SOUTHWEST MAUI WATERSHED PLAN
VOLUME II

IMPLEMENTATION AND MANAGEMENT STRATEGIES

Central Maui
Soil & Water Conservation District

United States Department of Agriculture
NRCS Natural Resources Conservation Service

SOUTHWEST MAUI WATERSHED PLAN

FUNDED BY:

HAWAII STATE DEPARTMENT OF HEALTH &
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

PREPARED FOR:

CENTRAL MAUI SOIL AND WATER CONSERVATION DISTRICT
& SOUTHWEST MAUI WATERSHED ADVISORY GROUP

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February 2013

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The following disclaimer statement must be included as a condition of the grant funding:

"This project has been jointly funded by the U.S. Environmental Agency (EPA) under Section 319(h) of the Clean Water Act (CWA), and the Hawaii State Department of Health (DOH) Clean Water Branch. Although the information in this document has been funded wholly or in part by a Federal Grant to the DOH, it may not necessarily reflect the views of the EPA and the DOH and no official endorsement should be inferred."

Acknowledgements

Our thanks to the contributing stakeholders, whose input led to the development of this Watershed Plan. We are especially grateful to our Water Resource Engineer, Dr. Mohammad Tufail, for his technical support and guidance and to the Maui Conservation Specialists, John Astilla and Kira Nims (former and current). We also acknowledge the Department of Health (DOH) Clean Water Branch, Polluted Runoff Control Staff for their assistance and patience in the development of this Watershed Plan.

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Kula Community Association
Maui Surfrider Foundation
Thompson Ranch
Ulupalakua Ranch
Leeward Haleakala Watershed Restoration Partnership
Whole Foods

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LIST OF ACRONYMS AND ABBREVIATIONS

AEHR	Annual Erosion Hazard Rates
ALISH	Agricultural Lands of Importance in the State of Hawaii
AURORA	Autonomous Unmanned Remote Monitoring Robotic Airship
BLM	Bureau of Land Management
BMPs	Best Management Practices
C-CAP	Coastal Change Analysis Program
CWA	Clean Water Act
CMSWCD	Central Maui Soil and Water Conservation District
CFS	Cubic Feet per Second
CFU	Colony Forming Unit
COM	County of Maui
CORAL	Coral Reef Alliance
CSC	Coastal Services Center
CTAHR	University of Hawaii College of Tropical Agriculture and Human Resources
CWB	Clean Water Branch
CWC	Clean Water Committee
CWD	Community Work Day
CWRM	Commission on Water Resource Management
CZMA	Coastal Zone Management Area
DAR	Division of Aquatic Resources
DEM	Digital Elevation Model
DHHL	Department of Hawaiian Homelands
DLNR	Department of Land and Natural Resources
DOFAW	Department of Fish and Wildlife
DOH	Hawaii Department of Health
DPW	Department of Public Works
DSILT	Detained Stormwater Infiltration using Low Technology
DWS	Department of Water Supply
EMC	Estimated Mean Concentration
EN	El Niño
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FTU	Formazin Turbidity Unit
HAR	Hawaii Administrative Rules
HAWP	Hawaii Association of Watershed Partnerships
HCRI	Hawaii Coral Reef Initiative
HEC-HMS	Hydrologic Engineering Center-Hydrologic Modeling System
HFRA	Healthy Forest Restoration Act
HIHWNMS	Hawaii Humpback Whale National Marine Sanctuary
HRS	Hawaii Revised Statutes

HUC	Hydrologic Unit Code
HWEA	Hawaii Water Environment Association
HWWA	Hawaii Water Works Association
KCA	Kula or Kihei Community Association
LHWRP	Leeward Haleakala Watershed Restoration Partnership
LICH	Landscape Industry Council of Hawaii
LIDAR	Light Detection and Ranging
MGD	Million Gallons per Day
MNMRC	Maui Nui Marine Resource Council
MRTP	Maui Research and Technology Park
MSL	Mean Sea Level
NEMO	Nonpoint Education for Municipal Officials
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NSP	Nonpoint Source Pollution
OM	Organic Matter
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RC&D	Research, Conservation, and Development
R-1 water	Reclaimed Effluent Meeting R-1 Quality Criteria for Reuse
SCAS/OSU	Spatial Climate Analysis Service at Oregon State University
SCS	Soil Conservation Service
SMA	Special Management Areas
SMWAG	Southwest Maui Watershed Advisory Group
SMWP	Southwest Maui Watershed Plan
SO	Southern Oscillation
SOEST	School of Ocean and Earth Science and Technology
SRLF	Southern Regional Library Facility (University of California)
SWCD	Soil & Water Conservation District
TMDL	Total Maximum Daily Load
TMK	Tax Map Key
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
WAG	Watershed Advisory Group
WET	Watershed Education Training
WQS	Water Quality Standards
WUDP	Water Use and Development Plan
WWRF	Wastewater Reclamation Facility
WWTP	Wastewater Treatment Plant
ZAED	Zoning Administration and Enforcement Division

GLOSSARY

Advection – The transfer of a property of the atmosphere, such as heat, cold, or humidity, by the horizontal movement of an air mass

Ahupua'a – Common subdivision of the land in Hawaii

Keiki – Child

Kona – Southerly, from the south

Leeward – "Dry side" of an island receiving orographic precipitation

Limu – Seaweed

Mauka – Toward the mountains, upslope

Makai – Toward the ocean, downslope

N.T.U. – Nephelometric Turbidity Units: A comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions

Orographic – Precipitation that results from the lifting of moist air over an orographic barrier such as a mountain range

Trade Winds – Northeasterly winds

Windward – "Wet side" of an island receiving orographic precipitation

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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 development of the Southwest Maui Watershed Plan (SMWP) (herein referred to as the Plan) began with the formation of a Watershed Advisory Group (WAG) and it involves stakeholders to determine how to manage the watershed in ways that satisfy environmental, human health, and economic interests. This Watershed Plan has been developed by the Central Maui Soil and Water Conservation District (SWCD) and the Southwest Maui Watershed Advisory Group (WAG) which consists of participants representing diverse interests including local, state, and federal agencies; private landowners and other residents; and nonprofit organizations. The WAG sought input from affected stakeholders in the process of developing the Watershed Plan. Three goals were identified in this process:

The Plan is composed of two volumes: Volume I: Watershed Characterization, and Volume II: Implementation and Management Strategies (this document). It 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 (intermittent) streams, estuaries, dune systems, tidal pools, rocky shorelines, and coral reefs.

The 3 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 (COM planning) reported that there are at 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 DOH Integrated Water Quality Report to the EPA and Congress pursuant to Clean Water Act Section 303(d) indicates that more than 26 coastal waterbodies are impaired and not meeting state and federal water quality standards. Total Maximum Daily Load studies to determine needed pollutant load reductions are mandated for more than 74 waterbody/pollutant combinations within the planning area, but none are listed as high priority for state program funding. Of the 33 waterbodies assessed, more than 28 lack adequate data for assessment.

The primary source of water pollutants identified by this Plan is contaminated runoff. While there is evidence of other pollutant sources in the planning area, it is beyond the scope of this planning project to address them. This process will depend on gathering additional watershed monitoring data for water quality model development, obtaining commitments from stakeholders, and obtaining funding.

The goal of the pollution control strategy and implementation plan is to focus on sediment reduction measures, utilizing treated wastewater for irrigation (replacing the use of potable water or brackish Kama'ole aquifer wells), and supporting ecosystem restoration projects that reduce flooding and runoff.

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 improved water quality to enhance all of these uses, and to establish management practices on the land which will support them into the future. All urban/rural, agricultural, and conservation land uses can benefit from improved management measures which reduce soil loss caused by erosion during heavy rainfall.

2.0 INTRODUCTION

A watershed is the area of land where all of the water that is under it or drains from it flows into the same place. 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 (NSP) 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 algal 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. Due to limited data and financial and time-based restrictions, this Plan focuses mainly on sedimentation as the major pollutant of the planning area's watersheds, and describes management measures which will reduce erosion and promote watershed health.

In order to make progress toward restoring waters impaired by nonpoint sources of pollutants, EPA recommends the creation and implementation of watershed-based plans that include nine specific components and a six-step process. The development of the Southwest Maui Watershed Plan (SMWP) involved stakeholders to determine how to manage the watershed in ways that satisfy environmental, human health, and economic interests. This Watershed Plan has been developed by the Central Maui Soil and Water Conservation District (SWCD) and the Southwest Maui Watershed Advisory Group (WAG) which consists of participants representing diverse interests including local, state, and federal agencies; private landowners and other residents; and nonprofit organizations.

The WAG sought input from affected stakeholders in the process of developing the Watershed Plan, and developed a conceptual model (Figure 2-1) that identifies pollutant sources, stressors, impacts, and impairments. Using this conceptual model as a guideline, pollutants of interest were identified for water quality modeling and practical and applicable management strategies were examined. These strategies are detailed in the chapters which follow.

Three goals were defined during this community based planning process: 1.Fishable/Swimmable waters, 2. Increased Safety and Reduced Flood Property Damage, and 3. Increased Future Water Resources. Due to the limitations of the present planning project, both financial and staffing, goal 1. Fishable/Swimmable Waters was chosen as the focus of this Watershed Plan.

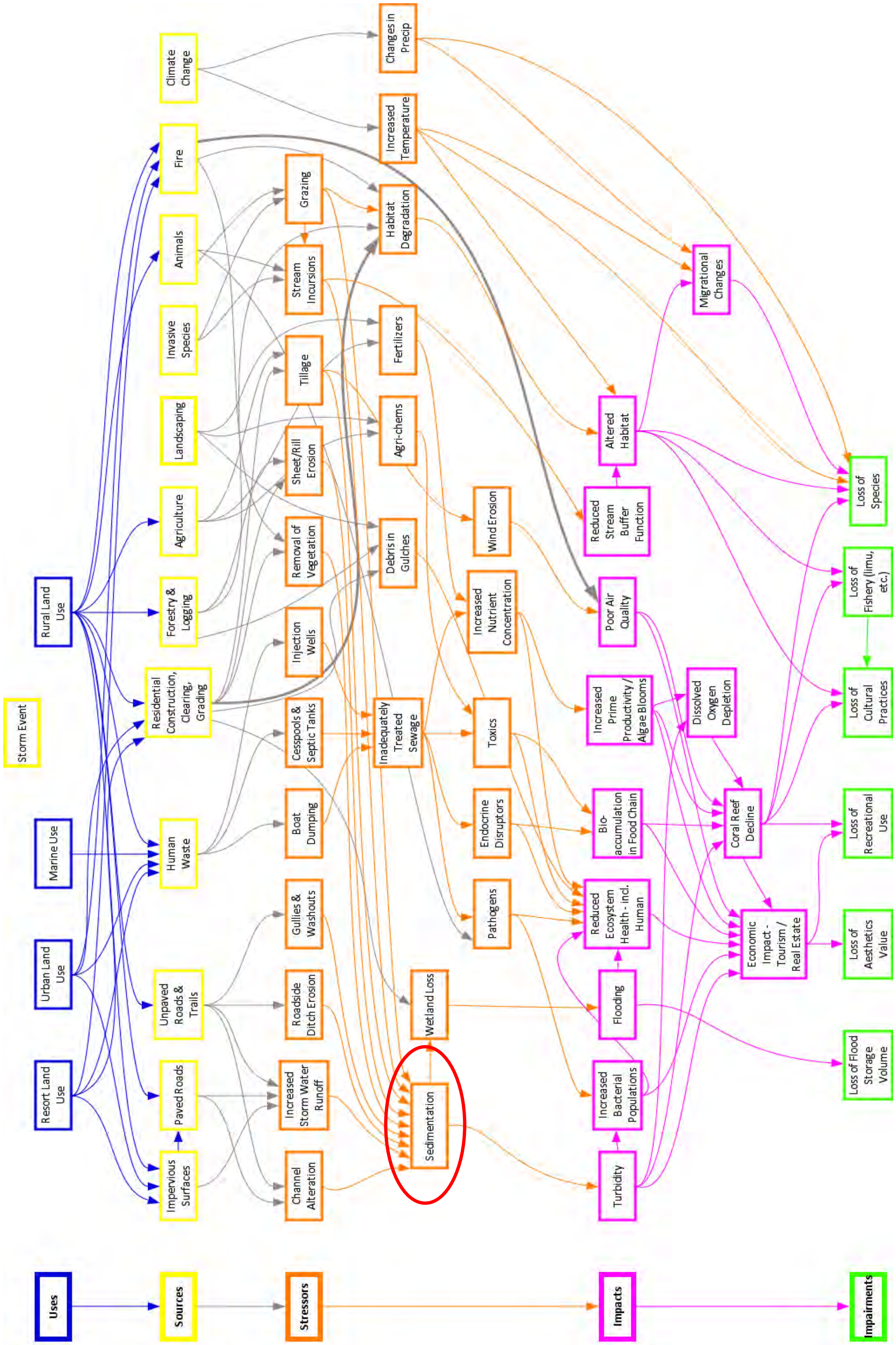


Figure 2-1 Conceptual Model

2.1 Estimate Pollutant Loads

The approach to pollutant load estimation is to develop a hydrologic model and apply literature data event mean pollutant concentrations (EMC) to calculate pollutant load. Those pollutant load estimates can then be further analyzed and evaluated to develop practical strategies for load reductions aimed at improving the water quality in the watershed under study. This section will briefly describe the modeling methodology that was used for the Southwest Maui Watershed Plan. A detailed report of the hydrologic and water quality modeling used in this Plan will not be presented in this document since it was determined that the EMC values established by this study do not relate fairly to the planning area. However, a summary of the Hydrology Report is provided below. An ongoing monitoring program is recommended for this watershed, to collect relevant data, so that the hydrologic models can be adequately calibrated in the future, and pollutant loads estimated.

2.1.1 *Watershed Modeling*

Given budgetary support, several key factors are considered in selecting the best model to be used in the development of a watershed management plan. These may include factors such as: applicability and accuracy of predictions; soundness of model theory and underlying equations; extent, availability, and cost of required input data; model familiarity and ease of use; long term modeling needs and requirements; financial constraints, etc. For this Plan, the choice of the recommended type and analysis of modeling technique was evaluated under the above factors, leading to the following conclusions:

- There is no data collection and monitoring program in place in the watershed to collect required data such as stream flow and water quality concentrations (discrete or continuous).
- There is no long term modeling need identified, to-date.
- Future technical expertise of who will maintain the models, once developed, is not clear at this stage.
- There are financial constraints that prohibit the purchase of expensive proprietary software for use in the modeling exercise of the watershed management plan.

Based on the above observations, a relatively simplified modeling plan was adopted that was easy to implement, and which fulfills the short term needs of the project in the absence of a reliable and effective data collection and water quality sampling and monitoring plan. Two different computational methods were investigated for runoff estimates: 1) *Rational Method of Peak Discharge Analysis* and 2) *SCS Runoff Curve Number Method, using the US Army of Corps hydrologic simulation program named HEC-HMS*. It should be noted that the Rational Method is often used to simulate runoff for smaller watersheds (up to 200 acres), and is not very applicable to this study, but was selected as a way of comparison to the more applicable SCS Runoff Curve Number Method.

Catchment data

The project area selected for hydrological analysis includes three major watersheds: Hapapa, Wailea, and Mo’oloa. These major watersheds are then further divided in to eleven sub-basins. The sub-basins present in each watershed along with their corresponding areas are given in the Table 2-1; maps of each sub-basin are given in Appendix B.

Rainfall Data

Rainfall data was collected and compiled for all the sub-basins in the project area from the NOAA Atlas 14 (http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_hi.html) of the region, and from local sources. Intensity Duration Frequency (IDF) Curves were plotted using the rainfall data for all relevant return periods for all sub-basins. Detailed rainfall data and IDF curves for each sub-basin are given in Appendix C.

Table 2-1 Details of Sub Basins

S. No.	Watershed	Sub-Basin	Accumulated areas	
			(Acres)	(km^2)
1	a. Hapapa	Kulanihako'i	10677.1	43.21
2		Waipu'ilani	7212.0	29.19
3		Keokea	8592.2	34.77
	Total		**26481.3**	
4	b. Wailea	Kama'ole	3847.4	15.57
5		Li'ilioholo	3120.9	12.63
6		Kilohana	4493.7	18.19
7		Paeahu	2708.8	10.96
8		Palauea	2543	10.29
9		Papa'anui	4243.8	17.17
10		Mohopilo	1030.3	4.17
	Total		**21987.9**	
11	c. Mo'oloa	Mo'oloa	**1213.0**	4.91

2.1.2 ***Rainfall-Runoff Modeling***

The main objective of the rainfall-runoff modeling for hydrological systems in the sub-basins is:

- To assess the peak flood discharge which occurs at the point of discharge for a particular basin or sub-basin under study for selected frequencies (return periods)
- To derive flood hydrographs (graph of discharge against time) for a particular basin or sub-basin under study for selected frequencies (return periods)

Not all the rain that falls on the catchment contributes to runoff; a part of it is lost as infiltration into the ground, interception and transpiration by vegetation, and to fill in surface depressions. The net rainfall contributing to runoff is called effective or excess rainfall and the difference between the total observed rainfall and excess rainfall is termed as abstractions or losses.

The rainfall-runoff model for any watershed can be conceptualized as a surface water budget model, incorporating the loss mechanism into the catchment model, as shown below.

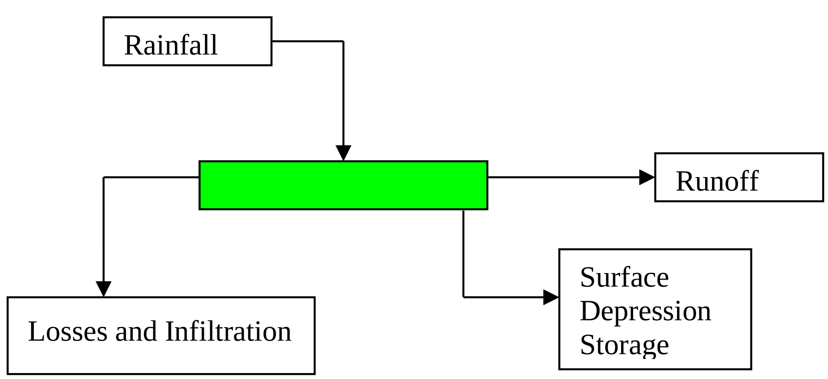


Figure 2-2 Rainfall Runoff Model as a Surface Water Budget Model

Rational Method

Although it is often considered simplistic, the Rational Method is still appropriate for estimating peak discharges for small drainage areas of up to about 200 acres (80 hectares) in which no significant flood storage appears. While this method is not very applicable to this study, it was used as a way of comparison to the more applicable SCS Runoff Curve Number Method.

The IDF curves were used for the calculation of rainfall intensity for each sub-basin, which were then used to calculate peak discharge for each sub-basin. The design period used for the analysis included 2, 5, 10, 25, 50, and 100-year return periods. The details of the Rational Method computations are given in Appendix E, Section 1.

SCS Runoff Curve Number Method

The hydrological study was facilitated with the computer model HEC-HMS that utilizes the commonly used SCS Curve Number method and unit hydrograph technique of routing. A HEC-HMS model was developed for each sub-basin in the study area to compute the peak discharge hydrograph of the sub-basin for various return periods. The HEC-HMS model consists of various components including 1) meteorological or rainfall data, 2) basin data describing the land use and loss data, and 3) control data describing the simulation time parameters such as total simulation time as well as simulation increments.

The sub-basins were delineated and included outlet points for each of the 11 sub-basins. The Time of Concentration (Tc) and Curve Numbers (CN) for these sub-basins were calculated by utilizing data either collected from the field or assumed based on visual inspection of the streams. The details of the HEC-HMS computations are given in Appendix E, Section 2. Once all the input data related to the sub-basin characteristics, land use, and rainfall data were finalized, the runoff computations were carried out to obtain runoff volume and peak runoff hydrographs for each sub-basin. The runoff hydrographs are included in Appendix F.

Results

The peak discharge results using each method are summarized in Appendix E. Comparison of peak discharges for both runoff methods (Rational method versus SCS Curve Number method) for all sub-basins is tabulated in Table 2-2.

Table 2-2 Comparison of Peak discharges using different methods

Sr. No.	**Water-shed**	Sub Basin	Method	**Peak Discharge-24 hour rainfall (cfs)**						
				1 Yr	**2 Yr**	**5 Yr**	**10 Yr**	**25 Yr**	**50 Yr**	**100 Yr**
1	**Hapapa**	Kulanihakoi	SCS Curve No	237	540	1112	1653	2508	3257	4078
			Rational method	*546*	*692*	*983*	*1202*	*1457*	*1785*	*2112*
2		Waipuilani	SCS Curve No	100	244	529	807	1248	1625	2076
			Rational method	*278*	*394*	*533*	*672*	*881*	*927*	*1136*
3		Keokea	SCS Curve No	117	279	582	872	1326	1727	2165
			Rational method	*331*	*463*	*629*	*761*	*993*	*1158*	*1357*

Sr. No.	Water-shed	Sub Basin	Method	Peak Discharge-24 hour rainfall (cfs)						
				1 Yr	2 Yr	5 Yr	10 Yr	25 Yr	50 Yr	100 Yr
4	**Wailea**	Kamaole	SCS Curve No	68	231	641	1061	1751	2360	3047
			Rational method	*655*	*819*	*1228*	*1474*	*1801*	*2096*	*2375*
5		Liilioholo	SCS Curve No	43	109	242	374	584	767	972
			Rational method	*184*	*250*	*355*	*421*	*513*	*631*	*658*
6		Kilohana	SCS Curve No	68	170	382	589	921	1213	1536
			Rational method	*385*	*499*	*658*	*794*	*1043*	*1202*	*1338*
7		Paeahu	SCS Curve No	51	133	301	466	730	960	1214
			Rational method	*292*	*390*	*543*	*668*	*808*	*961*	*1086*
8		Palauea	SCS Curve No	82	289	727	1152	1820	2400	3037
			Rational method	*864*	*1115*	*1478*	*1778*	*2167*	*2467*	*2743*
9		Papaanui	SCS Curve No	59	152	256	563	902	1210	1559
			Rational method	*372*	*496*	*682*	*867*	*1074*	*1219*	*1404*
10		Mohopilo	SCS Curve No	29	124	341	553	902	1214	1567
			Rational method	*317*	*420*	*562*	*669*	*821*	*947*	*1070*
11	**Mooloa**	Mooloa	SCS Curve No	41	152	391	623	1002	1336	1706
			Rational method	*325*	*430*	*584*	*689*	*855*	*981*	*1085*

A summary of the **runoff volume** for each sub-basin corresponding to different return periods as simulated in the HEC-HMS model is given in below.

Table 2-3 24-Hour runoff volume for sub-basin

S. No.	Watershed	Sub Basin	Total Volume-24 hour rainfall (acre-ft)						
			1 Year	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
1	**Hapapa**	Kulanihakoi	320	708	1413	2066	3087	3975	4946
2		Waipuilani	146	364	782	1184	1819	2384	3004
3		Keokea	187	454	954	1430	2173	2831	3550
4	**Wailea**	Kamaole	68	178	393	596	920	1203	1518
5		Liilioholo	58	148	321	488	749	975	1226
6		Kilohana	88	223	478	721	1103	1435	1800
7		Paeahu	61	147	307	457	694	897	1120
8		Palauea	65	151	308	454	682	880	1097
9		Papaanui	73	194	428	656	1023	1351	1720
10		Mohopilo	23	56	118	177	272	356	450
11	**Mooloa**	Mooloa	31	71	147	218	331	430	539

2.1.3 *Water Quality Modeling*

The purpose of water quality modeling is to determine the water quality loads generated in all the sub-basins included in the study area of the watershed. The following pollutants of interest were identified for water quality modeling for each sub-basin in the study area:

- Total suspended solids
- Total nitrogen
- Nitrite-nitrate nitrogen
- Ammonia nitrogen
- Enterococcus bacteria
- Total phosphorus

The water quality loads for all parameters of interest identified for the sub-basins would usually be calculated based on the Event Mean Concentration (EMC) values for all such pollutants of interest. Since there is no monitoring data (discrete or continuous) available for the watersheds that would typically provide for estimates of the pollutant concentrations for all pollutants of interest, no water quality modeling was feasible.

In the absence of on-site actual monitoring data, secondary data collected in the US during various water quality studies were analyzed to determine if the base conditions observed in such studies and database sets relate to the base conditions of the Southwest Maui watersheds, particularly with regard to runoff, rainfall, and land use data. The secondary data studied were: 1) the *National Stormwater Quality Database* (NSQD) and the 2) *Nationwide Urban Runoff Program* (NURP).

After studying the land use and rainfall/runoff characteristics the NSQD and NURP, it was determined that the EMC values determined by these studies do not relate to the land use and runoff/rainfall characteristics of the watershed under study. It would not be practical and feasible to apply these EMC values to the sub-basins of our study area to calculate the loading estimates of the watershed.

2.1.4 ***Recommendations for Future Work***

The peak discharge and water quality analysis for the sub-basins in the study area point to the lack of monitoring data related to both flows and water quality constituents of interest. In order for the flow calculations and loading estimates to provide a practical mechanism for load reduction strategies, it is important that an extensive data collection exercise is made part of the watershed planning process. It is the recommendation of this study that a comprehensive data collection program is developed and implemented in the Southwest Maui Watershed and its associated sub-basins including stream flow and water quality sampling over an extended period of time. Data collected during such an exercise can then be effectively used to develop more thorough and reliable hydrologic and water quality models for long term use in the watershed. The hydrologic and water quality models can only then be effectively calibrated using the monitoring data leading to more reliable estimates of flow and water quality loading estimates. The loading estimates obtained in such a manner can then be further analyzed and evaluated to develop practical strategies for load reductions aimed at improving the water quality in the watershed.

2.2 **Set Goals and Identify Load Reductions**

Although data are lacking at present that would allow for the estimation of pollutant loads and load reductions, the Watershed Advisory Group was able to establish some basic qualitative goals, objectives, targets, and indicators (discussed in Volume I, Chapter 2, Section 2.1.7.) The primary and most feasible goal at present, fishable swimmable waters, is summarized in the following tables.

Goal 1 - Fishable Swimmable Waters

Objective 1 – Reduce Sediments

Indicators	Targets
Turbidity – measure of water clarity expressed by ability to transmit light through sample; suspended solids raise turbidity and lower water clarity.	Intermittent streams and ocean waters meet numeric criteria in State Water Quality Standards at HRS 11-54.
Total Suspended Solids – indicator of materials contributing to turbidity in the form of suspended solids; monitored in order to establish correlation between turbidity (which has a state standard) and pollutant load	Levels in streams and oceans decrease from initial monitoring to levels correlated with pollutant reduction goals; used to establish correlation of load (mass/time of suspended solids) to State Water Quality standard for turbidity
Total Suspended Solids Load; requires estimation or measurement of flow volumes for storm events where TSS is measured.	Reduction from initial load estimate in accordance with implementation strategy estimated load reductions.
Volume of Sediment	Reduction from volumes observed and removed from streets and waterways after 2010 storms

Objective 2 – Reduce Pathogens

Indicators	Targets
Presence of detectable quantity of fecal source/pathogenic indicator organisms (e.g., enterococcus or clostridium)	None detectable in recreational waters in dry weather
Concentration of fecal source/ pathogenic indicators	Where detectable, levels decrease; concentration is less than state water quality criteria for recreational waters at all times; recreational, fisheries, and cultural uses are supported by microbial water quality

Objective 3 – Reduce Nutrients

Indicators	Targets
Nutrient concentration of water column	Intermittent streams and ocean waters meet applicable numeric criteria in State Water Quality Standards at HRS 11-54.
Nutrient Load - requires estimation or measurement of flow volumes for storm events where nutrient concentrations are measured.	Levels in streams and oceans decrease from initial monitoring to levels correlated with pollutant reduction goals;
Nuisance and/ or harmful Algal blooms	Absent; narrative criteria and designated uses at HRS 11-54 are attained

3.0 MANAGEMENT STRATEGIES

3.1 Pollution Control Strategies

The pollution control strategy is meant to integrate management of water resources to prevent and control point and nonpoint source pollution while supporting ecosystem restoration and natural resource conservation. In the words of Watershed Advisory Group member Michael Howden: "If using Keyline principles, we run swales on contour out across the landscapes…these channels will help us hold both the moisture and the organic matter carried in these waters…rather than running out into the ocean, helping to kill our corals and otherwise polluting the nearshore waters" (Maui Weekly, 2/16/12).

