STORM WATER BEST MANAGEMENT PRACTICES (BMP) PLAN

FOR FOUR MAJOR OUTLETS AT KAELEPULU POND

Kailua, Hawaii

November 2008

Prepared for:

City and County of Honolulu

Department of Environmental Services

Storm Water Best Management Practices (BMP) Plan

For Four Major Outlets at Kaelepulu Pond, Kailua, Hawaii

City and County of Honolulu
Department of Environmental Services

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November 2008

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ACRONYMS AND ABBREVIATIONS

BMPs	Best Management Practices
BOD	Biological Oxygen Demand
cfs	cubic feet per second
cy	Cubic Yards
COC	Chain of Custody
CWA	Clean Water Act
CWB	Clean Water Branch, State of Hawaii Department of Health
DDC	Department of Design and Construction, City and County of Honolulu
DPP	Department of Planning and Permitting, City and County of Honolulu
EAL	Environmental Action Level
ELSC	Enchanted Lake Shopping Center
ELRA	Enchanted Lake Resident Association
ERL	Effects Range- Low
ERM	Effects Range- Medium
ESN	Environmental Services Network (Pacific)
ft	feet
GC	Gas Chromatography
GIS	Geographical Information Systems
HAR	Hawaii Administrative Rules
HDOH	Department of Health, State of Hawaii
in	inches
K-Hwy	Kalanianaole Highway
MASTED	Massachusetts Storm water Technology Evaluation Project
MDL	Method Detection Limit
MEP	Maximum Extent Practicable
mg/kg	milligrams per kilogram
mg/L	milligrams per Liter
mm	millimeters
MS4s	Municipal Separate Storm Sewer System
msl	mean sea level
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	non-point source
O&M	Operation and Maintenance
PSD	Particle Size Distribution
PSEP	Puget Sound Estuary Protocols
RCRA	Resource Conservation and Recovery Act
RRSDS	Rules Relating to Storm Drainage Standards
SQRT	Screening Quick Reference Tables
SSC	Suspended Sediment Concentration
sf	Square Feet
sy	Square Yards
TEC	TEC Inc.
TKL	Total Kjedahl Nitrogen
Tm	Recurrence Interval
TMDL	Total Maximum Daily Load
TMK	Tax Map Key

TSS	Total Suspended Solids
µg/L	micrograms per Liter
µg-N/L	micrograms Nitrogen
µg-P/L	micrograms Phosphorous
UH	University of Hawaii
µm	micrometer
U.S.	United States
USEPA	Environmental Protection Agency
USGS	US Geological Survey
WQFR	Water Quality Flow Rate
WQS	Water Quality Standards

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EXECUTIVE SUMMARY

This storm water best management practices (BMPs) plan is prepared for the City and County of Honolulu (City), Department of Environmental Services (ENV) and evaluates four major outlets, as defined in 40 CFR Part 123 Subpart B, and their corresponding drainage areas. The major outlets are associated with the Windward District in the Kailua Watershed and discharge into Kaelepulu Pond (ID# WKIP). The outlets were chosen for this study after field reconnaissance and Enchanted Lake Resident Association (ELRA) interviews and were identified as major contributors of sediment and gross pollutants into Kaelepulu Pond.

The original scope of the project included analysis and evaluation of potential structural and non-structural improvements at the outfalls and drainage areas associated with WKIP 14 and 52. A July 2007 modification (MOD) to the Scope of Work (SOW) included additional and equal analysis and evaluation for WKIP 10 and WKIP 44. The following general tasks were evaluated for each drainage area (Figure ES-1): 1) Field survey identifying pollutant sources; 2) Overview of drainage area; 3) Develop BMPs Plan for two commercial facilities associated with WKIP 10; 4) Develop BMPs Plan for structural (and non-structural) improvements, including maintenance issues and suggestions for improvements based on field observations; and 5) sediment sampling and testing for 3 of the 4 outlets associated with the drainage basins and a composite sample within the WKIP 10 Hele Channel near the proposed structural BMP site.

The main intent of this storm water BMPs Plan is to address complaints of sediment build up and odors at Kaelepulu Pond through structural (and non-structural) BMPs. Additionally, this report attempts to address gross pollutant issues that were discovered through field investigation and resident interviews for the drainage areas. Specific tasks are identified in Section 1.2.5.

The Rules Relating to Storm Drainage Standards (RRSDS) (City 2000) was used to complete two separate hydrological analyses of the four WKIP outfalls (WKIP 14, WKIP 52, WKIP 10, and WKIP 44; [plus the WKIP 44 outfall accumulative drainage area, see section 1.3.4], here after referred to as WKIP 30-44) into Kaelepulu Pond (see also Section 3). Each drainage area outlet was examined for peak storm drainage flows expected from rainfall intensities of storm events with recurrence intervals of 10 and 50 years for WKIP 14 and WKIP 44; and 100 years for WKIP 52, WKIP 10, and WKIP 30-44 as required for drainage areas greater than 100 acres. Additionally, the volume of storm water generated and diverted to each drainage outlet during the initial flush of a storm is also addressed. The first flush condition, as expected, was found to be significantly less than the peak flows for 10-, 50-, and 100-year storm event of each of these major open-channel outlets. Therefore, the design for any structural BMP should take into account the ability to convey peak discharge flows during major storm event, along with full treatment of storm water quality flow rates (QWQ_{FR}) generated during the initial flush.

Table ES-1 summarizes the four outlets and respective drainage areas in this study.

Table ES-1. Kaelepulu Pond Outlet Summary

Drainage Outfall	Area (acres)	Flow Generated During 10-year Storm Event (cfs)	Flow Generated During 50-year Storm Event (cfs)	Flow Generated During 100-year Storm Event (cfs)	Q_{WQFR} (cfs)	Outlet Description
WKIP 14	87.4	208	312	na	24.47	19 ft. wide Open Un-lined Channel
WKIP 52	138	na	na	1,300	27.60	20x7 ft. Open Concrete-Lined Channel
WKIP 10	323	na	na	2,200	90.44	35 ft. wide Open Un-lined Channel
WKIP 30-44	425	na	na	3,000	85.00	Culmination of Drainage Through WKIP 44
WKIP 44*	4.7	4.7	7.1	na	0.376	18 ft. wide Open Un-lined Channel

na Not Applicable
cfs cubic feet per second
ft. feet
* Separated based on City drainage maps

A summary of hydrological analysis, literature search, recommendations and conclusions were completed at the end of each section to help the City select the appropriate structural BMP devices for each of the drainage areas. A literature search was performed to review the latest available BMPs for treatment of discharged urban storm water. An overall storm water management strategy, with suitable treatment for the open channels, associated with WKIP 14, 52, 10, and 44 drainage areas was developed based on the following criteria:

- Review applicable non-structural BMPs to remove sediment from the WKIP 14, 52, 10 and 44 storm water conveyance system, decreasing sediment input into Kaelepulu Pond;
- Review and analysis of commercially available structural BMPs presented in Section 4 to remove sediment from the WKIP 14, 52, 10, and 44 storm water conveyance system, decreasing sediment input into Kaelepulu Pond; and
- Hydrological and physical characteristics of the four drainage areas discussed.

Due to the urbanization of the four drainage areas and lack of space for BMP installation, BMP associated with storm water storage and reuse was not feasible. There are numerous commercial hydrodynamic separator options for storm water treatment in areas with limited space.

The overall peak runoff discharge rate for WKIP 14, 52, 10, and 44 drainage areas are very high at the drainage channel outlets and upstream portions of the open channel. Individual storm flows from the multitude lateral pipe connections discharging into the open channels associated studies drainage area have manageable flow rates but were ruled out as potential locations for inline placement of BMPs for the following reasons: 1. Lack of right-of-way for installation; 2. Lack of City maintenance access easements; and 3. Any potential installation at a select location(s) would offer only minimal pollution prevention treatment benefits due to the sheer number of these "lower flow" connections.

The major factors driving the selection and design of the storm water management strategy or treatment train for each drainage area and site specific recommendations of non-structural and/or placement of structural BMP treatment options is: 1). the achievement goal of up to 80% TSS removal as stipulated by Rules Relating to Storm Drainage Standards (City 2000) – a requirement only if DPP permits are required for installation (i.e. grading permits etc.); 2) the capability of conveying peak runoff flows produced during major storm events; and 3) installation and maintenance crew accessibility to the structural BMP.

The primary function of this storm water strategy is to improve storm water discharge quality into Kaelepulu Pond. In order to achieve this goal a combination of BMPs, non-structural and structural, were selected for each drainage area based on current practices. Structural BMPs that were recommended and installation locations were based on: locations of maintenance access easements, "hot spots" or high pollutant areas, storm water flow rates, location of tail waters, water quality treatment flow rates, sediment removal efficiencies, and overall cost of the BMP device including installation and operations and management (O&M).

The recommendations for each drainage area includes a Hydrothane Systems, Inc. Trash Tack to be installed near the outlet and last serviceable location of each of the drainage areas to capture gross pollutants (i.e. floatable debris [green waste and trash]) before it enters Kaelepulu Pond. Additional options include installing Bio Clean curb inlet baskets with shelf system to treat the street runoff into the system, and Bio Clean grate inlet skimmer boxes to treat the Enchanted Lake Shopping Center (ELSC) parking lot run off (see Section 5 figures and Appendix A respectively).

Since the open channels are conveying the majority of the flow (and pollutants), compared to the lateral in-line pipe systems, they became the focus areas for a structural BMP approach. Considering the lack of tested structural BMPs for an open-system this size, it is recommended that a pilot project be initiated utilizing the Suntree Technology, Inc. Bio Clean Nutrient Separating Baffle Box (NSBB) for the WKIP 10 Hele concrete-lined channel. The NSBB effectively separates organics and litter from sediments and standing water preventing organic leaching and the possibility of the system going septic. Additionally, there are areas within Hele Channel that need wall rehabilitation, and areas downstream in the natural portions of the channel which require bank stabilization to eliminate erosion.

Structural BMP recommendations and estimated costs for each drainage area are summarized below and in Table ES-2:

- At WKIP 10, a pilot project utilizing a Bio Clean NSBB within the 20-foot Hele concrete open-channel. A conceptual design will need to be developed to assess the specific location and potential hydraulic impacts on the channel. The anticipated location will be just west of the Keolu Drive Bridge (Figure 5-3), within serviceable reach of City vacuum trucks positioned on the bridge. A trash pump could also be used to service this BMP. The drainage area upstream of this location is approximately 260 acres (calculated using GIS) with a flow rate of over 700 cfs based on City drainage reports. The Q_{WQFR} is approximately 70 cfs. It is anticipated that the NSBB hydrodynamic separator will be cast-in-place below channel grade and within the City right-of-way.

- Bio Clean curb inlet baskets with shelf system are recommended for installation at all four drainage areas. Two Bio Clean grate inlet skimmer box installations are recommended within the ELSC parking area (Figures 5-1 through Figures 5-4). Prior to installation it is recommended that existing debris be removed from the catch basins. A street sweeping/catch basin cleaning program should be established within the drainage areas for full BMP effectiveness.

- As a final measure to prevent gross pollutant discharge into Kaelepulu Pond, a Hydrothane Systems, Inc. trash rack are recommended for installation in all four drainage areas near the outlets and/or City maintenance access areas (see Figures 5-1 through Figures 5-4). The Hydrothane trash rack is made of High Density Polyethylene (HDPE) which provides "end-of-system" containment of floating debris. Specific trash rack angles and blade spacings will be determined, but will be approximately a 10-15 degree angle with 4 to 8-inch blade spacing:

    - Within the WKIP 14 and 10 drainage areas, the trash racks will be positioned in the downstream portions of the channel, on the upstream side of bridge culverts (Figures 5-1 and 5-3) ;

    - Within the WKIP 52 and 44 drainage areas, the trash racks will be positioned within the concrete-lined channel near the outlets (Figures 5-2 and 5-4).

- As a measure to prevent erosion along the banks of the WKIP 10 drainage area two bank stabilization projects are recommended:

    - Approximately 500 feet of either vegetative and/or mechanical riprap revetment, or concrete revetment, within the Hele Channel is recommended downstream from the NSBB pilot project (Figure 5-3). The concrete revetment designed would match existing sections of concrete bank stabilization in this area of the channel;

    - Approximately 50 feet (on each side) of vegetative and/or mechanical riprap revetment located within the Kamahele Ditch is recommended just downstream from the Keolu Drive Bridge (Figure 5-3). A combination of deposited sediment removal blocking the pipe culvert and protection of bank and root system in this ditch is required (Photos 1-21 and 1-22).

Table ES- 2. Kaelepulu Pond Storm Water Management Strategy Cost Summary

Drainage Outfall	Total Estimated Cost	
	BMP	**Cost***
WKIP 14 Area = 87.4 acres C factor = 0.70 Q_{WQFR} = 24.47 cfs	(10) Bio Clean Curb Inlet Baskets (CIBs)	$41,500
	(2) HDPE Hydrothane Trashracks (4x6 ft)	$5,530
WKIP 52 Area = 138.0 acres C factor = 0.48 Q_{WQFR} = 26.50 cfs	(8) Bio Clean CIBs	$32,700
	(1) HDPE Hydrothane Trashrack (20x7 ft)	$9,500
WKIP 10 Area = 323 acres C factor = 0.70 Q_{WQFR} = 90.44 cfs	(1) NSBB (20x32 ft)	$75,800
	(4) Bio Clean CIBs	$16,600
	(2) Bio Clean Grate Inlet Skimmer Boxes for ELSC Parking	$3,950
	(1) HDPE Hydrothane Trashracks (4x6 ft)	$2,290
Option 1 or 2	Bank Stabilization (concrete) cy or Bank Stabilization (vegetation/mechanical riprap) sy	$89,900 $162,031
	Bank Stabilization (combination vegetative/rip rap revetment) 23 sy	$13,739
WKIP 30-44 Area = 425 acres C factor = 0.55 Q_{WQFR} = 93.50 cfs	(15) Bio Clean Curb Inlet Basket	$62,000
	(1) HDPE Hydrothane Trashrack (18x6)	$7,880
WKIP 44^ Area = 4.7 acres C factor = 0.20 Q_{WQFR} = 0.376 cfs	NA	n/a
	SUBTOTAL BMPs	**$523,420**
Kailua/Enchanted Lake Area	(1) Street Sweeper (1) Vacuum Truck (1) Trash Pump	$185,000 $250,000 3,000
	TOTAL	**$961,420**

* includes estimated shipping, materials, installation labor, and construction costs (see Appendix F for worksheet)
NA Not Applicable
cfs cubic ft per second
sf/sy square foot/square yard
cy cubic yards
ft feet
C factor Coefficient of Runoff
Q_{WQFR} Water Quality Flow Rate
^ Separated based on City drainage maps

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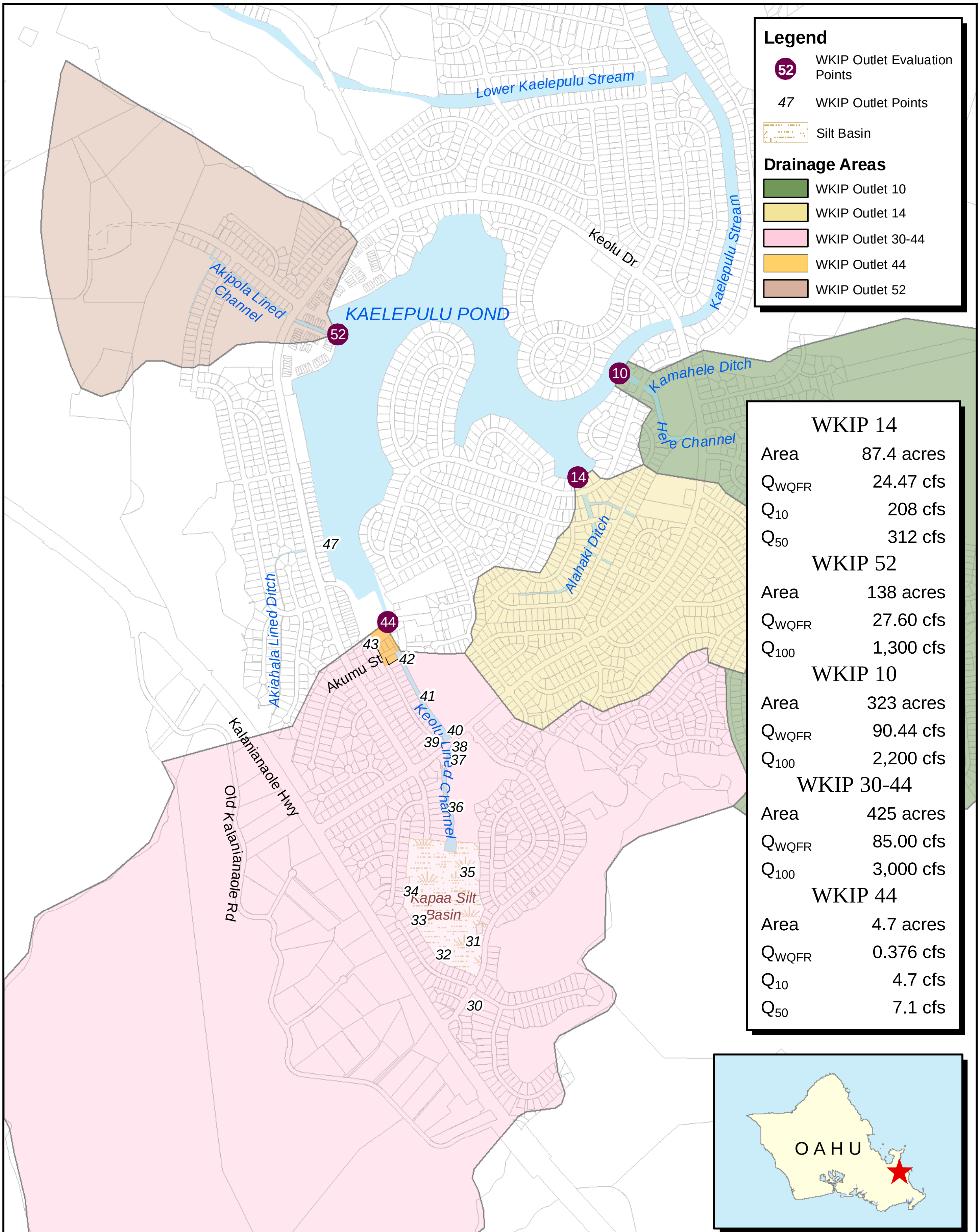

Figure ES-1
Site Map

TEC inc

Meters
0 385 770
0 700 1,400 2,800
Feet

N

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1.0 INTRODUCTION

1.1 BACKGROUND

This storm water best management practices (BMPs) plan is prepared for the City and County of Honolulu (City), Department of Environmental Services (ENV); it evaluates four major outlets and their corresponding drainage areas. The major outlets, as defined in 40 CFR part 123 Subpart B, are associated with the Windward District in the Kailua Watershed and discharge sediment and gross pollutants into Kaelepulu Pond (ID# WKIP).

The study area, Enchanted Lake (Kaelepulu Pond), is located in the Windward Judicial District (68.1 square miles of land area) and is one of three subwatersheds included in the Kailua watershed (20.2 square miles). The Kaelepulu Subwatershed is approximately 3,450 acres and extends to approximately 1,500 feet (ft) up the Koolau Mountain Range (Dashiell 1998).

Kaelepulu Pond is an estuary remnant of an ancient Hawaiian fishpond located in the town of Enchanted Lake, Kailua, on the windward side of Oahu (Figure 1-1). The City & County of Honolulu (City) has over 50 storm water discharge points associated with the study area and Kaelepulu Pond (Figure 1-2) (City 1992).

Before development of the Enchanted Lake subdivision in the 1960s, Kaelepulu Pond covered nearly 190 acres with an additional marsh area of 90 acres. With the development of the area, the pond was renamed Enchanted Lake and was reduced to approximately 79 acres. In 1966, a flood control project permanently diverted thousands of gallons of fresh water to Kawainui Channel that once flowed daily into Kaelepulu Pond from Kawainui Marsh. As part of the Enchanted Lake development agreement, the infrastructure including storm drains was deeded to the City with a drainage easement to the pond.

1.2 SCOPE

The general scope of the project includes the tasks below for four major outlets (as defined by 40 CFR Part 123 subpart B) and their corresponding drainage areas at Kaelepulu Pond shown in Figure 1-2 aerial photo.

1.2.1 WKIP 10 OUTLET

- Located near St. John Vianney School and Mid Pacific Country Club golf course
- Provide overview of drainage area
- Field Survey identifying pollutant sources
- Develop BMP Plan for two commercial facilities
- Letter report of findings (maintenance issues, suggestions for improvements based on field observations, etc.)

- A modification (Mod) to the contract added this outlet to the BMP Plan for analysis of potential structural and non-structural improvements. Additional sediment sampling to establish a target particle size was performed. The results of that sampling event and description of the results is incorporated into Section 3 of this report.

1.2.2 WKIP 14 OUTLET

- Located near intersection of Akumu and Holoholo Street
- Develop BMP Plan for structural and non-structural improvements
- Sediment sampling and testing

1.2.3 WKIP 44 OUTLET

- Located near Keolu Elementary School
- Provide overview of drainage area
- Field Survey identifying pollutant sources
- Letter report of findings (maintenance issues, suggestions for improvements based on field observations, etc.)
- A Mod to the contract added this outlet to the BMP Plan for analysis of potential structural and non-structural improvements.

1.2.4 WKIP 52 OUTLET

- Located near Kaelepulu Elementary School
- Develop BMP Plan for structural and non-structural improvements
- Sediment sampling and testing

1.2.5 SPECIFIC TASKS

Site Investigation and Field Sampling and Analysis - A site investigation was conducted for the drainage areas associated with WKIP 14, 52, 10, and 44 as identified on Figure 1-3. Observations were made of sediment deposits, trash and debris, and any soil erosion problems. An evaluation of potential pollution sources and odors in and around the vicinity of the pond and drainage area was also performed and documented, along with the identification of structural and non-structural BMPs locations and applicable current and future City maintenance programs and scheduled information to be incorporated into the BMPs plan. Sediment sampling was performed at WKIP 14, 52 and 10.

Storm Water Commercial Facility Site Investigation - A BMPs site investigation was conducted at two commercial facilities in the Enchanted Lake area. The Enchanted Lake Shopping Center (ELSC) and Tenn's Auto. A Letter Report BMPs Plan was prepared for each of the commercial facilities recommending site-specific structural and/or non-structural

BMPs (i.e. good housekeeping measures, preventative maintenance program, visual inspection program, improvements to storm water management, etc.) and a schedule for implementation (Appendix A).

Draft Best Management Practices (BMPs) Plan - A BMPs Plan incorporating information gathered from all previous tasks in the original statement of work (SOW) including:

- Commercial Facilities BMP Plan (Appendix A);
- Identification of pollutant sources, existing maintenance issues, recommendations for possible improvements based on field observations, and respective photo sheets (Section 1);
- Interpretation of the analytical results of the sediment sampling and grain-size analysis (Section 3 and Appendix B);
- Figures showing applicable drainage areas and representative design flows taken from existing paper documents (ES-1, and 1-4 through 1-7);
- A list of considered alternatives and preferred BMPs with draft conceptual designs and targeted flows (Appendix D and Section 5);
- Cost for site-specific structural BMPs, as well as preliminary construction cost estimates (Table ES-2 and 5-1); and
- The identification of potential permits (Section 4) necessary for installation of the BMPs for controlling odors associated with sediment and debris loading into Kaelepulu Pond from the identified outlets.

1.3 PURPOSE

Residents bordering Kaelepulu Pond, located in Kailua, Hawaii, have complained of sediment build-up and odors. In response to these complaints, the City has initiated an investigation with the goal of alleviating identified sediment and odor issues. The intent for recommending BMPs is to reduce the non-point source (NPS) pollution, specifically sediment, discharged by City storm water outfalls, into Kaelepulu Pond. Another goal is to work closely with the Kaelepulu Pond stakeholders (the Enchanted Lake Resident Association [ELRA]), to prepare appropriate planning documents for field events to support the storm water BMPs Plan. The BMPs Plan will address the identified complaints and supplement previous environmental investigations in the vicinity of the Kaelepulu Pond.

1.4 KAELEPULU EXISTING DRAINAGE SYSTEMS

All four storm drain outlets and the associated drainage areas that were investigated discharge storm water runoff into the privately owned Kaelepulu Pond. Storm water outlets within the Windward District, Kailua Subwatershed, Kaelepulu Stream are identified by "WKIP" followed by a number for each storm drain outlet (City 1992). The following paragraphs describe the Drainage areas evaluated for appropriate structural and non-structural BMPs. Drainage reports and records from the City Department of Planning and Permitting (DPP) were used unless identified otherwise.

1.4.1 WKIP 14

WKIP 14 is located on a 6,003-square foot (ft^2) (0.138 acres) City-owned parcel identified by Tax Map Key (TMK): 4-2-056:061, near the corner of Alahaki Street and Holoholo Street. Figure 1-4 depicts the general layout of WKIP 14 storm water collection and conveyance system and identifies representative design flows collected from City drainage reports, and the calculated water quality flow rate (WQFR) of the WKIP 14 drainage area. The photo log at the end of Section 1 (Photos 1-1 through 1-6) shows corresponding site photos and descriptions for WKIP 14 drainage area.

The peak flow at WKIP 14 outlet is 381.3 cubic feet per second (cfs) and is generated in a drainage area of 3,807,159 ft^2 (87.4 acres) (Appendix E). The drainage area is associated with the Alahaki Street residential area, encompassing approximately 110 drain inlets and two interceptor ditches (located on the Kaelepulu Pond side of Keolu Drive). It also includes a network of storm drainage inlets associated with residential areas on the mountain (*mauka)* side of Keolu drive up to an elevation of 360 ft above mean sea level (msl), all of which feed into the main tributary Alahaki Ditch.

The Alahaki Ditch discharges through the WKIP 14 outlet into a cove located in the southeast corner of Kaelepulu Pond. The mouth of the Alahaki Ditch is approximately 30 ft wide, 3 ft deep, and is 1,800 ft in length. The Alahaki Ditch continues south under Akumu Street (through twin concrete box culverts) and continues southeast toward the Kahili Street culvert. The Alahaki Interceptor Ditch #1 junction is located approximately 150 ft south of the Akumu Street Bridge running east and west. The Alahaki Ditch bends to the west after Kahili Street culvert, following the curvature of Alahaki Street before ending near the intersection of Holoholo Street. The Alahaki Interceptor Ditch #2 is located approximately 400 ft after the first bend.

1.4.2 WKIP 52

WKIP 52 is located on a 16,212 ft^2 (0.372 acres) City-owned parcel identified by Tax Map Key (TMK): 4-2-094:044, near Kaelepulu Elementary School. Figure 1-5 depicts the general layout of WKIP 52 storm water collection and conveyance system and identifies representative design flows collected from City drainage reports and the calculated WQFR. The photo log at the end of Section 1 (Photos 1-7 through 1-15) shows corresponding site photos and descriptions for WKIP 52 drainage area.

The peak flow at WKIP 52 outlet is 1,350 cfs and is generated in a drainage area of 6,011,304 ft^2 (138 acres) (Appendix E). The drainage area is associated with the Kaelepulu Elementary School and residential area encompassing approximately 55 drain inlets.

The outlet discharges to the northwestern portion of Kaelepulu Pond via a 20-ft concrete-lined open channel (Akipola Lined Channel) in approximately three ft of water. The Akiopola Lined Channel is approximately 1,750 ft in length. The Channel travels west from the mouth of the Kaelepulu Pond for approximately 450 ft to Keolu Drive, where it receives its first storm water junctions: a 48-inch pipe from the east and 30-inch pipe from the west along Keolu Drive. The concrete lined ditch continues west running parallel to Akiohala Street and receives storm water discharge at approximately five other major locations: a 42-inch pipe at the Akiohala Place intersection; a 42-inch pipe at the Akipola Street intersection, and three other connections including a 36-inch concrete ditch from the south, and a 36-inch pipe at the beginning of Akipola Lined Channel, which collects sheet flow runoff from the hill to the north and north west including Kailua High School. Existing BMP vegetation screening bars are associated with all the drainage structures.

1.4.3 WKIP 10

WKIP 10 outlet is located on a 138 acres City parcel identified by Tax Map Key (TMK): 4-2-050:064 and 4-2-050:009, located on the northeast side of the Kaelepulu Pond before entering Kaelepulu Stream. Figure 1-6 depicts the general layout of WKIP 10 storm water collection and conveyance system and identifies representative design flows collected from City drainage reports and the calculated WQFR. The photo log at the end of Section 1 (Photos 1-16 through 1-34) shows corresponding site photos and descriptions for the WKIP 10 drainage area.

The peak flow at WKIP 10 outlet is 846.0 cfs and is generated in a drainage area of 14,069,940 ft^2 (323 acres) (Appendix E).

TEC Inc. (TEC) personnel utilized an ELRA-owned barge to investigate the WKIP 10 outlet and Hele Channel segment to Akumu Street. Hele Channel and Kamahele Ditch were investigated to its terminus on foot and the streets of the drainage area were driven by vehicle. During the investigation observations of pollutant source and maintenance issues were noted.

