ALA WAI CANAL FLOOD RISK MANAGEMENT STUDY, O'AHU, HAWAI'I FEASIBILITY STUDY WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

INTERIM FINAL REPORT

MAY 2017

US Army Corps of Engineers®

FINAL REPORT

FEASIBILITY STUDY WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

ALA WAI CANAL FLOOD RISK MANAGEMENT STUDY, O'AHU, HAWAI'I

This document has been prepared in accordance with the requirements of the National Environmental Policy Act (NEPA) and Hawai'i Revised Statutes (HRS) Chapter 343.

Proponent (NEPA):
Honolulu District
U.S. Army Corps of Engineers
Building 230 (CEPOH-PP-C)
Fort Shafter, Hawai'i 96858

Non-Federal Sponsor and
Proposing Agency (HRS Section 343):
State of Hawai'i
Department of Land and Natural Resources
1151 Punchbowl Street, Room 130
Honolulu, Hawai'i 96813

This document was prepared under my direction and to the best of my knowledge; the information contained herein fully addresses the content requirements as set forth in section 11-200-17 and 11-200-18, as appropriate.

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Suzanne Case, Chairperson
Board of Land and Natural Resources

May 2017

Ala Wai Canal Flood Risk Management Study, O'ahu, Hawai'i

Document Type:	Feasibility Study Report with Integrated Environmental Impact Statement (EIS)
Responsible Agencies (Project Sponsors):	State of Hawai'i, Department of Land and Natural Resources (DLNR)[a] U.S. Army Corps of Engineers[b]
Study Authority:	Section 209 of the Flood Control Act of 1962 (Public Law 87-874)
Location:	Ala Wai Watershed, City and County of Honolulu; O'ahu, Hawai'i
Tax Map Key(s):	(1)2-9-054:019, 029, 034, 004, 002; (1)2-9-055:009, 001; (1)2-5-020:005, 008, 001; (1)2-9-036:003; (1)2-9-029:053; (1)2-7-036:001; (1)2-9-043:002; (1)3-4-016:059; (1)3-4-034:001, 008, 009; (1)3-4-019:003 through 010, 052; (1)2-8-029:011, 004; (1)2-7-036:002; 2-9-067:008 through 012, 015 through 017
Actions Requiring HRS Chapter 343 Review	Use of State and County lands and funds; Use of Conservation District lands; Use within historic site as designated in the National Register and Hawai'i Register; Use within Waikīkī Special District
Determination	The USACE and DLNR have determined that the proposed action requires the preparation of an EIS, based on the requirements of NEPA and HRS Chapter 343.

NOTES:
[a] The State of Hawai'i is the proposing agency for purposes of complying with Hawai'i Revised Statutes (HRS) Chapter 343; the accepting authority would be the Governor.
[b] The USACE is the lead agency for purposes of complying with the National Environmental Policy Act (NEPA).

ABSTRACT

This Feasibility Study Report with integrated Environmental Impact Statement (Feasibility Report/EIS) has been prepared for the Ala Wai Canal Flood Risk Management Study, Oahu, Hawaii. The purpose of the Ala Wai Canal Flood Risk Management Study is to reduce riverine flood risks in the Ala Wai Watershed. The study is authorized by Section 209 of the Flood Control Act of 1962 (Public Law 87-874), which is a general study authority for surveys in harbors and rivers in Hawai'i "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, and other beneficial water uses, and related land resources." Section 209 does not authorize implementation of the proposed action.

Flooding associated with a 1-percent annual chance exceedance (ACE) rainfall event would affect approximately 1,358 acres within the Ala Wai Watershed, including over 3,000 properties with an estimated $1.14 billion in structural damages alone (at 2016 price levels). In response to identified flood-related problems and opportunities, a series of flood risk management measures were identified and formulated into five alternatives. The alternatives were evaluated through an iterative screening and reformulation process, resulting in tentative selection of a plan for implementation. The recommended plan would reduce flood risks by improving the flood warning system, and constructing six in-stream debris and detention basins in the upper reaches of Makiki, Mānoa and Pālolo streams, one standalone debris catchment feature, three multi-purpose detention areas in open spaces through the developed watershed, and concrete floodwalls averaging 4 feet high along one or both sides of approximately 1.9 miles of the Ala Wai Canal (including two pump stations). Potential adverse impacts include those related to biological resources (aquatic habitat), cultural resources, recreation, and visual resources; however, measures to avoid, minimize, and mitigate these impacts have been incorporated to the extent practicable. Although some degree of impact would occur, project analyses have not identified significant, unavoidable adverse impacts that would remain after implementation of proposed mitigation measures. Unavoidable environmental impacts to aquatic habitat would be fully compensated for by eliminating

migratory passage barriers at two in-stream structures in Mānoa Stream to improve connectivity for native aquatic fauna. This mitigation would be monitored for up to 5 years to ensure its performance. The recommended plan is the national economic development plan.

The State of Hawaii Department of Land and Natural Resources, Engineering Division is the non-Federal cost-sharing sponsor for all features. Based on October 2016 price levels, the estimated total project first cost of the recommended plan is $306,095,000. In accordance with the cost-sharing provisions of Section 103 of the Water Resources Development Act (WRDA) of 1986, as amended [33 U.S.C. 2213(a)], the Federal share of the project first cost would be about $198,962,000 (65 percent) and the non-Federal share would be about $107,133,000 (35 percent). The cost of lands, easements, rights-of-way, relocations, or disposal areas is estimated at approximately $17,194,000. The non-Federal sponsor would be responsible for the operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) of the project after construction, a cost currently estimated at about $985,000 per year.

Based on a 2.875 percent discount rate and a 50-year period of analysis, the expected annual costs are estimated to be $13,117,000, including OMRR&R. The recommended plan is estimated to be 99.9 percent reliable in protecting portions of Honolulu, Hawaii from a flood which has a 1 percent chance of occurrence in any year. The recommended plan would reduce average annual flood risks and would leave average annual residual damages estimated at $5.4 million. The expected annual benefits are estimated to be $48,331,000 with net average annual benefits of $35,214,000. The benefit-cost ratio is approximately 3.68 to 1.

PUBLIC REVIEW

Comments on the Draft Feasibility Report/EIS were received during a 45-day public review period. Written comments have been submitted to USACE (pursuant to NEPA) and DLNR (pursuant to HRS Chapter 343); the applicable addresses are listed below. Comments postmarked by November 9, 2015 have been included in this report.

- Honolulu District, U.S. Army Corps of Engineers (ATTN: Ala Wai Canal Project); Building 230, CEPOH-PP-C; Fort Shafter, HI 96858 (email: AlaWaiCanalProject@usace.army.mil)
- State of Hawai'i, DLNR Engineering Division (ATTN: Gayson Ching); P.O. Box 373; Honolulu, HI 96809 (email: Gayson.Y.Ching@hawaii.gov)

For further information on the project, please contact Derek Chow at USACE at (808) 835-4026 or Derek.J.Chow@usace.army.mil, or Gayson Ching at DLNR Engineering Division at (808) 587-0232 or Gayson.Y.Ching@hawaii.gov.

Executive Summary

This Feasibility Study Report with Integrated Environmental Impact Statement (EIS), hereafter referred to as the “Feasibility Report/EIS,” has been prepared for the Ala Wai Canal Project, O’ahu, Hawai’i. It assesses the risk of flooding in the Ala Wai Watershed, and describes a range of potential alternative plans formulated to reduce flood risk, with identification of a recommended plan for implementation. It constitutes both a Feasibility Study Report in accordance with the U.S. Army Corps of Engineers (USACE) planning process, and an Environmental Impact Statement (EIS) as required to comply with both the National Environmental Policy Act (NEPA) and Hawaii Revised Statutes (HRS) Chapter 343. Following public and governmental agency review, the Feasibility Report/EIS is finalized and submitted to Headquarters USACE, the Assistant Secretary of the Army for Civil Works, and the Office of Management and Budget for review and approval. If approved, a Chief of Engineers Report would be sent to Congress recommending authorization of the Ala Wai Canal Project.

ES-1 Purpose and Need

The purpose of the project is to reduce flood risk within the Ala Wai Watershed. Flooding has occurred within the watershed on multiple occasions, resulting in recorded property damages and health and safety risks. Analyses conducted in support of this project show that the 1-percent annual chance exceedance (ACE) floodplain extends over approximately 1,358 acres of the watershed. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $1.14 billion in structural damages alone (2016 price levels), not accounting for loss in business income or other similar economic losses. A rendering of the potential extent of inundation resulting from the 1-percent ACE flood is illustrated in Figure ES-1.

Figure ES-1. USACE Rendering of 1-Percent Annual Chance Exceedance Flood

ES-2 Study Area and Need for Action

The Ala Wai Watershed is located on the southeastern side of the island of O‘ahu, and includes Makiki, Mānoa, and Pālolo streams, all of which drain to the Ala Wai Canal. The Canal is a 2-mile-long waterway constructed during the 1920s to drain extensive coastal wetlands, thus allowing development of the Waikīkī District. A large portion of the watershed, including most of Waikīkī, is highly susceptible to flooding.

A high risk of flooding exists within the watershed because of the natural geography, coupled with aging and undersized flood conveyance infrastructure. Based on the peak flows computed for this study, it is estimated that the Ala Wai Canal has the capacity to contain about a 20-percent ACE flood before overtopping the banks. The risk of flooding is exacerbated by the flashy nature of the streams in the watershed, with heavy rains flowing downstream extremely quickly due to steep topography and relatively short stream systems.

Overtopping of the Canal has previously flooded Waikīkī multiple times, including during the November 1965 and December 1967 storms and during the passage of Hurricane Iniki in 1992. Upstream areas are also at risk of flooding, as demonstrated by several recent events, including the October 2004 storm that flooded Mānoa Valley and the March 2006 storm that flooded Makiki. The October 2004 event was estimated to have a 4 percent chance of occurring in any single year, and caused more than $85 million in damages (USACE, 2006a). Multiple other past flood events have been documented within the watershed over the course of the past century. In addition to recorded property damages, these events have contributed to health and safety risks, including two known deaths associated with flooding in December 1918 and December 1950 (USACE, 2006a).

Within the 1-percent ACE floodplain, the affected population is comprised of approximately 54,000 residents plus an additional estimated 79,000 visitors in Waikīkī on any given day. In addition to threatening the safety of both residents and visitors, a major flood event could result in catastrophic damages to structures and property throughout the watershed, with impacts to Waikīkī crippling the local economy. Given the extent of development within the watershed (particularly in the Waikīkī District), there are potentially significant benefits associated with implementing flood risk management measures.

ES-3 Study Authority

The Ala Wai Canal Project feasibility study is authorized under Section 209 of the Flood Control Act of 1962 (Public Law 87-874). Section 209 is a general study authority that authorizes surveys in harbors and rivers in Hawai'i "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply, and other beneficial water uses, and related land resources." Section 209 does not provide authority to implement the recommended project.

ES-4 Study Sponsor

The USACE is the Federal sponsor of the project; the non-Federal sponsor is the State of Hawai'i Department of Land and Natural Resources (DLNR), represented by the Engineering Division. A Feasibility Cost Sharing Agreement (FCSA) was originally executed with DLNR in March 2001; the agreement was amended in December 2006 and November 2012.

ES-5 Objectives and Constraints

Based on the flood risk management goal, specific flood-related problems were defined for the Ala Wai Watershed, as listed below.

- Flooding can result from typical rainfall events, and is exacerbated by the flashy nature of the streams and debris generated by the surrounding watershed.
- Urbanization of the watershed has placed more people and properties at risk of flooding.
- Historic alterations to the stream channels do not adequately manage flood risk.
- Stream channel capacities are diminished due to debris and sediment.
- Flooding may be exacerbated by climate change and associated projected increases in sea level rise.

Opportunities to reduce flood risk in the study area generally correspond to the problems, and include reducing flood peaks, improving channel and bridge conveyance capacities, reducing debris contributions, and improving education and communication of flood risks. Other opportunities that were identified, but were determined to be outside the scope of the study include reducing runoff and improving the storm drainage system, routine dredging of the Canal, and addressing land ownership boundaries and maintenance responsibilities.

In response to the flood-related problems and opportunities identified for the study area, the planning objective for the Ala Wai Canal Project is to reduce riverine flood risks in the Ala Wai Watershed through the 50-year period of analysis. Constraints considered in the planning process include, to the extent practicable, avoidance and/or minimization of the following: induced flood damages and/or shifting of flooding to downstream areas; development of infrastructure that is incompatible with existing regulations or policies; induced development in the existing floodplain; significant reduction of migratory pathways or habitat for native aquatic species, or increase of habitat for invasive aquatic species; and impacts to nearshore marine resources at the mouth of the Canal.

ES-6 Alternative Plan Formulation Strategy

The strategy for formulating alternative plans incorporated a methodical approach to assembling flood risk management measures into alternative plans, and a multi-criteria screening process based upon existing data and available information, coordinated professional judgment, and risk-informed assumptions. In general, the process involved an initial grouping of conceptual flood risk management measures based on the identified problems within the watershed; these groupings were used to compile alternative plans, which were then focused from broad flood risk management concepts to a combination of site-specific actions that best met the overall planning objectives/constraints.

An iterative planning process was utilized in the development of the recommendation contained within this report. An increasing level of detail was used at each successive iteration, as needed to develop and refine the conceptual management measures and alternative plans, and ultimately, to provide the basis for evaluation and comparison of the final array of alternatives. In general, the early iterations of the plan formulation process were based on concept-level information using available information from existing studies coupled with professional judgment, and culminated with the development of 35% design-level engineering plans and cost estimates for the recommended plan. As noted in the following sections, the nomenclature for the alternatives was modified over the course of the plan formulation process to reflect refinements made to each alternative (e.g., after refinements were made, Alternative 2 was renamed Alternative 2A).

ES-7 Management Measures and Alternative Plans

Over the course of the planning process, a variety of structural and non-structural flood risk management measures were identified, with a focus on the following approaches to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, and (4) minimization of flood damages. This effort relied on the results of previous reports and studies, particularly the Ala Wai Flood Study (USACE, 2006) and the Mānoa Watershed Project (Oceanit, 2008a), as well as sponsor and stakeholder input and professional judgment. The conceptual measures were sited and screened using a set of project-specific criteria, including technical feasibility, availability of land, implementation costs, operations and maintenance (O&M) requirements, legal and public acceptability, flood damage reduction, and life safety risks. Through the screening process, some measures were eliminated while others were refined and combined into an array of alternatives. The conceptual flood risk management measures that were carried forward from the screening process were then grouped to address the existing flood-related problems and opportunities, with the grouping used to define the initial array of alternatives based on various strategies for addressing flood risk. The resulting alternatives, and the primary focus of each is listed below:

- **Alternative 1 (Mānoa Dam):** This alternative was formulated to maximize attenuation of water in the upper Mānoa watershed, where the majority of peak flows are generated.

- **Alternative 2 (Multiple Debris and Detention Basins in Developed Portion of Watershed):** This alternative was formulated to maximize attenuation of water through multi-purpose detention basins within open spaces in the currently developed portions of the watershed.
- **Alternative 3 (Multiple Debris and Detention Basins in Upper Watershed):** This alternative was formulated to modify the location and dimension of measures in Alternatives 1 and 2, with debris and detention basins in the upper watershed to address concerns related to construction of a single, large dam and use of park space.
- **Alternative 4 (Ala Wai Focus):** This alternative was formulated to maximize structural solutions where the majority of the benefits occur (i.e. along the Ala Wai Canal).
- **Alternative 5 (Non-Structural):** This alternative was formulated based on all of the non-structural measures that were initially identified, including raising or waterproofing (and in some cases, installing ring levees or non-structural berms) for approximately 340 structures within the watershed.

In general, each alternative was formulated to address existing flood risk throughout the watershed, while maintaining focus on the primary strategy for each alternative. In addition, debris catchment was incorporated into the upper reaches of Mānoa and Pālolo streams (either as a stand-alone measure, or as part of a detention basin), in order to address known debris-related problems. Where economically feasible, opportunities to reduce flood damages through non-structural measures were included as part of the four structural alternatives. In particular, improvements to the existing flood warning system were included in all of the alternatives.

Over the course of the planning process, the alternatives were screened and reformulated, with additional technical analysis and refinement as needed to maximize completeness, effectiveness, efficiency, and acceptability; an "A" was added to each alternative name to reflect these refinements. Through this process, Alternatives 1A, 4A, and 5A were eliminated from further consideration. Alternative 1A was eliminated as it was determined that the most effective location for a single, large dam would be in the middle of the watershed (where there is an adequately-sized drainage area), but given the density of urban development, this is not considered a practicable solution. Alternative 4A included several measures along the Ala Wai Canal that were determined to not be practicable or effective (pumping peak flows from the Canal, widening/deepening the Canal, and adding another outlet to the Canal); in the absence of these other measures, the floodwalls along the Canal would need to be up to 14 feet tall, which was determined to be unacceptable. Alternative 5A was iteratively refined based on the economic justification for individual non-structural measures, and ultimately was reduced to only 100 to 125 structures (or less than 2 percent of the structures in the floodplain displaying sufficient damage to be economically justified); it was determined that this alternative would not meet the project objective.

Based on the outcome of this process, the No Action Alternative and Alternatives 2A and 3A were defined as the Final Array of Alternatives, and were carried forward for evaluation and comparison. This process incorporated agency and public input obtained through scoping efforts and other stakeholder engagement activities.

ES-8 Evaluation and Comparison of Alternatives

To support the evaluation and comparison of the Final Array of Alternatives, the design and engineering information for Alternatives 2A and 3A was developed to a 10% level of design. Cost estimates were developed based on the design plans (with placeholder costs for mitigation activities based on the anticipated amount of impact to aquatic habitat and cultural resources); contingencies were identified according to a cost risk analysis. The resulting cost estimates were used to refine the economic benefits. The preliminary cost and benefit estimates are summarized in Table ES-1.

Table ES-1. Preliminary Cost and Benefit Estimates for the Final Array of Alternatives ($000)

	Alternative 2A	Alternative 3A
Estimated Cost (at October 2013 price level)[a]	$221,231	$178,096
Estimated Average Annual Cost (3.5% for 50 years)[a,b]	$11,097	$8,923
Total Annual Benefits	$24,814	$32,272
Annual Net Benefits	13,717	23,349
BCR	2.24	3.62

Notes:
[a] The price level is based on the preparation date of the cost estimate. [b] Estimated Average Annual Cost includes Interest During Construction (IDC) and O&M requirements.

For flood risk management projects, the primary criteria for plan selection are based on total benefits and total cost, in which the results of the economic analyses are used to establish Federal interest. In the case of this project, life safety considerations were also taken into account. Consistent with the requirements of the USACE Planning Guidance Notebook (Engineer Regulation [ER] 1105-2-100), the evaluation and comparison of alternative plans was presented in terms of the plan contributions to National Economic Development (NED), Environmental Quality (EQ), Regional Economic Development (RED), and Other Social Effects (OSE); this evaluation is presented in Section 3.9.1.

ES-9 Plan Selection

The USACE planning process requires detailed economic analyses (and associated refinements) to ensure that an alternative plan being considered for selection is economically justified, such that no other variation of that plan could be more economically beneficial (i.e., no other variation could better maximize the NED account). Specifically, these analyses include incremental justification (to ensure that each measure included in the alternative is economically justified) and optimization (to ensure that the scale of each measure maximizes benefits). In the case of this project, it was determined that the alternative plans in the final array provided a reasonable basis for evaluation and comparison, and that detailed economic analyses and refinements should only be performed for the higher-ranking alternative identified through the evaluation and comparison process. It was determined that similar analysis and refinements were not needed for the other action alternative in the final array, as they would not affect the relative comparison between the alternatives. Based on this approach, additional detailed economic analyses and design refinements were conducted for Alternative 3A. Various increments and refinements were considered (with additional alternative number modifiers added accordingly), leading to identification of Alternative 3A-2.2 as the NED plan.

Federal policy requires that the NED plan be recommended for implementation unless there are overriding reasons for recommending another plan. The attributes of the NED plan were reviewed relative to the planning objectives, criteria and engineering standards, and it was determined that there were no overriding reasons that warranted recommendation of another plan, such that the NED Plan was identified as the recommended plan.

ES-10 Compensatory Mitigation Measures

Consistent with USACE regulations (ER 1105-2-100), which require that changes in habitat value be quantified using ecosystem output model, the Hawai'i Stream Habitat Equivalency Procedure (HSHEP) was used to quantify the loss of habitat function associated with implementation of the recommended plan. The HSHEP model was developed to support management of Hawai'i's streams and associated habitat for freshwater flora and fauna through a collaborative effort by biologists at the State of Hawai'i Division of Aquatic Resources (DAR) and researchers at various universities, agencies, museums, and private companies. To confirm its applicability to the Ala Wai Canal Project, the model was reviewed by the USACE Ecosystem Planning Center of Expertise (ECO-PCX), and was certified for project use on May 19, 2015.

Using the HSHEP model, the habitat quality of the existing and future without-project conditions were quantified. Anticipated changes in the model variables were defined for the with-project condition, based on the design for the recommended plan. The modeling results indicate a loss of 295 habitat units (HUs). Potential mitigation concepts that could be implemented to offset this anticipated loss of habitat quality were identified and refined through an iterative process, in coordination with the resource agencies, resulting in the identification of a suite of possible mitigation alternatives. These mitigation alternatives were developed to the 10-percent design level; habitat benefits were estimated using the HSHEP model and cost estimates were prepared. The habitat modeling results and the cost estimates were used to complete a Cost Effectiveness and Incremental Cost Analysis (CE/ICA), which provided the basis for selection of the mitigation alternative to be included as part of the recommended plan. Based on this process, the selected mitigation alternative is comprised of two measures, both of which involve removal of a migratory passage barrier for native aquatic species in Mānoa Stream. A detailed description of the mitigation development and selection process, and the conceptual mitigation design information is provided in the Mitigation and Monitoring Plan (Appendix E).

ES-11 Recommended Plan

Following identification of Alternative 3A-2.2 as the recommended plan, additional engineering and design work was completed, up to an approximately 35% level of design. The flood risk management measures included in the tentatively select plan are listed in Table ES-2; maps showing the location of these measures are presented as Figure 12.

Table ES-2. Summary of the Recommended Plan

Flood Risk Management Measure	Description
Waihi Debris and Detention Basin	Earthen structure, approximately 37 feet high and 225 feet across; box culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert. New access road to be constructed for construction and O&M.
Waiakeakua Debris and Detention Basin	Earthen structure, approximately 34 feet high and 185 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert.
Woodlawn Ditch Detention Basin	Three-sided berm, approximately 15 feet high and 840 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side.
Mānoa In-stream Debris Catchment	Concrete pad, approximately 8 feet wide and 60 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad.
Kanewai Field Multi-Purpose Detention Basin	Earthen berm, approximately 9 feet high, around 3 sides of the field; grouted rip-rap inflow spillway along bank of Mānoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.
Wai'ōma'o Debris and Detention Basin	Earthen structure, approximately 33.5 feet high and 120 feet across; box culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert. Excavation of approx. 3,060 yd^3 to provide required detention volume upstream of berm; new access road to be constructed for construction and O&M.
Pūkele Debris and Detention Basin	Earthen structure, approximately 30 feet high and 120 feet across; box culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert. Excavation of approx. 14,330 yd^3 to provide required detention volume upstream of berm; new access road to be constructed for construction and O&M.
Makiki Debris and Detention Basin	Earthen structure, approximately 24 feet high and 100 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris

Table ES-2. Summary of the Recommended Plan

Flood Risk Management Measure	Description
	catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert. New access road to be constructed for construction and O&M.
Ala Wai Canal Floodwalls	Concrete floodwalls ranging up to approximately 4 feet high, offset from existing Canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to Canal; floodgate to be installed near McCully Street. Two pump stations to accommodate storm flows and gates installed at existing drainage pipes to prevent backflow from the Ala Wai Canal during a flood event.
Hausten Ditch Detention Basin	Concrete floodwalls and an earthen berm (approximately 4.3 feet high) to provide detention for local drainage; install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to prevent a backflow from the Ala Wai Canal during a flood event.
Ala Wai Golf Course Multi-Purpose Detention Basin	Earthen berm, on average 2.7 feet high, around the north and east perimeter of the golf course; grouted rip rap inflow spillway along bank of Mānoa-Pālolo Drainage Canal to allow high flows to enter the basin; sediment basin within western portion of golf course; floodgate across the main entrance road; passive drainage back into Ala Wai Canal.
Floodwarning System	Installation of 3 real-time rain gages (Mānoa, Makiki, and Pālolo streams) and 1 real-time streamflow or stage gage (Ala Wai Canal) as part of flood warning system for Ala Wai Watershed.

Each of the measures includes life-cycle maintenance costs, with maintenance performed on a routine basis. Consistent with USACE regulations, the O&M responsibilities would be fulfilled by the non-Federal sponsor. General O&M requirements are described in Section 3.6.5.1; a detailed plan will be prepared during the detailed design phase for the project.

ES-12 Expected Project Performance

The recommended plan provides protection for the 1-percent ACE flood event with a 95-percent conditional non-exceedance probability (CNP) and has been identified as the economically optimal plan. Although the recommended plan would protect the majority of the watershed from the 1-percent ACE floodplain, it would not entirely eliminate flood risk. The without-project expected annual damages are estimated to be approximately $45.2 million; the residual expected annual damages associated with the recommended plan are estimated to be $5.4 million (with the highest residual damages in Makiki and the area surrounding the University of Hawaii, Manoa).

ES-13 Project Costs

The project first cost (October 2016 price level) for the recommended plan is summarized in Table ES-3. The project first cost (constant dollar cost) serves as the basis for providing the cost of the project for which authorization is sought; it includes costs associated with (1) preconstruction engineering and design (PED),[1] (2) construction (including mitigation activities for impacts to aquatic habitat and cultural resources), (3) lands, easements, rights-of-way, relocations and disposal (LERRD), and (4) contingencies. In accordance with ER 1110-2-1302 and Engineering Construction Bulletin (ECB) 2007-17, a cost risk analysis was conducted to identify and measure the cost impact of project uncertainties. Contingencies were identified using a Cost Risk Analysis.

[1] PED costs were estimated using historical and default percentages for elements includes project management, planning and environmental compliance, engineering and design, document reviews, value engineering, life cycle updates, contracting and reprographics, and engineering/planning during construction.

Table ES-3. Cost Summary

Construction Item	Cost ($000)
Lands and Damages	$7,309
Relocations	$9,885
Elements[a]	
Dams (Debris and Detention Basins)	$71,288
Fish & Wildlife	$229
Levees and Floodwalls	$58,912
Pumping Plants	$67,009
Floodway Control and Diversion Structures	$6,470
Cultural Resources Preservation	$786
Buildings, Grounds and Utilities (Flood Warning System)	$356
SUBTOTAL	**$205,050**
PED	$56,627
Construction Management	$27,224
TOTAL PROJECT FIRST COST (October 2016 Price Level) [b]	**$306,095**

Notes:
[a] Elements are based on the Civil Works Breakdown Structure as required in ER 1110-2-1302 and Engineering Manual (EM) 1110-2-1304, "Civil Works Construction Cost Index System (CWCCIS)" which is used in the Micro Computer-Aided Cost Engineering System (MCACES) software program used to develop the cost estimates. Detailed cost estimates are presented in Appendix D.
[b]The price level for project first cost is the date of the common point in time of the pricing used in the cost estimate.

ES-14 Equivalent Annual Costs and Benefits

The expected annual costs and benefits, and the resulting benefit-cost ratio are summarized in Table ES-4. The calculations are based on the estimated project cost[2] (October 2016 [Fiscal Year 2017] price level), and assume a 50-year period of analysis and a Federal discount rate of 2.875 percent (i.e., the Federal discount rate established for the evaluation of water resources development projects in Fiscal Year 2016).

Table ES-4. Expected Annual Benefits and Costs

Category	Cost ($000)
Total Estimated Cost (October 2016 Price Level)	$306,095
Interest During Construction	$13,602
Total Investment Cost	**$319,697**
Interest and Amortization of Initial Investment	$12,132
OMRR&R	$985
Expected Annual Cost	**$13,117**
Expected Annual Benefits	$48,331
Net Annual Benefits	**$35,214**
Benefit-Cost Ratio	**3.68**

2 The estimated project cost differs from the project first cost (presented in Table ES-3), as the project first cost is the estimated cost brought to the effective price level (that is, the date of the common point in time of the pricing used in the cost estimate).

ES-15 Cost Sharing

In accordance with the cost share provisions in Section 103(a) of the WRDA of 1986, as amended (33 U.S.C. 2213(a)), the non-Federal sponsor is responsible for providing a minimum 5 percent cash contribution, all LERRDs required for the project, and any additional funds necessary to make its total contribution equal to at least 35 percent of total project costs. In addition, the non-Federal sponsor is responsible for 100 percent of the OMRR&R. . Table ES-5 summarizes the estimated cost-shared amounts based on project first cost (October 2016 price level).

The total project cost, which is the constant dollar cost (that is, the project first cost) fully funded with escalation to the estimated midpoint of construction, is estimated to be $352,204,000. This is the estimate used in Project Partnership Agreements (PPA); these costs will continue to be refined through the detailed design phase.

Table ES-5. Cost-Sharing Responsibilities for the Recommended Plan

Category	Federal Cost ($000)	Non-Federal Cost ($000)	Total Cost ($000)
Project Features	$151,438	$81,544	$232,982
LERRD	$0	$19,215	$19,215
PED[a]	$42,323	$22,790	$65,113
Construction Management	$22,682	$12,213	$34,895
Subtotal	$216,443	$135,761	$352,204
5 percent Cash Contribution	($17,610)	$17,610	
Additional Contribution	$30,099	($30,099)	
TOTAL (October 2016 price level)	**$228,932**	**$123,272**	**$352,204**
Percent of Total	**65%**	**35%**	

Notes:
[a] PED costs incurred after completion of the Feasibility Report/EIS will be cost shared between the Government and the project sponsors in accordance with a Design Agreement. Upon initiation of project construction, all costs incurred under the Design Agreement will be included as part of the total project costs and subject to the project cost sharing requirements in accordance with the construction agreement, which will be executed before award of the first construction contract.

ES-16 Environmental Consequences

Consistent with the requirements of NEPA and HRS 343, the consequences of implementing each alternative were assessed, based on the range of resources that comprise the human and natural environment. The assessment of environmental consequences involves the comparison of the effects of each alternative plan (i.e. the recommended plan and Alternative 2A) relative to the No Action (future without-project) conditions. For those resources that may be adversely affected, measures that would be implemented to mitigate the potential impacts were identified. The environmental consequences and associated mitigation measures are summarized in Table ES-6.

Potential adverse impacts include those related to biological resources (aquatic habitat), cultural resources, recreation, and visual resources; however, measures to avoid, minimize, and mitigate these impacts have been incorporated to the extent practicable. Although some degree of impact would occur, the analysis has not identified significant, unavoidable adverse impacts that would remain after implementation of proposed mitigation measures. Implementation of the proposed project is expected to protect a large portion of the watershed (including its residents and visitors) from flooding and flood-related safety hazards. These benefits are expected to outweigh any remaining adverse impacts.

ES-17 Public Involvement and Agency Coordination

A significant number of stakeholder and agency meetings and other public involvement efforts have been conducted throughout the planning process to date. In general, the timing and focus of these events has been determined in response to project-related needs and stakeholder interests and desires.

A wide range of input has been provided as part of the various public and agency meetings held to date. In general, stakeholders have expressed support for the project and emphasized the need for near-term action to reduce the risk of flooding. Concerns have been raised relative to the project sponsors' ability to fund and maintain the project, as well as potential impacts of the project (particularly those associated with visual, cultural and recreational resources), and acquisition of private property. Input received to date is summarized in Section 6, with additional detail in Appendix G.

ES-18 Required Permits and Environmental Compliance

There are a variety of Federal and State laws and regulations that are applicable to the project, and for which compliance is required before construction. The status of regulatory compliance, as well as compatibility with local plans and policies is provided in Section 7. Permits and approvals that are expected to be required include the following:

- National Environmental Policy Act (NEPA) compliance
- Clean Water Act Section 404 compliance
- Endangered Species Act (ESA) Section 7 compliance
- Fish and Wildlife Coordination Act (FWCA) compliance
- National Historic Preservation Act (NHPA) Section 106 compliance
- Hawai'i Revised Statutes (HRS) Section 343 compliance
- Coastal Zone Management Act (CZMA) Federal Consistency Determination
- Department of Health Section 401 Water Quality Certification
- National Pollutant Discharge Elimination System (NPDES) permit
- Conservation District Use Permit
- Forest Reserve Special Use Permit
- Stream Channel Alteration Permit
- HRS Section 6E Historic Preservation review
- Special Management Area (SMA) permit
- Waikīkī Special District permit
- Community Noise Permit
- Building and Grading Permits

ES-19 Recommendation

The recommendation of the District Engineer of Honolulu District, U.S. Army Corps of Engineers, is that the recommended plan (Alternative 3A-2.2) be authorized for implementation as a Federal project.

Based on October 2016 price levels, the estimated total project first cost of the recommended plan is $306,095,000. The Federal share of the project first cost would be about $198,962,000 (65 percent), and the non-Federal share would be about $107,133,000 (35 percent). The non-Federal sponsor would be responsible for OMRR&R of the project after construction, a cost currently estimated at about $985,000.

This recommendation will be contingent upon such discretionary modifications as deemed necessary by the Chief of Engineers and funding requirements satisfactory to the Administration and Congress.

Table ES-6. Summary of the Environmental Consequences (IMP) and Proposed Mitigation Measures (MM) for the Recommended Plan and Alternatives

Impact[a]	No Action Alternative	Recommended Plan	Alternative 2A
GEOLOGY, SEISMICITY, and SOILS			
Impact (IMP) GEO-1: Erosion resulting from construction-related ground disturbance	No impact	Approximately 55 acres of ground disturbance; best management practices (BMPs) would be implemented as part of Stormwater Pollution Prevention Plan (SWPPP). **Less than significant; no mitigation required.**	Greater extent of ground disturbance (approximately 67 acres). **Less than significant; no mitigation required.**
IMP GEO-2: Erosion resulting from O&M activities	No impact	BMPs would be implemented as part of SWPPP. **Less than significant; no mitigation required.**	Same as recommended plan.
IMP GEO-3: Reduced functionality and/or unintended hydraulic consequences due to landslide, subsidence, liquefaction or collapse	No impact	Mitigation Measure (MM) GEO-1: Detailed geotechnical analyses to be conducted as part of PED and design refinements to be made accordingly. **Less than significant with mitigation.**	Lower risk associated with debris catchment measures in upper watershed. **Less than significant; no mitigation required.**
SURFACE WATER RESOURCES			
IMP SUR-1: Placement of dredged or fill material within Waters of the U.S. (including areas considered to be riffle and pool complexes)	No impact	Construction would involve placement of approximately five acres of fill in waters of the U.S.; in addition to avoidance and minimization measures, compensatory mitigation would be implemented (see MM BIO-4). **Less than significant with implementation of mitigation.**	Debris catchment structures would involve less fill; additional fill for 600-foot-long culvert along Mānoa Stream; the same mitigation would be implemented (see MM BIO-4). **Less than significant with mitigation.**
IMP SUR-2: Increased channel/bank erosion due to disturbance during construction	No impact	Measures sited and designed to minimize the need for excavation and grading; BMPs would be implemented as part of SWPPP. **Less than significant; no mitigation required.**	Same as recommended plan.
HYDROLOGY AND HYDRAULICS			
IMP HYD-1: Reduced extent of potential flooding	Existing flood risks would not be addressed.	Implementation of recommended plan would substantially reduce the 1-percent ACE floodplain, with decreased water surface elevations of approximately 2.2 feet. **Beneficial.**	More residual flooding above Ala Wai Golf Course, and along upper Mānoa and Pālolo streams; decreased water surface elevation of approximately 1 foot. **Beneficial.**
WATER QUALITY			
IMP WQ-1: Increased sediment and associated pollutants in stormwater runoff during construction	No impact	BMPs would be implemented as part of SWPPP; excessive levels of sediment-bound pollutants not anticipated. **Less than significant; no mitigation required.**	Same as recommended plan.
IMP WQ-2: Accidental release of hazardous materials during construction	No impact	BMPs would be implemented as part of SWPPP. **Less than significant; no mitigation required.**	Same as recommended plan.

Table ES-6. Summary of the Environmental Consequences (IMP) and Proposed Mitigation Measures (MM) for the Recommended Plan and Alternatives

Impact[a]	No Action Alternative	Recommended Plan	Alternative 2A
IMP WQ-3: Flushing and mobilization of contaminants by flood waters within multi-purpose detention areas	No impact	Multi-purpose detention basin locations already subject to flooding; pathways and/or concentration levels of contaminants not expected to significantly change. **Less than significant; no mitigation required.**	Mānoa District Park detention basin (and associated culvert) in area that could have higher levels of anthropogenically derived contaminants. **Less than significant; no mitigation required.**
IMP WQ-4: Capture and removal of sediment and debris (including trash and other man-made debris)	No capture and removal of debris/sediment.	Removal of sediment/debris would provide water quality benefit to downstream waters; project is not explicitly designed to capture sediment, so quantity of sediment and any associated pollutants to be removed has not been quantified. **Beneficial.**	Same as recommended plan.
BIOLOGICAL RESOURCES			
IMP BIO-1: Displacement of *kukui* copse at Makiki Detention Basin, and *niu* and *milo* trees along Ala Wai floodwall	No impact	MM BIO-1: Trees will be either replaced in-kind following construction or relocated to a suitable location near the project area. **Less than significant with site restoration.**	Same as recommended plan.
IMP BIO-2: Ongoing vegetation management, including trimming and clearing, as part of operations and maintenance	No impact	Approximately 18 acres subject to vegetation management; predominantly non-native and/or landscaped species. **Less than significant; no mitigation required.**	Approximately 27 acres subject to vegetation management. **Less than significant; no mitigation required.**
IMP BIO-3: Temporary flood-related impacts to vegetation during large-scale flood events	Vegetated areas within floodplain subject to flooding.	Approximately 148 acres subject to inundation during 1-percent ACE flood; predominantly non-native or landscaped species. **Less than significant; no mitigation required.**	Approximately 153 acres subject to inundation. **Less than significant; no mitigation required.**
IMP BIO-4: Introduction of new invasive plant species	No impact	MM BIO-2: Implementation of BMPs, including washing/inspection of construction equipment, certification/inspection of revegetation materials, and monitoring of revegetated areas. **Less than significant with mitigation.**	Same as recommended plan.
IMP BIO-5: Disturbance and decreased habitat availability for native (non-listed) terrestrial wildlife species	No impact	Non-listed native terrestrial species are generally common and widespread; affected habitat represents very small part of range available to species. **Less than significant; no mitigation required.**	Same as recommended plan.
IMP BIO-6: Direct impacts (e.g., injury, death) to native aquatic species as a result of construction and O&M activities	No impact	MM BIO-3: In-stream work would be limited to low-flow conditions and standard dewatering and fish exclusion protocols would be implemented. **Less than significant with mitigation.**	Same as recommended plan.

Table ES-6. Summary of the Environmental Consequences (IMP) and Proposed Mitigation Measures (MM) for the Recommended Plan and Alternatives

Impact[a]	No Action Alternative	Recommended Plan	Alternative 2A
IMP BIO-7: Impacts to in-stream aquatic habitat	No impact	Approximately 1,898 linear feet of stream within the permanent construction footprint; approximately 295 HUs would be lost. MM BIO-4: In addition to avoidance and minimization measures, compensatory mitigation would be implemented (removal of existing barriers to native species passage at two in-stream structures). **Less than significant with mitigation.**	Approximately 1,742 linear feet of stream within construction limits; a similar amount of HUs would be lost; the same mitigation would be implemented (MM BIO-4). **Less than significant with mitigation.**
IMP BIO-8: Potential impacts to Hawaiian hoary bat resulting from construction activities (e.g., use of heavy equipment, vegetation removal)	No impact	MM BIO-5: Removal of vegetation >15 feet in height to be conducted outside the breeding season (July through August).August All construction activities would occur during daytime hours to avoid potential bat foraging activities. **Less than significant with mitigation.**	Less potential for impact in upper watershed as compared to recommended plan; the same mitigation would be implemented. **Less than significant with mitigation.**
IMP BIO-9: Potential impacts to Oahu elepaio from construction activities (e.g., use of heavy equipment, vegetation removal)	No impact	MM BIO-6: Trimming or clearing of vegetation in areas of suitable habitat would be restricted during the nesting season (January through June). **Less than significant with mitigation.**	Less potential for impact in upper watershed as compared to recommended plan; the same mitigation would be implemented. **Less than significant with mitigation.**
IMP BIO-10: Potential impacts to Hawaiian waterbirds from construction-related disturbance and increased predation in detention basins during inundation	No impact	In the unlikely event that species are present, it is expected they would readily disperse to nearby areas with higher quality habitat in response to disturbance. **Less than significant; no mitigation required.**	Same as recommended plan.
IMP BIO-11: Potential impacts to blackline Hawaiian damselfly from construction activities (e.g., use of heavy equipment, vegetation removal)	No impact	MM BIO-7: Actions to avoid and minimize potential impacts to the species have been identified through consultation with USFWS; potential actions could range from relocation of ESA protected species prior to construction to implementation of other measures to minimize impacts. The objective would be to reduce impacts to a less-than-significant level. **Less than significant with mitigation.**	Less potential for impact in upper watershed as compared to recommended plan; the same approach to mitigation would be implemented. **Less than significant with mitigation.**
CULTURAL RESOURCES			
IMP CUL-1: Construction and operations related impacts to archaeological and historic resources within the APE	No impact	MM CUL-1: Treatment recommendations to mitigate potential impacts include avoidance, historic documentation, data recovery, and community assistance. A Programmatic Agreement is also being developed to establish a process for further resource identification and effects determinations, and resolving adverse effects. **Less than significant with mitigation.**	Less potential for impact in upper watershed as compared to recommended plan, but additional potential for impact at Mānoa District Park; the same mitigation would be implemented. **Less than significant with mitigation.**

Table ES-6. Summary of the Environmental Consequences (IMP) and Proposed Mitigation Measures (MM) for the Recommended Plan and Alternatives

Impact[a]	No Action Alternative	Recommended Plan	Alternative 2A
IMP CUL-2: Construction of floodwalls and pump stations that diminish views toward and along Ala Wai Canal	No impact	MM CUL-2: Solicitation of design input from interested consulting parties and the State Historic Preservation Officer (SHPO), and incorporation of such input as feasible into the final design; historic documentation would also be developed. **Less than significant with mitigation.**	Floodwalls would be approximately one foot higher (on average) than for the recommended plan; the same mitigation would be implemented. **Less than significant with mitigation.**
IMP CUL-3: Temporary impacts to cultural practices associated with access limitations within measure locations during construction	No impact	Measure locations are dominated by non-native species, and there would still be abundant opportunities to gather resources along streams in the upper watershed. Following construction, none of the measures are expected to limit access to cultural resources or practices. **Less than significant; no mitigation required.**	Less area within the upper watershed would be temporarily impacted during construction. **Less than significant; no mitigation required.**
IMP CUL-4: Removal or destruction of rocks from the streambed as a result of construction	No impact	MM CUL-3: Micro-site measure locations to avoid impacts to traditional cultural properties (TCPs), assess measure locations prior to construction for significant cultural resources and avoid impacts to TCP resources to the greatest extent possible during construction. **Less than significant with mitigation.**	Same as recommended plan.
IMP CUL-5: Inadvertent discovery of human remains or other cultural materials	No impact	MM CUL-4: Construction contractor would immediately cease all work in the area, and appropriate agencies would be notified according to applicable laws, including NHPA and HRS Section 6E. **Less than significant with mitigation.**	Same as recommended plan.
LAND USE			
IMP LU-1: Temporary construction-related disruption of existing land uses	No impact	MM LU-1: Construction phasing, easements, and restoration of temporarily disturbed areas to pre-project conditions. **Less than significant with mitigation.**	Same as recommended plan.
RECREATION			
IMP REC-1: Temporary loss of access and use of recreational facilities during construction	No impact	MM REC-1: Provide adequate notification to inform users of construction and alternative recreation locations/access. **Less than significant with mitigation.**	No measures in the Honolulu Forest Reserve, but temporary recreation impacts at Mānoa District Park; the same mitigation would be implemented (MM REC-1). **Less than significant with mitigation.**
IMP REC-2: Displacement of recreational area by permanent footprint of debris and detention features	No impact	Measures designed to have the smallest footprint possible, and to minimize impacts to recreational activities during non-flood conditions. **Less than significant; no mitigation required.**	Same as recommended plan.

Table ES-6. Summary of the Environmental Consequences (IMP) and Proposed Mitigation Measures (MM) for the Recommended Plan and Alternatives

Impact[a]	No Action Alternative	Recommended Plan	Alternative 2A
IMP REC-3: Limited access and/or use of recreational facilities during and immediately following flood conditions (to allow for post-flood clean-up and recovery)	Recreational areas would continue to be subject to flooding	Multi-purpose detention basin sites currently flood (thereby impacting recreational uses); O&M activities would be programmed as part of the standard flood responses activities to minimize post-flood maintenance response time. **Less than significant; no mitigation required.**	Same as recommended plan.
VISUAL RESOURCES			
IMP VIS-1: Temporary visual impacts associated with construction (e.g., equipment, staged materials, etc.)	No impact	Construction area to be kept free of litter and excess equipment/materials, and maintained in a clean and organized condition. **Less than significant; no mitigation required.**	Same as recommended plan.
IMP VIS-2: Addition of in-stream detention basins and debris catchment features in the mid to upper watershed	No impact	In-stream detention basins would be screened by existing vegetation; measures have also been designed to sit within the existing stream channel to the extent possible, and would not be substantially visible from locations beyond the immediately adjacent areas. **Less than significant; no mitigation required.**	In-stream debris catchment would be installed in lieu of detention basins in most upper watershed locations, resulting in less visual impact. **Less than significant; no mitigation required.**
IMP VIS-3: Addition of multi-purpose detention basins in open space areas	No impact	Multi-purpose detention basins would be comprised of an earthen/grass berm, which are expected to blend and be visually commensurate with the existing park or golf course facilities. **Less than significant; no mitigation required.**	Additional multi-purpose detention basin at Mānoa District Park. **Less than significant; no mitigation required.**
IMP VIS-4: Addition of flood walls and associated pump stations along Ala Wai Canal	No impact	MM VIS-1: Design refinements will consider opportunities to reduce the structure dimensions and incorporate design details to reduce visual impacts (e.g., use of construction materials and/or landscaping to blend structures into surrounding environment); this effort will incorporate design input solicited as part of the NHPA Section 106 consultation process. **Less than significant with mitigation.**	Floodwalls would be approximately 1 foot higher (on average) than for the recommended plan; the same mitigation would be implemented (MM VIS-1). **Less than significant with mitigation.**
HAZARDOUS AND TOXIC WASTE			
IMP HAZ-1: Accidental release of hazardous materials (e.g., gasoline, diesel fuel) during construction or O&M	No impact	BMPs would be implemented as part of SWPPP. **Less than significant; no mitigation required.**	Same as recommended plan.
AIR QUALITY			
IMP AQ-1: Construction-related impacts to air quality due to fugitive dust and internal combustion engine emissions	No impact	BMPs would be implemented to avoid and minimize potential impacts. **Less than significant; no mitigation required.**	Same as recommended plan.
IMP AQ-2: Air emissions from vehicles used for O&M	No impact	Emission levels would be very low, and would be expected to have negligible impact. **Less than significant; no mitigation required.**	Same as recommended plan.