The following paragraphs discuss the main pollution control strategies developed by this Plan. Each pollution control strategy will then be further dissected into specific implementation projects.

NOTE: Pollution control strategies not only support the clean water goal (fishable swimmable waters) but also support the goals of reducing the effects of flooding and increasing available future water supplies.

DSILT (Detained Stormwater Infiltration using Low Technology)

These are projects to control pollutant delivery to the ocean by detaining stormwater, trapping sediment, and facilitating infiltration (reducing sediment, nutrients, debris, and pathogens). DSILT endeavors include projects such as riparian buffers, terracing, and off-line peak flow diversion/storage/infiltration.

Water Reuse

These are projects that can reduce pollutant delivery to the ocean by re-using rather than disposing of recycled water. Use of these water resources for restoring ecosystem function is included (e.g. use R-1 water to irrigate riparian buffers, stabilize stream banks through establishing vegetation, and restore wetlands).

Best Management Practices (BMPs) and Other Strategies

Identify appropriate BMPs for categories of sources/land use/cover/activity.

Education and Outreach

- Identify target audiences and develop training materials
- Conduct targeted stakeholder education and outreach (events, workshops, meetings, presentations, newsletters)

Monitoring Plan

A long term monitoring plan of NSP "pollutants of concern", designed to develop a data base to inform decision making regarding funding and implementation projects, needs to be conducted. Ongoing and rain-event sampling, photo-monitoring, and stream flow gage installations are also recommended.

3.2 Implementation Strategies

An overarching comprehensive implementation ambition of this Plan is to identify watershed plan linkages to existing programs, policies and plans; identify potential projects; seek funding; develop local, fiscal project management and technical capacity; identify project teaming partners and make teaming agreements; scope projects; write grants; raise funds; and implement projects through partnering arrangements.

Broad to specific:

While there are many other important stressors identified in the conceptual model (Figure 2-1) of this Watershed Plan, sedimentation is clearly the stressor with the most contributing factors and the most impact, causing the most impairment in the Southwest Maui Watershed planning area. Therefore implementation strategies that aim to reduce sedimentation are most fully assessed. Six DSILT (Detained Stormwater Infiltration using Low Technology) sediment reduction projects were identified by the WAG for implementation: 1) Excavated basins, 2) High impact zone mitigation sites, 3) Riparian protection and restoration, 4) Unpaved roads, 5) Grazing management measures, and 6) Pi'ilani basin utilization strategy. The DSILT projects have been prioritized by their importance to water quality improvements and by feasibility. They will be listed below, in order, from higher to lower priority. In addition, one water reuse project was identified and a brief summary of BMPs, and an innovative coral reef rejuvenation project, are presented. Each will present a description of its implementation methodology or provide links to informational websites.

…

4.0 DSILT PROJECTS

Climate extremes are increasing, causing larger, more intense rain events, which lead to flooding. Sediment, nutrients, and other non-point source pollutants carried by runoff, from many diverse sources, are transported through the watershed by a few large gulch systems. These systems drain the watershed from near 9,000 feet to sea level. From 200 or more acres of wetland in 1965, to 83 acres in 2001, the capacity of the Kihei wetlands to manage storm flows has been reduced dramatically by development, leading to flooding in the urban area along the shore (Erickson, NRCS, 2002). Protecting the community requires draining these floodwaters into the nearshore marine environment, causing impacts to the reef and marine life. Intercepting the sediment flow is a primary objective of the methods described in this chapter.

4.1 Excavated Basins in Series

The following DSILT project will describe what could be the most effective stormwater management system for the Southwest Maui watersheds.

Excavated basins in series, (affectionately known as “String of Pearls”) 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, CWRM).

Suitable locations for the installation of these facilities 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 field

- After 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

The following pictures show examples of shallow, flatter sections of gulches suitable for intake and drain field installations.

“Maui 2 Location- Southwest Maui Watershed Stabilization and Central Maui Soil and Water Conservation- Construct stormwater infiltration basins or contour terrace ditches to capture, store, and infiltrate stormwater. 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. This dry area of Maui is also prone to wildfires, which could be slowed by the moisture around these stormwater retention areas.” (Kula Stormwater Reclamation Study-KSWRS Final 2011,p.11, Task 1, Existing Conditions Report).

Four of the nine priority candidate projects for stormwater management in the State of Hawaii, which were identified by The Bureau of Reclamation 2005 study which is quoted in the paragraph above, emphasize stormwater infiltration into the aquifer.

It is suggested that the cautious approach would provide a stormwater intake capable of removing only a portion of the total peak flow, and that the volume collected would be distributed through a suitably sized drain field with its over flow returning to the stream. The following pictures are examples of 3 different types of stormwater intakes taken from the

Figure 4-1 Waikamoi Intakes: Side Intake, West Intake, & East Intake (Respectively)

KSWRS Task 2, pp.42-44.

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 adjoining landscapes, aquifer recharge providing future water supply, flood mitigation reducing property damage, water quality improvements, and therefore less impact to the shoreline and reef.

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 Warren S. Unemori Engineering Inc., 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, would 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.

The following chart lists the major permits which may be required for the implementation of this management measure. It is recommended that a feasibility study be conducted to determine the magnitude of this endeaver. The benefits of aquifer recharge in this watershed where limited recharge is occuring, reduced impact to the marine ecosystem where reef degredation is rampant, and flood mitigation to reduce property damage, all make this the most important of the recommended implementation practices considered in this Watershed Plan.

Table 4-1 Major Permits Required for Project Installation

Permit Name	Issuer	Trigger	Application requirements	Project Improvements
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.
Department of Army Permit	U.S. Army Corps of Engineers	Any activity resulting in "filling" of water bodies in the US, 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 crossing 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 District as designated by the State Land Use Commission. Five subzones each have allowable activities.	Application will require a Hawaii Chapter 343 EA/EIS	Pipeline or reservoir installation in the Conservation District.
Grubbing and Grading Permit	Department of Public Works, County of Maui	Required for removal of vegetation and earthmoving associated with construction.	Application will require construction plans to be submitted	Any activity that bares or grades the ground surface, such as structure installation, access roads, and equipment and material staging sites.
Perform Work on County Highways Permit	Department of Public Works, County of Maui	Required when a County roadway is disturbed by installation of pipelines.	Application will require construction plans for the affected area.	Any activities that affect County-owned roadways or structures, such as pipeline installation, use of bridges, and traffic control.
National Point Discharge Elimination System Permit (NPDES)	Clean Water Branch, State of Hawaii Department of Health	Required for construction site runoff management when affected construction area exceeds one acre and if the operation of the improvement results in discharge to water bodies	Application will require runoff and sediment management designs and 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 requests 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.

4.2 High Impact Zone Mitigation Sites

Any land use activity that reduces the vegetative cover and loosens soil can produce a site vulnerable to erosion called a high impact zone. The picture to the left is an example of a high impact zone in 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 runoff carrying eroding sediments 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. Yet many high impact zones in the watershed are left without mitigation measures.

In order to protect water quality, the practices that can be adopted to capture sediment from stormwater runoff in HIZMS include vegetated buffers, fabric roll runoff interceptors, berms and terraces, small detention basins, and fenced riparian corridors. These are just a sample of the low cost mitigation measures that can reduce the impact of these sites on water quality.

An example of a High Impact Zone Mitigation Site in grazing lands is included in the schematic below.

Figure 4-2 High Impact Zone Mitigation Site Schematic

This HIZMS is a trough site much like the site shown in the picture provided previously. A strip of land downslope of the trough (or other primary stressor factor) is fenced, separately, and vegetated (*green lines*) to produce a sediment filtering effect. Water from the trough system would be available at the site to establish the vegetation, and various types of sediment filtering plants, such as native grasses, vetiver, etc. could be planted. In addition, seeded fabric rolls can be staked on the contour to intercept sediment/nutrient-laden runoff. Sediment buildup can be monitored to demonstrate the effectiveness of this technique. It has proven successful in other similar locations. The fabric rolls can be seeded with a combination of native shrubs and grasses to enhance native habitat and create a living filter. A berm designed to catch and infiltrate runoff could also be installed in the buffer as an additional deterrent to sediment transport.

Cost Estimates

- Fencing - 6’ game fencing costs are estimated between $12 -$18 per foot, including materials and installation, depending on access, terrain, soil conditions, etc.
- Fabric rolls - 9’ by 50’ rolls are approximately $150 each, including wooden stakes, seed, and installation.
- Irrigation – systems would depend on the size and extent of the buffer and are estimated to be between $200 and $500, installed.
- Plantings - vetiver - $10 to $15 per foot with irrigation installed
- Native grasses and shrubs –These are available locally and cost will vary depending on whether seed is dispersed or nursery-grown plants are used, and according to size and rarity. Costs will also depend on plant selection and quantity. General prices for nursery grown plants range from dibbles@$4, 1 gal.@$12-$18, 5gal.@$45-$85,7gal.@$125, 15gal.@$50-$225, and 20gal. tubs with larger trees for $200 or more

4.3 Riparian Protection and Restoration

All of the gulches in the Southwest Maui Watershed project area can benefit from protection and restoration management measures (see Implementation Map in Appendix A). Various site-specific measures can be utilized depending on the resources available. A general description of riparian protection and restoration follows.

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 muddy streamwater during runoff events. Fencing is the primary tool for 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.

A fenced, re-vegetated corridor will 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 (pictures to right, and sediment trapped in buffer shown).

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). Native plant charts from Pelekane Bay Watershed Restoration Project, Final Report, May 31, 2011, are shown below.

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 cost for a 9-foot wide, 50-foot long roll is approximately $150 installed.

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.
Māmaki	*Pipturus albidus*	N	Field conditions too dry for this species.
Māmane	*Sophora crysophylla*	Y	Abundant seed available, esp. Mauna Kea.
Maʻo 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.
Pāʻū o Hiʻiaka	*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.
ʻŪlei	*Osteomeles anthyllidifolia*	Y	Powdery mildew reduced viability.
Wiliwili	*Erythrina sandwicensis*	Y	Abundant seed. Easy to grow.

The expense of fencing prevents landowners from committing riparian areas for protection and restoration. 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. An example of per foot material costs for a typical fence can be found in the following table from the Pelekane Bay Watershed Restoration Project, Final Report, May 31, 2011. It should be noted that the fence was designed to keep goats and cattle out.

Material	Details	Cost per Foot
7 ft. steel "T" posts	Pounded by hand; placed maximum 8 feet between posts. Holes drilled first when placed in rock.	$1.87
48 in. bezinal-coated woven wire	Stretched tight between posts; bottom edge no more than 2 inches above the ground.	0.91
Short steel posts	Used as "anchors" to pin down wire between posts	0.36
Bezinal-coated barbed wire	Three strands equally spaced above the woven wire.	0.48
24 in. woven wire	Added as additional "skirting" at bottom of fence when 48 in. wire is more than 2 inches above ground.	0.31
Galvanized steel pipe and fittings	Used to construct corner posts, braces, and gate posts.	0.31
Stainless steel fence hardware	Fence clips, smooth wire, etc.	0.24
Welded corral panels	Used at stream crossings & to make gates animal-proof	0.23
Rubber stall mats	Suspended from wire over streams.	0.15
	Total Fencing Materials Cost Per Foot	**$4.86**

On Maui, in the last 10 years, the deer population has 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 $12 to $14 per foot in the open and accessible grazing lands, to $18 per foot in inaccessible, remote upland areas at 6,000 to 8,000 foot elevation.

The following quote from the "Erosion and Sediment Control Course and Field Practicum", prepared for the Hawaii Coastal Zone Management Program (2004), states clearly that, "Erosion is the process in which, by the actions of wind or water, soil particles are detached and transported. Sediment is eroded material suspended in wind or water. Sedimentation is the deposition of eroded material…Erosion control is a source control that treats the soil as a resource that has value and should be kept in place… When possible, use erosion controls as the primary protection, with sediment controls as a secondary system."

Therefore, the benefits of riparian fencing higher up in the landscape cannot be over stressed, and can prevent the need for bigger, more expensive solutions downslope, (i.e. large expensive detention basins). However, riparian buffer fencing in the lower elevations is also important to prevent sediments from entering the stream corridors. It is difficult to prioritize the specific areas for the installation of riparian BMPs because it is such a compelling need in the entire southwest Maui watershed, but a commitment to funding incremental installation is advised (see Implementation Map in Appendix A)

Another potential source of pollutants in the gulches is the dumping of waste, which has been the traditional method of disposal. Education is needed to change peoples' behaviors and habits. Even yard waste thrown in a gulch is problematic when a big storm comes. Workshops should be provided to educate gulch landowners about the methods available for water quality protection, and a “Gulch Guardian “ protocol promoted through educational fliers, workshops, etc.

4.4 Unpaved Roads

Many of the unpaved roads in the Southwest Maui Watershed are on slopes and much of the landscape is dry, most of the time. Occasional storms lead to runoff, which moves sediments down roads. This situation is common in many places in this and other watersheds.

“Roads alter water movement across the landscape, which can concentrate and accelerate flow and cause soil erosion and gully formation.” Bill Zeedyk, Water Harvesting From Low Standard Rural Roads, April 2006. http://www.nm.nrcs.usda.gov/technical/tech-notes/eng/eng1a.pdf

While this can be a problem for water quality because of sediments and other pollutants, it can also be an opportunity. In an area that has very low average rainfall (10 to 20 inches/year in the lower elevations), stormwater from these roads could be harvested to the benefit of the surrounding land.

Roads guru, Bill Zeedyk of Sandia Park, New Mexico, has put together a manual for water harvesting techniques and road maintenance programs (see quote and website above), which includes a list of management strategies, guidelines, and practices. Landowners can use this resource to help solve some of their road maintenance problems and harvest stormwater at the same time.

Workshops with Zeedyk and other experts could help land managers and equipment operators understand the principles of better road design, and ultimately reduce sediment-laden stormwater runoff. These and other educational workshops are an inexpensive way to raise awareness about watershed issues. Approximate cost per workshop is between $1500 to $2500.

4.5 Grazing Management Measures

More than half of the lands in the Southwest Maui Watershed 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. While some of the ranchers have adopted managed grazing practices, much of the acreage could benefit from improved management, as outlined below.

NRCS promotes what is called “Prescribed Grazing”.

DEFINITION
Managing the harvest of vegetation with grazing and/or browsing animals.
PURPOSE
This practice may be applied as a part of conservation management system to achieve one or more of the following:
• Improve or maintain desired species composition and vigor of plant communities.
• Improve or maintain quantity and quality of forage for grazing and browsing animals' health and productivity.
• Improve or maintain surface and/or subsurface water quality and quantity.
• Improve or maintain riparian and watershed function.
• Reduce accelerated soil erosion, and maintain or improve soil condition.
• Improve or maintain the quantity and quality of food and/or cover available for wildlife.
• Manage fine fuel loads to achieve desired conditions.
Promote economic stability through grazing land sustainability.

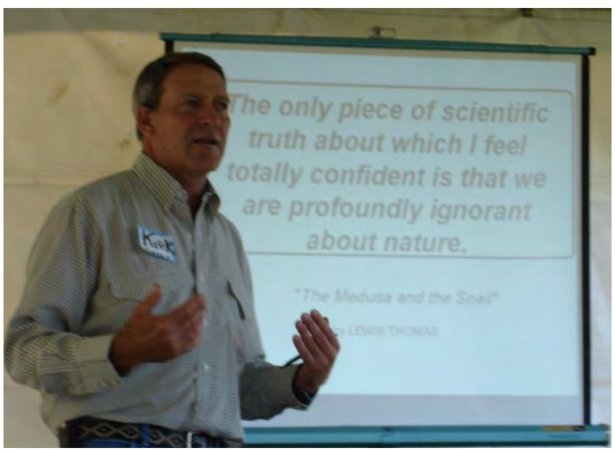
CONDITIONS WHERE PRACTICE APPLIES
This practice applies to all lands where grazing and/or browsing animals are managed.
CRITERIA
General Criteria Applicable to All Purposes
Removal of herbage will be in accordance with site production limitations, rate of plant growth, and physiological needs of forage plants and the nutritional needs of the animals.
Adequate quantity and quality drinking water will be supplied at all times during period of occupancy.
Adjust intensity, frequency, timing and duration of grazing and/or browsing to meet desired objectives for the plant communities and the associated resources, including the grazing and/or browsing animal.
Manage kind of animal, animal number, grazing distribution, length of grazing and/or browsing periods, and timing of use to provide grazed plants sufficient recovery time to meet planned objectives. The recovery period of non-grazing can be for the entire year or during the growing season of key plants.
Deferment (non-grazing period less than one year) and/or rest (non-grazing period equal or greater than one year) will be planned for critical periods of plant needs.
Provide deferment or rest from grazing or browsing to ensure the success of prescribed fire, brush management, seeding or other conservation practices that cause stress or damage to key plants.
Manage grazing and/or browsing animals to maintain adequate vegetative cover on sensitive areas (i.e. riparian, wetland, habitats of concern, karst areas).
Manage livestock movements based on rate of plant growth, available forage, and allowable utilization *or stubble height* target.

Develop contingency plans to deal with expected episodic disturbance events e.g. insect infestation, drought, wildfire, etc.

In addition, mob-grazing practices, as described in Allan Savory's book, Holistic Resource Management, Island Press, 1988, increase the benefits to the plant community, soil microbes, the hydrologic cycle, and overall diversity and health of the pasturelands. As stated on p.176,

"The discovery that brittle environments need periodic disturbance to maintain stable soil cover…leads us to recognize animal impact as perhaps the *only* practical tool that can realistically halt the advance of deserts over billions of acres of rough country."

A holistic grazing management clinic on Maui, led by Kirk Gadzia, a Certified Educator with the Allan Savory Center for Holistic Management, was held in 2005. Central Maui SWCD sponsored it with modest funding from NOAA and the Hawaii Coastal Zone Management Program, to educate graziers (term for people who manage grazing animals) about the methods and benefits of mob grazing. The free clinic also provided ranchers and others with tools for increasing productivity of grazed lands, improving animal health and soil quality, managing plants and reducing erosion, and harvesting water from low maintenance roads. Participants had the opportunity to observe well-managed pasturelands and learn to make a grazing plan. (see pictures below) A program of similar workshops would be worthy of future funding to continue this educational effort. Approximate cost per workshop is between $1500 and $2500.



4.6 Pi’ilani Basin Utilization Strategy

The Pi’ilani Mauka Detention Basin No.1, located above Elleaire Golf Course in central Kihei, intercepts and captures a portion of the offsite surface runoff from a drainage basin extending up Mount Haleakala, which is slowly released downstream into an existing drainage way through Elleaire Golf Course. This drainage way continues downstream through Elleaire Golf Course to Pi’ilani Highway.

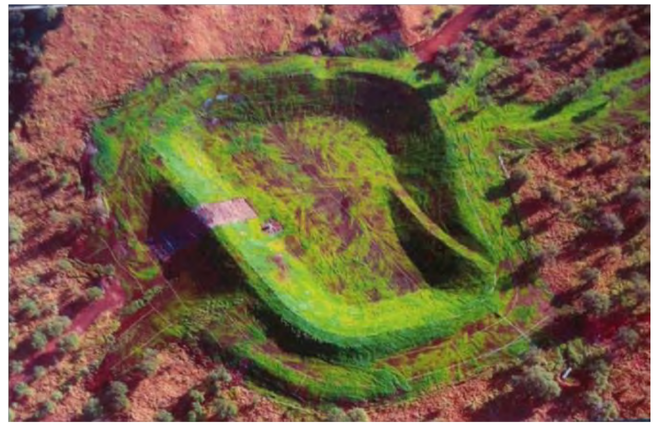


Figure 4-3 Pi'ilani Mauka Detention Basin

The Pi’ilani Mauka Detention Basin No.1, an approximately 50 acre-ft. detention basin occupying approximately 5 acres, consists of 48” and 60” diameter drain inlet risers with grated inlets.

Figure 4-4 42" Diameter Drain Outlet Structure

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.

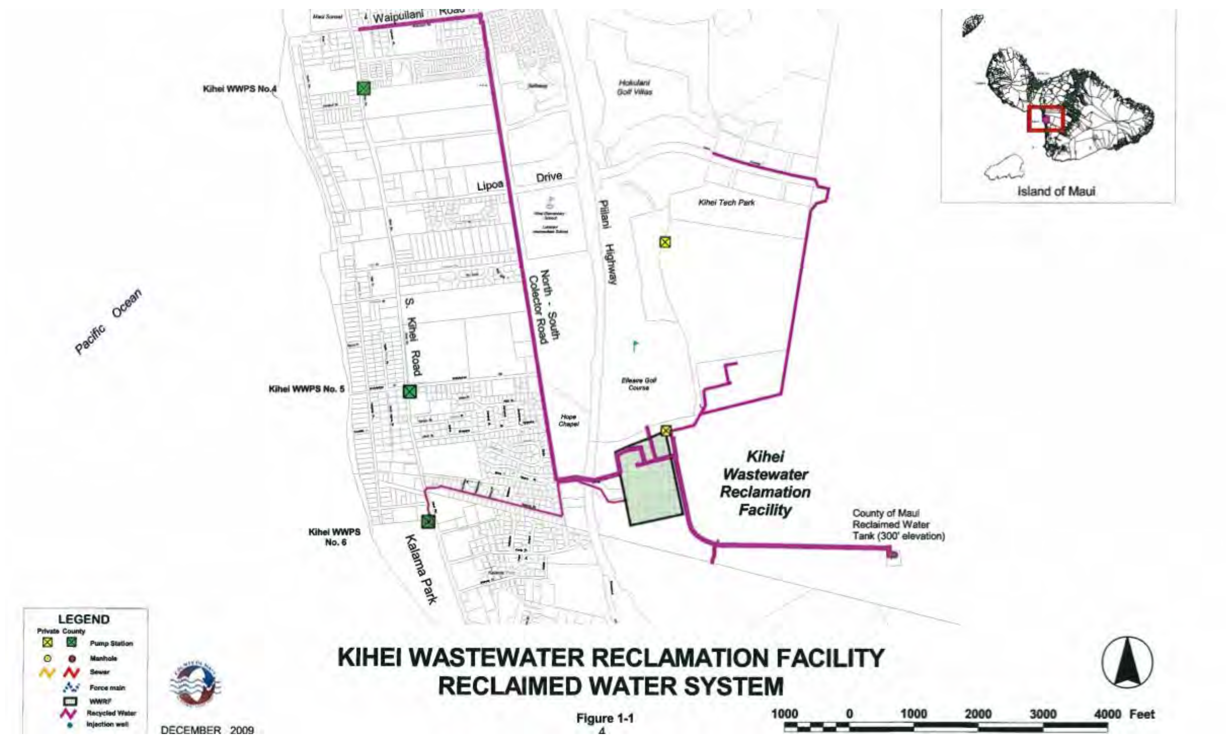
This huge unlined detention basin is a potential resource for DSILT in the Waipu'ilani drainage basin. If engineering studies would accommodate it, a portion of the flow from Waipu’ilani could be diverted through this basin to allow stormwater sediments to be settled out before continuing down the stream. It would require the outlet structure to be redirected back into Waipu’ilani after detention. 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. Using this method, some of the muddy stormwaters could be cleaned up before returning to the stream and the 8 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. Cost estimate is $25,000 to $30,000.

5.0 WATER REUSE

5.1 Expansion of R-1 Reuse Area

Most of the wastewater from the Kihei urban area is collected and treated at a central Wastewater Reclamation Facility (presently, approximately 4 to 5 mgd). Some of this wastewater is greywater from sinks, showers, washing machines, etc. Easing the restrictions on the use of this water for onsite irrigation would reduce the cost for wastewater treatment at the WWRF. Presently, regulations prohibit this onsite use. Rules and regulations regarding greywater use need to be examined in the light of recently developed technologies for safe re-use.

The current County of Maui Wastewater Operations Program Superintendent has indicated that at present, 50% to 60% of the treated R-1 recycled water is being reused for irrigation purposes by a golf course, park, residential, commercial, and agricultural entities. He provided us with a copy of the potential expansion plan for the R-1 system in Kihei (South Maui R-1 Recycled Water Verification Study, December 2009). Refer to the maps below.



SOUTH MAUI POTENTIAL R-1 RECYCLED WATER EXPANSION OPTIONS

He indicated that he is committed to providing R-1 water to certain expansion projects that are coming online in the next few years, and there won't be much R-1 to inject after that. This plan is currently beyond the County’s ability to fund. It is considered a priority by this Watershed Plan that funding be made available for R-1 reuse expansion, so that this valuable resource can be utilized and not injected and wasted. A multi-agency financial support mechanism is recommended in order to accomplish this goal. Consult with Maui County on the estimated cost of this project.

6.0 BEST MANAGEMENT PRACTICES (BMPS)

The Hawaii Watershed Guidance has outlined the management measures for reducing NSP in urban/rural areas.

See Coastal Nonpoint Pollution Control Program, http://hawaii.gov/dbedt/czm/initiative/nonpoint/HI%20Watershed%20Guidance%20Final.pdf

http://hawaii.gov/dbedt/czm/initiative/nonpoint.php

Also recommended are the techniques described in the following websites:

LID – http://www.lowimpactdevelopment.org

The list below highlights some of the main goals and principles of LID:

- Provide an improved technology for environmental protection of receiving waters.
- Provide economic incentives that encourage environmentally sensitive development.
- Develop the full potential of environmentally sensitive site planning and design.
- Encourage public education and participation in environmental protection.
- Help build communities based on environmental stewardship.
- Reduce construction and maintenance costs of the stormwater infrastructure.
- Introduce new concepts, technologies, and objectives for stormwater management such as micromanagement and multi- functional landscape features (bioretention areas, swales, and conservation areas); mimic or replicate hydrologic functions; and maintain the ecological/biological integrity of receiving streams.
- Encourage flexibility in regulations that allows innovative engineering and site planning to promote "smart growth" principles.
- Encourage debate on the economic, environmental, and technical viability and applicability of current stormwater practices and alternative approaches.

NEMO - http://nemo.uconn.edu/ Nonpoint Education for Municipal Officials

Google **NEMO Hawaii** for more information.

The goal of NEMO is to "provide decision makers with the skills and resources that they need to identify local water quality problems and to adopt effective pollution controls".

SEEP - http://www.plrcd.org/SEEP/ Stormwater & Erosion Education Program

The SEEP Program's Purpose:

- Increase skill and knowledge levels in the stormwater and erosion fields.
- Foster communication and collaboration between industry, agencies, and landowners.
- Protect resources, including people, water, and the economy.
- Develop a local pool of experts as resources for the development community.
- Change current perception in development practices.

7.0 REEF REJUVENATION

Figure 7-1 5 year-old Biorock reef on formerly barren sand. Reef restored with GCRA Biorock® Technology. Photo May 2012, Pemuteran, Bali, by EunJae Im

“Mineral accretion was first developed by architect Wolf Hilbertz in order to provide alternative construction materials, and he and Thomas Goreau of the Global Coral Reef Alliance developed its use for reef restoration and shore protection. They hold a patent on such applications. They have recently joined forces with Professor Alexander Gorlov, the inventor of a remarkable new electrical generator which can be powered by ocean tidal currents that holds great promise with typical tidal flows found around oceanic islands. They are seeking to develop projects using mineral accretion for reef restoration, shore protection, and renewable energy development with interested groups around the world." (New Wave Coral Reef Rejuvenation, Asian Geographic June/August 2000, Michael Aw)

With all the publicity given to the degradation of the coral reefs, because of climate change and land based pollution, very little about ways to rebuild them has been proposed. At the Hawaii Conservation Conference in 2006, Thomas Goreau made a presentation about a proven method he has developed to rejuvenate and rebuild dying reefs by growing coral on electrically energized rebar grids. (Refer to the websites below)

http://www.globalcoral.org/coral_and_coral_reefs_commentary.htm

http://www.biorock.net/Technologies/

http://www.globalcoral.org/

According to Goreau, rules and regulations are so restrictive in Hawaii that he was prevented from installing any of these systems here. It is recommended that research be initiated to find ways to legally allow this technology to be used in Hawaii's waters to rebuild degraded reefs.

