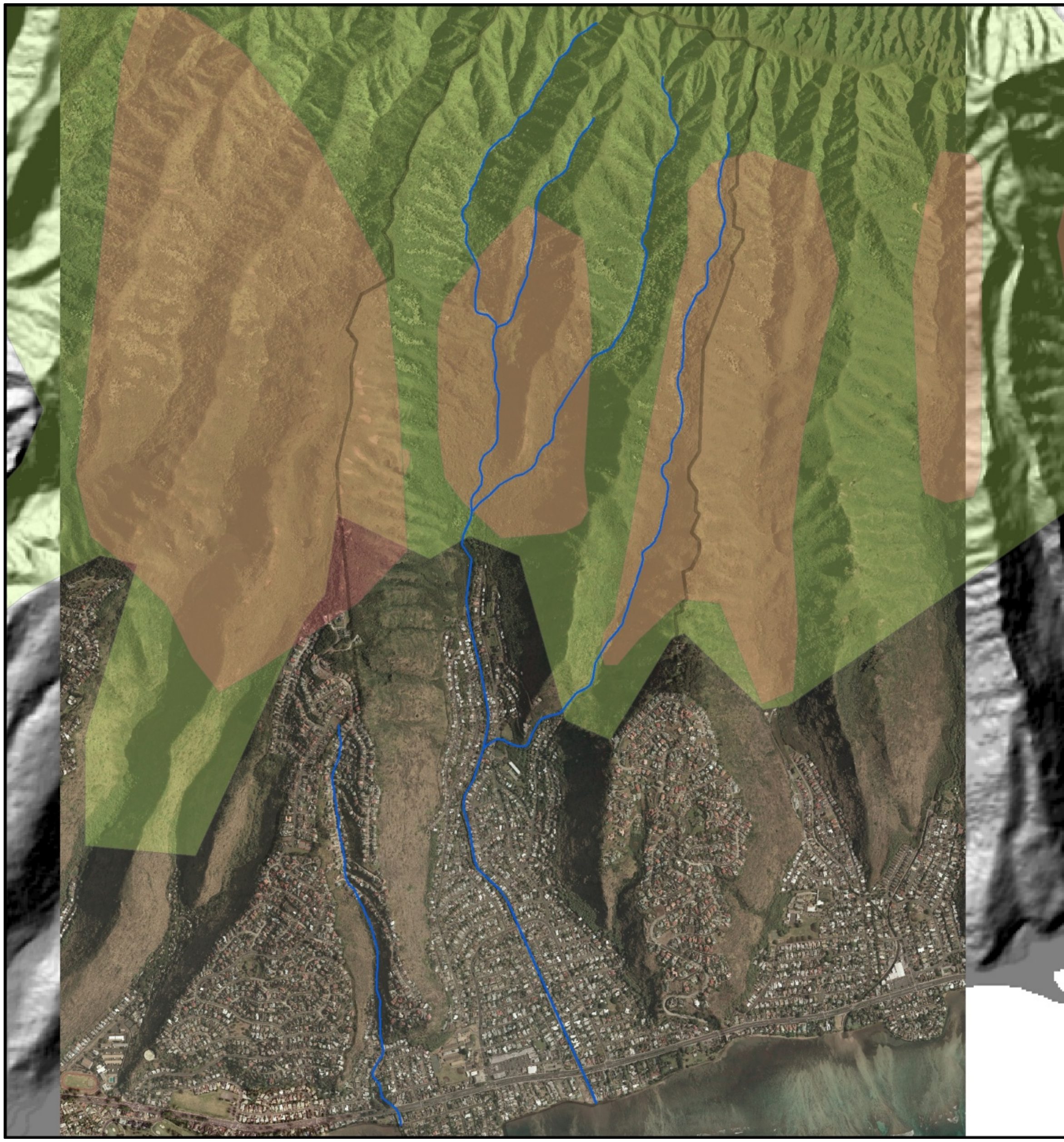

Figure 13

Distribution of O'ahu 'Elepaio (*Chasiempis sandwichensis ibidis*)

Legend

Natural Communities

Critical Habitat

N

0 0.25 0.5 0.75 1

Miles

Wailupe Watershed Based Plan

Source: U.S. Fish and Wildlife Service. Pacific Islands Ecoregion. Honolulu, HI; Hawaii Natural Heritage Program, Natural Diversity Database.

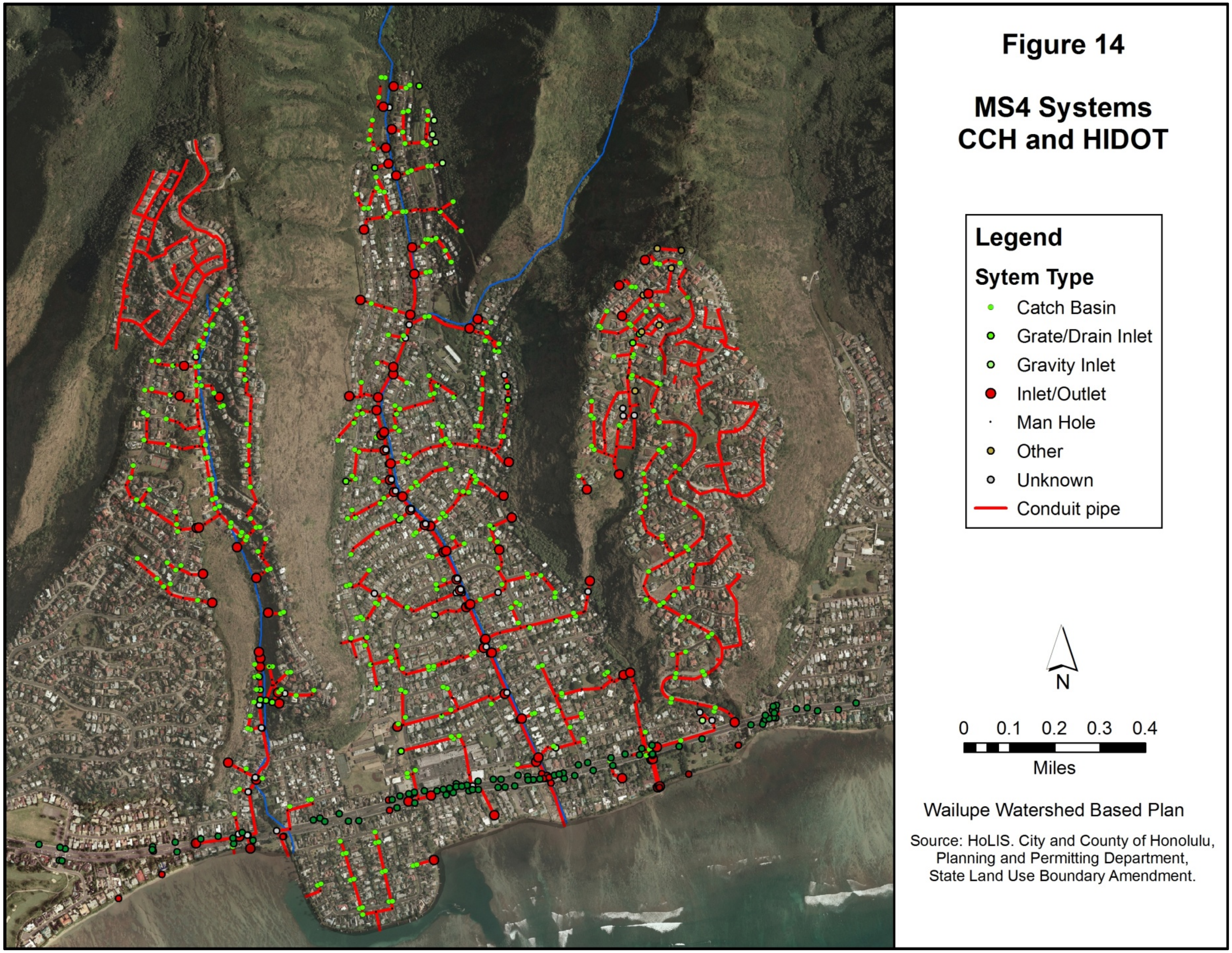
Figure 14
MS4 Systems
CCH and HIDOT
Legend
Sytem Type
Catch Basin
Grate/Drain Inlet
Gravity Inlet
Inlet/Outlet
Man Hole
Other
Unknown
Conduit pipe
N
0 0.1 0.2 0.3 0.4
Miles
Wailupe Watershed Based Plan
Source: HoLIS. City and County of Honolulu, Planning and Permitting Department, State Land Use Boundary Amendment.

Watershed Based Plan for Reduction of Nonpoint Source Pollution in Wailupe Stream Watershed

Pollution Control Strategies Report

Draft

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1 Introduction

The goal of the *Wailupe Watershed Based Plan* is to characterize and assess the condition of the watershed and to identify management objectives and pollutant control strategies to reduce generation and discharge of non-point source (NPS) pollutants into the receiving waters of Wailupe Stream and Maunalua Bay. A watershed characterization is presented in the *Watershed Characterization Report*. The objectives of this *Pollution Control Strategies Report* are (1) to identify the types of and locations where NPS pollutants are generated and transported off the watershed into the receiving waters and (2) to identify management measures necessary to prevent NPS pollutant generation or treat it before it reaches the receiving water body. The management measures are focused on addressing generation and delivery of land-based pollutants to the marine environment, with particular emphasis on fine terrigenous sediments that are having a significant adverse impact on the ecology of Maunalua Bay.

2 Defining Management Measures

Management measures are defined in Section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990 as economically achievable measures to control the addition of pollutants to coastal waters, which reflect the greatest degree of pollutant reduction achievable through the application of the best available NPS pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives. Simply, the term 'management measures' is used to describe practices, treatments, strategies, and plans to lessen generation and transport of NPS pollutants.

Management measures can be used to guide the implementation of a comprehensive NPS pollutant and runoff management program. In general, management measures are groups or categories of cost-effective management practices implemented to achieve a comprehensive goal, such as reducing NPS pollutant loads.[1] Some examples of management measures that can help control the delivery of pollutant loads to receiving waters are: reducing the availability of pollutants (reduce fertilizer applications), reducing pollutant generation (through erosion control), and treating pollutants before or after delivery to water (through biological transformation). Individual management practices are specific actions or structures that are often site-based that aid in the achievement of a management measure. Management measures and practices can be implemented for various purposes, such as:

- Protecting water resources and downstream areas from increased pollution and flood risks
- Conserving, protecting, and restoring Wailupe's stream habitat
- Setting aside permanent terrestrial buffers for flow reduction and increased infiltration

EPA documents including *National Management Measures to Control Nonpoint Source Pollution from Urban Areas* (USEPA 2005) and the *National Management Measures to Control Nonpoint Source Pollution from Hydromodification* (USEPA 2007) are valuable resources for information on management measures. Management measures identified for Wailupe Watershed are targeted for specific locations and types of NPS pollutants. There are numerous management measures that could be used, and ones not

[1] This report will follow the lead of EPA and use the term management practice instead of the more familiar term best management practice. The word "best" has been dropped for the purpose of this report, as it was in the *Coastal Management Measures Guidance* (USEPA 1993) and *Hydromodification National Management Measures* (USEPA 2007) because the adjective is too subjective. A "best" practice in one region or situation might be entirely inappropriate in another region or situation.

presented should not necessarily be excluded. A primary consideration when selecting management measures was to choose those that would address several types of NPS and/or attenuate generation of storm water runoff.

Management measures can be grouped into two major types, preventative or treatment control. Preventative measures focus on controlling or eliminating the pollutant at its source. From a watershed science perspective, preventative source control is the best way to address NPS pollutants. However, preventative measures are not always technically feasible or cost-effective, and it often takes considerable time after they are installed for benefits to be realized. In some cases, a treatment control, which involves treating the NPS pollutant along its pollution stream[2] will be the most effective and immediate means to reduce pollutant loads. Both types of controls can be achieved through structural (hard) and nonstructural (soft) type practices. Structural or hard engineering practices generally rely on the use of structures made of concrete or synthetic materials, (e.g. storm water basins and hydrodynamic separators). Soft engineering practices, such as bioengineering, utilize vegetation and materials made from synthetic and natural fibers and designs based on ecologic practices. In many situations hard and soft engineering practices are used to maximize the best elements of each approach. Selection of the specific practice is based on site conditions, the type of NPS pollutant or hydrologic condition it is remediating, and life expectancy of the design.

This report identifies practical and implementable measures to be installed or practiced across the watershed that are expected to reduce NPS pollutant delivery into Maunalua Bay. The management practices recommended in this report address existing watershed impairments and/or features that generate and transport NPS pollutants in the watershed, and are not management practices targeting new construction work. However, several of the management practices could be also incorporated into construction designs to attenuate NPS pollutants generated both during and after completion of new construction projects. In addition, this report is not intended to be a design manual for management practices or best management practices. Design considerations are included to guide policy discussions and present practical considerations to assist in deciding what measures to implement. Prior to implementation the management practices will require varying levels of detailed design based on the complexity of the measure, site physiographic conditions, and land ownership and regulatory considerations. Strategies for implementing the range of management practices are discussed in the *Implementation Strategy Report*.

3 Delineating Management Units

The Wailupe Watershed was delineated into four management units based primarily on dominant land use, and land type and ownership to lesser degree (see Table 1, Figure 1). Delineating the watershed into management units creates discrete geographic areas for discussion of the sources and pathways of NPS pollutants and allows specific management measures to be recommended for each unit. The boundaries were delineated using high resolution one and three dimensional air images and data available in the Geographic Information System (GIS). This section provides additional detail on each management unit, including site descriptions and pollutant types generated and transported across the unit.

[2] Pollution stream refers to the pathway a pollutant follows across a watershed from its source to its sink.

Table 1. Management Units in Wailupe Watershed

Management Unit	Area (acres)	Land Use	Land Type
Upland Forest	1260	Preservation	Vegetated/Forest
Steep Slopes	220	Open Space	Steep, exposed, vegetated
Urban	800	Residential/Commercial	Impervious, low and high Density
Stream Channel	12	Water Conveyance	Exposed banks, hardened and unhardened

The units were ranked based on priority for implementation of the management practices. A metric was developed with several criteria that were weighted subjectively. The criteria included: unit size, topography, drainage density, amount of sediment generation and transport, proximity to receiving waters, NPS pollutant sources and pathways, and land use and cover. The dominant criterion was the probability that the unit generates and transports fine terrigenous sediments to the marine environment. The rationale for making this the dominant criterion is the identification of fine sediment as the priority threat to the health of Maunalua Bay (Mālama Maunalua 2009). Primary pollutant types that are generated from each management unit are identified in Table 2.