Table ES-6. Summary of the Environmental Consequences (IMP) and Proposed Mitigation Measures (MM) for the Recommended Plan and Alternatives

Impact[a]	No Action Alternative	Recommended Plan	Alternative 2A
NOISE			
IMP NOI-1: Temporary construction-related noise that exceeds the State's maximum permissible noise levels	No impact	MM NOI-1: Community Noise Permit to be obtained; BMPs would be implemented as part of permit requirements. **Less than significant with mitigation.**	Same as recommended plan.
IMP NOI-2: Temporary increase in noise levels associated with O&M activities	No impact	Noise levels during O&M would be short-term and would only occur on a periodic basis. **Less than significant; no mitigation required.**	Same as recommended plan.
TRAFFIC AND TRANSPORTATION			
IMP TRN-1: Construction-related impacts to traffic and transportation resources (e.g., increased congestion; reduced capacity; reduced access and parking, etc.)	No impact	MM TRN-1: Preparation and implementation of Transportation Management Plan. **Less than significant with mitigation.**	Same as recommended plan.
IMP TRN-2: Reduced potential for flooding within important thoroughfares and collector roads (as well as smaller access roads)	Roadways would continue to be at risk of flooding.	Reduced potential for flooding would provide improved access within and out of the watershed during flood conditions, including routes used for evacuation and flood response activities. **Beneficial.**	Same as recommended plan.
PUBLIC HEALTH AND SAFETY			
IMP SAF-1: Decreased number of residents and visitors subject to flood-related health and safety risks	Flood-related health and safety risks would not be addressed.	Increased protection for the majority of the watershed's residents and most (if not all) of the visitors to Waikīkī. **Beneficial.**	Slightly less protection than recommended plan due to additional residual flooding north of the Ala Wai Golf Course, and along the upper reaches of Mānoa and Pālolo streams. **Beneficial.**
IMP SAF-2: Removal of critical infrastructure and other public facilities including schools from the 1-percent ACE floodplain, thus increasing resiliency in response to flood events	Critical infrastructure would not be removed from floodplain.	2 of the 4 fire stations, the police station, both medical clinics, and 6 of the 9 emergency shelters would be removed from the 1-percent ACE floodplain. **Beneficial.**	Same as recommended plan.
IMP SAF-3: Heightened awareness of flood-related risks, which is expected to translate to increased levels of preparedness	No impact	Increased understanding of potential for flooding, as well as increased communication of imminent flood events via improvements to the flood warning system. **Beneficial.**	Same as recommended plan.
IMP SAF-4: Potential safety concerns with detention basins related to risk of failure and water-related safety hazards (e.g., drowning)	No impact	Multi-purpose detention basin locations already subject to flooding; only would be inundated during large-scale floods. MM SAF-1: Regulation under Dam Safety Program (including compliance with safety requirements). **Less than significant with mitigation.**	MM SAF-2: Because inlet for Mānoa District Park detention basin is not visible to park users, a flood warning system would be provided and would activate when water enters the basin.

Table ES-6. Summary of the Environmental Consequences (IMP) and Proposed Mitigation Measures (MM) for the Recommended Plan and Alternatives

Impact[a]	No Action Alternative	Recommended Plan	Alternative 2A
PUBLIC SERVICES AND UTILITIES			
IMP UTL-1: Decreased flood-response burden on police, fire and medical emergency services	No impact	**Beneficial.**	Same as recommended plan.
IMP UTL-2: Temporary interruption in utility service during construction	No impact	**Less than significant; no mitigation required.**	Same as recommended plan.
IMP UTL-3: Development and implementation of detailed O&M plan	No impact	**Beneficial.**	Same as recommended plan.
SOCIOECONOMICS AND ENVIRONMENTAL JUSTICE			
IMP SOC-1: Reduced potential for displaced people/housing, impacts to employment/income, and improved social connectedness in response to flood	No impact	**Beneficial.**	Same as recommended plan.

Note:

[a] The impact number (IMP) and associated mitigation number (MM) listed in the table are also indicated in the impact analysis discussion in Section 5.0, so as to provide a quick reference between the summary table and the corresponding text.

Contents

* *Indicates information required to comply with the National Environmental Policy Act (NEPA).*
\+ *Indicates information required to comply with Hawai'i Revised Statutes (HRS) Chapter 343.*

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Appendices

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List of Acronyms

%	percent
ACHP	Advisory Council on Historic Preservation
ACE	annual chance exceedance
ACS	American Community Survey
Alt.	Alternative
APE	Area of Potential Effects
ATR	Agency Technical Review
AWWA	Ala Wai Watershed Association
BCR	benefit cost ratio
BLNR	Board of Land and Natural Resources
BMP	best management practice
BWS	Honolulu Board of Water Supply
C&D	construction and demolition
CCH	City and County of Honolulu
CDUP	Conservation District Use Permits
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CEQ	Council on Environmental Quality
CE/ICA	cost effectiveness and incremental cost analyses
CFR	*Code of Federal Regulations*
CIA	Cultural Impact Assessment
CIP	capital improvement programs
CN	Curve Number
CNP	conditional non-exceedance probability
CRM	concrete masonry
CRS	Community Rating System
CWCCIS	Civil Works Construction Cost Index System
CWRM	(State of Hawai'i) Commission on Water Resource Management
CZM	Coastal Zone Management
DAR	(State of Hawai'i, Department of Land and Natural Resources) Division of Aquatic Resources

dBA	A-weighted decibel
DBEDT	(State of Hawai'i) Department of Business Economic Development and Tourism
DDC	(City and County of Honolulu) Department of Design and Construction
DES	(City and County of Honolulu) Department of Enterprise Services
DFM	(City and County of Honolulu) Department of Facilities and Maintenance
DLNR	(State of Hawai'i) Department of Land and Natural Resources
DOBOR	(State of Hawai'i, Department of Land and Natural Resources) Division of Boating and Ocean Recreation
DoD	(U.S.) Department of Defense
DOE	(State of Hawai'i) Department of Education
DOFAW	(State of Hawai'i, Department of Land and Natural Resources) Division of Forestry and Wildlife
DOH	(State of Hawai'i) Department of Health
DOT	(State of Hawai'i) Department of Transportation
DPP	(City and County of Honolulu) Department of Planning and Permitting
DPR	(City and County of Honolulu) Department of Parks and Recreation
DTS	(City and County of Honolulu) Department of Transit Services
EA	Environmental Assessment
EAB	expected annual benefits
EAC	expected annual cost
EC	Engineer Circular
ECB	Engineering Construction Bulletin
ECO-PCX	Ecosystem Planning Center of Expertise
EEZ	Exclusive Economic Zone
EFH	essential fish habitat
EIS	Environmental Impact Statement
EISPN	Environmental Impact Statement Preparation Notice
ELG	effluent limitations guideline
ELR	Educational Level Ratings
EM	Engineering Manual
ENSO	El-Niño Southern Oscillation
ENV	(City and County of Honolulu) Department of Environmental Services
EO	Executive Order

EOP	Environmental Operating Principles
EPA	U.S. Environmental Protection Agency
EQ	Environmental Quality
ER	Engineer Regulation
ESA	Endangered Species Act
FCSA	Feasibility Cost Sharing Agreement
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FMA	Fisheries Management Area
FPMP	Floodplain Management Plan
FR	Federal Register
FSM	Feasibility Scoping Meeting
ft^3/s	cubic feet per second
FWCA	Fish and Wildlife Coordination Act
GIS	geographic information system
GWPP	(State of Hawai'i) Groundwater Protection Program
HAAQS	Hawai'i Ambient Air Quality Standards
HAR	Hawai'i Administrative Rules
HEC-FDA	(U.S. Army Corps of Engineers) Hydrologic Engineering Center-Flood Damage Reduction Analysis
HEC-HMS	(U.S. Army Corps of Engineers) Hydrologic Engineering Center Hydrologic Modeling System
HEC-RAS	(U.S. Army Corps of Engineers) Hydrologic Engineering Center River Analysis System
HEC-SSP	(U.S. Army Corps of Engineers) Hydrologic Engineering Center Statistics Software Package
HECO	Hawaiian Electric Company
HFD	Honolulu Fire Department
HPD	Honolulu Police Department
HRS	Hawai'i Revised Statutes
HSA	Hawai'i Stream Assessment
HSHEP	Hawai'i Stream Habitat Equivalency Procedure
HTRW	hazardous, toxic and radioactive waste
HU	habitat unit

IBC	International Building Code
IEPR	Independent External Peer Review
IPCC	Intergovernmental Panel on Climate Change
IWR	(U.S. Army Corps of Engineers) Institute for Water Resources
KMWP	Koʻolau Mountains Watershed Partnership
kV	kilovolt
LCA	Land Commission Award
LEDPA	least environmentally damaging alternative
LERRD	Lands, Easements, Rights-of-way, Relocations, and Dredge/Disposal
m^3	cubic meters
m^3/yr	cubic meters per year
MCACES	Micro Computer-Aided Cost Engineering System
MD	minimized flood damages
mgd	million gallons per day
mi^2	square mile
MHHW	mean higher high water
MS4s	municipal separate storm sewer systems
MUS	Management Unit Species
N/A	not applicable
NAAQS	National Ambient Air Quality Standards
NED	National Economic Development
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NFRAP	No Further Remediation Action Planned
NHO	Native Hawaiian organization
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	(U.S. Department of Agriculture) Natural Resources Conservation Service
NSPS	new source performance standards

O&M	operations and maintenance
OCCL	(State of Hawai'i, Department of Land and Natural Resources) Office of Conservation and Coastal Lands
OEQC	(State of Hawai'i, State Department of Health) Office of Environmental Quality Control
OISC	O'ahu Invasive Species Council
OSE	Other Social Effects
PAH	polycyclic aromatic hydrocarbon
PAS	Planning Assistance to States
PCB	polychlorinated biphenyl
PCX	Planning Center of Expertise
PDT	Project Delivery Team
PED	Preconstruction Engineering and Design
PM	particulate matter
PPA	Project Partnership Agreement
ppb	parts per billion
RCRA	Resource Conservation and Recovery Act
RED	Regional Economic Development
ROD	Record of Decision
ROH	Revised Ordinances of Honolulu
ROM	rough order of magnitude
RED	Regional Economic Development
S&A	Supervision & Administration
SCORP	State Comprehensive Outdoor Recreation Plan
SHPD	State Historic Preservation Division
SHPO	State Historic Preservation Officer
SIHP	State Inventory of Historic Properties
SMA	Special Management Area
SMART	Specific, Measurable, Attainable, Risk Informed, Timely
SVOC	semi-volatile organic compound
SWPPP	stormwater pollution prevention plan
TCP	traditional cultural property
TMDL	Total Maximum Daily Loads

UBC	Uniform Building Code
UH	University of Hawai'i
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VOC	volatile organic compounds
WRRC	(University of Hawai'i) Water Resources Research Center
yd^3	cubic yard
yd^3/yr	cubic yards per year

1.0 Introduction

The Ala Wai Watershed is located on the southeastern side of the island of Oʻahu, Hawai'i, and includes Makiki, Mānoa, and Pālolo streams, all of which drain to the Ala Wai Canal. The Canal is a 2-mile-long waterway constructed during the 1920s to drain extensive coastal wetlands, thus allowing development of the Waikīkī District. A large portion of the watershed, including most of Waikīkī, is highly susceptible to flooding. At the request of the State of Hawai'i Department of Land and Natural Resources (DLNR), the Ala Wai Canal Project[3] (hereafter referred to as "the project") is a flood risk management study being investigated by the U.S. Army Corps of Engineers (USACE) under the authority of Section 209 of the Flood Control Act of 1962.

Investigations, such as those carried out under Section 209 of the Flood Control Act of 1962, are funded by specific appropriations and are conducted through a feasibility phase. The feasibility phase consists of a study to investigate and determine the extent of Federal interest in plans to reduce flood risk. Specifically, the study includes (1) an assessment of the risk of flooding, (2) analysis of a range of alternatives formulated to reduce flood risk, and (3) identification of a recommended plan for implementation. The Feasibility Study Report describes the process to arrive at a Federal recommended plan, and includes an integrated Environmental Impact Statement (EIS), as needed to comply with the National Environmental Policy Act (NEPA) and Hawai'i Revised Statutes (HRS) Chapter 343. Following public and governmental agency review, the Feasibility Study Report with Integrated EIS, hereafter referred to as the "Feasibility Report/EIS," will be finalized and submitted to USACE Headquarters for review and approval, then transmitted to Congress as part of a request for project authorization. Project construction is dependent upon Congressional appropriation of funding for the Federal share of the project. Once authorized and funded, the USACE can provide assistance through construction; operations and maintenance (O&M) are the responsibility of the non-Federal sponsor.

1.1 Study Authority

The Ala Wai Canal Project feasibility study is authorized under Section 209 of the Flood Control Act of 1962 (Public Law 87-874). Section 209 is a general study authority that authorizes surveys of harbors and rivers in Hawai'I, but does not provide authority to implement the recommended project. The authorization reads as follows:

> The Secretary of the Army is hereby authorized and directed to cause surveys for flood control and allied purposes including channel and major drainage improvements, and floods aggravated by or due to wind or tidal effects, to be made under the direction of the Chief of Engineers, in drainage areas of the United States and its territorial possessions, which include the following named localities: *Provided*, That after the regular or formal reports made on any survey are submitted to Congress, no supplemental or additional report or estimate shall be made unless authorized by law except that the Secretary of the Army may cause a review of any examination or survey to be made and a report theron submitted to Congress, if such review is required by the national defense or by changed physical or economic conditions: *Provided further*, That the Government shall not be deemed to have entered upon any project for the improvement of any waterway or harbor mentioned in this title until the project for the proposed work shall have been adopted by law:
>
> Harbors and rivers in Hawaii, with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply and other beneficial water uses, and related land resources.

[3] The project title was originally named the "Ala Wai Canal Project" and for consistency purposes, will remain as such in the congressional documentation.

1.2 Study Sponsor

The USACE is the Federal sponsor of the project; the non-Federal sponsor is the State of Hawai'i DLNR, represented by the Engineering Division. A Feasibility Cost Sharing Agreement (FCSA) was originally executed with DLNR in March 2001; the agreement was amended in December 2006 and November 2012.

1.3 Study Scope (Federal Interest)

Consistent with the study authority, the scope of this study is to assess the feasibility of a project to reduce the risk of flooding in the Ala Wai Watershed; flood risk management is a primary mission of the USACE.

Justification for Federal investment in a project is based on the significance of the problem and the benefits of possible solutions from a national perspective. A plan recommended for Federal investment must be cost-efficient, wherein the benefits exceed costs; benefits can include non-monetary benefits such as reducing life-safety issues. Flooding has occurred within the Ala Wai Watershed on multiple occasions, resulting in recorded property damages and health and safety risks. Given the extent of development within the watershed (particularly in the Waikīkī District), there are potentially significant benefits associated with implementing flood risk management measures. As such, investigation of a project to reduce the risk of flooding is within the Federal interest.

Originally this study was scoped to address multiple purposes, incorporating both flood risk management and ecosystem restoration.[4] However, justification for ecosystem restoration needs to be based on national, public, and technical biological resource significance. An analysis of biological resource significance determined that the resources within the Ala Wai Watershed are significant at a regional level (versus at a national level). As such, ecosystem restoration was removed from the scope of the study. The flood risk management measures have been developed in compliance with existing laws, USACE regulations and policies, with ecosystem impacts avoided and minimized to the full extent practicable. In particular, the USACE Environmental Operating Principles (EOP) require "mutually supporting economic and environmental sustainable solutions." The ecosystem-related information previously identified as part of the study has been incorporated as part of environmentally sustainable design considerations, particularly as related to maintaining in-stream habitat and migratory pathways for native aquatic species, including endemic gobies (*o'opu*), shrimp (*'opae*) and mollusk species (*hapawai* and *hihiwai*).

1.4 Purpose and Need

In accordance with the requirements of NEPA, a statement should be developed for Federal actions that briefly specifies the underlying purpose and need to which the agency is responding (40 *Code of Federal Regulations* [CFR] Section 1502.13). The purpose and need statement establishes why the Federal agency is proposing an action and drives the process for alternatives consideration, in-depth analysis and selection of the preferred alternative through the NEPA process.

The purpose of the project is to reduce flood risk within the Ala Wai Watershed. A high risk of flooding exists within the Ala Wai Watershed because of aging and undersized flood conveyance infrastructure. Based on the peak flows computed for this study, it is estimated that the Ala Wai Canal has the capacity to contain about a 20-percent annual chance exceedance (ACE) flood[5] before overtopping the banks. The risk of flooding is exacerbated by the flashy nature of the streams in the watershed, with heavy rains flowing downstream extremely quickly due to steep topography and relatively short stream systems.

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[4] Previous phases of the project also contemplated secondary objectives including water quality, water supply, and recreation. Based on the rescoping of the project to focus on flood risk management, these secondary objectives were not carried forward.

[5] The 1-percent ACE floodplain is the area that is inundated by a flood with a 1-percent chance (1 in 100) of occurring in any single year. These are also commonly referred to as the 100-year floodplain and 100-year flood (but does not necessarily mean that this degree of flooding occurs every 100 years). This definition also applies to floods of other magnitudes (e.g., a 20-year flood is a flood that has a 5-percent chance of occurring and a 10-year flood has a 10-percent chance of occurring in any single year, respectively).

Overtopping of the Canal has previously flooded Waikīkī multiple times, including during the November 1965 and December 1967 storms and during the passage of Hurricane Iniki in 1992. Upstream areas are also at risk of flooding, as demonstrated by several recent events, including the October 2004 storm that flooded Mānoa Valley and the March 2006 storm that flooded Makiki. The October 2004 event was estimated to have a 4 percent chance of occurring in any single year, and caused more than $85 million in damages (at 2004 price levels) (USACE, 2006a). Multiple other past flood events have been documented within the watershed over the course of the past century. In addition to recorded property damages, these events have contributed to health and safety risks, including two known deaths (associated with flooding in December 1918 and December 1950) (USACE, 2006a).

Analyses conducted in support of this project show that the 1-percent ACE floodplain extends over approximately 1,358 acres of the watershed. Within the floodplain, the affected population is comprised of approximately 54,000 residents plus an additional estimated 79,000 visitors in Waikīkī on any given day. In addition to threatening the safety of both residents and visitors, a major flood event could result in catastrophic damages to structures and property throughout the watershed, with impacts to Waikīkī crippling the local economy. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $1.14 billion in structural damages alone (2016 price levels), not accounting for loss in business income or other similar economic losses.

1.5 Study Area

The Ala Wai Watershed is located on the southeastern side of the island of Oʻahu, Hawaiʻi. The watershed encompasses 19 square miles (mi^2) (12,064 acres) and extends from the ridge of the Koʻolau Mountains to the nearshore waters of Māmala Bay. It includes Makiki, Mānoa, and Pālolo streams, which flow to the Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands. This construction and subsequent draining allowed the development of the Waikīkī District. The study area is shown in Figure 1.

Overall, the Ala Wai Watershed contains approximately 200,000 residents, and is the most densely populated watershed in Hawaiʻi. The upper portion (approximately 7.5 mi^2 or 40 percent of the watershed) is zoned as Conservation District, which is intended to protect natural and cultural resources, including the island's aquifer. The remaining approximately 11 mi^2 of the middle and lower watershed is heavily urbanized, supporting a high density of single-family residences, condominiums, hotels and businesses, as well as many public and private schools, including the University of Hawaiʻi at Mānoa (UH), the largest university in the state. Within this urban footprint, the population density is one of the highest in the nation with 12.36 persons per urbanized acre (Fulton et al., 2001). In addition to a variety of residential, commercial, and institutional development, the watershed also includes the Waikīkī District, a prime tourist destination that attracts more than 79,000 visitors per day. In large part because of the tourism industry, Waikīkī is the primary economic engine for the state, providing 7 percent of the gross state product, 7 percent of the civilian jobs in the state, and 9 percent of the State and County tax revenue (DBEDT, 2013).

1.6 Study History and Background

In response to a request from DLNR, the reconnaissance phase of the Ala Wai Canal Project was initiated in April 1999. At that time, Federal, State, and local agencies sought a comprehensive management and restoration plan to restore aquatic habitat and biological diversity in the Canal and upstream tributaries. The reconnaissance report was submitted in August 1999 and recommended that the USACE assist the State with restoration of the Canal. Approval by USACE for continuation into the feasibility phase was granted in September 1999.

Independently, the Ala Wai Flood Study was initiated in September 1998 under the Planning Assistance to States (PAS) Program (Section 22 of the Water Resources Development Act [WRDA] of 1974) to determine the potential flood risk to the Waikīkī area, in response to a request by the DLNR Land Division. The study was completed in October 2001 and documented a high flood hazard associated with potential overtopping of the Ala Wai Canal. This study identified several mitigative measures and conceptual alternatives that could potentially minimize flood damages to Waikīkī and surrounding area. The results of this technical study were used to establish that the USACE could be involved in the investigation of flood risk management in the Canal. As a result, a flood risk management objective was added to the Ala Wai Canal Project, thus expanding the project focus to both ecosystem restoration and flood risk management in the Canal area.

The FCSA was executed between USACE and the non-Federal sponsor, DLNR Engineering Division, in 2001. The feasibility phase of the project was initiated in July 2002, and an EIS scoping meeting was held in June 2004. Subsequently, in October 2004, heavy rains caused Mānoa Stream to overtop its banks, resulting in significant damages. In response, the USACE temporarily ceased work on the feasibility study, such that the project could be expanded to include the upstream portions of the Ala Wai Watershed. While the cost-share agreement was being amended to address a more comprehensive scope, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) received Federal funds to identify specific actions to address flooding in Mānoa Valley. The Mānoa Watershed Project was initiated in 2006 and resulted in detailed topographic mapping, hydrologic and hydraulic modeling, and identification of potential measures to address specific flood problems.[6] However, because of insufficient Federal funding to complete the project, the Mānoa Watershed Project was terminated before implementation.

Information developed through the Mānoa Watershed Project by NRCS was subsequently incorporated into the Ala Wai Canal Project, which was re-started in 2007. A second EIS scoping meeting was held in October 2008. Project-related efforts were primarily focused on bringing the technical information for the entire watershed up to the same level of detail as produced for Mānoa under the Mānoa Watershed Project.

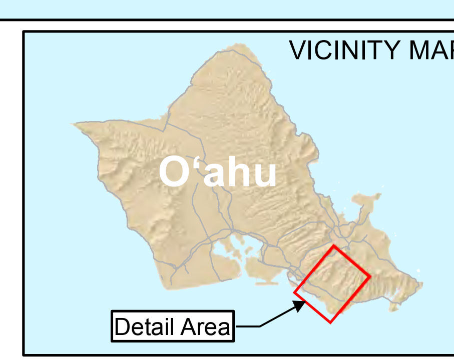
In October 2012, a charrette was held to re-scope the study as part of the USACE Civil Works Planning Modernization process.[7] The purpose of the charrette was to bring together the USACE project delivery team (PDT), Pacific Ocean Division, and Headquarters staff with the non-Federal sponsor and other cooperating agencies, in order to determine the path forward for completing the feasibility study in compliance with current USACE planning requirements. Key outcomes of the charrette included consensus on the problems and opportunities, objectives and constraints, screening and decision criteria, the initial array of alternatives, and a framework for identification of the recommended plan. Based on the project review at the charrette, ecosystem restoration was eliminated as a study objective, as it was determined that the biological resources within the watershed do not have enough national significance to adequately justify ecosystem restoration as an objective. However, as described in Section 1.3, the ecosystem-related information previously identified as part of the study is being incorporated where possible as part of environmentally sustainable design considerations, particularly as related to maintaining in-stream habitat and migratory pathways for native aquatic species.

[6] This work was conducted by the USACE on behalf of NRCS via a Support Agreement in compliance with a Memorandum of Agreement between USACE and USDA, pursuant to the Economy in Government Act (31 .US.C. s.1535.).

[7] The charrette was held on October 16 through 19, 2012, with the purpose of reaching consensus on the actions needed to complete the project on budget and schedule, including a clear path for identification of the recommended plan (USACE, 2012). Participants included the project delivery team, non-Federal sponsor, USACE Division and Headquarters staff, and cooperating agency representatives.

LEGEND

- Stream
- Major Road
- Watershed Boundary



0 0.5 1 Mile

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

FIGURE 1
Overview of the Ala Wai Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

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Figure 1 back

1.7 Related Projects and Activities

A variety of projects and activities have been recently completed, are ongoing, or are planned for implementation in the watershed. Although not part of the project, the scope and status of these efforts have been tracked for consideration in the planning process, conceptual design development, and impact analysis. Table 1 summarizes the related projects and activities that have been identified, and the applicability to the planning process. This list will continue to be updated and refined based on ongoing input from the non-Federal sponsor and project stakeholders.

Table 1. Related Projects and Activities

Project Name	Description	Project Sponsor	Status	Applicability to Planning Process
Hamilton Library Reconstruction Project	Three major components to address damage from 2004 flood: (1) library renovation, (2) construction of new chiller and transformer building, and (3) hazard mitigation to minimize impact of any future flood on library operations	UH	Completed in 2010	Reduces potential flood damages; incorporated as part of existing conditions in economic model
UH Campus Drainage Master Plan	Development of drainage plan for UH campus, as part of overall Master Plan	UH	Updated in 2013	Specifically focused on internal drainage, which is not part of USACE authority
UH Hazard Multi-Mitigation Plan	Development of hazard mitigation plan for the UH system	UH	Plan adopted in 2009	Identifies specific flood mitigation actions, but plan itself does not reduce extent of flooding or damages
Rainfall Dispersion Channels, Round Top Drive	Construction of two concrete dispersion channels designed to spread out point discharge from existing drainage culverts on Round Top Drive	DLNR	Completed in 2010	Does not affect hydrologic modeling of peak flows or extent of flooding; considered as part of existing conditions
Ala Wai Elementary School Drainage Improvements	Earthen swales leading to the Canal were filled in when the bike path and community garden were created; project re-established drainageways from the school to Canal	State Dept. of Education (DOE)	Completed in 2012	Specifically focused on internal drainage, which is not part of USACE authority
Ala Wai Sewer Pipe Replacement	Replacement of temporary sewer pipe from the Ala Wai Canal behind Ala Wai Elementary School down Ala Wai Boulevard to Ala Moana park	City and County of Honolulu (CCH)	Completed in 2013	Does not affect flood risk management in watershed
HECO 46kV Underground Cable Relocation Project	Removal of existing 46-kilovolt (kV) transmission line that crosses the Canal adjacent to Ala Wai Elementary School; to be replaced via directional drilling below Canal	Hawaiian Electric Co. (HECO)	Permitting underway; construction planned for 2017-2018	Does not affect flood risk management, but would be coordinated for purposes of design/implementation
Waikīkī Sea Water Air Conditioning	Cold deep sea water pumped up from the bottom of the ocean and passed through heat exchanger, with chilled water then distributed via an underground distribution system to various buildings; intake pipe proposed for routing through the Ala Wai Canal, with landing between Ala Moana and McCully Bridge	Kaiuli Energy	In planning stage	Does not affect flood risk management, but would be coordinated for purposes of design and implementation
Woodlawn Bridge Flood Mitigation Project	Demolition of existing concrete chute structure and construction of a new grouted rip-rap drop structure to increase the bridge opening conveyance capacity	DLNR	Construction contract awarded in 2016	Reduces potential flood damages; incorporated as part of existing condition in hydraulic model

Table 1. Related Projects and Activities

Project Name	Description	Project Sponsor	Status	Applicability to Planning Process
Waikīkī Regional Circulator Study	Transit planning study to address transportation needs through Waikīkī; study presents eight proposals to address existing problems, including core network of pedestrian and bike paths (e.g., pedestrian bridge over Ala Wai Canal)	CCH	Study completed in 2013	Does not affect flood risk management, but would be coordinated for purposes of design/implementation
Riparian Restoration Pilot Project	Planting of native plants in riparian corridor along tributary to Mānoa Stream to test survivorship rates in shaded areas	Ala Wai Watershed Association (AWWA)	In progress	Does not affect flood risk management, but would be coordinated for purposes of design/implementation
Watershed Management Plan	Development of a watershed management plan for the Primary Urban Center, as required by the State Water Code; the goal of the plan is to provide short-, mid-, and long-range guidance for the sustainable management and use of surface and ground water resources	Honolulu Board of Water Supply (BWS)	Planned for future	Plan development has not started
Ala Wai Dredging and Improvement Project	Bathymetric (hydrographic) survey of the Ala Wai Canal and the Mānoa-Pālolo Drainage Canal, and a topographic survey of the existing Ala Wai Canal walls and pedestrian walkway area to be conducted. Based on the survey results, the Canals will be dredged and improvements will be made to the Canal walls and pedestrian walkway area.	DLNR	Survey work starting in 2015; dredging expected to occur in 2017	Does not significantly affect potential flood damages; maintenance dredging does not reduce flood impacts, but would be coordinated for purposes of design/implementation
Ala Wai Partnership Working Group	Formed as a result of the Hawai'i Disaster Risk Workshop; the purpose of the group is to increase awareness regarding catastrophic natural disaster risk, and facilitate stakeholder engagement in designing, funding, building and maintaining integrated infrastructure systems that improve the resilience of vulnerable communities in the Ala Wai Watershed and Waikīkī.	Various	In progress	Current actions of working group are not expected to affect project analyses, but outcomes will be used to inform the planning process as appropriate
Ala Wai Canal Watershed Implementation and Monitoring Plan	Implementation of best management plans (BMPs) (including street sweeping, erosion control, construction site runoff management, discharge management) in compliance with National Pollutant Discharge Elimination System (NPDES) permit requirements	State Department of Transportation (DOT)	In progress	Does not affect flood risk management in watershed
Stream Clean-ups	Periodic removal of trash/debris and other clean-up activities along Mānoa and Makiki streams	Community groups	Ongoing	Does not affect flood risk management

1.8 Planning Process

The USACE feasibility planning process is comprised of six steps, as specified by USACE planning regulations and guidance, including Engineer Regulation (ER) 1105-2-100 "Planning Guidance Notebook" (USACE, 2000). These steps include (1) specification of water and related land resources problems and opportunities, (2) inventory, forecast, and analysis of water and related land resources conditions within the study area, (3) formulation of alternative plans, (4) evaluation of the effects of the alternative plans, (5) comparison of the alternative plans, and (6) identification of a recommended plan based upon the comparison of the alternative plans. This process is based on a 50-year period of analysis extending from the base year (which in the case of this project is assumed to be 2026, based on the proposed construction schedule).

Recognizing the need to modernize their planning process with an emphasis on delivering high-quality feasibility studies within shorter timeframes and at lower costs, the USACE has recently applied a SMART [Specific, Measurable, Attainable, Risk Informed, Timely] planning approach to the six-step process (USACE, 2012a). The SMART planning approach emphasizes risk-based decision making (focusing on Specific, Measurable, Attainable, Risk Informed, [and] Timely goals and decisions) and focuses on three primary requirements for feasibility studies (referred to as the "3x3x3 Rule"): completion within 3 years, at a cost of no more than $3 million, and with 3 levels of vertical team alignment (including the applicable USACE District, Major Subordinate Command (MSC), and Headquarters). Other key components include (1) focusing the detailed analysis and design on the recommended plan, and (2) identifying the appropriate level of detail, data collection, and modeling based only on what is necessary to complete the feasibility study.

The planning process was primarily conducted by the PDT, which comprises designated representatives from the project sponsors (USACE and DLNR Engineering Division), partnering agencies (CCH), and consultants. The PDT is responsible for overseeing the planning process, and meets on a regular basis to review and make decisions relative to project development tasks. Consistent with the requirements of the SMART planning process and 3x3x3 Rule, periodic reviews are held with the vertical team (comprising USACE District, Division, and Headquarters staff) to confirm the direction of project development relative to major milestones.

1.9 Report Organization

As noted above, this report integrates into a single document the results of the USACE feasibility planning process, as well as the NEPA and HRS Chapter 343 environmental review requirements, including analysis and disclosure of the potential environmental impacts and mitigation (as needed to inform planning and decision-making). An overview of the report chapters as related to the planning process is provided below. Those chapters or sections required by NEPA and/or HRS Chapter 343 are indicated by an asterisk in the Table of Contents.

- **Chapter 2 (Need for and Objectives of Action)** addresses the specification of water and related land resources problems and opportunities, which is the first step in the planning process. Building on this information, it presents the objectives and constraints of the proposed project.
- **Chapter 3 (Plan Formulation)** is the heart of the feasibility process and therefore is presented before the detailed discussion of resources and effects. It summarizes key elements of the second step of the planning process (inventory and forecast of watershed conditions) to the extent necessary to establish the future "without-project condition" for consideration in the development of alternative plans. It presents the results of the third through sixths steps with increasing detail per each successive iteration, including formulation, evaluation and comparison of alternative plans, as well as the identification of the recommended plan.
- **Chapter 4 (Summary of Alternatives)** briefly summarizes the alternatives that were considered as part of the environmental impact analysis, pursuant to NEPA and HRS Chapter 343. This chapter also includes a summary of those alternatives eliminated from further consideration (and the rationale for their elimination).
- **Chapter 5 (Affected Environment and Environmental Consequences)** covers the second step of the planning process (inventory, forecast, and analysis of water and related land resources) in greater detail than what was provided in Chapter 3. It also provides additional detail on the fourth step of the planning process (evaluation of the effects of the alternative plans).

The remaining chapters discuss public involvement and agency coordination (Chapter 6); describe compliance with applicable laws, policies, and plans (Chapter 7); provide a detailed description of the recommended plan (Chapter 8), present the recommendation (Chapter 9); list the report preparers (Chapter 10); and provide the index and references (Chapters 11 and 12).

2.0 Need for and Objectives of Action

2.1 Problems and Opportunities

Problems and opportunities are those conditions that can be addressed through water and related land resource management of the study area, and serve as the foundation for the remainder of the planning process. Based on the broadly defined goal for flood risk management, specific flood-related problems and opportunities were defined for the study area. This information was compiled as part of an iterative process, based on the results of previous studies and input from the project stakeholders. The resulting list of problems and opportunities is summarized below.

2.1.1 Flood-Related Problems

- **Flooding can result from typical rainfall events, and is exacerbated by the flashy nature of the streams and debris generated by the surrounding watershed.**

  Within the study area, rain typically falls in the mountainous areas of the upper watershed, often with little precipitation in the lower elevations. Rain storms can be intense in volume but typically are of a limited duration, and the timing of the peak flow rate from mountains to sea is approximately 30 minutes. The flashy nature of these flood events can result in conditions that threaten life safety and cause significant property damages.

  The results of modeling conducted in support of this project indicate that peak flow discharge from the 1-percent ACE flood would be approximately 19,500 cubic feet per second (ft^3/s) at the mouth of the Ala Wai Canal.[8] The modeling results indicate that the majority of the peak flow delivered to the Ala Wai Canal is from Mānoa Stream; Pālolo Stream has the next highest contribution, followed by Makiki Stream. Peak flows are enhanced by decreased infiltration, both as a result of impervious surface area in the urbanized watershed and invasive species dominated forests in the upper watershed.

  In October 2004, flash flooding occurred in Mānoa Stream that was an estimated 4- to 5-percent ACE flood event. The energy of the flood dislodged trees in the upper watershed and from the stream banks and transported debris from the urbanized watershed, resulting in blocked bridges; cars were also transported from one stream bank to the other (see Figure 2). Over $85 million in damages was caused by this event.

Figure 2. October 2004 Flood, Debris Blockage and Car Damage at Woodlawn Bridge, Mānoa Stream

8 Additional detail regarding the hydrologic and hydraulic modeling effort is provided in Appendix A.

In March 2006, 40 days of consistent rainfall fell within the watershed. Although none of the storm events were very large (typically a 10-percent ACE event or less), the consistent rain resulted in flooding in the Makiki and Mōʻiliʻili neighborhoods (see Figure 3).

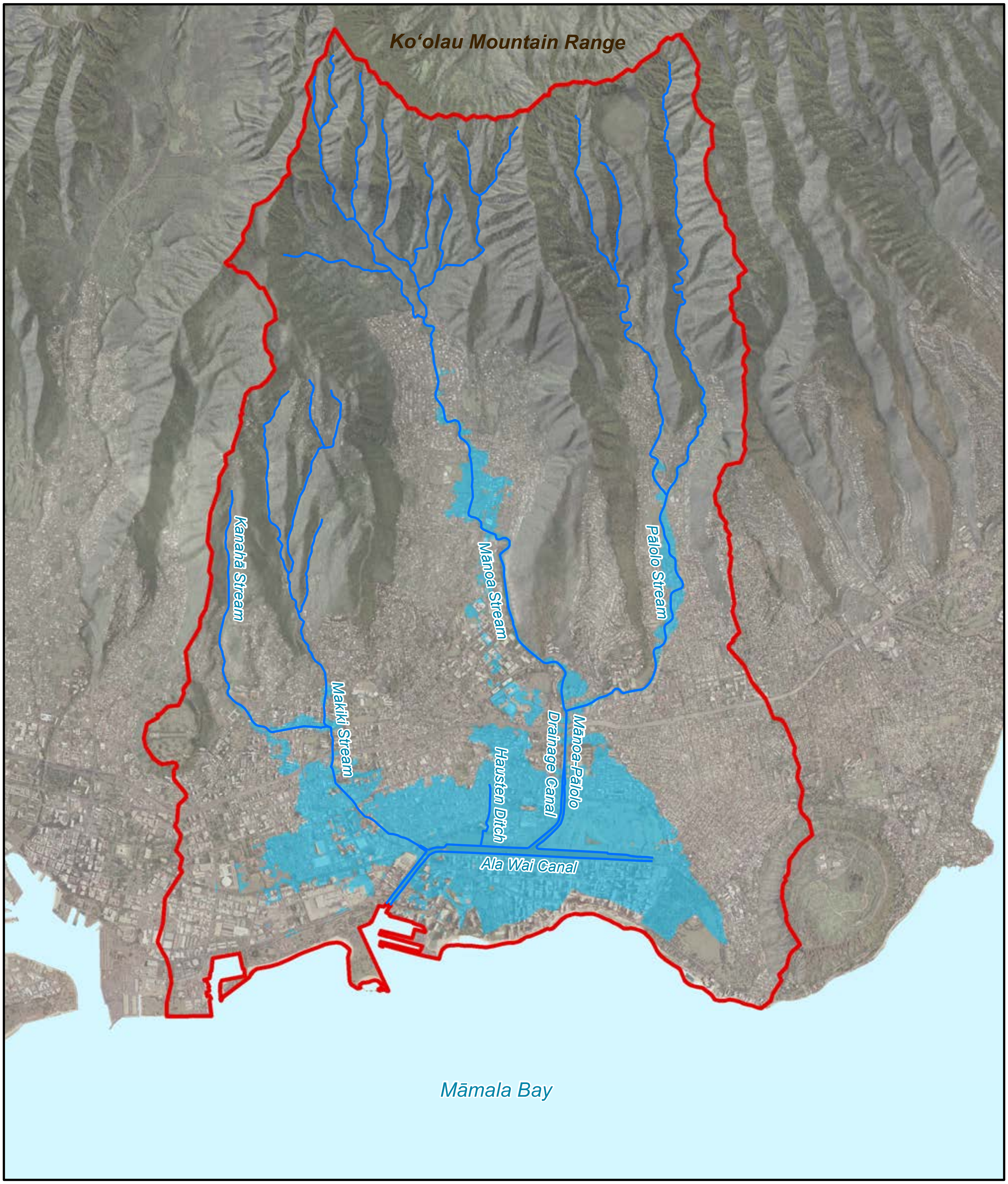
Figure 3. Flooding on Makiki Stream in 2006
(Source of photo (left): M. Baker, Century Center; (right): D. Oda, Honolulu Star Bulletin)

- **Urbanization of the watershed has placed more people and properties at risk of flooding.**

  Modeling conducted in support of the project indicates that approximately 1,358 acres of the Ala Wai Watershed is within the 1-percent ACE floodplain, as shown in Figure 4. Over 3,000 properties are in the 1-percent ACE floodplain, with an estimated $1.14 billion in structural damages alone (at a 2016 price level). The majority of the economic damages are expected to occur within Waikīkī, given the type and value of development within this portion of the existing floodplain. It is important to note that the USACE modeled floodplain shows a greater extent of flooding than the National Flood Insurance Program (NFIP) maps, which were recently updated and are in the process of being adopted by the Federal Emergency Management Agency (FEMA), as the USACE model incorporates a larger area into the analysis and accounts for impacts from increased urbanization in the upper watershed.

  The potential for flooding creates a life safety risk for residents, visitors and workers in the watershed. The affected population within the existing 1-percent ACE floodplain is comprised of an estimated 54,000 residents, plus an additional estimated 79,000 visitors in Waikīkī on any given day. The affected population is expected to be even larger during daytime hours, when there is an influx of students to at least 11 schools (with approximately 48,000 students), as well as workers to the Waikīkī District and other centers of employment (e.g., UH), which collectively provide more than 65,000 jobs. As evidenced by past flooding events, there is a potential for life loss from flooding in the watershed; in addition, health and safety threats include injuries associated with movement of debris and/or health concerns related to contaminated floodwaters. These threats are compounded by the fact that many people within the study area are unaware of the potential threats, so may not be adequately prepared or able to respond in the event of a flood.

  Much of the critical infrastructure in the watershed is located within the existing 1-percent ACE floodplain, which elevates the life safety risks and decreases the community's ability to recover from potential flooding events. This infrastructure includes 4 fire stations, 1 police station, 2 hospitals, 2 nursing facilities and 9 emergency shelters. In addition, the existing floodplain includes many of the major roadways in the watershed, including the primary access in and out of Waikīkī.

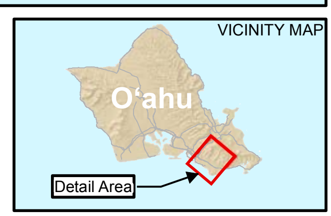


LEGEND

Stream

Watershed Boundary

1-Percent Annual Chance Exceedance Floodplain



0 1 2 Miles

Projection: State Plane Hawaiʻi Zone 3 feet NAD83 HARN

FIGURE 4
1-Percent Annual Chance Exceedance Floodplain
Ala Wai Canal Project
Oʻahu, Hawaiʻi

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- **Historic alterations to the stream channels do not adequately manage flood risk.**

  The Ala Wai Canal was originally designed and constructed to provide drainage, not flood protection.[9] Based on current modeling (which incorporates canal depths based on bathymetric survey data from 2008), the Canal is expected to hold the capacity to contain a 20-percent ACE flood. Development activities along Makiki, Mānoa, and Pālolo streams have resulted in channel projects with different capacities along the same stream. As a result of these non-systematic channel projects, choke-point locations have been created, such as those on Makiki Stream at Fern Street and on Mānoa Stream at Woodlawn Drive, resulting in a reduced channel capacity to handle flood flows. In addition, much of the existing flood risk management infrastructure is approaching the end of its design life. This aging infrastructure may not be functional in 2076 (the end of the design life for the Ala Wai Canal Project).

  Similarly, the storm drainage system managed by CCH is also aging and, in many cases, in need of improvements to meet the present day development and runoff levels. Some of the storm drainage systems do not adequately convey the water off the landscape and to the stream channels, thus increasing sheet flow flooding on streets and other open areas within the watershed. Local drainage issues are not a focus of this study but have the potential to add to the localized flooding issues. CCH is developing plans and projects to address the storm drainage issue in areas of concern within the study area.

- **Stream channel capacities are diminished due to debris and sediment.**

  Historically, the upper watershed was dominated by a native forest that was well adapted to the tropical flash flood systems in the watershed. The canopy structure was complex and captured rainfall, absorbing and slowing its energy before it hit the ground. The trees had strong, stable roots to withstand high water and wind velocities and secure sediment. The understory also helped to stabilize soil. The upper watershed is now dominated by invasive tree species with shallow root systems, limited understory cover, and a simple canopy structure that does not adequately slow the rainfall. As a result, during large storm events, the upper watershed contributes a high amount of large woody debris and sediment, beyond natural background levels. This sediment and debris decreases channel capacities and blocks flow under bridges, thus exacerbating flooding. For example, debris from both the upper watershed and surrounding urban areas resulted in blockage of flow under the Woodlawn Drive Bridge during the 2004 Mānoa flood; this caused flows to jump out of the channel and flood the UH campus (USACE, 2006a).

  In addition to debris from the upper watershed, debris from adjacent properties also contributes to the problem. In Hawai'i, land is typically owned to the centerline of the stream and landowners are responsible for maintaining the stream. Within the study area, there are more than 1,000 property owners of the stream channels. CCH has some responsibilities to maintain the stream when there is an imminent threat of flood or to clean up in response to a flood event. However, regular maintenance has been limited to the properties and bridges owned by CCH or the State of Hawai'i. There is no regular comprehensive maintenance program for the entire stream system within the watershed.

- **Flooding may be exacerbated by climate change and associated projected increases in sea level rise.**

  In the last 30 years, Hawai'i has seen the 1 percent ACE daily rainfall events increase by 12 percent. Climate change models, while not conclusive, indicate that this trend may continue, which has the potential to affect the frequency of intense flooding in the future.

  The island of Oʻahu is already experiencing impacts from sea-level rise. The Waikīkī area has experienced an increase in flooding and inundation of underground parking areas and stormwater outfalls associated with high tide events. As a result, climate change scenarios were integrated into the study to evaluate current and

[9] It has been estimated that in the early 1900s, approximately 85 percent of the modern Waikīkī district was under water (Hibbard and Franzen, 1986). Growing health concerns over mosquitoes and a desire to more fully develop the Waikīkī District led to the construction of the Ala Wai Canal to divert the streams and drain the wetlands (Weigel, 2008). The Canal was constructed in the 1920s, with dredged material used to fill the wetlands *makai* (oceanward) of the Canal; this allowed these areas to be developed for residential and commercial purposes.

forecasted future conditions. Following USACE sea level rise guidance, the low, intermediate and high sea-level rise rates for 2075 are 0.41, 1.02 and 2.96 feet (0.12, 0.31, and 0.90 meters).

- **Hurricanes and tsunamis cause flood damage in the lower portions of the watershed, in addition to the rainfall flooding events.**

  Hurricane-related storm surge can cause extensive flooding. In Hawai'i, Hurricane Iniki (1992) resulted in flooding of roads and underground garages and the first level of some Waikīkī hotels. However, hurricanes in Hawai'i typically occur between June and November, which is primarily during the dry season (May to September). Hurricanes are not the same as the meteorological events that can bring intense flood-producing rainfall, which usually occur during the wet season (October to April). Rain associated with hurricanes passing Oahu historically has not been heavy enough to cause significant flooding. The largest recorded storm events in Hawaii were caused by different meteorological conditions from hurricanes, such as an upper level trough or low pressure system over a tradewind condition, which allows moist air to aggregate and produce heavy showers and thunderstorms. Such events are meteorologically different than passing hurricanes or tropical storms. The November 2000 flood in Hilo, Hawaii had 32 inches in 24 hours, the East Honolulu New Year's Eve flood of 1987/88 had 22 inches in 24 hours, and the downtown Honolulu Flood of March 5-6, 1958 had 17.41 inches in 24 hour are examples of damaging floods of this type of meteorological condition (US Amy Corps of Engineers, 1985). Fortunately, Oahu has never been directly hit by a hurricane in modern recorded history, so there is no data that hurricane wave run-up and hurricane produced rainfall can occur at the same critical time period. The passage of Hurricane Iniki to the south of Oahu in 1992 did caused water to top the banks of the Ala Wai canal due to wave set-up but rainfall on Oahu from this hurricane was insignificant. Thus, based on the data, high rainfall storm events were considered independent of hurricanes. Similarly, tsunamis are not expected to be coincident with a major storm resulting in riverine flooding. Given the low probability of these events occurring at the same time, it was decided that potential storm surge would not be included as part of the hydraulic conditions utilized in the economic modeling;[10] a discussion of the risks of sea level rise and coincident flooding are further discussed in Section 8.3. Regardless of this decision, the flood-risk reduction measures (e.g., Ala Wai Canal floodwalls) were evaluated under coincident storm conditions, but only in terms of project performance. The results of this analysis show that line of protection improvements would be expected to provide protection from storm surge within the Ala Wai Canal.

2.1.2 Flood Reduction Opportunities

Opportunities to reduce flood risk in the study area generally correspond to the problems described in Section 2.1.1. Opportunities that have been identified to date include the following:

- Reduce flood peaks in the watershed.
- Improve channel and bridge conveyance capacities.
- Reduce runoff though increased infiltration.
- Improve the storm drainage system.
- Reduce debris contributions from the watershed and stream channels.
- Incorporate environmentally-sustainable design features into flood risk management features (including those to maintain fish passage).
- Clarify land ownership boundaries and maintenance responsibilities.
- Improve flood warning system.
- Educate and increase communication of flood risks.