* * * * * * * *

Summary of Actions for Plan Development

Identify Programmatic Linkages

Develop a matrix or graphic depiction of the applicable State, Federal, and County regulations in the watershed planning area, the implementing programs, policy, authorities, managers, facilities, and activities within the watershed. Linkages identified will refine understanding of potential project partners, resources, and constraints.

Identify projects

The following general project concepts were developed by the WAG. All projects and practices at a minimum should be consistent within the framework of the Management Measures in the Hawaii Watershed Guidance and the EPA Watershed Planning Guidance. All projects will require monitoring of metrics for actions (e.g. number of measures implemented) and water quality improvements or pollutant load reduction accountability. Other programmatic criteria may apply to specific projects and will be identified during the programmatic analysis and partnering efforts.

Four major categories of project are envisioned:

1. DSILT projects to reduce sediment delivery to the ocean, reduce or mitigate flood volume, and increase stormwater infiltration.
2. Reclaimed water reuse to better capture this valuable resource.
3. Monitoring projects to gather data for water quality modeling, pollutant and load estimation, assessment of designated use support, water quality standards attainment, and other measures of waterbody health or project performance.
4. Best Management Practices (BMPs) derived for specific sources, land uses, or activities. BMPS will fall within the framework of the existing management measures. Projects include BMP training and technology transfer programs, and development or adaptation of BMPs to address issues specific to Hawaii watersheds.

More Specifically…

DSILT Project Concepts (see map in Appendix A for potential locations)

1. Projects that facilitate stormwater diversion, sedimentation, and infiltration on undeveloped lands. Project objectives are to reduce flood peak volume and sediment load delivered to the urban coastal areas and increase stormwater infiltration into the Kama'ole shallow coastal aquifer. Design concepts suggested for consideration include 1) sedimentation basins and 2) "String of Pearls" creation of artificial meanders (use of terraces, diversions, and other features) to divert water away from stream bed across the landscape and facilitate sedimentation and infiltration by allowing the water to slow in a series of shallow impoundments. Areas of highest priority are in Kulanihako'i, Waipu'ilani, and Keokea sub-basins.
2. Stream bank stabilization and riparian corridor restoration – mauka to makai, where needed, to reduce sediment loads with priority in Kulanihako'i, Waipu'ilani, and Keokea Sub-basins; also may be compatible with dryland forest restoration and cultural access preservation efforts in Kama'ole and potentially other Wailea and Mo'oloa (Makena) sub-basins.
3. Green infrastructure pilot or demonstration projects to both retrofit existing urban areas and to reduce impact of future development of impervious surfaces.
    - Green rooftops, which will reduce localized flood volume, could be irrigated with R-1 or grey water, reducing wastewater treatment volumes and loads, and will help alleviate urban hot spots in Kihei.
    - Rain garden at Whale Sanctuary/Kalepolepo to publicly demonstrate the effectiveness of healthy soil conditions and native plants to protect the ocean from land-based nonpoint source pollution.
4. Coastal wetland restoration/flood zone restoration/planned shoreline retreat. Identify projects that can meet multiple objectives related to flood control, wetland and floodplain development and restoration, and mitigation of coastal hazards and nonpoint source pollution. Potential project areas along South Kihei Road include the La'ie Wetlands,

Kalama Park, Kama'ole Park, and the area from Maui Lu Resort to Menehune Shores Condominium Complex.

Water Reuse Projects

1. Irrigated green belts or riparian buffers to improve water quality
2. Use of R-1 water in ecosystem restoration (including DSILT project irrigation)
3. Expansion of R-1 reuse area to provide infrastructure for 100% reuse

Monitoring Projects

- Interagency/stakeholder monitoring coordination
- Water Guardians – Mauka to Makai Gulch and Shoreline Watch program
- Under direction of Watershed Coordinator and coordinated community programs that provide training, trained professionals and volunteers will supervise all work in the field. All monitoring sites will have appropriate safe and legal access. Data will be used in watershed planning and to monitor results of plan implementation.
- Citizen Scientists will:
    - Conduct visual assessment of gulches and shorelines over time
    - Collect and ground truth physical stream and outlet data and drainage basin conditions
    - Collect ocean and groundwater samples for water quality analysis
    - Conduct flow and water level monitoring
    - Sample stormwater runoff
    - Record data and report via CORAL Data Portal

Establish BMPs for Land Uses/Activities

Provide financial support for landowners and others to facilitate BMP implementation for the various land use categories defined in the Hawaii Watershed Guidance

Other Actions Supporting the Plan

1. Identify Teaming Partners and Make Agreements

a. WAG hosting/grant management

b. Projects

c. Project management

d. Watershed coordinator

e. Community coordination

2. **Seek Funding**
    a. Grant writing, fund raising; in-kind support is provided by partners/stakeholders
    b. Potential funding sources/grants
        i. NOAA programs for monitoring, marine education, coral reef preservation, climate change adaptation, fisheries, coastal zone and watershed management
            1. Bay Watershed Education and Training Program (B-WET)
            2. Coastal Resilience Network (CRest)
            3. Marine Debris Removal Project Grants
            4. Marine Education and Training Mini Grants
        ii. USDA
            1. Landowner incentives or project funding
        iii. EPA http://water.epa.gov/grants_funding/shedfund/federal.cfm
            1. Community Action for a Renewed Environment
            2. State Clean Water Revolving Loan Fund
            3. Environmental Education Grant Programs
            4. Environmental Justice Grant programs
            5. Five Star Restoration Program
            6. Nonpoint Source Pollution Control (319)
            7. Targeted Watersheds Grants
            8. Regional Grants
3. **Develop Capacity**
    a. Hire professional staff
    b. Intern programs

Targeted education/outreach to stakeholders

Table 7-1 Implementation Strategy Matrix

Project Type	Technical Resources (TYPE OF RESOURCE)	Financial Resources $$$$	Funding Sources	Teaming Partners	Measure-able Milestones
Reforestation - mauka and dryland	Forestry/native restoration, WQ monitoring GIS; regulatory/	Check watershed partnership annual report for order of	DWS DOFAW	Dept. of Water Supply; Leeward Haleakala Partnership;	See Leeward Managem ent Plan

	permitting	magnitude estimates;		NRCS/ CMSWCD; DLNR Aha Make; Kihei CA; Kula CA; Maui Nui Botanical Gardens	for examples
Stormwater diversion, sedimentation infiltration (sediment basins)	Civil/water resource engineering; conservationist WQ Monitoring; regulatory/ permitting; public works	Basins- $20/cu.ft. installed	EPA 319, Bureau of Reclamation FEMA; SRLF; DWS; DPW; FEMA; EPA Urban Watersheds	NRCS/CMSWCD; DPW; DLNR developers/ ZAED planning; Maui Nui Botanical Gardens; Civil defense;	# projects; sediment reclaimed;
Streambank stabilization and riparian corridor restoration	Civil/water resources/ ecological engineer; conservationist; GIS; WQ monitoring		USACE USDA/NRCS	NRCS/ CMSWCD; developers/ ZAED planning; Kula/Kihei CA; Maui Nui Botanical Gardens	
Rain Gardens	Civil engineering; conservation or native plant specialist; regulatory/ permitting	NRCS/ NOAA		NRCS/ CMSWCD KCA; HIHWNMS Grow some good/school gardens Maui Nui Botanical Gardens; CWD; MNMRC-CWC	
Coastal wetland/flood zone/planned retreat restoration	Coastal engineer or coastal geologist; civil or water; resources engineer; water quality/wetland specialist; native plant/conservation FEMA data	$101,377/ acre of wetland[1]	NOAA WET; EPA Urban Watersheds	FEMA/Civil Defense CZMA section 309; FEMA Civil Restoration; USACE	
Water Reuse Projects					
Urban Irrigation (residential, commercial, industrial)	Agronomists, agricultural engineer; conservationist; landscape irrigation specialists		EPA, SRLF, BLM; EPA Urban Watersheds	CTAHR: LICH; HWEA	
DSILT/ Restoration Projects	Civil engineer; conservationist; native plant specialists		County DPW, DWS, Bureau of Reclamation	NRCS, Ranches and other landowners; County	

[1] Total cost for construction of Kawai Nui Marsh was $3,953,700 including all appurtenant features and actions (mobilization, demobilization, temporary facilities, erosion control, unclassified excavation and embankment, 12 well pumping systems, channel weir structures, water level control structures, field fence and gates, partial placement of geotextile fabric, and all incidental items) Total restoration - 39 acres of wetlands Cost per habitat unit (1 acre wetland) = ~$101,377. Cindy S. Barger, Watershed Program Manager
Civil and Public Works Branch, US Army Corps of Engineers, Honolulu District

Identify BMPS for each land use and activity	Local engineering; NRCS; LICH; aha Moku	NRCS		LICH; Aha Moku ;Trade professional associations	
Identify targeted stakeholders			Trade professional associations; County and professional agencies	MNMRC; LICH;	
Develop targeted educational materials	Educators, editing, publishing, graphics		NOAA; EPA/NEMO	CTAHR; UH Maui; FEMA	
Conduct Outreach Events	Event coordination and logistics			MNMRC; HIHWNMS	
Monitoring Projects					
Interagency/ Stakeholder Monitoring workgroup	Water quality scientists; social scientists		HCRI, EPA, DOH, DAR, UH Maui Sea Grant; Pacific Services Center	HCRI; Pacioos; HIHWNMS; UH Maui	
Water Guardians	WQ scientist;	Coral		MNMRC; HIHWNMS CORAL; CWD;UH MAUI; Kihei and Kula CA	
Management/Administration					
Project and Grant Management	Grant and Project Manager; Project fiscal and administrative support	Project/grant manager (part-time)	Grant admin fees; Hawaii Community Fund; Interagency personnel placement	Tri-Isle RC&D; SWCD; UH County	
Watershed Coordination	Environmental professional (scientist engineer)	$150,000/yr (full time plus benefits and overhead)	Hawaii Community Foundation; EPA 319	HAWP;HWWA; Hawaii Community Foundation	
Community Coordination	Event coordinator Social Networker	$70k/year (part-time plus benefits and overhead)	Hawaii Community Foundation; NOAA B-WET; EPA public education/ outreach grants	MNMRC; HIHWNMS; CORAL; Surfrider. Maui Tomorrow Foundation	

8.0 EDUCATION AND OUTREACH PLAN

The WAG proposed an Education and Outreach Plan outlined below:

1. **WHO ARE WE EDUCATING?**
    a. Keiki (Children)
    b. Water Users
    c. Average community member
    d. Policy makers
    e. Planners
    f. Developers
2. **WHY ARE WE EDUCATING?**
    a. To further the implementation of WAG planning recommendations
    b. So that the community can make informed policy decisions
        i. Voting
        ii. Land use
        iii. Who to support
    c. To establish and maintain a connection to the land and the interconnectedness of water resources to the land
    d. To establish a "culture of care" i.e. community-based peer pressure to prevent pollution
3. **WHAT ARE WE EDUCATING ABOUT?**
    a. What a watershed is
    b. Why a watershed is important to protect
    c. How each person as an individual can help
    d. How we collectively can help (through kupuna, businesses, community, and government organizations)
4. **HOW ARE WE EDUCATING?**
    a. Mauiwatershed.org
    b. Facebook.com
    c. Water quality monitoring sites
    d. Akaku
    e. Internships
    f. Handouts and fliers
    g. Talks and presentations
    h. Volunteer activities
5. **HOW ARE WE EDUCATING?**
    a. Keiki
        i. Community events (club meetings, fairs, festivals)
        ii. Water Quality Monitoring (beach or stream water sites)
        iii. Classroom demonstrations by volunteers
    b. Water users
        i. Posters or fliers at popular stores
        ii. Turbidity Task Force\raises awareness through observation and monitoring
    c. Average community member
        i. Mauiwatershed.org

        ii. Facebook.com page
        iii. Akaku advertisement campaign
        iv. Public meetings
        v. Booths at fairs and festivals (Whale Day, County Fair, etc.)
        vi. Speakers at neighborhood/community associations or civic clubs (Rotary, etc.)
    d. Policy Makers
        i. Invitation to WAG meetings
        ii. Write letters or testimony
        iii. Presentations to County Council Committees, Planning Commission, County Planning Department
    e. Planners and Developers
        i. Develop workshops for Pollution Prevention Techniques (Best Management Practices) for construction, roads, drainage etc., Nonpoint Source Education for Municipal Officials (NEMO)
    f. Stakeholders
        i. Presentations or workshops for landowners and managers at ranches, resorts, community associations
        ii. Educate businesses engaging in practices that make a difference to water quality

6. **ADDITIONAL RESOURCES FOR OUTREACH AND EDUCATION**
    a. Volunteers
        i. Identify existing and potential sources of volunteers
            1. Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS) Citizen Scientist/ Volunteer Water Quality Monitoring Program
            2. Maui Nui Marine Resource Council , Clean Water Committee and Turbidity Task Force
            3. South Maui Sustainability Group
            4. Upcountry Sustainability Group
        ii. Establish what aspect of outreach could be helped by volunteers
        iii. Establish co-ordination of volunteer efforts with existing groups
    b. Meeting spaces, educational materials, and visual aids?
        i. County
        ii. Schools
        iii. Nonprofits (PWF, Hawaii Ecotube, Digital Bus, Aquanimity NOW)
        iv. State (DAR, DOH, UH) and Federal (NOAA, EPA, HIHWNMS)

As a part of the education and outreach effort a signage program for the three main roads (South Kihei Rd, Pi’ilani Hwy, and Kula Hwy) that travel through the watershed that identifies the watersheds by name (Hapapa, Wailea, Mo’oloa) would raise public awareness.

9.0 MONITORING PLAN

Cultural practices are being impaired due to declining marine ecosystem health (less fish, coral, native algae (limu)) and restricted access to cultural gathering sites. Kihei was historically one of the largest sites for fishing and other coastal cultural activities. In addition, the economic health of the tourist industry depends on preserving the health of the marine ecosystem.

A monitoring program is needed to develop a database for this area to aid management efforts. Components of the monitoring plan would include an ongoing water sampling effort to determine the primary pollutants causing the decline of the health of the reef and nearshore waters.

Data that needs to be collected to further the implementation of the pollution control strategy:

- Location/ground truthing, mapping of all ocean outfalls (including storm outlets), especially the Wailea and Makena watersheds.
- Monitoring to characterize stormwater pollutant loads (flow and pollutant concentration for TSS, Nutrients, and fecal indicators) during runoff events (Gulch monitoring with Kulanihako'i and Waipu'ilani as priority). USGS stream gages need to be re-established.
- Monitoring of the daily irrigation runoff for flow, nutrients (there are several flowing locations in Wailea)
- Monitoring to characterize the range of nearshore oceanographic conditions occurring along the coastlines of the watersheds (wind velocity and direction, current velocity and direction, turbidity, salinity, temperature).
- Monitoring of ocean water quality (turbidity, nutrients, salinity, pH, dissolved oxygen and fecal indicators) under a range of conditions and locations (e.g., include areas near stream mouths, wet weather conditions).

Monitoring of groundwater well levels and water quality (salinity, silica, turbidity, nutrients, dissolved oxygen, redox, and pH) will also be important to understanding the contribution of groundwater to the overall pollutant load. Well monitoring is suggested as an important component in a future Monitoring Plan.

10.0 CONCLUSIONS AND RECOMMENDATIONS

Existing data and assessments indicate that water quality and designated use impairments exist within the watershed planning area. The major streams in the Hapapa watershed have documented heavy sediment discharges, in some cases to shallow coastal waters with limited flushing, where wind and waves can drive re-suspension of past sediment deposits. Sediment plumes offshore after runoff events are evidence of the lack of adequate erosion prevention in the watershed. The development of coral reef ecosystems is inhibited, and algal blooms proliferate in the areas of high sedimentation. Algal blooms, water quality impairments, and elevated dissolved nutrient levels are seen at locations further south in the Wailea and Mo'oloa Watersheds. Dissolved nutrients are likely transported from land by both surface runoff and submarine discharges of groundwater.

Preliminary Conclusions and Recommendations include:

1) Funding support for management measures outlined in the Implementation Strategy is needed to accomplish the desired results of cleaner water going to the sea.
2) The most effective methods of runoff control need to be aggressively established, including stormwater management in the upcountry landscape, buffering of the major gulches, and infiltration features where feasible.
3) Given the reduced size and capacity of the historic wetlands in the area, protection and restoration of the remaining wetlands is critical, and new artificial wetland installations will be important to replacing that lost storage and treatment capacity.
4) Reuse of all of the available recycled R-1 water for irrigation will avoid wasting this valuable resource, and reduce the amount of potable water that is needed in the coastal region. The expansion plan for the Kihei WWTF will help to accomplish this goal.
5) Further analysis of existing data:
   - Review of existing compiled reports, EIS, etc., submitted late in the review process, or not readily analyzed (due to hard copy only or no electronically editable files)
   - Compilation and reporting of new data generated by the watershed coordinator and WAG (whale sanctuary volunteers data, La'ie wetland data, data from flooding events, photo documentation of stream flow, flood aftermath, sedimentation events, stream reconnaissance)

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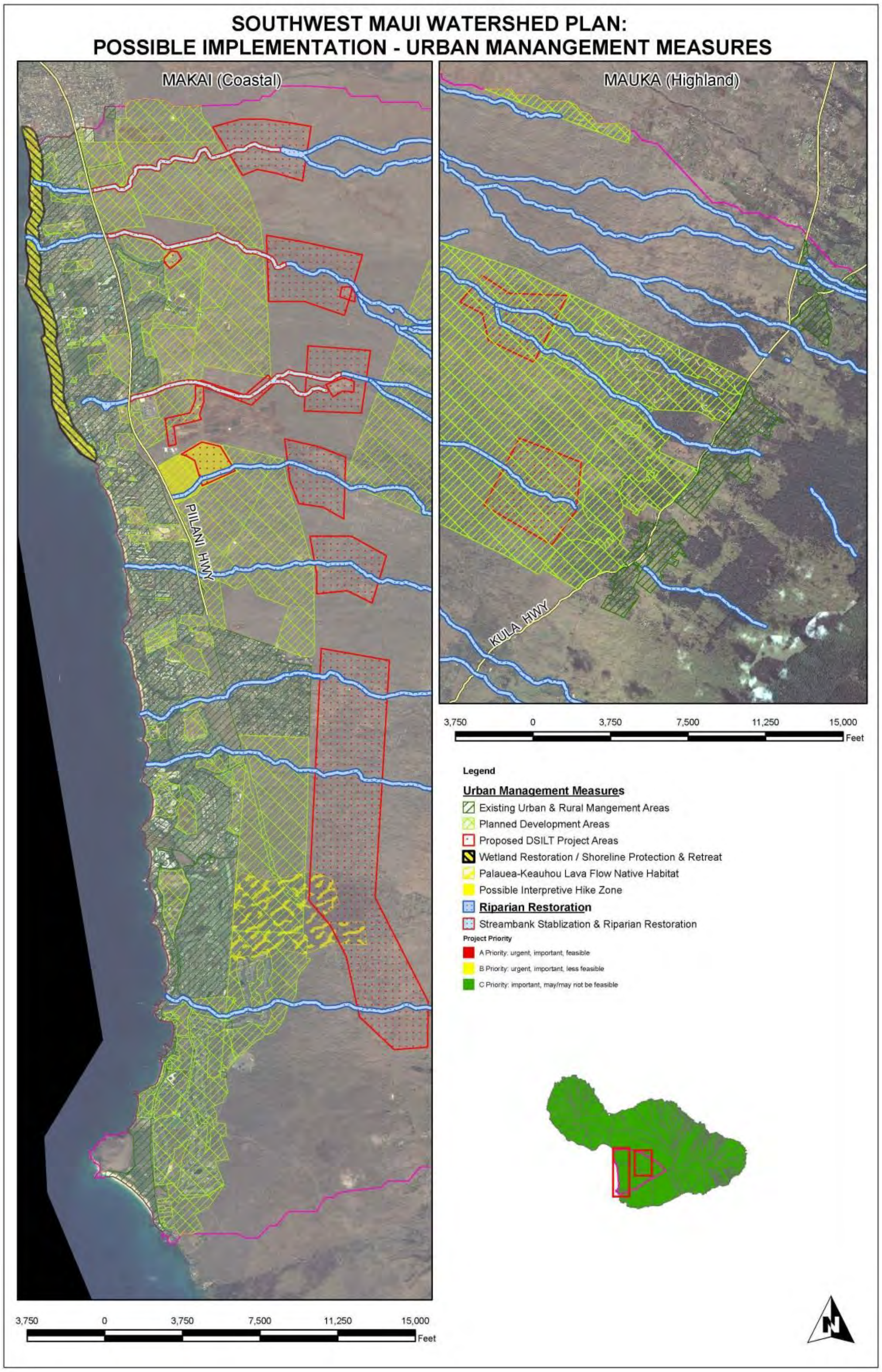
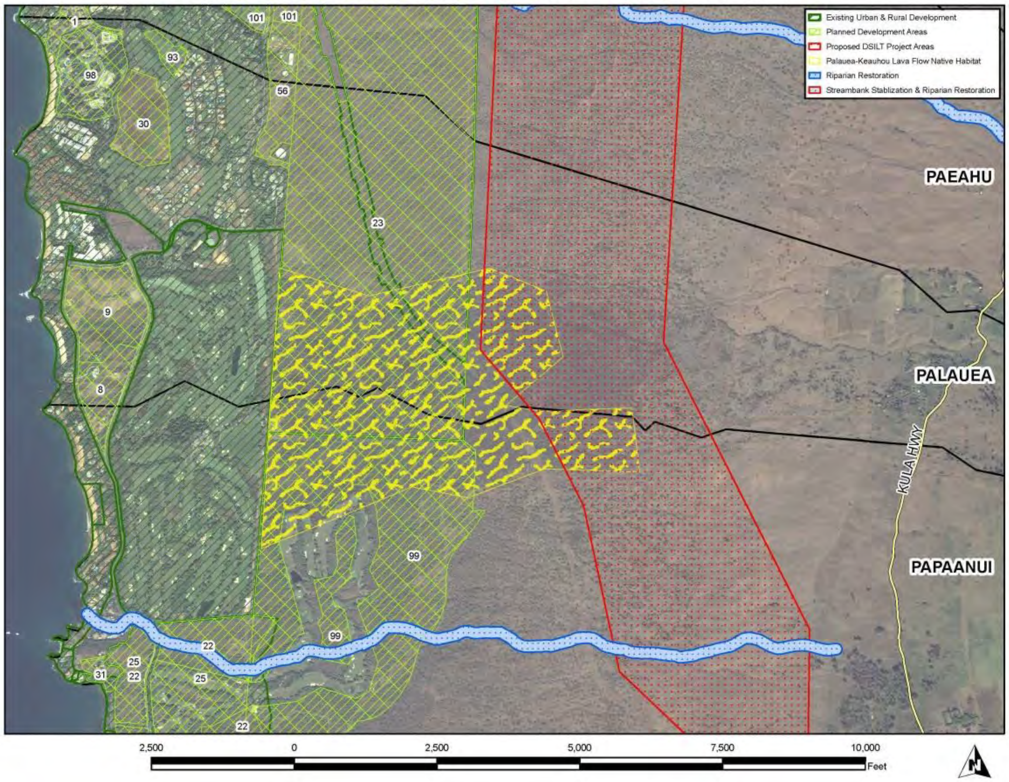
Appendix A. Southwest Maui Watershed Plan Possible Implementation Maps



URBAN MANANGEMENT MEASURES: MAKAI PALAUEA & N. PAPAANUI



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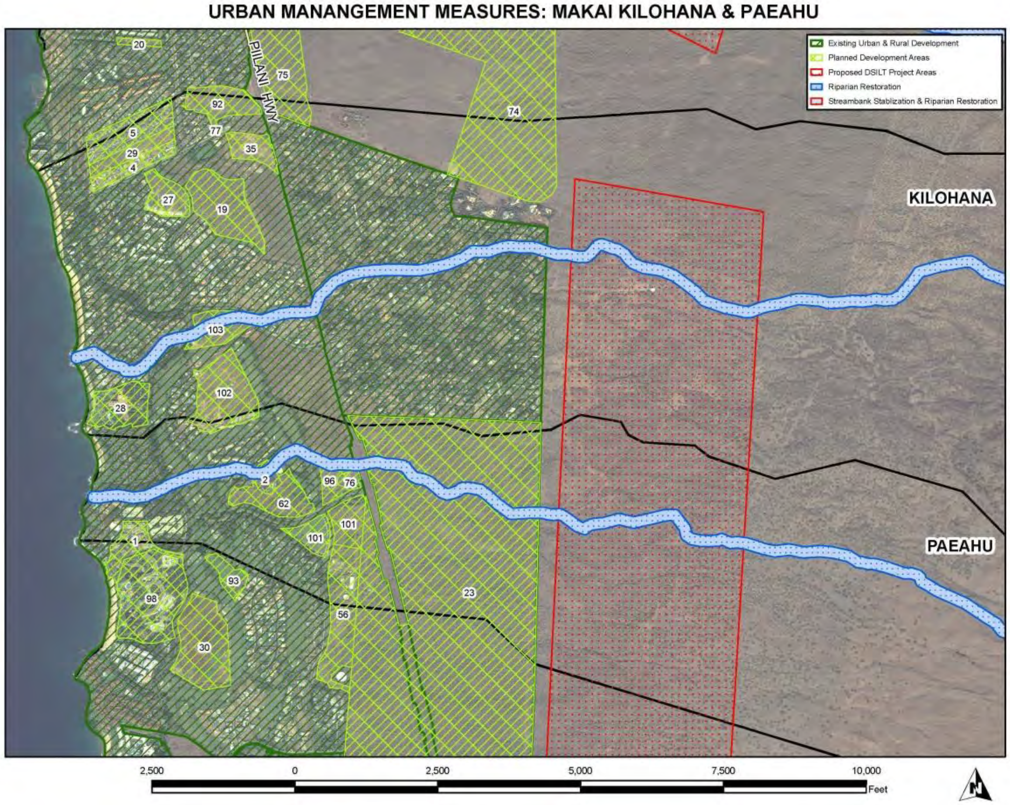

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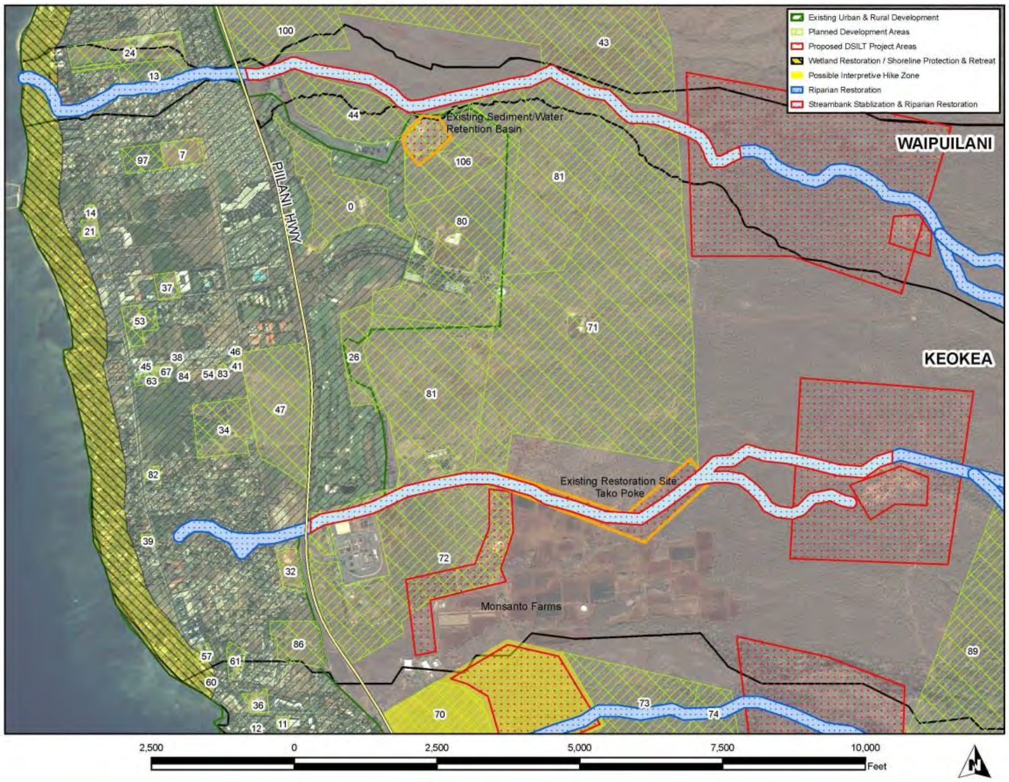

