Study Element 3:

An Appraisal of Stormwater Reclamation and Reuse Opportunities in Hawaii

FINAL REPORT SEPTEMBER 2008

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- Mr. John Jackson (retired)
- Ms. Tina Mullis
- Ms. Amy Porter
- Mr. Dennis Watt

Hawaii Commission on Water Resource Management:

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- Mr. Jeremy Kimura
- Ms. Lenore Ohye

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Table of Contents

Tables

Figures

Appendices

Acronyms

AACE	Association for the Advancement of Cost Engineering
ADC	Agribusiness Development Corporation
BMPs	Best Management Practices
BWS	Honolulu Board of Water Supply
CCH	City and County of Honolulu
Code	Hawaii's State Water Code
CWRM	Commission on Water Resource Management
EPA	Environmental Protection Agency
HAR	Hawaii Administrative Rules
HRS	Hawaii Revised Statutes
DAR	Division of Aquatic Resources
DLNR	Department of Land and Natural Resources
DOH	Department of Health
GIS	Geographical Information System
GWUDI	Groundwater Under the Direct Influence
mgd	million gallons per day
NRCS	National Resources Conservation Services
NPDES	National Pollutant Discharge Elimination System
Plan	Hawaii Water Plan
Polychlorinated biphenyls	PCB
Reclamation	U.S. Department of the Interior Bureau of Reclamation
TMDLs	Total Maximum Daily Loads
UIC	Underground Injection Control
USDA	U.S. Department of Agriculture
WWRF	Wastewater Reclamation Facility
WWTP	Wastewater Treatment Plant

An Appraisal of Stormwater Reclamation and Reuse Opportunities in Hawaii

Executive Summary

Introduction

Groundwater is the principal source of potable water in Hawaii. As sugar cane and pineapple production has declined over the past decade, prime agricultural land is being opened for new residential and commercial development. Over 50,000 new, single-family homes are under construction or planned for Oahu. Development has two impacts on Hawaii's groundwater supply: (1) it increases potable water demand; and (2) it decreases groundwater recharge from rainfall, which is critical for sustaining aquifer levels.

The U.S. Department of the Interior Bureau of Reclamation (Reclamation), in partnership with the Hawaii Commission on Water Resource Management (CWRM) is conducting an appraisal of stormwater reclamation and reuse in Hawaii. Unlike most stormwater management approaches, this appraisal is exploring opportunities to capture and reuse stormwater to augment potable supplies, rather than to simply improve water quality for continued discharge to our streams and near-shore coastal waters.

The appraisal consists of three study elements:

1. Study Element 1 has two components: (1) develop a state-wide framework for identifying and resolving institutional barriers to stormwater reclamation and reuse, and (2) develop a handbook for reclamation and reuse technologies and best management practices for existing and new developments.

2. Study Element 2 consists of an appraisal of opportunities for groundwater recharge of stormwater over a brackish water (caprock) aquifer in a dry, but rapidly developing area on Oahu called the Ewa Plain.

3. Study Element 3 consists of an appraisal of statewide opportunities for augmenting groundwater supplies with stormwater, including groundwater recharge.

This report presents the results of Study Element 3.

Statewide Framework

A comprehensive discussion of issues affecting stormwater reclamation and reuse is provided in a separate report, *An Appraisal of Hawaii's Framework for Stormwater Reclamation and Reuse*. A summary of some of the issues is provided in Table ES-1 as background for reclamation and reuse opportunity development and evaluation.

Table ES-1. Potential Impact of Current Regulations on Stormwater Reclamation and Reuse

Applicable Regulation	Applicable Language	Potential Impact
State Water Code	Groundwater and surface water are held as public trusts for the benefit of all people. The CWRM has considerable authority to protect surface and groundwater quantity and quality.	Issues such as stream flow standards, in-stream diversions, and Native Hawaiian Water Rights can potentially promote or detract from stormwater reclamation and reuse
State Water Code 174C-51.5	The commission can require dual water line systems in new industrial and commercial developments when located in designated water management areas. This requirement is contingent on an available source of *nonpotable water.* Though the intent of the language was to promote the use of recycled wastewater, its use of the term *nonpotable water* could apply equally to reclaimed stormwater.	Though there is no requirement for developers to develop nonpotable water sources, the language could promote the use of reclaimed stormwater if a source is made available.
HAR 11-20 *Rules Pertaining to Potable Water Systems*	Direct connections between surface and groundwater can result in a groundwater drinking water source being designated as Groundwater Under the Direct Influence (GWUDI) of surface water.	GWUDI designation would require that groundwater be treated in the same manner as surface water, which would be costly. Situations that would result potentially in a GWUDI designation would be resisted by public (and private) water supply agencies.
HAR 11-23 *Underground Injection Control*	Any new injection well cannot be sited closer than ¼-mile from any part of a drinking water source.	The location of any stormwater injection well for direct recharge would be limited by the spatial dimensions of this regulation. An entire aquifer could be considered the drinking water source, further limiting direct injection. UIC control areas are significant parts of each island.
HAR 11-54 *Water Quality Standards*	Total maximum daily loads (TMDL) will limit discharge of certain pollutants (receiving water dependent) from point sources, such as stormwater system outfalls.	TMDLs might require that stormwater be treated to meet specific waste load allocations. Such treatment would be expensive and encourage developers to seek alternatives to direct discharge of stormwater to surface waters. This could promote technologies and best management practices for stormwater reclamation and reuse.
HAR 11-62 *Wastewater Systems* *Guidelines for Treatment and Use of Recycled Water*	There are three classes of recycled water. Each class is determined by the level of treatment. The two highest levels of recycled water must meet specific microbiological quality requirements, and, in the case of the highest level of recycled water, turbidity requirements. Compliance with quality requirements for recycled water is determined at the end of the treatment process.	The DOH has verbally said that integration of recycled water and stormwater would require that stormwater meet recycled water quality.

Table ES-1. Potential Impact of Current Regulations on Stormwater Reclamation and Reuse (continued)

Applicable Regulation	Applicable Language	Potential Impact
County Stormwater Drainage Standards	Specific treatment levels (i.e., infiltration, vegetated swales, bioretention filters, and other filters) are required for stormwater flow-through treatment (little or no storage). Design standards for flood control include the following variables: ▪ Recurrence interval based on acreage ▪ Runoff quantity based on acreage The design volume for detention basins to enhance stormwater quality is based on impervious surface area, a 1-inch storm, and site acreage.	Some level of treatment is required for stormwater injection into potable and non-potable water aquifers irrespective of water quality. Design standards do not include any credit for reducing runoff quantity nor any allowance for reducing the size of detention basins if stormwater reclamation and reuse is included in designs. Consequently there are no financial incentives to developers to incorporate stormwater and reclamation reuse features.

Initial Opportunity Screening Criteria

Initial screening of stormwater reclamation and reuse opportunities was planned to be accomplished using Geographical Information System (GIS) databases from various state, federal, and municipal authorities. A matrix of information needs was developed and included the following evaluation criteria:

- Soil Permeability
- Land Zoning
- Well Locations
- UIC Line Location
- Annual Rainfall
- Proximity to Recycled Water Infrastructure
- Proximity to Contaminated Sites
- Proximity to Historic Cultural Sites
- Proximity to Critical Habitats
- Depth to Groundwater
- Stormwater Infrastructure
- Agricultural Irrigation Ditches

Agencies were contacted to determine the availability of database information, and requests were made for obtaining existing database information. As database information was obtained from various public agencies, it became apparent that geographical coverage for the selected screening criteria was not consistent. Oahu had the best geographical coverage for most of the criteria, but inconsistencies were still common.

Field visits provided the most effective means of assessing potential opportunities. These visits provided first-hand knowledge of the possible infrastructure and its relationship to areas of stormwater collection, conveyance, and use. GIS information, in conjunction with Google™ Earth, was then used to refine the opportunities.

Infrastructure Needs

Infrastructure needs for stormwater reclamation and reuse can be separated into five general categories: collection, conveyance, treatment, storage, and distribution. Each of these infrastructure categories and their role in stormwater reclamation and reuse is discussed in the report.

End Use

The end use of reclaimed stormwater could take many forms, but the most likely options are direct irrigation and non-potable groundwater recharge. Direct irrigation would likely integrate with existing irrigation systems for recreational areas, such as parks and golf courses, or agricultural areas. Reclaimed stormwater could have other end uses as well, depending on the level of treatment provided. Table ES-2 shows the level of treatment that would be required for various end uses, including groundwater recharge.

Table ES-2. Level of Treatment Required Based on End Use

End Use	Treatment						Comments
	Screening	Grit Removal	Sedimentation	Chemical Addition	Filtration	Disinfection	
Injection Well (Potable)	Y	Y	Y	Y	Y	Y	
Injection Well (Non-Potable)	Y	Y	Y	*	N	N	
Recharge Trench	Y	Y	Y	N	N	N	
Spreading Basin	Y	N	N	N	N	N	O&M required to ensure infiltration
Excavated Pond	Y	N	N	N	N	N	Series operation
Industrial Reuse	Y	Y	Y	Y	Y	N	
Direct Irrigation:							
Contact with edible portion of crop	Y	Y	Y	Y	Y	Y	Not specific to stormwater; based on Hawaii's recycled water guidelines
No contact with edible portion of crop	Y	Y	*	N	N	N	
Human contact	Y	Y	Y	Y	Y	Y	

* Depends on quality of stormwater

Opportunity Development

The preceding information was used to develop stormwater reclamation and reuse opportunities. Fifteen opportunities outside the Ewa Plain on Oahu were identified and developed for Hawaii. The opportunities are listed below and are designated by an alphanumeric character for reference. The alphabetic character references the island on which they are located and the number references a specific opportunity on the island.

- O-1 - Wheeler Army Air Base and Schofield Barracks
- O-2 – Mililani North Stormwater Channel

- O-3 – Mililani South Stormwater Channel
- O-4 – Waipahu Stormwater Channel
- O-5 – Waikele Stormwater Channel
- O-6 – Nu'uanu Valley Surface Water
- O-7 – Palolo Stream Stormwater Channel
- E-7 – Waiahole Ditch Conveyance to Ewa Recharge Trench
- M-1 – Waiale Road Stormwater Drainage
- M-2 – Kahului Flood Control Channels
- M-3 – Kahoma Stream Flood Control
- M-4 – Lahaina Flood Control Channel
- K-1 – Nawilwili Diversion
- K-2 – Lihue Airport
- H-1 – Lower Hamakua Ditch.

A separate report, *An Appraisal of Stormwater Reclamation and Reuse Opportunities on the Ewa Plain of Oahu*, discusses five additional opportunities specific to the Ewa Plain. Opportunity E-7 (above) is located in the Ewa Plain, but is not a stand-alone opportunity. It is an additional consideration for integration with opportunities O-1, O-2, and O-3.

Each of the opportunities was evaluated for the criteria presented in Table ES-3. These criteria are discussed further in Opportunity Ranking.

Table ES-3. Opportunity Prioritization Criteria

Criterion	Discussion
Potential Reuse Demand	Potential reuse demand is determined by the amount of land that the opportunity could serve with non-potable water irrigation. The available land could include parks, golf courses, and agriculture. Opportunities adjacent to agricultural areas are given higher priority that opportunities located in urban areas.
Cost Estimate	Cost estimates were based on bid tabulations from recent Oahu water projects were used to determine the potential cost of common elements associated with the opportunities, including unit cost of conveyance and collection pipe, reservoirs, infiltration trenches, and pumping stations. The cost estimates are not absolute planning level costs, but are relative costs to each opportunity.
Potential Stormwater Volume	The potential stormwater volume is based on the collection area of the opportunity and the annual average rainfall in the collection area.
Potential Partnerships	Potential partnerships include public agencies and private companies that would possibly support implementation of a stormwater reclamation and reuse opportunity through direct funding or indirect funding (e.g. use of land or existing infrastructure). Potential partnerships do not consider public water supply agencies that would benefit from reduced demand on potable water supplies since all opportunities would result in this benefit.
Likelihood of Implementation	Likelihood of implementation includes non-economic benefits and constraints associated with the opportunity, including, but not limited to, public acceptance and environmental impacts.
Institutional Constraints	Institutional constraints include policies, regulations, laws, and social or cultural issues that would be potential barriers to implementation of any opportunity. They also include potential barriers from agencies that are responsible for infrastructure associated with the opportunity.

Opportunity Ranking

Once the opportunities for stormwater reclamation and reuse were identified, prioritization was necessary to differentiate and rank the opportunities. The approach used for the prioritization process is known as a Pairwise Comparison.

The first step for ranking the opportunities was to identify the criteria that will be used to evaluate the opportunities. Two representatives from Reclamation and three representatives from CWRM performed the Pairwise Comparison to rank the criteria. The point totals for all five raters were averaged to determine the final ranking and value.

Table ES-4 presents the final ranking of the criteria and the average points from all raters. The average points were normalized to 1.0. The normalized value was used as a weighting factor for further evaluation of each opportunity.

Table ES-4. Evaluation Criteria Ranking

Criterion	Average Points	Weighting Factor
Potential Reuse Demand	17.0	0.19
Cost Estimate	16.6	0.18
Potential Stormwater Volume	15.2	0.17
Potential Partnerships	14.8	0.16
Likelihood of Implementation	14.4	0.16
Institutional Constraints	12.0	0.13

Final Ranking of Opportunities

Once the Pairwise Comparison for each criterion was complete, the total points each opportunity received was multiplied by the weighting factor for the respective criterion. The products of the weighted values for each criterion were totaled, and the totals were used to rank the opportunities. The results of the combined Pairwise Comparisons are provided in Appendix B. The final ranking of each of the opportunities is shown in Table ES-5.

Table ES-5. Final Ranking of Stormwater Reclamation and Reuse Opportunities

Rank	Opportunity	Summary Description
1	O-1 Wheeler Army Air Base	Convey runoff from Wheeler Army Air Force Base runway to Schofield Barracks WWTP for treatment, to former underground oil storage tanks for storage, then to Waiahole Ditch for distribution for agricultural irrigation.
2	K-1 Nawiliwili Diversion	Divert stormwater from Nawiliwili Stream and associated tributaries for surface spreading or recharge trenches to improve water quality in potable wells and Nawiliwili Bay.
3	M-1 Waiale Road Stormwater Drainage	Collect stormwater from an urban area (including a large detention pond) along Waiale Road on Maui and use for irrigation in agricultural areas to south of the area.
4	O-2 Mililani North Stormwater Channel	Collect stormwater in a stormwater drainage channel for use at Mililani Golf Course, Mililani Agricultural Park, or to Waiahole Ditch for agricultural irrigation in the Kunia area.
5	O-3 Mililani South Stormwater Channel	Collect stormwater in a stormwater drainage channel in south Mililani and convey to the abandoned Mililani WWTP for treatment and storage, prior to use Mililani Agricultural Park.
6	M-3 Kahoma Stream Flood Control	Collect stormwater from a drainage channel and convey for agricultural irrigation to the north.
7	H-1 Lower Hamakua Ditch	Divert stormwater from intermittent drainage on the north side of Hawaii into Lower Hamakua Ditch for conveyance to points of surface-related groundwater recharge to improve water quality of potable water wells.
8	M-2 Kahului Flood Control Channels	Collect stormwater from drainage channels in the Kahului area and convey for agricultural irrigation to the south and east.
9	M-4 Lahaina Flood Control	Collect stormwater from a drainage channel and detention pond and convey for agricultural irrigation to the north, south, and east.
10	O-4 Waipahu Stormwater Channel	Collect stormwater in a stormwater drainage channel and convey it to Waikele Golf Course, Ted Makalena Golf Course, or Waipio Soccer Complex for irrigation.
11	O-5 Waikele Stormwater Channel	Collect stormwater in a stormwater drainage channel and convey to Waikele Golf Course for irrigation.
12	O-7 Palolo Stream Stormwater Channel	Divert stormwater from two locations in the concrete-lined portions of Palolo Stream for irrigation at parks and institutions.
13	O-6 Nu'uanu Valley Surface Water	Treat stormwater runoff from the Nu'uanu surface water reservoirs at BWS microfiltration plant and convey to Oahu Country Club for irrigation.
14	K-2 Lihue Airport	Diver runoff from Lihue Airport to recharge trenches to improve water quality in Nawiliwili Bay and Hanamaula Bay.

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Introduction

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This report presents the results of Study Element 3.

Current Approach to Stormwater Management

As with many public agencies throughout the U.S. Mainland, stormwater regulations in Hawaii consist primarily of best management practices to reduce pollutants in stormwater runoff and to ensure that stormwater discharges from new developments do not exceed pre-development peak flow rates. The latter approach is effective for reducing peak pollutant loads, but not effective for reducing total pollutant loads unless the flow mitigation measures remove pollutants physically (e.g. settling in a detention basin) or biologically (e.g. wetlands treatment).

The number of green and low impact development approaches to stormwater management is increasing. Some, such as pervious paving, green roofs, and rainwater harvesting for toilet flushing have been implemented on a small scale in Hawaii. Large-scale capture and reuse of stormwater is a new concept in Hawaii, but one that can help replace some potable water being used currently for non-potable uses, such as irrigation.

Statewide Framework

A comprehensive discussion of issues affecting stormwater reclamation and reuse is provided in a separate report, *An Appraisal of Hawaii's Framework for Stormwater Reclamation and Reuse*. A summary of some of the issues is provided in this section as background for reclamation and reuse opportunity development and evaluation.

Water Quality Regulations

Hawaii Revised Statutes (HRS) Chapter 174C establishes Hawaii's State Water Code (Code). The Code is the basis for regulating and protecting all waters of the State, except coastal waters, for the benefit of the people. The Code establishes the CWRM to oversee surface water and groundwater as public trusts.

The Code establishes a requirement for a Hawaii Water Plan (Plan) that includes a water resource protection plan prepared by the CWRM, water use and development plans prepared by the Department of Agriculture and each of Hawaii's four counties, and a State water projects plan that identifies projects that potentially affect groundwater and surface water resources. The Plan also requires the Hawaii Department of Health (DOH) to develop a water quality plan.

The CWRM can designate water management areas for administrative control over withdrawals and diversions of groundwater and surface waters. The purpose is to ensure reasonable beneficial use of water resources in the public trust. The CWRM is also responsible for establishing in-stream flow standards (including minimum flow) on a stream-by-stream basis; for overseeing the registration, permit issuance, and oversight of wells for groundwater withdrawal or long-term monitoring; for registration and permitting of stream alterations and diversion works relating to surface water; and for establishing aquifer sustainable yields.

The CWRM can require dual water supply systems for new commercial and industrial developments in designated water management areas if a non-potable source of water is available. Stormwater could serve potentially as a non-potable water source. The purpose of this requirement is to further protect the quantity and quality of potable water supplies.

The Code also includes provisions to protect Native Hawaiian Water Rights. These rights extend to ensuring adequate water reserves for current and foreseeable development and use of Hawaiian homelands, and for traditional and customary rights associated with cultural and subsistence agricultural practices.

As indicated previously, Part V of the Code establishes the Hawaii DOH as the administrator of the State's water quality control program. The DOH is responsible for developing a water quality plan for all existing and potential sources of drinking water. Though the Code provides for it, the current plan does not include any water quality criteria for the designation of ground water management areas and surface water management areas.

The Hawaii DOH further regulates the quality of other water resources in the State. Though not all potential uses of reclaimed stormwater have been established, integration with recycled wastewater, recharge of drinking water aquifers, and recharge of non-potable water aquifers has been identified. Water quality-based regulations associated with these potential reuse opportunities are discussed below.

- Hawaii Administrative Rules (HAR) 11-54, *Water Quality Standards* – These standards pertain to surface discharges to inland lakes and streams, as well as coastal and ocean discharges. These rules establish narrative and numerical criteria that must be met in surface waters to prevent toxicity and water quality degradation.

- HAR 11-55, *Water Pollution Control and National Pollutant Discharge Elimination System (NPDES) General Permits,* Appendices B and C – These regulations pertain to stormwater discharges through the NPDES permit program and are intended to protect surface water quality. These discharges are considered point sources that can be readily monitored and controlled. Though stormwater discharges can have a direct impact on the water quality standards promulgated in HAR 11-54, the stormwater NPDES permits do not include numerical limits, only monitoring of pollutants. Permittees are required to implement management plans that include best management practices (BMPs) to reduce the discharge of pollutants in stormwater.

  Though stormwater discharge permits do not contain numerical limits currently, they could in the future as total maximum daily loads (TMDLs) are developed for the approximately 241 impaired waters in Hawaii. Impaired waters are those that exceed water quality standards. Stormwater reclamation and reuse could be an effective means of reducing pollutant loads as stormwater discharges to these impaired waters would be reduced. Table 1 identifies the causes of impairment and the number of water bodies with that specific impairment. The total causes of impairment exceeds the number of impaired water bodies because some water bodies exceed more than one water quality standard. Over 70 of the impaired water bodies are on Oahu, including streams and coastal waters. The State of Hawaii has only received approval for 17 TMDLs from the Environmental Protection Agency (EPA).

Table 1. Causes of Impaired Water Bodies

Water Quality Standard	Number of Water Bodies Impaired
Turbidity	197
Nutrients	177
Algal Growth	90
Pathogens	52
Floatables	17
Ammonia	13
Pesticides	6
Metals (other than mercury)	4
Polychlorinated biphenyls (PCB)	1

- HAR 11-62-26, *Wastewater Systems* and *Guidelines for the Treatment and Use of Recycled Water* – These establish three classifications of recycled water: R-1, R-2, and R-3. These classifications are based on the degree of treatment, which in turn governs applicable use. R-1 recycled water is the highest quality.

- HAR 11-20, *Rules Pertaining to Potable Water Systems* – The DOH has authority delegated from the EPA to enforce applicable federal rules (40 CFR Parts 141 through 143) and adopt more stringent rules if necessary. There are 88 numerical primary drinking water standards for microbiological and chemical parameters. These are enforceable as violations if they are exceeded. There are 15 secondary drinking water standards, which are not enforceable, but are intended to improve the aesthetics of drinking water.

- HAR 11-23, *Underground Injection Control (UIC)* – These regulations do not regulate water quality directly, but indirectly by determining where underground injection wells can be located in relation to potable water sources.

In addition to the DOH regulations, each of Hawaii's four counties – Kauai, Hawaii, Maui, and Honolulu – has stormwater design standards that establish requirements for mitigating peak flow stormwater discharges and poor water quality for developments.

The Honolulu Board of Water Supply's (BWS), Rules and Regulations, *Chapter III, Protection, Development and Conservation of Water Resources,* establish "No Pass Zones" on Oahu that further limit the location of waste disposal facilities that may "affect the quality and/or quantity of water resources used or expected to be used for domestic water." The "No Pass Zones" established by BWS are more restrictive than UIC lines.

The previous discussion identifies regulations that can affect stormwater reclamation and reuse in Hawaii. Table 2 summarizes potential impacts of these regulations.

Table 2. Potential Impact of Current Regulations on Stormwater Reclamation and Reuse

Applicable Regulation	Applicable Language	Potential Impact
State Water Code	Groundwater and surface water are held as public trusts for the benefit of all people. The CWRM has considerable authority to protect surface and groundwater quantity and quality.	Issues such as stream flow standards, in-stream diversions, and Native Hawaiian Water Rights can potentially promote or detract from stormwater reclamation and reuse
State Water Code 174C-51.5	The commission can require dual water line systems in new industrial and commercial developments when located in designated water management areas. This requirement is contingent on an available source of *nonpotable water.* Though the intent of the language was to promote the use of recycled wastewater, its use of the term *nonpotable water* could apply equally to reclaimed stormwater.	Though there is no requirement for developers to develop nonpotable water sources, the language could promote the use of reclaimed stormwater if a source is made available.
HAR 11-20 *Rules Pertaining to Potable Water Systems*	Direct connections between surface and groundwater can result in a groundwater drinking water source being designated as Groundwater Under the Direct Influence (GWUDI) of surface water.	GWUDI designation would require that groundwater be treated in the same manner as surface water, which would be costly. Situations that would result potentially in a GWUDI designation would be resisted by public (and private) water supply agencies.
HAR 11-23 *Underground Injection Control*	Any new injection well cannot be sited closer than ¼-mile from any part of a drinking water source.	The location of any stormwater injection well for direct recharge would be limited by the spatial dimensions of this regulation. An entire aquifer could be considered the drinking water source, further limiting direct injection. UIC control areas are significant parts of each island.

Table 2. Potential Impact of Current Regulations on Stormwater Reclamation and Reuse (continued)

Applicable Regulation	Applicable Language	Potential Impact
HAR 11-54 *Water Quality Standards*	TMDLs will limit discharge of certain pollutants (receiving water dependent) from point sources, such as stormwater system outfalls.	TMDLs might require that stormwater be treated to meet specific waste load allocations. Such treatment would be expensive and encourage developers to seek alternatives to direct discharge of stormwater to surface waters. This could promote technologies and best management practices for stormwater reclamation and reuse.
HAR 11-62 *Wastewater Systems* *Guidelines for Treatment and Use of Recycled Water*	There are three classes of recycled water. Each class is determined by the level of treatment. The two highest levels of recycled water must meet specific microbiological quality requirements, and, in the case of the highest level of recycled water, turbidity requirements. Compliance with quality requirements for recycled water is determined at the end of the treatment process.	The DOH has verbally said that integration of recycled water and stormwater would require that stormwater meet recycled water quality.
County Stormwater Drainage Standards	Specific treatment levels (i.e., infiltration, vegetated swales, bioretention filters, and other filters) are required for stormwater flow-through treatment (little or no storage). Design standards for flood control include the following variables: ▪ Recurrence interval based on acreage ▪ Runoff quantity based on acreage The design volume for detention basins to enhance stormwater quality is based on impervious surface area, a 1-inch storm, and site acreage.	Some level of treatment is required for stormwater injection into potable and non-potable water aquifers irrespective of water quality. Design standards do not include any credit for reducing runoff quantity nor any allowance for reducing the size of detention basins if stormwater reclamation and reuse is included in designs. Consequently there are no financial incentives to developers to incorporate stormwater and reclamation reuse features.

Public Issues

Water issues are very visible and of much importance to Hawaii residents. Voluntary water restrictions have been put in place in recent years as a result of drought. Recycled water from wastewater treatment plants has gained public acceptance in the past decade and is used for irrigating golf courses, parks, and transportation median strips. In 2006, an extended rainfall period contributed to a dam collapse on the island of Kauai, and a 50 million gallon sewer spill on Oahu. Events such as these that result in loss of life or beach closures bring stormwater issues to headline news, but for the most part, stormwater is not much of a public concern.

Water issues are extremely important to native Hawaiians and environmental groups alike. During the early 1900s, Waiahole Ditch was constructed to convey stream-diverted water from the windward side of Oahu to the pineapple and sugar cane fields on the leeward side. When the sugar industry declined and water use from Waiahole Ditch decreased, the CWRM allocated the water in a manner that resulted in a lawsuit by windward parties to protect in-stream flow and cultural uses of the watershed that supplied the water. The Hawaii Supreme Court ruled in the favor of the Windward parties affirming that water resources are part of the public trust. The Hawaii Supreme Court further identified three public trust purposes, which do not include commercial agriculture. Similar legal challenges to stream diversions have occurred on Maui and Hawaii.

Funding

Stormwater is considered an unreliable water source since supply does not match water demand. Each of the four major public water suppliers in Hawaii has implemented approximate 40-percent rate increases over the next five years to maintain their existing potable water infrastructure. Stormwater is not the responsibility of the water supply utilities and investment in an unreliable water source is not attractive to them.

Public stormwater management BMPs for compliance with NPDES permits are funded through the general fund of each county. There are no stormwater utilities to provide capital or operation and maintenance funding. Consequently, stormwater reclamation and reuse is forced to compete with more tangible public desires, such as parks and transportation.

As more TMDLs are implemented, stormwater runoff will be targeted for point source control of pollutant discharges. When this occurs, funding for reclamation and reuse, rather than treatment for continued discharge, might be more readily available.

Another funding consideration is the cost to develop potable water supplies. The BWS estimates that development of a 1.0 million gallons per day (mgd) groundwater source costs between 6 and 8 million dollars. If an equivalent volume of stormwater can be reclaimed and reused (even seasonally) for a similar cost, then stormwater might be an attractive investment.

Initial Opportunity Screening Criteria

Initial screening of stormwater reclamation and reuse opportunities was planned to be accomplished using Geographical Information System (GIS) databases from various state, federal, and municipal authorities. A matrix of information needs was developed and included the following evaluation criteria:

- Soil Permeability
- Land Zoning
- Well Locations
- UIC Line Location
- Annual Rainfall
- Proximity to Recycled Water Infrastructure
- Proximity to Contaminated Sites
- Proximity to Historic Cultural Sites
- Proximity to Critical Habitats
- Depth to Groundwater
- Stormwater Infrastructure
- Agricultural Irrigation Ditches

Table 3 summarizes these criteria, their intended use, and a GIS database and figure reference.

Agencies were contacted to determine the availability of database information, and requests were made for obtaining existing database information. As database information was obtained from various public agencies, it became apparent that geographical coverage for the selected screening criteria was not consistent. Oahu had the best geographical coverage for most of the criteria, but inconsistencies were still common. Figure 1 illustrates a common discrepancy. The figure shows the stormwater collection system in the Mililani area of central Oahu. Some of the collection system lines lack continuity and are simply shown as dead-end pipes. In addition, two major stormwater drainage channels in the Mililani area are not shown.

Another example of discrepancies is the numerous agricultural irrigation ditches that have been used historically in Hawaii. Many of the irrigation ditches are still shown in GIS coverage, but have been abandoned and/or displaced by construction. Location of agricultural irrigation ditches that are still in use was obtained from the Department of Agriculture's *Agricultural Water Use and Development Plan* (December 2003). The plan included topographical maps showing the location of the ditches in each County.

Other sources were also used to supplement information that would benefit the selection and evaluation of stormwater reclamation and reuse opportunities. The Hawaii DOH's 2006 State of Hawaii Water Quality Monitoring and Assessment Report (September 2007) identified a list of impaired streams and coastal waters, and the limiting pollutants for each. This information was used to assess the benefits of reduced stormwater flow on stream and coastal water quality.

The DOH's *Groundwater Contamination Maps* (July 2006), show the names and location of wells impacted by human activity, and the types and concentrations of pollutants found in the wells. This information was used to assess the benefit of groundwater recharge of stormwater for improving groundwater quality.

Field visits provided the most effective means of assessing potential opportunities. These visits provided first-hand knowledge of the possible infrastructure and its relationship to areas of stormwater collection, conveyance and use. GIS information, in conjunction with Google™ Earth, was then used to refine the opportunities. Figures 2 through 10 provide examples of the GIS database information for the Mililani area of Central Oahu.