[10] The backwater condition for the hydraulic model is based on mean high tide, inter-annual tidal variability and future sea level rise.

- Provide tools or incentives to help property owners protect their property (such as flood insurance).

It is important to note that some of these opportunities may exceed the authority of the USACE and/or non-Federal sponsor, and therefore may not be pursued as part of this project. Beyond those opportunities listed above, routine dredging of the Ala Wai Canal, coastal storm protection and localized drainage issues are not within the scope of study and may be addressed through other Federal, State, and City and County programs and projects. However, relevant information from those efforts would be incorporated by reference into the study where applicable.

2.2 Objectives and Constraints

2.2.1 Federal Objective

As specified in the USACE Planning Guidance Notebook (ER 1105-2-100), the Federal objective of water and related land resources planning is to contribute to national economic development (NED) consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable Executive orders (EOs), and other Federal planning requirements. To demonstrate consistency with the Federal objective, the effects of a project must be analyzed to demonstrate that the project benefits outweigh the costs within the context of the NED account. The NED account displays changes in the economic value of the national output of goods and services.

2.2.2 Planning Objective

In general, the Federal objective is not specific enough to guide the plan formulation process, so rather is considered as an overarching goal. As such, a focused planning objective was developed specifically for this project. Planning objectives represent desired positive changes from the future without-project conditions, and should be defined based upon the problems and opportunities identified for the study area.

The planning objective for the Ala Wai Canal Project is to reduce riverine flood risks in the Ala Wai Watershed through the 50-year period of analysis.

2.2.3 Planning Constraints

Constraints are restrictions that limit the planning process, and should be considered as part of project development; these can include resource constraints (such as limitations on schedule, budget, and/or technical knowledge) and legal constraints (such as limitations in USACE policy), as well as study-specific constraints identified by the PDT and project stakeholders. Constraints identified to date and considered in the planning process include, to the extent practicable, avoidance and/or minimization of the following:

- Shifting of flooding to downstream areas
- Induced flood damages (e.g., through impacts to internal drainage)
- Development of infrastructure that is incompatible with existing land uses, regulations or policies;
- Induced development in the existing floodplain
- Significant reduction of migratory pathways or habitat for endemic aquatic species, or increase of habitat for invasive aquatic species
- Impacts to nearshore marine resources at the mouth of the Canal

2.2 Related Issues

Based on the scoping and stakeholder involvement efforts conducted to date, there are several issues and concerns that have been identified beyond the flood-related problems listed in Section 2.1.1; these are summarized in the following bullets. It is important to recognize that not all stakeholder concerns can be addressed within the current project authority; however, to the extent possible, these issues and concerns were considered throughout the feasibility planning process.

- **Need for stream maintenance:** One of the issues repeatedly raised by stakeholders is inadequate maintenance of the waterways within the watershed. Maintenance-related issues are complicated by the fragmented land ownership along the waterways, inconsistent approaches to maintenance by different landowners, limited accessibility, limited resources and excessive costs. Several State and County agencies are tasked with maintenance of waterways, but overlapping jurisdictions and non-coordinated approaches result in poor maintenance practices.
- **Desire for more natural stream conditions:** Stakeholders have expressed the desire that no additional stream channelization occur within the watershed, as well as an interest in restoring existing concrete channels to a more natural condition.
- **Degraded water quality:** Stakeholders have repeatedly expressed concerns regarding the water quality of the streams and channel in the watershed. Water quality is an important health and safety concern, particularly to recreational users in the Ala Wai Canal (e.g., canoe paddlers). Water quality issues start in the upper watershed with such problems as uncontrolled erosion and bacteria. Water quality issues also include polluted runoff and the input of trash into the streams from adjacent residential and urbanized areas. Trash and debris exiting the Canal is also a concern to the DLNR Division of Boating and Ocean Recreation (DOBOR) and to users of the Ala Wai Boat Harbor, as debris can damage boats and is expensive to remove.
- **Low awareness of flood risks:** Many residents are not aware of the potential flood risks. In some parts of the watershed (e.g., the urbanized portion of Pālolo Valley), flooding has not occurred since the storm drain system was put in place and the stream was channelized. Significant flooding from the Ala Wai Canal has not occurred since the late 1960s; therefore, residents are generally not aware of the potential magnitude of flooding. However, many stakeholders are concerned about the potential additional impact of sea-level rise in the lower reaches of the watershed. Community members throughout the watershed highlighted the need for better information and education of both adults and children on watershed issues, including flood risks and how to better care for the streams.

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3.0 Plan Formulation

Based on the six-step feasibility planning process, plan formulation involves development and evaluation of alternative plans to address the specific planning objectives. Consistent with the requirements of the USACE Planning Guidance Notebook (ER-1105-2-100), the planning objectives and determination of Federal interest guide the planning process, which results in identification of a recommended plan. This chapter summarizes the specific plan formulation process that was conducted for the project.

3.1 Plan Formulation Strategy

Given the multiple layers of complexity and geographic scope of the study, the PDT developed a strategy to guide the plan formulation process. The plan formulation strategy incorporated a methodical approach to assembling flood risk management measures into alternative plans, and a multi-criteria screening process based upon existing data and available information, coordinated professional judgment, and risk-informed assumptions. Figure 5 shows the overall structure and results of the formulation process. In general, the process involved an initial grouping of conceptual flood risk management measures based on the identified problems within the watershed; these groupings were used to compile alternative plans, which were then focused from broad flood risk management concepts to a combination of site specific actions that best met the overall planning objectives/constraints. The nomenclature for the alternatives was modified over the course of this process to reflect refinements made to each alternative (e.g., after refinements were made, Alternative 2 was renamed Alternative 2A). Details regarding the approach and outcome of the plan formulation process are provided in the subsequent sections.

An increasing level of detail was used at each stage of the alternatives formulation process, as needed to develop and refine the conceptual management measures and alternative plans, and ultimately, to provide the basis for evaluation and comparison of the final array of alternatives. In general, the early stages of plan formulation were based on concept-level information using available information from existing studies coupled with professional judgment, and culminated with the development of 35% design-level engineering plans and Class 3 cost estimates for the recommended plan. The planning process consisted of a number of iterations which include the following:

- Iteration 1: Initial Formulation of Alternative Plans – Development and grouping of management measures into alternative plans at a conceptual level; screened via qualitative criteria; completed in 2012
- Iteration 2: Viable Array of Alternative Plans – Cursory technical analysis was performed to site management measures in the landscape; site-specific conditions were then evaluated under broader environmental, cultural and effectiveness criteria to screen to a final array; completed in 2013
- Iteration 3: Final Array of Alternative Plans – Conceptual designs (10%) were developed for each plan along with detailed modeling, cost estimates and environmental analysis; comparison between plans in the final array was completed and a recommended plan selected; completed in 2015
- Iteration 4: Refinement of the Selected Plan – The selected plan was evaluated in increments using economic criteria and optimized for levels of protection; a cost-schedule risk analysis was completed and design refinements (35% design) integrated to fully estimate the anticipated costs of plan implementation; completed in 2016

A variety of models were used to support the plan formation process, including Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) for the hydrologic modeling, Hydrologic Engineering Center's River Analysis System (HEC-RAS) for hydraulic modeling, and Hydrologic Engineering Center's Flood Damage Reduction Analysis (HEC-FDA) for the economic analysis.

3.2 Screening Criteria

A comprehensive set of screening criteria were developed for the formulation of flood risk management measures and alternatives as part of the Re-scoping Charrette.[11] The criteria were defined within the context of the Federal criteria specified in the USACE Planning Guidance Notebook (ER 1105-2-100), which should be considered for all Federal water resource projects, and include the following:

- Completeness (or the extent to which a given alternative plan provides and accounts for all necessary investments or actions to ensure realization of the planned effects)
- Effectiveness (or the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities)
- Efficiency (or the extent to which an alternative plan is the most cost effective means of alleviating the specific problems and realizing the specified opportunities)
- Acceptability (or the viability of the alternative plan with respect to acceptance by State and local entities and the public, and compatibility with existing laws, regulations, and public policies)

The resulting screening criteria are summarized in Table 2. These criteria were used at each stage of the formulation process, with the metrics reflecting the increasing level of detail, so as to help focus and refine the measures and alternative plans.

Table 2. Screening Criteria Considered in Plan Formulation Process

Criteria	Description
Technical feasibility[a]	The extent to which the measure/alternative can be constructed and/or implemented
Implementation cost[c]	The cost to implement the measure/alternative (not including operations and maintenance costs)
O&M requirements[c]	The actions (and associated cost) required to operate and maintain the measure/alternative
Cost-effectiveness[c]	The extent to which the benefits of the measure/alternative outweigh the overall cost
Availability of land[a]	The extent to which the necessary land (and adequate space) is available for implementation of the measure/alternative
Acceptability – public sentiment[d]	The extent to which the measure/alternative would displace people and/or activities, or would generate significant stakeholder concerns
Acceptability – legal[d]	The extent to which the measure/alternative is consistent with applicable laws, regulations and policies
Compatibility/dependency[a]	The extent to which the measure/alternative requires additional actions to function properly
Social fairness[d]	The extent to which the measure/alternative treats each community fairly (i.e., does not transfer flood risk to another community, or does not unfairly favor one community over another)
Flood damage reduction[b]	The extent to which the measure/alternative reduces flood damages within the watershed
Reduction in life safety risks[b]	The extent to which the measure/alternative reduces life safety risk factors (e.g., affected population and flood characteristics)
Community resilience[b]	The extent to which the measure/alternative contributes to the community's ability to recover from a large flood event (considering impacts to critical infrastructure)
Environmental (biological) impact[d]	The extent to which the measure/alternative would result in significant impacts to biological resources (including in-stream habitat and fish passage for key aquatic species, riparian habitat, and water quality)
Archaeological/cultural impact[d]	The extent to which the measure/alternative would result in significant impacts to historical, archaeological, and/or cultural resources

Note: The screening criteria were defined within the context of the four Federal criteria, as follows:
[a] completeness [b] effectiveness [c] efficiency [d] acceptability

[11] Criteria specific to ecosystem restoration were originally identified as part of the Re-Scoping Charrette, before ecosystem restoration was eliminated as a project purpose. These related to aquatic species habitat, fish passage, riparian habitat, and water quality. Although these were applied during early stages of the alternatives formulation process, they were no longer used for screening once the ecosystem restoration purpose was eliminated. However, given the overall interest in avoiding/minimizing environmental impacts and providing environmentally sustainable solutions, a more general environmental impact criterion was added for the flood risk management measures and alternatives.

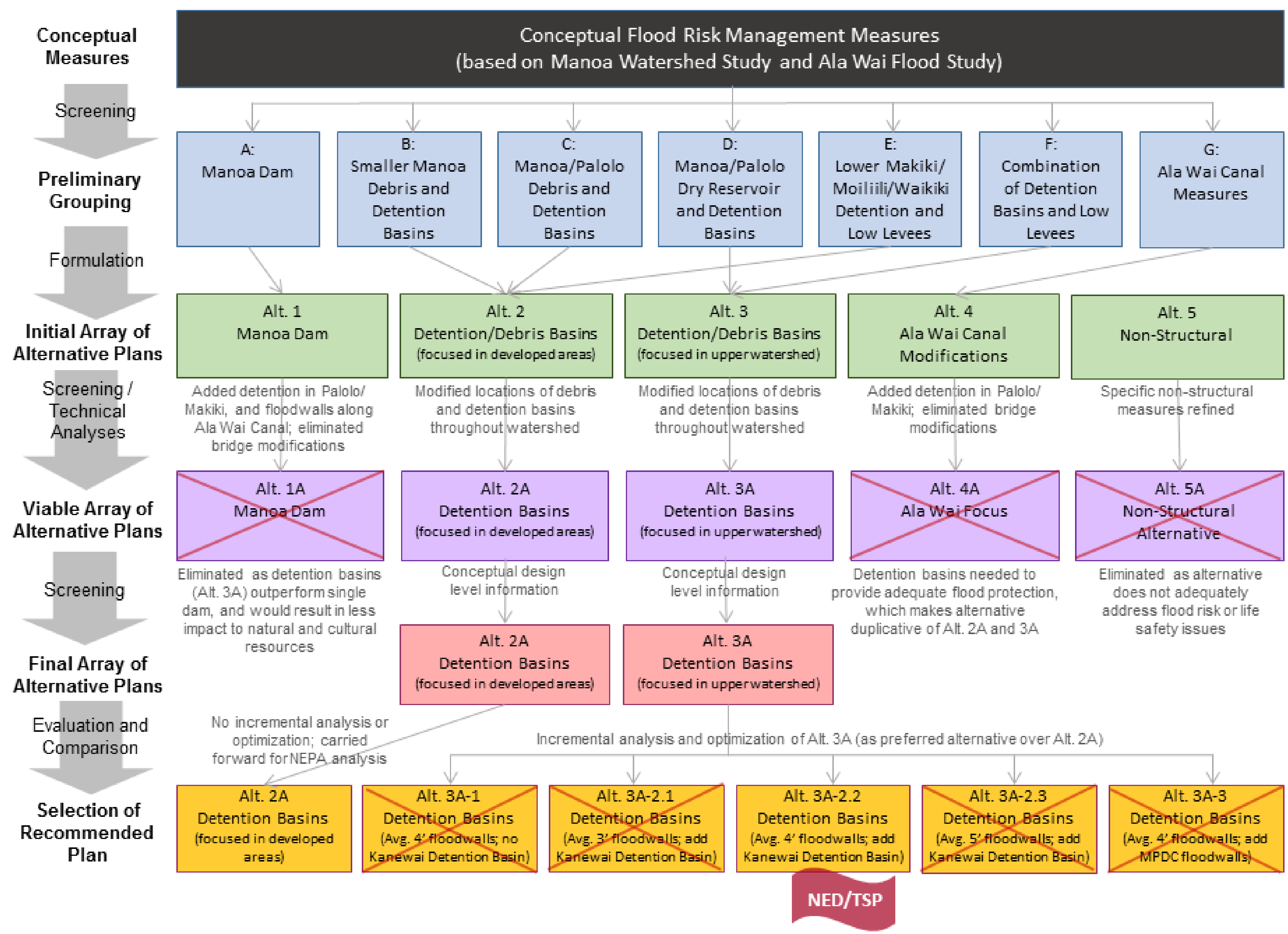


Figure 5. Plan Formulation Approach

3.3 Key Assumptions Regarding Anticipated Future Conditions

The future without-project condition (i.e., the No Action Alternative for the NEPA and HRS Chapter 343 analysis) is the most likely condition expected to exist in the future in the absence of a proposed project. The future without-project condition defines the benchmark against which the alternative plans are evaluated. In general, the anticipated future conditions should consider present day actions, laws, and policies (such as regular maintenance of existing structures), as well as reasonably foreseeable actions (such as capital improvement program [CIP] budgeted items, changes in land use, and climate change), with assumptions based on existing literature or best professional judgment from subject matter experts.

The key assumptions relative to future conditions are summarized below; a detailed discussion of the methodology and assumptions is provided in Appendix A (with results of the hydrologic and hydraulic modeling of the future without-project floodplain summarized in Chapter 5.4.2.1).

- **Sea-level Rise:** Sea-level rise within the project area will range between 0.41 to 2.96 feet (0.125 to 0.90 meters) by 2075 (based on USACE analysis of the low, intermediate, and high rates). The modeling of future conditions is based on the intermediate rate of sea-level rise, which was added to the starting backwater condition (mean high high tide of 1.08 feet) plus the inter-annual variability of the tidal data of 0.4 feet in the Ala Wai Canal.
- **Rainfall:** Recent studies have indicated that the frequency of heavy rainfall events on Oahu will not increase or decrease under future climate change. The modeling of the future-without project condition is based on National Oceanic and Atmospheric Administration (NOAA) Atlas 14 values, which do not quantitatively take the projections for future rainfall intensity resulting from climate change into account.
- **Increased Imperviousness:** Land uses within the watershed are not anticipated to significantly change in the future, but redevelopment of the urban areas is expected to result in increased imperviousness within the watershed; the overall impact relative to quantity of runoff is expected to be small, but cumulative over time. The increase in runoff from the urban areas was incorporated into the hydrologic modeling of the future without-project conditions by increasing the Curve Number (CN) values for those areas within the urbanized portion of the watershed to account for less infiltration.[12]
- **Debris Generation:** The amount of debris generated within the watershed is not expected to significantly increase from the estimates used in the existing without-project condition model. Invasive species, which can result in increased debris and sediment contributions because of their shallow root systems and brittle branches, are already dominant throughout much of the upper watershed. The modeling of the future without-project condition assumed no increase in debris generation for the low rate, a 5 percent increase in the bulking factor for the intermediate rate, and a 10 percent increase for the high rate.

3.4 Conceptual Flood Risk Management Measures

In response to the identified problems and opportunities, a broad array of potential flood risk management measures was compiled. Specifically, this included conceptual structural measures within the following five categories, each of which represent a different approach to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, and (4) minimization of flood damages. This effort relied on the results of existing report and studies, particularly the Mānoa Watershed Study and the Ala Wai Study (Oceanit, 2008a; USACE, 2001), as well as sponsor and stakeholder input and professional judgment.

[12] The CN method (Natural Resources Conservation Service, 2004) is used in the existing without-project model to account for infiltration and impervious areas and is based on land cover and hydrologic soil group classification.

Based on the screening criteria listed in Section 3.2, the management measures were screened, resulting in several measures being eliminated from further consideration. In particular, a number of the flood risk management measures were based on a broader multi-purpose, comprehensive watershed planning approach and therefore were determined to not be within the USACE's authority specific to flood risk management. The initial measure screening effort was conducted as part of the Re-Scoping Charrette (USACE, 2012), with additional screening by the PDT based on subsequent analysis. The conceptual flood risk management measures identified for consideration in the plan formulation process and the final results of the conceptual measure screening process are listed in Table 3.

3.5 Non-Structural Solutions

Consistent with USACE policies and regulations which require equal consideration of structural and non-structural solutions, non-structural measures were also formulated. In general, flood risk is based on a combination of probability and consequence; non-structural measures focus on reducing the consequence of flooding (as opposed to the probability of flooding), Specifically, non-structural measures reduce the consequence of flooding by modifying the characteristics of development in the floodplain and the behavior of people living within the floodplain (as opposed to modifying the characteristics of floods). That is, they change the use of the floodplain or accommodate existing uses in the floodplain, without changing the extent and nature of the flood itself.

The initial effort to identify non-structural measures was based on a high-level screening of structures/ buildings within the existing floodplain that would sustain enough damage to economically justify some kind of non-structural solution, and determination of whether a non-structural solution would be technically adequate, cost effective and capable of implementation. This effort identified opportunities for floodproofing and other non-structural approaches for approximately 340 structures or buildings (including approximately 115 residential and 225 commercial/institutional structures and buildings) along Mānoa, Pālolo, and Makiki streams, as well as in Waikīkī. These generally include raising, relocating, and acquiring or buying-out structures; floodproofing; and building individual berms and floodwalls to protect small clusters of buildings. Acquisition and permanent relocation were not further considered, as these solutions are not justifiable due to the land prices in Hawai'i. Flood warning systems were also identified as another form of nonstructural solution that could be developed for the Ala Wai Watershed. As these systems contribute to improving life safety and community resilience for a relatively small cost, there is no separate economic justification.

Non-structural solutions were considered both as a stand-alone non-structural plan, as well as in combination with structural solutions; these efforts are discussed further throughout the remainder of Section 3. A detailed description of the methods and results of the non-structural formulation process is provided in Appendix B.

3.6 Iteration 1 – Initial Formulation of Alternative Plans

3.6.1 Definition of Stream Reaches

To allow for consideration of problems and opportunities on a site-specific basis, as the foundation for the plan formulation process, the streams and canals within the watershed were delineated into distinct reaches. The stream reaches were primarily defined based on hydraulic conditions (such as stream confluences and bridge locations), and were further delineated based on geomorphologic characteristics (e.g., steep upper reaches vs. depositional lower reaches), channel conditions (e.g., natural vs. concrete), and surrounding land use. The extent of each reach is shown in Figure 6.

3.6.2 Preliminary Grouping of Structural Measures

The conceptual flood risk management measures that were carried forward from the screening process, as indicated in Table 3, were then grouped into various combinations. This effort was conducted as part of the Re-Scoping Charrette, using focus groups to combine various management measures to address the existing flood-related problems and opportunities in the geographic subregions of the watershed (i.e., Mānoa, Makiki, and

Pālolo streams and the Ala Wai Canal), with the location of each measure generally assigned based on the stream reaches shown in Figure 6. This process was informed by the results of the previous studies specific to Mānoa and the Ala Wai Canal (Oceanit, 2008a; USACE, 2001); these concepts were then extrapolated to address problems within Makiki and Pālolo.

Through this process, some measures that had been initially carried forward were screened from further consideration. In particular, the measure that involves pumping peak flows from the Ala Wai Canal was eliminated due to technical feasibility and significant implementation cost (including real estate acquisition requirements). As summarized in Table 3, it was determined that the size of the pumps needed to move the necessary volume of water would be excessive; the discharge pipes would need to extend into the ocean to avoid discharge into the boat harbor; and floodwalls would still be needed along the Canal (to account for increased hydraulic head when the gates are closed). In addition, the cost of the pumps and the land needed to house the pumps would be significant.

These efforts resulted in identification of eight preliminary groups of conceptual management measures, as listed in Table 4 and shown in Figure 5.

3.6.3 Initial Array of Alternative Plans

Based on a review of the preliminary grouping of management measures within the context of the identified problems, planning objectives and previous study results, it was determined that the formulation of alternative plans should build on these groupings, with a focus on maximizing solutions that address flood risk and benefits in key areas likely to be impacted throughout the watershed (as opposed to taking a reach by reach approach). Using the results of the measure screening and preliminary measure groupings, as well as the preliminary identification of non-structural solutions, the following strategies were developed by the PDT to guide the formulation of an initial array of alternatives:

- Attenuate water in areas with the highest volume of peak flow (i.e., the upper reaches of Mānoa Stream).
- Distribute floodwater attenuation across available open space areas in the urbanized watershed.
- Maximize solutions where the majority of the flood risk and damages occurs (i.e., the Ala Wai Canal).
- Incorporate non-structural solutions, where possible.

Based on these strategies, the PDT generated a total of four structural alternative plans. Of the four structural plans, two involved solutions centering on a single measure: one based on a dry reservoir (dam) in Mānoa, and one focused on modifications to the Ala Wai Canal. The other two alternatives were comprised of a composite of detention basins that sought to cumulatively attenuate floodwaters across the watershed. Of these, one involved siting detention basins in available open space areas throughout the urbanized watershed (with minimal detention in the upper watershed). Recognizing the potential community impacts associated with use of park space, the other alternative sought to maximize detention in the upper watershed (in a similar location as the dam, but through a combination of smaller-scale features). Formulation of the detention alternatives generally involved combining several of the preliminary measure groups, in order to eliminate duplication in the initial array of alternatives. Consistent with USACE requirements, a non-structural alternative was also formulated, and was comprised of all the potentially justifiable non-structural measures that were initially identified for the watershed.

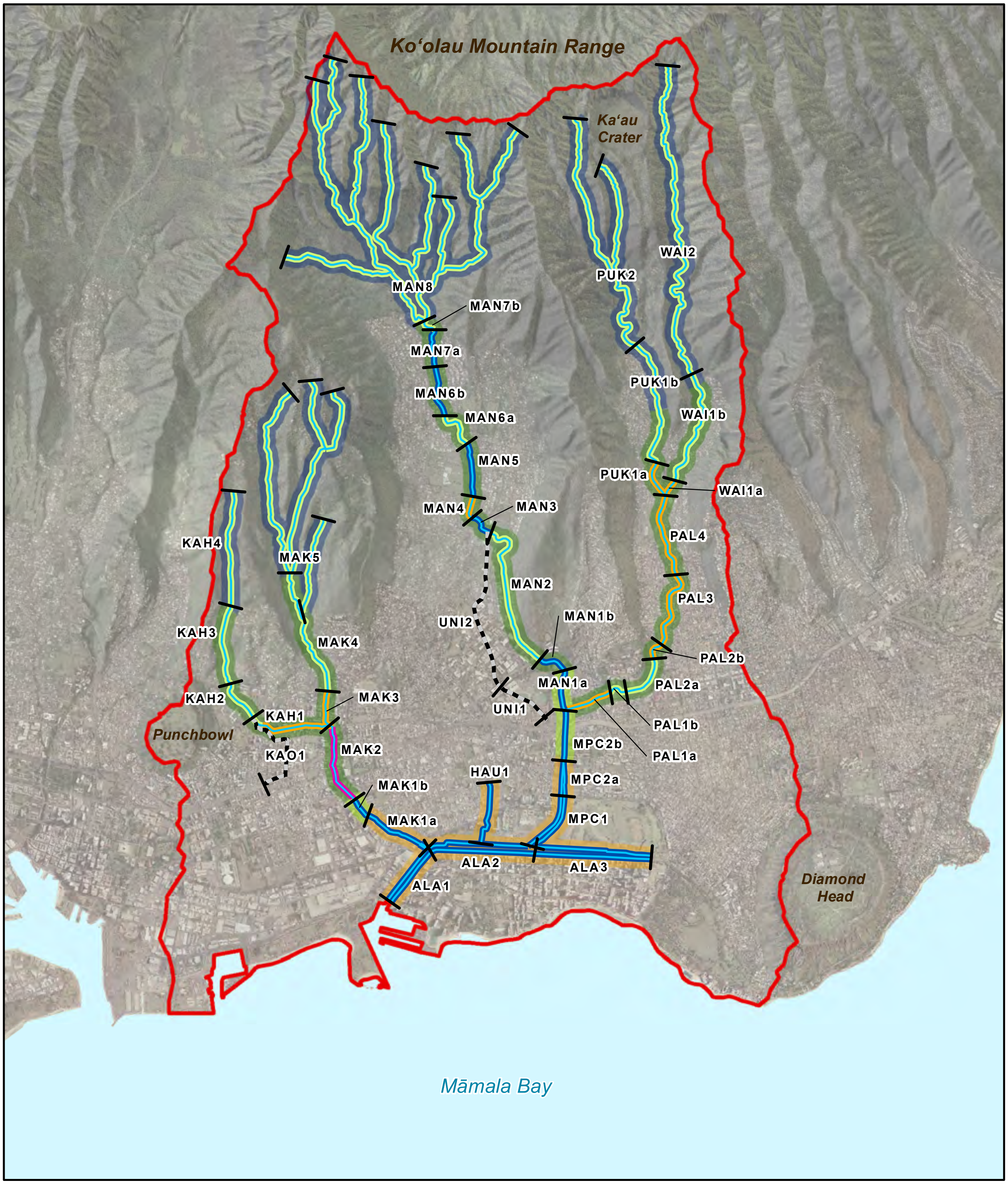
Table 3. Identification and Screening of Conceptual Flood Risk Management Measures

Measure Category	Conceptual Measure	General Description	Results of Measure Screening[a]		
			Carried Forward	Eliminated	Rationale
Peak Flow Reduction	Detention basins (surface and sub-surface)	Create surface and/or subsurface temporary storage facilities to collect flood flows during larger storm events; operate to control storm flow	•		Subsurface detention basins were initially carried forward, but were eliminated from further consideration during reformulation of the initial array due to limited flood damage reduction (e.g., small storage capacity) and high implementation cost (i.e., not cost effective). Surface detention basins were retained for further analysis.
	Retention and infiltration basins / injection wells / wet ponds	Create facilities to capture and return storm flows into shallow or deep groundwater areas; can be used to intercept hill slope runoff; can be used to create wetlands for habitat		•	Eliminated from further consideration based on limited flood damage reduction (e.g., small storage capacity) and high implementation cost (i.e., not cost effective).
	Dams / reservoirs	Create larger storage facilities than detention basins; can also create permanent pools for habitat	•		Carried forward for further analysis.
	Diversion/Bypass structures (surface and sub-surface)	Create sub-surface diversions to divert flows from constricted channel areas; create surface diversions to protect hillslope areas; create sub-surface or surface diversion from Canal to ocean		•	Initially carried forward for further analysis; must be paired with an associated measure (e.g., detention basin). Woodlawn Ditch bypass structure subsequently eliminated from further consideration, as it was determined to be cost prohibitive (including significant real estate requirements). Noelani bypass structure also eliminated because detention basin was not carried forward.
	Pump peak flows	Install pump system to pump peak flows out of streams/Canal		•	Initially carried forward, but subsequently eliminated from further consideration based on technical feasibility and high implementation cost associated with excessively large pumps, extensive discharge pipes into ocean, and floodwalls.
	Low Impact Development	Various methods of retaining stormwater to allow for natural infiltration and decreased runoff; typically implemented on individual properties (residential or commercial) in many locations throughout watershed		•	Eliminated from further consideration as measure is not within the USACE authority and does not substantially decreased flood risk. If desired, measure would need to be pursued by the non-Federal sponsor.
Increase Channel, Storm Drain and Bridge Capacities	Widen stream channel/Canal	Widen stream channels/Canal to increase flow capacities; channels can also be widened to allow more natural channel evolution (e.g., channel migration)		•	Initially carried forward, but subsequently eliminated from further consideration based on high implementation costs and lack of available land. Measure also presents significant cultural impact concerns for the Canal, which is a historic property.
	Deepen stream channel/Canal	Deepen existing stream channels and/or dredge Canal to increase flow capacities		•	Eliminated from further consideration as the cost is substantial, and measure does not provide for significant increase in capacity; therefore the measure is not cost effective.
	Levees and floodwalls	Create levees and floodwalls to increase capacities of streams/Canal	•		Carried forward for further analysis.
	Add outlet for Canal	Create additional outlet for the Ala Wai Canal (e.g., extend on the Kapahulu end to exit near Natatorium)		•	Initially carried forward, but subsequently eliminated from further consideration due to land cost/availability. In addition, measure would result in water quality and other significant environmental impacts.
	Add overflow channel for Canal	Add overflow channel for the Ala Wai Canal; could function as a wetland swale		•	Eliminated from further consideration due to high implementation cost and limited land availability, as well as a limited capacity to reduce flood damages; therefore the measure is not cost effective.
	Improve local drainage system	Modify or improve storm drainage system where needed or to work with other flood risk management improvements; retrofit to reduce maintenance requirements		•	Eliminated from further consideration as measures is not within USACE authority. If desired, measure would need to be pursued by the non-Federal sponsor.
	Modify or replace bridges	Modify or replace bridges (and modify channel as needed) to allow more capacity to pass peak flows; create flow modification structures upstream of bridges to increase velocities under bridges		•	Carried forward for further analysis, but subsequently eliminated as measure would not substantially address existing flooding problem and the cost is excessive.

Table 3. Identification and Screening of Conceptual Flood Risk Management Measures

Measure Category	Conceptual Measure	General Description	Results of Measure Screening[a] Carried Forward	Eliminated	Rationale
Debris Management	Debris basins / collection structures	Construct debris basins to collect natural debris and/or install structures (e.g., vortex trash separators, net systems, screen/rack systems, trash booms, etc.) to collect urban debris in streams	●		Carried forward for further analysis.
	Vegetation management program	Develop and implement vegetation management program that includes inspection, clearing and trimming of vegetation likely to contributes debris to streams		●	Eliminated from further consideration as measure is not within USACE authority; O&M responsibilities are the purview of the non-Federal sponsor.
Channel Maintenance	Flood control district	Obtain no-cost maintenance easement from stream-side landowners; a single entity would be responsible for operations and maintenance as a special drainage district		●	Eliminated from further considerations as the USACE does not have the authority to implement this measure.
	Third-party land trust	Use third-party land trust to acquire land adjacent to the streams/canal and improve maintenance under single ownership		●	Eliminated from further considerations as the USACE does not have the authority to implement this measure.
	Maintenance permitting	Develop general permits to facilitate maintenance activities by both private landowners and government agencies		●	Eliminated from consideration as measure is not within USACE authority; O&M responsibilities are the purview of the non-Federal sponsor.
	Stream bank maintenance program	Manual and/or organization to help landowners design, permit and implement actions to restore and maintain portions of the stream bank located on private property		●	Eliminated from consideration as measure is not within USACE authority; O&M responsibilities are the purview of the non-Federal sponsor.
	Maintenance fund	Establish maintenance fund for operations and maintenance (responsibility assigned to single entity); fees could be assigned based on degree of risk reduction (e.g., those no longer within floodplain as a result of project)		●	Eliminated from consideration as measure is not within USACE authority; O&M responsibilities are the purview of the non-Federal sponsor.
Minimize Flood Damages	Decrease susceptibility of existing structures	Elevate or flood-proof structure in the flood hazard areas; encourage construction of structures in the flood prone areas to use flood resilient materials; acquire and relocate residences outside the flood hazard areas	●		Carried forward for further analysis.
	Manage future development	Implement floodplain development standards through zoning ordinances, building codes, or establishment of flood easements		●	Eliminated from further considerations as the USACE does not have the authority to implement this measure.
	Flood preparedness planning	Outreach communication strategies to communicate flood risk, encourage flood preparedness, and purchase of flood insurance; provide improved site specific flood warning system; update flood management plans	●		The primary responsibility to undertake this activity would be the non-Federal sponsor. Workshops to address flood preparedness planning for the Ala Wai Canal would be initiated prior to the completion of the study.

Note:
[a] The measure screening was initially conducted as part of the Re-Scoping Charrette held on October 16 through 29, 2012 (USACE, 2012b); additional screening was subsequently conducted by the PDT.



LEGEND

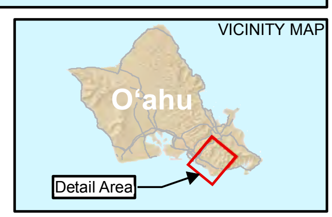
- Stream
- Problem Overflow Zone[1]
- Reach Extent
- Watershed Boundary

Reach Type

- Estuarine
- Lower
- Middle
- Upper

Channel Condition

- Misc Revetment/ Natural Bottom
- Natural
- Concrete Channel
- Underground



0 1 2 Miles

Projection: State Plane Hawai‘i Zone 3 feet NAD83 HARN

N

Notes:
1. The problem overflow zones are defined by the HEC-RAS model, as discussed in the Hydrology and Hydraulic Appendix.

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

FIGURE 6
Overview of Stream Reaches
Ala Wai Canal Project
O‘ahu, Hawai‘i

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Table 4. Preliminary Grouping of Conceptual Management Measures[a]

A	Mānoa Dam
B	Mānoa Debris and Detention Basin Measures (including Noelani School detention basin and a series of detention basins and diversions throughout Mānoa)
C	Mānoa/Pālolo Debris and Detention Basin Measures
D	Mānoa/Pālolo Dry Reservoir and Detention Basin Measures
E	Lower Makiki, Mōʻiliʻili, and Waikīkī Detention and Low Levee Measures (including a dry reservoir in Mānoa)
F	Combination of Mānoa and Pālolo Dry Reservoir and Detention Basin Measures with the Lower Makiki, Mōʻiliʻili and Waikīkī Detention and Low Levee Measures
G	Ala Wai Canal Measures (including widening the Canal and building an additional outlet to the ocean through Kapiʻolani Park)

Note:

[a] The preliminary measure groupings were developed at the Re-Scoping Charrette. They initially included a group of ecosystem restoration measures, as ecosystem restoration was still a project objective at this time. As previously described, ecosystem restoration was subsequently dropped as an objective, based on which, this group of measures was eliminated from further consideration in the plan formulation process.

Through the course of this effort, additional screening was performed on the management measures, based on further consideration of technical data and best professional judgment. The following summarizes the management measures that were eliminated from further consideration and the rationale for screening; this information is also reflected in Table 3.

- **Woodlawn Ditch Bypass.** This measure would require a large underground diversion structure (8-foot by 8-foot box culvert) to be constructed along Woodlawn Drive from Woodlawn Ditch and entering Mānoa Stream downstream of Woodlawn Bridge. Based on the high implementation cost (including significant real estate requirements), this measure was determined to not be cost effective and was therefore eliminated from further consideration.
- **Additional Outlet for Ala Wai Canal.** The group of measures focused on modifications to the Ala Wai Canal (Group G) was originally conceptualized to include construction of an additional outlet from the Canal to the ocean. However, further analysis identified land availability as a key concern (as the measure would require use of Kapiʻolani Park, which is a heavily used regional park). In addition, long-shore current studies suggest that polluted waters from the Ala Wai Canal would be transported to beaches throughout Waikīkī and could result in impacts to designated Federal and State marine protected areas, favored surfing spots, and coral reef areas. As such, the measure was eliminated from further consideration.
- **Widening Ala Wai Canal:** The group of measures focused on the Ala Wai Canal also originally included widening of the Canal. Further analysis indicated that this measure would involve extremely high implementation costs. In particular, a significant amount of land acquisition would be required, presenting concerns with land availability and overall real estate cost (due to both the large number of properties, as well as the real estate values in the Waikīkī District). This measure would also require major modification of the Canal, which is listed as a historic property on the Hawai'i Register of Historic Places.

The resulting alternatives, and the primary focus of each is listed below:

- **Alternative 1 (Mānoa Dam):** This alternative was formulated to maximize attenuation of water in the upper Mānoa watershed, where the majority of peak flows are generated.
- **Alternative 2 (Multiple Debris and Detention Basins in Developed Portion of Watershed):** This alternative was formulated to maximize attenuation of water through multi-purpose detention basins within open spaces in the currently developed portions of the watershed.

- **Alternative 3 (Multiple Debris and Detention Basins in Upper Watershed):** This alternative was formulated to modify the location and dimension of measures in Alternatives 1 and 2, with debris and detention basins in the upper watershed to address concerns related to construction of a single, large dam and use of park space.
- **Alternative 4 (Ala Wai Focus):** This alternative was formulated to maximize structural solutions where the majority of the benefits occur (i.e., along the Ala Wai Canal).
- **Alternative 5 (Non-Structural):** This alternative was formulated based on all of the non-structural measures that were initially identified, including raising or waterproofing (and in some cases, installing ring levees or non-structural berms) for approximately 340 structures within the watershed.

In general, each alternative was formulated to address existing flood risk throughout the watershed, while maintaining focus on the original strategy for each alternative. In addition, debris catchment was incorporated into the upper reaches of Mānoa and Pālolo streams (either as a stand-alone measure, or as part of a detention basin), in order to address known debris-related problems. Where economically feasible, opportunities to reduce flood damages through non-structural measures were included as part of the four structural alternatives. In particular, improvements to the existing flood warning system were included in all of the alternatives. The measures that were included in each alternative in the initial array, and the general location of each measure (based on the reaches defined in Section 3.6.1), are listed in Table 5.

The initial array of alternatives was then screened by the PDT using the screening criteria described in Section 3.2. Based on the principles of SMART planning, the screening process relied on existing information from previous studies (e.g., Mānoa Technical Report and Ala Wai PAS Study), as well as best professional judgment. The results of this process confirmed that all five alternatives in the initial array were suitable to carry forward for further refinement and consideration as part of the plan formulation process.

Table 5. Initial Array of Alternative Plans

Sub-watershed	Measure	Stream Reach	Location	Alternative				
				1	2	3	4	5
Mānoa	Dry dam	MAN8	Upper watershed	●				
	Debris and detention basin	MAN8	Waihi Stream			●	●	
	Debris catchment	MAN8	Waihi Stream		●			
	Debris and detention basin	MAN8	Waiakeakua Stream			●	●	
	Debris catchment	MAN8	Waiakeakua Stream		●			
	Detention basin	MAN6a	Below Woodlawn Cemetery		●	●		
	Debris catchment	MAN6a	Po`elua Place	●	●	●		
	Multi-purpose detention basin	MAN4	Mānoa District Park		●			
	Debris catchment	MAN3	Innovation Center		●	●		
	Multi-purpose detention basin	MAN2	Noelani School		●			
	Multi-purpose detention basin	MAN1a/1b	UH Athletic Field		●			
	Non-structural (e.g., floodproofing)[a]	MAN 1-6, MPC1/2	Various structures	●	●	●	●	●
Pālolo	Debris and detention basin	WAI2	Waiʻōmaʻo Stream			●		
	Debris catchment	WAI2	Waiʻōmaʻo Stream	●	●		●	
	Debris and detention basin	PUK2	Pūkele Stream			●		
	Debris catchment	PUK2	Pūkele Stream	●	●		●	
	Floodwalls	PAL4	Pālolo Stream	●			●	
	Floodwalls (right bank)	MPC1	Just before Ala Wai Canal	●			●	
	Non-structural (e.g., floodproofing)[a]	PAL3/4	Various structures	●	●	●	●	●
Makiki	Debris and detention basin	KAH2	Roosevelt High School		●	●		
	Detention basin	MAK5	Old BWS Site		●	●		
	Floodwalls	MAK1a	Adjacent to Jack-In-The-Box	●			●	
	Non-structural (e.g., floodproofing)[a]	MAK 1-4, KAH1, KAO1	Various structures	●	●	●	●	●
Ala Wai	Low floodwalls (<6 feet)	ALA1, ALA2, ALA3	Both sides of canal		●	●		
	Floodwalls (>6 feet)	ALA1, ALA2, ALA3	Both sides of canal				●	
	Detention/pump system	HAU1	Hausten Ditch				●	
	Multi-purpose detention basin	ALA3	Golf course		●	●		
	McCully Bridge modifications	ALA2	McCully Bridge	●			●	
	Non-structural (e.g., floodproofing)[a]	ALA2, ALA3	Various structures	●	●	●	●	●
All	Flood warning system	Not applicable (N/A)	Throughout watershed	●	●	●	●	●

Note:
[a] All of the identified non-structural measures were included in Alternative 5; select non-structural measures were added to each structural alternative, where economically justified.

3.7 Iteration 2 - Viable Array of Alternative Plans

To further refine the alternatives, a variety of technical analyses were conducted. This effort incorporated additional water surface elevation modeling and a more detailed siting process, with an overall focus on maximizing completeness, effectiveness, efficiency, and acceptability. Based upon the results of these analyses, the PDT reformulated the alternatives; an "A" was added to each alternative name to reflect these refinements. In addition, mitigation requirements for environmental impacts were estimated and considered as part of the screening process. These efforts are further described in the following subsections; the resulting changes to each alternative as part of the reformulation process from the Initial Array to the Viable Array are summarized in Table 6.

3.7.1 Technical Analysis and Refinement

Structural Measures

To supplement the additional water surface elevation modeling, a multi-disciplinary site visit was conducted in July 2013.[13] The purpose of the site visit was to validate assumptions regarding site-specific conditions, and refine the conceptual design and engineering information for the suite of measures. Particular attention was paid to constructability, construction and maintenance access, and potential impacts to sensitive biological and cultural resources. The PDT used both the modeling results and the site visit observations to reformulate each alternative, with measures added/removed based on the extent of their contribution to potential flood risk reduction. Measure locations were modified as needed to improve efficiency and effectiveness. Key outcomes of the technical analyses and reformulation process are as follows:

- It was originally assumed that the peak flows in the watershed primarily originate in the upper-most reaches of Mānoa. However, the hydrologic analysis indicated that the volume is also high in the mid-Mānoa watershed. Thus concentrating attenuation in just the upper Mānoa watershed does not provide as much protection as originally assumed. As such, it was determined that low floodwalls were needed along the Ala Wai Canal as part of Alternative 1 to address flooding in Waikīkī (additional detention capacity within the urbanized watershed did not adequately address flooding in Waikīkī).
- The measure at Po'elua Place was designed to include both the intake for the Mānoa District Park detention basin and a debris catchment feature. For those alternatives that do not include the Mānoa District Park detention basin, the debris catchment was moved from Po'elua Place downstream adjacent to the park, thus eliminating the need to acquire privately-owned real estate (Alternatives 1 and 3).
- Based on the design inflow (950 ft^3/s), it was determined that the Noelani underground detention basin would be full in less than five minutes (based on a 1-percent ACE flood), and thus would have minimal impact on reducing flood peaks. Given the high land and construction costs ($25.6 million and $9.3 million, for the detention basin and associated bypass structure), this measure was determined to not be cost effective and was eliminated from further consideration (Alternative 2).
- The detention basin that was originally sited at the UH Athletic Field was switched to nearby Kanewai Field, because it was determined to be more cost effective (Alternative 2). Specifically, the Kanewai Field detention basin has a larger capacity, and does not require the use of pumps.
- Based on the site visit, several of the debris and detention basins were re-sited to better accommodate construction and maintenance access requirements and to minimize potential environmental and cultural impacts. Specifically, the detention basin at the old Board of Water Supply dam (Makiki) and the debris and detention basin measures on Pūkele and Waiʻōmaʻo streams (Pālolo) were originally sited in far upstream reaches; however, these areas were found to have steep topography (which inhibited access) and a high potential for sensitive natural and cultural resources. As such, the measures were re-sited to more suitable locations, generally still in the upper reaches but far enough downstream to address the identified concerns.
- Based on observations made during the site visit, the Pālolo Stream floodwalls were eliminated from further consideration (Alternatives 1 and 4); specific issues include insufficient space for construction

[13] The site visit was conducted on July 30 through August 1, 2013 and included the following participants: USACE, DLNR (Engineering and DOFAW), City & County of Honolulu (ENV, DDC), and USFWS.

access, extensive private property requirements for construction easements, and high construction costs. Given the existing constraints, the addition of detention basins in the upper watershed was determined to be the only viable structural solution that would address flood risk in Pālolo.

- The proposed floodwalls along Makiki Stream were determined to be technically impracticable as they would have to be 16 feet high to adequately contain 1-percent ACE flows (Alternatives 1 and 4). Similar to Pālolo Stream, the addition of detention basins was determined to be the only viable structural solution that would address flood risk in Makiki. However, even with the addition of detention basins, there are sizable portions of Makiki in which flooding would still occur that cannot be addressed by the project, given the existing constraints.
- Alternatives 1 and 4 initially included modification of McCully Bridge, as needed to increase conveyance of floodwaters through the Ala Wai Canal; various modifications (including bridge replacement) were considered and analyzed. The cost of bridge modification was determined to be excessive; in addition, there would be significant impacts to historic properties and traffic. Modeling results showed that upstream detention could replace the need for bridge modifications, and would also allow for lower floodwall heights. As upstream detention was determined to be a more cost-effective and acceptable approach, the bridge modification measure was eliminated from further consideration.
- With the addition of floodwalls along the Ala Wai Canal, it was determined that drainage from Hausten Ditch needed to be addressed. A detention basin and a pump system were both considered; a detention basin (with sluice gates) was found to be more cost effective (in large part because of the high O&M costs for the pump system), so was incorporated into the viable array of alternatives.

Non-Structural Measures

Additional analysis of the non-structural measures was conducted using the updated hydrologic modeling results to further assess the potential benefits and costs; in particular, this effort placed more emphasis on the recurring frequency of damages and resulting larger potential flood damage totals. Based on this analysis, many of the structures were found to be much larger and more expensive to protect than what was initially assumed. As a result, the initial list of 340 structures that were considered as candidates for inclusion in the non-structural alternative was narrowed to a list of between 100 and 125 structures (as further described in Appendix B).

Environmentally Sustainable Design Considerations (Avoidance and Minimization of Impacts)

Guidance in ER 1105-2-404 specifies that the plan formulation process should (where practical and supportable) incorporate efforts to avoid or minimize significant adverse impacts within the guiding principle of limiting damage to the natural ecosystem. Compensatory mitigation should only be considered after these principles have been considered. In the spirit of this requirement, the conceptual designs were reviewed for opportunities to avoid and minimize impacts and otherwise incorporate environmentally sustainable design features. This effort considered site-specific information regarding ecosystem-related problems and opportunities generated during previous phases of the project, including those related to in-stream habitat and migratory pathways for native aquatic species, erosion and sedimentation, and riparian habitat (USACE, 2011). Specific approaches that were incorporated into the conceptual designs include the following:

- Flood risk management structures were designed to have the smallest footprint possible, while still meeting engineering and structural requirements for providing adequate flood control.
- In-stream detention basins were sited to take advantage of the natural topography, such that existing topographic features were used to form the detention basin to the extent possible, thus minimizing the extent of grading.
- Specific to Waiʻōmaʻo debris and detention basin, which requires excavation for the detention basin, the low-flow channel and existing substrate would be replaced within the excavated basin following construction, to minimize potential habitat impacts.