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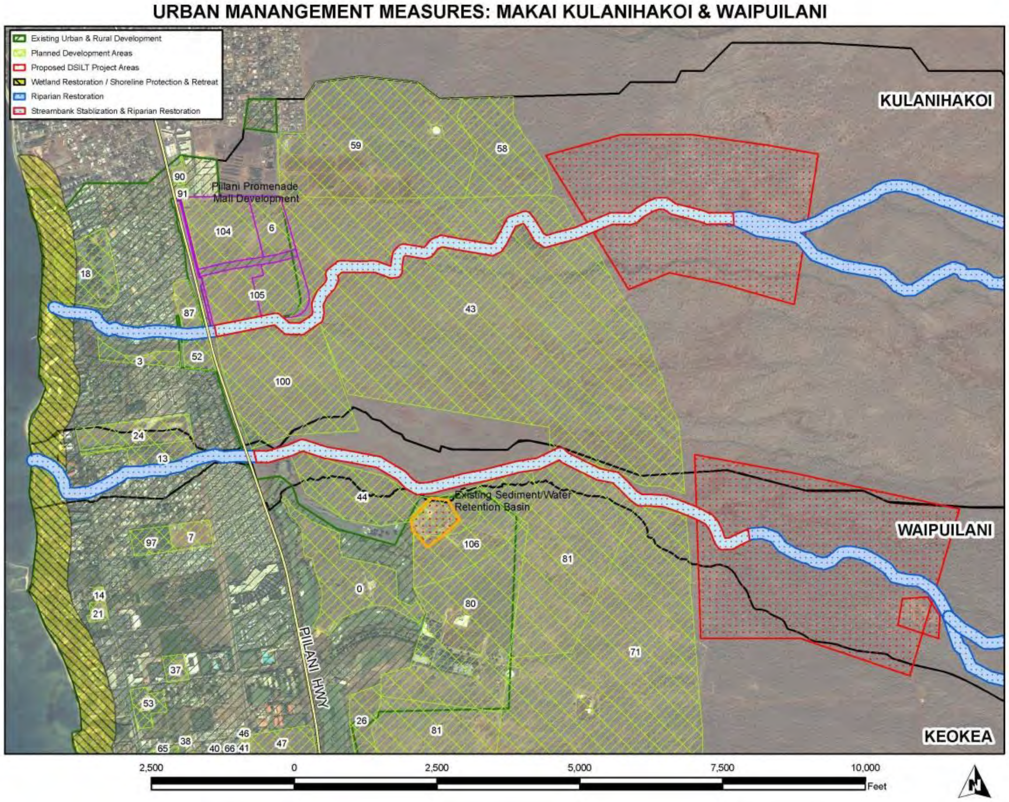

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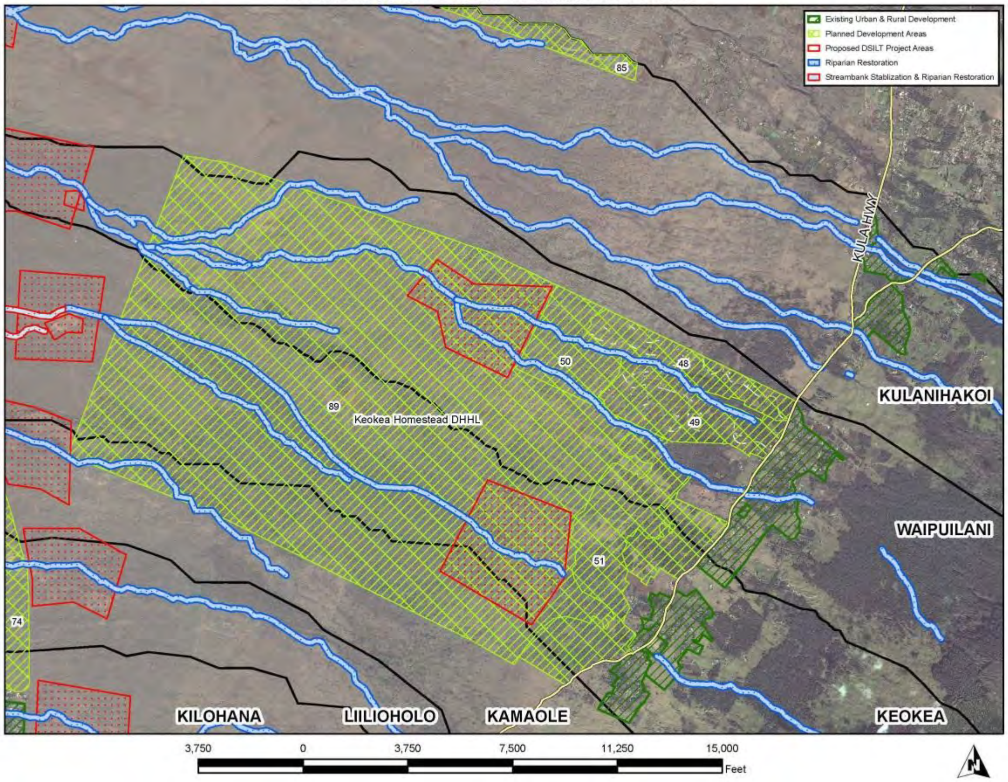
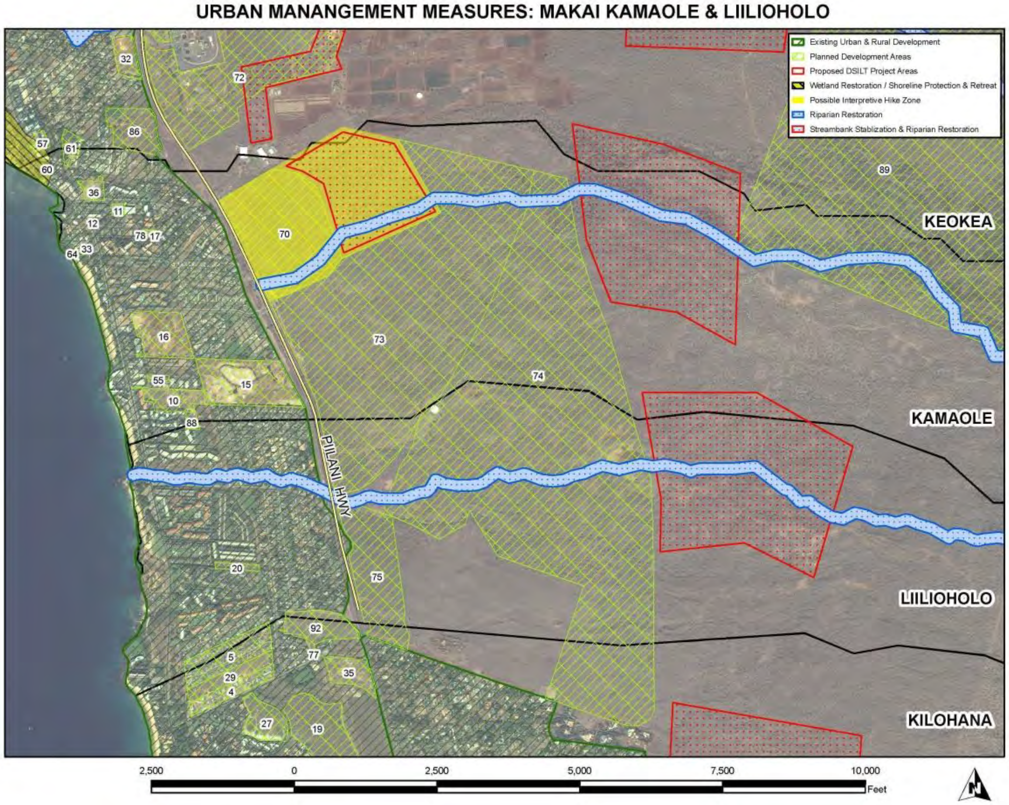
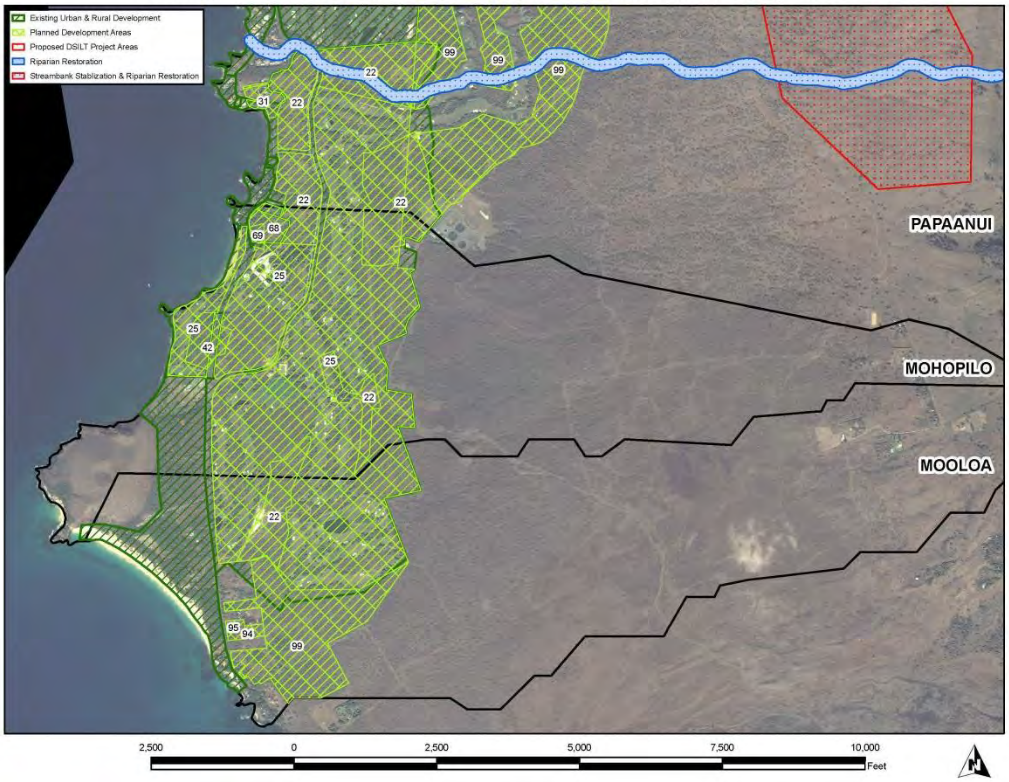
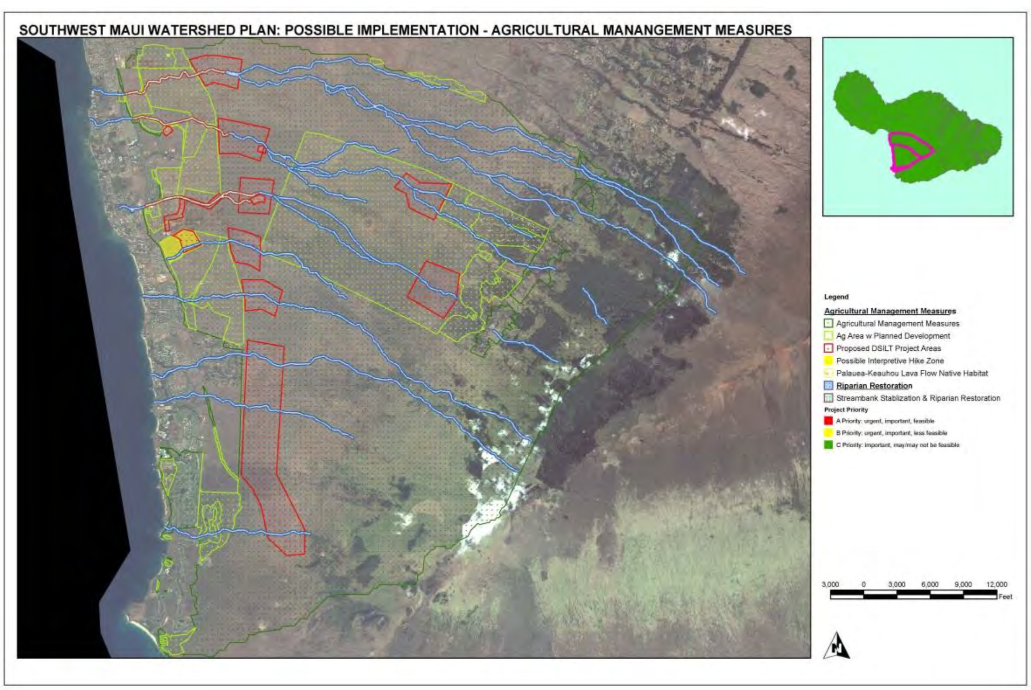


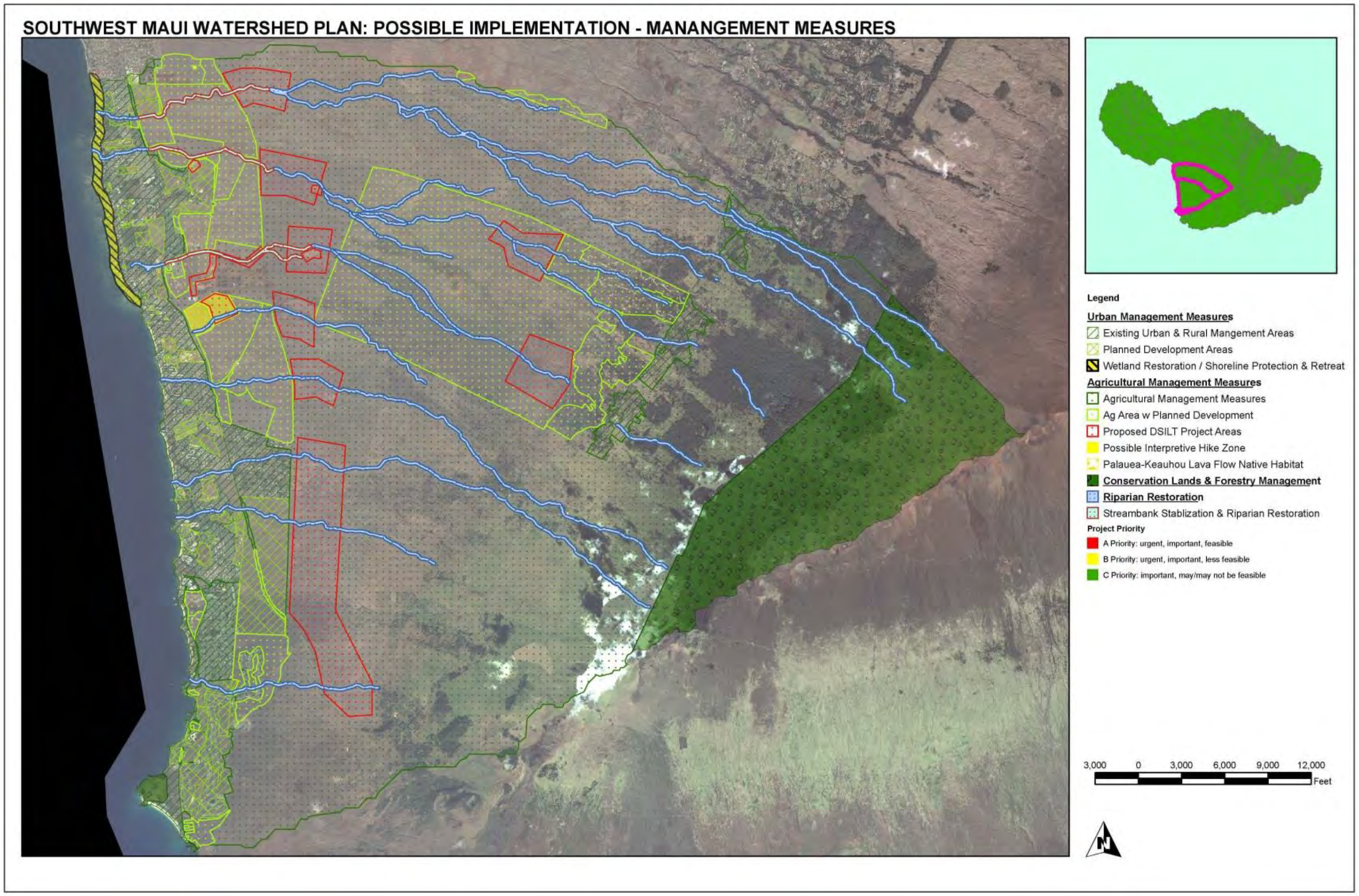
URBAN MANANGEMENT MEASURES: MAKAI KAMAOLE & LIILIOHOLO



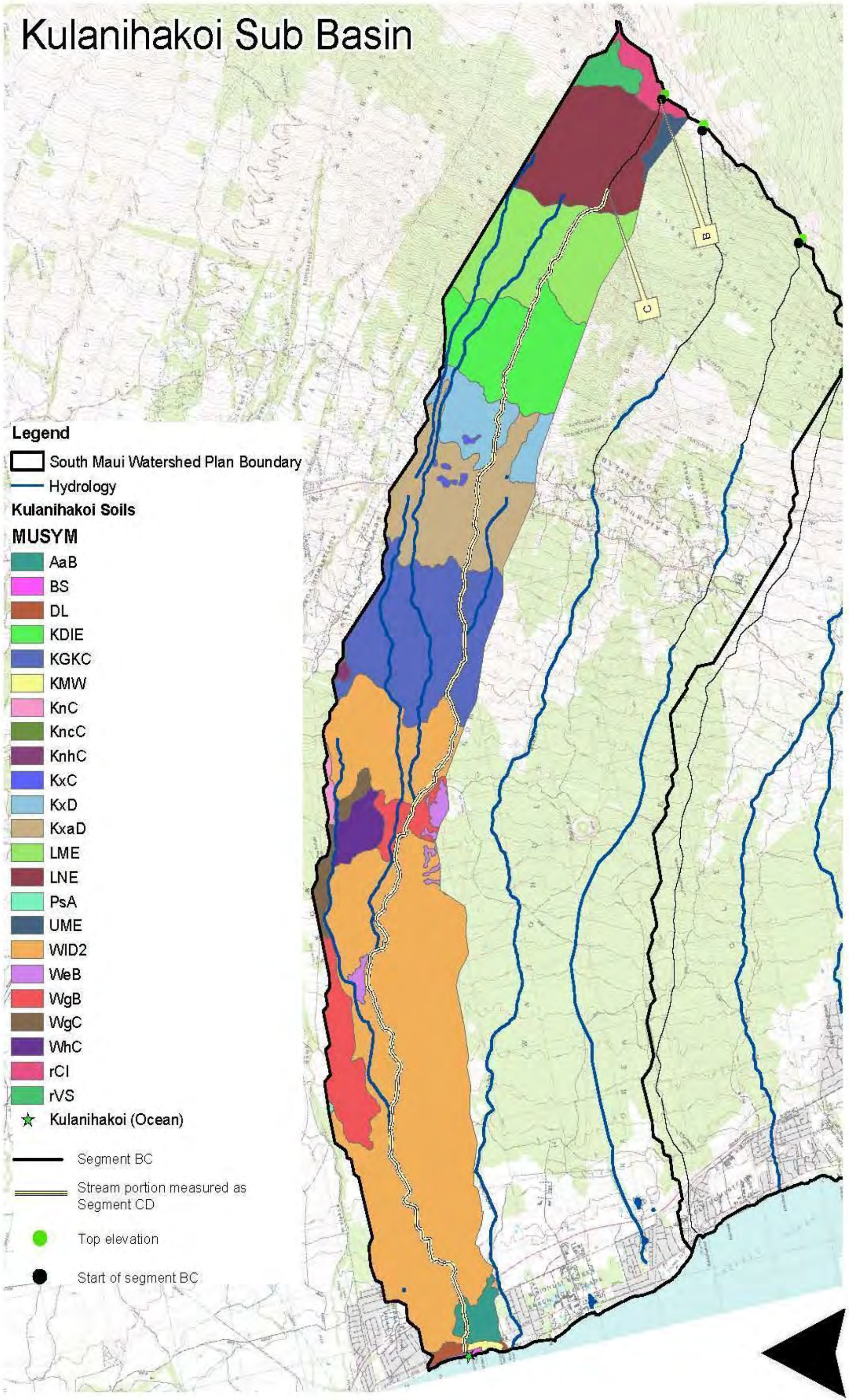
URBAN MANANGEMENT MEASURES: MAKAI S. PAPAANUI, MOHOPILO, & MOOLOA

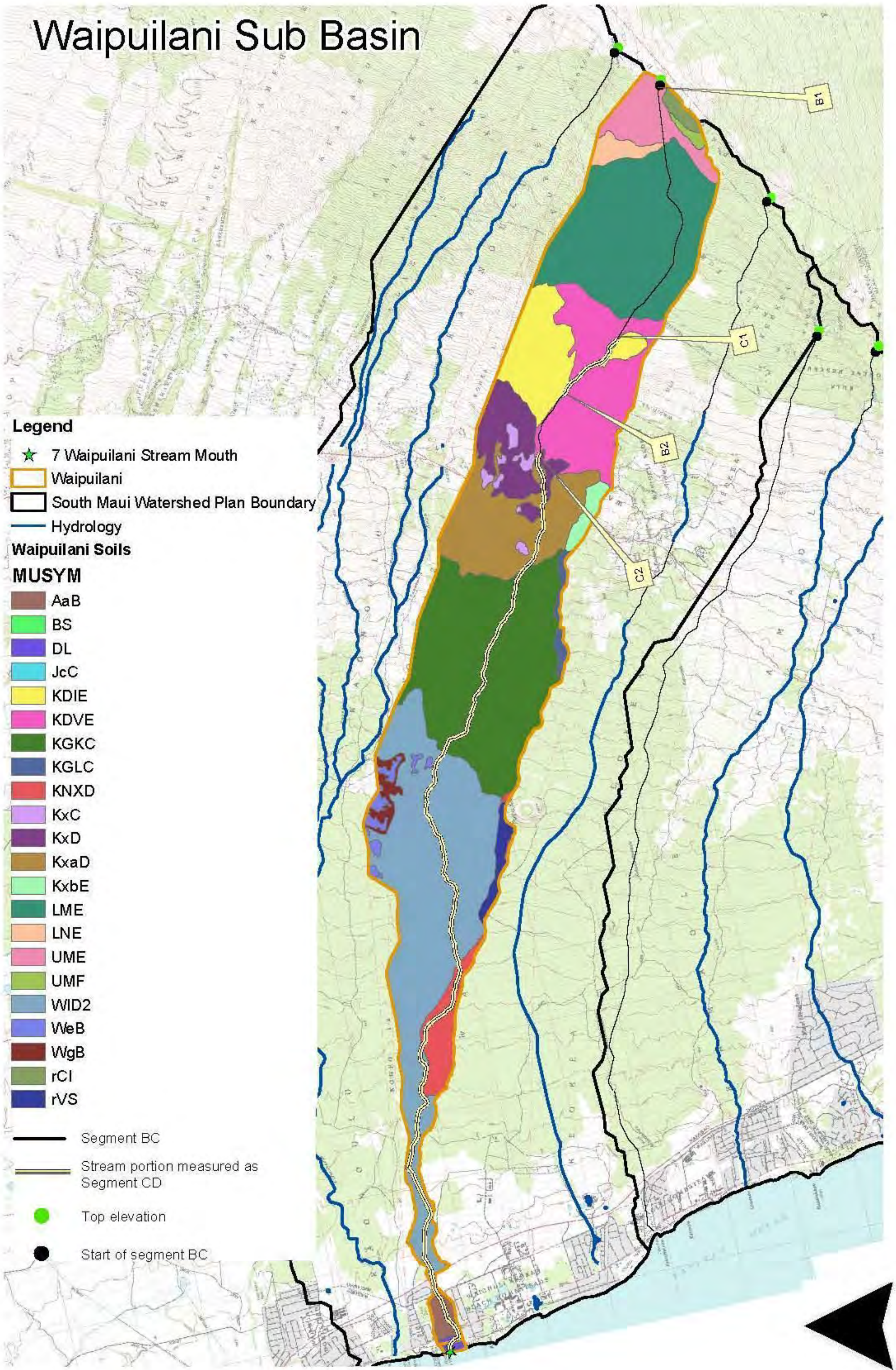


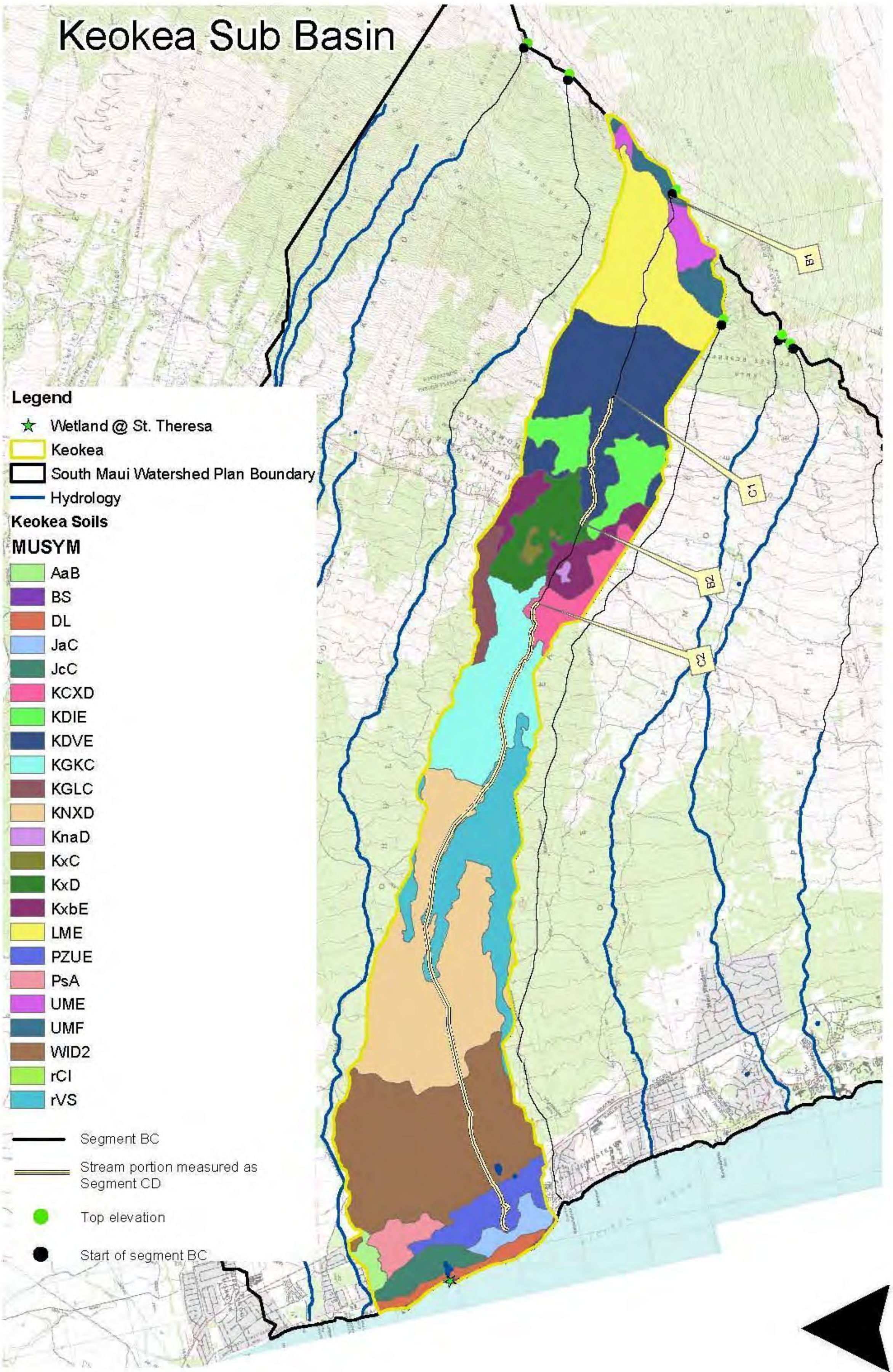



SOUTHWEST MAUI WATERSHED PLAN: POSSIBLE IMPLEMENTATION - MANANGEMENT MEASURES
Legend
Urban Management Measures
Existing Urban & Rural Mangement Areas
Planned Development Areas
Wetland Restoration / Shoreline Protection & Retreat
Agricultural Management Measures
Agricultural Management Measures
Ag Area w Planned Development
Proposed DSILT Project Areas
Possible Interpretive Hike Zone
Palauea-Keauhou Lava Flow Native Habitat
Conservation Lands & Forestry Management
Riparian Restoration
Streambank Stablization & Riparian Restoration
Project Priority
A Priority: urgent, important, feasible
B Priority: urgent, important, less feasible
C Priority: important, may/may not be feasible
3,000 0 3,000 6,000 9,000 12,000
Feet
N