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Table 3. Initial Screening Criteria for Stormwater Reclamation and Reuse Opportunities

Criteria	Basis	Measure	Impact	Opportunity	GIS Layer and Figure Reference
Conveyance & Storage Infrastructure (Including stormwater collection systems and agricultural irrigation ditches)	Existing conveyance and storage infrastructure can be used for the purpose of groundwater recharge and can minimize the capital costs that would arise from having to build new facilities. These can be in the form of streams, ditches, stormwater facilities, lakes, ponds, etc.	Available	Provides existing infrastructure that could potentially be used for direct injection of stormwater.	Cost savings from utilizing existing infrastructure.	City and County of Honolulu(CCH) GIS Database **Reference: Figure 1**
		Not available	New infrastructure would be required for stormwater recharge programs.	No cost savings. New Infrastructure required.	USGS, Digital Line Graph, 1983. Department of Land and Natural Resources (DLNR), Division of Aquatic Resources (DAR), 2004 **Reference: Figure 2**
Soil Permeability	Affects aquifer recharge using both surface application and underground injection.	Moderately Slow	May require detention structures; Recharge may be feasible if applied over larger land areas.	Incorporate into low-impact developments; BMPs such as permeable paving and subsurface infiltration chambers are possible; increase green space; may also utilize detention/infiltration ponds/trenches.	National Resources Conservation Services (NRCS), U.S. Department of Agriculture (USDA), 2007. **Reference: Figure 3**
		Moderate			
		Moderately Rapid	Recharge can be accomplished easily and efficiently; Relatively large amounts of stormwater can be reclaimed.	In addition to opportunities identified for very slow to moderate permeability, injection wells may be possible.	
		Rapid			
		Very Rapid			
Depth to Groundwater	Areas with high water tables may have decreased recharge potential due to limited infiltration capacity.	< 5 feet	The subsurface soil would be saturated at a relatively shallow depth, greatly decreasing the amount of infiltration capacity.	May be limited to natural infiltration through low-impact development BMPs such as permeable paving and landscaping/vegetated areas.	DLNR, Division of Water Resource Management wells database (maintained in dBase) October, 1998 (Received from State of Hawaii - CWRM) **Reference: Figure 4**
		5- 10 feet	The subsurface soil would be saturated at a moderate depth, making stormwater infiltration feasible.	Recharge through infiltration trenches or retention ponds may be feasible.	
		> 10 feet	The subsurface soil would be saturated at a moderate depth, making stormwater infiltration feasible.	Recharge through injection wells may be feasible.	

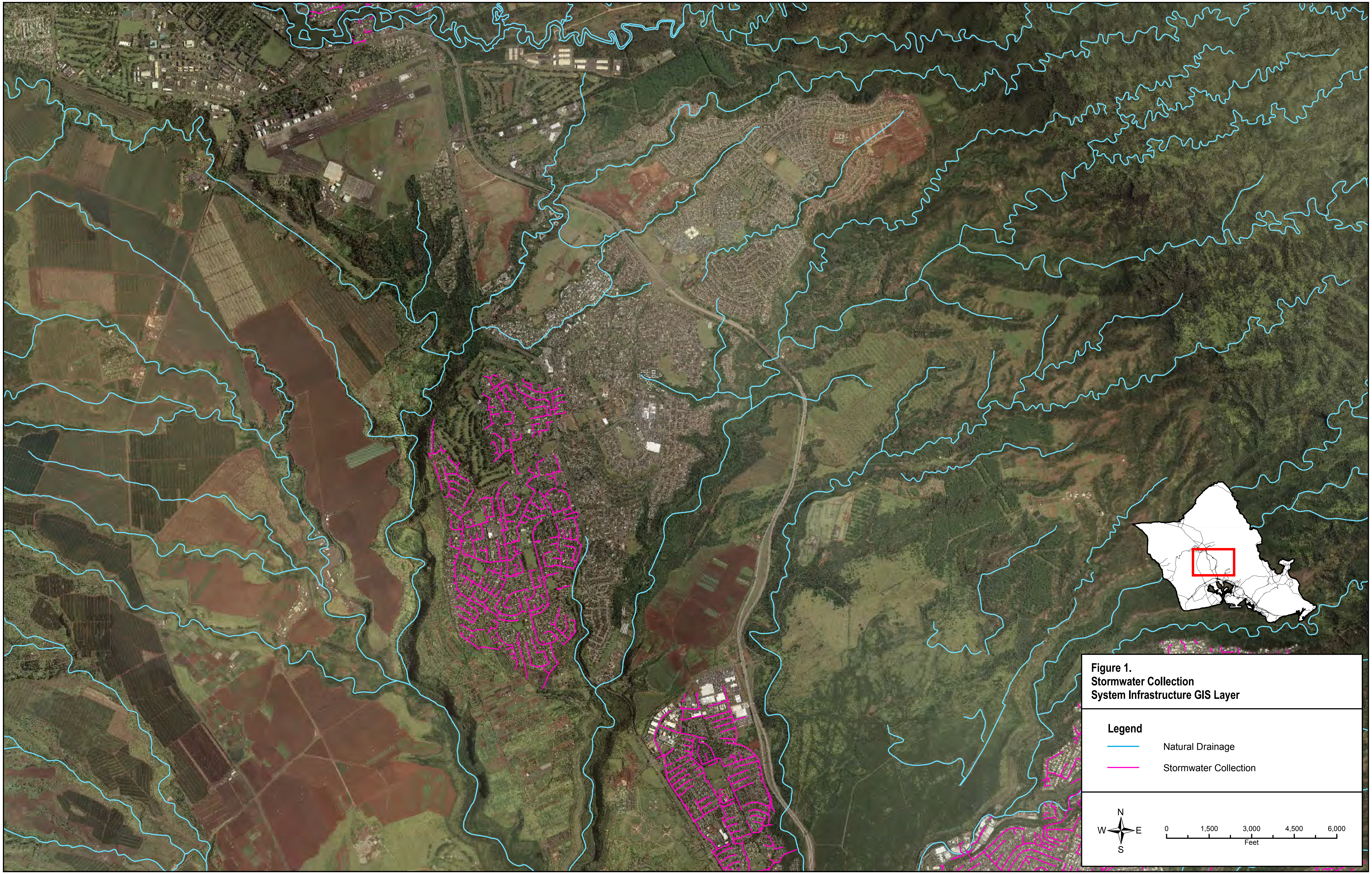


Figure 1.
Stormwater Collection
System Infrastructure GIS Layer
Legend
Natural Drainage
Stormwater Collection
N
S
E
W
0
1,500
3,000
4,500
6,000
Feet

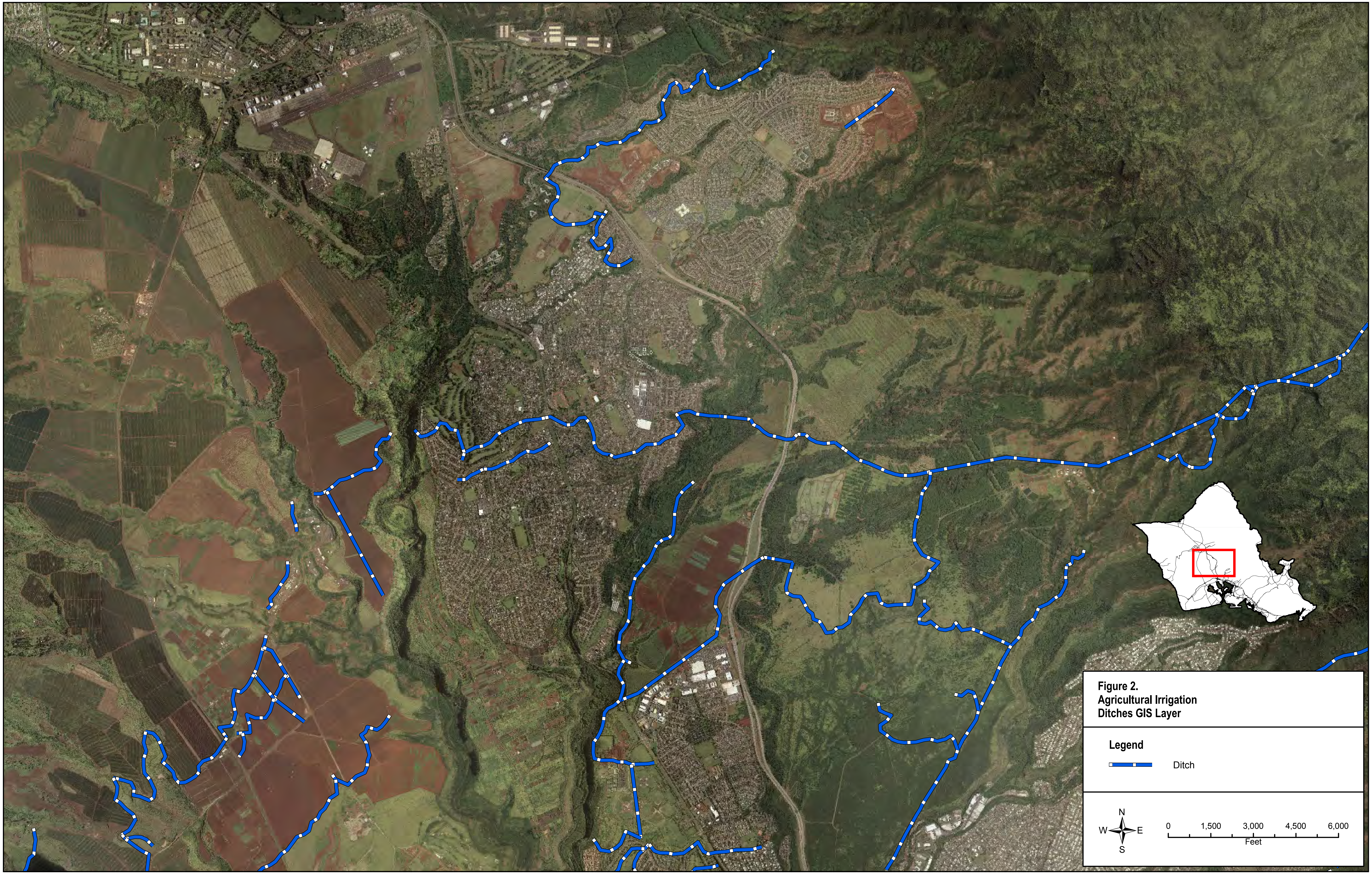


Figure 2.
Agricultural Irrigation
Ditches GIS Layer

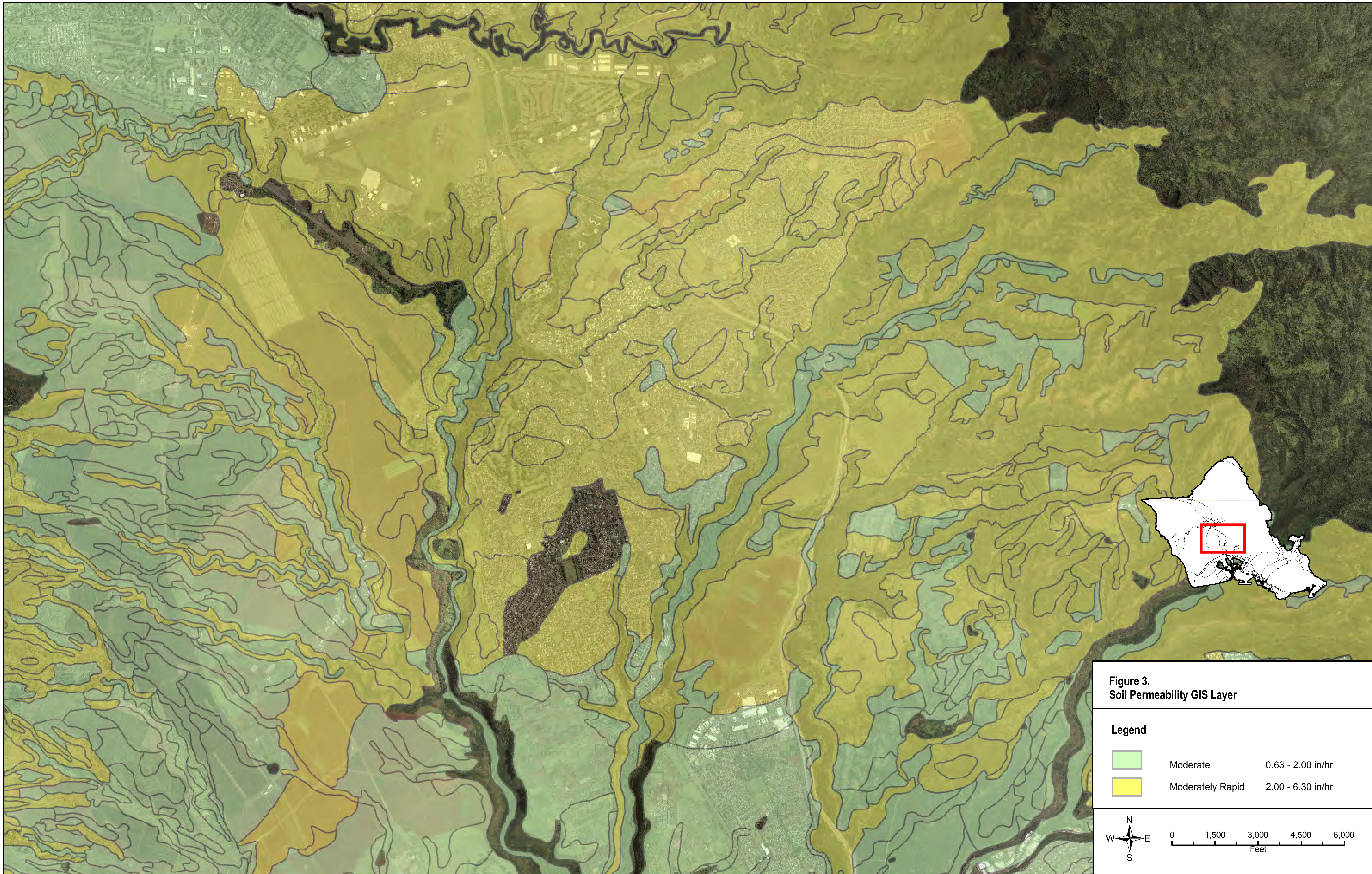


Figure 3.
Soil Permeability GIS Layer
Legend
Moderate 0.63 - 2.00 in/hr
Moderately Rapid 2.00 - 6.30 in/hr
N
W
E
S
0
1,500
3,000
4,500
6,000
Feet

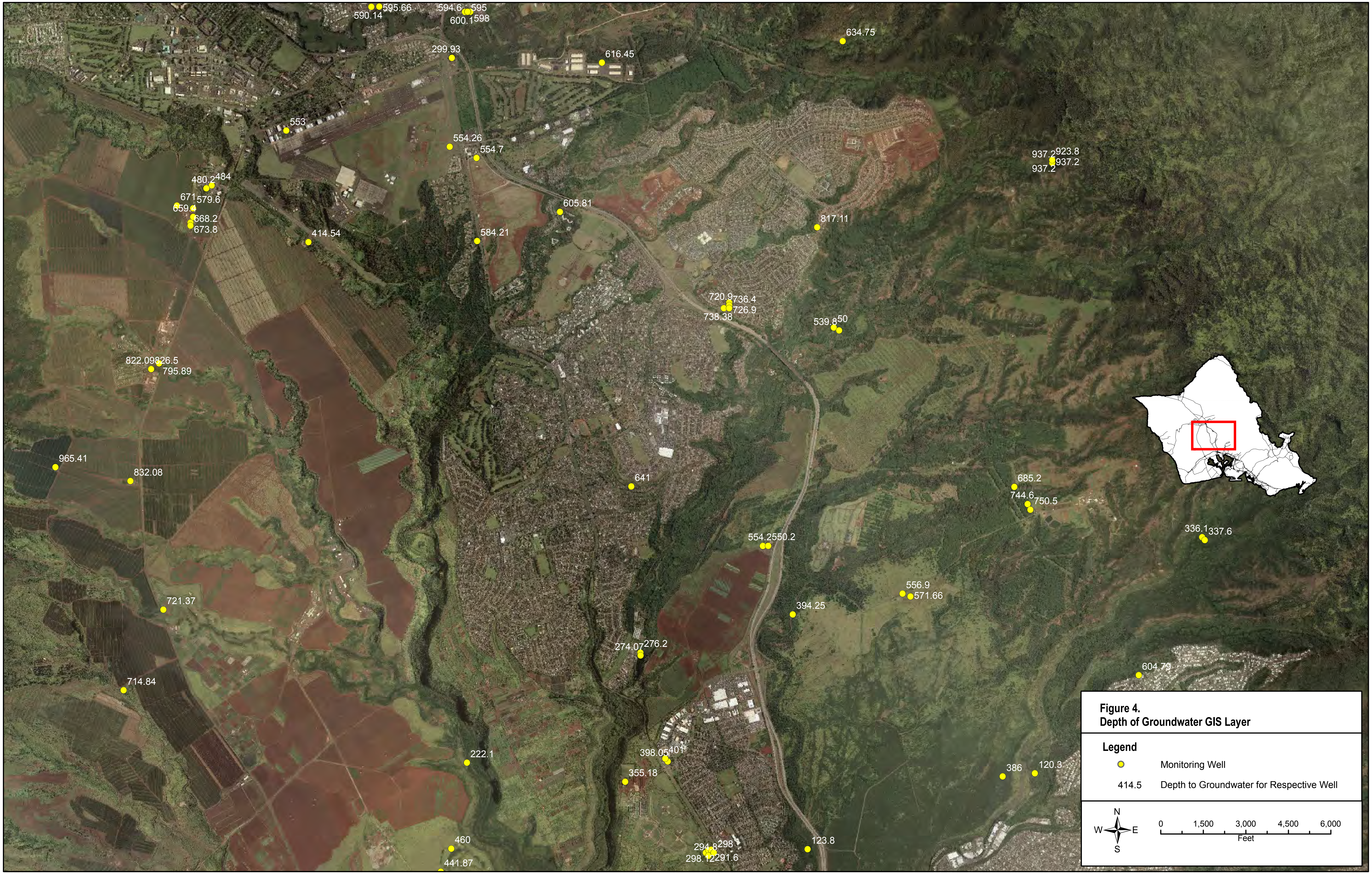

590.14
595.66
594.6
595
600.1598
299.93
616.45
634.75
553
554.26
554.7
480.2
484
671
579.6
659
668.2
673.8
414.54
584.21
605.81
817.11
937.2
923.8
937.2
937.2
720.9
736.4
726.9
738.38
539.8
50
822.09
826.5
795.89
965.41
832.08
641
685.2
744.6
750.5
336.1
337.6
554.25
550.2
556.9
571.66
394.25
721.37
274.07
276.2
604.79
714.84
222.1
398.05
401
355.18
386
120.3
460
441.87
294.8
298
298.12
291.6
123.8
Figure 4.
Depth of Groundwater GIS Layer
Legend
Monitoring Well
414.5 Depth to Groundwater for Respective Well
N
W
E
S
0
1,500
3,000
4,500
6,000
Feet

Table 3. Initial Screening Criteria for Stormwater Reclamation and Reuse Opportunities (continued)

Criteria	Basis	Measure	Impact	Opportunity	GIS Layer and Figure Reference
Land Zoning	Identifies areas that may or may not be suitable locations for stormwater reclamation, based on current land use plans.	Park/Recreation	Significant land area may be available; high potential to incorporate stormwater reclamation on a larger scale, particularly aquifer recharge.	Irrigation with stormwater; detention/infiltration ponds/trenches; injection wells; subsurface infiltration chambers.	CCH, Department of Planning and Permitting (ftp://gisftp.hicentral.com/LayrZips/) **Reference: Figure 5**
		Agricultural/Preservation			
		Low/Medium Density Residential	Decrease in available land; however, potential for stormwater reclamation still exists on a smaller scale.	Incorporate into low-impact developments; use BMPs such as permeable paving, recessed lawns, subsurface infiltration chambers, and eliminating roof drains. Injection wells may be possible if hidden and protected.	
		High Density Residential	Minimal land area available for stormwater reclamation; potential for significant increases in runoff.	Vegetated roofs, rain catchment for landscaping and/or toilet use, subsurface infiltration chambers, landscape/planter boxes, aesthetic ponds incorporated into landscape.	
		Commercial	Minimal land area available for stormwater reclamation; potential for significant increases in runoff.		
		Industrial	Minimal land area available for stormwater reclamation; potential for significant increases in runoff. Hazardous material operations may prohibit stormwater reclamation.		
		Military	Stormwater reclamation opportunities depend on land usage.	Depending on land use plan for military areas, the above recommendations may be used.	
Well Locations	May prohibit stormwater reclamation infrastructure such as injection wells or recharge trenches in the immediate vicinity of potable wells.	> 1/4 mile from potable well	Least restrictive to groundwater recharge infrastructure.	More freedom to utilize more direct recharge methods such as injection wells and recharge trenches.	DLNR, Division of Water Resource Management wells database (maintained in dBase) October, 1998 (Received from State of Hawaii - CWRM) **Reference: Figure 6**
		< 1/4 mile from potable well	Most restrictive to groundwater recharge infrastructure.	May be limited to indirect recharge methods only such as surface infiltration.	
	Abandoned wells may provide a means for direct injection of stormwater utilizing existing infrastructure.	Available	Provides existing infrastructure that could potentially be used for direct injection of stormwater.	Cost savings from utilizing existing infrastructure.	
		Not available	New infrastructure would be required for direct injection of stormwater.	No cost savings. New Infrastructure required.	

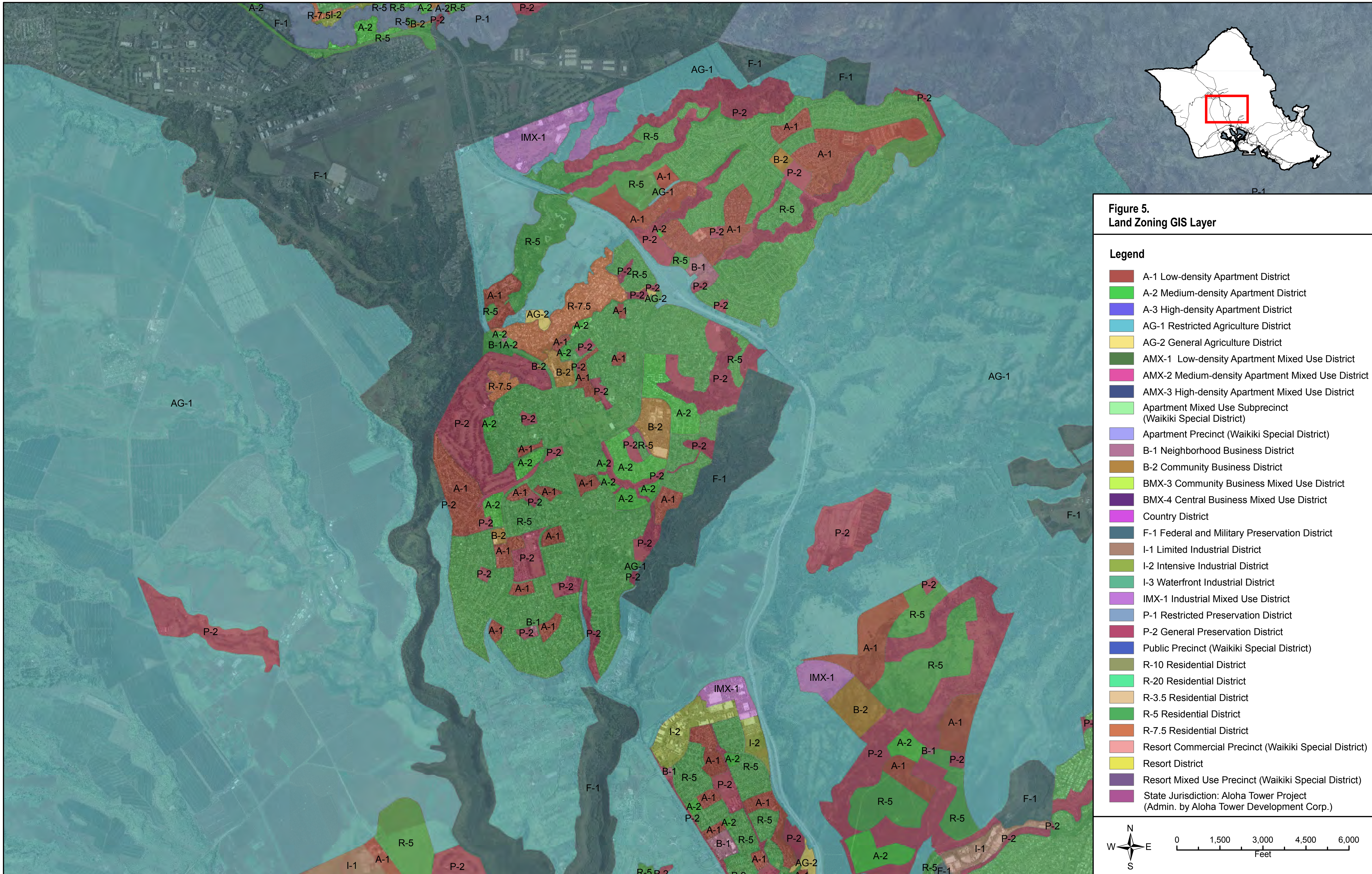


Figure 5.
Land Zoning GIS Layer
Legend
A-1 Low-density Apartment District
A-2 Medium-density Apartment District
A-3 High-density Apartment District
AG-1 Restricted Agriculture District
AG-2 General Agriculture District
AMX-1 Low-density Apartment Mixed Use District
AMX-2 Medium-density Apartment Mixed Use District
AMX-3 High-density Apartment Mixed Use District
Apartment Mixed Use Subprecinct (Waikiki Special District)
Apartment Precinct (Waikiki Special District)
B-1 Neighborhood Business District
B-2 Community Business District
BMX-3 Community Business Mixed Use District
BMX-4 Central Business Mixed Use District
Country District
F-1 Federal and Military Preservation District
I-1 Limited Industrial District
I-2 Intensive Industrial District
I-3 Waterfront Industrial District
IMX-1 Industrial Mixed Use District
P-1 Restricted Preservation District
P-2 General Preservation District
Public Precinct (Waikiki Special District)
R-10 Residential District
R-20 Residential District
R-3.5 Residential District
R-5 Residential District
R-7.5 Residential District
Resort Commercial Precinct (Waikiki Special District)
Resort District
Resort Mixed Use Precinct (Waikiki Special District)
State Jurisdiction: Aloha Tower Project (Admin. by Aloha Tower Development Corp.)
N
W
E
S
0
1,500
3,000
4,500
6,000
Feet

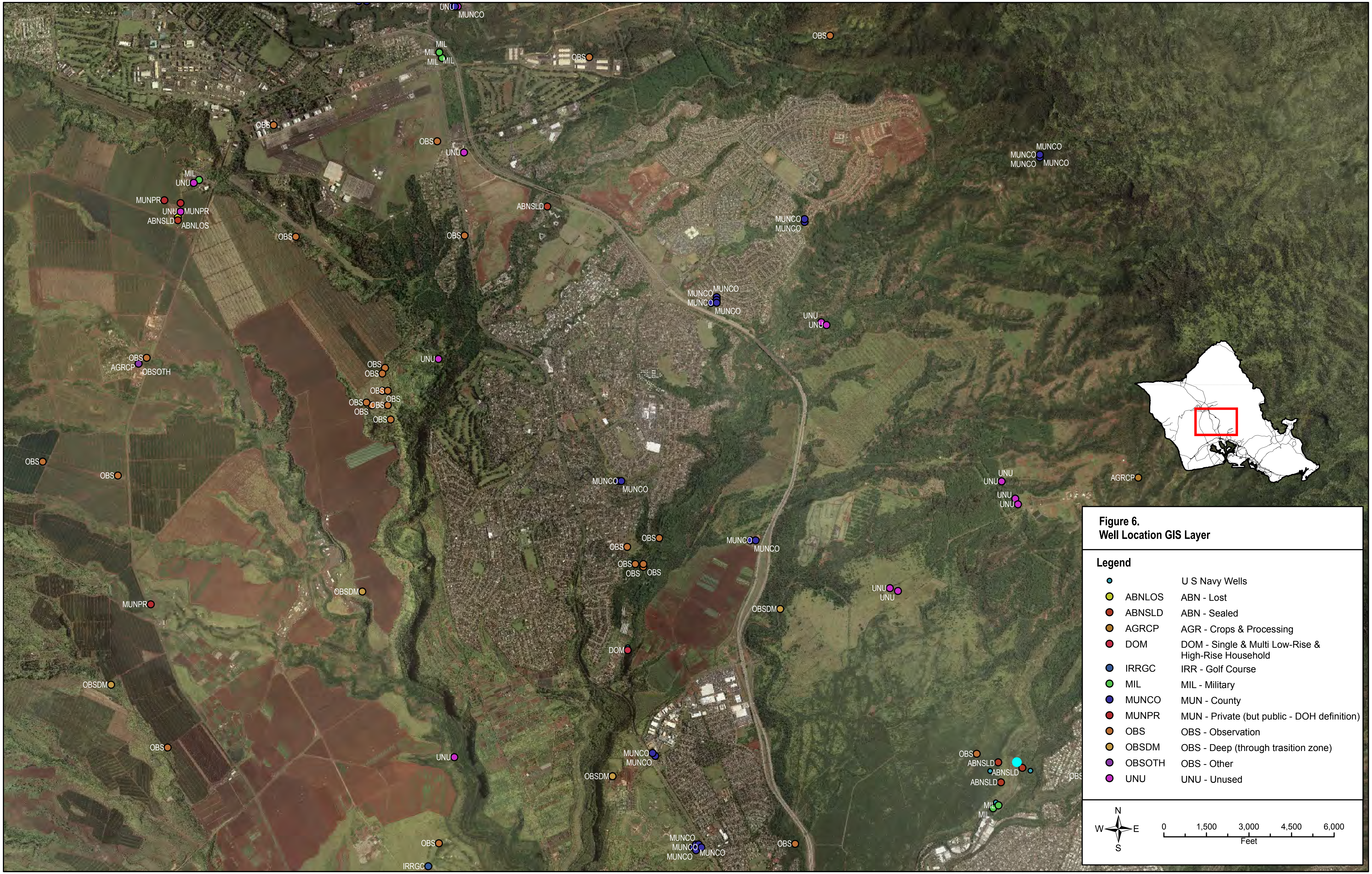
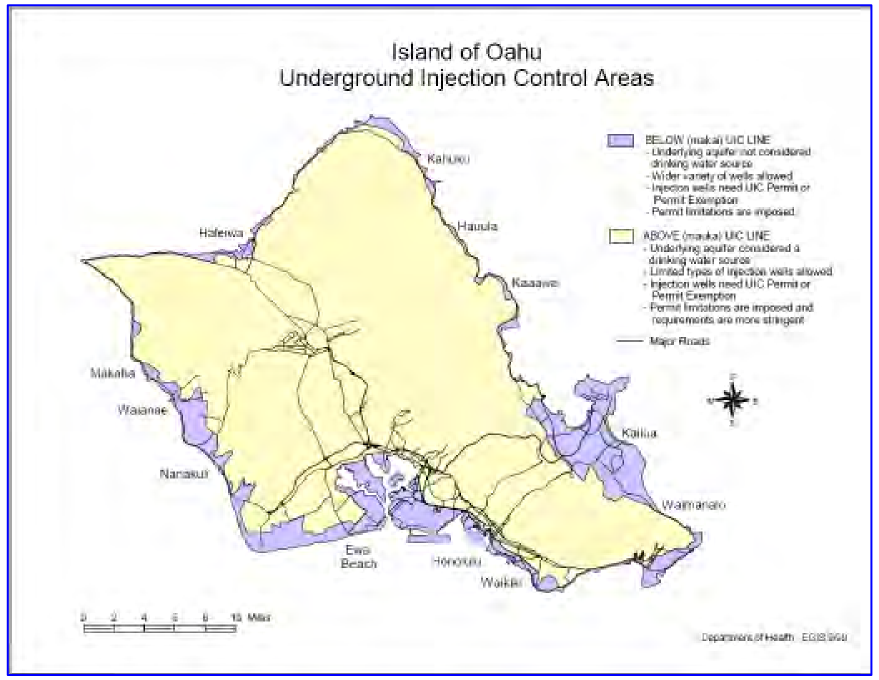
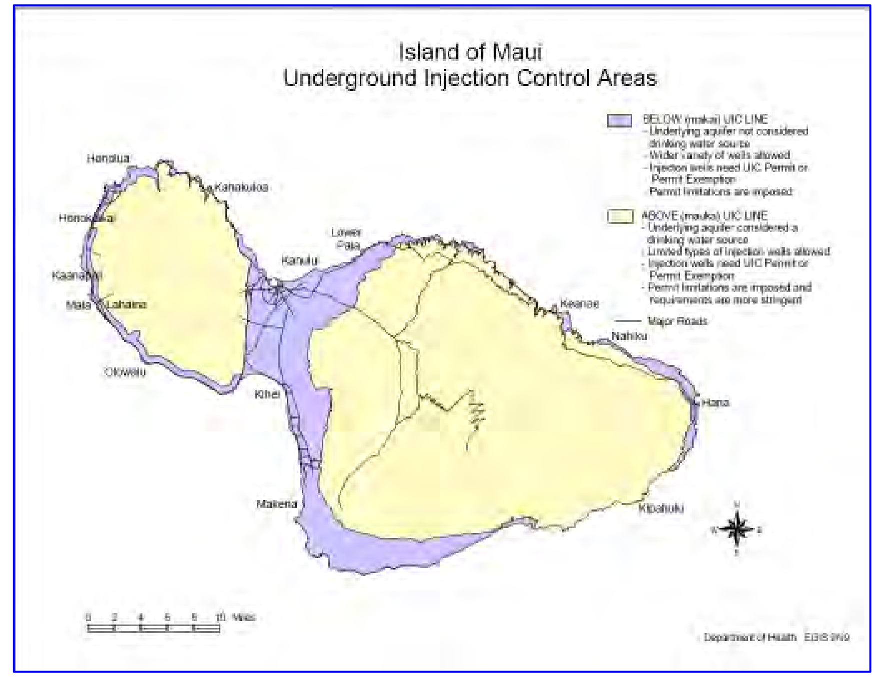


