Waikele Watershed Plan

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Contents

Appendices

List of Figures

List of Tables

List of Abbreviations

ACEP	Agricultural Conservation Easement Program
AMA	Agricultural Management Assistance Program
BMP	Best Management Practice
CCH	City and County of Honolulu
CSP	Conservation Stewardship Program
CTA	Conservation Technical Assistance Program
CWA	Clean Water Act
CWSRF	Clean Water State Revolving Fund
CZARA	Coastal Zone Act Reauthorization Amendments of 1990
DLNR	Hawaii Department of Land and Natural Resources
DOD	U.S. Department of Defense
DOE	Hawaii Department of Education
DOH	Hawaii Department of Health
DWSRF	Drinking Water State Revolving Fund
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FOTG	Field Office Technical Guide
FSA	USDA Farm Service Agency
GM	Geometric Mean
HAR	Hawaii Administrative Rules
HARC	Hawaii Agriculture Research Center
HAWP	Hawaii Association of Watershed Partnerships
HFRP	Healthy Forests Reserve Program
HRS	Hawaii Revised Statutes
IDDE	Illicit Discharge Detection and Elimination
KMWP	Koolau Mountains Watershed Partnership
MS4	Municipal Separate Storm Sewer System
NIFA	National Institute of Food and Agriculture

NFWF	National Fish and Wildlife Foundation
NPDES	National Pollutant Discharge Elimination System
NRCS	USDA Natural Resources Conservation Service
NWR	Oahu National Wildlife Refuge
OWOW	One World One Water
RC&D	Oahu Resource Conservation and Development Council
RCPP	Regional Conservation Partnership Program
RFP	Request for Proposal
SOAP	Sustainable and Organic Agriculture Program
SSC	Suspended Sediment Concentration
STEPL	Spreadsheet Tool for Estimating Pollutant Loads
STORET	Storage and Retrieval Data Warehouse
TMDL	Total Maximum Daily Load
TSPs	Technical Service Providers
TSS	Total Suspended Solids
UH CTAHR	University of Hawaii College of Tropical Agriculture and Human Resources
USACE	U.S. Army Corps of Engineers
USAG	U.S. Army Garrison
USGS	U.S. Geological Survey
WQC	Water Quality Criteria
WQS	Water Quality Standards
WY	Water Year

Executive Summary

The Waikele watershed is a 45-square-mile area draining to the West Loch of Pearl Harbor on the island of Oahu, Hawaii (Izuka, 2012). This drainage area is composed of five subwatersheds (see Figure ES-1), including Waikele Stream's main tributaries, Waikakalaua and Kipapa streams. The Waikele watershed is the second largest watershed on Oahu, draining the plain situated between the Koolau and Waianae mountains.

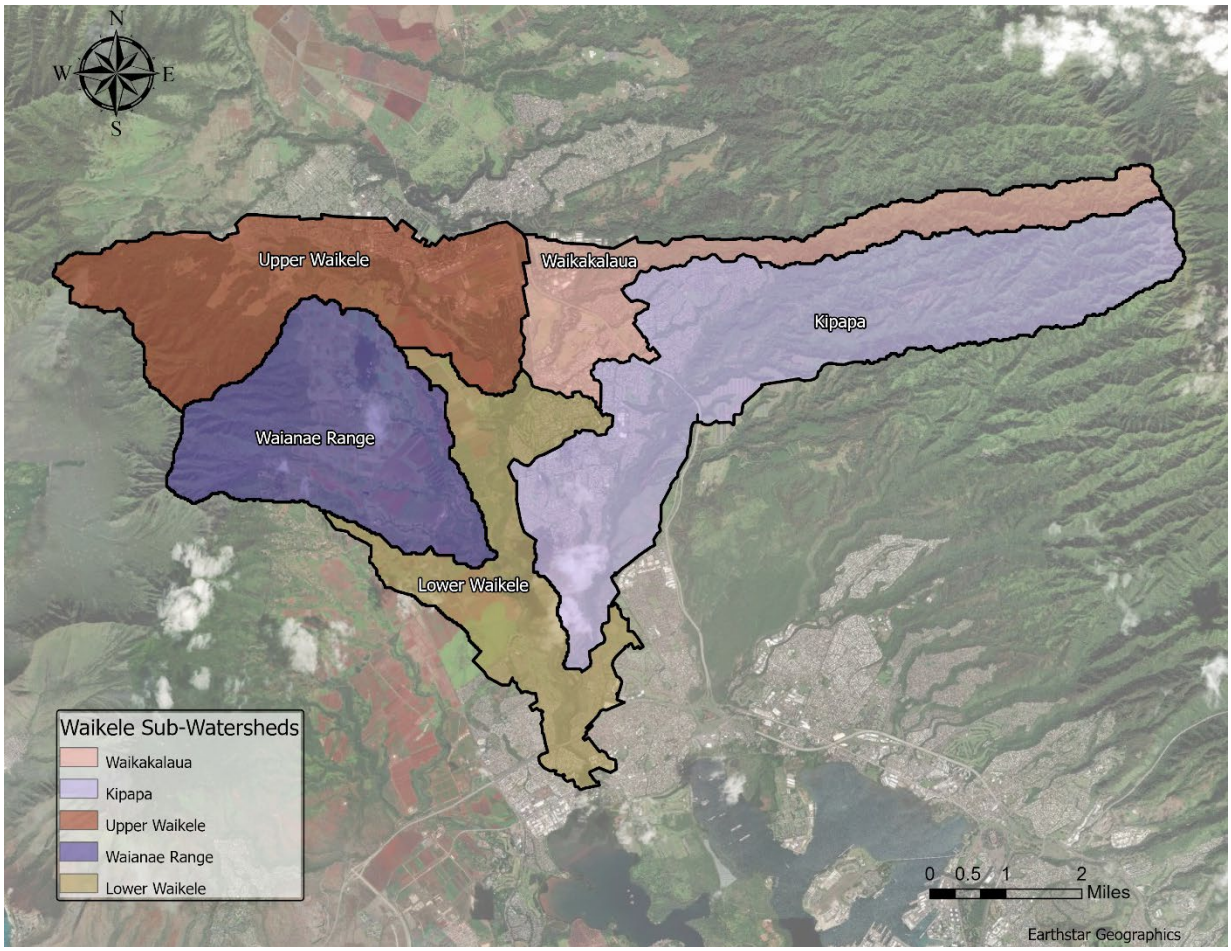


Figure ES-1. Subwatersheds in the Waikele watershed.

This area contains important agriculture, military, and conservation lands, along with growing residential communities. Improvements are needed to water quality, aesthetics, and ecological function to ensure that the waterbodies are available for use by stakeholders into the future.

Waikele Stream was included on Hawaii's section 303(d) list in 2002 due to non-attainment of water quality criteria for nutrients (total nitrogen and nitrate-nitrogen) and turbidity (Hawaii State Department of Health, 2020). A 2019 total maximum daily load (TMDL) study identified the sources of nutrients and sediment (related to the turbidity impairment) and the levels of improvement needed to meet water quality standards (WQS) in the Waikele watershed (EPA and DOH, 2019). The TMDL focused on reducing

the loading of total nitrogen and sediment from different watershed sources through wasteload allocations for point sources and load allocations for nonpoint sources.

This watershed plan presents a strategy to achieve the Waikele TMDL nonpoint source load allocations by reducing sediment and total nitrogen loads to attain WQS and concurrently reducing total phosphorus and nitrate-nitrite levels. Developing the TMDL, finalizing the Waikele Watershed Plan, and procuring funding for implementation are near-term objectives of Hawaii's Nonpoint Source Management Plan: 2021-2025. Consistent with the Hawaii Watershed Guidance, this plan incorporates EPA's nine minimum elements of a watershed-based plan. Once approved by EPA, implementation projects identified in this plan would be eligible to receive funding under Clean Water Act Section 319.

As illustrated in Figure 14 and Figure 15 in the report, the highest load reductions are needed in the upper portions of the watershed. These areas, particularly the subwatersheds of Kipapa and Waianae Range, represent the highest priority locations for implementation of this watershed plan. The greatest pollutant reductions can be achieved by focusing implementation activities in these areas. Many of these lands are in agricultural and conservation areas, but due to the steep slopes and high annual precipitation, these areas can be significant sources of pollutants.

This watershed plan describes the watershed (Section 3), discusses the water quality (Section 4), identifies the pollutant sources (Section 5) and pollutant load reductions needed (Section 6), describes the best management practices (BMPs) available (Section 7) and the number and type of BMPs needed to meet WQS (Section 8), and discusses the ways to evaluate successful implementation (Section 9).

The specific BMPs and projects described in this plan provide a reference point for the extent of nonpoint source management needed to meet the TMDL load allocations and achieve WQS. Extensive implementation across all land uses throughout the watershed is necessary to achieve the needed sediment and nutrient load reductions. As such, outreach and monitoring are important components of the watershed plan. By continuing the stakeholder outreach conducted in the development of this plan (Section 2), Hawaii Department of Health can raise and maintain awareness of the need for load-reducing practices and help identify opportunities for collaboration and creative funding solutions to facilitate implementation. In addition, monitoring both practice implementation and water quality trends will be essential to demonstrating progress and supporting adaptive management. The water quality data used to develop the TMDL load allocations date to 2013 or earlier. Initial stakeholder outreach suggests that many practices have been implemented in the watershed since that time; implementation monitoring and tracking should quantify and account for those existing practices to better define the remaining effort needed. Water quality monitoring at strategic locations throughout the watershed, under both wet and dry weather regimes, is needed to evaluate progress and articulate the current status of water quality to stakeholders and the general public.

1 Waikele Watershed Plan Overview

The Waikele watershed drains to the West Loch of Pearl Harbor on the island of Oahu, Hawaii. This area contains important agriculture, military, and conservation lands, along with growing residential communities. Improvements are needed to water quality, aesthetics, and ecological function to ensure the waterbodies are available for use by stakeholders into the future.

Streams in the watershed have a range of beneficial uses. The headwater streams are designated for protection of their natural state, including protection of native breeding stock. Downstream waters are protected for recreational uses, support of aquatic life, and agricultural uses, among others. Beginning in 2002, the entire stream network of the Waikele watershed was identified as impaired and not achieving these beneficial uses. Total nitrogen, nitrate-nitrite, and turbidity levels were degrading water quality in the watershed. Nutrient-related issues were documented year-round, while turbidity was found to be a wet season concern.

Waikele Stream has been included on Hawaii's section 303(d) list due to non-attainment of nutrient and turbidity water quality criteria (WQC) since 2002 (Hawaii State Department of Health, 2020). The waterbody is specifically listed for turbidity, total nitrogen, and nitrite-nitrate impairments. A total maximum daily load (TMDL) study was completed in 2019 by the Hawaii Department of Health (DOH) and the U.S. Environmental Protection Agency (EPA) to identify the sources of nutrients and sediment (related to the turbidity impairment) and the levels of improvement needed to meet water quality standards (WQS) and restore and maintain the beneficial uses of the Waikele watershed (EPA and DOH, 2019). The TMDL focuses on reducing the loading of total nitrogen and sediment from different watershed sources through wasteload allocations for point sources and load allocations for nonpoint sources. Hawaii's Nonpoint Source Management Plan: 2021-2025 also highlights the development of the TMDL and this watershed plan; finalizing this plan and procuring funding for implementation is a near-term objective of the management plan.

1.1 Goals and Management Objectives

The purpose of this plan is to present a strategy to achieve the Waikele TMDL load allocations (EPA and DOH, 2019). This strategy will reduce sediment and total nitrogen loads to attain WQS and concurrently reduce total phosphorus and nitrate-nitrite levels.

"TMDL compliance will be based on the GM [geometric mean] criteria for TN [total nitrogen], and the 10 percent wet season criteria for TSS [total suspended solids]."
- EPA and DOH (2019)

Goals and associated management objectives and indicators are identified in Table 1 to control the nonpoint sources of total nitrogen and sediment in the watershed. Management objectives identify the source or action needed to meet the goals, while the indicators identify the metric(s) to be measured and tracked. The strategy presented in this plan focuses on achieving one or more of the goals below.

Table 1. Goals, Management Objectives, and Indicators of Waikele Watershed Plan.

Goal	Management Objective	Indicator(s)
Achieve WQS in the Waikele watershed stream network	Reduce total nitrogen and sediment contributions from nonpoint sources	• Total nitrogen and TSS measurements
Reduce flood levels during large storms	Reduce runoff flow from upland areas and downstream of impervious surfaces	• Peak flow rates • Impervious cover
Decrease pollutant loads discharged from Waikele Stream	Implement management or conservation measures, especially in high priority areas	• Total nitrogen, TSS, and flow measurements • Number of management measures implemented
Improve streambank stability	Restore degraded streambanks and control stream access	• Fencing installation • Area revegetated • Streambank characteristics
Support implementation of management measures by watershed stakeholders	Increase access to information on resources to support management measure implementation and conservation practices (technical and financial)	• Grant applications • Website statistics • Requests for information
Increase public awareness of water quality issues and pollutant reduction strategies	Increase coordinated outreach activities and develop watershed-specific materials	• Participation in community events • Questionnaire results

1.2 Watershed Plan Components

This plan addresses the first four of EPA's six watershed planning steps: (1) Build partnerships; (2) Characterize your watershed; (3) Finalize goals and identify solutions; (4) Design an implementation program; (5) Implement watershed plan; (6) Measure progress and make adjustments. Consistent with the Hawaii Watershed Guidance, these four steps incorporate EPA's nine minimum elements. Table 2 identifies where each of EPA's nine minimum elements of a watershed plan are addressed in this plan.

Table 2. Crosswalk of Plan sections with EPA's 9 Elements of a Watershed Plan.

EPA's 9 Elements of a Watershed Plan*	Plan Section(s)
a. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions and any other goals identified in the watershed plan.	✓ Section 5 (Pollutant Sources and Existing Loads)
b. An estimate of the load reductions expected from management measures.	✓ Section 7 (Pollutant Control Practices) ✓ Section 8.1 (Priority Projects)
c. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions and a description of the critical areas where those measures will be needed to implement this plan.	✓ Section 7 (Pollutant Control Practices) ✓ Section 7.1 (Prioritization for Implementation Activity) ✓ Section 8.1 (Priority Projects)
d. Estimate of the amounts of technical and financial assistance needed, associated costs, and the sources and authorities that will be relied on to implement this plan.	✓ Section 8.5 (Technical and Financial Resources)
e. An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.	✓ Section 2 (Stakeholder Participation) ✓ Section 8.2 (Education and Outreach)
f. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.	✓ Section 8.4 (Schedule for Implementation)
g. A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.	✓ Section 9.1 (Milestones and Criteria for Success)
h. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining WQS.	✓ Section 6.1 (Water Quality Standards) ✓ Section 9.1 (Milestones and Criteria for Success)
i. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.	✓ Section 9.2 (Monitoring Program)

*EPA (2008).

2 Stakeholder Participation

Stakeholder engagement is critical to the development and successful implementation of the Waikele Watershed Plan and targeted engagement was implemented throughout plan development. Collaboration and communication with local constituents throughout plan development will help ensure that there is local buy-in. Without stakeholder participation, proposed activities typically do not get much support and are less likely to be implemented.

Starting from the headwaters and working down, critical nonpoint source stakeholders were identified by DOH, One World One Water (OWOW), and Oahu Resource Conservation and Development Council (RC&D), among others, in conservation, agriculture, and urban areas, with a focus on landowners where structural measures may be implemented. DOH engaged key stakeholders who were involved in the development of the TMDL, and made efforts to reach out to others, such as agricultural stakeholders, who were not engaged in TMDL development. Targeted outreach to these stakeholders was conducted to reach the nonpoint source stakeholders who are connected to watershed sources of nutrients and sediments, are interested in the watershed, and/or will implement management measures to support achievement of the water quality goals.[1]

Key stakeholders in the watershed were broken down into two categories: public and agricultural. The public category included the City and County of Honolulu (CCH), the U.S. Department of Defense (DOD), the Hawaii Department of Land and Natural Resources (DLNR) and Hawaii Association of Watershed Partnerships (HAWP). These stakeholders have professional staff focused on water quality and are generally aware of the water quality improvements needed in the watershed. These stakeholders are also either subject to permit requirements for water quality or are interested in pursuing additional conservation practices in the watershed.

Agricultural stakeholders, on the other hand, typically do not have dedicated staff focused on water quality. However, there are several champions of best practices and agricultural research in the watershed that are familiar with the water quality challenges and TMDL goals. Those stakeholders (including Oahu RC&D and the Hawaii Agriculture Research Center [HARC]) were instrumental in making connections to the broader agricultural community in the watershed and providing on-the-ground feedback for this plan.

One-on-one meetings were held with these key stakeholders to discuss load reduction maps and data, implementation measures, and future partnerships in the watershed. A cornerstone to plan development was engaging stakeholders through existing relationships, where possible, to strengthen partnerships and build trust. Stakeholder meetings facilitated knowledge and opinion sharing and provided a forum for the plan development team to discuss benefits of load reductions on water quality. This process of securing local support increases the likelihood of attaining TMDL allocations. In addition to individual meetings, stakeholders shared resources, such as plans and other documents, and relevant components were incorporated into this implementation plan. Stakeholder engagement conducted during plan development is summarized in Table 3.

[1] DOH initially planned to hold public meetings, establish work groups, and conduct other traditional engagement methods; however, the COVID-19 pandemic prevented public gatherings during the time frame planned for these meetings. To avoid delays in completing the implementation plan, DOH instead focused on one-on-one meetings with stakeholders.

Table 3. Stakeholder Participation.

Planned Activities	Stakeholders involved/details	Date(s) of engagement
One-on-one engagement	Public • Military • CCH • DLNR • HAWP	CCH: 9/13/21 DLNR & HAWP: 9/14/21 Military: 11/9/21, 5/4/22
	Agriculture • University of Hawaii College of Tropical Agricultural and Human Resources (UH CTAHR) • USDA Natural Resources Conservation Service (NRCS) • Oahu RC&D • HARC • Hawaii Agricultural Foundation • Waikele Farms • Fat Law Farm • Kunia Loa Ridge Farmland • Kunia Water Association (R1) • Seed corn Golf courses • Hawaii County Club • Mililani Golf Club • Royal Kunia County Club • Waikele Country Club • Leilehua Golf Course	Oahu RC&D: Multiple HARC: 2/9/22, 4/20/22 Pacific Gateway Center: 4/20/22 West Oahu Soil and Water Conservation District: 4/20/22
Presentations	• Public Webinar: Draft Waikele Watershed Plan, Stakeholder Review Draft	4/4/2022

Outreach efforts in addition to one-on-one stakeholder meetings included:

- Secondary contacts by key stakeholders (such as Oahu RC&D) to individual landowners and other stakeholders that may have normally participated in a traditional public meeting.
- A summary of the watershed plan was included in Oahu RC&D's December newsletter, which is sent to hundreds of recipients. Feedback was requested, but no comments were received.
- A public webinar was held on April 4, 2022, to provide a summary of the plan. Notice of the webinar was distributed through key stakeholders and was posted on DOH's website.

3 Watershed Description

The Waikele watershed is a 45-square-mile area draining to the West Loch of Pearl Harbor on the island of Oahu (Izuka, 2012). This drainage area includes Waikele Stream and its main tributaries, Waikakalaua and Kipapa streams. The Waikele watershed is the second largest watershed on the island of Oahu, draining the plain situated between the Koolau and Waianae mountains. The confluence of Waikele Stream and its tributaries occurs on the Schofield Plateau, where Waikele Stream flows southward into Pearl Harbor. From the northeast, Waikakalaua Stream originates in the Koolau Mountains, joining Waikele Stream toward the lower end of Wheeler Army Airfield. Located south of Waikakalaua Stream, Kipapa Stream also finds its source atop the Koolau Mountains. The two streams run parallel until Waikakalaua Stream flows to its confluence with Waikele Stream (Dashiell, 2007) (Figure 1).

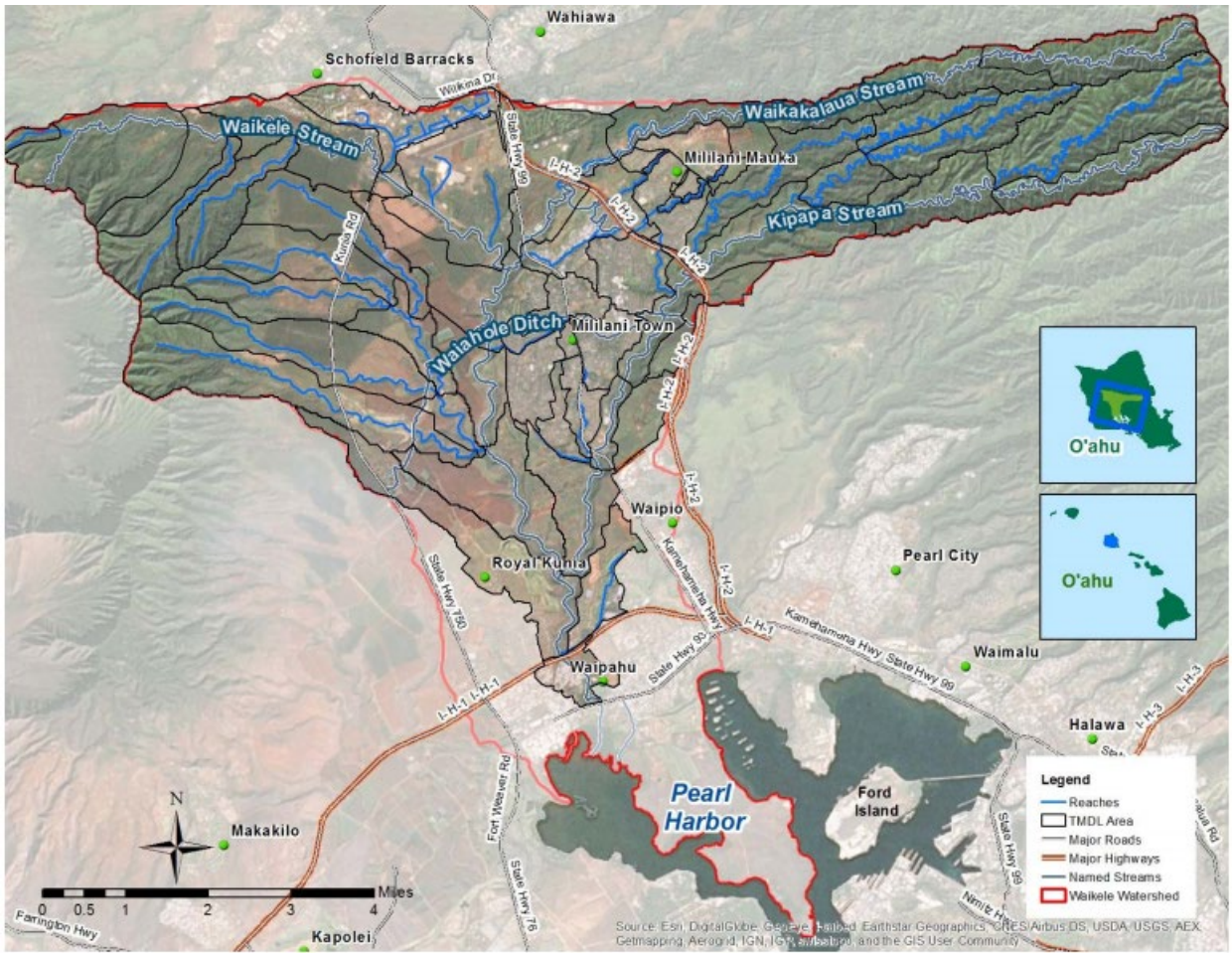


Figure 1. Location of the Waikele watershed.

Source: Figure 1, *Turbidity, Sediment, and Nutrient Total Maximum Daily Loads for the Waikele Watershed*

3.1 Climate and Precipitation

Oahu's climate is characterized by mild temperatures and moderate humidity. Mean monthly rainfall is the greatest in the rainy season (particularly January) and lowest in the dry season (particularly June and July) (Izuka, 2012). Figure 2 is an excerpt from the 2019 TMDL Report (EPA and DOH, 2019) and depicts the precipitation zones that were developed to account for spatial variability of rainfall within the watershed. The rainfall patterns align with the elevation contours of the watershed, with the greatest rainfall occurring in the higher elevations. The Koolau Mountains receive the highest rainfall on the island and form the headwaters of the Waikakalaua and Kipapa streams. The eastern edge of the Waikakalaua subwatershed receives the highest average annual precipitation, at over 200 inches of precipitation per year, and the Kipapa subwatershed receives between 100 and 200 inches of precipitation annually. To the west, the Upper Waikele and Waianae Range subwatersheds receive approximately 50 inches of rainfall per year while the lower portion receives the least precipitation in the watershed (approximately 32 inches annually).

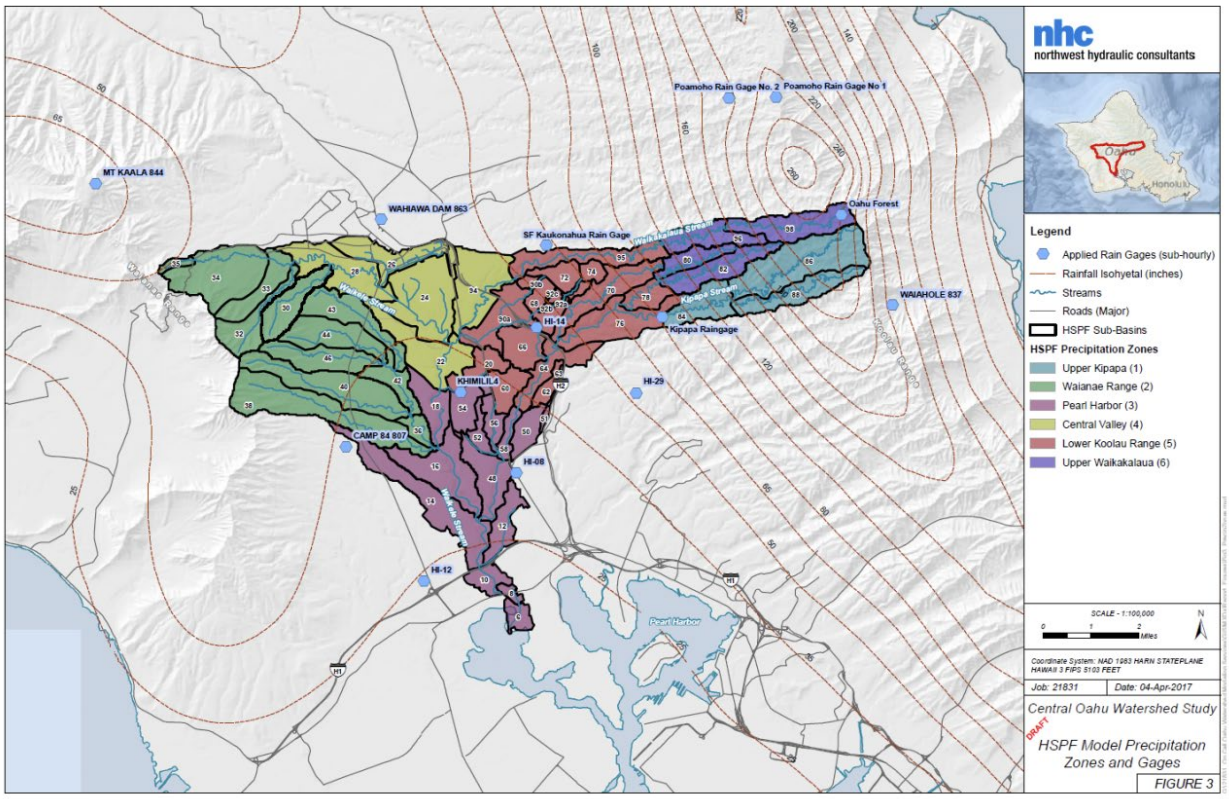


Figure 2. Precipitation zones within the Waikele watershed.

Source: Figure 8, *Turbidity, Sediment, and Nutrient Total Maximum Daily Loads for the Waikele Watershed*

3.2 Topography and Hydrology

Elevation in the Waikele watershed ranges from 0 feet at the mouth of the stream to over 3,000 feet at the headwaters (Figure 3). The central-leeward side of the Koolau Mountains are dissected by narrow valleys while the windward and southeast-leeward areas have wide, alluviated, and flat valleys (Izuka,

2012). The Waianae Mountain valleys are wider and more alluviated than in the leeward-central Koolau Mountains (Izuka, 2012). Many of the higher elevation areas have steep slopes and receive the greatest volume of rainfall, creating the potential for erosion and contributing to downstream turbidity.

As with many streams on Oahu, water systems within the Waikele watershed are flashy for both perennial and ephemeral reaches due to small drainage areas and steep gradients. The upper reaches of the watershed experience perennial flows due to high rainfall. The lower reaches of the streams have a baseline flow as a result of discharges from springs near Pearl Harbor (Izuka, 2012).

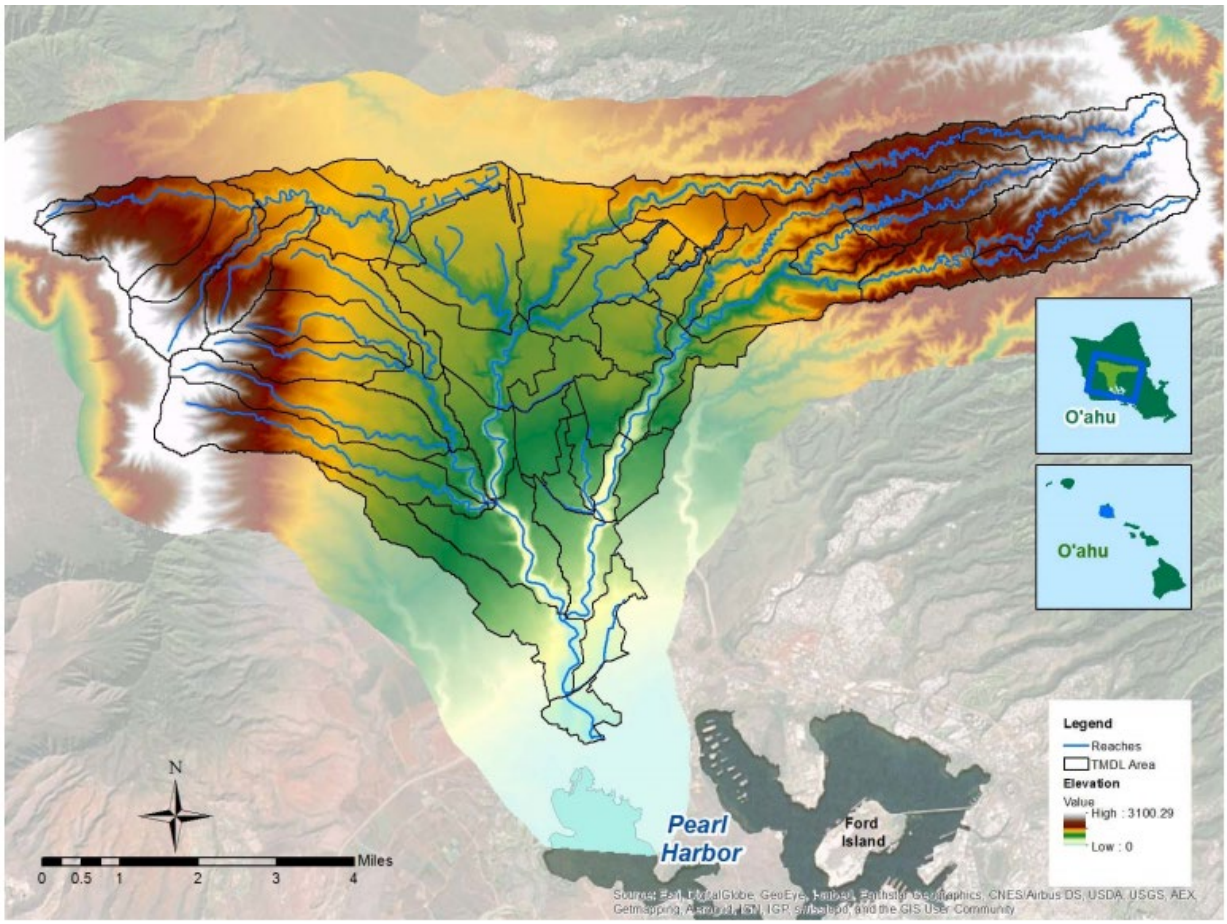


Figure 3. Topography of the Waikele watershed.