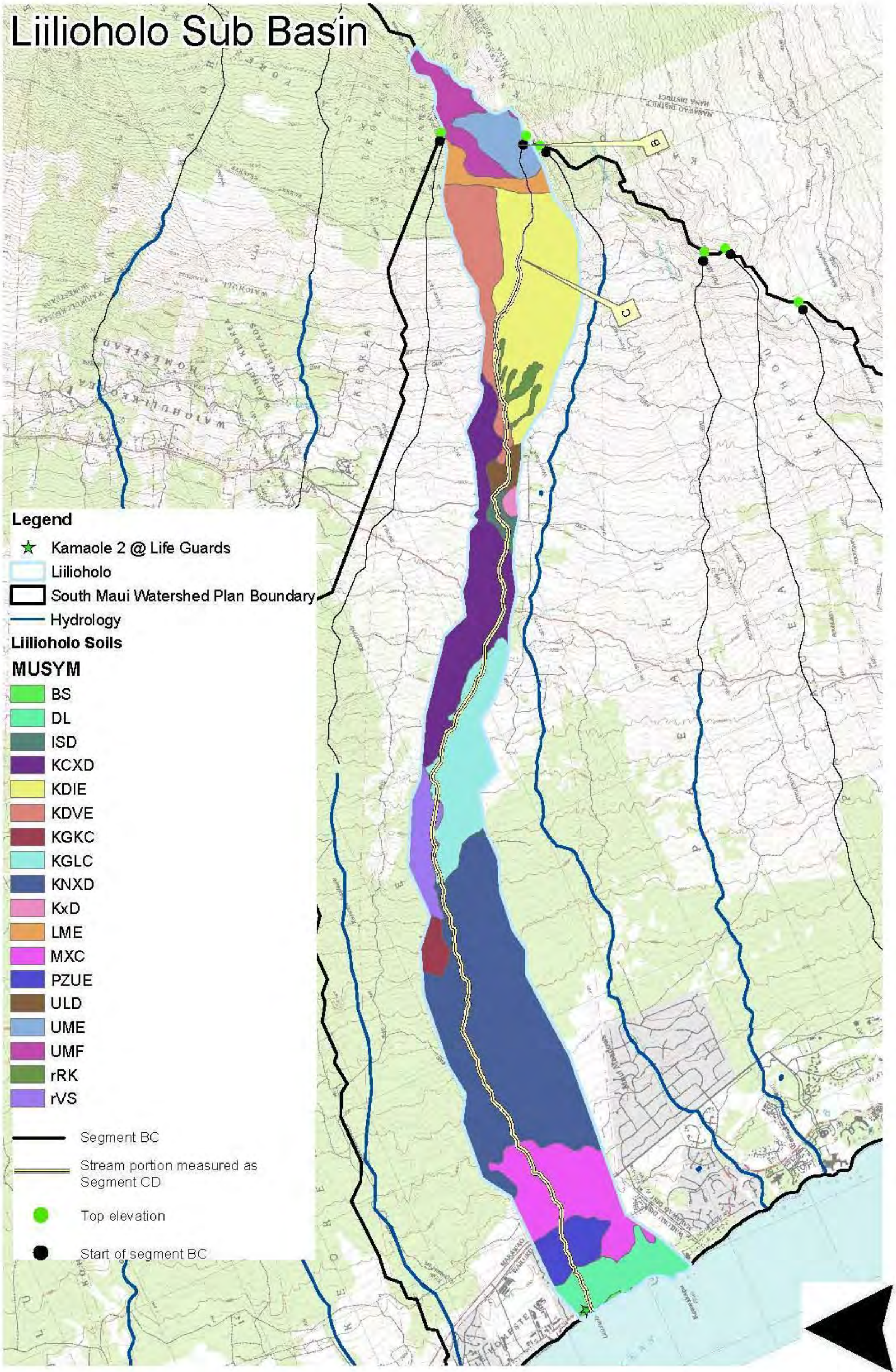
Appendix B. SOUTHWEST MAUI WATERSHED SUB-BASIN MAPS

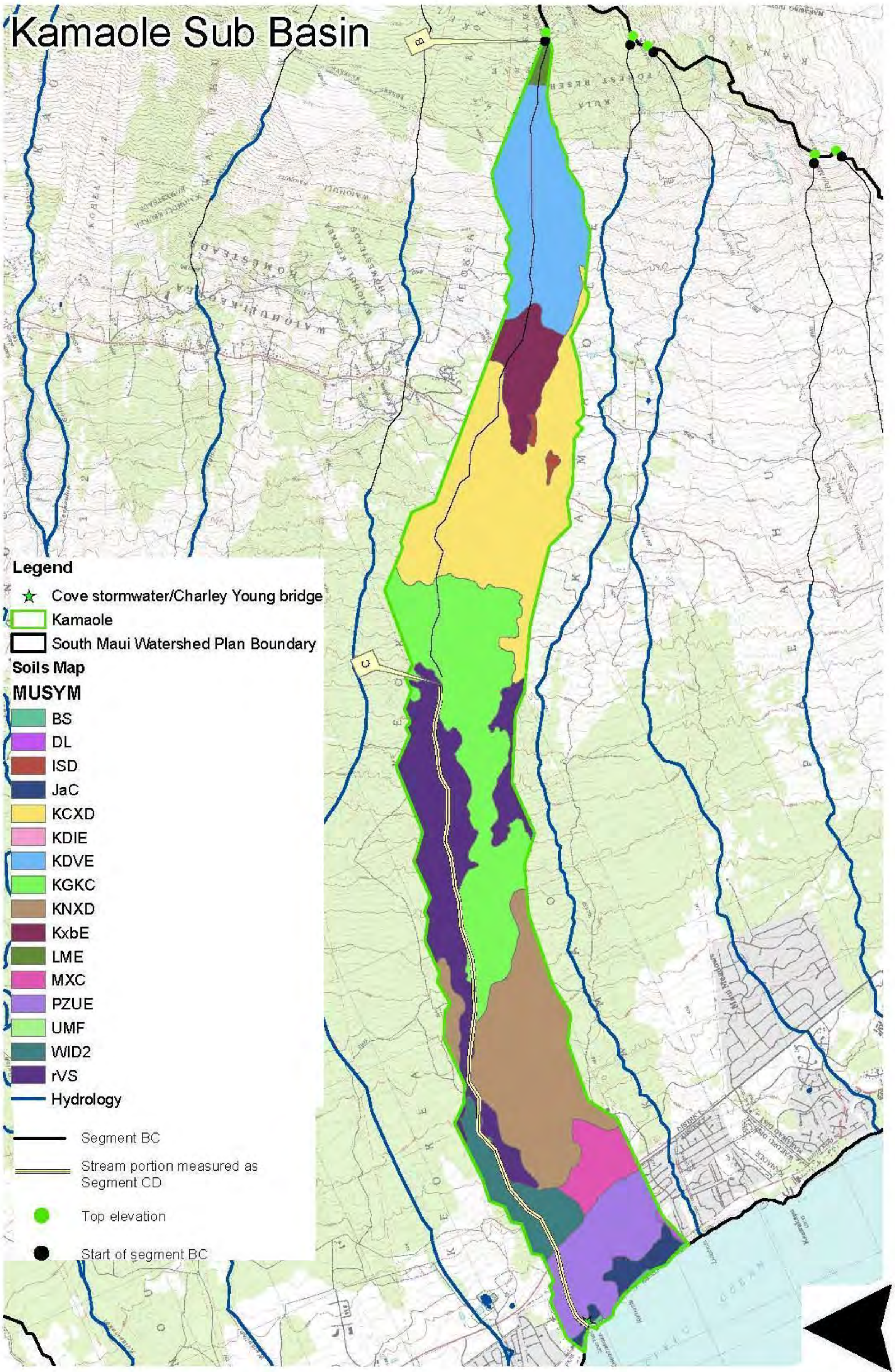



Waipuilani Sub Basin
Legend
7 Waipuilani Stream Mouth
Waipuilani
South Maui Watershed Plan Boundary
Hydrology
Waipuilani Soils
MUSYM
AaB
BS
DL
JcC
KDIE
KDVE
KGKC
KGLC
KNXD
KxC
KxD
KxaD
KxbE
LME
LNE
UME
UMF
WID2
WeB
WgB
rCI
rVS
Segment BC
Stream portion measured as Segment CD
Top elevation
Start of segment BC
B1
C1
B2
C2

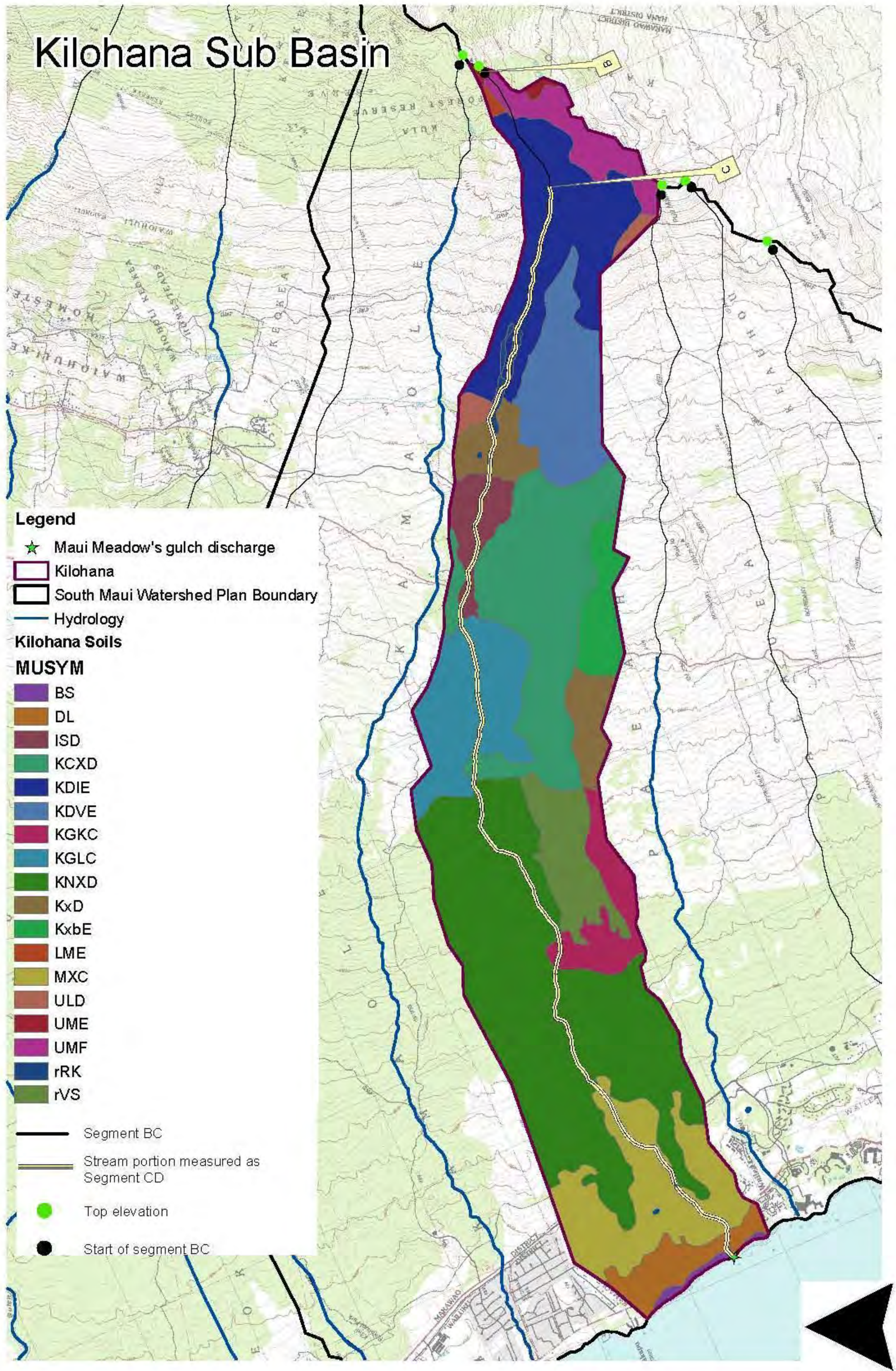


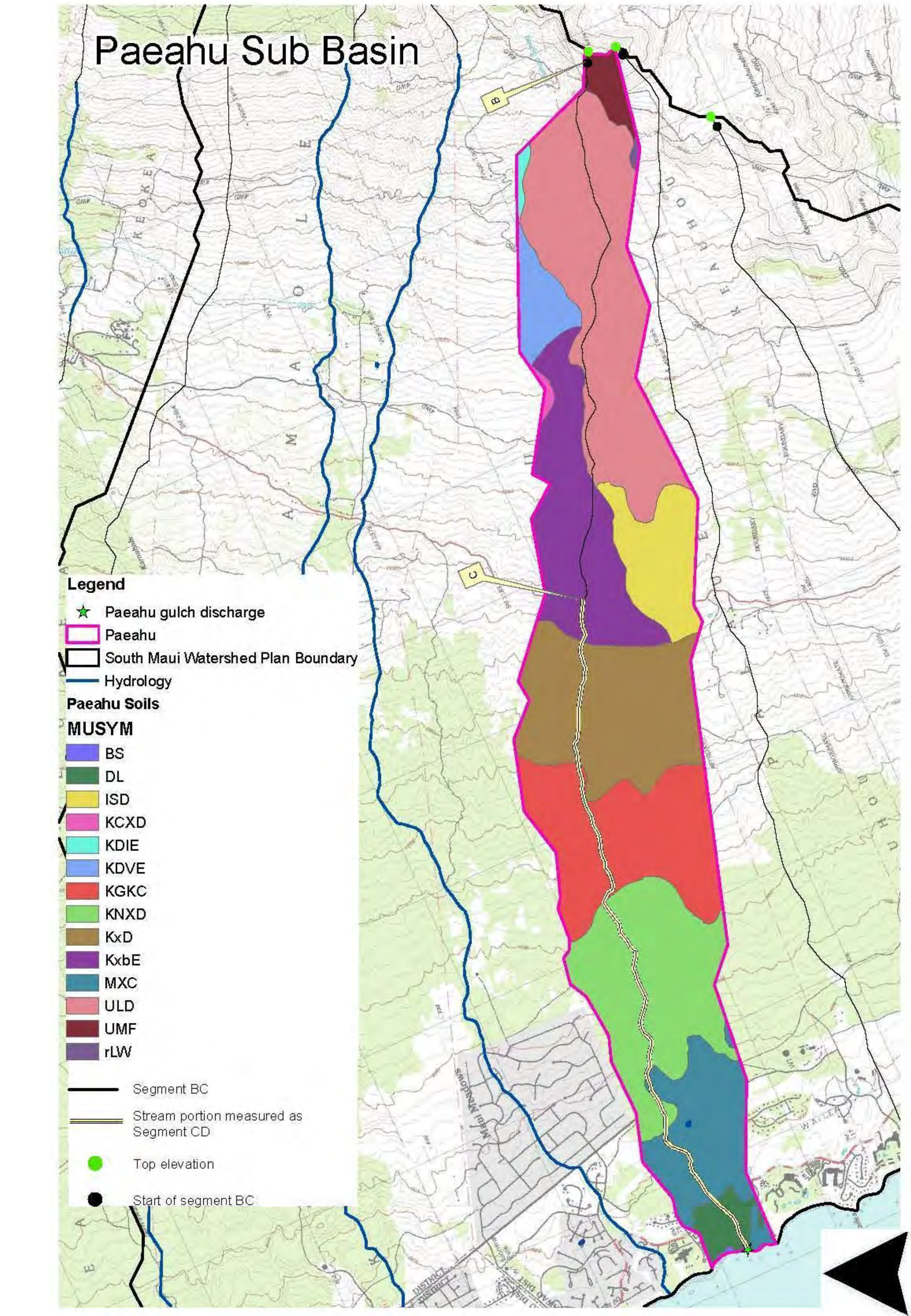
Keokea Sub Basin
Legend
Wetland @ St. Theresa
Keokea
South Maui Watershed Plan Boundary
Hydrology
Keokea Soils
MUSYM
AaB
BS
DL
JaC
JcC
KCXD
KDIE
KDVE
KGKC
KGLC
KNXD
KnaD
KxC
KxD
KxbE
LME
PZUE
PsA
UME
UMF
WID2
rCl
rVS
Segment BC
Stream portion measured as Segment CD
Top elevation
Start of segment BC
B1
C1
B2
C2

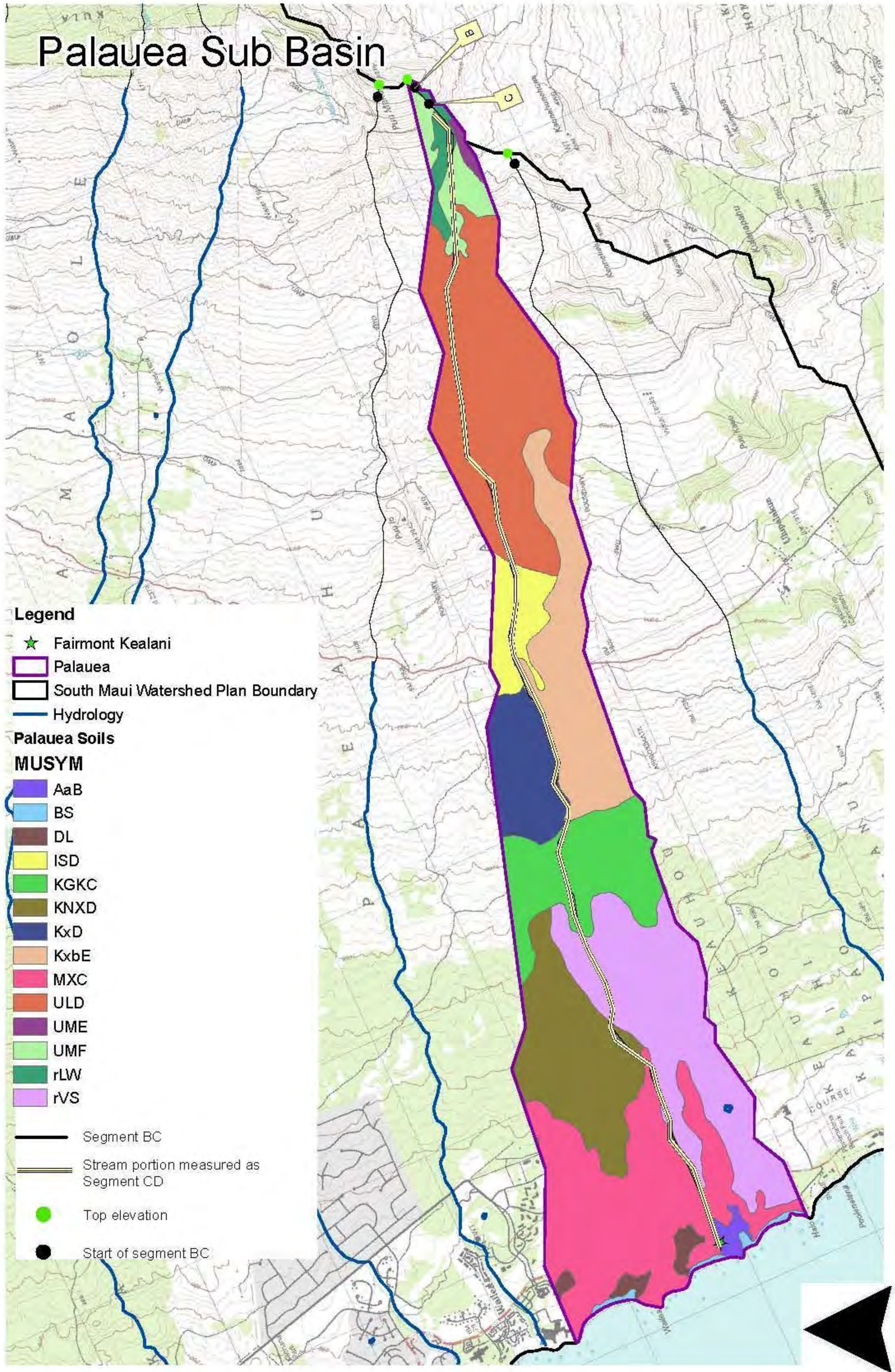

Liilioholo Sub Basin
B
C
Legend
Kamaole 2 @ Life Guards
Liilioholo
South Maui Watershed Plan Boundary
Hydrology
Liilioholo Soils
MUSYM
BS
DL
ISD
KCXD
KDIE
KDVE
KGKC
KGLC
KNXD
KxD
LME
MXC
PZUE
ULD
UME
UMF
rRK
rVS
Segment BC
Stream portion measured as Segment CD
Top elevation
Start of segment BC



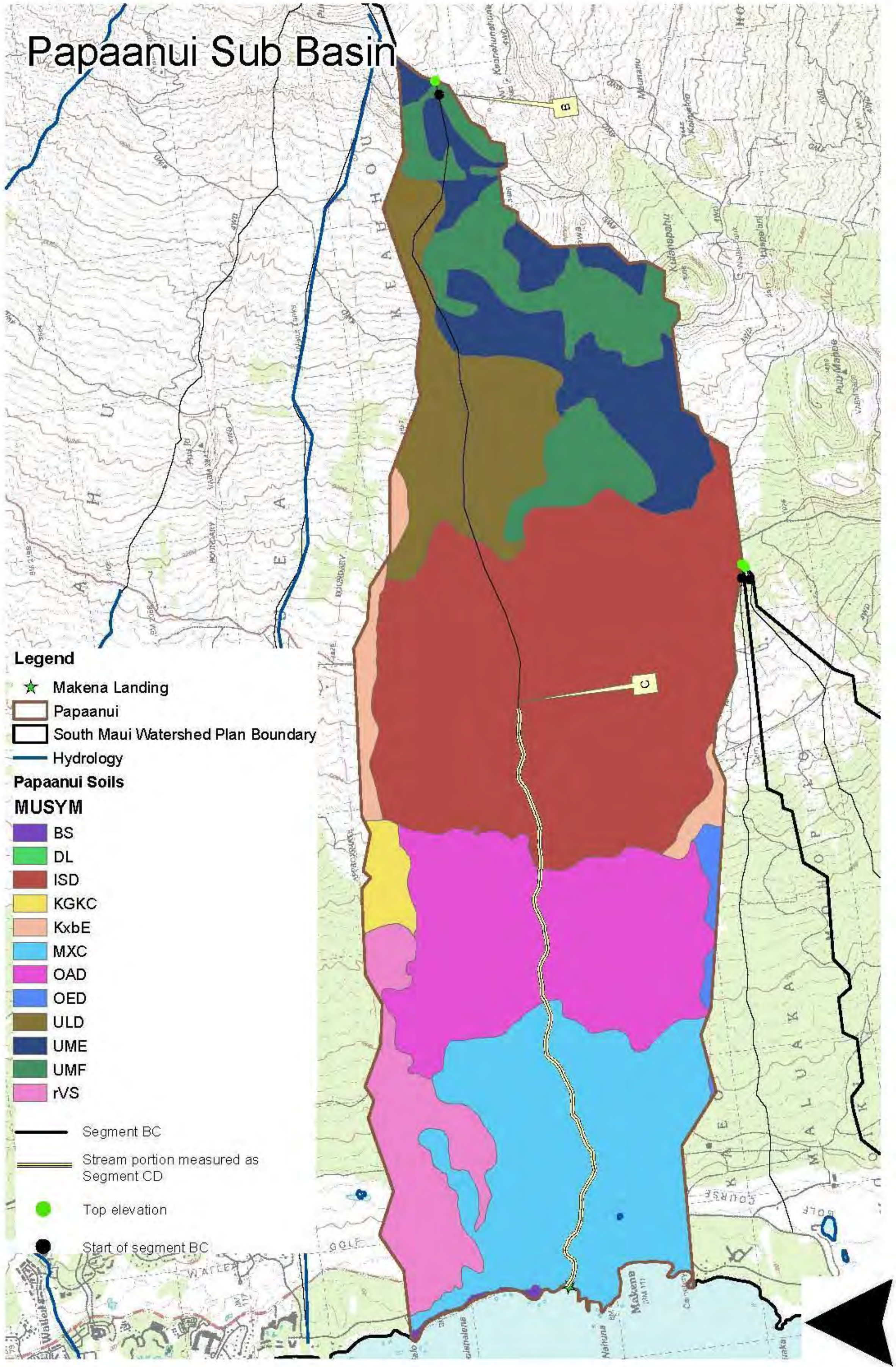
Kamaole Sub Basin
Legend
Cove stormwater/Charley Young bridge
Kamaole
South Maui Watershed Plan Boundary
Soils Map
MUSYM
BS
DL
ISD
JaC
KCXD
KDIE
KDVE
KGKC
KNXD
KxbE
LME
MXC
PZUE
UMF
WID2
rVS
Hydrology
Segment BC
Stream portion measured as Segment CD
Top elevation
Start of segment BC
B
C


Kilohana Sub Basin
B
C
Legend
Maui Meadow's gulch discharge
Kilohana
South Maui Watershed Plan Boundary
Hydrology
Kilohana Soils
MUSYM
BS
DL
ISD
KCXD
KDIE
KDVE
KGKC
KGLC
KNXD
KxD
KxbE
LME
MXC
ULD
UME
UMF
rRK
rVS
Segment BC
Stream portion measured as Segment CD
Top elevation
Start of segment BC


Paeahu Sub Basin
B
C
Legend
Paeahu gulch discharge
Paeahu
South Maui Watershed Plan Boundary
Hydrology
Paeahu Soils
MUSYM
BS
DL
ISD
KCXD
KDIE
KDVE
KGKC
KNXD
KxD
KxbE
MXC
ULD
UMF
rLW
Segment BC
Stream portion measured as Segment CD
Top elevation
Start of segment BC



Palauea Sub Basin
B
C
Legend
Fairmont Kealani
Palauea
South Maui Watershed Plan Boundary
Hydrology
Palauea Soils
MUSYM
AaB
BS
DL
ISD
KGKC
KNXD
KxD
KxbE
MXC
ULD
UME
UMF
rLW
rVS
Segment BC
Stream portion measured as Segment CD
Top elevation
Start of segment BC


Papaanui Sub Basin
Legend
Makena Landing
Papaanui
South Maui Watershed Plan Boundary
Hydrology
Papaanui Soils
MUSYM
BS
DL
ISD
KGKC
KxbE
MXC
OAD
OED
ULD
UME
UMF
rVS
Segment BC
Stream portion measured as Segment CD
Top elevation
Start of segment BC
B
C

Appendix C. RAINFALL DATA (INTENSITY AND IDF

Appendix D. CURVES)