Hele Channel extends approximately 400-ft from the outlet, past Akumu Street Bridge where the Kamahele Ditch tributary (an earthen ditch) approaches from the northeast. This earthen ditch continues past St. John’s Vianney School and under Keolu drive via two pipe culverts. The earthen ditch continues east collecting sheet flow runoff from Mid Pacific Golf Course fairway and Kamahele Street pipe connections.

Hele Channel continues past the Kamahele Ditch junction approximately 800-ft to the Keolu Drive Bridge dual box culverts. Hele Channel continues southeast between Loho and Hele Streets and into the southeast portion of the drainage area, collecting runoff from hills bordering the drainage area, the residential area, and roads.

1.4.4 WKIP 44

The WKIP 44 outlet is located on a 16,212 ft^2 (0.372 acres) City parcel identified by Tax Map Key (TMK): 4-2-083:080, located on the south side of the Kaelepulu Pond at terminus of the Keolu Lined Channel, northwest of the Keolu Elementary School. Figure 1-7 depicts the general layout of WKIP 44 storm water collection and conveyance system and identifies representative design flows collected from City drainage reports and the calculated WQFR. The photo log at the end of Section 1 (Photos 1-35 through 1-50) shows corresponding site photos and descriptions for portions of the WKIP 44 accumulative drainage area.

The peak flow of WKIP 44 is 9.9 cfs generated as sheet flow in a heavily-vegetated area of 204,733 sq. ft. (4.7 acres). The unlined portion of the Channel meets the lined portion approximately 400 ft up stream. The Keolu Lined Channel receives drainage from numerous upstream storm drain outlets; which begins at the Kapaa Silt Basin, between Kanapu'u Drive and Kalanianaole Highway (K-Hwy), approximately 3,000 ft from the WKIP 44 outlet. The Kapaa Silt Basin receives discharges from WKIP 31 through WKIP 35 outlets prior to discharging to the Keolu Lined Channel through a City debris control structure. The City structure is outfitted with debris bars at the two 18-inch reinforced concrete pipe (RCP) inlet. The Keolu Lined Channel receives discharges from WKIP 36 through WKIP 42 outlets from Kanapu'u Drive, Aupupu Street, Old Kalanianole Highway (K-Hwy), and the surrounding area. The WKIP 43 outlet, which is located approximately 200-feet southwest of Keolu Lined Channel (WKIP 44) and the end of Akumu Street, is typically blocked with several feet of sediment (Photo 1-52 in WKIP44 log). WKIP 43 has a peak flow of 360 cfs and collects an area of 53 acres (City DPP drainage reports) from Kalanianaole Highway down Akeke Place to Akumu Street where it makes a hard 90 degree turn to the northwest. A significant amount of sediment from street runoff comprised of asphalt, organic matter and soil eroded from the west side of Kalanianaole Highway regularly fills WKIP 43 outlet to the point that it is buried and water flow is severely restricted causing enough back pressure for the upstream storm drain manholes to "fly off" during large storm events as reported by residents.

The accumulative drainage area discharging through WKIP 44 outlet is approximately 18,513,070 sq. ft. (425 acres) with a peak flow of 3,070 cfs based on City drainage reports (Appendix E).

TEC personnel investigated the lower reaches of WKIP 44 and combined drainage area by foot noting potential sources of pollutants and maintenance issues. Sediment samples were not part of the scope for this drainage area. The upper portions of the drainage area and Keolu Lined Channel were investigated by foot and the streets of the drainage area were driven by vehicle noting pollutant source and maintenance issues.

The mouth of the WKIP 44 drainage area continues to shoal to a very shallow depth, creating islets within Kaelepulu Pond after each major storm event. The private Kaelepulu Wetland Bird Preserve, which was created in 1995 and consists of three islands, is located in area just west of the shoaled area at WKIP 44 and is habitat for Hawaiian waterbirds and migratory birds. Ongoing work in the wetlands includes invasive plant removal, enhancing nesting and feeding areas, and keeping the waterway open.

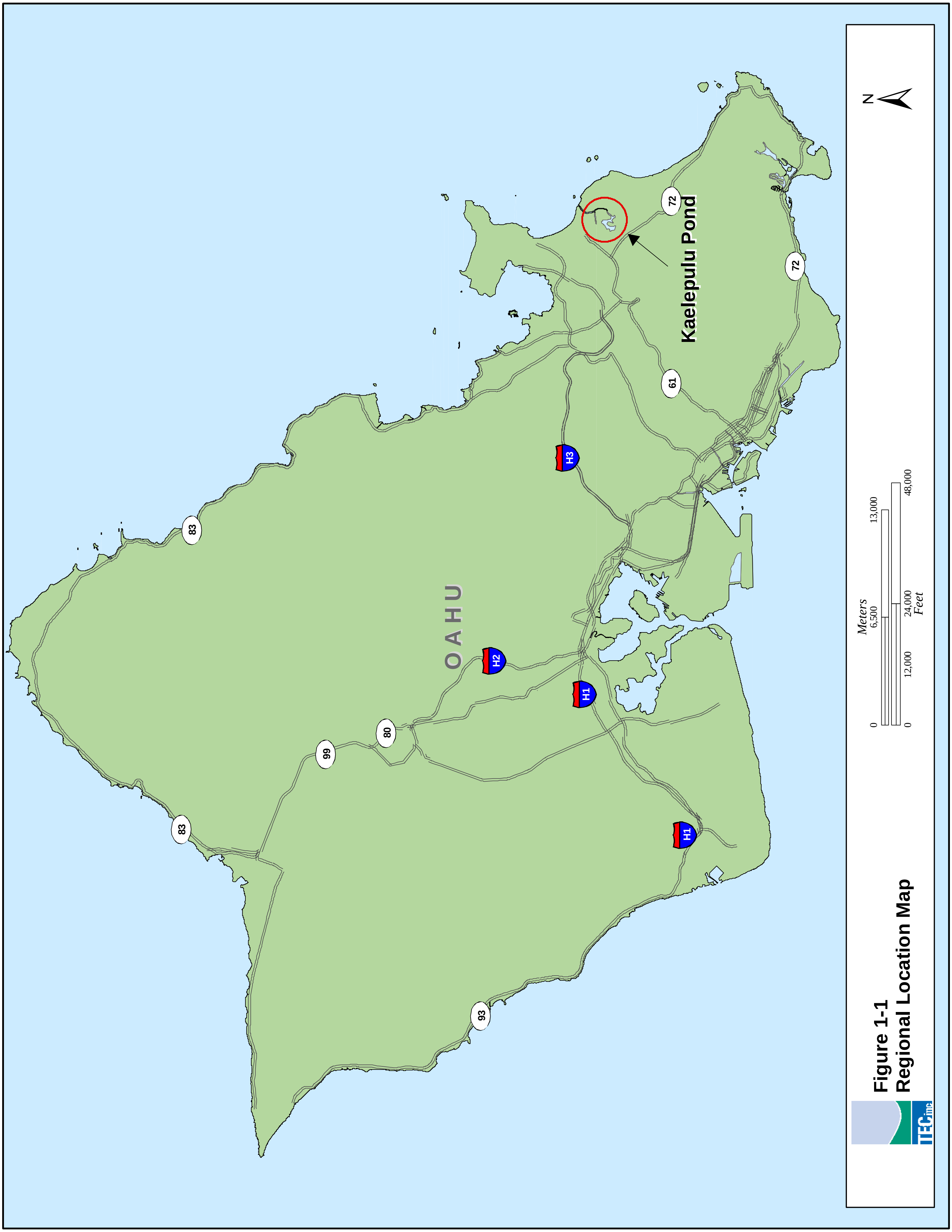

Figure 1-1
Regional Location Map

Figure 1-2
Aerial View

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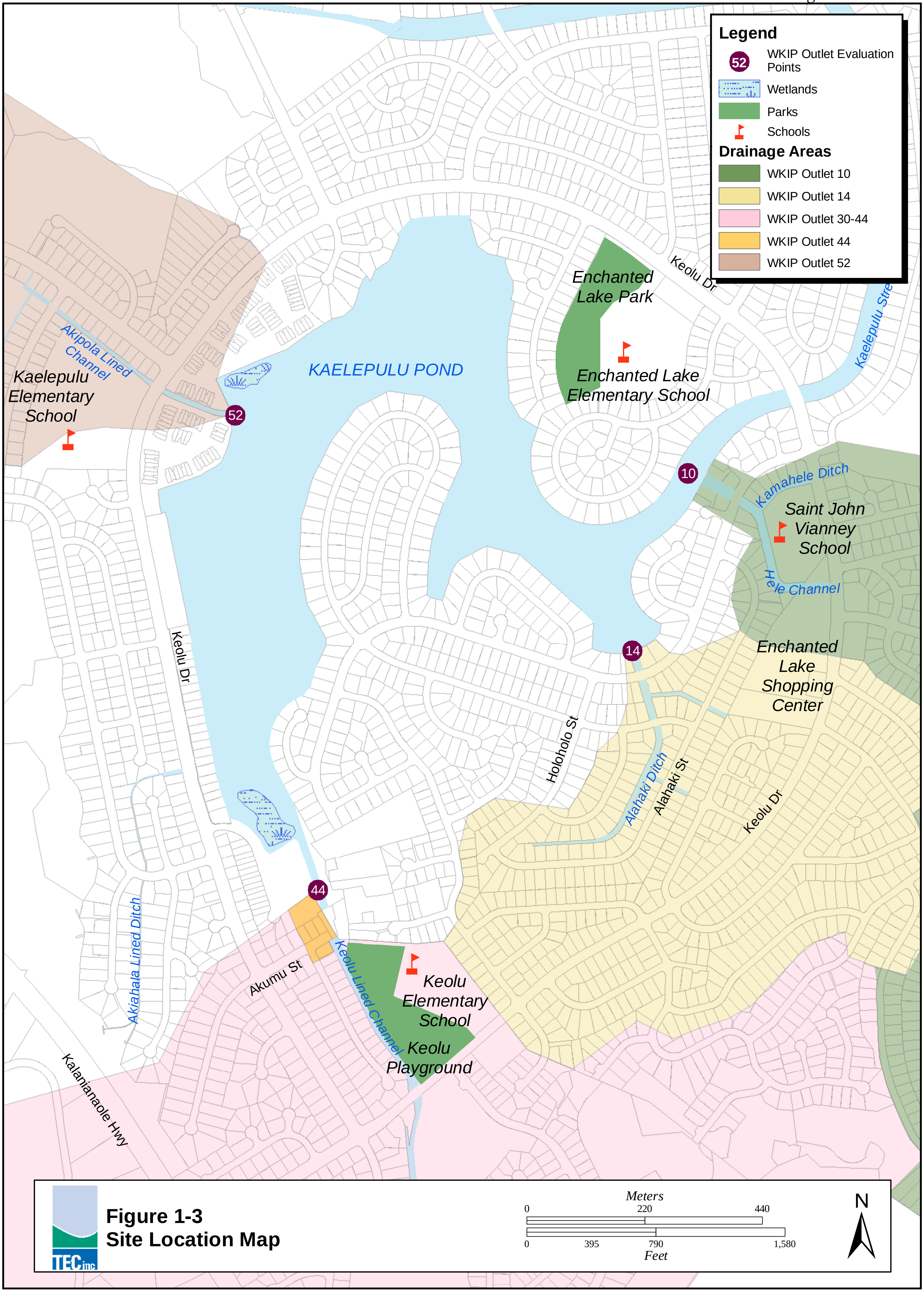

Figure 1-3
Site Location Map

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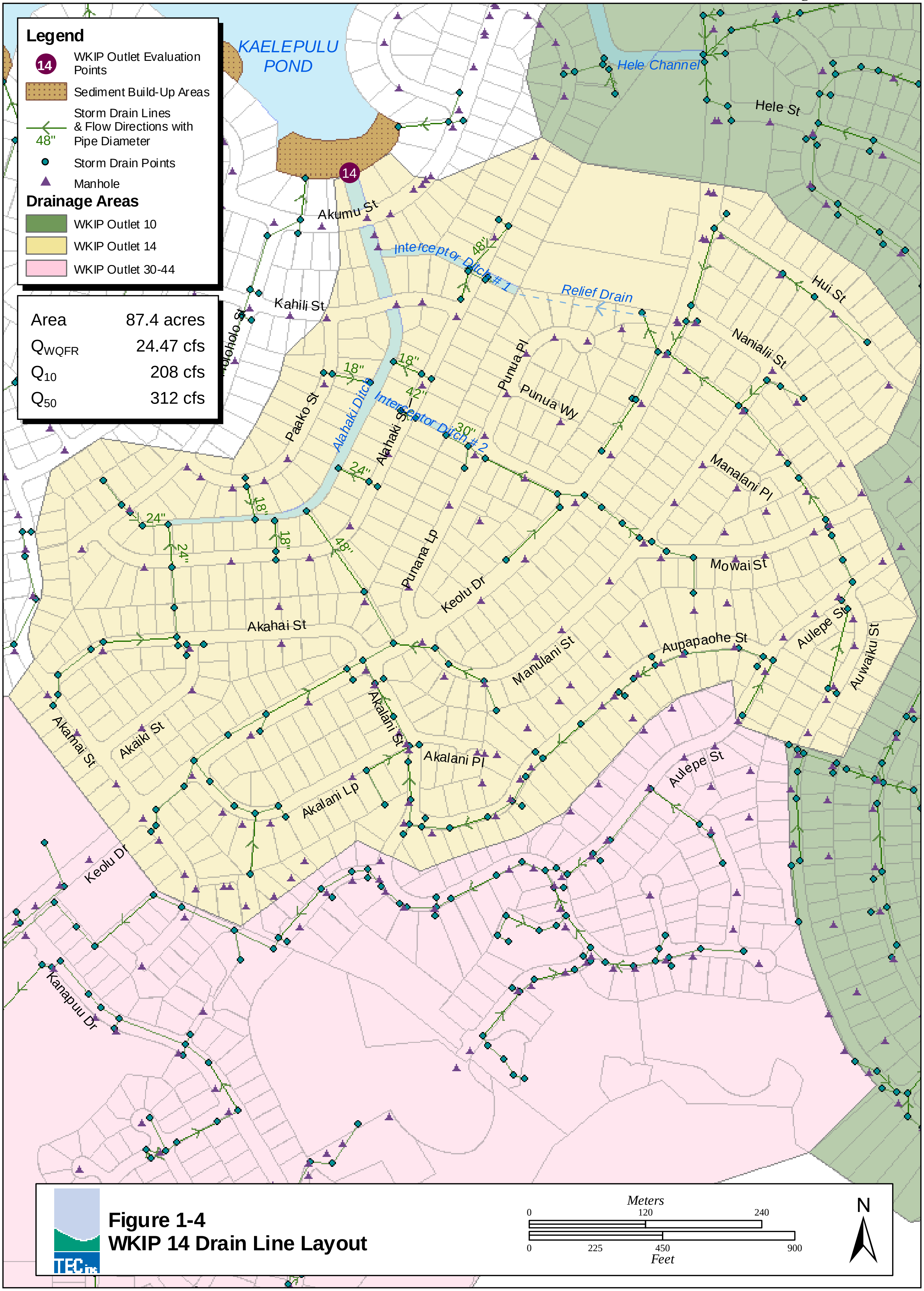

Figure 1-4
WKIP 14 Drain Line Layout

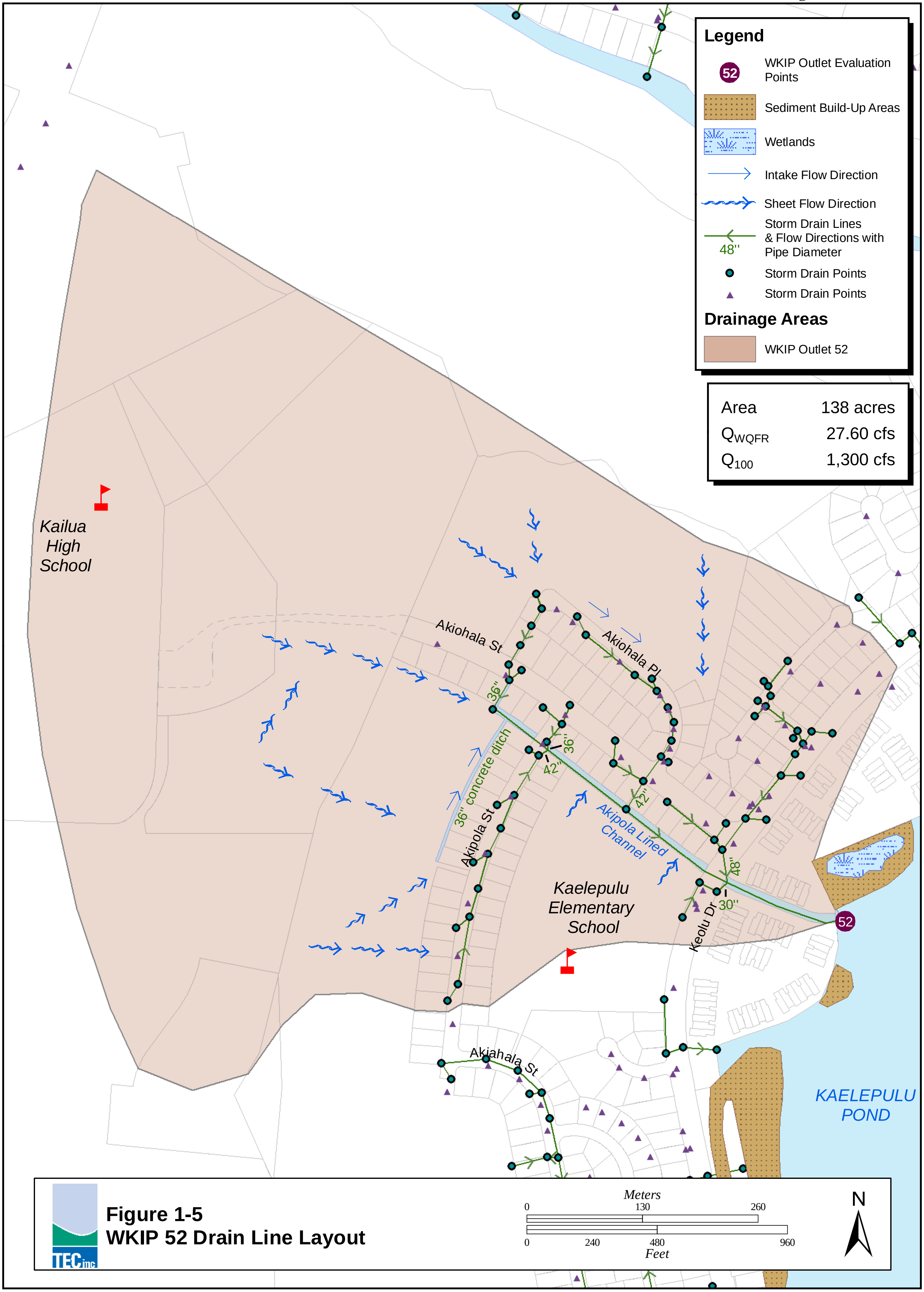

Figure 1-5
WKIP 52 Drain Line Layout

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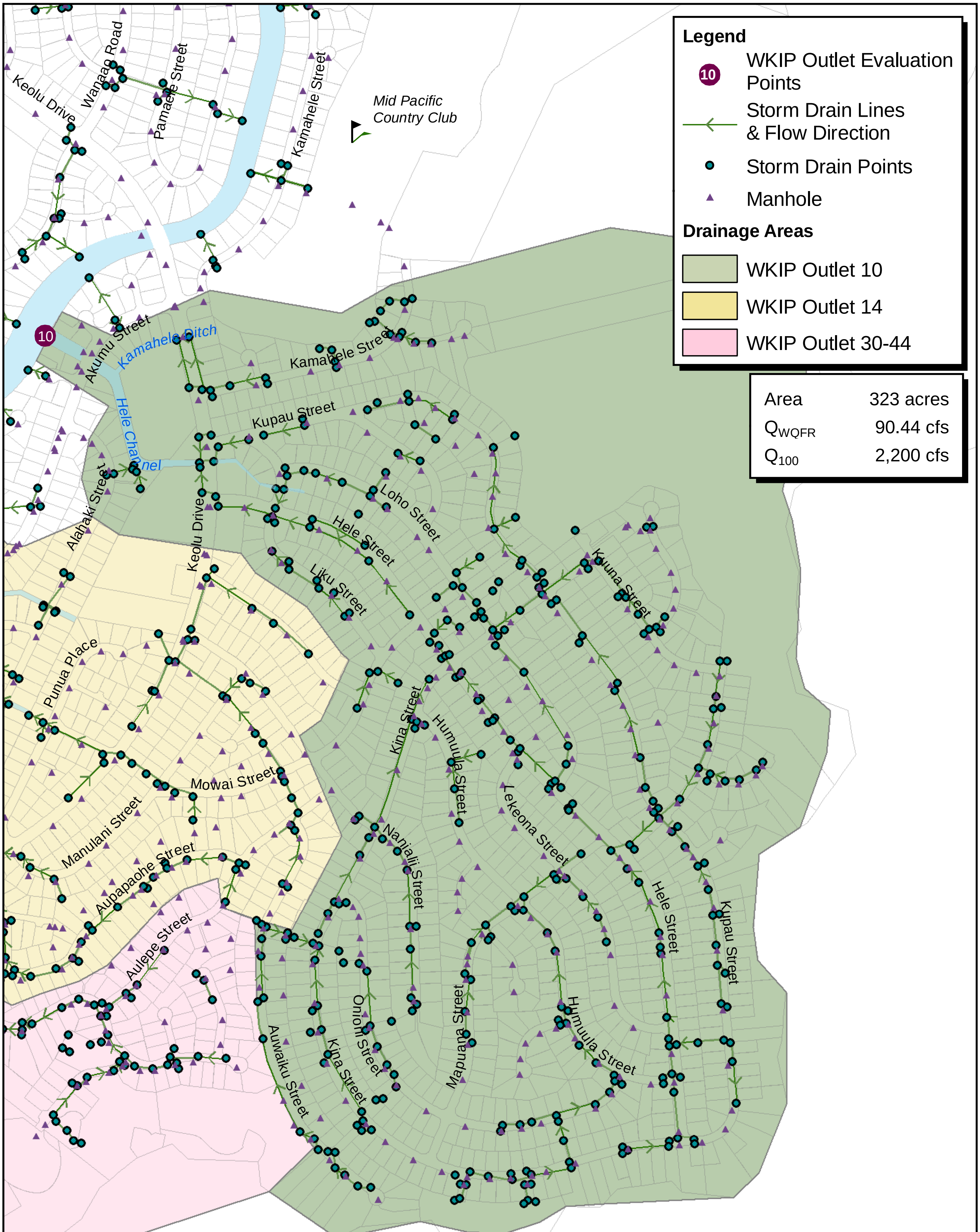

Figure 1-6
WKIP 10 Drain Line Layout

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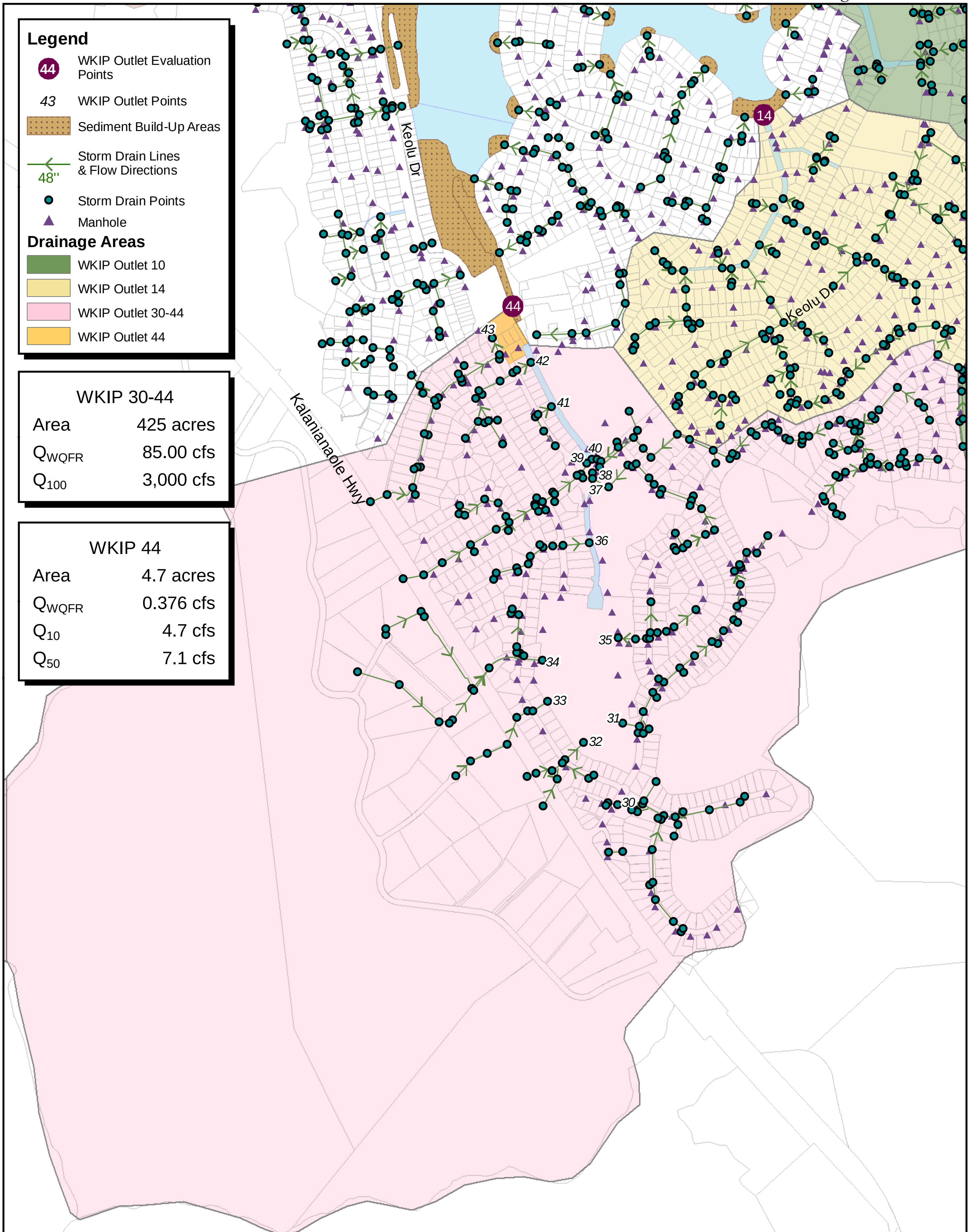

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Figure 1-7
WKIP 44 Drain Line Layout

Meters: 0, 287.5, 575
Feet: 0, 500, 1,000, 2,000

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CHAPTER 1 PHOTO LOG

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Chapter 1

WKIP 14 Photo Log

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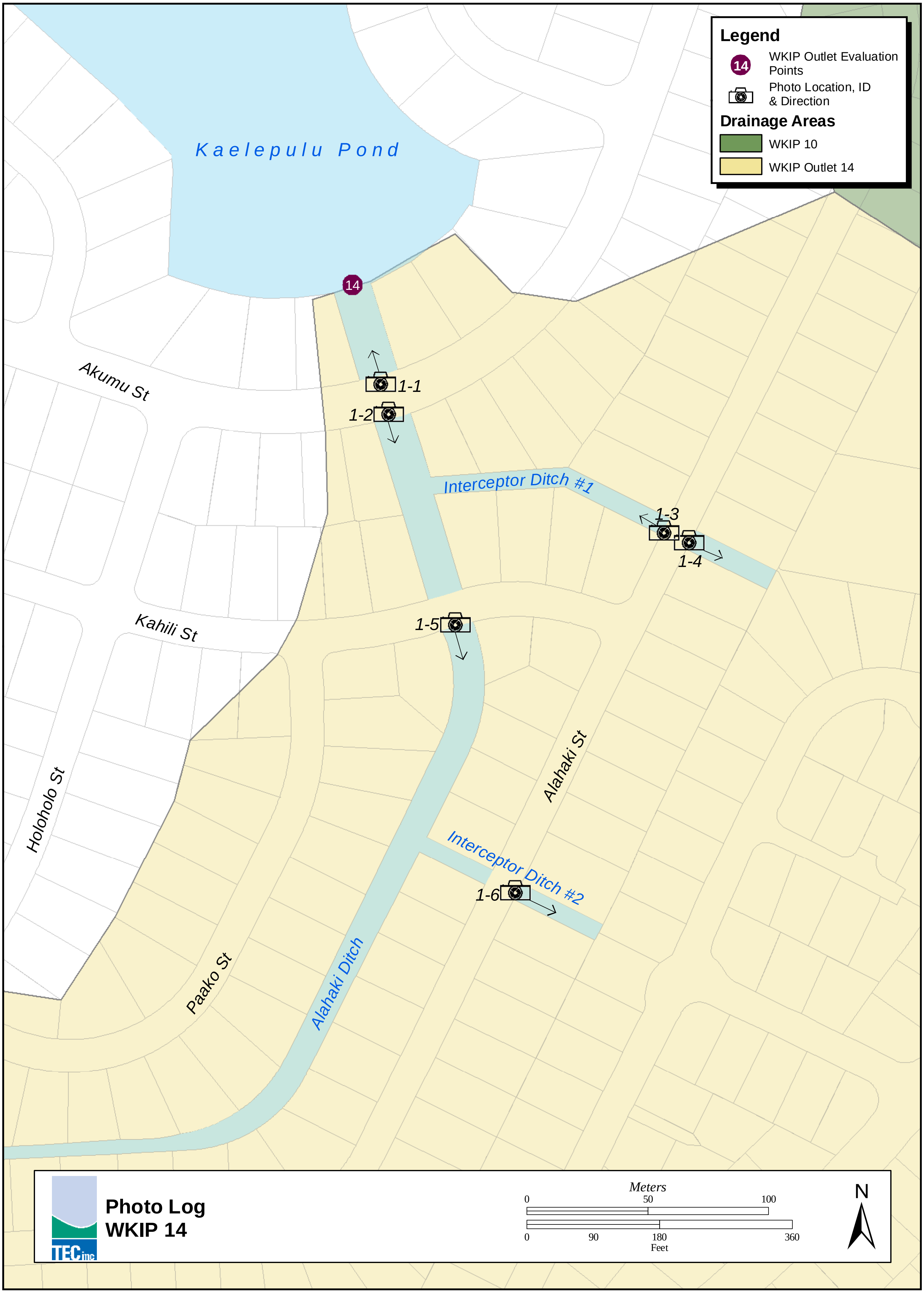
Legend
WKIP Outlet Evaluation Points
Photo Location, ID & Direction
Drainage Areas
WKIP 10
WKIP Outlet 14
Kaelepulu Pond
14
Akumu St
Kahili St
Holoholo St
Paako St
Alahaki St
Alahaki Ditch
Interceptor Ditch #1
Interceptor Ditch #2
1-1
1-2
1-3
1-4
1-5
1-6
Meters
0
50
100
0
90
180
360
Feet
N
TECinc
Photo Log
WKIP 14
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Photo 1-1 WKIP 14, Alahaki Ditch outlet at Kaelepulu Pond

Photo 1-2 Alahaki Ditch looking upstream toward Kahili Street Bridge. Note Interceptor Ditch #1 junction and excessive dead vegetation from spraying.