- The in-stream detention basins use natural-bottom arch culverts where feasible (as opposed to standard box or circular culvert) to minimize habitat loss and maintain in-stream passage for native aquatic species.
- All measures were designed to maintain a suitable grade for migration of native species. In particular, the designs avoid any features that could result in free-falling water (e.g., through the formation of an overhanging lip/culvert), which would eliminate passage of native species.
- The in-stream detention basins incorporate energy dissipation features, as needed, to maintain channel form and minimize the potential for erosion and sedimentation.

Compensatory Mitigation for Impacts to Biological Resources

The USACE Planning Guidance Notebook (ER 1105-2-100) requires demonstration that "damages to significant ecological resources have been avoided or minimized to the extent practicable; that unavoidable damages to these resources have been compensated to the extent justified; and, that restoration opportunities for significant ecological resources have been given appropriate consideration." The regulations further specify that mitigation requirements should be considered as an integral component of each alternative plan. Based on these requirements, and after consideration of the avoidance and minimization measures described above, the PDT determined that compensatory mitigation would be required for unavoidable impacts to biological resources. In particular, impacts to the aquatic environment are anticipated in order to achieve the project objective of reducing flood risk.

Table 6. Refinements from the Initial Array to the Viable Array of Alternatives

Sub-watershed	Measure	Stream Reach	Location	Alternative										Summary of Changes from Initial Array to Viable Array for Each Alternative
				1	1A	2	2A	3	3A	4	4A	5	5A	
Mānoa	Dry dam	MAN8	Waihi/Waiakeakua Streams	•	•									No substantial changes
	Debris and detention basin	MAN8	Waihi Stream					•	•	•	•			No substantial changes
	Debris catchment	MAN8	Waihi Stream			•	•							No substantial changes
	Debris and detention basin	MAN8	Waiakeakua Stream					•	•	•	•			No substantial changes
	Debris catchment	MAN8	Waiakeakua Stream			•	•							No substantial changes
	Detention basin	MAN6a	Below Woodlawn Cemetery			•	•	•	•					No substantial changes
	Debris catchment	MAN6a	Po`elua Place	•		•	•	•						Location changed for Alternative (Alt.) 1 and 3 (based on cost effectiveness); Po'elua Place still proposed for Alt. 2, as part of the intake for the Mānoa District Park Detention Basin.
	Debris catchment	MAN5	Mānoa District Park		•				•					
	Multi-purpose detention basin	MAN4	Mānoa District Park			•	•							No substantial changes
	Debris catchment	MAN3	Innovation Center			•	•	•	•					No substantial changes
	Multi-purpose detention basin	MAN2	Noelani School			•								Eliminated from further consideration as measure would not be cost effective (fills with water in less than 5 minutes).
	Multi-purpose detention basin	MAN1a/1b	UH Athletic Field			•								Measure location changed from UH Athletic Field to Kanewai Field as this location is more cost effective (does not require pumps).
	Multi-purpose detention basin	MAN1a/1b	Kanewai Field				•							
	Floodproofing[a]	MAN1/4/5, MPC2	Various structures	•	•	•	•	•	•	•	•	•	•	Refined to include approx. 50 structures with potential for floodproofing.
Pālolo	Debris and detention basin	WAI2	Wai'ōma'o Stream		•			•	•		•			Detention added for Alt. 1 and 4 (in place of floodwalls and bridge modification along Ala Wai Canal). Locations modified to address access requirements and minimize potential environmental/ cultural impacts.
	Debris catchment	WAI2	Wai'ōma'o Stream	•		•	•			•				
	Debris and detention basin	PUK2	Pūkele Stream		•			•	•		•			
	Debris catchment	PUK2	Pūkele Stream	•		•	•			•				
	Floodwalls	PAL4	Pālolo Stream	•						•				Eliminated from further consideration as there is insufficient construction access; detention basins added in its place.
	Floodwalls (right bank)	MPC1	Just before Ala Wai Canal	•	•		•			•	•			Floodwall added to Alt. 2 to eliminate flooding at 'Iolani School.
	Floodproofing[a]	PAL3-4	Various structures	•	•	•	•	•	•	•	•	•	•	Refined to include approx. 20 structures with potential for floodproofing.

Table 6. Refinements from the Initial Array to the Viable Array of Alternatives

Sub-watershed	Measure	Stream Reach	Location	Alternative										Summary of Changes from Initial Array to Viable Array for Each Alternative
				1	1A	2	2A	3	3A	4	4A	5	5A	
Makiki	Debris and detention basin	KAH2	Roosevelt High School		•	•	•	•	•		•			Localized modification of measure location to maximize cost-effectiveness.
	Detention basin	MAK5	Old BWS Site			•		•						Location modified to address access requirements and minimize potential environmental/cultural impacts.
	Debris and detention basin	MAK4	Above BWS Pump Station				•		•					
	Floodwalls	MAK1a	Adjacent to Jack-In-The-Box	•						•				Eliminated from further consideration as modeling indicated floodwalls would need to be 16 feet high; detention basin added its place.
	Floodproofing[a]	MAK2, KAH1, KAO1	Various structures	•	•	•	•	•	•	•	•	•	•	Refined to include approx. 40 structures with potential for floodproofing.
Ala Wai	Low floodwalls (<6 feet)	ALA1/2/3	Both sides of canal		•	•	•	•	•		•			Floodwalls added to Alt. 1 as attenuation in upper Mānoa watershed does not provide adequate protection.
	Floodwalls (>6 feet)	ALA1/2/3	Both sides of canal							•				No substantial changes
	Detention/pump system	HAU1	Hausten Ditch		•		•		•	•	•			Measure added to accommodate drainage from Hausten Ditch; detention feature was found to be more cost effective than pump system (less O&M).
	Multi-purpose detention basin	ALA3	Golf course			•	•	•	•					No substantial changes
	McCully Bridge modifications	ALA2	McCully Bridge	•						•				Eliminated from further consideration based on excessive cost and significant impacts to traffic and historic properties; replaced with detention on upstream reaches.
	Floodproofing[a]	ALA2, ALA3	Various structures	•	•	•	•	•	•	•	•	•	•	Refined to include approx. 15 structures with potential for floodproofing.
Non-structural	Flood warning system	N/A	Throughout watershed	•	•	•	•	•	•	•	•	•	•	No substantial changes

Note:
[a] All of the identified non-structural measures were included in Alternative 5; select non-structural measures were added to each structural alternative, where economically justified.

The USACE planning process requires that the mitigation for the recommended plan be based on functional habitat loss and quantified using a habitat-based methodology (i.e., ecosystem output model). However, recognizing the need to consider mitigation as part of each alternative plan for purposes of plan formulation (with associated costs included as part of the total project cost), a preliminary estimate of the potential mitigation requirement was developed for each alternative plan (with the understanding that the mitigation requirements would be refined for the recommended plan; see Section 3.10). To identify the preliminary mitigation estimates, the approximate extent of impacts to aquatic habitat and adjacent forested upland habitat was determined based on conceptual engineering and design information, and a proxy cost was developed for mitigation based on publically available information for similar projects. The resulting estimates were included as part of the implementation costs, which are summarized as part of the screening results (see Table 7).

Mitigation for Impacts to Cultural Resources

Similar to the considerations for environmental mitigation, it was determined that there could be substantial requirements for addressing potential impacts to archaeological, historical, and cultural resources, and that these should also be accounted for as part of the screening-level costs. Based on the understanding that the specific impacts to these resources were not yet defined, the approach to estimating screening-level costs was based on identifying areas with a high potential for impact. The potential occurrence of archaeological, historical and cultural resources was assessed based on a review of previous archaeological studies and a site reconnaissance survey, as summarized in the *Cultural Resources and Ethnographic Study for the Ala Wai Watershed* (Cultural Surveys Hawai'i, 2010); this information was also supplemented by observations made by the team during the multi-disciplinary site visit. For those areas with known archaeological, historical and cultural resources (or a high likelihood that these resources could occur), screening-level costs were assigned based on the estimated extent of ground disturbance in that area (using a proxy cost per acre). The screening-level costs are intended to capture the range of activities that may be required to mitigate potential archaeological, historical and cultural resource impacts through the design and construction phases, including (but not limited to) additional resource evaluation, archaeological monitoring and data recovery.

3.7.2 Screening of the Viable Array

Based on the reformulation and refinements described above, the PDT reviewed each alternative within the context of the plan formulation strategy and overall planning objectives. This evaluation resulted in two key findings:

- Alternatives 1A and 3A are similar in that they both focus on attenuation of water in the upper watershed: Alternative 1A through a single, large dam and Alternative 3 through several smaller detention basins. Other measures originally in Alternative 1A include floodwalls along Pālolo and Makiki streams, as well as modification of McCully Bridge. However, as detailed in Section 3.6, these measures were all subsequently screened out and replaced with detention (consistent with the measures included in Alternative 3A). Based on the modeling of peak flows, both alternatives also require floodwalls along the Ala Wai Canal to provide adequate protection in the Waikīkī area. As such, the main distinction between Alternatives 1A and 3A is the use of a single, large dam versus multiple, smaller detention basins. Analysis of these measures indicates that the smaller detention basins outperform the single, large dam (i.e., substantially less cost for similar level of protection), with less transfer of risk to the downstream community. Efficiency of the single, large dam is limited by siting constraints, as the areas with sufficient open space for a dam have smaller drainage areas; siting the dam further downstream would increase the drainage area (thus increasing its efficiency), but would displace a substantial number of residential properties. As Alternative 1A would impact significantly more area within the upper watershed, it is also expected to result in a higher degree of impact to biological and cultural resources, thus a greater mitigation burden than Alternative 3A.
- Alternative 4A was originally conceptualized to focus on measures in the lower watershed, as part of the strategy to maximize solutions where the majority of the damages occur. However, as described in

Section 3.6.4.1, these measures were subsequently screened from further consideration, with upstream detention found to be a more cost-effective and acceptable approach to addressing the existing flood-related problems. By replacing the measures in the lower watershed with detention, it was determined that Alternative 4A would essentially duplicate the strategy assumed for Alternative 3A, and would thus be too similar to allow for adequate comparison and differentiation.

After confirming that neither Alternative 1A nor Alternative 4A would represent the NED plan (based on the conceptual costs and benefits, as further discussed in Appendix B), the PDT eliminated both from further consideration according to the rationale described above. Additional screening was then performed on the remaining three alternatives (Alternatives 2A, 3A, and 5A), as needed to define the final array of alternatives. This process utilized the same set of screening criteria as previously described, with further refinement of the metrics. The results of the screening are presented in Table 7.

Consistent with principles of the SMART planning process, screening was based on existing information generated for the Mānoa Watershed Study and Ala Wai PAS Study, with additional concept-level information developed as needed. For those measures identified in the Mānoa Watershed Study (primarily those in Mānoa), the existing design information, cost estimates, and real estate requirements were used. For those measures identified in the Ala Wai PAS Study (USACE, 2001), the existing design information was used, based upon which concept-level costs and real estate requirements were developed. For newly-identified measures (primarily those in Makiki and Pālolo), new concept-level design information, cost estimates and real estate requirements were developed. Based on this information and the water surface elevations from the HEC-RAS model, economic benefits were estimated using the HEC-FDA model.

Analysis of this information resulted in elimination of Alternative 5A, as it would provide very low net benefits and would be ineffective at improving life safety. As the focus of non-structural solutions is on modification of existing development in the floodplain, purely non-structural plans are often not efficient or effective in highly urbanized environments. Specifically, Alternative 5A does little to address the overall flooding problem throughout the watershed and results in high levels of residual flooding (more than 94 percent of the total expected annual damages). Relatively few properties incur enough flood damage to economically justify individual non-structural solutions (e.g., flood proofing or elevating the structure), thus the total benefits of this alternative are relatively small (which translates to few, if any, net benefits). Although the stand-alone non-structural alternative was eliminated, selective non-structural measures were still considered as part of other alternatives, where economically justifiable.

3.8 Iteration 3 - Final Array of Alternative Plans

Based on screening of the viable array, two alternatives were carried forward as part of the final array: Alternative 2A and Alternative 3A. As further described in the following subsections, each of the measures in these alternatives were further refined to provide an adequate basis for evaluation and comparison. The conceptual design information for each measure is summarized in Table 8; the location of the measures in Alternative 2A and 3A are shown in Figures 7 and 8, respectively.

3.8.1 Refinement and Analysis of Final Array

The design and engineering information for each of the alternatives was developed to a 10% level of design, building on the existing design concepts. Updates to the HEC-RAS model were performed, as needed to support the design development process. Key refinements that were incorporated as part of this effort are listed below.

- The Hausten Ditch detention basin was modified to accommodate trailer access for the adjacent canoe clubs.
- A floodgate was added at the entrance to the Ala Wai Golf Course to accommodate incoming and outgoing traffic. The floodgate consists of a passive structure that would rise and fall with water levels within the canal. This is intended to be a completely autonomous operation and will not require manual operation during flood events.

- Staging and access requirements were identified and incorporated into the designs for all measures.
- Different possible floodwall configurations were identified to account for historic property constraints and the possibility that the floodwalls cannot be built on top of the existing walls (due to insufficient structural integrity).
- A total of two pump stations were incorporated into the Ala Wai Canal floodwall system to prevent flooding behind the floodwalls from interior drainage.
- Gates were added to the existing drainage pipes into the Ala Wai Canal to prevent floodwaters from flowing back up the pipes and flooding behind the floodwalls.

Table 7. Screening of the Viable Array of Alternatives (10% Design, 2013 Price Level)

Criteria	Metric	Alternative		
		2A	3A	5A
Technical feasibility	N/A (already established as part of previous screening)			
Implementation Cost	Total Project Cost (at less than 10% level of detail), including Planning Engineering and Design (PED), Supervision & Administration (S&A), environmental, and real estate	$272,885,153	$223,917,299	$78,691,000
Interest During Construction (IDC)	Calculated from rough order of magnitude (ROM) costs	$11,919,000	$8,858,000	$2,791,000
O&M Costs	Rough order of magnitude (ROM) cost of O&M requirements	$1,881,500	$771,500	$50,000
Cost-effectiveness	Screening-level benefit cost ratio (BCR) and net benefits (eliminate alternative if BCR <1.0)	1.77 $10.8 million	3.04 $21.5 million	2.81 $6.3 million
Availability of Land	N/A (already established as part of previous screening)			
Acceptability – Public Sentiment	Qualitative assessment on stakeholder and/or sponsor concerns (based on previous stakeholder engagement efforts and sponsor input)	Use of park space; use of golf course; infiltration and ground movement near Woodlawn Cemetery	Use of upper watershed and golf course; O&M requirements; infiltration/ ground movement near Woodlawn Cemetery	None identified
Acceptability - Legal	Qualitative assessment of conflicts with study authority or applicable laws, regulations and policies	None identified	None identified	None identified
Compatibility/ dependency	N/A (already established as part of previous screening)			
Social Fairness	Qualitative assessment of whether neighborhoods receive same level of protection (based on estimated benefits); number of measures per neighborhood	Medium (flood protection); high number of measures	High (flood protection); medium number of measures	Low (flood protection); low number of measures
Flood Damage Reduction	Flood damage reduction benefits (based on preliminary HEC-RAS/HEC-FDA model runs)	$24.8 million	$32.3 million	$9.8 million
Reduction in Life Safety Risks	Approximate number of persons impacted by reduced flooding	100,000	200,000	6,000
Community Resilience	Qualitative assessment based on reduction of flood impacts to streets, parks, critical infrastructure and commercial buildings	Medium	High	Low
Environmental Impacts	Degree of impact and potential mitigation requirements	Medium (400 linear feet of stream impacts plus 600-foot-long culvert along Mānoa Stream, 3.2 acres of upland impacts)	Medium (950 linear feet of stream impacts, 8.0 acres of upland impacts)	Low (assumes no mitigation)
Cultural impacts	Degree of impact and potential mitigation requirements	Medium (assumes mitigation for 27.2 acres; could include burials)	Medium (assumes mitigation for 20.7 acres; could include burials)	Low (assumes no mitigation)

Additional detail on these refinements, and the resulting 10% level of designs for Alternatives 2A and 3A are provided in Appendix A.

Non-Structural Components

Additional analysis of potential non-structural components was conducted to identify those that are practicable and economically justified, such that they should be included as part of the alternatives in the final array. An iterative process was used to evaluate the economic justification of non-structural measures, with an increasing level of detail as needed to identify individual measures that would strengthen the alternatives in the final array. The results of this analysis indicate that none of the non-structural measures would add net benefits to any of the alternatives, and therefore, it is not economically justifiable to protect individual structures through non-structural measures. The structural solutions in the final array of alternatives alleviate the most frequent and problematic flooding, such that they capture the majority of the benefits; the residual damages are insufficient to offset the incremental cost of including any non-structural measures. Additional detail regarding the evaluation of non-structural measures is provided in Section 4.2.2 of the Economic Analysis (Appendix B).

Table 8. Final Array of Alternatives

Measure	Alt.		Brief Description of Measure
	2A	3A	
MĀNOA			
Waihi debris and detention basin		•	Earthen berm, approximately 24 feet high and 225 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with rip-rap on upstream and downstream side
Waihi debris catchment	•		Concrete pad, approximately 8 feet wide and 140 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad
Waiakeakua debris and detention basin		•	Earthen berm, approximately 20 feet high and 185 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with rip-rap on upstream and downstream side
Waiakeakua debris catchment	•		Concrete pad, approximately 8 feet wide and 140 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad
Woodlawn Ditch detention basin	•	•	Three-sided berm, approximately 15 feet high and 840 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with rip-rap on upstream and downstream side
Po'elua debris catchment	•		Basin with small berm and debris catcher to capture debris on east side of stream; grate with inlet to culvert for delivery of water to Mānoa District Park detention basin; requires acquisition of residential lot
Mānoa in-stream debris catchment		•	Concrete pad, approximately 8 feet wide and 60 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad
Mānoa District Park multi-purpose detention basin	•		Earthen berm (approximately 13 feet high) around 3 sides of Mānoa District Park; 600-foot-long culvert from Poelua Place to detention basin; concrete spillway with rip-rap; drain pipe to release water back to stream
Innovation Center Improvements	•	•	Acquisition of residential property; lower grade to allow high flows across site; debris catchment structures installed along edge to catch debris as flows re-enters stream
Kanewai Field multi-purpose detention basin	•		Earthen berm (approximately 7 feet high) around 3 sides of field; inflow spillway on northwest end that allows high flows to enter basin; existing drainage pipe at south end to allow water to re-enter stream
PĀLOLO			
Waiʻōmaʻo debris and detention basin		•	Earthen berm, approximately 24 feet high and 120 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with rip-rap on upstream and downstream side; excavation of approximately 2,000 cubic yards (yd^3) to provide required detention volume
Waiʻōmaʻo debris catchment	•		Concrete pad, approximately 8 feet wide and 50 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad
Pūkele debris and detention basin		•	Earthen berm, approximately 24 feet high and 120 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with rip-rap on upstream and downstream side
Pūkele debris catchment	•		Concrete pad, approximately 8 feet wide and 25 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad
Mānoa-Pālolo Drainage Canal floodwall	•		Add floodwalls (approximately 9 to 12 feet high) along the right bank of the Canal from the Ala Wai Canal up to Date Street

Table 8. Final Array of Alternatives

Measure	Alt.		Brief Description of Measure
	2A	3A	
MAKIKI			
Roosevelt debris and detention basin	•	•	Earthen berm, approximately 24 feet high and 260 feet across; arch culvert to allow small storm flows to pass; concrete spillway with rip-rap on upstream and downstream side
Makiki debris and detention basin	•	•	Earthen berm, approximately 24 feet high and 100 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with rip-rap on upstream and downstream side
ALA WAI			
Ala Wai Canal floodwalls	•	•	Concrete floodwalls along Ala Wai Canal, on average approximately 4 feet high; two pump stations and gates to address potential flooding on land-side of floodwalls
Hausten Ditch detention basin	•	•	Concrete floodwalls and earthen berm (4.3 feet high) to provide detention for local drainage; install slide gates at existing bridge to control flow of floodwaters between Hausten Ditch and Ala Wai Canal
Ala Wai Golf Course multi-purpose detention basin	•	•	Earthen berm, on average 2.7 feet high around outside perimeter of golf course property, with floodgate across main entrance road; passive drainage back into Ala Wai Canal
ENTIRE WATERSHED			
Floodwarning system	•	•	Installation of 3 real-time rain gages (Mānoa, Makiki, and Pālolo streams) and 1 real-time streamflow or stage gage (Ala Wai Canal) as part of flood warning system for Ala Wai Watershed

Operations and Maintenance Requirements

For each measure included in the final array, the anticipated O&M requirements were refined using the technical information developed for the project to date, an understanding of the requirements for similar features that have been implemented elsewhere, and input received from the non-Federal sponsor. The O&M costs were calculated using construction and engineering information along with the estimated dimensions of each measure. As the non-Federal sponsor would be responsible for fulfilling all O&M requirements, this information was provided for review and input by the non-Federal sponsor. A summary of the O&M requirements for each measure type is summarized in Table 9; the cost estimates for each alternative are summarized as part of the screening results (see above).

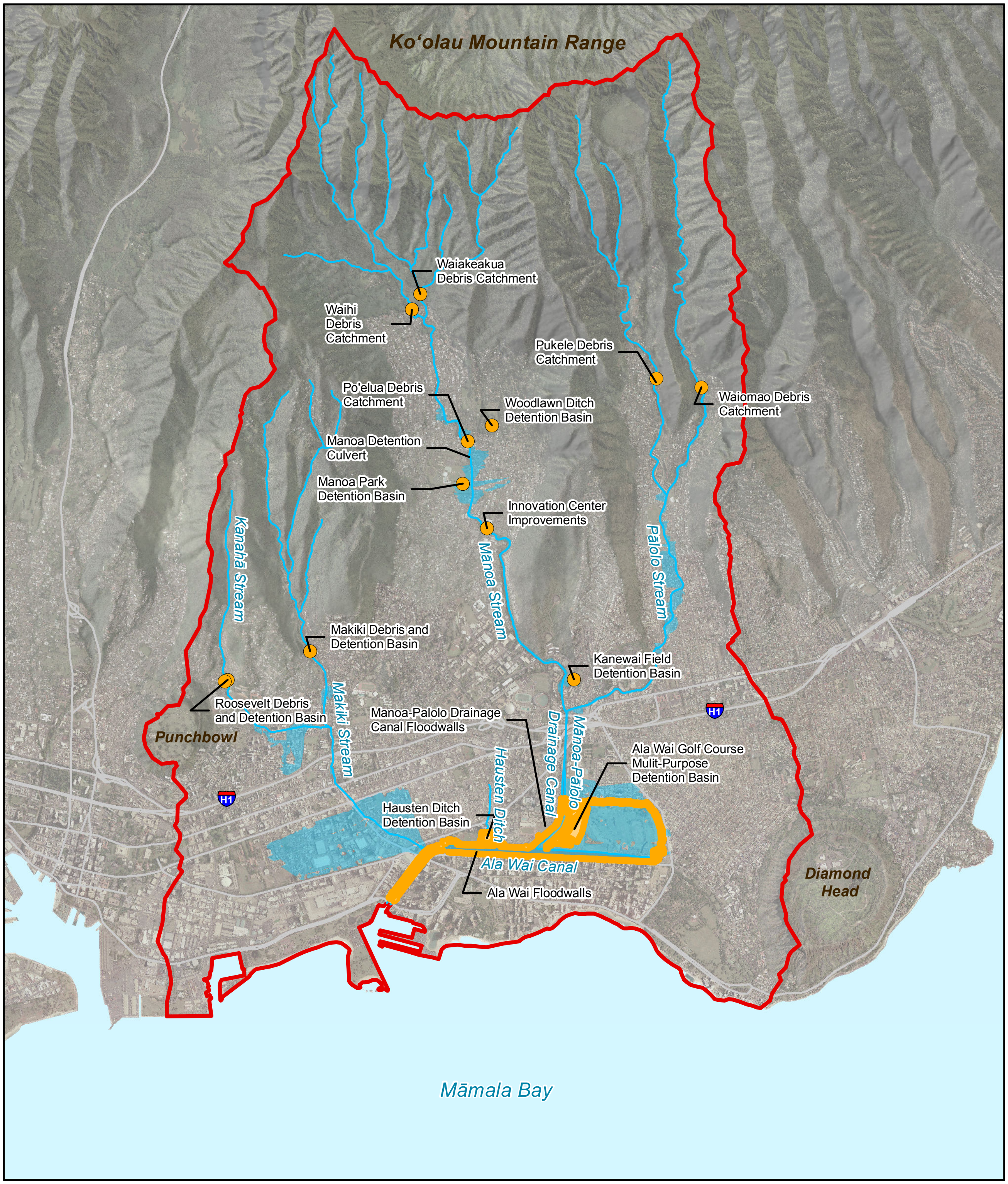
Given that Alternatives 2A and 3A are comprised of similar types of measures, a similar range of O&M activities would be required. However, the total O&M cost is anticipated to be higher for Alternative 2A as the measures included in that alternative require a larger area to be maintained (e.g., cutting/clearing vegetation), which translates to a higher O&M cost.

Table 9. O&M Requirements for Measures in Final Array of Alternatives

Measure Type	Summary of O&M Requirements
Debris and detention basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year; Clear accumulated debris following flood event or annually (whichever is greater)
Multi-purpose detention basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year; Assumes minimal sediment or debris removal would be required
Debris catchment	Clear accumulated debris twice per year
Floodwalls	Inspect and maintain gates (e.g., greased) annually; Inspect, test, and maintain pump system annually; Inspect floodwalls and repair as needed (e.g., patching)
Flood warning system	Inspect and test annually (includes annual operating cost)

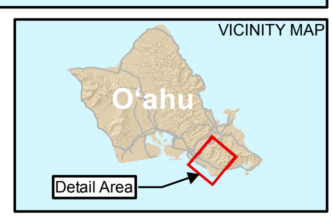
Note:

[1] Debris and sediment cleared from the flood risk management measure locations would be disposed of at an existing authorized facility that is qualified to accept the material.



LEGEND

- Stream
- Major Road
- Watershed Boundary
- 1-Percent Annual Chance Exceedance Floodplain (Alternative 2A)
- Flood Control Measures (Alternative 2A)



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Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

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DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

FIGURE 7
Location of Measures in Alternative 2A
Ala Wai Canal Project
O'ahu, Hawai'i

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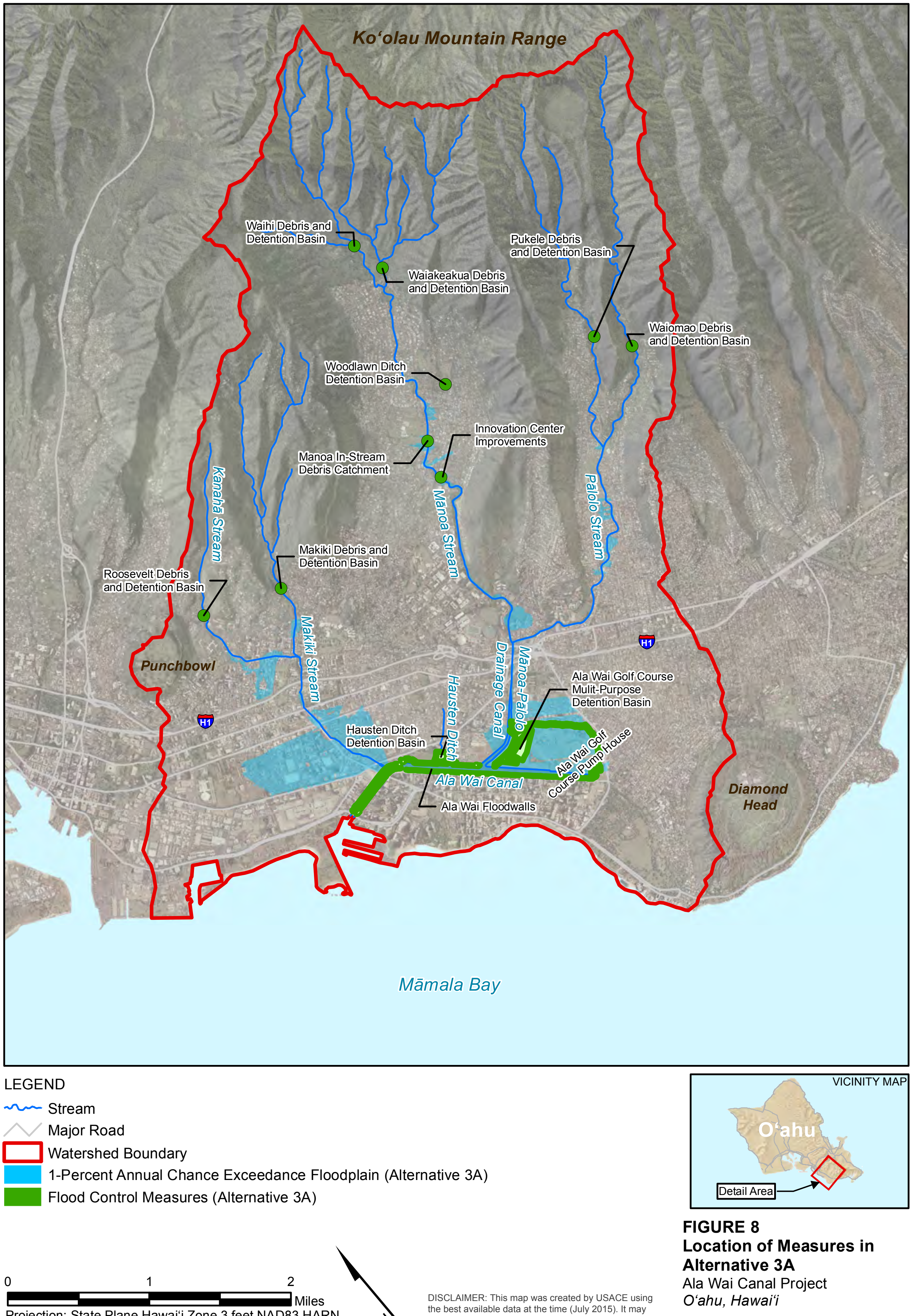

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

FIGURE 8
Location of Measures in Alternative 3A
Ala Wai Canal Project
O'ahu, Hawai'i

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Flood Risk Management and Life Safety

Overall, both alternatives in the final array would significantly reduce flood risk and contribute to life safety within the watershed, with some relatively minor differences. Alternative 2A would reduce the extent of the 1-percent ACE floodplain from approximately 1,358 acres to 494 acres. In general, the water depths within the floodplain would decrease and velocities would slightly decrease (or stay the same), particularly within the adjacent roadways; a summary of the depths and velocities at sample locations throughout the floodplain is provided in Table 10. The portions of the affected population comprised of residents would be significantly reduced from approximately 54,000 to 16,000 people;[14] the approximately 79,000 visitors to the Waikīkī District would also be removed from the affected population. In addition, many of the areas to which students and workers routinely migrate into the watershed (e.g., UH) would no longer be within the 1-percent ACE floodplain. Most of the critical infrastructure within the existing 1-percent ACE floodplain would no longer be subject to flooding; infrastructure remaining in the floodplain would include 2 fire stations (the Makaloa station in Ala Moana and the Wilder station in Makiki), 2 nursing facilities (Hale Nani in Makiki and Mānoa Cottage in Kaimuki), and 2 emergency shelters (Lunalilo Elementary and Washington Intermediate in McCully-Mō'ili'ili).

Alternative 3A would result in approximately the same amount of area taken out of the 1-percent ACE floodplain, with similar depths and velocities of floodwaters as Alternative 2A. The affected population would be slightly higher (an additional 1,300 people), with approximately 2,250 more students within the floodplain during daytime hours (at Hokulani Elementary and Iolani School). Most of the same critical infrastructure would be protected as compared to Alternative 2A, although an additional evacuation shelter would remain in the floodplain (Hokulani Elementary). Management of these residual risks is explored in Section 3.9.3 through the addition of a Manoa-Palolo Drainage Canal floodwall to the selected plan, however, as shown in further sections of this report, the additional infrastructure could not be justified economically. Further, Alternative 3A significantly reduces the magnitude of peak flood stages in affected areas (by approximately two feet), and as a result, the relative depth of flooding in the vicinity of the Manoa-Palolo Drainage Canal is significantly reduced. Further residual risk management for the recommended plan is discussed in Section 8.3 of this report.

Although they would contribute to flood protection, several of the detention basins are located in central areas of the community and are immediately proximate to emergency shelter facilities (in particular, those at Mānoa District Park and Kanewai Field). These could preclude the use of the adjacent shelters during flood events, and could also present some degree of health and safety concerns associated with detention of water in publically accessible areas. As Alternative 2A was formulated to focus on detention within the urbanized watershed, these concerns are more pronounced than for Alternative 3A (which is intended to focus detention in the less publicly accessible areas of the upper watershed); the fundamental difference between the two alternatives is based on the use of Mānoa District Park.

[14] The affected population was approximated using the percentage of each individual census block that falls within the 1-percent ACE floodplain multiplied by the population of that census block.

Table 10. Depth and Velocities at Select Locations for the Final Array of Alternatives

Location[a]		Overbank	Existing Without-Project		Alternative 2A		Alternative 3A	
			Depth (ft)	Velocity (ft/sec)	Depth (ft)[b]	Velocity (ft/sec)	Depth (ft)[b]	Velocity (ft/sec)
MAKIKI	Makiki St (at Nehoa St)	Left	7.0	0.6	2.4	0.6	2.4	0.6
	Moku Pl (at Keeaumoku)	Left	7.0	0.0	5.6	0.0	5.6	0.0
	Wilder Ave (at Kewalo St)	Channel	2.5	2.8	1.7	2.0	1.7	2.0
	Punahou St (at Philip St)	Left	1.5	1.4	0.2	1.5	0.2	1.5
	Kalakaua Ave (at Makaloa St)	Right	4.0	0.1	3.6	0.1	3.6	0.1
MĀNOA	Pakanu Place	Left	1.0	0.6	1.0	0.6	-	-
	Poelua Street	Right	4.0	1.2	4.0	1.2	-	-
	Kinohou Place	Left	3.5	0.6	3.5	0.6	-	-
	East Mānoa Road (at Mānoa District Park)	Left	2.0	1.3	0.5	1.3	-	-
	Lowrey Avenue	Right	4.0	0.9	1.0	1.0	-	-
	Woodlawn Drive	Left	2.0	1.1	-	-	-	-
	Kalawao Street	Left	1.0	0.7	-	-	-	-
	UH Split (near East-West Road)	Channel	1.0	1.2	-	-	-	-
	Stan Sheriff Center (UH)	Channel	1.0	0.4	-	-	-	-
	Kanewai Field	Left	6.0	1.1	-	-	5.7	0.8
PĀLOLO	Ahe Street (Waiʻōmaʻo)	Left	2.0	1.1	2.0	1.1	-	-
	10th Avenue (Pūkele)	Left	1.0	1.2	1.0	1.2	-	-
	9th Avenue (near Pālolo Valley District Park)	Left	0.9	1.4	0.9	1.4	-	-
	Mahana Street	Right	7.0	1.2	7.0	1.2	6.7	0.7
	Kekona Place (at Pālolo Avenue)	Left	3.5	1.4	3.5	1.4	-	-
	Below Kekona Place	Left	4.0	1.5	4.0	1.5	-	-
	Waialae Ave (at Kapiʻolani Boulevard)	Left	2.0	1.1	2.0	1.1	-	-
	Lukepane Ave and Winam Ave (Lower Pālolo)	Left	7.0	0.0	1.0	0.6	2.2	0.8
	Kapiʻolani (at Kamoku)	Right	3.0	1.1	2.8	0.3	-	-
ALA WAI	Ala Wai Boulevard (at Liliuokalani Ave)	Left	3.0	0.1	-	-	-	-
	Kapiʻolani (at University)	Right	3.0	1.0	-	-	-	-
	Kalakaua (at Kalaimoku)	Left	2.0	0.8	-	-	-	-

NOTES:

[a] Locations selected by USACE engineers based on representative sites within the existing 1-percent ACE floodplain; depths and velocities are estimated based on HEC-RAS modeling.

[b] "-" indicates site is no longer within 1-percent ACE floodplain. It is important to notes that there may still be localized flooding in these locations (e.g., due to internal drainage issues, inadequate storm drain capacity, etc.).

Estimated Costs and Benefits

To further evaluate the differences between Alternatives 2A and 3A, the preliminary estimates of cost and benefit were refined. Costs were developed based on the 10% level of design plans (at a Class 4 estimate level), with contingencies identified according to a cost risk analysis. Economic benefits were refined based on additional HEC-FDA modeling. The results are summarized in Table 11; further detail regarding the cost estimates and economic benefits for the final array are presented in Appendices D and B, respectively.

Table 11. Refined Cost and Benefit Estimates for the Final Array of Alternatives ($000)

	Alternative 2A	Alternative 3A
Estimated Cost (October 2013 price level)[a]	$221,231	$178,096
Estimated Average Annual Cost (3.5% for 50 years)[a,b]	$11,097	$8,923
Total Annual Benefits	$24,814	$32,272
Annual Net Benefits	13,717	23,349
BCR	2.24	3.62

Notes:
[a] The price level is based on the preparation date of the cost estimate.
[b] Estimated Average Annual Cost accounts for Interest During Construction and O&M requirements.

Residual Damages

Residual damages are those remaining after implementation of a plan, and can be measured in terms of the difference in expected annual damages between the with- and without-project conditions. Based on the additional economic analysis, the residual damages associated with Alternatives 2A and 3A were identified; the distribution of residual damages by reaches is listed in Table 12. Under Alternative 3A, all of the communities have a moderate to large reduction in residual damages, as compared to Alternative 2A. The most significant difference is in the Ala Wai community, where Alternative 3A yields $9.6 million less residual damages than Alternative 2A, thus making Alternative 2A less desirable.

Table 12. Residual Expected Annual Damages for the Final Array of Alternatives ($000)

Reach	Alternative 2A				Alternative 3A			
	Damage Categories			Residual Damages	Damage Categories			Residual Damages
	Commercial	Public	Residential		Commercial	Public	Residential	
ALA1	0	0	0	**0**	4	1	0	**5**
ALA2	0	0	0	**0**	0	0	0	**0**
ALA3	4,864	0	156	**5,020**	0	0	0	**0**
MPC1	19	0	20	**39**	12	0	13	**25**
MPC2	150	15	420	**585**	3	0	20	**23**
Ala Wai Subtotal	**5,033**	**15**	**596**	**5,644**	**19**	**1**	**33**	**53**
KAH1	0	0	110	**110**	0	0	156	**156**
KAH2	0	0	1	**1**	0	0	1	**1**
KAO1	6	0	48	**55**	7	0	66	**73**
MAK1	1,660	0	474	**2,134**	1,594	0	446	**2,039**
MAK2	207	14	143	**365**	112	8	85	**205**
MAK3	0	0	28	**28**	0	0	26	**26**
MAK4	0	0	25	**25**	0	0	7	**7**
Makiki Subtotal	**1,874**	**14**	**829**	**2,717**	**1,712**	**8**	**787**	**2,507**

Table 12. Residual Expected Annual Damages for the Final Array of Alternatives ($000)

Reach	Alternative 2A				Alternative 3A			
	Damage Categories			Residual Damages	Damage Categories			Residual Damages
	Commercial	Public	Residential		Commercial	Public	Residential	
MAN1	0	904	116	**1,020**	0	459	58	**517**
MAN2	0	10	0	**10**	0	0	0	**0**
MAN3	8	0	12	**20**	0	0	0	**0**
MAN4	0	0	17	**17**	0	0	9	**9**
MAN5	0	0	67	**67**	0	0	42	**42**
MAN6	0	0	46	**46**	0	0	1	**1**
MAN7	0	0	4	**4**	0	0	0	**0**
UNI1	0	185	0	**185**	0	0	0	**0**
UNI2	0	665	0	**665**	0	0	0	**0**
Mānoa Subtotal	**8**	**1,764**	**261**	**2,033**	**0**	**459**	**110**	**570**
PAL1	0	0	11	**11**	0	0	8	**8**
PAL2	0	1	15	**15**	0	0	8	**8**
PAL3	0	0	185	**185**	0	0	140	**140**
PAL4	0	1	53	**54**	0	0	62	**62**
PUK1	0	0	0	**0**	0	0	0	**0**
WAI1	0	0	0	**0**	0	0	0	**0**
Pālolo Subtotal	**0**	**2**	**264**	**266**	**0**	**0**	**218**	**218**
TOTAL	**6,915**	**1,795**	**1,950**	**10,660**	**1,731**	**468**	**1,148**	**3,348**

3.8.2 Screening of the Final Array

To ensure that the alternative plans in the final array should be carried forward for evaluation and comparison, a final round of screening was performed. Similar to previous stages of formulation, screening focused on the same set of criteria as previously described, with further refinements to the metrics. As shown in Table 13, the results of the screening process indicated that the remaining alternatives in the final array were suitable to carry forward for consideration. These results were confirmed as part of an In-Progress Review with the USACE Vertical Team on April 21, 2014.

Table 13. Screening of the Final Array of Alternatives[a]

Criteria	Metric	Alternative 2A	Alternative 3A
Implementation Cost	Total project cost (fully funded)	$221 million	$178 million
O&M Requirements	Estimated O&M cost; assessment of whether O&M activities requires a change in practice, equipment, or access	$1.3 million (change from existing practices relates to pump stations and gates along the Canal)	$1.0 million (change from existing practices relates to pump stations and gates along the Canal)
Cost-effectiveness	Screening-level BCR and net benefits	2.24 $13.7 million	3.62 $23.3 million
Public Sentiment	Qualitative assessment of stakeholder concerns based on sponsor/stakeholder input to date	Sponsor concern over use of park space; use of golf course; O&M requirements; infiltration and ground movement associated with Woodlawn Cemetery	Sponsor concerns over use of upper watershed land; use of golf course; O&M requirements; infiltration and ground movement associated with Woodlawn Cemetery
Legal Acceptability	Qualitative assessment of whether alternative complies with authority granted by Congress and applicable laws, regulations and policies	None identified	None identified
Social Fairness	Qualitative assessment of whether neighborhoods receive same level of protection based on flood damage reduction benefits	High flood protection in most neighborhoods, high number of measures in Mānoa	High flood protection in most neighborhoods, medium number of measures in Mānoa
Flood damage reduction	Expected annual benefits (based on preliminary HEC-RAS/HEC-FDA model runs)	$25 million	$32 million
Life safety risk	Assessment of reduction in life safety risk factors (affected population, flood characteristics, warning system)	Floodplain area decreased to 494 acres; affected population decreased to approximately 16,100 residents; visitors to Waikīkī removed from affected population. Safety concerns associated with detention basins located in publically accessible areas (e.g., Mānoa District Park and Kanewai Field).	Floodplain area decreased to 506 acres; affected population decreased to approximately 17,300 residents; visitors to Waikīkī removed from affected population.
Community Resilience	Assessment of resiliency factors, including critical infrastructure and other facilities	Minimal critical infrastructure is located in the floodplain (2 fire stations, 2 nursing facilities, and 2 emergency shelters).	Minimal critical infrastructure is located in the floodplain (2 fire stations, 2 nursing facilities, and 3 emergency shelters).
Environmental impacts	Degree of impact and potential mitigation requirements	Approx. 400 linear feet of stream impacts plus 600-foot-long culvert along Mānoa Stream, 3.2 acres of upland impacts	Approx. 950 linear feet of stream impacts, 8.1 acres of upland impacts
Archaeological/ cultural impacts	Degree of impact and potential mitigation requirements	Assumes mitigation required for impacts to 37.8 acres; could include burials	Assumes mitigation required for impacts to 35.2 acres; could include burials

Note:
[a] Pursuant to the requirements of NEPA, the No Action Alternative is carried forward as part of the Final Array of Alternatives, but is not shown as part of this table.

3.8.3 Process for Plan Selection Based on Final Array

Consistent with the requirements of the USACE planning process, detailed economic analyses (and associated refinements) are needed to ensure that an alternative plan being considered for selection is economically justified, such that no other variation of that plan could be more economically beneficial (i.e., no other variation could better maximize the NED account). Specifically, these analyses include incremental justification (to ensure that each measure included in the alternative is economically justified) and optimization (to ensure that the scale of each measure maximizes benefits).

Based on the principles of the SMART planning process (and the outcome of screening), it was determined that the alternative plans in the final array provided a reasonable basis for evaluation and comparison, and that detailed economic analyses and refinements should only be performed for the higher-ranking alternative, as identified through the evaluation and comparison process. It was determined that similar analysis and refinements were not needed for the other action alternative in the final array, as they would not affect the relative comparison between the alternatives.

As such, the evaluation and comparison process was used to identify which of the alternatives in the final array best meets the criteria for selection. Based on the outcome of this effort, detailed economic analyses were then used to refine that alternative as needed to identify the NED plan, thus providing the basis for tentative plan selection. Following is a discussion of the evaluation and comparison of the final array of alternative plans, followed by a discussion of the detailed economic analyses and refinements that were subsequently conducted.

3.9 Evaluation and Comparison of Alternative Plans

For flood risk management projects, the primary criteria for plan selection are based on total benefits and total cost, in which the results of the economic analyses are used to establish Federal interest. In the case of this project, life safety considerations were also taken into account. Consistent with the requirements of the USACE Planning Guidance Notebook (ER 1105-2-100), the evaluation and comparison of alternative plans is also presented in terms of the four national accounts, as summarized below.

3.9.1 System of Accounts

The USACE planning process incorporates four accounts to facilitate the display and comparison of the beneficial and adverse effects of each alternative plan. The mode of analysis, commonly referred to as the “System of Accounts,” displays the positive and negative effects of broad categories of impacts in a tabular format. The accounts include those that relate to contributions to NED, Environmental Quality (EQ), Regional Economic Development (RED), and Other Social Effects (OSE). As previously described, the NED account displays changes in the economic value of the national output of goods and services. The EQ account displays the beneficial and adverse effects of the plans on ecological, cultural, and aesthetic resources. The RED account displays changes in the distribution of regional economic activity (e.g., income and employment). The OSE account displays plan effects on social aspects such as community impacts, health and safety, and recreational opportunities.

Table 14 presents the evaluation and comparison of the final array of alternatives based on the System of Accounts, as well as other plan evaluation factors, including contributions to the planning objectives, avoidance of the planning constraints, and response to the Federal evaluation criteria specified in the Planning Guidance Notebook (ER 1105-2-100).