Table 2. Storm Water Pollutant Generation Types for Management Units

	Management Unit (✓ = Pollutant Applies)			
Pollutant Type[3]	Upland Forest	Steep Slopes	Urban Footprint	Stream Corridor
Sediment	✓	✓	✓	✓
Nutrient	✓	✓	✓	✓
Oxygen-Depleting Substances	✓	✓	✓	
Pathogens	✓	✓	✓	✓
Metals			✓	
Hydro-carbons			✓	
Organics			✓	
Storm Water Flow[4]		✓	✓	

Management measures for implementation were prioritized within each management unit. Similar to ranking the units for priority, specific areas and management measures were evaluated and prioritized. The priority for implementation should not be considered rigid, and if a land owner or entity responsible for a particular parcel has resources to implement a management measure that is lower priority, the opportunity should be taken. Any installation of a management measure is a positive gain towards reducing NPS pollution regardless of order. Units that are contributing the most sediment should, to the

[3] Pollutant types are described in detail in the *Watershed Characterization Report*, Table 3.
[4] Storm water flow refers to runoff per unit area that, for current conditions, is estimated to be greater than historic or background levels.

extent possible, be targeted first in order to reduce the largest contribution of sediment to the ocean in a timely manner.

3.1 Upland Forest Management Unit

Site: Conservation and preservation lands in the upper watershed. Steep valleys and mountainous terrain with forest canopy and hiking trails.

Pollution Type: Sediments; nutrients; oxygen-depleting substances; pathogens.

Description: The upland forest management unit consists of State-owned conservation land and a smaller area designated preservation land that is owned and zoned by the City and County of Honolulu (CCH). The upper watershed is undeveloped except for an area that houses radio and television repeater towers, and a high voltage electric line that traverses the west ridge of the watershed. This unit contains the headwater drainage area of the four sub-watersheds that drain into Wailupe Stream. The soils in this unit generally consist of steep rocky mountainous land (Udorthents) in the higher elevations where the original soil has been cut away; rockland (Lithic Ustorthents) along the lower exposed cliffs; and Molokai series soils near the toe of upper slopes. Runoff from the upland areas is slow to rapid with moderate permeability.

<u>Mass Wasting</u>. Surficial erosion and the movement of both fine and coarse sediments are generated from infrequent mass wasting events that occur in the upland forest management unit. Mass wasting is movement of particles in large amounts due to slipping, sloughing or debris flows that occur on steep valley walls and the ridgelines. Areas affected by mass wasting in this unit are depicted on high resolution air images along the power line/repeater access road along the west ridge of the watershed. Figures 2 and 3 show areas where an exposed ridgeline road has likely contributed to bare and exposed mass wasting sites.

> Mass wasting is often induced when the toe of a slope fails and is usually associated with high intensity rainfall events. Mass wasting is impairing the watershed in two ways, by delivering fine sediments that are rapidly transported through the stream system, and by depositing large particles such as boulders in stream channels that may decrease the conveyance capacity and induce erosion of the bed and banks due to the displaced water in the channel (Martin 2003). Mass wasting and erosion are both natural processes, as evidenced by the steep valleys that dominant the watershed. However, when human activities or other introduced agents alter ground cover, reduce slope stability or generate concentrated over flow to areas where it would not naturally occur, the outcome is increased rates of erosion and occurrence of mass wasting.

<u>Vegetation</u>. The upland forest management unit includes patches of dense forest canopy of both native and alien vegetation. It is likely that alterations to the watershed induced by humans, including alien plants and animals, have altered the canopy structure, resulting in erosion and runoff rates that are greater than background in this management unit.

> Rainfall is intercepted by leaves, branches, and understory plants, which reduces the kinetic energy and erosive energy of the rain drops. Roots facilitate infiltration of rain water into the ground and often anchor soil and rock they are in contact with. Vegetated ground cover reduces the velocity and volume of concentrated overland flows, protecting the soil surface from detachment and erosion. Overland flows occur during and following rainfall events when the rate of rainfall exceeds the soil's infiltration rate or when the soil is saturated. Under either runoff scenario, alterations to the land surface that affect infiltration rates result in changes to the timing and magnitude of runoff. Since the rate and

magnitude of runoff usually increases, this in turn increases erosion rates and sediment transport across the watershed.

The impact alien vegetation has on erosion rates is not as well understood in Hawai‘i. Some scientists hypothesize that, besides altering natural ecological processes, alien vegetation increases erosion and storm water runoff rates in forested areas. It is likely that the modified canopy structure and the density of vegetative cover impact erosion and runoff rates.

<u>Feral Pigs</u>. Feral pigs remove vegetated ground cover, turn up soil, and trample the ground surface. These activities alter the physical structure of soil, change infiltration and runoff rates, and increase erosion rates.

Pollution Type: Sediments and oxygen-depleting substances are the primary NPS pollutant concern from the upland forest management unit, nutrients and pathogens are secondary concerns. Erosion rates and sediment generated from the upland forest management unit have not been quantified using models or empirical data. The analysis conducted for the watershed assessment included review of high resolution air images, use of GIS to assess physiographic variables, and interviews with persons familiar with the area. Based on this analysis it is postulated that the upland forest management unit generates the largest amount of sediment per year of the four management units (see *Watershed Characterization Report*). Sediments are generated by surficial erosion and mass wasting. Due to steep topography they are routed quickly into the stream network, and transported to Wailupe Stream and then the ocean. Generation and delivery of NPS pollutants from this unit to lower elevation areas of the watershed are greater during high magnitude rainfall events that generate overland flow and runoff into streams. The upland forest management unit is also a source of large debris (e.g. boulders and branches) and oxygen-depleting substances in the form of fecal coliform concentrations (FCC) and other biodegradable materials (e.g. plant and animal matter). Conservation lands in Hawai‘i have exhibited lower and more consistent values for dissolved nitrogen and phosphorous during low-flow conditions and a higher FCC correlation with increased discharge when compared to urban and agricultural areas (Hoover 2002).

3.2 Steep Slope Management Unit

Site: Steep slopes adjacent to the urban neighborhoods. Residential communities border this unit and are primarily located along the toe of the slopes that begin on the two ridgelines bordering the Aina Haina neighborhood.

Pollution Type: Sediments; nutrients; oxygen-depleting substances; storm water flow.

Description: Adjacent to the developed urban zone are steep, exposed slopes with scarce vegetation consisting of non-native kiawe-koa haole, closed strawberry guava forest, and scrubland and alien grasses. Soil in this unit is characterized largely as rock land that is highly weathered and eroded. This management unit has a lower mean annual rainfall compared to the upland forest management unit; however similar to the upland area, erosion and runoff rates are higher than natural background rates. These exposed slopes are prone to eroding during storm events that can form rills along slopes, causing the surface to weaken and increase the chance of slope failure. There are numerous large gullies that extend from the ridgelines down to the outer boundary of the urban unit. Sediment and runoff derived from these steep slopes and transported in the gullies is routed directly into the municipal separate storm sewer system (MS4) located at the base of the steep slopes.[5] The NPS pollutants are then rapidly transported via the MS4 pipe network to Wailupe Stream. At present there are no practices in place to filter or treat runoff conveyed in the MS4 and storm water discharges to Wailupe Stream and the ocean are untreated (CCH-ENV 2010). Protecting water quality in the stream channel from sediment runoff from this region will require hard and soft engineering methods due to the extremely steep topography and the direct connection of runoff into the MS4. Figure 4 depicts the steep side slopes with the cutoff ditch located on the west side of the Aina Haina neighborhood.

Pollution Type: The primary NPS pollutant concern from the steep slopes is the runoff containing soil particles of various sizes classes that wind up in ditches and drainage inlets that are conveyed into the stream channel via the MS4. Although the rate of erosion from this steep slope unit has not been quantified, there is evidence of significant erosion. For example, there are sediment deposits at the toe of the slopes and the existence of cutoff ditches maintained by the CCH at the downslope area of Wiliwilinui ridge above the Aina Haina community and at the base of the slopes below Hawaii Loa Ridge. These cut-off ditches intercept overland flow and debris transported in it to protect the residential units down slope. In both cases the ditch outlets are tied to inlets of the MS4.

3.3 Urban Management Unit

Site: Residential and commercial footprint within the Aina Haina, Wiliwilinui, and Hawaii Loa neighborhoods, and Kalanianaole Highway.

Pollution Type: Sediments; nutrients, oxygen-depleting substances; pathogens; metals; hydro-carbons; organics; storm water flow.

Description: The urban footprint in Wailupe Watershed is comprised of the Aina Haina neighborhood that lies along the valley floor, a portion of the residential development on top of the adjacent steep slopes of Hawai‘i Loa to the east and Wiliwilinui Ridge to the west, as well as the commercial district and Kalanianaole Highway. Land use in this region ranges from residential to commercial and includes a school district, public parks, and a highway system (see *Watershed Characterization Report* for further details on land use). This range of land use practices generates a variety of pollutant types from numerous sources throughout the urban region.

Land coverage, topography, and the MS4 facilitate the conveyance of storm water runoff to the stream channel and the ocean at numerous storm water pipe outlets. The urbanized area is covered with impervious surfaces across nearly half of its total area. In many locations the impervious surfaces form a nearly contiguous layer extending from the edge of the waterways and the ocean to the edge of the urban footprint. The urban unit is serviced by two extensive MS4 systems, one owned and operated by the CCH and a second by the Hawai‘i Department of Transportation (HIDOT). The CCH MS4 is located in the residential and commercial areas, while the HIDOT MS4 is located primarily along Kalanianaole Highway. Rainfall for all but the smallest of storms generates overland flow that is quickly transported

[5] *MS4*: A municipal separate storm sewer system consisting of a conveyance or system of conveyances designed or used for collecting or conveying stormwater (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains). Stormwater discharges associated with MS4s are regulated through the use of National Pollutant Discharge Elimination System permits.

into the MS4 and discharged into Wailupe Stream and the ocean. The runoff carries various NPS pollutants that concentrate across the landscape in between rainfall events.

> Prior to urbanization small to moderate rainfall events likely did not generate overland flow at the frequency seen today since the ground was covered with vegetation that facilitated water infiltration. The increased frequency of runoff associated with urbanization means that there are more frequent pulses of runoff and an increase in the generation of contaminants when compare to pre-urbanized conditions. This increase in frequency of discharge of polluted waters is a contributing factor to the degraded ocean water quality in Maunalua Bay. This scenario is not isolated to Wailupe Watershed, and is occurring across all ten watersheds draining into the bay.

The CCH MS4 servicing the three neighborhoods contains 489 inlets, none of which are fitted with devices to trap, filter or otherwise remediate polluted runoff that enters the inlets or the pipe network. The HIDOT MS4 inlets are fitted with catchments that trap, via gravity settling, an unknown percentage of the total suspended solids contained in the storm water runoff that is routed into their inlets. Fine particles carried in the runoff most likely do not fall out of suspension, so the percentage of fine particles trapped in the catchments is probably less than coarser or heavier particles. Catchment capture efficiency is also function of storage space; if the vaults are full, material will pass through the device and flow to the outfall. Although HIDOT schedules cleaning at six month intervals, the frequency at which HIDOT cleans the catchments varies.

Pollution Type: Based on the conditions observed across the management unit and the land uses that take place within it, it is hypothesized that the urban management unit generates the largest diversity of NPS pollutants and for some of the NPS pollutant types (i.e. metals), the highest loads. The exception is fine sediments, which are primarily generated from the upland forest and steep slope management units. The types of pollutants that diminish water quality and negatively impact aquatic ecosystems can oftentimes be traced to residential and commercial activities and practices. The urban region presents numerous opportunities for pollutants to be introduced into the environment. The types of pollutants that occur in urban storm water vary widely, from common organic material to highly toxic metals (see Table 3). Some pollutants, such as fertilizers and detergents, are intentionally placed in the urban environment while other pollutants, such as oil dripping from automobiles are indirect results of urban activities. Whether intentional or not, these pollutants are carried off land and have been linked to the degradation of urban waterways (USEPA 2005).

The commercial and highway corridor within the urban unit is a potential "hot-spot" for increased incidents and processes that produce NPS pollutants, particularly hydrocarbons (see Tables 4 and 5). Large impervious surfaces (i.e. commercial parking lots) essentially function as water harvesting surfaces and generate high magnitude runoff containing by-products of the numerous vehicles that use them. None of the parking lots in the unit were found to be fitted with management measures to attenuate runoff volume or timing or remediate NPS pollutants. A few parking lots at the Aina Haina School border grassy areas and in some cases it appeared that storm water runoff would discharge onto the grass, however, this did not appear to be intentionally designed. The standard drainage design for parking lots servicing commercial and public parcels in this management unit is to slope the concrete or asphalt surface towards a storm water inlet.

Table 3. Typical Pollutant Concentrations Found in Urban Storm Water
(MDE 2000)

Typical Pollutants Found in Storm Water Runoff	Units	Average Concentration*
Total Suspended Solids	mg/l	80
Total Phosphorus	mg/l	0.3
Total Nitrogen	mg/l	2
Total Organic Carbon	mg/l	12.7
Fecal Coliform Bacteria	MPN/100 ml	3600
***E. coli* Bacteria**	MPN/100 ml	1450
Petroleum Hydrocarbons	mg/l	3.5
Cadmium	ug/l	2
Copper	ug/l	10
Lead	ug/l	18
Zinc	ug/l	140
Insecticides	ug/l	0.1 to 2.0
Herbicides	ug/l	1 to 5.0

*These concentrations represent mean or median storm concentrations measured at typical sites, and may be greater during individual storms. Mean or median runoff concentrations from storm water hotspots are 2 to 10 times higher than those shown here. Units = mg/l = milligrams/liter, μg/l = micrograms/liter.

Table 4. Common Road Runoff Pollutants and Source
(Kobringer 1984)

Constituent	Primary Sources
Particulates	Pavement wear, vehicles, atmosphere, maintenance, sediment disturbance
Nitrogen, Phosphorus	Atmosphere, roadside fertilizer use, sediments
Lead	Tire wear, lubricating oil and grease, bearing wear, atmospheric fallout
Zinc	Tire wear, motor oil, grease
Iron	Auto body rust, steel highway structures, engine parts
Copper	Metal plating, bearing wear, engine parts, brake lining wear, fungicides and insecticides use
Cadmium	Tire wear, insecticide application
Chromium	Metal plating, engine parts, brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving
Manganese	Engine parts
Bromide	Exhaust
Sodium, Calcium	Grease
Sulphate	Roadway beds, fuel
Petroleum	Spills, leaks, blow-by motor lubricants, hydraulic fluids, asphalt surface leachate

Constituent	Primary Sources
PCBs, pesticides	Spraying of highway right of ways, atmospheric deposition, PCB catalyst in synthetic tires
Pathogenic bacteria	Soil litter, bird droppings, trucks hauling livestock/stockyard waste
Rubber	Tire wear
Asbestos	Clutch and brake lining wear

Table 5. Mean Pollutant Concentration in Runoff from Urban and Rural Highways
(Driscoll, Shelley et al. 1990)

Pollutant	Urban (ADT> 30,000) (µg/l)	Rural (ADT< 30,000) (µg/l)
TSS (Total Suspended Solids)	142,000	41,000
VSS (Volatile Suspended Solids)	39,000	12,000
TOC (Total Organic Carbon)	25,000	8,000
COD (Chemical Oxygen Demand)	114,000	49,000
NO3/NO2 (Nitrate + Nitrite)	760	570
TKN (Total Kjeldahl Nitrogen)	1,830	870
Phosphorus as PO4	400	160
Cu (Total Copper)	54	22
Pb (Total Lead)	400	80
Zn (Total Zinc)	329	80

3.4 Wailupe Stream Channel Management Unit

Site: Wailupe Stream from the existing debris basin near the mauka end of Hao Street downstream to the ocean.