Photo 1-3
Photo taken from Alahaki Street Bridge looking northwest (downstream) of Interceptor Ditch #1.

Photo 1-4
Photo taken from Alahaki Street Bridge looking northeast (upstream) of Interceptor Ditch #1. Note corner of movie theater from Enchanted Lake Shopping Center, relief drain and pipe from Keolu Drive.

Photo 1-5 Photo from Kahili Street Bridge looking south at bend up Alahaki Ditch. Note lined embankment and excessive growth.

Photo 1-6
Photo taken from Alahaki Street Bridge looking east (upstream) of Interceptor Ditch #2. Note dead vegetation reportedly from spraying.

WKIP 52 Photo Log

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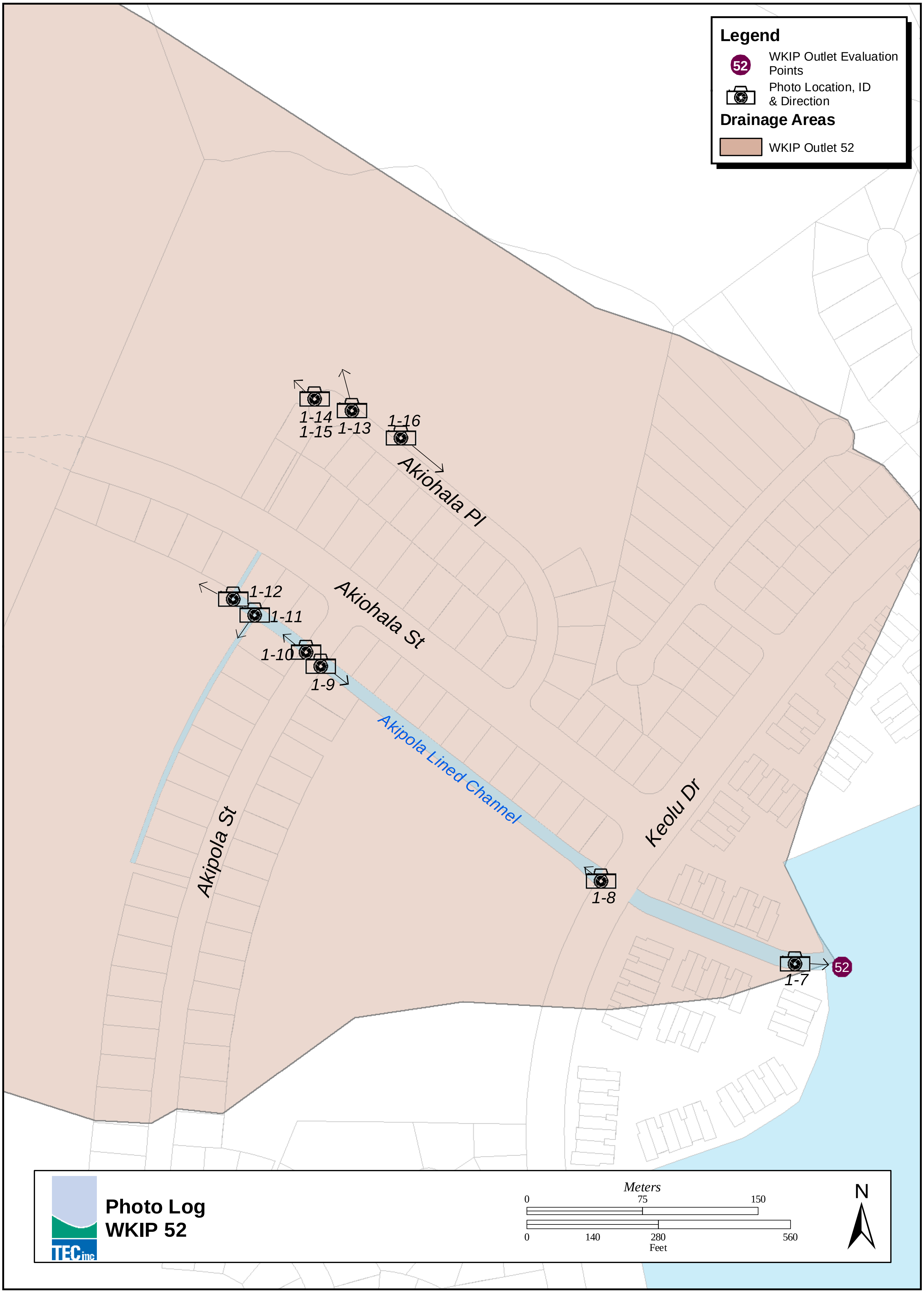
Legend
52
WKIP Outlet Evaluation Points
Photo Location, ID & Direction
Drainage Areas
WKIP Outlet 52
1-14
1-15
1-13
1-16
Akiohala Pl
1-12
1-11
Akiohala St
1-10
1-9
Akipola Lined Channel
Akipola St
Keolu Dr
1-8
1-7
52
Photo Log
WKIP 52
Meters
0
75
150
0
140
280
560
Feet
N
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Photo 1-7 WKIP 52, Akipola Lined Channel outlet at Kaelepulu Pond

Photo 1-8
Akipola Lined Ditch from Keolu Drive Bridge looking upstream. City maintenance easement shown in photo at right extends past Akipola Street to beginning of channel.

Photo 1-9
Akipola Lined Channel looking downstream. Note: concrete covering over this section of the channel helps reduce green waste buildup in the channel.

Photo 1-10
Akipola Lined Channel looking upstream. Note: City and County maintenance easement extends to beginning of channel.

Photo 1-11
36-inch concrete ditch intersecting upstream portion of Akipola Lined Channel.

Photo 1-12 Intermittent stream from Kailua High Schools general area ends and Akipola Lined Channel begins at vegetation barscreen BMP.

Photo 1-13 Typical vegetative hill "source area" associated with WKIP 52 drainage area. A 24-inch concrete ditch runs parallel to fence and Akiohala Pl. (Photo 1-15).

Photo 1-14 showing lined drainage ditch collection system from the hill behind Akiohala Place.

Photo 1-15 vegetation screening bars at intake pipe from lined ditch collection system at Akiohala Place.

Photo 1-16
24-inch concrete ditch runs the length of the fence along Akiohala Place and terminated at a grated inlet and 30-inch intake pipe. Note plant growth and leaf litter.

WKIP 10 Photo Log

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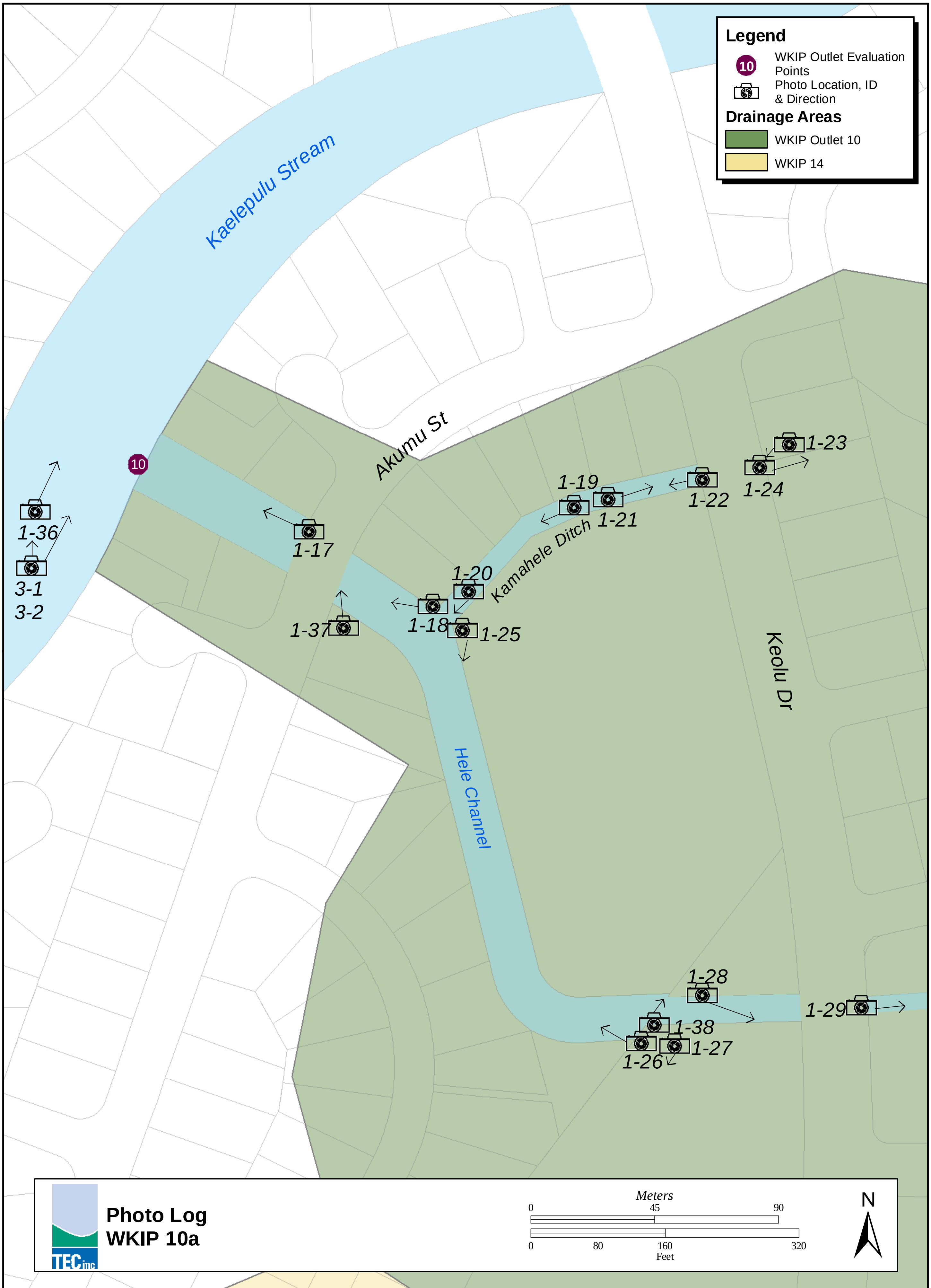

Photo Log
WKIP 10a

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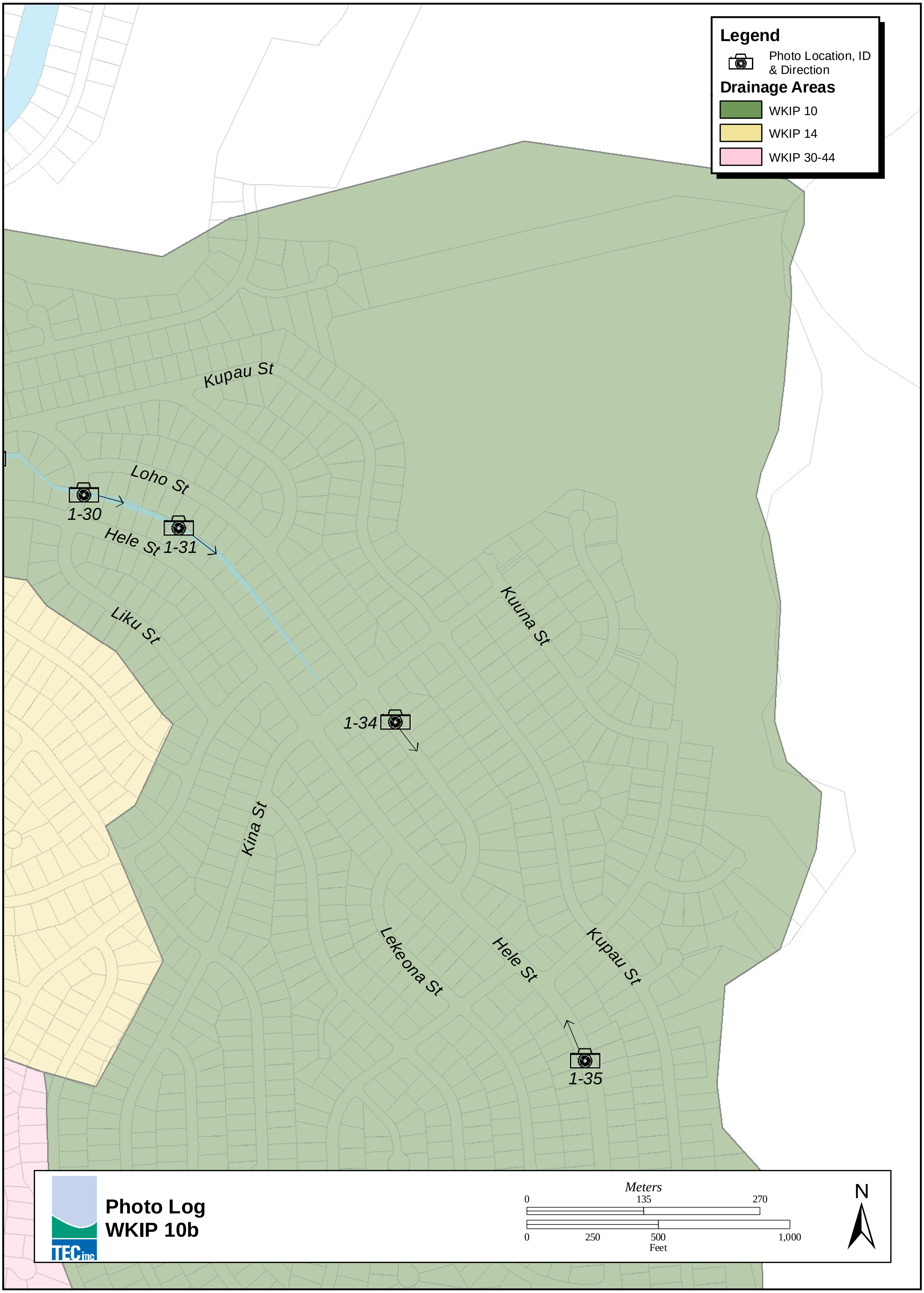

Photo Log
WKIP 10b

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Photo 1-17 WKIP 10, Hele Channel outlet taken from Akumu Street Bridge

Photo 1-18 WKIP 10, Hele Channel looking north at Akumu Street Bridge from Kamahele Ditch junction. Note sediment build up and barren embankment. Recommended bank stabilization area using vegetative riprap and/or mechanical revetment .

Photo 1-19 Kamahele Ditch looking south toward WKIP 10 Hele Drainage Channel.

Photo 1-20 Mouth of Kamahele Ditch at WKIP 10 Hele Drainage Channel

Photo 1-21 Kamahele Ditch looking northeast toward Keolu Drive. Recommended area for ditch excavation of deposited soils and bank stabilization (both sides) using vegetative riprap and/or mechanical revetment.

Photo 1-22 Kamahele earthen ditch looking southwest from Keolu Drive. Note scouring of embankment, road debris accumulation in the ditch, and church drainpipe outlet .

Photo 1-23 Kamahele Ditch looking southwest toward Keolu Drive pipe culvert.

Photo 1-24 Kamahele Ditch looking northeast from Keolu Drive. The Mid Pacific Country Club Golf Course is on the other side of the residential lot in the photo.

Photo 1-25 WKIP 10 Hele Drainage Channel looking south from Kamahele Ditch junction. Note erosion of unlined channel bank. Recommended bank stabilization area using vegetative riprap and/or mechanical revetment.

Photo 1-26 Hele Drainage Channel looking downstream. Note large Mango Tree, Alahaki Street outlet, sediment deposits with vegetation growing on the north bank, gross debris within channel, and dead grass (sprayed) on south bank.

Photo 1-27 Hele Drainage Channel looking upstream toward Keolu Drive.
Note: previous location of Tenn's Service Station

Photo 1-28 Hele Drainage Channel and twin Keolu Drive box culverts. Note RCP coming in from Enchanted Lakes Shopping Center to the right (south).

Photo 1-29 Hele Drainage Channel looking east from Keolu Drive. Tenn's Auto is the property adjacent to the south.

Photo 1-30 Hele Channel looking east from Liku Street.

Photo 1-31 Hele Drainage Channel looking east from 6th parcel from Liku Street Bridge. Two RCPs (24 and 36-inch) come in from Loho Street here.

Photo 1-32 and 1-33 Road debris and barren slopes along Kupau Street in the southeast corner of the WKIP 10 drainage area were common observations for this drainage area and the others in this study.

Photo 1-34 Road construction on Loho Street looking southeast.

Photo 1-35 Road construction and barren area on Hele Street looking northwest. A typical scene within this drainage area and others in the study.

Photo 1-36 Preparation for first sediment sample at WKIP 10. Note Kaelepulu Pond entrance sign and failed turbidity curtain wrapped around it.

Photo 1-37 WKIP 10 drainage area Akumu Street Bridge. Potential location for vegetation screening bars.

Photo 1-38 Dilapidated wall on north side of Hele Channel near Keolu Drive.

WKIP 44 Photo Log

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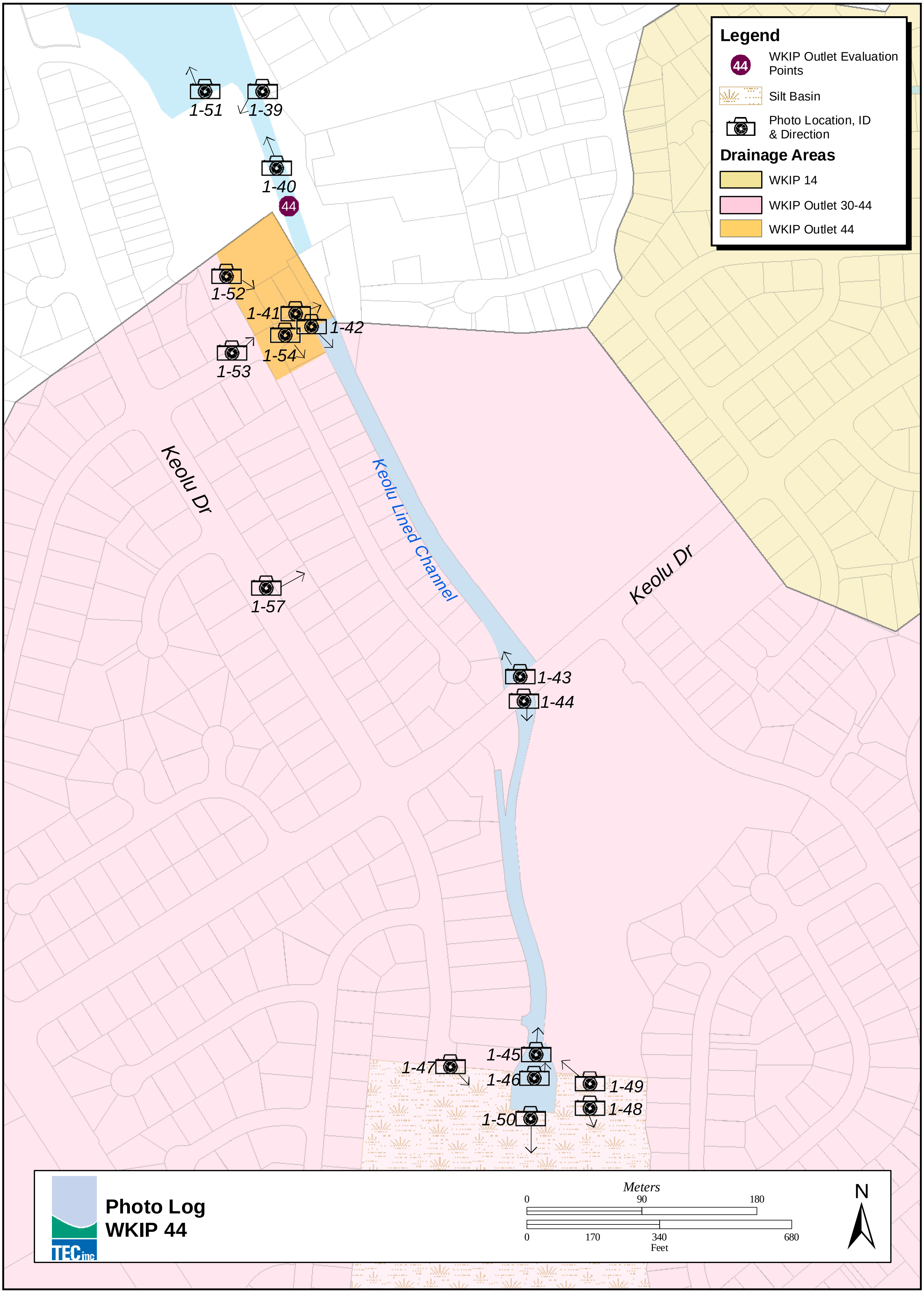

Photo Log
WKIP 44

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Photo 1-39 Approximate location of WKIP 44 outlet; sediment buildup in this area continues to alter the outlet location.

Photo 1-40 Unlined portion of Keolu Drainage Channel.

Photo 1-41
End of Keolu Lined Channel and beginning of unlined portion of channel. Note this area is typically stagnant, even during significant flows (see following photo) due to increased depth from scouring of unlined channel bottom.

Photo 1-42
Keolu Lined Channel after an April 2005 storm event looking upstream (southeast) with Keolu Elementary School on its eastern border.

Photo 1-43
Keolu Lined Channel looking downstream (north) from Keolu Drive.

Photo 1-44
Keolu Lined Channel looking upstream (south) from Keolu Drive.

Photo 1-45 Keolu Lined Channel looking downstream (north) from on top of the City debris control system. Paint can debris is a common.

Photo 1-46 City debris control system at beginning of Keolu Lined Channel.
Note recently cleared area with debris scattered. Grated inlet houses two 18-inch RCPs.

Photo 1-47 Cleared area between City debris control structure (left side of photo) and Kapaa Silt Basin (grass on right side of photo).

Photo 1-48 Northeast portion of Kapaa Silt Basin and apparent discharge point during large storm events based on observed bank configuration and elevation.

Photo 1-49 Apparent spillway from Kapaa Silt Basin toward City debris control structure.

Photo 1-50 Central portion of Kapaa Silt Basin and wetland grass. Note Keolu Hills development in the background and general area of WKIP 32 and 33 outlet.

Photo 1-51 Hawaiian coot foraging in the shallow waters near the wetland at mouth of WKIP 44.

Photo 1-52 WKIP 43 outlet buried by sediment and debris.

Photo 1-53 Storm drain manhole on Akumu Street is frequently popped during storm events due to back pressure from WKIP 43 outlet blockage and 90-degree alignment bend at this junction.

Photo 1-54 Erosion and sediment deposits at the end of Akumu Street. Note Keolu Lined Channel and City access easement in background.

Photo 1-55 Concrete lined silt off of Old Kalanianaole Highway, which is part of WKIP 34 outlet discharging into Kapaa Silt Basin.

Photo 1-56 Pollutant source area for runoff into WKIP 43 drainage system.

Photo 1-57
Residential construction site on Keolu Drive without BMPs. Pollutant source area for storm water runoff into WKIP 42 drainage system.

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2.0 STORM WATER QUALITY

Water quality in Kaelepulu Pond is affected by the runoff from storms, biological activity and nutrient pollutants from the surrounding community. This section presents impacts to the water quality of Kaelepulu Pond from storm water runoff; an analysis of nationally and locally implemented administrative rules regarding storm water runoff; BMPs; and recommendations for further storm water impact research of the four surveyed drainage outlets.

Research of recent and past investigations of the Kaelepulu Subwatershed water quality were conducted by TEC via the City Department of Planning and Permitting (DPP) and City Department of Design and Construction (DDC) research archives; privately funded research investigations; and University of Hawaii (UH) documentation.

2.1 STORM WATER POLLUTION SOURCES

Figure 2-1 and Figure 2-2 present a Zoning Map and Property Ownership for portions of the areas surrounding Kaelepulu Pond (City GIS Base Layers). The Kaelepulu Subwatershed occupies 3,450 acres of mixed land use including residential (2,043 acres), preservation (1,122 acres), agricultural (275 acres) and industrial (12 acres) zoned areas (Babcock 2005). Water bodies associated with the subwatershed include Kaelepulu Stream (upland), Kaelepulu Pond, Hamakua Canal and Extension, Kaelepulu Stream (low land), and Kailua Bay, all of which are affected in the form of diminished water quality, mainly total suspended solids (TSS), during storm conditions. Kaelepulu Pond functions well as a flood control and sediment basin, diminishing the effects of non-point source pollution downstream. Table 2-1 identifies typical pollutant loading data collected by the United States Geological Survey (USGS) during a nationwide urban runoff program.

2.1.1 RESIDENTIAL

The residential areas that contribute to the drainage outlets analyzed in this report during storm conditions consist of permeable and impermeable sources. Permeable sources in the residential section of the subwatershed include landscaping and parks. Impermeable surfaces in the urban areas contributing to the drainage outlets include streets, driveways, sidewalks and roofing structures.

The permeable sources in the residential section of the subwatershed allow infiltration of storm water, acting as a naturally occurring barrier for storm water influxes into the Kaelepulu Pond. Whereas, impermeable sources increase the storm water inflow through the drainage system. Elevated levels of metals, organic hydrocarbons and surfactants are also increased with additional non-pervious surface development. Other common materials found in storm water runoff from residential areas include nutrient pollutants, bacteria, pesticides, pet droppings, oil, grease, coolants and sediment loss.

Table 2-1. Typical Urban Pollutant Loading from Runoff by Land Use

Land Use	TSS	TP	TKN	NH3-N	NO2+ NO3-N	BOD	COD	Pb	Zn	Cu
Commercial	1000	1.5	6.7	1.9	3.1	62	420	2.7	2.1	0.4
Parking Lot	400	0.7	51	2	2.9	47	270	0.8	0.8	0.04
HDR	420	1	4.2	0.8	2	27	170	0.8	0.7	0.03
MDR	190	0.5	2.5	0.5	1.4	13	72	0.2	0.2	0.14
LDR	10	0.04	0.03	0.02	0.1	NA	NA	0.01	0.04	0.01
Freeway	880	0.9	7.9	1.5	4.2	NA	NA	4.5	2.1	0.37
Industrial	860	1.3	3.8	0.2	1.3	NA	NA	2.4	7.3	0.5
Park	3	0.03	1.5	NA	0.3	NA	2	0	NA	NA

Note: Concentrations in mg/L, Data from Nationwide Urban Runoff Program, USGS

TSS	Total Suspended Solids	NH3-N	Ammonia Nitrogen
TP	Total Particulates	N02+N03-N	Nitrate-Nitrite Nitrogen
TKN	Total Kjeldahl Nitrogen	BOD	Biological Oxygen Demand
Pb	Lead	COD	Chemical Oxygen Demand
Zn	Zinc	MDR	Medium Density Residential
Cu	Copper	LDR	Low Density Residential
HDR	High Density Residential		

During an intense 3-hour storm the amount of sediment entering the lake is estimated at 17 to 35 tons. It is also estimated that the pond removes 77% of the sediment received (Bourke 2006).