Source: Figure 2, *Turbidity, Sediment, and Nutrient Total Maximum Daily Loads for the Waikele Watershed*

Figure 3 depicts the topography of the watershed, showing the greatest elevations in the mountain ranges and elevation decreasing towards the center and lower watershed. For the TMDL, the Waikele watershed was divided into five subwatersheds, largely based on topography and hydrologic features (Table 4 and Figure 4 below). These subwatersheds are used throughout the rest of the implementation plan to focus management measures by geographic area.

Table 4. Waikele Watershed Subwatersheds.

Corresponding TMDL Subgroup	Location in the Watershed	Subwatershed Name	Area (acres)
1	Northeast	Waikakalaua	3,685.5
2	South of Waikakalaua	Kipapa	9,991.3
3	Northwest	Upper Waikele	5,792.8
4	Western	Waianae Range	5,406.4
5	Central and southern	Lower Waikele	4,596.4

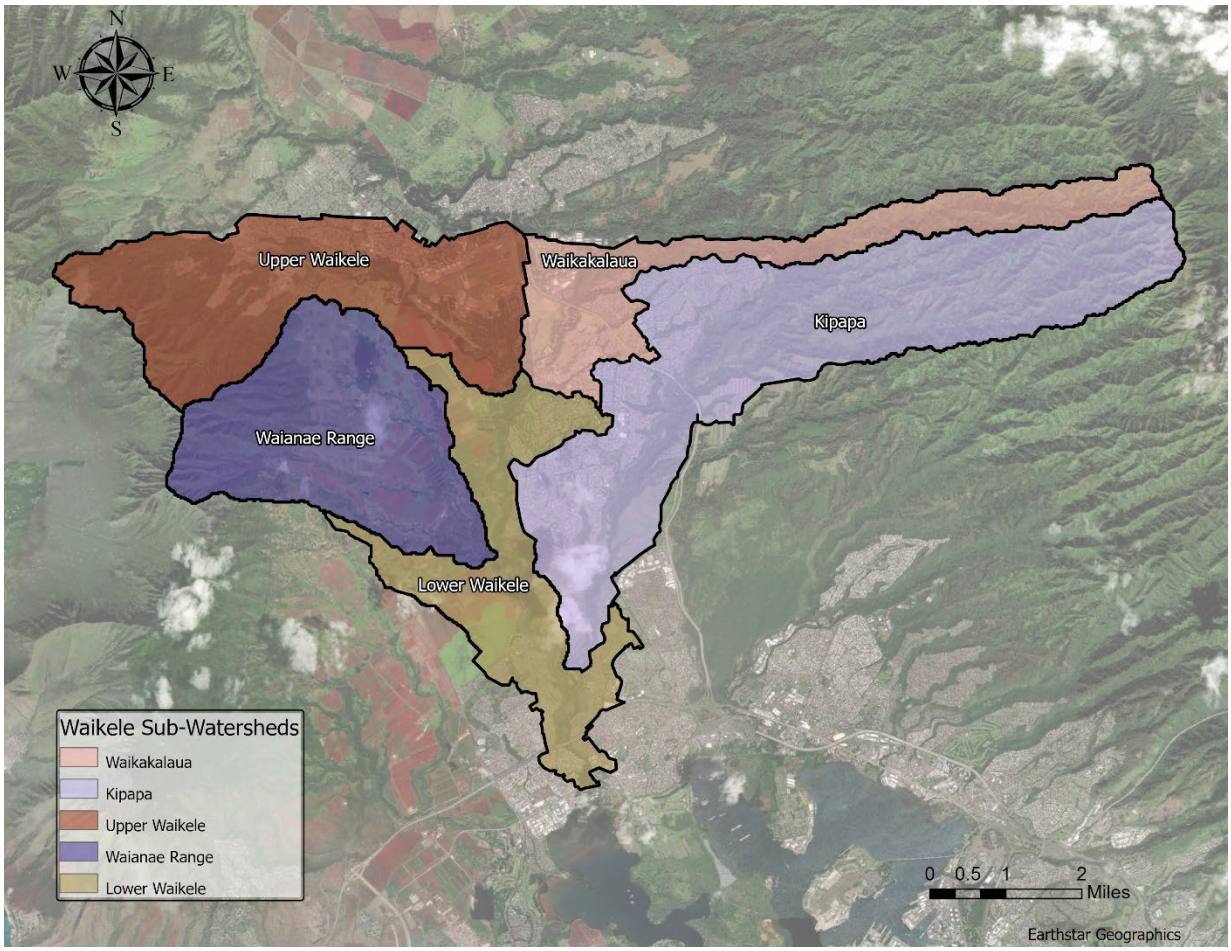


Figure 4. Subwatershed boundaries in the Waikele watershed.

The headwaters of Waikakalaua Stream in the northeast drain the Koolau Range and have perennial stream flow (Northwest Hydraulic Consultants, 2017). The upper subwatershed is largely comprised of conservation land and is characterized by narrow floodplains, coarse bed material, and steep banks. Waikakalaua Stream joins the upper Waikele Stream near the Wheeler Airforce Base (elevation 540 feet).

The headwaters of the Kipapa subwatershed (including both north and south forks of the stream) are directly south of the Waikakalaua subwatershed. The north and south forks are similar to the

Waikakalaua Stream (narrow floodplains, coarse bed material, and steep banks), but are smaller than the stream channels of Waikakalaua Stream.

The elevations of the Upper Waikele and Waianae Range subwatersheds are greatest in the mountain ranges along the western areas of the subwatersheds and decrease toward the east. The headwaters of the upper Waikele subwatershed are located within the Waianae Range (with a maximum elevation at 2,900 feet) (NHC, 2017). The upper forested areas are deeply dissected with patches of exposed bedrock. The lower area of this subwatershed is adjacent to the Schofield Barracks and Wheeler Airfield. The lower 5,000 feet of the stream (near Wheeler Airfield) are characterized by steep banks and portions of the stream have been straightened. Downstream of the steep headwaters, the Waianae Range subwatershed flattens out to an area dominated by agricultural uses.

The elevation of the Lower Waikele subwatershed decreases moving south through the lower reaches of the subwatershed. The Waikele Stream has a broad gulch that is incised up to 300 feet with a width of approximately 1,500 feet. Waikele has a wide streambed throughout most of the subwatershed and banks are vegetated with grass and trees. Springs near Pearl Harbor discharge into the stream, providing consistent baseflow.

3.3 Soils

Soils in the watershed largely consist of Waianae Mountain soils in the western headwaters and Koolau Mountain soils in the eastern headwaters with silty-clay soils in the valleys (Figure 5). The soils originate from volcanic sources, as Oahu was built on two volcanoes, the remnants of which comprise the Koolau and Waianae Mountains. Mountain formations in Hawaii largely consist of finely crystalline mafic minerals that weather to clays and oxides (Izuka, 2012). The Koolau and Waianae Mountains are connected by a high saddle, referred to as the Schofield Plateau (Izuka, 2012). Waikele Stream and tributaries have carved gulches (with a maximum depth of a few hundred feet) into the Schofield Plateau (Izuka, 2012). The Waikele TMDL (EPA and DOH, 2019) has additional discussion about the soils in the watershed, predominantly in Appendix A of the TMDL.

3.4 Land Ownership and Responsibility

Consistent with the TMDL, there are six categories of land ownership and responsibility in the watershed. Some “owners” are characterized by the broad use of the land, including agriculture and conservation, where many different entities actually own or are responsible for the land. The remaining areas in the watershed fall under the responsibility of CCH, the military, the state of Hawaii, and the Hawaii Department of Education (DOE). Distribution of owners by subwatershed is shown in Table 5 and Figure 6. These owners are responsible for implementing the wasteload and load allocations in the TMDL to address reductions in point and nonpoint sources loads, respectively.

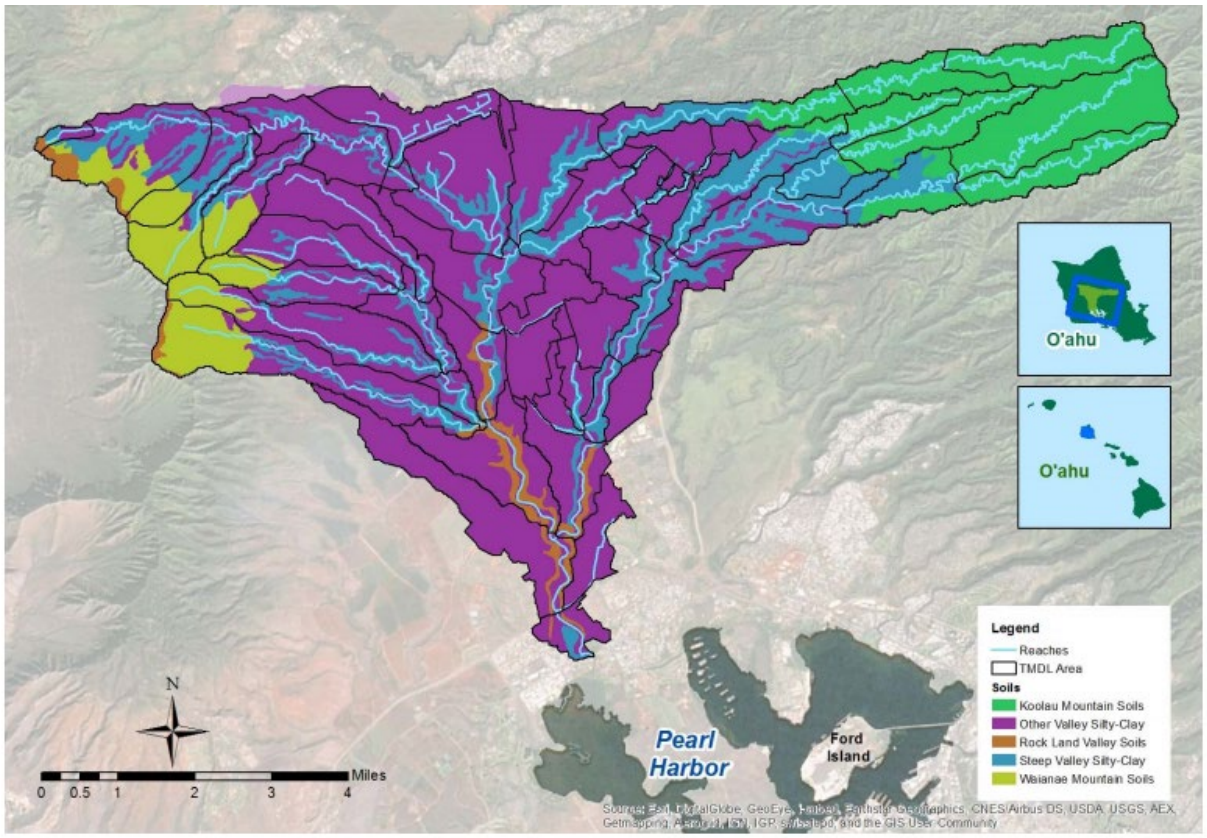


Figure 5. Soil types within the Waikele watershed.

Source: Figure 3, *Turbidity, Sediment, and Nutrient Total Maximum Daily Loads for the Waikele Watershed*

Table 5. Ownership by subwatershed.

Subwatershed	Area (acres) by Owner						Total
	City and County of Honolulu	Military	State of Hawaii	Department of Education	Agriculture	Conser-vation	
Waikakalaua	824.8	285.8	145.1	4.1	753.0	1,672.8	**3,685.5**
Kipapa	2,477.9	328.3	122.3	55.0	3,203.3	3,804.5	**9,991.3**
Upper Waikele	3.3	2,406.9	425.1	17.9	1,349.5	1,590.1	**5,792.8**
Waianae Range	147.5		44.1		3,988.9	1,225.8	**5,406.4**
Lower Waikele	1,406.1	670.9	387.7	46.4	2,085.3		**4,596.4**
Total	**4,859.6**	**3,691.9**	**1,124.3**	**123.4**	**11,380.0**	**8,293.2**	**29,472.4**

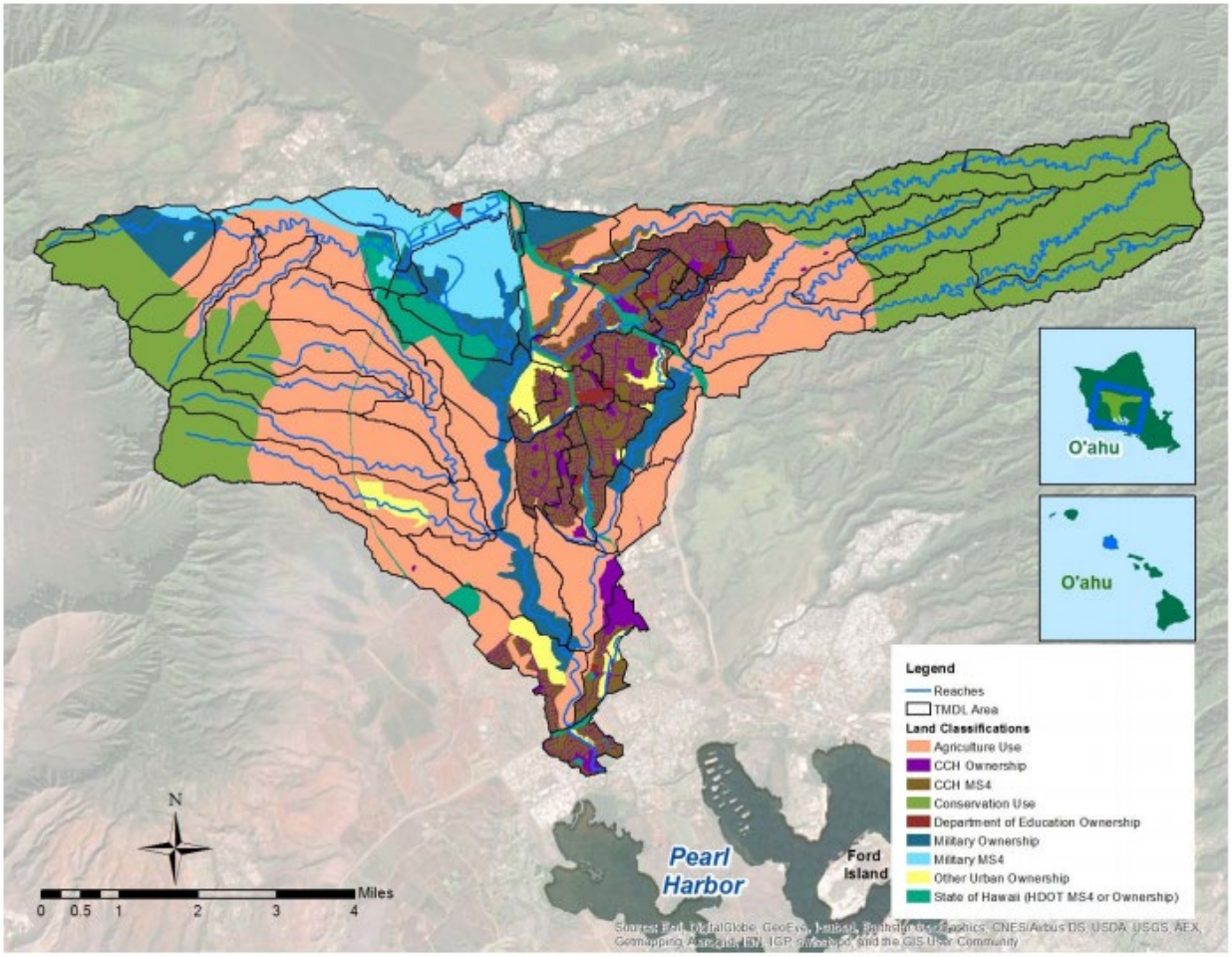


Figure 6. Ownership by subwatershed.

Source: Figure 33, *Turbidity, Sediment, and Nutrient Total Maximum Daily Loads for the Waikele Watershed*

Note: the ownership and MS4 sub-categories are an approximation and do not exactly represent permitted vs. unpermitted areas. This map is provided to demonstrate overall land owners.

3.5 Land Use

The Waikele watershed includes a variety of land cover and land uses, including agriculture, urban development, and undeveloped conservation land (Izuka, 2012; Figure 7). Conservation land is the predominant land use in the upper areas of the Waikakalaua and Kipapa subwatersheds. Most of the developed land is located in the Lower Waikele subwatershed and the Kipapa subwatershed. Agriculture is predominantly located in the Waianae Range and Lower Waikele subwatersheds. The Kipapa subwatershed also has agricultural areas along its eastern border. Table 6 identifies the land use areas incorporated into the TMDL by subwatershed.

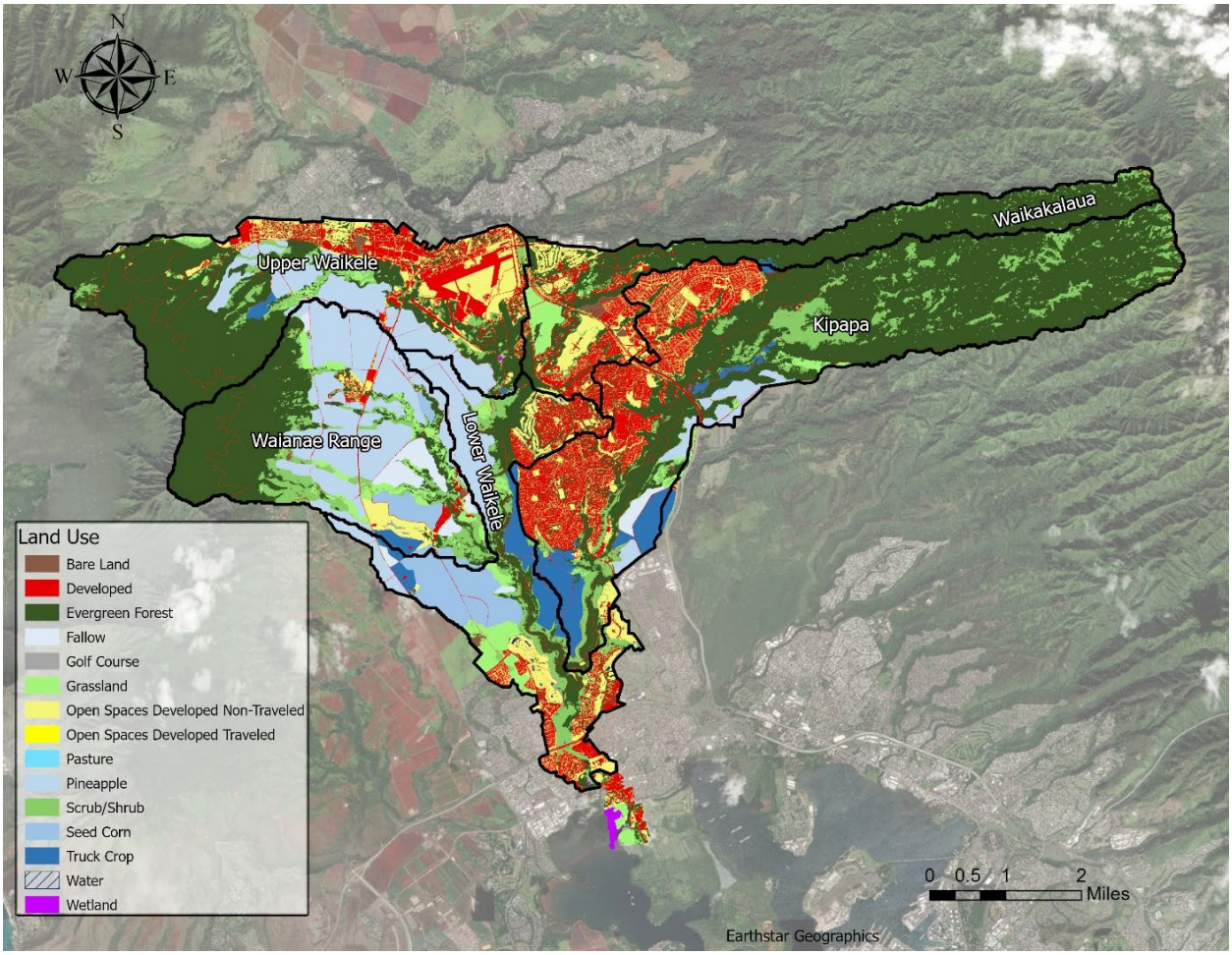


Figure 7. Waikele watershed land use.

Table 6. Land use area by subwatershed.

Land Use Category[1] *(corresponding land use(s) in Figure 7)*	Land Use (acres) by Subwatershed					Grand Total
	Waikakalaua	Kipapa	Upper Waikele	Waianae Range	Lower Waikele	
Conservation *(Fig. 7: **Evergreen Forest, Grassland, Scrub/shrub**)*	1,654.8	3,802.0	1,590.1	1,225.8		8,272.7
Fallow	151.4	296.2	732.0	1,121.9	533.8	2,835.3
Golf Course	171.4			147.4	351.6	670.4
Open Space	741.4	2,304.9	1,576.4	807.7	677.9	6,108.3
Pasture[2]		16.2				16.2
Pineapple		299.8	219.2	1,684.3	800.0	3,003.3
Seed Corn				235.3	584.9	820.2
Truck Crop	29.1	651.0	8.3	66.0	355.4	1,109.8
Commercial *(Fig. 7: **Developed**)*	39.8	71.3	16.7		80.1	207.9
Low-Medium Density Residential *(Fig. 7: **Developed**)*	347.1	1,318.5		39.4	475.4	2,180.4
Right of Way/Parking (not swept) *(Fig. 7: **Developed**)*	229.3	673.8	503.8	22.0	253.6	1,682.5
High Density Residential *(Fig. 7: **Developed**)*	204.3	320.9	1,110.3		132.8	1,768.2
Right of Way/Parking (swept) *(Fig. 7: **Developed**)*	48.5	40.2	18.0		16.2	122.8
Commercial-Industrial *(Fig. 7: **Developed**)*	68.6	196.5	18.0	56.5	334.8	674.5
Total	**3,685.5**	**9,991.3**	**5,792.8**	**5,406.4**	**4,596.4**	**29,472.4**

Note: The last four rows above the total (those shaded in gray) are land uses generally associated with areas covered by an NPDES permit.

[1] Land use categories in Table 6 correspond with land uses depicted in Figure 7 as indicated in parentheses; where not indicated, the land use category in Table 6 corresponds to a land use in Figure 7 with the same name. Bare Land, Water, and Wetland land uses were excluded from the analysis.

[2] Through stakeholder outreach, DOH learned that the total acreage of pasture land in the watershed may be much higher than shown here. This and other potential inaccuracies could reflect land use changes that occurred after the date of the imagery and data used to generate these land use values, gaps in data reporting, etc.

The remainder of this section describes the land use areas by subwatershed. ***Because the focus of this watershed plan is to reduce sediment and nutrient loadings from nonpoint sources of pollution, the discussion below describes the land uses typically associated with nonpoint sources of pollution*** (see Appendix A) and does not include areas covered by a wastewater discharge permit under the National Pollutant Discharge Elimination System (NPDES; last four land use categories in Table 6).

3.5.1 Waikakalaua Subwatershed

The predominant nonpoint source land use types in the Waikakalaua subwatershed are conservation and open space, which fall largely under the conservation and agriculture ownerships, respectively (Table 7).

CCH and Military-owned lands account for approximately 15 percent and 10 percent, respectively, of the nonpoint source land in the watershed;this area is mostly open space or golf courses (Table 7).

Table 7. Land use area by ownership category within the Waikakalaua subwatershed.

Owner	Land Use Area (acres)						
	Developed	Conservation	Fallow	Golf Course	Open Space	Truck Crop	Total
CCH	34.7		0.0	13.9	70.1		433.7
Military				157.5	110.7		268.2
State of Hawaii	2.8		0.0	0.0	1.2		4
DOE	4.1				0.0		4.1
Agriculture	28.0	1.5	151.4		559.3	11.8	752
Conservation	2.3	1,653.3				17.3	1,672.9
Total	**386.9**	**1,654.8**	**151.4**	**171.4**	**741.3**	**29.1**	**3,134.9**

3.5.2 Kipapa Subwatershed

The land uses in the Kipapa subwatershed are largely conservation (43 percent) and open space (26 percent; mostly under agriculture ownership). Developed lands make up 16 percent of the nonpoint source lands and fall largely within CCH ownership; CCH is the third largest land owner in the subwatershed (Table 8). State of Hawaii- and DOE-owned lands make up the smallest portions of the subwatershed and consist of unpermitted developed land. Additional land uses include a range of agricultural land uses such as fallow, pineapple, and truck crops (Table 8).

Table 8. Land use area by ownership category within the Kipapa subwatershed.

Owner	Land Use Area (acres)							
	Developed	Conservation	Fallow	Open Space	Pasture	Pineapple	Truck Crop	Total
CCH	1,229.50		0.3	285.1	8.9		1.4	1,525.2
Military	0.0		0.0	301.0		0.6	0.5	302.1
State of Hawaii	22.2			0.0		0.0		22.2
DOE	37.7			0.0				37.7
Agriculture	100.3		295.8	1,718.7	7.3	299.2	646.6	3,067.9
Conservation		3,802.0					2.5	3,804.5
Total	**1,389.7**	**3,802.0**	**296.1**	**2,304.8**	**16.2**	**299.8**	**651.0**	**8,759.6**

3.5.3 Upper Waikele Subwatershed

Conservation- and agriculture-owned lands each make up more than one-third of the Upper Waikele subwatershed. The military is the next largest nonpoint source landowner in the subwatershed with approximately 20 percent of the nonpoint source land. The predominant land use types in the Upper Waikele subwatershed are conservation (38 percent) and open space (38 percent) (Table 9). The open space is in military and agriculture ownership.

Table 9. Land use area by ownership category within the Upper Waikele subwatershed.

Owner	Land Use Area (acres)						
	Developed	Conservation	Fallow	Open Space	Pineapple	Truck Crop	Total
Military			28.0	806.7	4.2	8.3	847.2
State of Hawaii			56.8	89.4	211.1		357.3
DOE	16.7						16.7
Agriculture			647.3	680.3	3.9		1,331.5
Conservation		1,590.1					1,590.1
Total	**16.7**	**1,590.1**	**732.0**	**1,576.4**	**219.2**	**8.3**	**4,142.8**

3.5.4 Waianae Range Subwatershed

Agriculture-owned land makes up almost 75 percent of all nonpoint source land in the Waianae Range subwatershed, with conservation-owned lands comprising an additional 25 percent. CCH owns less than five percent of the nonpoint source land in the subwatershed. Similarly, the predominant land use types in the Waianae Range subwatershed are various types of agriculture (37 percent, largely pineapple cultivation), conservation (23 percent), and fallow land (21 percent). Developed land makes up the smallest portion (0.7 percent) of the subwatershed, while golf courses make up nearly all of the CCH ownership (Table 10).

Table 10. Land use area by ownership category within the Waianae Range subwatershed.

Owner	Land Use Area (acres)								
	Developed	Conserv-ation	Fallow	Golf Course	Open Space	Pineapple	Seed Corn	Truck Crop	Total
CCH			0.0	146.6	0.0				146.6
State of Hawaii	2.0		0.4		0.0	20.4			22.8
Agriculture	37.4		1,121.5	0.8	807.6	1,663.8	235.3	66.0	3,932.4
Conservation		1,225.8							1,225.8
Total	**39.4**	**1,225.8**	**1,121.9**	**147.4**	**807.6**	**1,684.2**	**235.3**	**66**	**5,327.6**

3.5.5 Lower Waikele Subwatershed

Agriculture-owned nonpoint source lands make up approximately half of the Lower Waikele subwatershed and include pineapple, seed corn, and truck crops, as well as fallow lands and open space. CCH is the next largest nonpoint source landowner in the subwatershed, with approximately 25 percent of the nonpoint source land, consisting largely of developed lands, golf courses, and open space (Table 11). The military is also responsible for nearly 500 acres of allow land and open space in the subwatershed (Table 11).

Table 11. Land use area by ownership category within the Lower Waikele subwatershed.

Owner	Land Use Area (acres)							
	Developed	Fallow	Golf Course	Open Space	Pineapple	Seed Corn	Truck Crop	Total
CCH	446.8	1.9	347.6	188.2		0.1	0.0	984.6
Military	0.0	198.2	3.2	275.2	0.1	0.4	13.7	490.8
State of Hawaii	7.8	33.4	0.0	13.9	229.9	57.3	0.4	342.7
DOE	41.4			0.4				41.8
Agriculture	59.4	300.2	0.8	200.2	570.0	527.2	341.3	1,999.1
Total	**555.4**	**533.7**	**351.6**	**677.9**	**800**	**585**	**355.4**	**3,859.0**

4 Water Quality and Hydrologic Conditions

Waikele Stream and its tributaries are not attaining some or all of their designated uses; therefore, Waikele is included on Hawaii's section 303(d) list for turbidity, total nitrogen and nitrite-nitrate impairments (DOH, 2020). The original listings date back to 2002 and include the entire freshwater network.

These impaired waters include Class 1.a, 1.b, and Class 2 inland waters. The Class 1.b inland waters are located in the eastern headwaters, while Class 1.a waters are the eastern headwaters that are part of the Oahu National Wildlife Refuge (NWR). While not fully evaluated for this watershed, the protection of native breeding stock is likely the most sensitive of these uses for both of these areas. For Class 2 waters, designated uses include protection for recreational purposes, support and propagation of fish and other aquatic life, and agricultural and industrial water supplies.

In the TMDL, it was determined that meeting the total nitrogen allocations would result in meeting the nitrite and nitrate objectives. Similarly, total phosphorus (which is not listed as impaired on the 303(d) list) and turbidity will be controlled by meeting the sediment allocations. For additional discussion, see Section 7.2 of the TMDL report[2] (EPA and DOH, 2019).

*This plan focuses on **total nitrogen** and **sediment** load reductions. Achieving these reductions will also address the other related impairments.*

Water quality conditions and impairments were characterized in the TMDL based on data from numerous sources. Water quality monitoring data for sediment and nutrients in the Waikele watershed were obtained from the Hawaii DOH Clean Water Branch, Storage and Retrieval Data Warehouse (STORET), U.S. Army Corps of Engineers (USACE), and the U.S. Geological Survey (USGS). Continuous flow measurements in the watershed included those collected at the USGS gage on Waikele Stream at Waipahu (station 16213000).

