested for the full suite of water quality parameters within the next ten years. These parameters include in-situ measurements for temperature, salinity, pH, and dissolved oxygen. They should also include grab samples for turbidity, total nitrogen and phosphorus, nitrate-nitrite, ammonia, orthophosphate, chlorophyll-a, silicate, and enterococcus for all water quality monitoring sites within the Southwest Maui Watershed Plan boundary.

12.13.2 *Watershed Coordinator*

An as-needed watershed coordinator was given high priority status as an implementation project within the Plan. The SWCD does not currently have adequate staffing and would need an as-needed watershed coordinator who can serve as an intermediary between the various stakeholders involved in the Plan. A watershed coordinator should be identified to represent the conservation district and to promote the Plan. Funding for this role should be established within the first year to ensure implementation projects outlined in this Plan are conducted properly and efficiently. This funding should continue as needed throughout the duration of the Plan, as projects continue to be implemented.

12.13.3 *Education and Outreach*

Education and outreach events will occur quarterly every year throughout the duration of the Plan being implemented. Each of the four events will focus on educating stakeholders on water quality standards and current trends, non-point sources of pollution, wetlands and riparian corridors, grazing management, and the various implementation projects either ongoing or proposed for the watershed.

Table 42. Interim Milestones

Implementation Project	Location (Gulch)	Description	Priority	Twenty Year Timeline			
				2025	2030	2035	2040
Excavated Basins/Basins in Series	Kulanihakoi, Waipuilani, and Keokea	Basins capturing sheet flow prior to stormwater entering gulches would have precedent over basins connecting directly to gulches	Medium	1 Basin Completed	2 Basins Completed	3 Basins Completed	4 Basins Completed
Pi’ilani Basin Utilization Strategy	Waipuilani	Utilize Pi‘ilani basin to capture water from Waipuilani gulch	Low	Completed by 2030		NA	NA
Contoured Terrace Ditches	Kulanihakoi, Waipuilani, and Keokea	Water bars and drainageways leading to detention basins	Low	1 Ditch per 1 Basin Completed	1 Ditch per 1 Basin Completed	1 Ditch per 1 Basin Completed	1 Ditch per 1 Basin Completed
High Impact Zone Mitigation Sites	Waipuilani	Swales and berms downslope from watering troughs	Medium	Two HIZM sites completed	Two HIZM sites completed	Two HIZM sites completed	Two HIZM sites completed
Grazing Management Measures	Throughout Watershed	Ensures rural lands are being managed to account for erosion	High	200 acres of ungulate fencing	400 acres of ungulate fencing	600 acres of ungulate fencing	600 acres of ungulate fencing
Riparian Protection and Rehabilitation	Keokea	Area surrounding Keokea gulch already has fencing and water to assist in riparian rehabilitation/protection	Medium	Keokea Stream	Liilioholo Stream	To Be Determined	To Be Determined

Implementation Project	Location (Gulch)	Description	Priority	Twenty Year Timeline			
				2025	2030	2035	2040
Illegal Dumping Controls	Throughout Watershed	Public outreach to educate about pollutants and the environment	Medium	Established throughout urban corridor	Maintained throughout urban corridor	Maintained throughout urban corridor	Maintained throughout urban corridor
Stream Restorations	Kulanihakoi, Waipuilani, and Keokea	Remove sediment buildup from streams	Medium	Kulanihakoi	Waipuilani	Keokea	NA
Low Impact Design	Throughout Watershed	Parking lots, Stormwater Wells, Nutrient Curtains, Floating Wetlands, etc.	High	Five large scale LID Projects implemented	Ten large scale LID Projects implemented	Fifteen large scale LID Projects implemented	Twenty large scale LID Projects implemented
Expansion of R-1 Reuse Area	Kulanihakoi, Waipuilani, and Keokea	Use of R-1 to augment existing wetlands and gulches	High	Kihei WTF upgrades	R-1 expansion to Ohukai Road	R-1 Expansion to Wailea	R-1 expansion to Makena
Unpaved Roads	Throughout Watershed	Stabilization of roads to prevent erosion	Low	Comprehensive assessment of all unpaved roads	Repairs and decommissioning to be determined	Repairs and decommissioning to be determined	Repairs and decommissioning to be determined
Cesspool Upgrade	Throughout Watershed	Cesspool upgrade to septic tanks	Medium	Annual education and outreach	Annual education and outreach	Annual education and outreach	Annual education and outreach
Water Quality Monitoring	Throughout Watershed	Captures current and future water quality data	High	Add 8 additional sampling sites	Sampling for full suite of water quality parameters at all sampling locations	Sampling for full suite of water quality parameters at all sampling locations	Sampling for full suite of water quality parameters at all sampling locations

Implementation Project	Location (Gulch)	Description	Priority	Twenty Year Timeline			
				2025	2030	2035	2040
Watershed Coordinator	Throughout Watershed	Watershed representative	High	Establish and fund a watershed coordinator through the SWCD	Maintain a watershed coordinator through the SWCD	Maintain a watershed coordinator through the CMSWCD	Maintain a watershed coordinator through the CMSWCD
Education and Outreach	Throughout Watershed	Conducted by Watershed Coordinator, ensures informed community participation	High	Four education/outreach events per year for a total of 20 events by 2025	40 events by 2030	60 events by 2035	80 events by 2040

13.0 ELEMENT H - INTERIM NUMERIC CRITERIA

13.1 Interim Numeric Criteria

Interim numeric criteria are needed due in part to the lack of surface water within the watershed for much of the year. Because load reductions cannot readily be measured in surface waters after projects have been implemented, evidence of load reductions will be observed by the continued monitoring of coastal waters over many years. Interim numeric criteria were developed to assist in the determination of how much progress is being made over time towards the attaining water quality standards (Table 43). To develop these criteria, Hui O Ka Wai Ola's entire period of record data from 18 sites was analyzed. The geometric mean was calculated from measurements of turbidity, total nitrogen, total phosphorus, nitrate + nitrite, and ammonia. Enterococcus data was not included as data reviewed from the Hawaii Department of Health Clean Water Branch IR reports from 2018, 2016 and 2014 show that all sites where enterococcus was measured, the locations attained water quality standards. Geometric means were compared with the listed Dry Season water quality standards due to the highly ephemeral nature of the streams in the Southwest Maui Watershed planning area. Dry season criteria apply when the open coastal waters receive less than three million gallons per day of fresh water discharge per shoreline mile. The difference between the geometric mean and the dry season water quality standard for the period of record for each pollutant listed above was calculated.

13.2 Expected Dates of Achievement

To define realistic dates of achievement, this difference between observed values and the dry standard were divided into thirds to create interim numeric criteria to be attained over the next 18 years. In other words, every six years the Plan aims to decrease pollutants by one-third of the amount that they are currently observed above the water quality standard.

As an example, the period of record geometric mean for total phosphorus at Cove Park is 29.03 µg/L. The Dry criteria for total phosphorus in open coastal waters is 16.00 µg/L. This means that currently, Cove park is 13.03 µg/L above the standard. To generate interim numeric criteria, we divided 13.03 by three to generate a six-year target reduction value of 4.34 µg/L. Therefore, beginning in 2020 and running through 2026, the geometric mean for this period needs to decrease by 4.34 µg/L to a value of 24.69 µg/L. Similarly, from the period between 2026 and 2032, the geometric mean for total phosphorus should decrease from 24.69 µg/L to 20.35 µg/L. In this manner, Cove Park would attain water quality standards for total phosphorous by 2038.

13.3 Review Process

Data will be reviewed annually by the watershed coordinator, the Hui O Ka Wai Ola staff, and by DOH CWB staff. While interim numeric criteria were developed along an 18 to 20-year timeline, many sampling locations may attain water quality standards in a much shorter timeframe.

13.4 Criteria for Plan revision

Whenever data shows that interim numeric criteria will not be met for a given pollutant, an analysis of potential pollutant sources will be conducted. Additional implementation projects will be developed to address pollutant loading not being reduced by current activities. Likewise, any on-going projects will be reviewed to determine their effect on removing pollutants.

13.5 Revisions Strategy

When interim numeric criteria are not being met, the watershed coordinator will work with the SWCD and other stakeholders in the community to change the management practices currently being implemented. This will include updating and or reevaluating critical source areas of pollution. Additional models or sampling will be utilized to better understand the sources of pollution affecting water quality. Timelines will be reassessed based on this information.