Table 14. System of Accounts Displaying Preliminary Effects of Final Array of Alternatives

		No Action Alternative	Alternative 2A	Alternative 3A
PLAN DESCRIPTION				
Alternative Plan Details		The No Action Alternative and future without-project condition provides no physical project constructed by the Federal Government.	Alt. 2A focuses detention within the urbanized watershed (Mānoa District Park, Kanewai Field, Woodlawn Ditch, Makiki and Roosevelt), with debris catchment in the upper watershed (Waihi, Waiakeakua, and Pūkele and Wai'ōma'o streams); measures in the lower watershed include detention at Hausten Ditch and the Ala Wai Golf Course, and floodwalls along the Ala Wai Canal.	Alt. 3A focuses detention in the upper watershed (Waihi, Waiakeakua, Pūkele and Wai'ōma'o streams), with limited detention in the urbanized watershed (Makiki, Roosevelt, Kanewai Field); measures in the lower watershed include detention at Hausten Ditch and the Ala Wai Golf Course, and floodwalls along the Ala Wai Canal.
PLANNING ASSESSMENT				
A. National Economic Development (NED)				
(1)	Estimated Cost (October 2013 price level)	$0	$221,231	$178,096
(2)	Estimated Average Annual Cost (50 years; 3.5%)	$0	$11,097	$8,923
(3)	Total Annual Benefit	$0	$24,814	$32,272
(4)	Annual Net Benefits	$0	$13,717	$23,349
(5)	BCR	N/A	2.24	3.62
B. Environmental Quality (EQ)				
(1)	Aquatic Habitat	The extent and quality of aquatic habitat is expected to be commensurate with the existing conditions	Approximately 400 linear feet of stream would be affected (primarily within urbanized portion of watershed) plus a 600-foot-long culvert would be installed along Mānoa Stream; design includes arch culverts with a natural substrate bottom where feasible to maintain in-stream passage for native aquatic species	Approximately 950 linear feet of stream would be affected (primarily within the upper portions of the watershed); design includes arch culverts with a natural substrate bottom where feasible to maintain in-stream passage for native aquatic species

Table 14. System of Accounts Displaying Preliminary Effects of Final Array of Alternatives

		No Action Alternative	Alternative 2A	Alternative 3A
(2)	Water Quality	Water quality is anticipated to be commensurate with that of the existing condition.	In-stream debris and detention is expected to provide some degree of water quality improvement through capture of debris and sediment (though not likely as much as Alt. 3A). Construction could result in short-term water quality impacts, but these would be minimized through BMPs.	In-stream debris and detention (particularly in the upper watershed) may provide some degree of water quality improvement through capture of debris and sediment. Construction could result in short-term water quality impacts, but these would be minimized through BMPs.
(3)	Threatened & Endangered Species	The distribution and occurrence of threatened and endangered species is anticipated to be commensurate with the existing conditions, although ongoing threats could further diminish populations.	Seasonal restrictions on vegetation clearing would be implemented to avoid impacts to Hawaiian hoary bats and O'ahu elepaio, should they occur. Given the smaller extent of disturbance in the upper watershed, potential impacts are expected to be less than for Alternative 3A.	Seasonal restrictions on vegetation clearing would be implemented to avoid impacts to Hawaiian hoary bats and O'ahu elepaio, should they occur.
(4)	Archaeological, Historic, and Cultural Resources	Archaeological, historic and cultural resources are anticipated to be commensurate with that of the existing condition.	Project would affect traditional cultural properties (TCPs) and historic properties (especially in and around the Ala Wai Canal, which is listed on the Hawai'i Register of Historic Places); there is also a potential for inadvertent discoveries. Alt. 2A has a smaller footprint in the upper watershed, which could reduce impacts to cultural resources. Additional areas of potential impact include the Mānoa District Park detention basin and Mānoa-Pālolo Drainage Canal Floodwalls.	Project would include impacts to TCPs and historic properties (especially in and around the Ala Wai Canal, which is listed on the Hawai'i Register of Historic Places); there is also a potential for inadvertent discoveries. Alt. 3A would impact a greater amount of area in the upper watershed, which could increase impacts to cultural resources.
(5)	Visual Resources	Visual resources are anticipated to be commensurate with that of the existing condition.	Measures in upper watershed are not expected to significantly affect views from publically-accessible locations (though some would be visible from adjacent areas). Measures in the urbanized watershed (including detention basins at Kanewai and Mānoa District Park) would be visible but have been designed to blend with the surrounding environment. The floodwalls would affect views toward and along the Canal; floodwall heights would be approximately one foot higher than Alt. 3A (on average).	Measures in upper watershed are not expected to significantly affect views from publically-accessible locations (though some would be visible from adjacent areas, including residences in Pālolo). Measures in the urbanized watershed (such as the Ala Wai Golf Course detention basin) would be visible but have been designed to blend with the surrounding environment. The floodwalls would affect views toward and along the Canal, but would be approximately one foot lower than Alt. 2A (on average).

Table 14. System of Accounts Displaying Preliminary Effects of Final Array of Alternatives

		No Action Alternative	Alternative 2A	Alternative 3A
C.	**Regional Economic Development**			
(1)	Business and Tax Revenues	Number of visitors, revenues, sales, inventories and taxes generated would all be commensurate with that of the existing conditions, although these could diminish in response to flooding, especially in Waikīkī.	Number of visitors, revenues, sales, inventories and taxes generated could experience a faster growth trend in comparison to the existing conditions as the risk of flooding is substantially decreased.	Number of visitors, revenues, sales, inventories and taxes generated could experience an even faster growth trend as compared to the existing conditions, as well as Alt. 2A, as the risk of flooding is even further reduced.
(2)	Employment	Jobs and wages would be commensurate with that of the existing conditions, although they could diminish over time due to the risk of flooding, especially in Waikīkī.	Jobs and wages could experience a faster growth trend than what would be commensurate with the existing conditions as the risk of flooding is substantially decreased. The millions of dollars invested by the Federal and local governments in the project would have a positive short-term, if not long-term, effect on local employment as the money turns and churns through the economy.	Jobs and wages could experience a faster growth trend than what would be commensurate with the existing conditions as the risk of flooding is substantially decreased. The millions of dollars invested by the Federal and local governments in the project would have a positive short-term, if not long-term, effect on local employment as the money turns and churns through the economy.
D.	**Other Social Effects (OSE)**			
(1)	Public Health and Safety	There is a high level of flood risk in watershed, with a large affected population, including 79,000 visitors in Waikīkī District. The potential for life loss is relatively low, in large part because of the existing flood warning system; however there are health and safety threats due to injuries associated with movement of debris and health concerns from contaminated floodwaters.	Health and safety risks would be reduced through a significant decrease in floodplain area and affected population (slightly better than Alt. 3A). New gages would be added to help maintain the existing warning system. The potential for life loss is expected to be minimal, but there is still some degree of threat due to injuries associated with debris and health concerns from contaminated floodwaters. There are also safety concerns associated with detention basins located in publically accessible areas (e.g., Mānoa District Park and Kanewai Field).	Health and safety risks would be reduced through a significant downsizing of the floodplain area and the size of the affected population (slightly less than Alt. 2A). New gages would be added to help maintain the existing warning system. The potential for life loss is expected to be minimal, but there is still some degree of threat due to injuries associated with debris and health concerns from contaminated floodwaters. The proposed detention basins are in less publically accessible areas, resulting in fewer safety concerns than Alt. 2A.
(2)	Population at Risk	Floodplain is approximately 1,358 acres; affected population includes 54,100 residents plus approximately 79,000 daily visitors in Waikīkī.	Floodplain area decreased to 494 acres; affected population decreased to approximately 16,100 residents; visitors to Waikīkī removed from affected population. Increased safety concerns associated with detention basins located in publically accessible areas (e.g., Mānoa District Park).	Floodplain area decreased to 506 acres; affected population decreased to approximately 17,300 residents; visitors to Waikīkī removed from affected population.

Table 14. System of Accounts Displaying Preliminary Effects of Final Array of Alternatives

		No Action Alternative	Alternative 2A	Alternative 3A
(3)	Critical Infrastructure	Watershed supports an aging population; much of the critical infrastructure is in the floodplain [4 (of 7) fire stations, 1 (of 2) police stations, 2 (of 9) hospitals, 2 (of 14) nursing facilities, and 9 (of 21) emergency shelters].	Minimal critical infrastructure is located in the floodplain (2 fire stations, 2 nursing facilities, and 2 emergency shelters).	Minimal critical infrastructure is located in the floodplain (2 fire stations, 2 nursing facilities, and 3 emergency shelters).
(4)	Recreation	Recreation is important to residents and visitors in the watershed. Recreational opportunities would continue to be provided, with some facilities subject to flooding during large storm events.	Alt. 2A would help protect existing recreational facilities, including Kapiʻolani Park. Detention basins at Mānoa District Park, Kanewai Community Park and Ala Wai Golf Course could impact recreational uses; floodwalls along the Ala Wai Canal would also impact pedestrians/ runners and paddlers/kayakers.	Alt. 3A would help protect existing recreational facilities, including Kapiʻolani Park. Recreational use could be impacted as a result of the Ala Wai Golf Course detention basin and the Ala Wai floodwalls; detention basins in the upper watershed areas could also affect recreational users.
PLAN EVALUATION				
A.	**Contribution to Planning Objectives**			
(1)	Reduce riverine flood risks in the Ala Wai Watershed through the 50-year period of analysis	Does not meet planning objective: flood hazards would not be reduced.	Floodplain area decreased to 494 acres. Affected population decreased to approximately 16,100 residents; visitors to Waikīkī removed from affected population. Alt. 2A includes detention in publically-accessible areas (e.g., Mānoa District Park), which generates additional safety concerns.	Floodplain area decreased to 506 acres. Affected population decreased to approximately 17,300 residents; visitors to Waikīkī removed from affected population.
B.	**Avoidance of Planning Constraints**			
(1)	Avoid shifting of flooding to downstream areas	No changes are anticipated under the No Action Alternative.	Alt. 2A is not expected to result in shifting of flooding to downstream areas.	Alt. 3A is not expected to result in shifting of flooding to downstream areas.
(2)	Avoid induced flood damages	No induced flood damages are anticipated under the No Action Alternative.	Alt. 2A is not expected to result in induced flood damages.	Alt. 3A is not expected to result in induced flood damages.
(3)	Avoid development of infrastructure that is incompatible with existing land uses or policies	No Federally sponsored development is expected within the project area under the No Action Alternative.	All of the flood-risk reduction measures in Alt. 2A are expected to be compatible with existing land uses and policies.	All of the flood-risk reduction measures in Alt. 3A are expected to be compatible with existing land uses and policies.
(4)	Avoid induced development in the existing floodplain	No Federally sponsored development is expected within the project area under the No Action Alternative.	Alt. 2A is not expected to induce development within the floodplain.	Alt. 3A is not expected to induce development within the floodplain.

Table 14. System of Accounts Displaying Preliminary Effects of Final Array of Alternatives

		No Action Alternative	Alternative 2A	Alternative 3A
(5)	Avoid significant reduction of migratory pathways or habitat for endemic aquatic species, or increase of habitat for invasive aquatic species	Migratory pathways and habitat for aquatic species is expected to be commensurate with the existing conditions.	Alt. 2A is not expected to affect migratory pathways or substantially reduce habitat for native aquatic species; compensatory mitigation would be implemented to offset any reduction in habitat quality.	Alt. 3A is not expected to substantially affect migratory pathways or habitat for native aquatic species; compensatory mitigation would be implemented to offset any reduction in habitat quality.
(6)	Avoid impacts to nearshore marine resources at the mouth of the Canal	No impacts to nearshore marine resources are anticipated as a result of the No Action Alternative.	Alt. 2A is not expected to adversely impact nearshore marine resources; minor improvements to water quality may be realized (as a result of sediment and debris capture in the detention basins), but the benefits are not expected to be measurable.	Alt. 3A is not expected to adversely impact nearshore marine resources; minor improvements to water quality may be realized (and possibly to a greater extent than Alt. 2A), but the benefits are not expected to be measurable.
C.	**Response to Federal Planning Criteria**			
(1)	Completeness	Meets criterion: However, no action does not achieve study objectives.	Meets criterion: Alt. 2A accounts for all actions necessary to achieve desired level of flood risk management.	Meets criterion: Alt. 3A accounts for all actions necessary to achieve desired level of flood risk management.
(2)	Effectiveness	Meets criterion: However, no action does not achieve study objectives.	Meets criterion: Alt. 2A would provide $12,928 in annual net benefits.	Meets criterion: Alt. 3A would provide $22,241 in annual net benefits.
(3)	Efficiency	Meets criterion: However, no action does not achieve study objectives.	Meets criterion: Alt. 2A has a BCR of 2.13	Meets criterion: Alt. 3A has a BCR of 3.36.
(4)	Acceptability	Does not meet criterion for Federal standards for community-based flood risk management and residual flood risks; the No Action Alternative is not acceptable because flood risks in the Ala Wai Canal would remain in the range of 10 to 20% ACE.	Meets criterion: Technically feasible and would generally satisfy other Federal standards for community-based flood risk management. Compatible with existing laws, regulations and public policies, reducing flood risks in the Ala Wai Canal Reach to 1% ACE.	Meets criterion: Technically feasible and would generally satisfy other Federal standards for community-based flood risk management. Compatible with existing laws, regulations and public policies, reducing flood risks in the Ala Wai Canal Reach to 1% ACE.

3.9.2 Analysis and Refinement of Alternative 3A

As shown in Table 14, the System of Accounts, Alternative 3A provides higher net benefits, which in combination with a lower project cost results in a significantly higher benefit-cost ratio than Alternative 2A (3.36 versus 2.13). Therefore, based on the process presented in Section 3.6, detailed economic analyses were conducted for Alternative 3A. Various increments and refinements were considered (with additional alternative number modifiers added accordingly). This includes the addition of the Manoa-Palolo Drainage Canal floodwall to Alternative 3A to provide public health and safety protection to Iolani School and Ala Wai Elementary. The analyses and refinement focused on maximizing the benefits of Alternative 3A as needed to identify the NED plan, thus providing the basis for tentative plan selection. The methodology and results of this effort are summarized below, with additional detail provided in Appendix B.

3.9.3 Incremental Justification

The focus of the incremental analysis was to confirm that each measure in Alternative 3A is economically justified. Based on best professional judgment, the increments considered in the analysis were defined based on economic efficiency; the analysis started with the increment that was assumed to add the most net benefits (Increment 0), with each subsequent increment added to the analysis based on contribution of benefits. The increments that were analyzed are listed in Table 15; key results are summarized in the following paragraph and illustrated in Figure 9.

Table 15. Increments Used for Incremental Justification

Increment	Measure(s) Added
0	Flood-warning system, Ala Wai Canal floodwalls, Ala Wai Golf Course multi-purpose detention basin, and Hausten Ditch detention basin
1	Waiakeakua Debris and Detention Basin, Waihi Debris and Detention Basin, and Mānoa In-stream Debris Catchment
2	Pūkele Debris and Detention Basin and Waiʻōmaʻo Debris and Detention Basin
3	Roosevelt Debris and Detention Basin
3.5	Makiki Debris and Detention Basin (remove Roosevelt Debris and Detention Basin)
4	Roosevelt Debris and Detention Basin and Makiki Debris and Detention Basin
5	Woodlawn Ditch Detention Basin
6	Kanewai Field Multi-purpose Detention Basin
7	Mānoa-Pālolo Drainage Canal Floodwall

Since the performance of the features included in increment zero (the base plan) is dependent on upstream detention, this increment initially appears to be at parity economically, or slightly negative, between costs and benefits. This increment, however, is integral towards providing line of protection to the most urbanized neighborhoods of the study area and dramatically increases in performance as additional upstream increments are added.

It was assumed that the Roosevelt debris and detention basin would add more net benefits than the Makiki debris and detention basin, however, these measures were analyzed individually (as Increments 3 and 3.5) to confirm this assumption. As shown in Figure 9, the results of the analysis instead indicated that the Makiki debris and detention basin added more net benefits than the Roosevelt debris and detention basin. The two measures were analyzed together (as Increment 4), but were found to have fewer net benefits than the Makiki debris and detention basin alone (Increment 3.5); thus, the Roosevelt debris and detention basin was eliminated. As such, Increment 5 was based on adding the Woodlawn Ditch detention basin to Increment 3.5 (Alternative 3A-1).

As part of the analysis, it was also determined that the Innovation Center Improvements did not provide any flood reduction benefit; instead, the Kanewai Field Multi-purpose detention basin was analyzed as Increment 6 (Alternative 3A-2) and was found to be economically justified. As there were still net benefits available, the Mānoa-Pālolo Drainage Canal Floodwall was analyzed as Increment 7 (Alternative 3A-3); this increment did not add net benefits, so was not further considered during this iteration.

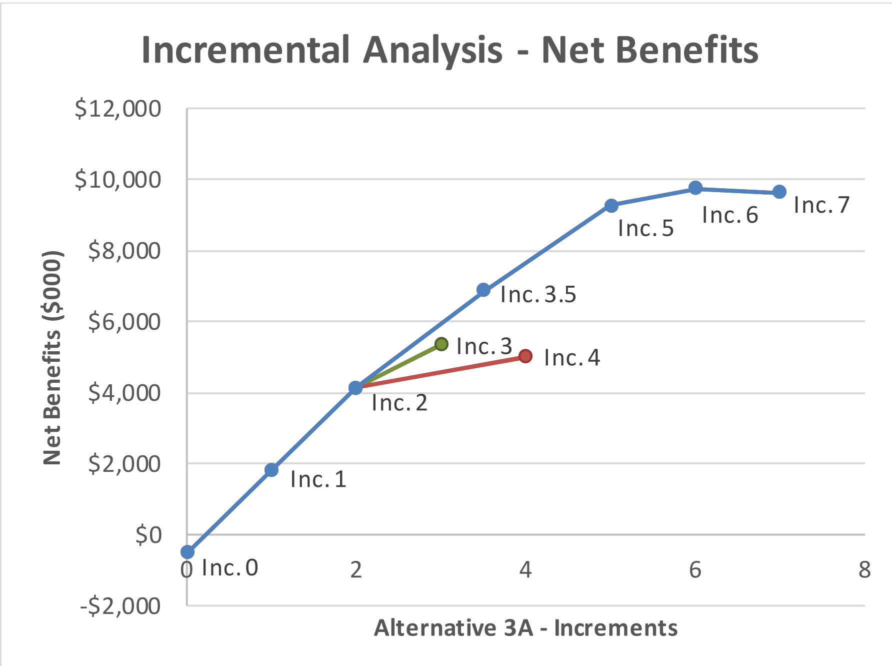


Figure 9. Results of Incremental Analysis

Building on the results of the incremental justification, further analysis was conducted to determine whether net benefits would be maximized if the height of the Ala Wai Canal floodwalls were increased, in lieu of the Kanewai Field detention basin (as Increment 6). This analysis also included consideration of non-structural solutions to protect Kanewai Field, as needed to allow for comparison of benefits. The results of the analysis confirmed that benefits were maximized with the addition of Kanewai Field detention basin, as the incremental cost of this measure was approximately $3 million, while replacing the detention basin with higher floodwalls and non-structural protection was more than ten times the cost. Additional information on this analysis is provided in Appendix B.

3.10 Iteration 4 – Economic Optimization of the Selected Plan

Consistent with EC 1165-2-214, USACE conducted a technical, policy and independent peer review of the draft Feasibility Report and Environmental Impact Assessment, which included Alternative 3.2 as the tentatively selected plan. The review noted changes in USACE guidance since the completion of the initial technical analysis which consequently required updates to hydrologic and hydraulic modeling. As modeling updates were completed, analysis focused on the evaluation of the effects of changes to modeling on the selected plan, Alternative 3.2. Changes to system hydrology and hydraulics resulted in changes to the following:

- Detention Basin Storage: Detention basins required the addition of storage to meet storage targets. In some cases, this included excavation upstream and in others, raising the spillway elevation to increase storage volumes.
- Water Surface Profiles: Water surface profiles in the area of Ala Wai Canal were found to be higher in the without-project condition (up to one foot higher)

Additional optimization analysis completed after the technical, policy and independent peer review are described below.

3.10.1 Summary of Design Changes

Changes to the underlying system hydrology and hydraulics resulted in a number of changes required to the design components of the selected plan. Changes include the following:

Table 16. Summary of Design Changes between Draft and Final Report

Flood Risk Management Measure	Original Design	Design Changes
Waihi Debris and Detention Basin	Earthen structure, approximately 24 feet high and 225 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Structure height increased to 37 ft. Arch culvert replaced with a 12'x6' box culvert. Culvert length increased from 130 ft to 205 ft. Approx. 150 linear ft of riprap scour protection added downstream of culvert. Project footprint increased from 12,714 ft^2 to 35,200 ft^2.
Waiakeakua Debris and Detention Basin	Earthen structure, approximately 20 feet high and 185 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert.	Structure height increased to 34 ft. Arch culvert length increased from 110 to 200 ft. Approx. 150 linear feet of riprap scour protection added downstream of culvert. Project footprint increased from 29,180 ft^2 to 41,620 ft^2
Woodlawn Ditch Detention Basin	Three-sided berm, approximately 15 feet high and 840 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side.	No change.
Mānoa In-stream Debris Catchment	Concrete pad, approximately 8 feet wide and 60 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad.	No change.
Kanewai Field Multi-Purpose Detention Basin	Earthen berm, approximately 7 feet high, around 3 sides of the field; grouted rip rap inflow spillway along bank of Mānoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.	Berm height increased to 9 ft.
Wai'ōma'o Debris and Detention Basin	Earthen structure, approximately 24 feet high and 120 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. Excavation of approx. 2,000 yd^3 to provide required detention volume upstream of berm; low-flow channel with existing substrate to be restored following excavation. New access road to be constructed for construction and O&M.	Structure height increased to 33.5 ft. Arch culvert replaced with a 12'x6' box culvert. Culvert length increased from 130 ft to 170 ft. Approx. 150 linear feet of riprap scour protection added downstream of culvert. Detention basin excavation increased to 3,060 yd^3. Project footprint increased from 6,985 ft^2 to 19,890 ft^2.

Flood Risk Management Measure	Original Design	Design Changes
Pūkele Debris and Detention Basin	Earthen structure, approximately 24 feet high and 120 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Structure height increased to 30 ft. Arch culvert replaced with a 12'x6' box culvert. Culvert length increased from 130 ft to 160 ft. Approx. 150 linear feet of riprap scour protection added downstream of culvert. Excavation of 14,330 yd^3 from 15,620 ft^2 upstream of structure for additional detention capacity. Project footprint increased from 2,920 ft^2 to 16,660 ft^2.
Makiki Debris and Detention Basin	Earthen structure, approximately 24 feet high and 100 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Structure height increased to 30 ft. Arch culvert length increased from 130 ft to 160 ft. Approx. 150 linear feet of riprap scour protection added downstream of culvert. Excavation of 3,035 yd^3 from 14,040 ft^2 upstream of structure for additional detention capacity. Project footprint increased from 7,250 ft^2 to 17,165 ft^2.
Ala Wai Canal Floodwalls	Concrete floodwalls ranging up to approximately 4 feet high, offset from existing Canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to Canal; floodgate to be installed near McCully Street. Two pump stations to accommodate storm flows and gates installed at existing drainage pipes to prevent backflow from the Ala Wai Canal during a flood event.	Floodwall height optimized as described below. The floodwall near the outlet to the ocean was extended at an elevation of 7.9 ft MSL between the Kalakaua Bridge and the Ala Moana Bridge to account for future sea level rise (described in Section 8.3).
Hausten Ditch Detention Basin	Concrete floodwalls and an earthen berm (approximately 4.3 feet high) to provide detention for local drainage; install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to prevent a backflow from the Ala Wai Canal during a flood event.	Floodwall and berm heights optimized as described below.
Ala Wai Golf Course Multi-Purpose Detention Basin	Earthen berm, averaging 4 feet high, around the north and east perimeter of the golf course; grouted rip rap inflow spillway along bank of Mānoa-Pālolo Drainage Canal to allow high flows to enter the basin; sediment basin within western portion of golf course; floodgate across the main entrance road; passive drainage back into Ala Wai Canal.	Berm height increased to an elevation ranging between 10.0-11.9 ft MSL; berm averages 2.7 feet in height above the existing surface

Changes resulting from design alterations have been reflected in the Table 17 description of the recommended plan, however, the alternatives utilized for comparison has not been changed in Iteration 4. Given the relative differences between in the comparison of Alternative Plans provided in Table 14 of Iteration 3, it is assumed that relative differences in evaluation criteria are similar and therefore the evaluation, comparison and selection outlined in Iteration 3 remains valid. Comparisons of Alternative Plans in the Section 5 EIS portions of the report have generally been updated to reflect the current estimated impacts of the recommended plan based on the most current information. The cost estimates and analysis of benefits associated with the selected plan were also updated during this iteration of the plan formulation.

3.10.2 Economic Analysis of Additional Increments

Changes in water surface profiles and the resulting changes to the benefits and costs provided the opportunity to revisit the incremental analysis discussed in Section 3.9.3. In particular, concerns were raised regarding the increases in the water surface profile at Ala Wai Canal and the effect of that future without-project condition on areas of the right bank that were without protection including Iolani School and Ala Wai Elementary School. The previous incremental economic analysis (Section 3.9.3) justified floodwalls around the Ala Wai Canal and a levee at the Ala Wai Golf Course, but was unable to justify the Manoa Palolo Drainage Canal floodwall (Increment 7), a floodwall between Iolani School, Ala Wai Elementary and the Ala Wai Canal. With updated cost estimates, benefits analysis, and system hydraulics, the inclusion of the Manoa Palolo Drainage Canal continued to remain unjustified economically as the economic benefits did not outweigh the costs and therefore did not add to the net benefits of the overall selected plan. In addition, because the water surface profiles were reduced between the with-project and the without-project condition, damages within this reach could not be considered induced flooding resulting from the with-project condition. As a result, it was determined that Increment 7 did not meet Federal interest requirements and would not be considered further in the recommended plan.

In accordance with USACE EM 1110-2-1413, economic analysis was conducted on pump station interior drainage features to verify that the stations meet applicable guidance and that the economic benefits exceed the costs. The three pump stations proposed as a part of the tentatively selected plan intercept trunk storm sewer systems and are intended to prevent backwater flooding due to the installation of flap gates on the storm sewer outfalls.

The flood footprint for interior flooding in the absence of Pump Stations 1 and 2 partially overlaps the existing flood footprint for the without-project condition, however, this footprint extends much further to the east across Kapahulu Avenue into adjacent residential neighborhoods which would otherwise be relatively unaffected by flooding in the Ala Wai Canal (Figure 22). Water surface elevations associated with interior flooding increase above the without project condition significantly within those areas of overlap (between 0.9’-1.7’). Further, interior flooding adversely affects two emergency shelters, one fire station and evacuation routes for Waikiki including Kapahulu Avenue, Monsarrat Avenue and Kalakaua Avenue. Given the increase in water surface elevations between the without-project and interior flooding condition, the inclusion of Pump Stations 1 and 2 meet the minimum facilities criteria designated by USACE guidance and are included as an integral element to the line of protection features for the Ala Wai Canal.

In the vicinity of Pump Station 3, the flood footprint for interior flooding exists entirely within the flood footprint for the without-project condition (Figure 22). Water surface elevations associated with interior flooding decrease below the without project condition significantly within those areas (-2.28’) as a result of the recommended plan. Consequently, Pump Station 3 does not meet the minimum facilities requirement prescribed by USACE guidance and was excluded from inclusion in the recommended plan. In the absence of a pump station, a backwater effect from local drainage is expected with approximately 1-foot depths within the intersection of Date Street and University Avenue, and approximately 1.5-foot depths near Ala Wai Canal, resulting from a 10% ACE storm. Flooding associated with the backwater effect in these areas is considered residual damage. Local drainage improvements implemented in this area could improve this condition.

3.10.3 Economic Optimization of Recommended Plan Features

The measures in Alternative 3A-2 (based on adding Kanewai Field detention basin as Increment 6) were then reviewed to confirm that each is optimally scaled (that is, whether the scale of each measure maximizes benefits). Based on previous analysis of the 10% level of design documents, it was determined that optimization was not necessary for the debris and detention basins. Debris and detention basins were designed to maximize storage to the greatest extent possible given the constraints of the built environment (neighborhoods, existing uses) and estimated environmental impacts. As debris and detention basins with a lower level of protection would still require nearly the same footprint and would not offer significant cost savings, it was determined that down-scaling would provide minimal (if any) benefit, and therefore was not considered as part of the optimization process. Therefore, the optimization efforts focused on the height of the floodwalls along the Ala Wai Canal.

Using the 35% level of design, the Ala Wai Canal floodwalls were assumed to have an average height of 4 feet. This was considered to be the baseline for the optimization effort; the floodwall heights were then subsequently adjusted in 1-foot increments. The analysis accounted for design elements that would differ depending on the floodwall height. Specifically, starting at an average height of 5 feet, the floodwalls include more robust footings and floodgates for access to the Canal; the 4-foot-high floodwalls include less robust footings and stair access. As shown in Table 17, lowering the floodwall heights by 1 foot (i.e., 3-foot average height; Alternative 3-A-2.1) resulted in lower net benefits, such that this iteration was not found to be economically justified. Similarly, raising the floodwall heights by 1 foot to an average of 5-feet-high (Alternative 3A-2.3) also resulted in lower net benefits. As such, average 4-foot-high floodwalls were determined to be the optimized level (Alternative 3A-2.2).

Table 17. Optimization Results ($000)

Cost/Benefit Description	Alt. 3A-2.1 (Avg. 3-ft Floodwalls)	Alt. 3A-2.2 (Avg. 4-ft Floodwalls)	Alt. 3A-2.3 (Avg. 5-ft Floodwalls)	Alt. 3A-2.4 (Avg. 6-ft Floodwalls)
Plans & Specs	$55,736	$56,627	$57,608	$58,624
Construction Management	$26,795	$27,224	$27,696	$28,183
Lands	$17,194	$17,194	$17,194	$17,194
Construction Contract	$201,660	$205,050	$208,764	$212,626
Estimated Cost (October 2016 price level)	**$301,385**	**$306,095**	**$311,262**	**$316,627**
Interest During Construction	$13,511	$13,602	$13,701	$13,805
Total Investment	**$314,896**	**$319,697**	**$324,963**	**$330,432**
Annualized Total Investment (50YR@2.875%)	**$11,950**	**$12,132**	**$12,332**	**$12,539**
Annual O&M	$985	$985	$985	$985
Expected Annual Cost (EAC)	**$12,935**	**$13,117**	**$13,317**	**$13,524**
Residential	$19,656	$19,803	$19,811	$19,811
Commercial	$24,841	$24,953	$24,962	$24,962
Public	$3,568	$3,575	$3,575	$3,575
Expected Annual Benefits (EAB)	**$48,065**	**$48,331**	**$48,348**	**$48,348**
Net Benefits	**$35,130**	**$35,214**	**$35,031**	**$34,824**
Benefit/Cost Ratio	**3.72**	**3.68**	**3.63**	**3.57**

3.11 Identification of NED Plan

Federal policy requires identification of the plan that reasonably maximizes net NED benefits (i.e., the NED plan); the NED plan must be recommended for implementation unless there are overriding reasons for recommending another plan. According to the results of the incremental justification and optimization process described above, Alternative 3A-2.2 was identified as the NED plan; the results summarized in Table 17 (and shown in Figure 10) illustrate how the costs and benefits were used to bracket Alternative 3A-2.2 as the NED plan. Given that the net benefits associated with 3-foot average height floodwalls (Alternative 3A-2.1) are only marginally lower than those associated with 4-foot average height floodwalls (Alternative 3A-2.2), additional analysis was conducted prior to finalizing this report to determine whether the floodwall heights can be further optimized (i.e., whether net benefits are further maximized at an average height between 3 and 4 feet). However, the initial results were confirmed and the NED plan is based on an average floodwall height of 4 feet.

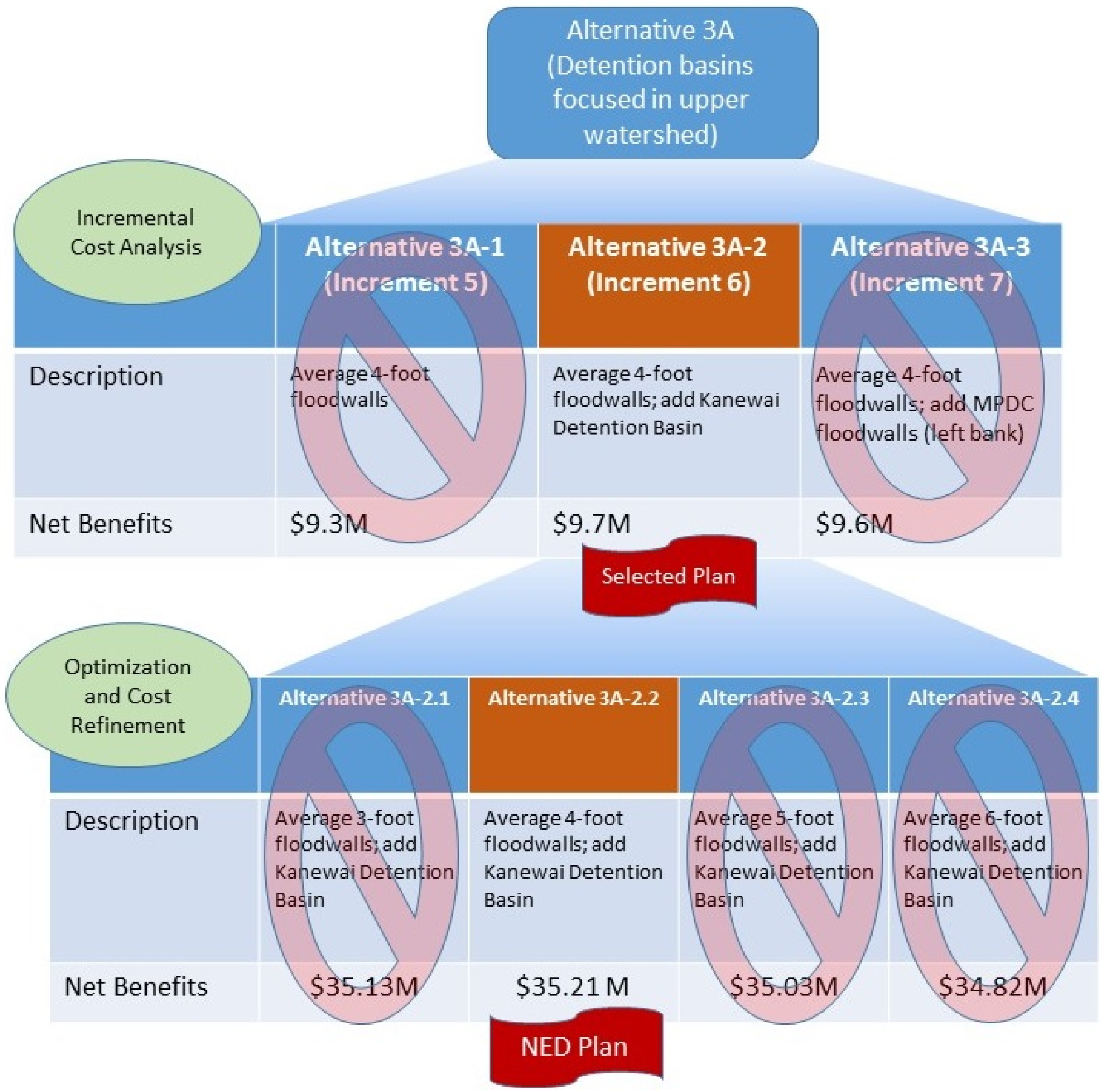


Figure 10. Identification of the NED Plan and the Recommended Plan

3.12 Selection of Recommended Plan

As described above, Alternative 3A-2.2 was identified as the NED plan; Federal policy requires that the NED plan be recommended for implementation unless there are overriding reasons for recommending another plan. The PDT reviewed the attributes of the NED plan relative to the planning objectives, criteria and engineering standards and determined that there were no overriding reasons that warranted recommendation of another plan, and as such identified the NED Plan as the recommended plan.

As part of this process, the PDT weighed the attributes of Alternative 3A-2.1 relative to those of the NED plan, as this alternative incorporates lower floodwalls (average height of 3 feet) with only a slight reduction in net benefits. Based on this evaluation, the PDT identified several important distinctions which underscore the designation of the NED plan as the recommended plan. In addition to maximizing net benefits, the NED plan provides an additional $2.2 million in expected annual benefits for only a minimal increase (approximately $211,000) in amoritized construction costs. Given these factors, the NED plan also provides for a more resilient and robust project, as further discussed in Section 8.3.

The only advantage of Alternative 3A-2.1 is that the floodwalls would be approximately one foot lower (at an average height of 3 feet), which would reduce the degree of potential visual impacts toward and along the Ala Wai Canal by increasing visibility over the floodwalls. However, this was not considered to be adequate justification for selection of Alternative 3A-2.1 as the recommended plan. It should be noted that the optimization of the floodwall heights was based upon the economic benefits and not to a specific level of protection, such as the 1% ACE flood event.

3.13 Compensatory Mitigation

Following identification of the recommended plan, the compensatory mitigation requirements were further refined for impacts to Waters of the U.S. (including streams and/or other aquatic resource functions).[15] This effort built upon the preliminary mitigation information that was originally incorporated into the Viable Array of Alternatives (as described in Section 3.6); the results fall within the range of mitigation requirements and costs that were identified to allow for evaluation and comparison of the alternatives.

Consistent with USACE regulations (ER 1105-2-100), which require that changes in habitat value be quantified using ecosystem output model, the Hawai'i Stream Habitat Equivalency Procedure (HSHEP) was used to quantify the loss of habitat function associated with implementation of the recommended plan. The HSHEP model was developed to support management of Hawai'i's streams and associated habitat for freshwater flora and fauna through a collaborative effort by biologists at the State of Hawai'i Division of Aquatic Resources (DAR) and researchers at various universities, agencies, museums, and private companies. To confirm its applicability to the Ala Wai Canal Project, the model was reviewed by the USACE Ecosystem Planning Center of Expertise (ECO-PCX), and was certified for project use on May 19, 2015. A detailed description of the HSHEP model and its applicability to the project is provided in Appendix E.

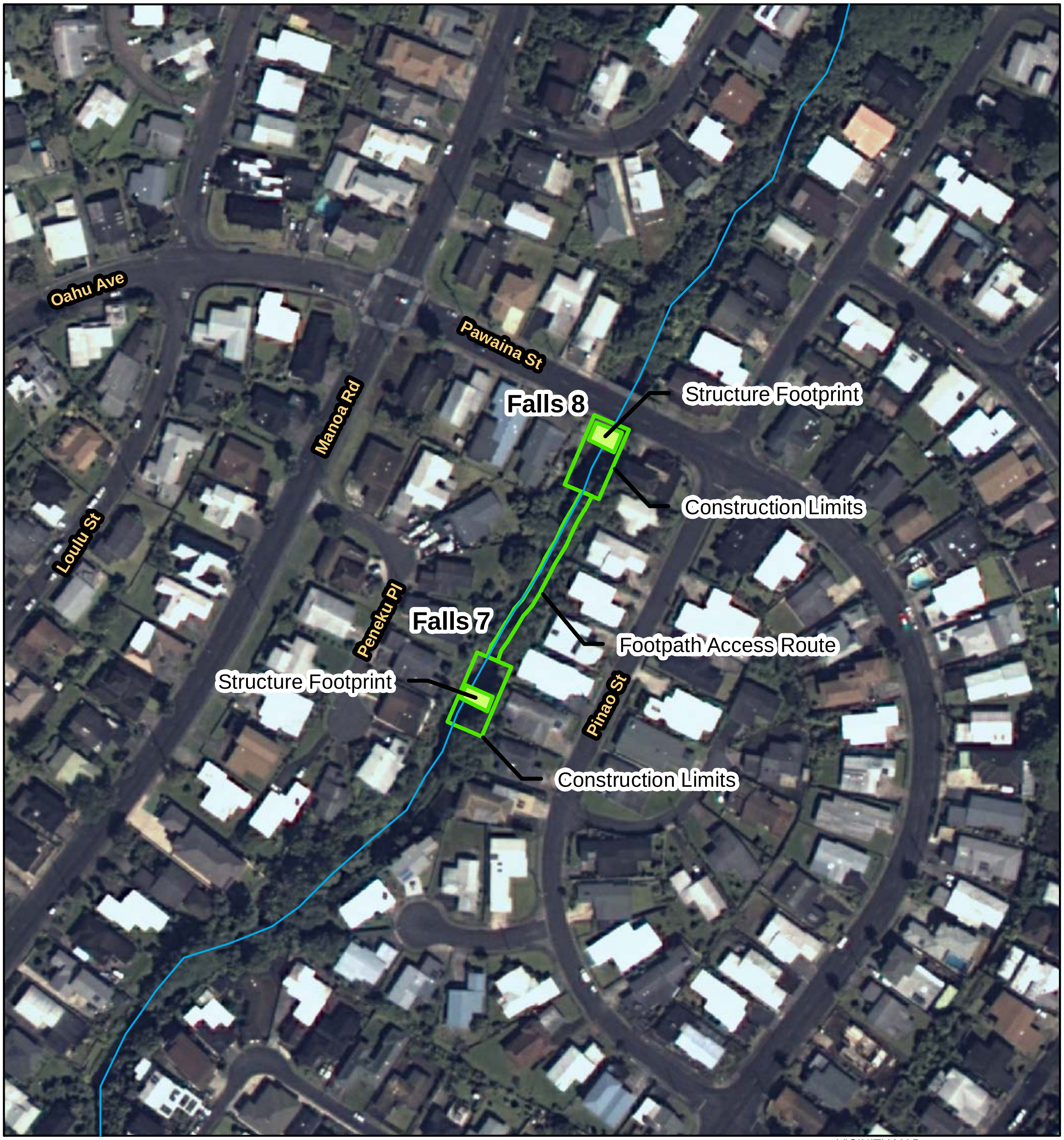
Detailed stream surveys were conducted throughout the watershed, with the resulting data processed according to the variables in the HSHEP model, as needed to quantify the habitat quality associated with the existing and future without-project condition (in terms of habitat units [HUs]). Anticipated changes in the model variables were then defined for the with-project condition, based on the conceptual design for the recommended plan. The modeling results were then compared, with the loss in habitat quality resulting from the with-project condition used to define the mitigation requirements.

The results of the stream surveys, in combination with best professional judgment, were also used to identify potential mitigation concepts that could be implemented to offset the anticipated loss of habitat quality. These

[15] Subsequent to screening of the Viable Array of Alternatives, it was determined there is not an adequate basis for consideration of upland forested habitat as a significant resource. Efforts have been incorporated into the design process to avoid and minimize impacts to the extent practicable; however, compensatory mitigation is not required for unavoidable impacts to upland (including non-wetland riparian) habitat.

concepts were refined through an iterative process, in coordination with the resource agencies, resulting in the identification of a suite of possible mitigation measures. The increase in habitat quality associated with each of the mitigation measures was quantified using the HSHEP model, and these results were used to combine the measures into different mitigation alternatives that could be implemented to compensate for the loss of habitat quality associated with the recommended plan. Each of the mitigation alternatives was developed to the 10-percent design level, and cost estimates (Class 4) were prepared. The habitat modeling results and the cost estimates were then used to complete a Cost Effectiveness and Incremental Cost Analysis (CE/ICA), which provided the basis for selection of the mitigation alternative to be included as part of the recommended plan.

Based on this process, the selected mitigation alternative is comprised of two measures, both of which involve in-stream improvements to eliminate a migratory passage barrier for native aquatic species in Mānoa Stream. The location of these measures is shown in Figure 11. In each location, there is currently an in-stream structure where undercutting has resulted in an overhanging lip (such that the stream flow is free-falling and does not maintain contact with the surface of the structures), which creates a passage barrier for native aquatic species. The proposed mitigation involves installation of grouted stone as part of the existing in-stream structure to provide a suitable surface for migration of the native species to upstream habitat. A detailed description of the mitigation development and selection process, and the conceptual mitigation design information is provided in Appendix E.



LEGEND

Stream

Compensatory Mitigation Measure

N

0 100 200
Feet

VICINITY MAP

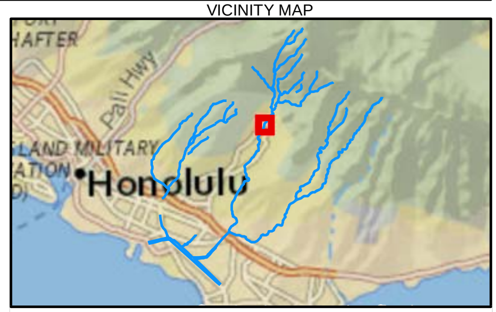


FIGURE 11
Compensatory Mitigation Measures
Ala Wai Canal Project
O'ahu, Hawai'i

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

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4.0 Summary of Alternatives

As described throughout Section 3, a range of alternative plans were identified as part of the plan formulation process. Several of the alternatives were eliminated from further consideration, resulting in a total of three alternatives that were carried through the plan formulation process (including the No Action alternative). These alternatives constitute the range of alternatives analyzed for the purpose of NEPA and HRS Chapter 343 compliance. Following is a summary of the alternatives that were eliminated from further consideration, followed by a brief description of the alternatives considered for the purposes of NEPA and HRS Chapter 343 compliance.

4.1 Alternatives Considered but not Evaluated in Detail

Both NEPA and HRS Chapter 343 require that an EIS describe alternatives that meet the objectives of the action, regardless of cost, in sufficient detail to explain why they were rejected. Following is a description of the alternatives that were considered but rejected from further evaluation. These include alternatives comprised of different flood-reduction measures in varying locations throughout the watershed, based on the broad flood-reduction strategies used to formulate the initial array of alternatives.

As described in Section 3, other approaches to reducing flood-related risks in the watershed, such as widening the Canal and modifying McCully Street Bridge, were eliminated in the early stages of formulation as they were determined to not be feasible or effective (see Table 3). Other locations outside of the watershed were not considered for implementation of flood-risk measures as these would not meet the planning objective, which is specific to reducing flood risk in the Ala Wai Watershed.

4.1.1 Maximize Attenuation in Upper Watershed (Single Large Dam)

As described in Section 3, one of the fundamental strategies contemplated in the plan formulation process was to attenuate the floodwaters entirely (or almost entirely) in the upper watershed. This concept was developed into Alternative 1A, and was designed to be an approximately 350-foot-wide dam across Waihi and Waiakeakua streams. The dam would be approximately 50 feet high, with two concrete and grouted rip-rap spillways. It would detain flows associated with the 1-percent ACE event, or approximately 17,000,000 cubic feet (390 acre-feet) of water.

However, based on the hydraulic modeling conducted over the course of the plan formulation process, it was determined that peak flow contribution occurs throughout the upper and middle reaches of the watershed. As such, the most effective location for a single, large dam would be in the middle of the watershed (where there is an adequately-sized drainage area), but given the density of urban development, this is not considered a practicable solution. In terms of providing detention in the upper watershed, smaller detention basins were found to outperform the single dam (i.e., substantially less cost for similar level of protection), with less transfer of risk to the downstream community. In addition, the single dam would impact more than three times the amount of area within the upper watershed (as compared to the smaller detention basins), which is expected to translate to proportionately more impacts to both biological and archaeological/cultural resources. In addition, the scale of the dam would result in greater visual impacts, as the structure would be more than twice the height of the detention structures. For these reasons, this alternative was rejected from further consideration.

4.1.2 Focus Solutions Where Most Damages Occur (Ala Wai Canal)

One of the other fundamental strategies considered in the plan formulation process was to address flooding through structural solutions along the Ala Wai Canal, which is the area where the most damage would occur. A variety of measures were initially considered, but most of these (such as pumping peak flows from the Canal, widening/deepening the Canal, and adding another outlet to the Canal) were eliminated in the early stages of formulation as they were determined to not be practicable or effective (see Table 3). One of the few remaining flood reduction measures that could be implemented along the Ala Wai Canal was the addition of floodwalls.

However, analyses previously conducted for the Ala Wai PAS Study indicated that in the absence of other flood risk management measures in the upper portions of the watershed, the floodwalls along the Ala Wai Canal would need to be up to 14 feet tall (USACE, 2001). This approach was determined to be unacceptable, primarily due to the visual impacts toward and along the Canal, as well as impacts to the Canal as a historic site; therefore, this alternative was dropped from further consideration. Shorter floodwalls were found to be an effective solution, when considered in combination with detention basins throughout the watershed; this approach is included as part of Alternatives 2A and 3A.

4.1.3 Non-Structural Plan

Consistent with USACE planning requirements, a purely non-structural plan was considered as part of the plan formulation process. Non-structural measures are proven methods and techniques for reducing the consequence of flooding (e.g., flood damages), and generally involve changing the use (or accommodating existing uses) in the floodplain, without changing the extent and nature of the flood itself. They include such measures as raising, relocating and acquiring or buying-out structures, floodproofing, and building individual berms and floodwalls to protect small cluster of buildings.

As detailed in Appendix B, the non-structural plan was formulated by screening for structures that sustain enough damage to economically justify some kind of non-structural solution. An iterative screening process was used to evaluate the economic justification for individual buildings. Through this process, it was determined that the non-structural plan would not reduce the overall flood risk in the watershed sufficiently to meet the project objective. Ultimately, the only structures that are justified for inclusion in the non-structural plan are selective properties with a high concentration of value. Such an alternative does not adequately meet the project objective, nor would it be considered socially fair or politically acceptable. The stand-alone non-structural alternative was, therefore, dropped from further evaluation.