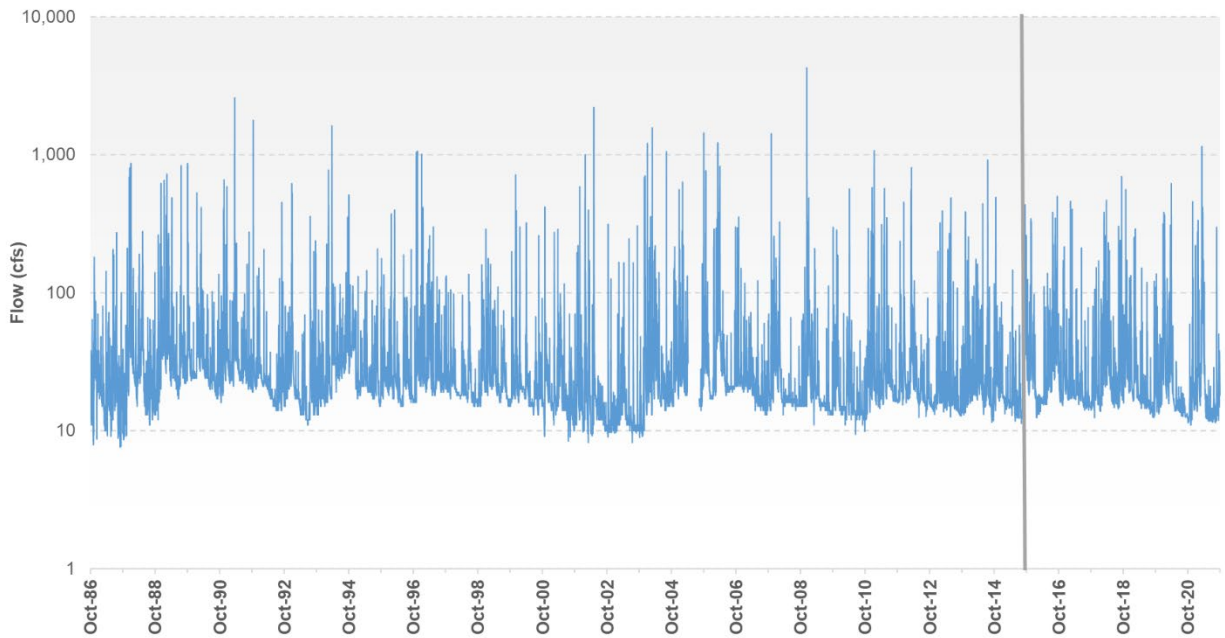
Limited additional data have been collected since TMDL development. These new data are summarized below and were compared with the TMDL to evaluate whether conditions have changed since the more detailed TMDL analyses were conducted.

The TMDL notes the flashiness of the system's hydrology due to small drainage areas and steep gradients for many reaches (for additional detail, see Section 4 of the TMDL). As shown in Table 12 and Figure 8 below, the additional flow data collected since the TMDL demonstrate that the hydrology has remained consistent through Water Year (WY) 2021 and no discernable changes have been measured since 2015. Monthly summary statistics were evaluated to determine whether seasonal patterns have changed; however, the monthly results remain similar, and discrepancies may be caused by the different periods of records (nearly 20 years used in the TMDL and only five years since).

[2] Loads in the TMDL report have been converted to pounds or tons in this plan for direct comparison with outputs from the load reduction tools.

Table 12. Monthly flow statistics at USGS station 16213000.

Data Period	Month	Monthly flow (cfs)		
		Minimum	Maximum	Mean
Data Used in TMDL Development (WY1987-2015)	January	10	1,210	46
	February	10	1,570	39
	March	8	2,590	52
	April	9	824	37
	May	9	2,200	33
	June	9	350	25
	July	8	914	29
	August	9	1,050	26
	September	8	452	28
	October	9	1,780	35
	November	8	1,420	48
	December	9	4,270	53
	Total Period	**8**	**4,270**	**38**
Data Collected Since TMDL Development (WY2016-2021)	January	12	382	37
	February	13	459	41
	March	14	1,150	64
	April	12	230	31
	May	12	138	22
	June	12	211	23
	July	12	382	23
	August	11	348	37
	September	12	697	33
	October	11	560	32
	November	11	457	48
	December	14	316	37
	Total Period	**11**	**1,150**	**36**



Note: The gray line separates data used in TMDL development (Water Years 1987-2015) from new data collected after TMDL development (Water Years 2016-2021).

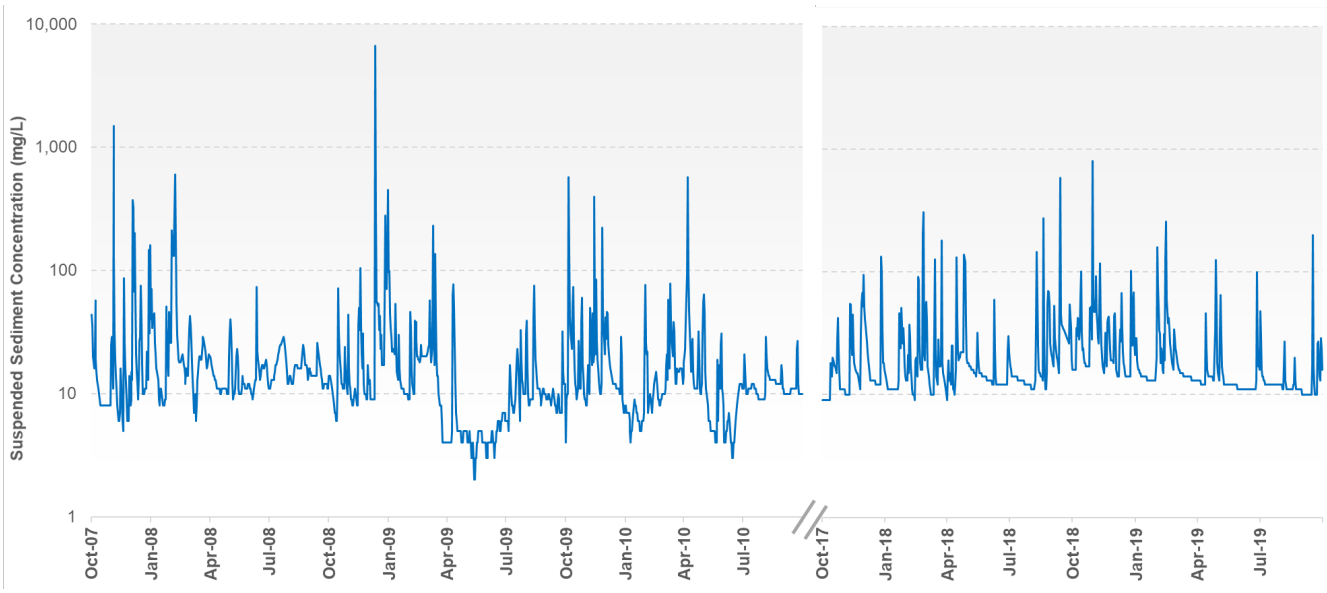
Figure 8. Continuous flow data time series at USGS Station 16213000 – WY 1987-2021.

In addition, suspended sediment concentration (SSC) data were collected in WY2018-2019 after the TMDL analyses were completed. As illustrated in Table 13 and Figure 9, the recent SSC concentrations are similar to the earlier period evaluated in the TMDL (WY2007-2010). Summary statistics for the two time periods (Table 13) show the comparability as the mean and 25th, 50th, and 75th percentile values are all within 4 mg/L when comparing the two time periods. For additional sediment and water quality data analysis, see Section 4 of the TMDL.

Table 13. Summary statistics for SSC at USGS station 16213000.

Summary Statistics (Data: 10/01/2007 to 9/30/2010 and 10/1/2017 to 9/30/2019 in mg/L)							
Water Years	Mean	Median	Min	Max	25th	75th	Number of Samples
2008-2010*	29	12	2	6,620	9	19	1,096
2018-2019	25	14	9	805	12	22	730

*The 2008-2010 data are included from Table 9 of the TMDL report.



Note: No data were available for WY 2011-2017.

Figure 9. Daily mean SSC at USGS 16213000 – WY 2008-2010 and 2018-2019.

While recent data to evaluate the system are limited, the comparisons above demonstrate that the overall assumptions and analyses in the TMDL remain applicable and can be useful to support load reduction estimates in this implementation plan.

5 Pollutant Sources and Existing Loads

Multiple sources of sediment and nutrients associated with both natural and anthropogenic activities contribute loads to the impaired waterbodies during wet and dry weather periods. Pollutant sources were quantified in the TMDL with the watershed model by land cover type since loadings can be highly correlated with land-based activities. Some of the land-based activities are associated with point sources, while other activities are nonpoint sources of pollution. Point sources typically discharge from a specific location via pipes, outfalls, and conveyance channels. Examples of point sources include municipal wastewater treatment plants, industries, or municipal separate storm sewer systems (MS4s). These are regulated through NPDES permits and receive wasteload allocations in the TMDL. Nonpoint sources are diffuse sources that have multiple routes of entry into surface waters. They are not permitted and are represented by load allocations in the TMDL.

The Waikele watershed TMDL report includes waste load allocations for point sources and load allocations for the nonpoint sources of pollution. This implementation plan focuses on only the nonpoint sources of nutrient and sediment pollution as point source loadings are managed by their NPDES permits.

The nonpoint sources in the Waikele watershed include runoff from agricultural lands, conservation lands, golf courses, developed/light urban areas, and open space areas. Wash-off of sediment and nutrients from various land uses during precipitation events is considered the primary mechanism for transport; therefore, the amount of runoff and associated pollutant concentrations are highly dependent on land-based activities. Specifically, sediment and nutrients build up on the land surface during various activities and a subset of the loads are washed off the surface during rainfall events. The amount of buildup and wash-off for different land use and soil types was estimated during TMDL development using a watershed model. Groundwater contributions were included in the watershed model and are captured within the land use-specific source loads quantified below. The TMDL model output is used throughout this implementation plan to estimate existing loads and required load reductions.

A primary objective of this pollutant source characterization is to identify the land uses and conditions associated with nonpoint sources that generate and transport nutrients and sediment. This information can then be compared with required reductions from the TMDL to determine areas best suited for management measures to reduce the nonpoint source loads. To understand pollutant loading conditions, it is useful to evaluate the proportional contributions of nonpoint source land uses during the dry and wet seasons (derived from the TMDL watershed model).

Pollutant loads throughout this plan are derived from the HSPF watershed model used during TMDL development. This tool allows for distribution of existing and allowable nonpoint source loads by land use, subwatershed, and owner (see Section 5.2).

Total Nitrogen

Agricultural land uses (consisting of pineapple, seed corn, truck crop, fallow land, and pasture) contributed over a third of total nitrogen pollutant loadings in both the dry and wet seasons. Developed land uses (consisting of commercial and low-medium density residential land use) contributed a slightly larger proportion in the wet season than dry, while conservation and open space lands contributed similar amounts during the two seasons (see Figure 10 and Figure 11). The contribution by land use type including specific activities is discussed in further detail in Section 5.1 below.

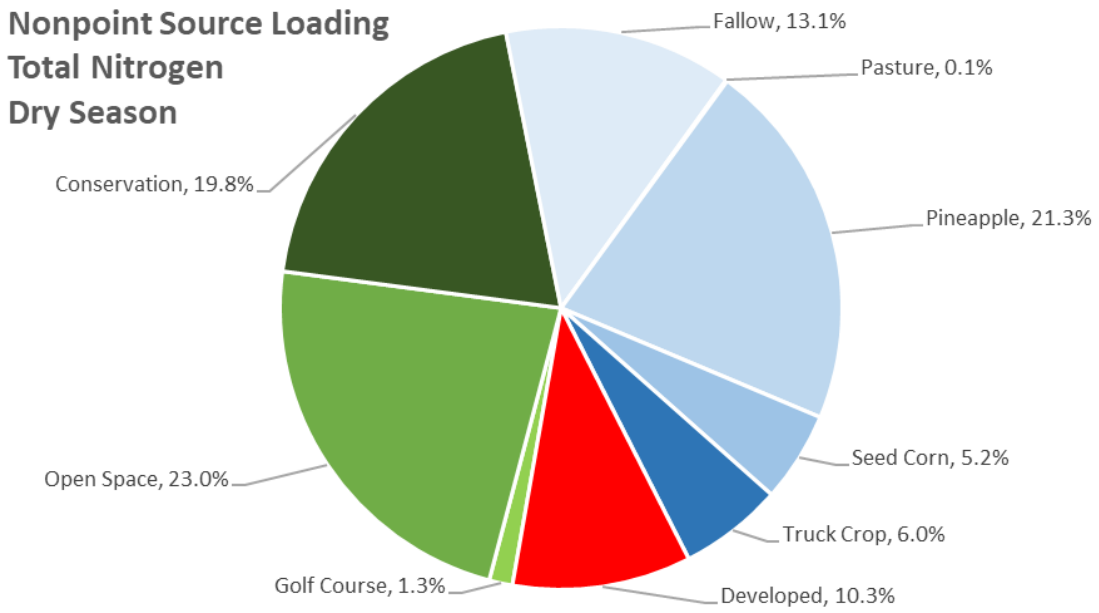


Figure 10. Dry season total nitrogen relative nonpoint source land use contributions.

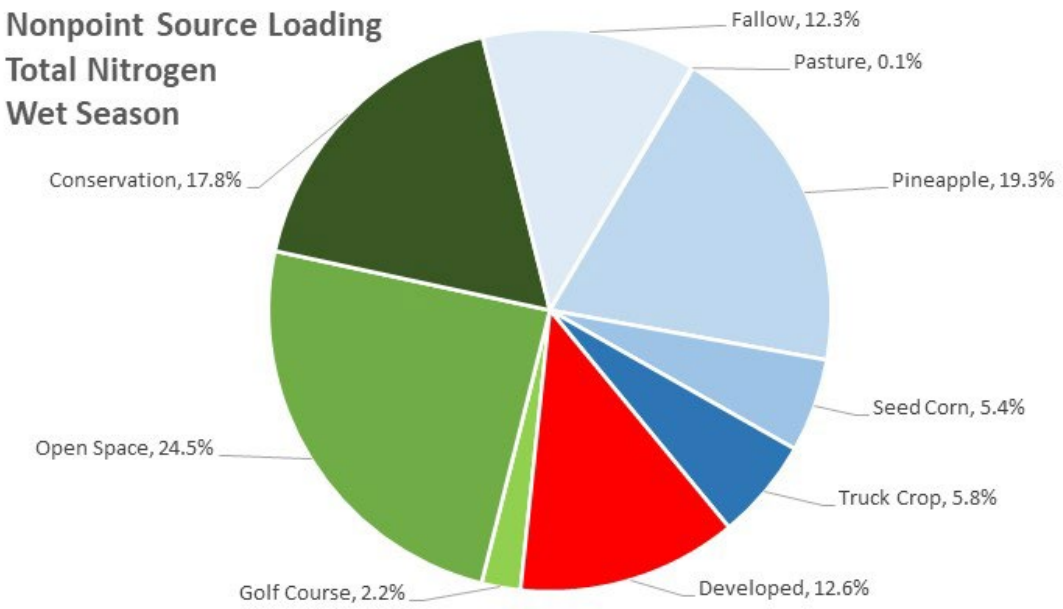


Figure 11. Wet season total nitrogen relative nonpoint source land use contributions.

<u>Sediment</u>

Conservation and open space contributed well over half of the sediment loading during the dry season and approximately 40 percent of the sediment loading during the wet season. Agricultural land uses followed the opposite pattern with over half of the wet season sediment loads and approximately one-third of the dry season loads. Developed land use loading was estimated at less than five percent of the

sediment loading during both the dry and wet seasons (see Figure 12 and Figure 13). Land use and activity-specific contributions for sediment are presented in in Section 5.1 below.

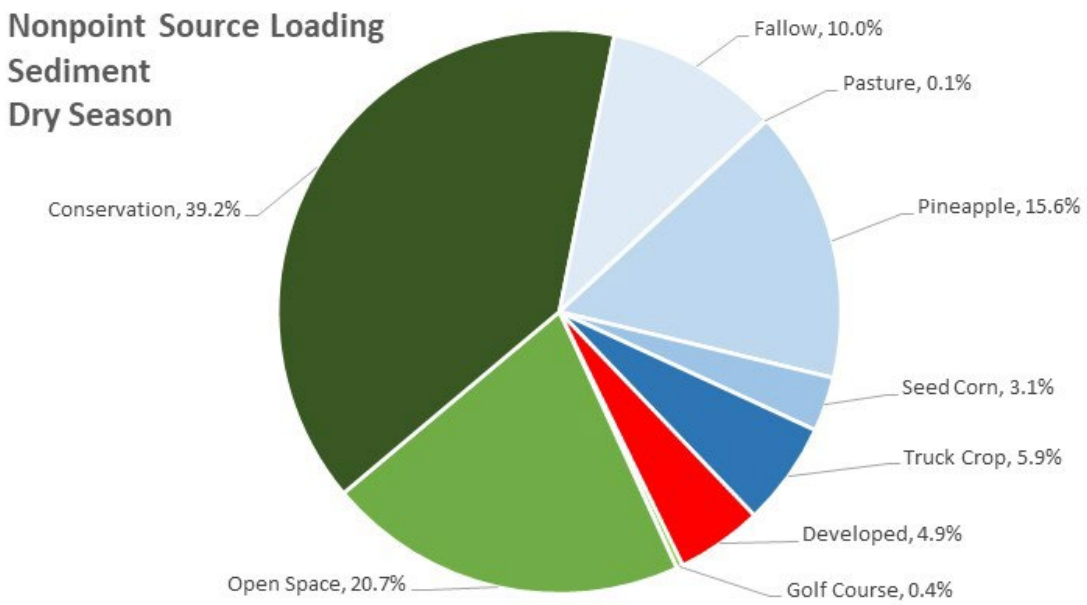


Figure 12. Dry season sediment relative nonpoint source land use contributions.

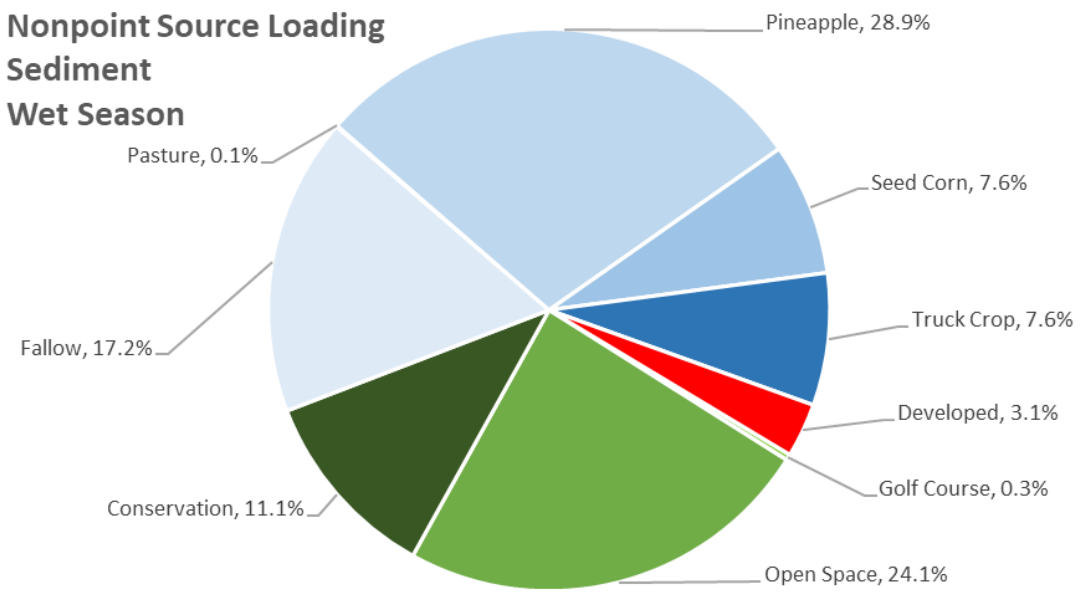


Figure 13. Wet season sediment relative nonpoint source land use contributions.

These pie charts and high-level summaries are supported by land use-specific characteristics and loading estimates in Sections 5.1 and 5.2, respectively. This additional detail is used to identify and prioritize management measures in Sections 7 and 8.1 and throughout the rest of the implementation plan.

5.1 Pollutant Source Areas

The land use categories discussed in Section 3.5 include conservation, fallow, golf course, open space, pasture, pineapple, seed corn, truck crop, commercial, and low-medium density residential. These land use categories were further grouped below when considering the sources of pollutants within each land use and, ultimately, the management measures anticipated for pollutant reduction. For example, pineapple, seed corn, and truck crop are types of diversified agriculture and, therefore, the processes in which pollutants are generated are similar. Fallow lands were also categorized as an agricultural pollutant source because fallow lands may undergo some of the same pollutant-generating processes as cultivated agricultural lands. Only a small area of land is designated as pasture within the Waikele watershed; however, it is adjacent to other agricultural lands and some of the land appears to be associated with farming operations. Low-medium density residential and commercial land use categories were grouped together as a developed/light urban pollutant source because they are expected to have more impervious surface and different pollutant-generating activities than the other nonpoint source land uses. These groupings resulted in a total of four land use categories. Pollutant generating and transport characteristics as well as estimated total nitrogen and sediment loads for each category are described below.

5.1.1 Agriculture

Agricultural lands contribute high loadings of sediment and total nitrogen within the Waikele watershed. These lands consist of fallow and pasture areas, as well as cultivated land, such as pineapple, seed corn, and truck crop. Relative contributions for all agricultural lands as well as individual agricultural areas are presented in the adjacent text box. For total nitrogen, contributions between dry and wet seasons are very similar and, overall, agriculture contributes over 40 percent of the total loading. Sediment demonstrates considerable differences between the dry and wet season loads. Agriculture contributes 35 percent of the dry season sediment load and over 60 percent during the wet season. In all cases, pineapple contributes the greatest loads, even though the total area is similar to fallow lands (Table 6).

Agricultural sources in the Waianae Range subwatershed contribute the highest relative loading of total nitrogen compared to agricultural sources in other subwatersheds, followed by the Lower Waikele and Kipapa

Total Nitrogen Loads

Dry Season

All agriculture = 46%

Source: Table 15, Table 19

- 21% pineapple
- 13% fallow
- 6% truck crop
- 5% seed corn
- <1% pasture

Wet Season

All agriculture = 43%

Source: Table 16, Table 20

- 19% pineapple
- 12% fallow
- 6% truck crop
- 5% seed corn
- <1% pasture

Sediment Loads

Dry Season

All agriculture = 35%

Source: Table 17, Table 21

- 16% pineapple
- 10% fallow
- 6% truck crop
- 3% seed corn
- <1% pasture

Wet Season

All agriculture = 61%

Source: Table 18, Table 22

- 29% pineapple
- 17% fallow
- 8% truck crop
- 8% seed corn
- <1% pasture

subwatersheds. In each subwatershed, land cultivated in pineapple crop contributes the highest total nitrogen loading. During the wet season, these subwatersheds also contribute the most sediment from agricultural sources (see Tables in Section 5.2).

One of the drainages in the Kipapa subwatershed that is currently characterized as agriculture is being developed as part of the Koa Ridge community (between Waipio and Mililani), which is reflective of the urbanization and development pressure in portions of the watershed. Since this land was characterized as agriculture in the TMDL, it is part of the total nonpoint source loading estimates. For this watershed plan, no changes to land use were made because of this new development; the plan followed the land use categorization in the TMDL. As a precaution, the analyses of BMPs and load reductions in this watershed plan did not include any agricultural BMPs in the area being developed. Ultimately, this area could be incorporated into CCH's wasteload allocation.

5.1.1.1 Diversified Agriculture

Agriculture contributes nutrients to streams through application of commercial fertilizers, manure, and sludge to crop fields. These applications contain high levels of nitrogen, phosphorus, and potassium, among others, to amend soil and support crop growth. Over-application of these nutrients as well as the timing, placement, and method of application may impact the amount of pollutants discharged from croplands into surface waters. Nutrients not taken up by plants are available for transport to streams during irrigation or rainfall events. These nutrients, such as nitrate, can be leached from soils into the groundwater or into surface water via overland flow.

Agriculture also contributes sediment to streams during crop planting and harvesting by disrupting the soil. Sediment primarily enters surface waters from cropland due to erosion of soils. Loosening of soils during tillage and cultivation of soil increases the loading of soil particles to rivers, streams, and lakes during wet weather events (EPA, 2003). The sediment that is deposited in surface waters often carries excess nutrients such as phosphorus adsorbed to sediment particles. Seed corn and truck crop require frequent tilling, soil exposure, and harvest, which may increase the amount of soil and nutrients transported to surface waters (El-Swaify, 2002). In addition, erosion and lower infiltration of agricultural access roads are a potential source of pollutants and can aid in the transport of sediment and nutrients to surface waters.

5.1.1.2 Other Agriculture Lands

Based on information provided by DOH, there are no Concentrated Animal Feeding Operations or Animal Feeding Operations in the watershed. However, pastures used for grazing livestock or farm animals contributes sediment and nutrients to surface waters through soil disruption, vegetation removal or trampling, and waste. Soil loosened soil by livestock movement may be carried to a nearby surface water during rain events. Dust generated by livestock movement can also be carried in the air and deposited into surface waters. Grazing and trampling of vegetation by livestock removes or limits vegetation which may result in increased overland flow to surface waters and less opportunity for plants to take up water and nutrients. Livestock that have access to streams for watering contribute sediment and nutrients directly into streams through streambank erosion and waste deposition, similar to pollutant generation and transport from the wildlife sources described in Section 5.1.2.

5.1.1.3 Fallow Lands

Fallow lands are lands that are suitable for growing crops but are left unseeded. These lands may or may not be plowed and tilled. If fallow lands are worked, they may contribute sediment and nutrient loads to surface waters as described in Section 5.1.1.1 above.

5.1.2 Conservation

Conservation lands, which are largely the forested upland portions of the watershed, contribute sediment and nutrients to surface waters through naturally occurring and anthropogenic activities. Proportional total nitrogen loading is similar during both the wet and dry seasons. Compared to other land uses, conservation lands contribute a larger proportion of sediment loading during the dry season than during the wet season (39 percent compared to 11 percent, respectively); however, the actual sediment loads are much higher in the wet season, making the wet season impact more significant.

The largest contributions of both sediment and total nitrogen from conservation lands are generated in the upper regions of the Waikele watershed, specifically in the Kipapa and Waikakalaua subwatersheds.

Total Nitrogen Loads

Dry Season	Wet Season
All conservation = 20%	All conservation = 18%
Source: Table 15, Table 19	*Source: Table 16, Table 20*

Sediment Loads

Dry Season	*Wet Season*
All conservation = 39%	All conservation = 11%
Source: Table 17, Table 21	*Source: Table 18, Table 22*

5.1.2.1 Streambank Erosion and Mass Wasting

Conservation lands are largely located in the upper parts of the watershed where steep gradients and high precipitation rates accelerate the risk of erosion. High rainfall in the headwaters of the Waikakalaua, Kipapa, Upper Waikele, and Waianae Range subwatersheds and increased streamflow contribute to erosion of streambanks, increasing downstream concentrations of suspended sediment. Removal of vegetation results in decreased ground cover and canopy density and disrupts soils, which increases erosion rates and transport of sediment to streams. Mass wasting, or slope movement, is the process by which soil and rock move down a slope due to gravity. This process may deposit sediment downslope closer to or directly into a stream.

5.1.2.2 Invasive Plant Species

In conservation lands, the presence of invasive plant species contributes to sediment loading due to their shallow root systems which fail to retain soil during rain events. DOH often coordinates with DLNR and other landowners to address invasive species.

5.1.2.3 Wildlife

Wildlife, such as feral pigs, cause soil and vegetation disruption and loss in forested areas which contributes to sediment and nutrient loading. Wildlife can also contribute to nutrients through their waste (EPA, 2005; Schueler and Holland, 2000).

5.1.3 Developed/Light Urban

Nonpoint source urban areas contribute both nutrients and sediment to surface waters. The impervious surfaces present in developed and urban areas allows sediment and nutrients to be transported to surface waters through stormwater runoff. The developed areas included in this implementation plan are areas not covered by an MS4 permit, typically including "lighter" developed uses, with less impervious cover than the permitted areas. There is little seasonal difference between the proportion of total nitrogen and sediment loads from nonpoint source developed lands, making up over 10 percent and 3 percent, respectively, throughout the year. The Kipapa subwatershed, which includes the town of Mililani, is the largest developed source contributor of total nitrogen and sediment in both the dry (6 percent and 3 percent, respectively) and wet seasons (8 percent and 2 percent, respectively).

Total Nitrogen Loads

Dry Season	Wet Season
All developed = 10%	All developed = 13%
Source: Table 15, Table 19	*Source: Table 16, Table 20*

Sediment Loads

Dry Season	*Wet Season*
All developed = 5%	All developed = 3%
Source: Table 17, Table 21	*Source: Table 18, Table 22*

5.1.3.1 Impervious Surfaces

The primary urban areas of the watershed include Mililani, Schofield Barracks, and Waipahu. A portion of these areas are covered by MS4 permits and are not part of this implementation plan; however, this plan does address those developed areas categorized as low density residential. Unlike soil, impervious surfaces present in developed areas do not allow water to penetrate and infiltrate into the soil. Impervious surfaces in these areas include parking lots, paved roads, sidewalks, and rooftops. Stormwater runoff flowing over impervious surfaces collects nutrients and sediment that have accumulated on these surfaces and carries them to storm drains, which deliver these pollutants directly into waterways. In what is known as the first flush effect, pollutants, such as sediment and nutrients, accumulate on impervious surfaces during prolonged dry periods and are then transported to surface waters, contributing a high loading of pollutants during the next runoff-producing rainfall event.

5.1.3.2 Residential Areas

Fertilizers from residential application to lawns also may be a source of nutrients. Like the contribution of nutrients from fertilizers applied to agricultural land (Section 5.1.1), excess fertilizer may be carried to surface waters via overland flow. In addition, humans can contribute nutrients to surface waters from human waste, food waste, improper disposal of pet waste, and soil erosion.

5.1.3.3 Septic Systems

Septic systems in residential areas also may be a source of nitrogen and phosphorus. Septic systems consist of a septic tank and a leach field. The septic tank retains solids, oil, and grease from the waste. The remaining liquid enters the leach field into pipes, chambers, or other units where the wastewater is further treated by allowing it to filter into soil where nutrients are further removed. Septic systems may introduce pollutants into groundwater if these systems are not maintained or if poorly treated wastewater is near surface waters or alluvial soils. There are only eleven septic systems in Waikele watershed; as a result, septic systems are not expected to be a significant source of nutrients or sediment in the Waikele watershed.

5.1.3.4 Cesspools

Cesspools are underground holding tanks or storage pits for collection of human waste and sewage and are a source of nutrients. Unlike septic tanks, cesspools do not provide much, if any, treatment of waste. Contribution of nutrients from cesspools is more likely to occur if these cesspools are located near surface waters or are located above groundwater.

Based on review of On-site Sewage Disposal Systems data and use of GIS shapefiles retrieved from the Hawaii Statewide GIS Program, the subwatersheds contain zero to 50 cesspools (Table 14).


Darcey Iwashita (DOH)

Table 14. Cesspool inventory by subwatershed.

Subwatershed	Number of Cesspools
Waikakalaua	26
Kipapa	50
Upper Waikele	0
Waianae Range	2
Lower Waikele	24

DOH has been authorized by Act 132 of SLH 2018 to establish a cesspool conversion working group. The purpose of this working group is to develop a long-range, comprehensive plan to address all cesspools statewide by 2050. It is expected that cesspools will be converted to other onsite systems or connected to a sewer where possible by 2050. Considering the small number of cesspools in the Waikele watershed, these features are not expected to be a significant source of nutrients or sediment in the watershed.