Trash and Debris. Three to four times a year, over the last decade, community volunteers have performed a Kaelepulu Pond floatable gross pollutant cleanup. In an effort to comprehend where these tons of gross pollutants are coming from, a log was kept of the types of debris collected during the last five cleanups in 2005 and 2006. Based on this assessment, visual observations during this study, and conversations with ELRA members, a large portion of debris is vegetative waste from yard clippings, tree trimmings and wind-blown material (coconuts and coconut fronds). Additionally, every cleanup also produces bag after bag of urban trash including plastic bottles, cans, balls, and fast food containers. Most of this material appears to come directly from the storm drains. For example, in the wetland area alone, during 2005 over 400 spray paint cans were removed. One cleanup effort was focused at the mouth of the Kaelepulu Pond (WKIP 10). WKIP 10 outlet is shoaled to a shallow depth (1 to 4 ft) at this location, and over 20 tires and large amounts of debris such as rags, cans, bicycle parts, and other items were removed that entered from the drainage channel and the upstream commercial areas (ELRA website http://www.kaelepulupond.com/ and conversations with ERLA members).

Water quality samples collected from storm drains around the Kaelepulu Pond, from January 2004 to March 2006 (five storm events) revealed that construction grading sites deliver significant loads of sediment during storm events. Sediment loads from residential areas in the Subwatershed tend to vary from about 50 to 150 milligrams per Liter (mg/L) during a heavy storm (Burke 2006). Visual observation during Subwatershed investigations identified several construction areas lacking structural BMPs associated with WKIP 42, 43, 44 (including WKIP 32, 33, and 34 discharging to Kapaa Silt Basin), and WKIP 47.

Observations of the subwatershed during storm events indicate multiple factors contributing to high sediment loads to Kaelepulu Pond. These include a combination of the steep slopes of Mount Olomana with active grading and construction on several home sites (Photo 2-1 and 2-2), along with several steep barren embankments along K-Hwy and Old K-Hwy (Photo 2-3 and 2-4).

2.1.2 PRESERVATION

Preservation areas in the watershed comprise 1,122 acres. These areas contribute primarily green-wastes including sediment and coconut fronds. A significant contributor of green-waste infiltration to the Kaelepulu Pond is Mount Olomana (Babcock 2005).

2.1.3 AGRICULTUAL

Agricultural areas encompass approximately 275 acres of the watershed. These areas contribute the inflow of pesticides, fertilizers and sediment into the Kaelepulu Pond during storm conditions (Babcock 2005).

2.1.4 LIGHT INDUSTRIAL/ COMMERCIAL

Light industrial/shopping areas cover approximately 12 acres of the watershed. Impermeable surfaces from roads, parking lots, and roof structures increase storm water flows into the watersheds. Metals commonly found in storm water runoff include lead, chromium, copper, cadmium, zinc, and nickel. A fraction of these metals and organic chemicals are linked to roadway asphalt particles which are eroded by vehicle tire friction (Babcock 2005).

Typical pollution and impacts from these urban source areas are presented in Table 2-2.

2.2 STORM WATER REGULATIONS

Regulations on storm water content discharges are implemented by federal and state entities.

2.2.1 FEDERAL STORM WATER REGULATIONS – THE CLEAN WATER ACT

The United States Environmental Protection Agency (USEPA) has prohibited and regulated national water body's water quality since the implementation of the Clean Water Act in 1972. The National Pollutant Discharge Elimination System (NPDES) permit was designed as a regulation measure for point source discharges; however, the EPA has also implemented Total Maximum Daily Loads (TMDLs) for water bodies under Section 303(d) of the Clean Water Act (CWA). This section requires states to "submit lists of surface waters that do not meet applicable water quality standards (impaired waters) after implementation of technology-based effluent limitations, and establish TMDLs for these waters on a prioritized schedule."

Table 2-2. Typical Storm Water Pollutant Sources and Impacts

Storm Water Pollutant	Sources	Related Impacts
Nutrients: Nitrogen, Phosphorus	Urban runoff; animal waste; fertilizers; failing septic systems	Algal growth; reduced clarity; lower dissolved oxygen; release of other pollutants
Solids: Sediment (clean and contaminated)	Construction sites; other disturbed and/or non-vegetated lands; eroding banks; road sanding; urban runoff	Increased turbidity; reduced clarity; lower dissolved oxygen; deposition of sediments; smother aquatic habitat including spawning sites; sediment and benthic toxicity
Pathogens: Bacteria, Viruses	Animal waste; urban runoff; failing septic systems	Human health risks via drinking water supplies; contaminated shellfish growing areas and swimming beaches
Metals: Lead, Copper, Cadmium, Zinc, Mercury, Chromium, Aluminum, others	Industrial processes; normal wear of automobile brakelines and tires; automobile emissions; automobile fluid leaks; metal roofs	Toxicity of water column and sediment; bioaccumulation in aquatic species and through food chain
Hydrocarbons: Oil and Grease, PAHs (Naphthalenes, Pyrenes)	Industrial processes; automobile wear; automobile emissions; automobile fluid leaks; waste oil	Toxicity of water column and sediment; bioaccumulation in aquatic species and through food chain
Organics: Pesticides, PCBs, Synthetic chemicals	Pesticides (herbicides, insecticides, fungicides, rodenticides, etc.); industrial processes	Toxicity of water column and sediment; bioaccumulation in aquatic species and through food chain

* Content borrowed from MA DEP & MA *CZM* Storm water Management - Storm water Technical Handbook (1997)

2.2.1.1 NPDES

Under Section 402 of the CWA, the EPA's NPDES permit has and continues to make significant improvements to the United States water quality. The program was created in 1972 under the CWA, for the purpose of control and regulation of point source discharge of pollutants to waters within each state. This program assists in maintaining, protecting and restoring the water quality of streams, lakes and rivers in the United States.

The NPDES storm water program is subdivided into two phases. Phase I of the NPDES storm water program was established in 1990. This phase of the program required coverage for large or medium municipalities with populations of greater than 100,000. Phase II of the NPDES storm water program was signed into law, nine years later (1999). Phase II of the program requires smaller communities, also known as small municipal separate storm sewer systems (MS4s), to be permitted, and develop and implement a comprehensive storm water management program that includes eight (8) minimum measures.

These 8 measures are:

- Public Education & Outreach
- Public Participation/Involvement
- Illicit Discharge Detection & Elimination
- Construction Site Run-off Control

- Post Construction Run-off
- Pollution Prevention/Good Housekeeping
- Permitting & Reporting
- Federal & State-Operated MS4s: Program Implementation

This storm water BMPs Plan attempts to include where applicable the aforementioned measures.

2.2.1.2 TMDLS

The EPA's definition of a TMDL is "the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and allocates pollutant loadings among point and non-point pollutant sources."

All watersheds with TMDLs are subject to storm water discharge limits for the pollutant(s) of concern. As storm water enters a pipe, it becomes subject to regulations and is then classified as a point source discharge. All point source discharges are subject to water quality standards. The enforcement of these standards is based on the CWA.

Kaelepulu Pond is listed as an impaired water body on the EPA's 303(d) list.

2.2.2 STATE REGULATIONS

The Hawaii Department of Health (HDOH) Clean Water Branch (CWB) is responsible for administrating the State's storm water management plan.

State storm water requirements are mirrored after the federal NPDES program, requiring that storm water be treated to the maximum extent practicable (MEP). Hawaii's NPDES program requires all construction sites disturbing more than one-acre, many industrial sites, and all designated MS4s to obtain permit coverage. Most sites in the state may obtain coverage under the state general permit. Sites that pose considerable risk to contaminate water may be required to obtain an individual permit.

No numeric requirements for storm water pollutant removal have been established at the state level, but regional and municipal regulations are in place. Kaelepulu Pond is designated as a Class AA marine classification and the surrounding inland is classified as Class 2. Hawaii Administrative Rules (HAR) Title 11, Chapter 54 has definitions of these classes.

Kaelepulu Stream (lowland) is listed on Hawaii's 303(d) list of impaired waters due to turbidity, nutrients, bacteria, and chlorophyll pollution. Potential sources of these contaminants include storm water runoff, septic tanks/cesspools, sanitary sewer overflows, domestic and wild animals, along with lakebed and water column processes (EPA 2006).

A summary of information collected from *Storm water Magazine* identify many communities around the nation that have passed new administrative rules for the prevention and management of polluted storm water runoff over the last five years. This community involvement has caused a chain reaction for development of TMDLs and requirements for up to 80% TSS removal requirements for new development, and 40% TSS removal in redevelopment areas in some areas of the country. In some existing urban areas rules require from 20% to 40% removal for upcoming years (Storm water October 2006). There are commercially available BMPs designed to meet the removal efficiencies for these target pollutants found in storm water runoff. To properly design structural BMPs to manage the quantity and improve the quality of storm water runoff in the most cost-effective manner, a water quality system engineer must have data for the drainage area or watershed in question; specifically, land use, target pollutants, particle size and rain fall and storm water sampling data.

2.3 CONCLUSIONS

The data presented in this section provides an estimate of the representative character for the storm water quality that enter into Kaelepulu Pond from the four drainage areas evaluated in this report. Based on the information above, typical runoff into Kaelepulu Pond contains urban trash, vegetative or green waste (organic debris), sediment and roadway particles with nutrients and other inorganic pollutants adhering to these particles. A large portion of the organic debris can be traced back to yard clippings, tree trimmings and wind-blown material (i.e. coconuts and coconut fronds).

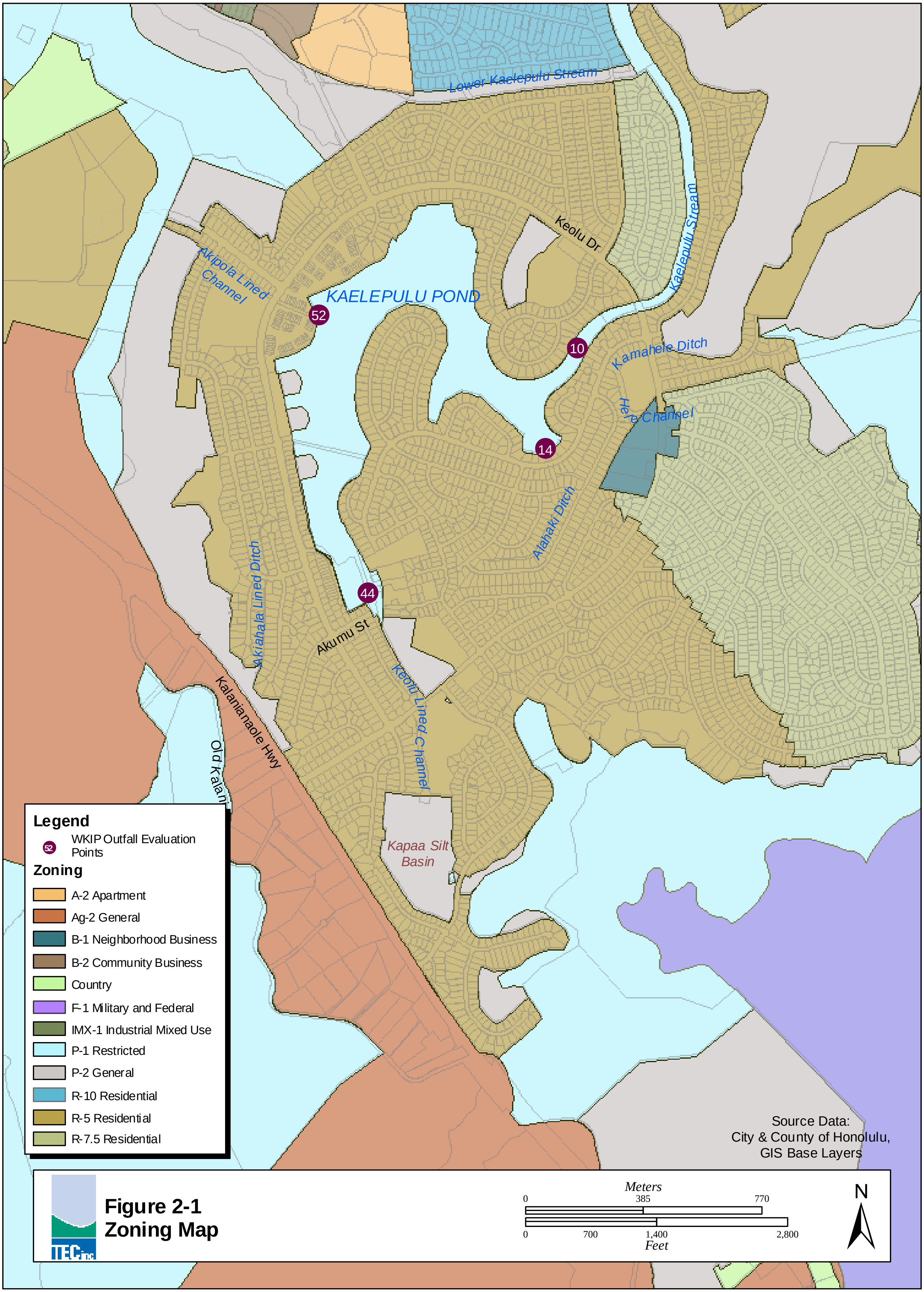

Figure 2-1
Zoning Map

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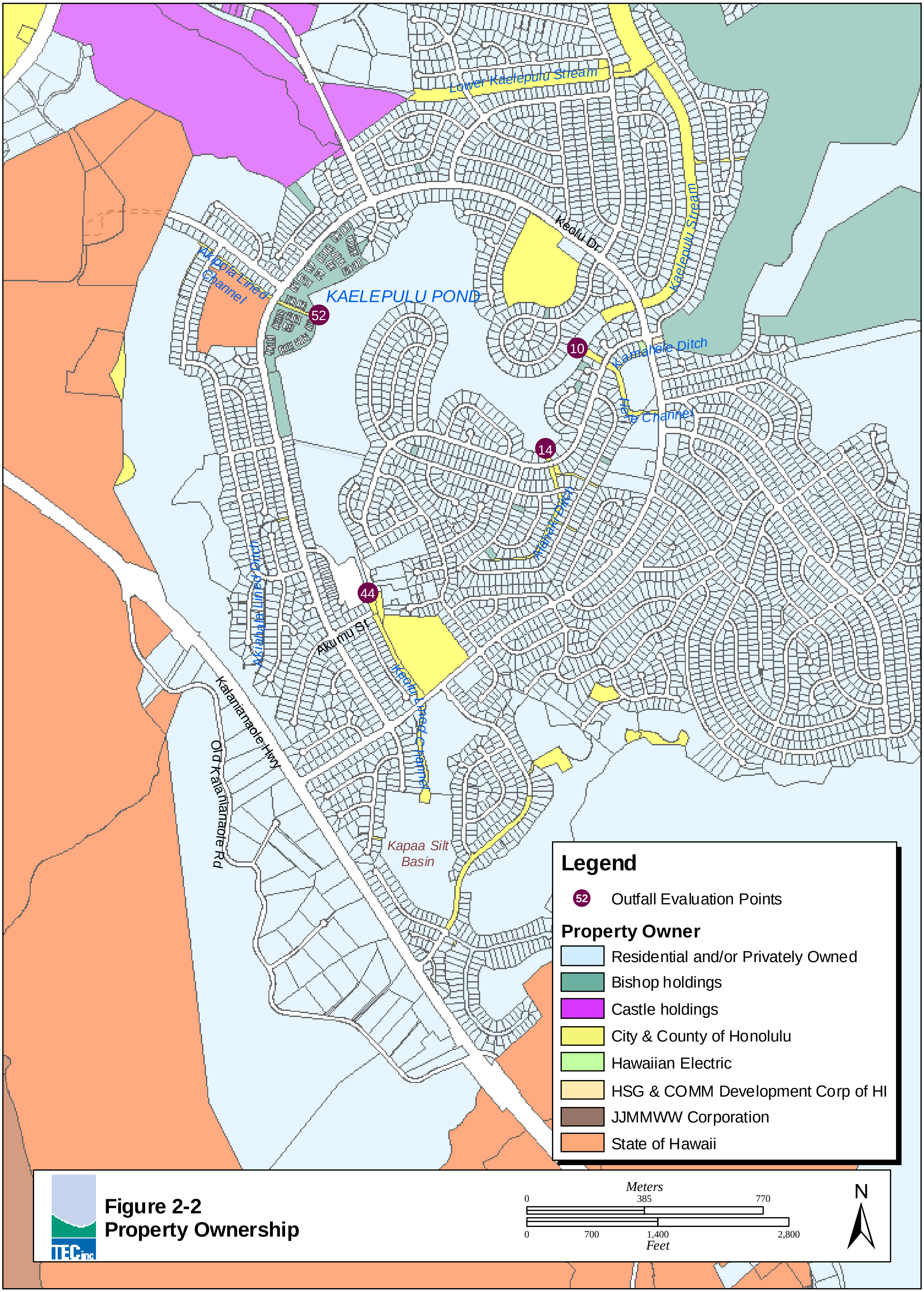

Figure 2-2
Property Ownership

CHAPTER 2 PHOTO LOG

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Photo 2-1 Construction site along Old K-Hwy. Structural BMPs were not observed on site. Photo taken from K-Hwy.

Photo 2-2 Construction site along Old K-Hwy. Structural BMPs were not observed on site.

Photo 2-3 Steep, barren embankments along K-Hwy are common.

Photo 2-4 Steep, barren embankments along Old K-Hwy are common.

3.0 HYDROLOGIC AND SEDIMENT ANALYSIS

This section investigates the expected flows which will be discharged by the four WKIP outfalls (WKIP 14, WKIP 52, WKIP 10, and WKIP 44 [plus the WKIP 44 outfall accumulative drainage area, [see section 1.3.4], here after referred to as WKIP 30-44) into Kaelepulu Pond. The drainage area flows are based on existing City drainage reports and focus on the quantity of storm water generated by the drainage area at each drainage segment. This section also describes the sediment sampling methodologies, laboratory analysis and an explanation of the results.

3.1 HYDROLOGIC ANALYSIS

The Rules Relating to Storm Drainage Standards (RRSDS) (City 2000) was used to complete the analyses of the four drainage area outlets. Each drainage area outlet was examined for peak storm drainage flows expected from rainfall intensities of storm events with recurrence intervals of 10 and 50 years for WKIP 14 and WKIP 44; and 100 years for WKIP 52, WKIP 10, and WKIP 30-44. The volume of storm water generated and diverted to each drainage outlet during the initial flush of a storm is also addressed.

3.1.1 HYDROLOGIC CRITERIA

Several hydrologic criteria were necessary to conduct a hydrologic analysis of the four drainage outlets. These include determination of a Recurrence Interval (T_m) and Runoff Quantity.

- Recurrence Interval – The drainage area of WKIP 14 is 87.4 acres, and WKIP 44 is 4.7 acres; the drainage area of WKIP 52, WKIP 10, and WKIP 30-44 is 138.0 acres, 323 acres and 425 acres, respectively; therefore, a T_m of 10 & 50 and a T_m of 100 years were used for the corresponding drainage outlets (i.e. Tm = 100 years was applied to drainage areas greater than 100 acres).
- Runoff Quantity – The rational method was employed for drainage areas WKIP 14 and WKIP 44. Plate 6 titled, “Design Curves for Peak Discharge vs. Drainage Area (more than 100 acres)” from the RRSDS was used for drainage area WKIP 52, WKIP 10, and WKIP 30-44. The Kaelepulu Pond drainage areas are all classified as Group A.

To calculate the storm water flow rate to each individual drain inlet within the WKIP 14, WKIP 52, WKIP 10, WKIP 44, and WKIP 30-44 drainage areas; drainage reports and as-built drawings for design flow were reviewed. These reports and maps were collected from the City archives. Appendix C presents a running total of WKIP 14 and 52 storm water collection areas and flow rate from the drainage inlets at any point within each drainage area. Running totals were not calculated for WKIP 10 and 44, which were added during the September 2007 contract modification. The structural BMP for the inline treatment of the Kaelepulu Subwatershed is not being further pursued as a viable alternative.

During an initial flush of a storm event, the highest concentrations of contaminants enter the Kaelepulu Pond through the drainage outlets. After this initial flush these contaminants entering Kaelepulu Pond decrease, as the runoff removes them from the surrounding surface areas. Structural BMPs treat this initial flush of storm water, rather than the peak flows of a storm event. According to the RRSDS, flow-through based water quality control measures are devices or measures that are designed to treat this initial flush of contaminants into the Kaelepulu Pond. This Water Quality Flow Rate (Q_{WQFR}) is determined by means of a Runoff Coefficient (C), Hourly Rainfall Intensity (0.4 inches per hour, maintainable for three (3) hours), and area (A) of the drainage area in acres giving the flow calculation of:

$$Q_{WQFR} = C \times 0.4'' \times A$$

Q_{WQFR} = water quality flow rate in cfs

C = runoff coefficient (determined from Table 1 or Table 2 of the RRSDS)

A = area of the site in acres

3.1.1.1 WKIP 14

The drainage area of WKIP 14 is 87.4 acres; accordingly the rational method was used to determine the runoff quantities (Q_{10}, Q_{50}). The rational method is based upon the formula:

$$Q = C \times I \times A$$

Q = water quality flow rate in cfs

C = runoff coefficient (determined from Table 2 of the RRSDS)

I = Rainfall intensity in inches per hour for a duration equal to the time of concentration (T_c)

A = area of the site in acres

The drainage area of WKIP 14 is primarily residential with gently rising slopes from the outlet to about 1,400 ft (427 m). The remainder of the drainage area is characterized by steep topography ranging from 20 to 195 ft above mean sea level (msl) at the top south-eastern corner (Figure 3-1). A C-factor of 0.70 was chosen for the drainage area due to the highly developed residential area located with-in. The calculation of the flow rate for T_m equal to 10-years (Q_{10}) and T_m equal to 50-years (Q_{50}) is located in Appendix C. Q_{10} for WKIP 14 is 208 cfs and Q_{50} is 312 cfs.

The Q_{WQFR} for WKIP 14 is 24.47 cfs.

3.1.1.2 WKIP 52

The drainage area of WKIP 52 is 138.0 acres. According to Plate 6 of the RRSDS a Group A, Q_{100} is approximately 1,300 cfs.

The WKIP 52 drainage area is comprised of a gentle to steep sloping residential neighborhood and steep vegetative pervious area. The topography along the Akipola Lined Channel ranges from 0 ft above msl at the interface of the Kaelepulu Pond to 20 ft above msl about 1,500 ft from the outlet. The topography then becomes steeper up to 300 ft at the northern corner of the drainage area and 370 ft at the southern end of the drainage area (Figure 3-2).

The drainage area was divided into two sub-areas to calculate runoff quantities as seen in Figure 3-3. The upper area is comprised of approximately 70 acres of steep forested/grass lands; a C-factor of 0.40 was chosen for the upper area. The lower area makes up the rest of the drainage area (approximately 68 acres). A C-factor of 0.60 was applied for this lower area, due to the residential nature of the area. In calculating the Q_{WQFR}, a weighted C-factor was used according to:

$$C_W = \frac{\sum_{j=1}^{n} C_j \times A_j}{\sum_{j=1}^{n} A_j}$$

Where:

Cw = weighted runoff coefficient

Aj = area for land cover j

Cj = runoff coefficient for area j

n = Number of distinct land covers within watershed

The weighted C-factor is therefore, 0.50. The Q_{WQFR} for WKIP 52 is 27.60 cfs.

3.1.1.3 WKIP 10

The drainage area of WKIP 10 is 323 acres. According to Plate 6 of the RRSDS a Group A, Q_{100} is approximately 2,200 cfs.

The WKIP 10 drainage area is comprised of a gentle to steep sloping residential neighborhood. The topography is 10 ft above msl at the interface of Hele Channel and Kamahele Ditch to 50 ft above msl about 2,000 ft from the outlet (WKIP 10). At the far northwest corner of the drainage area the topography is 605 ft. At the southern end (top) of the drainage area the topography reaches 325 ft (Figure 3-4).

The drainage area is comprised of a residential neighborhood and a shopping complex with high concentrations of impermeable surface; therefore a C-factor of 0.70 was employed. The Q_{WQFR} for WKIP 10 is 90.44 cfs at the outlet and approximately 70 cfs at the propose Hele Channel/Keolu Drive Bridge BMPs pilot project location. The Q_{WQFR} of 70 cfs assumes an area of approximately 260 acres, calculated using GIS, influences the BMP).

3.1.1.4 WKIP 44

The drainage area of WKIP 44 is 4.7 acres; accordingly the rational method was used to determine the runoff quantities (Q_{10}, Q_{50}). The rational method is based upon the formula:

$$Q = C \times I \times A$$

Q =	water quality flow rate in cfs
C =	runoff coefficient (determined from Table 2 of the RRSDS)
I =	Rainfall intensity in inches per hour for a duration equal to the time of concentration (T_c)
A =	area of the site in acres

The drainage area of WKIP 44 is heavily vegetated with topography of approximately 6 ft; therefore a C-factor of 0.20 was chosen (Figure 3-5). The calculation of the flow rate for T_m equal to 10-years (Q_{10}) and T_m equal to 50-years (Q_{50}) is located in Appendix C. Q_{10} for WKIP 44 is 4.7 cfs and Q_{50} is 7.1 cfs.

The Q_{WQFR} for WKIP 44 is 0.376 cfs.

The drainage area of WKIP 30-44 is 425 acres. According to Plate 6 of the RRSDS a Group A, Q_{100} is approximately 3,000 cfs.

Along the Keolu Lined Channel the topography varies from 6 ft to 65 ft at the base of the Kapaa Silt Basin. The drainage area forms a valley-like topographic gradient with the Keolu Lined Channel in the center. Within the drainage area a residential area subsides as well as a steep pervious vegetated area (Figure 3-5).

The drainage area was therefore, divided into two sub-areas to calculate runoff quantities as seen in Figure 3-6. The upper area is comprised of approximately 213 acres of steep forested/grass lands; a C-factor of 0.40 was chosen for the upper area. The lower area makes up the rest of the drainage area (approximately 212 acres). A C-factor of 0.60 was applied for this lower area, due to the residential nature of the area. In calculating the Q_{WQFR}, a weighted C-factor was used according to:

$$C_W = \frac{\sum_{j=1}^{n} C_j \times A_j}{\sum_{j=1}^{n} A_j}$$

Where:

Cw = weighted runoff coefficient

Aj = area for land cover j

Cj = runoff coefficient for area j

n = Number of distinct land covers within watershed

The weighted C-factor is therefore, 0.50. The Q_{WQFR} for WKIP 30-44 is 85 cfs.

3.2 SEDIMENT SAMPLING AND ANALYSIS

The following section provides a description of the sediment sampling methodology and analysis overview for Kaelepulu Pond.

3.2.1 SEDIMENT SAMPLING METHODOLOGY

Sediment sampling was conducted at WKIP 10, WKIP 14, and WKIP 52 using acetate tubes and rubber stoppers to extract undisturbed samples. Six sub-samples with approximately equal volumes were collected from each site; these sub-samples were then composited into a single sample and sent to the laboratory, Environmental Services Network (ESN) Pacific for analysis (See photos 3-1 and 3-2). The aqueous layer above the sediment ranged in thickness from 16 to 48 inches. Subsample recovery in the acetate tubes ranged from 3 to 5 ft. After "chain-of-custody" (COC) transfer, each laboratory sample was managed by ESN Pacific for Chlorinated Pesticides, RCRA 8 Metals, Total Nitrogen, Total Phosphorus, and Grain Size by Analytical Resources, Incorporated. Table 3-1 identifies the different constituents sampled for and methods used for analysis.

Table 3-1. Analytical Methodology

Name	Analytical Method	Container	Sample Volume	Preservation	Maximum Holding Time
RCRA 8 Metals	EPA 7000 series mod.	Glass	8oz	None	6 Months (Hg 28 Days)
Chlorinated Pesticides	EPA 8081 mod.	Glass	8oz	None	14 Days
Total Nitrogen	EPA 351.4	Poly	32oz	None	28 Days
Total Phosphorous	EPA 365.2	Poly	32oz	None	28 Days
Grain Size	PSEP	Poly	32oz	None	na

RCRA Resource Conservation and Recovery Act
EPA Environmental Protection Agency
PSEP Puget Sound Estuary Protocol
na Not Applicable

Sample Equipment

- 1.5” x 48”, 1” x 72”, and 1” x 12 Acetate Tube Samplers.
- Collection containers – 4-oz jars and 500ml Polypropylenes.
- Stainless Steel lab spoon
- Plastic homogenizing tray
- Nitrile gloves

Sample Collection

A new pair of gloves was worn at each sampling location. Each sampling location was recorded in the field sampling report prior to collecting the sample. All sampling equipment was decontaminated prior to use. The acetate tube was driven into the sediment and used to extract a core. The various depths represented by the cores were homogenized into a composite sample. Table 3-2 describes the location, depth of water, sampler used and length of core recovered.

Sample Preservation

Preservation techniques ensure that the sample remains representative of the sediment at the time of collection. Since pollutants collected within the samples are considered to be stable, the samples needed no preservation additives. Samples collected did not need to be analyzed immediately (Table 3-1). After sediment collection and compositing, the samples were put into containers that were logged, labeled, returned to the ice chest, and packed with ice around and over them. Packages of loose ice cubes were used to cool the samples.

Sample Handling

The COC form tracked changes in possession that occurred during transit of the samples. The COC record allows an accurate step-by-step recreation of the sampling path, from origin through analysis. In general, custody transfers are done for each individual sample, however, during this sampling event, samples were transferred as a group.

A COC form was filled out completely, including a listing for each sample in the ice chest, delivery dates, and times. The transferee signed and recorded the date and time on the COC record when transferring possession of samples (Appendix B).