Pollution Type: Sediments; nutrients; pathogens; storm water flow.

Description: Although partially channelized, Wailupe Stream is the only completely unhardened stream that discharges into Maunalua Bay (see *Watershed Characterization Report*, Section 2.2.5). There are two sections between the existing debris basin near the *mauka* end of Hao Street and the ocean that are lined with concrete-rubble masonry walls; below the debris basin for approximately 1,000 ft and also from Kalanianaole Highway downstream to the mouth. This section is bounded by the urban management unit. The stream above the existing debris basin is in a natural morphologic condition and does not appear to have been altered.

The Wailupe Stream channel management unit contains a two acre debris basin fitted with a slotted concrete weir designed to trap large rocks generated from potential upland sapprolite failures (collapse of large mass of weathered residual rock) and to prevent debris flows from blocking or damaging the downstream channel during flood events. By design this debris basin does not trap or filter fine sediments or other NPS pollutants that are carried in runoff from the upland forest management unit. The stream is cleared annually by the CCH Road Maintenance Division, which uses a bull dozer to push deposited debris found on the bed of the stream channel toward the sides. The debris basin is cleared every six months or after major storm events (FWS 1998).

In many sections the stream banks have steep slopes covered with unconsolidated particles that vary in size from fine clay to large boulders. Vegetation is a mix of native and alien grasses, trees, and shrubs that grow along the flat area at the top of the upper banks and in and along the low flow channel. Many sections of the stream banks between the low flow channel and the upper banks are free of vegetation and unstable. Because the channel slope is relatively high (approximately five percent except for the last 1,000 feet of its alignment), when there are sustained flows that fill the channel the energy is sufficient to transport fine sediments in the stream. Field observations indicate that there are few deposits of fine sediments along most of the stream. The stream in the reach between the debris basin and the stream mouth could be classified as a net transporter of sediments. The stream is both transporting sediments that are delivered into it and is itself a source of sediment. The percentage of the total amount of sediment transported by the stream derived from upland sources versus the amount derived along the stream channel is unknown. It is likely during high flows when the channel is near capacity, that a significant percentage, or approximately 10 percent the total load of suspended and bedload sediment transported by the stream, is generated from the bank and channel bed along the stream reach in this management unit.

According to the U.S. Army Corps of Engineers (USACE) 1998 Feasibility Report, there are 36 existing storm water outfalls that drain into the Wailupe Stream channel between the Kalanianaole Highway Bridge and the debris basin access road (USACE 1998). These piped outfalls enter the channel at an angle perpendicular to the normal stream flow and are the terminus of the urban region's MS4. Storm water conveyed in the CCH MS4 that discharges into Wailupe Stream for all the outfalls carries with it untreated storm water runoff.

At several locations along the stream residents discharge runoff collected in rain gutters off their property into the stream channel. In several of these locations the water discharges onto unprotected channel banks causing localized scouring and in some instances undermining the banks beneath the residences.

Pollution Type: Wailupe Stream ultimately becomes the main conveyance feature for most of the storm water generated off Wailupe Watershed and contains pollutants from all other management units. Stream bank erosion from the unhardened banks is also a source of sediment that is carried downstream and re-deposited in the channel bottom or discharged into the bay.[6]

As described in the *Watershed Characterization Report*, flooding is a major concern in the region, and flood control is a primary topic of discussion and study by USACE. Management measures recommended for the stream and urban units are not expected to significantly attenuate the runoff generated from infrequent high magnitude rainfall events i.e. 100 year return storm. They are however, expected to attenuate flows and remediate NPS for the more frequent small to moderate storms. Over time these storms cumulatively result in the transport of high quantities of runoff and NPS pollutants versus the infrequent high magnitude events.

[6] Stream bank erosion is the wearing away of material from the land area along the stream banks. Stream channel erosion occurs when the erosive force of the water is greater than the resisting force of the bed and bank material.

4 Management Measures for Implementation

The development of a run-off management program is guided by management measures. Management measures establish performance expectations and, in many cases specify practices that can be taken to prevent or minimize NPS pollution. Management measures for targeted pollutants and priority concerns for each management unit are shown in Table 6. Recommend priority practices and technologies for improvement purposes in each management unit are presented in Table 7. Examples of management practices are presented in Appendix B.

There are numerous publications and resources to guide land managers in the selection, acquisition, and installation of management measures to control storm water runoff and remediate NPS pollutants. During preparation of this section literature reviews, interviews, and site inspections were conducted to narrow the list of recommended management measures to address the specific issues and physiographic variables identified in Wailupe Watershed.

The primary NPS pollutant to control and reduce is the fine terrigenous derived sediments. The management measures selected and prioritized were weighted heavily to those that either prevent or reduce generation of fine sediments or treat the pollutant stream for fine sediments. Consideration was also given to other NPS pollutants the measure could remediate; cost; the practical and logistic elements of installation; and the link to regulatory or management objectives that either require or promote measures to reduce NPS pollutants.

4.1 Upland Forest Management Unit

Management Measures: Flow regulators; enhancement of vegetative ground cover; storm water detention and retention; restoring natural systems; retrofit opportunities; operation and maintenance.

Management Practices: Extended detention basins; invasive species control; natural/native vegetation; road and trail maintenance.

The upland forest management unit likely generates the most fine sediments of the four management units due primarily to its size, the rainfall regime, and steep topography. Lowering erosion rates would result in significant reduction of fine sediment generation from this unit. However, a preventative strategy to control erosion rates in this steep and somewhat inaccessible and passively managed unit presents logistical and regulatory challenges. After reviewing the regulatory and management plans for the unit, considering the challenges that reforestation activities face, and noting the lack of direct funding programs for preventative measures, it was concluded that while preventative measures would be recommended, they would not be the priority for this unit.

Table 6. Management Measures Applicable to Management Units

Management Unit (✓ = Management Measure Applies)					**Objective**	
Upland Forest	**Steep Slopes**	**Urban**	**Stream Channel**	**Management Measure**	**Preventative**	**Treatment**
✓		✓		Bioengineered Filtering System		✓
	✓	✓		Capture and Filter Sediment		✓
			✓	Channel Stabilization	✓	
✓		✓		Detention/Retention	✓	✓
	✓		✓	Erosion Protection of Bare or Exposed Areas	✓	
	✓	✓		Flow Restrictors/Regulators	✓	
		✓		Household Generation	✓	
✓	✓	✓	✓	Indentify, Prioritize, Schedule Retrofit Opportunities		✓
	✓	✓	✓	Infiltration		✓
✓			✓	Instream Sediment Load Control		✓
✓	✓	✓	✓	Operation and Maintenance		✓
✓	✓		✓	Restore Natural Systems	✓	
	✓	✓		Runoff Interception/Control	✓	
	✓	✓	✓	Slope Energy	✓	
			✓	Streambank Preservation/Enhancement	✓	
✓	✓		✓	Vegetative Cover	✓	✓

Table 7. Management Practices Applicable to Management Units

Management Practice	Management Unit (✓ = Management Practice Applies)			
	Upland Forest	Steep Slopes	Urban	Stream Channel
Baffle box		✓	✓	
Coir logs		✓		
Curb inlet baskets		✓	✓	
Extended detention basin	✓			✓
Good housekeeping practices			✓	
Grass swale			✓	
Green roof – Green grid			✓	
Infiltration trench		✓	✓	
Invasive species control	✓			
Modular wetland			✓	
Natural/Native vegetation	✓	✓	✓	✓
Porous pavement			✓	
Rain barrels			✓	
Subsurface storage			✓	
Turf reinforcement mats		✓		✓

Extended Detention Basins. The recommended priority measures are treatment controls that are expected to have immediate positive impacts on reducing transport of fine sediments and other NPS pollutants upon implementation. The primary recommendation is the installation of extended detention (ED) basins at the location of the present debris basin on Wailupe Stream and at Kului Gulch. When properly designed and maintained, ED basins can reduce fine sediment concentration in suspension; trap large particles resulting in protection and maintenance of downstream channel geometry and flow conveyance; reduce downstream peak flows decreasing in channel erosion rates; enhance ground water recharge; and assist USACE in achieving their mission to help attenuate flood impacts along Wailupe Stream.

ED basins are designed to allow particulates to settle out of the water and to control channel erosion by reducing the rate of discharge such that the velocity is below the critical velocity for the downstream channel. The specific engineering design needs to consider the resident time of water in the ED basin to allow for the fine particles derived off the upland soils and carried in the inflow to settle out. Constructing terraces for vegetation at various heights and planting vegetation able to sustain certain flow events or low flow in the basin is compatible with USACE flood reduction project ideas.

The major drawbacks of ED basins are that they require substantial land area, are costly to design and construct, and require routine and somewhat labor intensive maintenance. Proposed locations in Wailupe Watershed include two areas: 1) at the existing debris basin on Wailupe Stream, and 2) at the base of Kului Watershed, behind the former Wailupe Valley School, which is on undeveloped property owned by

CCH. The proposed locations are based on the existing basin and USACE's plan for a future retention basin in the Kului Gulch. Figures 5 and 6 depict the recommended locations for the ED basins.

Invasive Species Control. Control and removal of invasive ungulates and vegetation in the upper watershed reserves of the Ko‘olau mountains is currently being studied by government entities, private entities (i.e. Ko‘olua Mountain Watershed Partnership) and public institutions (i.e. University of Hawai‘i). Management measures that address invasive species control can be expensive, lengthy, politically charged and require a strategic plan involving multiple stakeholders to be implemented. Partnerships between conservation groups working towards invasive species control will greatly enhance efforts in the upper watershed region. Programs to reduce or eliminate feral pig activity should be pursued regardless of the current numbers of pigs that reside in the watershed.

4.2 Steep Slope Management Unit

Management Measures: Capture and filter sediment; erosion protection of bare or exposed areas; flow restrictors/regulators; infiltration; retrofit opportunities; operation and maintenance; restoring natural systems; runoff interception/control; slope energy; vegetative cover.

Management Practice: Baffle boxes; coir logs; curb inlets baskets; infiltration trenches; natural/native vegetation; turf reinforcement mats.

Attenuating concentrated overland flow and preventing sediment laden runoff from flowing into the MS4 from the steep slopes will require both preventative and treatment controls that include soft and hard engineering methods due to the extremely steep topography and direct connection of runoff into the MS4 at several locations. Recommended preventative controls include reducing slope length, and increasing vegetative groundcover with preferably native or endemic species adapted to the dry conditions of the slopes. Treatment practices for this unit will address the reduction of fine sediments via filtering and traps.

Revegetation. Prevention practices will decrease the rate of overland flow and erosion generated from the steep side slopes. The type and feasibility depends on site conditions, including existing vegetative cover and slope angles. Bare exposed areas are considered hot spots for sediment production and should be addressed first. A soft engineering practice to remediate these areas includes protecting the ground surface from rainfall and overland flow while at the same time providing micro habitat for plant growth. Biodegradable erosion mats and coir logs are recommended to provide ground cover on exposed areas and decrease slope length and trap sediments. Covering exposed areas with an erosion mat and seeding the mat with species such as dry land Pili grass (*Heteropogon contortus*), the drought tolerant a‘ali‘i (*Dodonaea viscose*), and alahe‘e (*Psydrax odorata*) are practices that have been successfully implemented during restoration efforts on the island of Kaho‘olawe. Figure 7 depicts locations where coir logs could be placed along contours of the slopes to slow overland flow and trap sediments.

Baffle Boxes. Treatment practices to filter and trap sediments and other NPS pollutants generated off the steep slopes and delivered into the MS4 at the urban interface is focused on the installation of baffle boxes. Baffle boxes should be placed on the MS4 at the inlets located nearest to the toe of the slopes. This recommendation is essentially a retro-fit to the MS4 and is expected to significantly and immediately reduce the concentration of fine sediments, nutrients, and other NPS pollutants. CCH is currently using curb inlet devices made by Bio Clean Environmental Services, Inc. on the MS4 system in the Waikiki area. This manufacturer makes a baffle box that can be customized to trap up to 95% of the sediment routed into its three chamber design. Based on the documented performance of this manufacturer's product and their existing relationship with CCH Department of Facilities Maintenance (the entity that services the MS4), baffle boxes from Bio Clean Environmental Services, Inc. are recommended. Figure 8 depicts the recommended locations and priority for installation of baffle boxes at the toe of the steep side slopes.

Retrofit Cutoff Ditch. CCH is currently in the engineering design phase to refurbish an existing cutoff ditch located along the west side of Aina Haina neighborhood at the toe of the steep slope management unit. The ditch has two outlets that discharge into the CCH MS4. The primary design considerations were to increase the ditch flow conveyance capacity and to trap large rocks from moving past the toe area and towards houses downslope. The designs described by CCH personnel familiar with the project do not contain provisions to sequester, filter or otherwise treat fine sediments or NPS pollutants carried in runoff water. Installing at least two baffle boxes on the ditch outlets as part of the refurbishment will provide a significant reduction of fine sediments and other NPS pollutants that would otherwise be routed untreated into Wailupe Stream. If baffle boxes are not installed, CCH should include design features within the ditch to capture and filter fine sediments. These include filters, screens, perforation holes, and energy dissipaters at the outlet of the ditch.

4.3 Urban Management Unit

Management Measures: Bioengineering filtering system; capture and filter sediment; flow restrictors/regulators; household generation; infiltration; retrofit opportunities; operation and maintenance; runoff interception/control; slope energy.

Management Practice: Baffle boxes; curb inlets baskets; good housekeeping practices; grass swale; green roof; infiltration trenches; modular wetlands; porous pavement; rain barrels; subsurface storage.

Recommended management measures and practices in the urban unit focus on reducing a range of NPS pollutants generated from moderately dense residential and commercial uses. Management measures range from prevention at the homeowner level to retrofits and hard engineering treatments to the existing MS4. Management practices include good housekeeping, retrofitting MS4 at priority locations, installation of onsite storm water storage structures to attenuate peak flow, and utilizing open spaces for nonstructural storm water attenuation and filtration. This management unit has the most potential for implementing preventative measures to reduce and attenuate storm water flow, as well as for treating sediments and other NPS pollutants that flow through the MS4. The MS4s convey most of the storm water through the urban region, and it is crucial to implement management practices on this system that target hotspot areas and inlets for sediment and pollutant capture.

Good Housekeeping Practices. Infrastructure associated with residential and commercial land use typically increases impervious surfaces. Activities in these areas affect the types and amounts of contaminants that are generated, which impacts pollutant concentrations mobilized in runoff. Stakeholders should be educated and encouraged to practice general good housekeeping practices (see

Table 8). Implementation of a good housekeeping program to reduce the generation of by-products associated with normal human activities is recommended for residents in Wailupe Watershed. The program should include specific recommendations on how each individual could contribute to towards the goal of reducing contaminants that create NPS pollution.