1. Rainfall Data for all Sub-basins

Table 11-1 Rainfall Intensities for each Sub-Basin

S. No.	Watershed	Sub Basin	Time of Concentration (hr) (1)	Rainfall Intensity (in/hr)						
				1-YEAR R.P(2)	2-YEAR R.P(2)	5-YEAR R.P(2)	10-YEAR R.P(2)	25-YEAR R.P(2)	50-YEAR R.P(2)	100-YEAR R.P(2)
1	**a. Hapapa**	Kulanihakoi	12.12	0.15	0.19	0.27	0.33	0.4	0.49	0.58
2		Waipuilani	16.21	0.12	0.17	0.23	0.29	0.38	0.4	0.49
3		Keokea	20.76	0.1	0.14	0.19	0.23	0.3	0.35	0.41
4	**b. Wailea**	Kamaole	2.72	0.4	0.5	0.75	0.9	1.1	1.28	1.45
5		Liilioholo	12.63	0.14	0.19	0.27	0.32	0.39	0.48	0.5
6		Kilohana	11.21	0.17	0.22	0.29	0.35	0.46	0.53	0.59
7		Paeahu	7.66	0.21	0.28	0.39	0.48	0.58	0.69	0.78
8		Palauea	1.6	0.69	0.89	1.18	1.42	1.73	1.97	2.19
9		Papaanui	10.12	0.18	0.24	0.33	0.42	0.52	0.59	0.68
10		Mohopilo	1.06	0.83	1.1	1.47	1.75	2.15	2.48	2.8
11	**c. Mooloa**	Mooloa	1.28	0.78	1.03	1.4	1.65	2.05	2.35	2.6

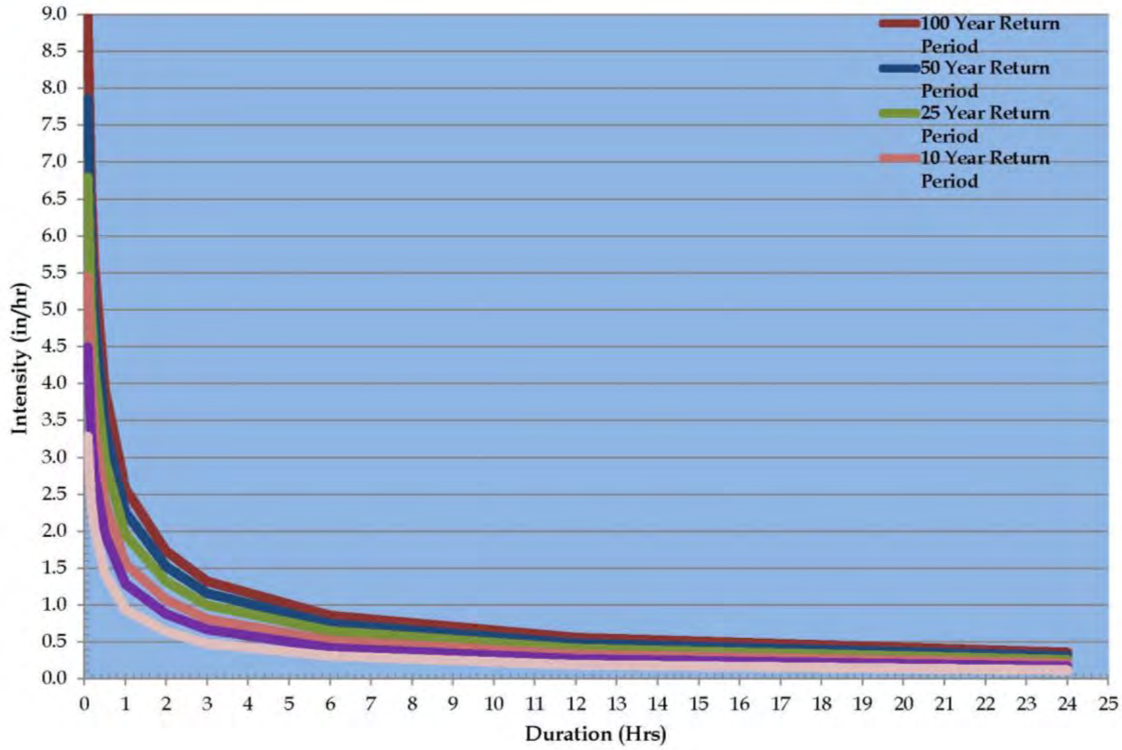
Note (1): **Computation of Time of Concentration** is provided in detail this report.
Note (2): R.P. stands for Return Period

Table 11-2 Rainfall Depths for each Sub-Basin

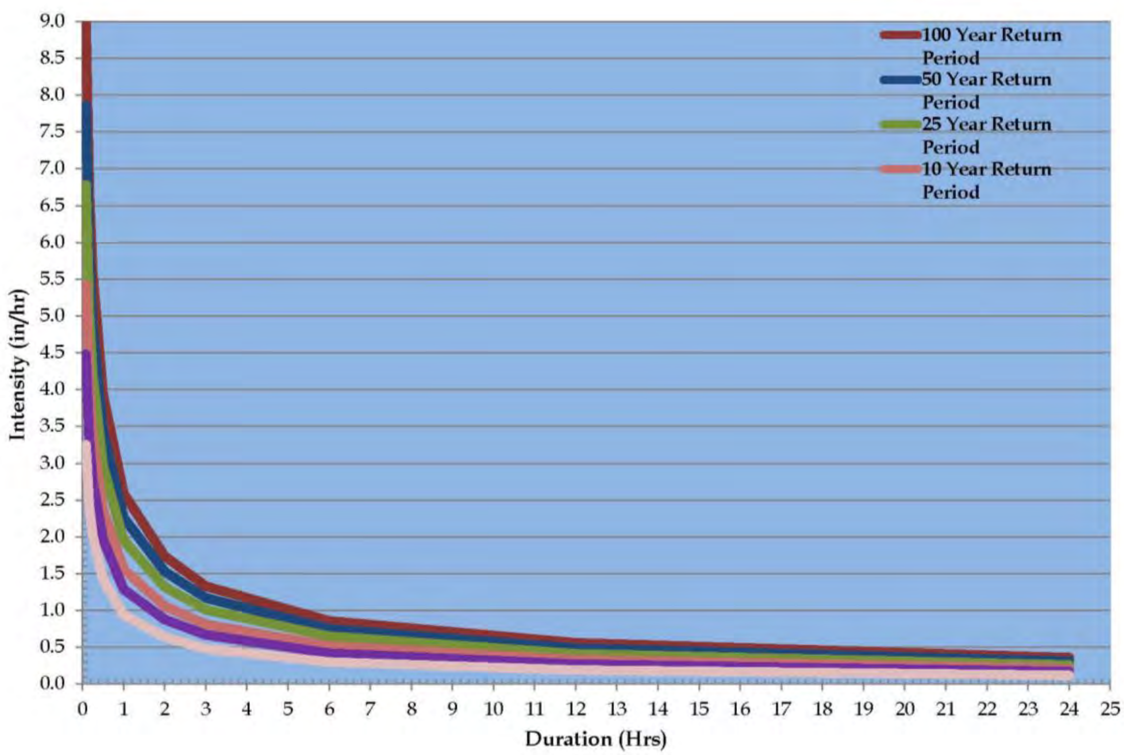
S. No.	Watershed	Sub Basin	Rainfall Depths-24 hour rainfall (inches)						
			1 Year	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
1	**a. Hapapa**	Kulanihakoi	2.03	2.83	4.00	4.96	6.35	7.50	8.72
2		Waipuilani	2.03	2.83	4.00	4.96	6.34	7.49	8.70
3		Keokea	2.03	2.84	4.01	4.97	6.34	7.48	8.68
4	**b. Wailea**	Kamaole	2.04	2.85	4.02	4.96	6.31	7.41	8.58
5		Liilioholo	2.06	2.87	4.03	4.98	6.32	7.40	8.55
6		Kilohana	2.06	2.87	4.03	4.97	6.31	7.40	8.55
7		Paeahu	2.06	2.87	4.03	4.97	6.32	7.41	8.56
8		Palauea	2.09	2.91	4.08	5.03	6.39	7.50	8.68
9		Papaanui	2.10	2.92	4.10	5.07	6.47	7.63	8.88
10		Mohopilo	2.08	2.89	4.07	5.04	6.46	7.63	8.90
11	**c. Mooloa**	Mooloa	2.08	2.89	4.07	5.04	6.44	7.60	8.84

2. **IDF Curves**

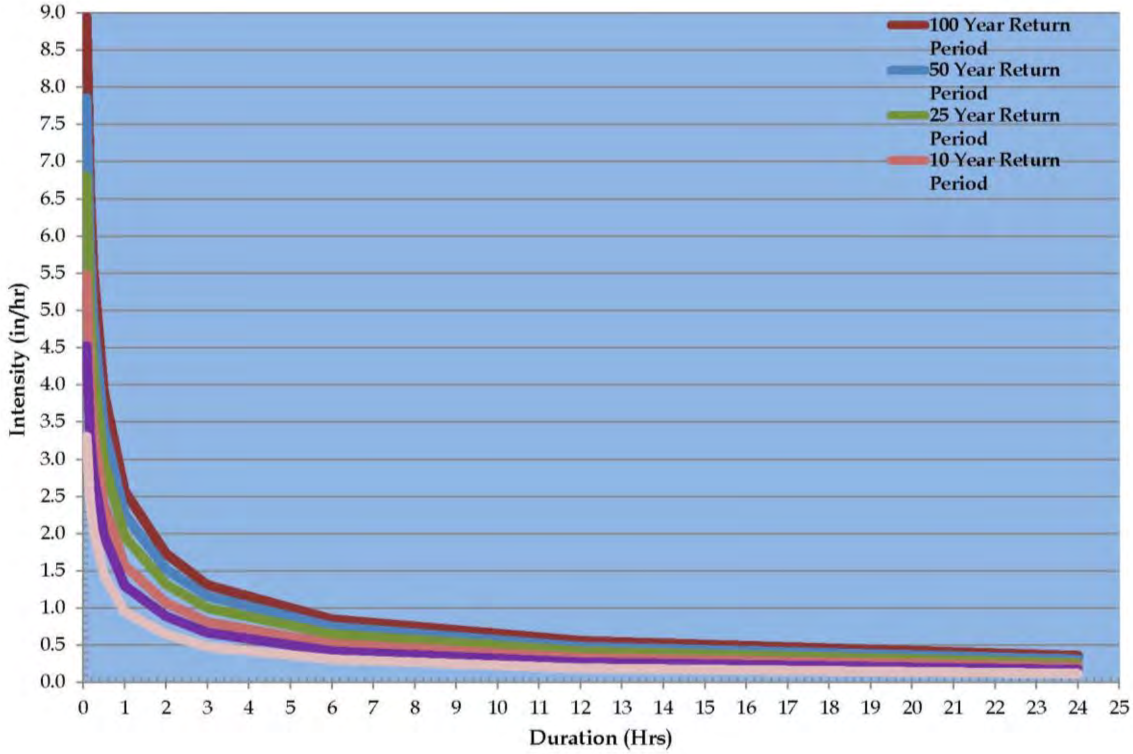
Kulanihako'i IDF Curves for 24 Hours Rainfall



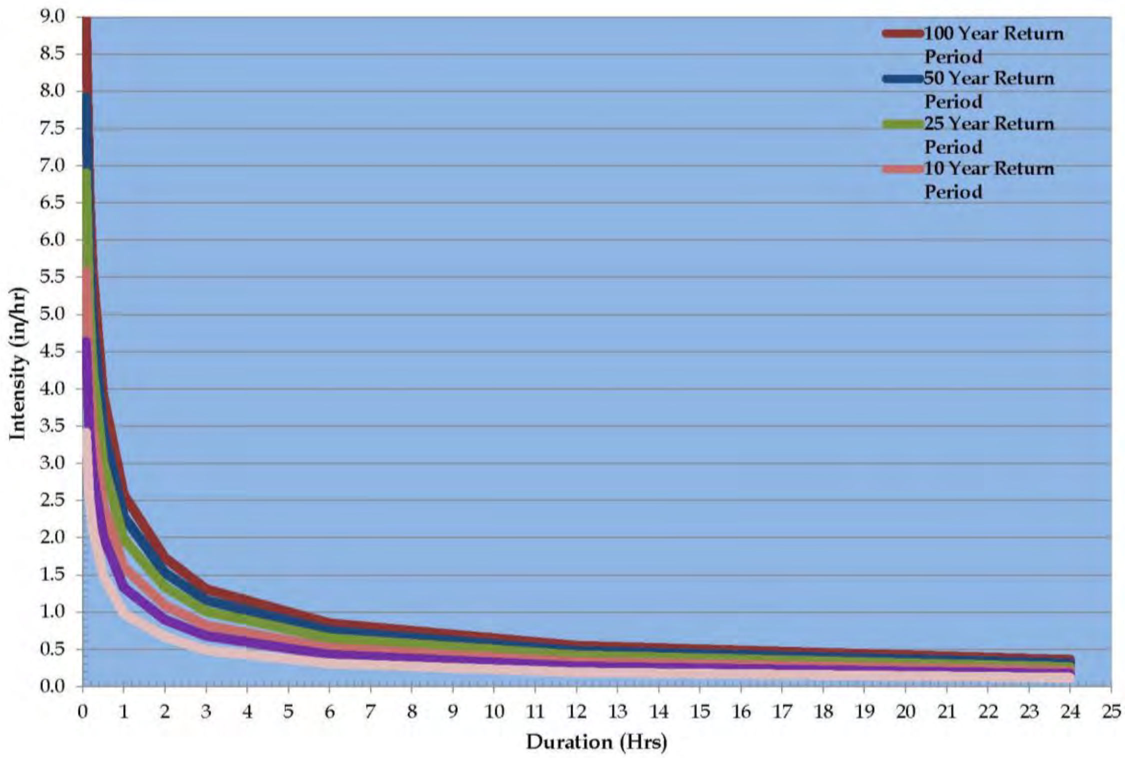
Waipu'ilani IDF Curves for 24 Hours Rainfall



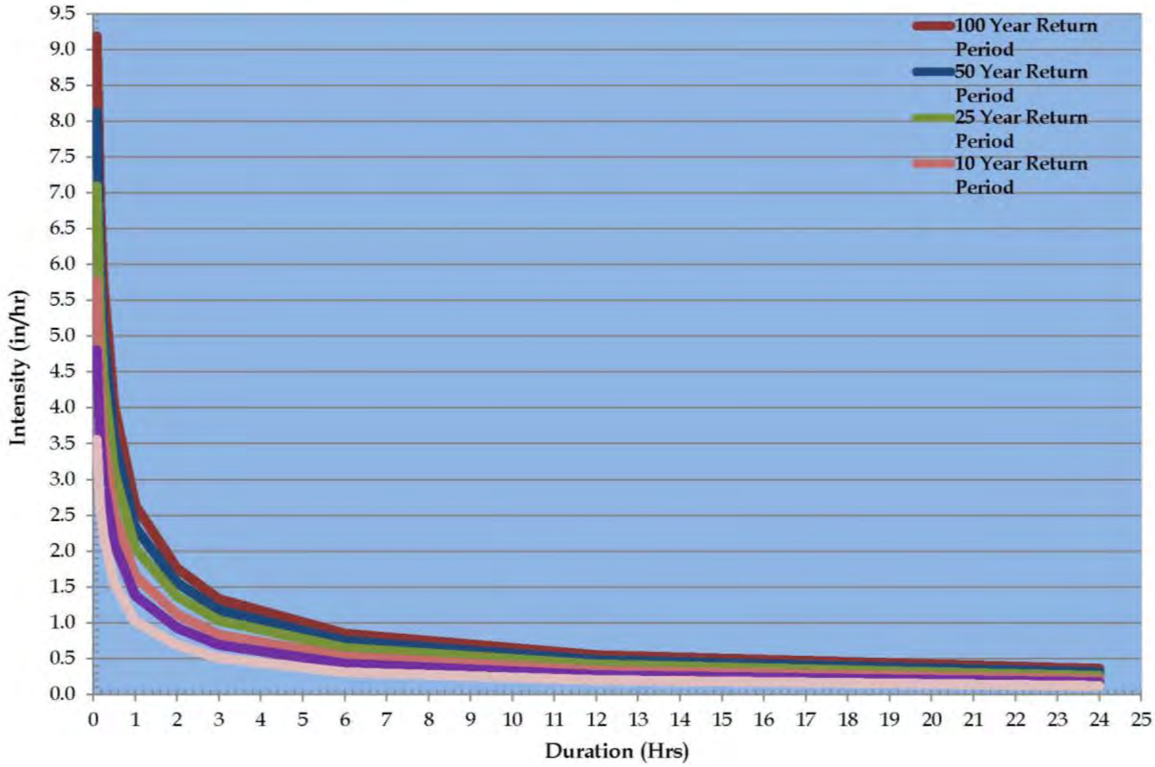
Keokea IDF Curves for 24 Hours Rainfall



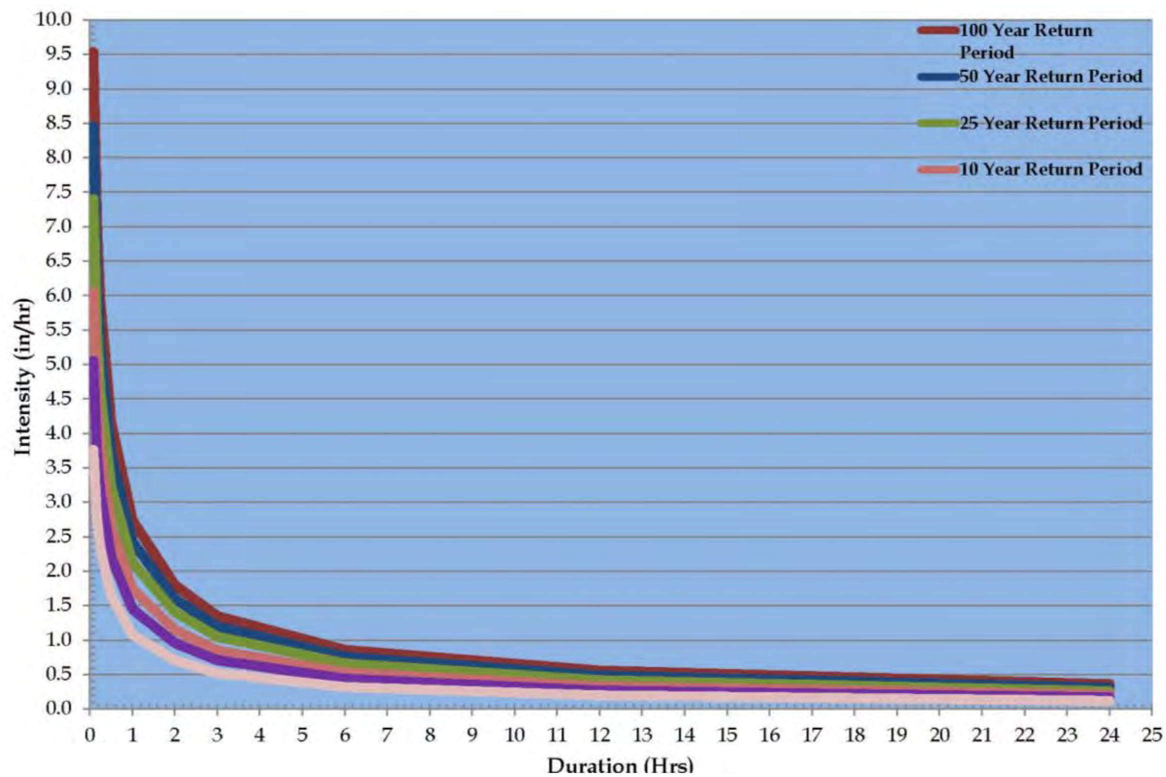
Kama'ole IDF Curves for 24 Hours Rainfall



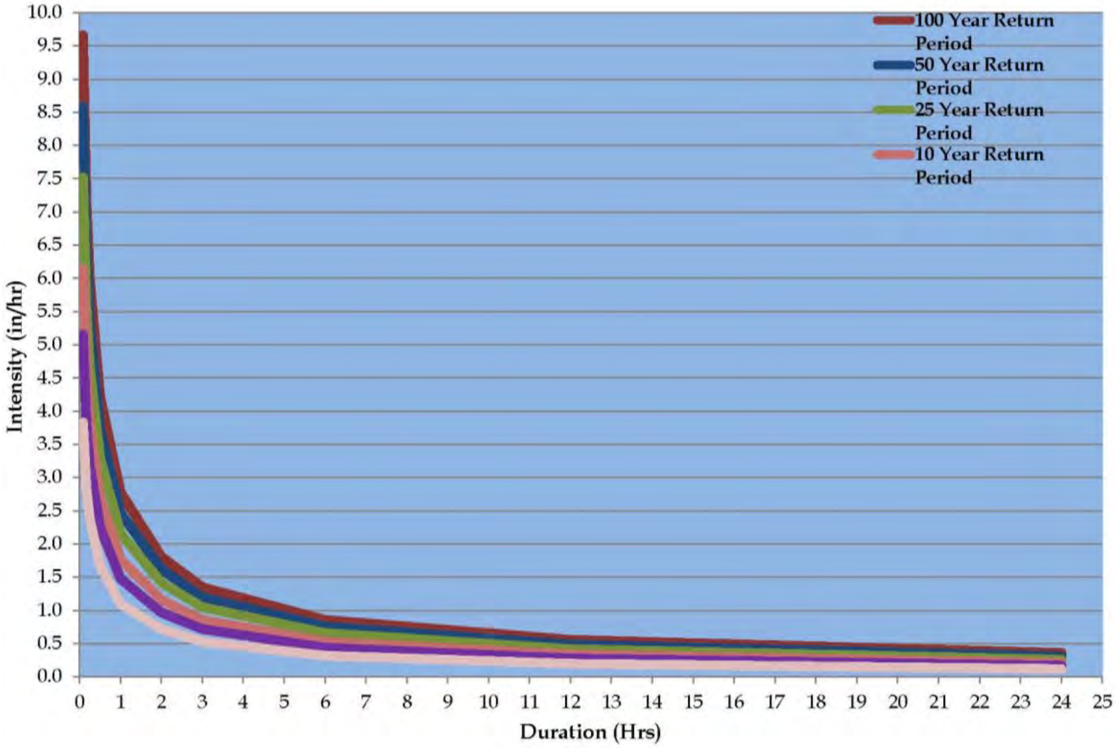
Liilioholo IDF Curves for 24 Hours Rainfall



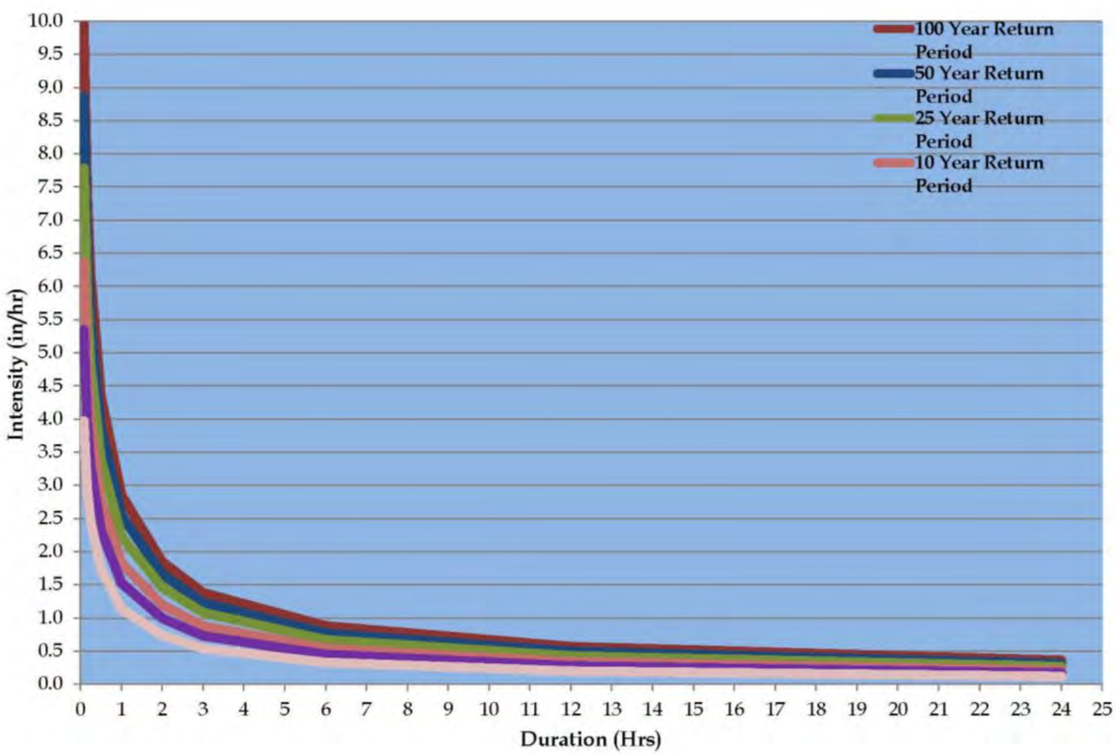
Kilohana IDF Curves for 24 Hours Rainfall



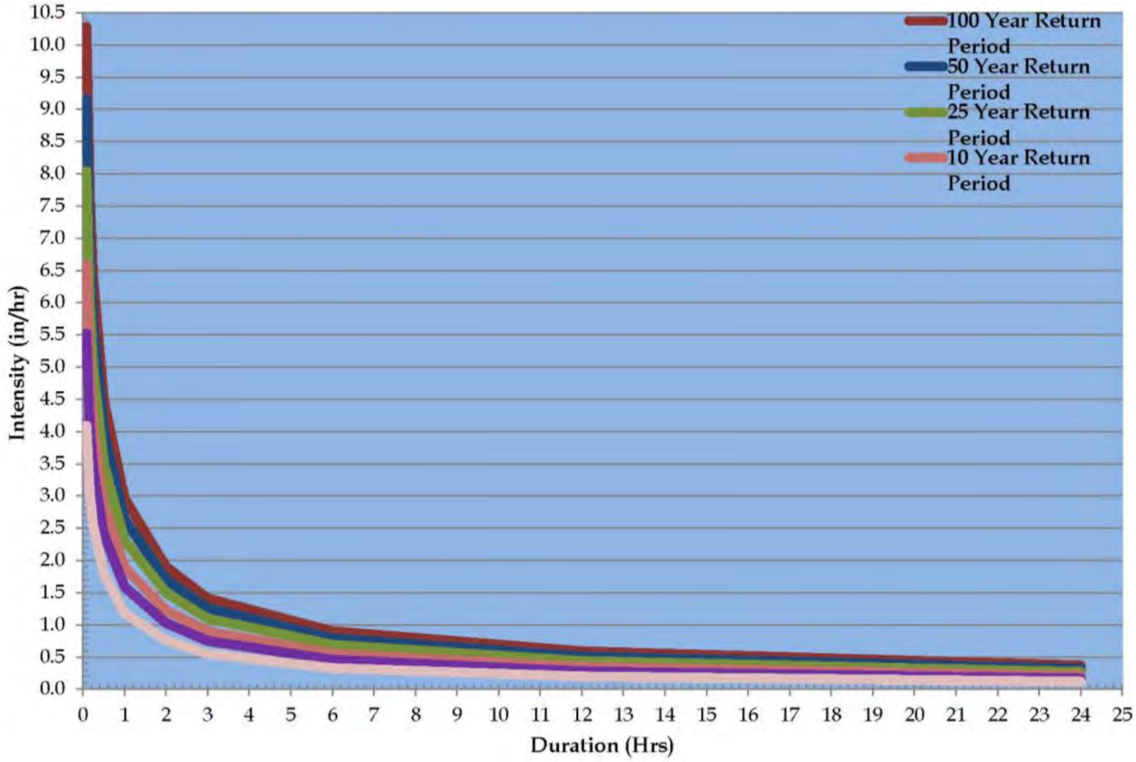
Paeahu IDF Curves for 24 Hours Rainfall



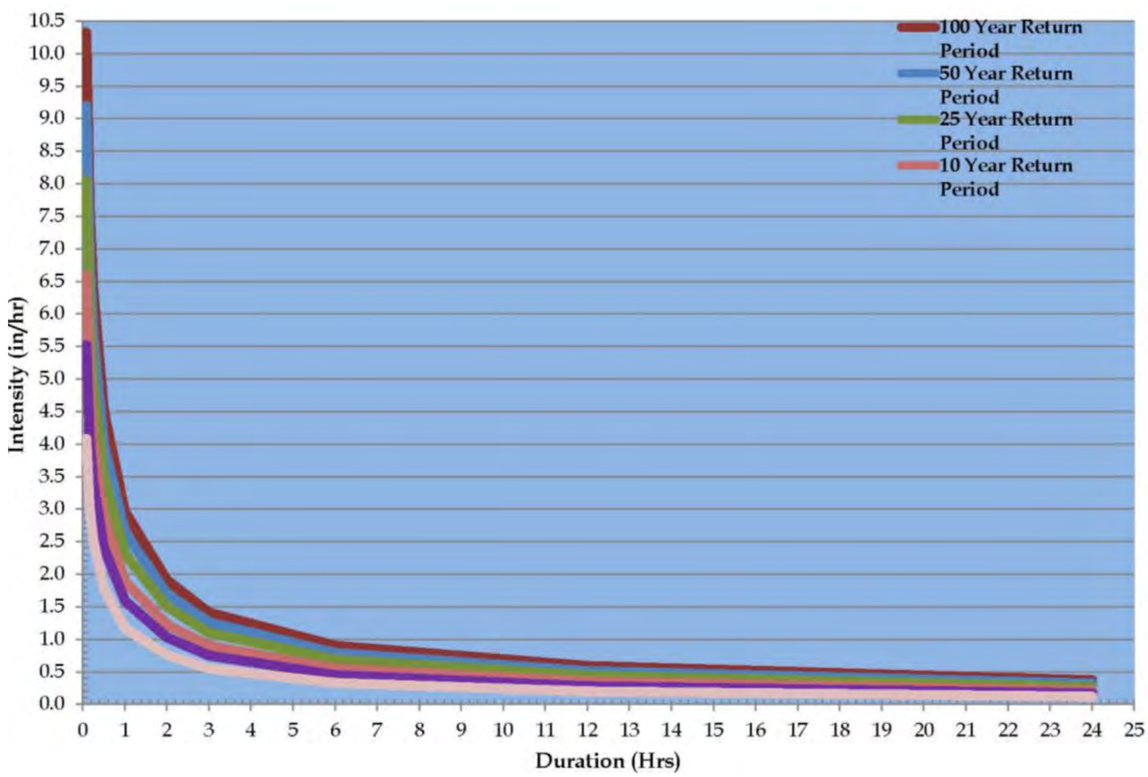
Palauea IDF Curves for 24 Hours Rainfall