13.6 Agency Responsible for Evaluating Progress

As implementation projects are executed on the landscape, their effectiveness at reducing pollutant loads will be analyzed by the watershed coordinator and the SWCD. In addition, the DOH CWB will play an active role in determining the overall success of the watershed plan.

Table 43. Interim Numeric Criteria

Site	Hui O Ka Wai Ola Period of Record	Number of Data Points	Interim Numeric Criteria - Difference between the Geometric Mean Value and the Dry Water Quality Standard	Pollutant				
				Turbidity (NTU)	Total Nitrogen (µg/L)	Total Phosphorus (µg/L)	Nitrate + Nitrite (µg/L)	Ammonia (µg/L)
				Geometric Mean Not to Exceed:				
				0.20	110.00	16.00	3.50	2.00
Kilohana Dr	2/23/2018 to 7/5/2019	26	2019	0.78	Meeting Standard	Meeting Standard	12.60	Meeting Standard
			2026 IR Report	0.52	NA	NA	8.40	NA
			2032 IR Report	0.26	NA	NA	4.20	NA
			2038 IR Report	0.00	NA	NA	0.00	NA
Keawakapu Beach	2/23/2018 to 7/5/2019	26	2019	0.53	Meeting Standard	Meeting Standard	7.71	1.22
			2026 IR Report	0.35	NA	NA	5.14	0.81
			2032 IR Report	0.18	NA	NA	2.57	0.41

Site	Hui O Ka Wai Ola Period of Record	Number of Data Points	Interim Numeric Criteria - Difference between the Geometric Mean Value and the Dry Water Quality Standard	Pollutant				
				Turbidity (NTU)	Total Nitrogen (µg/L)	Total Phosphorus (µg/L)	Nitrate + Nitrite (µg/L)	Ammonia (µg/L)
				Geometric Mean Not to Exceed:				
				0.20	110.00	16.00	3.50	2.00
			2038 IR Report	0.00	NA	NA	0.00	0.00
Ulua Beach	2/23/2018 to 7/5/2020	26	2019	1.02	51.09	Meeting Standard	64.37	1.45
			2026 IR Report	0.68	34.06	NA	42.92	0.97
			2032 IR Report	0.34	17.03	NA	21.46	0.48
			2038 IR Report	0.00	0.00	NA	0.00	0.00
Poolenalena (Chang's Beach)	2/23/2018 to 7/5/2020	26	2019	0.45	Meeting Standard	Meeting Standard	20.80	Meeting Standard
			2026 IR Report	0.30	NA	NA	13.87	NA
			2032 IR Report	0.15	NA	NA	6.93	NA
			2038 IR Report	0.00	NA	NA	0.00	NA
Maluaka Beach	11/8/2017 to 7/3/2019	32	2019	0.81	5.78	Meeting Standard	27.51	Meeting Standard
			2026 IR Report	0.54	3.85	NA	18.34	NA
			2032 IR Report	0.27	1.93	NA	9.17	NA
			2038 IR Report	0.00	0.00	NA	0.00	NA
Kalepolepo North	2/22/2018 to 7/2/2019	27	2019	2.98	139.04	Meeting Standard	132.30	2.70
			2026 IR Report	1.99	92.69	NA	88.20	1.80
			2032 IR Report	0.99	46.35	NA	44.10	0.90
			2038 IR Report	0.00	0.00	NA	0.00	0.00
Kihei South (Lipoa)	11/7/2017 to 7/2/2019	34	2019	6.02	31.64	Meeting Standard	53.60	1.73
			2026 IR Report	4.01	21.09	NA	35.73	1.15
			2032 IR Report	2.01	10.55	NA	17.87	0.58

Site	Hui O Ka Wai Ola Period of Record	Number of Data Points	Interim Numeric Criteria - Difference between the Geometric Mean Value and the Dry Water Quality Standard	Pollutant				
				Turbidity (NTU)	Total Nitrogen (µg/L)	Total Phosphorus (µg/L)	Nitrate + Nitrite (µg/L)	Ammonia (µg/L)
				Geometric Mean Not to Exceed:				
				0.20	110.00	16.00	3.50	2.00
			2038 IR Report	0.00	0.00	NA	0.00	0.00
Cove Park	11/7/2017 to 7/2/2019	34	2019	2.75	366.90	13.03	379.32	8.21
			2026 IR Report	1.83	244.60	8.69	252.88	5.47
			2032 IR Report	0.92	122.30	4.34	126.44	2.74
			2038 IR Report	0.00	0.00	0.00	0.00	0.00
Kalama Park	11/7/2017 to 7/2/2019	34	2019	6.80	20.38	Meeting Standard	41.32	1.97
			2026 IR Report	4.53	13.59	NA	27.54	1.32
			2032 IR Report	2.27	6.79	NA	13.77	0.66
			2038 IR Report	0.00	0.00	NA	0.00	0.00
Kamaole Beach I	11/7/2017 to 5/29/2018	15	2019	1.41	11.68	Meeting Standard	32.05	Meeting Standard
			2026 IR Report	0.94	7.79	NA	21.37	NA
			2032 IR Report	0.47	3.89	NA	10.68	NA
			2038 IR Report	0.00	0.00	NA	0.00	NA
Kamaole Beach III	11/7/2017 to 5/29/2018	15	2019	0.79	7.50	Meeting Standard	30.28	0.90
			2026 IR Report	0.53	5.00	NA	20.19	0.60
			2032 IR Report	0.26	2.50	NA	10.09	0.30
			2038 IR Report	0.00	0.00	NA	0.00	0.00
Mai Poina 'Oe Ia'u	2/22/2018 to 7/3/2019	25	2019	3.20	151.15	Meeting Standard	172.86	1.24
			2026 IR Report	2.13	100.77	NA	115.24	0.82
			2032 IR Report	1.07	50.38	NA	57.62	0.41
			2038 IR Report	0.00	0.00	NA	0.00	0.00

Site	Hui O Ka Wai Ola Period of Record	Number of Data Points	Interim Numeric Criteria - Difference between the Geometric Mean Value and the Dry Water Quality Standard	Pollutant				
				Turbidity (NTU)	Total Nitrogen (µg/L)	Total Phosphorus (µg/L)	Nitrate + Nitrite (µg/L)	Ammonia (µg/L)
				Geometric Mean Not to Exceed:				
				0.20	110.00	16.00	3.50	2.00
Makena Beach Shoreline	11/8/2017 to 5/30/2018	13	2019	0.31	Meeting Standard	Meeting Standard	Meeting Standard	Meeting Standard
			2026 IR Report	0.21	NA	NA	NA	NA
			2032 IR Report	0.10	NA	NA	NA	NA
			2038 IR Report	0.00	NA	NA	NA	NA
Makena Landing	11/8/2017 to 7/3/2019	32	2019	1.58	9.42	Meeting Standard	26.52	1.70
			2026 IR Report	1.05	6.28	NA	17.68	1.13
			2032 IR Report	0.53	3.14	NA	8.84	0.57
			2038 IR Report	0.00	0.00	NA	0.00	0.00
Oneuli	11/8/2017 to 7/3/2019	29	2019	1.94	Meeting Standard	Meeting Standard	17.23	1.13
			2026 IR Report	1.30	NA	NA	11.48	0.75
			2032 IR Report	0.65	NA	NA	5.74	0.38
			2038 IR Report	0.00	NA	NA	0.00	0.00
Palauea	2/23/2018 to 7/5/2020	26	2019	1.04	9.60	Meeting Standard	31.27	0.75
			2026 IR Report	0.69	6.40	NA	20.85	0.50
			2032 IR Report	0.35	3.20	NA	10.42	0.25
			2038 IR Report	0.00	0.00	NA	0.00	0.00
Wailea	2/23/2018 to 6/1/2018	8	2019	0.56	Meeting Standard	Meeting Standard	16.92	Meeting Standard
			2026 IR Report	0.37	NA	NA	11.28	NA
			2032 IR Report	0.19	NA	NA	5.64	NA
			2038 IR Report	0.00	NA	NA	0.00	NA