5.1.4 Open Space

Open space areas consist of a variety of land use types. In many cases, areas identified as Open Space have similarities to other land use categories described above. These areas typically make up just over 20 percent of the total nitrogen and sediment loading throughout the year. Based on a review of aerial imagery, the land designated as Open Space in the modeling effort can be divided into pollutant source areas and separated at the subwatershed level, where possible.

Total Nitrogen Loads

Dry Season
All open space = 24%
Source: Table 15, Table 19

Wet Season
All open space = 27%
Source: Table 16, Table 20

Sediment Loads

Dry Season
All open space = 21%
Source: Table 17, Table 21

Wet Season
All open space = 24%
Source: Table 18, Table 22

5.1.4.1 Maintained Greenspace

The majority of open space land use in the Waikakalaua, Kipapa, and Lower Waikele subwatersheds can be further categorized as maintained greenspace. This land is maintained in residential greenbelts and city and neighborhood parks. The military-owned open space land also appears to be maintained greenspace. These types of lands contribute nutrients to streams from the application of fertilizer and irrigation to maintain the grass. Nutrients not taken up by the vegetation are carried to streams during stormwater runoff events. Parks and greenbelts are often over-irrigated leading to additional runoff.

5.1.4.2 Forest/Shrub-scrub

Open space land use throughout the Waikele watershed can also be categorized as forest/shrub-scrub, which have similar characteristics to conservation lands (Section 5.1.2). These areas serve as habitat for wildlife, thereby contributing nutrients from wildlife waste and sediment via disruption of soil to surface waters. Removal of vegetation also contributes sediment loading to surface waters.

5.1.4.3 Commercial/Residential

The commercial and residential open space areas in the Waikele watershed consist of impervious surfaces with adjacent small green spaces. Similar to processes described for developed lands (Sections 5.1.3.1 and 5.1.3.2), pollutant transport typically occurs due to stormwater runoff flowing over the impervious surfaces (e.g., rooftops, parking lots, sidewalks) collecting nutrients and sediment that have accumulated on these surfaces and entering storm drains. Fertilizer application or irrigation of the adjacent greenspaces can also contribute to nutrient loading via overland flow to storm drains or surface waters.

5.1.4.4 Golf Courses

Golf courses are large with pervious cover that have many similarities to city parks and other maintained greenspace. Golf courses, when compared to other land uses, are a fairly small, yet manageable, source of total nitrogen and sediment in the watershed (less than 2 percent of the total load, regardless of season). They typically contribute nutrients to streams from application of fertilizer to maintain grass throughout the course. Nutrients not taken up by the vegetation are carried to streams during stormwater runoff events. The highest loadings of total nitrogen and sediment from golf courses are generated in the Lower Waikele subwatershed. Golf courses in the watershed include Hawaii Country Club Golf Course, Mililani Golf Club, Royal Kunia Country Club, Waikele Country Club, and Leilehua Golf Course (several of which are owned by the military and included in the military load allocation).

5.2 Estimated Pollutant Source Loading

Relative loads (percent) and estimated pollutant loadings (in mass per day) of total nitrogen and sediment for the dry and wet seasons are presented in Table 15 through Table 22 below (note that the loads presented in the TMDL report have been converted to pounds for nitrogen and tons for sediment in this plan). The first four tables present relative loads, while the last four display the estimated daily loads based on watershed model output. These tables include values for the different land use categories and are further divided by subwatershed and owner, as discussed in Section 5.1 above. They are the basis for future load reduction estimates and identification and prioritization of areas for management measure implementation.

Table 15. Relative dry season total nitrogen existing loads by pollutant source category, subwatershed, and owner.

Dry Weather Total Nitrogen Seasonal Existing Loads (%)												
Subwatershed	**Ownership**	**Commercial**	**Low-Medium Density Residential**	**Conservation**	**Golf Course**	**Open Space**	**Pasture**	**Fallow**	**Pineapple**	**Seed Corn**	**Truck Crop**	**Total % Loading**
Waikakalaua	CCH	0.16	1.47	-	0.06	0.33	-	0.00	-	-	-	2.02
	Military	-	-	-	0.26	0.18	-	-	-	-	-	0.44
	State of Hawaii	0.00	0.02	-	0.00	0.01	-	0.00	-	-	-	0.03
	Department of Education	0.04	0.00	-	-	0.00	-	-	-	-	-	0.04
	Agriculture	0.00	0.05	0.00	-	1.00	-	0.27	-	-	0.02	1.34
	Conservation	-	0.01	3.93	-	-	-	-	-	-	0.04	3.98
Waikakalaua Source Loading		0.21	1.54	3.94	0.32	1.52	-	0.27	-	-	0.06	7.86
Kipapa	CCH	0.20	5.15	-	-	1.24	0.04	0.00	-	-	0.01	6.64
	Military	-	0.00	-	-	0.29	-	0.00	0.00	-	0.00	0.29
	State of Hawaii	-	0.10	-	-	0.00	-	-	0.00	-	-	0.10
	Department of Education	0.23	0.12	-	-	0.00	-	-	-	-	-	0.35
	Agriculture	-	0.57	-	-	9.82	0.04	1.69	1.71	-	3.69	17.52
	Conservation	-	-	14.13	-	-	-	-	-	-	0.01	14.14
Kipapa Source Loading		0.43	5.95	14.13	-	11.34	0.08	1.69	1.71	-	3.71	39.04
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	0.00
	Military	-	-	-	-	1.58	-	0.05	0.01	-	0.02	1.66
	State of Hawaii	-	-	-	-	0.25	-	0.16	0.60	-	-	1.02
	Department of Education	0.06	-	-	-	-	-	-	-	-	-	0.06
	Agriculture	-	-	-	-	0.44	-	0.42	0.00	-	-	0.86
	Conservation	-	-	0.92	-	-	-	-	-	-	-	0.92
Upper Waikele Source Loading		0.06	-	0.92	-	2.27	-	0.64	0.61	-	0.02	4.51
Waianae Range	CCH	-	-	-	0.27	0.00	-	0.00	-	-	-	0.27
	State of Hawaii	-	0.02	-	-	0.00	-	0.00	0.18	-	-	0.20
	Agriculture	-	0.28	-	0.01	6.10	-	8.47	12.57	1.78	0.50	29.71
	Conservation	-	-	0.77	-	-	-	-	-	-	-	0.77
Waianae Range Source Loading		-	0.30	0.77	0.27	6.10	-	8.48	12.75	1.78	0.50	30.96
Lower Waikele	CCH	0.08	0.87	-	0.74	0.40	-	0.00	-	0.00	0.00	2.11
	Military	-	0.00	-	0.00	0.14	-	0.10	0.00	0.00	0.01	0.25
	State of Hawaii	0.00	0.11	-	0.00	0.21	-	0.50	3.42	0.85	0.01	5.10
	Department of Education	0.43	0.01	-	-	0.00	-	-	-	-	-	0.44
	Agriculture	-	0.29	-	0.00	0.97	-	1.46	2.78	2.57	1.66	9.73
Lower Waikele Source Loading		0.51	1.29	-	0.75	1.73	-	2.06	6.20	3.42	1.67	17.63
Total % Loading		**1.21**	**9.07**	**19.76**	**1.35**	**22.96**	**0.08**	**13.14**	**21.27**	**5.20**	**5.96**	**100.00**

Table 16. Relative wet season total nitrogen existing loads by pollutant source category, subwatershed, and owner.

Wet Weather Total Nitrogen Seasonal Existing Loads (%)												
Subwatershed	Ownership	Commercial	Low-Medium Density Residential	Conservation	Golf Course	Open Space	Pasture	Fallow	Pineapple	Seed Corn	Truck Crop	Total % Loading
Waikakalaua	CCH	0.22	1.95	-	0.09	0.43	-	0.00	-	-	-	2.69
	Military	-	-	-	0.47	0.33	-	-	-	-	-	0.80
	State of Hawaii	0.00	0.03	-	0.00	0.01	-	0.00	-	-	-	0.04
	Department of Education	0.04	0.00	-	-	0.00	-	-	-	-	-	0.04
	Agriculture	0.00	0.06	0.00	-	1.29	-	0.35	-	-	0.03	1.73
	Conservation	-	0.01	3.72	-	-	-	-	-	-	0.04	3.77
Waikakalaua Source Loading		0.26	2.04	3.73	0.56	2.07	0.00	0.35	0.00	0.00	0.07	9.07
Kipapa	CCH	0.25	6.36	-	-	1.53	0.05	0.00	-	-	0.01	8.20
	Military	-	0.00	-	-	0.51	-	0.00	0.00	-	0.00	0.52
	State of Hawaii	-	0.14	-	-	0.00	-	-	0.00	-	-	0.14
	Department of Education	0.29	0.15	-	-	0.00	-	-	-	-	-	0.45
	Agriculture	-	0.50	-	-	8.63	0.04	1.49	1.50	-	3.25	15.41
	Conservation	-	-	12.29	-	-	-	-	-	-	0.01	12.30
Kipapa Source Loading		0.54	7.15	12.29	0.00	10.68	0.08	1.49	1.50	0.00	3.27	37.01
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	0.00
	Military	-	-	-	-	3.42	-	0.12	0.02	-	0.04	3.60
	State of Hawaii	-	-	-	-	0.33	-	0.21	0.77	-	-	1.31
	Department of Education	0.10	-	-	-	-	-	-	-	-	-	0.10
	Agriculture	-	-	-	-	0.68	-	0.64	0.00	-	-	1.32
	Conservation	-	-	0.98	-	-	-	-	-	-	-	0.98
Upper Waikele Source Loading		0.10	0.00	0.98	0.00	4.43	0.00	0.97	0.80	0.00	0.04	7.31
Waianae Range	CCH	-	-	-	0.65	0.00	-	0.00	-	-	-	0.65
	State of Hawaii	-	0.02	-	-	0.00	-	0.00	0.18	-	-	0.21
	Agriculture	-	0.23	-	0.00	5.03	-	6.98	10.36	1.46	0.41	24.48
	Conservation	-	-	0.77	-	-	-	-	-	-	-	0.77
Waianae Range Source Loading		0.00	0.25	0.77	0.66	5.03	0.00	6.98	10.54	1.46	0.41	26.11
Lower Waikele	CCH	0.12	1.20	-	1.02	0.55	-	0.01	-	0.00	0.00	2.90
	Military	-	0.00	-	0.00	0.33	-	0.24	0.00	0.00	0.02	0.59
	State of Hawaii	0.00	0.10	-	0.00	0.19	-	0.45	3.11	0.78	0.01	4.64
	Department of Education	0.51	0.01	-	-	0.00	-	-	-	-	-	0.53
	Agriculture	-	0.35	-	0.00	1.19	-	1.78	3.38	3.12	2.02	11.85
Lower Waikele Source Loading		0.63	1.67	0.00	1.03	2.26	0.00	2.47	6.49	3.90	2.04	20.05
Total % Loading		**1.53**	**11.11**	**17.77**	**2.25**	**24.46**	**0.08**	**12.26**	**19.33**	**5.37**	**5.82**	**100.00**

Table 17. Relative dry season sediment existing loads by pollutant source category, subwatershed, and owner.

Dry Weather Sediment Seasonal Existing Loads (%)												
Subwatershed	Ownership	Commercial	Low-Medium Density Residential	Conservation	Golf Course	Open Space	Pasture	Fallow	Pineapple	Seed Corn	Truck Crop	Total % Loading
Waikakalaua	CCH	0.06	0.54	-	0.02	0.12	-	0.00	-	-	-	0.75
	Military	-	-	-	0.05	0.03	-	-	-	-	-	0.08
	State of Hawaii	0.00	0.01	-	0.00	0.00	-	0.00	-	-	-	0.01
	Department of Education	0.02	0.00	-	-	0.00	-	-	-	-	-	0.02
	Agriculture	0.00	0.04	0.00	-	0.72	-	0.19	-	-	0.02	0.96
	Conservation	-	0.01	8.32	-	-	-	-	-	-	0.09	8.42
Waikakalaua Source Loading		0.08	0.60	8.32	0.07	0.88	-	0.19	-	-	0.10	10.24
Kipapa	CCH	0.09	2.27	-	-	0.55	0.02	0.00	-	-	0.00	2.93
	Military	-	0.00	-	-	0.46	-	0.00	0.00	-	0.00	0.46
	State of Hawaii	-	0.06	-	-	0.00	-	-	0.00	-	-	0.06
	Department of Education	0.07	0.04	-	-	0.00	-	-	-	-	-	0.11
	Agriculture	-	0.72	-	-	12.29	0.05	2.12	2.14	-	4.62	21.94
	Conservation	-	-	24.94	-	-	-	-	-	-	0.02	24.96
Kipapa Source Loading		0.16	3.09	24.94	-	13.30	0.07	2.12	2.14	-	4.64	50.46
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	0.92	-	0.03	0.00	-	0.01	0.96
	State of Hawaii	-	-	-	-	0.12	-	0.08	0.28	-	-	0.48
	Department of Education	0.03	-	-	-	-	-	-	-	-	-	0.03
	Agriculture	-	-	-	-	0.05	-	0.05	0.00	-	-	0.10
	Conservation	-	-	3.18	-	-	-	-	-	-	-	3.18
Upper Waikele Source Loading		0.03	-	3.18	-	1.09	-	0.15	0.29	-	0.01	4.75
Waianae Range	CCH	-	-	-	0.00	0.00	-	0.00	-	-	-	0.00
	State of Hawaii	-	0.01	-	-	0.00	-	0.00	0.14	-	-	0.16
	Agriculture	-	0.21	-	0.00	4.63	-	6.43	9.54	1.35	0.38	22.55
	Conservation	-	-	2.79	-	-	-	-	-	-	-	2.79
Waianae Range Source Loading		-	0.23	2.79	0.01	4.63	-	6.43	9.69	1.35	0.38	25.51
Lower Waikele	CCH	0.03	0.36	-	0.31	0.17	-	0.00	-	0.00	0.00	0.87
	Military	-	0.00	-	0.00	0.06	-	0.05	0.00	0.00	0.00	0.12
	State of Hawaii	0.00	0.07	-	0.00	0.13	-	0.31	2.16	0.54	0.00	3.22
	Department of Education	0.14	0.00	-	-	0.00	-	-	-	-	-	0.15
	Agriculture	-	0.14	-	0.00	0.47	-	0.71	1.34	1.24	0.80	4.70
Lower Waikele Source Loading		0.18	0.57	-	0.31	0.83	-	1.07	3.50	1.78	0.81	9.04
Total % Loading		**0.44**	**4.49**	**39.24**	**0.38**	**20.72**	**0.07**	**9.97**	**15.61**	**3.13**	**5.94**	**100.00**

Table 18. Relative wet season sediment existing loads by pollutant source category, subwatershed, and owner.

Wet Weather Sediment Seasonal Existing Loads (%)												
Subwatershed	Ownership	Commercial	Low-Medium Density Residential	Conservation	Golf Course	Open Space	Pasture	Fallow	Pineapple	Seed Corn	Truck Crop	Total % Loading
Waikakalaua	CCH	0.03	0.23	-	0.01	0.05	-	0.00	-	-	-	0.32
	Military	-	-	-	0.07	0.05	-	-	-	-	-	0.12
	State of Hawaii	0.00	0.00	-	0.00	0.00	-	0.00	-	-	-	0.00
	Department of Education	0.00	0.00	-	-	0.00	-	-	-	-	-	0.00
	Agriculture	0.00	0.03	0.00	-	0.58	-	0.16	-	-	0.01	0.78
	Conservation	-	0.00	2.21	-	-	-	-	-	-	0.02	2.24
Waikakalaua Source Loading		0.03	0.26	2.22	0.08	0.68	-	0.16	-	-	0.04	3.46
Kipapa	CCH	0.03	0.81	-	-	0.20	0.01	0.00	-	-	0.00	1.05
	Military	-	0.00	-	-	0.29	-	0.00	0.00	-	0.00	0.29
	State of Hawaii	-	0.02	-	-	0.00	-	-	0.00	-	-	0.02
	Department of Education	0.03	0.01	-	-	0.00	-	-	-	-	-	0.04
	Agriculture	-	0.67	-	-	11.43	0.05	1.97	1.99	-	4.30	20.40
	Conservation	-	-	5.82	-	-	-	-	-	-	0.00	5.83
Kipapa Source Loading		0.06	1.51	5.82	-	11.91	0.05	1.97	1.99	-	4.30	27.62
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	0.61	-	0.02	0.00	-	0.01	0.64
	State of Hawaii	-	-	-	-	0.26	-	0.16	0.61	-	-	1.03
	Department of Education	0.02	-	-	-	-	-	-	-	-	-	0.02
	Agriculture	-	-	-	-	0.42	-	0.40	0.00	-	-	0.82
	Conservation	-	-	1.64	-	-	-	-	-	-	-	1.64
Upper Waikele Source Loading		0.02	-	1.64	-	1.29	-	0.58	0.61	-	0.01	4.14
Waianae Range	CCH	-	-	-	0.12	0.00	-	0.00	-	-	-	0.12
	State of Hawaii	-	0.02	-	-	0.00	-	0.00	0.18	-	-	0.21
	Agriculture	-	0.38	-	0.01	8.19	-	11.37	16.86	2.38	0.67	39.86
	Conservation	-	-	1.42	-	-	-	-	-	-	-	1.42
Waianae Range Source Loading		-	0.40	1.42	0.13	8.19	-	11.37	17.05	2.38	0.67	41.61
Lower Waikele	CCH	0.02	0.16	-	0.13	0.07	-	0.00	-	0.00	0.00	0.38
	Military	-	0.00	-	0.00	0.15	-	0.11	0.00	0.00	0.01	0.27
	State of Hawaii	0.00	0.17	-	0.00	0.30	-	0.72	4.93	1.23	0.01	7.35
	Department of Education	0.05	0.00	-	-	0.00	-	-	-	-	-	0.05
	Agriculture	-	0.45	-	0.01	1.51	-	2.27	4.31	3.99	2.58	15.12
Lower Waikele Source Loading		0.07	0.77	-	0.14	2.04	-	3.10	9.24	5.22	2.60	23.17
Total % Loading		**0.17**	**2.95**	**11.10**	**0.35**	**24.10**	**0.05**	**17.17**	**28.89**	**7.60**	**7.61**	**100.00**

Table 19. Dry season total nitrogen existing loads by pollutant source category, subwatershed, and owner.

Dry Weather Total Nitrogen Seasonal Existing Loads (pounds per day)												
Subwatershed	Ownership	Commercial	Low-Medium Density Residential	Conservation	Golf Course	Open Space	Pasture	Fallow	Pineapple	Seed Corn	Truck Crop	Total Load
Waikakalaua	CCH	0.22	1.92	-	0.08	0.43	-	0.00	-	-	-	2.64
	Military	-	-	-	0.34	0.24	-	-	-	-	-	0.57
	State of Hawaii	0.00	0.02	-	0.00	0.01	-	0.00	-	-	-	0.04
	Department of Education	0.05	0.00	-	-	0.00	-	-	-	-	-	0.05
	Agriculture	0.00	0.06	0.00	-	1.30	-	0.35	-	-	0.03	1.75
	Conservation	-	0.01	5.14	-	-	-	-	-	-	0.05	5.20
Waikakalaua Source Loading		0.27	2.01	5.14	0.42	1.98	-	0.35	-	-	0.08	10.26
Kipapa	CCH	0.26	6.72	-	-	1.62	0.05	0.00	-	-	0.01	8.66
	Military	-	0.00	-	-	0.38	-	0.00	0.00	-	0.00	0.38
	State of Hawaii	-	0.14	-	-	0.00	-	-	0.00	-	-	0.14
	Department of Education	0.30	0.16	-	-	0.00	-	-	-	-	-	0.46
	Agriculture	-	0.75	-	-	12.81	0.05	2.21	2.23	-	4.82	22.87
	Conservation	-	-	18.44	-	-	-	-	-	-	0.01	18.45
Kipapa Source Loading		0.57	7.76	18.44	-	14.81	0.11	2.21	2.23	-	4.84	50.96
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	2.06	-	0.07	0.01	-	0.02	2.16
	State of Hawaii	-	-	-	-	0.33	-	0.21	0.78	-	-	1.33
	Department of Education	0.07	-	-	-	-	-	-	-	-	-	0.07
	Agriculture	-	-	-	-	0.58	-	0.55	0.00	-	-	1.13
	Conservation	-	-	1.21	-	-	-	-	-	-	-	1.21
Upper Waikele Source Loading		0.07	-	1.21	-	2.96	-	0.83	0.80	-	0.02	5.89
Waianae Range	CCH	-	-	-	0.35	0.00	-	0.00	-	-	-	0.35
	State of Hawaii	-	0.02	-	-	0.00	-	0.00	0.24	-	-	0.27
	Agriculture	-	0.37	-	0.01	7.97	-	11.06	16.41	2.32	0.65	38.79
	Conservation	-	-	1.01	-	-	-	-	-	-	-	1.01
Waianae Range Source Loading		-	0.39	1.01	0.36	7.97	-	11.07	16.65	2.32	0.65	40.41
Lower Waikele	CCH	0.11	1.14	-	0.97	0.53	-	0.01	-	0.00	0.00	2.75
	Military	-	0.00	-	0.00	0.18	-	0.13	0.00	0.00	0.01	0.32
	State of Hawaii	0.00	0.15	-	0.00	0.27	-	0.65	4.47	1.11	0.01	6.66
	Department of Education	0.55	0.01	-	-	0.01	-	-	-	-	-	0.57
	Agriculture	-	0.38	-	0.00	1.27	-	1.91	3.62	3.35	2.17	12.71
Lower Waikele Source Loading		0.67	1.68	-	0.98	2.25	-	2.69	8.09	4.47	2.19	23.01
Total Load		**1.58**	**11.84**	**25.79**	**1.76**	**29.97**	**0.11**	**17.15**	**27.77**	**6.79**	**7.78**	**130.53**

Table 20. Wet season total nitrogen existing loads by pollutant source category, subwatershed, and owner.

Wet Weather Total Nitrogen Seasonal Existing Loads (pounds per day)												
Subwatershed	**Ownership**	**Commercial**	**Low-Medium Density Residential**	**Conservation**	**Golf Course**	**Open Space**	**Pasture**	**Fallow**	**Pineapple**	**Seed Corn**	**Truck Crop**	**Total Load**
Waikakalaua	CCH	0.41	3.64	-	0.16	0.81	-	0.00	-	-	-	5.02
	Military	-	-	-	0.88	0.62	-	-	-	-	-	1.50
	State of Hawaii	0.00	0.05	-	0.00	0.02	-	0.00	-	-	-	0.07
	Department of Education	0.08	0.00	-	-	0.00	-	-	-	-	-	0.08
	Agriculture	0.00	0.12	0.01	-	2.41	-	0.65	-	-	0.05	3.23
	Conservation	-	0.01	6.95	-	-	-	-	-	-	0.07	7.04
Waikakalaua Source Loading		0.49	3.81	6.96	1.04	3.86	-	0.65	-	-	0.12	16.94
Kipapa	CCH	0.47	11.87	-	-	2.86	0.09	0.00	-	-	0.01	15.31
	Military	-	0.00	-	-	0.96	-	0.00	0.00	-	0.00	0.96
	State of Hawaii	-	0.26	-	-	0.00	-	-	0.00	-	-	0.26
	Department of Education	0.55	0.29	-	-	0.00	-	-	-	-	-	0.83
	Agriculture	-	0.94	-	-	16.12	0.07	2.77	2.81	-	6.07	28.78
	Conservation	-	-	22.95	-	-	-	-	-	-	0.02	22.97
Kipapa Source Loading		1.01	13.36	22.95	-	19.94	0.16	2.78	2.81	-	6.10	69.10
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	6.39	-	0.22	0.03	-	0.07	6.71
	State of Hawaii	-	-	-	-	0.61	-	0.39	1.45	-	-	2.45
	Department of Education	0.18	-	-	-	-	-	-	-	-	-	0.18
	Agriculture	-	-	-	-	1.26	-	1.20	0.01	-	-	2.47
	Conservation	-	-	1.83	-	-	-	-	-	-	-	1.83
Upper Waikele Source Loading		0.18	-	1.83	-	8.27	-	1.81	1.49	-	0.07	13.65
Waianae Range	CCH	-	-	-	1.22	0.00	-	0.00	-	-	-	1.22
	State of Hawaii	-	0.03	-	-	0.00	-	0.01	0.34	-	-	0.39
	Agriculture	-	0.43	-	0.01	9.39	-	13.03	19.34	2.73	0.77	45.70
	Conservation	-	-	1.44	-	-	-	-	-	-	-	1.44
Waianae Range Source Loading		-	0.47	1.44	1.23	9.39	-	13.04	19.68	2.73	0.77	48.75
Lower Waikele	CCH	0.22	2.24	-	1.91	1.03	-	0.01	-	0.00	0.00	5.41
	Military	-	0.00	-	0.01	0.61	-	0.44	0.00	0.00	0.03	1.09
	State of Hawaii	0.00	0.19	-	0.00	0.35	-	0.84	5.81	1.45	0.01	8.66
	Department of Education	0.96	0.02	-	-	0.01	-	-	-	-	-	0.99
	Agriculture	-	0.66	-	0.01	2.22	-	3.32	6.31	5.83	3.78	22.12
Lower Waikele Source Loading		1.18	3.11	-	1.92	4.22	-	4.62	12.12	7.28	3.82	38.27
Total Load		**2.86**	**20.75**	**33.18**	**4.20**	**45.68**	**0.16**	**22.90**	**36.09**	**10.02**	**10.87**	**186.72**

Table 21. Dry season sediment existing loads by pollutant source category, subwatershed, and owner.

Dry Weather Sediment Seasonal Existing Loads (tons per day)												
Subwatershed	Ownership	Commercial	Low-Medium Density Residential	Conservation	Golf Course	Open Space	Pasture	Fallow	Pineapple	Seed Corn	Truck Crop	Total Load
Waikakalaua	CCH	0.06	0.54	-	0.02	0.12	-	0.00	-	-	-	0.75
	Military	-	-	-	0.05	0.03	-	-	-	-	-	0.08
	State of Hawaii	0.00	0.01	-	0.00	0.00	-	0.00	-	-	-	0.01
	Department of Education	0.02	0.00	-	-	0.00	-	-	-	-	-	0.02
	Agriculture	0.00	0.04	0.00	-	0.72	-	0.19	-	-	0.02	0.96
	Conservation	-	0.01	8.32	-	-	-	-	-	-	0.09	8.42
Waikakalaua Source Loading		0.08	0.60	8.33	0.07	0.88	-	0.19	-	-	0.10	10.25
Kipapa	CCH	0.09	2.27	-	-	0.55	0.02	0.00	-	-	0.00	2.93
	Military	-	0.00	-	-	0.46	-	0.00	0.00	-	0.00	0.46
	State of Hawaii	-	0.06	-	-	0.00	-	-	0.00	-	-	0.06
	Department of Education	0.07	0.04	-	-	0.00	-	-	-	-	-	0.11
	Agriculture	-	0.72	-	-	12.30	0.05	2.12	2.14	-	4.63	21.95
	Conservation	-	-	24.95	-	-	-	-	-	-	0.02	24.96
Kipapa Source Loading		0.16	3.09	24.95	-	13.30	0.07	2.12	2.14	-	4.65	50.47
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	0.92	-	0.03	0.00	-	0.01	0.96
	State of Hawaii	-	-	-	-	0.12	-	0.08	0.28	-	-	0.48
	Department of Education	0.03	-	-	-	-	-	-	-	-	-	0.03
	Agriculture	-	-	-	-	0.05	-	0.05	0.00	-	-	0.10
	Conservation	-	-	3.19	-	-	-	-	-	-	-	3.19
Upper Waikele Source Loading		0.03	-	3.19	-	1.09	-	0.15	0.29	-	0.01	4.75
Waianae Range	CCH	-	-	-	0.00	0.00	-	0.00	-	-	-	0.00
	State of Hawaii	-	0.01	-	-	0.00	-	0.00	0.14	-	-	0.16
	Agriculture	-	0.21	-	0.00	4.63	-	6.43	9.54	1.35	0.38	22.56
	Conservation	-	-	2.79	-	-	-	-	-	-	-	2.79
Waianae Range Source Loading		-	0.23	2.79	0.01	4.63	-	6.44	9.69	1.35	0.38	25.52
Lower Waikele	CCH	0.03	0.36	-	0.31	0.17	-	0.00	-	0.00	0.00	0.87
	Military	-	0.00	-	0.00	0.07	-	0.05	0.00	0.00	0.00	0.12
	State of Hawaii	0.00	0.07	-	0.00	0.13	-	0.31	2.16	0.54	0.00	3.22
	Department of Education	0.14	0.00	-	-	0.00	-	-	-	-	-	0.15
	Agriculture	-	0.14	-	0.00	0.47	-	0.71	1.34	1.24	0.80	4.70
Lower Waikele Source Loading		0.18	0.57	-	0.31	0.83	-	1.07	3.50	1.78	0.81	9.05
Total Load		**0.44**	**4.49**	**39.25**	**0.38**	**20.73**	**0.07**	**9.97**	**15.61**	**3.13**	**5.94**	**100.03**

Table 22. Wet season sediment existing loads by pollutant source category, subwatershed, and owner.

Wet Weather Sediment Seasonal Existing Loads (tons per day)												
Subwatershed	Ownership	Commercial	Low-Medium Density Residential	Conservation	Golf Course	Open Space	Pasture	Fallow	Pineapple	Seed Corn	Truck Crop	Total Load
Waikakalaua	CCH	0.10	0.88	-	0.04	0.20	-	0.00	-	-	-	1.21
	Military	-	-	-	0.26	0.19	-	-	-	-	-	0.45
	State of Hawaii	0.00	0.01	-	0.00	0.00	-	0.00	-	-	-	0.01
	Department of Education	0.02	0.00	-	-	0.00	-	-	-	-	-	0.02
	Agriculture	0.00	0.11	0.01	-	2.20	-	0.60	-	-	0.05	2.96
	Conservation	-	0.01	8.46	-	-	-	-	-	-	0.09	8.56
Waikakalaua Source Loading		0.12	1.01	8.47	0.30	2.59	-	0.60	-	-	0.13	13.22
Kipapa	CCH	0.12	3.11	-	-	0.75	0.02	0.00	-	-	0.00	4.01
	Military	-	0.00	-	-	1.10	-	0.00	0.00	-	0.00	1.10
	State of Hawaii	-	0.06	-	-	0.00	-	-	0.00	-	-	0.06
	Department of Education	0.10	0.05	-	-	0.00	-	-	-	-	-	0.16
	Agriculture	-	2.55	-	-	43.65	0.19	7.51	7.60	-	16.42	77.92
	Conservation	-	-	22.25	-	-	-	-	-	-	0.01	22.26
Kipapa Source Loading		0.23	5.78	22.25	-	45.50	0.21	7.51	7.60	-	16.44	105.52
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	2.34	-	0.08	0.01	-	0.02	2.45
	State of Hawaii	-	-	-	-	0.98	-	0.62	2.32	-	-	3.93
	Department of Education	0.06	-	-	-	-	-	-	-	-	-	0.06
	Agriculture	-	-	-	-	1.59	-	1.51	0.01	-	-	3.12
	Conservation	-	-	6.25	-	-	-	-	-	-	-	6.25
Upper Waikele Source Loading		0.06	-	6.25	-	4.91	-	2.22	2.34	-	0.02	15.80
Waianae Range	CCH	-	-	-	0.46	0.00	-	0.00	-	-	-	0.46
	State of Hawaii	-	0.07	-	-	0.00	-	0.01	0.71	-	-	0.79
	Agriculture	-	1.45	-	0.03	31.27	-	43.42	64.42	9.11	2.56	152.25
	Conservation	-	-	5.43	-	-	-	-	-	-	-	5.43
Waianae Range Source Loading		-	1.52	5.43	0.49	31.27	-	43.44	65.12	9.11	2.56	158.93
Lower Waikele	CCH	0.06	0.60	-	0.51	0.28	-	0.00	-	0.00	0.00	1.46
	Military	-	0.00	-	0.01	0.58	-	0.42	0.00	0.00	0.03	1.04
	State of Hawaii	0.01	0.63	-	0.00	1.14	-	2.74	18.83	4.70	0.03	28.07
	Department of Education	0.18	0.00	-	-	0.00	-	-	-	-	-	0.19
	Agriculture	-	1.72	-	0.02	5.78	-	8.68	16.47	15.23	9.86	57.76
Lower Waikele Source Loading		0.25	2.95	-	0.54	7.79	-	11.83	35.30	19.93	9.92	88.52
Total Load		**0.66**	**11.26**	**42.39**	**1.34**	**92.06**	**0.21**	**65.60**	**110.36**	**29.04**	**29.08**	**381.99**

6 Pollutant Load Reductions and Prioritization

TMDL analyses used a watershed model that quantified allowable loads and estimated the reductions required to achieve WQS (EPA and DOH, 2019). The WQS and estimated load reductions for nonpoint sources that this plan will address are presented in Sections 6.1 and 6.2, respectively. The reductions are the decrease from the existing loads in Section 5.2, not the target or allowable load (represented by the load allocations in the TMDL).