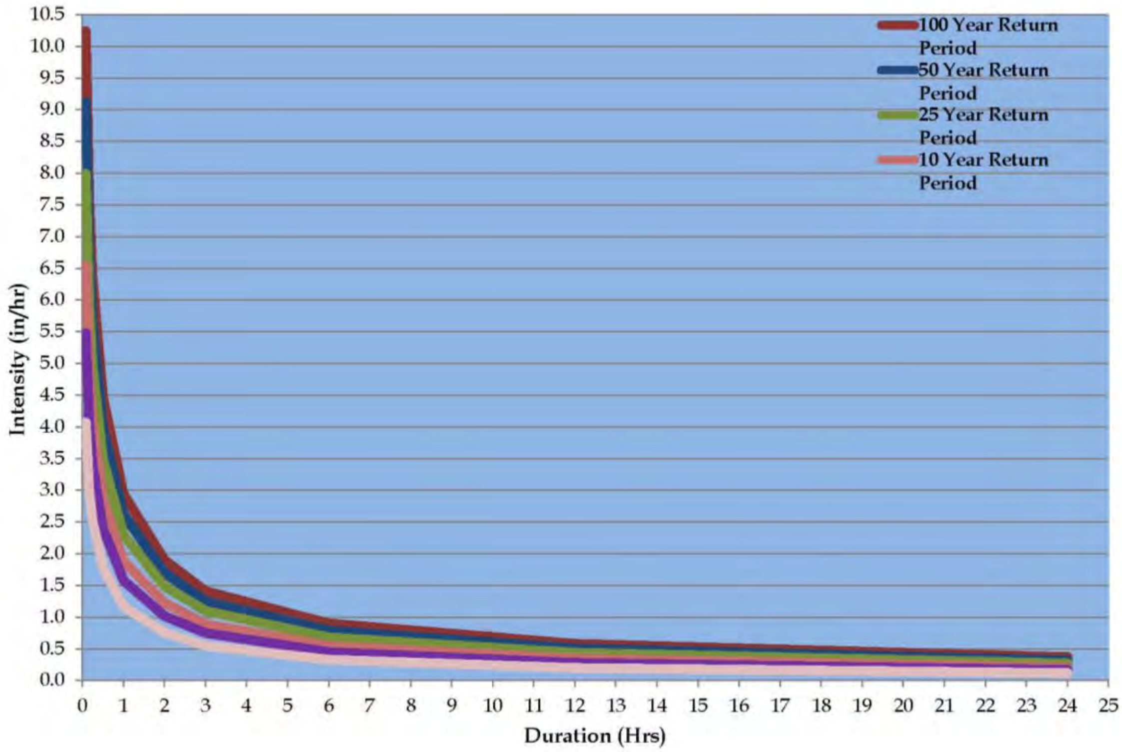
Papa'anui IDF Curves for 24 Hours Rainfall



Mohopilo IDF Curves for 24 Hours Rainfall



Mo'oloa IDF Curves for 24 Hours Rainfall



Appendix E. HYDROLOGIC MODELING METHODS

1. Rational Method

The Rational Method was first introduced in 1889. Although it is often considered simplistic, it still is appropriate for estimating peak discharges for small drainage areas of up to about 200 acres (80 hectares) in which no significant flood storage appears. The peak discharge for all the sub-basins was determined by using the Rational Method. The design period used for the analysis included 2, 5, 10, 25, 50, and 100-year return periods. According to the Rational Method, the peak discharge is given by the following equation:

Equation 11-1 $$Q = CIA$$

- Q is defined as the maximum rate of runoff generated in cubic feet per second (cfs).
- C is a runoff coefficient and is a function of the land use type of the sub-basin,
- I represents the average intensity of rainfall in inches per hour for durations equal to the time of concentration, and
- A is the contributing basin or catchment area in Acres.

The runoff coefficient, C, represents the integrated effects of infiltration, evaporation, retention, flow routing, and interception, all which effect the time distribution and peak rate of runoff. The values are presented for different surface characteristics as well as for different aggregate land uses. Given the land use in each of the sub-basin, the C values were obtained from Table 11-3.

The rainfall intensity "I" for all the sub-basins is derived from the Intensity Duration Frequency (IDF). The rainfall intensity is read from the IDF curve using the storm duration (which is set to the time of concentration) and corresponding return period.

Table 11-3 Runoff Coefficient C values

Ground Cover	Selected Land Cover	Runoff Coefficient, C	Selected C Values
Lawns		0.05 - 0.35	
Forest	Evergreen Forest and scrub/shrub	0.05 - 0.25	0.25
Cultivated land	Cultivated Land	0.08-0.41	0.41
Meadow		0.1 - 0.5	
Parks, cemeteries	Open Water	0.1 - 0.25	0.25
Unimproved areas	Bare Land	0.1 - 0.3	0.3
Pasture	Pasture/Hay and Grassland	0.12 - 0.62	0.62
Residential areas		0.3 - 0.75	
Business areas		0.5 - 0.95	
Industrial areas		0.5 - 0.9	
Asphalt streets	Developed Open space	0.7 - 0.95	0.95
Brick streets		0.7 - 0.85	
Roofs		0.75 - 0.95	
Concrete streets	Impervious	0.7 - 0.95	0.95

Table 11-4 Peak Discharge for each sub-basin based on Rational Method of Peak Discharge

Sr No	Water-shed	Sub Basin	Runoff (ft^3/sec)					
			2-YEAR Q	5-YEAR Q	10-YEAR Q	25-YEAR Q	50-YEAR Q	100-YEAR Q
1	**Hapapa**	Kulanihakoi	692.0	983.4	1201.9	1456.9	1784.7	2112.5
2		Waipuilani	394.1	533.2	672.3	881.0	927.4	1136.0
3		Keokea	463.3	628.7	761.1	992.7	1158.2	1356.7
4	**Wailea**	Kamaole	818.8	1228.2	1473.9	1801.4	2096.2	2374.6
5		Liilioholo	249.9	355.1	420.8	512.9	631.3	657.6
6		Kilohana	498.8	657.5	793.6	1043.0	1201.7	1337.7
7		Paeahu	389.9	543.1	668.4	807.7	960.8	1086.2
8		Palauea	1114.6	1477.8	1778.4	2166.6	2467.2	2742.7
9		Papaanui	495.7	681.5	867.4	1074.0	1218.5	1404.4
10		Mohopilo	420.2	561.6	668.5	821.3	947.4	1069.6
11	**Mooloa**	Mooloa	429.8	584.2	688.5	855.4	980.6	1084.9

2. HEC-HMS Model for Sub-basins

Delineation of Sub-Basins

Sub-basins are delineated including outlet points for these sub-basins. As already discussed, there are a total of eleven (11) Sub-basins delineated as part of three major Watersheds in the Project area. The Time of Concentration (Tc) and Curve Numbers (CN) for these sub-basins were calculated by utilizing data either collected from the field or assumed based on visual inspection of the streams. The summary of computed Time of concentration (Tc), and Curve numbers for the Sub-basins along with Lag time are given in the full hydrology modeling report found at www.mauiwatershed.org .

Table 11-5 Time of Concentration, Lag time and Curve Number (CN) for Sub-Basins

Sr. No.	Watershed	Sub Basin	Accumulated areas		Curve N0.	Time of concentration	Lag Time
			(Acres)	(mi^2)	CN	min	min
1	a. Hapapa	Kulanihakoi	10677	16.68	74	727	436
2		Waipuilani	7212	11.27	70	972	583
3		Keokea	8592	13.43	71	1246	747
4	b. Wailea	Kamaole	3847	6.01	68	163	98
5		Liilioholo	3121	4.88	68	758	455
6		Kilohana	4494	7.02	69	673	404
7		Paeahu	2709	4.23	70	460	276
8		Palauea	2543	3.97	71	96	58
9		Papaanui	4244	6.63	67	607	364
10		Mohopilo	1030	1.61	70	64	38
11	c. Mooloa	Mooloa	1213	1.9	71	77	46

Computation of Runoff Volumes

The options in HEC-HMS include infiltration-based methods, continuous soil moisture accounting techniques, and SCS abstraction method, i.e. Curve Number approach.

The chosen method is SCS Curve Number method. Developed in 1972, the method estimates the precipitation excess as a function of cumulative precipitation, soil cover, land use, and antecedent moisture conditions. The theory of the method is available in many text references, such as Chow 1988.

Despite some of the inherent drawbacks, the method still has many advantages to consider it most appropriate for use, such as:

- Simple, predictable, and stable method
- Relies on only one parameter, which varies as a function of soil group, land use and treatment, surface conditions, and antecedent moisture conditions
- Features readily grasped and reasonably well documented environmental input
- Well-established method, widely accepted for use in US and abroad
- Has widely been used on various large irrigation and river engineering projects

Once the losses are accounted for, and excess rainfall computed, the runoff hydrograph is computed using the SCS unit hydrograph technique available as an option in the HEC-HMS program. In summary, the parameters needed to compute the hydrograph include the catchment area, curve number, and the lag time T_{lag}. While catchment area is read from the delineated sub-basin maps marked on the topographic sheets, the time lag is computed from the relationship:

Equation 11-2 $$T_{lag} = 0.6\, T_c$$

Where Tc is the time of concentration defined as the travel time of water from the hydraulically most distant point in the catchment to reach the point of interest, which in this case the outlet of the sub-basin.

Computation of Curve Number (CN)

Computation of Curve number is the most important aspect of SCS curve number method. Curve number is a dimensionless parameter that defines the relationship between the actual and excess rainfall. The curve number depends upon the catchment characteristics including the soils; cover type, treatment, and hydrologic conditions/land use etc.

In general our project area of eleven sub-basins considered for hydrological modeling is characterized as:

1. Impervious
2. Open spaces
3. Cultivated land
4. Pastured land

5. Grass land
6. Ever green forest
7. Shrubs
8. Barren land

Typically, floods are generated in the upland hill ranges, where steep slopes, thin soils, and exposed bare rock are conducive to runoff. In lowland and piedmont areas the deep dry soils and pervious gravels are not conducive to runoff, which may be confined to particularly impervious land (e.g. tracks, fine silt/clay land bordering nullahs and similar material in depressions) or intense storms, which have been preceded by a considerable depth of rainfall, sufficient to saturate the soil. Exceptionally, very intense storms may cause runoff by exceeding the infiltration capacity of the soil. For the CN estimation the above land use classifications are further divided in to three hydrologic groups as given below:

- Soil Hydrologic Group A: Soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission (> 0.30 in/hr).
- Soil Hydrologic Group B: Soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).
- Soil Hydrologic Group C: Soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine-to-fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).

Composite CN representative of the entire watershed is calculated by following equation:

Equation 11-3 $$CN_{Composite} = \sum A_i CN_i / \sum A$$

Computation of Time of Concentration

Travel time (Tt) is the time it takes water to travel from one location to another in a watershed. Tt is typically computed for various flow paths in a sub-basin and the sum of all travel paths provides the total travel time or time of concentration (Tc), which is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed.

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is a function of the conveyance system and is best determined by field inspection.

Travel time (Tt) is the ratio of flow length to flow velocity:

Equation 11-4 **Tt = L/3600 V**

Where:

- Tt = travel time (hr)
- L = flow length (ft)
- V = average velocity (ft/s)
- 3600 = conversion factor from seconds to hours.

Time of concentration (Tc) is the sum of Tt values for the various consecutive flow segment paths including sheet flow, shallow concentrated flow, and open channel flow as described below:

Equation 11-5 **Tc = Tt1 + Tt2 +........... Ttm**

Where:

- Tc = time of concentration (hr)
- m = number of flow segments

Sheet Flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute Tt:

Equation 11-6 **Tt = 0.007 (nL) 0.8/P2 0.5 s0.4**

Where:

- Tt = travel time (hr)
- n = Manning's roughness coefficient
- L = flow length (ft)
- P_2 = 2-year, 24-hour rainfall (in)
- s = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time.

Shallow Concentrated Flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from the graphs given in TR-55 Manual in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in Figure 11-1 taken from Appendix F of the TR-55 Manual. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope. After determining average velocity in Figure 11-1, use above equation of sheet flow to estimate travel time for the shallow concentrated flow segment.

Open Channels

Shallow concentrated flow becomes open channel flow when it enters a well-defined channel. For the sub-basins under study, field visits were conducted in the sub-basin to determine or assume the shape of the channel. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank full elevation.

Equation 11-7 Manning's equation is: V = 1.49 r2/3 s1/2/n

Where:

- V = average velocity (ft/s)
- r = hydraulic radius (ft)
- a = cross sectional flow area (ft2)
- s = slope of the hydraulic grade line (channel slope, ft/ft)
- n = Manning's roughness coefficient for open channel flow

The time of concentration (Tc) is thus calculated by adding the travel times for all different flow paths (overland flow, shallow concentrated flow, and channels flow).

Meteorological Model of HEC-HMS

The meteorological models consist of point rainfall depths in inches for each sub-basin and a method to distribute this rainfall with the help of an appropriate rainfall distribution to establish the rainfall hydrograph. In the SCS unit hydrograph method, the point rainfall depth is converted into a rainfall hyetograph by using the appropriate SCS dimensionless 24-hour distribution applicable for this part of the US i.e. the SCS Hypothetical Storm Distribution Type I, which is available as an option in the HEC-HMS program. 24-hour rainfall depths for different return periods are used as input to the meteorological model. The return periods selected for hydrological modeling are 1, 2, 5, 10, 25, 50, and 100 years.

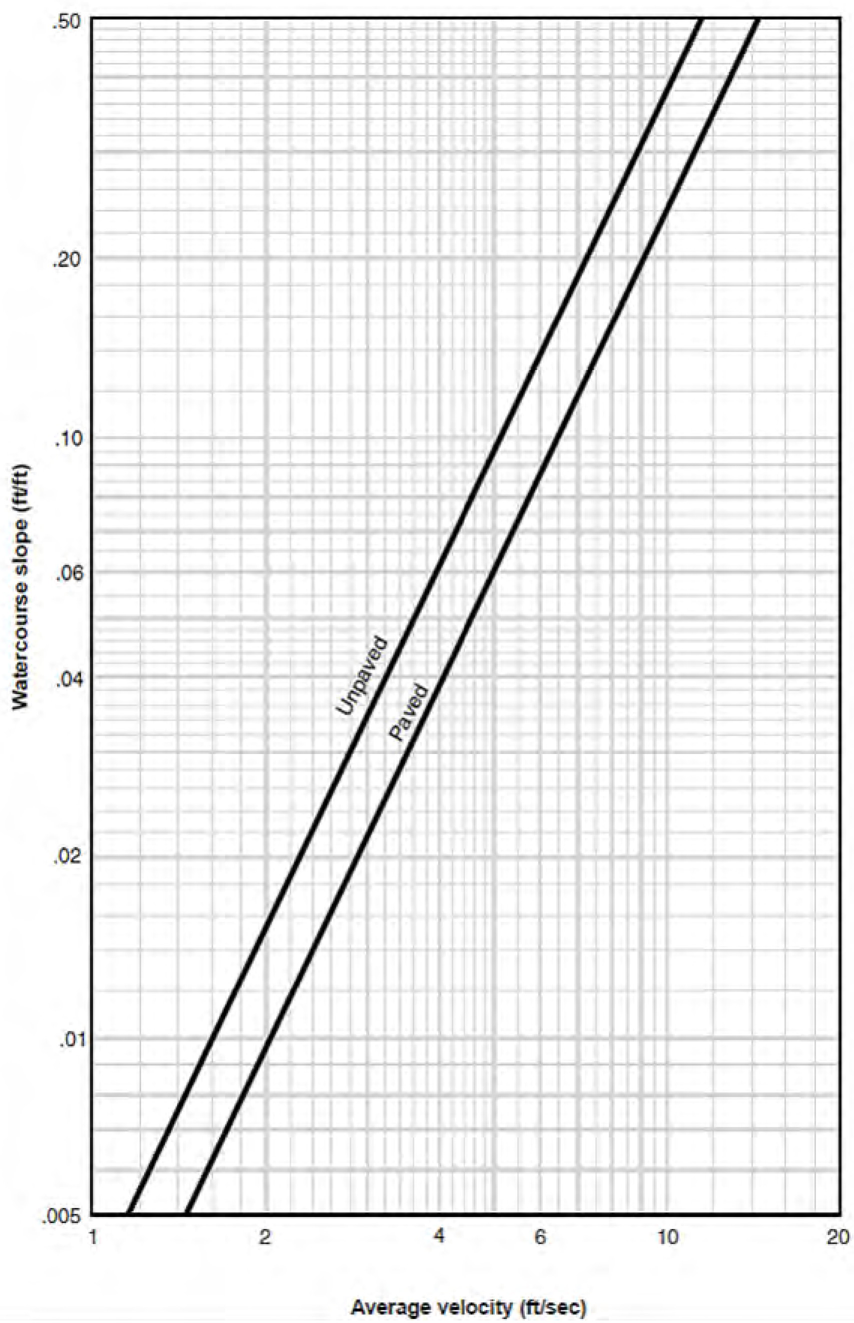


Figure 11-1 Average Velocities for Estimating Time for Shallow Concentrated Flow (TR-55 Manual Figure 3-1)

Runoff Simulations

Once all the input data related to the sub-basin characteristics, land use, and rainfall data were finalized for all sub-basins; the runoff computations were carried out in the hydrologic software program HEC-HMS program to obtain runoff volume and peak runoff hydrograph. The simulations were performed for rainfall data corresponding to return periods of 1, 2, 5, 10, 25, 50, and 100 years as described above.

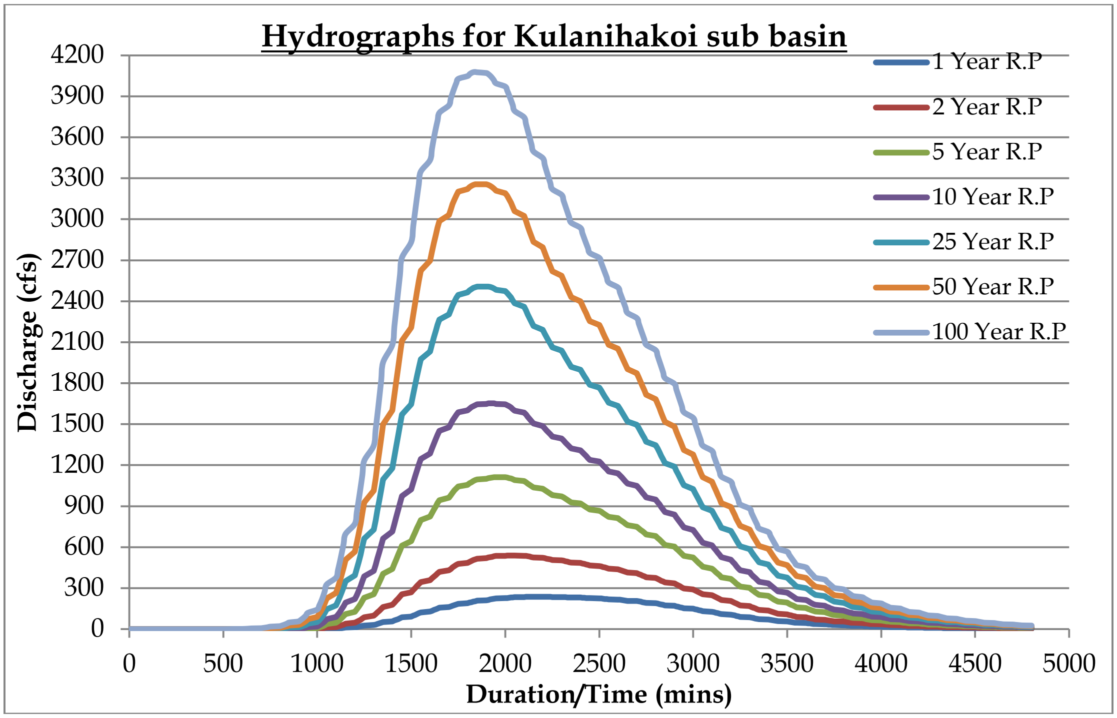
Table 11-6 Selected 24 hour rainfall depths for SCS Hypothetical storm method

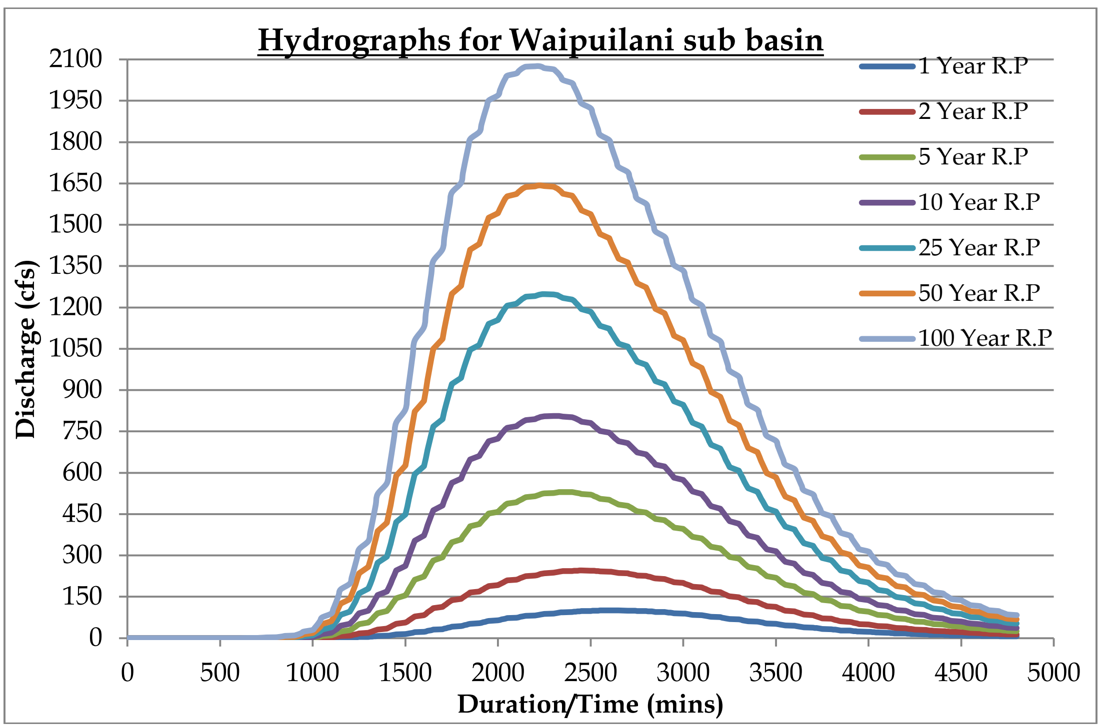
Sr. No.	Watershed	Sub Basin	Rainfall Depths-24 hour rainfall (in)						
			1 Year	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
1	Hapapa	Kulanihakoi	2.03	2.83	4.00	4.96	6.35	7.50	8.72
2		Waipuilani	2.03	2.83	4.00	4.96	6.34	7.49	8.70
3		Keokea	2.03	2.84	4.01	4.97	6.34	7.48	8.68
4	Wailea	Kamaole	2.04	2.85	4.02	4.96	6.31	7.41	8.58
5		Liilioholo	2.06	2.87	4.03	4.98	6.32	7.40	8.55
6		Kilohana	2.06	2.87	4.03	4.97	6.31	7.40	8.55
7		Paeahu	2.06	2.87	4.03	4.97	6.32	7.41	8.56
8		Palauea	2.09	2.91	4.08	5.03	6.39	7.50	8.68
9		Papaanui	2.10	2.92	4.10	5.07	6.47	7.63	8.88
10		Mohopilo	2.08	2.89	4.07	5.04	6.46	7.63	8.90
11	Mooloa	Mooloa	2.08	2.89	4.07	5.04	6.44	7.60	8.84

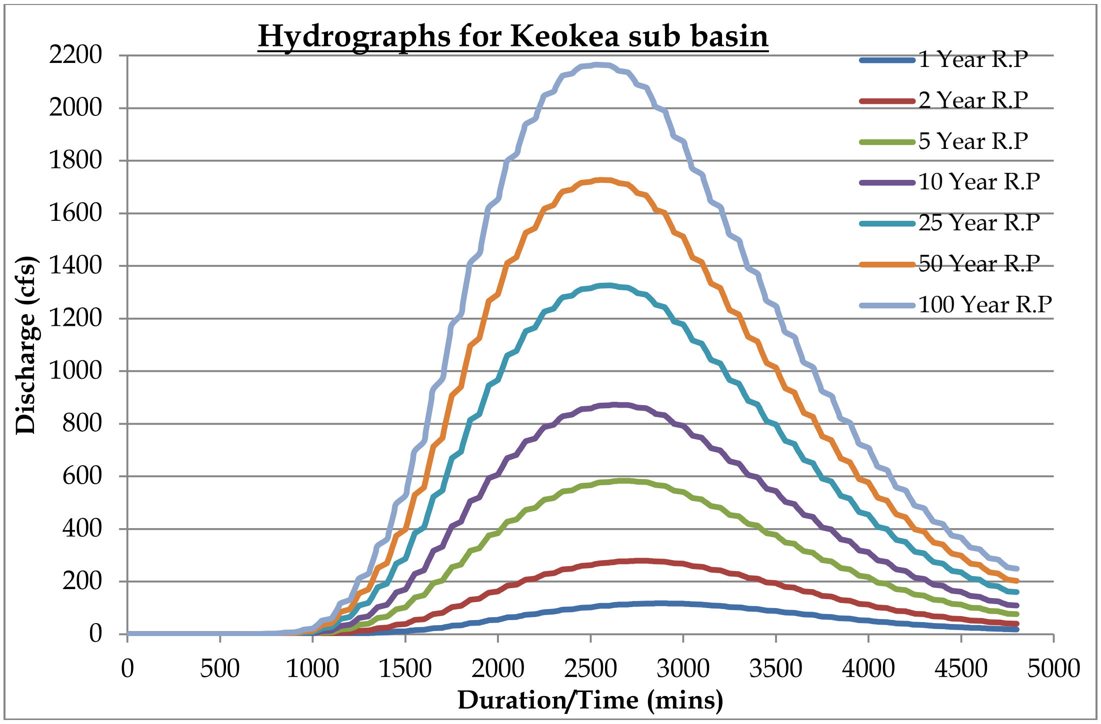
Table 11-7 Peak discharge using SCS Curve Number method (Hypothetical storm Type I)