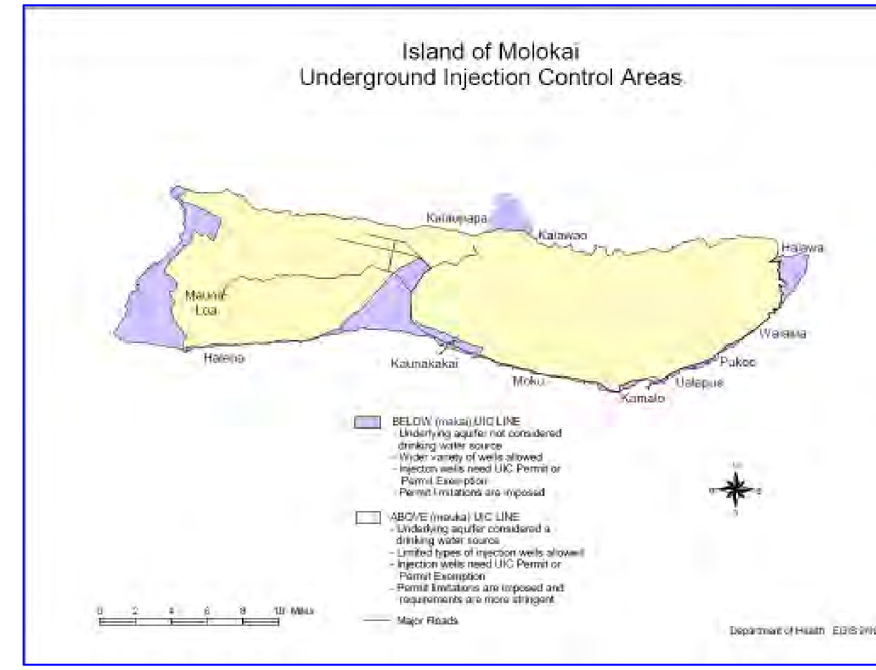
Figure 6.
Well Location GIS Layer

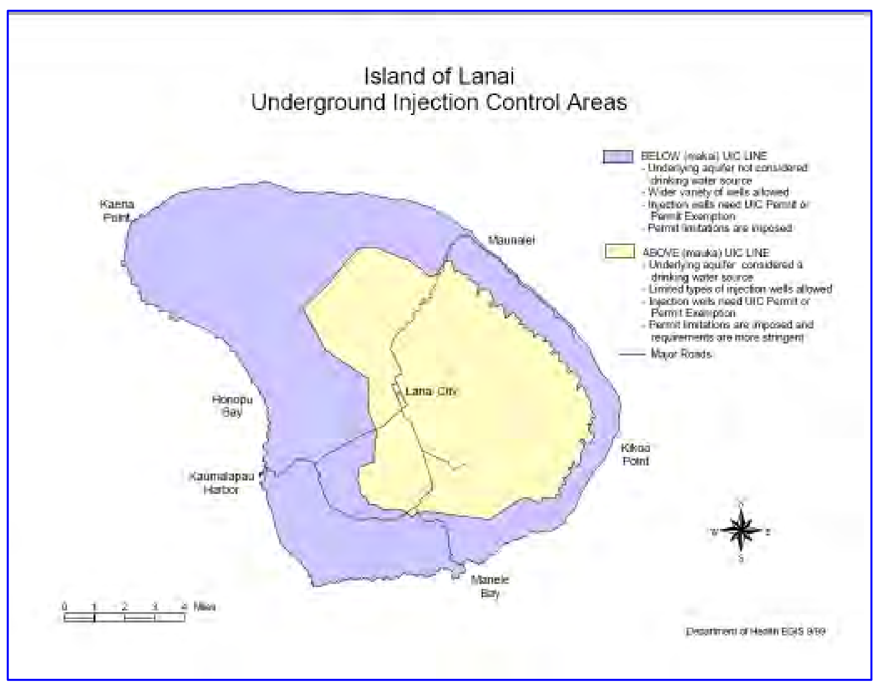
Table 3. Initial Screening Criteria for Stormwater Reclamation and Reuse Opportunities (continued)

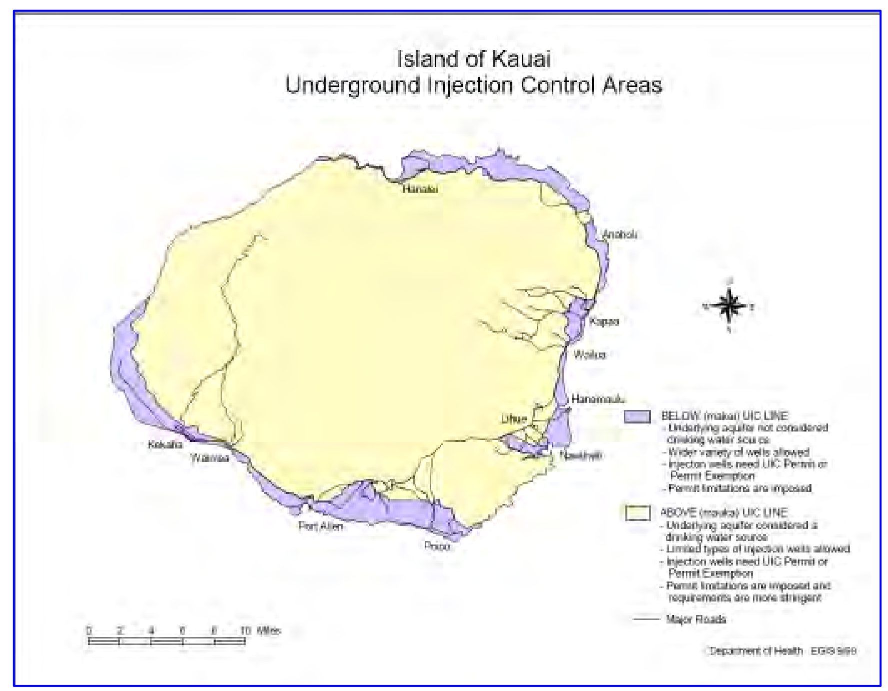
Criteria	Basis	Measure	Impact	Opportunity	GIS Layer and Figure Reference
UIC Lines	Locations within the UIC Line may be more restrictive to certain recharge methods such as direct injection and large recharge trenches.	Below UIC Line	Least restrictive area for groundwater recharge.	More freedom to utilize more direct recharge methods such as injection wells and recharge trenches.	State of Hawaii - Department of Health (Received directly from DOH) **Reference: Figure 7**
		Above UIC Line	Extent of restrictions unknown. Recharge methods such as direct injection may require treatment to R-1 standards.	May be limited to indirect recharge methods such as surface infiltration.	
Annual Rainfall	The higher the rainfall in a given area, the greater the opportunity for stormwater collection.	> 30inches	Greatest opportunity for capturing stormwater	Infrastructure for capturing, conveying, and storing stormwater may be beneficial as a water resource.	Giambelluca, T.W., Nullet, M.A., and Schroeder, T.A. 1986. Hawaii Rainfall Atlas, Report R76, Hawaii Division of Water and Land Development, DLNR, Honolulu. Vi + 267 p.(http://www.hawaii.gov/dbedt/gis.htm) **Reference: Figure 8**
		< 30 inches	Cost of building infrastructure for stormwater capture may outweigh the benefits.	May need to focus more on increasing surface infiltration and decreasing runoff to address the times when rainfall does occur.	
Proximity to Hazardous Waste Sites	HAR 11 Chapter 23 prohibits injection wells from hazardous waste sites within ¼ mile of the subsurface collection system of a drinking water source. This distance has been extended to ½ mile for a known hazardous waste site due to the potential of spreading contamination deeper into the subsurface.	Within 1/2 mile	Groundwater recharge may not be feasible. A study of the contaminant plume should be performed.	Very limited to no opportunity.	No Data
		> 1/2 mile	Represents the minimum safe distance from a known hazardous waste site. A study of the contaminant plume should be performed.	No limitations to groundwater recharge due to hazardous waste.	
Proximity to Recycled Water Infrastructure	May provide a means for conveying captured stormwater to existing recharge or reuse sites.	Within 1/2 mile	Provides existing infrastructure that could potentially be used for conveying stormwater	Cost savings from utilizing existing infrastructure.	Recycled Water Infrastructure (Ewa Area Only) BWS GIS database
		> 1/2 mile	Additional infrastructure would be required to hook up to existing lines	No cost savings. New Infrastructure required.	











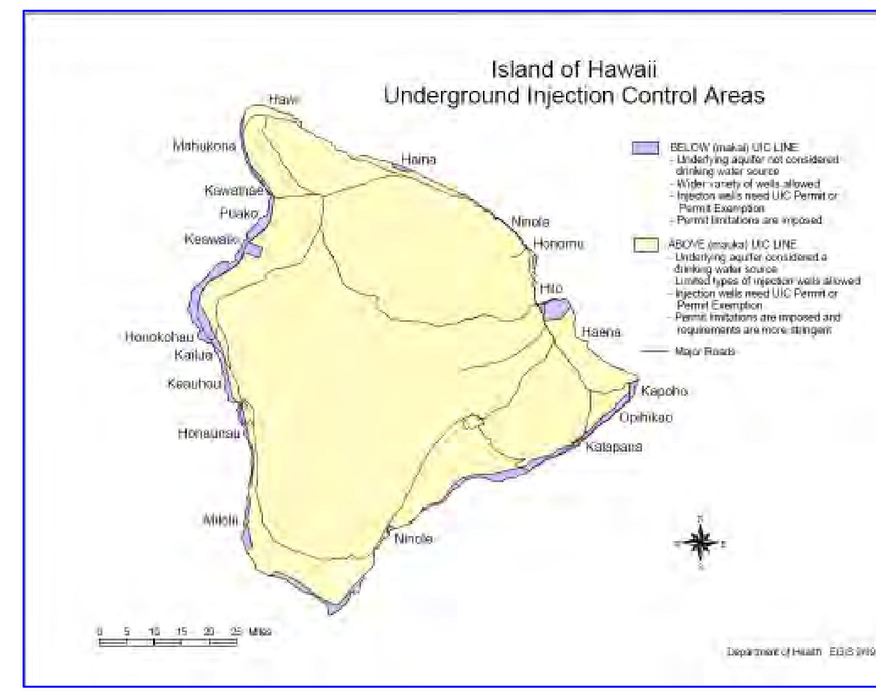


Figure 7.
UIC Lines

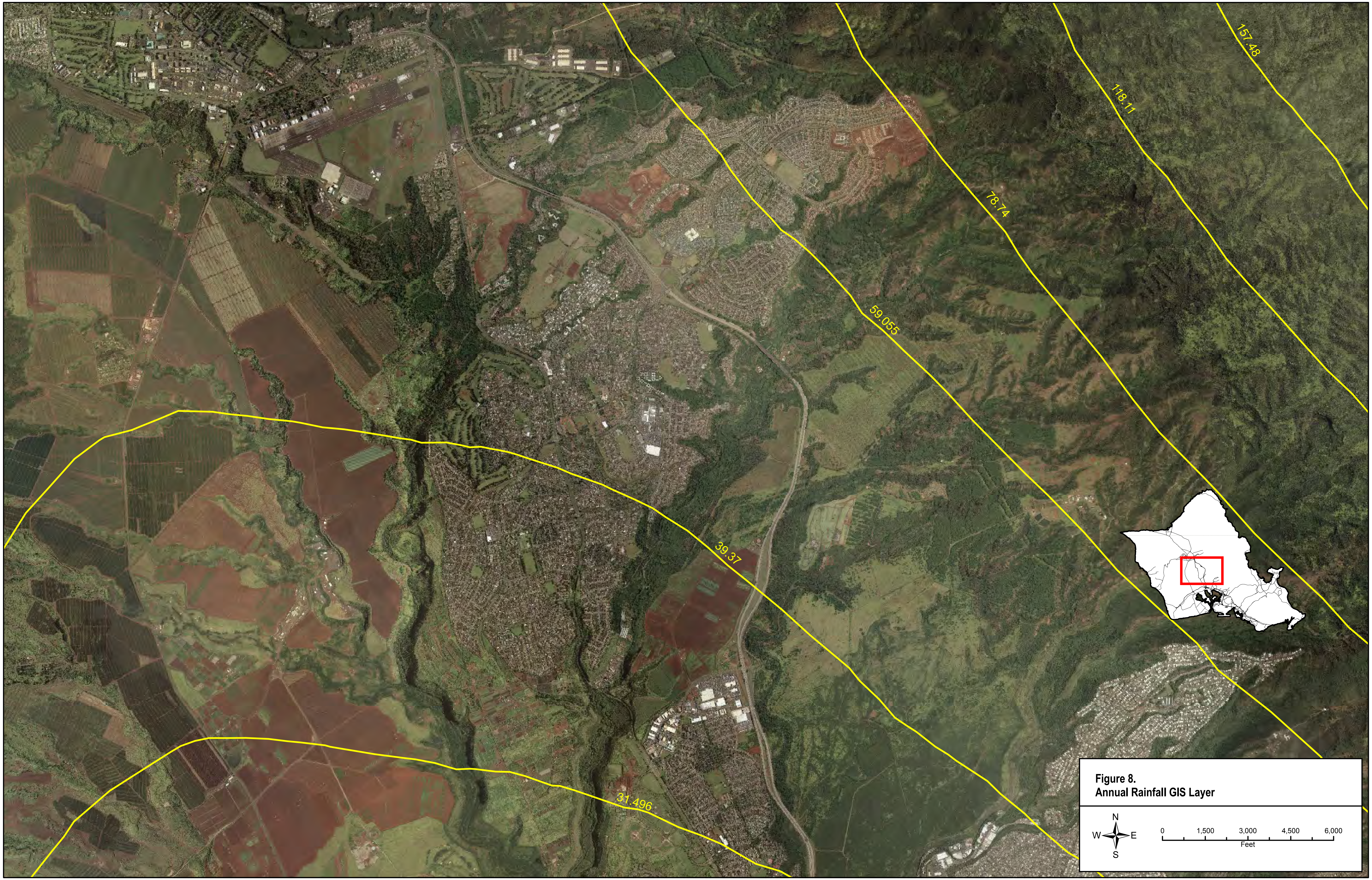


Figure 8.
Annual Rainfall GIS Layer

Table 3. Initial Screening Criteria for Stormwater Reclamation and Reuse Opportunities (continued)

Criteria	Basis	Measure	Impact	Opportunity	GIS Layer and Figure Reference
Proximity to Critical Habitats	May present an obstacle to groundwater recharge efforts, especially if disturbance to existing habitat is required.	Within 1 mile	Groundwater recharge may not be feasible. An EIS of the critical habitat should be performed.	Very limited to no opportunity.	U.S. Fish and Wildlife Service, Pacific Islands Office, 2004. (Received directly from State of Hawaii - CWRM) **Reference: Figure 9**
		> 1 mile	Represents the minimum safe distance from a known critical habitat area. An EIS of the critical habitat may need to be performed.	Should not limit stormwater reclamation and reuse.	
Proximity to Historic Cultural Sites	May present an obstacle to groundwater recharge efforts, especially if disturbance to existing cultural sites is possible.	Within 1/2 mile	Groundwater recharge may not be feasible. An EIS of the cultural site should be performed.	Very limited to no opportunity.	DLNR, Historic Preservation Division, 1996 **Reference: Figure 10**
		> 1/2 mile	Represents the minimum safe distance from a known cultural site. An EIS of the cultural site may need to be performed.	Should not limit stormwater reclamation and reuse.	

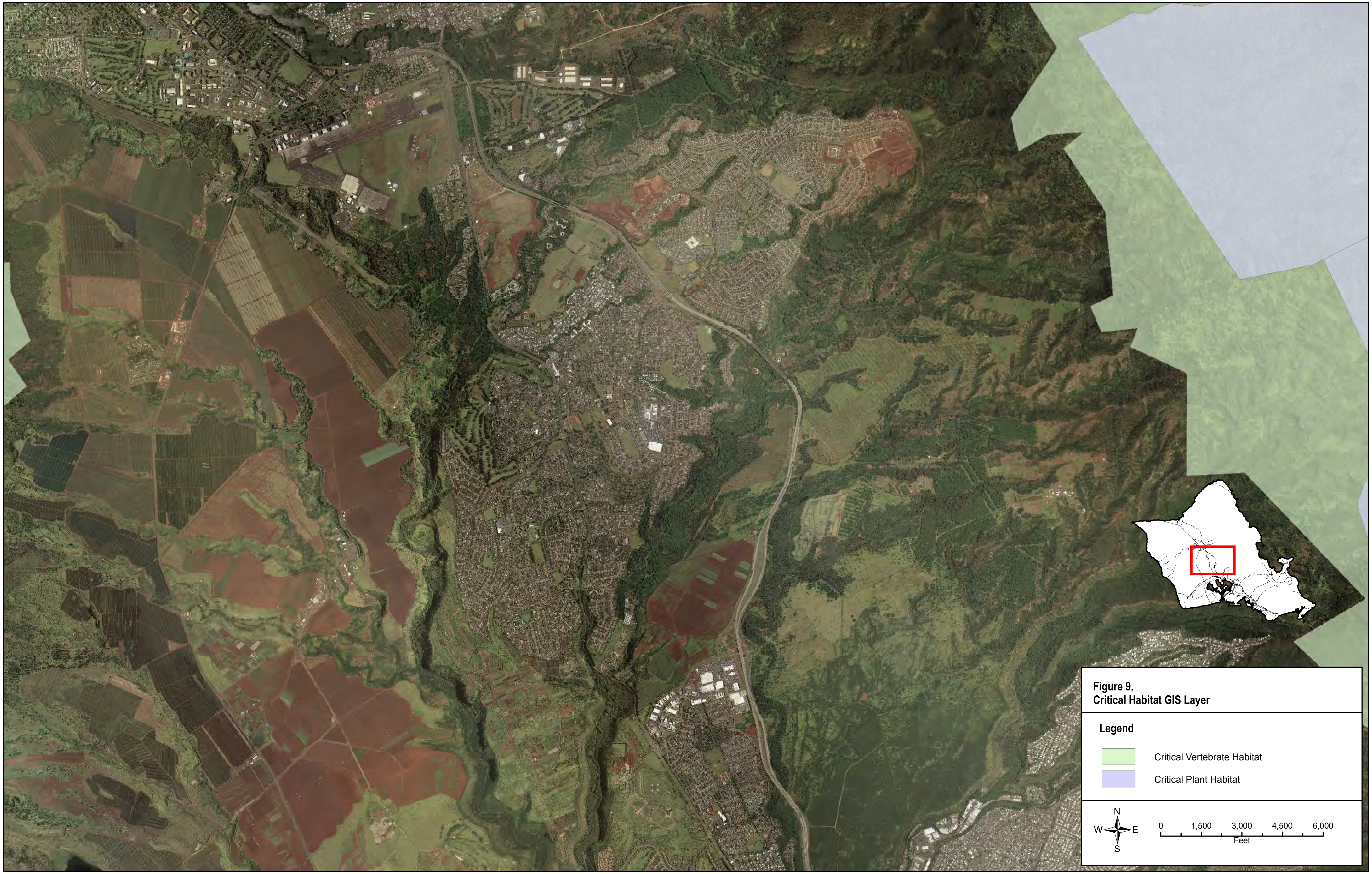
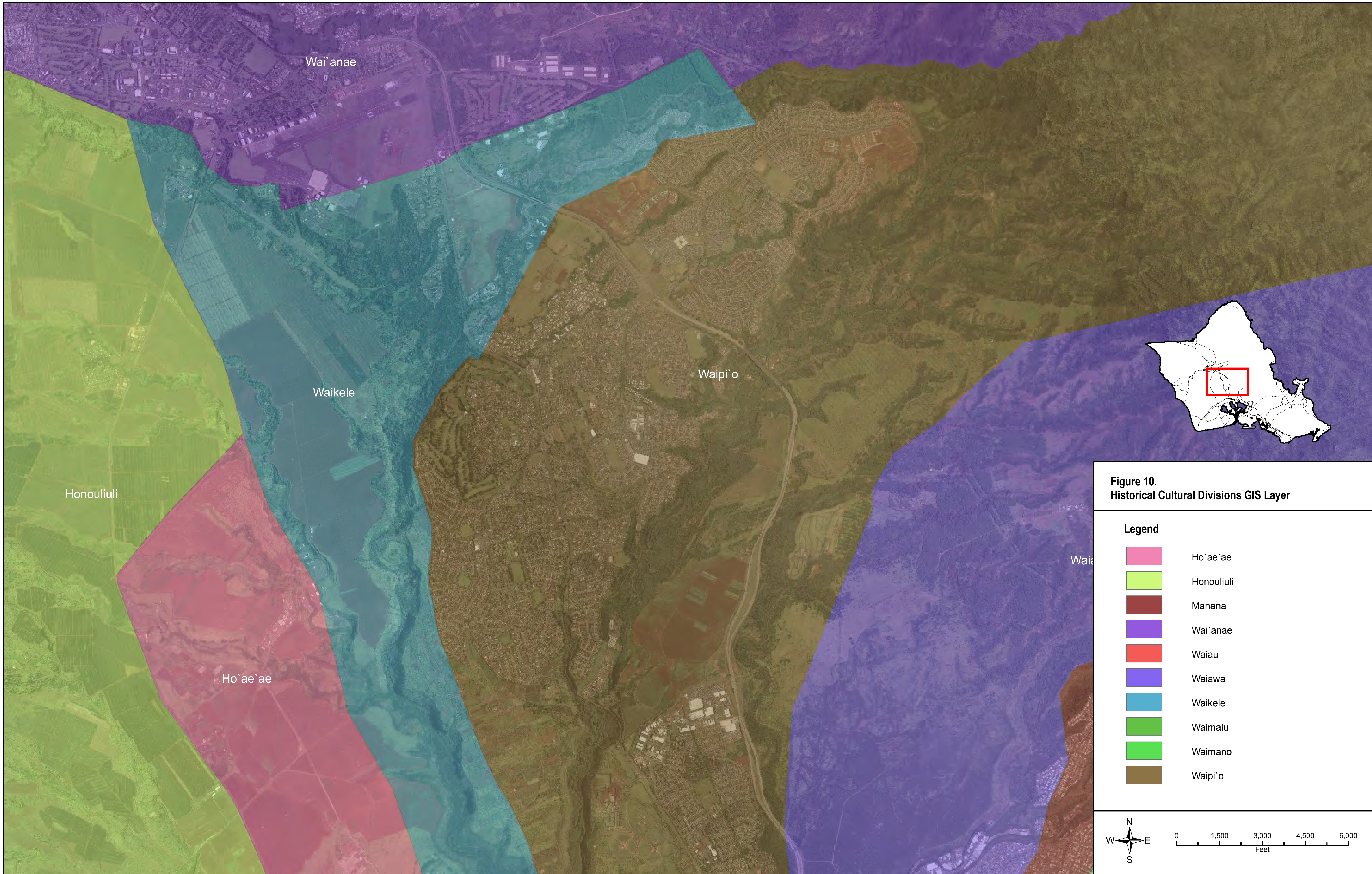


Figure 9.
Critical Habitat GIS Layer
Legend
Critical Vertebrate Habitat
Critical Plant Habitat
N
W
E
S
0
1,500
3,000
4,500
6,000
Feet


Wai`anae
Waikele
Waipi`o
Honouliuli
Ho`ae`ae
Wai
Figure 10.
Historical Cultural Divisions GIS Layer
Legend
Ho`ae`ae
Honouliuli
Manana
Wai`anae
Waiau
Waiawa
Waikele
Waimalu
Waimano
Waipi`o
N
W
E
S
0
1,500
3,000
4,500
6,000
Feet

Infrastructure Needs

Infrastructure needs for stormwater reclamation and reuse can be separated into five general categories: collection, conveyance, treatment, storage, and distribution. Each of these infrastructure categories is discussed in this section.

Collection

Stormwater collection begins when rainfall hits impervious surface area or ground that is sufficiently saturated to cause runoff. Stormwater collection infrastructure is integral to most existing residential, commercial, and industrial developments, and is a requirement of new developments. This infrastructure consists of impervious area (e.g., roads), curbs and gutters, and stormwater pipes and channels. Use of existing stormwater collection systems is ideal to avoid the need to fund and construct infrastructure specifically for stormwater reclamation and reuse.

There are often multiple points of stormwater discharge from a developed area since existing stormwater collection systems are designed to simply move stormwater to the nearest point of conveyance for discharge into streams or the ocean. In some cases (Figure 11) the multiple discharge points enter common stormwater drainage or flood control channels. In other cases, stormwater discharges to the most convenient location such as streams, open ground, or normally dry gulches. Stormwater collection systems with a small number of discharge pipes requires less additional infrastructure for collection.

Figure 11. Mililani Flood Control Channel

Conveyance

Once stormwater is collected it must be conveyed to a point of treatment, storage, or use. Two important aspects of stormwater conveyance systems are their size and location. The size of the conveyance system must be sufficient to convey enough stormwater to make reclamation and reuse practical. The location of the conveyance system should be in close proximity to treatment or storage to minimize the need for additional infrastructure.

If a residential, commercial, or industrial development has few points of stormwater discharge, the collection system itself might serve the need for collection and conveyance. Conversely, as the number of stormwater discharge points increases, some means of integrating the discharge points into a conveyance system is required.

As shown in Figure 11, large stormwater conveyance or flood control channels can move large quantities of stormwater. These channels are typically designed for a 100-year storm. Some are undersized due to the failure to expand or build additional channels as the runoff from new developments has increased over time. An example of how a stormwater conveyance or flood control channel could be integrated into a stormwater reclamation and reuse opportunity is shown in Figure 12. Similar structures have been used for decades to divert stream flow to irrigation ditches (Figure 13).

Figure 12. Stormwater Channel Collection Sump Conceptual Design

Figure 13. Stream Diversion Channel

Agricultural irrigation ditches can also be effective means of conveyance since they often transport water over large geographic areas to multiple points of use. All of Hawaii's main islands have agricultural irrigation ditches that are still in use or abandoned. Agricultural irrigation ditches have become controversial in recent years as the sugar industry for which they were constructed has subsided. Many of these irrigation ditches divert from local streams and convey the water to points of use far from their origin. These diversions have affected stream flow, local groundwater recharge, and Hawaiian cultural activities. Any use of irrigation ditches for conveyance of stormwater would need to include operational strategies that would not affect (reduce) existing water allocations to users, and not increase or give the perception of increasing diversions from streams.

Treatment

The type of treatment required for stormwater reclamation and reuse will depend on the quality of the stormwater and its intended use. For example, stormwater collection from an existing residential, commercial, or industrial development would require some form of screening as a minimum. This would be necessary to remove trash, debris, and objects that could cause operational problems to downstream equipment (e.g., pumps, irrigation nozzles, etc.) or be a barrier to reuse applications. On the other extreme, groundwater recharge of stormwater into a potable water aquifer would require a full array of treatment technologies similar to those used by potable surface water treatment plants.

There are six general categories of treatment: screening, grit removal, sedimentation/floatation, chemical addition, filtration, and disinfection. The size of each treatment unit would depend on the concentration of pollutants and the expected stormwater flow to be treated. Each of these treatment categories is discussed below.

Screening. Screening is intended to remove trash (i.e., manmade material such as cups, paper, and cans) and debris (i.e. natural material such as limbs and leaves) from the stormwater. Trash and debris can plug or damage pumps and subsequent treatment units. Screening can be accomplished by manual or automatic means, and usually consists of some type of rack or screen with a spacing of less than 1/4-inch. Larger, more robust screens may be needed in front of the finer screens to protect the finer screen from damage by large, heavy objects. Figure 14 shows an example of a mechanical screening device. Screened material that is collected would need to be recycled or disposed in a landfill.

Figure 14. Screening Device

Grit Removal. Grit consists of sand, gravel, rocks, and other similar material. Grit can plug and cause abrasion of downstream treatment units. Grit is removed by settling (i.e., slowing the stormwater flow to less than 2 feet per second), or by vortex action. Grit removal can be accomplished with aerated grit tanks, gravity settling channels, and vortex systems. Figure 15 shows a vortex-type grit removal system. Grit that is collected and removed must be recycled or disposed in a landfill.