Site	Hui O Ka Wai Ola Period of Record	Number of Data Points	Interim Numeric Criteria - Difference between the Geometric Mean Value and the Dry Water Quality Standard	Pollutant				
				Turbidity (NTU)	Total Nitrogen (µg/L)	Total Phosphorus (µg/L)	Nitrate + Nitrite (µg/L)	Ammonia (µg/L)
				Geometric Mean Not to Exceed:				
				0.20	110.00	16.00	3.50	2.00
Waipuilani	11/7/2017 to 7/2/2019	34	2019	10.82	21.93	Meeting Standard	31.45	2.93
			2026 IR Report	7.21	14.62	NA	20.96	1.96
			2032 IR Report	3.61	7.31	NA	10.48	0.98
			2038 IR Report	0.00	0.00	NA	0.00	0.00

14.0 ELEMENT I – MONITORING PROGRAM FOR EVALUATING IMPLENTATION PROJECT SUCCESS

14.1 Water Quality Monitoring and Data Gaps

Due to the efforts of both the DOH CWB and the Hui O Ka Wai Ola, a robust water quality monitoring program is already in existence within Southwest Maui. That being said, some data gaps have been identified. The 2018 DOH CWB IR report lists 29 water quality monitoring sites in the Hapapa, Wailea, and Moʻoloa coastlines, many of these sites are not currently being monitored for one or more water quality parameters. As many as 17 sites in the Wailea watershed alone had insufficient data for assessment as reported in the 2018 IR report. Another major data gap to consider is a lack of information on pollutant loads originating in streams. Due to the ephemeral nature of streams in Leeward Haleakala, budget constraints, difficult terrain, and private property issues, virtually no data exists on pollutant loads in stormwater discharge from these streams. This lack of data makes identifying land-based sources of pollution more difficult as water samples collected from the coastline are diluted and affected by currents and tides.

Table 44. Water Quality Stations and Data Gaps

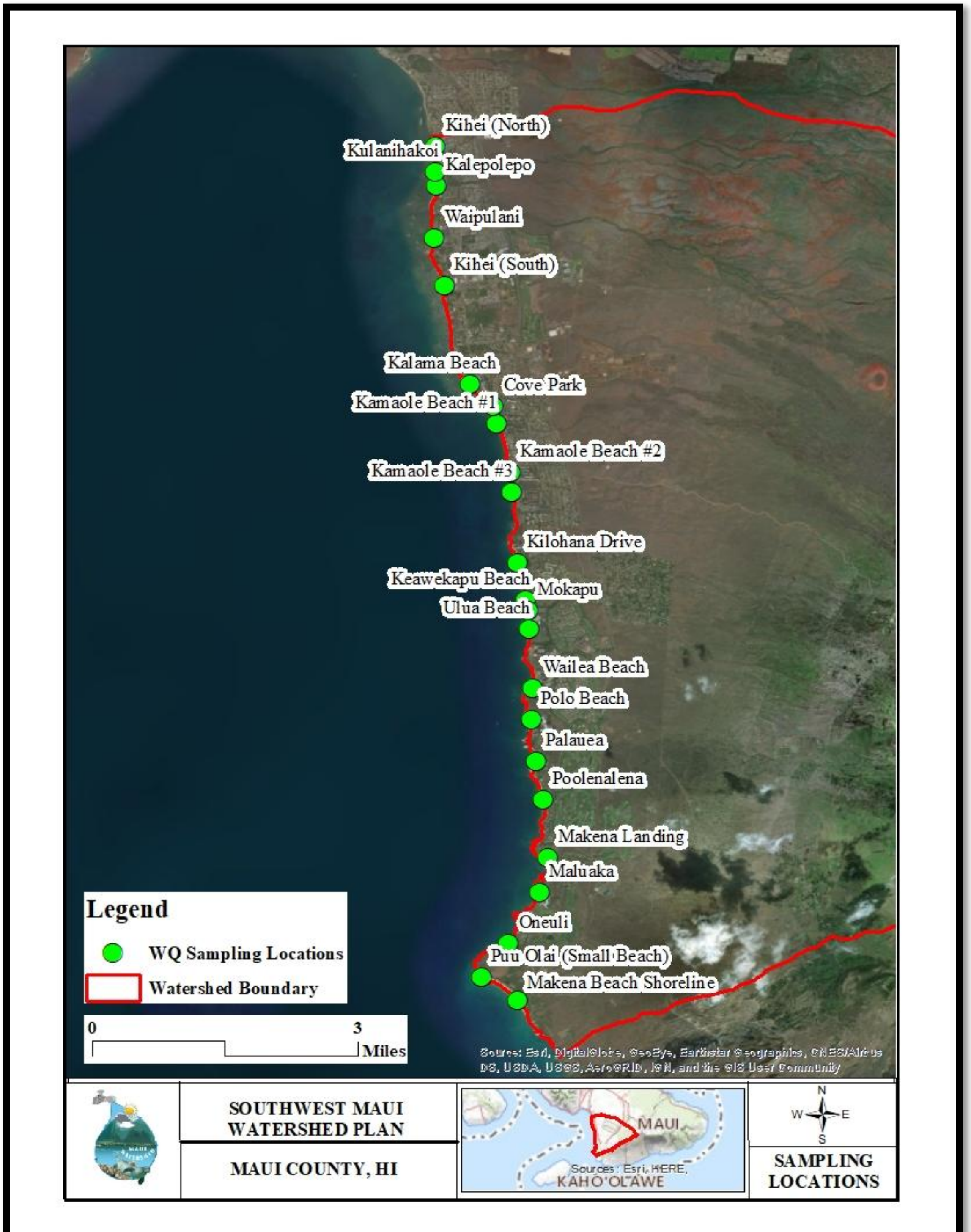
Currently Sampled for Enterococcus	Currently Sampled for Water Chemistry*
Kalama Beach Co. Park (Cove Park)	Kilohana Dr
Kalama Beach Co. Park (Beach)	Keawekapu Beach
Kalepolepo Beach	Ulua Beach
Kamaole Beach 1	Palauea
Kamaole Beach 2	Poolenalena (Chang's Beach)
Kamaole Beach 3	Makena Landing
Keawakapu Beach	Maluaka Beach
Keawakapu Beach	Oneuli
Mai Poina Oe Iau Beach Co. Park	Kalepolepo North
Kalepolepo (Waimahaihai)	Waipuilani Park
Oneloa Beach (Big Beach) (Makena Beach Station)	Kihei South (Lipoa)
Makena Landing Beach	Kalama Park
Malu'aka Beach	Cove Park
Mokapu Beach Par	
Palauea Beach Park	
Polo Beach Park	
Poolenalena Beach	
Pu'u ola'i (Small Beach)	
Ulua Beach Park	
Wailea Beach Park	
Waipuilani	

*Hui O Ka Wai Ola Water Quality Monitoring Sites

14.2 Meeting Interim Criteria

As mentioned in Section 13, existing period of record water quality data was used as a baseline to determine interim criteria. Implementation projects performed over the next 20 years are expected to bring those areas in the watershed with water quality exceedances into attainment.

Figure 47. Current Water Quality Monitoring Locations



14.3 Water Quality Monitoring to Evaluate Implementation - Baseline, Project Specific, and Post Project Monitoring

In an effort to generate quality-assured coastal water-quality data, and to provide this data to DOH CWB and other interested entities, a Quality Assurance Project Plan (QAPP) should be prepared for any water quality monitoring methodology to ensure this data is able to assist the DOH CWB and that the data can be included in their beach monitoring Program. Fortunately, a QAPP already exist for the Hui O Ka Wai Ola monitoring program to ensure Standard Operating Procedures (SOPs) such as sample depths, proper equipment usage, labeling, sample chain of custody etc., are being met and data is being collected, compiled, and reported accurately.

Baseline water quality monitoring is being completed along coastal waters throughout the watershed. While data from this monitoring is essential to ensuring our coastlines are swimmable, fishable, and generally healthy, this data set does little to provide information on the sources of pollution originating on the landscape. While water quality monitoring within streams would provide better information on the sources of land-based pollution, streams within Southwest Maui rarely flow.

The streams within the Plan are ephemeral and are considered losing or disappearing streams because water is infiltrated into the aquifer as it flows downstream. This results in generally more water volume upstream than downstream, and is characterized by deep gulches and canyons upstream and relatively small rivulets and stream channels downstream. While the downstream reaches of these streams may not flow for years at a time, and discharges from gulches and gullies into coastal waters are infrequent, when stormwater events do occur, the potential for flash floods, and very large stormwater volumes is possible within this watershed. Data specific to a particular implementation project and its effect on water quality will therefore require water quality samples be collected from stormwater runoff flows. Furthermore, to better understand potential pollution sources within the watershed, and their water quality impacts to nearshore marine water quality over time, stormwater sampling will be required.