Sample Analysis

Once the proper transfer procedures were completed, the laboratory performed the following analytical tests as summarized below and shown in Table 3-2.

Samples WKIP 52 and WKIP 14 were analyzed for:

Chlorinated Pesticides by EPA method 8081;

- RCRA 8 Metals (Arsenic, Barium, Cadmium, Chromium, Mercury, Lead, Selenium, and Silver) by EPA 7000 series;
- Total Nitrogen by EPA method 351.4;
- Total Phosphorus by EPA method 365.2; and
- Grain Size by PSEP.

Sample WKIP 10 was analyzed for:

- Chlorinated Pesticides by EPA method 8081;
- RCRA 8 Metals (Arsenic, Barium, Cadmium, Chromium, Mercury, Lead, Selenium, and Silver) by EPA 7000 series; and
- Grain Size by PSEP (sample taken within Hele Lined Channel near the Keolu Drive Bridge).

Table 3-2. Laboratory Analysis Performed

Location	Sub Samples	Distance from Outfall (ft)	Acetate Tube Used (in)	Water Depth (in)	Core Recovered (ft)	RCRA 8 Metals	Chlorinated Pesticides	TKN	Total P	Grain Size
WKIP 52	1 & 2	40	1.5 x 48	16	3	Yes	Yes	Yes	Yes	Yes
	1 & 2	40	1.5 x 48	16	3					
	1 & 2	40	1.5 x 48	16	3					
WKIP 14	1&2	20	1.5 x 48	18	3	Yes	Yes	Yes	Yes	Yes
	3&4	30	1.5 x 48	30	3					
	5&6	40	1.5 x 48	38	3					
WKIP 10	1&2	50	1.5 x 48	18	3	Yes	Yes	Yes	Yes	No
	3&4	55	1.5 x 48	18	3					
	5&6	60	1.5 x 48	20	3					
Hele Channel	na	1,100	1.5 x 6	12	0.2-0.5	No	No	No	No	Yes

RCRA Resource Conservation and Recovery Act
ft = Feet
in = Inches
TKN = Total Kjeldahl Nitrogen
P = Phosphorus
na = not applicable

3.3 CONCLUSIONS

The results from composite samples collected from Kaelepulu Pond were compared to the National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (SQRT) for marine sediment. The SQRT tables were designed as an internal NOAA screening document and do not reflect criteria or clean-up levels. NOAA's SQRT tables will be used for guidance because there is no formal environmental action levels (EALs) for sediment. Sample resultant values were compared to the NOAA SQRT "Effects Range-Low" (ERL) value (contaminants in sediment are not likely to have adverse effects on animals that live in sediment); and the "Effects Range-Median" (ERM) value (contaminants in sediment probably have adverse effects on animals that live in sediment).

EPA method 8081A, Gas Chromatography (GC), was used to analyze the samples for organochlorine pesticides. The NOAA SQRT tables only contain ERL and ERM data on the following organochlorine pesticides; chlordane, p,p'-DDE, p,p'-DDD, and p,p'-DDT. The method detection limit (MDL) for the four compounds mentioned earlier falls between the ERL and ERM (Table 3-3). Organochlorine pesticides were not detected in the composite samples from outfalls WKIP 10, WKIP 14, and WKIP 52.

Analytical results for RCRA 8 metals using EPA 7000 series analysis detected the presence of lead at all three outlets; however, the detected amounts were below the NOAA SQRT ERL and ERM values. Chromium was detected in sample WKIP 10 and WKIP 14 but the amount present was below the NOAA SQRT ERL and ERM values. WKIP 52 resultant data was J flagged (the analyte was positively identified, but the quantitation is an estimation) see Table 3-4. Estimated values fall well below NOAA SQRT ERL and ERM values.

Total Kjeldahl Nitrogen (TKN) and Total Phosphorus analyses were run on composite samples from WKIP 14 and WKIP 52. The methods used to analyze the samples were EPA method 351.4 for TKN and EPA method 365.2 for Total Phosphorous. To compare these sediment concentrations to Hawaii Administrative Rules (HAR) 11-54-5.2 Water Quality Standards (WQS) geometric mean not to exceed the given value for estuaries, the following method was used: If it is assumed that the sediment measured is suspended in the water column, at the concentration limit (wet season geometric mean not to exceed the given value 20 mg/L) specified in the regulatory standard, and all of the available nitrogen and phosphorous attached to the sediment would dissolve into the water column, then a concentration of TKN and Total Phosphorous can be calculated for the water column. The composite sediment sample from WKIP 52 had a TKN concentration of 1060 mg-N/kg and a Total Phosphorous concentration of 1050 mg/kg. Under the previous assumptions the concentration of TKN would be 21.2 µg/L and the concentration of Total Phosphorous would be 21.0 µg/L. The composite sediment sample from WKIP 14 had a TKN concentration of 1300 mg-N/kg and a Total Phosphorous concentration of 987 mg/kg. Under the previous assumptions the concentration of TKN would be 26.0 µg/L and the concentration of Total Phosphorous would be 19.74 µg/L.

HAR 11-54-5.2 WQS for estuaries, geometric mean not to exceed value, for Total Nitrogen is 200.0 µg-N/L and for Total Phosphorous is 25.0 µg-P/L. Using these geometric mean values, the calculated TKN and Total Phosphorous for both WKIP 52 and WKIP 14 are below the geometric mean value. The calculated values of TKN and Total Phosphorous are very conservative because of the assumptions made in calculating the concentration. It is highly likely that not all of the sediment analyzed would be suspended, and that all of the available nitrogen and phosphorous attached to the sediment would dissolve into the water column.

It is difficult to assess the sources and amount of sediment introduced into the channel limited data. Additional storm water runoff information obtained through representative storm water sampling efforts of the four major drainage areas would assist with analysis. It is recommended that a small pilot project, scoped to provide information on incoming water into the channels, incorporating collection at key points along the length of the channels taken several times within a storm event. Data collected with automatic equipment would include: rain fall, water depths, GPS locations, and flow velocities. This information, along with water sample analysis, would then establish a perspective of the amount of sediment being introduced into the channel versus sediment simply being re-suspended and/or carried downstream from prior storm events. This would also help establish a perspective on the issue of cleaning and maintaining the channel upstream of the pond and provide a more realistic target particle size distributions (PSD) for appropriate design of structural BMPs with the goal being more efficient TSS removal meeting future TMDLs requirements. BMPs for construction (City, 1999) and post-construction (Section 4 and Appendix D) should be followed to reduce water quality degradation in the Kaelepulu Subwatershed.

Table 3-3. Analytical Results

Organochlorine Pesticides	Method Blank	WKIP 52	WKIP 52 Dup	WKIP 14	WKIP 10	PQL	MDL	ERL	ERM	Units	MDL ERL Comp	MDL ERM Comp
Alpha-BHC	nd	nd	nd	nd	nd	0.005	0.002	*	*	mg/Kg		
Beta-BHC	nd	nd	nd	nd	nd	0.005	0.005	*	*	mg/Kg		
Gamma-BHC (Lindane)	nd	nd	nd	nd	nd	0.005	0.002	*	*	mg/Kg		
Delta-BHC	nd	nd	nd	nd	nd	0.005	0.004	*	*	mg/Kg		
Heptachlor	nd	nd	nd	nd	nd	0.005	0.002	*	*	mg/Kg		
Aldrin	nd	nd	nd	nd	nd	0.005	0.003	*	*	mg/Kg		
Heptachlor epoxide	nd	nd	nd	nd	nd	0.005	0.003	*	*	mg/Kg		
Gamma-Chlordane	nd	nd	nd	nd	nd	0.005	0.003	*	*	mg/Kg		
Endosulfan I	nd	nd	nd	nd	nd	0.005	0.004	*	*	mg/Kg		
Alpha-Chlordane	nd	nd	nd	nd	nd	0.005	0.003	*	*	mg/Kg		
Dieldrin	nd	nd	nd	nd	nd	0.01	0.003	*	*	mg/Kg		
p,p’-DDE	nd	nd	nd	nd	nd	0.01	0.005	0.002	0.027	mg/Kg	>ERL	<ERM
Endrin	nd	nd	nd	nd	nd	0.01	0.003	*	*	mg/Kg		
Endosulfan II	nd	nd	nd	nd	nd	0.01	0.005	*	*	mg/Kg		
p,p’-DDD	nd	nd	nd	nd	nd	0.01	0.003	0.002	0.020	mg/Kg	>ERL	<ERM
Endrinaldehyde	nd	nd	nd	nd	nd	0.01	0.005	*	*	mg/Kg		
Endosulfan sulfate	nd	nd	nd	nd	nd	0.01	0.005	*	*	mg/Kg		
p,p’-DDT	nd	nd	nd	nd	nd	0.01	0.005	0.001	0.007	mg/Kg	>ERL	<ERM
Endrin ketone	nd	nd	nd	nd	nd	0.01	0.005	*	*	mg/Kg		
Methoxychlor	nd	nd	nd	nd	nd	0.01	0.009	*	*	mg/Kg		
Chlordane (technical)	nd	nd	nd	nd	nd	0.05	0.005	0.001	0.006	mg/Kg	>ERL	<ERM
Toxaphene	nd	nd	nd	nd	nd	0.25	0.1	*	*	mg/Kg		

RCRA 8 Metals	**Method Blank**	**WKIP 52**	**WKIP 52 Dup**	**WKIP 14**	**WKIP 10**	**PQL**	**MDL**	**ERL**	**ERM**	**Units**
Lead (Pb)	nd	15	11	20	35	5	3.5	46.7	218	mg/Kg
Cadmium (Cd)	nd	nd	nd	nd	nd	1.25	0.5	1.2	9.6	mg/Kg
Chromium (Cr)	nd	11 (J)	9.1 (J)	30	53	12.5	5	81	370	mg/Kg
Arsenic (As)	nd	nd	nd	nd	nd	5	2	8.2	70	mg/Kg
Silver (Ag)	nd	nd	nd	nd	nd	1.25	1.5	1	3.7	mg/Kg
Barium (Ba)	nd	nd	nd	nd	nd	25	21	*	*	mg/Kg
Selenium (Se)	nd	nd	nd	nd	nd	12.5	7.5	*	*	mg/Kg
Mercury (Hg)	nd	nd	nd	nd	nd	0.5	0.1	0.15	0.71	mg/Kg
Nutrients	**Method Blank**	**WKIP 52**	**WKIP 52 Dup**	**WKIP 14**	**WKIP 10**	**PQL**	**RL**	**ERL**	**ERM**	**Units**
Total Kjeldhal Nitrogen	<1.0 (U)	1060	n/t	1300	n/t	257	257	*	*	mg-N/Kg
Total Phosphoruos	<.04 (U)	1050	n/t	987	n/t	130	130	*	*	mg/Kg
Grain Size	**Method Blank**	**WKIP 52**	**WKIP 52 Dup**	**WKIP 14**	**WKIP 10**					**Units**
% Gravel	na	20	na	30	n/t	na	na	na	na	%
% Sand	na	52	na	20	n/t	na	na	na	na	%
% Silt	na	18	na	22	n/t	na	na	na	na	%
% Clay	na	10	na	28	n/t	na	na	na	na	%

(J) = Estimated concentration when the value is less than ARI's established reporting limits

(U) = Indicates that the target analyte was not detected at the reported concentration

PQL = Practical Quantization Limit

MDL = Method Detection Limit

ERL = Effect Range-Low

ERM = Effect Range-Median

RL = Reporting Limit

n/t = Not Taken

* = No Data

Mg/Kg = milligrams per kilogram

Mg-N/Kg = Mg-Nitrogen per Kg

Dup = duplicate

na = not applicable

nd = not detected

PSD within the composite sediment samples was attained by using the PSEP method. Particle size distribution using this method is broken down into Gravel (>2000 microns), Sands (2000 - 62 microns), Silts (62 - 3.9 microns), Clays (3.9 - <1 microns), and total fines (<62 microns). Table 3-4 identifies the particle size distribution in percent through each size fraction for the outlet at WKIP 52 and 14, and Hele Lined-Channel near the Keolu Bridge, which feeds to WKIP 10 outlet. See Appendix B for presentation of laboratory data and supporting information.

Table 3-4. Sediment Analysis Percent Retained in Each Size Fraction

Location	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Coarse Silt	Medium Silt	Fine Silt	Very Fine Silt	Clay	Total Fines
WKIP 52	21.3	12	14.1	14.9	7.3	3	11.4	2.5	2.2	2.0	9.3	27.4
WKIP 14	28.9	3.5	3.9	4.3	4.7	4.6	3.5	7.5	6.0	5.4	27.6	50.1
Hele Channel	68.7	18	6.5	2.5	1.6	1.1	na	na	na	na	na	1.7

na = Not Available (there was not enough fines to be split and stay within capacity of the balance)

Fine sediments are typically a combination of sands, silts and clays less than 100 µm in diameter. Removal efficiencies for 100-500 µm particle size range from 20-70% for retrofit liquid/solid separator applications, with lower percent removals at smaller particle sizes.

WKIP 14 had a total of 50% fines, 23% higher total fines than WKIP 52. This is due to the following:

- WKIP 14 is located in a cove on the southeastern end of Kaelepulu Pond so is typically calmer than other portions, including WKIP 52;
- WKIP 14 also receives tradewind head on which keeps trash, debris and sediment closer to the outfall;
- WKIP 14 receives drainage from a relatively flat area associated with the Alahaki Ditch and two interceptor ditches. Both these ditches are for the most part un-lined and due to the lack of relief, storm flows are slower here in this drainage area. The sands and gravels therefore settle out relatively early (in the interceptor ditches and tributaries) leaving only the silts and clays to make it to the outfall and deposit due to the slow moving flows and head winds near the outfall;
- WKIP 52 receives drainage from the Akipola Lined Channel from a relatively steep upper area area. Peak flow rates (Q_{100}) of 1,300 cfs discharge into Kaelepulu Pond dispersing the sediment and debris in a wide arch which are kept in the suspended state.

- Re-suspension of sediments within the Alahaki Ditch associated with WKIP 14, during subsequent low flow storm events may also be a contributing issue to the fines deposited at the outlet.

WKIP 10 grain size sediment sampling location in Hele Lined-Channel, located near the Keolu Bridge consisted mainly of gravel deposits, having a total of 1.7% fines. This was a little lower than anticipated, however considering the channel is concrete lined and receives peak flows of approximately 700 cfs at the sampling location, this was not surprising.

<u>Solids Sampling Issues</u>

TSS sampling methods become less accurate when sand-size particles (60 – 2000 μm) exceed 25% of the sample mass. The USGS considers TSS data for open channel flow not appropriate and recommends that both TSS and Suspended Sediment Concentration (SSC) be considered due to potential bias in TSS tests. Sampling both TSS and SSC highlights importance of PSD and the ability of BMPs to treat solids.

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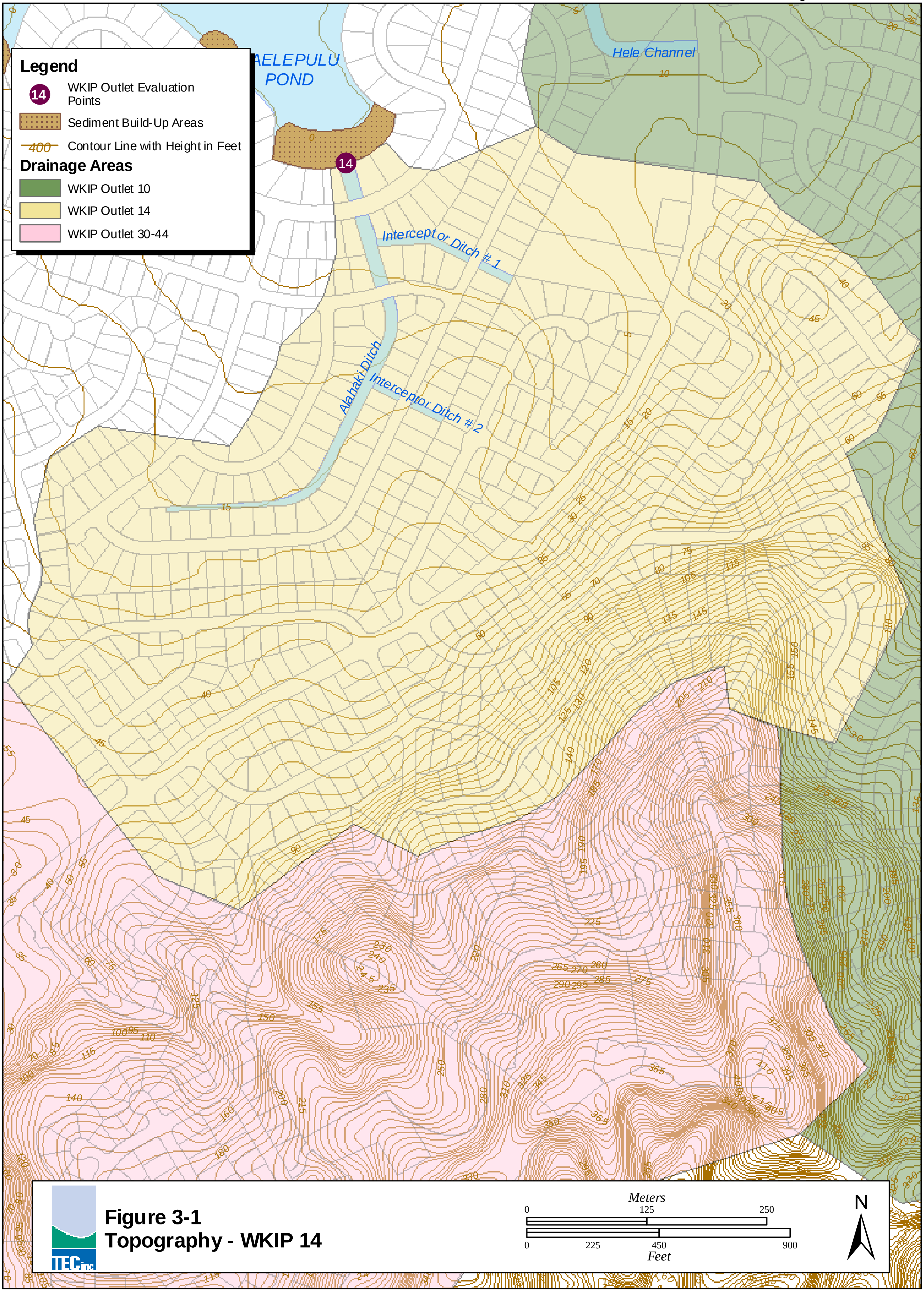

Figure 3-1
Topography - WKIP 14

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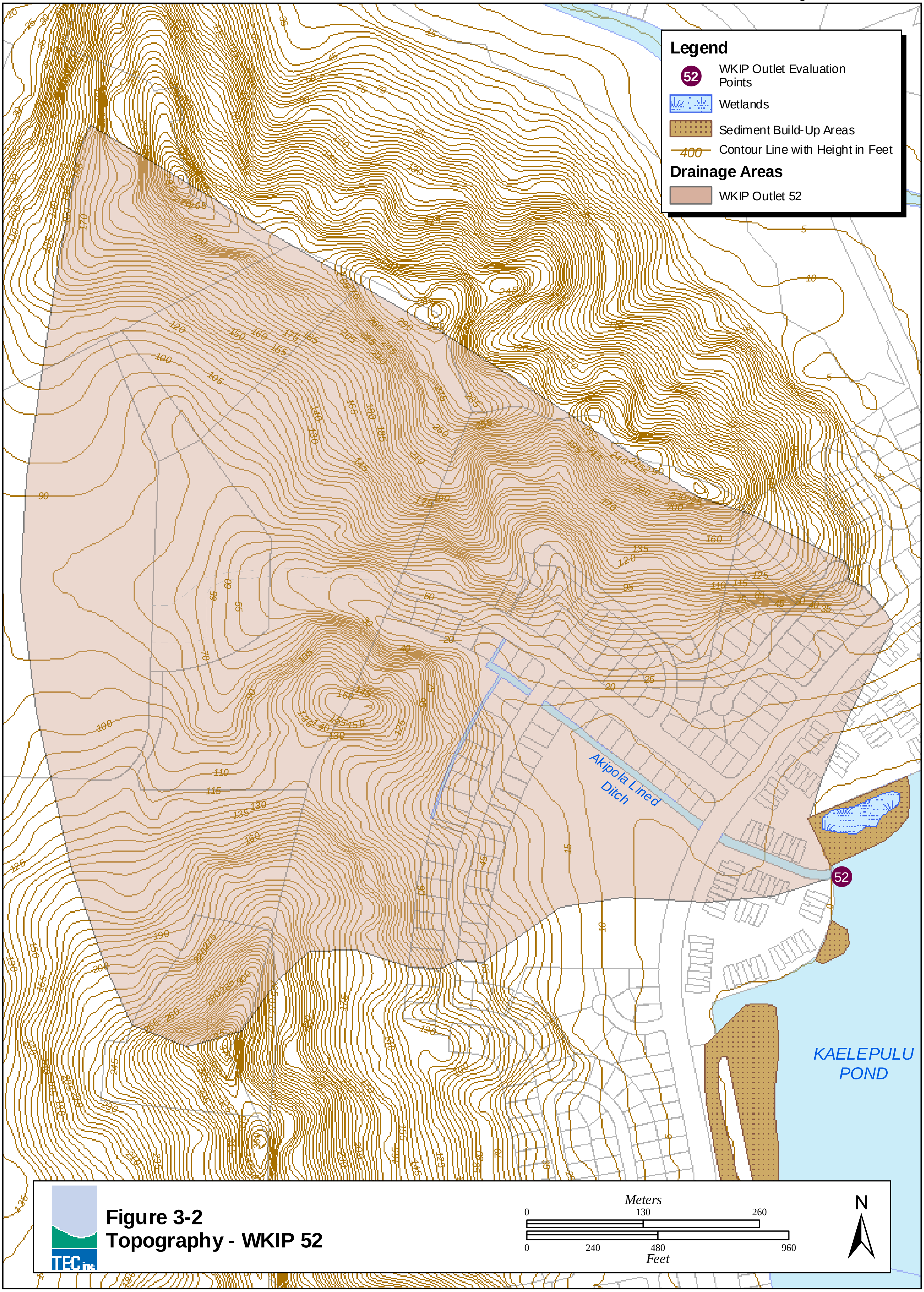

Figure 3-2
Topography - WKIP 52

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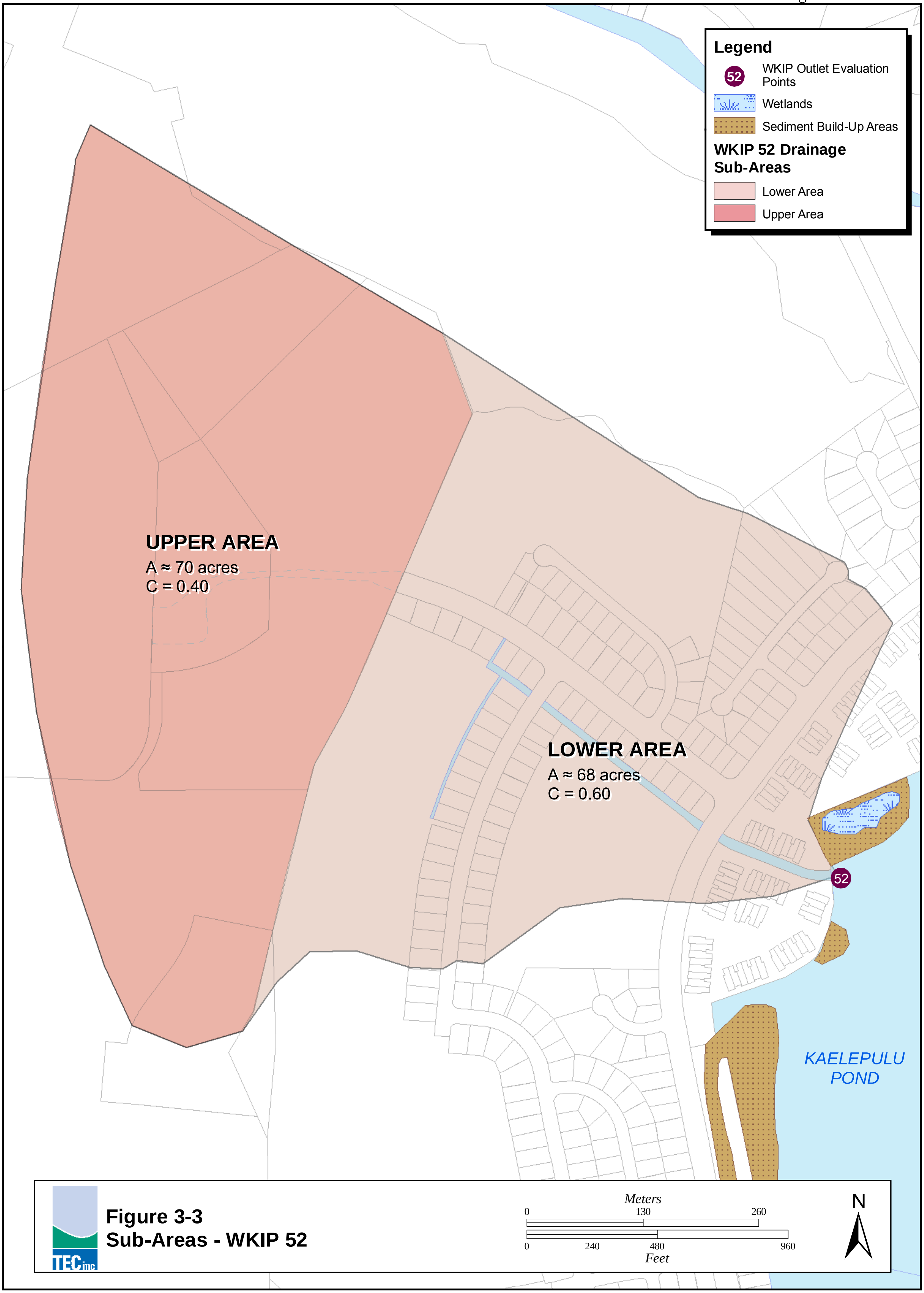

Figure 3-3
Sub-Areas - WKIP 52

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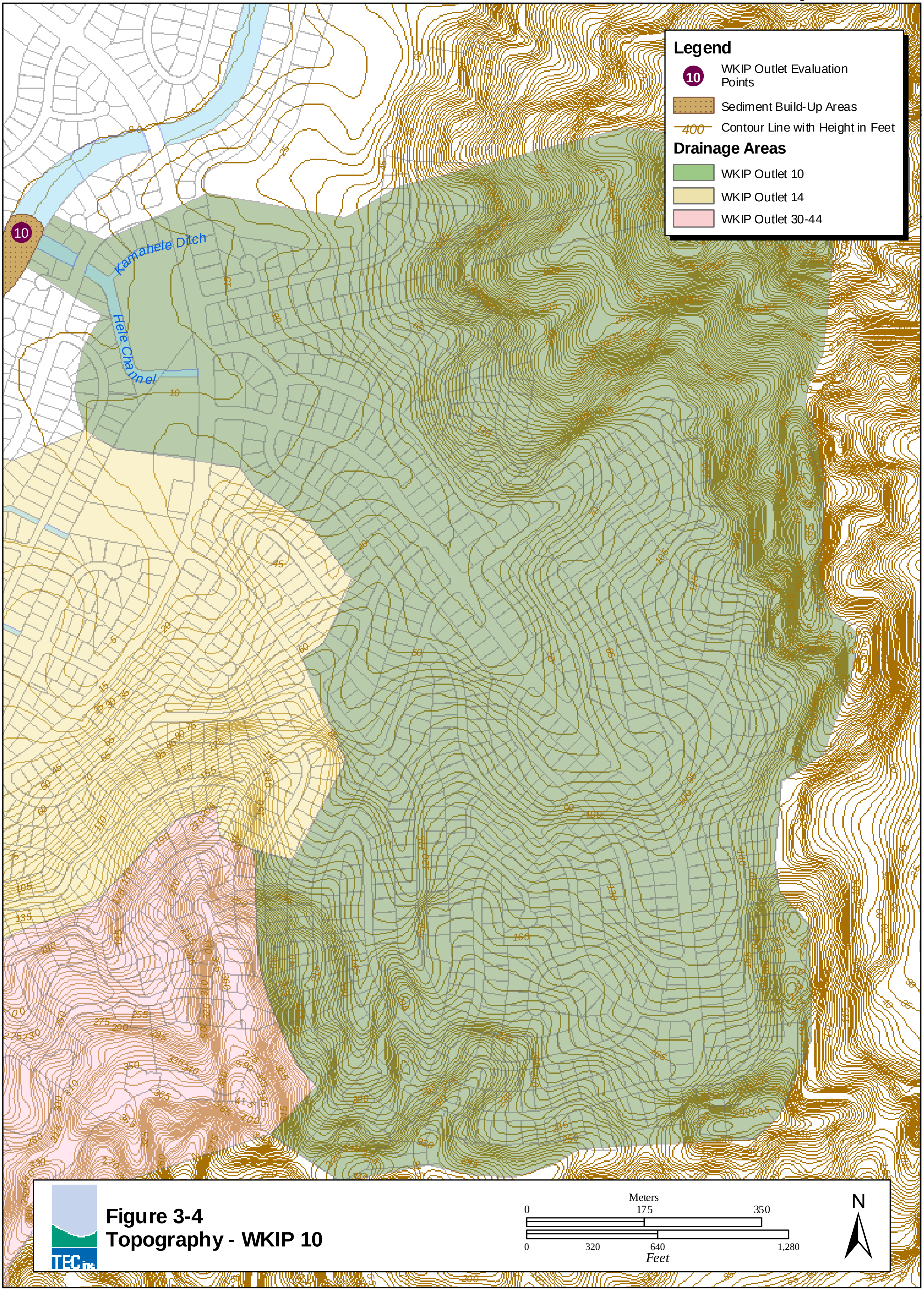