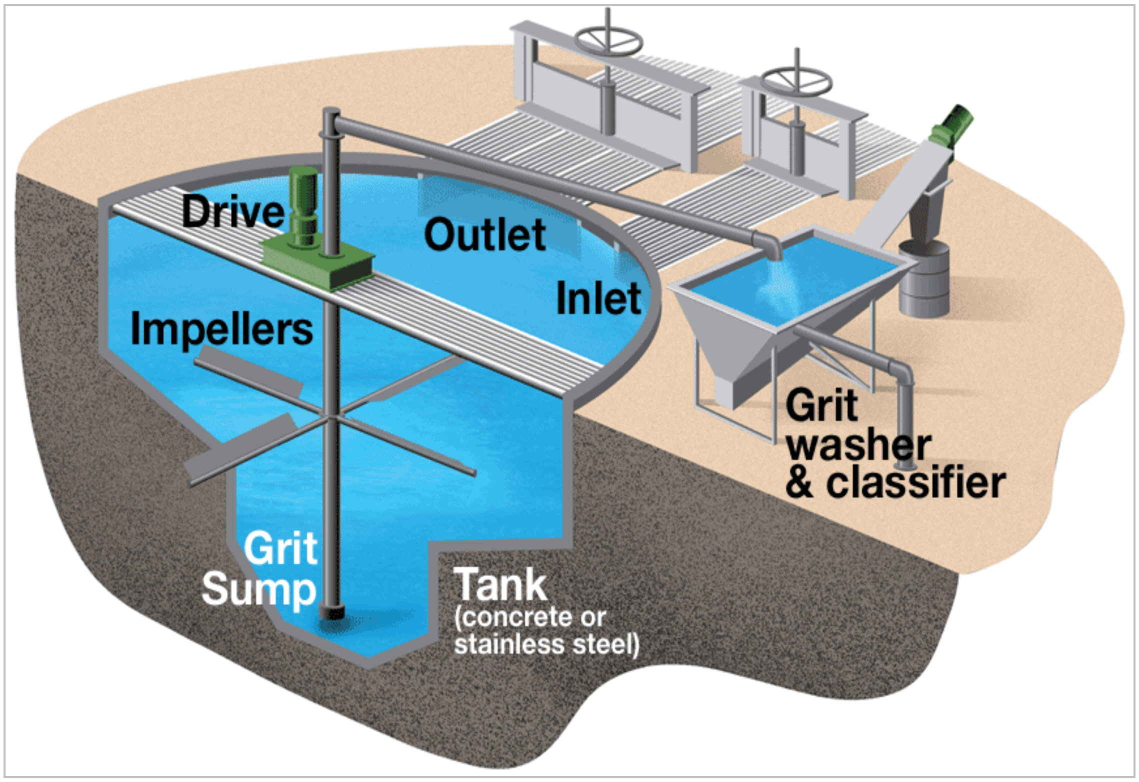


Figure 15. Vortex Grit Removal Device

Photo: JWC Environmental

Sedimentation/Floatation. Sedimentation typically involves a basin that slows the velocity of the water to allow solids to settle out, and floatable material (e.g., grease and oil) to float. The basin can be a pond, or it can be a concrete structure with mechanical components. The sediment and floatable material that collects in the basin is removed on a routine basis, depending on the actual load. Figure 16 shows two means of removing sediment and floatable material: Mechanical clarifiers and ponds. The collected material must be recycled or disposed in a landfill.

Sedimentation basins are not effective for removal of colloidal material or dispersed solids.


Figure 16. Sedimentation/Floatation – Mechanical Clarifier / Sedimentation Pond

Chemical Addition. Chemical addition is often used to remove dissolved or colloidal materials that might affect the intended use of the reclaimed stormwater. These materials could include nutrients, metals, and fine suspended solids. Chemical addition would involve chemicals that are used commonly in potable water treatment and would require on-site storage of chemicals and a chemical feed system. Chemicals might be in a liquid or solid form, depending on the material to be removed from the stormwater. Chemical addition would be integrated with sedimentation/floatation, or applied immediately prior to filtration. The chemical solids would need to be removed and disposed in a landfill.

Figure 17. Disc Filtration System

Filtration. Filtration is intended to remove solids, whether suspended or colloidal, that might affect the intended water use. Filtration might also be necessary as pretreatment for disinfection. Filters use a range of media for solids removal including cloth, sand, and plastic discs. More advanced forms of filtration such as microfilters could also be used. Figure 17 shows a plastic disc filter system that is common to agricultural irrigation practices. Solids that are collected on filter media would need to be removed routinely (typically automated) and disposed in a landfill.

Disinfection. There are no specific regulations for disinfection of stormwater for reclamation and reuse. However, end uses that would involve direct human contact might require disinfection. Though there are a number of possible disinfection methods, including ultraviolet radiation and ozonation, chlorination would likely be the most reliable for intermittent stormwater flows. Chlorine is commonly used for the disinfection of public swimming pools, public drinking water supplies, and treated wastewater. Since chlorine is a hazardous gas, security for the system would be necessary to protect from vandalism. Figure 18 shows a typical chlorination system.

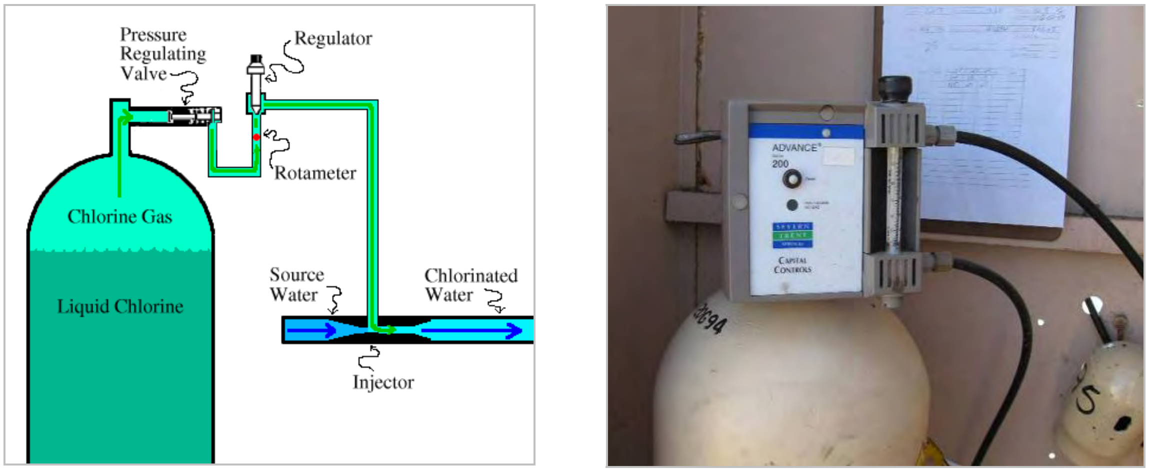


Figure 18. Chlorine Disinfection

Storage

Matching supply and demand is a critical issue for any type of water use. When it is raining, the water demand for irrigation of agricultural and recreational areas decreases. If desired stormwater cannot be conveyed from the point of collection to a point of immediate use, then some form of storage is necessary.

Figure 19. Portable Reservoirs

Storage can include open surface reservoirs, ponds, and above- or below-ground closed tank reservoirs. Aquifer storage and recovery can also be used, particularly for non-potable aquifers. Figure 19 shows an example of portable 50,000-gallon “storage bags” that could be used singly or in combination at multiple locations. Existing infrastructure that could be used potentially include tanks at abandoned wastewater treatment plants, and abandoned fuel storage reservoirs.

Distribution

Distribution systems convey reclaimed stormwater from storage to the point of application. Such systems would necessarily be non-potable. It might be necessary to add infrastructure that would connect reclaimed stormwater storage to existing distribution systems used for irrigation, such as parks, golf courses, and agricultural lands.

Integrated Infrastructure Use

It is possible that some infrastructure could be used for multiple purposes. Stormwater drainage and flood control channels are the best examples of the potential for multiple uses. Flood control channels are designed typically for 100-year storms. Consequently, the channel is oversized for most rainfall events.

Many of the flood control channels are long with standard geometrical shapes (e.g., trapezoidal and rectangular) that could serve a combination of uses including conveyance, treatment, and storage. This could be accomplished by using separation devices (such as the inflatable dam shown in Figure 20) to compartmentalize the channels for each need.

Some flood control channels have paved segments and some have both paved and native soil embankments. Using devices such as berms to pond water in the areas of native soil embankments could aid in groundwater recharge.

To accomplish integrated use of flood control channels effectively, it would be essential to have an operational strategy that would allow multiple uses of the channels, while eliminating any chance of upstream flooding.

Figure 20. Inflatable Dam

End Use

The end use of reclaimed stormwater could take many forms, but the most likely options are direct irrigation and non-potable groundwater recharge. Direct irrigation would likely integrate with existing irrigation systems for recreational areas, such as parks and golf courses, or agricultural areas. Reclaimed stormwater could have other end uses as well, depending on the level of treatment provided. Table 4 shows the level of treatment that would be required for various end uses, including groundwater recharge.

Table 4. Level of Treatment Required Based on End Use

End Use	Treatment						Comments
	Screening	Grit Removal	Sedimentation	Chemical Addition	Filtration	Disinfection	
Injection Well (Potable)	Y	Y	Y	Y	Y	Y	
Injection Well (Non-Potable)	Y	Y	Y	*	N	N	
Recharge Trench	Y	Y	Y	N	N	N	
Spreading Basin	Y	N	N	N	N	N	O&M required to ensure infiltration
Excavated Pond	Y	N	N	N	N	N	Series operation
Industrial Reuse	Y	Y	Y	Y	Y	N	
Direct Irrigation:							
Contact with edible portion of crop	Y	Y	Y	Y	Y	Y	Not specific to stormwater; based on Hawaii's recycled water guidelines
No contact with edible portion of crop	Y	Y	*	N	N	N	
Human contact	Y	Y	Y	Y	Y	Y	

* Depends on quality of stormwater

Groundwater recharge of stormwater could be used for several purposes:

- Establish saltwater intrusion barriers in coastal aquifers,
- Provide treatment for future reuse,
- Augment potable or nonpotable aquifers,
- Provide storage of stormwater for subsequent retrieval and reuse, and
- Control or prevent ground subsidence.

Guidance documents for stormwater recharge are sparse compared to those for the reclamation and indirect reuse of treated municipal wastewater. This report therefore relies heavily on the latter. This is a conservative approach, which may be relaxed when site-specific data are available in the feasibility and implementation stages. Many guidance documents are also designed for Mainland soils, vadose zone, and aquifer systems, which are typically alluvial sediments, composed of clay, silt, sand, and/or gravel, rather than Hawaiian volcanic and caprock terrains. As a result, Pacific Northwest, Northeast, or Florida state guidance documents may be more useful than desert Southwest state guidance documents. Site-specific investigation and pilot testing are therefore even more critical to ultimate project acceptance and success.

The specific groundwater recharge technique that is most suitable for a given location depends on a number of factors, including:

- Quality of the recharge water

- Topography
- Soil permeability
- Physical characteristics of the vadose zone
- Depth to groundwater
- Land zoning and availability
- Proximity to potential contaminant sites
- Underlying aquifer classification, characteristics (particularly vertical and horizontal permeability), and uses (potable vs. non-potable)
- Conveyance and storage infrastructure
- Proximity to critical habitats or historic cultural sites
- Water residence time and the amount of blending with other sources prior to extraction for use

The above factors are discussed as appropriate for each of the following recharge techniques.

Recharge Techniques

The appraisal considered a variety of groundwater recharge measures including: unlined canals, stream-bed enhancement, various surface recharge techniques (flooded fields, shallow spreading basins, and excavated basins), infiltration trenches, drywells, and injection wells. Based on cost, environmental setting, and the project goal of recharging periodic floodwaters, four primary measures were selected for detailed descriptions in this Appraisal:

- Surface spreading (including flooded fields or bermed shallow spreading basins)
- Excavated basins (including existing or new golf course ponds)
- Infiltration trenches (such as that present at the Honouliuli WWTP)
- Injection wells

These four methods are shown schematically in Figure 21.

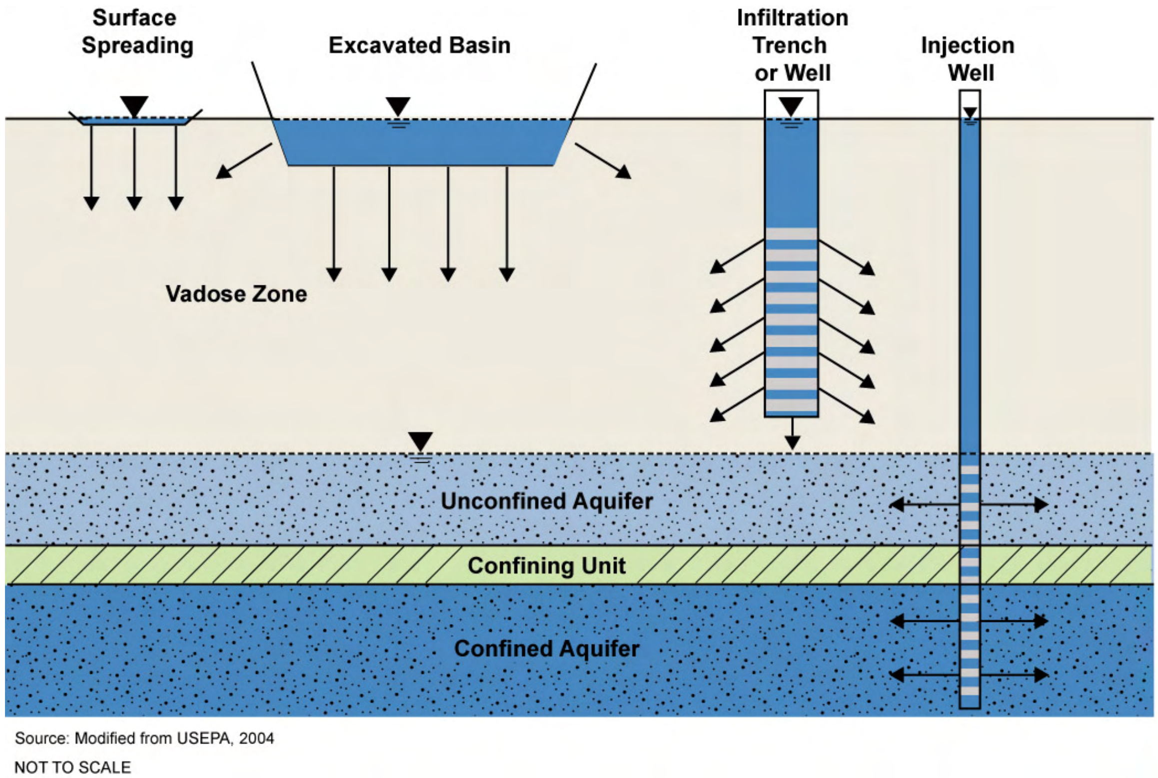


Figure 21. Recharge Techniques

In general, the selection of a recharge technique requires balancing competing factors. For example, the above list (from surface spreading to injection wells) would require decreasing land area and disturbance, but increasing levels of treatment for the same level of protection of the aquifer water quality. A comparison of the major factors for groundwater recharge methods is presented in Table 5.

Table 5. Comparison of Major Engineering Factors for Groundwater Recharge

	Surface Spreading	Excavated Basins	Vadose Zone Trenches or Wells	Direct Injection Wells
Aquifer type	Unconfined	Unconfined	Unconfined	Unconfined or confined
Pretreatment requirements	Minimal	Low technology	Removal of solids	High technology
Estimated major capital costs (US$)	Land and distribution system	Land, excavation and distribution system	$25,000-75,000 per well	$500,000-1,500,000 per well
Capacity	40-8,000 m^3/acre-day	40 - 8,000 m^3/acre-day	1,000-3,000 m^3/d per well	2,000-6,000 m^3/d per well
Maintenance requirements	Drying, scraping, and/or ripping	Drying and scraping	Drying and disinfection	Disinfection and flow reversal
Estimated life cycle	>100 years	>100 Years	5-20 Years	25-50 Years
Soil aquifer treatment	Surface soils, vadose zone and saturated zone	Vadose zone and saturated zone	Vadose zone and saturated zone	Saturated zone only
Subject to USEPA Class V UIC requirements	No	No	Sometimes	Yes

Source: Modified from USEPA, 2004

Surface Spreading

This measure involves applying water to a relatively undisturbed field and allowing it to infiltrate. Depending on water availability, the field could be flooded quickly to a standing depth of about 1 foot, or water could be delivered continuously at a rate that nearly matches the infiltration rate. The field may be surrounded by a small (two- to three-foot tall) berm and may also include several interior berms to regulate the water levels and flow across the field. Interior berms would be needed on gradually sloped sites. The ridge and furrow variation uses narrow ridges to maintain recharge rates even when the intervening flat bottom ditches plug over time, and is more suitable on sloping land. Figure 22 shows a conceptual layout for surface spreading.

This technique is most suitable in the following circumstances:

- Relatively flat to gentle terrains (< 3% slopes), which can be identified on USGS topographic maps
- Hard rocky terrains in which excavation would be expensive
- Areas with moderate (0.63 to 2.0 in/hr) to rapid (6.3 to 20.0 in/hr) soil permeability, which includes most basaltic terrains and much of the Ewa Plain Caprock
- Rural or open areas with land availability since it requires the most area/volume of infiltration
- Suitable geology such as an absence of impermeable layers between the surface and the water table aquifer
- Absence of surficial contamination, critical habitats or historic cultural sites
- A potable or non-potable aquifer
- If above a potable aquifer, an absence of expanding-contracting clays or fractures in the vadose zone that could allow short-circuiting of the soil horizon, and sufficient clay, organic-rich sediments, and/or available carbon for adsorption and biodegradation processes (or pretreatment).

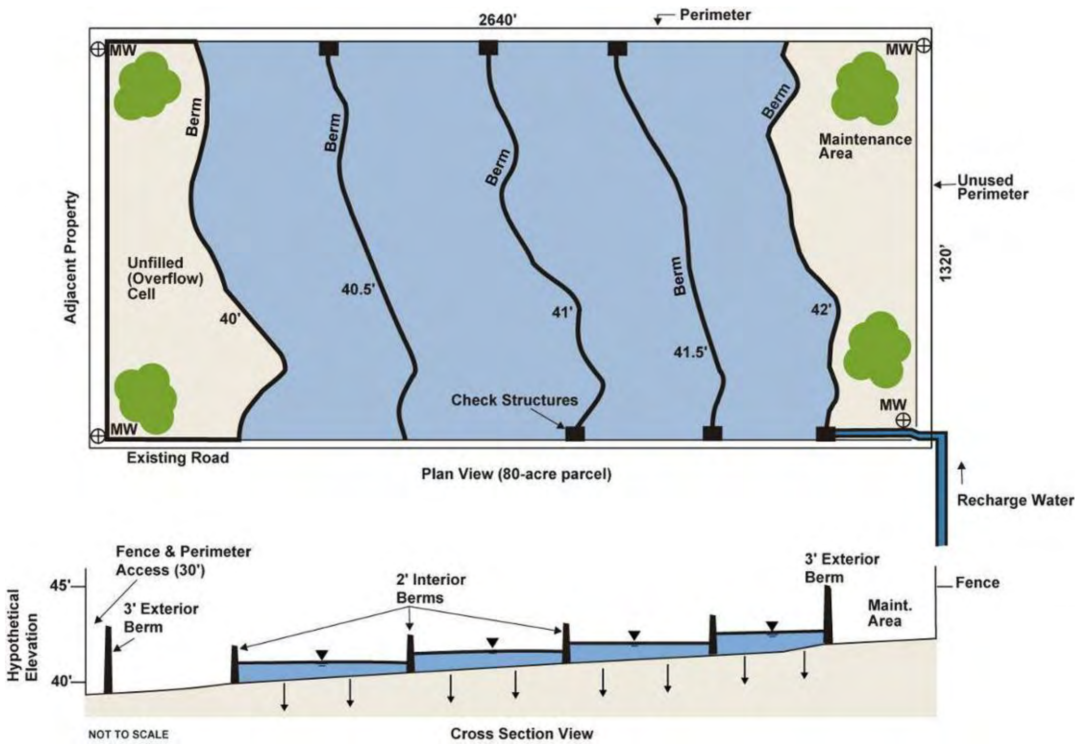


Figure 22. Spreading Basin Conceptual Design

Excavated Basins

This measure includes the construction of ponds or other basins by excavating to depths on the order of 10 to 20 feet below ground surface. This measure is most appropriate in areas where vertical impediments such as low permeability soils are thick or where existing ponds are present, such as at golf courses or parks, which may double as temporary stormwater storage facilities. This technique may be applicable in cases where additional purposes, such as flood control, can be developed, since the basins provide water storage. Since the amount of stormwater recharge is dependent on contact time of the water with the basin bottom, total recharge is typically higher than for surface spreading methods. Figure 23 shows a conceptual layout for excavated basins.

This technique is most suitable in the following circumstances:

- Vadose zones with moderate (0.63 to 2.0 in/hr) to rapid (6.3 to 20.0 in/hr) soil permeability, which includes most basaltic terrains and much of the Ewa Plain Caprock
- Rural or open areas with moderate to high land availability since it requires a moderate area/volume of infiltration
- Suitable geology such as an absence of impermeable layers between the base of the aquifer and the water table aquifer
- Absence of surficial contamination, critical habitats or historic cultural sites
- A potable or non-potable aquifer
- If above a potable aquifer, an absence of expanding-contracting clays or fractures in the vadose zone that could allow short-circuiting of the soil horizon, and sufficient clay, organic-rich sediments, and/or available carbon for adsorption and biodegradation processes (or pretreatment).

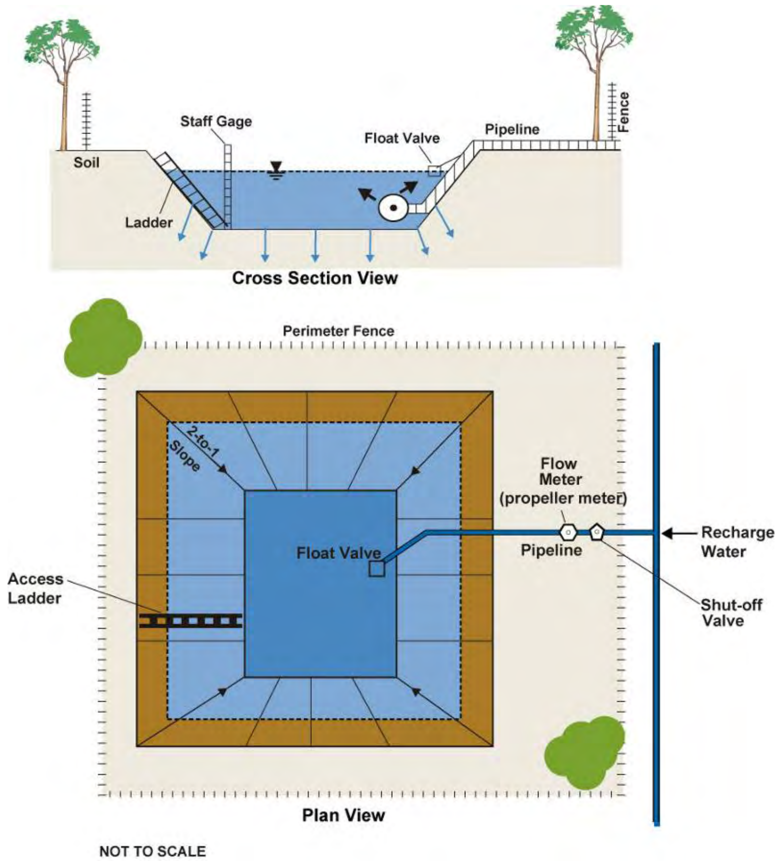


Figure 23. Excavated Basin Conceptual Design

Infiltration Trenches

Typical vadose zone infiltration trenches are wider than they are deep, and therefore are not considered Class V injection wells by the USEPA. They are backfilled with porous media. Water may enter at one end into a perforated pipe for distribution along the length of the trench. Alternatively a riser pipe is used to allow water to enter at the bottom of the infiltration trenches to prevent air entrainment. An advantage of vadose zone infiltration trenches is the significant cost savings as compared to direct injection wells. A significant disadvantage is that they cannot be backwashed and a severely clogged trench can be permanently destroyed. Therefore, reliable pretreatment is considered essential to maintaining the performance. Since vadose zone infiltration trenches allow for percolation of water through the vadose zone, water quality improvements commonly associated with soil aquifer treatment can be expected.

Dry wells, also known as vadose zone infiltration wells, are wells installed above the water table but below low permeability soils such as clay. The dry well typically contains a perforated pipe that extends from approximately 1-2 feet below ground surface to the bottom of the well. The entire well is filled with a permeable material, usually a gravel pack consisting of cobbles, which allows water to percolate through the well to lower, more permeable underlying soils, such as sand and gravel. Dry wells would be installed with a direct water supply to each well. Operation of infiltration trenches or wells would likely not cause any significant adverse environmental impacts. Figure 24 shows a conceptual layout for an infiltration trench.

This technique is most suitable in the following circumstances:

- Vadose zones with moderate (0.63 to 2.0 in/hr) to rapid (6.3 to 20.0 in/hr) soil permeability, which includes most basaltic terrains and much of the Ewa Plain Caprock
- Areas with moderate land availability since it requires a moderate area/volume of infiltration
- Suitable geology such an absence of impermeable layers between the base of the aquifer and the water table aquifer
- Absence of surficial contamination, critical habitats or historic cultural sites
- A potable or non-potable aquifer
- If above a potable aquifer, and absence of expanding-contracting clays or fractures in the vadose zone that could allow short-circuiting of the soil horizon, and sufficient clay, organic-rich sediments, and/or available carbon for adsorption and biodegradation processes (or pretreatment).

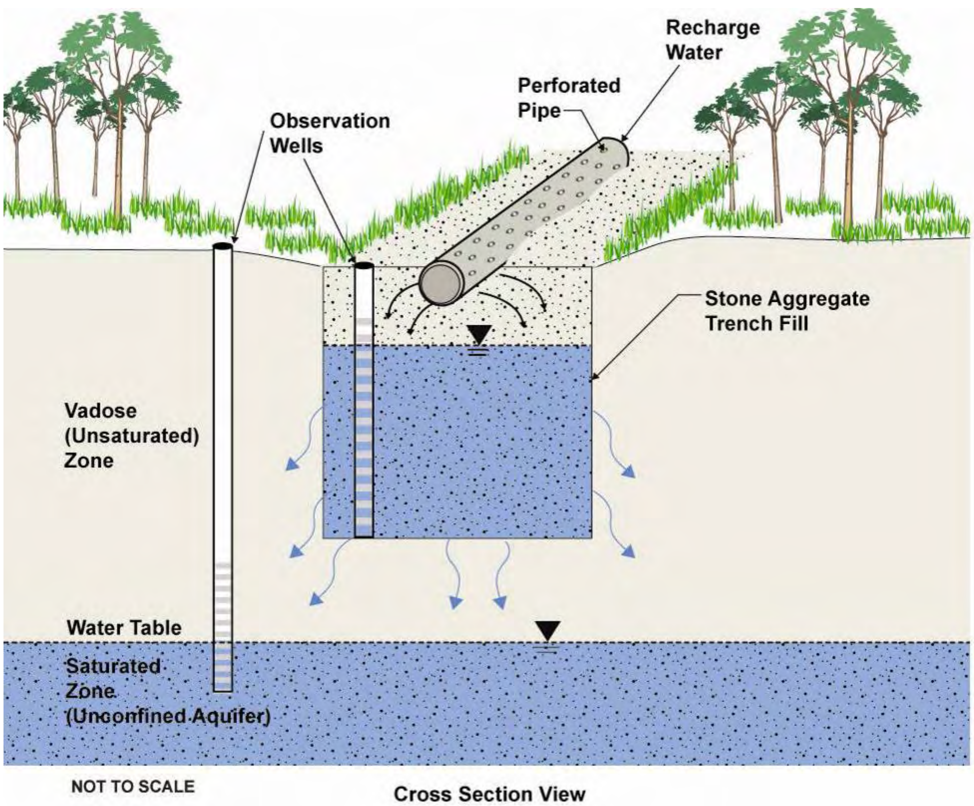


Figure 24. Recharge Trench Conceptual Design

Injection Wells

Direct injection involves conveying stormwater directly into the groundwater aquifer, which is usually a confined aquifer. Direct injection is used where groundwater is deep or where hydrogeological or other conditions are not conducive to surface spreading. Such conditions might include unsuitable soils of low permeability, unfavorable topography for construction of basins, the desire to recharge confined aquifers, or scarcity of land. Direct injection into a saline aquifer can create a freshwater “plume” from which water can be extracted for reuse, particularly in aquifer storage and recovery (ASR) systems. Direct injection is also an effective method for creating barriers against saltwater intrusion in coastal areas.

The Hawaii Department of Health (DOH) identifies Class V wells as those used to inject non-hazardous fluids underground. Most Class V wells are shallow disposal systems that depend on gravity to drain fluids directly in the ground. There are over 20 well subtypes that fall into the Class V category and these wells are used by individuals and businesses to inject a variety of non-hazardous fluids underground. The Class V well category includes complex injection wells that are typically deeper and often used at commercial or industrial facilities. Figure 25 shows a conceptual layout for an injection well.

This technique is most suitable in the following circumstances:

- Steep terrains and/or areas with slow or vadose zone permeability, which includes parts of the Ewa Plain Caprock
- Urban areas with limited land availability since it requires the least area/volume of infiltration
- Unsuitable geology for surface infiltration due to impermeable confining layers above the targeted aquifer
- Presence of surficial contamination, critical habitats or historic cultural sites since the surface disturbance is minimal
- A non-potable aquifer (since no soil or vadose zone treatment occurs).

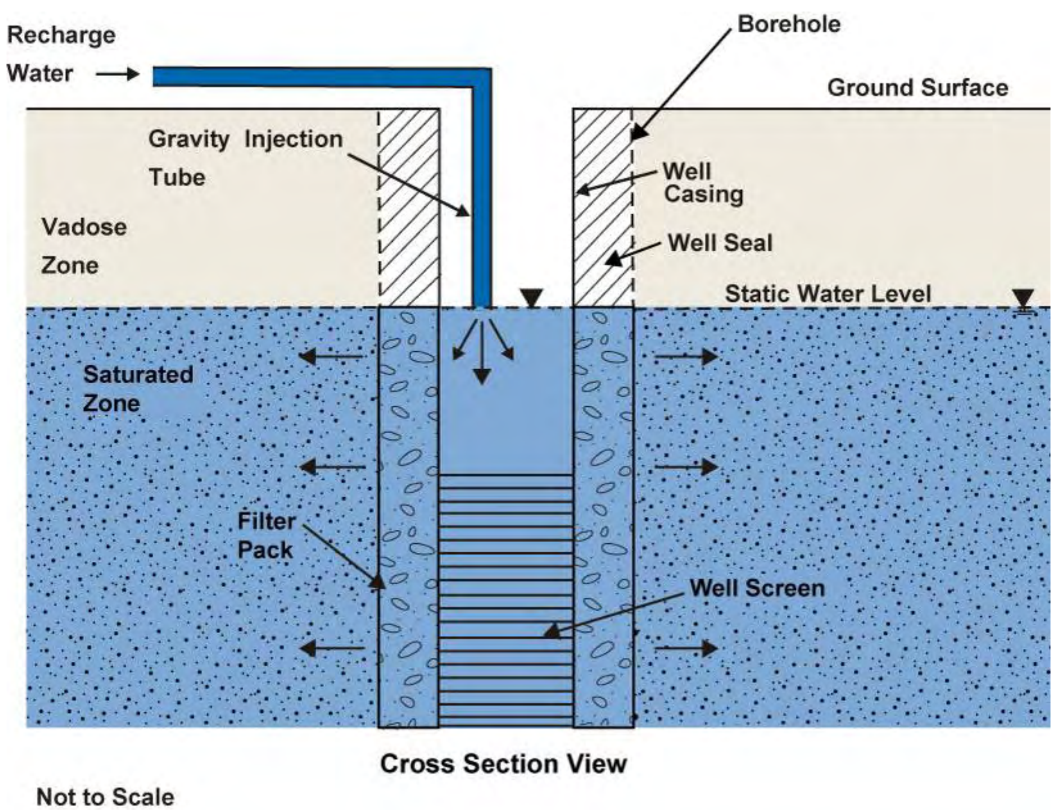


Figure 25. Injection Well Conceptual Design

Opportunity Development

The preceding information was used to develop stormwater reclamation and reuse opportunities. Fifteen opportunities outside the Ewa Plain on Oahu were identified and developed for Hawaii. The opportunities are listed below and are designated by an alphanumeric character for reference. The alphabetic character references the island on which they are located and the number references a specific opportunity on the island.