If stormwater sampling remains unfeasible, the efficacy of implementation projects will have to be determined utilizing the interim numeric criteria developed and discussed in Section 13. While this method relies on coastal water that is not immediately adjacent to land-based pollution sources and that has been diluted, water quality trends in this dataset will approach and attain water quality standards as implementation projects reduce pollutant loads.

14.4 Responsible Parties

Responsibility for reviewing and revising the plan is assigned to the watershed coordinator and the Central Maui Soil and Water Conservation District. The watershed coordinator will also work with the DOH CWB, the Hui O Ka Wai Ola, and the numerous stakeholders listed in Section 2.1.3.

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APPENDIX A. ADDENDUM TO THE SOUTHWEST MAUI WATERSHED MANAGEMENT PLAN

August 2025

Estimating Pollutant Load Reductions Resulting from Control and Removal of Invasive Plant and Animal Species and Establishment of Native Species

Introduction

This addendum has been developed by the Hawaii Department of Health (HDOH) to address additional considerations and updates relevant to watershed management efforts. This addendum supplements the Southwest Maui Watershed Management Plan to include activities and additional guidance related to the removal of invasive plants and animals, as well as the reintroduction of native species. In addition to including these activities in the menu of best management practices (BMPs) that are eligible for 319 funding, this addendum provides an approach for calculating the pollutant reductions associated with these restoration activities. These pollutant reductions can be used by project managers and sub-grantees to develop individual project plans and by HDOH to calculate annual pollutant reductions for the broader NPS program.

Pollutant Loading from Invasive Species

Invasive plants and animals are an increasingly challenging source of pollution in many of Hawaii's watersheds. Invasive plants, such as miconia, have shallow root systems, which are unable to stabilize the soil and are susceptible to erosion and landslides during rainfall events. Invasive animals, such as feral hogs, are destructive grazers, uprooting plant material and exposing additional areas to erosion.

As a result, sediment is the primary pollutant of concern from invasive species, although other pollutants may also be transported during rainfall events (e.g., nutrients and bacteria). Sediment has been identified by HDOH as a pollutant of concern across the state and is a focus of water quality improvement efforts. This watershed-based plan already includes a discussion of pollutants of concern and the load reductions needed to return the impaired waters to attainment. This addendum supplements that discussion; invasive species are one of multiple pollutant sources to be addressed.

Pollution Control Practices

Across Hawaii, many organizations (including federal, state and local government, as well as watershed groups) are working to mitigate these problems. In many cases, this involves removing the invasive species and replacing them with native species. Native plant species[1] are better adapted to the soils and climate and provide improved soil retention, among other benefits. Excluding invasive animals, such as using fencing to block access to an area, allows vegetation to recover and thrive.

Table 1 below includes BMPs that can address pollutant loading caused by invasive species.[2] As shown by the large number of potential BMPs, vegetative plantings are a common element of

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[1] See, for example, https://dlnr.hawaii.gov/forestry/plants/ for a discussion of native plant species.

[2] The table shows only a selection of BMPs. Other BMPs may also accomplish the goals of invasive removal and re-establishment of native species. Watershed planners should consult with HDOH when developing project plans to ensure BMP eligibility.

many BMPs; ensuring that native species are used (and in the necessary quantities for establishment) will help to restore native plant communities. Managing invasive animal species is typically limited to exclusion or removal.

Table 1. Selection of BMPs to Address Invasive Species

Management Practice	Description
Bioretention Cell (Rain Garden)	Depression consisting of native plant species and soil mixtures that receives stormwater flow and infiltrates to treat pollutants.
Channel Maintenance and Restoration	Practices used to control sediment and plant pollution into waterways during earthwork such as stream bank stabilization or habitat enhancement. Examples include floating booms and silt curtains extended across river or stream banks downstream of work.
Constructed Wetlands	Creation of an artificial wetland ecosystem to improve the quality of stormwater runoff or other water flows. A constructed wetland provides biological treatment in areas where wetland function can be created or enhanced. Constructed wetlands also can be used to treat runoff from agricultural land uses and stormwater runoff and other contaminated flows from urban areas and other land uses. The practice involves establishment of inlet and outlet control structures for an impoundment designed to accumulate settleable solids, decayed plant matter, and microbial biomass and support propagation of hydrophytic vegetation.
Critical Area Planting	Establishment of permanent vegetation in areas with heavy erosion problems. Particularly useful for areas that need stabilization before/after flood events.
Grassed Waterway	A shaped or graded channel that is established with suitable vegetation to convey surface water at a non-erosive velocity using a broad and shallow cross section to a stable outlet. Used to convey runoff from terraces, diversions, or similar; to prevent gully formation; and to protect or improve water quality.
Herbaceous Weed Treatment/Invasive Species Removal	The removal or control of herbaceous weeds, including invasive, noxious, and prohibited plants.
Sediment Basin	Captures and retains stormwater runoff until sediments settle out; water is released through engineered outlet.
Feral Ungulate Fencing	A structural conservation practice that prevents movement of ungulates across a given boundary. Within areas impacted by feral ungulate presence, fences prevent their movement into the forested lands. Ungulate fencing prevents direct contact of fecal matter with waterways, allows for restoration of vegetation, and reduces bacteria and nitrogen loadings and sediment input into waterways.
Feral Ungulate Removal	Hunting or trapping wild goats, pigs, and other non-native hoofed mammals to reduce erosion caused by trampling and vegetation

Management Practice	Description
	removal, as well as nutrient and bacterial impacts from defecation in and around water bodies.

Through this addendum, these BMPs are now eligible for funding under Section 319 to address water quality concerns caused by invasive species (if the BMPs were not already identified in the original plan). Implementation of these BMPs will lead to a reduction in pollutant loading in the watershed. The original watershed-based plan may include information on specific locations or land use types that may be most appropriate for invasive species BMPs. Additional information can be found in other resources, such as the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's *Field Office Technical Guide* for Hawaii.[3]

Calculating Pollutant Reductions

Accounting for the total pollutant reductions is an important step in tracking water quality improvements. HDOH and watershed stakeholders develop watershed-based plans under the state's nonpoint source pollution (NPS) program; these plans include a projected level of pollutant reduction for the proposed project.

There are various models that can be used to calculate the pollutant reductions associated with BMP implementation. HDOH researched the advantages and disadvantages of each model, including the ease of use for watershed project managers and evaluating the model's appropriateness for use in Hawaii. After reviewing several models, HDOH selected the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model.

Description of the InVEST Model

InVEST is a suite of models focused on ecosystems and how they connect to downstream economics. This addendum is focused on the sediment delivery ratio model in the InVEST suite. The InVEST sediment delivery ratio model was chosen by HDOH because it is easy to use and its ability to estimate sediment loading both with current condition and with BMPs implemented. Additionally, the InVEST model can be modified to accommodate the unique geologic conditions in Hawaii.

The InVEST sediment delivery ratio model is focused on sediment loading and erosion. The model outputs a set of maps showing the sediment erosion, including the amount of sediment soil loss per pixel, and the amount of erosion that is prevented by the presence of vegetation per pixel. The effect of BMPs on sediment erosion can be measured by comparing model outputs ran under the current conditions against model outputs ran with BMPs implemented. To calculate the annual soil loss per pixel, the InVEST model uses the Revised Universal Soil Loss Equation (RUSLE; Renard et al., 1997). Along with the factors that are in the RUSLE equation (rainfall erosivity, soil erodibility, slope length gradient, cover management, and support practice), this addendum recommends including an additional terrain factor to accommodate for the geology of Hawaii. The inclusion of the terrain factor prevents the model from overestimating the soil loss in places with geologically new basaltic bedrock which has minimal soil cover (Falinski, 2016).

[3] https://efotg.sc.egov.usda.gov/#/state/HI/documents

The required data inputs for this model are integrated into the RUSLE equation. To determine the effects of BMPs on sediment load reduction and erosion, the model should be run with altered data inputs.

The required data inputs include GIS data, a table, and five additional values. These five inputs are described in detail in the Step-by-Step Procedure below. To measure the reduction in sediment load and erosion with BMP implementation, these inputs can be changed to integrate the increase in vegetation that would come along with BMP implementation. The Step-by-Step Procedure section of this addendum describes each of these required inputs in further detail along with recommended values and sources for GIS data inputs.