Storm Water Capture. Field observations made in the urban management unit found that many houses were fitted with downspout pipes that discharge storm water off the property and onto the adjacent sidewalk and/or street. This practice is likely being conducted to reduce ponding on residential parcels that occurs during rainfall events. The funneled runoff combines with runoff generated from CCH-owned impervious areas (streets/sidewalks). This higher volume of runoff increases the frequency and efficiency by which NPS pollutants are carried to MS4 inlets. Rainfall falling on house lots is lost as source water for the home's landscaped areas and adds to the disruptions to the hydrologic regime (see *Watershed Characterization Report*). Mālama Maunalua has initiated a program called Every Drop Counts that is focused on reducing storm water runoff from urban areas. A low tech, moderately low cost solution is to harvest runoff generated off roofs and other elevated surfaces and store it in rain barrels on the homeowner's property. Storing water attenuates runoff and captures some contaminants generated off the roof areas. Water can be used to water lawns or garden plots. Capture of rainwater at the individual house level will not significantly reduce runoff volume reaching the MS4, nor will it increase the time of peak flows. Programs to harvest rainwater should be scaled up across watersheds in order to increase the number of homeowners that participate and the volume of water captured, and correspondingly decrease runoff.

A similar approach to capture and potentially use excess runoff from large parking lots in the commercial and public areas would be to install subsurface water tanks. In several municipalities on the mainland U.S. subsurface storage of storm water runoff has proven to be effective in reducing peak flows delivered to receiving water bodies, remediating NPS, and in some applications providing water for irrigation of landscaped areas. Subsurface systems can be designed to either hold the water for use as irrigation, or fitted with perforated holes to allow the water to slowly drain into the substrate beneath the storage device. The Hawaiʻi Commission on Water Resource Management published *A Handbook for Stormwater Reclamation and Reuse Best Management Practices in Hawaiʻi* in December 2008 (DLNR 2008). This publication is a useful guide on methods and practices to harvest rainwater. Although the intent of the publication was not remediation of NPS pollution, many of the practices will assist in remediating NPS pollutants.

Table 8. Good Housekeeping Practices for Residential Participation
Adapted from (HIDOT 2007)

Good Housekeeping Practices
a) Know the property boundaries, and where storm water from the property goes.
b) Use biodegradable and recyclable cleaners when possible.
c) Carefully select and control inventory. Having fewer materials on hand simplifies operations, reduces inventory cost, more effectively uses available roofed storage space, and lessens the opportunities for spills or leaks.
d) Use good material storage practices (avoid toxic materials to the extent possible, store containers of liquids in a way they are unlikely be knocked over, cover stockpiled materials, consider the best place to conduct specific activities.)
e) Conduct property maintenance (clean up the site, but not by washing grit and grime into the storm drainage system).
f) Eliminate improper discharges to storm drains - only rainwater should run off the site.
g) Clean up spills of materials or from equipment now, not later.
h) Practice waste management (pick up litter, sweep areas and dispose of sweepings in the garbage (unless they are hazardous and require special disposal)
i) Use good waste storage practices (keep dumpsters and other containers closed; store containers under cover)
j) Dispose of mop water to a sanitary sewer.
k) Maintain equipment and vehicles regularly. Check for and fix leaks.
l) Wash cars over grass patches, use phosphorus free soaps
m) Capture rainfall using rain barrels, placing downspouts on grass areas, install rain gardens.

MS4 Retrofits. Retrofits to the MS4 inlets and pipe network are recommended to reduce NPS pollutants conveyed in the MS4. Two structures are recommended: curb/grate inlet baskets and baffle boxes. Curb/grate inlet baskets trap gross solids and are ideal for removing large quantities of hydrocarbons, including oils and grease when fitted with an optional absorbent polymer. Bio Clean Environmental, Inc. has tested their curb inlet basket system in Hawai‘i and reports having the lowest installation time and highest rated catch basin insert for performance and maintenance (Bio Clean 2009). MS4 inlets on both MS4s targeted for curb basket inlet retrofits are located in areas that receive high traffic volume (i.e. commercial parking lots, school pick-up zones) and inlets adjacent to areas where vehicles stop frequently (i.e. stoplights along Kalanianaole Hwy). There are 489 inlets on the CCH MS4 system and it was not possible to identify or prioritize installation locations.

Baffle boxes are designed to trap both coarse and fine sediments, filter nutrients, capture hydrocarbons and are relatively easy to maintain using conventional storm inlet equipment. Baffle boxes (also made by Bio Clean) should be placed along the CCH MS4 subsurface pipe network at accessible locations above outfalls. Bio Clean is presently working with CCH to install several baffle boxes on the MS4 servicing the Pearl City area.

The use of curb/grate inlets and baffles boxes on the same pipe network is somewhat redundant and not necessary. When a baffle box is placed near the outfall of a pipe network it will treat all the runoff entering the curb/grate inlets on the same pipe network and will essentially render the inlet structures obsolete. If baffle boxes are not installed, then it is strongly recommend that curb/grate inlets be installed. A general recommendation is to place inlet baskets on the most heavily used streets, near parking lots, and near areas where trash accumulates. Figure 9 depicts the recommended locations and priority for the baffle boxes installation.

Infiltration Trenches and Swales. Infiltration trenches and grass swales are recommended to reduce NPS pollutants and attenuate runoff generated off public and commercial parking areas and other impervious surfaces. Infiltration trenches and grass swales temporarily store runoff and remove fine sediments, are useful for controlling higher frequency flood events (generally less than the 2-year), and can be designed with a spillway outlet to handle large rainfall events. They should be constructed along and adjacent to parking lots where there is room and non-impervious surfaces. Specific areas for installation include CCH parcels such as the Wailupe and Aina Haina Elementary Schools and public parks.

Modular Wetlands. Modular wetlands can be used to reduce NPS pollutants generated off parking lots and roadways. Modular wetlands are four-stage treatment storm water devices that are retrofitted to the MS4 pipe system in or adjacent to parking lots or roadways. These state-of-the-art products are a hybrid technology that combines traditional storm water separators and filters with plants grown in proprietary grow medium. Bio Clean manufactures a modular wetland that is appropriate for the hydrologic conditions of Wailupe Watershed. Figure 10 depicts the recommended locations for grass swales, infiltration trenches, and modular wetlands.

4.4 Stream Channel Management Unit

Management Measures: Channel stabilization; erosion protection of bare or exposed areas; flow restrictors/regulators; infiltration; instream sediment load control; retrofit opportunities; operation and maintenance; slope energy; stream bank preservation/enhancement; vegetative cover.

Management Practice: Natural/native vegetation; channel reinforcement mats, coir logs, articulated concrete mats, anchor pins, tie backs, drop structures.

Specific locations where channel erosion were noted during field inventories along Wailupe Stream have been identified and described by Mālama Maunalua (Prescott 2009). Prevention controls recommended for Wailupe Stream channel focus on rehabilitation, restoration and protection of the exposed banks using a combination of soft and hard engineering practices. Management measures are expected to reduce bank and stream bed erosion and facilitate remediation of NPS pollutants conveyed in runoff.

Stream Bank Protection. During preparation of this report meetings were held between SRGII, Mālama Maunalua and USACE to discuss potential strategies to control channel erosion, remediate NPS pollutants and provide for flood control along Wailupe Stream. USACE is taking the lead on developing engineering solutions to the issues identified above. Designs will consider the need to implement solutions that maintain channel flow conveyance for flood issues and maintain a natural channel, to the extent possible, to provide for ecosystem functions.

Stream Bank Stabilization. Stream bank stabilization is defined as the stabilization of an eroding stream bank using practices that consist primarily of ‘hard’ engineering such as, but not limited to, turf reinforcement matting, concrete lining, rip rap or other rock, and gabions. The use of ‘hard’ engineering techniques is not considered a restoration or enhancement strategy but may be necessary in certain location where erosion threatens adjacent properties and the probability of success using soft engineering practices is low. Other sections along the channel banks can be treated with bioengineering and soft engineering practices, which can be expected to reduce bank erosion, increase site aesthetics, enhance instream habitat, and be less costly compared to hardened structures.

In Channel Treatment. When eroding stream banks are protected using a non-hardening pervious practice, they can serve as a filter for surface water runoff from upstream areas, or as a sink for nutrients, contaminants, or sediment present as NSP pollution in surface waters. Treatment potential within the stream channel can be enhanced with the use of vegetation as part of the remedial design. Use of native and/or endemic plants in channel stabilization designs that do not impair flow conveyance can enhance habitat structure, aesthetics, and phytoremediate NPS pollutants, especially elevated nutrient levels, (Unser 2009). The practice of using coir logs with native sedges to stabilize stream banks and remediate nutrients has been tested and proven to be successful along two streams located on O‘ahu (SRGII 2009).

5 Pollutant Load Reductions

Suitable management practices for management units will address appropriate target parameters. Drawing from multiple handbooks and management practice guidebooks, Table 9 screens management practices for their relative performance in addressing pollutant loading and storm water flow (LA-SMD 2000; USEPA 2003; Field, Tafuri et al. 2004; USEPA 2005; USEPA 2007; USEPA 2008; Bio Clean 2009). The table also identifies the complimentary benefits of various management practices. The load reduction potential qualitatively describes the potential reduction of loading achieved by implementing the practice. The actual reduction depends on the extent of the practice, existing loading levels, and local features like soil and hydrology. EPA, in their *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, recommends identifying the effectiveness of each management practice in reducing pollutant loading and addressing hydrologic impacts using a scale of high, medium, or low (USEPA 2008).

Pollutant load removal efficiency of selected management practices has been the subject of many studies. There are wide discrepancies in methods for evaluating and quantifying the effectiveness of management practices. Management practice performance is best described by how much storm water and associated runoff is treated and what effluent quality is achieved (Strecker et al. 2001). Storm water management practices by definition are specific devices, practices, or methods used to support the intensions of the storm water management measure (Field et al. 2004). However this umbrella term lumps widely varying techniques and objections into a single category. There is great variability in storm water quality and hydrology of the runoff. Since nonpoint sources are recognized as the major contributor to pollution in Wailupe Stream, the recommended management practices are the primary tool to be used to mitigate the deleterious effects of NPS pollution on the receiving coastal resources of Maunalua Bay.

Table 9. Management Practices and Expected Load Reduction

Pollutant Factor (Low, Moderate, High Performance)									
Sediment	Nutrient	Oxygen-Depleting Substances	Pathogens	Metals	Hydro-carbons	Organics	Storm water Flow	Management Practice	Load Reduction Potential
H	H	H	M	H	M	H	L	Baffle box	High
M							L	Coir logs	Moderate
H	H	H	M	H	H	M		Curb inlet baskets (with filter)	High
M	M			M			H	Extended detention basin	Moderate
L	M	M	L	L	L	M	L	Good housekeeping practices	Moderate
M	L	L	L	H			L	Grass swale	Low
L	L	L	L				M	Green roof – Green grid	Low
H	H	H	H	H			M	Infiltration trench	Moderate
M	M		M				L	Invasive species control	Moderate
H	H	H	H	H		H	H	Modular wetland	High
L	L		L				L	Natural/Native vegetation	Low
M			M				M	Porous pavement	Moderate
							L	Rain barrels	Low
H	H	H	M	H	H	H	H	Subsurface storage	High
M								Turf reinforcement mats	High

Appendix A

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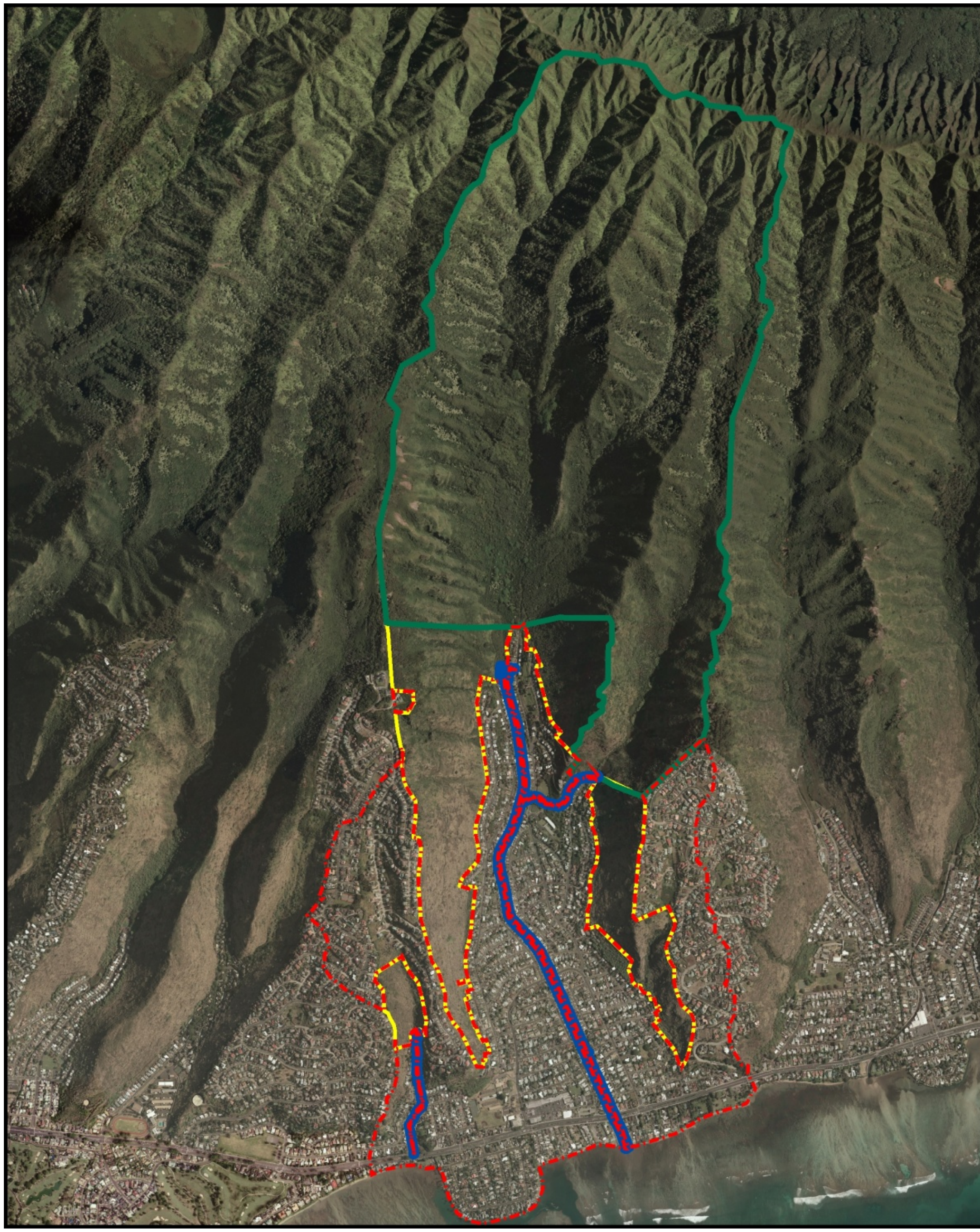