- O-1 - Wheeler Army Air Base and Schofield Barracks
- O-2 – Mililani North Stormwater Channel
- O-3 – Mililani South Stormwater Channel
- O-4 – Waipahu Stormwater Channel
- O-5 – Waikele Stormwater Channel
- O-6 – Nu'uanu Valley Surface Water
- O-7 – Palolo Stream Stormwater Channel
- E-7 – Waiahole Ditch Conveyance to Ewa Recharge Trench
- M-1 – Waiale Road Stormwater Drainage
- M-2 – Kahului Flood Control Channels
- M-3 – Kahoma Stream Flood Control
- M-4 – Lahaina Flood Control Channel
- K-1 – Nawilwili Diversion
- K-2 – Lihue Airport
- H-1 – Lower Hamakua Ditch.

A separate report, *An Appraisal of Stormwater Reclamation and Reuse Opportunities on the Ewa Plain of Oahu*, discusses five additional opportunities specific to the Ewa Plain. Opportunity E-7 (above) is located in the Ewa Plain, but is not a stand-alone opportunity. It is an additional consideration for integration with opportunities O-1, O-2, and O-3.

Each of the opportunities was evaluated for the criteria presented in Table 6. These criteria are discussed further in Opportunity Ranking.

Table 6. Opportunity Prioritization Criteria

Criterion	Discussion
Potential Reuse Demand	Potential reuse demand is determined by the amount of land that the opportunity could serve with non-potable water irrigation. The available land could include parks, golf courses, and agriculture. Opportunities adjacent to agricultural areas are given higher priority than opportunities located in urban areas.
Cost Estimate	Cost estimates based on bid tabulations from recent Oahu water projects were used to determine the potential cost of common elements associated with the opportunities, including unit cost of conveyance and collection pipe, reservoirs, infiltration trenches, and pumping stations. The cost estimates are not absolute planning level costs, but are relative costs to each opportunity.
Potential Stormwater Volume	The potential stormwater volume is based on the collection area of the opportunity and the annual average rainfall in the collection area.
Potential Partnerships	Potential partnerships include public agencies and private companies that would possibly support implementation of a stormwater reclamation and reuse opportunity through direct funding or indirect funding (e.g. use of land or existing infrastructure). Potential partnerships do not consider public water supply agencies that would benefit from reduced demand on potable water supplies since all opportunities would result in this benefit.
Likelihood of Implementation	Likelihood of implementation includes non-economic benefits and constraints associated with the opportunity, including, but not limited to, public acceptance and environmental impacts.
Institutional Constraints	Institutional constraints include policies, regulations, laws, and social or cultural issues that would be potential barriers to implementation of any opportunity. They also include potential barriers from agencies that are responsible for infrastructure associated with the opportunity.

Each of the opportunities listed above is presented in a tabular format in Tables 7 through 21 on the following pages and are supported with figures showing their locations.

Table 7. O-1 - Wheeler Army Air Base and Schofield Barracks

Description	This opportunity involves stormwater collection from the Wheeler Army Air Force Base and uses Waiahole Ditch for conveyance to users. It includes the potential to use a significant amount of existing infrastructure for collection, treatment, storage, and conveyance of stormwater: ▪ Collection of stormwater from the impervious area (approximately 190 acres) associated with the Wheeler Army Air Base runway, helicopter pads, and support buildings. ▪ Treatment using existing, but discontinued use, clarifiers at the Schofield Barracks Wastewater Treatment Plant (WWTP). ▪ Storage in former Waikakalaua Fuel Annex underground oil storage reservoirs. ▪ Conveyance to points of use in the Kunia and Ewa Plains areas by means of Waiahole Ditch.
Figure	Figure 26. O-1 - Wheeler Army Air Base and Schofield Barracks
Existing Infrastructure	▪ Three clarifiers at the Schofield Barracks WWTP for sedimentation and scum removal. ▪ Nine, 1.8 million gallon (16.2 million gallon total) underground storage tanks used formerly for oil storage. ▪ Waiahole Ditch.
Needed Infrastructure	▪ Pipelines to connect the existing infrastructure from the point of stormwater collection to discharge into Waiahole Ditch. ▪ Preliminary treatment (e.g., screening) to remove debris and coarse material from stormwater before entering the clarifiers at the WWTP. ▪ Pumping station to pump from underground storage to Waiahole Ditch.
Benefits	▪ Uses existing infrastructure to mitigate cost of implementation. ▪ Use of Waikakalaua Fuel Annex storage helps balance supply and demand issues. ▪ Potential for gravity flow from point of collection to storage. ▪ Potential for integration with R-1 recycled water (see Additional Considerations). ▪ Large number of potential users. ▪ Potential reduction of water from Windward Oahu, allowing streamflow restoration.
Issues Needing Resolution	▪ Condition of underground storage tanks. ▪ Buy-in of key stakeholders. ▪ Determination of potential stormwater volume. ▪ Means of interception stormwater conveyance points from the airfield to the WWTP.

Table 7. O-1 - Wheeler Army Air Base and Schofield Barracks (continued)

<table>
<tr><td rowspan="1">Stakeholders</td><td colspan="2">Key Stakeholders:
▪ U.S. Army – Owner of Wheeler Army Air Force Base and underground storage tanks.
▪ Aqua Engineers – Owner and operator of the Schofield Barracks WWTP.
▪ Agribusiness Development Corporation (ADC) – Owner and operator of Waiahole Ditch.
Potential Stakeholders:
▪ BWS.
▪ CCH Department of Environmental Services – Owner and operator of the Wahiawa WWTP.</td></tr>
<tr><td rowspan="7">Ranking Considerations</td><td>Ranking Criterion</td><td>Discussion</td></tr>
<tr><td>Potential Reuse Demand</td><td>This opportunity could provide reclaimed stormwater to the Kunia agricultural areas in Central Oahu.
If combined with opportunity E-7, it could also provide groundwater recharge for the non-potable caprock aquifer in the Ewa Plain.</td></tr>
<tr><td>Potential Stormwater Volume</td><td>The collection area for this opportunity is approximately 190 acres of impervious surface area. The area could be doubled if grassy areas subject to sheet flow of stormwater were included. The average annual rainfall is approximately 40 to 50 inches.</td></tr>
<tr><td>Potential Partnerships</td><td>Potential partners for this opportunity include:
▪ U.S. Army
▪ Aqua Engineers
▪ State of Hawaii Agribusiness Development Corporation</td></tr>
<tr><td>Likelihood of Implementation</td><td>Reducing stormwater flow will help reduce pollutant load into Pearl Harbor, which is on the State of Hawaii's 303(d) List of Impaired waters, and will likely be subject to maximum daily loads.
If this opportunity is coupled with Opportunity E-7, the available stormwater could be reused beneficially irrespective of reuse demand for irrigation.</td></tr>
<tr><td>Institutional Constraints</td><td>No institutional constraints have been identified for this opportunity.</td></tr>
<tr><td>Cost Estimate</td><td>$8.3 million
Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.</td></tr>
<tr><td>Additional Considerations</td><td colspan="2">Both the Schofield Barracks and Wahiawa WWTPs are capable of producing R-1 recycled water. Both lack pipelines presently to convey recycled water to points of use such as Mililani Golf Course, Central Oahu Regional Park (Patsy Mink Park), a proposed development in Waiawa, and other greenspace. Likely routes for pipelines from both facilities would be along Kamehameha Highway, which crosses Waiahole Ditch. An alternative for the Schofield Barracks pipeline could extend the same route as the stormwater pipeline identified in this opportunity, which would permit integration of stormwater and recycled water for conveyance through Waiahole Ditch.</td></tr>
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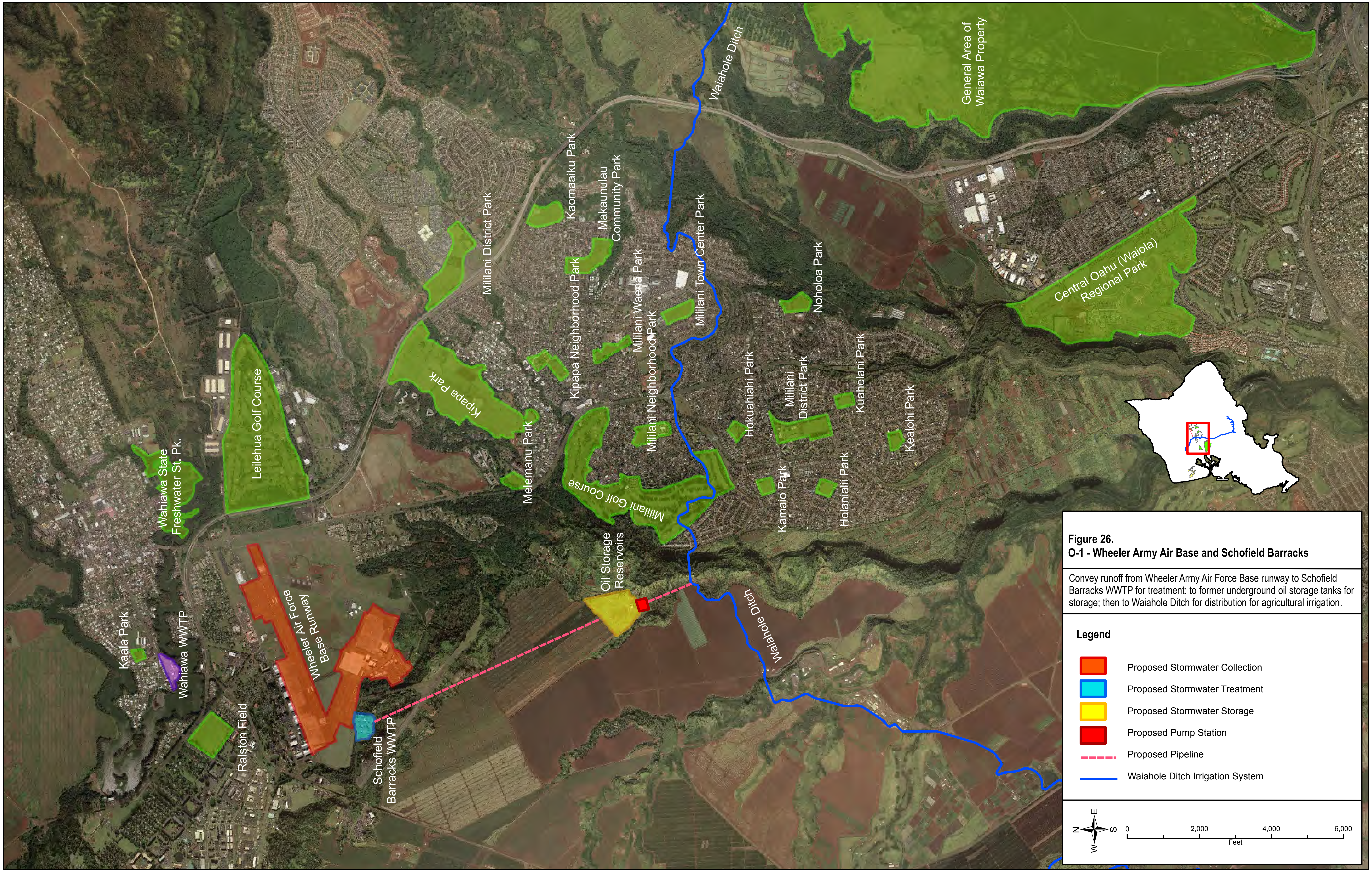


Figure 26.
O-1 - Wheeler Army Air Base and Schofield Barracks

Convey runoff from Wheeler Army Air Force Base runway to Schofield Barracks WWTP for treatment: to former underground oil storage tanks for storage; then to Waiahole Ditch for distribution for agricultural irrigation.

Table 8. O-2 – Mililani North Stormwater Channel

Description	This opportunity involves stormwater collection from a large urban area north of Waiahole Ditch (estimated at 650 acres). It includes the potential to use existing infrastructure for collection and conveyance of stormwater, but would need additional infrastructure for treatment, and storage if desired: ▪ Use of existing stormwater collection system to collect stormwater from the urban area north of Waiahole Ditch. ▪ Use of the stormwater channel that drains this area to pool water for pumping. ▪ Construction of a screening/grit removal facility and pumping station. ▪ Discharge to Waiahole Ditch for conveyance to downstream uses or use at Mililani Agricultural Park.
Figure	Figure 27. Mililani Stormwater Channel Locations Figure 28. O-2 - Mililani North Stormwater Channel
Existing Infrastructure	▪ Existing stormwater collection infrastructure north of Waiahole Ditch and the stormwater channel. ▪ Concrete-lined stormwater channel that currently conveys stormwater to Poliwai Gulch.
Needed Infrastructure	▪ Flow regulation dam or diversion in the stormwater channel. ▪ Screening and grit removal treatment as a minimum.
Benefits	▪ Reduce stormwater runoff and pollution. ▪ Collects stormwater from a large impervious urban area. ▪ Adjacent to Waiahole Ditch, a conveyance system for large farming operations.
Issues Needing Resolution	▪ Buy-in of key stakeholders. ▪ Determination of potential stormwater volume. ▪ Operational plan to maximize storage in channel without flooding and to prevent excess flow in Waiahole Ditch. ▪ Best management practices plan for reducing stormwater contamination. ▪ Capacity of Waiahole Ditch for conveyance.
Stakeholders	*Key Stakeholders:* ▪ CCH Department of Public Works – Manages stormwater collection system. ▪ Mililani Golf Course - Pipeline would need to cross part of course. ▪ ADC – owner of Waiahole Ditch ▪ Mililani Agricultural Park – Manages farming operation in Mililani.

Table 8. O-2 – Mililani North Stormwater Channel (continued)

Ranking Considerations	Ranking Criterion	Discussion
	Potential Reuse Demand	This opportunity could provide reclaimed stormwater to the following areas: ▪ Kunia agricultural areas ▪ Mililani Agricultural Park ▪ Mililani Golf Course
	Potential Stormwater Volume	The collection area for this opportunity is greater than 650 acres. The size of the stormwater channel suggests a much bigger collection area, but poorly defined GIS layers for stormwater collection make it difficult to determine. The average annual rainfall is approximately 30 to 40 inches.
	Potential Partnerships	Potential partners for this opportunity include: ▪ Mililani Agricultural Park ▪ State of Hawaii ADC
	Likelihood of Implementation	Reducing stormwater flow will help reduce pollutant load into Pearl Harbor, which is on the State of Hawaii's 303(d) List of Impaired waters, and will likely be subject to maximum daily loads. If this opportunity is coupled with Opportunity E-7, the available stormwater could be reused beneficially irrespective of reuse demand for irrigation.
	Institutional Constraints	The channel is owned and maintained by the CCH. When the opportunity was reviewed with them they expressed concern about any attempt to pool water in the channel, stating that the channel is undersized for a 100-year storm due to growth in the service area without expansion of the channel.
	Cost Estimate	$9.4 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	This opportunity could also incorporate use of the former Waikakalaua Fuel Annex underground oil storage reservoirs identified in Opportunity O-1. The modification would require an additional pump station on the west side of Poliwai Gulch to convey the water from Waiahole Ditch to the reservoirs. This modification is shown in Figure 29.	

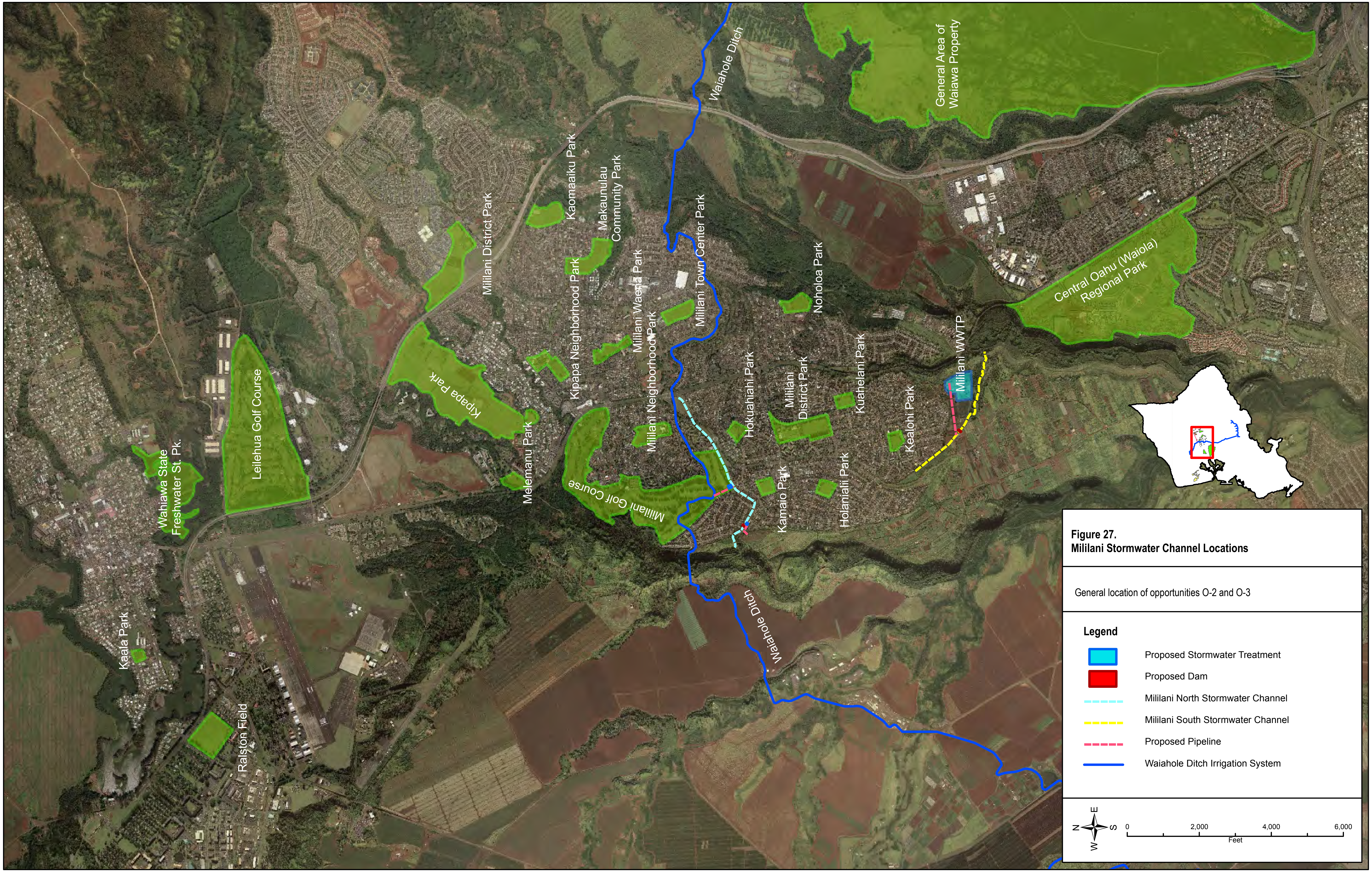


Figure 27.
Mililani Stormwater Channel Locations

Figure 28.
O-2 - Mililani North Stormwater Channel

Collect stormwater in a stormwater drainage channel for use at Mililani Golf Course, Mililani Agricultural Park, or for agricultural irrigation in the Kunia area via Waiahole Ditch.


Oil Storage Reservoirs
Kipapa Neighborhood Park
Mililani Golf Course
Mililani Waena Park
Mililani Neighborhood Park
Mililani Town Center Park
Waiahole Ditch
Hokuahiahi Park
Kamaio Park
Figure 29.
O-2 Alternative - Mililani North Stormwater Channel
Collect stormwater in a stormwater drainage channel for pumping to Waiahole Ditch and then to former underground oil storage tanks for stroage until needed.
Legend
Proposed Stormwater Treatment
Proposed Dam
Proposed Stormwater Storage
Proposed Pump Station
Mililani North Stormwater Channel
Proposed Pipeline
Waiahole Ditch Irrigation System
N
W
E
S
0
500
1,000
1,500
2,000
Feet

Table 9. O-3 – Mililani South Stormwater Channel

Description	This opportunity involves stormwater collection from a large urban area south of Waiahole Ditch (estimated at 640 acres). It includes the potential to use existing infrastructure for collection, treatment, storage, and conveyance of stormwater, but improvements would be needed for treatment and storage: ▪ Use of existing stormwater collection system to collect stormwater from the urban area north of Waiahole Ditch. ▪ Use of the stormwater channel that drains this area to pool stormwater. ▪ Use of the Mililani WWTP (currently abandoned) to treat and store stormwater. ▪ Use for irrigation at Mililani Agricultural Park.
Figure	Figure 27. Mililani Stormwater Channel Locations Figure 30. O-3 - Mililani South Stormwater Channel
Existing Infrastructure	▪ Existing stormwater collection infrastructure south of Waiahole Ditch and the stormwater channel. ▪ Concrete-lined stormwater channel that currently conveys stormwater to Kipapa Gulch. ▪ Mililani WWTP (currently abandoned except for on-site pumping station) for treatment and some storage.
Needed Infrastructure	▪ Flow regulation dam or diversion in the stormwater channel. ▪ Pipeline from stormwater channel to treatment facility. ▪ Mechanical/structural rehabilitation of processes at Mililani WWTP. ▪ Reclaimed stormwater distribution pipeline.
Benefits	▪ Reduce stormwater runoff and pollution. ▪ Collects stormwater from a large impervious urban area. ▪ Adjacent to large farming operations.
Issues Needing Resolution	▪ Buy-in of key stakeholders. ▪ Determination of potential stormwater volume. ▪ Operational plan to maximize storage in channel without flooding. ▪ Condition and rehabilitation of Mililani WWTP infrastructure. ▪ Best management practices plan for reducing stormwater contamination.
Stakeholders	*Key Stakeholders:* ▪ CCH Department of Public Works – Manages stormwater collection system. ▪ CCH Department of Environmental Services – Owner of the Mililani WWTP. ▪ Mililani Neighborhood Association – Neighbors adjacent to Mililani WWTP. ▪ Mililani Agricultural Park – Manages farming operations in Mililani.

Table 9. O-3 – Mililani South Stormwater Channel (continued)

	Ranking Criterion	Discussion
Ranking Considerations	Potential Reuse Demand	This opportunity could provide reclaimed water to Mililani Agricultural Park.
	Potential Stormwater Volume	The collection area for this opportunity is approximately 640 acres. The average annual rainfall is approximately 30 to 40 inches.
	Potential Partnerships	Mililani Agricultural Park is a potential partner for this opportunity.
	Likelihood of Implementation	Reducing stormwater flow will help reduce pollutant load into Pearl Harbor, which is on the State of Hawaii's 303(d) List of Impaired waters, and will likely be subject to maximum daily loads. Citizens in the Mililani area have expressed concern about re-starting the Mililani WWTP for treating wastewater. Since stormwater does not have the same issues associated with it (except perhaps for solids transport), objections for converting the plant to a stormwater treatment facility might not occur.
	Institutional Constraints	The channel is owned and maintained by the CCH. When the opportunity was reviewed with them they expressed concern about any attempt to pool water in the channel, stating that the channel is undersized for a 100-year storm due to growth in the service area without expansion of the channel.
	Cost Estimate	$5.1 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	There has been some consideration given to developing the Mililani WWTP as a wastewater "scalping" facility to produce recycled water, but the neighbors have been against it historically. If it were upgraded for wastewater treatment, stormwater reclamation and reuse could be integrated into the design.	

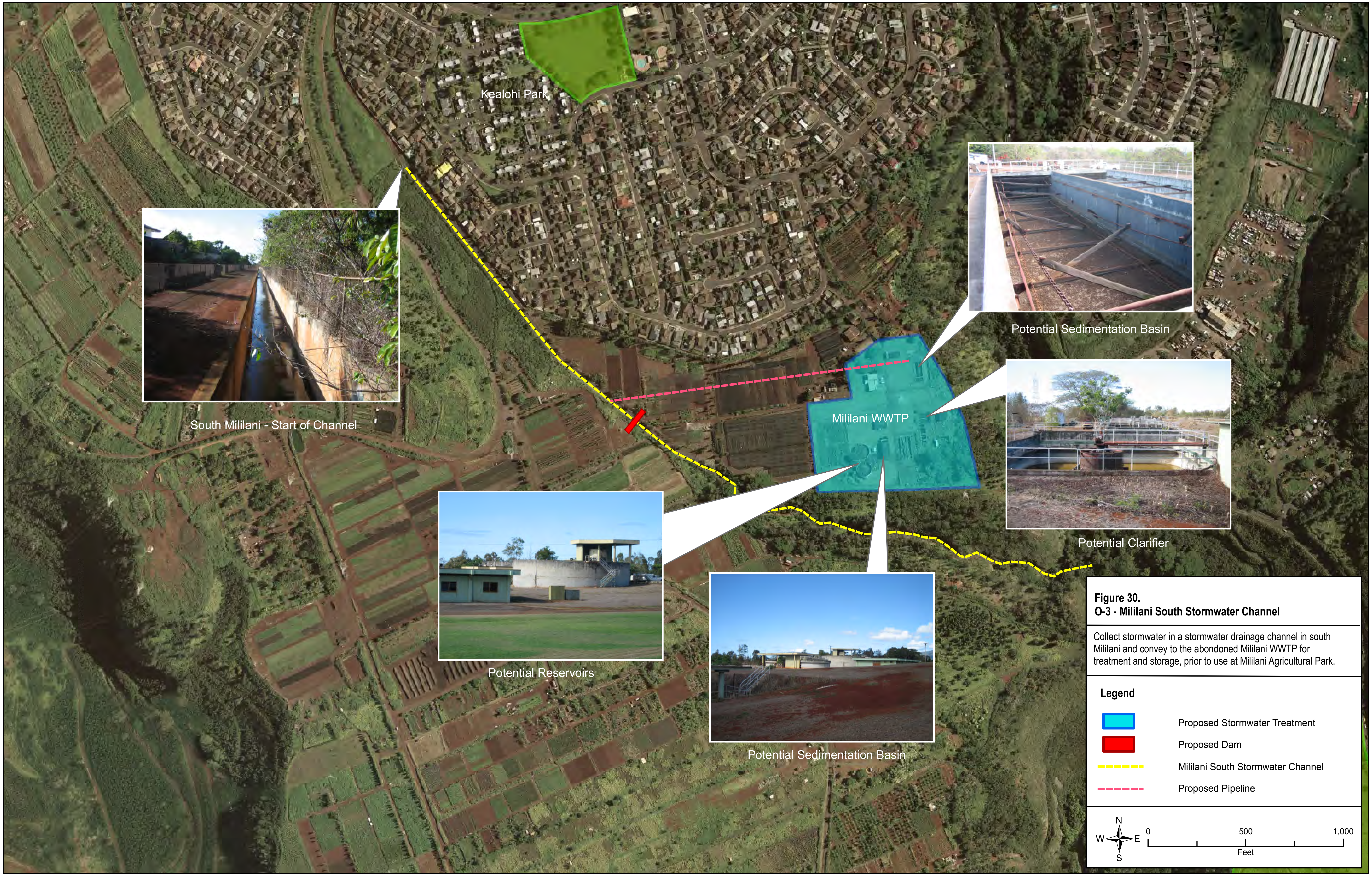


Figure 30.
O-3 - Mililani South Stormwater Channel

Collect stormwater in a stormwater drainage channel in south Mililani and convey to the abondoned Mililani WWTP for treatment and storage, prior to use at Mililani Agricultural Park.

Table 10. O-4 – Waipahu Stormwater Channel

Description	This opportunity involves stormwater collection in Waipahu between the H-1 freeway and Paiwa Street and using the water for irrigation at the Waikele Golf Course and Ted Makalena Golf Course.
Figure	Figure 31. Waikele/Waipahu Area Figure 32. O-4 - Waipahu Stormwater Channel
Existing Infrastructure	▪ Stormwater channel extending from Waikele Golf Club to Ted Makalena Golf Course.
Needed Infrastructure	▪ Flow regulation dam in the stormwater channel. ▪ Screening and grit removal treatment as a minimum. ▪ Pumping station and pipeline to both golf courses.
Benefits	▪ Reduce stormwater runoff and pollution. ▪ Collects stormwater from a large impervious urban area. ▪ Augments potable water use for golf course irrigation.
Issues Needing Resolution	▪ Buy-in of key stakeholders. ▪ Determination of potential stormwater volume. ▪ Operational plan to maximize storage in channel without flooding. ▪ Area of tidal influence in stormwater channel. ▪ BMPs plan for reducing stormwater contamination.
Stakeholders	*Key Stakeholders:* ▪ Waikele Golf Club – Owner and operator of Waikele Golf Course. ▪ CCH Department of Parks and Recreation – Owner and operator of Ted Makalena Golf Course and Waipio Soccer Complex. ▪ Hawaii Department of Transportation – Owner and operator of the stormwater channel.