Step-by-Step Procedure

The step-by-step procedure begins with collecting and creating the proper data inputs for the current conditions in the watershed and running the InVEST model with those data inputs. After the first model run, the next step is to use multiple lines of evidence, including model outputs and other information, to determine the most appropriate areas in the watershed to implement BMPs. Next, the model should be run again with inputs that incorporate the impacts that BMPs would have on the land cover or support practices. The reduction in pollutant loading is the difference between the two model output runs. The steps to compile each data input and descriptions of each required data input are shown in Table 2. All GIS inputs must be the same coordinate reference system. The coordinate reference system must be projected and in linear units of meters.

Table 2. Required Data Inputs for the Invest Model

GIS Data Inputs		
Input Name and Description	**Data Type**	**Suggested Sources**
Digital Elevation Model: A digital elevation map (DEM) showing elevation in meters. The map should be clipped beyond the watershed boundary.	Raster	The 3D Elevation Program (3DEP) from USGS.[4] The best available resolution for the state is 1/3 arc-second.
		The Hawaii Statewide GIS Program's Digital Terrain Model.[5] Data is only available for portions of the state and as a JPEG or PNG, so it must be converted to a raster format. The resolution is 1 meter, and the elevation values are in meters.
Erosivity: A map of rainfall erosivity in units of MJ • mm/(h • ha • year). The map should illustrate both intensity and duration of rainfall.	Raster	For the island of Hawaii, NOAA's digitized version of the rainfall erosivity map from the Agriculture Handbook No. 703.[6] The units are US customary units, so the units must be converted by multiplying each value by 17.02 (Renard, et al., 1997).
		For the island of Oahu, NOAA's digitized version of the rainfall erosivity map from the Agriculture Handbook No. 703.[7] The units are US customary units, so the units must be converted by multiplying each value by 17.02 (Renard, et al., 1997).
		The rainfall erosivity map on page 57 of the Agriculture Handbook No. 703. This map must be digitized into raster data by a GIS specialist and units must be converted to SI by multiplying each value by 17.02 (Renard, et al., 1997).
		A rainfall erosivity raster can be made using precipitation from the Hawaii Climate Data Portal.[8] Rainfall erosivity can be calculated using the Roose equation (Renard and Freimund, 1994): $R = 0.5 \times P \times 17.02$, where R is the rainfall erosivity value in the proper SI units and P is the annual rainfall in mm/year.

[4] https://apps.nationalmap.gov/downloader/
[5] https://geoportal.hawaii.gov/datasets/HiStateGIS::hawaii-dtm-elevation/about
[6] https://www.fisheries.noaa.gov/inport/item/48225
[7] https://www.fisheries.noaa.gov/inport/item/48230
[8] https://www.hawaii.edu/climate-data-portal/data-portal/

Soil Erodibility: A map showing the soil erodibility in the watershed. Soil erodibility, also called K factor, is the likelihood of soil particles to erode and be transported downstream by precipitation or runoff. The soil erodibility raster must be in units of t · h · ha / (ha · MJ · mm).	Raster	Soil data, including K factors, is available from the Soil Survey Geographic Database (SSURGO).[9] This database provides raster data of soil type in an area of interest, and a table showing the K factor of each soil type. Raster data of K factors in a projected coordinate system will have to be generated by combining the soil raster data and the K factor table.
Land Use/Land Cover: A map showing the land use and land cover within the watershed. The C-CAP raster described below must also be combined with geology data. Each pixel should be categorized by its land use/land cover and geologic origin from the geology dataset. Every combination of land use/land cover and geologic origin should be assigned a unique LULC code.	Raster	NOAA has C-CAP high resolution land cover raster data available for the entire state of Hawaii from 2021.[10] NOAA's land cover data has a resolution of 1-meter and includes up to 25 classifications including forests and urban development.
		Geology data for the state of Hawaii is available for download from USGS.[11] This data is available as shapefiles, so it must be converted to raster data.
Watersheds: A map of the boundary of the watershed.	Vector (polygon/ multipolygon)	The USGS Watershed Boundary Dataset has vector watershed delineation data available at different hydrologic unit levels for the entire state of Hawaii.[12]
		The Hawaii Statewide GIS Program has vector watershed delineation data available that was created by the Division of Aquatic Resources (DAR).[13]
		The InVEST suite includes the Delineatelt tool, used for generating watersheds based on user inputs. This tool outputs a GeoPackage containing a vector with the model's estimated watershed delineations. More information on this tool can be found in the Delineatelt section of the InVEST suite.[14]
		Watershed delineations can be generated using a USGS StreamStats's tool.[15] Delineations can be downloaded as vectors.

[9] https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo
[10] https://coast.noaa.gov/digitalcoast/data/
[11] https://pubs.usgs.gov/of/2007/1089/
[12] https://www.usgs.gov/national-hydrography/watershed-boundary-dataset
[13] https://geoportal.hawaii.gov/datasets/HiStateGIS::watersheds-dar-version/about
[14] https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/delineateit.html
[15] https://www.usgs.gov/streamstats

Other Required Data Inputs		
Input Name and Description	**Data type**	**Suggested Input Value**
Threshold Flow Accumulation: The minimum number of pixels that flow into another pixel for it to be classified as a stream.	Number of pixels	This value should be determined by the user via trial and error. Users should test different values until the streams on the output maps resemble the streams in the watershed.
Borselli k Parameter: A calibration parameter in the sediment delivery ratio equation.	Number	This value is based on watershed location. Table 3 shows the Borselli k Parameter by location.
Maximum SDR Value: The maximum sediment delivery ratio a pixel is allowed to have.	Number between 0 and 1	For all watersheds in the state of Hawaii, the value should be 0.5 (Falinski, 2016).
Borselli IC_0 Parameter: A calibration parameter in the sediment delivery ratio equation.	Number	For all watersheds in the state of Hawaii, the value should be 0.1 (Falinski, 2016).
Maximum L Value: The maximum allowed slope value in the slope length-gradient factor.	Number	For all watershed in the state of Hawaii, the value should be 122 (Falinski, 2016).
Biophysical Table: A table mapping each LULC code to its cover-management factor (C) and support practice factor (P). One column should be named "lucode" and contain the LULC code from the land cover and land use raster. The other two columns should be named "usle_c" and "usle_p" and contain the associated C factor and P factor, respectively. The C factor indicates how much erosion is likely to occur at this land use/land cover type. The smaller the C factor value, the less erosion is expected to come from that type. To account for the terrain factor in the model run, the C factor in the biophysical table should be modified. The C factor for each LULC code should be the original C factor from Table 4 multiped by the terrain factor from Table 5 that is associated with the geologic origin under that LULC code. The P factor indicates whether erosion reduction practices are implemented in that area. A value of 1 means there are no erosion reduction practices implemented in that land cover/land use type and a	.CSV file	Table 4 shows the C factors for land use/land covers in Hawaii, and Table 5 shows the terrain factor by geologic origin.

smaller value indicates best management practices are implemented in that land cover/land use type.		
Workspace: The folder where outputs will be written.	Folder name	--

Table 3. Borselli k Parameter by Watershed Location (Falinski, 2016)

Watershed Location	Borselli k Parameter
Windward part of the island of Hawaii	4
Leeward part of the island of Hawaii	2.5
Oahu	2.5
Maui	2
Lanai	2
Molokai	1.25
Kahoolawe	2.4
Kauai	1.6
Niihau	1.5

Table 4. C Factor Values for Land Use/Land Cover (Falinski, 2016)

Land Use/Land Cover	C Factor	Land Use/Land Cover	C Factor
Evergreen	0.014[16]	Developed, Medium Intensity	0.01
Scrub Shrub	0.014[17]	Impervious Surface	0.001
Bare Land	0.7	Palustrine Scrub Shrub Wetland	0.003
Pasture/Hay	0.05	Palustrine Emergent Wetland	0.003
Grassland	0.05	Unconsolidated Shore	0.003
Open Water	0	Estuarine Forested Wetland	0.003
Cultivated Land	0.24[18]	Estuarine Scrub Shrub Wetland	0.003
Developed, Low Intensity	0.03	Estuarine Emergent Wetland	0.003
Palustrine Forested Wetland	0.003	Background	0
Open Space Developed	0.05	Palustrine Aquatic Bed	0

Table 5. Terrain Factor by Geologic Origin (Falinski, 2016)