Figure 1

Management Units

Wailupe Watershed Based Plan

Source: SRGII

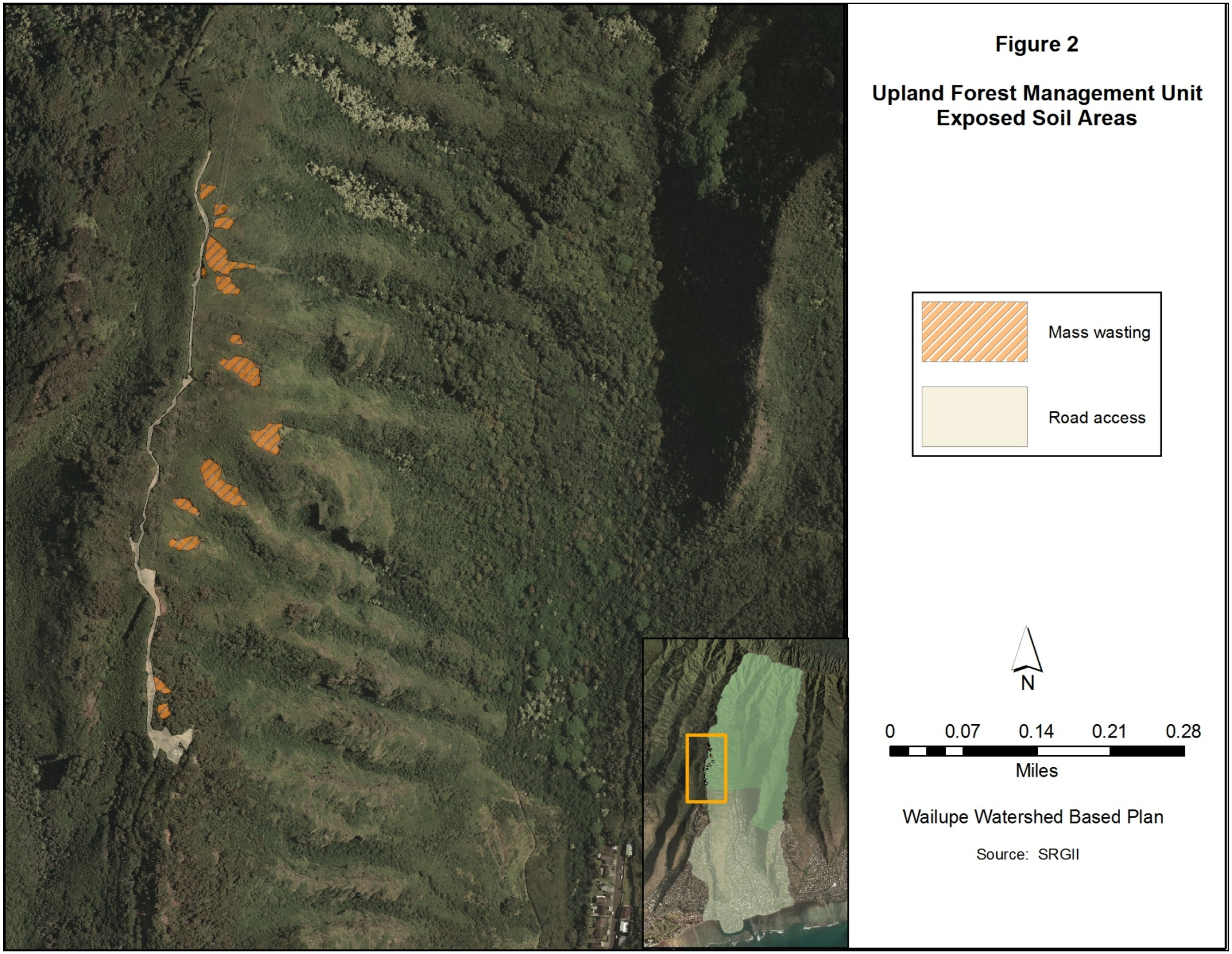
Figure 2
Upland Forest Management Unit
Exposed Soil Areas
Mass wasting
Road access
N
0
0.07
0.14
0.21
0.28
Miles
Wailupe Watershed Based Plan
Source: SRGII

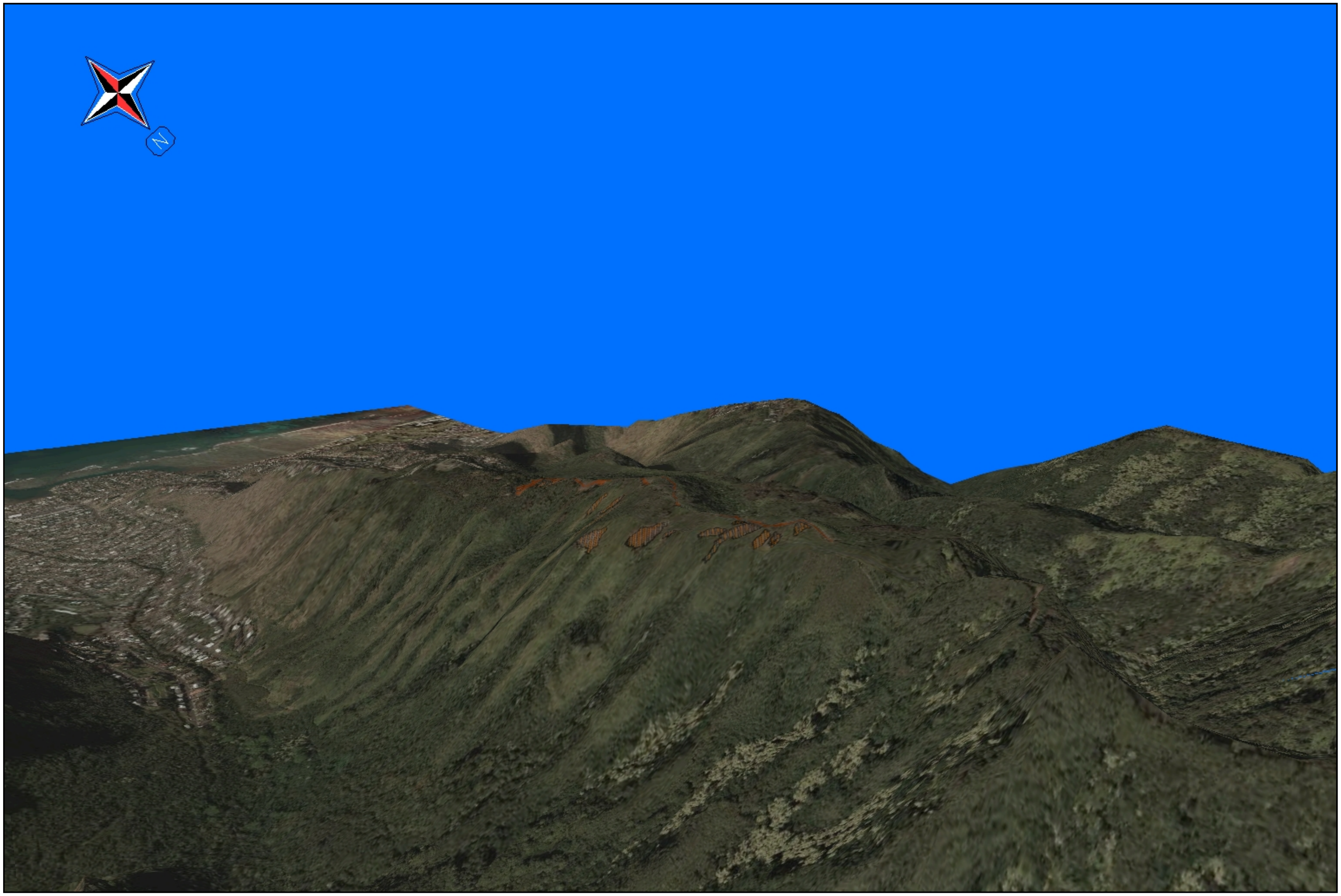

Figure 3. Upland Forest Management Unit: Exposed Soil Areas (3D)

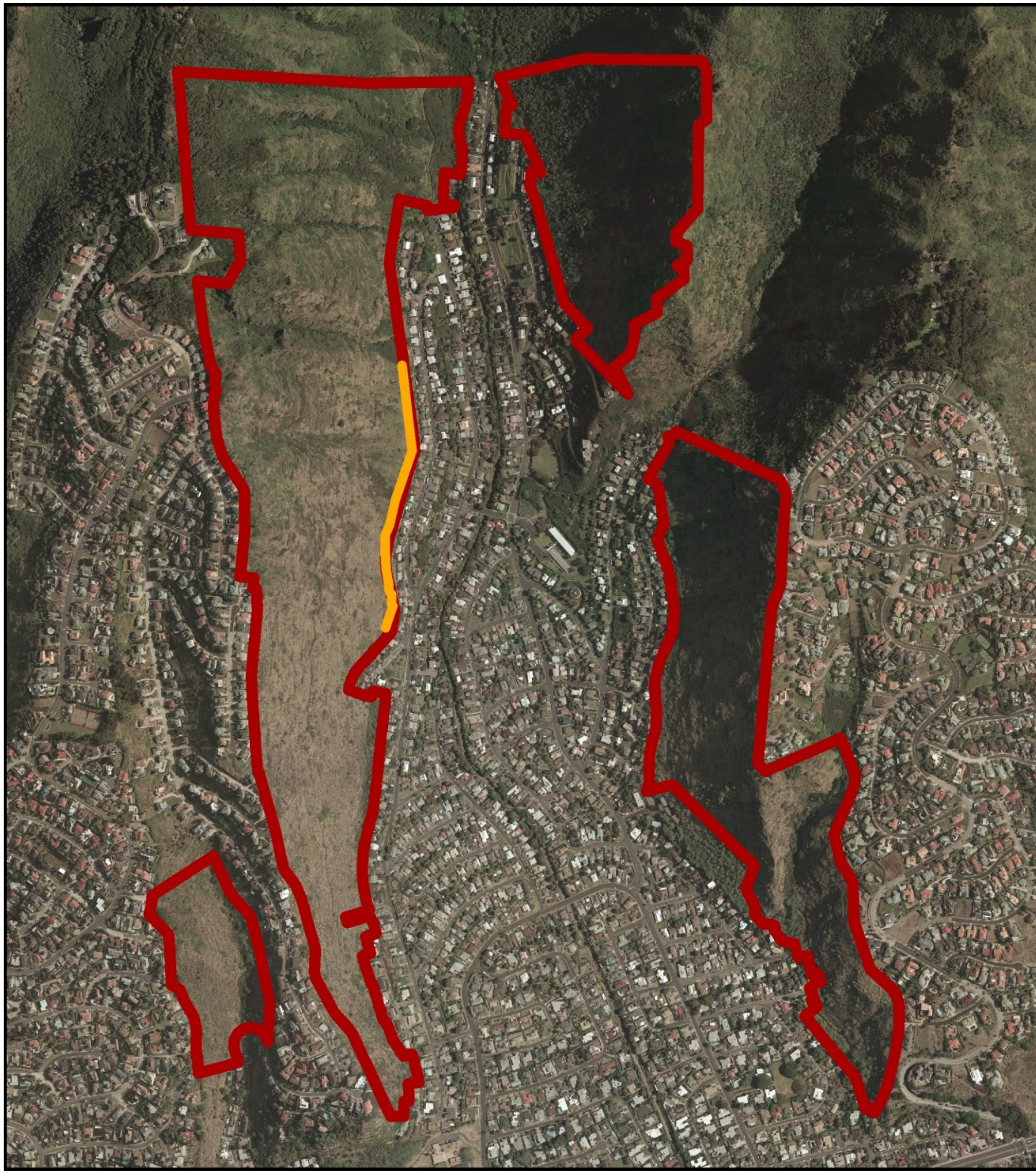

Figure 4

Steep Slope Management Unit Cutoff Ditch Location

Wailupe Watershed Based Plan

Source: SRGII

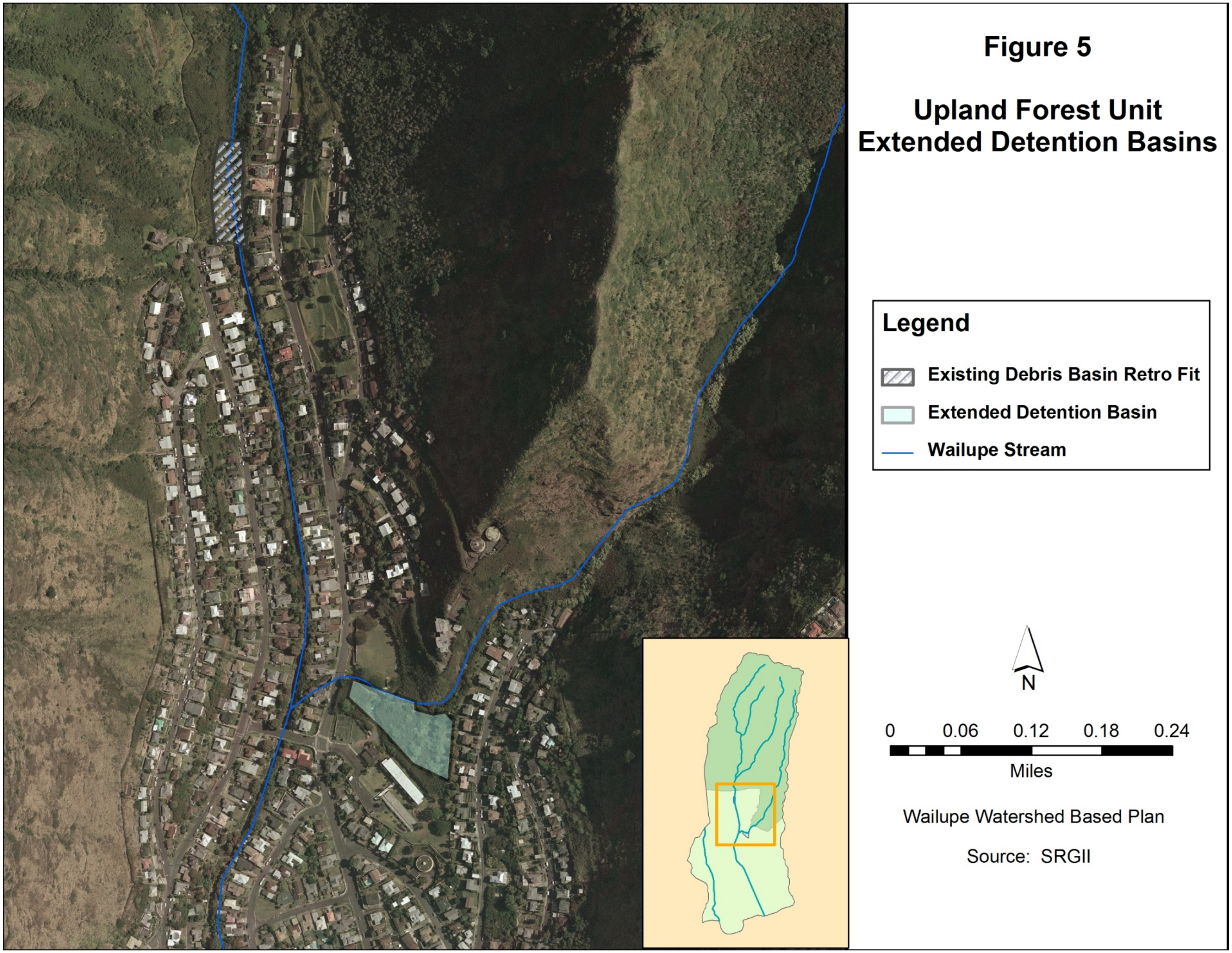

Figure 5

Upland Forest Unit Extended Detention Basins

Figure 6. Upland Forest Management Unit: Extended Detention Basin Locations (3D)