Table 10. O-4 – Waipahu Stormwater Channel (continued)

Ranking Considerations	Ranking Criterion	Discussion
	Potential Reuse Demand	This opportunity could provide reclaimed stormwater to the following areas: ▪ Waikele Golf Course ▪ Ted Makalena Golf Course ▪ Waipio Soccer Complex
	Potential Stormwater Volume	The collection area for this opportunity is approximately 470 acres that receives an annual average rainfall of approximately 30 inches per year.
	Potential Partnerships	No potential partners for this opportunity were identified. Though it could serve three different recreational complexes, there is no apparent incentive for the operators of these complexes to change their source water used for irrigation.
	Likelihood of Implementation	Reducing stormwater flow will help reduce pollutant load into Pearl Harbor, which is on the State of Hawaii's 303(d) List of Impaired waters, and will likely be subject to maximum daily loads. Implementation could possibly result in a reduction in stream flow from Waikele Stream, which is supplying irrigation water currently to Ted Makalena Golf Course and Waipio Soccer Complex.
	Institutional Constraints	The channel is owned and maintained by the Hawaii Department of Transportation. When the opportunity was reviewed with them they expressed concern about any attempt to pool water in the channel, stating that the channel is undersized for a 100-year storm due to growth in the service area without expansion of the channel.
	Cost Estimate	$9.9 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	None	

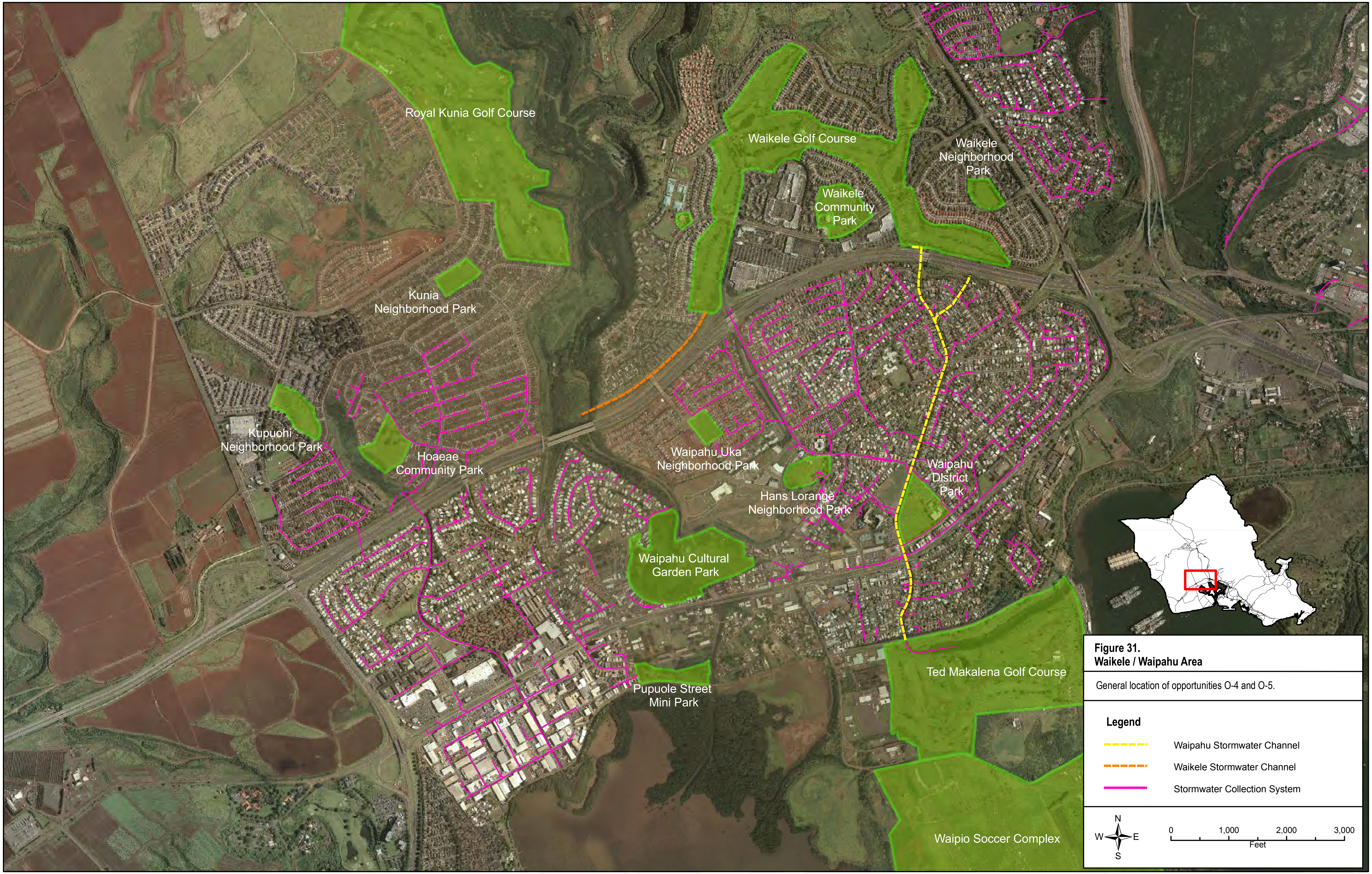


Figure 31.
Waikele / Waipahu Area

General location of opportunities O-4 and O-5.

Figure 32.
O-4 - Waipahu Stormwater Channel

Collect stormwater in a stormwater drainage channel and convey it to Waikele Golf course, Ted Makalena Golf Course, or Waipio Soccer Complex for irrigation.

Table 11. O-5 – Waikele Stormwater Channel

Description	This opportunity would collect stormwater in a stormwater drainage channel and convey to Waikele Golf Course for irrigation.
Figure	Figure 31. Waikele/Waipahu Area Figure 33. O-5 - Waikele Stormwater Channel.
Existing Infrastructure	▪ Concrete-lined stormwater drainage channel located north of H-1 freeway and south of multi-family residential complex in Waikele.
Needed Infrastructure	▪ Diversion structure, pumping station, and 3.0 million gallon reservoir. ▪ Screening and grit removal treatment as a minimum.
Benefits	▪ Replace approximately 700,000 gallons per day of groundwater with stormwater reuse during periods when stormwater can be collected and stored. ▪ Reduce stormwater pollutant discharges to Pearl Harbor
Issues Needing Resolution	▪ Buy-in of key stakeholders ▪ Determination of potential stormwater volume. ▪ Location of a reservoir to receive and distribute the reclaimed stormwater. ▪ Disconnection of the existing potable water distribution system at the Waikele Golf Course from the irrigation system.
Stakeholders	*Key Stakeholders:* ▪ CCH Department of Public Works – Owner and operator of the stormwater drainage channel. *Potential Stakeholders:* ▪ Waikele Golf Club – Owner and operator of golf course.

Table 11. O-5 – Waikele Stormwater Channel (continued)

	Ranking Criterion	Discussion
Ranking Considerations	Potential Reuse Demand	Waikele Golf Club is the only potential user of reclaimed stormwater from the drainage channel.
	Potential Stormwater Volume	The drainage channel receives stormwater from impervious surface of a large residential/commercial area that receives between 30 and 40 inches per year of rainfall.
	Potential Partnerships	The Honolulu Board of Water Supply is a potential partner since implementation would reduce groundwater pumping as much as 700,000 gallons per day during certain periods. There is little incentive for the end user to switch from potable water.
	Likelihood of Implementation	Reducing stormwater flow will help reduce pollutant load into Pearl Harbor, which is on the State of Hawaii's 303(d) List of Impaired waters, and will likely be subject to maximum daily loads.
	Institutional Constraints	The channel is owned and maintained by the CCH. When the opportunity was reviewed with them they expressed concern about any attempt to pool water in the channel, stating that the channel is undersized for a 100-year storm due to growth in the service area without expansion of the channel.
	Cost Estimate	$9.5 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	Stormwater from the Waikele Stormwater Channel could also be used to irrigate Central Oahu Regional Park (Patsy Mink Park) but would require additional piping and potential disruption to public infrastructure.	

Figure 33.
O-5 - Waikele Stormwater Channel

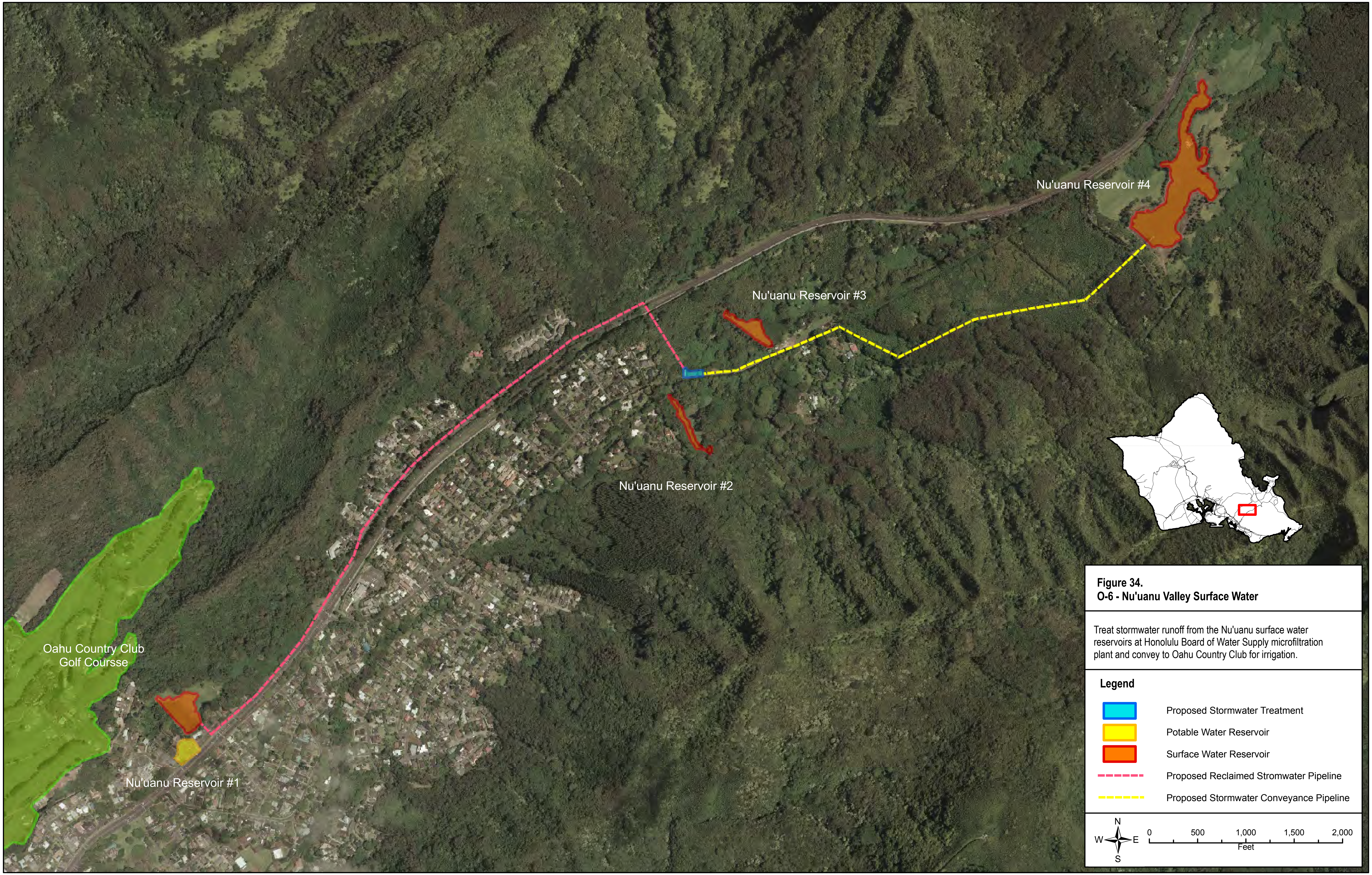
Collect stormwater in a stormwater drainage channel and convey to Waikele Golf Course for irrigation.

Table 12. O-6 - Nu'uanu Valley Surface Water

Description	This opportunity would use existing surface water reservoirs in the Nu'uanu Valley and an out-of-service potable water microfiltration plant to treat stormwater for irrigation use at Oahu Country Club Golf Course. ▪ Collect surface water (stormwater) runoff in the Nu'uanu surface water reservoirs. ▪ Convey the collected runoff to the Nu'uanu Microfiltration Plant for treatment. ▪ Convey the treated stormwater to the Oahu Country Club Golf Course for storage and use.
Figure	Figure 34. O-6 - Nu'uanu Valley Surface Water
Existing Infrastructure	▪ Existing surface water reservoirs: Nu'uanu #2, Nu'uanu #3, and Nu'uanu #4 ▪ Nu'uanu Microfiltration Plant for treatment of stormwater
Needed Infrastructure	▪ Repairs and connections to existing pipeline to convey stored water from Nu'uanu Reservoirs #3 and #4 to the Nu'uanu Microfiltration Plant ▪ Pipeline to convey reclaimed stormwater from Nu'uanu Microfiltration Plant to Oahu Country Club Golf Course ▪ Storage reservoir at Oahu Country Club Golf Course
Benefits	▪ Replace approximately 0.06 mgd of groundwater with surface water.
Issues Needing Resolution	▪ Buy-in of key stakeholders. ▪ Determination of potential stormwater volume. ▪ Liability issues associated with operating the surface water reservoirs at optimum levels. The BWS wants to sell or transfer ownership of the reservoirs due to liability concerns. ▪ Routing of pipeline from the Nu'uanu Microfiltration Plant to the Oahu Country Club Golf Course.
Stakeholders	*Key Stakeholders:* ▪ BWS – Owner and operator of the Nu'uanu reservoirs and the Nu'uanu Microfiltration Plant. ▪ Oahu Country Club Golf Course – End user of the reclaimed stormwater.

Table 12. O-6 - Nu'uanu Valley Surface Water (continued)

	Ranking Criterion	Discussion
Ranking Considerations	Potential Reuse Demand	This opportunity would provide reclaimed stormwater to Oahu Country Club.
	Potential Stormwater Volume	The reservoirs discussed in this opportunity are fed by runoff from areas in the Ko'olau Range that can exceed 100 inches per year.
	Potential Partnerships	BWS is a potential partner for this opportunity. The benefit to the BWS would be very limited unless Nu'uanu Stream were used to convey the stormwater to urban Honolulu for reuse.
	Likelihood of Implementation	Installation of a pipeline to convey the reclaimed stormwater from the microfiltration plant to Oahu Country Club might cause public inconvenience, including traffic disruption and right-of-way issues.
	Institutional Constraints	Extending a pipeline across Pali Highway would require approval of the Hawaii Department of Transportation. Use of Nu'uanu Stream as a means of conveyance would require a permit to divert the flow from the stream for reuse.
	Cost Estimate	$11.9 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	The pipeline that conveys the treated stormwater from the microfiltration plant to the golf course could be used for irrigation of median strips and other green space along Pali Highway. Nu'uanu Stream could be used to convey stormwater to urban Honolulu for broader opportunities but would require a stream diversion.	



Nu'uanu Reservoir #4
Nu'uanu Reservoir #3
Nu'uanu Reservoir #2
Oahu Country Club
Golf Coursse
Nu'uanu Reservoir #1
Figure 34.
O-6 - Nu'uanu Valley Surface Water
Treat stormwater runoff from the Nu'uanu surface water reservoirs at Honolulu Board of Water Supply microfiltration plant and convey to Oahu Country Club for irrigation.
Legend
Proposed Stormwater Treatment
Potable Water Reservoir
Surface Water Reservoir
Proposed Reclaimed Stromwater Pipeline
Proposed Stormwater Conveyance Pipeline
N
W
E
S
0
500
1,000
1,500
2,000
Feet

Table 13. O-7 – Palolo Stream Stormwater Channel

Description	This opportunity would divert stormwater from two locations in the concrete-lined portions of Palolo Stream for irrigation at parks and institutions.
Figure	Figure 35. O-7 - Palolo Stream Stormwater Channel
Existing Infrastructure	▪ Concrete lined channel extending through Palolo Valley.
Needed Infrastructure	▪ Two diversions. ▪ Two pump stations for conveying the stormwater to treatment/storage. ▪ One 3.0 million gallon reservoir. ▪ Screening and grit removal treatment as a minimum.
Benefits	▪ Provide irrigation to a park and an educational institution
Issues Needing Resolution	▪ Buy-in of key stakeholders. ▪ Location of the diversions, pump stations, and reservoir. ▪ Disconnection of the existing potable water distribution system from the irrigation systems at Palolo District Park and Chaminade University.
Stakeholders	*Key Stakeholders:* ▪ CCH Department of Public Works – Manages stormwater collection system. ▪ CCH Department of Parks and Recreation – Manages Palolo Valley District Park. *Potential Stakeholders:* ▪ Chaminade University – Administers institutional sports fields and landscaping.

Table 13. O-7 – Palolo Stream Stormwater Channel (continued)

	Ranking Criterion	Discussion
Ranking Considerations	Potential Reuse Demand	Reuse is limited to a sports field at Palolo Valley District Park and a sports field and landscaping at Chaminade University.
	Potential Stormwater Volume	The potential stormwater volume is large since the headwaters of Palolo Stream are located in the Ko'olau Range and receive over 100 inches average rainfall annually.
	Potential Partnerships	BWS is a potential partner. The potential users have little incentive for discontinuing use of potable water for irrigation.
	Likelihood of Implementation	Location of infrastructure and acceptance of users are the only barriers to implementation.
	Institutional Constraints	Implementing this opportunity would involve two stream diversions and require approval from CWRM. Even though a large segment of Palolo Stream is concrete lined, it provides flow to other natural drainage areas.
	Cost Estimate	$9.2 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	The maintenance access along the concrete-line channel provides an opportunity to extend pipelines to other users with minimal disruption to public infrastructure.	

Figure 35.
O-7 - Palolo Stream Stormwater Channel

Divert stormwater from two locations in the concrete-line portions of Palolo Stream for irrigation at parks and institutions.

Table 14. E-7 – Waiahole Ditch Conveyance to Ewa Recharge Trench

Description	This opportunity combines stormwater collection opportunities in Central Oahu (e.g., O-1 and O-2) with recharge of the caprock aquifer in the Ewa Plain. The key element of this opportunity would be to extend a pipe from the current terminus of Waiahole Ditch to a proposed recharge trench above the caprock aquifer. The basis for this opportunity is to more closely match supply and demand. If the volume of stormwater introduced into Waiahole Ditch exceeds the irrigation demand (i.e., during high rainfall), the excess water can be conveyed to the Ewa Plain for recharge.
Figure	Figure 36. E-7 - Waiahole Ditch Conveyance to Ewa Recharge Trench
Existing Infrastructure	▪ Waiahole Ditch. ▪ Infrastructure associated with opportunities O-1 and O-2, though additional infrastructure would be needed for their implementation.
Needed Infrastructure	▪ Approximate 2.5-mile pipeline from the terminus of Waiahole Ditch to the Ewa Plain (the pipeline could vary in length depending on the desired location for the recharge trench). ▪ Recharge trench in the Ewa Plain.
Benefits	▪ Reduce stormwater runoff and pollution. ▪ Recharge the caprock aquifer in the Ewa Plain. ▪ Match supply and demand more closely.
Issues Needing Resolution	▪ Routing for pipeline. ▪ Location and size of recharge trench. ▪ Control strategy for determining when to recharge. ▪ Capacity of Waiahole Ditch for conveyance of stormwater from Central Oahu.
Stakeholders	*Key Stakeholders:* ▪ Hawaii ADC. *Potential Stakeholders:* ▪ Agricultural interests who use the water. ▪ Windward interests (provide assurance that this opportunity does not involve recharge of water from the Windward side of Oahu).
Ranking Considerations	This opportunity is not included in the ranking of opportunities because it is not a stand-alone opportunity. Opportunity O-1 or O-3 would need to be implemented for the conveyance from Waiahole Ditch to the Ewa Plain to be practical.
Additional Considerations	None.

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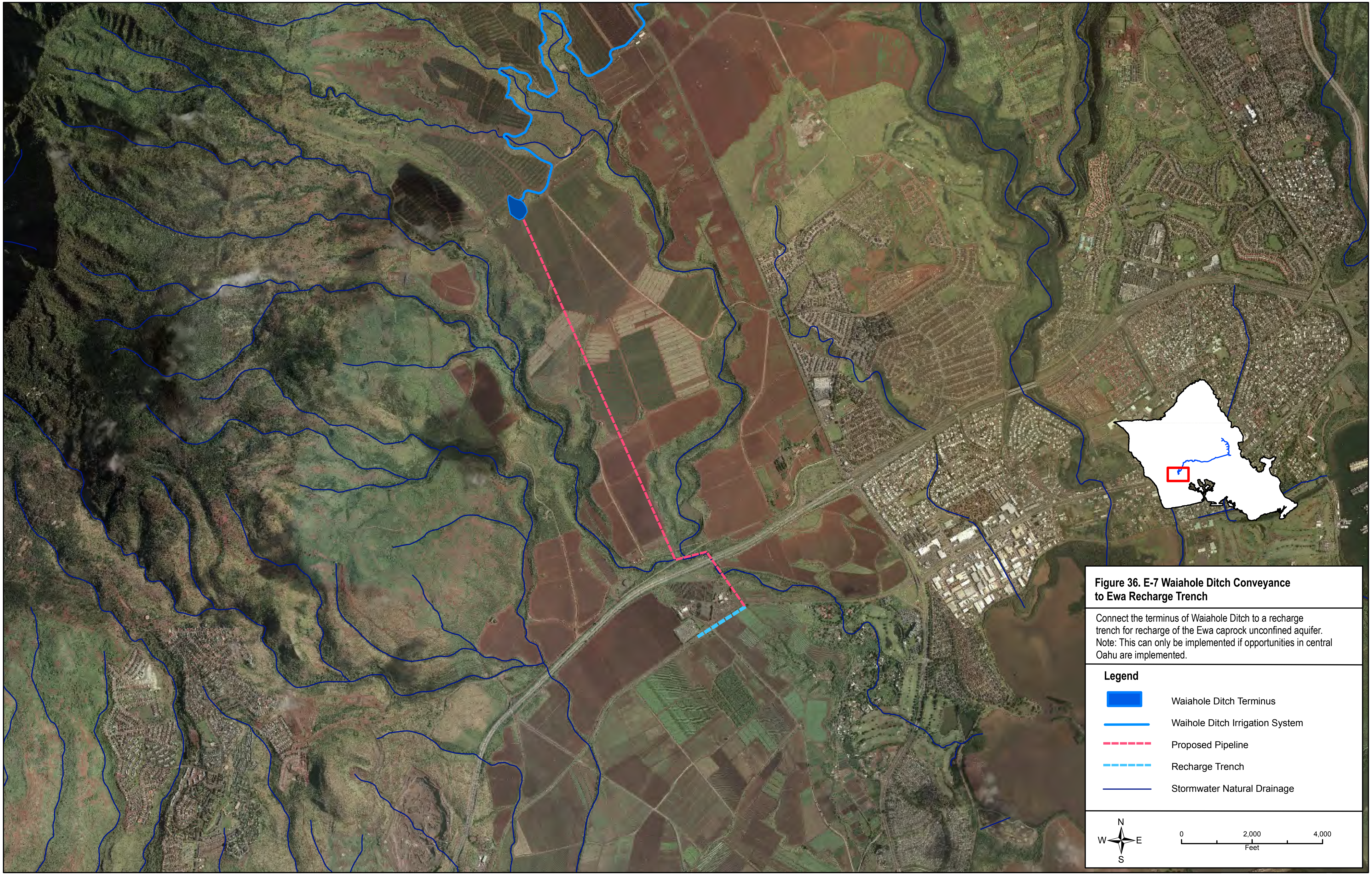

Figure 36. E-7 Waiahole Ditch Conveyance to Ewa Recharge Trench

Connect the terminus of Waiahole Ditch to a recharge trench for recharge of the Ewa caprock unconfined aquifer. Note: This can only be implemented if opportunities in central Oahu are implemented.

Table 15. M-1 – Waiale Road Stormwater Drainage

Description	This opportunity uses an existing stormwater drainage channel and detention pond located along Waiale Road to capture and convey stormwater into the Waihee and Spreckels Irrigation Ditch Systems for agricultural irrigation to the south and east.
Figure	Figure 37. M-1 - Waiale Road Drainage
Existing Infrastructure	▪ Stormwater drainage channel extending from the south end of Wailuku Town to Waiko Road. ▪ Stormwater detention basin located on the east side of Waiale Road. ▪ Waihee and Spreckels agricultural irrigation ditches in the surrounding area (some of these ditches are still in use and some are abandoned but still in existence).
Needed Infrastructure	▪ Pumping station and pipeline to a point of conveyance or use. ▪ Some treatment might be necessary depending on the end use and stormwater quality.
Benefits	▪ Reduce stormwater runoff and pollution. ▪ Augment agricultural irrigation water that is diverted currently from streams in the Waihee Valley of Maui.
Issues Needing Resolution	▪ Operational strategy for managing water in detention basin. ▪ Means of integrating pumping station discharge with agricultural irrigation. ▪ BMPs plan for reducing stormwater contamination.
Stakeholders	*Key Stakeholders:* ▪ Spencer Homes – owner of much of the drainage channel and detention basin. ▪ Wailuku Agribusiness Company, Inc. – Part owner and operator of Spreckels and Waihee Irrigation Ditches. ▪ Alexander & Baldwin, Inc. - Part owner and operator of Spreckels and Waihee Irrigation Ditches. *Potential Stakeholders:* ▪ Agricultural interests who use the water.

Table 15. M-1 – Waiale Road Stormwater Drainage (continued)

	Ranking Criterion	Discussion
Ranking Considerations	Potential Reuse Demand	This opportunity is immediately adjacent to large tracts of agricultural land.
	Potential Stormwater Volume	The collection area for this opportunity is approximately 560 acres in an area where the average rainfall is between 20 and 30 inches per year.
	Potential Partnerships	Potential partners for this opportunity include: ▪ Wailuku Agribusiness Company, Inc. ▪ Alexander & Baldwin, Inc. ▪ Spencer Homes
	Likelihood of Implementation	The pressure to reduce stream diversions associated with Spreckels and Waihee Ditches puts increased pressure on agricultural water demands for Central Maui. The decline in agriculture in Central Maui has resulted in a significant decline in return irrigation recharge of the aquifers.
	Institutional Constraints	No institutional constraints have been identified for this opportunity.
	Cost Estimate	$10.0 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	None.	

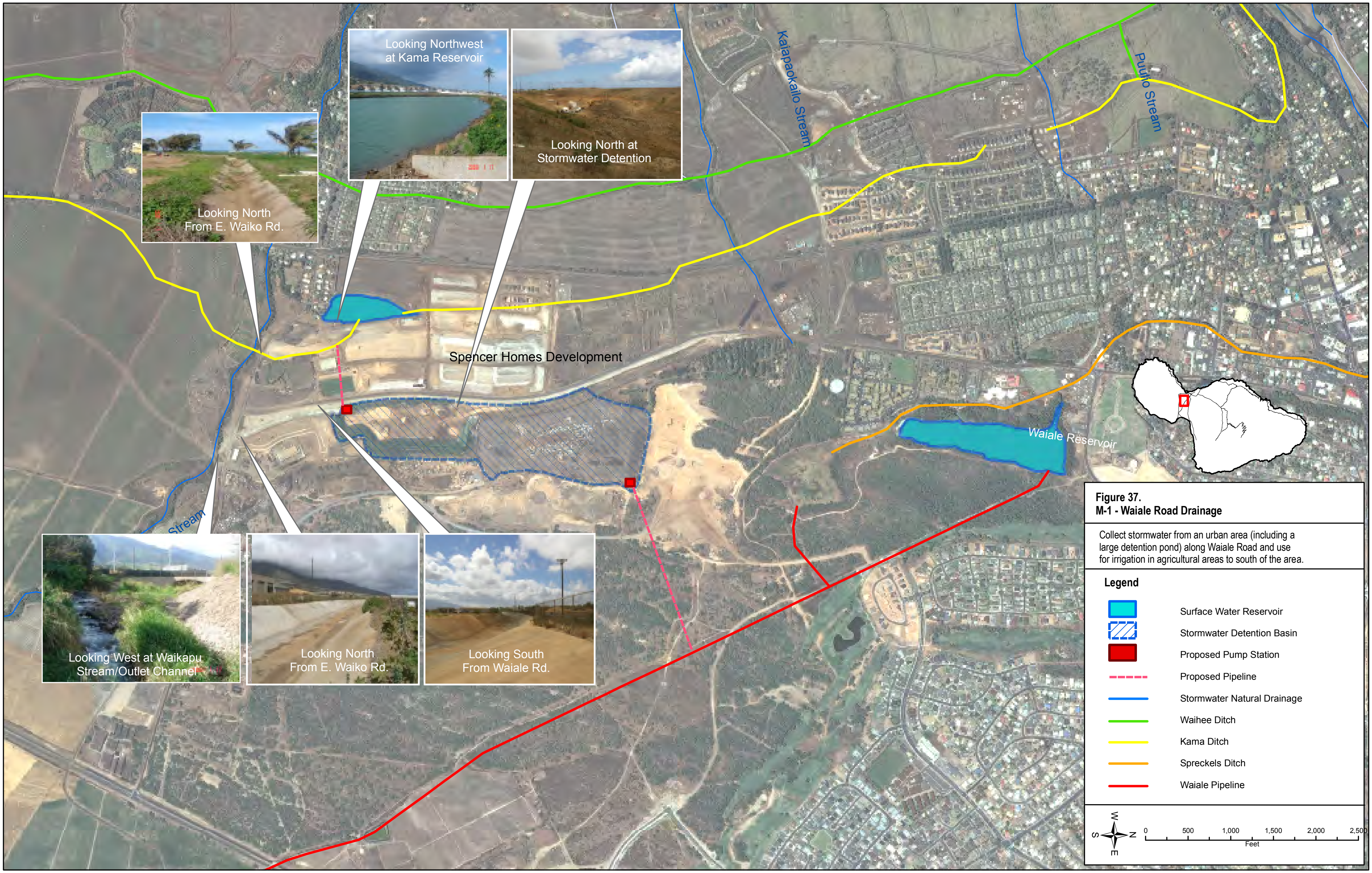

Figure 37.
M-1 - Waiale Road Drainage

Collect stormwater from an urban area (including a large detention pond) along Waiale Road and use for irrigation in agricultural areas to south of the area.