6.1 Water Quality Standards

WQS include the beneficial uses of a waterbody as well as narrative or numeric criteria to protect those uses. The TMDL used numeric targets that were equal to the WQC and vary based on wet or dry season conditions. The numeric values included in the DOH WQS used in the TMDL and carried forward as criteria in this plan are presented in Table 23. Since turbidity is not a mass-based parameter, TSS is a surrogate to quantify loadings in both the TMDL and this implementation plan. The criteria values are the geometric mean dry and wet season criteria for total nitrogen and the 10 percent not to exceed wet season criteria for TSS. While all values are shown in Table 23, the criteria for compliance are shaded in grey. These values will be used for comparison with water quality measurements to determine progress towards and attainment of beneficial uses.

Table 23. Applicable water quality standards.

Parameter	Geometric Mean		10% exceedance value		2% exceedance value	
	Wet Season[1]	Dry Season[1]	Wet Season[1]	Dry Season[1]	Wet Season[1]	Dry Season[1]
Total Nitrogen (µg/L)	250	180	520	380	800	600
Total Suspended Solids (mg/L)	20	10	50	30	80	55

[1]The wet season is the period from November 1 to April 30 and the dry season is from May 1 to October 31.

6.2 Load Reductions to Achieve Water Quality Standards

To begin prioritization of management measures throughout the Waikele watershed, required load reductions were calculated for each land use grouping within each subwatershed. The wet and dry season load reductions were calculated using the existing loads (see Section 5.2) and the load allocations from the TMDL report (to achieve the total nitrogen geometric mean WQS and the 10 percent not to exceed WQS for sediment; EPA and DOH, 2019). The wet and dry season load reductions, in mass per day, were combined and transformed into annual required load reductions, in mass per year, based on the number of days in the wet and dry seasons (Table 24). The resulting required annual load reductions, by subwatershed and land use category, are illustrated in Figure 14 and Figure 15 for total nitrogen and sediment, respectively. These maps are high-level screening tools to visualize the areas estimated to need the greatest load reductions.

Tables were also developed to separate these total nitrogen and sediment results by season, ownership, and land use (Table 25 through Table 28). The table formatting is consistent with the tables presented in Section 5.2. This additional detail is a step closer to identifying where management measures could be implemented and the potential partners that can work collaboratively to make improvements.

Table 24. Annual required load reductions by subwatershed and land use grouping.

Subwatershed	Developed	Conservation	Open Space	Agriculture	Total
Total Nitrogen (pounds per year)					
Waikakalaua	1,031.64	1,905.28	1,142.93	189.47	4,269.32
Kipapa	3,560.66	6,527.85	5,473.26	3,346.57	18,908.33
Upper Waikele	39.94	477.90	1,749.69	784.26	3,051.80
Waianae Range	135.86	384.82	2,985.53	10,561.12	14,067.33
Lower Waikele	1,039.72	-	1,469.15	7,110.55	9,619.42
Sediment (tons per year)					
Waikakalaua	312.55	2,910.57	665.34	178.11	4,066.58
Kipapa	1,604.11	8,179.67	10,190.79	7,060.83	27,035.41
Upper Waikele	14.80	1,634.93	1,039.50	872.60	3,561.83
Waianae Range	302.66	1,425.45	6,308.03	23,930.29	31,966.43
Lower Waikele	686.12	-	1,641.60	14,581.20	16,908.92

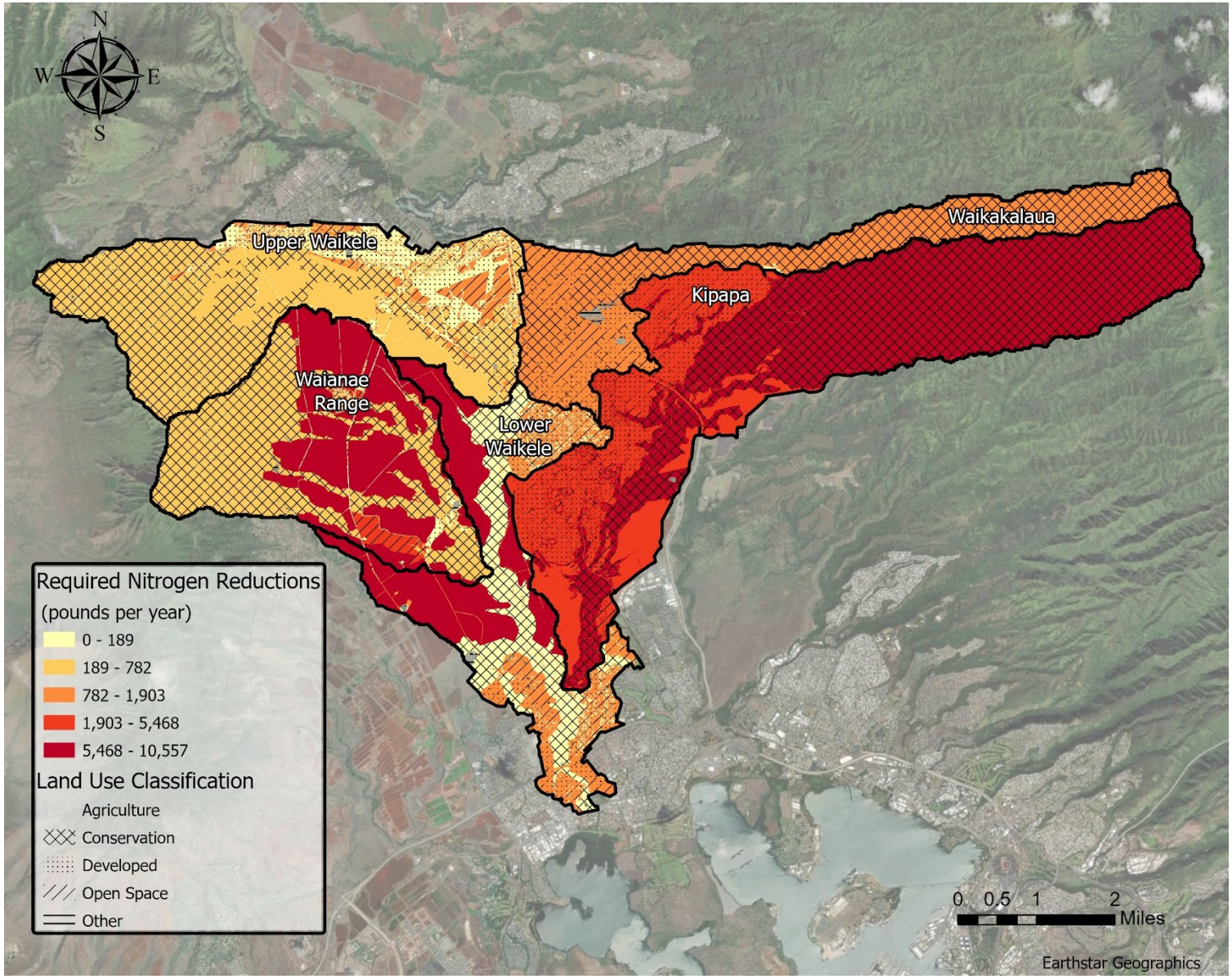


Figure 14. Required total nitrogen load reductions by subwatershed and land use category.

Table 25. Dry season total nitrogen load reductions by pollutant source category, subwatershed, and owner.

		Dry Weather Total Nitrogen Seasonal Load Reductions (pounds per day)										
Subwatershed	**Ownership**	**Commercial**	**Low-Medium Density Residential**	**Conservation**	**Golf Course**	**Open Space**	**Pasture**	**Fallow**	**Pineapple**	**Seed Corn**	**Truck Crop**	**Total Load**
Waikakalaua	CCH	0.19	1.72	-	0.08	0.38	-	0.00	-	-	-	2.37
	Military	-	-	-	0.30	0.21	-	-	-	-	-	0.52
	State of Hawaii	0.00	0.02	-	0.00	0.01	-	0.00	-	-	-	0.03
	Department of Education	0.05	0.00	-	-	0.00	-	-	-	-	-	0.05
	Agriculture	0.00	0.06	0.00	-	1.17	-	0.32	-	-	0.02	1.57
	Conservation	-	0.01	4.60	-	-	-	-	-	-	0.05	4.66
Waikakalaua Required Reductions		0.24	1.80	4.61	0.38	1.78	-	0.32	-	-	0.07	9.20
Kipapa	CCH	0.24	6.03	-	-	1.45	0.05	0.00	-	-	0.01	7.77
	Military	-	0.00	-	-	0.34	-	0.00	0.00	-	0.00	0.34
	State of Hawaii	-	0.12	-	-	0.00	-	-	0.00	-	-	0.12
	Department of Education	0.27	0.14	-	-	0.00	-	-	-	-	-	0.41
	Agriculture	-	0.67	-	-	11.49	0.05	1.98	2.00	-	4.32	20.51
	Conservation	-	-	16.54	-	-	-	-	-	-	0.01	16.55
Kipapa Required Reductions		0.51	6.96	16.54	-	13.28	0.09	1.98	2.00	-	4.34	45.70
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	1.84	-	0.06	0.01	-	0.02	1.94
	State of Hawaii	-	-	-	-	0.30	-	0.19	0.70	-	-	1.19
	Department of Education	0.07	-	-	-	-	-	-	-	-	-	0.07
	Agriculture	-	-	-	-	0.52	-	0.49	0.00	-	-	1.01
	Conservation	-	-	1.08	-	-	-	-	-	-	-	1.08
Upper Waikele Required Reductions		0.07	-	1.08	-	2.66	-	0.74	0.72	-	0.02	5.28
Waianae Range	CCH	-	-	-	0.31	0.00	-	0.00	-	-	-	0.31
	State of Hawaii	-	0.02	-	-	0.00	-	0.00	0.21	-	-	0.24
	Agriculture	-	0.33	-	0.01	7.14	-	9.92	14.72	2.08	0.58	34.78
	Conservation	-	-	0.90	-	-	-	-	-	-	-	0.90
Waianae Range Required Reductions		-	0.35	0.90	0.32	7.14	-	9.92	14.93	2.08	0.58	36.23
Lower Waikele	CCH	0.10	1.02	-	0.87	0.47	-	0.00	-	0.00	0.00	2.47
	Military	-	0.00	-	0.00	0.16	-	0.12	0.00	0.00	0.01	0.29
	State of Hawaii	0.00	0.13	-	0.00	0.24	-	0.58	4.00	1.00	0.01	5.97
	Department of Education	0.50	0.01	-	-	0.00	-	-	-	-	-	0.51
	Agriculture	-	0.34	-	0.00	1.14	-	1.71	3.25	3.00	1.95	11.39
Lower Waikele Required Reductions		0.60	1.51	-	0.88	2.02	-	2.41	7.25	4.00	1.96	20.64
Total Load		**1.41**	**10.62**	**23.13**	**1.58**	**26.88**	**0.09**	**15.38**	**24.90**	**6.08**	**6.98**	**117.05**

Table 26. Wet season total nitrogen load reductions by pollutant source category, subwatershed, and owner.

Wet Weather Total Nitrogen Seasonal Load Reductions (pounds per day)												
Subwatershed	Ownership	Commercial	Low-Medium Density Residential	Conservation	Golf Course	Open Space	Pasture	Fallow	Pineapple	Seed Corn	Truck Crop	Total Load
Waikakalaua	CCH	0.34	3.05	-	0.13	0.68	-	0.00	-	-	-	4.21
	Military	-	-	-	0.74	0.52	-	-	-	-	-	1.26
	State of Hawaii	0.00	0.04	-	0.00	0.02	-	0.00	-	-	-	0.06
	Department of Education	0.07	0.00	-	-	0.00	-	-	-	-	-	0.07
	Agriculture	0.00	0.10	0.01	-	2.02	-	0.55	-	-	0.04	2.71
	Conservation	-	0.01	5.83	-	-	-	-	-	-	0.06	5.90
Waikakalaua Required Reductions		0.41	3.20	5.83	0.87	3.23	-	0.55	-	-	0.10	14.20
Kipapa	CCH	0.39	9.95	-	-	2.40	0.07	0.00	-	-	0.01	12.83
	Military	-	0.00	-	-	0.80	-	0.00	0.00	-	0.00	0.81
	State of Hawaii	-	0.22	-	-	0.00	-	-	0.00	-	-	0.22
	Department of Education	0.46	0.24	-	-	0.00	-	-	-	-	-	0.70
	Agriculture	-	0.79	-	-	13.51	0.06	2.33	2.35	-	5.08	24.12
	Conservation	-	-	19.23	-	-	-	-	-	-	0.01	19.25
Kipapa Required Reductions		0.85	11.19	19.23	-	16.71	0.13	2.33	2.35	-	5.11	57.91
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	5.36	-	0.19	0.03	-	0.06	5.63
	State of Hawaii	-	-	-	-	0.51	-	0.33	1.21	-	-	2.05
	Department of Education	0.15	-	-	-	-	-	-	-	-	-	0.15
	Agriculture	-	-	-	-	1.06	-	1.01	0.01	-	-	2.07
	Conservation	-	-	1.54	-	-	-	-	-	-	-	1.54
Upper Waikele Required Reductions		0.15	-	1.54	-	6.93	-	1.52	1.25	-	0.06	11.44
Waianae Range	CCH	-	-	-	1.02	0.00	-	0.00	-	-	-	1.02
	State of Hawaii	-	0.03	-	-	0.00	-	0.01	0.29	-	-	0.32
	Agriculture	-	0.36	-	0.01	7.87	-	10.92	16.20	2.29	0.64	38.30
	Conservation	-	-	1.21	-	-	-	-	-	-	-	1.21
Waianae Range Required Reductions		-	0.39	1.21	1.03	7.87	-	10.93	16.49	2.29	0.64	40.85
Lower Waikele	CCH	0.18	1.88	-	1.60	0.87	-	0.01	-	0.00	0.00	4.53
	Military	-	0.00	-	0.01	0.51	-	0.37	0.00	0.00	0.03	0.92
	State of Hawaii	0.00	0.16	-	0.00	0.29	-	0.71	4.87	1.21	0.01	7.26
	Department of Education	0.80	0.02	-	-	0.01	-	-	-	-	-	0.83
	Agriculture	-	0.55	-	0.01	1.86	-	2.78	5.29	4.89	3.16	18.54
Lower Waikele Required Reductions		0.99	2.61	-	1.61	3.54	-	3.87	10.16	6.10	3.20	32.07
Total Load		**2.40**	**17.39**	**27.81**	**3.52**	**38.28**	**0.13**	**19.19**	**30.25**	**8.40**	**9.11**	**156.47**

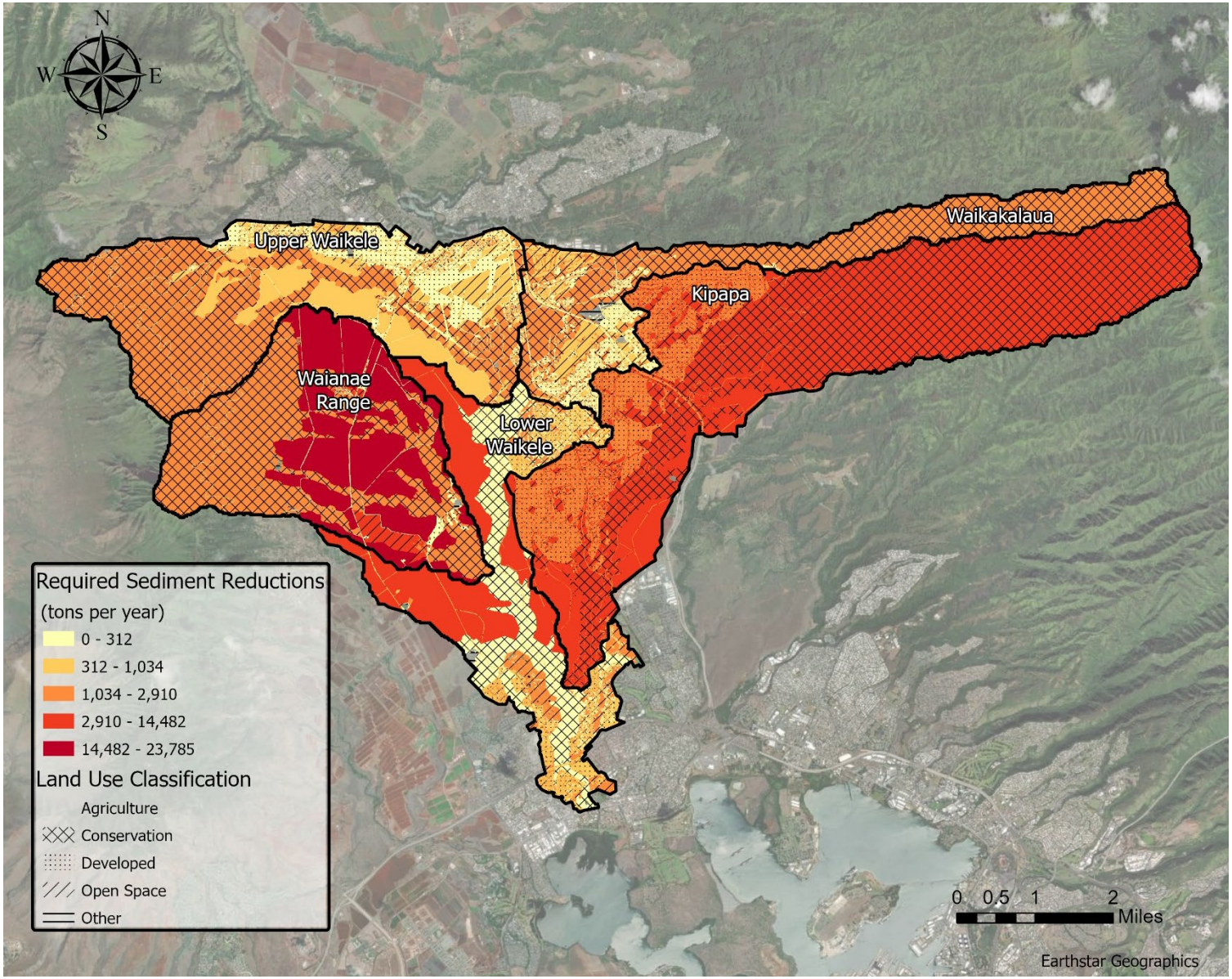


Figure 15. Required sediment load reductions by subwatershed and land use category.

Table 27. Dry season sediment load reductions by pollutant source category, subwatershed, and owner.

Dry Weather Sediment Seasonal Load Reductions (tons per day)												
Subwatershed	Ownership	Commercial	Low-Medium Density Residential	Conservation	Golf Course	Open Space	Pasture	Fallow	Pineapple	Seed Corn	Truck Crop	Total Load
Waikakalaua	CCH	0.06	0.52	-	0.02	0.12	-	0.00	-	-	-	0.71
	Military	-	-	-	0.04	0.03	-	-	-	-	-	0.07
	State of Hawaii	0.00	0.01	-	0.00	0.00	-	0.00	-	-	-	0.01
	Department of Education	0.02	0.00	-	-	0.00	-	-	-	-	-	0.02
	Agriculture	0.00	0.03	0.00	-	0.68	-	0.18	-	-	0.01	0.92
	Conservation	-	0.01	7.91	-	-	-	-	-	-	0.08	8.00
Waikakalaua Required Reductions		0.08	0.57	7.91	0.07	0.83	-	0.18	-	-	0.10	9.73
Kipapa	CCH	0.09	2.16	-	-	0.52	0.02	0.00	-	-	0.00	2.78
	Military	-	0.00	-	-	0.43	-	0.00	0.00	-	0.00	0.43
	State of Hawaii	-	0.06	-	-	0.00	-	-	0.00	-	-	0.06
	Department of Education	0.07	0.04	-	-	0.00	-	-	-	-	-	0.10
	Agriculture	-	0.68	-	-	11.68	0.05	2.01	2.03	-	4.39	20.85
	Conservation	-	-	23.69	-	-	-	-	-	-	0.02	23.71
Kipapa Required Reductions		0.15	2.94	23.69	-	12.63	0.07	2.01	2.03	-	4.41	47.94
Required Reductions	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	0.87	-	0.03	0.00	-	0.01	0.92
	State of Hawaii	-	-	-	-	0.11	-	0.07	0.27	-	-	0.45
	Department of Education	0.02	-	-	-	-	-	-	-	-	-	0.02
	Agriculture	-	-	-	-	0.05	-	0.04	0.00	-	-	0.09
	Conservation	-	-	3.03	-	-	-	-	-	-	-	3.03
Upper Waikele Required Reductions		0.02	-	3.03	-	1.03	-	0.15	0.27	-	0.01	4.51
Waianae Range	CCH	-	-	-	0.00	0.00	-	0.00	-	-	-	0.00
	State of Hawaii	-	0.01	-	-	0.00	-	0.00	0.14	-	-	0.15
	Agriculture	-	0.20	-	0.00	4.40	-	6.11	9.07	1.28	0.36	21.43
	Conservation	-	-	2.65	-	-	-	-	-	-	-	2.65
Waianae Range Required Reductions		-	0.22	2.65	0.01	4.40	-	6.11	9.20	1.28	0.36	24.24
Lower Waikele	CCH	0.03	0.34	-	0.29	0.16	-	0.00	-	0.00	0.00	0.82
	Military	-	0.00	-	0.00	0.06	-	0.04	0.00	0.00	0.00	0.11
	State of Hawaii	0.00	0.07	-	0.00	0.12	-	0.30	2.05	0.51	0.00	3.06
	Department of Education	0.14	0.00	-	-	0.00	-	-	-	-	-	0.14
	Agriculture	-	0.13	-	0.00	0.45	-	0.67	1.27	1.18	0.76	4.46
Lower Waikele Required Reductions		0.17	0.54	-	0.29	0.79	-	1.01	3.32	1.69	0.77	8.59
Total Load		**0.42**	**4.27**	**37.28**	**0.36**	**19.69**	**0.07**	**9.47**	**14.83**	**2.97**	**5.65**	**95.01**

Table 28. Wet season sediment load reductions by pollutant source category, subwatershed, and owner.

Wet Weather Sediment Seasonal Load Reductions (tons per day)												
Subwatershed	**Ownership**	**Commercial**	**Low-Medium Density Residential**	**Conservation**	**Golf Course**	**Open Space**	**Pasture**	**Fallow**	**Pineapple**	**Seed Corn**	**Truck Crop**	**Total Load**
Waikakalaua	CCH	0.09	0.83	-	0.04	0.19	-	0.00	-	-	-	1.15
	Military	-	-	-	0.25	0.18	-	-	-	-	-	0.43
	State of Hawaii	0.00	0.01	-	0.00	0.00	-	0.00	-	-	-	0.01
	Department of Education	0.02	0.00	-	-	0.00	-	-	-	-	-	0.02
	Agriculture	0.00	0.10	0.01	-	2.09	-	0.57	-	-	0.04	2.81
	Conservation	-	0.01	8.03	-	-	-	-	-	-	0.08	8.13
Waikakalaua Required Reductions		0.11	0.96	8.04	0.29	2.46	-	0.57	-	-	0.13	12.55
Kipapa	CCH	0.12	2.96	-	-	0.71	0.02	0.00	-	-	0.00	3.81
	Military	-	0.00	-	-	1.04	-	0.00	0.00	-	0.00	1.05
	State of Hawaii	-	0.06	-	-	0.00	-	-	0.00	-	-	0.06
	Department of Education	0.10	0.05	-	-	0.00	-	-	-	-	-	0.15
	Agriculture	-	2.42	-	-	41.45	0.18	7.13	7.21	-	15.60	73.99
	Conservation	-	-	21.13	-	-	-	-	-	-	0.01	21.14
Kipapa Required Reductions		0.21	5.49	21.13	-	43.21	0.20	7.14	7.22	-	15.61	100.20
Upper Waikele	CCH	-	-	-	-	-	-	-	-	-	-	-
	Military	-	-	-	-	2.22	-	0.08	0.01	-	0.02	2.33
	State of Hawaii	-	-	-	-	0.93	-	0.59	2.20	-	-	3.73
	Department of Education	0.06	-	-	-	-	-	-	-	-	-	0.06
	Agriculture	-	-	-	-	1.51	-	1.44	0.01	-	-	2.96
	Conservation	-	-	5.93	-	-	-	-	-	-	-	5.93
Upper Waikele Required Reductions		0.06	-	5.93	-	4.66	-	2.11	2.22	-	0.02	15.01
Waianae Range	CCH	-	-	-	0.44	0.00	-	0.00	-	-	-	0.44
	State of Hawaii	-	0.07	-	-	0.00	-	0.01	0.67	-	-	0.75
	Agriculture	-	1.37	-	0.03	29.69	-	41.23	61.17	8.65	2.43	144.58
	Conservation	-	-	5.16	-	-	-	-	-	-	-	5.16
Waianae Range Required Reductions		-	1.44	5.16	0.46	29.69	-	41.25	61.84	8.65	2.43	150.92
Lower Waikele	CCH	0.06	0.57	-	0.49	0.26	-	0.00	-	0.00	0.00	1.39
	Military	-	0.00	-	0.01	0.55	-	0.40	0.00	0.00	0.03	0.99
	State of Hawaii	0.01	0.60	-	0.00	1.08	-	2.60	17.88	4.46	0.03	26.66
	Department of Education	0.18	0.00	-	-	0.00	-	-	-	-	-	0.18
	Agriculture	-	1.63	-	0.02	5.49	-	8.24	15.64	14.46	9.36	54.85
Lower Waikele Required Reductions		0.24	2.80	-	0.52	7.39	-	11.24	33.52	18.92	9.42	84.06
Total Load		**0.62**	**10.69**	**40.26**	**1.27**	**87.42**	**0.20**	**62.29**	**104.80**	**27.57**	**27.61**	**362.74**

7 Pollutant Control Practices

Overall, the goals and management objectives for Waikele (Table 1) focus on reduced watershed loading from nonpoint sources and improved stream conditions. Implementation of management measures is needed to achieve these goals. Management measures are defined as "economically achievable measures for control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives" by the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) and HAR 11-56-1. There are many different management measures that can be considered, which are described in EPA's *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (EPA 840-B-92-002, 1993). A more detailed guidance for each CZARA category of nonpoint source pollution can be found in EPA's *National Management Measures to Control Nonpoint Source Pollution* series for agriculture, urban areas, forestry, hydromodifications, and wetlands and riparian areas.

This section identifies a suite of the potential BMPs that can be implemented to control total nitrogen and sediment loads (see Table 29). These BMPs were identified based on experience with past projects implemented in and around Oahu and overall applicability to the watershed sources. They are not inclusive of all management measures that can be implemented to reduce total nitrogen and sediment loads; rather, they represent a subset of possible BMPs relevant to the land uses and conditions present in the watershed.

STEPL is a spreadsheet-based tool that uses simple algorithms to calculate current pollutant loads from a variety of land use types and estimated load reductions associated with implementation of BMPs. Loads can be calculated at different geographic scales, from subwatersheds to individual field levels, and across diverse land use types (e.g., urban, cropland, forest). The STEPL application for the Waikele watershed is described in Appendix B.

The BMPs identified in Table 29 can also be represented by some loading analysis tools to estimate load reductions. For the Waikele Watershed Plan, the Spreadsheet Tool for Estimating Pollutant Loads (STEPL) was used to estimate total nitrogen and sediment existing loads and load reductions associated with implementation of the various BMPs. The existing loads were compared with the TMDL existing loads to ensure STEPL was representing the system similar to the more sophisticated TMDL model (Appendix B).[3]

7.1 Prioritization for Implementation Activity

As illustrated in Figure 14 and Figure 15 above (recreated in Figure 16 on the next page), the highest load reductions are needed in the upper portions of the watershed. Many of these lands are in agricultural and

[3] As noted in Appendix B, STEPL also has a specific list of BMPs that are available to model water quality improvements. In practice, landowners may install BMPs that are not on the "menu" of BMPs that were modeled in STEPL but are also effective in reducing pollutant loads. Appendix D includes an expanded list of BMPs that may be effective in reducing nitrogen and sediment loads in the Waikele watershed.

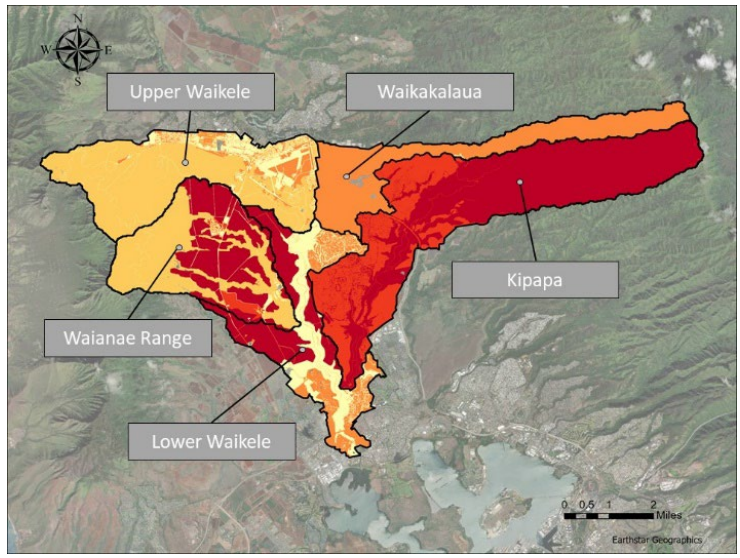
conservation areas, but due to the steep slopes and high annual precipitation, these areas can be significant sources of pollutants. This is supported by Figure 10 through Figure 13 and the inset boxes in Section 5.1 for each land use category. In the agricultural areas, pineapple crops appear to be the largest pollutant source. In wet weather, agriculture is by far the largest contributor of sediment (see Table 18). And while conservation areas would normally be associated with less disturbed areas with lower pollutant loading rates, the large land areas and steep slopes are a significant source. Geographically, Section 5 (specifically Table 15 through Table 22) shows that the Kipapa and Waianae Range are the largest sources of pollutants, followed by the Lower Waikele.