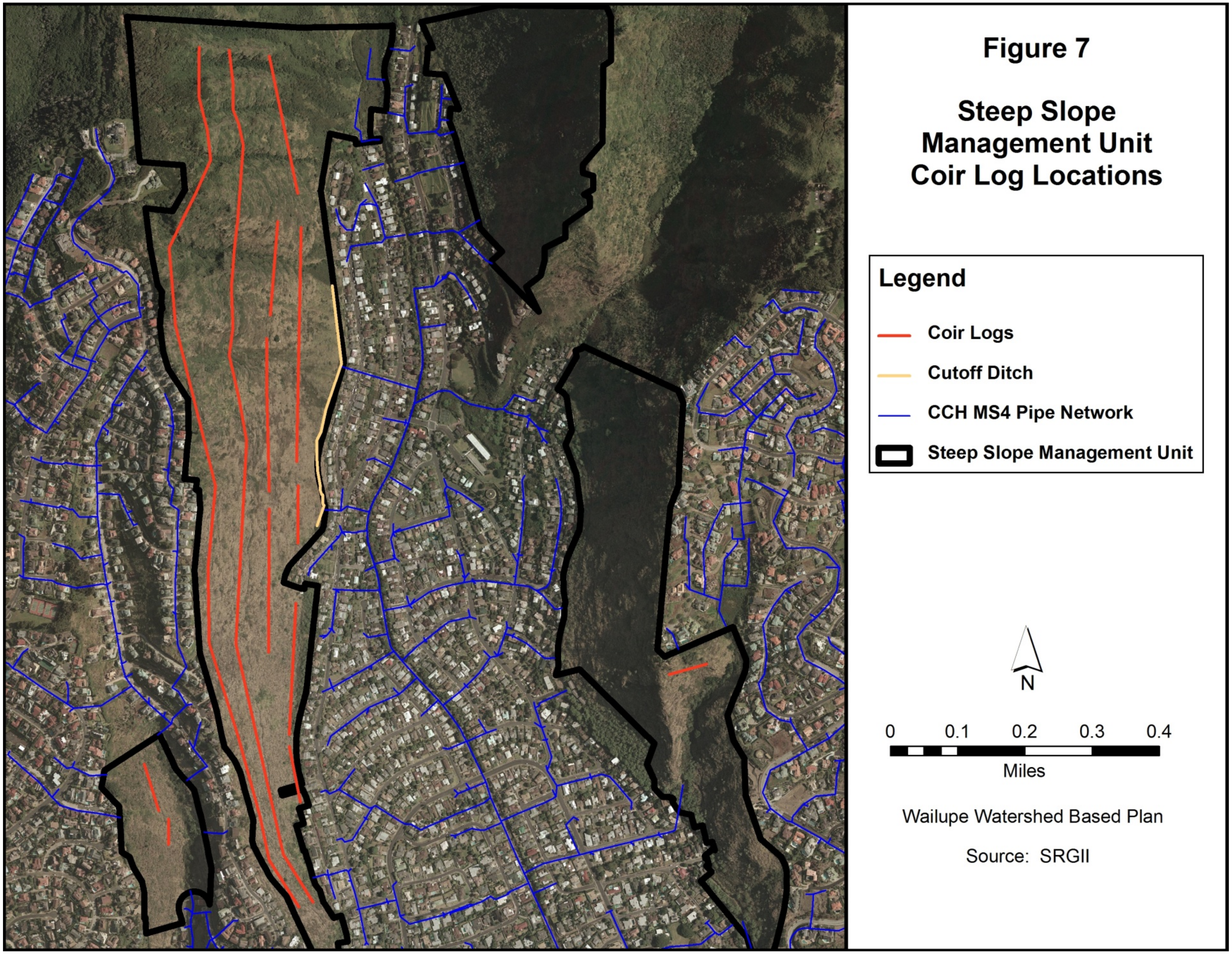

Figure 7

Steep Slope Management Unit Coir Log Locations

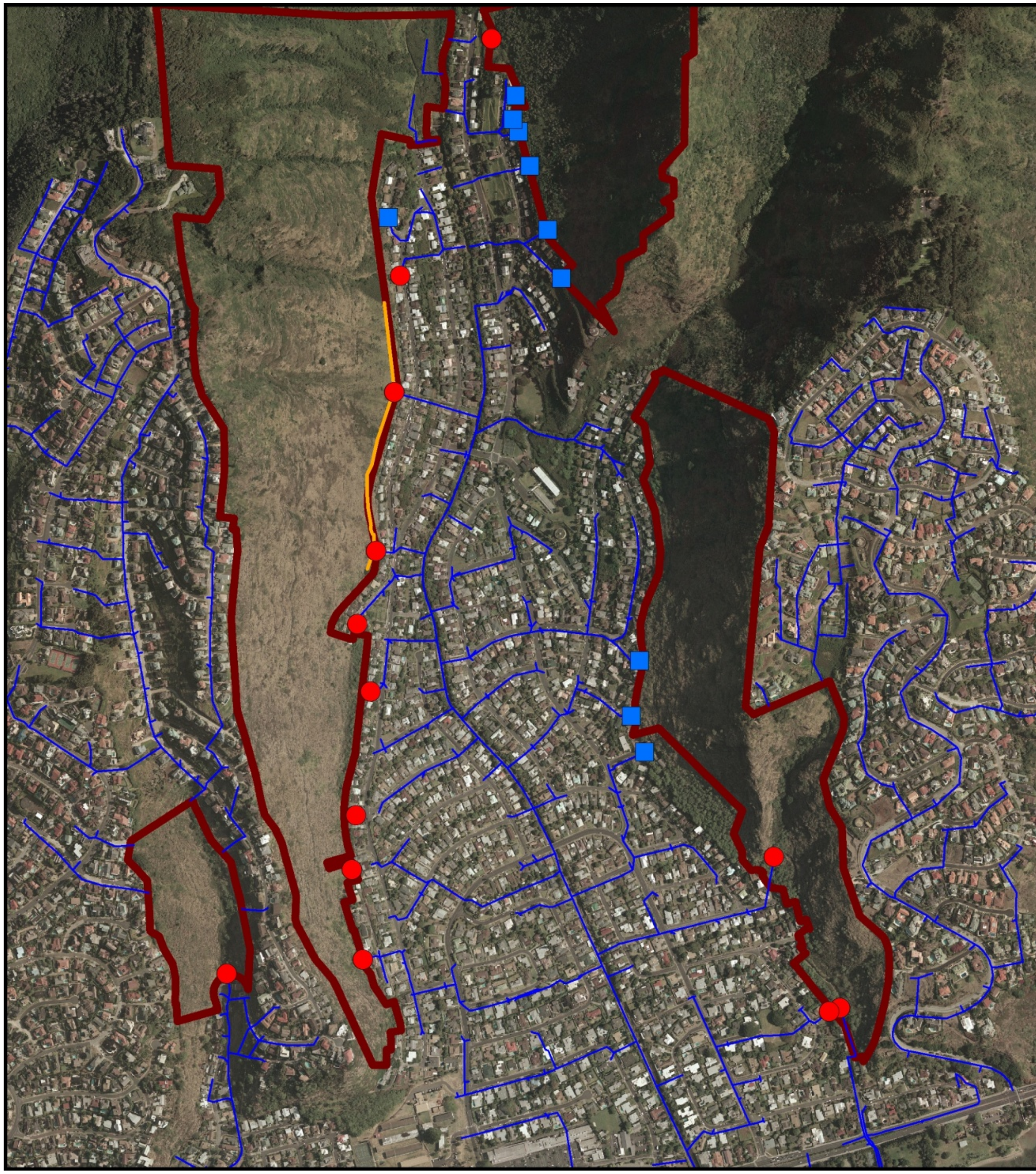

Figure 8

Steep Slope Management Unit Baffle Box Locations

Legend

Retrofit Priority

- High
- Moderate
- Cutoff Ditch
- CCH MS4 Pipe Network
- Steep Slope Management Unit

Wailupe Watershed Based Plan

Source: SRGII

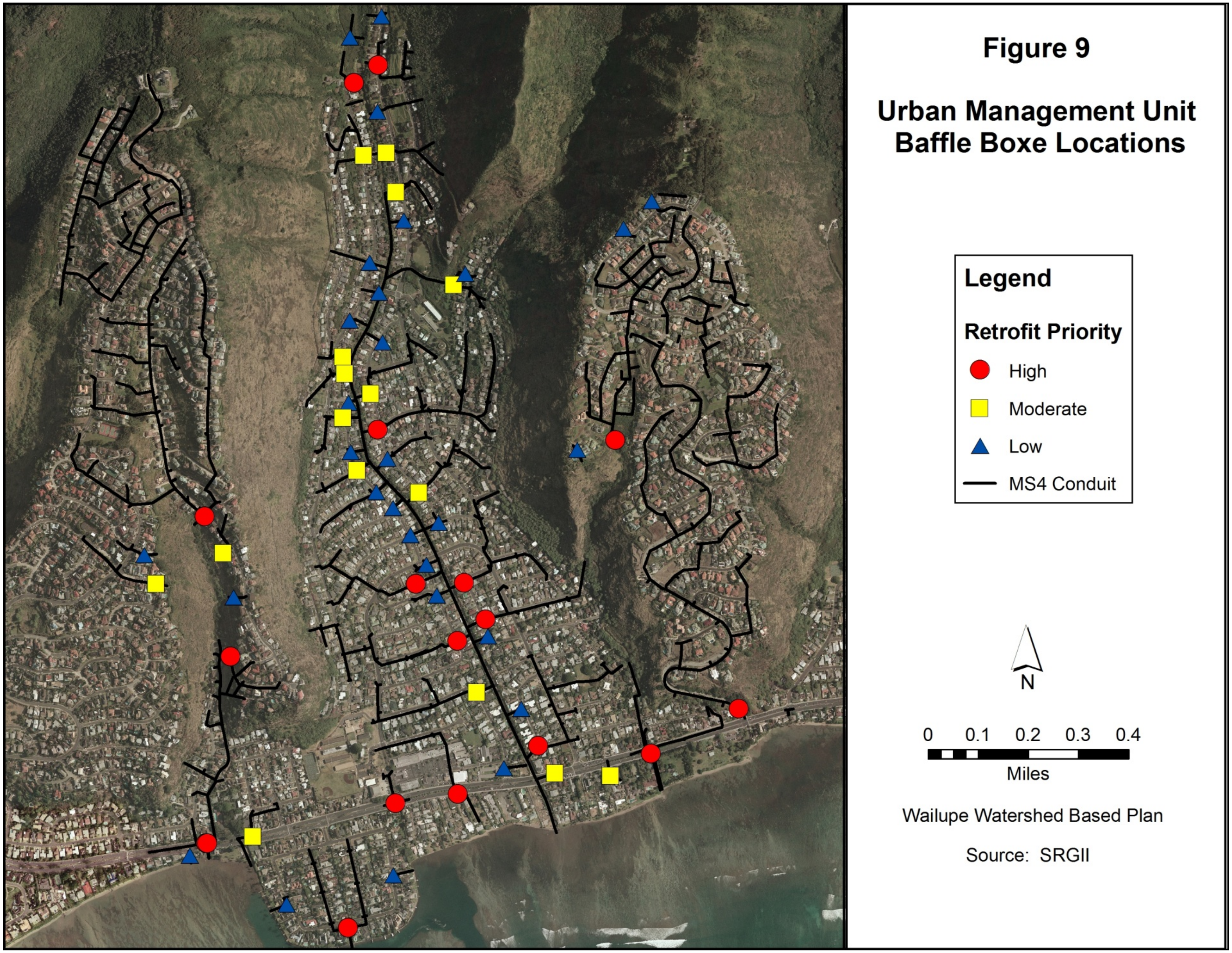
Figure 9
Urban Management Unit
Baffle Boxe Locations
Legend
Retrofit Priority
High
Moderate
Low
MS4 Conduit
N
0 0.1 0.2 0.3 0.4
Miles
Wailupe Watershed Based Plan
Source: SRGII

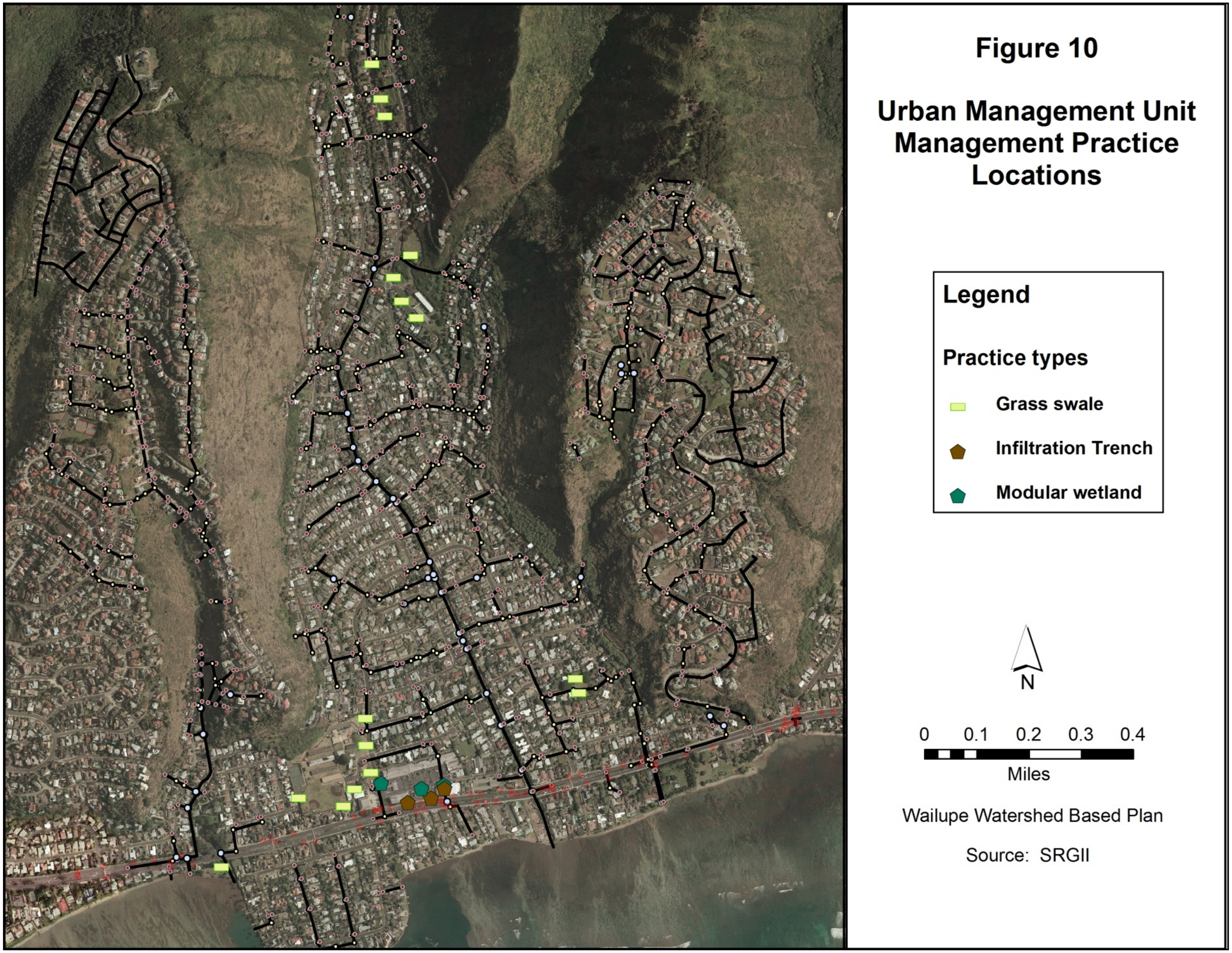

Figure 10

Urban Management Unit Management Practice Locations

Appendix B: Management Practices: Glossary and Design Features

This appendix provides detailed information about pollution control structures and management practices recommended in this report, including a glossary of terms and drawings, images, and product specifications.