Table 16. M-2 – Kahului Stormwater Drainage

<table>
<tr><td>Description</td><td colspan="2">This opportunity uses an existing stormwater drainage channel in urban Kahului Town to collect stormwater for agricultural irrigation to the south of Kahului Town.</td></tr>
<tr><td>Figure</td><td colspan="2">Figure 38. M-2 - Kahului Stormwater Drainage</td></tr>
<tr><td>Existing Infrastructure</td><td colspan="2">▪ Series of connected stormwater drainage channels that extend from urban Kahului Town and discharge into the Pacific Ocean at Kite Beach.</td></tr>
<tr><td>Needed Infrastructure</td><td colspan="2">▪ Inflatable dam or bottom collection sump in the drainage channel.
▪ Pumping station and pipeline to a point of conveyance or use.
▪ Some treatment might be necessary depending on the end use and stormwater quality.</td></tr>
<tr><td>Benefits</td><td colspan="2">▪ Reduce stormwater runoff and pollution.
▪ Augment agricultural irrigation water that is diverted currently from Maui streams.</td></tr>
<tr><td>Issues Needing Resolution</td><td colspan="2">▪ BMPs plan for reducing stormwater contamination.
▪ Means of integrating stormwater with agricultural irrigation.</td></tr>
<tr><td>Stakeholders</td><td colspan="2">Key Stakeholders:
▪ County of Maui – owner of the stormwater drainage channel.
▪ Agricultural interest that would use the water and own the irrigation ditches.</td></tr>
<tr><td rowspan="7">Ranking Considerations</td><td>Ranking Criterion</td><td>Discussion</td></tr>
<tr><td>Potential Reuse Demand</td><td>This opportunity is immediately adjacent to large tracts of agricultural land.</td></tr>
<tr><td>Potential Stormwater Volume</td><td>The collection area for this opportunity is approximately 829 acres in an area that receives an annual rainfall of approximately 20 inches per year.</td></tr>
<tr><td>Potential Partnerships</td><td>There are no potential partnerships for this opportunity.</td></tr>
<tr><td>Likelihood of Implementation</td><td>Though the coastal area to which this stormwater drainage channel discharges would benefit from reduced pollutant load, the area is not water quality limited at this time.</td></tr>
<tr><td>Institutional Constraints</td><td>This opportunity would involve modifications to a flood control channel, which might meet resistance from the County of Maui Public Works Department.</td></tr>
<tr><td>Cost Estimate</td><td>$10.3 million
Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.</td></tr>
<tr><td>Additional Considerations</td><td colspan="2">One of these channels is adjacent to the east side of Kanaha Ponds Wildlife Refuge and the water could be used to supplement the pond water if needed.</td></tr>
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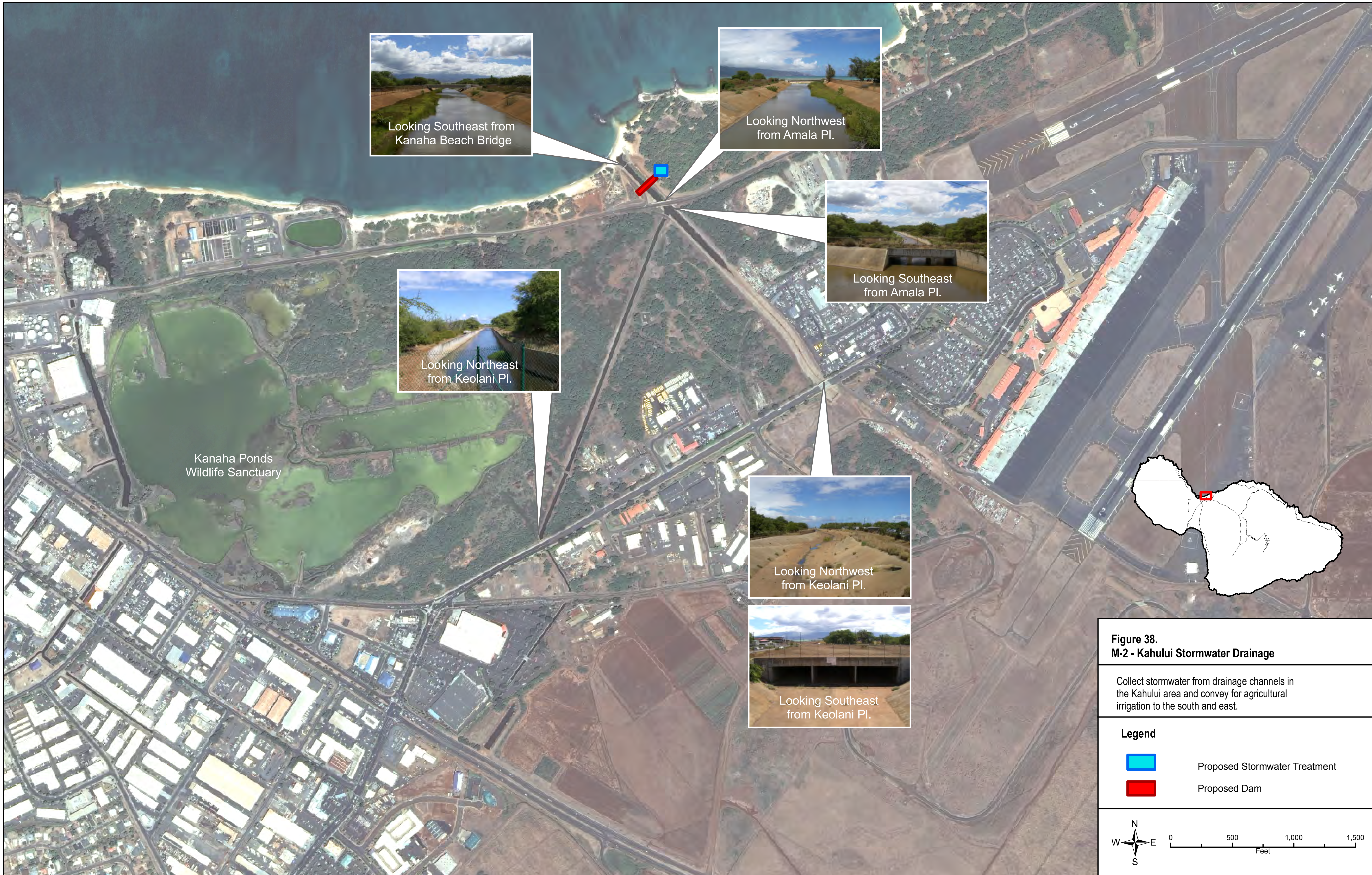

Looking Southeast from Kanaha Beach Bridge
Looking Northwest from Amala Pl.
Looking Southeast from Amala Pl.
Looking Northeast from Keolani Pl.
Kanaha Ponds Wildlife Sanctuary
Looking Northwest from Keolani Pl.
Looking Southeast from Keolani Pl.
Figure 38.
M-2 - Kahului Stormwater Drainage
Collect stormwater from drainage channels in the Kahului area and convey for agricultural irrigation to the south and east.
Legend
Proposed Stormwater Treatment
Proposed Dam
N
W
E
S
0
500
1,000
1,500
Feet

Table 17. M-3 – Kahoma Stream Flood Control

<table>
<tr><td>Description</td><td colspan="2">This opportunity uses an existing stormwater drainage channel (Kahoma Stream) to collect and convey stormwater for agricultural use to the north.</td></tr>
<tr><td>Figure</td><td colspan="2">Figure 39. M-3 - Kahoma Stream Flood Control</td></tr>
<tr><td>Existing Infrastructure</td><td colspan="2">▪ Stormwater drainage channel (Kahoma Stream) that roughly parallels Lahainaluna Road.</td></tr>
<tr><td>Needed Infrastructure</td><td colspan="2">▪ Inflatable dam or bottom collection sump in the drainage channel.
▪ Pumping station and pipeline to a point of conveyance or use.
▪ Some treatment might be necessary depending on the end use and stormwater quality.</td></tr>
<tr><td>Benefits</td><td colspan="2">▪ Reduce stormwater runoff and pollution.
▪ Augment agricultural irrigation water that is diverted currently from Maui streams.</td></tr>
<tr><td>Issues Needing Resolution</td><td colspan="2">▪ Control strategy to permit reuse of stormwater yet prevent flooding.
▪ Locations for integration with agricultural irrigation systems.
▪ Best management practices plan for reducing stormwater contamination.</td></tr>
<tr><td>Stakeholders</td><td colspan="2">Key Stakeholders:
▪ County of Maui – Owner of the stormwater drainage channel.
▪ Agricultural interests who use the water.</td></tr>
<tr><td rowspan="7">Ranking Considerations</td><td>Ranking Criterion</td><td>Discussion</td></tr>
<tr><td>Potential Reuse Demand</td><td>This opportunity is immediately adjacent to large tracts of agricultural land.</td></tr>
<tr><td>Potential Stormwater Volume</td><td>This stream is part of a major drainage from the West Maui Mountains where rainfall can exceed 100 inches per year and would generate large quantities of stormwater.</td></tr>
<tr><td>Potential Partnerships</td><td>The Hawaii Department of Agriculture could be a potential partner for this opportunity, but the drivers would not be limited water supply.</td></tr>
<tr><td>Likelihood of Implementation</td><td>The coastal area to which Kahoma Stream discharges is water quality limited and would benefit from reduced stormwater pollutant loads.</td></tr>
<tr><td>Institutional Constraints</td><td>Kahoma Stream would require a permit from the CWRM for a diversion.
This opportunity would involve modifications to a flood control channel, which might meet resistance from the County of Maui Public Works Department.</td></tr>
<tr><td>Cost Estimate</td><td>$11.3 million
Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.</td></tr>
<tr><td>Additional Considerations</td><td colspan="2">None.</td></tr>
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Figure 39.
M-3 - Kahoma Stream Flood Control

Collect stormwater from a drainage channel and detention pond and convey for agricultural irrigation to the north, south, and east.

Table 18. M-4 – Lahaina Flood Control Channel

Description	This opportunity uses an existing stormwater drainage channel and detention pond located adjacent to the Lahaina Wastewater Reclamation Facility (WWRF) to collect stormwater for conveyance to agricultural areas to the north, south, and east.	
Figure	Figure 40. M-4 - Lahaina Flood Control Channel	
Existing Infrastructure	▪ Stormwater detention basin east of the drainage channel. ▪ Flow regulating structure located in the detention basin. ▪ Unused tanks at the Lahaina WWRF that could be used potentially for treatment.	
Needed Infrastructure	▪ Automatic gates for further flow regulation in the flow regulating structure. ▪ Pumping station to convey the stormwater for agricultural use. ▪ Connection of stormwater pumping station discharge to existing agricultural irrigation systems.	
Benefits	▪ Reduce stormwater runoff and pollution. ▪ Augment agricultural irrigation water that is diverted currently from Maui streams.	
Issues Needing Resolution	▪ Control strategy to permit reuse of stormwater yet prevent flooding. ▪ Locations for integration with agricultural irrigation systems.	
Stakeholders	*Key Stakeholders:* ▪ County of Maui – Owner of the stormwater detention basin and the Lahaina WWRF. ▪ Agricultural interests who use the water.	
Ranking Considerations	**Ranking Criterion**	**Discussion**
	Potential Reuse Demand	This opportunity is immediately adjacent to large tracts of agricultural land.
	Potential Stormwater Volume	This dry gulch is part of a major drainage from the West Maui Mountains where rainfall can exceed 100 inches per year and would generate large quantities of stormwater.
	Potential Partnerships	No potential partnerships have been identified for this opportunity.
	Likelihood of Implementation	The coastal area to which the flood control channel discharges is water quality limited and would benefit from reduced stormwater pollutant loads.
	Institutional Constraints	This opportunity would require modification of a flood control structure and basin and might meet resistance from the County of Maui Public Works Department.
	Cost Estimate	\$31.5 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	The Lahaina WWRF has process tanks that are out of service currently. They are being evaluated for upgrade as growth in the service area expands. The tanks could be used potentially for stormwater treatment if they are abandoned. The WWRF recycled water system is also being expanded and provides an opportunity for integrating stormwater with the system.	

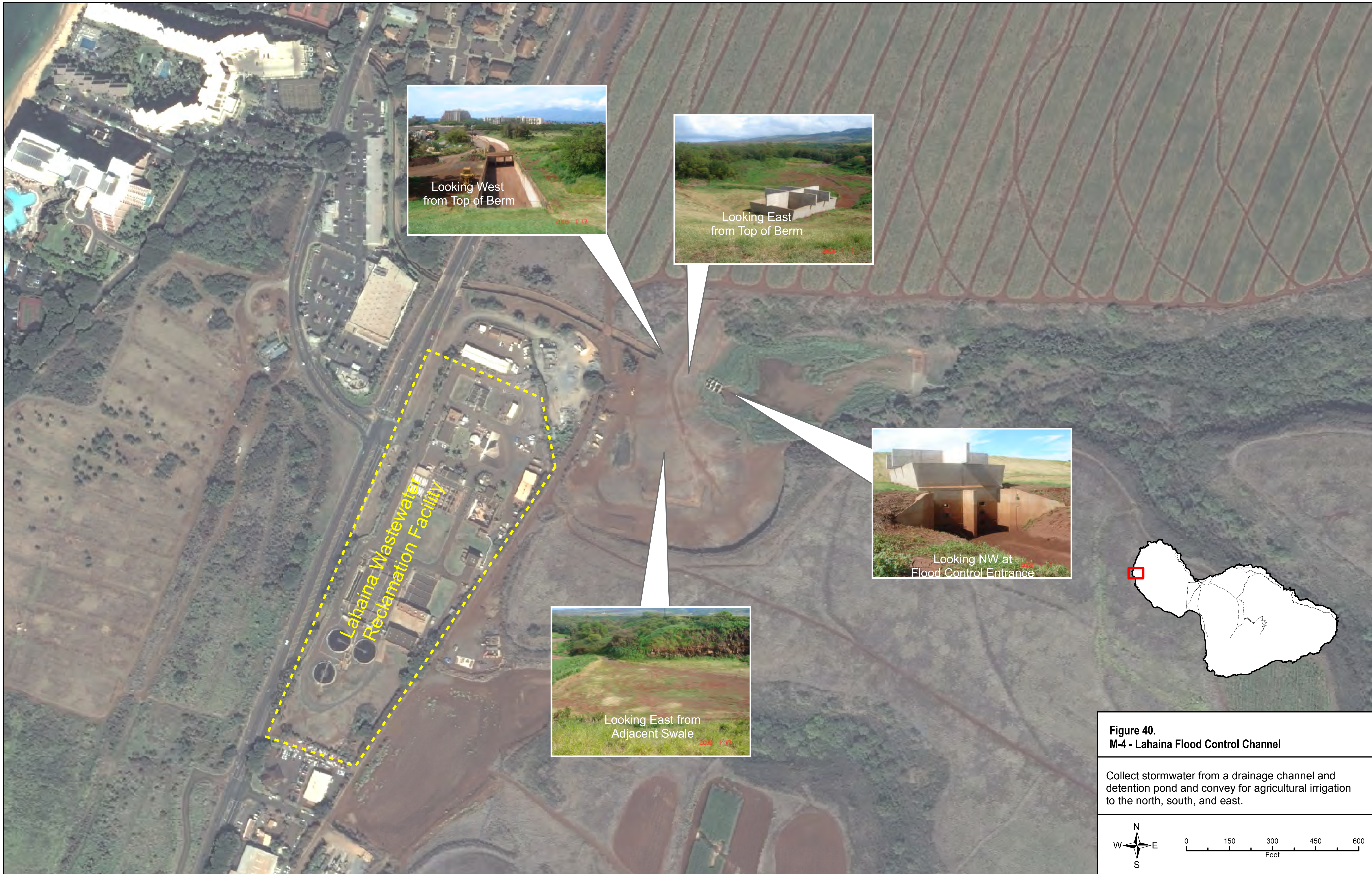

Figure 40.
M-4 - Lahaina Flood Control Channel

Collect stormwater from a drainage channel and detention pond and convey for agricultural irrigation to the north, south, and east.

Table 19. K-1 – Nawiliwili Diversion

<table>
<tr><td>Description</td><td>This opportunity would divert stormwater before or after entering Nawiliwili Stream for recharge of groundwater by means of spreading basins, irrigation, or recharge trenches. The purpose of this recharge would be two-fold: raise groundwater levels in potable water wells that are down gradient, and reduce pollutant loads in Nawiliwili Stream and Bay and Hanamaulu Bay.

Two wells have been shut down due to insufficient groundwater levels:
▪ Kilohana Well C (5923-03)
▪ Kilohana Well G (5923-05)

Nawililwili Stream and Bay are listed as impaired waters for the following pollutants:
▪ Nawiliwili Bay
- Turbidity
- Enterococci (wet season)
- Nitrite/nitrate (wet/dry season)
- Ammonium (wet/dry season)
- Turbidity (dry season)
- Chlorophyll a (wet/dry season)
▪ Nawiliwili Stream
- Turbidity (wet/dry season)
- Nitrite/nitrate (wet season)
- Total nitrogen (wet season)
Total maximum daily loads (TMDLs) are being developed currently for Nawiliwili Stream.
Hanamaulu Bay is listed as an impaired water for the following pollutants:
▪ Turbidity.
▪ Enterococci (wet/dry season).</td></tr>
<tr><td>Figure</td><td>Figure 41. K-1 - Nawiliwili Diversion</td></tr>
<tr><td>Existing Infrastructure</td><td>None</td></tr>
<tr><td>Needed Infrastructure</td><td>▪ Diversion structures.
▪ Surface spreading basins or infiltration trenches for groundwater recharge.
▪ Pipelines to connect diversions to recharge locations or irrigation areas.</td></tr>
<tr><td>Benefits</td><td>▪ Improve water quality of wells and tunnels.
▪ Reduce stormwater runoff and pollution.</td></tr>
<tr><td>Issues Needing Resolution</td><td>▪ Location of diversions.
▪ Location of recharge trenches or spreading basins.</td></tr>
</table>

Table 19. K-1 – Nawiliwili Diversion (Continued)

<table>
<tr><td rowspan="1">Stakeholders</td><td colspan="2">Key Stakeholders:
▪ Kauai Department of Water Supply
▪ County of Kauai Department of Public Works
▪ Hawaii DOH
▪ CWRM
Potential Stakeholders:
▪ Agriculture interests</td></tr>
<tr><td rowspan="7">Ranking Considerations</td><td>Ranking Criterion</td><td>Discussion</td></tr>
<tr><td>Potential Reuse Demand</td><td>This opportunity is adjacent to large tracts of agricultural land.</td></tr>
<tr><td>Potential Stormwater Volume</td><td>The area that feed the streams for this opportunity receives an annual average rainfall of over 75 inches.</td></tr>
<tr><td>Potential Partnerships</td><td>No potential partners have been identified for this opportunity.</td></tr>
<tr><td>Likelihood of Implementation</td><td>This opportunity would have multiple environmental benefits:
▪ Reduced pollutant load on Nawiliwili Bay, which is on the State of Hawaii's 303(d) List of Impaired waters, and will likely be subject to maximum daily loads.
▪ "Flushing" of contaminants from the potable water aquifer.
Agricultural land would need to be modified to allow infiltration by means of spreading basins.</td></tr>
<tr><td>Institutional Constraints</td><td>This opportunity would involve one or more diversions from streams, and would require permits from CWRM.
Diversions might meet with some resistance from environmental groups, but concerns might be mitigated by the near-shore water quality benefits.</td></tr>
<tr><td>Cost Estimate</td><td>$2.8 million
Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.</td></tr>
<tr><td>Additional Considerations</td><td colspan="2">None.</td></tr>
</table>

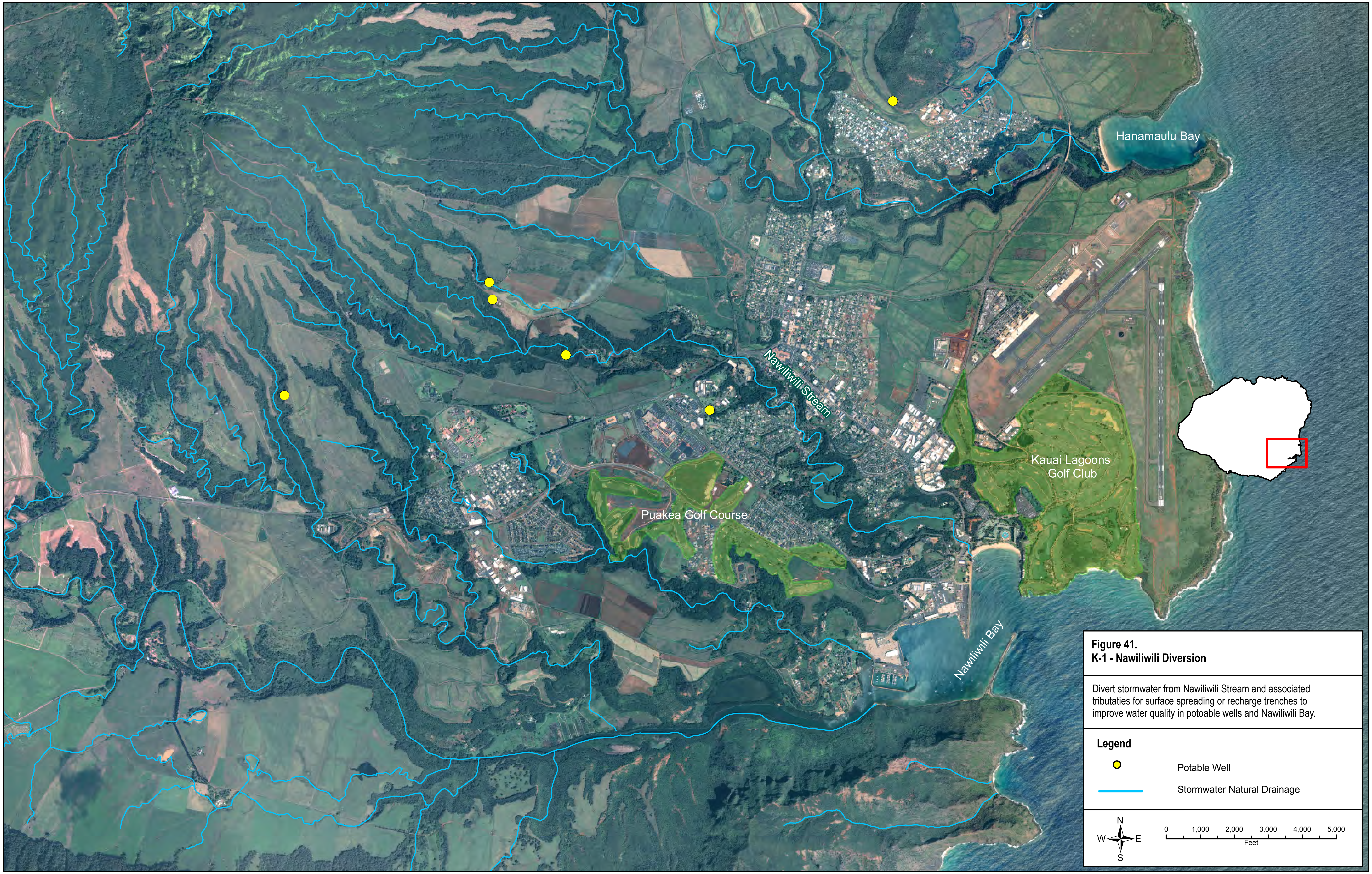

Figure 41.
K-1 - Nawiliwili Diversion

Divert stormwater from Nawiliwili Stream and associated tributaties for surface spreading or recharge trenches to improve water quality in potoable wells and Nawiliwili Bay.

Table 20. K-2 – Lihue Airport

Description	This opportunity would collect runoff from the Lihue Airport and use it by one of three means to prevent runoff into Nawiliwili Bay: ▪ Irrigation of the airport green space ▪ Irrigation of Puakea and Kauai Lagoons Golf Courses ▪ Groundwater recharge See opportunity K-1 for the water quality issues in Nawiliwili Bay
Figure	Figure 42. K-2 - Lihue Airport
Existing Infrastructure	▪ Paved runway at the Lihue Airport for stormwater collection ▪ Lihue Airport irrigation system ▪ Puakea Golf Course irrigation system
Needed Infrastructure	▪ Stormwater conveyance system to point of irrigation use ▪ Recharge trench
Benefits	▪ Reduce stormwater runoff and pollution into near shore coastal waters ▪ Augment potable water supplies
Issues Needing Resolution	▪ Best end use of the stormwater ▪ Means of integration with irrigation systems ▪ Location and size of recharge trench
Stakeholders	*Key Stakeholders:* ▪ State of Hawaii Department of Transportation – owner and operator of the Lihue Airport. *Potential Stakeholders:* ▪ Puakea Golf Course. ▪ Kauai Lagoons Golf Club.

Table 20. K-2 – Lihue Airport (continued)

	Ranking Criterion	Discussion
Ranking Considerations	Potential Reuse Demand	This opportunity could provide reclaimed stormwater for the following areas: ▪ Lihue Airport ▪ Kauai Lagoons Golf Club ▪ Puakea Golf Course
	Potential Stormwater Volume	The collection area for this opportunity is approximately 822 acres, of which 170 acres is impervious. The average annual rainfall for the area is between 40 and 50 inches.
	Potential Partnerships	Though this opportunity could serve three separate users, there does not appear to be an incentive for any user to change source water at the present time.
	Likelihood of Implementation	The near-shore water quality benefits from this opportunity do not appear to be as significant as those from stream diversions included in Opportunity K-1, Nawiliwili Diversion.
	Institutional Constraints	This opportunity would require concurrence with the Hawaii Department of Transportation.
	Cost Estimate	$13.9 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	None.	

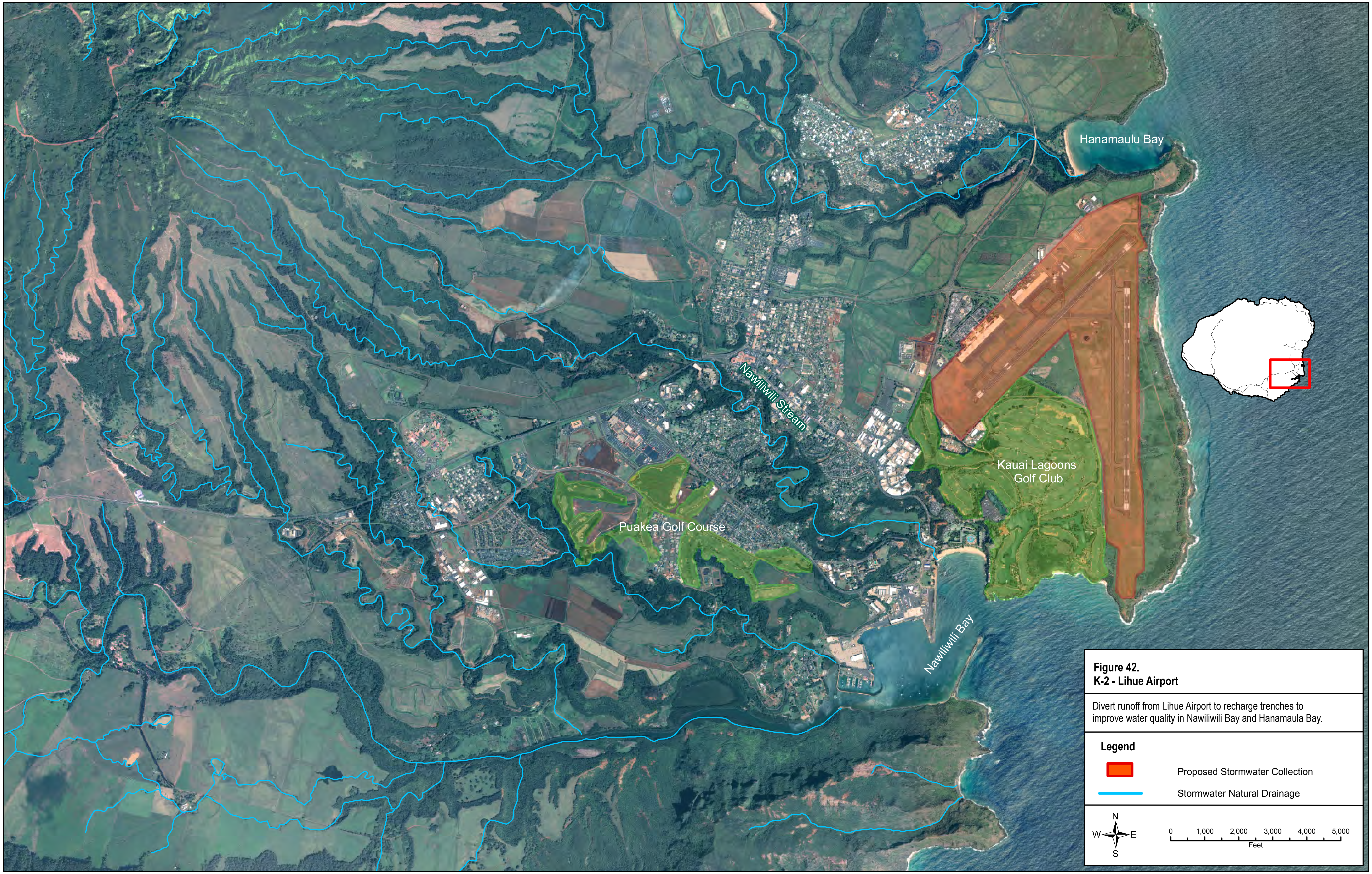
Hanamaulu Bay
Nawiliwili Stream
Kauai Lagoons
Golf Club
Puakea Golf Course
Nawiliwili Bay
Figure 42.
K-2 - Lihue Airport
Divert runoff from Lihue Airport to recharge trenches to improve water quality in Nawiliwili Bay and Hanamaula Bay.
Legend
Proposed Stormwater Collection
Stormwater Natural Drainage
N
W
E
S
0
1,000
2,000
3,000
4,000
5,000
Feet

Table 21. H-1 – Lower Hamakua Ditch Recharge

Description	This opportunity would divert stormwater from natural drainage areas into Lower Hamakua Ditch for conveyance to injection wells or recharge trenches that are intended to re-fresh groundwater supplies and potentially flush or dilute contaminants present in drinking water wells and shafts. A series of wells that stretch from Laupahoehoe to Haina are contaminated with herbicides (atrazine and hexazinone) and solvents (isophorone). These include: ▪ Laupahoehoe Wells 1 and 2 (drinking water) ▪ Ookala Well (drinking water) ▪ Ookala Shaft (inactive) ▪ Paauilo Well (drinking water) ▪ Paauilo Shaft (inactive) ▪ Big Island Meat (Inactive) ▪ Haina Well (drinking water)
Figure	Figure 43. H-1 - Lower Hamakua Ditch
Existing Infrastructure	▪ Lower Hamakua Irrigation Ditch ▪ Flumes and culverts above and below the ditch that divert stormwater away from the ditch
Needed Infrastructure	▪ Physical diversions into Lower Hamakua Ditch ▪ Injection wells or infiltration ditches (these would not be direct recharge of groundwater since they would be designed to inject water above the groundwater level) ▪ Diversion structures out of the ditch for recharge
Benefits	▪ Improve water quality of wells and shafts ▪ Provide additional irrigation water ▪ Reduce stormwater runoff and pollution
Issues Needing Resolution	▪ Operational strategy to ensure water needed for irrigation is not impacted ▪ Locations for diversion into the irrigation ditch ▪ Locations for diversion for groundwater recharge
Stakeholders	*Key Stakeholders:* ▪ Hawaii Department of Water Supply ▪ Hawaii Department of Agriculture *Potential Stakeholders:* ▪ Big Island Meat (Paauilo)

Table 21. H-1 – Lower Hamakua Ditch Recharge (continued)

	Ranking Criterion	Discussion
Ranking Considerations	Potential Reuse Demand	The reuse demand for this opportunity will depend on the number of diversions to infiltration trenches and injection wells.
	Potential Stormwater Volume	The streams and drainages in this area receive an average annual rainfall of 20 to 80 inches.
	Potential Partnerships	The Hawaii Department of Agriculture is a potential partner for this opportunity. However, this opportunity focuses on groundwater recharge primarily since the demand for irrigation water does not correspond with the supply. The Lower Hamakua Irrigation Ditch would primarily be used for conveyance for recharge, which does not benefit agricultural interests.
	Likelihood of Implementation	Despite the potential water quality benefits, the number of locations required for groundwater recharge is a potential limiting factor for implementation.
	Institutional Constraints	Diversions are required that might require approval of CWRM. Stream diversions from the Waipio Valley into Hamakua Ditch have been challenged recently by environmental and cultural groups.
	Cost Estimate	$1.8 million Please read discussion of cost estimates in the section Using Criteria to Evaluate Opportunities before relying on this cost estimate for decision making.
Additional Considerations	If stormwater diverted into Lower Hamakua Ditch could also be used for irrigation if demand is adequate for the supply.	