These areas, particularly the subwatersheds of Kipapa and Waianae Range, represent the highest priority locations for implementation of this watershed plan. By focusing implementation activities in these areas, the greatest pollutant reductions can be achieved.

The prioritization can take several forms:

- Outreach efforts would focus on landowners in these higher priority areas.
- Funding awards by DOH and other entities would prioritize projects in the high priority areas. For example, DOH could preferentially select Section 319 project applications that address these areas.
- BMP selection would target the most cost-effective practices for achieving reductions in these priority areas.

Nitrogen



Sediment

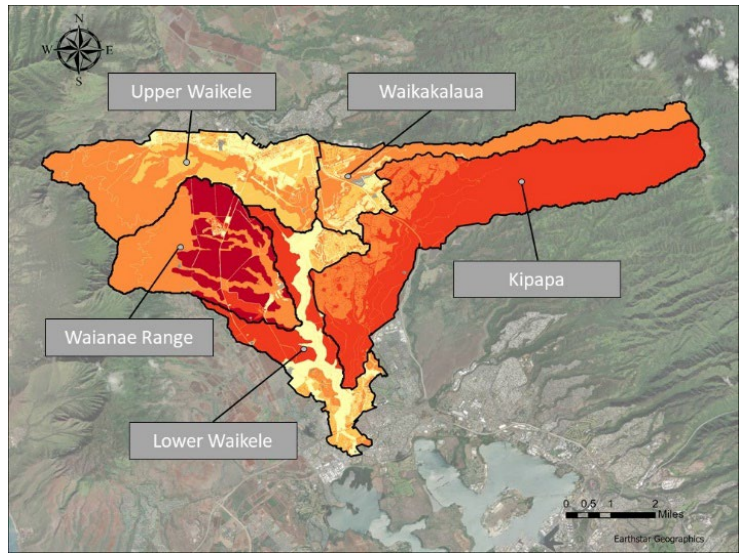


Figure 16. Required load reductions by subwatershed.

Implementation in the other areas of the Waikele watershed would also proceed as feasible, but initial efforts should be focused on the highest priority areas. Lower priority areas could be opportunistic (e.g., a large landowner that has property in both higher and lower priority areas) or could be addressed in the later stages of implementation. See Section 8.4 for more information about the overall schedule for implementing this watershed plan.

7.2 Available Best Management Practices

The BMPs in Table 29 were identified as among the most appropriate to achieve the necessary nitrogen and sediment reductions. Agricultural management measures focus on reducing nutrient runoff and soil erosion from crop lands. In addition, land with heavy impacts from animals, such as cattle, horses, or pigs, must also be managed to reduce nutrient and sediment delivery to streams. Similarly, in conservation areas, the goal of management measures is to slow or prevent soil erosion. Developed areas also require considerable nitrogen load reductions, specifically in the Kipapa subwatershed; therefore, green infrastructure or low impact development BMPs can be useful. Potential implementation projects featuring these BMPs are described in more detail in Section 8.1.

Table 29. Summary of potential best management practices applicable in the Waikele watershed.

	Land Use Applicability			
Management Practice	Agriculture	Conservation	Developed/ Light Urban	Open Space
1. Bioretention Cell (Rain Garden)			●	●
2. Channel Maintenance and Restoration	●	●	●	●
3. Constructed Wetlands	●	●	●	●
4. Cover Crop	●			
5. Critical Area Planting	●	●	●	●
6. Feral Ungulate Fencing		●		
7. Fertilizer Management Plan	●			●
8. Field Border	●			
9. Filter Strip	●		●	●
10. Grass Swale	●		●	●
11. Grazing Management System	●			
12. Livestock Rotation	●			
13. Riparian Forest Buffers	●	●	●	●
14. Riparian Herbaceous Cover	●	●	●	●

	Land Use Applicability			
Management Practice	Agriculture	Conservation	Developed/ Light Urban	Open Space
15. Sediment Basin	●		●	●
16. Sediment Traps	●		●	●
17. Terrace	●	●		●
18. Tree/Shrub Establishment	●	●	●	●
19. Vegetative Barrier	●			

As noted above, implementation of this plan is not limited these BMPs. Appendix D includes an expanded list of BMPs that also may be appropriate to specific sites and circumstances in the Waikele watershed. Because this plan includes modeled load reductions only for the 19 BMPs in Table 29, load reductions for implementation projects that include other BMPs will need to be estimated independently. Note, however, that the expanded list in Appendix D includes a number of practices that are similar in function and structure to those in Table 29 and might be expected to achieve similar load reductions. For instance, Appendix D includes grassed waterway, which is applicable to agricultural land uses but is very similar in structure and function to the grass swale practice listed in Table 29.

The following BMP fact sheets supplement the table above. These BMP fact sheets include the applicable land use(s), a brief explanation, costs (if available), BMP name used in STEPL, associated conservation practice standard code in the NRCS Field Office Technical Guide (FOTG; if available), the name of the CZARA management measure associated with the BMP (if applicable), and STEPL-estimated removal efficiencies by land use for nitrogen and sediment (if applicable; Appendix B). BMP cost data were gathered from the USDA NRCS Fiscal Year 2021 Hawaii Practice Scenario spreadsheets.

1. Bioretention Cell (Rain Garden)

☐ Agriculture ☐ Conservation
☑ Developed/Light Urban ☑ Open Space

Depression consisting of native plant species and soil mixtures that receives stormwater flow and infiltrates to treat pollutants.

Cost: Not determined

STEPL BMP Name: Developed – LID/Bioretention (43% removal); Open Space – Bioretention Facility (63% removal)

NRCS FOTG: N/A

CZARA Management Measure: Vegetated Treatment Systems

Nitrogen

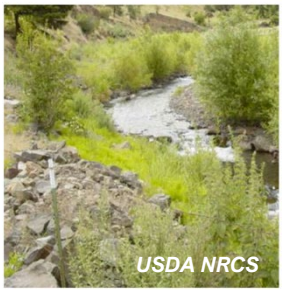
Removal Efficiency: **varies**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)*	Open Space
W1 - Waikakalaua	n/a	n/a	3.01	0.59
W2 - Kipapa	n/a	n/a	3.01	0.59
W3 - Upper Waikele	n/a	n/a	3.08	0.59
W4 - Waianae Range	n/a	n/a	2.50	0.59
W5 - Lower Waikele	n/a	n/a	2.50	0.59

Sediment

Removal Efficiency: **n/a**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)*	Open Space
W1 - Waikakalaua	n/a	n/a	0	0
W2 - Kipapa	n/a	n/a	0	0
W3 - Upper Waikele	n/a	n/a	0	0
W4 - Waianae Range	n/a	n/a	0	0
W5 - Lower Waikele	n/a	n/a	0	0

**Note: Developed BMPs required an estimate of percent impervious. 33% was used for the unit-area loading rate calculations.*

2. Channel Maintenance and Restoration



☑ Agriculture ☑ Conservation
☑ Developed/Light Urban ☑ Open Space

Practices used to control sediment and plant pollution into waterways during earthwork such as stream bank stabilization or habitat enhancement. Examples include floating booms and silt curtains extended across river or stream banks downstream of work.

Cost: Not determined

STEPL BMP Name: Streambank Protection without Fencing

NRCS FOTG: N/A

CZARA Management Measures: Streambank and Shoreline Erosion, Streamside Management Areas

Nitrogen

Removal Efficiency: **15%**

	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	n/a	n/a	1.05	0.90
W2 - Kipapa	n/a	n/a	1.05	2.65
W3 - Upper Waikele	n/a	n/a	1.07	0.41
W4 - Waianae Range	n/a	n/a	0.87	2.44
W5 - Lower Waikele	n/a	n/a	0.87	0.38

Sediment

Removal Efficiency: **57.5%**

	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	n/a	n/a	0.10	0.38
W2 - Kipapa	n/a	n/a	0.10	1.26
W3 - Upper Waikele	n/a	n/a	0.10	0.27
W4 - Waianae Range	n/a	n/a	0.08	1.44
W5 - Lower Waikele	n/a	n/a	0.08	0.20

3. Constructed Wetlands

☑ Agriculture
☑ Conservation
☑ Developed/Light Urban
☑ Open Space

Creation of an artificial wetland ecosystem to improve the quality of stormwater runoff or other water flows. A constructed wetland provides biological treatment in areas where wetland function can be created or enhanced. Although the associated STEPL practice is specific to agricultural land uses, constructed wetlands also can be used to treat stormwater runoff and other contaminated flows from urban areas and other land uses. The practice involves establishment of inlet and outlet control structures for an impoundment designed to accumulate settleable solids, decayed plant matter, and microbial biomass and support propagation of hydrophytic vegetation.

Cost: $4,743.39/Acre (Scenario #1: Wetland Creation,* Wildlife Pond)

STEPL BMP Name: Wetland Detention

NRCS FOTG: #656 (https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025770.pdf)*

CZARA Management Measure: Vegetated Treatment Systems

Nitrogen

Removal Efficiency: **20%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.78	n/a	n/a	n/a
W2 - Kipapa	3.84	n/a	n/a	n/a
W3 - Upper Waikele	0.84	n/a	n/a	n/a
W4 - Waianae Range	4.71	n/a	n/a	n/a
W5 - Lower Waikele	3.58	n/a	n/a	n/a

Sediment

Removal Efficiency: **77.5%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.23	n/a	n/a	n/a
W2 - Kipapa	1.76	n/a	n/a	n/a
W3 - Upper Waikele	0.52	n/a	n/a	n/a
W4 - Waianae Range	2.75	n/a	n/a	n/a
W5 - Lower Waikele	2.72	n/a	n/a	n/a

**Note: NRCS has not adopted a conservation practice standard for constructed wetlands specific to the Pacific Islands Area (PIA). This fact sheet lists costs for the related PIA practice standard for Wetland Creation (Conservation Practice Standard Code 658) but links to the national standard for Constructed Wetlands (Code 656). Other related PIA practices include Wetland Restoration (Code 657) and Wetland Enhancement (Code 659).*

4. Cover Crop

☑ Agriculture ☐ Conservation
☐ Developed/Light Urban ☐ Open Space

Crops including grasses, legumes, and forbs for seasonal cover and other conservation purposes.

Cost: $207.89/Acre (Scenario #11: Pac. Island Area Cover Crop)

STEPL BMP Name: Cover Crop 2 (Group A Traditional Normal Planting Time) (High Till only for TP and Sediment)

NRCS FOTG: #340 (https://efotg.sc.egov.usda.gov/api/CPSFile/6449/340_PI_CPS_Cover_Crop_2016)

CZARA Management Measure: Erosion and Sediment Control

Nitrogen

Removal Efficiency: **19.6%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.37	n/a	n/a	n/a
W2 - Kipapa	0.77	n/a	n/a	n/a
W3 - Upper Waikele	0.38	n/a	n/a	n/a
W4 - Waianae Range	0.88	n/a	n/a	n/a
W5 - Lower Waikele	0.74	n/a	n/a	n/a

Sediment

Removal Efficiency: **10%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.03	n/a	n/a	n/a
W2 - Kipapa	0.23	n/a	n/a	n/a
W3 - Upper Waikele	0.07	n/a	n/a	n/a
W4 - Waianae Range	0.35	n/a	n/a	n/a
W5 - Lower Waikele	0.35	n/a	n/a	n/a

5. Critical Area Planting

☑ Agriculture ☑ Conservation

☑ Developed/Light Urban ☑ Open Space

Establishment of permanent vegetation in areas with heavy erosion problems. Particularly useful for areas that need stabilization before/after flood events.

Cost: $1,041.05/Acre (Scenario #17: Pacific Island Critical Area Planting)

STEPL BMP Name: Critical Area Planting

NRCS FOTG: #342 (https://efotg.sc.egov.usda.gov/api/CPSFile/6452/342_PI_CPS_Critical_Area_Planting_2017)

CZARA Management Measures: Erosion and Sediment Control, Revegetation of Disturbed Areas, Restoration of Wetlands and Riparian Areas

Nitrogen

Removal Efficiency: **17.5%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.53	0.61	1.22	0.72
W2 - Kipapa	2.19	0.96	1.22	2.00
W3 - Upper Waikele	0.56	0.26	1.25	0.36
W4 - Waianae Range	2.66	0.70	1.02	1.85
W5 - Lower Waikele	2.05	n/a	1.02	0.34

Sediment

Removal Efficiency: **42%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.12	0.22	0.07	0.28
W2 - Kipapa	0.95	0.39	0.07	0.92
W3 - Upper Waikele	0.28	0.08	0.07	0.20
W4 - Waianae Range	1.49	0.33	0.06	1.05
W5 - Lower Waikele	1.47	n/a	0.06	0.14

6. Feral Ungulate Fencing

☐ Agriculture ☑ Conservation
☐ Developed/Light Urban ☐ Open Space

A structural conservation practice that prevents movement of ungulates across a given boundary. Within areas impacted by feral ungulate presence, fences prevent their movement into the forested lands. Ungulate fencing prevents direct contact of fecal matter with waterways, allows for restoration of vegetation, and reduces bacteria and nitrogen loadings and sediment input into waterways.

This practice supports pollutant load reductions in the forested areas that are fenced but leaves other parts of the watershed vulnerable. To avoid simply relocating this sediment and nutrient pollution source (excluded ungulates) to other areas of the watershed, it may be necessary to combine fencing with feral ungulate removal.

Cost: $15.45/Foot (Scenario #5: Woven Wire (8 ft tall))

STEPL BMP Name: Livestock Exclusion Fencing

NRCS FOTG: #382 (https://efotg.sc.egov.usda.gov/api/CPSFile/6507/382_PI_CPS_Fence_2018)

Nitrogen

Removal Efficiency: **20.3%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	n/a	0.85	n/a	n/a
W2 - Kipapa	n/a	1.36	n/a	n/a
W3 - Upper Waikele	n/a	0.32	n/a	n/a
W4 - Waianae Range	n/a	0.98	n/a	n/a
W5 - Lower Waikele	n/a	n/a	n/a	n/a

Sediment

Removal Efficiency: **62%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	n/a	0.33	n/a	n/a
W2 - Kipapa	n/a	0.58	n/a	n/a
W3 - Upper Waikele	n/a	0.12	n/a	n/a
W4 - Waianae Range	n/a	0.49	n/a	n/a
W5 - Lower Waikele	n/a	n/a	n/a	n/a

7. Fertilizer Management Plan

☑ Agriculture ☐ Conservation
☐ Developed/Light Urban ☑ Open Space

A conservation practice recommended to be prepared for any activities where fertilizers are actively applied or stored and present the potential for introduction into the environment. Objective is to provide only amount of fertilizer needed to minimize loss and export to receiving waters.

Cost: $20.01/Acre (Scenario #4: Basic NM with Manure and/or Compost (Non-Organic/Organic))

STEPL BMP Name: Nutrient Management 1 (Determined Rate)

NRCS FOTG: #590 (https://efotg.sc.egov.usda.gov/api/CPSFile/26941/590_PI_CPS_Nutrient_Management_2020)

CZARA Management Measure: Nutrient Management

Nitrogen

Removal Efficiency: **15.4%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.25	n/a	n/a	0.14
W2 - Kipapa	0.25	n/a	n/a	0.14
W3 - Upper Waikele	0.25	n/a	n/a	0.14
W4 - Waianae Range	0.25	n/a	n/a	0.14
W5 - Lower Waikele	0.25	n/a	n/a	0.14

Sediment

Removal Efficiency: **n/a**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0	n/a	n/a	0
W2 - Kipapa	0	n/a	n/a	0
W3 - Upper Waikele	0	n/a	n/a	0
W4 - Waianae Range	0	n/a	n/a	0
W5 - Lower Waikele	0	n/a	n/a	0

8. Field Border

☑ Agriculture ☐ Conservation
☐ Developed/Light Urban ☐ Open Space

Strips of permanent vegetation bordering agricultural fields. This management practice can help reduce runoff and wind erosion from fields and thereby improve water quality.

Cost: $1,074.62/Acre (Scenario #18: Grass/Forb Establishment; typical scenario size: 0.1 acre)

STEPL BMP Name: Filter Strip-Agricultural

NRCS FOTG: #386 (https://efotg.sc.egov.usda.gov/api/CPSFile/6522/386_PI_CPS_Field_Border_2017)

CZARA Management Measure: Erosion and Sediment Control

Nitrogen

Removal Efficiency: **53.3%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	1.24	n/a	n/a	n/a
W2 - Kipapa	3.80	n/a	n/a	n/a
W3 - Upper Waikele	1.29	n/a	n/a	n/a
W4 - Waianae Range	4.54	n/a	n/a	n/a
W5 - Lower Waikele	3.59	n/a	n/a	n/a

Sediment

Removal Efficiency: **65%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.19	n/a	n/a	n/a
W2 - Kipapa	1.47	n/a	n/a	n/a
W3 - Upper Waikele	0.43	n/a	n/a	n/a
W4 - Waianae Range	2.30	n/a	n/a	n/a
W5 - Lower Waikele	2.28	n/a	n/a	n/a

9. Filter Strip

☑ Agriculture ☐ Conservation
☑ Developed/Light Urban ☑ Open Space

Strip of herbaceous vegetation planted in an area where it captures runoff from overland flow. This can help reduce suspended solids and other contaminants in the watershed.

Cost: $110.44/Acre (Scenario #52: PIA – Filter Strip – All Species)

STEPL BMP Name: Filter Strip-Agricultural

NRCS FOTG: #393 (https://efotg.sc.egov.usda.gov/api/CPSFile/6530/393_PI_CPS_Filter_Strip_2017)

CZARA Management Measures: Erosion and Sedimental Control, Vegetated Treatment Systems

Nitrogen

Removal Efficiency: **53.3%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	1.24	n/a	3.72	1.35
W2 - Kipapa	3.80	n/a	3.72	3.34
W3 - Upper Waikele	1.29	n/a	3.81	0.80
W4 - Waianae Range	4.54	n/a	3.09	3.10
W5 - Lower Waikele	3.59	n/a	3.09	0.76

Sediment

Removal Efficiency: **65%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.19	n/a	0.11	0.43
W2 - Kipapa	1.47	n/a	0.11	1.42
W3 - Upper Waikele	0.43	n/a	0.11	0.31
W4 - Waianae Range	2.30	n/a	0.09	1.63
W5 - Lower Waikele	2.28	n/a	0.09	0.22

10. Grass Swale

☑ Agriculture ☐ Conservation
☑ Developed/Light Urban ☑ Open Space

Engineered vegetated conveyance channel constru
at a gentle grade. Designed such that water quality
treatment can occur for a specific contributing drainage
area through infiltration of runoff and pollutants into the
soil.

Cost: $0.75/Square Foot (Scenario #1: Waterway Shaping and Vegetation Establishment; typical scenario size: 4,800 square feet)

STEPL BMP Name: Grass Swales

NRCS FOTG: #412 (Grassed Waterway)
(https://efotg.sc.egov.usda.gov/api/CPSFile/6554/412_PI_CPS_Grassed_Waterway_2016)

CZARA Management Measure: Vegetated Treatment Systems

Nitrogen

Removal Efficiency: **10%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	n/a	n/a	0.70	0.95
W2 - Kipapa	n/a	n/a	0.70	2.94
W3 - Upper Waikele	n/a	n/a	0.72	0.40
W4 - Waianae Range	n/a	n/a	0.58	2.70
W5 - Lower Waikele	n/a	n/a	0.58	0.36

Sediment

Removal Efficiency: **65%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	n/a	n/a	0.11	0.43
W2 - Kipapa	n/a	n/a	0.11	1.42
W3 - Upper Waikele	n/a	n/a	0.11	0.31
W4 - Waianae Range	n/a	n/a	0.09	1.63
W5 - Lower Waikele	n/a	n/a	0.09	0.22

11. Grazing Management System

☑ Agriculture ☐ Conservation
☐ Developed/Light Urban ☐ Open Space

Set of strategies implemented on grazing lands to manage vegetation removal. Reduces nutrient and sediment loads by maintaining vegetation/ground cover to reduce soil erosion and runoff velocity and volume.

Cost: $102.00/Acre (Scenario #1: Range/Pasture, Medium)

STEPL BMP Name: Prescribed Grazing

NRCS FOTG: #528
(https://efotg.sc.egov.usda.gov/api/CPSFile/6715/528_PI_CPS_Prescribed_Grazing_2018)

CZARA Management Measure: Grazing

Nitrogen

Removal Efficiency: **40.8%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.85	n/a	n/a	n/a
W2 - Kipapa	2.16	n/a	n/a	n/a
W3 - Upper Waikele	0.88	n/a	n/a	n/a
W4 - Waianae Range	2.54	n/a	n/a	n/a
W5 - Lower Waikele	2.06	n/a	n/a	n/a

Sediment

Removal Efficiency: **33%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.10	n/a	n/a	n/a
W2 - Kipapa	0.76	n/a	n/a	n/a
W3 - Upper Waikele	0.22	n/a	n/a	n/a
W4 - Waianae Range	1.18	n/a	n/a	n/a
W5 - Lower Waikele	1.17	n/a	n/a	n/a

12. Livestock Rotation

☑ Agriculture ☐ Conservation
☐ Developed/Light Urban ☐ Open Space

Livestock are moved to portions of the pasture while the other portions rest; intent is to allow the pasture plants and soil time to recover.

Cost: $102.00/Acre (Scenario #1: Range/Pasture, Medium)

STEPL BMP Name: Grazing Land Management

NRCS FOTG: #528
(https://efotg.sc.egov.usda.gov/api/CPSFile/6715/528_PI_CPS_Prescribed_Grazing_2018)

CZARA Management Measure: Grazing

Nitrogen

Removal Efficiency: **43%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.69	n/a	n/a	n/a
W2 - Kipapa	0.69	n/a	n/a	n/a
W3 - Upper Waikele	0.69	n/a	n/a	n/a
W4 - Waianae Range	0.69	n/a	n/a	n/a
W5 - Lower Waikele	0.69	n/a	n/a	n/a

Sediment

Removal Efficiency: **n/a**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0	n/a	n/a	n/a
W2 - Kipapa	0	n/a	n/a	n/a
W3 - Upper Waikele	0	n/a	n/a	n/a
W4 - Waianae Range	0	n/a	n/a	n/a
W5 - Lower Waikele	0	n/a	n/a	n/a

13. Riparian Forest Buffers

☑ Agriculture ☑ Conservation
☑ Developed/Light Urban ☑ Open Space

Areas of selected trees and shrubs planted upgradient of a streambed to reduce excess sediments, organic material, nutrients, and pesticides. This practice would be best implemented after removing invasive species from an area to restore native habitat or in areas where vegetation may be sparse.

Cost: $140.18/Acre (Scenario #5: Direct Seeding, Native Species)

STEPL BMP Name: Agriculture land use – Buffer-Forest (100 feet wide) (47.8% nitrogen removal, 58.6% sediment removal); all other land uses – Forest Buffer (minimum 35 feet wide) (45.2% nitrogen removal, 53.3% sediment removal)

NRCS FOTG: #391 (https://efotg.sc.egov.usda.gov/api/CPSFile/7265/391_PI_CPS_Riparian_Forest_Buffer_2013)

CZARA Management Measures: Protection and Restoration of Wetlands and Riparian Areas, Erosion and Sediment Control

Nitrogen

Removal Efficiency: **varies**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	1.11	1.00	3.16	1.12
W2 - Kipapa	3.42	1.44	3.16	2.75
W3 - Upper Waikele	1.16	0.55	3.24	0.67
W4 - Waianae Range	4.09	1.12	2.62	2.56
W5 - Lower Waikele	3.23	n/a	2.62	0.64

Sediment

Removal Efficiency: **varies**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.17	0.28	0.09	0.35
W2 - Kipapa	1.33	0.50	0.09	1.17
W3 - Upper Waikele	0.39	0.11	0.09	0.25
W4 - Waianae Range	2.08	0.42	0.07	1.33
W5 - Lower Waikele	2.06	n/a	0.07	0.18

14. Riparian Herbaceous Cover

☑ Agriculture ☑ Conservation
☑ Developed/Light Urban ☑ Open Space

Planting grasses, sedges, and other plants in riparian zones. Benefits include improved water quality and streambank stabilization, among others. Riparian herbaceous cover is appropriate in areas adjacent to perennial or intermittent waters where the natural plant community is dominated by herbaceous vegetation that tolerates periodic flooding or saturated soils.

Stakeholder input suggests that vetiver grass (pictured at right) may be a preferred option for riparian plantings in the Waikele watershed. Vetiver grass is fast-growing, develops an extensive root system, and provides more soil coverage than sawgrass or other species common in the area. Research has demonstrated the effectiveness of vetiver grass in reducing soil erosion and nitrate transport (for example, Kavian et al., 2018; Mondal and Patel, 2020).

Cost: $1,353.45/Acre (Scenario #1: Plugging and Seeding)

STEPL BMP Name: Agriculture land use – Buffer-Grass (35 feet wide) (33.8% nitrogen removal, 53.3% sediment removal); all other land uses – Grass Buffer (minimum 35 feet wide) (86.8% nitrogen removal, 64.8% sediment removal)

NRCS FOTG: #390 (https://efotg.sc.egov.usda.gov/api/CPSFile/6525/390_PI_CPS_Riparian_Herbaceous_Cover_2011)

CZARA Management Measures: Protection and Restoration of Wetlands and Riparian Areas, Erosion and Sediment Control

Nitrogen

Removal Efficiency: **varies**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.86	0.89	6.07	1.02
W2 - Kipapa	2.96	1.33	6.07	2.65
W3 - Upper Waikele	0.90	0.44	6.21	0.57
W4 - Waianae Range	3.56	1.00	5.04	2.45
W5 - Lower Waikele	2.79	n/a	5.04	0.53

Sediment

Removal Efficiency: **varies**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.16	0.28	0.11	0.35
W2 - Kipapa	1.21	0.50	0.11	1.17
W3 - Upper Waikele	0.36	0.11	0.11	0.25
W4 - Waianae Range	1.89	0.42	0.09	1.33
W5 - Lower Waikele	1.87	n/a	0.09	0.18

15. Sediment Basin

☑ Agriculture ☐ Conservation
☑ Developed/Light Urban ☑ Open Space

Captures and retains stormwater runoff until sediments settle out; water is released through engineered outlet.

Cost: $25.24/Cubic Yard (Scenario #1: Excavated Basin)

STEPL BMP Name: Infiltration Basin

NRCS FOTG: #350
(https://efotg.sc.egov.usda.gov/api/CPSFile/6460/350_PI_CPS_Sediment_Basin_2017)

CZARA Management Measure: Erosion and Sediment Control

Nitrogen

Removal Efficiency: **60%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)*	Open Space
W1 - Waikakalaua	n/a	n/a	4.20	1.55
W2 - Kipapa	n/a	n/a	4.20	3.84
W3 - Upper Waikele	n/a	n/a	4.29	0.91
W4 - Waianae Range	n/a	n/a	3.48	3.56
W5 - Lower Waikele	n/a	n/a	3.48	0.87

Sediment

Removal Efficiency: **75%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)*	Open Space
W1 - Waikakalaua	n/a	n/a	0.13	0.49
W2 - Kipapa	n/a	n/a	0.13	1.64
W3 - Upper Waikele	n/a	n/a	0.13	0.35
W4 - Waianae Range	n/a	n/a	0.10	1.88
W5 - Lower Waikele	n/a	n/a	0.10	0.26

**Note: Developed BMPs required an estimate of percent impervious. 33% was used for the unit-area loading rate calculations.*

16. Sediment Traps

☑ Agriculture ☐ Conservation
☑ Developed/Light Urban ☑ Open Space

A sediment trap is a small excavated or bermed area where runoff from small drainage areas is detained and sediment can settle.

Cost: $25.24/Cubic Yard (Scenario #1: Excavated Basin)

STEPL BMP Name: Sand Filter/Infiltration Basin

NRCS FOTG: #350
(https://efotg.sc.egov.usda.gov/api/CPSFile/6460/350_PI_CPS_Sediment_Basin_2017)

CZARA Management Measure: Erosion and Sediment Control

Nitrogen

Removal Efficiency: **35%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)*	Open Space
W1 - Waikakalaua	n/a	n/a	2.45	1.38
W2 - Kipapa	n/a	n/a	2.45	3.82
W3 - Upper Waikele	n/a	n/a	2.51	0.70
W4 - Waianae Range	n/a	n/a	2.03	3.53
W5 - Lower Waikele	n/a	n/a	2.03	0.65

Sediment

Removal Efficiency: **80%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)*	Open Space
W1 - Waikakalaua	n/a	n/a	0.14	0.53
W2 - Kipapa	n/a	n/a	0.14	1.75
W3 - Upper Waikele	n/a	n/a	0.14	0.38
W4 - Waianae Range	n/a	n/a	0.11	2.00
W5 - Lower Waikele	n/a	n/a	0.11	0.27

**Note: Developed BMPs required an estimate of percent impervious. 33% was used for the unit-area loading rate calculations.*

17. Terrace

☑ Agriculture ☑ Conservation
☐ Developed/Light Urban ☑ Open Space

Terraces are constructed benches on slopes which consist of level field or paddy areas held in place by embankments of soil or rock. Terraces enable water to be stored temporarily on slopes to allow sediment deposition and water infiltration; reduce slope length, erosion, and soil particle content in runoff water; improve water quality; retain runoff for moisture conservation; prevent gully development; and reduce flooding.

There are three types of terraces: bench terraces, contour terraces, and parallel terraces. Bench terraces are the type that most often come to mind when the word terrace is used, and they are commonly employed in mountain regions around the world.

Cost: $11.09/Foot (Scenario #1: Gradient Terrace)

STEPL BMP Name: Terrace

NRCS FOTG: #600 (https://efotg.sc.egov.usda.gov/api/CPSFile/7041/600_PI_CPS_Terrace_2016)

CZARA Management Measure: Erosion and Sediment Control

Nitrogen

Removal Efficiency: **25.3%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.64	0.67	n/a	0.76
W2 - Kipapa	2.22	1.00	n/a	1.99
W3 - Upper Waikele	0.67	0.33	n/a	0.42
W4 - Waianae Range	2.67	0.75	n/a	1.84
W5 - Lower Waikele	2.09	n/a	n/a	0.40

Sediment

Removal Efficiency: **40%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.12	0.21	n/a	0.26
W2 - Kipapa	0.91	0.37	n/a	0.87
W3 - Upper Waikele	0.27	0.08	n/a	0.19
W4 - Waianae Range	1.42	0.32	n/a	1.00
W5 - Lower Waikele	1.40	n/a	n/a	0.14

18. Tree/Shrub Establishment

☑ Agriculture ☑ Conservation
☑ Developed/Light Urban ☑ Open Space

Establishing woody vegetation by planting seedlings or cuttings, by direct seeding, and/or through natural regeneration.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Cost: $140.18/Acre (Scenario #5: Direct Seeding)

STEPL BMP Name: Site preparation/steep slope seeder/transplant

NRCS FOTG: #612 (https://efotg.sc.egov.usda.gov/api/CPSFile/7067/612_PI_CPS_Tree-Shrub_Establishment_2017)

CZARA Management Measure: Revegetation of Disturbed Areas, Erosion and Sediment Control

Nitrogen

Removal Efficiency: **n/a***	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	n/a	0.85	n/a	1.07
W2 - Kipapa	n/a	1.52	n/a	3.54
W3 - Upper Waikele	n/a	0.16	n/a	0.38
W4 - Waianae Range	n/a	1.02	n/a	3.24
W5 - Lower Waikele	n/a	n/a	n/a	0.33

Sediment

Removal Efficiency: **81%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	n/a	0.43	n/a	0.53
W2 - Kipapa	n/a	0.76	n/a	1.77
W3 - Upper Waikele	n/a	0.16	n/a	0.38
W4 - Waianae Range	n/a	0.64	n/a	2.03
W5 - Lower Waikele	n/a	n/a	n/a	0.28

**Note: Nitrogen load reductions due to sediment association rather than nitrogen efficiency itself.*

19. Vegetative Barrier

☑ Agriculture ☐ Conservation
☐ Developed/Light Urban ☐ Open Space

Permanent strips of stiff vegetation established along slope contours or across concentrated flow areas such as ephemeral gullies, which are typical for agricultural areas with tillage and irrigation.