Contents

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Glossary

The following glossary terms relating to management practices are adopted from multiple sources, including but not limited to (USEPA 1993; Field, Tafuri et al. 2004; USEPA 2005; USEPA 2007)

BANK STABILIZATION	Methods of securing the structural integrity of earthen stream channel banks with structural supports to prevent bank slumping and undercutting of riparian trees, and overall erosion prevention. To maintain the ecological integrity of the system, recommended techniques include the use of willow stakes, imbricated riprap, or brush bundles.
BANKFULL EVENT (ALSO BANKFULL DISCHARGE)	A flow condition in which streamflow completely fills the steam channel up to the top of the bank. In undisturbed watersheds, the discharge condition occurs on average every 1.5 to 2 years and controls the shape and form of natural channels.
BASEFLOW	The portion of stream flow that is not due to storm runoff, and is supported by groundwater seepage into a channel.
BIOFILTRATION	The use of natural materials and vegetation to trap and remove pollutants from storm water. Grass swales and constructed wetlands can both be used for biofiltration.
BIOLOGICAL MONITORING	Periodic surveys of aquatic biota as an indicator of the general health of a waterbody. Biological monitoring surveys can span the trophic spectrum, from macro-invertebrates to fish species.
CATCH BASIN	Catch Basins collect the rainwater and Urban runoff from the street and serve as the neighborhood entry point in the MS4 system leading into the ocean.
CATCHMENT AREA	See CONTRIBUTING WATERSHED AREA. Also known as drainage catchment area.
CFS	Cubic feet per second. A measure of volumetric flow rate. One CFS is about 449 gallons per minute.
CHANNEL	A natural or artificial waterway that periodically or continuously contains moving water. It has a definite bed and banks that confine the water.
CHANNEL EROSION	The widening, deepening, and headward cutting of small channels and waterways, due to erosion caused by moderate to larger floods.
CONCENTRATION	The density or amount of a pollutant, or other constituent, in solution. This is commonly measured as the average density of pollutants and expressed as milligrams/liter (mg/l).
CONTRIBUTING WATERSHED AREA	Portion of the watershed contributing its runoff to the site or management practice in question.
CONVEYANCE SYSTEM	The drainage facilities, both natural and human-made, which collect, contain, and provide for the flow of surface water and urban runoff from the highest points on the land down to receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities.
DEBRIS	Any material, organic or inorganic, floating or submerged, moved by a flowing stream.
DESIGN STORM	A rainfall event of specified size and return frequency (e.g., a storm that occurs only once every 2 years) that is used to calculate the runoff volume and peak discharge rate to a management practice.
DETENTION	The temporary storage of storm water runoff in a structural device to reduce the peak discharge rates and to provide settling of pollutants.
DETENTION POND	A constructed pond or vault that temporarily stores storm water runoff and releases it at controlled rates.
DETENTION TIME	Time required for detention of storm water runoff in a storm water quality facility (also see "Detention").
DISCHARGE	Outflow; the flow of a stream, canal, or aquifer. One may also speak of the discharge of a canal or stream into a lake, river, or ocean. (Hydraulics) Rate of flow, specifically fluid flow; a volume of fluid passing a point per unit of time, commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, gallons per day, or millions of gallons per day.

DISSOLVED OXYGEN (DO)	Oxygen which is present (dissolved) in water and available for use by fish and other aquatic animals. If the amount of dissolved oxygen in the water is too low, aquatic animals will suffocate.
DIVERSION	A channel, embankment, or other man-made structure constructed to divert water from one area to another
DRAINAGE BASIN	A geographic and hydrologic subunit of a watershed
DRY POND CONVERSION	A modification made to an existing dry storm water management pond to increase pollutant removal efficiencies. For example, the modification may involve a decrease in orifice size to create extended detention times, or the alteration of the riser to create a permanent pool and/or shallow marsh system.
DRY-WEATHER FLOW	Flow occurring during the dry season (generally considered to be May through September) which may be associated with reservoir releases or releases of water from industrial or residential activities.
ECOSYSTEM	The interacting system of a biological community and its nonliving environmental surroundings.
EFFECTIVE IMPERVIOUS AREA (EIA)	The portion of total impervious cover that is directly connected to the storm drain network (MS4). These surfaces usually include street surfaces and paved driveways and sidewalks connected to or immediately adjacent to them, parking lots, and rooftops that are hydraulically connected to the drainage network (eg. downspouts).
EFFLUENT CONCENTRATION	The average concentration of a pollutant or other constituent in storm water runoff flowing out of the management practice.
EMBANKMENT	A bank (of earth or riprap) used to keep back water.
EMERGENT PLANT	An aquatic plant that is rooted in the sediment but whose leaves are at or above the water surface. Such wetland plants provide habitat for wildlife and waterfowl in addition to removing storm water pollutants.
END OF PIPE CONTROL	Water quality control technologies suited for the control of existing urban storm water at the point of storm sewer discharge to a stream. Due to typical space constraints, these technologies are usually designed to provide water quality control rather than quantity control.
ENERGY DISSIPATION	The loss of kinetic energy of moving water due to internal turbulence, boundary friction, change in flow direction, contraction, or expansion.
EROSION	The wearing away of the land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, residential or industrial development, road building, or timber cutting.
EXTENDED DETENTION (ED)	A storm water design feature that provides for the gradual release of a volume of water (0.25 - 1.0 inches per impervious acre) over a 12 to 48 hour interval time to increase settling of urban pollutants, and protect channel from frequent flooding.
EXTENDED DETENTION (ED) POND	A conventional ED pond temporarily detains a portion of storm water runoff for up to twenty-four hours after a storm using a fixed orifice. Such extended detention allows urban pollutants to settle out. The ED ponds are normally dry between storm events and do not have any permanent standing water. An enhanced ED pond is designed to prevent clogging and resuspension. It provides greater flexibility in achieving target detention times. It may be equipped with plunge pools near the inlet, a micropool at the outlet, and utilize an adjustable reverse-sloped pipe at the ED control device.
EXTENDED DETENTION ZONE	A pondscaping zone that extends from the normal pool to the maximum water surface elevation during extended detention events. Plants within this zone must be able to withstand temporary inundation from 5 to 30 times per year.
FLOODPLAIN	Any lowland that borders a stream and is inundated periodically by its waters.
FOREBAY	An extra storage space provided near an inlet of a management practice to trap incoming sediments before they accumulate in a pond management practice.
FRINGE MARSH CREATION	Planting of emergent aquatic vegetation along the perimeter of open water to enhance pollutant uptake, increase forage and cover for wildlife and aquatic species, and improve the appearance of a pond.

GEOTEXTILE FABRIC	Textile of relatively small mesh or pore size that is used to (a) wallow water to pass through while keeping sediment out (permeable), or (b) prevent both runoff and sediment from passing through (impermeable). Also known as filter fabric.
GRADING	The cutting and/or filling of the land surface to a desired slope or elevation.
GRASSED SWALE	An earthen conveyance system in which the filtering action of grass and soil infiltration are utilized to remove pollutants from urban storm water. An enhanced grass swale, or biofilter, utilizes checkdams and wide depressions to increase runoff storage and promote greater settling of pollutants.
GRAVEL	Sediment particles larger than sand and ranging from 2 to 64 mm (0.25 to 3 inches) in diameter.
GRAVITATIONAL SETTLING	The tendency of particulate matter to drop out of storm water runoff as it flows downstream when runoff velocities are moderate and/or slopes are not too steep.
GROUNDWATER TABLE	The level below which the soil is saturated, that is, the pore spaces between the individual soil particles are filled with water. Above the groundwater table and below the ground surface, water in the soil does not fill all pore spaces.
DETENTION VOLUME	The volume of runoff that is held and treated in a management practice structure.
HABITAT	A place where a biological organism lives. The organic and non-organic surroundings that provide life requirements such as food and shelter.
HEAD	Pressure.
HEAVY METALS	Metals of relatively high atomic weight, including but not limited to chromium, copper, lead, mercury, nickel, and zinc. These metals are generally found in minimal quantities in storm water, but can be highly toxic even at trace levels and tend to accumulate in the food chain.
ILLICIT DISCHARGE	All nonurban runoff discharges to urban runoff drainage systems that could cause or contribute to a violation of State water quality, sediment quality, or ground-water quality standards, including but not limited to sanitary sewer connections, industrial process water, interior floor drains, car washing, and greywater systems.
IMPERMEABLE	Properties that prevent the movement of water through the material.
IMPERVIOUS SURFACE	A hard surface area that either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development and/or a hard surface area that causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam, or other surfaces that similarly impede the natural infiltration of urban runoff. Open, uncovered retention/detention facilities shall not be considered as impervious surfaces.
INFILTRATION	The penetration of water through the ground surface into subsurface soil or the penetration of water from the soil into sewer or other pipes through defective joints, connections, or manhole walls. The infiltration rate is expressed in terms of inches/hour. Infiltration rates will be slower when the soil is dense (e.g., clays) and faster when the soil is loosely compacted (e.g., sands). Can also refer to seepage of groundwater into sewer pipes through cracks and joints.
INFLOW	The volume of storm water that enters a management practice.
INFLUENT CONCENTRATION	The average concentration of a pollutant or other constituent in storm water runoff flowing into the management practice.
INLET	(1) A drainage passway. (2) A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water. (3) An arm of the sea (or other body of water) that is long compared to its width and may extend a considerable distance inland.
INVASIVE EXOTIC PLANTS	Non-native plants having the capacity to compete and proliferate in introduced environments.
LAND CONVERSION	A change in land use, function, or purpose.

LAND-DISTURBING ACTIVITY	Any activity that results in a change in the existing soil cover (both vegetative and nonvegetative) and/or the existing soil topography. Land-disturbing activities include, but are not limited to, demolition, construction, clearing, grading, filling, and excavation.
LEVEL SPREADER	A device used to spread out storm water runoff uniformly over the ground surface as sheet flow (i.e., not through channels). The purpose of level spreaders is to prevent concentrative, erosive flows from occurring, and to enhance infiltration.
LOAD ALLOCATION (LA)	The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources.
LOADING CAPACITY (LC)	The greatest amount of loading [pollutant] that water can receive without violating water quality standards.
LOCAL GOVERNMENT	Any county, city, or town having its own incorporated government for local affairs.
LOWFLOW CHANNEL	An incised or paved channel from inlet to outlet in a dry basin which is designed to carry low runoff flows and/or baseflow, directly to the outlet without detention.
MASS WASTING	Dislodgement and downslope transport of loose rock and soil material under the direct influence of gravitational body stresses.
MULTIPLE POND SYSTEM	A collective term for a cluster of pond designs that incorporate redundant runoff treatment techniques within a single pond or series of ponds. These pond designs employ a combination of two or more of the following: extended detention, permanent pool, shallow marsh, or infiltration. The wet ED pond is an example of a multiple pond system.
MUNICIPAL SEPARATE STORM SEWER SYSTEMS (MS4)	MS4 is a storm water conveyance system comprised of inlet, pipes and outfalls that is owned or operated by the State or local government entity, is used for collecting and conveying storm water, and is not part of a publicly owned treatment works, as defined in EPA 40 CFR Part III. MS4 systems are
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)	A national program under Section 402 of the Clean Water Act for regulation of discharges of pollutants from point sources to waters of the United States. Discharges are illegal unless authorized by an NPDES permit.
NATURAL BUFFER	A low sloping area of maintained grassy or woody vegetation located between a pollutant source and a waterbody. A natural buffer is formed when a designated portion of a developed piece of land is left unaltered from its natural state during development. A natural vegetative buffer differs from a vegetated filter strip in that it is natural and in that they need not be used solely for water quality purposes. To be effective, such areas must be protected against concentrated flow.
NONPOINT SOURCE (NPS) POLLUTION	Pollution that , unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and manmade pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water. Loadings of pollutants from NPS enter waterbodies via sheet flow, rather than through a pipe, ditch or other conveyance.
NUTRIENTS	Elements or substances, such as nitrogen or phosphorus, that are necessary for the growth and development of living things (e.g., plants). Large amounts of these substances reaching water bodies can lead to reduced water quality and eutrophication by promoting excessive aquatic algae growth. Some nutrients can be toxic at high concentrations.
OIL/WATER (OR OIL/GRIT) SEPARATOR	A best management practice consisting of a three-stage underground retention system designed to remove heavy particulates and absorbed hydrocarbons. Also known as a WATER QUALITY INLET.
ON-LOT STORAGE	Refers to a series of practices that are designed to contain runoff from individual lots.
ORGANOPHOSPHATE	Pesticide chemical that contains phosphorus; used to control insects. Organophosphates are short-lived, but some can be toxic when first applied.
OTHER REPORTED MEASURES OF PERFORMANCE	These are measures other than effluent concentration. Other reported measures of performance can include percent removal or similar measures.