Sr. No.	**Water-shed**	**Sub Basin**	**Peak Discharge-24 hour rainfall (cfs)**						
			1 Yr	**2 Yr**	**5 Yr**	**10 Yr**	**25 Yr**	**50 Yr**	**100 Yr**
1	**Hapapa**	Kulanihakoi	237	540	1112	1653	2508	3257	4078
2		Waipuilani	100	244	529	807	1248	1625	2076
3		Keokea	117	279	582	872	1326	1727	2165
4	**Wailea**	Kamaole	68	231	641	1061	1751	2360	3047
5		Liilioholo	43	109	242	374	584	767	972
6		Kilohana	68	170	382	589	921	1213	1536
7		Paeahu	51	133	301	466	730	960	1214
8		Palauea	82	289	727	1152	1820	2400	3037
9		Papaanui	59	152	256	563	902	1210	1559
10		Mohopilo	29	124	341	553	902	1214	1567
11	**Mooloa**	Mooloa	41	152	391	623	1002	1336	1706

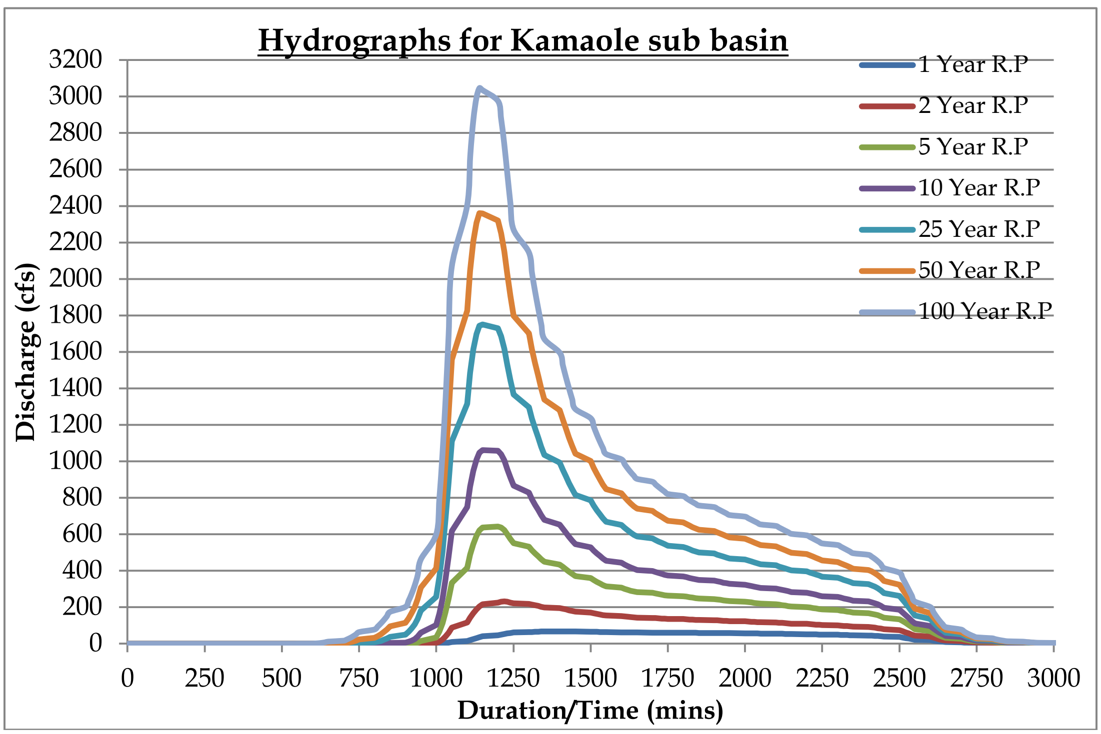
Appendix F. HYDROGRAPHS FOR SUB-BASINS BY SCS HYPOTHETICAL STORM (TYPE-1)



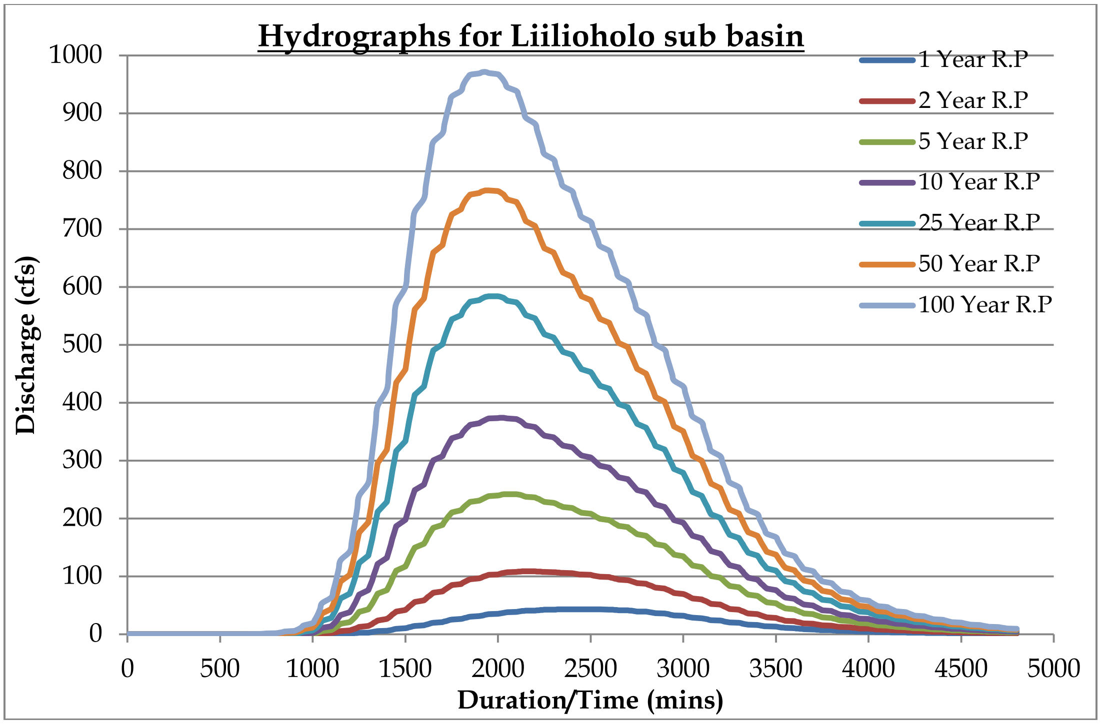


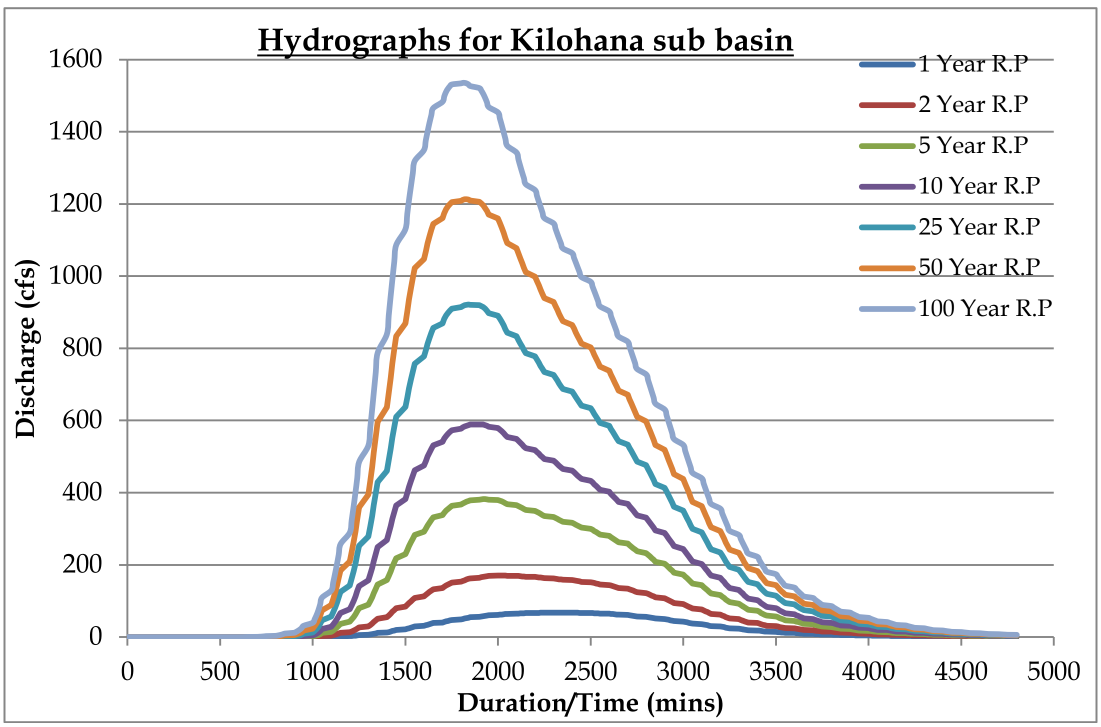


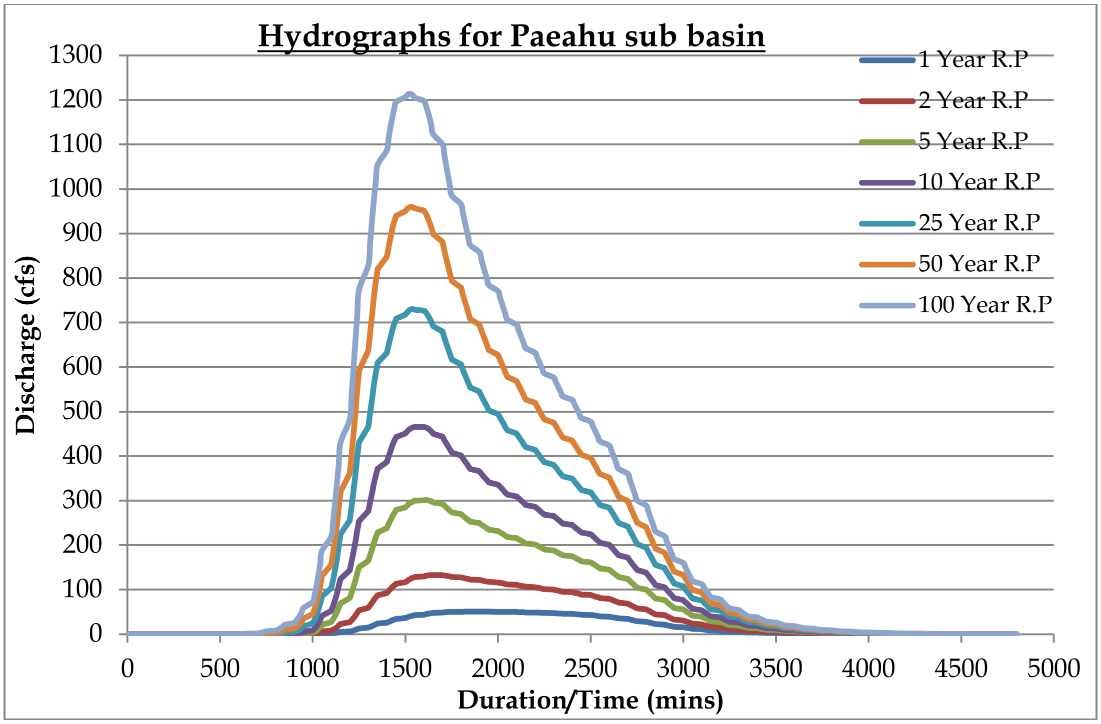
Hydrographs for Keokea sub basin
Discharge (cfs)
Duration/Time (mins)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1 Year R.P
2 Year R.P
5 Year R.P
10 Year R.P
25 Year R.P
50 Year R.P
100 Year R.P

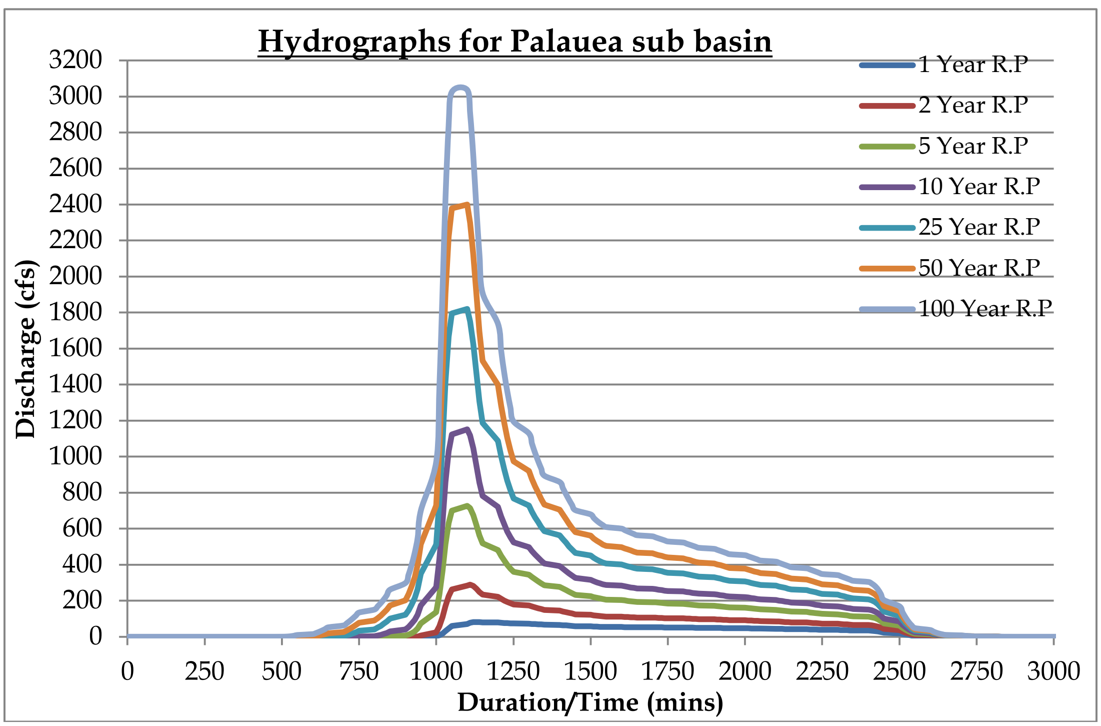


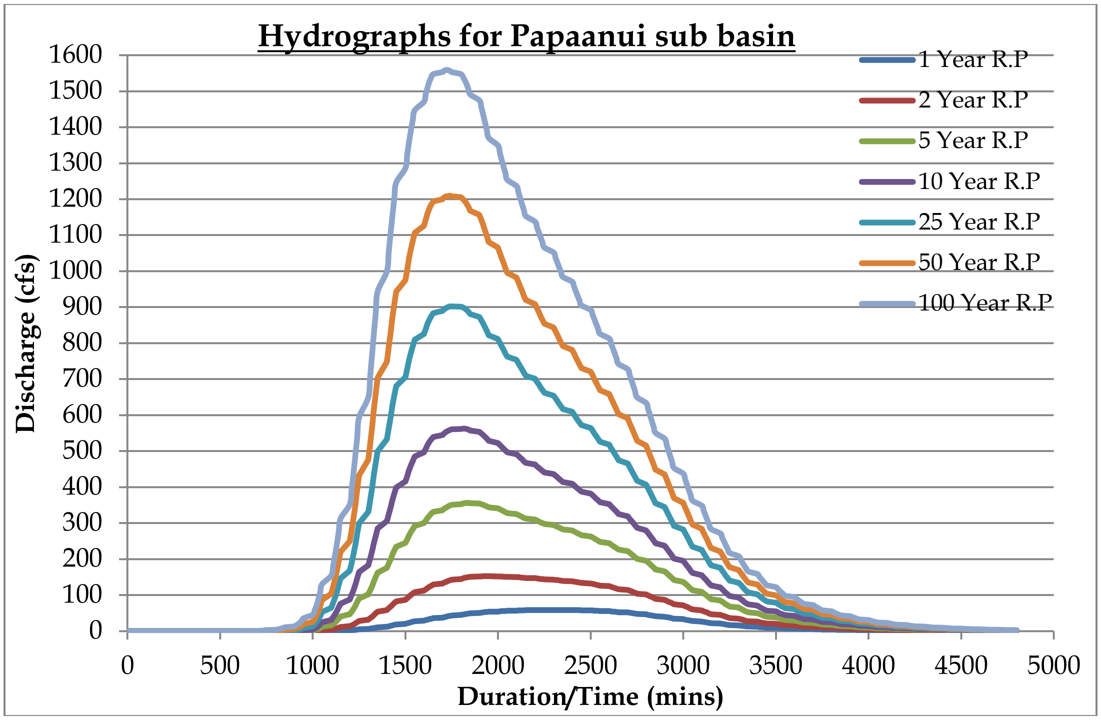
Hydrographs for Kamaole sub basin
Discharge (cfs)
Duration/Time (mins)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
1 Year R.P
2 Year R.P
5 Year R.P
10 Year R.P
25 Year R.P
50 Year R.P
100 Year R.P

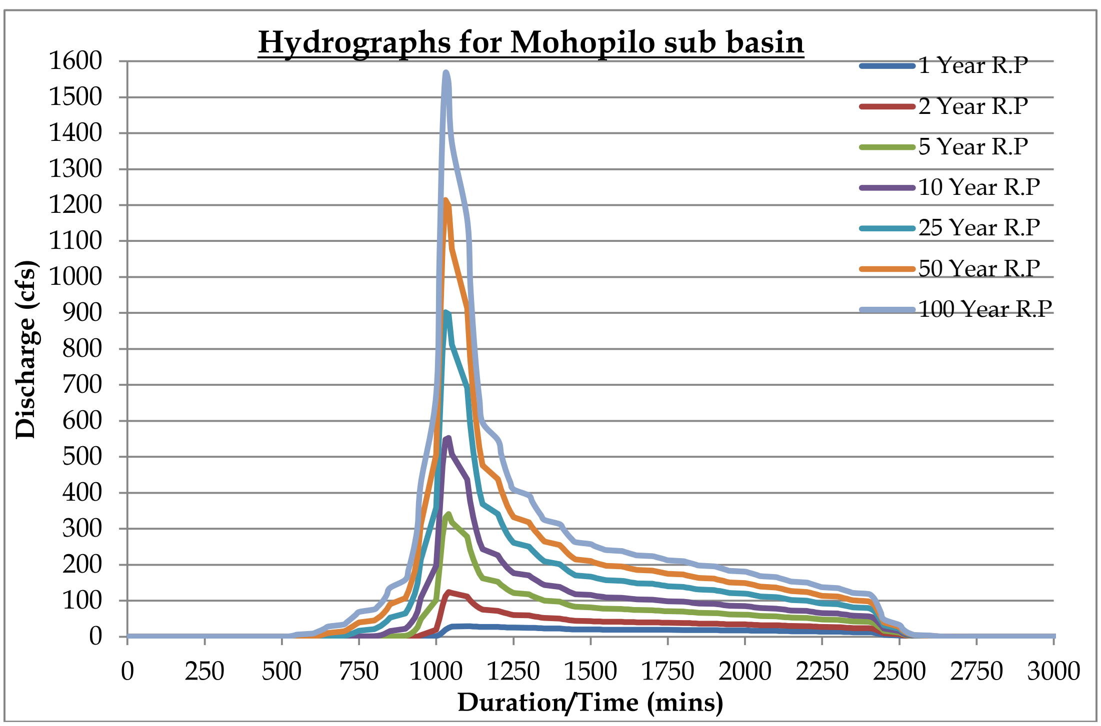

Hydrographs for Liilioholo sub basin
Discharge (cfs)
Duration/Time (mins)
0
100
200
300
400
500
600
700
800
900
1000
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1 Year R.P
2 Year R.P
5 Year R.P
10 Year R.P
25 Year R.P
50 Year R.P
100 Year R.P

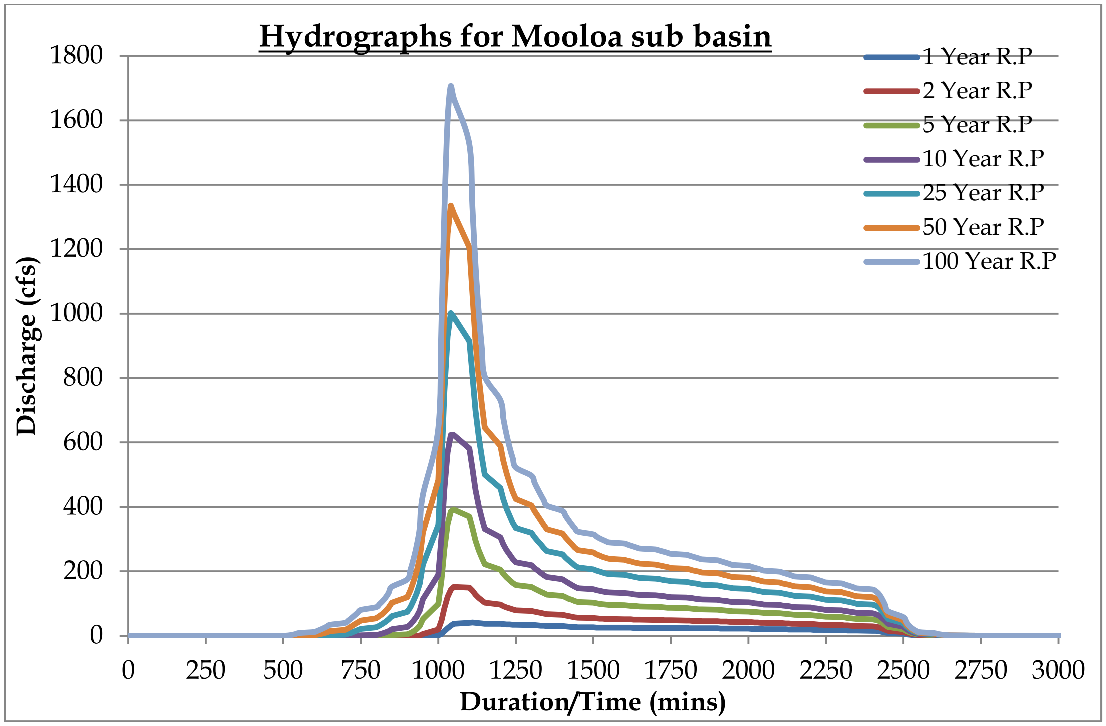

Hydrographs for Kilohana sub basin
Discharge (cfs)
Duration/Time (mins)
0
200
400
600
800
1000
1200
1400
1600
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1 Year R.P
2 Year R.P
5 Year R.P
10 Year R.P
25 Year R.P
50 Year R.P
100 Year R.P


Hydrographs for Paeahu sub basin
1 Year R.P
2 Year R.P
5 Year R.P
10 Year R.P
25 Year R.P
50 Year R.P
100 Year R.P
Discharge (cfs)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Duration/Time (mins)


Hydrographs for Palauea sub basin
1 Year R.P
2 Year R.P
5 Year R.P
10 Year R.P
25 Year R.P
50 Year R.P
100 Year R.P
Discharge (cfs)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Duration/Time (mins)

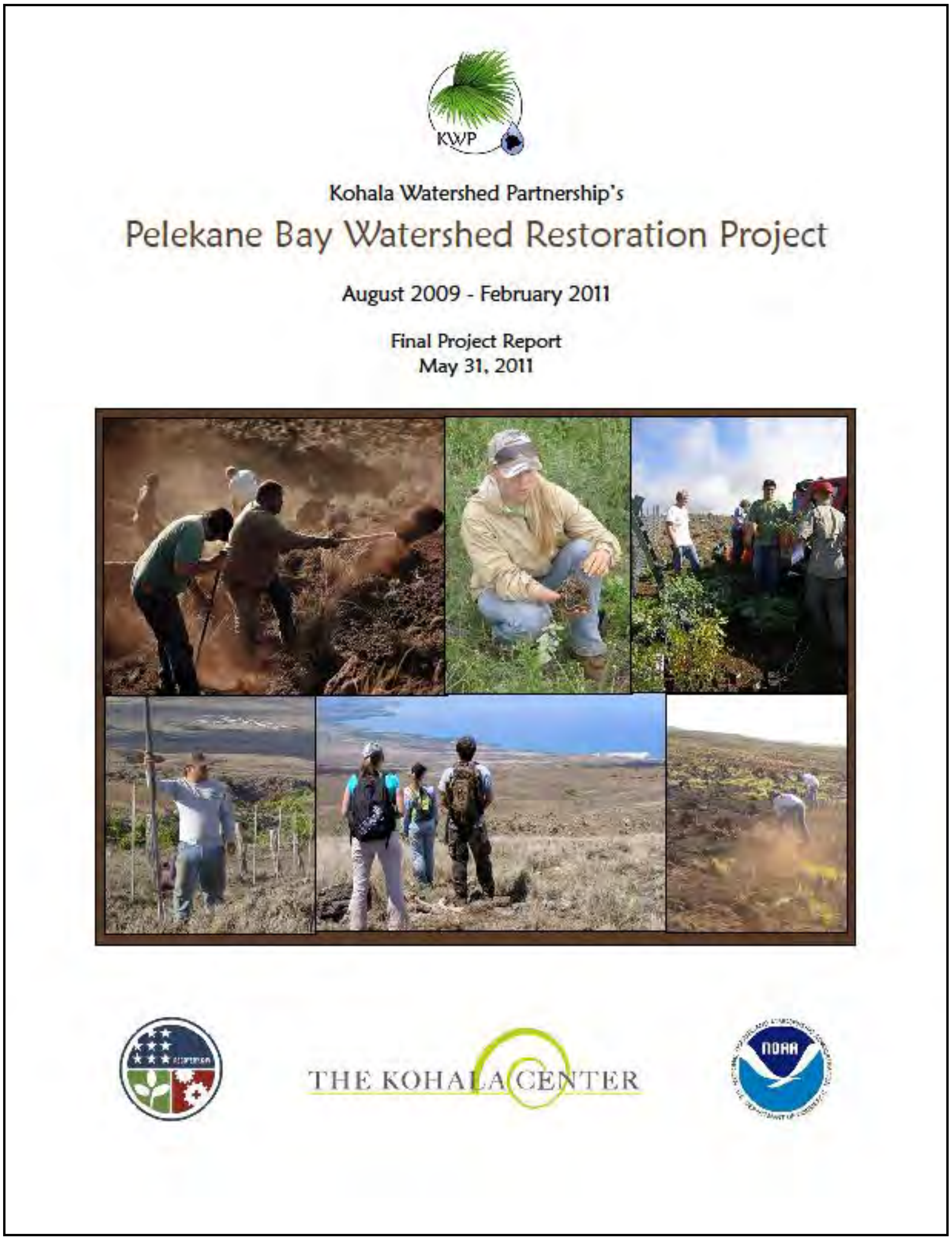

Hydrographs for Papaanui sub basin
Discharge (cfs)
Duration/Time (mins)
1 Year R.P
2 Year R.P
5 Year R.P
10 Year R.P
25 Year R.P
50 Year R.P
100 Year R.P
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


Hydrographs for Mohopilo sub basin
Discharge (cfs)
Duration/Time (mins)
1 Year R.P
2 Year R.P
5 Year R.P
10 Year R.P
25 Year R.P
50 Year R.P
100 Year R.P
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000


Hydrographs for Mooloa sub basin
Discharge (cfs)
Duration/Time (mins)
1 Year R.P
2 Year R.P
5 Year R.P
10 Year R.P
25 Year R.P
50 Year R.P
100 Year R.P
0
200
400
600
800
1000
1200
1400
1600
1800
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000

Appendix G. PELEKANE BAY WATERSHED RESTORATION PROJECT- FINAL REPORT, MAY 31, 2011.

- The Kohala Center, www.kohalacenter.org/kwp**pelekane**/about.html


KWP

Kohala Watershed Partnership's

Pelekane Bay Watershed Restoration Project

August 2009 - February 2011

Final Project Report
May 31, 2011

THE KOHALA CENTER

NOAA