Cost: $1.34/foot (Scenario #10: Pac. Island Area Vegetative Barrier)

STEPL BMP Name: Vegetated Filter Strips

NRCS FOTG: #601
(https://efotg.sc.egov.usda.gov/api/CPSFile/7045/601_PI_CPS_Vegetative_Barrier_2017)

CZARA Management Measure: Erosion and Sediment Control

Nitrogen

Removal Efficiency: **40%**	Unit-area Load Reduction (pounds/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	1.07	n/a	n/a	n/a
W2 - Kipapa	3.95	n/a	n/a	n/a
W3 - Upper Waikele	1.13	n/a	n/a	n/a
W4 - Waianae Range	4.78	n/a	n/a	n/a
W5 - Lower Waikele	3.72	n/a	n/a	n/a

Sediment

Removal Efficiency: **73%**	Unit-area Load Reduction (tons/acre/year)			
	Agriculture	Conservation	Developed (Light)	Open Space
W1 - Waikakalaua	0.22	n/a	n/a	n/a
W2 - Kipapa	1.66	n/a	n/a	n/a
W3 - Upper Waikele	0.49	n/a	n/a	n/a
W4 - Waianae Range	2.59	n/a	n/a	n/a
W5 - Lower Waikele	2.56	n/a	n/a	n/a

8 Watershed Implementation Program

An implementation program to achieve load reductions combines pollutant source characterization with appropriate BMP selection. The load reduction priority maps and detailed tables in Sections 6 and 7.1 can be used to home in on where load reductions are needed. Then, the potential BMPs in Table 29 and the associated unit area load reductions in the BMP fact sheets (Section 7) can be used to identify management measures to achieve the necessary load reductions, working towards attainment of the WQS and other watershed goals (Table 1).

The overall implementation program consists of priority projects, an education and outreach strategy, a schedule for implementation and achieving milestones, and information on technical and financial resources. These components are summarized below, while Section 9 identifies the process to ensure implementation and attainment of the watershed goals (Table 1).

8.1 Priority Projects

A key component of the implementation program is identifying management measures, whose combined implementation will achieve the required load reductions. This section identifies these management measures along with their estimated load reductions based on STEPL scenarios and/or unit area load reductions. The content below is divided among current and future implementation projects and additional management measures needed to achieve the required load reductions. Collaboration among watershed stakeholders will result in the most cost-effective implementation approach. Estimated load reductions are compared to the total reductions necessary in Section 6.2 to evaluate progress towards meeting water quality standards.

8.1.1 Current Implementation Projects

Several organizations have been implementing management measures in the watershed to help restore and protect water quality. Known projects and reports are summarized below, including information provided by the Koolau Mountains Watershed Partnership (KMWP), CCH, and the U.S. Army Garrison (USAG). Other partners may also be active in the watershed, and information gained through stakeholder outreach suggests that more practices have been implemented, particularly on agricultural lands, than are quantified here.

8.1.1.1 Koolau Mountains Watershed Partnership

The KMWP developed their Strategic Plan for Watershed Fencing in the Koolau Mountains (2019), which identifies the importance of conservation, reforesting, and fencing in protecting the forest and related ecosystem services. The KMWP is a voluntary group composed of public and private landowners in the Koolau Mountains, including 18 landowning partners and 11 associate partners. The partners' goals include maintaining and promoting the health of forests within the Koolau mountain range, with a focus on providing high-quality drinking water for Oahu (KMWP, 2022). KMWP estimates that approximately 133 billion gallons of freshwater are provided annually through the watershed forests of the Koolau Mountains. To protect these valuable resources from feral ungulates, which are known to contribute to erosion and the spread of invasive species, KMWP developed a plan to install fences in prioritized areas of the mountain range (KMWP, 2019).

The plan identifies 2,282 acres within the mountain range that have been fenced since 2001 and another 8,991 acres of proposed fencing (KMWP, 2019). Although the plan evaluates the larger Koolau

Mountains, it identifies specific areas within the Waikele watershed (Figure 17), with a completed fencing project within the Kipapa Mauka area. The plan does not include additional information on the size or exact location of the Kipapa Mauka fence project. However, based on estimates of completed fence projects depicted in Figure 17, the completed Kipapa Mauka project covers approximately 120 acres. A portion of the Waiawa area is also within the Waikele watershed and has an ongoing fencing project, which will protect 1,345 acres of land upon completion (KMWP, 2019). Lastly, the plan includes prioritized areas for future fence installation, including those within the Waikele watershed (Table 30).

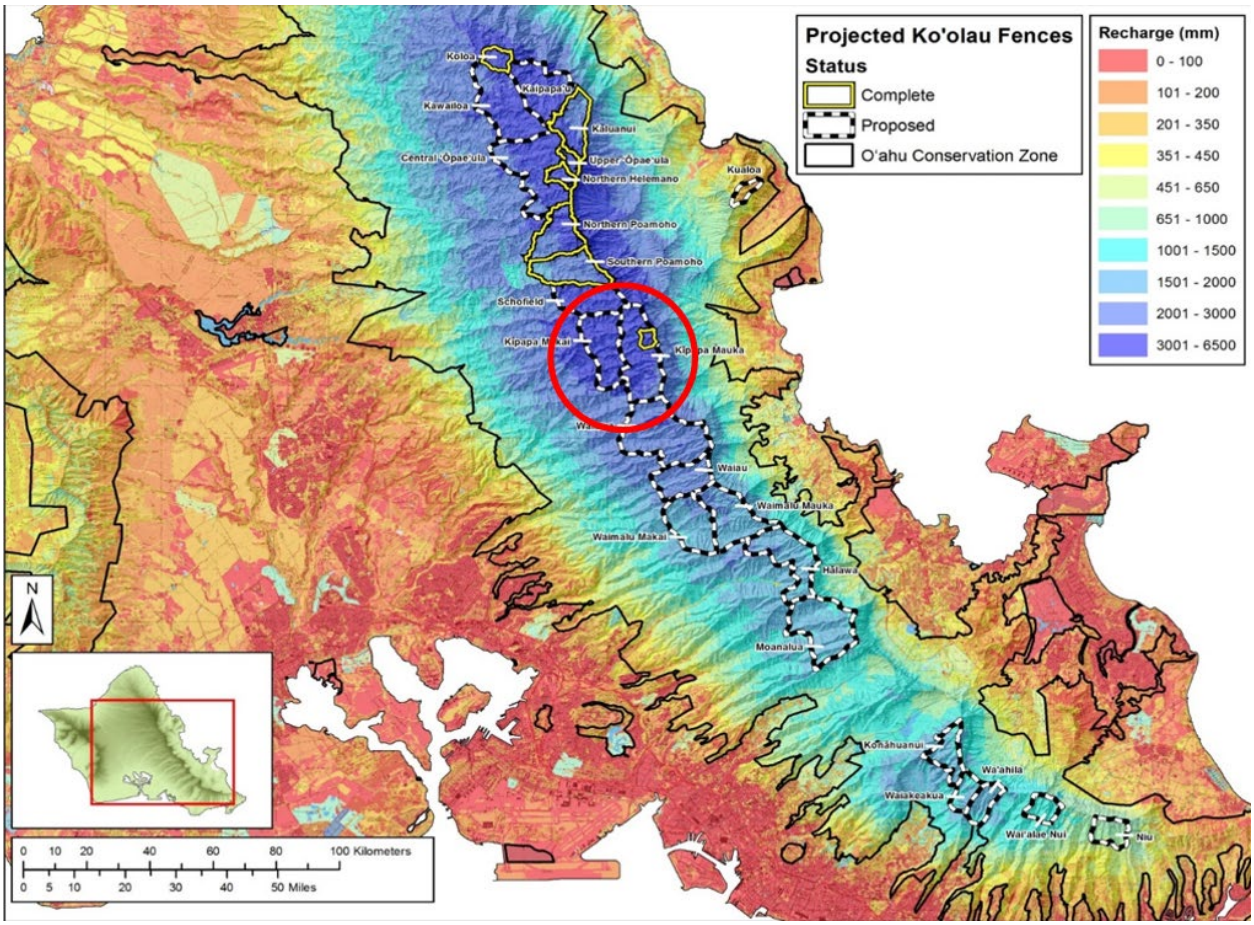

Figure 17. Complete and proposed fencing projects along the Koolau Mountains.

Note: The red circle provides an approximation of projects located within the Waikele watershed.

Source: Figure 2, *Strategic Plan for Watershed Fencing in the Koolau Mountains*.

Table 30. Summary of prioritized locations for proposed Koolau watershed fences within the Waikele watershed.

Fence Name/Location (Priority Ranking)	Primary Agency	Fenced Acres	Proposed Fence Length
Kipapa (Priority 1)	U.S. Fish and Wildlife Service and Kamehameha Schools	1,057	29,721
Kaukonahua (Priority 1)	Oahu Army Natural Resource Program	628	16,056
Total Proposed Fencing:		**1,685**	**45,777**

Using the unit area load reductions from Section 7.2, these two fencing BMPs are expected to yield an approximate pollutant reduction of 1,638 pounds per year of nitrogen and 688 tons per year of sediment.

8.1.1.2 City and County of Honolulu

In accordance with the requirements of its MS4 permit (HIS000002), CCH developed its Implementation and Monitoring Plan (CCH, 2020), which lists various BMPs that are to be implemented to reduce pollutants for the wasteload allocation component of the TMDL. Given that the geographic distribution of the wasteload allocation and load allocation areas associated with developed land uses demonstrates some interconnectedness, these BMPs also likely reduce some loading from nonpoint sources. These BMPs include Community Involvement and Communication, Pollution Prevention and Good Housekeeping, and Permanent BMPs, as outlined below.

- Community Involvement and Outreach/Education
    - Homeowner Outreach/Downspout Disconnection
    - Volunteer Cleanup Events
- Pollution Prevention and Good Housekeeping
    - Street Sweeping
    - Maintenance of Storm Drainage System
    - Stream Cleaning
- Permanent BMPs
    - Industrial and Small MS4 Facilities
        - Vegetated Swale
        - Catch Basin Filters
    - Existing Permanent BMPs
        - Hydrodynamic Devices, Hydrodynamic Devices + Filter
        - AquaSwirl, AquaSwirl + Filter
    - New (Proposed) Permanent Structural BMPs
        - Bioswales
        - Catch Basin Inserts/Retractable Screens
        - Detention Ponds
        - Grass Swales
        - Modular Wetlands
        - Permeable Pavers
        - Rain Gardens/Bioretention Areas

CCH has taken great strides to address load reductions through the implementation of these BMPs. According to the CCH plan, the current and proposed BMPs will help to achieve the pollutant reductions from point sources (Table 31); these are also listed in CCH's FY 21 MS4 Annual Report, confirming that the load reductions achieved by these BMPs are associated with the regulated MS4 area.

Table 31. Summary of current and proposed BMPs and load reductions within CCH's MS4 area.

BMP	Total Nitrogen Load Reduction (lbs/season)		Sediment Load Reduction (tons/season)
	Wet Season	Dry Season	Wet Season
Homeowner Outreach/Downspout Disconnection	--	--	--
Volunteer Cleanup Events	0.3	0.3	
Street Sweeping	1,000	1,000	26.5
Storm Drain Maintenance	--	--	--
Stream Cleaning	--	--	--
Industrial and Small MS4 Facilities	28.8	16.1	0.21
Existing Permanent BMPs	76.7	37.4	13.7
New Permanent Structural BMPs	60	--	30
Total Estimated Reductions	**1,166**	**1,054**	**70**

"--" indicates that efforts to support this BMP or activity are ongoing and pollutant reduction estimates have not yet been established.
Source: CCH, 2020.

This plan uses the conservative assumption that no nutrient or sediment nonpoint source reductions are quantifiable for these BMPs, even though there is likely some benefit to non-MS4 areas. Since the initial purpose is presumably to comply with CCH's permit, these BMPs would be "counted" towards the wasteload allocation for the TMDL and not the load allocation. However, as CCH continues to install more BMPs, this dynamic may change and CCH may consider applying any BMPs towards the load allocation portion of the TMDL.

8.1.1.3 USAG

In accordance with the requirements of its MS4 permit (HIS000090), USAG developed its Implementation and Management Plan (USAG, 2020), which lists various BMPs that are to be implemented to reduce pollutants for the wasteload allocation component of the TMDL. USAG has indicated that they implement many BMPs across all of their lands. These BMPs include both qualitative and quantitative management measures, as outlined below.

- Qualitative Measures
  - Construction Site Runoff Control Policy
  - Illicit Discharge Detection and Elimination (IDDE) Program
  - Public Education and Outreach
  - Soldier Training
  - Erosion Control BMPs
- Quantitative Measures
  - Street Sweeping
  - Storm Drain Cleaning
  - Green Waste Management Program
  - Post Construction Low Impact Development Features
  - Wash Facilities for Vehicles Leaving Training Lands

USAG has made significant progress to reduce pollutant loads through the implementation of these BMPs. According to the USAG, the current and proposed BMPs will help to achieve the pollutant load reductions from point sources (Table 32). Similar to CCH, as a conservative assumption, no quantified pollutant reductions are assumed for these BMPs that are primarily intended to address the MS4 requirements, even though some of these BMPs likely address nonpoint sources on USAG's lands as well.

Table 32. Summary of current and proposed BMPs and load reductions within USAG's MS4 area.

BMP	Total Nitrogen Load Reduction (lbs/season)		Sediment Load Reduction (tons/season)
	Wet Season	Dry Season	Wet Season
Street Sweeping*,**	239.07	259.64	14.3
Storm Drain Cleaning*	94.60	96.16	17.5
Post-Construction Low Impact Development Features	--	--	--
Wash Facilities for Vehicles Leaving Training Lands	--	--	--
Green Waste Program*	4.13	6.18	--
Total Estimated Reductions	**337.8**	**361.98**	**31.8**

* This number is not reflective of complementary work/debris removed by USAG contractor, Island Palm Communities.
**USAG currently tracks the amount of debris collected from all street sweeping efforts, including areas within the Waikele and the KiiKii watershed.
"--" indicates that efforts to support this BMP or activity are ongoing and pollutant reduction estimates have not yet been established.
Source: USAG, 2020.

8.1.1.4 Load Reductions from Current Implementation Projects

Table 33 summarizes the quantified reductions from nonpoint sources from the ongoing activities by the stakeholders.

Table 33. Summary of quantifiable load reductions from ongoing implementation activity.

Partner	Total Nitrogen Load Reduction (lbs/season)	Sediment Load Reduction (tons/season)
KMWP (fencing, see Section 8.1.1.1)	1,638	688
CCH	*	*
USAG	*	*
Total	**1,638**	**688**

* Since most of these activities are likely to occur within an MS4, no load reductions are assumed.

8.1.2 Future Implementation Projects

To supplement existing or proposed projects in Section 8.1.1 and work towards attainment of WQS, additional BMPs will need to be installed. These additional BMPs are analyzed in two ways in this section: site-specific example BMPs and watershed-wide BMPs.

8.1.2.1 Example BMPs

As an initial step, potential site-specific BMP opportunities were identified throughout the watershed (Table 34 and Figure 18). These are *example projects located in areas identified as high priority for load*

reductions (see Figure 14 and Figure 15). They are not vetted or approved by the landowners and are ***provided for illustrative purposes to demonstrate the types of projects that can help to achieve the watershed goals***. They are, however, reflective of feedback from stakeholders; outreach to landowners indicated that ungulate fencing in the upland areas is a significant concern and that riparian vegetation (especially along the gulch) would be favorable, assuming cost-share rates are adequate. This approach enables a detailed analysis of specific sites, selection of appropriate BMPs for that site, an estimate of the areal extent required, and other site-specific details. This level of detail may be helpful for stakeholders to visualize the type and scope of projects needed and what resources and planning will be required.

To estimate load reductions for these example projects, subwatershed- and land use-specific unit-area load reduction estimates from the BMP fact sheets (Section 7) were multiplied by the potential BMP area. Costs were estimated by multiplying the BMP area with the cost ranges in the BMP fact sheets. The load reductions can be compared with the annual required load reductions (Table 24) to evaluate progress towards meeting the load allocations.

Implementation Challenges

Section 8 illustrates the extensive need for BMP implementation to meet the TMDL load allocations. Widespread participation across the watershed will be needed to reduce nonpoint source loads to a level that will meet WQS. Ongoing outreach and stakeholder collaboration are also critical to overcome key challenges to implementation. For example, initial stakeholder outreach suggests that larger agricultural landowners in the Waikele watershed have already implemented many conservation practices and their willingness to do more may depend on the potential for other benefits that may be realized through additional conservation (e.g., increased production, reduced labor, reduced chemical inputs, tax benefits). As discussed in Section 9.2, work is needed to quantify the practices that have been implemented to date. Smaller agricultural operators who lease the land they farm may have limited incentive to invest in conservation practices for land they do not own, particularly if those practices reduce the amount of land that can be farmed (e.g., field borders). Leased land is often owned by trusts, estates, or other entities that may see limited value in investments for water quality protection or land conservation. Ongoing outreach and collaboration are necessary to identify solutions to these and other barriers to widespread adoption of BMPs throughout the Waikele watershed.

Table 34. Potential opportunities for BMP implementation.

Project ID	Subwatershed	Land Use Classification	Land Ownership	BMP	BMP Acreage[1]	Estimated Load Reduction		Estimated Cost ($)
						Nitrogen (lbs/yr)	Sediment (t/yr)	
1	Kipapa	Conservation	Govt. Federal	Feral Ungulate Fencing	900	1,224	523	$417,150[2]
2	Waikakalaua	Conservation	Govt. Federal	Feral Ungulate Fencing	400	340	132	$185,400[2]
3	Waianae Range	Conservation	Govt. State	Feral Ungulate Fencing	700	952	407	$324,450[2]
4	Upper Waikele	Conservation	Govt. State	Feral Ungulate Fencing	300	255	99	$139,050[2]
5	Waianae Range	Agriculture	Not Attributed by GIS Data	Field Border	200	908	460	$214,924[3]
6	Kipapa	Conservation	Not Attributed by GIS Data	Riparian Herbaceous Cover	200	178	56	$270,690[3]
7	Kipapa	Conservation	Not Attributed by GIS Data	Critical Area Planting	200	192	78	$208,210
8	Lower Waikele	Agriculture	Govt. State	Field Border	20	72	46	$21,492[3]
9	Kipapa	Conservation	DOD Non-MS4	Critical Area Planting	20	19	8	$20,821
10	Kipapa	Majority Conservation	DOD Non-MS4	Critical Area Planting	20	19	8	$20,821
11	Lower Waikele	Agriculture	Not Attributed by GIS Data	Riparian Herbaceous Cover	40	112	75	$54,138[3]
12	Kipapa	Open Space	Govt. County of Honolulu	Tree/Shrub Establishment	10	10	18	$1,402
13	Kipapa	Conservation	Govt. Federal	Critical Area Planting	20	19	8	$20,821
14	Waikakalaua	Conservation	Not Attributed by GIS Data	Riparian Forest Buffer	50	50	14	$7,009[3]
15	Lower Waikele	Agriculture	Not Attributed by GIS Data	Field Border	2	7	5	$2,149[3]
Total					**3,082**	**4,357**	**1,937**	**$1,908,527**

1. BMP acreage refers to the number of acres that are treated using that practice, not the number of acres occupied by the BMP itself.
2. Assumed 30 linear feet of fencing per acre treated. Data from KMWP projects in Table 30 used to calculate an approximate value, which was rounded up as a conservative assumption.
3. This cost is likely overestimated because it calculated using the cost per acre of the practice established from the applicable BMP fact sheet in Section 7.2; data were not readily available on the cost per acre treated by these practices.

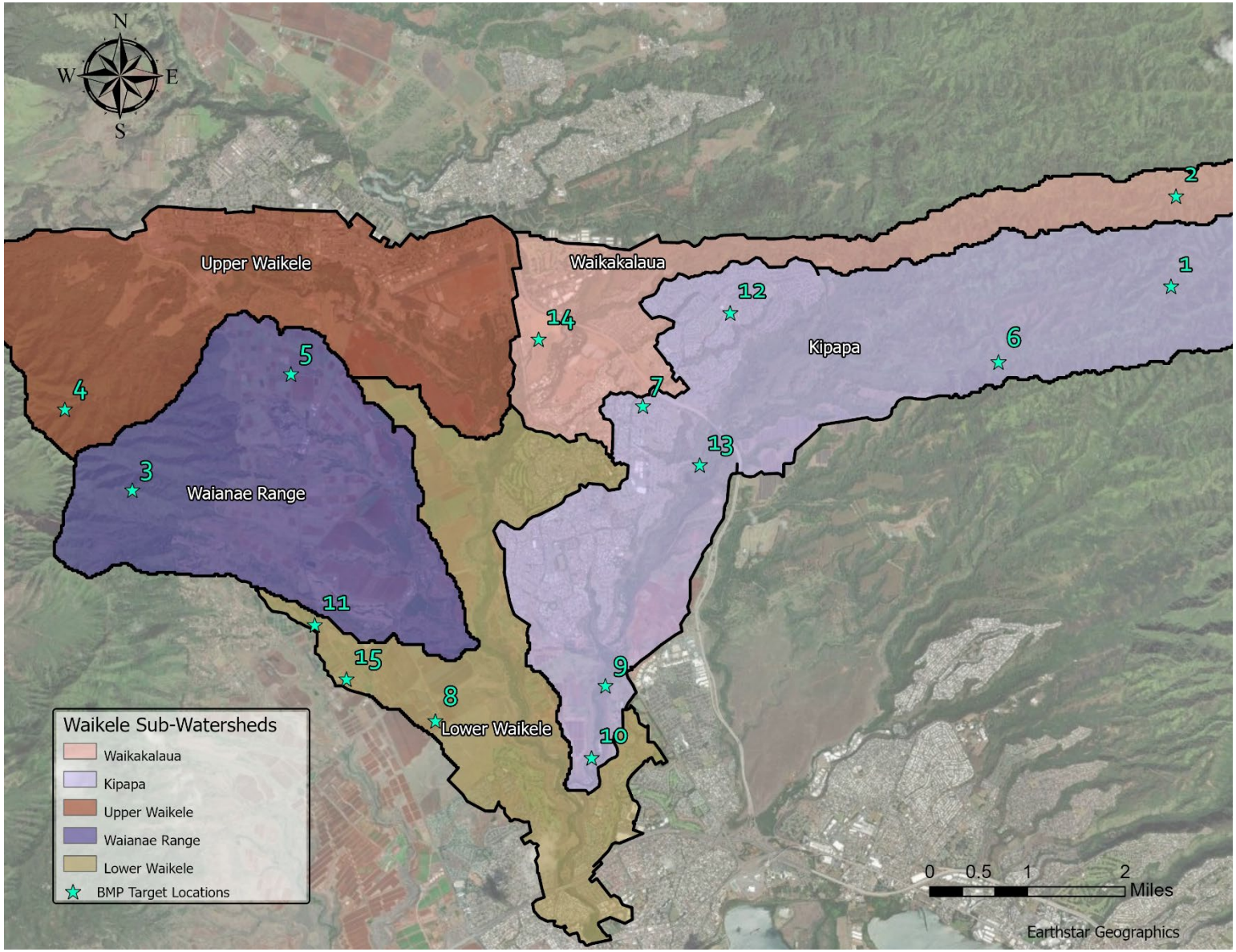

Figure 18. Location of example BMP sites.

8.1.2.2 Watershed-Wide BMPs

The BMPs described in Section 8.1.1 and Section 8.1.2.1 will not be sufficient to meet the total pollutant load reductions that are needed for the watershed. This analysis provides a broader look at the extent of BMPs that would be needed across the entire watershed to reach the necessary load reductions. Table 35 shows the load reductions from these BMPs compared to the total load reductions called for in Table 24 from all five subwatersheds.

Table 35. Summary of load reductions needed.

	Total Nitrogen Load Reduction (lbs/yr)	Sediment Load Reduction (t/yr)
Current Implementation Projects	1,638	688
Example BMPs	4,357	1,937
Total Annual Load Reduction for All Subwatersheds	5,995	2,625
Annual Required Load Reductions (see Table 24)	49,916	83,539
Current and Example Reductions as a Percent of Total Needed	12%	3%

To meet the additional load reductions, more BMPs will be needed throughout the watershed. Table 36 provides a broad, planning-level scenario that outlines a selection of BMPs (and the associated reduction in nitrogen for each BMP type) that are likely to be installed in the watershed over the course of implementing this watershed plan. These BMPs are not associated with any given site but are simply grouped by subwatershed. Table 36 focuses on total nitrogen reductions. Using the unit area loading rates from Section 7.2, the BMPs identified in the table are estimated to meet the full nitrogen load reductions called for in the TMDL. Sediment reductions from these BMPs are expected to be approximately 25% of the total load reductions in the TMDL. See Section 9.1 for further discussion.

Table 36. Selection of BMPs needed to meet load reductions for total nitrogen, by subwatershed.

BMP	Acres Treated, by subwatershed[1]					Waikele Watershed	
	Waikakalaua	Kipapa	Upper Waikele	Waianae Range	Lower Waikele	Total BMPs (acres treated)[1]	Nitrogen Load Reductions (lbs/yr)
Bioretention Cell (Rain Garden)	50	50	50	50	75	275	767.5
Channel Maintenance and Restoration	25	25	25	25	50	150	161.75
Constructed Wetlands	50	75	50	100	75	350	1108.5

BMP	Acres Treated, by subwatershed[1]					Waikele Watershed	
	Waikakalaua	Kipapa	Upper Waikele	Waianae Range	Lower Waikele	Total BMPs (acres treated)[1]	Nitrogen Load Reductions (lbs/yr)
Cover Crop	100	800	600	2,000	1,300	4,800	3,603
Critical Area Planting	1,000	3,000	1,000	1,500	1,000	7,500	10,309.38
Feral Ungulate Fencing	1,000	2,500	1,000	900	0	5,400	5,452
Fertilizer Management Plan	200	450	100	1,200	1,450	3,400	663
Field Border	150	250	150	250	100	900	2,823.5
Filter Strip	150	250	150	250	100	900	2,778.5
Grass Swale	150	150	150	150	50	650	750.25
Grazing Management System	0	16	0	0	0	16	34.56
Livestock Rotation	0	5	0	0	0	5	3.45
Riparian Forest Buffers	40	40	40	40	20	180	374.97
Riparian Herbaceous Cover	40	40	40	40	20	180	475.93
Sediment Basin	200	200	200	200	300	1,100	3,255.5
Sediment Traps	100	100	100	100	150	550	1,144.5
Terrace	150	150	150	150	50	650	760.25
Tree/Shrub Establishment	600	1,800	1,000	600	350	4,350	6,793.5
Vegetative Barrier	150	250	150	250	100	900	2,884.5
Total							**44,144.54**

[1.] The acres provided for each BMP refer to the number of acres in the subwatershed that are treated using that practice, not the number of acres that the BMP itself occupies.

8.2 Education and Outreach

Education and outreach strategies build a community of stewards who understand and partake in maintaining a healthy environment. It is important to develop awareness and knowledge of the Waikele watershed by sharing resources and engaging residents and visitors in discussion and projects. As water pollutant concentrations are highly dependent on land-based activities, engaging agricultural and conservation stakeholders in these efforts is critical.

This section identifies suggested efforts that fortify and build upon existing education and outreach initiatives in the watershed. Since the key areas for implementation in this watershed include conservation and agricultural lands, the following outreach strategies were tailored to target the managers, organizations, and landowners in these areas.

- Further partnerships between DOH and public entities to identify ways to support and encourage more implementation work, as well as document progress
    - Public Partners
        - CCH Department of Facilities Maintenance
        - State Department of Land and Natural Resources
        - Environmental Division of USAG, Clean Water Program
    - Strategies
        - Reach out bi-annually to discuss Waikele implementation plans, progress, and opportunities
        - Request copies of annual public progress reports and plans
        - Conduct site visits in the watershed
- Incorporate water quality into Agricultural Research and Extension programs outreach and education efforts
    - Agricultural Partners
        - Oahu RC&D
        - HARC
        - West Oahu Soil Water Conservation District

Implementing these existing practices and distributing existing content can help to improve and/or maintain water quality and expose landowners to information that will encourage practice changes in accordance with greater awareness of water quality issues. However, there are benefits to tailoring existing content, generating additional materials, and mapping outreach goals to an estimated timeline to ensure that all stakeholders have a role and are engaged. Recommendations for expanding and tailoring education and outreach initiatives to better fit the Waikele watershed include the following:

- Provide information to stakeholders to increase awareness about contributing factors of sediment and nutrient loading.
- Generate and disseminate resources, such as brochures, emails, and newsletters, that educate about nutrient and sediment loading and reductions. Emphasize the importance of water quality protection and maintenance.
- Build knowledge about how to manage loading.
- Educate land use decision makers.
- Foster ownership by engaging the broader community in restoration activities, including installation, monitoring, and maintenance.

- Develop materials that are tailored to meet the needs of target audiences, emphasizing the relationships between agricultural activities, water quality, and BMPs.
- Encourage partnerships with local and regional groups to build upon small-scale initiatives and develop comprehensive education and outreach programs.
- Increase organizational, agency, and community support for actions that promote water quality health.
- Document education and outreach efforts (i.e., targeted audience, attendees).
- Engage the public in vegetation planting and riparian restoration to demonstrate the feasibility of management practices.
- Hold demonstrations, workshops, and field trips to provide opportunities to learn about pollution control management practices being implemented on agricultural grounds to protect water quality.
- Create and post signage at restoration locations to educate the community on the purpose and benefits of these projects.

Many of these outreach tasks rely on single stakeholders coordinating with each other. Improved coordination at the watershed level would greatly enhance restoration efforts. This coordination could be accomplished in several ways:

- Establish a watershed coordinator position. This person would lead efforts to coordinate among stakeholders, seek out funding, lead outreach to the public, etc.
- Establish a watershed round table or similar organization. This workgroup would be composed of the same stakeholders that are discussed in this plan but would represent a more formalized structure for them to meet on a regular basis, plan holistically, coordinate efforts, identify funding opportunities, discuss BMPs, share lessons learned, build relationships, leverage each other's ongoing work, and inform the general public.

Although education materials that are applicable and distributable state-wide are important, it is also vital to tailor communication and outreach to individual communities to foster trust and draw connections that are relatable to stakeholders.

8.2.1 The City and County of Honolulu

Certain ongoing education and outreach efforts are listed on the City and County of Honolulu's website, which is designed to inform different audiences about stormwater pollution reduction. For example, the website includes various brochures, video clips, best management practice guides, information toolkits, graphical depictions, and tip cards tailored to homeowners, teachers, children, industry/retail workers, construction workers, and property maintenance workers about stormwater management. A few of these resources are linked below:

- Stormwater Overview Brochure
- Stormwater Management Program Plan, which includes a comprehensive education and outreach plan (Appendix B1)
- City rules relating to water quality

The website also offers visitors the ability to sign up for volunteer opportunities, such as stream clean-ups and marking storm drains, and other community events and challenges.