Figure 3-4
Topography - WKIP 10

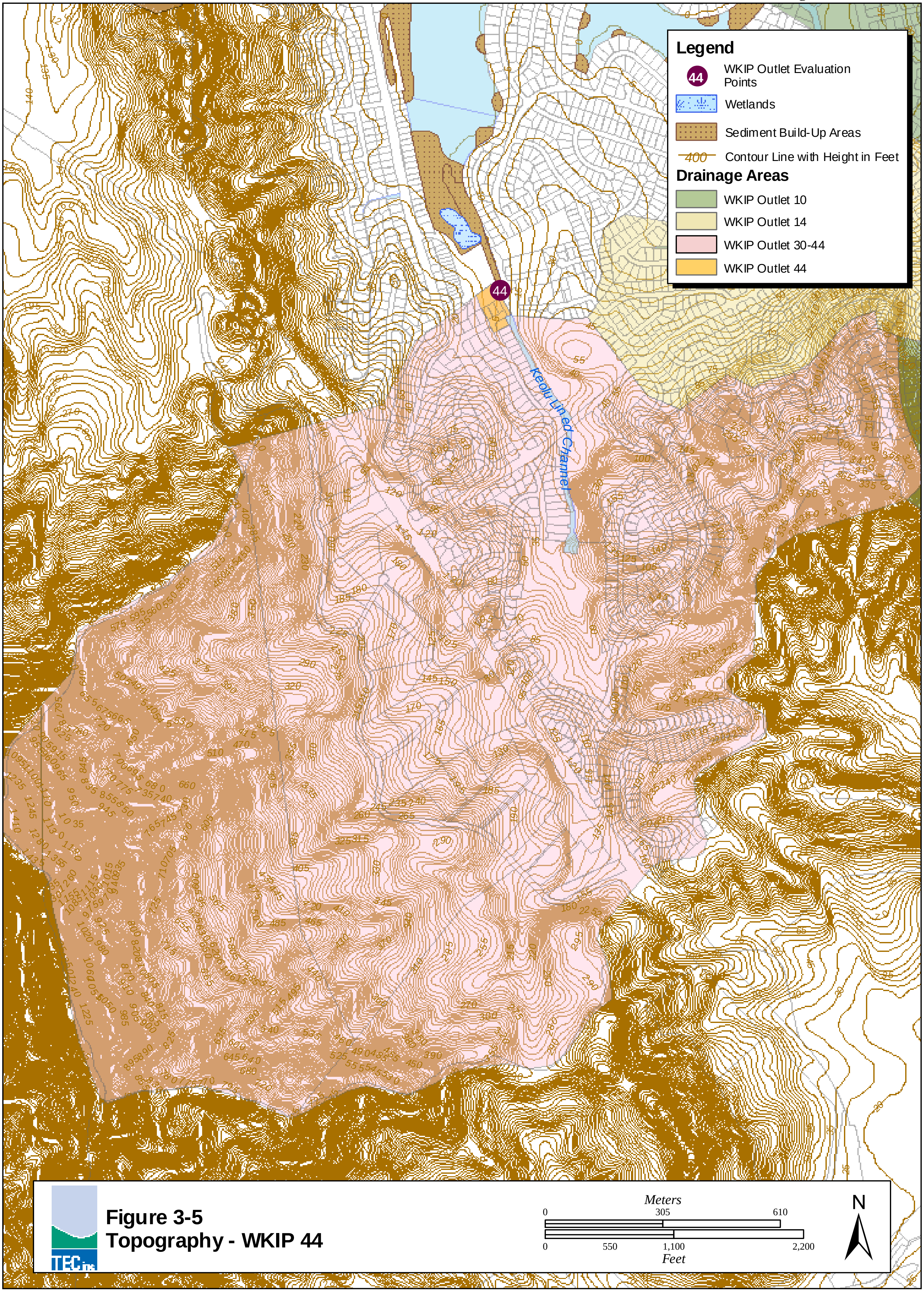

Figure 3-5
Topography - WKIP 44

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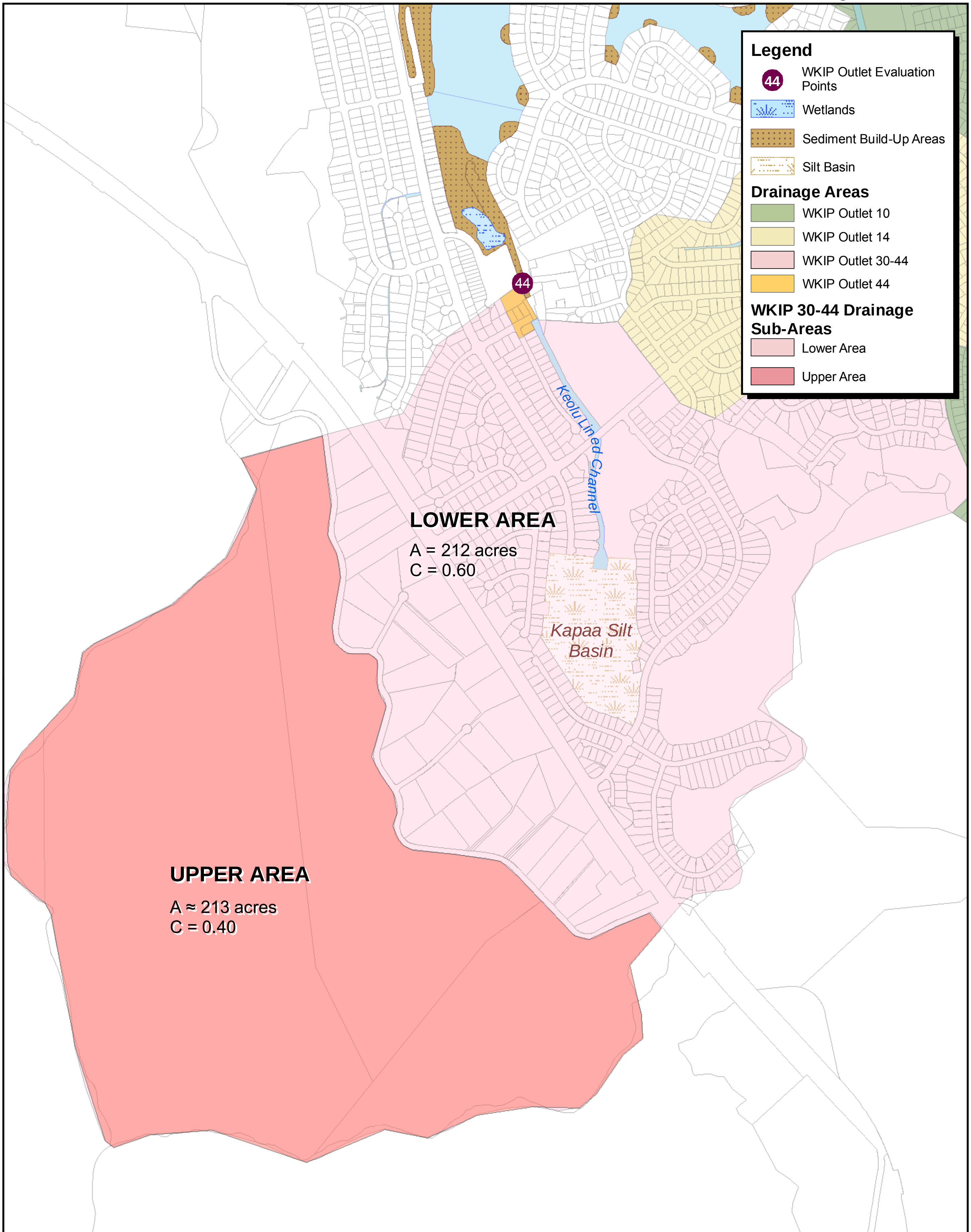

TECinc

Figure 3-6
Sub-Areas - WKIP 44

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CHAPTER 3 PHOTO LOG

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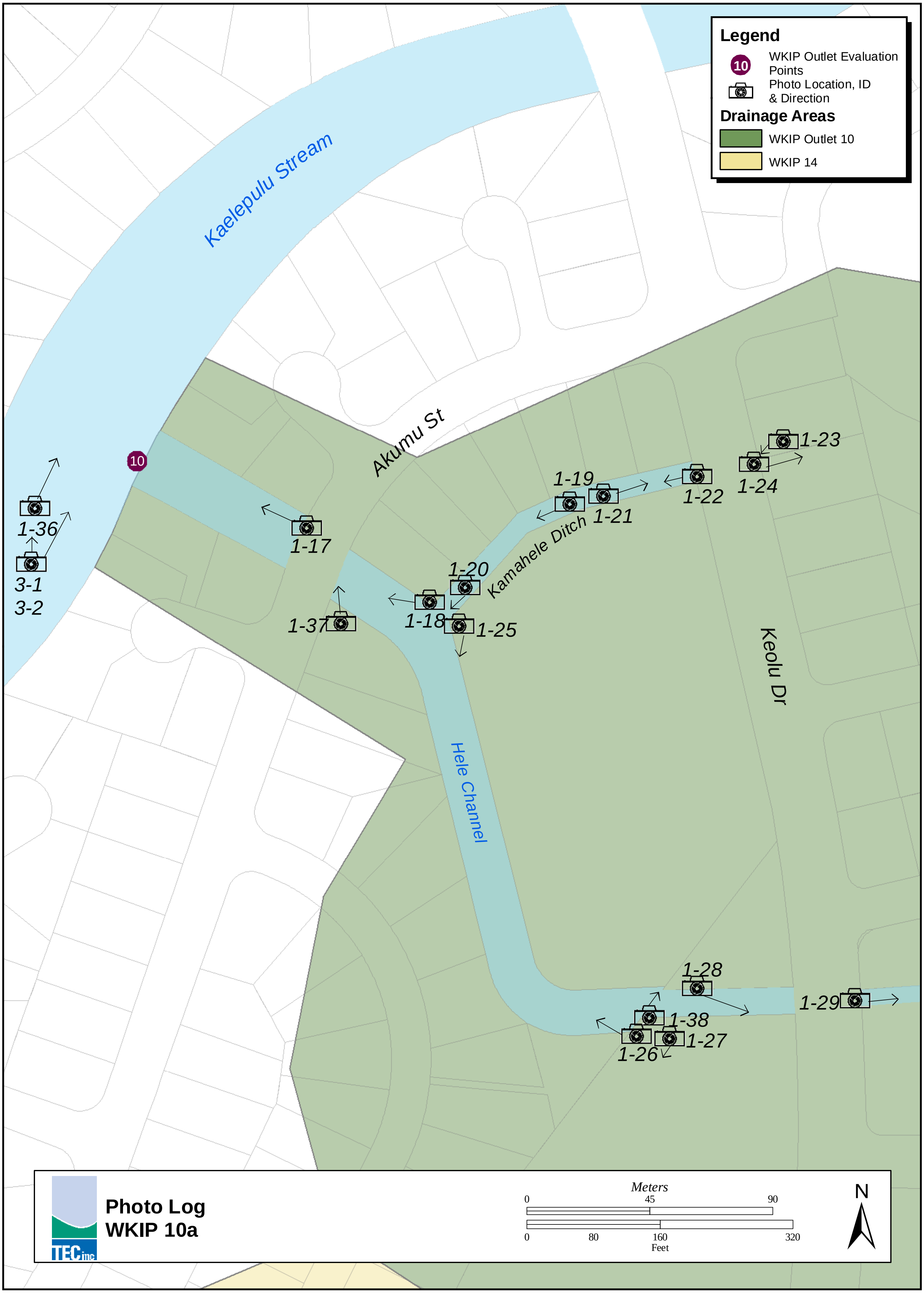

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Photo 3-1 WKIP 10 sediment sampling.

Photo 3-2 Acetate tubing with WKIP 10 sediment subsample #1

4.0 ANALYSIS OF BEST MANAGEMENT PRACTICES

Best management practices (BMPs) are techniques used to control sediment, storm water runoff, and stabilization soil; as well as management decisions to prevent or reduce non-point source pollution. The EPA defines a BMP as a "technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of storm water runoff in the most cost-effective manner." BMPs are designed as guides to increase the quality of the nation's water bodies. Structural BMPs seem to be most effective when they can be combined in a treatment train. Treatment train refers to the application of a series of physical storm water BMPs to achieve improved drainage water quality. However, BMPs will fail if improperly located within the treatment train or not properly maintained (storm water authority.org, 2006).

A literature search was performed reviewing available BMPs (structural and non-structural) of urban storm water runoff discharges associated with WKIP 10, 14, 44 and 52 of the Kaelepulu Subwatershed.

4.1 CONSTRUCTION BMPS

Both construction and post-construction areas should implement BMPs. This report focuses mainly on post-construction BMPs, however based on visual observations described in Section 1 of this report; lack of BMPs at residential construction sites was a reoccurring issue.

A combination of structural and non-structural BMPs at construction sites can lessen runoff of the fine sediment (sands, silt and clay [less than 100 μm]) into the City NPDES MS4 permitted storm conveyance system associated with Kaelepulu Pond. Strict enforcement of erosion control plans, grading plans, storm water management plans, and implemented construction BMPs based on review of *Best Management Practices Manual for construction sites in Honolulu, Department of Environmental Services, May 1999)* is critical for successfully eliminating site runoff.

4.2 POST CONSTRUCTION BMPS

Post-construction BMPs include structural and nonstructural methodologies. A structural BMP is a physical device. The device is typically designed and constructed to trap or filter pollutants from runoff, or reduce runoff velocities. Non-structural BMPs are designed to limit the amount of pollutants available in the environment that would potentially end up in storm water runoff. There are no physical structures associated with nonstructural BMPs.

4.2.1 NON STRUCTURAL BMPS

Non-structural BMPs can be achieved through education, management and appropriate development practices. There is a wide variety of non-structural BMPs and based on visual observations during the drainage area investigations (detailed descriptions can be found in 5.1.1) the following BMPs would be very effective at reducing pollutants into the Kaelepulu Subwatershed:

- Pollution prevention/source controls - i.e. street sweeping and vacuum truck operations, storm water conveyance system cleaning and maintenance;
- Barren area/bank soil stabilization through vegetative planting or sodding in conjunction with mulching and regular maintenance;
- General "good housekeeping' measures throughout the residential and commercial community;
- Continued and expanded public education program in the Enchanted Lake public schools system and community; and
- Increase enforcement personnel for more frequent inspections at construction sites.

Street sweepers and vacuum trucks are the two types of equipment that provide a quick and efficient cleaning combination in minimizing pollutants discharged through storm water runoff, addressing the storm water challenges above and below ground. Street sweepers remove debris and particulate matter from road surfaces that would otherwise find their way into the storm drain system through runoff, and vacuum trucks clean storm sewer lines, catch basins, and structural BMPs. Both pieces of equipment provide water-quality benefits to a storm water program as well as conveyance benefits allowing storm water to drain unimpeded from paved surfaces.

Baseline prices for a street sweeper and vacuum truck are $185,000 and $250,000 respectively. A lease-purchase study of refuse trucks, street sweeper and wastewater vacuum trucks, performed by the City of Santa Cruz had the following recommendation: *"that the City Council, by motion: 1) authorize the sole source purchase of two (2) front loader refuse trucks and one (1) roll-off truck from Central Valley Truck Center of Fresno, CA in the amount of $582,487.67; 2) authorize the sole source purchase of one (1) street sweeper from GCS Western Power and Equipment of Tracy, CA in the amount of $195,557.44; and 3) authorize the purchase of one (1) Vac-Con Combination Sewer/Storm Drain Cleaner truck from Municipal Maintenance Equipment of Sacramento, CA in the amount of $287,162.61."*

The Schwarze Industries Model A7000, which also has a vacuum hose at the rear, or Tymco Model 600 had received good reviews (Storm water November/December 2006). The street sweeper's pickup head is reported to be the most import factor; when the brooms and pickup head work as one unit, it helps eliminate excess dust.

The following should be considered when purchasing a sweeper or vacuum truck: numbers of units needed, price, manufacturer reputation, features that help accomplish the storm water goals, repair considerations, turnover rates, and after-purchase support.

Catch basins can capture sediments up to approximately 60% of the sump volume, however when sediment fills greater than 60% of their volume catch basins reach steady state and storm flows may then bypass treatment as well as re-suspend sediments trapped in the catch basin. Frequent clean-out can retain the volume in the catch basin sump available for treatment of storm water flows (Pitt, 1985). Monthly cleaning in one study, increased total annual sediment collected to six times the amount collected by annual cleaning (Mineart and Singh, 1994).

The City and County Road Division is responsible for cleaning catch basins. Based on conversations with Tyler Sugihara, Assistant Road Division Chief, there are currently four crews utilizing five Vactor trucks for the Kaneohe, Pearl City, and Halawa areas. Kailua does not have a crew and currently no cleaning is performed. The Vactor hose extends to approximately 10 ft. The truck must therefore position itself directly over the catch basin in order to clean it properly. It is reported that the catch basin cleanings are infrequent; however required inspections are done at least twice every five years based on the City's NPDES MS4 permit.

4.2.2 STRUCTURAL BMPS

The criteria used to evaluate these BMPs are based on:

- Existing City NPDES MS4 Permit, WKIP storm water outfall data, and drainage reports;
- RRSDS § 1-5 Section II – Storm Water Quality;
- Sediment sample chemical analysis for pollutants;
- Sediment sample grain size analysis; and
- Visual observations during subwatershed investigations.

The five categories of structural BMPs evaluated in this report include:

1. Detention/Retention and Vegetated Treatment; detention basins, wet retention ponds, constructed wetlands, and water quality swales;
2. Filtration: sand and organic filters;
3. Advanced Sedimentation/Separation: hydrodynamic separators, oil and grit chamber;
4. Infiltration: infiltration trenches, infiltration basins, dry wells (rooftop infiltration); and;
5. Pretreatment: water quality inlets, hooded and deep sump catch basins, sediment traps (forebays), and drainage channels.

A summary of these five categories of structural BMPs are shown in Table 4-1 comparing removal efficiencies, key features, maintenance, and cost.

Table 4-1. Structural BMPs Summary and Comparison

Structural BMP	TSS Removal Efficiency	Key Features	Maintenance	Cost
1. Detention Basins	60-80% average 70% design	- Large area - Peak flow control	Low	Low to moderate
1. Wet (Retention) Ponds	60-80% average 70% design	- Large area - Peak flow control	Low to moderate	Low to high
1. Constructed Wetlands	65-85% average 70% design	- Large area - Peak flow control - Biological treatment	Low to moderate	Marginally higher than wet ponds
1. Water Quality Swales	60-80% average 70% design	- Higher pollutant removal rates than drainage channels - Transport peak runoff and provide some infiltration	Low to moderate	Low to moderate
4. Infiltration Trenches/Basins	75-85% average 80% design	- Preserves natural water balance on site - Susceptible to clogging - Reduces downstream impacts	High	Moderate to high
4. Dry Wells	80% average 80% design	- On-site infiltration - For untreated storm water from roofs only	High	Low
2. Sand and Organic Filters	80% average 80% design	- Large area - Peak flow control	High	High
5. Sediment Traps/ Forebays	25% average 25% design	- Pretreatment - Retrofit expansion - Larger space requirement than inlet	Moderate	Low to moderate
3. Inline Treatment - Advance Sedimentation	50-80% average 80% design	- Small area - Oil and grease control	Moderate	Moderate
3. Inline Treatment - Sand Filtration	50-80% average 80% design	- Small area - Nutrient and pathogen (potential)	Moderate	Moderate
3. Inline Treatment - Hydrodynamic	50-80% average 80% design	- Small area - Oil and grease control	Moderate	Moderate
3. Inline Treatment - Media Filtration	50-80% average 80% design	- Small area - Oil and grease control	Moderate	Moderate
5. Inlets and Catch Basins - Grate Alone	15-35% average 25% design	- Debris removal - Pretreatment		
5. Inlets and Catch Basins - Inlet Inserts	30-90% - only a few studies	- Retrofit - Construction - Oil and grease control	Moderate	Moderate

Note of Caution Regarding Treatment Methodologies

"Laser particle sizing has indicated that a considerable proportion of the particulates in road runoff are less than 10 µm (0.01 mm). This size fraction is difficult to capture in current storm water pollution control devices and has been shown to contain significant quantities of heavy metals, which are of concern in aquatic ecosystems." (Drapper *et al*). Table 4-2 compares settling rates between different sized particles found in storm runoff.

Table 4-2. Rate of Settling in Pure, Still Water

Material	Diameter (mm)	Hydraulic subsiding value (mm/sec)	Time required to settle 1 ft.
Gravel	10.0	1000.0	0.3 sec
Coarse Sand	1.0	100.0	3.0 sec
Fine Sand	0.1	8.0	38.0 sec
Silt	0.01	0.154	33.0 min
Bacteria	0.001	0.00154	55.0 hr
Clay	0.0001	0.0000154	230.0 days
Colloidal Particles	0.00001	0.000000154	63 years

Rate of settling in pure, still water (temp=10^{o}C, sp. gravity of particles=2.65, shape of particles=spherical) (Welch, 1935)

4.2.2.1 FLOW CONTROL BMPS

The flow control-type BMPs (detention/retention, filtration type BMPs) refer to structures designed to control both flow and the intensity of storm water discharge. They are proven to be quite effective storm water management tools, however are limited by the large open areas of land required for their construction and are usually difficult for retrofit-type projects in ultra urban areas.

A storm water retrofit is a storm water management practice (usually structural) put into place after development has occurred to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Dry extended detention ponds can be very useful storm water retrofits, and they have two primary applications as a retrofit design. In many communities in the past, detention basins have been designed for flood control. It is possible to modify these facilities to incorporate features that encourage water quality control and/or channel protection. Due to the high degree of development within the four Drainage areas studied in this report, there is a lack of available space for retrofit detention/retention type systems.

The privately owned Kapaa Silt Basin receives storm water from the Keolu Hills community and is associated with the WKIP 44 outlet and drainage area. The City has a debris control structure, identified in Section 1.3.4, that is adjacent to the silt basin located just prior to discharge into the Keolu Lined Channel. Based on personal observations and conversations with Bob Burke, ELRA, "the Kapaa Silt Basin appears to be functioning more as a flood control basin than as a silt basin."

4.2.2.2 POLLUTION REMOVAL BMPS

Pollution removal BMPs refer to the use of innovative settling chambers or filtration devices to lower the concentration of TSS from the storm water prior to discharge. There are several types of BMPs available in this category that accomplish this type of treatment through the use of various baffle boxes, hydrodynamic principles and/or a combination of those with filtration media. This technology is referred to as "Flow Through based Treatment" is available commercially from vendors and must remove a minimum of 80% of TSS of the sized fractions typical for urban runoff from the design flow rate. The commercially available devices can be categorized into either Storm Drain Inline Devices or Storm Drain Inlet Devices.

4.2.2.3 INLINE TREATMENT

Description

Inline treatment is flow-through structures with a settling or separation unit to remove sediments and other pollutants that are widely used in storm water treatment. No outside power source is required, because the physics of the flowing water (hydrodynamic separators) allows the sediments to efficiently separate. Variations of hydrodynamic systems have been designed to meet specific needs to remove particulates, which can be settled, or floatables, which can be captured, rather than solids with poor settle-ability or dissolved pollutants. Some systems have supplemental features to reduce the velocity of the flow entering the system. This increases the efficiency of the unit by allowing more sediment to settle out.

Applicability

This technology may be used by itself or in conjunction with other storm water BMPs as part of a treatment train (an overall storm water management strategy). Hydrodynamic separators come in a wide range of shapes and sizes. This makes hydrodynamic separators ideal for areas where land availability is limited. Also, because they can be placed in almost any specific location in a collection system, hydrodynamic separators are ideal for use in potential storm water "hotspots"- such as gas station islands. The need for hydrodynamic separators is growing as a result of the increased desire to utilize every square foot of developable land and for retrofit pollution control directed by more stringent water quality discharge regulations.

Limitations

The use of hydrodynamic separators as wet weather treatment options may be limited by the various dynamics of net solids removal. While some data suggest excellent removal rates, these rates often depend on site-specific conditions as well as other contributing factors. Pollutants such as nutrients, which adhere to fine particulates or are dissolved, will not be significantly removed by the unit. Site constraints, including the availability of suitable land, appropriate soil depth, and stable soil to support the unit structurally, may also limit the applicability of the hydrodynamic separator. The slope of the site or collection system may necessitate the use of an underground unit, which can result in an extensive excavation.

Sizing and Design Considerations

Sizing hydrodynamic separators is usually based on a certain set of treatment objectives; i.e., treating a water quality design flow. In order to prevent washout of a flow-based system, the system is typically designed with an external bypass although some systems have a flow through capability. When the peak flow exceeds the water quality flow by a factor of 5 or more, an off-line configuration or a spill way for in-channel units is usually a cost effective solution. Upstream diversion structures can also be used to bypass higher flows around the device. Using structural BMPs that can be placed underground and are designed to withstand site specific soil, groundwater and traffic loading conditions provide valuable savings in land area compared to conventional volume-based storm water treatment practices such as ponds, wetlands, and swales. However, these devices may provide challenges for retrofit operations in the acquisition of land.

Maintenance Considerations

Hydrodynamic separators do not have any moving parts, and are consequently not maintenance intensive. Maintaining the system properly is very important in ensuring that it is operating as efficiently as possible. Proper maintenance involves frequent inspections throughout the first year of installation. When the unit has reached capacity, it must be cleaned out. This may be performed with vacuum truck, depending on which unit is used. In general, hydrodynamic separators require a minimal amount of maintenance, but lack of attention will lower their overall efficiency.

Effectiveness

Hydrodynamic separators are designed primarily for removing floatable and material settleable solids. The reported removal rates of sediments, floatables, and oil and grease differ depending on the vendor and reporting article. These stand-alone proprietary devices are not expected to remove all of the typical post-development post-human occupation derived pollutants, such as phosphorus, nitrogen, heavy metals, hydrocarbons, and pesticides. This is because varying percentages of these post-development pollutants absorb or adhere to particles smaller than 100 microns and/or are in dissolved form. These stand-alone devices will remove larger particles to a considerable degree and/or act as gross pollutant traps thus serving as pre-treatment devices (cf. Herr and Harper). Table 4-3 compares the actual (and estimated) removal efficiencies of four structures. The cost for these four structures are compared in Table 4-5.

During 1998-99, evaluations were conducted for the City of Orlando, the City of Winter Haven, and the City of Atlantic Beach related to the removal of gross pollutants. Based on information found in the literature and information obtained from technology manufacturers removal efficiencies were estimated and compared for the four separate technologies.

The evaluation considered removal efficiencies for litter, debris, and coarse sediment, estimated initial cost, and operation and maintenance requirements.

Based on removal efficiencies for coarse sediments, removal efficiencies were estimated for common storm water constituents including total nitrogen, total phosphorus, total suspended solids, Biological Oxygen Demand (BOD), and heavy metals. Based on typical fractions of particulate matter in runoff, liquid/solid separators are capable of removing approximately 20-50% of nutrients and heavy metals under ideal conditions.

Limitations of liquid/solid separators must be understood when considering these systems for retrofit applications. While performing the evaluations, it became apparent there is insufficient field data to accurately predict the removal efficiencies for various gross pollutants contained in storm water runoff.

As described earlier, gross pollutants in storm water runoff generally consist of litter, debris, and coarse sediments. Most gross pollutants cannot be sampled by traditional automatic samplers, and gross pollutants are often overlooked when evaluating the impact of storm water runoff on receiving waters.

Litter is typically defined as human-derived material, including paper, plastic, metal, glass, cloth, or any other man-made material.

Debris is typically defined as any natural organic matter transported by storm water runoff, such as leaves, twigs, and grass clippings.

Coarse sediments are defined as inorganic particulates. Particle diameters of inorganic particulates considered as gross pollutants vary from 5 mm (5,000 µm) to much smaller diameter suspended solids.

Table 4-3. Comparison of Estimated Removal Efficiencies (cf. Herr and Harper)

Structure	Removal Efficiencies (%)		
	Litter	Debris	Sediments
Vortechs System	? (10-50)	? (10-50)	60-80
Storm*ceptor*	? (10-50)	? (10-50)	60-80
CDS	98	98	? (10-50)
Baffle Box	? (10-50)	? (10-50)	60-80

? = estimated removal efficiencies based on reference

The removal of sediments from storm water runoff using liquid/solids separation structures will remove a portion of the particulate fraction of various pollutants contained in runoff which attach to sediment particles.