Hawaii		**Oahu, Kauai and Niihau**	
Geologic origin	**Terrain factor**	**Geologic origin**	**Terrain factor**
Hamakua Volcanics	1	Honolulu Volcanics	1
Hawi Volcanics	1	Kolekole Volcanics	1
Hilina Basalt	0.001	Koolau Basalt	1
Hualalai Volcanics	0.001	Waianae Volcanics	1
Kahuku Basalt	0.001	Kiekie Volcanics	1
Kau Basalt	0.001	Koloa Volcanics	1
Laupahoehoe Volcanics	0.1	Paniau Basalt	0.1
Ninole Basalt	1	Waimea Canyon	0.1
Pololu Volcanics	1	--	--

[16] Evergreen forest: 0.035 for Hamakua and Kohala volcanoes
[17] Scrub/shrub: 0.05 for leeward volcanic units
[18] Cultivated land: 0.4 for pineapple (Lanai) or 0.51 for sugarcane crop (central Maui)

Puna Basalt	0.001	--	--
Maui, Molokai, Lanai and Kahoolawe		**All Islands**	
Geologic Origin	**Terrain factor**	**Geologic origin**	**Terrain factor**
East Molokai Volcanics	1	Open water	1
Hana Volcanics	0.001	Fill	1
Honolua Volcanics	1	Alluvium	1
Honomanu Basalt	1	Landslide Deposits	1
Kalaupapa Volcanics	1	Slope Deposits	0.001
Kanapou Volcanics	1	Tephra Deposits	0.1
Kaupo Mud Flow	1	Beach Deposits	0.1
Kula Volcanics	0.01	Lagoon Deposits	1
Lahaina Volcanics	1	Older Dune Deposits	1
Lanai Basalt	1	Younger Dune Deposits	0.1
Wailuku Volcanics	1	Talus and Colluvium	0.1
West Molokai Volcanics	1	Marine Conglomerate and Breccia	0.1
--	--	Caldera Wall Rocks	0.001

The most relevant output is the "sed_export.tif", showing the sediment exported from every pixel. Because of the geology of Hawaii, data on the pixel level from this raster may be inaccurate. The model tends to predict higher sediment export from areas with steeper slopes. In Hawaii, high slopes occur in high elevation areas where the sediment supply may be naturally limited by the unique geology of Hawaii. Therefore, the model overestimates the amount of sediment export in the mountains because it assumes unlimited sediment supply in steep areas with thin or little soil. For this reason, the sediment export raster data should not be used as the sole or main method for determining where BMPs should be implemented within the watershed.

The sediment export raster can be combined with land use/land cover data to determine which land use classes are disproportionately contributing to sediment loading. The amount of sediment mass exported per acre for each land use can be calculated by adding up the value of every pixel in the sediment export raster in each land use and dividing that sum by the number of acres that the land use covers.

It is crucial that multiple lines of evidence are considered when determining where BMPs should be implemented. The normalized difference vegetation index (NDVI)[19] is a satellite-based measurement that could be useful in identifying areas with minimal vegetation which may be susceptible to increased erosion. The NDVI quantifies vegetative health and density. NDVI values closer to positive 1 indicate the presence of abundant and healthy vegetation, and a value closer to 0 indicates there is less vegetation (NASA, 2025). Looking at NDVI data in a raster format would allow a user to visualize areas within the watershed that have little vegetation or

[19] One potential source of NDVI data is NOAA's Suomi National Polar-orbiting Partnership (Suomi NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Vegetation Indices (VNP13A2) Version 2 data product which can be queried using the 'modisfast' R package.

unhealthy vegetation, indicating that the area could benefit from BMP implementation. If the resolution of the NDVI data is a lower resolution, it may be difficult to pinpoint areas where BMP implementation would be the most valuable. Therefore, further evidence should be used when selecting areas for BMP implementation. A high resolution and recent satellite image can supplement older land use/land cover data and lower resolution NDVI raster data. A satellite image can be used to more accurately identify areas with minimal vegetative cover which could benefit most from BMP implementation. Further useful evidence can be collected on-site in the watershed. If possible, a person can walk along streams in the watershed and identify locations in the watershed where BMP implementation would be the most advantageous, such as locations with invasive plant species, minimal vegetation and/or the presence of feral ungulates. Each of the options listed above is important evidence that should be considered when the user is deciding on locations for BMP implementation.

After determining where BMPs will be implemented, the next step is to re-run the model with inputs that account for the BMPs that would be implemented to determine how they would affect sediment loading. The model inputs for the revised run should remain almost entirely the same. A different directory should be entered into the Workspace field or the results from the last model run will be overwritten. Additionally, either the support practice factors in the biophysical table or the land use/cover raster should be edited:

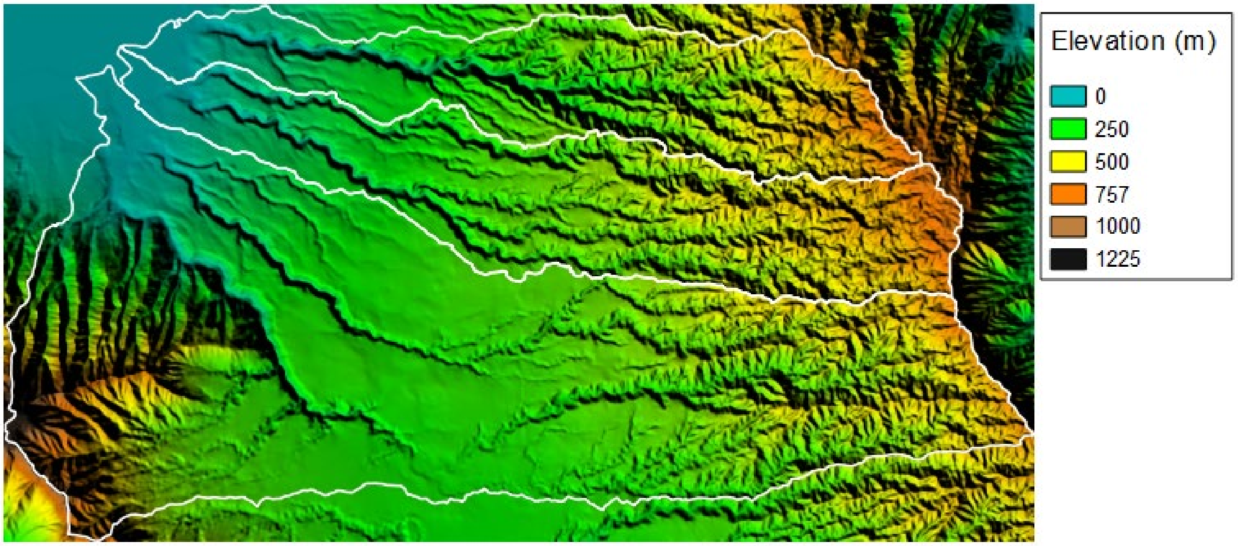
- The P factors in the biophysical table should be decreased for each land use/land cover type where an erosion reduction practice will be implemented.
- Alternatively, the land cover/land use raster should be edited to show how the land use/land cover would change with erosion reduction practices implemented. For example, bare land could be changed to a type of forest cover if a best management practice would be to plant native species on non-vegetated land.

To determine the effect that the implementation of best management practices would have on sediment exports, the outputs from both model runs can be compared. The sum across every pixel in "sed_export.tif" outputs illustrate how much sediment load reduction would occur with BMP implementation on the watershed level.