8.2.2 The Department of Land and Natural Resources

Hawaii's Department of Land and Natural Resources webpage offers educational resources and materials, especially related to forests and wildlife. A significant portion of the content targets school-age children.

8.2.3 Oahu RC&D

Oahu RC&D provides "boots on the ground" assistance to farmers to improve the management of natural resources, including water quality management strategies. Outreach and education are central to their work. Hosting educational events for farmers is one of the key ways that Oahu RC&D can engage around BMP implementation. Their watershed restoration projects are "assisting farmers in watershed areas develop conservation plans and implement practices that improve water quality," though these aren't currently serving the Waikele watershed. Expanding the program into the Waikele watershed should be explored.

8.2.4 University of Hawaii, College of Tropical Agricultural and Human Resources Cooperative Extension

The UH CTAHR Cooperative Extension "extends practical applications of science to support local food systems… and the stewardship of natural resources for future generations." The Cooperative Extension's county agents are available to consult with farmers, consumers, and other interested individuals or provide educational workshops and short courses on agricultural topics. Brochures, publications, videos and other educational materials are available at county extension offices for use by the general public. Most services are provided free of charge, but there may be a small fee for workshops and other organized activities (UH CTAHR, n.d.).

In particular, the Cooperative Extension's Sustainable and Organic Agriculture Program (SOAP) aims to promote environmental stewardship in agriculture. SOAP provides workshops and technical resources on BMPs, integrated pest management, and other agriculture-related topics.

8.3 Hawaii Nonpoint Source Pollution Control Regulations

In June 2021, pursuant to its authority under Hawaii Revised Statutes (HRS), Chapter 342E (Nonpoint Source Pollution Management and Control), DOH adopted Hawaii Administrative Rules (HAR) Chapter 11-56 to provide a mechanism for DOH to prevent, abate, and control new and existing nonpoint sources of pollution. These Nonpoint Source Pollution Control Rules establish requirements for certain publicly owned nonpoint sources of pollutants; other public and private entities also may be subject to the requirements under specified conditions. Specifically, the rules apply to the following:

- Publicly owned agricultural lands with 1,000 or more contiguous acres under common ownership.
- Publicly owned forest lands where commercial forestry operations are conducted on more than 5 contiguous acres or where certain forestry activities are conducted on publicly owned land regardless of acreage (road construction or maintenance, revegetation, streamside management zones, or chemical application).
- Publicly owned marinas and recreational boating facilities that can accommodate 10 or more boats, where a boat for hire is docked, or with a boat maintenance or repair yard adjacent to the water.

In addition, DOH has discretion to issue a Nonpoint Source Order requiring compliance with Chapter 11-56 to anyone, including privately owned entities, found to be causing or contributing to nonpoint source pollution.

Chapter 11-56 requires regulated entities to register with DOH and develop and implement a Water Pollution Prevention Plan. The plan must identify the specific management measures that will be used to control nonpoint source pollution from that facility. The management measures to be included in a Water Pollution Prevention Plan are largely based on those identified in Hawaii's Coastal Nonpoint Pollution Control Program. Plans must also include a monitoring strategy for verifying BMP implementation, maintenance, and effectiveness. The rules also require regulated entities to keep their Water Pollution Prevention Plans current and report on plan implementation and monitoring annually.

This plan emphasizes voluntary BMP implementation as the preferred route to improving water quality. However, where voluntary implementation is not controlling nonpoint source nutrient or sediment loss is causing or contributing to WQS exceedances, the Nonpoint Source Pollution Control Rules provide a mechanism for DOH to require BMP implementation.

8.4 Schedule for Implementation

The implementation schedule below (Table 37) includes a 10- to 15-year timeline to meet watershed goals and attain WQS (Table 1). Activities under this watershed plan can be divided into two phases that reflect the prioritization of activities described in Section 7.1. Phase I will focus on restoration activity in the higher priority subwatersheds and implementation of the most feasible and impactful BMPs, with a goal of achieving the highest load reductions possible over the near term. Phase II would continue Phase I implementation but look to expand the geographic focus and include additional, targeted activities needed to meet water quality standards. Some activities will be continuous throughout both phases; outreach, for example, will be critical to both identify near-term opportunities and to cultivate relationships with the various stakeholders that could result in additional implementation in the later phase. Monitoring will also be important during both phases. Monitoring conducted throughout Phase I would support evaluation of progress and identification of targeted activities in Phase II to address remaining needs. Continued monitoring in Phase II will support ongoing progress tracking and adaptive management.

As shown in Section 8.1.2.2, a significant number of BMPs will be needed to return the watershed to an unimpaired condition. Given such a large scope of BMP installation, implementation of this plan will take time. As a result, flexible management will be important to incorporate watershed priorities and leverage any available resources. A holistic approach that capitalizes on landowner interest, coordination with government partners, and enhanced outreach will be needed, so the implementation schedule may vary as implementation proceeds. Adaptive management will be key.

Table 37 illustrates the principles behind the two phases. Also see Section 9.1 for more information about measuring progress in implementing this plan.

Table 37. Proposed implementation schedule.

	Phase I Implementation	Phase II Implementation
Goal	Focus on highest priority watersheds; BMPs that offer the largest reductions or are most feasible; leverage partnerships	Expand focus to other subwatersheds and BMP categories; targeted implementation to meet WQS
Timeframe	Year 0 to Year 5-10	Year 5-10 to Year 15
Activities	• Install as many BMPs as possible in Kipapa and Waianae Range, with Lower Waikele a secondary priority • Install (or have identified) BMPs needed to meet 67% of nitrogen load reductions, with a focus on upland BMPs such as ungulate fencing, critical area planting, tree/scrub planting, sediment basins and traps (or practices with similar or better pollutant removal potential) • Leverage activities of government partners (local, state, federal) to the maximum extent possible • Focus on BMPs that are most attractive to landowners (e.g., cover crop, sediment basin, riparian forest buffers, riparian herbaceous cover) • Actively engage private landowners and watershed groups • Capitalize on targets of opportunity as they present themselves • Track BMP implementation metrics (e.g., number/type installed, location, acres treated, estimated load reductions) • By Year 3, implement ongoing water quality monitoring to support trend identification and adaptive management	• Install BMPs in remaining watersheds • Install BMPs from other categories • Continue to leverage government partnerships • Continue to engage private landowners and watershed groups • Continue tracking BMP implementation metrics (e.g., number/type installed, location, acres treated, estimated load reductions) • Continue ongoing water quality monitoring to support trend identification and adaptive management • Consider regulatory action (HAR 11-56) as needed to attain WQS

8.5 Technical and Financial Resources

Many different types of resources are available to support implementation of the management measures suggested by this plan. These include both technical and financial assistance programs. Table 38 provides a list with brief description of several existing financial and technical resources often used for implementation of management measures on public and private lands. Additional detail on these programs and resources is provided in Appendix C. This table and appendix provide a wide range of available resources; however, the majority of technical resources are associated with different USDA programs. Many of these technical programs are also potential sources of funding (illustrated by icons in Table 38). In addition to USDA programs, several EPA grant and loan programs are important to support nonpoint source management, including the CWA Section 319(h) grant program, which is highlighted below.

<u>Clean Water Act Section 319(h) Funding Overview</u>

The State's annual CWA 319 Nonpoint Source Management Program grant appropriation is generally between $1.2 and $1.3 million. At least half of these funds are designated as **Watershed Project Funds**, which must be spent on implementing watershed-based plans or acceptable alternative plans to restore impaired waters and protect high quality waters. These Watershed Project Funds are made available through an annual Request for Proposal (RFP) and through agreements with state or local government agencies. The remaining grant funds are designated as **Program Funds**, which are spent primarily on personnel and watershed-based planning.

Highlights of Hawaii's CWA 319 program

- The primary goal of the CWA 319 program is to restore impaired waters.
- DOH administers the State's CWA 319 program.
- CWA 319 Watershed Project Fund information and requirements:
    - At least $600,000 in Watershed Project Funds are available annually.
    - Watershed Project Funded projects must implement a DOH-approved watershed-based plan or acceptable alternative plan to achieve measurable water quality outcomes and pollutant load reductions.
    - Projects generally include monitoring activities and an education and outreach component.
    - Projects may also include technical assistance for BMP prioritization and implementation, water quality monitoring, and watershed management coordination.
    - **Past and current project information can be found on the DOH Polluted Runoff Control Viewer: https://eha-cloud.doh.hawaii.gov/cwb/#!/project/list.**
- Applying for CWA 319 Watershed Project Funds:
    - DOH releases an RFP for nonpoint source pollution management projects annually. Potential applicants can contact DOH to receive email notifications regarding CWA 319 RFPs and can also register with Hawaii Awards and Notices Data System.
    - Any entity that has legal status to accept funds from the State of Hawaii and is in good standing with the State is eligible to apply for funds.
    - Applicants must be able to provide a minimum of 25% matching funds and/or in-kind contributions from non-federal sources.

- CWA 319 project awards and contracts:
    - It can take between 10 to 12 months to receive a contract start date from the time of award.
    - Projects are funded through reimbursement contracts in which the subgrantee will be reimbursed by the State on a quarterly basis.
    - Subgrantees must submit quarterly status reports, quarterly grant fund expense reports, quarterly invoices, and a final report to DOH.
    - *For more information, about the application process, please see this website.*

In contrast to Watershed Project Funds, Program Funds are not made available on a regular basis via RFPs or agreements with government agencies. A potential use of Program Funds is revising or updating this watershed plan or the Waikele TMDL.

Case study: 319(h) Funding

The Waimanalo Stream Restoration and Community Outreach Project is a project funded by EPA under Section 319 with an award amount of $247,716 as well as a separate match. In Phase 3 of the project, seven new conservation plans were developed and nine farms utilized grant funds to install BMPs, resulting in annual load reductions of 203.8 tons of sediment, 472.8 pounds of nitrogen, and 203.8 pounds of phosphorous in addition to stream restoration activities. On average, each farm was awarded $8,350 to implement three to six different BMPs, and other grant funds were utilized for related overarching expenses (e.g., travel, materials and supplies, professional services, operating expenses).

Table 38. Summary of financial and technical assistance resources.

Program	Description
Agricultural Conservation Easement (ACEP) Program	The ACEP provides financial assistance to help protect, restore, and enhance wetlands, grasslands, and working farms and ranches through agricultural and wetland reserve easements.
Agricultural Management Assistance (AMA) Program	NRCS helps producers develop an AMA plan of operations and construct or improve water management structures or irrigation structures, plant trees for windbreaks or to improve water quality, and mitigate risk through production diversification or resource conservation practices, including soil erosion control, integrated pest management, or transition to organic farming.
CWA Section 319 Nonpoint Source Management Program	The Section 319 program funds projects such as implementing an existing watershed management plan, TMDL, or other work/action plan to address water quality issues. The Waikele watershed implementation plan is discussed in *Hawaii Nonpoint Source Management Plan: 2021-2025*.
Clean Water State Revolving Fund (CWSRF)	The CWSRF Program provides low interest loans to county and state agencies to construct point source and nonpoint source water pollution control projects. Eligible nonpoint source projects include watershed planning/assessment, implementation of projects to restore nonpoint source-impaired waters, and installation of septic tanks, aerobic units, constructed wetlands, or treatment plants. Nonpoint source management projects that implement approved nine-element watershed plans are eligible for CWSRF loans (EPA, 2016a). CWSRF offers flexible financing options, including principal forgiveness and sponsorship lending, that can facilitate implementation of nonpoint source projects.
Conservation of Private Grazing Land Initiative	This initiative offers technical assistance to owners and managers of grazing land and seeks to improve grazing land management, soil erosion, energy efficiency, water conservation, and wildlife habitat.
Conservation Stewardship Program (CSP)	CSP helps agricultural producers maintain and improve existing conservation systems and adopt additional conservation practices.
Conservation Technical Assistance (CTA) Program	The CTA program provides technical assistance to individuals, communities, conservation districts, or state and local governments to conserve, maintain, and improve natural resources.
Current Research Information System	This information system provides documentation and reporting for agricultural and forestry research, education, and extension activities for the USDA with a focus on the National Institute of Food and Agriculture (NIFA) grant programs.
Drinking Water State Revolving Fund (DWSRF)	Up to 15% of the DWSRF Capitalization Grant is set-aside to support Local Assistance and Other State Programs, which includes source water protection related activities. These activities include development of source water protection plans and strategies and implementation of protection activities, including outreach and educational programs.
Environmental Quality Incentives Program (EQIP)	EQIP provides financial and technical assistance to agricultural producers to address natural resource concerns with goals such as improving water and air quality, conserving ground and surface water, and increasing soil health to reduce erosion and sedimentation.
Farm Service Agency (FSA) Loan Programs	The FSA offers loans to help farmers and ranchers get financing needed to start, expand, or maintain a family farm. Farm Ownership Loans can be used to purchase or expand a farm or ranch, including expenses

Program	Description
	such as closing costs, building construction or improvement, or conservation and protection of soil and water resources.
Healthy Forests Reserve Program (HFRP)	HFRP helps landowners restore, enhance, and protect forestland resources on private lands through easements and financial assistance.
Legacy Resource Management Program	The program assists DOD in protecting and enhancing natural resources, including projects to support regional ecosystem management, habitat preservation efforts, and invasive species control.
National Fish and Wildlife Foundation (NFWF) Grant	NFWF provides funding on a competitive basis to projects that sustain, restore, and enhance fish, wildlife, and plants and their habitats. NFWF has a number of conservation programs (including the Conservation Partners Program and the Hawaii Conservation Program), each with a business plan. Grants are available to support the actions identified in each business plan.
NRCS Field Office Technical Guide (FOTG) Pacific Islands Area	The FOTG contains technical information about conservation of soil, water, air, and related plant and animal resources. Technical guides are localized to apply to specific geographic areas. The FOTG is available electronically for users to search for conservation practice standards and other technical and financial information.
Regional Conservation Partnership Program (RCPP)	RCPP works through partnerships to install and maintain conservation practices. Partner entities (e.g., non-profit groups, conservation districts, other state or local agencies) submit project proposals to NRCS, and farmers apply to participate once the project has been selected.
State Technical Committees	State Technical Committees may include members from state and federal agencies, tribes, agricultural and environmental organizations, and agricultural producers. The Committees meet regularly to provide information, analysis, and recommendations to NRCS.
Technical Service Providers (TSPs)	TSPs are individuals or businesses with technical expertise in conservation planning and design of conservation activities. TSPs are hired by farmers, ranchers, private businesses, nonprofits, or public agencies to provide services on behalf of the NRCS. Each certified TSP is listed in an online registry.
UH CTAHR Cooperative Extension Service	The UH CTAHR Cooperative Extension Service is a partnership between federal, state, and local governments and is responsible for providing science-based information and educational programs in agriculture, natural resources, and human resources.
Water Pollution Control Program (Section 106) Grants	Section 106 grants support state CWA programs and activities, including monitoring and assessing water quality; identifying impaired waters and TMDLs; protecting source water; and managing outreach and education programs.
Watershed Partnerships Program Grant	The Watershed Partnerships Program provides technical and financial support for the implementation of watershed management plans. Public and private landowners form partnerships to protect forested watersheds for water recharge and other ecosystem services.

Key: $ represents Financial Assistance

represents Technical Assistance

9 Measuring Progress and Success

Different metrics are available to measure progress of both plan implementation and attainment of WQS. Milestones associated with plan implementation are discussed below and documented within the schedule of implementation, while monitoring programs can be used to measure progress.

9.1 Milestones and Criteria for Success

Implementation milestones and criteria for success serve as a guide to incrementally restore water quality and meet WQS (Table 23), as described in Sections 1.1 and 6.1. Table 37 above describes a general timeline to achieve the milestones and criteria.

Successful implementation will be measured by tracking progress toward attaining the required load reductions presented in Section 6.2 and meeting the watershed's WQS (Table 23). Collectively, the milestones and criteria provide metrics to determine whether plan implementation is on track or whether revisions may be necessary to meet milestones over the proposed timelines (adaptive management). The schedule in Table 37 also incorporates monitoring and evaluation to quantify progress towards the milestones and criteria. These metrics are useful to determine whether it is necessary to revisit the implementation schedule and/or identify land use categories that require additional management measures to achieve the watershed-wide goals.

As noted in the implementation schedule in Section 8.4, the pollutant reductions needed to meet WQS are very high, especially for sediment. The effort to implement the requisite number of BMPs should not be discounted. By focusing on the highest priority activities in Phase I, the largest and most strategically important reductions will be realized the soonest. Adaptive management will be used to periodically assess progress and adjust the priorities and activities as needed.

Measurement of progress will rely on assessing improvements to the indicators listed in Table 1. For example, water quality monitoring should be used to assess progress in reducing nitrogen and sediment levels. Monitoring the load reduction efficiency of a limited set of representative BMPs also could help predict progress toward achieving WQS. Tracking the BMPs installed (e.g., number of practices, acres treated, geographic extent) will indicate whether watershed managers are successfully recruiting landowners. Engagement with the landowners and the general public also can be measured as a way to gauge the success of outreach efforts. Not all of these indicators will have readily quantifiable results, but as implementation proceeds, progress should become evident

Implementation Milestones

Phase I

- ✓ *Meet with all major landowners to identify opportunities for BMPs*
- ✓ *Install (or have identified) BMPs needed to meet 67% of nitrogen load reductions*
- ✓ *By year 3, initiate a water quality monitoring program*
- ✓ *Assess progress toward meeting success criteria*

Phase II

- ✓ *Install additional BMPs needed to meet WQS*
- ✓ *Continue water quality monitoring program*
- ✓ *Assess progress toward meeting success criteria*

Success Criteria

- ✓ *Reduce nitrogen and sediment loads to meet the TMDL load allocations*
- ✓ *Attain the WQS*

by tracking these indicators. Watershed managers and DOH can then periodically assess that progress and determine if changes to the plan are necessary.

Additionally, this watershed plan incorporates several conservative assumptions that may provide additional flexibility later in implementation or allow water quality to improve at a faster rate (i.e., by installing fewer BMPs) than expected.

- There may be more active implementation of BMPs than is reflected in Section 8.1.1, which would reduce the amount of reductions needed. For example, Oahu RC&D continues to work with landowners in the watershed and has written conservation plans for many of the farms in the watershed. To the extent that the conservation plans document BMPs that were implemented after the TMDL analyses (i.e., post-2013), load reductions from those BMPs might be creditable toward plan implementation.
- The unit area load reductions were calculated in the STEPL model as single BMPs. However, in practice, multiple BMPs are being installed across the watershed concurrently. STEPL has a function to connect these BMPs to estimate the cumulative effects of multiple, interacting BMPs, but the analysis in this plan conservatively used the single BMP values. As discussed in Appendix B, a test case was developed to quantify the effects on overall reductions when using a multiple BMP modeling approach where the BMPs are interacting. For the selected set of interacting BMPs, the test case suggested additional load reductions of up to 35-45% may be realized (compared with estimated cumulative load reductions when modeling those same BMPs individually).
- Information from the Hawaii DLNR suggests that the nitrogen reductions in the BMP fact sheet for Feral Ungulate Fencing in Section 7.2 may be too low. Since this is a BMP that is expected to be prioritized in Phase 1, revised unit area load reductions may indicate that water quality would improve sooner.
- In Section 8.1.1.4, no reductions were credited for current activities by CCH and DLNR because they may be applied to MS4 areas and therefore be credited against the WLA. However, there may be areas within those political boundaries that are not connected to the MS4 and are actually discharging as nonpoint sources. Any BMPs installed in those areas would be credited towards the LA.
- Table 34 may overestimate the costs of several BMPs. Costs for field borders, riparian buffers, and riparian cover are based on NRCS practice scenario costs which reflect the cost per acre of BMP (i.e., the area that *the BMP itself* occupies), whereas the load reductions are based on STEPL estimates and reflect the area *treated by* the BMP.[4] Therefore, for those practices that treat runoff from a larger area than is actually occupied by the BMP, the estimated load reductions could be achieved at a lower cost than reflected in Table 34.
- Implementation of the nonpoint source pollution control regulations (HAR 11-56) may result in load reductions in addition to, or sooner than, those anticipated in this plan.

[4] For reference, based on data obtained from NRCS's Soil and Water Resources Conservation Act (RCA) Data Viewer, from 2005 – 2020, a field border installed through NRCS conservation programs treated, on average, from 5 to 17 acres. Over the same time period, riparian forest buffers installed through NRCS treated, on average, from 1 to 81 acres, and riparian herbaceous cover projects treated from 3 to 20 acres.

As noted in Section 8.4, adaptive management over the long term will be needed to meet the water quality goals. Successful adaptive management will require monitoring of BMP implementation and water quality improvements combined with ongoing outreach and coordination to identify and capitalize on new opportunities and share learning from past experiences. Ultimately, the goal of this plan is to restore water quality, primarily through BMP implementation. If the plan implementation reaches the end of the two phases and WQS are still not being met, stakeholders will continue to work towards the WQS.

9.2 Monitoring Program

The purpose of the monitoring plan is to evaluate progress towards attaining or maintaining WQS and achieving the watershed goals (Table 1). This can be achieved by determining the effectiveness of management measure implementation as well as determining compliance with the allocations identified in the TMDL report. The milestones and criteria for success identified in Section 9.1 will be measured through ongoing monitoring throughout the watershed.

This plan will focus on two types of monitoring: implementation and trend monitoring. Other types of monitoring could be implemented on a project-by-project basis as need arises or funding allows.

9.2.1 Implementation Monitoring

Implementation monitoring is used to determine whether management measures are being implemented as specified in a watershed-based plan to achieve load reductions. This type of monitoring tracks the extent to which management measures are implemented, compares rates of adoption of different management measures throughout the watershed, and identifies whether management measures are properly maintained and operated. Implementation monitoring quantifies a subset of the indicators included in Table 1, including number of management measures, areas addressed, and stakeholder engagement, and requires a lower level of effort than water quality sampling or statistical analysis. Implementation monitoring can be used to ensure that some level of pollutant reduction is occurring by simply documenting that management measures are installed and maintained, which is useful for tracking progress until water quality monitoring begins and to augment water quality data that are ultimately collected to track progress toward achieving water quality goals.

As part of the implementation monitoring process, it is important to document and maintain various types of information for each management measure installed, including:

- Management measures being implemented;
- Location and date of installation;
- Size/scale of the management measure;
- Expected performance of the management measure;
- Expected practice lifespan (the period of time the practice is expected to function efficiently, with necessary operation and maintenance);
- Anticipated need or plan for operation and maintenance;
- Entities involved and/or responsible party; and
- Purpose and targeted pollutants.

Evaluation of management measure implementation should occur at least annually to document accomplishments and prioritize upcoming actions. Annual evaluation provides a status update on

operations, efficiencies, and challenges for existing management measures as well as the documentation of measures that have been implemented more recently.

Through stakeholder outreach as described in Section 2, DOH is aware that a number of sediment- and nutrient-reducing practices have been implemented since 2013 (the date of the most recent water quality data used in developing the TMDL). These include field borders, cover crops, and road hardening, among others. Identifying the exact types, extent, and location of these BMPs should be a first step in the implementation monitoring process. This information can support estimates of implementation progress to date and help target and prioritize future investments in nonpoint source project implementation.

To supplement implementation tracking, software programs such as STEPL can be used to estimate benefits from implementation of the management measures. These tools can specifically estimate the amount of pollutant reductions that should be achieved by each management measure as long as the practices are properly installed and maintained. The estimated load reductions can be compared to the reductions required by the TMDL to document progress.

Implementation monitoring is necessary for evaluating the watershed management program because effectiveness cannot be determined without thoroughly documenting which practices have been implemented and the level of stakeholder engagement. By tracking management measures and water quality simultaneously (see Section 9.2.2 below), the performance of the management measures implemented can be evaluated.

If funding is available, water quality measurements quantifying BMP performance and impact on water quality would be extremely useful to confirm STEPL loading estimates, providing information that may help inform selection of future management measures. BMP effectiveness monitoring could be included as part of project proposals for funding and should be prioritized to 1) representative BMPs for which effectiveness data can be extrapolated to other parts of the watershed, and 2) novel practices for which data on anticipated effectiveness is unavailable or very limited. Projects receiving CWA Section 319 funding through DOH's Polluted Runoff Control Program are required to provide a quarterly status report; water quality data presented in these status reports are useful to quantify effectiveness of the management measure.

9.2.2 Trend Monitoring

To quantify implementation of management measures and document changes in ambient water quality and peak flow over time, trend monitoring should be performed at various locations throughout the watershed, addressing several water quality and flow-related indicators in Table 1. Trend monitoring refers to monitoring concentrations of one or more parameters (e.g., total nitrogen and TSS) on a watershed scale to evaluate changes over time as well as associated flow measurements. Long-term trend monitoring is suggested as there may be long or uncertain lag times between management measure implementation and the response at the watershed level.

There are nine types of trend monitoring design options identified in EPA's Monitoring and Evaluating Nonpoint Source Watershed Projects, including single watershed before/after and single-station long-term trends (EPA, 2016b). Trend monitoring is recommended at the outlet of the Lower Waikele subwatershed (mouth of the TMDL watershed), and at several additional locations in the watershed, to collect data on trends within each of the different land use types and at the outlet of each upstream subwatershed. Figure 19 depicts the locations of the monitoring stations in the TMDL, which would be logical choices for monitoring water quality improvements due to BMP implementation. While the

monitoring could be conducted at any appropriate location in the watershed, the historical data from the TMDL sites would be useful in a trend analysis.

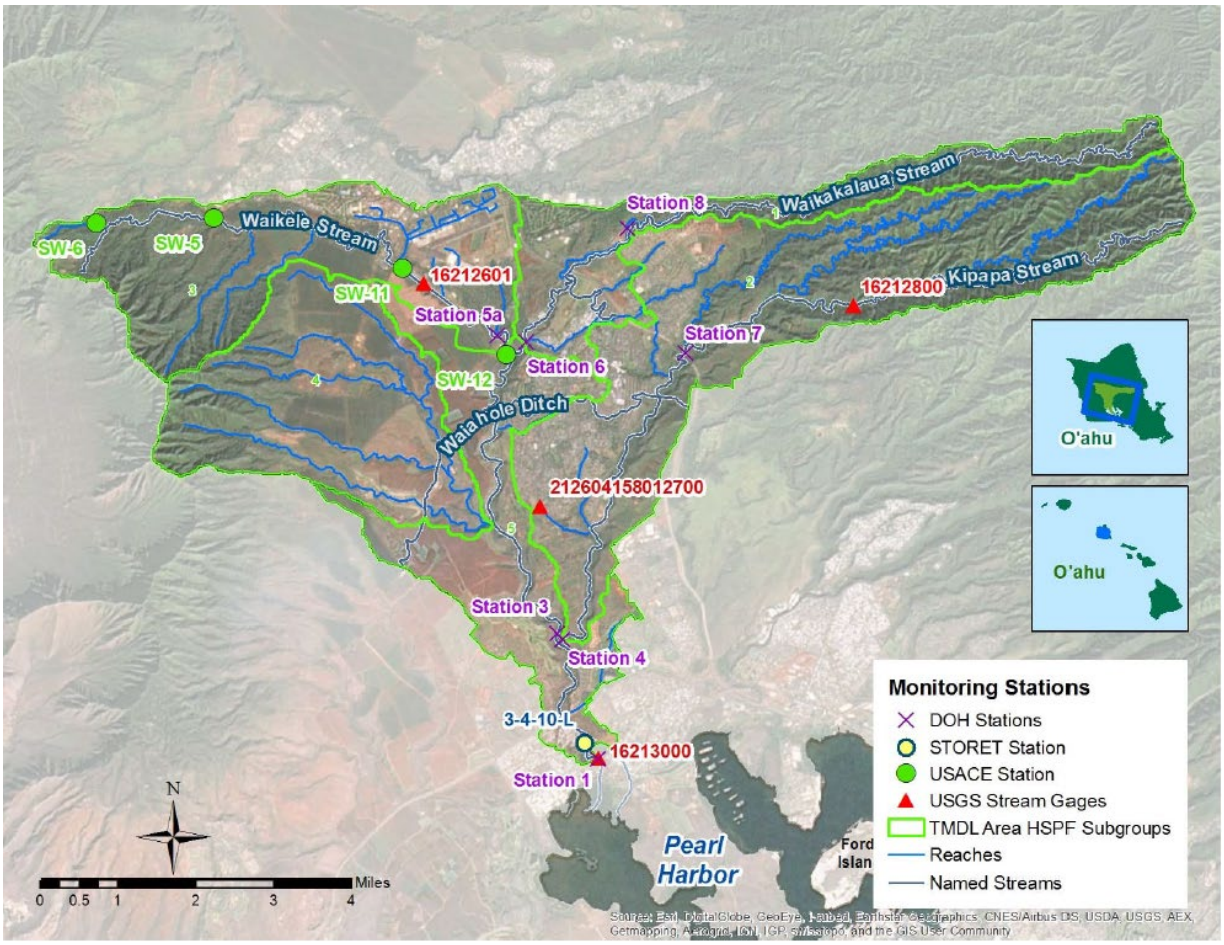

Figure 19. Monitoring stations used in developing Waikele TMDL.

Source: Figure 7, *Turbidity, Sediment, and Nutrient Total Maximum Daily Loads for the Waikele Watershed*

Trend monitoring is likely to be performed by DOH or another regulatory agency. Once this plan is approved, DOH will coordinate internally to establish a consistent monitoring strategy for the watershed. Volunteer monitoring, such as monitoring conducted by a watershed group, could also be used. Additionally, grantees that receive Section 319 (or other) funding to implement this plan could be encouraged to include a monitoring component to their project. These outside groups will likely need training and oversight by DOH to ensure that they are collecting high quality data.

Further, watershed stakeholders should coordinate to build upon anticipated or existing monitoring efforts to ensure consistency, comparability, and representativeness; this will also reduce the potential

for overlapping efforts. Overall recommendations for a trend monitoring approach that incorporates this collaborative framework are identified below, presented from coarse to fine scale:

- **Overall watershed monitoring**: Monitoring at the mouth of the Waikele watershed would reflect all measures implemented in the watershed and would determine compliance with the TMDL WLAs and LAs. This would represent both point and nonpoint sources in the watershed but is important for overall understanding of waterbody conditions and whether water quality standards are attained.
- **Subwatershed-level monitoring**: Data collected at the mouth of each subwatershed over time can help further refine and facilitate understanding of pollutant sources in the watershed's different drainage areas. Assessing these areas can identify specific subwatersheds that should be targeted for additional implementation efforts if conditions are not improving at the anticipated rate.

Stakeholders should collaborate on monitoring efforts. This will allow for more sampling to avoid duplicating efforts and take advantage of collective resources. For example, many MS4 NPDES permittees may already be required to perform ambient water quality monitoring. This type of existing monitoring program could supplement nonpoint source-focused data collection efforts. In some cases, minor changes to sampling protocols may be necessary to ensure comparability of the data (i.e., same parameters or standard methods, documentation of field conditions).

- **Tributary or management measure monitoring**: Monitoring upstream and downstream of a tributary or management measure can provide further information on potential areas of concern or areas of improvement. These data can help identify new locations for management measures and quantify which management measures are most effective in the watershed.
- **Site-specific sampling**: Stations identified in the TMDL report can continue to be sampled to evaluate changes in concentrations over time, especially compared to the conditions represented in the TMDL report.
- **Third party monitoring**. Volunteer groups (e.g., a watershed group) can be encouraged to also collect water quality data, as could grantees that receive project funding under a Section 319 award. Proper training and support, such as development of a Quality Assurance Project Plan template for data collection, would facilitate third party data collection and add to the depth of the analysis.

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