4.2 Alternatives Carried Forward

4.2.1 No Action (Future Without-Project)

The future without-project condition is defined as the most likely condition expected to exist in the future in the absence of the project, and serves as the benchmark against which other alternatives are evaluated. In general, future without-project forecasting should account for conditions such as climate variability, sea-level rise, subsidence, geomorphologic changes, and changes in development over the 50-year period of analysis. Based on an analysis of the anticipated future conditions within the watershed, the future without-project condition for this study were defined according to changes in sea-level, rainfall frequency, debris generation and transport, and extent of impervious area. Substantial changes in land subsidence, seismic influences, and geomorphologic conditions are not expected over the period of analysis, so were not further evaluated. A detailed discussion of these conditions is provided in Section 5.

Under the No Action (future without-project) alternative, the Federal government would take no action toward implementing a specific flood risk management plan. A large portion of the watershed, including approximately 54,000 residents (plus 79,000 visitors), would remain within the 1-percent ACE floodplain. In addition to threatening public health and safety, a large-scale flood event would be expected to result in significant structural damages throughout the watershed, including most (if not all) of the Waikīkī District; estimated structural damages associated with the 1-percent ACE flood are approximately $1.14 billion. Emergency costs associated with responding to the flood event, impacts to critical infrastructure, and disruptions to local business would also be substantial.

4.2.2 Recommended Plan (Alternative 3A-2.2)

The recommended plan is comprised of a series of in-stream debris and detention basins in the upper reaches of the watershed (one in Makiki, three in Mānoa, and two in Pālolo), one stand-alone debris catchment feature in the middle reach of Mānoa Stream, three multi-purpose detention basins in open spaces adjacent to the streams/Canal (Kanewai Field, Ala Wai Community Park, and Ala Wai Golf Courses), floodwalls along most of the

Ala Wai Canal (at an average of 4 feet high) and the Manoa Palolo Drainage Canal along with two associated pump stations, and improvements to the flood warning system. In addition, the plan includes removal of two migratory passage barriers for native aquatic species in Mānoa Stream as compensatory mitigation for impacts to aquatic habitat. A brief description (including the approximate extent of disturbance) of each measure, as well as the associated O&M activities, is presented in Table 17; the location of the measures is shown in Figure 12. Figure 14 shows the locations of measures included in the recommended plan following refinement outlined in Iteration 4 (Section 3.10).

4.2.3 Alternative 2A

As described for the plan formulation process, several of the measures in Alternative 2A are also part of the recommended plan; these include several of the multi-purpose detention basins, the Ala Wai Canal floodwalls (but at an average height of approximately 5 feet) and improvements to the floodwarning system. Differences between Alternative 2A and the recommended plan include (1) debris catchment features in the upper watershed rather than debris and detention basins and (2) additional detention in the urbanized watershed (Mānoa District Park) in lieu of detention in the upper watershed. Given the smaller project footprint in the upper watershed, it is expected that Alternative 2A would require slightly less compensatory mitigation for impacts to Waters of the U.S. than the recommended plan (although the reduced impacts in the upper watershed would be at least partially offset by the need for a 600-foot-long culvert along the edge of Mānoa Stream, as needed to divert flood waters to the Mānoa District Park detention basin). A detailed analysis of the mitigation requirements was not conducted, but it is assumed that the compensatory mitigation measures (or a subset of those measures) defined for the recommended plan would also be incorporated as part of Alternative 2A (see Figure 11).

Based on the process described in Section 3.6, additional analysis and refinement of Alternative 2A was not conducted subsequent to the evaluation and comparison process, such that Alternative 2A is based on the information described for the final array of alternatives. A brief description (including the approximate extent of disturbance) of each measure is presented in Table 17; the location of each measure is shown in Figure 13. The O&M requirements are also listed in Table 17; these are expected to be similar in nature to those required for the recommended plan, but the level of effort (and associated cost) is assumed to be higher as the measures in Alternative 2A require a larger area to be maintained (e.g., cutting/clearing vegetation).

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Table 18. Summary of the Recommended NED Plan and Alternative 2A (Iteration 3)

Measure	Alt.		Description of Measure	O&M Requirements	Total Area of Disturbance		Permanent Structure Footprint		Temporary Disturbance (e.g., Staging) (ac)	Vegetation Management		Extent of Inundation (duration for 1% ACE)
	2A	NED			Total Area (ac)	Length of Stream (ft)	Total Area (ac)	Length of Stream (ft)		Total Area (ac)	Length of Stream (ft)	
MĀNOA												
Waihi Debris and Detention Basin		•	Earthen structure, approximately 37 feet high and 225 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of structure) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	1.5	355	0.8	355	0.1	0.3	40	1.35 acres inundated for up to 4.5 hours
Waihi Debris Catchment	•		Concrete pad, approximately 8 feet wide and 140 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of concrete pad) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	0.3	48	0.07	8	0.1	0.2	40	None
Waiakeakua Debris and Detention Basin		•	Earthen structure, approximately 34 feet high and 185 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of structure) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	1.7	350	1.0	350	0.1	0.5	40	3.2 acres inundated for up to 9 hours
Waiakeakua Debris Catchment	•		Concrete pad, approximately 8 feet wide and 140 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of concrete pad) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	0.2	48	0.03	8	0.1	0.2	40	None
Woodlawn Ditch Detention Basin	•	•	Three-sided berm, approximately 15 feet high and 840 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area.	1.9	120	1.1	60	0.1	1	40	1.7 acres inundated for up to 10 hours
Po'elua Place Debris Catchment	•		Earthen berm and debris catcher with metal poles to capture debris on east side of Mānoa Stream; grate with inlet to culvert for intake of water to the Mānoa District Park multi-purpose detention basin.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	0.6	165	0.2	0	0.1	0.1	0	None
Mānoa In-stream Debris Catchment		•	Concrete pad, approximately 8 feet wide and 60 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of concrete pad) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	0.1	48	0.01	8	0.1	0.1	40	None
Mānoa District Park Multi-Purpose Detention Basin	•		Earthen berm (approximately 13 feet high) around 3 sides of Mānoa District Park; 600-foot-long culvert from Poelua Place to detention basin; concrete spillway with grouted rip-rap on detention and stream side; 2-foot drain pipe to release water back to Mānoa Stream	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for park use (with no woody vegetation) during non-flood conditions.	12.9	600	2.2	0	0.1	9.4	0	6.6 acres inundated for up to 10 hours
Innovation Center Improvements	•		Decrease existing grade to allow high flows onto the site; debris catcher installed with metal pipes along edge of site to catch debris as flows re-enter Mānoa Stream.	Cut/clear vegetation within cleared zoned (entire site) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	1.1	0	1	0	0.1	1	0	None
Kanewai Field Multi-Purpose Detention Basin	•	•	Earthen berm, approximately 9 feet high, around 3 sides of the field; grouted rip-rap inflow spillway along bank of Mānoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for park use (with no woody vegetation) during non-flood conditions.	6.1	70	0.9	70	0.1	5.5	0	5.1 acres inundated for up to 10 hours
PĀLOLO												
Waiʻōmaʻo Debris and Detention Basin		•	Earthen structure, approximately 33.5 feet high and 120 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert. Excavation of approx. 3,060 yd^3 to provide required detention volume upstream of berm; new access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of structure and excavation area) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	1.6	720	0.5	320	0.1	1.1	40	1.0 acre inundated for up to 10 hours
Waiʻōmaʻo Debris Catchment	•		Concrete pad, approximately 8 feet wide and 50 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of concrete pad) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	0.4	48	0.1	8	0.1	0.1	40	None
Pūkele Debris and Detention Basin		•	Earthen structure, approximately 30 feet high and 120 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of	Cut/clear vegetation within cleared zoned (20 feet around perimeter of structure) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	1.6	810	0.4	310	0.1	0.1	40	0.8 acre inundated

Table 18. Summary of the Recommended NED Plan and Alternative 2A (Iteration 3)

Measure	Alt.		Description of Measure	O&M Requirements	Total Area of Disturbance		Permanent Structure Footprint		Temporary Disturbance (e.g., Staging) (ac)	Vegetation Management		Extent of Inundation (duration for 1% ACE)
	2A	NED			Total Area (ac)	Length of Stream (ft)	Total Area (ac)	Length of Stream (ft)		Total Area (ac)	Length of Stream (ft)	
			culvert; energy dissipation structure to be located on downstream end of culvert. Excavation of approx. 14,330 yd³ to provide required detention volume upstream of berm; new access road to be constructed for construction and O&M.									for up to 9 hours
Pūkele Debris Catchment	•		Concrete pad, approximately 8 feet wide and 25 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of concrete pad) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	0.2	48	0.1	8	0.1	0.1	40	None
Mānoa-Pālolo Canal Floodwalls	•		Add concrete floodwalls (9 to 12 feet in elevation) along the right bank of the Canal from the Ala Wai Canal to Date Street.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of floodwalls) twice per year, allowing no woody vegetation to grow in this area.	2.1	0	0	0	0.1	0	0	None
MAKIKI												
Roosevelt Debris and Detention Basin	•		Earthen structure, approximately 24 feet high and 260 feet across; arch culvert to allow small storm flows to pass; concrete spillway with grouted rip-rap on the upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of structure) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	1.1	170	0.5	120	0.1	0.2	40	0.8 acre inundated for up to 9 hours
Makiki Debris and Detention Basin	•	•	Earthen structure, approximately 24 feet high and 100 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of structure) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	1.5	780	0.4	310	0.1	0.1	40	0.5 acre inundated for up to 9 hours
ALA WAI												
Ala Wai Canal Floodwalls	•	•	Concrete floodwalls, offset from existing Canal walls. Floodwalls would range up to 4 feet high for the recommended plan and up to 5 feet high for Alt. 2A. Existing stairs to be extended and new ramps to be installed to maintain access to Canal; floodgate to be installed near McCully Street. Two pump stations to accommodate storm flows and gates installed at existing drainage pipes to prevent backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of floodwalls) twice per year, allowing no woody vegetation to grow in this area. Periodically inspect drainage pipes and gates, and remove any impediments to movement. Inspect, test, and maintain pump systems annually. Paint and/or grease metal parts, as needed.	11.8	0	0.3	0	0.3	0	0	None
Hausten Ditch Detention Basin	•	•	Concrete floodwalls and an earthen berm (approximately 4.3 feet high) to provide detention for local drainage; install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to prevent a backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm and floodwalls) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for recreational use during non-flood conditions. Periodically inspect slide gates and actuators and remove any impediments to movement. Paint and/or grease metal parts, as needed.	1.4	70	0.2	35	0.1	1.1	35	3.5 acres inundated for up to 4 hours
Ala Wai Golf Course Multi-Purpose Detention Basin	•	•	Earthen berm, on average 2.7 feet high, around the north and east perimeter of the golf course; grouted rip-rap inflow spillway along bank of Mānoa-Pālolo Drainage Canal to allow high flows to enter the basin; sediment basin within western portion of golf course; floodgate across the main entrance road; passive drainage back into Ala Wai Canal.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a golf course (with no woody vegetation in sediment basin) for recreational use during non-flood conditions. Periodically inspect floodgate and remove any impediments to movement. Paint and/or grease metal parts, as needed.	25.6	70	4	70	0.6	8.4	0	134 acres inundated for up to 10 hours
NON-STRUCTURAL												
Floodwarning System	•	•	Installation of 3 real-time rain gages (Mānoa, Makiki, and Pālolo streams) and 1 real-time streamflow or stage gage (Ala Wai Canal) as part of flood warning system for Ala Wai Watershed.	Periodically inspect gages for proper operating conditions. Keep area around sensors free from sediment deposits and plant growth, or other impediments to data collection.	minimal	minimal	minimal	minimal	minimal	0	0	None
COMPENSATORY MITIGATION												
Falls 7 and 8	•	•	Installation of grouted stones to eliminate passage barrier by providing a suitable surface for migration of native species at 2 in-stream structures.	Periodically inspect in-stream structure for potential erosion or undercutting; reinforce as needed.	0.05	110	0.004	10	0.05	0	0	None
TOTAL FOR ALTERNATIVE 2A					**67.3**	**2347**	**11.1**	**707**	**2.3**	**27**	**315**	**152.6**
TOTAL FOR ALTERNATIVE 3A (NED Plan)					**57.0**	**3503**	**9.5**	**1898**	**2.0**	**18**	**315**	**147.7**

Note:
NED = National Economic Development Plan; the recommended plan

LEGEND

- Stream
- Watershed Boundary
- 1- Percent Annual Chance Exceedance Floodplain (with Implementation of Tentatively Selected Plan)
- Flood Risk Management Measure

0 0.5 1 Miles

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

VICINITY MAP

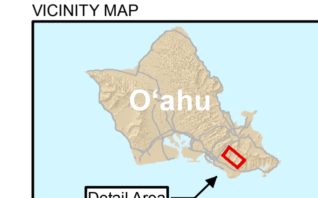


FIGURE 12a
Tentatively Selected Plan (Alternative 3A-2.2) - Upper Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

CH2MHILL

LEGEND

- Stream
- Watershed Boundary
- 1- Percent Annual Chance Exceedance Floodplain (with Implementation of Tentatively Selected Plan)
- Flood Risk Management Measure

0 0.5 1 Miles

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

VICINITY MAP

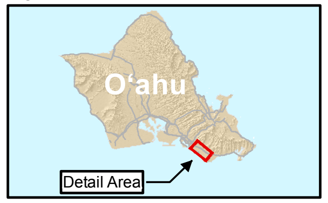
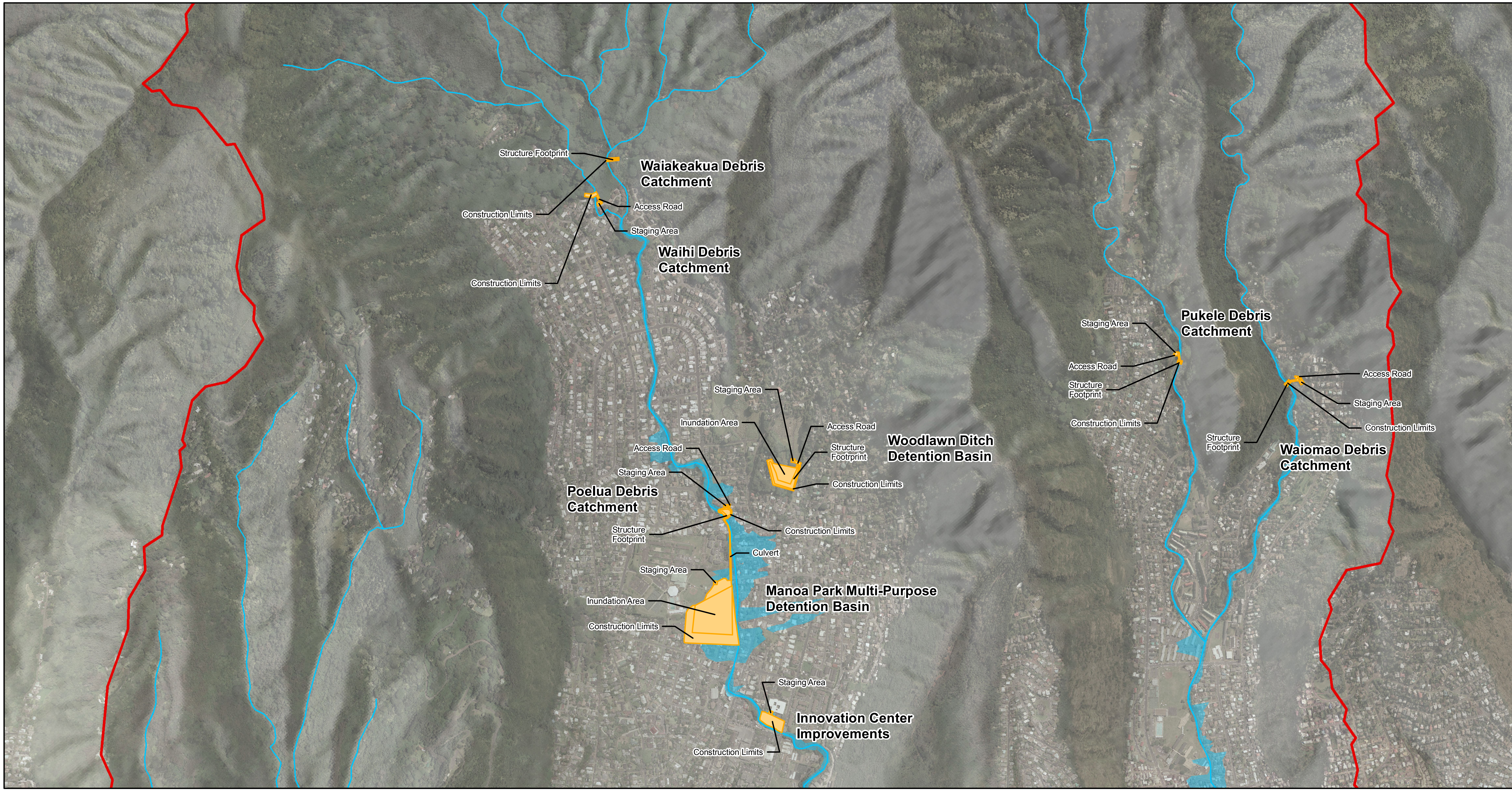


FIGURE 12b
Tentatively Selected Plan (Alternative 3A-2.2) - Lower Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

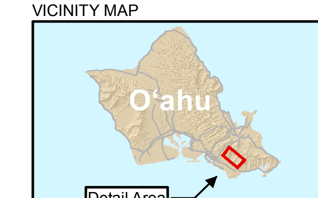
CH2MHILL



LEGEND

- Stream
- Watershed Boundary
- 1-Percent Annual Chance Exceedance Floodplain
- Flood Risk Management Measure

VICINITY MAP



0 0.5 1 Miles

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

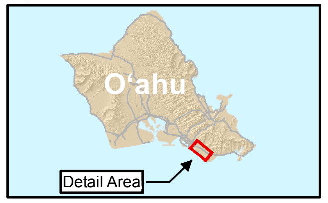
FIGURE 13a
Alternative 2A - Upper Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

CH2MHILL

LEGEND

- Stream
- Watershed Boundary
- 1-Percent Annual Chance Exceedance Floodplain
- Flood Risk Management Measure

VICINITY MAP



0 0.5 1 Miles

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

FIGURE 13b
Alternative 2A - Lower Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

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LEGEND

- Stream
- Watershed Boundary
- 1- Percent Annual Chance Exceedance Floodplain (with Implementation of Recommended Plan)
- Flood Risk Management Measure

0 0.5 1 Miles

N

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

VICINITY MAP

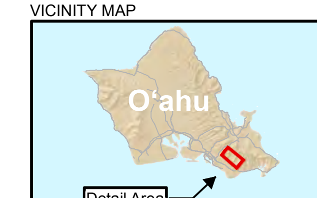

FIGURE 14a
Recommended Plan
(Alternative 3A-2.2) - Upper Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

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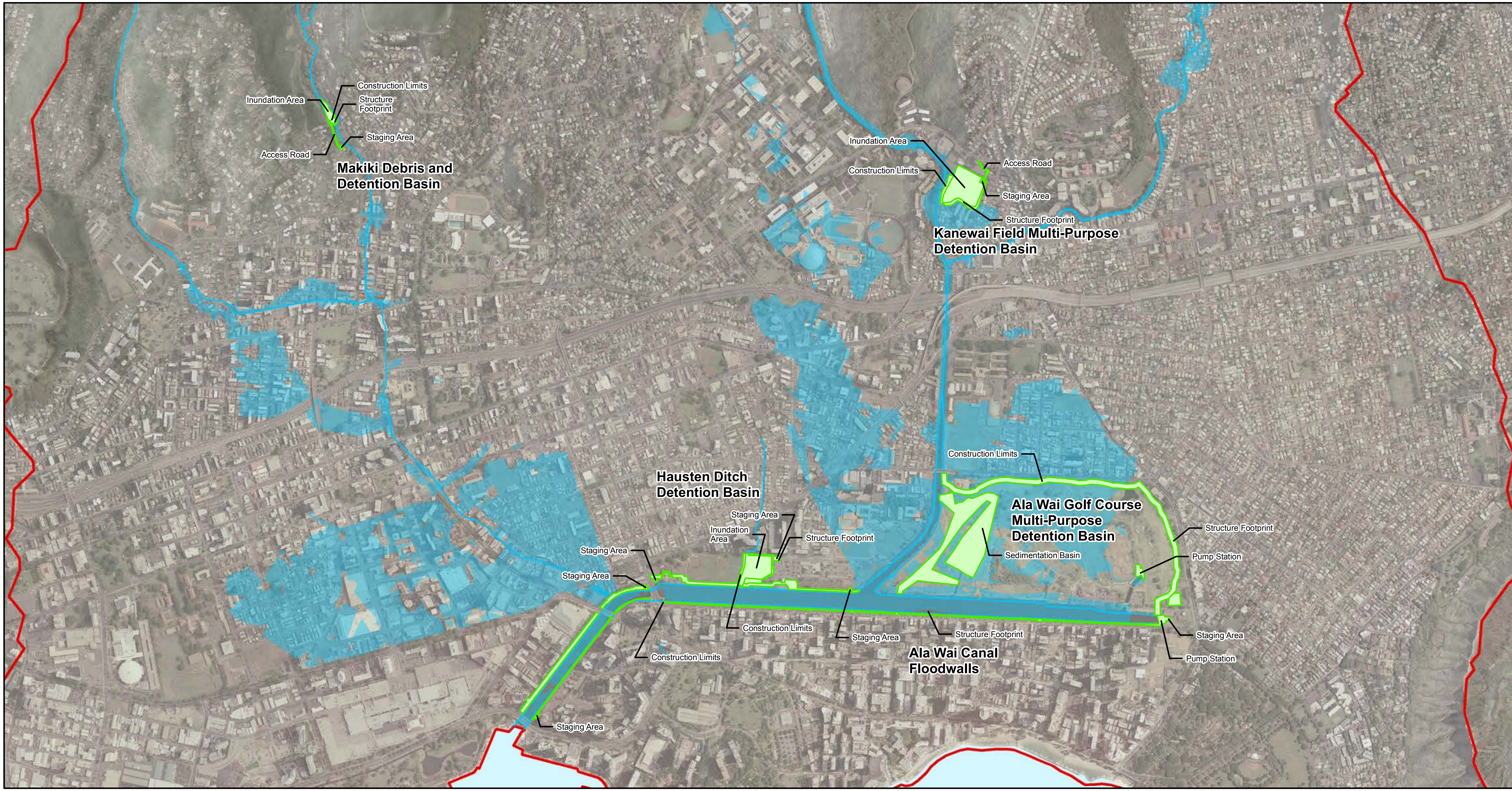

LEGEND

Stream

Watershed Boundary

1- Percent Annual Chance Exceedance Floodplain (with Implementation of Recommended Plan)

Flood Risk Management Measure

0 0.5 1 Miles

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

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VICINITY MAP

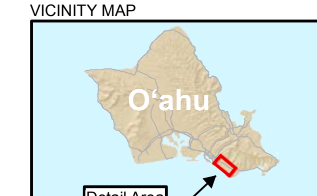

FIGURE 14b
Recommended Plan
(Alternative 3A-2.2) - Lower Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

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5.0 Affected Environment (Existing Conditions) and Environmental Consequences

5.1 Introduction

Pursuant to NEPA and its implementing regulations (40 CFR Part 1500 through Part 1508), Federal agencies are required to assess the environmental effects of their proposed actions before making decisions. Similarly, HRS Chapter 343 and its implementing rules (Hawai'i Administrative Rules [HAR] 11-200) also require environmental review for projects that include certain regulatory triggers; in the case of this project, DLNR is required to comply with HRS Chapter 343 given the use of State and County lands or funds, use of the Conservation District, use within a historic site (as designated in the Hawai'i Register), and use within the Waikīkī District. The purpose of both NEPA and HRS Chapter 343 is to inform decision-makers and the public of the likely environmental effects of a proposed action and its alternatives.

HRS 343-5(f) states that "[w]henever an action is subject to both the National Environmental Policy Act of 1969 … and the requirements of [HRS 343], the [Office of Environmental Quality Control (OEQC)] and agencies shall cooperate with Federal agencies to the fullest extent possible to reduce duplication between Federal and State requirements. Such cooperation, to the fullest extent possible, shall include joint environmental impact statements with concurrent public review and processing at both levels of government. Where Federal law has environmental impact statement requirements in addition to but not in conflict with [Chapter 343, HRS], the [OEQC] and agencies shall cooperate in fulfilling these requirements so that one document shall comply with all applicable laws." Under NEPA, the Federal agency is responsible for determining whether an EIS is required, based on assessment of whether a Federal action has the potential to "significantly affect the quality of the human environment." In the case of HRS Chapter 343, an agency may determine that an EIS is required, thereby choosing to not prepare an environmental assessment (EA) and instead proceeding directly to preparation of an EIS, beginning with an EIS Preparation Notice (EISPN) as provided by the rules. In the case of this project, it was determined that an EIS was the proper form of compliance under both NEPA and HRS Chapter 343; pursuant to 343-5(f), this report serves as a joint document. Pursuant to the respective requirements of NEPA and HRS Chapter 343, a Notice of Intent (NOI) to prepare an EIS was published in the Federal Register on October 2, 2008,[16] and an EISPN was published in OEQC's Environmental Bulletin on October 23, 2014.

Consistent with the intent of NEPA and HRS 343, this chapter presents information on the existing conditions for the affected environment and describes the consequences of implementing each alternative, based on the range of resources that comprise the human and natural environment. Specific requirements and considerations for these analyses are discussed below.

5.1.1 Affected Environment

For each resource, the existing conditions within the project area are described, with a brief summary of historic conditions where applicable. The analysis of effects described in the subsequent Environmental Consequences section uses the Affected Environment description as the baseline to identify changes to the resource under future with- and without-project conditions. In addition to the environmental setting, this section also describes the regulatory setting, as appropriate. Key regulatory compliance activities are described in the subsections below, as appropriate; the status of regulatory compliance is further addressed in Section 7.0. Additional detail regarding applicable regulations and policies is provided in Appendix E.

For most resources, the area of concern is generally limited to the construction limits for each measure, as shown in Figures 11 through 13. However, for some resources, the project-related effects must be considered

[16] An NOI was originally published on June 14, 2004 (69 Federal Register [FR] 32996) with a supplemental NOI published on October 2, 2008 [73 FR 57339) to address the scope changes in the FCSA Amendment 1, dated December 2006.

within the context of the surrounding vicinity. For example, the evaluation of land use, aesthetics, noise, traffic, and socioeconomics also includes the surrounding areas. Potential effects relative to resources that occur across a broader area – climate, geology, and air quality – were considered at a regional scale.

Although environmental conditions are generally subject to some change over time, most of these resources are not expected to change significantly under the without-project condition over the period of analysis. However, any changes expected in the future-without-project condition are described in the Environmental Consequences section for the No Action alternative, as further described below.

5.1.2 Environmental Consequences

The evaluation of environmental consequences involves the comparison of the effects of each alternative plan relative to the No Action (future without-project) conditions. Environmental consequences (also referred to as effects or impacts) may be adverse or beneficial, and include both direct and indirect effects. Direct effects are caused by the action and occur at the same time and place; indirect effects are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. For those resources that may be adversely affected, measures that would be implemented to mitigate the potential impacts are described. The approach taken for mitigation follows the recommended steps set forth by the President's Council on Environmental Quality in the NEPA regulations (40 CFR Part 1508.20 [a-e]), and includes (in order of preference) avoidance, minimization, and compensation.

Criteria were identified for each resource to assist with evaluation of the potential for significant adverse effects; the criteria are based on the definitions of significance and the specific considerations identified for NEPA (40 CFR 1508.27) and HRS Chapter 343 (HAR 11-200-12), as well as other standards of professional practice. Based on the significance criteria, the analysis presented for each resource concludes the degree of potential impact as one of the following:

- **Beneficial**. This effect would provide benefit to the environment as defined for that resource.
- **No Effect**. This effect would cause no discernible change in the environment as measured by the applicable significance criteria; therefore, no mitigation would be required.
- **Less than Significant**. This effect would cause no substantial adverse change in the environment as measured by the applicable significance criteria; in general, no mitigation would be required (but in some cases may be incorporated as a best practice or to meet other regulatory requirements).
- **Significant**. This effect would cause a substantial adverse change in the physical conditions of the environment or as otherwise defined based on the significance criteria. Effects determined to be significant fall into two categories: those for which there is feasible mitigation available that would avoid or reduce the environmental effects to less-than-significant levels, and those for which there is either no feasible mitigation available or for which, even with implementation of feasible mitigation measures, there would remain a significant adverse effect on the environment. Those effects that cannot be reduced to a less-than-significant level by mitigation are identified as significant and unavoidable.

For each identified impact and associated mitigation measure (if applicable), a discrete impact and mitigation number is indicated (IMP and MM, respectively); these numbers allow for a quick reference between the text and the summary of impacts (as provided in Table ES-6). Based on the plan formulation strategy, as described in Section 3, the recommended plan and Alternative 2A share many similarities, but differ in terms of a few key measures. Given this, the discussion of impacts associated with Alternative 2A focuses only on the differences from the recommended plan.

5.2 Geology, Seismicity and Soils

5.2.1 Affected Environment

5.2.1.1 Regulatory Framework

Regulations and policies that relate to geology, seismicity, and soils and are being considered as part of the proposed project include the following:

- Clean Water Act, Section 402
- HRS Chapter 342D (*Water Pollution*), with implementing rules in HAR 11-55
- Revised Ordinances of Honolulu (ROH), Chapters 16 (Building Code)

5.2.1.2 Environmental Setting

Geologic Conditions

The Ala Wai Watershed lies on the southern slope of the Koʻolau volcano, the younger and more easterly of two shield volcanoes that built the island of Oʻahu. Much of the eastern side of the Koʻolau volcanic shield has been removed through erosion and structural collapse; the remnants form the Koʻolau Mountain Range. The Koʻolau Mountain Range has been deeply dissected by erosional forces, resulting in gullies and gulches separated by steep ridges. Tributary streams generally originate in the upper elevations of the watershed and join to form single master streams (such as Mānoa Stream), converging in deep and wide valleys. Alluvial soil from the ridges and mountainous areas has been gradually removed by sheet erosion and transported to the lower valley floor by surface runoff, accumulating as thick alluvial sequences. The Honolulu coastal plain, which generally extends from Pearl Harbor to Koko Head, is comprised of interlayered terrigenous and marine sediments and calcareous materials, as well as volcanic deposits produced by rejuvenated-stage volcanism (Stearns, 1939).

Seismicity

In Hawaiʼi, seismicity is closely linked with volcanism; earthquakes tend to be concentrated in volcanically active areas, primarily around the island of Hawaiʼi. In the area encompassing Oʻahu and Maui, seismicity is generally related to tectonic activity along seafloor fractures and faults, such as the Diamond Head Fault, which extends along the seafloor northeast of Oʻahu (Furumoto et al., 1990). Several earthquakes ranging in magnitude from 4.0 to 5.0 have been historically documented along this fault (Fletcher et al., 2002). Although the seismic risk on Oʻahu is relatively low compared to more volcanically active areas, the sedimentary layer that underlies Honolulu, particularly along the shoreline, is more prone to heightened ground motion than adjacent areas of bedrock (Fletcher et al., 2002; Furumoto et al., 1990). In 1997, the Uniform Building Code (UBC) seismic risk ranking for Oʻahu was upgraded from 1 to 2A, indicating a higher risk of seismicity than previously thought.[17] The current seismic site class code is the International Building Code (IBC).

Subsidence

The potential for and rate of subsidence in Hawaiʼi is generally linked to volcanic activity (and the associated weight of material contributed by the active volcanoes), with the rate of subsidence increasing with proximity to currently active volcanoes. As such, the highest rates of subsidence occur on Hawaiʼi Island, where geologically young volcanic rocks are causing flexure in the underlying lithosphere. Some degree of subsidence also occurs on Maui, because of its proximity to Hawaiʼi Island and its relatively young geological age. In contrast, the islands of Oʻahu and Kauai lie outside the area of subsidence, and are subject to uplift due to material moving down and outward from the subsidence zone. In general, Oʻahu and Kauai are considered relatively stable; rates of uplift have been less than 0.1 millimeter per year (mm/yr) since the last interglacial period with an estimated mean of 0.06 mm/yr over the last 200,000 years (Fletcher and Jones, 1996; Caccamise, 2003).

[17] The UBC system classifies seismic hazards on the basis of the expected strength of ground shaking and the probability of the shaking actually occurring within a specified time. The ranking is based on six seismic zones, ranging from 0 (no chance of severe ground shaking) to 4 (10 percent chance of severe shaking in a 50-year interval).

Surface Soils

Based on maps published by the USDA (1972), the soil series and land types in the Ala Wai Watershed are summarized below; additional information, including the physical and engineering properties of each soil type, is contained in the *Final Geotechnical Assessment for the Ala Wai Watershed* (Pacific Geotechnical Engineers, Inc., 2009).

The uppermost portion of the watershed generally consists of rocky mountainous land, where the ground surface is very steep and soil cover is very thin. Upper Mānoa and Pālolo Valleys are dominated by Lolekaa soils, which are derived from older alluvium and colluvium deposited at the foot of steep, mountainous areas. The alluvium and colluvium that cover the valley floors and extend along the stream channels are mapped as Hanalei and Ka'ena soil series in Mānoa Valley, and as Lualualei, Kawaihapai, and Ka'ena soil series in Pālolo Valley; these are all younger, unconsolidated soils. Surface soil conditions in Makiki Valley are dominated by volcanic cinders; these include Tantalus soils in the upslope areas and Makiki soils in the downslope areas. Some of the sidewalls of the gulches carved by the tributary streams are mapped as Rock land. Deposits of younger alluvium found in portions of these gulches and at the lower end of Makiki Stream are mapped as Ka'ena and Kawaihapai soil series.

A large portion of the coastal plain within the watershed consists of fill (Sherrod et al., 2007), including some areas mapped as Pearl Harbor soil and Jaucus sand. Based on data from available borings drilled in the area, fill materials were placed on lowlands and shallow offshore areas, and are largely underlain by younger, underconsolidated alluvium and marsh and lagoonal deposits. Portions of the Honolulu coastal plain are mapped as ʻEwa soil, which generally consists of younger alluvium underlain by limestone.

Landslides and Debris Flows

Landslides include a variety of processes that result in the downward and outward movement (e.g., falling, sliding, spreading, or flowing) of slope-forming materials, such as rock, soil, or fill. They typically involve substantial volume of material, and occur in soft, clay-rich colluvium (often far removed from streams). Previously documented landslides within the watershed include the Paty-Alani landslide and the Hulu-Woolsey Landslide, both of which occurred on the eastern side of Mānoa Valley in 1988, as well as the previous Waiʻōmaʻo Slide in Pālolo Valley. These were generally slow-moving landslides, which involve incremental movement of land that remains saturated over a relatively long period of time (Baum and Reid, 1992).

In contrast to slow-moving landslides, debris flows (also referred to as soil avalanches, mud flows, or mudslides) are related to intense rainfall on steep hillslopes, wherein the mass of sliding soil with the underlying bedrock and overtopping vegetation moves rapidly, typically down a drainage channel, potentially damaging homes and other structures located in its path. Previous studies have investigated debris flow events and hazards in the project vicinity. Based on a landslide inventory by Peterson et al. (1993), most debris flows in the Ala Wai Watershed occur in the upper slopes of the Koʻolau Range where annual rainfall is greatest, exceeding 150 inches. Historical debris flows are concentrated in the headwaters of Waihi Stream, on the east crest of Waʻahila Ridge in upper Pūkele Stream, and around Kaʻau Crater.[18] Ellen et al. (1993) developed a debris-flow hazard map for southern Oʻahu from Moanalua Stream to Makapuʻu Point, which includes the Ala Wai Watershed. Although not intended to predict debris flow locations, the map is designed to provide a large-scale overview of potential hazards in areas underlain by Koʻolau basalt based on average long-term debris flow properties. It defines areas with high hazard (return period of 500 years or less), moderate hazard (return periods of 501 to 2,000 years) and low hazard (return periods of 2,001 to 10,000 years) (Ellen et al., 1993). The portion of the hazard map that covers the Ala Wai Watershed area is shown in Figure 15. The results of this study indicate that the potential landslide hazard is greatest in highly weathered soil on steep slopes in areas of high annual rainfall.

As part of a separate study, Deb and El-Kadi (2009) assessed shallow landslide hazards in southern Oʻahu using a deterministic model called SINMAP. The model uses slope-stability parameters and geotechnical data to create a

[18] The inventory did not include landslide activity on the Honolulu Volcanic rocks in the upper Makiki watershed.

soil cohesion index and hydrologic data to create a wetness index. These data were then applied to a geographic information system (GIS) framework with topographic data and land cover data to compute a stability index. This index classifies areas by various degrees of susceptibility from low to very high. In general, the areas of high to very high susceptibility are similar to the moderate and high debris-flow hazard areas identified in Ellen et al. (1993).

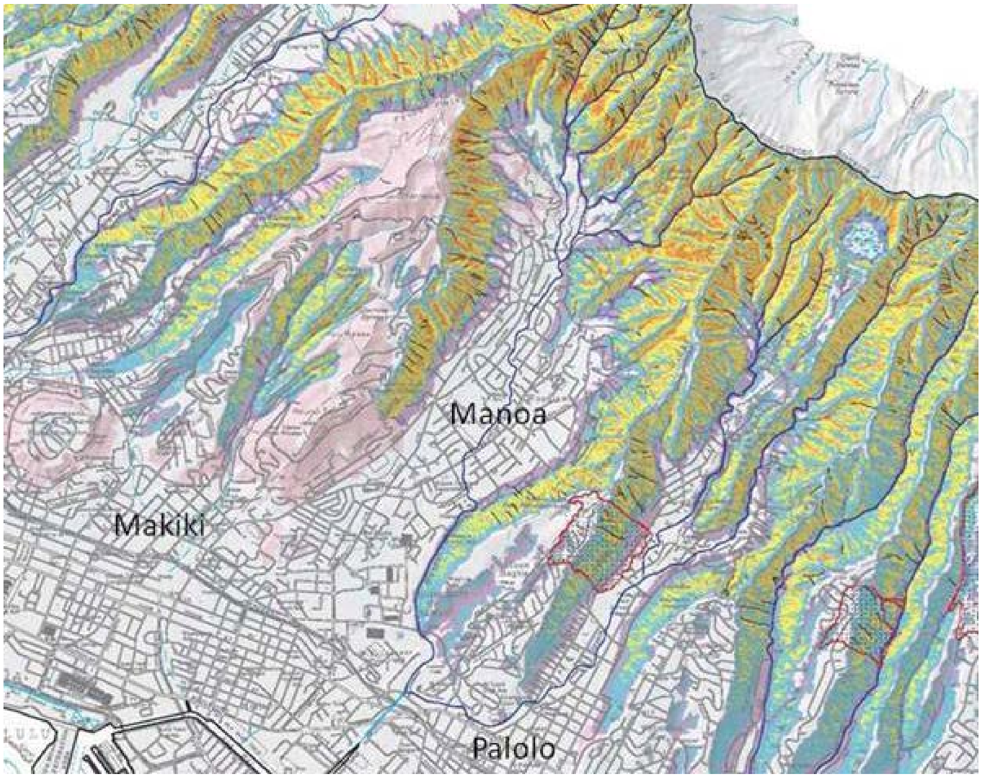

Figure 15. Portion of Landslide Hazard Map

Note: Orange represents high hazard areas, yellow represents moderate hazard areas, and blue are low hazard areas. Purple areas indicate possible hazards under extreme conditions, and pink areas were not evaluated. The red outlined dotted area represents an increased hazard because of windblown soil deposits (Ellen et al., 1993).

5.2.2 Impacts and Mitigation

Effects on geology, seismicity, and soil conditions were considered to be significant if implementation of an alternative would result in any of the following:

- Substantially alter an important natural geologic feature
- Cause substantial soil erosion
- Increase exposure of people or structures to seismic-related hazards
- Substantially contribute to an increased potential for (or otherwise be affected by) an onsite or offsite landslide/debris flow, subsidence, liquefaction, or collapse

The potential effects to geology, seismicity, and surface soil conditions that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.2.2.1 No Action Alternative

Under the No Action Alternative, none of the flood risk management measures would be implemented. As no features would be constructed, there would be no project-related activities that would affect geologic, seismic or soil conditions. The physical conditions within each of the measure locations would be expected to be generally commensurate with the current onsite conditions.

Erosional processes, including debris flows and landslides, are expected to continue across the watershed, especially in areas of potential hazard including steep slopes and high annual rainfall, as noted by Ellen et al. (1993). Given the potential for more intense episodes of rainfall, these events could potentially occur on a more frequent basis. In addition, expansion of invasive trees species (particularly those that easily uproot because of shallow root systems [such as *Miconia calvescens*]) into the steep upper slopes of the watershed could further contribute to increased frequency of mass wasting events.[19]

5.2.2.2 Recommended Plan (Alternative 3A-2.2)

The recommended plan would involve implementation of both structural and non-structural measures throughout the watershed. Non-structural measures (i.e., improvements to the flood warning system) would not affect the geology, seismic or soil conditions within the study area, and therefore are not discussed further.

The structural measures include construction of detention basins and floodwalls, as well as mitigation measures, each of which would involve ground disturbance. The majority of the sites in the mid to lower portions of the watershed are located in highly disturbed environments, with no natural topography or substrate present. The proposed location for flood risk management measures in the upper watershed are generally comprised of native substrate, but none include important geologic landforms or topographic features. Although no impacts are expected to geologic or topographic features, erosion could occur during construction as a result of ground disturbance associated with vegetation clearing, excavation and/or grading during construction (**IMP GEO-1**). A summary of the relevant activities at each measure site and the estimated extent of ground disturbance associated with each is provided in Table 17. To the extent possible, the measures have been sited to minimize the need for excavation and grading, and to take advantage of existing cleared areas that can be used for staging and access. For example, where possible, the detention basins use natural topography to minimize the extent of ground disturbance needed to construct the berm. In addition, site-specific BMPs to control erosion would be implemented at each measure location. The BMPs would be specified in the Stormwater Pollution Prevention Plan (SWPPP) that would be developed in compliance with the requirements for an NPDES permit; further discussion of the SWPPP and NPDES permit requirements is provided in Section 5.6. With implementation of these BMPs, the extent of erosion is expected to be less than significant; no mitigation is required.

Following construction, no major forms of ground disturbance are anticipated at any of the measure sites. It is expected that normal operation of the debris and detention basins would help to capture sediment and debris that is transported via streamflow. Sediment and debris that accumulates within the debris and detention features would be removed as part of the routine O&M activities and disposed of at an approved, offsite location that is qualified to accept the material. Sediment and debris removal would have some potential to result in erosion (**IMP GEO-2**). BMPs to control erosion, similar to those used during the construction phase, would be identified and implemented as necessary. With implementation of these measures, erosion-related impacts as part long-term O&M are expected to be less than significant; no mitigation is required.

Although there is some degree of seismic hazard on the island of Oʻahu, the proposed measures are not expected to be highly susceptible to seismic activity or otherwise increase exposure to seismic-related hazards. All of the measures would be designed to meet IBC standards and other relevant requirements related to earthquake safety, such that seismic-related impacts are not anticipated.

Some of the proposed measures, particularly those located in the upper watershed area, may be located downslope of areas that are subject to increased risk of debris flows or landslides. As described above, areas where potential landslide hazards are greatest are those with highly weathered soil on steep slopes in areas of high annual rainfall (e.g., Waihi, Waiakeakua, Pālolo, and Waiʻōmaʻo debris and detention basins). Construction and operation of the measures is not expected to increase the risk of landslide or debris flow events, as these features are not designed to hold water for long periods of time, such that they would not substantially increase soil saturation over time. However, debris flows are most likely to occur during heavy rainfall, when water

[19] This assumption is based on the best professional judgment of knowledgeable biologists, including Rob Hauff (DOFAW), Stephen Miller (USFWS), Rachel Neville (OISC), Miranda Smith (KMWP), and Deanna Spooner (Hawaiʻi Conservation Alliance), as discussed on April 22, 2010.

retention for flood control is most needed; as previously noted, future climate conditions are expected to further increase the potential for these events. In addition to subjecting the structure to high-momentum impacts from boulders and other debris, any such debris flows could rapidly fill the detention structure, leading to overtopping and unintended hydraulic consequences (**IMP GEO-3**). The design is based on the assumption that none of the measures have been sited in unstable or unsuitable substrate, such that they would increase the risk for any such event. However, detailed geotechnical analyses would be conducted as part of the PED effort during the next phase of the project, as needed to finalize the design for each measure **(MM GEO-1)**. With implementation of this measure, impacts related to debris flows and landslides are expected to be less than significant.

5.2.2.3 Alternative 2A

In general, the type of flood management measures included in Alternative 2A are consistent with those in the recommended plan, such that the nature and degree of impacts are generally expected to be similar. However, the locations of the measures (and the associated impacts) differ between alternatives. They key differences in the potential impacts of Alternative 2A versus the recommended plan are as follows:

- Construction and operation of the measures in Alternative 2A would result in a greater extent of disturbance (see Table 17); however, with implementation of erosion control BMPs, potential impacts associated with erosion and sedimentation would be expected to be less than significant.
- Under Alternative 2A, the debris and detention basins in the upper Mānoa and Pālolo watershed are replaced by debris catchment structures. Although these structures would function to capture debris, there is expected to be a lower risk associated with unintended hydraulic consequences because of landslide or debris flow events, as compared with the debris and detention basins in the recommended plan.

Based on these factors, and with implementation of erosion control BMPs, the potential impacts of Alternative 2A on geology, seismicity, and soils is expected to be less than significant.

5.3 Groundwater Resources

5.3.1 Affected Environment

5.3.1.1 Regulatory Framework

Regulations and policies that protect groundwater resources and are being considered as part of the proposed project include the following:

- HRS Chapter 174C (State Water Code)

5.3.1.2 Environmental Setting

On Oʻahu, groundwater primary occurs in flank basal aquifers or in high level dike-impounded systems. In most of the island's coastal areas, including the southern shore, low permeability sedimentary deposits (commonly referred to as "caprock") restrict the seaward flow of groundwater, thus increasing the overall thickness of the basal aquifer. The basal aquifers are recharged by infiltration of precipitation and inflows from upgradient groundwater systems. Groundwater discharge typically occurs directly to streams, or by seepage and springs (especially near the coast).

Within the Ala Wai Watershed, groundwater generally occurs within basal unconfined flank aquifers. The basal aquifers located within the Ala Wai Watershed are the Nuʻuanu, Pālolo, and Waiʻalae-West aquifer systems, which are part of the Honolulu aquifer sector. It is expected that, where present, high-level dike-impounded and perched groundwater in the upper portion of the watershed contribute to the recharge of the underlying basal aquifers.

The State of Hawai'i Commission on Water Resource Management (CWRM) is responsible for determining the sustainable yield for each aquifer; the total estimated sustainable yield for the island of Oʻahu is 407 million gallons per day (mgd) (CWRM, 2008b). The estimated sustainable yield for the Honolulu aquifer sector is

50 mgd. Of this total, the Nu'uanu, Pālolo, and Wai'alae-West aquifer systems have estimated sustainable yields of 5, 14, and 4 mgd, respectively (CWRM, 2008a). Because of concerns for diminishing reserves of developable groundwater and threats to water quality at developed sources, protection of the Honolulu aquifer sector as a groundwater management area was instituted in 1981, resulting in a requirement for water use permits (CWRM, 1990).

5.3.2 Impacts and Mitigation

Effects on groundwater resources were considered to be significant if implementation of an alternative plan would result in any of the following:

- Substantially deplete groundwater supplies
- Interfere with groundwater recharge

The potential effects to groundwater supply and recharge that could result from implementation of the alternatives are discussed in the following subsections. Discussion of potential impacts to groundwater quality is provided in Section 5.6.

5.3.2.1 No Action Alternative

Under the No Action Alternative, none of the flood risk management measures would be constructed, such that no activities affecting groundwater conditions would occur. The physical conditions within each of the measure locations would be expected to be generally commensurate with the current onsite conditions.