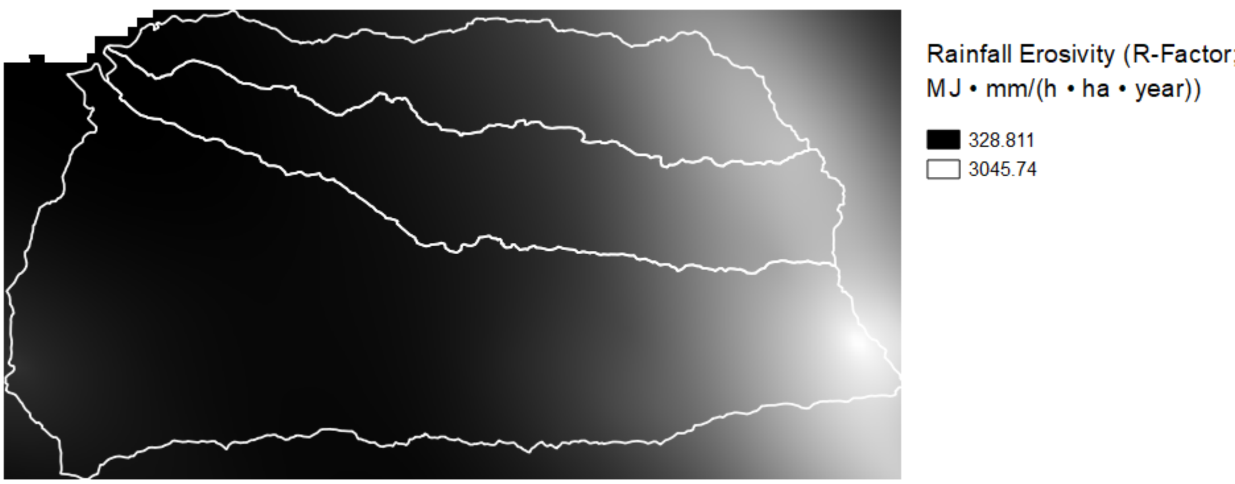
Example Use of the Procedure

To illustrate the Step-by-Step Procedure, this section looks at an example watershed: Kaiaka Bay. The Kaiaka Bay watershed is on the coast of the island of Oahu. The Kaiaka Bay and several streams that drain into the bay are listed as impaired. Both invasive plant species and feral ungulates are thought to cause high levels of erosion in this watershed, making the Kaiaka Bay watershed a good example watershed for the procedure (AECOM et al., 2018). The GIS data inputs for the InVEST model must all be in the same projected coordinate reference system, so every GIS data input is in the NAD83 coordinate reference system. The data inputs used for running the model with current conditions are below:

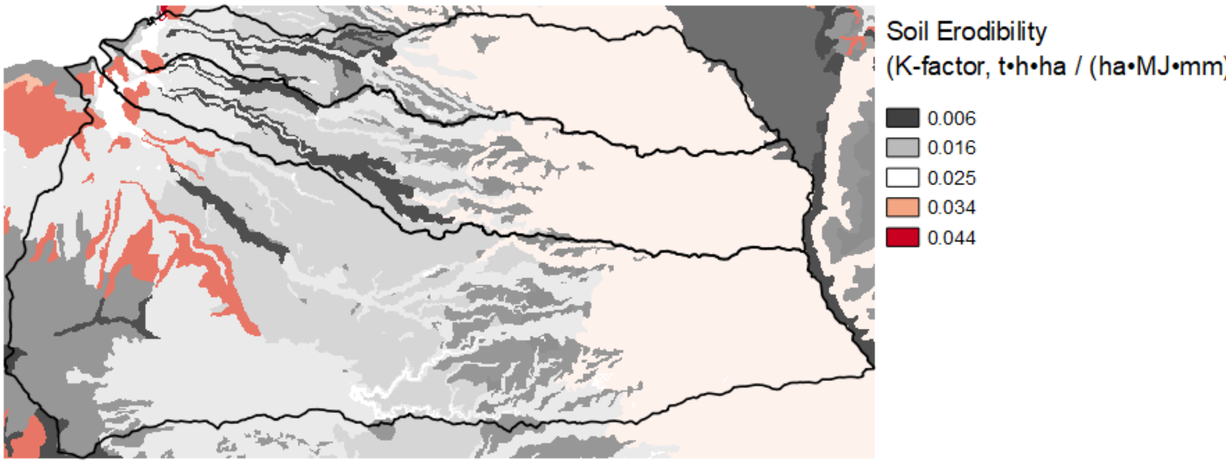
- Elevation Map: A DEM raster showing elevation in meters in the Kaiaka Bay and the surrounding area. This raster is a valid input for the InVEST model because the elevation is in meters and it extends beyond the Kaiaka Bay watershed boundary.



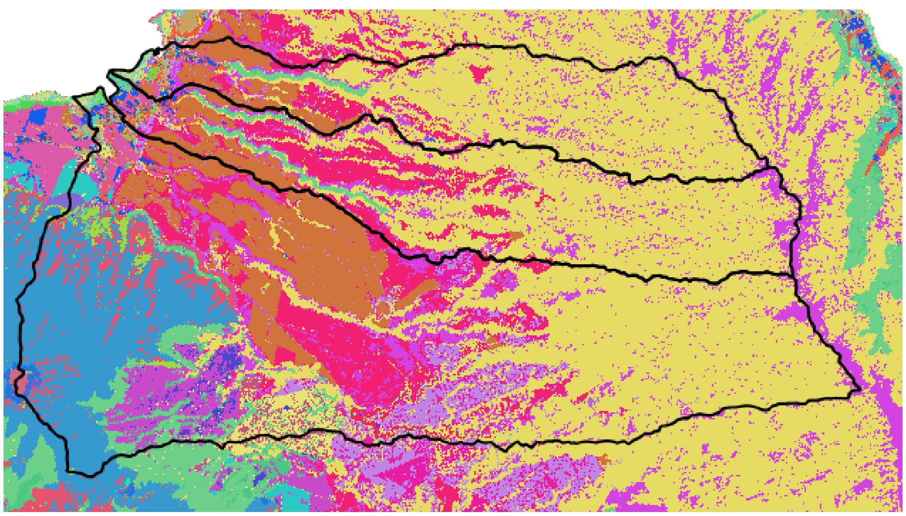
- Rainfall Erosivity: A rainfall erosivity map in raster format showing the rainfall erosivity throughout the Kaiaka Bay watershed in MJ • mm/(h • ha • year), the units required by the model.



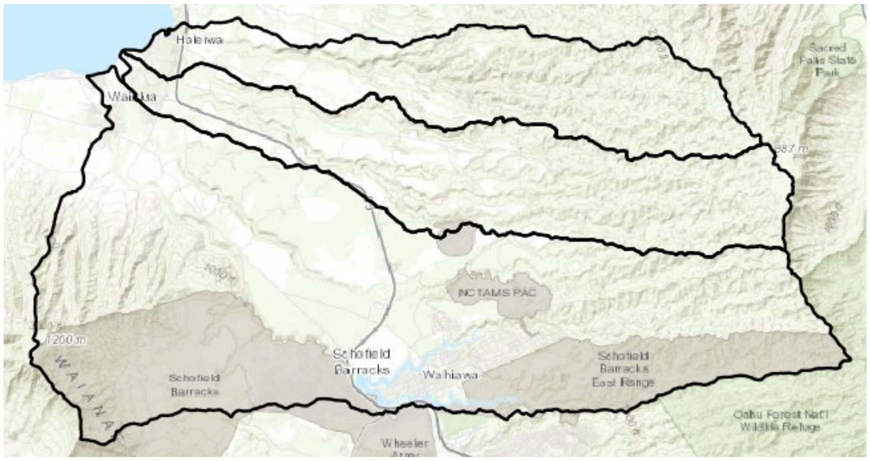
- Soil Erodibility: A map showing soil erodibility, or K factors, within the Kaiaka Bay watershed in raster format. The values in the raster format are in the proper units for the model, t • h • ha / (ha • MJ • mm).



- Land Use & Land Cover and Geologic Formation: A raster categorizing the land in Kaiaka Bay watershed by their land use/land cover and their geologic formation. This raster has over 1000 land cover/geologic formation categories, but not all categories have pixels that belong to them. Each land cover/geologic formation category has a unique LULC code so that this raster can be connected to the biophysical table.



- Watershed boundary: A vector outlining the Kaiaka Bay watershed.



- Threshold Flow Accumulation: 200. Value was derived through trial and error, and was identified when the delineated stream network approximately matched the "real" stream network for the watershed.