However, particulate matter contributing to loadings of nutrients and heavy metals in storm water runoff is typically 500-100 µm (0.5-0.1 mm) or smaller. The removal efficiencies for particles of this size range from 20-70%, with lower removals at smaller particle sizes. For purposes of this evaluation, a removal efficiency of 50% is assumed for particles in this size range. Table 4-4 provides an estimated annual net mass load reduction of 10 water quality parameters based on the achieved 70% TSS removal.

Table 4-4. Estimated Net Mass Reduction in Storm Water Constituents Achieved Based on 70% TSS Removal (cf. Herr and Harper)

Parameter	Estimated Annual Mass Load Reduction (%)
Total N	30
Total P	25
TSS	70
BOD	20
Cadmium	15
Chromium	18
Copper	15
Lead	38
Nickel	15
Zinc	33

N = Nitrogen; P = Phosphorus

Cost Considerations

The capital costs for hydrodynamic separators depend on site-specific conditions. These costs are based on several factors including the amount of runoff required to be treated and the amount of land available. A typical swirl separator costs between \$5,000 and \$35,000, or between \$5,000 and \$10,000 per impervious acre. This cost is within the range of some sand filters, which also treat highly urbanized runoff. Swirl separators consume very little land, making them attractive in highly urbanized areas.

Total costs for hydrodynamic separators often include pre-design costs, capital costs, installation costs, and operation and maintenance (O&M) costs. The pre-design and installation costs depend upon the complexity of the treatment site. O&M costs vary based on the company contracted to clean out the unit, and may depend on travel distances and cleaning frequency. Maintenance typically involves the use of a vactor truck and typically occurs on a quarterly or annual basis depending on the sediment loads. Maintenance costs can range from \$500 to \$2500 per cleaning. Costs may be higher if the sediment is characterized as a hazardous or contaminated material.

Table 4-5. Capital Cost Comparison for Liquid/Solids Separation Structures (cf. Herr and Harper)

Structure	Recommended Flow Rate (cfs)	Estimated Installed Cost (US $)	Estimated Installed Cost per cfs Treated (US $)
Baffle Box	18 - 49	20,000 - 35,000	2,800 - 1,600
CDS Unit	3 - 270	35,000 - 667,000	12,800 - 2,470
Vortechs System	0.4 - 6.0	22,700 - 86,500	59,800 - 14,400
Stormceptor	0.6 - 2.5	16,400 - 72,600	29,000 - 27,400

4.2.2.4 CATCH BASIN INSERT TREATMENT

Description

A catch basin (a.k.a., storm drain inlet, curb inlet) is an inlet to the storm drain system that typically includes a grate or curb inlet where storm water enters the catch basin and a sump to capture sediment, debris and associated pollutants. They are also used in combined sewer watersheds to capture floatables and settle some solids. Catch basins act as pretreatment for other treatment practices by capturing large sediments. The performance of catch basins at removing sediment and other pollutants depends on the design of the catch basin (e.g., the size of the sump), and routine maintenance to retain the storage available in the sump to capture sediment.

Applicability

Catch basins are used in drainage systems throughout the United States. However, many catch basins are not designed for sediment and pollutant capture. Ideal application of catch basins is as a pretreatment to another storm water management practice. Retrofitting existing catch basins may help to improve their performance substantially. A simple retrofit option of catch basins is to ensure that all catch basins have a hooded outlet to prevent floatable materials, such as trash and debris, from entering the storm drain system.

Limitations

Catch basins have three major limitations, including:

- Even carefully designed catch basins cannot remove pollutants as well as storm water treatment practices, such as wet ponds, sand filters and storm water wetlands.
- Unless frequently maintained, catch basins can become a source of pollutants through resuspension.
- Catch basins cannot effectively remove soluble pollutants or fine particles.

Sizing and Design Considerations

The performance of catch basins is related to the volume in the sump (i.e., the storage in the catch basin below the outlet). Lager *et al.* (1997) described an "optimal" catch basin sizing criteria, which relates all catch basin dimensions to the diameter of the outlet pipe (D). Dimensions are:

- The diameter of the catch basin should be equal to 4D;
- The sump depth should be at least 4D. This depth should be increased if cleaning is infrequent or if the area draining to the catch basin has high sediment loads;
- The top of the outlet pipe should be 1.5 D from the inlet to the catch basin.

Catch basins can also be sized to accommodate the volume of sediment that enters the system. Pitt *et al*. (1997) proposed a sizing criteria based on the concentration of sediment in storm water runoff. The catch basin sump is sized, with a factor of safety, to accommodate the annual sediment load to the catch basin with a factor of safety. This method is preferable where high sediment loads are anticipated, and the optimal design described above is suspected to provide little treatment. Note: standard City and County of Honolulu catch basins are not designed or sized as sediment basins.

The basic design should also incorporate a hooded outlet to prevent floatable materials and trash from entering the storm drain system. Adding a screen to the top of the catch basin would not likely improve the performance of catch basins for pollutant removal, but would help capture trash entering the catch basin (Pitt *et al*., 1997).

A variety of other products, known as "catch basin inserts," may also be used to filter runoff entering the catch basin. There are two basic types of catch basin inserts. One insert option consists of a series of trays, with the top tray serving as an initial sediment trap, and the underlying trays comprised of media filters. Another option uses filter fabric to remove pollutants from storm water runoff. These devices have a very small volume compared to the volume of the catch basin sump, and would typically require very frequent sediment removal. Bench test studies found that a variety of products showed little removal of total suspended solids, partially due to scouring from relatively small (6-month) storm events (ICBIC, 1995).

Maintenance Considerations

Typical maintenance of catch basins includes trash removal if a screen or other debris capturing device is used, and removal of sediment using a vactor truck. Operators need to be properly trained in catch basin maintenance. Maintenance should include keeping a log of the amount of sediment collected, and the date of removal. Some cities have incorporated the use of GIS systems to track sediment collection, and to optimize future catch basin cleaning efforts.

One study (Pitt, 1985) in Bellevue, Washington, concluded that catch basins can capture sediments up to approximately 60% of the sump volume. When sediment fills greater than 60% of their sump volume, catch basins reach steady state. Storm flows may then bypass treatment as well as re-suspend sediments trapped in the catch basin. Frequent clean-out can retain the volume in the catch basin sump available for treatment of storm water flows.

At a minimum, catch basins should be cleaned once or twice per year (Aronson *et al*, 1983). Two studies suggest that increasing the frequency of maintenance can improve the performance of catch basins, particularly in industrial or commercial areas. One study of sixty catch basins in Alameda County, California, found that increasing the maintenance frequency from once per year to twice per year could increase the total sediment removed by catch basins on an annual basis (Mineart and Singh, 1994). Annual sediment removed per inlet was 54 pounds for annual cleaning, 70 pounds for semi-annual and quarterly cleaning, and 160 pounds for monthly cleaning. For catch basins draining industrial uses, monthly cleaning increased total annual sediment collected to six times the amount collected by annual cleaning (180 lbs. versus 30 lbs.) (Mineart and Singh, 1994). These results suggest that, at least for industrial uses, more frequent cleaning of catch basins may improve removal efficiency. However, the cost of increased operation and maintenance costs needs to be weighed against the improved pollutant removal.

Another study (The Practice of Watershed Protection, Article 122) addressed the following questions for public works departments that annually remove accumulated sediment in storm drain inlets using vactor trucks or manual methods: (1) If urban pollutants are present within the trapped sediments, would more frequent cleaning have any value as a storm water treatment practice? (2) If so, would cleanouts be a feasible and cost-effective strategy compared to other storm water treatment practices? To answer these questions, a consortium of local agencies in Alameda County, California, began an extensive study of sediments trapped in 60 storm drain inlets. The study examined both the volume and quality of trapped sediments within residential, commercial and industrial storm drain inlets that had been cleaned with either a monthly, quarterly, semi-annual, or annual frequency. Table 4-6 summarizes the debris characteristics of this study. The drop inlet designs were 41-inches long x 25-inches wide and with depths ranging from 16 to 54 inches. The inlets were not designed to trap sediments. The study found that maximum annual sediment volume could be removed by monthly cleanouts (3 to 5 cubic ft), while quarterly, semi-annual and annual cleanouts removed about the same amount of material (1.5 to 2.5 cubic ft). For more information, see *The Value of More Frequent Cleanouts of Storm Drain Inlets* in The Practice of Watershed Protection, Article 122.

In some regions, it may be difficult to find environmentally acceptable disposal methods. The sediments may not always be land-filled or land-applied due to hazardous waste, pretreatment or groundwater regulations. This is particularly true when catch basins drain runoff from hotspot areas.

Table 4-6. Summary of Storm Inlet Debris Characteristics (reported as a percent of inlets with indicated characteristics)

Characteristics	Residential Inlets (%)	Commercial Inlets (%)	Industrial Inlets (%)
Wet	30	26	55
Trash	60	63	52
Soils	34	48	69
Leaves & Wood	63	75	67
Organic Material	32	28	59
Rotten Egg Smell	4	1	21
Illegal Discharges	2	5	1
Oil/Sheen	4	1	15

Effectiveness

What is known about the effectiveness of catch basins is limited to a few studies. Table 4-7 outlines the results of some of these studies:

Table 4-7. Percent Pollutant Removal Capability of Catch Basins

Study	Notes	TSS	COD	BOD	TN	TP	Metals
Pitt *et al.*, 1997	-	32	-		-	-	-
Aronson *et al.*, 1983	Only very small storms were monitored in this study.	60-97	10-56	54-88	-	-	-
Pitt and Shawley, 1982	-	10-25	5-10	-	5-10 (TKN)	5-10	10-25 (Pb) 5-10 (Zn)
Mineart and Singh, 1994	Annual load reduction estimated based on concentrations and mass of catch basin sediment.	-	-	-	-	-	For Copper: 3-4* 15**

* Annual cleaning
** Monthly cleaning

Cost Considerations

Typical pre-cast catch basin material costs is between $2,000 and $3,000 . The true pollutant removal cost associated with catch basins, however, is the long-term maintenance cost. A vactor truck, the most common method of catch basin cleaning, is around $250,000 plus or minus 20% (Santa Cruz, City Council Agenda Report, December 2006). This initial cost may be high for smaller communities; however, it may be possible to share a vactor truck with another community. Typical vactor trucks can store between 10 and 15 cubic yards of material, which is enough storage for between three and five catch basins with the "optimal" design and an 18" inflow pipe. Assuming semi-annual cleaning, and that the vactor truck could be filled and material disposed of twice in one day, one truck would be sufficient to clean between 750 and 1,000 catch basins. Another maintenance cost is the staff time needed to operate the truck. Depending on the rules within a community, disposal costs of the sediment captured in catch basins may be significant.

4.2.3 COMMERCIALLY AVAILABLE BMPS

A literature search of commercially available storm water treatment devices was conducted using reports evaluating reliable data on BMP product performance, storm water BMP manufacture meetings and telecoms, various storm water related periodicals, and internet research.

Municipalities have concerns centered on how BMPs – proprietary and nonproprietary-worked and could help meet these requirements. The University of Massachusetts at Amherst recently created the Massachusetts Storm water Technology Evaluation Project (MASTEP) Web site (www.mastep.net) as a storm water technologies clearinghouse detailing performance characteristics for proprietary storm water treatment BMPs. Proprietary storm water devices are often favored for their small footprints, enabling them to be used in urban settings and should provide an adequate level of treatment for the storm water regardless of the site specific water quality data. The list of structural BMPs tested by MASTEP is included in Appendix D; along with devices carried forward (Status 2 column or yellow highlighted) for preliminary engineering evaluation.

4.3 CONCLUSIONS

The four drainage areas analyzed in this report are all within highly developed residential, with WKIP 14 and 10 also associated with light industrial/commercial areas. The utilization of large scale storm water flow control devices for retro fit BMPs is not a feasible option for these drainage areas due to the lack of open space that would be required for their installation and maintenance access.

The various types of commercially available structural BMPs provide a wide array of treatment options for the storm water runoff. Determining the placement of these types of devices in each drainage area will be based on:

- Physical constraints of infrastructure;
- Existing easements for maintenance;
- Specific structural BMPs selected; and
- Non-structural BMPs suggested in association with Structural BMPs for the overall storm water management strategy.

5.0 RECOMMENDED BEST MANAGEMENT PRACTICES

This section presents an overall storm water management strategy with suitable storm water treatment for the open channels associated with WKIP 14, 52, 10, and 44 drainage areas based on the following criteria: Review applicable non-structural BMPs presented in Section 4, to remove and prevent sediment and gross pollutants from entering the WKIP 14, 52, 40 and 44 storm water conveyance system, decreasing sediment input into Kaelepulu Pond; Review and analysis of commercially available structural BMPs presented in Section 4 and Appendix D, to remove and prevent sediment and gross pollutants from the WKIP 14, 52, 10, and 44 storm water conveyance system, decreasing sediment input into Kaelepulu Pond; and Hydrological and physical characteristics of the four drainage areas discussed.

The major factors driving the selection and design of the storm water management strategy or treatment train for each drainage area and site specific recommendations of non-structural and/or placement of structural BMP treatment options is: 1). the achievement goal of up to 80% TSS removal as stipulated by Rules Relating to Storm Drainage Standards (City 2000) – a requirement only if DPP permits are required for installation (i.e. grading permits etc.); 2) researching the capability of conveying peak runoff flows produced during major storm events, however focusing on first flush removals; and 3) maintenance crew accessibility and use of existing equipment and procedures to maintain the structural BMP.

The overall peak runoff discharge rate for WKIP 14, 52, 10, and 44 drainage area are relatively high at the drainage channel outlets and upstream portions of the open channel. Flows from the individual drainage pipe segments that feed into the storm water open channels associated with these outlets have manageable flows, and are potential locations for inline placement of BMPs prior to discharge, however in most instances are lacking City access and/or right-of-way for installation and maintenance.

Inline structural BMPs that have the capability to treat larger flow rates for an initial first flush condition are not always engineered to convey the larger flows via a designed internal bypass or offline system. Most inline structural BMPs designs have not been tested or are not adaptable to an open channel system. As such, the structural BMPs (Appendix D) Downstream Defender (HIL Technology, Inc.), Storm water Management StormFilter (Storm water Inc.), AquaFilter™ Storm water Filtration System (AquaShield), Vortechs® Storm water Treatment System (CONTECH® Storm water Solutions Inc.), all need to be either placed at a location meeting peak flow requirements or installed as bypass systems in which only storm water generated during the initial flush of a storm would be diverted to the inline system and treated and then returned to the drainage system. The CDS Technologies Offline Storm Water Treatment System is designed as an offline system and would require no modification for bypass due to the internal diversionary weir within a "weir box" that is integrated into the existing drain pipe or box culvert structure; however is limited by space available and land acquisition issues for installation. Similarly, the Bay Saver Separation System (BaySaver Technologies, Inc.) would not require any modification for by-pass; however, is limited by the space available and by connection to only circular drain lines with a diameter of 48-inches and less and a maximum treated flow rate of 21.8 cubic ft per second. The inline Bio Clean Nutrient Separating Baffle Box (NSBB) (Suntree

Technologies) system is designed to treat the entire storm, not just the first flush, with no need for bypass. The In-Line Stormceptor® and the VortSentry® (CONTECH) structural BMPs are equipped with internal bypass for peak flows; however, the treated flow capacities of these units are relatively low and thus several units in a treatment train would be needed throughout the drainage area to provide adequate treatment.

The Bio Clean NSBB can also be designed for open-channel installation and is comprised of three sediment trapping chambers, a nutrient separating screen, and a hydrocarbon baffle wall and skimmer basket to trap oil and grease. The treated flow capacities of the NSBB-8-14-96 are 46cfs for 80% removal of TSS and 168cfs for gross solids and sediment. This model can be delivered to Hawaii for under $34,000 as reported by the Bio Clean representative. NSBB data associated with removal efficiencies, flow rates, and storage capacities can be seen in Appendix D, along with design and specifications for the NSBB-8-14-97, which represents an open channel installation associated with an existing Bio Clean project in Atlantic Beach, Fl. The open channel design is equipped with a rip rap by-pass spill way and hydrodynamic lid design to convey larger flows pass the unit.

The presence of tail water (i.e. water surface elevation at the downstream side of a hydraulic structure [culvert, bridge, etc.]) is a physical characteristic common to all four drainage areas and is encountered as a result of the influence of Kaelepulu Pond. The water level within Kaelepulu Pond varies with seasonal rain fall and whether the Kaelepulu Stream outlet to Kailua Bay has been mechanically opened. Tail water in the WKIP 14 drainage system is associated with most of the Alahaki Drainage Ditch and Interceptor Ditches to some extent. Tail water associated with WKIP 52 (Akipola Lined Ditch) and WKIP 10 (Hele Channel) extends just past the Keolu Street Bridge during the rainy season; however the lateral storm drain lines are not impacted. The WKIP 44 outlet is affected by tail water typically up to the lined portion of the Keolu Lined Channel near the intersection of Akumu Street. It is proposed that catch basin insert devices be installed at sediment accumulating hot spots to treat storm water runoff prior to entering the system.

5.1 PROPOSED BMPS

For outlets WKIP 14, 52, 10 and 44 that were analyzed in this report, a storm water pollution management strategy was recommended based on several different factors. The primary function of this storm water strategy is to improve storm water discharge quality into Kaelepulu Pond. In order to achieve this goal a combination of BMPs, non-structural and structural, were selected for each drainage area based on current practices. Structural BMPs that were recommended for the system were based on: locations of maintenance access easements; sediment accumulation “hot spots” or high pollutant areas; storm water flow rates; location of tail waters; and water quality treatment flow rates, sediment removal efficiencies, and overall cost of the BMP devise including installation and O&M.

5.1.1 NON-STRUCTURAL BMPS

TEC personnel investigated the outlet and drainage area of WKIP 14, 52, 10 and 44 noting potential sources of pollutants and maintenance issues. This information was used for suggestion of improvements to the drainage system to potentially improve water quality in this drainage area. The photo log at the end of Section 1 shows corresponding site photos and descriptions for the drainage areas: WKIP 14 (Photos 1-1 through 1-6); WKIP 52 (Photos 1-7 through 1-15); WKIP 10 (Photos 1-16 through 1-34); and WKIP 44 (Photos 1-35 through 1-50).

1. Overgrown vegetation, litter and trash are common sites throughout the Kaelepulu Subwatershed. Green waste (palm fronds, coconuts, and grass clippings) litter all the drainage areas, typically blocking or partially blocking culverts.

    a. Initiate/increase use of City vacuum truck maintenance operations at catch basins/curb inlets and bridge culverts. This will help alleviate gross pollutant discharge into Kaelepulu Pond and will assist at reducing resuspension of debris in the storm catch basins, drainage ditches and channels.

    b. Community-wide awareness and an "adopt a ditch" segment program to help reduce waste disposal into the drainage channel. Landscaping companies and homeowners will assist in improving water quality for the Kaelepulu Pond by bagging and properly disposing all grass clippings and plant cuttings.

    c. Owners of residential and commercial property that run parallel to the four drainage areas need to keep vegetation that originates from their property clear of the water way. City crews, where access easements are available, will maintain tree canopies over storm water drainage systems and/or place covers over the channel to catch falling plant debris.

2. Sediment and vegetation debris is deposited within the conveyance systems are partially blocking narrow waterways and culvert systems at several locations. This sediment creates a foundation for vegetation growth. During large storms these vegetative areas constrict flows and would eventually wash out creating blockage at culverts. The sediment is resuspended and carried downstream increasing turbidity in the water column.

    a. Periodic maintenance of the drainage system, including structural repair of lined channel and culverts, removal of accumulated sediment and vegetation, and dredging operations is required for the drainage system to function as designed.

    b. The eastern and western portion of Kamahele Ditch should be maintained through minor sediment removal operations and vegetation cutting (no herbicide spraying). The promotion of a grass-lined ditch through maintenance of vegetation height within the earthen ditch by mechanical means is ideal; such operation allows vegetation growth to bind soil, decrease flows, and increase sediment capture and removal of pollutants. Scheduled maintenance of accumulated sediment is required as with all sediment removal technologies.

3. At different stages of the study, road work was observed throughout the drainage areas to contribute to road debris. Road debris (0.1 to 10 mm particle sizes) is common place in all the drainage areas. These particles are transported into the many

curb inlet/catch basins lining the residential and commercial area streets and parking lots. They make their way through the drainage system and into Kaelepulu Pond.

a. City to budget for a street sweeper and/or vacuum truck for use in the Kailua/Enchanted Lake area. Implement regular street sweeping and vacuum trucks program, including catch basins (curb inlet type) conveyance system sediment removal operations to maintain residential and commercial areas. The program, which would encourage and have the ability to respond to community reports of trouble areas, will cost effectively address source pollutants. A Schwarze Industries Model A7000 regenerative air sweeper, or similar model, is a chassis-mounted regenerative air sweeper with an 8.4-cubic yard hopper, 144-inch sweeping path, and 600-gallon water tank for dust suppression. The closed loop regenerative system is most effective in removing PM-10 fines by producing a high volume air blast that loosens pavement debris into the hopper through a 14-inch suction tube. The A7000 model also has a 30-foot vacuum hose at the rear for debris removal from accessible catch basins. A vacuum truck with boom this length would increase access by maintenance crews at difficult to reach catch basins, storm drain lines, channels and ditches, and structural BMPs (Storm water Journal November/December 2006).

b. Street sweeping operations at road construction sites will reduce asphalt concrete debris wash out. These events should take place after minor road patching events, periodically when road construction is ongoing (e.g. during pipe replacement operations), or as requested by construction foreman or community, and before storm events. Specifically, road construction that uses asphalt to smooth steel plates to roadway interface needs to be done in a manner where excess and loose asphalt is collected after the construction event.

4. The portion of Hele Channel near the Keolu Drive Bridge is typically littered with varies gross pollutants (i.e. trash, tires, garbage bags, shopping carts, wood, cardboard boxes, etc.) This is a common area for waterfowl, including the endangered Coot and Moorhen (*Fulica americana alai and Gallinula chloropus sandvicensis*), to feed and loaf, as is other tributaries throughout the study area and Kaelepulu subwatershed.

   a. Community-wide awareness and an “adopt a ditch” program to help eliminate gross pollutant disposal and illegal dumping into the drainage channel will assist in improving water quality for the Kaelepulu Pond. The city “hot line” for illegal dumping and removal should be more common place within the community.

5. Barren areas associated with the drainage channels and ditches, residential yards, and hills bordering the perimeter of the drainage areas contribute sediment to the storm water drainage system. Miscellaneous residential construction sites lacking structural BMPs contribute sediment to the storm water drainage system throughout the Kaelepulu subwatershed. The barren area between Kapaa Silt Basin and the City

debris control structure should be planted with appropriate ground cover for the area. Several non-structural soil stabilization resolutions and when needed structural (see riprap revetment in 5.1.2), are available.

a. Community-wide awareness program will also assist with identifying barren residential and city areas and those responsible parties for keeping these areas vegetated. The city "hot line" for point source sediment runoff during storm events should be more common place within the community.

b. Homeowners need to take responsibility for construction grading, vertical cuts, and barren areas on their property and be aware of the potential fines for these discharges during storm events. Planting of low maintenance ground cover should be encouraged.

c. NPDES requirements need to be enforced to minimize pollutants discharged through storm water runoff. All construction sites will be visited by proper permitting agency's enforcement officers to make sure permits are being adhered to and appropriate construction BMPs implemented.

5.1.2 STRUCTURAL BMPS

Based on the criteria described in 5.1 above the following BMPs were recommended:

5.1.2.1 INLINE HYDRODYNAMIC SEPARATORS

Flows from the individual drainage pipe segments that feed into the storm water open channels associated with these outlets have manageable flows and are potential locations for inline placement of BMPs prior to discharge into the channel, however would be cost prohibitive (based on installation and maintenance efforts) due to the sheer number of lateral pipe connections that feed into the open channels within the Kaelepulu Subwatershed. Additionally, most locations are either lacking City maintenance access points, right-of-way for installation, and if installed at select locations would only offer only minimal treatment benefits. Inline treatment for the Kaelepulu Subwatershed is not being further pursued as a viable alternative for structural BMP sediment removal at this time.

5.1.2.2 OPEN CHANNEL HYDRODYNAMIC SEPARATORS

The Bio Clean Nutrient Separating Baffle Box (NSBB) has been chosen for conceptual design and a pilot project installation within the WKIP 10 Hele Channel. The NSBB's ability to maintain high removal efficiencies at peak flows, effectively separating organics and litter from sediment and standing water, low installation costs, and in-channel design makes it unique to the industry and an ideal storm water treatment pilot project and potential pollution solution for Kaelepulu Pond.

Installation of the NSBB will require demolition of an area for the NSBB foot print within the Hele Channel at a location where maintenance crews can efficiently maintain the unit. The NSBB 10-14-96 unit, which was under $34,000 for shipment to Hawaii, is about half the size of the Hele Channel NSBB as shown in the concept drawing in Appendix D. Considering the size of the Hele Channel NSBB and that the majority of the cost for the unit is in the concrete vault, a cast-in-place option would be further explored during the conceptual design phase, which would significantly reduce the cost of shipping and materials.

5.1.2.3 CATCH BASIN INSERT TREATMENT

A report prepared by the University of Hawaii, Department of Oceanography, evaluated the efficiency of four commercially available storm drain filters to remove non point source pollution from street runoff in urban and suburban Honolulu, Hawaii. The four systems analyzed included: the Abtech Ultra Urban Filter; Kri-Star Flogard System; Hydro Compliance Hydro Kleen Filtration Unit; and the Bio Clean Curb Inlet Basket. The results of this analysis indicated that the Bio clean and Kri-Star catch basin insert devices would be best suited for installation within the drainage basins feeding into the Ala Wai Canal (Siah, 2005). This BMP was recommended in the Siah 2005 report and the City and County of Honolulu recently awarded a contract to Bio Clean Environmental Services, Inc. to install their Curb Inlet Baskets (CIB's) at 54 locations near Waikiki Beach. Bio Clean has also installed their Grate Inlet Skimmer Box (GISB) drop in units at the Halawa Valley Collection System Maintenance base yard in 2005.

Taking this information into account, we recommend that Bio Clean CIB's with shelf system be installed into the curb inlets within the four drainage areas analyzed in this report. However, considering the study area does not currently have a catch basin maintenance program or servicing equipment, it is recommended that a maintenance program be initiated with data collection for a year prior to purchasing and installing Bio Clean system.

The Bio Clean CIBs are designed to be installed into both Type A and Type B Catch Basins. Street corner curb inlets have special weirs designed to direct storm water to the retention basket placed beneath the service manhole to the catch basin resulting in a reduced servicing time for each inlet. The servicing requirements for these catch basin inserts would be compatible with existing servicing equipment owned by the City and County of Honolulu.

The cost for the Bio Clean CIB is $120 per linear ft. ($145 per linear foot on curved inlet structures) or $1,200 total for a typical Type A catch basin installed according to Bio clean representative. However, recent City projects using this product have shown the base cost to be in the range of $3,000 per CB. Table 5-1 identifies additional costs associated with this BMP. A worksheet is included in Appendix F.

The Bio Clean Grate Inlet Skimmer Box (GISB) is recommended for two drain inlets that are of the top loading variety located within the ELSC and are designed as drop-in units for top loading grate inlets. These devices performed relatively well as shown in the 2006 removal efficiencies data at several locations (Appendix D).

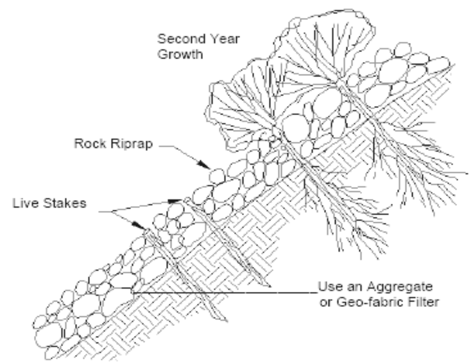
The base price for the two Bio Clean GISB is approximately $2,500 per catch basin. Table 5-1 identifies additional costs associated with this BMP. A worksheet is included in Appendix F.

5.1.2.4 TRASH RACK SYSTEM

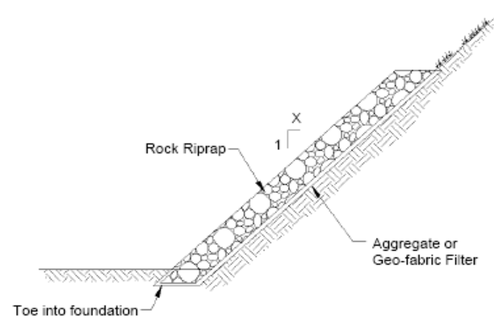
As a final measure to prevent trash and debris from entering Kaelepulu Pond, a HDPE Hydrothane Trashrack Sytem is recommended for installation near the outlet of each drainage area. This structural BMP will contain floating debris not captured by the BMP devices installed upstream. Each Hydrothane System will be located in an area that is easily accessible to facilitate maintenance and cleaning operations. Regular scheduled maintenance of these systems and before and after storm events is necessary in order to prevent obstruction at these locations, which could result in overtopping the bridge culvert and flooding nearby homes within the drainage area.