OUTFALL	The point of discharge for a river, drain, pipe, etc.
OUTFLOW	The volume of storm water that leaves a management practice.
PASSIVE TREATMENT FACILITY	Facilities which use natural materials and vegetation to cleanse storm water and/or reduce storm water flow. Examples include grass swales, constructed wetlands, etc.
PERCENT REMOVAL	For a management practice, the percentage difference between the effluent concentration and the influent concentration for a given pollutant parameter.
PERCENT VOLUME REDUCTION	The percentage of volume reduced between the maximum influent volume and the maximum effluent volume for a given time period.
PERCOLATION	The downward movement of water through the soil.
PERMANENT POOL	A three to ten foot deep pool in a storm water pond system that provides removal of urban pollutants through settling and biological uptake. (Also referred to as a wet pond).
PERMEABILITY	The quality of a soil horizon that enables water or air to move through it.
PERVIOUS SURFACE	Surface area which allows infiltration of water.
PHYSICAL INFILTRATION	The separation of particulates from runoff by grass, leaves and other organic matter on the surface, as the runoff passes across or through the ground.
PHYTOREMEDIATION	Mitigation of environmental problems through the use of natural plant processes and production to contain, degrade, or eliminate contaminant material such as metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants, from the media that contain them.
POINT SOURCE	Any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural storm water runoff.
POINT SOURCE OF POLLUTION	Discrete conveyances, such as pipes or man made ditches that discharge pollutants into waters of the United States. This includes not only discharges from municipal sewage plants and industrial facilities, but also collected storm drainage from larger urban areas, certain animal feedlots and fish farms, some types of ships, tank trucks, offshore oil platforms, and collected runoff from many construction sites.
POLLUTANT	Dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq.)), heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water [40 CFR 122.2].
POLLUTION	Pollution is the introduction of contaminants into an environment that causes instability, disorder, harm or discomfort to the ecosystem i.e. physical systems or living organisms. Pollution can take the form of chemical substances or energy, such as noise, heat, or light. Pollutants, the elements of pollution, can be foreign substances or energies, or naturally occurring; when naturally occurring, they are considered contaminants when they exceed natural levels. Pollution is often classified as point source or nonpoint source pollution.
PONDSCAPING	A method of designing the plant structure of a storm water marsh or pond using inundation zones. The proposed marsh or pond system is divided into zones which differ in the level and frequency of inflow. For each zone, plant species are chosen based on their potential to thrive, given the inflow pattern of the zone.
POST-DEVELOPMENT PEAK RUNOFF	Maximum instantaneous rate of flow during a storm, after development is complete.
PRIORITY POLLUTANTS	Those pollutants considered to be of principal importance for control under the CWA based on the NRDC consent decree settlement [(NRDC et al. v. Train, 8 E.R.C. 2120 (D.D.C. 1976), modified 12 E.R.C. 1833 (D.D.C. 1979)]; a list of these pollutants is provided as Appendix A to 40 CFR Part 423
RECEIVING WATER	The "Water of the United States" as defined in 40 CFR 122.2 into which the regulated storm water discharges.

RETENTION POND	Retention ponds, or "wet ponds," are among the most common stormwater treatment systems used today. They are not to be confused with detention basins or "dry basins," which hold runoff for a specified period of time, and then release the entire volume of the runoff. Retention ponds retain a resident pool of standing water, which improves water quality treatment between storms. Retention ponds demonstrate a reasonably strong water quality treatment, particularly in comparison to dry pond systems.
RETROFIT	The creation or modification of an urban runoff management system in a previously developed area. This may include wet ponds, infiltration systems, wetland plantings, streambank stabilization, and other management practice techniques for improving water quality and creating aquatic habitat. A retrofit can consist of the construction of a new management practice in a developed area, the enhancement of an older urban runoff management structure, or a combination of improvement and new construction.
RIPARIAN	A relatively narrow strip of land that borders a stream or river, often coincides with the maximum water surface elevation of the one-hundred year storm.
RIPRAP	A combination of large stone, cobbles, and boulders used to line channels, stabilize banks, reduce runoff velocities, or filter out sediment.
ROOT ZONE	The part of the soil that is, or can be, penetrated by plant roots.
RUNOFF CONVEYANCE	Methods for safely conveying storm water to a management practice to minimize disruption of the stream network, and promote infiltration or filtering of the runoff.
RUNOFF PRETREATMENT	Techniques to capture or trap coarse sediments before they enter a management practice to preserve storage volumes or prevent clogging within the management practice. Examples include forebays and micropools for pond management practices, and plunge pools, grass filter strips, and filter fabric for infiltration management practices.
RUNON	Off-site flows which flows onto a site.
SCOUR	Concentrated erosive action of flowing water in streams that removes material from the bed and banks.
SEDIMENT	The product of erosion processes; the solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice.
SEDIMENT FOREBAY	Storm water design feature that employs the use of a small settling basin to settle out incoming sediments before they are delivered to a storm water management practice. Particularly useful in tandem with infiltration devices, wet ponds, or marshes.
SEDIMENTATION	The process of sand and mud settling and building up on the bottom of a creek, river, lake, or wetland.
SEEDBANKS	Refers to the large number and diversity of dormant seeds of plant species that exist within the soil. The seeds may exist within the soil for years before they germinate under the proper moisture, temperature, or light conditions. Within marsh soils, this seedbank helps to maintain above-ground plant diversity and can also be used to rapidly establish marsh plants within a newly constructed storm water marsh.
SEEPAGE	Water escaping through or emerging from the ground along an extensive line or surface as contrasted with a spring, where the water emerges from a localized spot.
SELF-MONITORING	Sampling and analyses performed by a facility to determine compliance with a permit or other regulatory requirements.
SHEET FLOW	Water, usually storm runoff, flowing in a thin layer over the ground surface.
SLOPE	The degree of deviation of a surface from horizontal, measured as a percentage, as a numerical ratio, or in degrees.
SOURCE CONTROL	A pollution control measure which operates by keeping pollutants from entering storm water
STORM DRAIN (OR STORM SEWER SYSTEM)	Above and below ground structures for transporting storm water to streams or outfalls for flood control purposes.
STORM WATER	Storm water runoff, snow melt runoff, and surface runoff and drainage [40 CFR 122.26(b)(13)].

STORM WATER DISCHARGE-RELATED ACTIVITIES	Activities that cause, contribute to, or result in storm water point source pollutant discharges, including excavation, site development, grading, and other surface disturbance activities; and measures to control storm water, including the siting, construction, and operation of management practices to control, reduce, or prevent storm water pollution.
STORM WATER RUNOFF	Excess precipitation that is not retained by vegetation, surface depressions, or infiltration, and thereby collects on the surface and drains into a surface water body.
STORM WATER TREATMENT	Detention, retention, filtering, or infiltration of a given volume of storm water to remove urban pollutants and reduced frequent flooding.
STREAM BUFFER	A variable width strip of vegetated land adjacent to a stream that is preserved from development activity to protect water quality, aquatic, and terrestrial habitats.
SUBSOIL	The bed or stratum of earth lying below the surface soil
SUSPENDED SEDIMENT	The very fine soil particles that remain in suspension in water for a considerable period of time.
SWALE	A natural depression or wide shallow ditch used to temporary store, route, or filter runoff.
TOPOGRAPHY	The relative positions and elevations of the natural or man-made features of an area that describe the configuration of its surface.
TOTAL LOAD REDUCTION	An estimate of the management practice removal efficiency target for reducing the total amount or load of pollutants (sediment, nutrients, oxygen-demanding material, or other chemicals or compounds) in storm water runoff.
TOTAL MAXIMUM DAILY LOAD (TMDL)	A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.
TOTAL SUSPENDED SOLIDS (TSS)	A measure of the filterable solids present in a sample, as determined by the method specified in 40 CFR Part 136.
TOXIC POLLUTANT	Pollutants or combinations of pollutants, including disease-causing agents, which after discharge and upon exposure, ingestion, inhalation or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will, on the basis of information available to the Administrator of EPA, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring. Toxic pollutants also include those pollutants listed by the Administrator under CWA Section 307(a)(1) or any pollutant listed under Section 405(d) which relates to sludge management.
TRASH AND DEBRIS REMOVAL	Mechanical or manual removal of debris, snags, and trash deposits from the streambanks to improve the appearance of the stream.
TREATMENT	The application of engineered systems that use physical, chemical, or biological processes to remove pollutants. Such processes include, but are not limited to, filtration, gravity settling, media adsorption, biodegradation, biological uptake, chemical oxidation and UV radiation.
TREATMENT CONTROL PRATCICE	Any engineered system designed to remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, media adsorption or any other physical, biological, or chemical process.
TURBIDITY	A cloudy condition in water due to suspended silt or organic matter.
URBAN RUNOFF	That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, underflow, or channels or is piped into a defined surface water channel or a constructed infiltration facility.
VEGETATED BUFFER	Strips of vegetation separating a waterbody from a land use with potential to act as a nonpoint pollution source; vegetated buffers (or simply buffers) are variable in width and can range in function from a vegetated filter strip to a wetland or riparian area.
VELOCITY	The distance that water travels in a given direction in a stream during an interval of time.
VOLUME	The amount of storm water (expressed in liters) that enters or leaves a management practice.

WASTELOAD ALLOCATION (WLA)	The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution
WATERS OF THE UNITED STATES	All waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide, all interstate waters and wetlands, tributaries of these waters, and the territorial seas
WATER QUALITY CRITERIA	Comprised of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.
WATER QUALITY INLET	See OIL/WATER SEPARATOR.
WATER QUALITY STANDARDS	Includes three major components: designated uses, water quality criteria, and antidegradation provisions.
WATERSHED	The land area that drains into a receiving waterbody.
WEEPHOLE	A small opening or pipe left in a revetment or bulkhead to allow groundwater drainage.
WET POND	A conventional wet pond has a permanent pool of water for treating incoming storm water runoff. In enhanced wet pond designs, a forebay is installed to trap incoming sediments where they can be easily removed; a fringe marsh is also established around the perimeter of the pond.
WETLANDS	Areas that are inundated or saturated by surface or ground water at a frequency and duration to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions; wetlands generally include swamps, marshes, bogs, and similar areas.
WET-WEATHER FLOW	Water derived primarily from rain, melting snow or irrigation during the wet season (generally considered to be October through April) that flows over the surface of the ground.
WETLAND PLANT UPTAKE	Marsh plant species rely on nutrients (i.e., phosphorous and nitrogen) as a food source; thus, they may intercept and remove nutrients from either surface or subsurface flow.

Management Practice Descriptions

Management practices are structural controls or non-structural procedures used to control pollutants. Management practices depicted include both those identified as part of the *Pollution Control Strategies Report*, as well as general management practices for reference. They are described for illustration purposes only. To provide effective control of runoff and pollution, management practices must be correctly designed, installed, and maintained. Management practices can be installed along existing stormwater conveyance systems to treat pollution. They can also be installed or implemented at the source areas of pollution.

Baffle Box. The Nutrient Separating Baffle Box is a unique hydrodynamic separator. Effective at capturing sediments, TSS, and hydrocarbons; this system is specially designed to capture trash and debris, organics, and gross solids in a raised screening basket which allows these pollutants to be stored in a dry state (http://www.biocleanenvironmental.com/product/ns_baffle_box).

Bio Sorb. Hydrocarbon Absorbent Bio Sorb is an absorbent polymer ideal for removing large quantities of hydrocarbons, including: oils and grease, Total Petroleum Hydrocarbons, and polynuclear aromatic hydrocarbons. The physical properties of the media prevent leaching of absorbed hydrocarbons; incredibly this media can absorb up to three times its weight in oils and grease.

Coir logs are rolled materials made from natural fibers of coconut and other degradable materials. The logs range in diameter from 6-18 inches and length from 6-12 feet. The logs are permeable, allowing surface water to pass at a reduced rate while trapping sediments and other detritus. They are placed on slopes to reduce the slope length and slow the overland flow velocity.. They can be installed in shallow excavation trenches around the base of stock piles containing fill and along excavated runoff ditches. Vegetation such as small woody shrubs and grasses can be planted in, and at the interface of the logs at their upslope side. The logs act like sponges and are expected to aid in plant establishment by trapping sediments, retaining water, and providing a microclimate (increase R.H.). They will also provide immediate erosion control. The logs are installed by excavating shallow trenches, placing the logs in direct contact with exposed substrate, and anchoring logs with wood stakes. The depth of the excavated housing trench is a function of the insitu conditions and will vary.

Detention and Retention Practices detain runoff to attenuate peak discharge rate to protect downstream channel erosion and bank failure and developments from flooding. Both can be designed to capture bedload and fine suspended sediments. These systems can be designed as a multi-parameter approach to ecological sustainability of receiving systems.

> **Dry Extended Detention (ED) Ponds** A conventional ED pond temporarily stores a portion of storm water runoff for a specified period of time (usually 24-48 hours) which allows sediment particles and associated pollutants to settle out. The ED ponds are normally dry between storm events and do not have any permanent standing water. An enhanced ED pond is designed to prevent clogging and resuspension. It provides greater flexibility in achieving target detention times. It may be equipped with plunge pools near the inlet, a micropool at the outlet, and utilize an adjustable reverse-sloped pipe at the ED control device. Water is discharged through a hydrologic outlet structure to a downstream conveyance system. Dry ED ponds are among the most widely applicable storm management practice.

Retention Ponds use permanent pools, extended detention basin, or shallow marsh to remove pollutants. Retention ponds can include a wet pond; micropool extended detention ponds; multiple pond systems. These ponds serve the same function as an ED pond and often contain a fringe wetland installed around the perimeter of the pond for the purpose to increase habitat and pollutant removal values.

Energy dissipaters are used to prevent erosion at the outlet of a channel or conduit by reducing the velocity of flow and dissipating the energy.

Erosion mats are materials constructed of either synthetic or natural fibers. They are used to cover bare ground to reduce rainfall impacts and overland flow. Depending on the type of materials and the density of the openings, they can be used to cover areas that have been seeded or planted as part of erosion control design. Natural fiber mats are biodegradable and provide protection during the interim period between seeding or planting and establishment of vegetative ground cover. Many manufacturers claim that the by-products of the biodegrading process do not contain any substances that adversely affect aquatic flora or fauna. The key to using erosion mats is to anchor them properly to the ground surface to prevent overland flow between the mats and the ground.

Geosynthetics are a broad class of materials designed primarily for use in engineered earth applications. These materials are used in locations where biodegradation could be a problem and in situations requiring inherent strength and durability of the material. Most geosynthetic materials used in erosion control applications are made of plastic, nylon, or other synthetic materials and may contain other chemical components added to create certain physical characteristics. Geosynthetic materials are divided into several different subcategories:

Geomembranes are probably the largest categories of geosynthetics. According to the Geosynthetic Research Institute (GRI), geomembranes are "impervious thin sheets of rubber or plastic material used primarily for linings and covers of liquid- or solid-storage facilities." GRI notes that although "nothing is strictly impermeable," when compared with competing materials such as natural or amended clay–substances with an impermeability of 10-7 cubic meters per second (m^3/s), geomembranes offer a much smaller diffusion permeability of 10-11 to 10-13 m^3/s and are considered relatively impermeable.

Geotextiles are the second largest category of geosynthetic products. Classified as textiles because of their fabric-like consistency, geotextiles consist of synthetic fibers, which are highly resistant to degradation when in contact with soil or water. Both woven and nonwoven geotextiles are manufactured. They are porous to water flow both across and through the sheet, although the density of the weave or matting determines the porosity through the fabric. Geotextiles can be used to line road sub-grades and runoff ditches to prevent vegetation from growing up through the surfaces.

Geogrids, unlike geotextiles, contain relatively large open spaces. Geogrids are used primarily for reinforcement, such as for soil reinforcement in the construction of retaining walls. This segment of the industry is rapidly growing, with at least 25 different applications already identified.

Other geosynthetic categories include geonets or geospacers, designed to move water through a drainage area, and geosynthetic clay liners, impervious products consisting of clay sandwiched between layers of geotextile or geomembrane. These geosynthetic materials are often used at landfill sites to prevent fluid infiltration into adjacent soils.