Changes in rainfall over time are expected to reduce groundwater recharge and therefore impact O'ahu's water supply, which is highly dependent on groundwater wells. Coupled with increased evaporation rates caused by rising air temperatures, groundwater recharge rates could be significantly affected, resulting in changes to both aquifer levels as well as base flow in the streams. In addition, rising sea levels could contribute to increased salt water intrusion into the freshwater lens (National Assessment Synthesis Team, 2000), although the presence of the caprock may limit the degree of intrusion (BWS, 2009b). These potential changes have been widely described, but no attempt to quantify future changes in groundwater availability or recharge rates for Hawai'i has been identified to date.

5.3.2.2 Recommended Plan (Alternative 3A-2.2)

The recommended plan would involve construction of a series of detention basins, debris catchment structures, and floodwalls, which would collectively function to reduce flooding hazards. None of these flood risk measures (or the associated mitigation measures) are expected to involve disturbance of the groundwater table or other impacts to the underlying aquifer.

As part of the focus of developing environmentally sustainable measures, each of the structures has been designed such that base stream flows would not be affected. In particular, the detention structures would include natural-bottom arch culverts or box culverts that are adequately sized to allow both base flows and small-scale storm flows to freely pass; the detention structures would only function to detain flood waters associated with larger storm events (i.e., those exceeding the 20-percent ACE level). As such, these features are not expected to affect groundwater infiltration by diminishing base flows.

As shown in Table 17, detention of water during peak flows could result in inundation behind each of the detention structures for up to approximately 10 hours (for a 1-percent ACE flood event). Although these conditions are not expected to occur on a frequent basis, they could serve to enhance groundwater recharge, at least on a short-term, localized basis. As the recurrence interval and scale of detention associated with future flood events cannot be predicted, the potential benefits to groundwater recharge (if any) are not readily quantifiable.

5.3.2.3 Alternative 2A

Alternative 2A is comprised of similar types of measures as those in the recommended plan, with the measures distributed throughout different locations in the watershed. Consistent with the analysis provided in Section

5.3.2.2, construction and operation of the measures in Alternative 2A is not expected to directly or indirectly affect groundwater resources, either based on disturbance of the groundwater table or reduced infiltration from diminished base flows. Detention of flood waters in the detention basins could provide short-term, localized enhancement of groundwater recharge; however this effect would likely be less pronounced than for the recommended plan, as Alternative 2A includes fewer detention basins.

5.4 Surface Water Resources

5.4.1 Affected Environment

5.4.1.1 Regulatory Framework

Regulations and policies that protect and/or regulate work within surface water features and are being considered as part of the proposed project include the following:

- Clean Water Act, Section 404
- Rivers and Harbors Act, Section 10
- HRS Chapter 174C (State Water Code)

5.4.1.2 Environmental Setting

Historically within the watershed, surface water occurred in a variety of settings, including streams, springs, ponds and wetlands. Urbanization and development activities have subsequently altered or destroyed many of these features, including the broad coastal wetlands that occurred throughout the Waikīkī area and most of the spring-fed ponds. At the present time, surface water within the Ala Wai Watershed is almost entirely confined to streams and canals. These are described below, followed by a discussion of channel stability and sediment transport associated with these features.

Streams

Streams in the Ala Wai Watershed include Mānoa, Pālolo, and Makiki streams (and their tributaries). Each stream generally consists of an upper, middle, and lower reach that flow to an estuarine reach and then to the Ala Wai Canal, before discharging to the ocean. In this context, upper reaches are the tributary streams, which are steep, relatively straight courses in down-cutting channels, and are dominated by step-pool or cascade features. With decreasing slope, the middle reaches are slightly meandering, and are dominated by plane bed and riffle-pool features. Lower reaches flow across the coastal plain and are typified by sediment accumulation. The estuarine reaches are those in which sea water and freshwater mix, typically along a gradient of increasing salinity seaward. The approximate extent of these reaches for the streams in the Ala Wai Watershed is shown in Figure 6.

Alteration of these streams over time to minimize flooding in adjacent areas has resulted in significant changes in the natural drainage patterns. All three of the major streams in the Ala Wai Canal system have been altered, with typical modifications including lined channels, elevated culverts, revetments, blocked or filled-in channels, and extended culverts (Timbol and Maciolek, 1978). Within the urbanized portion of the watershed, Makiki Stream is an almost entirely man-made system comprised of underground and open-ditch concrete-lined channels, (Kido, 2006); the reach between Wilder Avenue and King Street is contained in an extended culvert, located almost entirely underground. Nearly the entire length of Pālolo Stream, from the confluence of Pūkele and Waiʻōmaʻo streams, to its juncture with Mānoa Stream, has been lined, consisting of a wide concrete channel and high concrete banks. Although significant portions of Mānoa Stream remain as a natural channel, as much as 60 percent of the middle and lower reaches have been modified, mostly involving earthen or concrete revetments (Kido, 2007). The approximate extent of channelization is shown in Figure 6.

These streams are fed by precipitation and surface water runoff, as well as by high-level or perched groundwater resources, such as dike-impounded aquifers in the upper portions of the watershed (Oceanit, 2008c). Streamflow in the areas corresponding with the Honolulu aquifer sector is generally not dependent on the basal aquifer (CWRM, 2008a).

Long-term continuous recording gaging stations have been in operated by the U.S. Geological Survey (USGS) to measure stream flows, mainly in the upper watershed areas with only more recent daily flow data collected the lower watershed. A recent study of long-term trends in streamflow characteristics detected a downward trend in base flows from 1913 to 2002 at long-term stream gaging locations throughout the State, including Kalihi Stream, located just west of the Ala Wai Watershed. These conditions are believed to be associated with decreasing annual rainfall amounts throughout much of the State, and may indicate a reduction in groundwater discharge to streams caused by a long-term decrease in groundwater storage and recharge (Oki, 2004).

Canals and Other Surface Drainage Features

The watershed includes two major canals, the Ala Wai Canal and the Mānoa–Pālolo Drainage Canal, as well as several smaller man-made drainage features. As previously described in Section 1.2, the Ala Wai Canal is an approximately 2-mile-long, man-made channel originally dredged in the 1920s to combine the meandering flow of several streams into one straight outlet to the ocean (Clark, 2002). The Canal intercepts flows from Mānoa and Pālolo streams (via the Mānoa–Pālolo Drainage Canal, as further described below) and Makiki Stream (as well as numerous storm drain outfalls), and empties into the Ala Wai Boat Harbor. The boat harbor connects to Māmala Bay via a channel that was dredged through the reef platform when the harbor was built in 1935. The width of the Canal ranges between 150 and 250 feet, with the widest section between McCully Street and the confluence with the Mānoa–Pālolo Drainage Canal. The original depths of the Ala Wai Canal were approximately 10 to 20 feet below means sea level (msl) behind Waikīkī, 10 to 13 feet below msl between the confluence with Makiki Stream and Ala Moana Boulevard Bridge and 25 feet below msl beyond the Ala Moana Boulevard Bridge (Edward K. Noda, 1992a). However, sedimentation has decreased the depths over time, particularly just below at the junction with the Mānoa–Pālolo Drainage Canal, where a sediment sill forms, decreasing circulation in the upper end of the Ala Wai Canal (Gonzalez, 1971). Depths in this area have been previously reduced to as little as 2 feet msl (Belt Collins, 1998). Portions of the Ala Wai Canal have been dredged a total of three times: in 1966, 1978-79, and 2002-03; the State is currently planning to conduct additional dredging in the 2017-2018 timeframe.

The Mānoa–Pālolo Drainage Canal was constructed between 1935 and 1936, realigning Mānoa and Pālolo streams into a straight outlet to the Ala Wai Canal (Mason Architects, 2010). It originates at the confluence of Mānoa and Pālolo streams just above Waiʻalae Avenue, and drains into the Ala Wai Canal, just west of the Ala Wai Golf Course. The Mānoa–Pālolo Drainage Canal is lined with concrete for most of its length, but has a natural bottom just before entering the Ala Wai Canal. The estuarine influence within the Mānoa–Pālolo Drainage Canal extends to about halfway between the Date Street and Kapi'olani Boulevard bridges, near Kaimukī High School (AECOS, 2002).

In addition to the Mānoa–Pālolo Drainage Canal and Makiki Stream, the Ala Wai Canal also receives inputs from two other primary surface drainage features, Hausten Ditch and the Kapahulu Drain. Hausten Ditch is a mostly open, lined drain that arises from springs in Mō'ili'ili, just *mauka* (mountainward) of the Willows Restaurant on Hausten Street. Although these springs are remnant features and produce minimal flows in comparison to the many springs that once fed the Waikīkī wetlands, Hausten Ditch has perennial flow, unlike other storm drains in the lower watershed.

Surface runoff from the southeastern corner of the watershed, which includes the areas surrounding the western face of Diamond Head, does not naturally drain to the Ala Wai Canal and is intercepted by a drainage system. This drainage system was originally constructed in 1951 and drained directly to the ocean at the base of Kapahulu Avenue, with the storm drain functioning as a groin (Weigel, 2008). Although the groin is still in place, the drainage system has since been re-routed to flow into the upper end of the Ala Wai Canal via the Kapahulu Drain, at the eastern end of the Ala Wai Golf Course.

In addition to these drainage features, there are approximately 60 other smaller drain outfalls that direct stormwater runoff into the Ala Wai Canal (CCH, 1991). In general, the storm drain system throughout the watershed does not have the capacity to handle the design storms under their current conditions (Oceanit, 2008b). Portions of the drainage system in the lower elevations of the watershed are also influenced by tidal waters, further reducing their capacity.

Jurisdictional Waters of the U.S.

Waters of the U.S. (including certain wetlands) are regulated under Section 404 of the Clean Water Act. A formal jurisdictional determination of Waters of the U.S. has not yet been completed for the project area; however, for the purposes of this Feasibility Report/EIS, all of the streams and canals in the watershed were assumed to be jurisdictional Waters of the U.S.[20]

As a subset of Waters of the U.S., special aquatic sites are geographic areas that possess special ecological characteristics that significantly contribute to overall ecosystem vitality, and therefore are afforded additional consideration. Special aquatic sites include sanctuaries and refuges, wetlands, mud flats, vegetated shallows, coral reefs, and riffle and pool complexes. The streams within the study area include a range of riffle and pool complexes, to the extent that they exhibit habitat complexity with a combination of higher-gradient riffles of fast-moving water and lower-gradient pools of slow-moving water. The riffle-pool complexes range along a spectrum, generally based on the underlying gradient, where the habitat in the upper reaches tends toward steeper plunge pool features, while the middle reaches tend toward a lower-gradient combination of riffles and pools. However, to the extent that these areas display high complexity with a combination of substrates and velocities that are typical of the underlying gradient (thus providing high quality habitat for native aquatic species), they have been identified as riffle and pool complexes. This includes the habitat within the proposed in-stream debris and detention basis on Waihi, Waiakeakua, Makiki, Pūkele, and Wai'ōma'o streams.[21] Jurisdictional wetlands are not expected to be present outside the defined channel limits. This information will be verified during the detailed design phase through a formal jurisdictional determination in accordance with the new Clean Water Rule: Definition of "Waters of the United States" (33 CFR Part 328).

Sediment Transport and Channel Stability

In general, sediment transported by the streams in the Ala Wai Watershed is believed to originate from a few major sources: slope failures (landslides or debris flows), stream erosion, erosion of disturbed land (e.g., landslide scars, fire, feral pig trails, etc.), and urban sheetflow. The majority of the sediment in the watershed is believed to originate from Mānoa and Pālolo valleys, with greater yields in the upper watershed where most sediment production is believed to occur and lower yields through the urban areas. Based on the available data, most of the sediment load is believed to be generated during storm events (NHC, 2015).

As previously described, the upper reaches of the watershed are generally characterized by step-pools and cascade features. These are typically comprised of very coarse bed and bank material, with only minimal quantities of fine sediment (site and clay) present in the bed load. In general, plane-bed and riffle-pool features, which are prevalent through the middle reaches, are more likely to experience lateral channel shifting and bank erosion, with storage of fine sediments in the stream bed. However, within the Ala Wai Watershed, many of the middle reaches have either been channelized (or armored as part of adjacent development) or are in narrow valleys where lateral erosion is limited by bedrock. Given the extensive channel alterations (as summarized above), the overall channel form throughout the watershed is relatively stable. However, there are localized areas of bank erosion (as well as failing channel infrastructure). Where stream banks and beds are erodible, rates of erosion are generally higher with increased discharge. Consequently, rates of erosion and fine sediment production generally increases with increasing peak flows. Most (if not all) of the suspended sediment transported by the streams is believed to be trapped in the Ala Wai Canal, which functions as a sediment sink.

[20] The Ala Wai Canal is a navigable Waters of the U.S., and therefore also subject to Section 10 of the Rivers and Harbors Act.

[21] The reach of Mānoa Stream adjacent to the Kanewai Field multi-purpose detention basin also exhibits riffle-pool complex characteristics; however, this measure would only affect a short stretch of stream bank, and is not expected to alter any characteristics of the stream bed that may contribute to riffle-pool complex habitat.

5.4.2 Impacts and Mitigation

Effects on surface water features, channel stability and sediment transport were considered to be significant if implementation of an alternative would result in any of the following:

- Obstruct or otherwise change the course of a stream or canal
- Remove, fill, or substantially disturb a jurisdictional wetland or other Waters of the U.S.
- Substantially modify or otherwise adversely affect a floodplain
- Significantly increase channel and/or bank erosion, or reduce channel stability
- Substantially affect sediment transport dynamics

The potential effects to surface water features and sediment transport that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.4.2.1 No Action Alternative

Under the No Action Alternative, none of the flood risk management measures would be implemented, such that no modifications to surface water features would occur. No major changes in channel stability and/or sediment transport are anticipated; therefore, future without-project conditions are expected to be commensurate with the existing condition.

5.4.2.2 Recommended Plan (Alternative 3A-2.2)

With the exception of the Ala Wai Canal floodwalls, all of the proposed measures would involve work within a stream or Canal. None of these measures would permanently obstruct or change the course of a waterway, or substantially modify the existing floodplain. However, they would involve placement of fill material within the channels, which are Waters of the U.S. and include areas considered to be riffle and pool complexes (**IMP SUR-1**). Specifically, construction of the measures would require placement of materials including compacted fill, concrete, grouted rip-rap, as well as steel poles for the debris catchment feature. Construction of the Waiʻōmaʻo and Pukele debris and detention basins would also involve excavation to provide adequate detention capacity. In addition, most of the measures would require periodic removal of sediment/debris from the debris catchment features. All of these materials would be disposed of in an approved offsite location. The estimated volume of fill material that would be placed within Waters of the U.S. is summarized in Table 19.

Table 19. Estimated Excavation and Discharge of Fill within Waters of the U.S.

Measure	Length of Stream to be Disturbed (feet)	Length of Stream in Permanent Footprint (feet)	Construction		O&M	
			Excavation (yd^3)[a]	Fill (acre)[a]	Excavation (yd^3)[a]	Fill (yd^3)[a]
Waihi debris and detention basin[b]	355	355	0	0.8	300	0
Waiakeakua debris and detention basin[b]	350	350	0	1.0	400	0
Woodlawn Ditch detention basin	120	60	0	1.1	0	0
Mānoa in-stream debris catchment	48	8	0	0.01	25	0
Kanewai Field multi-purpose detention basin	70	70	0	0.9	0	0
Waiʻōmaʻo debris and detention basin[b]	720	320	3,060	0.5	300	0
Pūkele debris and detention basin[b]	810	310	14,330	0.4	100	0
Makiki debris and detention basin[b]	780	310	0	0.4	250	0
Ala Wai Canal floodwalls	0	0	0	0	0	0
Hausten Ditch detention basin	70	35	0	0.2	0	0
Ala Wai Golf Course multi-purpose detention basin	70	70	40,097	0.2	200	0
Flood warning system	0	0	0	0	0	0
Mitigation – Falls 7	50	5	0	0	0	0
Mitigation – Falls 8	60	5	0	0	0	0
TOTAL	**3,503**	**1,898**	**57,487**	**5**	**1,575**	**0**

Notes:
[a] For the purpose of the Feasibility Report/EIS, quantities of dredged and fill material proposed to be discharged into Waters of the U.S. were calculated based on the conservative assumption that the jurisdictional limit of Waters of the U.S. is approximately at the level of the 50-percent ACE event. A formal jurisdictional determination of Waters of the U.S. would be conducted during the next phase of the project, based upon which this analysis would be updated (with associated refinements to the project design, as appropriate).
[b] These measures are located along stream reaches that support habitat that is considered riffle and pool complexes.

Without mitigation, discharge of dredged or fill material could result in significant adverse impacts to Waters of the U.S. BMPs would be implemented to further avoid and minimize potential impacts, to the extent practicable; these include the following:

- Limiting work within the stream channels to periods of low flow and employment of proper dewatering techniques, as appropriate
- Sequencing construction activities to limit the extent of exposed soil at any given time
- Implementing erosion prevention and sedimentation control measures and maintaining such measures for the duration of construction
- Acquisitioning all fill materials from approved sources and ensuring fill material is free of contaminants.
- Using appropriate vehicles and equipment for all stages of construction and adequately training construction crews to avoid and minimize impacts to the aquatic environment

In addition, compensatory mitigation is proposed for unavoidable impacts to aquatic resources pursuant to 33 CFR Part 332, as further discussed in Section 5.7.2.2. With implementation of the proposed avoidance, minimization, and compensatory mitigation measures, impacts to Waters of the U.S. would be reduced to a less-than-significant level.

In-stream channel improvements have the potential to increase channel and/or bank erosion, due to the disturbance and exposure of channel material during construction (**IMP SUR-2**). Each measure has been sited and designed to minimize the need for excavation and grading. In addition, site-specific BMPs to control erosion would be implemented as part of the SWPPP that would be developed in compliance with the requirements for an NPDES permit (see Section 5.6.2). With implementation of these BMPs, construction-related impacts associated with channel and/or bank erosion are expected to be less than significant.

Following construction, increased channel and/or bank erosion is not anticipated. Overall, the detention basins are designed to reduce peak flows, which could effectively reduce erosion rates and provide some degree of benefit to channel stability. In addition, the in-stream detention basins have been designed to include energy dissipation features, where needed to reduce flow velocity and the potential for stream bed erosion within and around each structure. Riprap scour protection will be added downstream of the Makiki, Waihi, Waiakeakua, Waiʻōmaʻo, and Pūkele detention basins. Similarly, the measures are not expected to significantly alter sediment transport dynamics. Natural-bottom arch culverts or large-capacity box culverts have been incorporated into the design, such that the flood risk management structures would not impede low flows. As such, changes in sediment transport dynamics are not anticipated under typical flow conditions. During larger flows, the detention structures would function to temporarily detain flood waters. Although the structures are not designed to capture sediment, some degree of sediment deposition is expected to occur within the detention basins. As previously described, sediment and debris that accumulates within the debris and detention features would be removed as part of the routine O&M activities and disposed of at an approved, offsite location. However, this is expected to occur on an infrequent basis, and sediment transport processes are not expected to be significantly affected.

5.4.2.3 Alternative 2A

Under Alternative 2A, the general nature of impacts to surface water features would be similar to those described for the recommended plan. However, the location of the impacts, as well as the overall extent of work within Waters of the U.S. would differ. Alternative 2A would involve stand-alone debris catchment structures in place of the larger debris and detention basins in upper Mānoa and Pālolo. Detention would instead be provided at a multi-purpose detention basin constructed in Mānoa District Park. Construction of Alternative 2A would disturb a greater length of stream (1,742 feet), in large part because of a 600-foot-long culvert that would be installed along the edge of Mānoa Stream, as needed to direct flood flows from the Po`elua Place debris catchment to the Mānoa District Park multi-purpose detention basin. However, given the relatively small size of the debris catchment structures in upper Mānoa and Pālolo, the length of stream within the permanent footprint of in-stream structures would be slightly less than for the recommended plan (527 feet). Based on the anticipated gain in habitat quality associated with the mitigation for the plan, it is assumed that the same mitigation measures would be implemented for Alternative 2A. With implementation of measures to avoid and minimize potential impacts, in combination with the compensatory mitigation measures, impacts to Waters of the U.S. would be less than significant.

5.4.3 Clean Water Act Section 404(b)(1) Evaluation

As specified in regulatory guidance for Civil Works Projects (USACE, 1988), the USACE does not issue itself permits under any of the regulatory authorities it administers, including Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act. Rather, the USACE is required to evaluate any proposed action that could affect a Waters of the U.S. to demonstrate compliance with the environmental criteria set forth in the Clean Water Act Section 404(b)(1) guidelines (40 CFR 230).[22] The Section 404(b)(1) evaluation for this project, which is contained in Appendix E, concludes that the proposed action is consistent with the specified guidelines, and that the recommended plan is the least environmentally damaging alternative (LEDPA).

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[22] If certain conditions are met, Clean Water Act Section 404(r) states that the discharge of dredged or fill material is not prohibited by or otherwise subject to regulation under Clean Water Act Section 404, Section 301(a), or Section 402 (except for effluent standards or prohibitions under Section 307). This applies only if information on the effects of such discharge, including consideration of the guidelines developed under Section 404(b)(1), is included in an EIS for such project pursuant to NEPA and such EIS has been submitted to Congress before (1) the actual discharge of dredged or fill material in connection with the construction of such project and (2) either authorization of such project or an appropriation of funds for each construction. The Clean Water Act Section 404(b)(1) evaluation is included in Appendix E.

5.5 Hydrology and Hydraulics

5.5.1 Affected Environment

5.5.1.1 Regulatory Framework

Regulations and policies that relate to hydrologic and hydraulic conditions and are being considered as part of the proposed project include the following:

- ER 1110-2-1450 ("Hydrologic Frequency Estimates") (USACE, 1994a)
- ER 1110-2-1464 ("Hydrologic Analysis of Watershed Runoff") (USACE, 1994b)
- ER 1110-2-1405 ("Hydraulic Design for Local Flood Protection Projects") (USACE, 1982)
- ER 1105-2-101 ("Risk Analysis for Flood Damage Reduction Studies") (USACE, 2006b)
- ER 1165-2-21 ("Flood Damage Reduction Measures in Urban Areas") (USACE, 1980)
- FEMA Floodplain Mapping Guidelines (FEMA, 2010)
- CCH Drainage Standards (2000)

5.5.1.2 Environmental Setting

Hydrologic and hydraulic modeling studies were conducted to estimate peak stream flow discharges and associated water surface elevations that could occur in the Ala Wai Watershed as a result of a range of potential storm events. These models built upon previous modeling work and incorporated up-to-date topographic and hydro-meteorological data. More detailed information regarding the modeling assumptions, techniques, methodologies, results and uncertainties can be found in the *Existing Without-Project Hydrologic Appendix* (Oceanit, 2008c) and the *Existing Without-Project Hydraulic and With-Project Hydrologic and Hydraulic Appendix* (USACE, 2010), both of which are contained in Appendix A.

Hydrology

Hydrologic modeling was conducted to calculate peak flow discharges at key locations throughout the watershed. Discharge estimates for the 50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent ACE floods were determined based on the results of various hydrologic methods that were used, depending on the location in the watershed and the availability of data.[23] The main method used was the USACE HEC-HMS hydrologic model. HEC-HMS model results were compared with results from other regional methods, including the USGS regional peak-discharge regression equations, the CCH Drainage Standards Plate 6 curve, existing peak flow values from the FEMA Flood Insurance Study, and site specific frequency analysis at USGS gage locations using the USACE Hydrologic Engineering Center-Statistics Software Package (HEC-SSP). Regional methods are primarily dependent on drainage area and do not account for other physical or meteorological factors in the watershed, which can be accounted for in a HEC-HMS model.

The resulting values for selected locations are shown in Table 20. As shown, the flow at the mouth of the Ala Wai Canal based on the 1-percent ACE flood was computed to be 19,500 ft^3/s. Previous estimates of the 1-percent ACE peak flow value in this location ranged from 22,900 ft^3/s (Edward K. Noda, 1994) to 28,200 ft^3/s (FEMA, 2004) and were based on regional methods. The current value is lower than previous estimates because of detailed modeling methods and accounting for channel and canal storage, which reduces the peak flow in the Canal.

[23] As discussed in Section 2.1.1, the modeling assumes no coincidence between hurricanes and high-rainfall-intensity flood-producing storm systems.

Table 20. Hydrologic Model Results for Peak Flow Discharge Values (ft^3/s) at Select Locations

Stream Location	Annual Chance Exceedance (ACE)							
	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Makiki Stream (at confluence with Ala Wai Canal)	900900	1,700700	2,600600	3,300300	4,500500	5,700700	6,800800	8,000000
Mānoa Stream (at confluence with Pālolo Stream)	2,600600	4,450450	6,150150	7,800800	9,700700	11,200200	12,500	15,300300
Pālolo Stream (at confluence with Mānoa Stream)	1,300300	2,600600	3,500	4,800800	6,300300	7,600600	9,400	12,000
Ala Wai Canal (at mouth)	8,000	11,500	13,500	16,000	18,000	19,500	20,900900	23,200200

Hydraulics

Hydraulic modeling was conducted to estimate peak water surface elevations from peak discharge data and evaluate sensitivity to stage-discharge relationships in the Ala Wai Watershed. Peak water surface elevations were estimated for the 50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent ACE flood events. The modeling was conducted using HEC-RAS and GIS software, utilizing the best available data, using a one-dimensional, steady state flow model with sub-critical flow step-backwater computations. A detailed discussion on the methodology and assumptions used in the modeling effort is presented as part of Appendix A.

The floodplain inundation map for the 1-percent ACE flood is shown in Figure 16. For comparison purposes, this figure also shows the current Flood Insurance Rate Map (FIRM) 1-percent ACE flood boundary.[24] This boundary indicates those areas with 1-foot or greater flood depths and also includes the coastal surge zone. To illustrate the extent of flooding associated with higher frequency storm events, Figure 17 shows the floodplain boundaries for the 10-, 5-, and 2-percent ACE floods. Because of the relatively flat terrain around the Ala Wai Canal, the floodplain extents are similar for many of the flood frequencies, with differences only in the depth of flooding. As further discussed in Appendix A, it is important to note that floodplain extent maps are a tool which help characterize the flood hazard but are not exact because of inherent limitations in the modeling process.

Based on the 1-percent ACE flood event, a flow of approximately 4,100 ft^3/s leaves the system and flows into the ocean through Waikīkī. Accounting for the effects of floodplain storage and the backwater along Makiki Stream, the peak flow at the mouth of the Canal is reduced to about 12,200 ft^3/s from its upstream peak of 21,600 ft^3/s. This results in a greatly reduced flood inundation area between Kalakaua Avenue and Ala Moana Boulevard. Based on the peak flow values computed for this study, the Ala Wai Canal has about a 20-percent ACE flood capacity before overtopping the banks. This is less than the 10-percent ACE flood capacity documented by Edward K. Noda (1994), even with the dredging completed in 2008. The reduced capacity may be because of the use of mean higher high water (MHHW) as a downstream boundary condition for all flood recurrence intervals and the use of a steady flow HEC-RAS model (which tends to be more conservative than the in-house model used by Edward K. Noda [1994]). The McCully Street Bridge is the main reason for high water-surface elevations in the upstream sections of the Canal. The model results also indicate other key limitations in channel capacity, including the following:

- Makiki Stream has the lowest channel capacity of all the streams in the watershed. Flooding primarily occurs because high water surface elevations in the Ala Wai Canal cause water to back up into Makiki

[24] The inundation maps prepared by USACE for this study do not supersede the FIRMs. If the project moves forward into construction, CCH may choose to adjust the FIRM to account for improved protection in the watershed.

Stream and overtop the channel. Most of the flooding along Makiki Stream occurs between King Street and Kapi'olani Boulevard. The elevations along Kapi'olani Boulevard are slightly higher than the surrounding ground, and as a result, this feature acts as a weir preventing most of the flow from flooding the downstream area. A small area in the vicinity of Kaheka Street allows water to flow over Kapi'olani Boulevard and eventually into the lower area of the parking facility of the Ala Moana Center.

- The confluence of Kanahā Ditch and Makiki Stream causes a backwater effect, which does not allow Kanahā Ditch to drain. Water overtops the channel, flows down slope across Wilder Street and floods the area approximately bounded by Kewalo Street and Keʻeaumoku Street. Flows are stopped at the H-1 Freeway where they would presumably drain into the stormwater drainage system.
- The model includes a detailed analysis of Pālolo Stream which has not been previously available or documented on the FIRM. Results of the detailed modeling indicate a channel capacity capable of containing a 2-percent ACE flood, with the section between Pālolo Avenue Bridge to Kalua Road Bridge having a lower capacity (between 5- to 2-percent ACE flood).
- Consistent with previous documentation (USACE, 2006a; Oceanit, 2008b), the modeling results indicate Mānoa Stream has channel capacity limitations between Kahaloa Drive Bridge and Woodlawn Drive Bridge, which creates a flooding hazard for the nearby residences and the UH campus.

Flood depths for the 1-percent ACE flood event around the Ala Wai Canal, Mānoa–Pālolo Drainage Canal, and lower Makiki Stream (Figure 16) are about 1.5 to 3 feet deep, on average, for the out of channel floodplain areas. Flood depths are about 2 to 3 feet deep, on average, for the split flow reaches of Kanahā and University overland flow areas. In upper Makiki, Mānoa, and Pālolo streams, flood depths may be up to 5 feet, depending on location.

The average bankfull capacity (based on peak discharge) for each reach is summarized in Table 21, both in terms of volume and annual chance exceedance.

Table 21. Approximate Average Bankfull Channel Capacities and Annual Chance Exceedance (Existing Conditions)

Stream	Reach	Reach Designation	Average Bankfull Peak Discharge Capacity (ft³/s)	Annual Chance Exceedance (%)
Ala Wai	Lower	ALA 1	12,200	2020
Ala Wai	Middle	ALA 2	6,900	20
Ala Wai	Upper	ALA 3	1,300	20
Kanahā	Ditch	KAH 1, KAH 2	350	5050
Kanahā	Split	KAO 1	N/A	20
Makiki	Upper	MAK 3, MAK 4	1,200	55
Makiki	Lower	MAK 1,MAK 2	650	5050
Mānoa	Main	MAN 1	4,300	20
Mānoa	Main	MAN 2	7,600	2
Mānoa	Main	MAN 3 to MAN 6	3,500	2020
Mānoa	Main	MAN 7	5,400	2
Pālolo	Main	PAL 1, PAL 2	6,000	2
Pālolo	Main	PAL 3, PAL 4	3,400	1010
Pālolo	Lower	MPC 1, MPC 2	15,400	2
Pūkele	Tributary	PUK 1	2,700	2
University	UH Split	UNI 1, UNI 2	N/A	10
Waiʻōmaʻo	Tributary	WAI 1	2,600	2

5.5.2 Impacts and Mitigation

Effects related to hydrology and hydraulics were considered to be significant if implementation of an alternative would result in any of the following:

- Significantly change drainage patterns within the watershed
- Substantially increase the extent, frequency or duration of flooding
- Create or contribute to runoff that would exceed the capacity of existing or planned stormwater drainage system

The potential effects to hydrology and hydraulics that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.5.2.1 No Action Alternative

Under the No Action Alternative, none of the flood risk management measures would be implemented, such that the existing flood-related related threats would remain. In addition, future climate changes are expected to contribute to increased water surface elevations due to sea-level rise.

Consistent with the USACE EC 1165-2-212 and ECB 2013-27, three scenarios (low, intermediate, and high) were modeled to define the future without-project hydrologic and hydraulic conditions, with each scenario defined based on the corresponding rate of change in the input conditions. Low is considered the best-case scenario (with a continuation in the current trends for sea-level rise and rainfall intensity), intermediate is the most probable scenario, and high is considered the worst-case scenario. The modeling inputs for these three scenarios are summarized in Table 22.

Table 22. Future Without-Project Scenarios

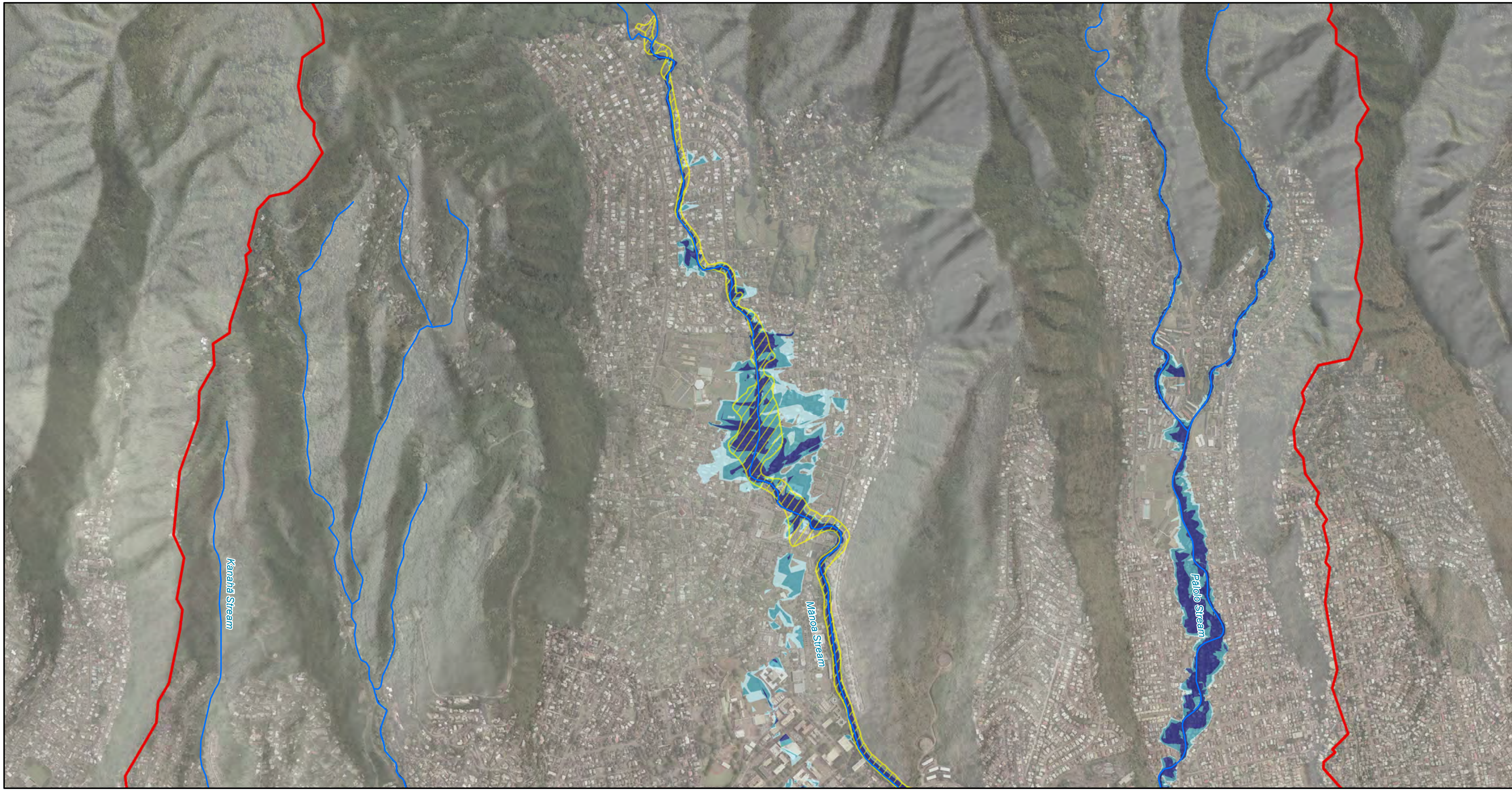
Component	Low	Intermediate (Most Probable)	High
Sea Level Rise	+1.89 ft	+2.50 ft	+4.44 ft

Hydraulics

HEC-RAS modeling was conducted to identify water surface elevations associated with the various ACE probabilities for the future without-project condition, based on anticipated changes in sea-level rise. The results for the 1-percent ACE flood (based on the intermediate scenario) are shown in Figure 16.

5.5.2.2 Recommended Plan (Alternative 3A-2.2)

The overall objective of the project is to reduce the risk of riverine flooding. The project is not expected to measurably affect hydrologic conditions within the watershed; as such, peak flow discharges are expected to be commensurate with those described for the No Action Alternative.



LEGEND

- Stream
- Watershed Boundary
- Flood Zone A (FEMA)

1-Percent Annual Chance Exceedance Floodplain (USACE)

- 0 - 1 ft.
- 1 - 3 ft.
- > 3 ft.
- 1 - 3 ft. (estimated)

0 0.5 1 Miles

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

VICINITY MAP

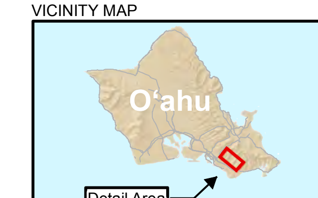
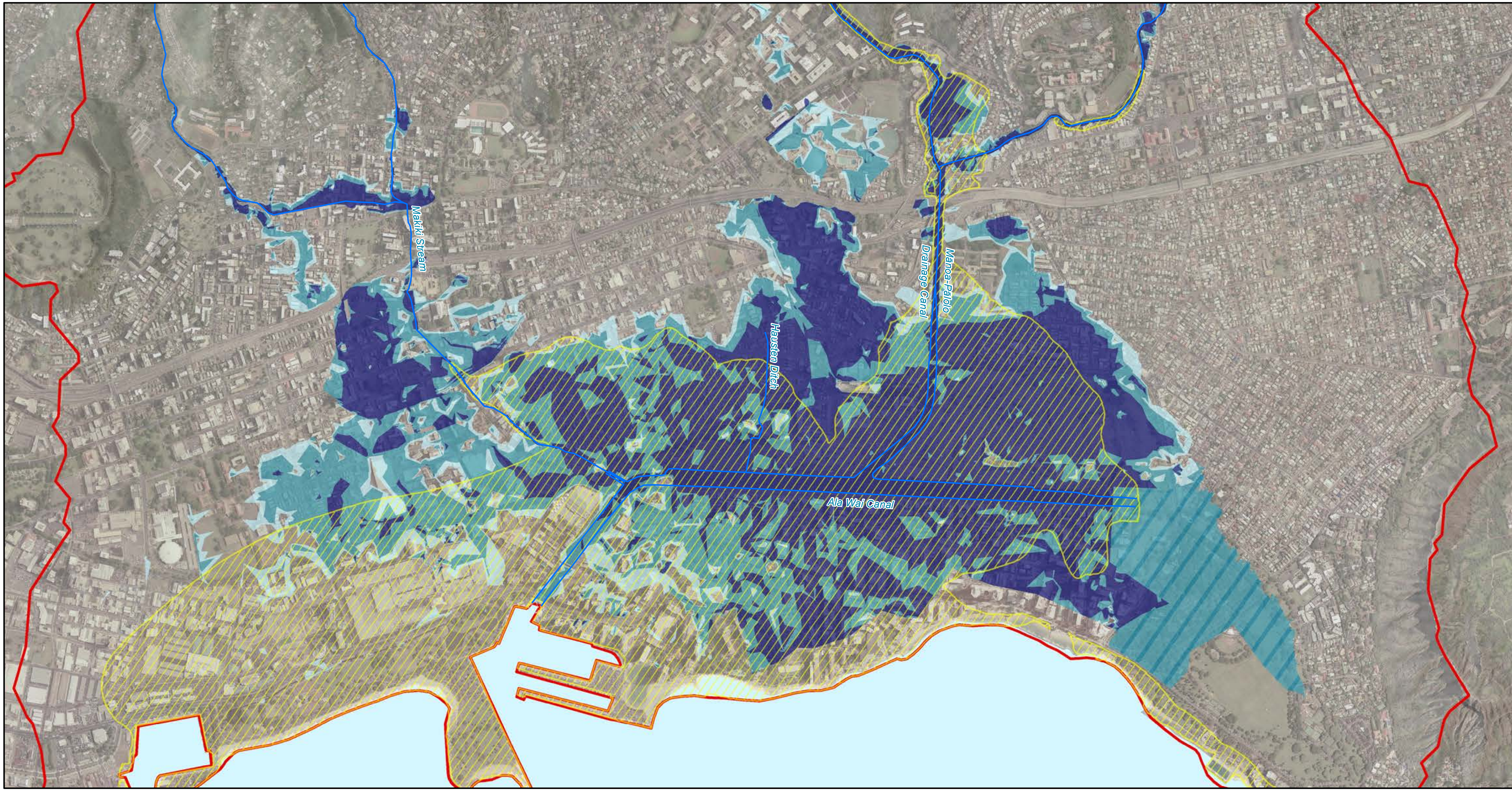


FIGURE 16a
1-Percent Annual Chance Exceedance Flood Inundation Map - Upper Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

CH2MHILL

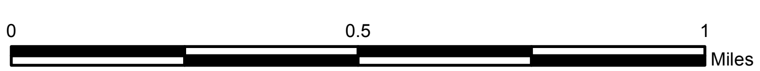


LEGEND

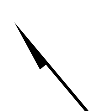
- Stream
- Watershed Boundary
- Flood Zone A (FEMA)

1-Percent Annual Chance Exceedance Floodplain (USACE)

- 0 - 1 ft.
- 1 - 3 ft.
- > 3 ft.
- 1 - 3 ft. (estimated)



Projection: State Plane Hawai‘i Zone 3 feet NAD83 HARN



VICINITY MAP

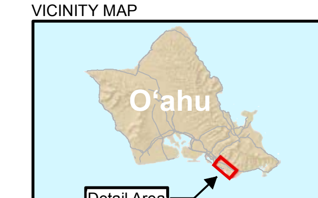


FIGURE 16b
1-Percent Annual Chance Exceedance Flood Inundation Map - Lower Watershed
Ala Wai Canal Project
O‘ahu, Hawai‘i

CH2MHILL

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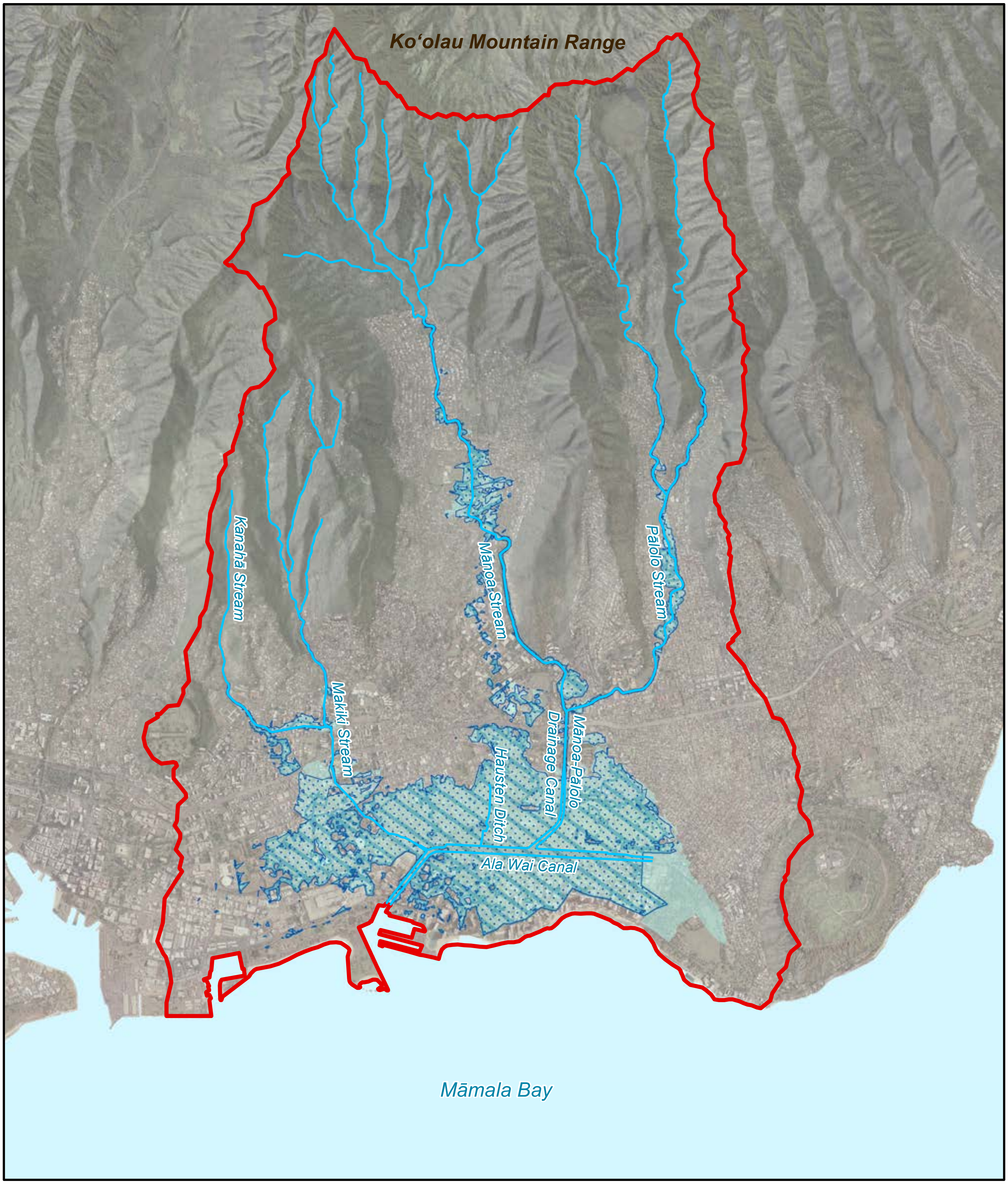

LEGEND

Stream

Watershed Boundary

Floodplain Extent (USACE)

10-Percent Annual Chance Exceedance

2-Percent Annual Chance Exceedance

1-Percent Annual Chance Exceedance

0 1 2 Miles

Projection: State Plane Hawaiʻi Zone 3 feet NAD83 HARN

N

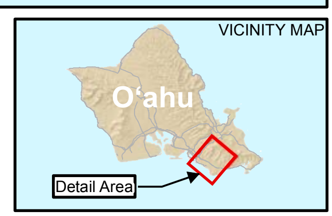

FIGURE 17
Comparison of Floodplain Extent for Different Flood Frequencies
Ala Wai Canal Project
Oʻahu, Hawaiʻi

CH2MHILL

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Table 23. Water Surface Elevations for the 1-Percent ACE Flood at Selected Cross-Sections

Reach Name (per HEC-RAS Model)	Cross-Section ID	Water Surface Elevation (feet)		Change in Elevation (Compared to Future Without-Project Condition) (feet)[a]
		Without-Project	NED	Difference
Ala Wai Lower	1477	3.62	2.89	0.73
Ala Wai Middle	4847	7.41	6.16	1.25
Ala Wai Upper	8015	8.27	6.92	1.35
Kanahā Ditch	1874	72.54	69.87	2.67
	3005	78.59	78.44	0.15
Kanahā Split	1393.96	43.01	42.85	0.16
Makiki Lower	1719	7.35	6.66	0.69
	4325	33.87	27.78	6.09
Makiki Upper	6606	71.57	70.17	1.40
	9666	178.40	177.94	0.46
Mānoa Stream Main Reach	948	38.50	38.30	0.20
	5461	116.77	113.87	2.90
	8367	153.24	151.26	1.98
	9032	163.52	155.59	7.93
	10309	173.34	171.54	1.80
	13136	211.44	208.10	3.34
	15753	260.72	256.48	4.24
Pālolo Lower	1813	7.44	6.44	1.00
	3406	13.19	11.72	1.47
Pālolo Main	6376	42.98	39.74	3.24
	8574	89.06	87.35	1.71
	11649	138.67	136.59	2.08
	14619	186.99	184.36	2.63
Pūkele	2184	287.58	283.77	3.81
UH Split	1107	13.55	11.45	2.10
	4606	102.12	99.72	2.40
Waiʻōmaʻo	1724	266.67	265.39	1.28
			Average Change	**2.19**

Notes:

[a] Elevation based on Mean Sea Level Datum

Nor is the project expected to significantly affect drainage patterns. However, the measures in the recommended plan have been designed to detain floodwaters and/or improve conveyance, so as to reduce the risk of flooding within the watershed (**IMP HYD-1**). The HEC-RAS hydraulic modeling results demonstrate the beneficial impact of the flood-reduction measures in the recommended plan; the 1-percent ACE floodplain based on implementation of the recommended plan is shown in Figure 14. The culverts draining the detention basins are generally designed to pass all flows under 10-20% ACE; in other words, 80-90% of all expected flow events will pass without increase to inundation beyond existing conditions. The resulting water surface elevations are presented in Table 23; the reduction in depth and velocity of floodwaters was previously presented in Table 10. Model results for other annual flood exceedance probabilities (50-, 20-, 10-, 5-, 2-, 0.5-, and 0.2-percent ACE floods) are presented in Appendix A.