5.1.2.5 VEGETATIVE AND/OR MECHANICAL RIPRAP REVETMENT

As a measure to prevent further erosion to the Hele Channel and Kamahele Ditch dirt embankments a vegetative riprap revetment is recommended. Riprap is a permanent, erosion-resistant layer made of stones. It is intended to protect soil from erosion in areas of concentrated runoff. Riprap may also be used to stabilize slopes that are unstable because of seepage problems. Vegetative Riprap Revetment covering the Hele Drainage Channel and Kamahele Ditch dirt embankment is recommended to eliminate erosion in this area (see photo log; 1-17, 1-20, 1-21, and 1-24). A lining of rock riprap covering the embankment with live stakes driven through the voids in the riprap and into the subgrade to provide enhanced stability and protection from erosive forces. This type of structure can be near permanent solution to problems recurring when flows and velocities reach extremes, and can also be used in design to reduce the thicknesses and height required in mechanical riprap.



Mechanical Riprap is used to protect steep slopes, sharp turns in the stream or channel itself, or where streams are constricted by bridges or culvers, etc. Rocks size is dependent upon the application. Larger stone will be required for stability where flow volumes and velocities against the riprap are high. Riprap layer thicknesses should be based on maximum rock diameter used and the application. A professional engineer should be consulted where stream flows will be encountered. Riprap armor against flow must always be underlain with a filter such as graded aggregate or geo-fabric.



Riprap should be inspected annually and after major storms. Channel obstructions such as trees and sediment bars can change flow patterns and cause erosive forces that may damage riprap. Control of weed and brush grown may be needed in some locations. The cost of riprap varies depending on location and the type of material selected. A cost of $55 to $80 per square yard (sy) of non-grouted riprap has been reported, while grouted riprap ranges from $70 to $95 per sy. Alternatives to riprap channel lining include grass and sod, which cost $5 and $14 to $20 per sy (1993 dollars extrapolated to 2008 (3% inflation increase); Mayo et al., 1993). Concrete is estimated at $150 to $350 per cubic yard (cy), including truck, pump and support crew.

5.1.3 DRAINAGE AREA PROPOSED STRUCTURAL BMPS

The locations (Figures 5-1 though 5-4) and estimated costs (Table ES-2, 5-1, and Appendix F worksheet) for each structural BMP installation are described below.

5.1.3.1 WKIP 14

The structural BMPs for the WKIP 14 drainage area are depicted in Figure 5-1. Within WKIP 14 drainage system two types of structural BMPs are recommended: The Bio Clean Curb Inlet Baskets (CIB) with shelving system and Hydrothane HDPE Trashrack system. Ten select areas where chosen for installation of the CIBs to capture road debris. The cost of the CIBs with shipping and installation is estimated at $41,500.

The Hydrothane System is recommended for installation at the Kahili Street Bridge culvert and the Akumu Street bridge culvert. The cost of the Hydrothane System installed is estimated at $5,530 total. This structural BMP will help remove gross pollutants from upstream inline connections, the two interceptor ditches, and the Alahaki Ditch prior to discharge into Kaelepulu Pond. Both locations are maintenance accessible by City crew.

5.1.3.2 WKIP 52

The structural BMPs for the WKIP 52 drainage area are depicted in Figure 5-2. Within WKIP 52 drainage system existing debris bars are utilized at several locations as sheet flow runoff enters the open-channel conveyance system. It is recommended that two types of structural BMPs be added to enhance the debris and sediment removal: The Bio Clean CIB with shelving system and Hydrothane HDPE Trashrack system. 8 select areas where chosen for installation of the CIBs to capture road debris. The cost of the CIBs with shipping and installation is estimated at $32,700.

The Hydrothane System is recommended for installation right before the Keolu Drive Bridge. This structural BMP will assist in accumulating gross pollutants at a location adjacent to City maintenance right-of-way. The cost of the Hydrothane System installed is estimated at $9,500

5.1.3.3 WKIP 10

The structural BMPs for the WKIP 10 drainage area are depicted in Figure 5-3. The Bio Clean Nutrient Separating Baffle Box (NSBB) hydrodynamic separator has been chosen for pilot project installation within the WKIP 10 drainage area. The location of the NSBB will be just west of the Keolu Drive Bridge, within serviceable reach of City vacuum trucks positioned on the bridge. It is anticipated that the NSBB will be cast-in-place, reducing costs, and installed below channel grade. The Hele Channel NSBB concept drawing in shown in Appendix D and the cost is estimated at $75,800. It is recommended that excavation/dredging to appropriate channel depths be performed prior to NSBB installation. The maintenance requirements for the NSBB, consists of intermittent removal (before and after major storm events) of captured sediments and gross pollutants.

Two areas within the WKIP 10 drainage area were selected for a bank stabilization project. Approximately 500 feet (667 sy) along Hele Channel and 50 feet (23 sy) along Kamahele Ditch will be stabilized with either concrete to match similar structures or a combination of vegetation and mechanical riprap. It is recommended that excavation and/or dredging to appropriate channel depth be performed prior to bank stabilization work. The estimate cost for the bank stabilization work in the Hele Channel is $89,900 and $162,000 for concrete (cy) and vegetative riprap (sy) respectively and $13,740 for the vegetative riprap for the Kamahele Ditch.

Four (4) areas on Keolu Drive, where potential debris and hydro carbon “hot spots” are recommended for Bio Clean CIBs with shelving system. The 4 locations are either Type A or Type B side loading inlets. Additionally, two (2) areas within ELSC are recommended for Bio Clean Grate Inlet Skimmer Box (GISB) installation. The cost of the Bio Clean CIB and GISB with shipping and installation is estimated at $16,600 and $4,000 respectively. The maintenance for these CIBs include cleaning out every one to two months and/or before and after large storm events and filter media replacement every 4 to 6 months (before and after the rainy season [Nov 1 and April 1])

As a final measure to capture gross pollutants and keep them from entering into the Kaelepulu Pond, a Hydrothane HDPE Trashrack is recommended for installation at the Akumu Street Bridge. The cost of the Hydrothane System installed is estimated at $2,300.

5.1.3.4 WKIP 44.

The structural BMPs for the WKIP 44 drainage area are depicted in Figure 5-4. WKIP 44 has an existing structural BMP, the Kapaa Silt Basin, TMK: 4-2-004:048, which was constructed during residential area development. It has a land area of 19.63 acres (855,126 sq ft) and is listed P-1 Restricted Preservation and P-2 General Preservation. The basin fee owner is listed as: KVL LLC 322 Aoloa Street, Suite 405 Kailua, HI 96734. In many communities in the past, detention basins have been designed for flood control, however it is possible to modify these facilities to incorporate features that encourage water quality control and/or channel protection. The Kapaa Silt Basin flows through the City debris control structure prior to entering Keolu Lined Channel. The Kapaa Silt Basin should be evaluated for its BMP effectiveness as a silt basin and scheduled for proper maintenance (i.e. sediment removal) if it is to function efficiently.

Fifteen (15) debris accumulation areas on Keolu Drive are recommended for Bio Clean CIBs with shelving system. The cost of the Bio Clean CIBs with shipping and installation is estimated at $62,000.

As a final measure to further prevent gross pollutants from entering into the Kaelepulu Pond, a Hydrothane HDPE Trashrack is recommended for installation within 18 x 8 foot Keolu Lined Channel just downstream of the WKIP 42 outlet. The cost of the Hydrothane System installed is estimated at $7,880.

The WKIP 43 outlet, which is located approximately 200-feet southwest of Keolu Lined Channel (WKIP 44) and the end of Akumu Street, is typically blocked with several feet of sediment (Photo 1-52 in WKIP44 log). WKIP 43 has a peak flow of 360 cfs and collects an area of 53 acres (City DPP drainage reports) from Kalanianaole Highway down Akeke Place to Akumu Street where it makes a hard 90 degree turn to the northwest. A significant amount of sediment from street runoff comprised of asphalt, organic matter and soil eroded from the west side of Kalanianaole Highway regularly fills WKIP 43 to the point that it is buried and water flow is severely restricted causing enough back pressure for the upstream storm drain manholes to “fly off” during large storm events as reported by residents. Photo 1-53 and 1-54 identify the upstream manhole, eroded surrounding asphalt concrete, and road debris due to this storm drain system issue. Photos 1-56 and 1-57 show construction source areas where storm runoff discharges into the WKIP 43 and WKIP 42 drainage system.

It is recommended that a thorough engineering study be performed for the realignment of the WKIP 43 drainage line and outlet at Akumu Street. It should be redirected and continue straight in the road easement to the end of Akumu Street and discharged to the Keolu Lined Channel. Considering the high peak flow this will need to be properly engineered. There appears to be enough space to install structural BMP devise(s) above submerged conditions to remove pollutants prior to discharge in the channel, however the selected commercial inline BMP would either need to be installed as a bypass system treating only initial first flush of the storm event or as an offline-type devise due to the excessive flows. Structural BMPs are discussed in Section 4 of the main report and the treated flow capacities of these BMPs vary greatly. Detailed engineering investigation for pipe realignment and installation of structural BMPs at this site is warranted.

5.2 CONCLUSIONS

The recommendation for the majority of storm water runoff generated within the WKIP 14, 52, 10 and 44 drainage area analyzed in this report is to focus on a group of non-structural pollutant controls classified as “household practices” which includes: street sweeping; storm drain (conveyance system, including channels and ditches) and catch basin maintenance and cleaning; refuse collection; planting appropriate groundcover to retain soil, and sidewalk cleaning. The objectives of these controls is to remove and dispose refuse, debris, and other particulate matter from the collection system, prior to rainfall events so they are not conveyed to receiving waters. The effectiveness of such controls depends on an intensified regular schedule maintenance program. Two other non-structural controls are public education and enforcement of grading ordinance, which can assist at reducing source loading into the system.

Commercially available structural BMPs were also recommended to remove pollutants from the storm water runoff prior to discharge into Kaelepulu Pond. The treatment of storm water for sediment removal within the WKIP 14, 52, and 44 drainage areas will be accomplished by installing the Bio Clean CIBs at select locations and Hydrothane Trashrack System to remove gross pollutants. The WKIP 10 drainage area will be the site for a cast-in-place Bio Clean Environmental Services, Inc. (Suntree Technologies, Inc) Nutrient Separating Baffle Box pilot project designed to be installed within Hele Channel, two bank stabilization projects within Hele Channel and Kamahele Ditch, and the installation of a Hydrothane Trashrack System at the Akumu Street Bridge Culvert as an additional measure to capture any floatable debris “gross pollutants” not collected by the upstream installed or existing structural BMP devices. Two Bio Clean GISBs are recommended for installation in two ELSC grate inlets which discharge to Hele Channel. The ELSC is private property and therefore the tenant/owner would be responsible for purchasing and maintaining the BMP.

The CIB locations are either Type A or Type B side loading inlets. The maintenance for these CIBs include cleaning out every one to two months and/or before and after large storm events and filter media replacement every 4 to 6 months (before and after the rainy season [Nov 1 and April 1]). After appropriate excavation/dredging operations, the Hydrothane Systems will be installed at approximately a 10 to 15-degree angle and sized at ½ to ¾-inch HDPE blades with 4-inch to 8-inch spacing on center. Maintenance would consist of vacuum truck operations and physical collection of debris before and after storm events.

Table 5-1 summarizes the costs, dimensions, and maintenance requirements for the various Structural BMPs recommended within the four drainage areas.

Table 5-1. Summary of Structural BMPs to be Installed within Kaelepulu Pond WKIP 14, 52, 10 and 44 Drainage Areas

BMP	#	*Total Estimated Cost	Size	O&M	Cleaning
WKIP 14					
Bio Clean Curb Inlet Box (CIB)	10	$41,500	Sized to fit	Every 1-2 months, replacing filter biannually (beginning of wet season and end of wet season)	Before and after major storms
Hydrothane HDPE Trashrack	2	$5,530	4x6 ft	Inspect before and after storm events	Inspect before and after storm events
Total		**$47,030**			

WKIP 52					
Bio Clean CIB	8	$32,700	Sized to fit	Every 1-2 months, replacing filter biannually (beginning of wet season and end of wet season)	Before and after major storms
Hydrothane HDPE Trashrack	1	$9,500	20x7 ft	Inspect before and after storm events	Inspect before and after storm events
Total		**$42,200**			

WKIP 10					
Bio Clean NSBB	1	$75,800	20 x 32ft	Yearly, however inspect during cleaning	Before and after major storms events
Bio Clean CIB	4	$16,600	Sized to fit	Every 1-2 months, replacing filter biannually (beginning of wet season and end of wet season)	Before and after major storm events
Bio Clean Grate Inlet Skimmer Box	2	$3,950	Sized to fit	Every 1-2 months, replacing filter biannually (beginning of wet season and end of wet season)	Before and after major storm events
Hydrothane HDPE Trashracks	1	$2,290	4x6 ft	Inspect before and after storm events	Inspect before and after storm events
Hele Channel Bank Stabilization **Option 1** - concrete **Option 2** - vegetation/ riprap revetment	1 1	$89,900 $162,031	(74 cy) (667 sy)	Inspect before and after storm events	Inspect before and after storm events
Kamahele Ditch Bank Stabilization (vegetative/ rip rap revetment)	1	$13,739	23 sy	Inspect before and after storm events	Inspect before and after storm events
Total Option 1 **Total Option 2**		**$202,279** **$274,410**			

WKIP 44					
Bio Clean Curb Inlet Basket	15	$62,000	Sized to fit	Every 1-2 months, replacing filter biannually (beginning of wet season and end of wet season)	Before and after major storm events
Hydrothane HDPE Trashracks	1	$7,880	18 x 6 foot	Inspect before and after storm events	Inspect before and after storm events
Total		**$69,880**			

Kailua/Enchanted Lake Area					
Street Sweeper	1	$185,000	TBD	Per manufacture	Per manufacture
Vacuum Truck	1	$250,000	TBD	Per manufacture	Per manufactures
Trash Pump	1	$3,000	TBD	Per manufacture	Per manufacture

***** includes estimated shipping costs, materials, labor for installation, and construction costs

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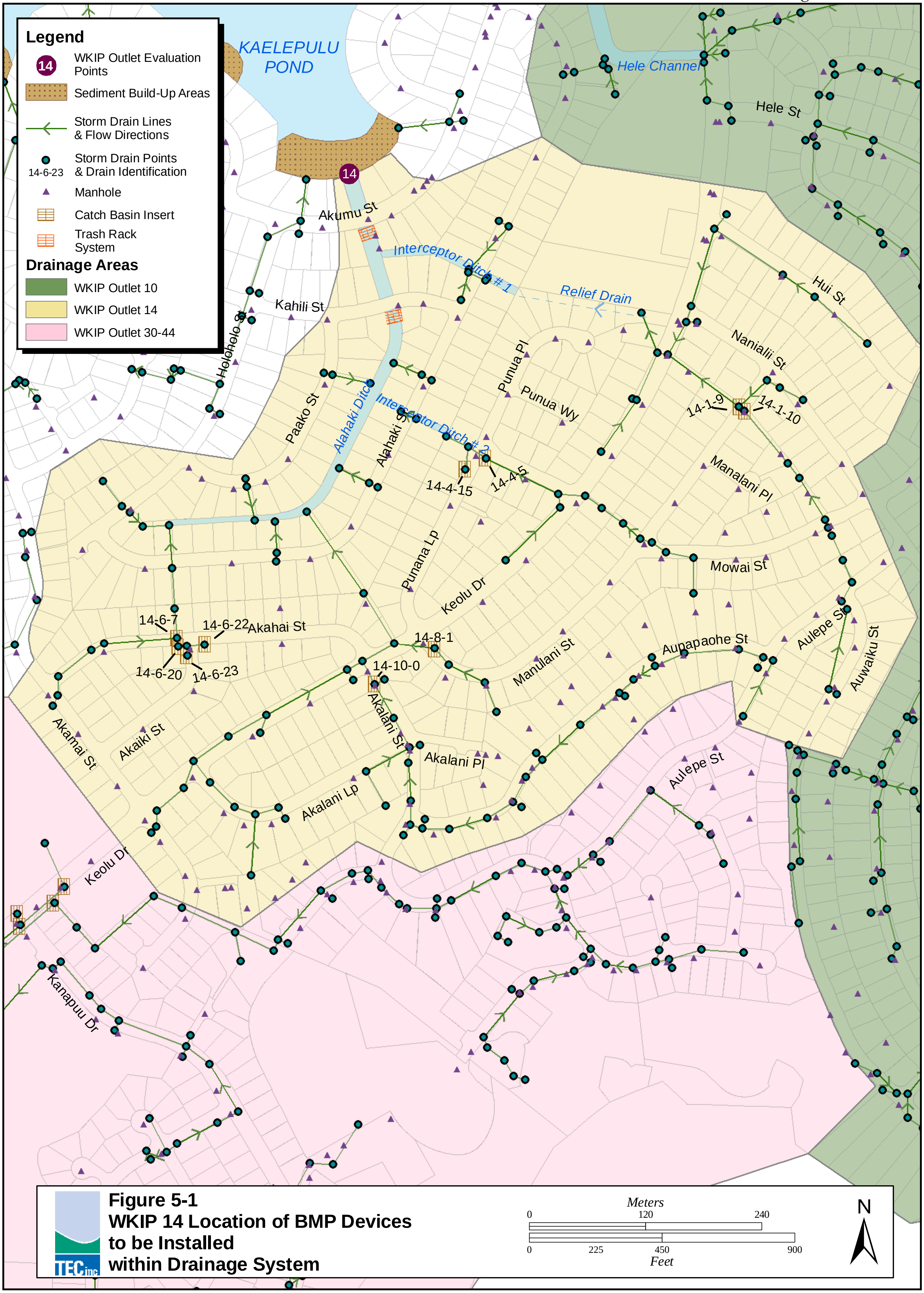

Figure 5-1
WKIP 14 Location of BMP Devices to be Installed within Drainage System

TEC inc

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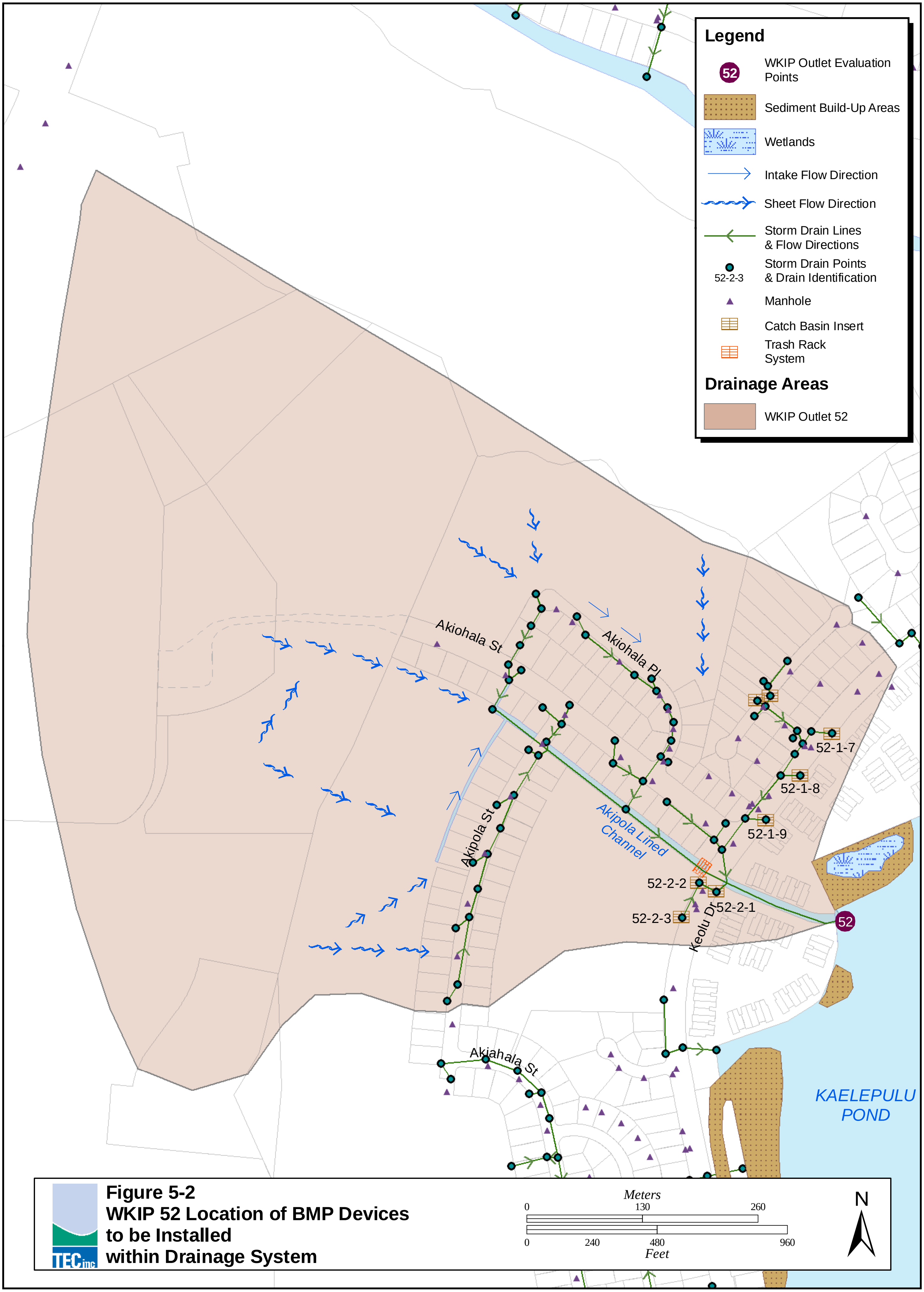

Figure 5-2
WKIP 52 Location of BMP Devices to be Installed within Drainage System

TECinc

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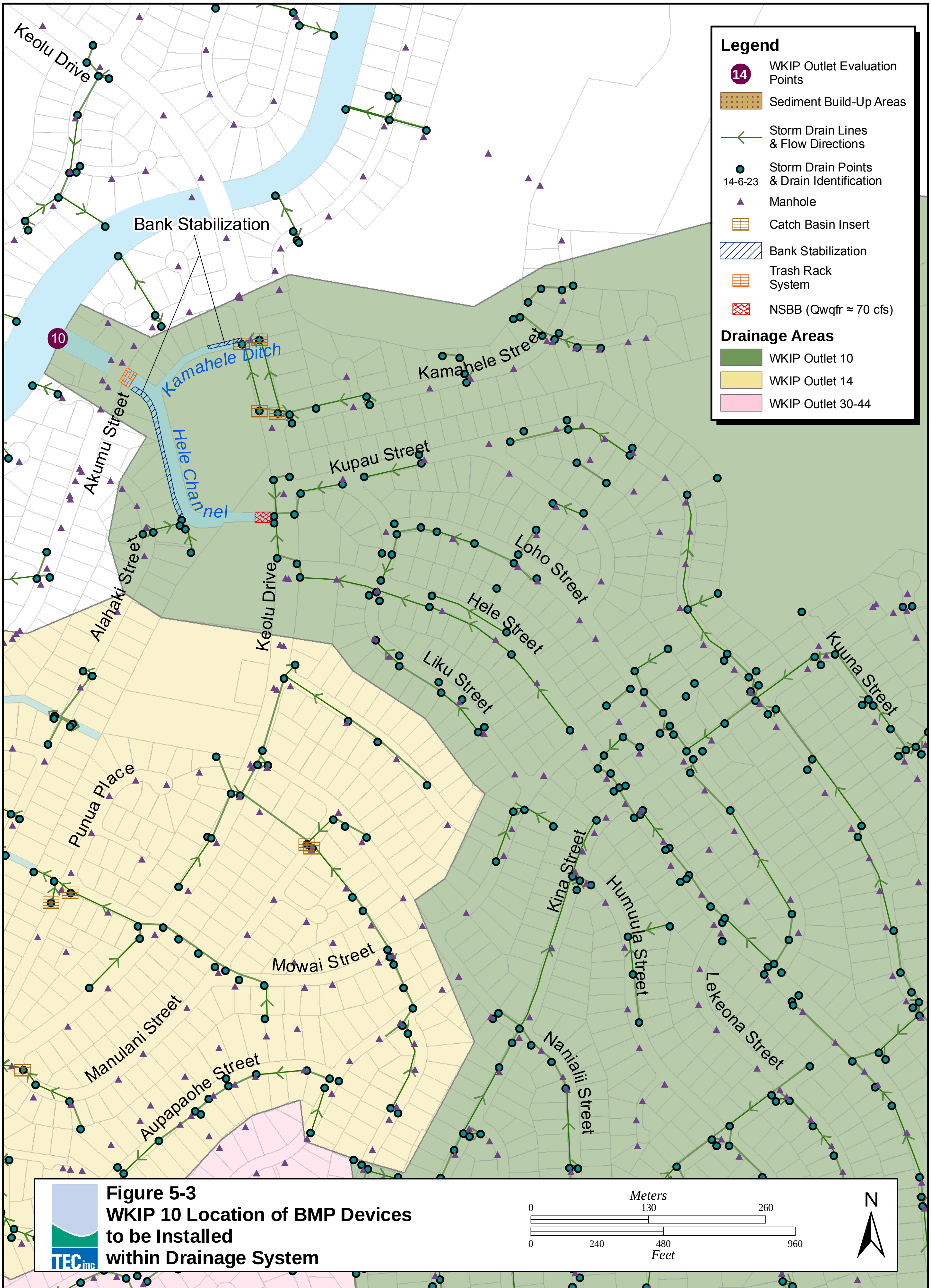

Figure 5-3
WKIP 10 Location of BMP Devices to be Installed within Drainage System

TEC inc

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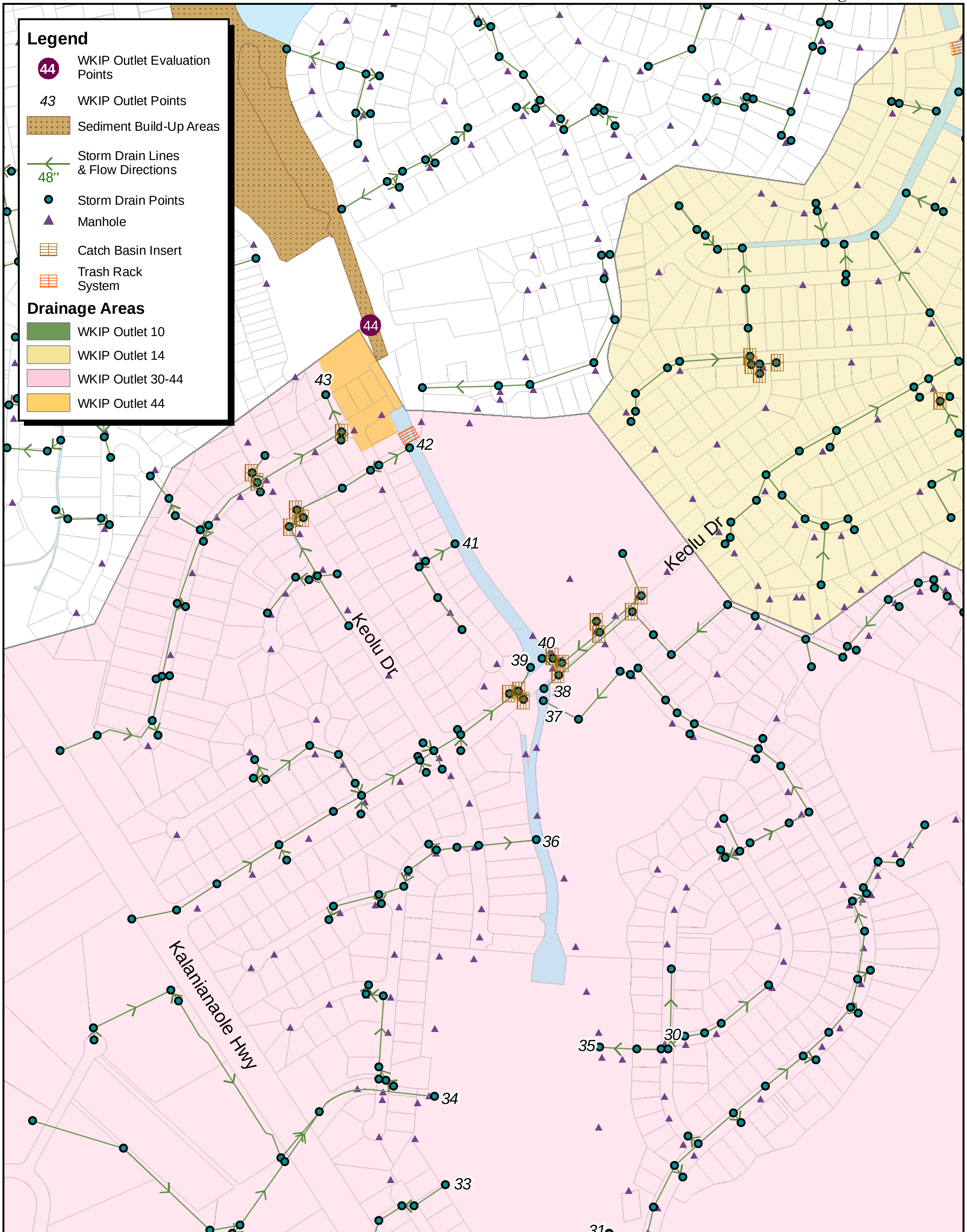

TEC inc

Figure 5-4
WKIP 44 Location of BMP Devices to be Installed within Drainage System

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