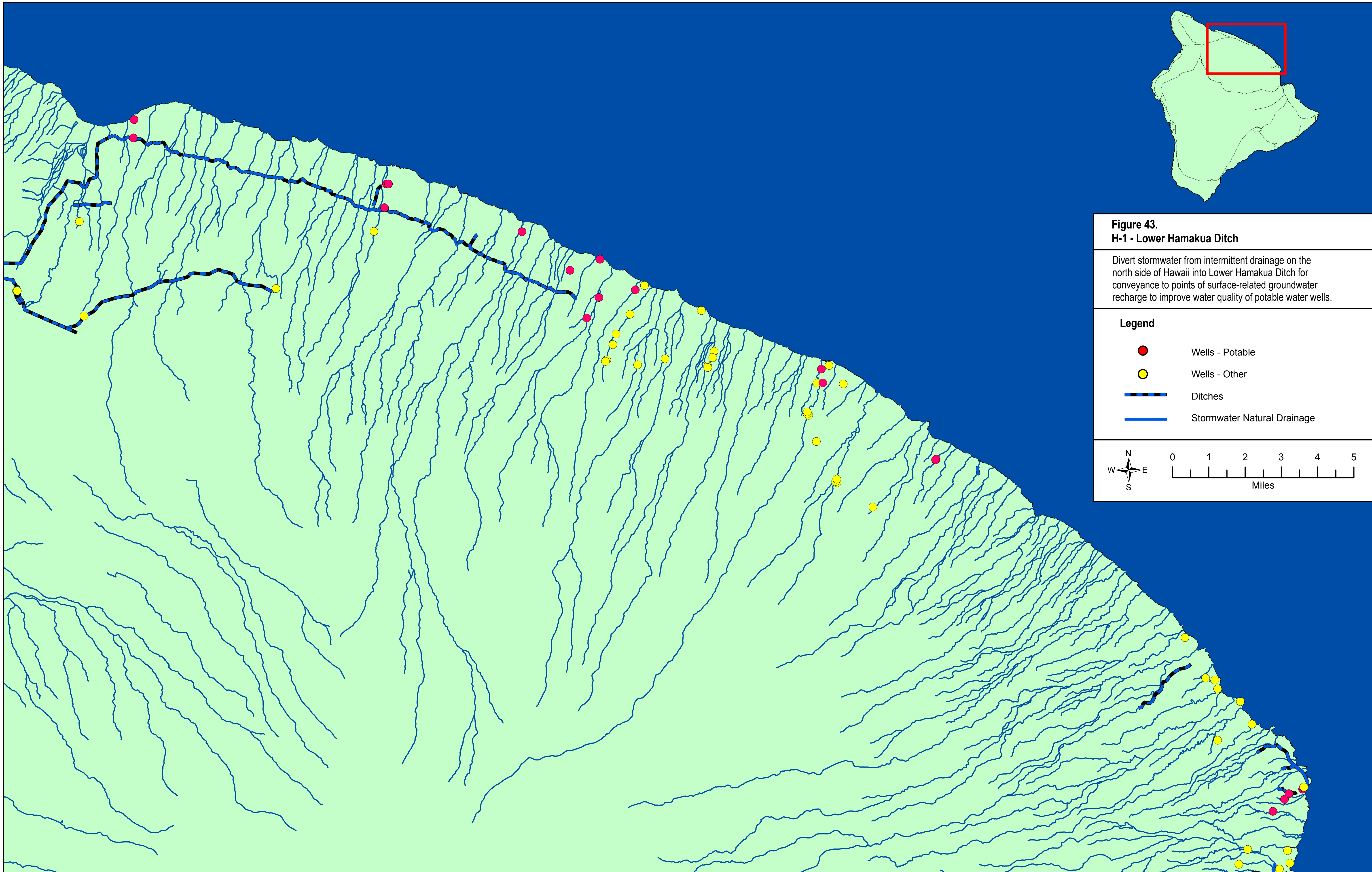
Figure 43.
H-1 - Lower Hamakua Ditch
Divert stormwater from intermittent drainage on the north side of Hawaii into Lower Hamakua Ditch for conveyance to points of surface-related groundwater recharge to improve water quality of potable water wells.
Legend
Wells - Potable
Wells - Other
Ditches
Stormwater Natural Drainage
N
W
E
S
0
1
2
3
4
5
Miles

Opportunity Ranking

Once all opportunities for stormwater reclamation and reuse have been identified, prioritization is necessary to differentiate and rank the opportunities. This can be difficult given the number of islands involved, and in the case of Oahu, two separate geographical areas for opportunities (Ewa Plain and the rest of Oahu). The approach used for the prioritization process is known as a Pairwise Comparison.

The first step for ranking the opportunities was to identify the criteria that will be used to evaluate the opportunities. A draft list of criteria was submitted to Reclamation and CWRM for review and comment. These criteria were presented in Table 6 and will be discussed further in this section.

After the criteria were identified, they were ranked using a method known as a Pairwise Comparison. The approach for a Pairwise Comparison is to compare each criterion with every other criterion by asking the following questions, and by assigning points based on the response to the questions.

1. Is criterion A much more important than criterion B? If the answer was “yes”, five points were assigned to criterion A, and 1 point was assigned to criterion B.

2. Is criterion A more important than criterion B? If the answer was “yes”, four points were assigned to criterion A, and two points were assigned to criterion B.

3. Is criterion A equal in importance to criterion B? If the answer was “yes”, three points were assigned to criterion A, and 3 points were assigned to criterion B.

4. Is criterion A less important than criterion B? If the answer was “yes”, two points were assigned to criterion A, and four points were assigned to criterion B.

5. Is criterion A much less important than criterion B? If the answer was “yes”, one point were assigned to criterion A, and five points were assigned to criterion B.

Two representatives from Reclamation and three representatives from CWRM performed the Pairwise Comparison to rank the criteria. The point totals for all five raters were averaged to determine the final ranking and value.

Table 22 presents the final ranking of the criteria and the average points from all raters. The average points were normalized to 1.0. The normalized value was used as a weighting factor for further evaluation of each opportunity.

Table 22. Evaluation Criteria Ranking

Criterion	Average Points	Weighting Factor
Potential Reuse Demand	17.0	0.19
Cost Estimate	16.6	0.18
Potential Stormwater Volume	15.2	0.17
Potential Partnerships	14.8	0.16
Likelihood of Implementation	14.4	0.16
Institutional Constraints	12.0	0.13

Using the Criteria to Evaluate Opportunities

Once the evaluation criteria were ranked, Brown and Caldwell conducted additional Pairwise Comparisons. Each opportunity was compared with all other opportunities for each evaluation criterion. Six separate Pairwise Comparisons were conducted. A discussion of how each criterion was used in these comparisons is discussed below:

Potential Reuse Demand

There are a number of potential end-uses for stormwater, which makes comparisons difficult, particularly given the cost that some end-uses might incur (e.g., use in industrial processes). This evaluation focused on availability and proximity of land that could be used for irrigation.

Cost Estimate

Cost estimating range of accuracy is defined based on level of project definition. The Association for the Advancement of Cost Engineering (AACE) International has created a Cost Estimate Classification System (Recommended Practice No. 18R-97) that defines 5 classes of cost estimates. Using this matrix as a guide, the opportunities discussed in this report should vary from -50% to +100%.

The construction cost estimates developed for these opportunities considered the following cost information resources and assumptions:

- Comparable bid tabs from similar Hawaii projects
- Conceptual cost estimates
- Fifty percent adjustment for level of project definition
- 2008 dollars

In addition, capital cost estimates (as distinguished from construction cost estimates) accounted for engineering and construction management services based on the following assumptions using construction cost as a base:

- Design fees – 10 %
- Engineering services during construction – 5 %
- Construction management – 7%

The number of opportunities and the uncertainties associated with their construction at an appraisal level posed difficulties for cost estimates and their comparisons. To accomplish relative cost comparisons among the opportunities, the following assumptions were made:

- Pumping of stormwater from each opportunity would be equal at a 3.0 mgd capacity. Two differentiations were made with regard to pumping stormwater: a low head pump station (e.g., one that would need to pump to only and slightly higher elevation and a shorter distance) and a high head pump station (e.g., one that would need to pump to higher elevations and longer distances.
- Treatment costs were assumed to be equal. No attempt was made to estimate treatment costs since the stormwater quality is unknown.
- Each opportunity would need a 3.0 million gallon reservoir, unless some form of rapid groundwater infiltration were used. Opportunities that had some form of possible storage were assigned a lower cost for reservoir than those that did not have any storage.

- Unit costs (per foot) were developed for collection and conveyance piping, including excavation, pipe, gravel, and appurtenances.
- Land costs were included if private land was required for the opportunity, and not included if public lands were available.
- No planning, engineering, and design costs were included since they would simply be percentages of the estimated costs.
- At this stage of opportunity development, cost estimates have an accuracy of +50 to -30 percent.

The cost estimates used in this report are preliminary and are based on data developed by Brown and Caldwell. The estimates are intended to be used as an assessment of the general magnitude of facilities and costs associated with stormwater reclamation and reuse needs in Hawaii.

Reclamation does not endorse these estimates and cautions against their use to assess the feasibility of developing stormwater reclamation and reuse facilities.

The basis for cost estimates is provided in Appendix A.

Potential Stormwater Volume

The potential stormwater volume was based on the potential stormwater collection area and the average annual rainfall for the area. Due to limitations in GIS information about stormwater collection systems in urban environments, the size of stormwater conveyance channels was also considered for some of the opportunities. For example, the North Mililani Stormwater Channel is significantly larger than the South Mililani Stormwater Channel. Since both channels are designed for a 100-year storm and have similar average annual rainfalls, the potential stormwater volume from the North Mililani Stormwater Channel was assumed be greater.

Potential Partnerships

Some of the opportunities will directly or indirectly benefit public or private organizations that might, in turn, drive their willingness to be a partner in implementation of the opportunity. An example of a direct benefit is the availability of reclaimed stormwater to augment existing non-potable water supplies, such as agricultural users of non-potable water from the Waiahole Ditch. An example of an indirect benefit is one that might promote one of their organizational objectives such as promoting sustainability concepts and improving public relations through environmental stewardship. Such partnerships might result in direct funding of opportunities, or indirect funding through use of existing infrastructure.

No discussion has occurred to determine the interest of any potential partnerships. The respective County water supply agencies would all benefit potentially from reduced reliance on potable water supplies, but are not included as potential partnerships since this would apply equally to all opportunities.

Likelihood of Implementation

Many factors will determine the likelihood of implementation of any opportunity. Some of these factors, including cost, partnerships, institutional constraints, and potential demand, are covered by other evaluation criteria. This criterion considers other barriers and benefits that could influence implementation. These could be positive or adverse public acceptance, potential for multiple reuse approaches, and environmental benefits.

Institutional Constraints

Institutional constrains include rules and regulations, laws, and policies that would adversely affect an opportunity. Possible institutional constraints are discussed in a separate report titled *An Appraisal of Hawaii's Framework for Stormwater Reclamation and Reuse*.

Final Ranking of Opportunities

Once the Pairwise Comparison for each criterion was complete, the total points each opportunity received was multiplied by the weighting factor for the respective criterion. The products of the weighted values for each criterion were totaled, and the totals were used to rank the opportunities. The results of the combined Pairwise Comparisons are provided in Appendix B. The final ranking of each of the opportunities is shown in Table 23.

Table 23. Final Ranking of Stormwater Reclamation and Reuse Opportunities

Rank	Opportunity	Summary Description
1	O-1 Wheeler Army Air Base	Convey runoff from Wheeler Army Air Force Base runway to Schofield Barracks WWTP for treatment, to former underground oil storage tanks for storage, then to Waiahole Ditch for distribution for agricultural irrigation.
2	K-1 Nawiliwili Diversion	Divert stormwater from Nawiliwili Stream and associated tributaries for surface spreading or recharge trenches to improve water quality in potable wells and Nawiliwili Bay.
3	M-1 Waiale Road Stormwater Drainage	Collect stormwater from an urban area (including a large detention pond) along Waiale Road on Maui and use for irrigation in agricultural areas to south of the area.
4	O-2 Mililani North Stormwater Channel	Collect stormwater in a stormwater drainage channel for use at Mililani Golf Course, Mililani Agricultural Park, or to Waiahole Ditch for agricultural irrigation in the Kunia area.
5	O-3 Mililani South Stormwater Channel	Collect stormwater in a stormwater drainage channel in south Mililani and convey to the abandoned Mililani WWTP for treatment and storage, prior to use Mililani Agricultural Park.
6	M-3 Kahoma Stream Flood Control	Collect stormwater from a drainage channel and convey for agricultural irrigation to the north.
7	H-1 Lower Hamakua Ditch	Divert stormwater from intermittent drainage on the north side of Hawaii into Lower Hamakua Ditch for conveyance to points of surface-related groundwater recharge to improve water quality of potable water wells.
8	M-2 Kahului Flood Control Channels	Collect stormwater from drainage channels in the Kahului area and convey for agricultural irrigation to the south and east.
9	M-4 Lahaina Flood Control	Collect stormwater from a drainage channel and detention pond and convey for agricultural irrigation to the north, south, and east.
10	O-4 Waipahu Stormwater Channel	Collect stormwater in a stormwater drainage channel and convey it to Waikele Golf Course, Ted Makalena Golf Course, or Waipio Soccer Complex for irrigation.
11	O-5 Waikele Stormwater Channel	Collect stormwater in a stormwater drainage channel and convey to Waikele Golf Course for irrigation.
12	O-7 Palolo Stream Stormwater Channel	Divert stormwater from two locations in the concrete-lined portions of Palolo Stream for irrigation at parks and institutions.
13	O-6 Nu'uanu Valley Surface Water	Treat stormwater runoff from the Nu’uanu surface water reservoirs at BWS microfiltration plant and convey to Oahu Country Club for irrigation.
14	K-2 Lihue Airport	Diver runoff from Lihue Airport to recharge trenches to improve water quality in Nawiliwili Bay and Hanamaula Bay.

Appendix A - Cost Estimate Spreadsheet

	Opportunity		Diversion	Low Head PS	High Head PS	Reservoir	Collection System	Conveyance System	Injection Well	Land	Excavation Only	Total Cost
1	0-1 - Schofield		0	1,000,000	0	2,000,000	646,000	863,080	0	0	0	$8.3
		Units	0	1	0	0	3800	10,153	0	0	0	
2	0-2 - Mililani North		100,000	1,000,000	0	3,870,000	0	85,000	0	0	0	$9.4
		Units	2	1	0	3	0	1,000	0	0	0	
3	0-3 - Mililani South		50,000	0	0	2,580,000	0	126,170	0	0	0	$5.1
		Units	1	0	0	2	0	1485	0	0	0	
4	0-4 - Waipahu		50,000	1,000,000	0	3,870,000	0	441,320	0	0	0	$9.9
		Units	1	1	0	3	0	5192	0	0	0	
5	O-5 - Waikele		50,000	1,000,000	0	3,870,000	0	226,100	0	0	0	$9.5
		Units	1	1	0	3	0	2,660	0	0	0	
6	O-6 - Nuuanu		0	0	2,000,000	3,870,000	0	562,096	0	0	0	$11.9
		Units	0	0	1	3	0	6610	0	0	0	
7	O-7 - Palolo		50,000	1,000,000	0	3,870,000	0	42,500	0	0	0	$9.2
		Units	1	1	0	3	0	500	0	0	0	
8	M-1 - Waiale Road		0	1,000,000	0	3,870,000	0	555,770	0	0	0	$10.0
		Units	0	1	0	3	0	6538	0	0	0	
9	M-2 - Kahului Channel		50,000	1,000,000	0	3,870,000	0	637,500	0	0	0	$10.3
		Units	1	1	0	3	0	7500	0	0	0	
10	M-3 - Kahoma Stream		50,000	0	2,000,000	3,870,000	0	255,000	0	0	0	$11.4
		Units	1	0	1	3	0	3,000	0	0	0	
11	M-4 - Lahaina Flood		50,000	0	2,000,000	3,870,000	0	680,000	0	0	10,400,000	$31.5
		Units	1	0	1	3	0	8,000	0	0	105,000	
12	K-1 - Nawililwili		500,000	0	0	0	0	4,250	0	1,000,000	0	$2.8
		Units	10	0	0	0	0	500	0	?	0	
13	K-2 - Lihue Airport		0	0	1	3,870,000	2,720,000	944,400	0	0	0	$13.9
		Units	0	0	1	3	16,000	11,100	0	0	0	
14	H-1 - Lower Hamakua		500,000	0	0	0	0	42,530	426,000	0	0	$1.8
		Units	10	0	0	0	0	500	8	0	0	

Appendix B - Potential Reuse Demand Pairwise

Opportunity	O-1 Wheeler Army Air Base	O-2 Mililani North Stormwater Channel	O-3 Mililani South Stormwater Channel	O-4 Waipahu Stormwater Channel	O-5 Waikele Stormwater Channel	O-6 Nu'uanu Valley Surface Water	O-7 Palolo Stream Stormwater Channel	M-1 Waiale Road Stormwater Drainage	M-2 Kahului Flood Control Channels	M-3 Kahoma Stream Flood Control	M-4 Lahaina Flood Control	K-1 Nawiliwili Diversion	K-2 Lihue Airport	H-1 Lower Hamakua Ditch	Total
O-1 Wheeler Army Air Base		2	4	4	5	5	5	3	3	3	3	3	4	4	48
O-2 Mililani North Stormwater Channel	4		5	5	5	5	5	3	3	3	3	3	4	4	52
O-3 Mililani South Stormwater Channel	2	1		4	4	5	5	2	2	2	2	2	3	3	37
O-4 Waipahu Stormwater Channel	2	1	2		4	5	5	2	2	2	2	2	3	3	35
O-5 Waikele Stormwater Channel	1	1	2	2		5	5	2	2	2	2	2	3	3	32
O-6 Nu'uanu Valley Surface Water	1	1	1	1	1		3	2	2	2	2	2	2	3	23
O-7 Palolo Stream Stormwater Channel	1	1	1	1	1	3		1	1	1	1	1	2	3	18
M-1 Waiale Road Stormwater Drainage	3	3	4	4	4	4	5		3	3	3	3	4	4	47
M-2 Kahului Flood Control Channels	3	3	4	4	4	4	5	3		3	3	3	4	4	47
M-3 Kahoma Stream Flood Control	3	3	4	4	4	4	5	3	3		3	3	4	4	47
M-4 Lahaina Flood Control	3	3	4	4	4	4	5	3	3	3		3	4	4	47
K-1 Nawiliwili Diversion	3	3	4	4	4	4	5	3	3	3	3		4	4	47
K-2 Lihue Airport	2	2	3	3	3	4	4	2	2	2	2	2		3	34
H-1 Lower Hamakua Ditch	2	2	3	3	3	3	3	2	2	2	2	2	3		32

Appendix B - Cost Estimate Pairwise

Opportunity	O-1 Wheeler Army Air Base	O-2 Mililani North Stormwater Channel	O-3 Mililani South Stormwater Channel	O-4 Waipahu Stormwater Channel	O-5 Waikele Stormwater Channel	O-6 Nu'uanu Valley Surface Water	O-7 Palolo Stream Stormwater Channel	M-1 Waiale Road Stormwater Drainage	M-2 Kahului Flood Control Channels	M-3 Kahoma Stream Flood Control	M-4 Lahaina Flood Control	K-1 Nawiliwili Diversion	K-2 Lihue Airport	H-1 Lower Hamakua Ditch	Total
O-1 Wheeler Army Air Base		3	1	3	3	4	3	3	4	4	5	1	4	1	39
O-2 Mililani North Stormwater Channel	3		1	3	3	4	3	3	3	4	5	2	5	1	40
O-3 Mililani South Stormwater Channel	5	5		4	4	5	4	4	4	5	5	2	5	1	53
O-4 Waipahu Stormwater Channel	3	3	2		3	4	3	3	3	3	5	1	5	1	39
O-5 Waikele Stormwater Channel	3	3	2	3		4	3	3	3	4	5	1	5	1	40
O-6 Nu'uanu Valley Surface Water	2	2	1	2	2		1	2	2	2	5	1	4	1	27
O-7 Palolo Stream Stormwater Channel	3	3	2	3	3	5		3	3	4	5	1	5	1	41
M-1 Waiale Road Stormwater Drainage	3	3	2	3	3	4	3		3	3	5	1	5	1	39
M-2 Kahului Flood Control Channels	2	3	2	3	3	4	3	3		3	5	1	4	1	37
M-3 Kahoma Stream Flood Control	2	2	1	3	2	4	2	3	3		5	1	4	1	33
M-4 Lahaina Flood Control	1	1	1	1	1	1	1	1	1	1		1	1	1	13
K-1 Nawiliwili Diversion	5	4	4	5	5	5	5	5	5	5	5		5	1	59
K-2 Lihue Airport	2	1	1	1	1	2	1	1	2	2	5	1		1	21
H-1 Lower Hamakua Ditch	5	5	5	5	5	5	5	5	5	5	5	5	5		65

Appendix B - Potential Stormwater Volume Pairwise

Opportunity	O-1 Wheeler Army Air Base	O-2 Mililani North Stormwater Channel	O-3 Mililani South Stormwater Channel	O-4 Waipahu Stormwater Channel	O-5 Waikele Stormwater Channel	O-6 Nu'uanu Valley Surface Water	O-7 Palolo Stream Stormwater Channel	M-1 Waiale Road Stormwater Drainage	M-2 Kahului Flood Control Channels	M-3 Kahoma Stream Flood Control	M-4 Lahaina Flood Control	K-1 Nawiliwili Diversion	K-2 Lihue Airport	H-1 Lower Hamakua Ditch	Total
O-1 Wheeler Army Air Base		3	4	3	3	2	2	3	2	2	2	2	4	3	35
O-2 Mililani North Stormwater Channel	3		4	3	3	2	2	4	2	2	2	2	4	3	36
O-3 Mililani South Stormwater Channel	2	2		2	2	1	1	2	1	1	1	1	4	3	23
O-4 Waipahu Stormwater Channel	3	3	4		3	2	2	3	2	2	2	2	4	3	35
O-5 Waikele Stormwater Channel	3	3	4	3		2	3	3	2	1	1	1	4	3	33
O-6 Nu'uanu Valley Surface Water	4	4	5	4	4		3	5	4	3	3	3	5	3	50
O-7 Palolo Stream Stormwater Channel	4	4	5	4	3	3		4	4	3	3	3	4	4	48
M-1 Waiale Road Stormwater Drainage	3	2	4	3	3	1	2		2	2	2	2	4	3	33
M-2 Kahului Flood Control Channels	4	4	5	4	4	2	2	4		2	2	3	4	4	44
M-3 Kahoma Stream Flood Control	4	4	5	4	5	3	3	4	4		3	3	5	4	51
M-4 Lahaina Flood Control	4	4	5	4	5	3	3	4	4	3		3	5	3	50
K-1 Nawiliwili Diversion	4	4	5	4	5	3	3	4	3	3	3		5	3	49
K-2 Lihue Airport	2	2	2	2	2	1	2	2	2	1	1	1		3	23
H-1 Lower Hamakua Ditch	3	3	3	3	3	3	2	3	2	2	3	3	3		36

Appendix B - Potential Partnerships Pairwise

Opportunity	O-1 Wheeler Army Air Base	O-2 Mililani North Stormwater Channel	O-3 Mililani South Stormwater Channel	O-4 Waipahu Stormwater Channel	O-5 Waikele Stormwater Channel	O-6 Nu'uanu Valley Surface Water	O-7 Palolo Stream Stormwater Channel	M-1 Waiale Road Stormwater Drainage	M-2 Kahului Flood Control Channels	M-3 Kahoma Stream Flood Control	M-4 Lahaina Flood Control	K-1 Nawiliwili Diversion	K-2 Lihue Airport	H-1 Lower Hamakua Ditch	Total
O-1 Wheeler Army Air Base		4	4	5	5	4	5	3	5	5	5	5	5	5	60
O-2 Mililani North Stormwater Channel	2		3	4	4	4	4	4	4	4	4	4	4	4	49
O-3 Mililani South Stormwater Channel	2	3		5	5	5	5	5	5	5	5	5	5	5	60
O-4 Waipahu Stormwater Channel	1	2	1		3	2	2	1	3	3	3	3	3	3	30
O-5 Waikele Stormwater Channel	1	2	1	3		2	3	1	3	3	3	3	3	3	31
O-6 Nu'uanu Valley Surface Water	2	2	1	4	4		4	2	4	4	4	4	4	4	43
O-7 Palolo Stream Stormwater Channel	1	2	1	4	3	2		1	3	3	3	3	3	3	32
M-1 Waiale Road Stormwater Drainage	3	2	1	5	5	4	5		5	5	5	5	5	5	55
M-2 Kahului Flood Control Channels	1	2	1	3	3	2	3	1		3	3	3	3	3	31
M-3 Kahoma Stream Flood Control	1	2	1	3	3	2	3	1	3		3	3	3	3	31
M-4 Lahaina Flood Control	1	2	1	3	3	2	3	1	3	3		3	3	3	31
K-1 Nawiliwili Diversion	1	2	1	3	3	2	3	1	3	3	3		3	3	31
K-2 Lihue Airport	1	2	1	3	3	2	3	1	3	3	3	3		3	31
H-1 Lower Hamakua Ditch	1	2	1	3	3	2	3	1	3	3	3	3	3		31

Appendix B - Likelihood of Implementation Pairwise

Opportunity	O-1 Wheeler Army Air Base	O-2 Mililani North Stormwater Channel	O-3 Mililani South Stormwater Channel	O-4 Waipahu Stormwater Channel	O-5 Waikele Stormwater Channel	O-6 Nu'uanu Valley Surface Water	O-7 Palolo Stream Stormwater Channel	M-1 Waiale Road Stormwater Drainage	M-2 Kahului Flood Control Channels	M-3 Kahoma Stream Flood Control	M-4 Lahaina Flood Control	K-1 Nawiliwili Diversion	K-2 Lihue Airport	H-1 Lower Hamakua Ditch	Total
O-1 Wheeler Army Air Base		3	4	4	4	4	4	4	4	4	4	4	4	4	51
O-2 Mililani North Stormwater Channel	3		3	3	3	4	3	3	4	3	3	2	3	4	41
O-3 Mililani South Stormwater Channel	2	3		3	3	4	3	3	4	3	3	2	3	4	40
O-4 Waipahu Stormwater Channel	2	3	3		3	4	3	3	4	3	3	2	3	4	40
O-5 Waikele Stormwater Channel	2	3	3	3		4	3	3	4	3	3	2	3	4	40
O-6 Nu'uanu Valley Surface Water	2	2	2	2	2		3	2	3	2	2	2	3	3	30
O-7 Palolo Stream Stormwater Channel	2	3	3	3	3	3		3	4	3	3	2	3	3	38
M-1 Waiale Road Stormwater Drainage	2	3	3	3	3	4	3		4	3	3	2	3	4	40
M-2 Kahului Flood Control Channels	2	2	2	2	2	3	2	2		2	2	1	3	2	27
M-3 Kahoma Stream Flood Control	2	3	3	3	3	4	3	3	4		3	2	3	4	40
M-4 Lahaina Flood Control	2	3	3	3	3	4	3	3	4	3		2	3	4	40
K-1 Nawiliwili Diversion	2	4	4	4	4	4	4	4	5	4	4		4	4	51
K-2 Lihue Airport	2	3	3	3	3	3	3	3	3	3	3	2		3	37
H-1 Lower Hamakua Ditch	2	2	2	2	2	3	3	2	4	2	2	2	3		31

Appendix B - Institutional Constraints Pairwise

Opportunity	O-1 Wheeler Army Air Base	O-2 Mililani North Stormwater Channel	O-3 Mililani South Stormwater Channel	O-4 Waipahu Stormwater Channel	O-5 Waikele Stormwater Channel	O-6 Nu'uanu Valley Surface Water	O-7 Palolo Stream Stormwater Channel	M-1 Waiale Road Stormwater Drainage	M-2 Kahului Flood Control Channels	M-3 Kahoma Stream Flood Control	M-4 Lahaina Flood Control	K-1 Nawiliwili Diversion	K-2 Lihue Airport	H-1 Lower Hamakua Ditch	Total
O-1 Wheeler Army Air Base		5	5	5	5	5	5	3	5	5	5	5	5	5	63
O-2 Mililani North Stormwater Channel	1		3	3	3	3	3	1	3	3	3	3	3	3	35
O-3 Mililani South Stormwater Channel	1	3		3	3	3	3	1	3	3	3	3	3	3	35
O-4 Waipahu Stormwater Channel	1	3	3		3	3	3	1	3	3	3	3	3	3	35
O-5 Waikele Stormwater Channel	1	3	3	3		3	3	1	3	3	3	3	3	3	35
O-6 Nu'uanu Valley Surface Water	1	3	3	3	3		3	1	3	3	3	3	3	3	35
O-7 Palolo Stream Stormwater Channel	1	3	3	3	3	3		1	3	3	3	3	3	3	35
M-1 Waiale Road Stormwater Drainage	3	5	5	5	5	5	5		5	5	5	5	5	5	63
M-2 Kahului Flood Control Channels	1	3	3	3	3	3	3	1		3	3	3	3	3	35
M-3 Kahoma Stream Flood Control	1	3	3	3	3	3	3	1	3		3	3	3	3	35
M-4 Lahaina Flood Control	1	3	3	3	3	3	3	1	3	3		3	3	3	35
K-1 Nawiliwili Diversion	1	3	3	3	3	3	3	1	3	3	3		3	3	35
K-2 Lihue Airport	1	3	3	3	3	3	3	1	3	3	3	3		3	35
H-1 Lower Hamakua Ditch	1	3	3	3	3	3	3	1	3	3	3	3	3		35

Appendix B - Combined Pairwise

Opportunity	Potential Reuse Demand	Weight	Total	Cost Estimate	Weight	Total	Potential Stormwater Volume	Weight	Total	Potential Partnerships	Weight	Total	Likelihood of Implementation	Weight	Total	Institutional Constraints	Weight	Total	Total
O-1 Wheeler Army Air Base	48	0.19	9.1	39	0.18	7.0	35	0.17	6.0	60	0.16	9.6	51	0.16	8.2	63	0.13	8.2	48.0
O-2 Mililani North Stormwater Channel	52	0.19	9.9	40	0.18	7.2	36	0.17	6.1	49	0.16	7.8	41	0.16	6.6	35	0.13	4.6	42.2
O-3 Mililani South Stormwater Channel	37	0.19	7.0	53	0.18	9.5	23	0.17	3.9	60	0.16	9.6	40	0.16	6.4	35	0.13	4.6	41.0
O-4 Waipahu Stormwater Channel	35	0.19	6.7	39	0.18	7.0	35	0.17	6.0	30	0.16	4.8	40	0.16	6.4	35	0.13	4.6	35.4
O-5 Waikele Stormwater Channel	32	0.19	6.1	40	0.18	7.2	33	0.17	5.6	31	0.16	5.0	40	0.16	6.4	35	0.13	4.6	34.8
O-6 Nu'uanu Valley Surface Water	23	0.19	4.4	27	0.18	4.9	50	0.17	8.5	43	0.16	6.9	30	0.16	4.8	35	0.13	4.6	34.0
O-7 Palolo Stream Stormwater Channel	18	0.19	3.4	41	0.18	7.4	48	0.17	8.2	32	0.16	5.1	38	0.16	6.1	35	0.13	4.6	34.7
M-1 Waiale Road Stormwater Drainage	47	0.19	8.9	39	0.18	7.0	33	0.17	5.6	55	0.16	8.8	40	0.16	6.4	63	0.13	8.2	45.0
M-2 Kahului Flood Control Channels	47	0.19	8.9	37	0.18	6.7	44	0.17	7.5	31	0.16	5.0	27	0.16	4.3	35	0.13	4.6	36.9
M-3 Kahoma Stream Flood Control	47	0.19	8.9	33	0.18	5.9	51	0.17	8.7	31	0.16	5.0	40	0.16	6.4	35	0.13	4.6	39.5
M-4 Lahaina Flood Control	47	0.19	8.9	13	0.18	2.3	50	0.17	8.5	31	0.16	5.0	40	0.16	6.4	35	0.13	4.6	35.7
K-1 Nawiliwili Diversion	47	0.19	8.9	59	0.18	10.6	49	0.17	8.3	31	0.16	5.0	51	0.16	8.2	35	0.13	4.6	45.6
K-2 Lihue Airport	34	0.19	6.5	21	0.18	3.8	23	0.17	3.9	31	0.16	5.0	37	0.16	5.9	35	0.13	4.6	29.6
H-1 Lower Hamakua Ditch	32	0.19	6.1	65	0.18	11.7	36	0.17	6.1	31	0.16	5.0	31	0.16	5.0	35	0.13	4.6	38.4

Final Ranking

O-1 Wheeler Army Air Base	48.0
K-1 Nawiliwili Diversion	45.6
M-1 Waiale Road Stormwater Drainage	45.0
O-2 Mililani North Stormwater Channel	42.2
O-3 Mililani South Stormwater Channel	41.0
M-3 Kahoma Stream Flood Control	39.5
H-1 Lower Hamakua Ditch	38.4
M-2 Kahului Flood Control Channels	36.9
M-4 Lahaina Flood Control	35.7
O-4 Waipahu Stormwater Channel	35.4
O-5 Waikele Stormwater Channel	34.8
O-7 Palolo Stream Stormwater Channel	34.7
O-6 Nu'uanu Valley Surface Water	34.0
K-2 Lihue Airport	29.6