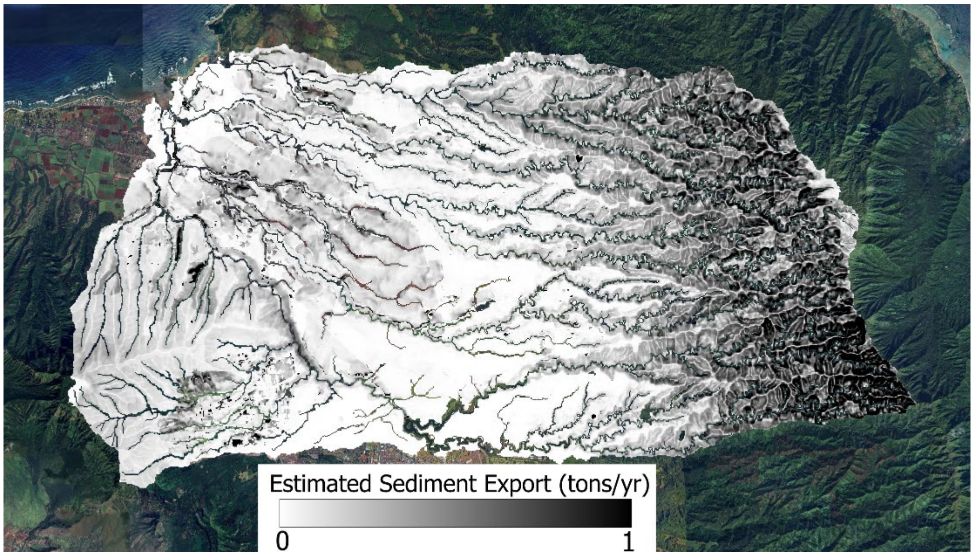
- Borselli k Parameter: The Borselli k parameter for this model run is 2.5, the value for all watersheds on Oahu.

- Maximum SDR Value: The maximum SDR value for this model run is 0.5, the value for all watersheds on the state of Hawaii.

- Maximum L Value: The maximum L value for this model run is 122, the value for all watersheds on the state of Hawaii.

- Biophysical Table: The biophysical table for this model run contains a column with each LULC code from the land use and land cover raster. Each LULC code is mapped to a modified C factor that is the original C factor from Table 4 multiplied by the terrain factor from Table 5 or the geologic origin associated with the LULC code. For example, a small piece of land in the Kaiaka Bay watershed is scrub shrub land (C factor = 0.014) with beach deposits as its geologic formation (terrain factor = 0.1), so the modified C factor in the biophysical table is 0.0014. The P factor for every LULC code is 1 because no support practices have been implemented in this watershed.

Once the inputs have been gathered, the baseline scenario is run. The model outputs suggest that a disproportionate amount of sediment export is occurring in the mountainous area of the Kaiaka Bay watershed. The sediment export raster is shown below:



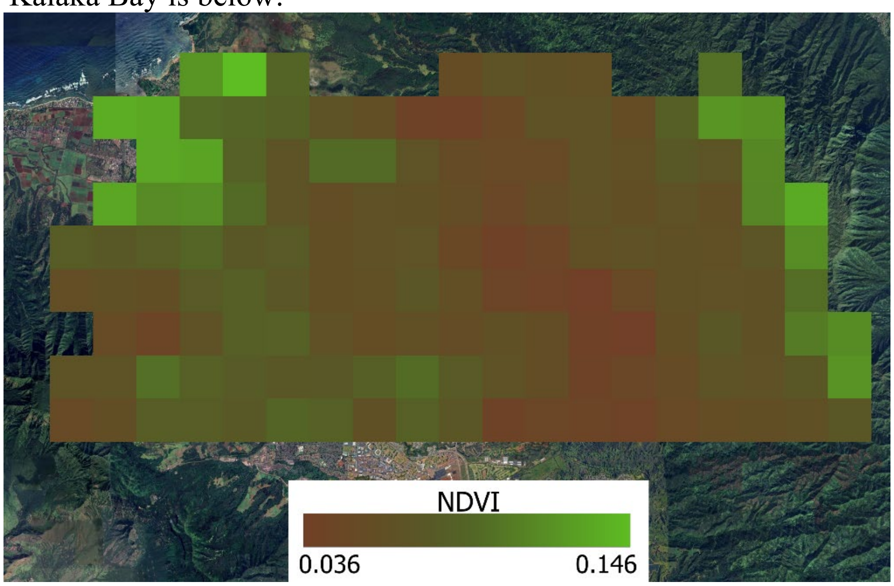
This raster indicates that the model expects the highest amount of sediment export to occur at the higher elevations of the watershed, but as discussed in the Step-by-Step Procedure section, the InVEST model tends to overestimate sediment export in high elevation areas. For this reason, multiple lines of evidence are considered when deciding on the locations for BMP implementation in this example. To determine the land class/land uses that contribute the most to sediment export relative to their area in the watershed, the pounds of sediment exported per acre is important evidence to evaluate as well. This value is calculated by adding the sediment export for every pixel in each land use/land cover and then dividing this sum by the acres each land use covers in the watershed. For example, bare land covers 405 acres of land in the Kaiaka Bay watershed and the model estimates that 1790.5 pounds of sediment are exported from bare land each year, so the pounds of sediment load per acre per year for bare land is 1790.5 divided by 405 which is 4.42. The sediment load per acre for each land use is shown in Table 6.

Table 6. Pounds of Sediment Load Per Acre Per Year by Land Use

Class	Edge of Stream Sediment Load (lbs/acre/year)
Developed, High Intensity	0.00
Developed, Med Intensity	0.00
Developed, Low Intensity	0.00
Developed, Open Space	0.11
Cultivated Crops	1.08
Pasture/Hay	0.26
Grassland/Herbaceous	0.44
Evergreen Forest	1.37
Scrub/Shrub	0.90
Palustrine Emergent Wetland	0.01
Palustrine Forested Wetland	0.01
Palustrine Scrub/Shrub Wetland	0.01

Class	Edge of Stream Sediment Load (lbs/acre/year)
Estuarine Forested Wetland	0.03
Estuarine Scrub/Shrub Wetland	0.23
Unconsolidated Shore	0.00
Bare Land	4.42
Open Water	0

This table indicates that bare land areas contribute the most sediment per acre in the Kaiaka Bay watershed, so bare land within the watershed may be a beneficial target for BMP implementation. Planting native plant species could minimize the sediment load coming from areas that are currently bare land by transforming it into vegetative cover (or evergreen forest in terms of land cover classes). Currently, bare land covers 405 acres of the watershed and the sediment export from this land is 1790.5 pounds. To calculate the amount of sediment load from this land after BMP implementation, assuming all the bare land becomes evergreen forest, the acres of bare land should be multiplied by the sediment load per acre for evergreen forest. This returns a value of 554.85 pounds of sediment load per year from this land, a 1235.65 pound decrease. These calculations should be considered when selecting locations for BMP implementation, but additional evidence should be evaluated as well. As discussed in the Step-by-Step Procedure section, NDVI data can be useful evidence as well. The NDVI data in raster format for the Kaiaka Bay is below:



The pixels with a lower NDVI index, which are shown in darker brown, are less vegetated areas. This image indicates that the middle section of the Kaiaka Bay watershed is less vegetated, so BMP implementation could be especially valuable in this area. However, the resolution of this raster data is low, so it is difficult to use it to precisely choose locations for BMP implementation. Therefore, other evidence such as high-resolution satellite images and drone footage can be used to pinpoint areas with minimal or invasive vegetation. As an additional line of evidence, people familiar with the Kaiaka Bay watershed can be interviewed to collect information on areas with minimal vegetation, invasive plants and/or feral ungulates.

Furthermore, a person can walk along streams in the Kaiaka Bay watershed and document the most eroded areas. The information gathered from the InVEST model run, the NDVI index raster, satellite images, drone footage, interviews and documentation from someone on site should all be carefully considered when determining where BMPs should be implemented.

Useful Resources and Materials

To supplement the information included in this addendum, more information on the InVEST model and using this model in the state of Hawaii is linked below:

- More information on the InVEST sediment ratio delivery model including background information, required data inputs, and guidance on interpreting outputs is here: SDR: Sediment Delivery Ratio — InVEST® documentation
- More information on the InVEST DelineateIt tool discussed in the Step-by-Step Procedure to create watershed boundaries: DelineateIt — InVEST® documentation
- Further details on the Kaiaka Bay watershed: Kaiaka Bay Watersheds Characterization
- For more information on running the InVEST model for watersheds in Hawaii, including the rationale for many of the non-GIS inputs see Predicting Sediment Export into Tropical Coastal Ecosystems to Support Ridge to Reef Management [dissertation], available for download here: (PDF) PREDICTING SEDIMENT EXPORT INTO TROPICAL COASTAL ECOSYSTEMS TO SUPPORT RIDGE TO REEF MANAGEMENT

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United States Geological Survey (USGS). 2025. 1/3rd arc-second Digital Elevation Models (DEMs) - USGS National Map 3DEP Downloadable Data Collection. https://data.usgs.gov/datacatalog/data/USGS:3a81321b-c153-416f-98b7-cc8e5f0e17c3