The project is designed to detain in-stream flows and/or improve conveyance within the stream channels, such that it is not expected to affect the quantity of stormwater runoff or the capacity of the stormwater drainage system. By reducing the floodplain, the project would reduce the extent of the stormwater drainage system that is subject to inundation. In addition, the design includes features to maintain the functionality of the stormwater drainage system during flood conditions. Specifically, as the proposed floodwalls would function to contain higher water levels within the Ala Wai Canal, flapgates would be installed over each of the stormdrain outfalls along the Canal to prevent the floodwaters from backing up into the stormwater drainage system. Slide gates and pump stations would be installed to allow for pumping of stormwater runoff from the larger outfalls to the Canal, including the Kapahulu storm drain.

5.5.2.3 Alternative 2A

Similar to the recommended plan, Alternative 2A would serve to significantly reduce the potential for flooding within the watershed, with no other anticipated impacts to hydrology and hydraulics. However, there are some variations in the potential for flood damage reduction. In particular, under Alternative 2A, there would be more area subject to flooding north of the Ala Wai Golf Course, and along the upper reaches of Mānoa and Pālolo streams (because of the lack of upstream detention). Furthermore, the average reduction of water surface elevations across the watershed would only be approximately 0.95 foot (as compared to approximately 2.19 feet for the recommended plan). The 1-percent ACE floodplain based on implementation of Alternative 2A is shown in Figure 13; anticipated depths and velocities are presented in Table 10. Model results for other ACE probabilities are presented in Appendix A.

Although the overall potential for flood damage reduction associated with Alternative 2A is not expected to be as great as that associated with the recommended plan, Alternative 2A is still expected to provide a significant beneficial impact relative to reduced potential for flooding in the watershed.

5.6 Water Quality

5.6.1 Affected Environment

5.6.1.1 Regulatory Framework

Regulations and policies that protect water quality and are being considered as part of the proposed project include the following:

- Clean Water Act, Sections 401 and 402
- HAR Chapter 11-54 (Water Quality Standards)
- Chapter 11-55 (Water Pollution Control)

5.6.1.2 Environmental Setting

The quality of surface water and groundwater resources can be affected by a variety of pollutants, resulting from both natural and human-derived sources. Given the heavily developed nature of the Ala Wai Watershed, groundwater and surface water resources are especially vulnerable to contamination and other changes in quality, particularly within the urbanized areas. Following is a description of the existing quality of surface and groundwater resources within the Ala Wai Watershed.

Surface Water Quality

Numerous studies have investigated the extent of pollution in the water column and sediments within the Ala Wai Canal, with a few studies also sampling the main streams in the watershed. In general, these studies have identified problems related to bacteria, trace metals, nutrients, pesticides, toxic organics, and sediment (Edward

K. Noda, 1992a, 1992b, and 1992c; Laws et al., 1993; DOH, 1997a; DOH, 2002; Anthony et al., 2004; De Carlo et al., 2004); these are briefly described below. In addition to these constituents, significant amounts of trash and debris are commonly observed in the streams and canals.

- **Bacteria**: High levels of fecal coliform, enterococcus bacteria and other indicators of fecal pollution (e.g., *Clostridium perfringens*) have been detected in the Ala Wai Canal and streams, particularly after runoff events (DOH, 1997a). Leptospirosis, a bacterial infection spread primarily through animals (e.g., rats), is another problem in tropical waters; cases in Hawai'i have been reported by people swimming in stream waters. Although no studies have been conducted to determine the degree of threat to public health, a blanket advisory has been issued for all fresh waters in the State (DOH, 2014).
- **Trace Metals**: Studies on dissolved and particulate trace metals in the Ala Wai Watershed by De Carlo et al. (2004)[25] show elevated levels, with ongoing inputs of lead, zinc, copper, barium, and cobalt from urban sources and less significantly, inputs of arsenic, cadmium, and uranium from agricultural sources. Although the lead concentrations have been decreasing since leaded gasoline was phased out, there are still continued inputs believed to be linked to lead-based paint used in older homes and from brake pads and other automotive uses (De Carlo et al., 2004; Sutherland, 2000). High levels of copper and zinc also result from heavy use of these substances in automobile brake pads and tires. De Carlo et al. (2004) propose that road-deposited sediments may also contribute to the elevated concentrations of barium and cobalt in the lower watershed.
- **Nutrients**: Nitrogen and phosphorus concentrations in the streams and Canal have consistently exceeded the State water quality standards (DOH, 1997a). The highest nutrient levels have consistently been reported at the upper end of the Ala Wai Canal (near Kapahulu Avenue), which receives urban runoff from storm drain outfalls (Edward K. Noda, 1992b); however, high levels have also been documented in forested upper watershed areas (Yim and Dugan, 1975). Sources of nitrogen and phosphorus are soil erosion, animal wastes, fertilizers, automobile exhaust, food wastes, rotting vegetation, sewage, and specifically in the lower canal areas, illicit discharges from boats in the yacht harbor.
- **Pesticides**: The organochlorine compounds dieldrin, chlordane, and heptachlor were used for many decades as pesticides to control termites in Hawai'i, until they were phased out in the 1980s. As these compounds typically have low solubility, they are mostly transported through soil erosion and surface runoff, then accumulate with bottom sediments in the streams and move through the food chain (Brasher and Wolff, 2004). Because of their widespread use, dieldrin and chlordane have been detected in fish and stream bed sediment samples from Mānoa Stream at concentrations that exceed aquatic life and wildlife protection guidelines (Brasher and Anthony, 2000). In comparison to other streams sampled across the nation, urban streams on O'ahu (such as Mānoa Stream) had the highest concentrations of chlordane and dieldrin detected (Brasher and Wolff, 2004).[26] Anthony et al. (2004) believe that, because of the persistence of dieldrin, soil and stream bed sediments in urban Honolulu serve as a long-term reservoir of dieldrin. Similarly, the valley-fill aquifer that contributes to low flows in Mānoa Stream may also be a persistent reservoir of dieldrin.

Most of the sampling efforts and analyses in the Ala Wai Watershed have concentrated on insecticides. Although not to the same degree, herbicides have also been detected in Mānoa Stream, with the most frequent detections involving prometon (in base flows) and bentazon (in storm runoff) (Anthony et al., 2004). Both of these herbicides are used in urban areas; bentazon is used for turfgrass, so detections are

[25] This work builds upon previous studies such as those by De Carlo and Spencer (1995), Sutherland (2000), and De Carlo and Anthony (2002).

[26] Concentrations of dieldrin in Mānoa Stream surface water were highest in base flows, but were also found to be elevated during storm conditions; this suggests the dieldrin enters the water column from multiple sources, including flushing from soil via storm runoff, groundwater inflow, and dissolving from stream sediments (Larson et al., 1997; Anthony et al., 2004).

believed to represent wash off from soils during rainstorms (Anthony et al., 2004). It is not clear if detections of these herbicides pose any risk to aquatic life.

- **Toxic Organics:** Toxic organics include such compounds as volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), phthalates, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs); these contaminants are commonly associated with products that are prevalent in urban areas, including gasoline compounds, construction materials, plastics, and vehicle exhaust. Similar to organochlorine pesticides, many of these compounds, particularly SVOCs and PCBs, have low solubility and are transported through soil erosion and surface runoff, ultimately moving up the food chain via benthic algae and invertebrates (Brasher and Wolff, 2004).
- **Sediment**: The Ala Wai Canal generally serves as a sink for the watershed, capturing sediment that is transported via its tributary streams, a function presumably provided by the former coastal wetlands in this area. Historical accounts reference large quantities of sediment being deposited in the nearshore waters during storm events (Weigel, 2008), as occurs in other steep tropical environments, but the natural background erosion and transport rates are not known. Nevertheless, input of fine sediment is believed to have increased over time because of feral pig wallows and shallow-rooted exotic vegetation in the upper watershed, eroding channel banks, and runoff from adjacent urban areas. Sediment loading contributes to habitat degradation in the streams and in the nearshore marine environment by smothering substrate, filling interstitial spaces, and harming coral reef communities. Calculations of the sedimentation rate in the Ala Wai Canal over time have been relatively consistent, ranging between approximately 7,000 to 8,000 cubic meters per year (m^3/yr) (Gonzalez, 1971; Laws et al., 1993; McMurty, 1995). The most recent dredging effort was conducted in 2002 and 2003, during which approximately 141,440 m^3 of sediment was removed from the Ala Wai Canal and the lower portion of the Mānoa–Pālolo Drainage Canal (D. Imada, personal communication, June 14, 2010).

Other parameters that are important to water quality in streams include temperature, pH and dissolved oxygen. Temperature is an important biological parameter, and is tied closely to water flow and shading by riparian vegetation. Temperature records comparing urban and forested streams on Oʻahu indicate that urban streams have a higher mean temperatures and much greater diurnal and seasonal swings in temperature as compared with forested streams (AECOS, 2010; Brasher, 2003). Dissolved oxygen and pH levels are temperature dependent, with reduced quality in waters with stagnant flow and warm temperatures. In general, neither low dissolved oxygen nor deviant pH levels occur in the natural stream reaches in the watershed (AECOS, 2010). However, channel modifications that result in stagnation and/or high temperature fluctuations can lead to detrimental dissolved oxygen and pH levels, in some cases leading to eutrophication, particularly in the Ala Wai Canal (AECOS, 2010; Laws et al., 1993).

Water Quality Standards

Specific water quality criteria have been promulgated in HAR Section 11-54, which, if met, are designed to allow water bodies to achieve designated beneficial uses. Water bodies that do not achieve the criteria are designated as "impaired" and are placed on the Clean Water Act Section 303(d) List of Impaired Waters. Based on the data presented in the 2014 State of Hawaiʻi Water Quality Monitoring and Assessment Report (DOH, 2014), several locations within the Ala Wai Watershed have been designated as impaired water bodies, including the three major streams and the Ala Wai Canal. Mānoa Stream is listed for total nitrogen, nitrate and nitrite nitrogen, total phosphorus, turbidity, dieldrin, and chlordane. Pālolo Stream is listed for trash, and Makiki Stream is listed for total nitrogen and total phosphorus. The Ala Wai Canal is listed for total nitrogen, nitrate and nitrite nitrogen, total phosphorus, turbidity, enterococci, pathogens, metals, suspended solids, and organochlorine pesticides.

For each water body on the Section 303(d) list, a Total Maximum Daily Load (TMDL) must be developed to bring that water body into compliance with water quality standards. To date, the only TMDLs that have been developed are for nitrogen and phosphorus in the Ala Wai Canal. Development of the remaining TMDLs has been designated by the State of Hawaiʻi Department of Health (DOH) as a low priority (DOH, 2014).

Groundwater Quality

The quality of groundwater can be affected by contamination from both natural and anthropogenic sources; chemical leaching and saltwater intrusion are two common sources of contamination. Chemical leaching occurs when residual contaminants such as petrochemicals or pesticides percolate from the surface soil layers into the freshwater lens. Saltwater intrusion can occur when brackish water infiltrates the freshwater lens, often caused by overpumping (or improper pumping) of the aquifer (CWRM, 2008a).

The Hawai'i Groundwater Protection Program (GWPP), administered by the DOH Safe Drinking Water Branch, is focused on assessment of water quality and development of pollution prevention and protection measures. As part of the program, a groundwater contamination map is maintained to identify drinking water wells, non-potable wells, and fresh water springs where contaminants have been detected (DOH, 2015). The map identifies dieldrin as the only contaminant detected within the three wells sampled within the watershed. The detection levels ranged from 0.01 to 0.03 parts per billion (ppb), which are below DOH and Federal drinking water standards.

5.6.2 Impacts and Mitigation

Effects on water quality were considered to be significant if implementation of an alternative plan would result in any of the following:

- Substantially degrade surface water quality such that it would violate water quality standards, contribute to exceedance of aquatic life guidelines, or otherwise impair beneficial uses
- Substantially increase contaminant levels in the groundwater

The potential effects to water quality that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.6.2.1 No Action Alternative

Under the No Action Alternative, no Federally sponsored flood risk management measures would be constructed. Although potential construction-related impacts to water quality would not occur, nor would the potential long-term benefits associated with the capture and removal of flood-related debris and sediment via the debris and detention features.

Input of sediment (such as that caused by erosion of the near-stream and upper watershed areas) and transport of sediment-bound contaminants is generally expected to continue at the same rate, as the factors that influence erosion (e.g., invasive species cover in the upper watershed) are already widespread.[27] Based on the existing TMDLs, it is expected that nutrient levels in the watershed would be reduced, although the extent to which the reductions are achieved cannot be predicted. Given the persistence of dieldrin and other pesticides, inputs from long-term reservoirs are expected to continue over time. Although there are ongoing discussions about the need to reduce anthropogenic sources of contaminants (e.g., use of heavy metals in brake pads and tires), the extent to which regulatory restrictions would be established at either the Federal or State level are unknown. As such, significant reductions for the range of contaminants in the watershed are not expected for the future without-project conditions. It is assumed that the Canal would continue to be dredged at approximately the same rate, or at least once every 25 years, and as such, the sediment and associated contaminants that accumulate in the Canal would continue to accumulate and be removed at approximately the current rate.

5.6.2.2 Recommended Plan (Alternative 3A-2.2)

In addition to impacting soil resources and channel stability, construction-related erosion could increase the delivery of sediment and associated pollutants via stormwater runoff, which could temporarily affect water

[27] This assumption is based on the best professional judgment of knowledgeable biologists, including Rob Hauff (DOFAW), Stephen Miller (USFWS), Rachel Neville (OISC), Miranda Smith (KMWP), and Deanna Spooner (Hawai'i Conservation Alliance) as discussed on April 22, 2010.

quality in the streams and downstream receiving waters (**IMP WQ-1**). Although sediment-bound pollutants are known to occur throughout the watershed (particularly in the urbanized areas), none of the soils that would be exposed by construction are expected to contain excessive levels of contamination. In general, construction of the flood risk measures would involve placement of imported materials, with only minimal amounts of excavation. All materials used to construct the measures would be from approved sources, and would be clean and free of contaminants. Areas requiring excavation (e.g., for the Waiʻōmaʻo detention basin, and to create the spillway for the Kanewai detention basin and the Ala Wai Golf Course detention basin) are either located in the upper watershed and/or in undeveloped open space areas, which are not subject to significant inputs of roadway sediments or other anthropogenic contaminants, such that a significant increase in pollutant delivery to the streams is not expected as a result of construction. As further discussed in Section 5.12, none of the measure locations are known to contain hazardous or toxic waste.

In addition, the proposed project would require the storage and use of some hazardous materials, which if handled inappropriately, could result in an accidental spill or inadvertent discharge to the streams or groundwater. In particular, construction activities would involve the use of heavy equipment, cranes, compactors, and other construction equipment that use petroleum products such as fuels, lubricants, hydraulic fluids, and coolants, all of which are detrimental to water quality (**IMP WQ-2**).

As construction would disturb more than 1 acre of land, the project would be regulated under the State's NPDES stormwater program, which requires preparation of a SWPPP to obtain permit coverage. The objective of a SWPPP is to describe the measures that would be implemented to prevent sedimentation, erosion, and stormwater contamination, in compliance with the requirements of the NPDES program. BMPs that would be implemented to avoid and minimize impacts associated with potential pollutants are listed in Table 24. Preparation and implementation of the SWPPP, as well as adherence to other requirements of the NPDES program, would reduce the potential construction-related water quality impacts to a less-than-significant level; no mitigation is required.

Table 24. Potential Pollutants from Construction Activities and Proposed Avoidance and Minimization Measures

Pollutant	Source/Activity	Control Measure (BMP)
General	All construction activities	Employee/subcontractor training; Sequencing of activities to minimize exposure of cleared areas; Timing construction to avoid wet winter months (to the extent possible)
Soil/Sediment	Excavation, grubbing, grading, stockpiling, watering for dust control	Minimize extent of clearing and grubbing; Maintain existing vegetation; Provide temporary soil stabilization (e.g., mulching; hydroseeding; soil binders, geotextiles, etc.); Install silt fencing and/or sediment traps; Provide dust control (but avoid excess dust control watering); Implement and maintain proper dewatering techniques; Protect and manage stockpiles; Cover loose materials in haul trucks; Stabilize construction entrance/exit and provide tire wash; Revegetate temporarily disturbed areas
Oil, Gas and Lubricants	Construction vehides and equipment	Regular vehicle and equipment inspection; Fueling and maintenance in designated areas; Use of drip pans; Proper storage and disposal techniques; Implement spill controls
Construction Waste	Construction debris, select fill, paint, chemicals, etc.	Protection of stockpiles; Provide watertight dumpsters, with regular waste removal and disposal; Proper containment, labeling and disposal of hazardous materials, such as petroleum products, solvents, etc.); Regular site inspection and litter collection; Salvage and reuse of materials, as appropriate
Concrete Compounds	Concrete floodwalls and spillways	Proper storage and handling techniques for concrete-curing compounds; Perform washout of concrete trucks in designated areas only; Containment in wash water pits; Proper disposal of material from washout facilities
Equipment and Vehicle Wash Water	Construction vehicles and equipment	Equipment and vehicle washing in designated areas; Provide containment of wash water
Sanitary Waste	Portable toilets or septic tank	Proper sanitary/septic waste management

Note:
BMPs include those adopted from and defined in the CCH *Best Management Practices Manual for Construction Sites in Honolulu* (2011).

Once constructed, the structures themselves are not expected to contribute pollutants to the streams or otherwise measurably affect water quality. The detention structures would be comprised of compacted, earthen berms with concrete or grouted rip-rap spillways; the debris catchment structures would be comprised of a concrete pad with metal posts; the floodwalls would be comprised of concrete walls; the downstream energy dissipation and scour protection features would be comprised of stone riprap; and the mitigation measures would be comprised of grouted stone. All materials used to construct the measures would be from approved sources, and would be clean and free of contaminants. Although the debris and detention basins may slightly reduce riparian shading (e.g., vegetation management around the perimeter of the detention berms), they are not expected to contribute to any measurable changes in water temperature, nor pH or dissolved oxygen levels.

Over the long term, the project features are not expected to increase channel or bank erosion, or otherwise contribute to sediment and/or contaminant inputs to the streams, such that water quality conditions are generally expected to be commensurate with the existing condition. During flood conditions, the flood risk management measures are designed to either detain or contain stream flows within and directly adjacent to the waterways; the project includes features to maintain stormwater delivery (e.g., pumps associated with the Ala Wai Canal floodwalls), but would not significantly alter the quality, quantity, or pattern of stormwater inputs to the streams and/or Canal. The energy dissipation and scour protection features constructed downstream of several detention structures will serve to reduce the risk of channel or bank erosion, and the mobilization of stream sediment during high flow periods. Likewise, concrete box culverts have been selected for some detention basins to accommodate extreme flows that could undercut the footings of arch culverts.

The detention basins would function to temporarily hold stream flows, slowly releasing them within the streams and Canal. To the extent that contaminants are present in the detention areas (particularly within the multi-purpose detention areas, which may be subject to herbicide applications), detained water could flush contaminants into the streams, thus contributing to degraded water quality conditions. Conversely, contaminants in the water column or stream sediments could be deposited in the detention basins, thus transferring contamination into those area (**IMP WQ-3**). However, the multi-purpose detention features are located within areas that are already subject to flooding under the existing without project condition, such that the project is not expected to substantially increase delivery of contaminants to the streams beyond that which already occurs or otherwise alter the location or degree of water quality contaminants. Similarly, in-stream detention in the upper reaches of the watershed is not expected to substantially increase mobilization of any contaminants beyond the existing condition. As such, the potential for water-quality impacts associated with detention of flood waters is expected to be less than significant.

Although the structures are not designed to capture sediment (with the exception of the Ala Wai Golf Course detention basin), some degree of sediment deposition is expected to occur within the detention basins, particularly during periods of inundation associated with flood stage flows. As previously described, sediment and debris (including trash and other man-made debris) that accumulates within the debris and detention features would be removed as part of the routine O&M activities and properly disposed of at an approved, offsite location that is qualified to accept the material. Removal of these materials from the debris and detention basins is anticipated to provide some degree of water quality benefit to downstream areas (**IMP WQ-4**). As the structures are not explicitly designed to capture sediment, the quantity of sediment and any associated pollutants to be removed has not been quantified. Given the anticipated sediment capture in the debris and detention basins, in combination with the Canal's function as a sediment sink, the project is not expected to increase (and could possibly decrease) sediment delivery to the nearshore waters.

5.6.2.3 Alternative 2A

Under Alternative 2A, the general nature of impacts to water quality would be similar to those described for the recommended plan. However, the location and overall extent of impacts would vary based on the different locations of the flood management measures.

Alternative 2A would result in a greater extent of disturbance, both overall and within the streams (see Table 17), thus increasing the potential for construction-related water quality impacts. This would include installation of a 600-foot-long culvert along the edge of Mānoa Stream, through an urbanized area that could contain soils with higher levels of anthropogenically-derived pollutants. However, consistent with the requirements described for the recommended plan, implementation of Alternative 2A would require compliance with the State's NPDES stormwater program. It is expected that the SWPPP would address the same range of pollutants and control measures as described in Table 24. Preparation and implementation of the SWPPP, as well as adherence to other requirements of the NPDES program, would reduce the potential construction-related impacts to a less-than-significant level; no mitigation is required.

The measures included in Alternative 2A would be constructed with the same type of materials as for the recommended plan, none of which are expected to contribute pollutants to the streams or otherwise measurably affect water quality. Once constructed, the debris and detention basins included in Alternative 2A are expected to have some potential to trap sediment, such that there could be some degree of long-term benefit to water quality, similar to that described for the recommended plan.

5.6.3 Clean Water Act Section 401 Water Quality Certification

In accordance with the Clean Water Act Section 401, DOH administers the State's Water Quality Certification Program. The objective of the program is to ensure that any Federally permitted activity will not adversely impact the existing uses, designated uses, and applicable water quality criteria of the receiving State waters. Based on the analysis provided above, Section 401 Water Quality Certification will be requested from the DOH prior to construction.[28]

[28] At the time of drafting this report, USACE has applied for, but not received Water Quality Certification from DOH.

5.7 Biological Resources

5.7.1 Affected Environment

5.7.1.1 Regulatory Framework

Regulations and policies that protect biological resources under consideration as part of the proposed project include the following:

- Endangered Species Act (ESA)
- Migratory Bird Treaty Act
- Magnuson-Stevens Fishery Conservation and Management Act
- Clean Water Act, Section 404
- HRS Chapter 195D (Conservation of Aquatic Life, Wildlife and Land Plants)
- HRS Chapter 174C (State Water Code)
- EO 11990 – Protection of Wetlands
- EO 13112 – Invasive Species

In addition to these regulations, the Fish and Wildlife Coordination Act (FWCA) requires Federal agencies to coordinate with the U.S. Fish and Wildlife Service (USFWS) and State wildlife agencies during project planning to provide for adequate consideration of wildlife resource conservation, including minimization of adverse effects and compensation for wildlife resource losses. Coordination with USFWS and DLNR (including both DOFAW and DAR) has been conducted throughout the planning process (including the various site visits and meetings listed in Table 38). Input received to date has been integrated into the planning process, as summarized in this report; no high-risk issues or concerns have been raised to date. Compliance with ESA Section 7 is discussed in Section 5.7.3. Supporting documentation is contained in Appendix E; this content is also being used for compliance with HRS Chapter 195D.

5.7.1.2 Environmental Setting

Biological resources include vegetation and wildlife, including species that are protected under Federal and/or State endangered species statutes. The resources that occur within the project area are generally described below.

Vegetation

Within the Ala Wai Watershed, the developed urban zone covers the coastal plain, extending to the back of the valley floors (and in some cases, up and along the ridges between the valleys). Within these areas (including all of the proposed measure locations within the urban zone), the vegetation is significantly limited by urban development; it is primarily comprised of landscaped vegetation or ruderal, weedy species. A limited amount of riparian vegetation occurs along the stream corridors.

Forest Vegetation

The most extensive vegetation is concentrated within the upper watershed, with vegetation communities including wet shrubland, wet forest, and mesic forest habitats; these generally occur along a decreasing precipitation gradient, ranging from the highest elevations in the watershed down to the interface with the urban areas.

The steeper slopes from the Koʻolau ridgeline to roughly about the 1,500-foot contour support relatively undisturbed shrubland, which includes the greatest concentration of native vegetation. Below the shrubland is a wet forest, which grades into a mesic forest at lower elevations just above the urban zone. A variety of activities have impacted these habitats over time, resulting in a dominance of introduced species (Ziegler, 2002). Early changes in the composition of the forest ecosystem resulted from the introduction of pigs, which had a deleterious impact on many endemic plant species (Mueller-Dombois, 1981). Similarly, harvesting of native woods and cattle grazing resulted in substantial loss of forest cover (Griffiths, 1902). Subsequent reforestation efforts introduced non-native species to broad sections of the upper watershed. Introduced species now dominate these habitats, particularly trees and shrubs such as albizia (*Falcateria moluccana*), eucalyptus (*Eucalyptus globulus* and *E. robusta*), Chinese banyan (*Ficus microcarpa*), octopus tree (*Schefflera actinophylla*), guava, java plum (*Syzygium cumini*), Christmas berry (*Schinus terebinthefolius*), mango (*Mangifera indica*), and shoebutton ardisia (*Ardisia elliptica*); many of these species are considered to be invasive. These species are prevalent at all of the project locations in the upper watershed.

Riparian Vegetation

Riparian habitat refers to the area along a stream or other freshwater body that is, at least periodically, influenced by flooding (Mitsch and Gosselink, 1986).[29] Riparian vegetation is an important contributor to stream habitat, providing both shade and leaf litter to the aquatic environment. Shade helps to maintain low in-stream temperatures, although excessive shading can be unfavorable to native stream fauna because of reduced instream photosynthetic activity (typically a function of aquatic algae). Similarly, leaf litter is an important organic resource in streams, but non-native trees can contribute excessive amounts of litter, thus altering water quality (Kido, 2008a).

Riparian vegetation is present along all of the upper stream reaches, and is generally dominated by non-native species (many of which are considered invasive), including large trees such as Chinese banyan, *kukui* (*Aleurites moluccana*), mango, octopus tree, *hau* (*Hibiscus tiliaceus*), fiddlewood (*Citharexylum spinosum*), mountain apple (*Syzygium malaccense*), gunpowder tree (*Trema orientalis*), and gum (*Eucalyptus* sp.), as well as smaller herbaceous species such as exotic ginger (*Hedychium* sp.) and Job's tears (*Coix lachryma-jobi*). The canopy coverage of these species is generally high, typically exceeding 60 percent, with some areas (e.g., the upper reaches of Pālolo stream) having complete canopy closure (Kido, 2006; Kido, 2007; Kido, 2008a; Oceanit, 2004).

Within the urbanized portion of the watershed, riparian vegetation is generally limited to unchannelized stream reaches, such as along portions of Mānoa Stream. A majority of Pālolo and Makiki streams are channelized and lack a riparian zone (Oceanit, 2004; Englund and Arakaki, 2004; Kido, 2008a). Mangrove trees (*Rhizophora mangle*) are present in some areas in the lower estuarine reaches of the Mānoa–Pālolo Drainage Canal and the Ala Wai Canal, although concrete and concrete masonry (CRM) walls constructed as banks have eliminated much of the riparian vegetation.

A 2004 survey of the streams in the Ala Wai Watershed identified a total of 238 species within the riparian corridors, the majority of which are non-native, naturalized species (Oceanit, 2004). Only 11 are indigenous (native to the Hawaiian Islands and other Pacific Islands), 1 is possibly endemic (uniquely native to the Hawaiian Islands), and 8 are early Polynesian introductions to the Islands. The complete list of species is contained in the *Natural Resources Review for the Ala Wai Watershed* (AECOS, 2010).

Invasive Vegetation

Invasive species are defined as non-native species whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Federal Register, 1999; USACE, 2009). As described above, except along the high-elevation ridges, the vegetation within the Ala Wai Watershed is dominated by non-native species; many of these are considered to be invasive. Commonly occurring species within the watershed that are included on the list of Hawai'i's most invasive species, as compiled by the Hawai'i State Alien Species Coordinator, include Chinese banyan, octopus tree, guava, Christmas berry, shoebutton ardisia, fiddlewood, and ginger (DOFAW, 2001). In addition, *hau* is of concern, as it spreads aggressively within the stream corridors, often forming an impenetrable thicket. Albizia is also widespread throughout the watershed, particularly in Mānoa Valley. Other species that occur, but are priority target species that are being actively controlled by the OISC include Miconia (*Miconia calvescens*) and Himalayan blackberry (*Rubus discolor*) (OISC, 2008).

29 In a dry climate, vegetation is a good indicator of the riparian zone, because it is fairly obvious from the vegetative growth how far the hydrologic influence of a stream extends. In a wet climate, as typifies the upper Ala Wai Watershed, the extent of the influence may not always be obvious. Certain plant species may owe their presence in a gulch or swale to the proximity of a stream, but many others do not (Bay Pacific Consulting, 1996).

The ecosystem impacts of these species vary, but in general, they are all capable of aggressively spreading and disrupting ecosystem structure or function (DOFAW, 2001). Most form dense, monotypic stands, displacing native species. As a result of the dense stands, infestation of some species (such as Miconia) may result in increased surface runoff, thereby reducing groundwater recharge and increasing soil erosion (Burnett et al., 2006). Of particular concern to flood risk management efforts, albizia has a shallow root system and relatively brittle branches that easily break, creating debris that can potentially impede streamflow.

Fauna

A variety of native and non-native wildlife species occur throughout the watershed, including birds, invertebrates, mammals and aquatic species. Given the degree of disturbance throughout the watershed, most of the terrestrial wildlife is comprised of non-native species, although some native species remain, particularly forest birds, including the Oʻahu *ʻelepaio* (*Chasiempis sandwichensis ibidis*), Oʻahu amakihi (*Hemignathus chloris*) and apapane (*Himatione sanguinea*). Other native species include endemic tree snails (*Achatinella* sp.) and damselfly species (*Megalagrion* sp.). The Hawaiian hoary bat *ʻōpeʻapeʻa* [*Lasiurus cinereus semotus*], the only land mammal native to Hawai'i, may also occur. Many of these native species are protected under Federal and/or State endangered species statutes, as further described below.

A variety of introduced mammals occur in the forested areas of the watershed, including feral pig (*Sus scrofa*), mongoose (*Herpestes aruopunctatus*), feral cats (*Felis catus*), and rats (*Rattus* sp.), many of which are invasive and pose a significant management concern. In particular, feral pigs are responsible for substantial modification of the forest habitat substrate (Stone and Scott, 1985; Roumasset et al., 1997; Kurdila, 1995); it is believed that feral pigs occur in all of the native and non-native habitats in the Koʻolau Mountains, with the exception of the cliff areas (KMWP, 2002). Non-native bird species that typically occur include the Shama thrush (*Copsychus malabaricus*), Japanese bush warbler (*Cettia diphone*), Japanese white-eye (*Zosterops japonicus*), red-vented bulbul (*Pycnonotus cafer*), red-whiskered bulbul (*Pycnonotus jocosus*), common mynah (*Acridotheres tristis*), and zebra dove (*Geopelia striata*) (KMWP, 2002). Several of these species, including the red-vented bulbul and the red-whiskered bulbul have been identified as invasive species (OISC, 2008). Several other common species, including the Japanese white-eye and mynah, are also of significant concern.

Given the extent of development, terrestrial wildlife in the urban portions of the watershed is primarily comprised of feral species (such as mongoose, cats, rats, and others). Shoreline areas may be used by waterbird species. Indigenous seabird species that have been previously documented in this area include the great frigatebird (*Fregata minor*), white-tailed tropicbird (*Phaethon lepturus*), white tern (*Gygis alba*), and brown booby (*Sula leucogaster*). Migratory shorebird species include the Pacific golden plover (*Pluvialis fulva*), wandering tattler (*Heteroscelus incanus*), and ruddy turnstone (*Arenaria interpres*) (Belt Collins, 1998). None of these are listed as endangered or threatened under Federal or State law. As further discussed below, native waterbirds (such as the Hawaiian stilt [*ae'o*], Hawaiian coot [*ʻalae ke'oke'o*], and Hawaiian moorhen [*ʻalae ʻula*]), all of which are Federally and State listed as endangered (Mitchell et al., 2005), could possibly use estuarine areas within the watershed as resting habitat.

Freshwater Aquatic Species

Native freshwater fish in Hawai'i are limited to five gobioid species (*o'opu*), including one indigenous (*o'opu nakea* [*Awaous guamensis*]) and three endemic (*o'opu alamoʻo* [*Lentipes concolor*], *o'opu nopili* [*Sicyopterus stimpsoni*], and *o'opu naniha* [*Stenogobius hawaiiensis*]) gobies, and one endemic eleotrid (*o'opu akupa*, *Eleotris sandwicensis*) (Kinzie, 1990). The native stream macrofauna assemblage also includes several shrimp species (*'opae kala'ole* [*Atyoida bisulcata*] and *ʻopae 'oeha'a* [*Macrobrachium grandimanus*]), and mollusk species (*hapawai* [*Neritina vespertina*] and *hihiwai* [*Neritina granosa*]). As part of their lifecycle, the adults of each of these species live and breed in freshwater streams; newly hatched larvae drift to the ocean, remaining there for several months before migrating back to freshwater habitat, cued by freshets (Yamamoto and Tagawa, 2000). All of these native species have been recently documented in the Ala Wai Watershed, with the exception of *o'opu alamoʻo* and *hihiwai* (Parham et al., 2015; Parham et al., 2008; Kido, 2008a).

In general, these species are well-adapted to the steep, flashy nature of Hawaiian streams. With the exception of *o'opu akupa*, the native fish species all have fused pelvic fins that form a sucking disc, which allows them to maintain position during swift flows and migrate up steep, rocky terrain (DAR, 2006).[30] Past studies have found that the various species are typically distributed along a relatively well-established continuum from the headwaters of a stream to the ocean, recognizing localized geologic conditions and physical characteristics affect species presence and distribution (Kido, 2008b; Fitzsimons et al., 2007; Kinzie, 1988; Kinzie, 1990). In general, habitat conditions believed to be favorable to native species include streams with complex, natural substrata that are relatively free of silt and detritus (which can smother eggs and contribute to oxygen depletion, respectively). These conditions are typically maintained by flashy stream hydrology, with freshets helping to flush organic debris and sediment, and scour the streambed, thus promoting the growth of algae, an important food source for stream animals (Kinzie, 1990; DAR, 2006).

Invasive Aquatic Species

A wide variety of non-native stream species have become established in Hawai'i's freshwater aquatic ecosystems, originating from a variety of sources as a result of both intentional introductions (e.g., for food, sport, or biocontrol purposes) as well as unintentional introductions. These include more than two dozen fish and invertebrate species that have been imported through the aquarium fish trade and subsequently released (OISC, 2008). Many of these non-native species are considered to be invasive, meaning their introduction causes (or is likely to cause) economic or environmental harm, or harm to human health (Federal Register, 1999; USACE, 2009). Collectively, these species disrupt the freshwater aquatic ecosystem and contribute to declines in endemic stream species populations.

The State Aquatic Invasive Species Management Plan (DLNR, 2003) identifies invasive freshwater fish and invertebrate species,[31] nearly all of which have been documented within the Ala Wai Watershed. These include smallmouth bass (*Micropterus dolomieui*), tilapia (*Tilapia* spp.), Chinese catfish (*Clarias fuscus*), armored catfish (*Hypostomus* c.f. *watwata*), poeciliids (*poecilia* spp.), Tahitian prawn (*Macrobrachium lar*), grass shrimp (*Neocaridina denticulata sinensis*), asiatic clam (*Corbicula fluminea*), leeches (*Myzobdella lugubris*), and caddisflies (*Trichoptera*) (Kido, 2006; Kido, 2007; Kido, 2008a; Englund and Arakaki, 2004; Englund et al., 2000).

Similar to other urban O'ahu streams, the dominant freshwater aquatic species (both in number and biomass) within the Ala Wai Watershed are catfish, poeciliids, and grass shrimp (Parham et al., 2015; Kido, 2008a). This includes two genera of catfish, *Hypostomus* spp. and *Ancistrus* spp., which generally appear to partition streams longitudinally, possibly because of differences in climbing abilities, with *Ancistrus* sp. more common at higher elevations and *Hypostomus* sp. more common at lower elevations.[32] Grass shrimp can reach very high densities along a continuum from the stream mouth to headwaters (Kido, 2006).

Occurrence of Freshwater Aquatic Species within the Ala Wai Watershed

The presence of native species of stream macrofauna can often be used as an indicator of stream ecosystem health (Kido, 2008b). In this context, portions of the watershed display signs of good stream habitat. However, the overall watershed lacks healthy populations of native fishes and aquatic invertebrates, likely because of degradation and fragmentation of usable habitat in the urban zone and the presence of introduced species (Parham et al., 2015; Parham, 2015; Oceanit, 2004). Recent observations of native species are typically limited to only a few individuals in the higher reaches of the upper watershed and in the estuarine environment.

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[30] *O'opu akupa* species lacks paired pelvic fins, so cannot climb steep terrain. *O'opu naniha* has a pelvic disk, but is better adapted to sitting in loose sand and gravel, rather than adhering to rocks in swift water. However, both species have adapted to allow them to maintain position in swiftly flowing water (Fitzsimons et al., 2007).

[31] The report acknowledges the difficulty in reaching consensus over which species should be considered invasive and states that the presented list of species is intended to be a "representation of the vast scope of [aquatic invasive species]…and should not be considered the sole threats to the aquatic ecosystems of Hawai'i" (DLNR, 2003).

[32] Both catfish species are obligate freshwater species and therefore cannot naturally expand their geographic range between watersheds. It is believed that any expansion in their geographic range is tied to the aquarium trade (such as release of species obtained from pet stores) and correlates with residential areas (Kido, 2008a).

Specifically, *o'opu nakea* has been observed in tributaries to all the streams in the upper watershed, including Lua'alaea, Kānealole, Pūkele, and Wai'ōma'o streams (Parham et al., 2015; Kido, 2006; Kido, 2007; Kido, 2008a). *O'opu naniha*, *o'opu nakea*, *o'opu nopili, o'opu akupa* and *aholehole* have all been documented in the lower reaches, particularly within the Mānoa–Pālolo Drainage Canal (Parham et al., 2015; Kido, 2006; Kido, 2008a; Parham et al., 2008; Englund and Arakaki, 2004). *'Opaekala'ole* has also been documented in Moleka, Lua'alaea, and Waiakeakua streams (Kido, 2006; Englund and Arakaki, 2004), and *'opae'oeha'a* in the Mānoa–Pālolo Drainage Canal (Kido, 2008a; Parham et al., 2008).

With these notable exceptions, the extant aquatic macrofauna is dominated by non-native species (Parham et al., 2015; Englund and Arakaki, 2004; Kido, 2008a). In addition to the invasive species noted above, other non-native species that commonly occur include liberty molly (*Poecilia sphenops*), guppy or rainbow fish (*Poecilia reticulata*), swordtail (*Xiphophorus helleri*), mosquitofish (*Gambusia affinis*), and convict cichlid (*Archocentrus nigrofasciatus*) and the crayfish (*Procambarus clarkii*).

In general, the aquatic fauna of the streams is very similar, which is not unexpected for streams that share a common mouth and occur within areas with similar development patterns. A comprehensive list of species identified during recent surveys is contained in the *Natural Resources Review for the Ala Wai Watershed* (AECOS, 2010).

Estuarine Species

The Ala Wai Canal is considered an estuary, defined by the State of Hawai'i Water Quality Standards (HAR Title 11, Chapter 54) as "characteristically brackish waters in well-defined basins with a continuous or seasonal surface connection to the ocean that allows entry of marine fauna." As such, the Canal provides important nursery grounds for native juvenile fish (Jokiel et al., 2004), and is an important component of the migratory pathway for native amphidromous species.

Recent surveys have found a relatively non-diverse assemblage of species in the Canal, presumably a result of degraded habitat conditions and water quality in the Canal. Non-native species such as tilapia (*Tilapia mozambiqua*), which thrive in slow-moving waters with low oxygen levels, are the most dominant species in the Canal. Other organisms that may occur include young trevally (*ulua* [family Carangidae]), Hawaiian flagtail (*aholehole* [*Kuhlia sandvicensis*]), bonefish (*Abula glossodonta*) Samoan crab (*Scylla serrata*), and mantis shrimp (*Odontodactylus scyllarus*) (DOH, 1997b). Both tilapia and Samoan crab have been identified as invasive in the State Aquatic Invasive Species Management Plan (DLNR, 2003).

Protected Species and Critical Habitat

Several of the wildlife species within the watershed are listed as threatened or endangered under the Federal ESA and/or State law (HRS Chapter 195D [Conservation of Aquatic Life, Wildlife and Land Plants]). Based on input from the USFWS, Federally and State listed species that could potentially occur in the Ala Wai Watershed include the following:[33]

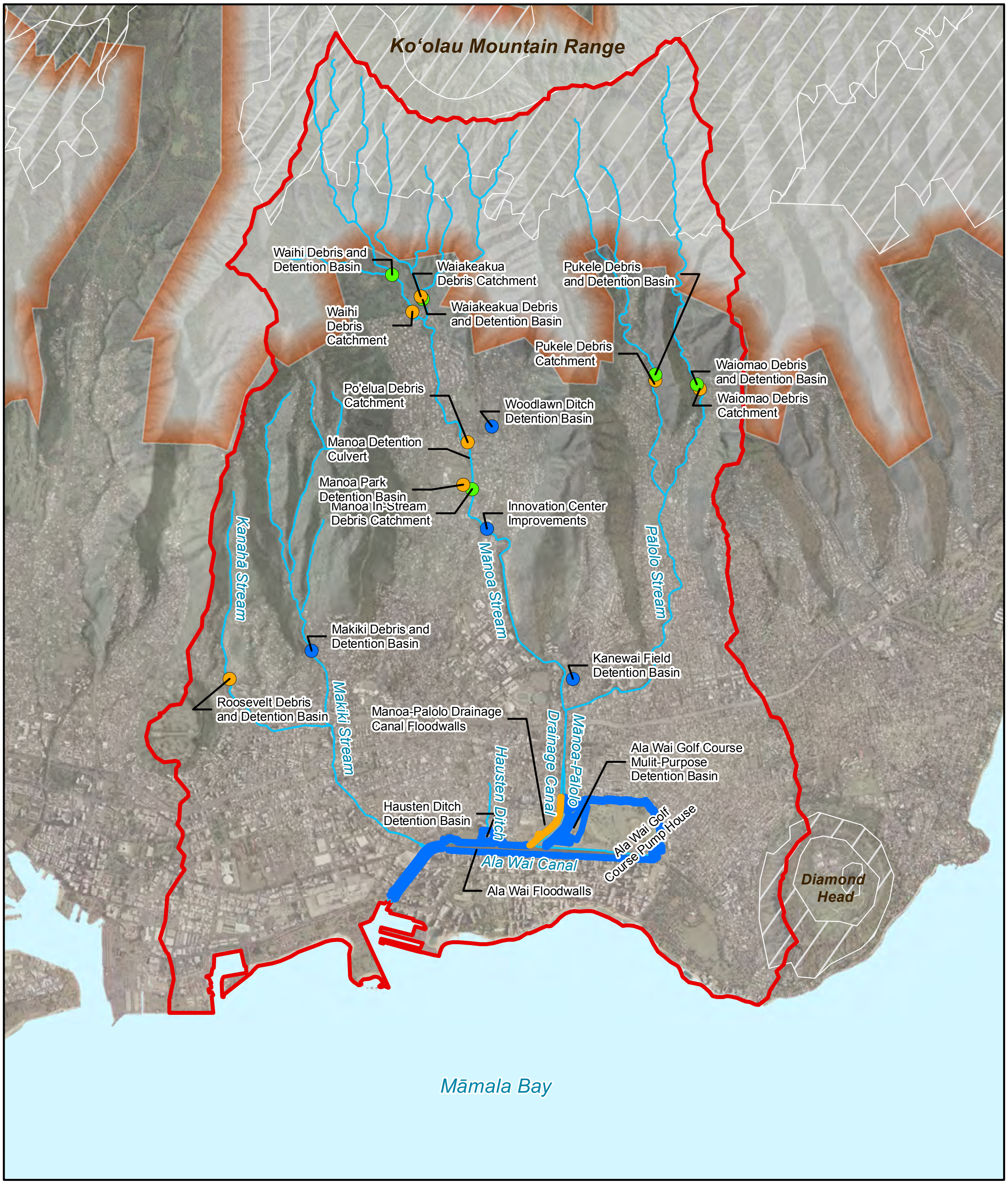
- Hawaiian hoary bat (*Lasiurus cinereus semotus*)
- Hawaiian monk seal (*Monachus schauinslandi*)
- O'ahu elepaio (*Chasiempis sandwichensis ibidis)*
- Hawaiian coot (*Fulica alai*)
- Hawaiian stilt (*Himantopus mexicanus knudseni*)
- Hawaiian duck (*Anas wyvilliana*)
- Hawaiian moorhen (*Gallinula chloropus sandvicensis*)
- O'ahu tree snails (*Achatinella* sp.)
- Hawaiian damselflies (*Megalagrion* sp.)

[33] In addition to these, the National Marine Fisheries Service (NMFS) identified a variety of marine-based species that could potentially occur in the nearshore marine waters of the watershed. Because the project is only addressing riverine-based flood risk management and is not expected to directly or indirectly affect the nearshore marine waters, the marine species are not further addressed.

- Various plant species including *haha* (*Cyanea* sp.), *Diellia erecta*, *nanu* (*Gardenia mannii*), *Gouania meyenii*, *wawae iole* (*Huperzia nutans*), *Lobelia oahuensis*, *Marsilea villosa*, *Pteris lidgatei*, *Schiedea nuttallii,* and *Spermolepis hawaiiensis*

However, many of these species are not expected to occur within the project area, either because the project area lacks suitable habitat and/or the species has a restricted distribution (or is believed to be extirpated). The only species that are expected to have the potential to occur within the measure locations are Hawaiian hoary bat, O'ahu elepaio, Hawaiian stilt, Hawaiian coot, Hawaiian moorhen, and the blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*). A detailed discussion of the habitat requirements, known distribution and potential occurrence of the listed species is provided in the Biological Assessment, which was prepared as part of the ESA Section 7 consultation process (Appendix E).

Critical habitat has been designated within the Ala Wai Watershed for the O'ahu elepaio and for several of the listed plant species, as shown in Figure 18. Not all of the species are presently known to occupy the designated critical habitat; some have not been recorded from the watershed since early in the last century and some are possibly extinct (Federal Register, 2012). None of the proposed measure locations are within critical habitat.

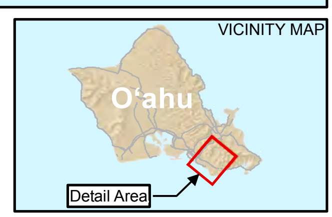


LEGEND

- Stream
- Watershed Boundary
- Critical Habitat (Consolidated for Multiple Species)
- Critical Habitat for O'ahu 'Elepaio (Chasiempis sandwichensis ibidis)

Flood Control Measures Category

- Alternative 2A
- Recommended Plan
- Alternative 2A and Recommended Plan



0 1 2 Miles

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Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

FIGURE 18
Critical Habitat
Ala Wai Canal Project
O'ahu, Hawai'i

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Essential Fish Habitat

Pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, essential fish habitat (EFH) is defined as those waters and substrate necessary for Federally managed species to spawn, breed, feed, and/or grow to maturity; these resources are managed by NMFS.

No EFH has been designated within the project area. However, there is designated EFH adjacent to the project area, in waters to which the streams and Canal drain (i.e., Māmala Bay). Specifically, in this area, EFH has been designated for the following Management Unit Species (MUS):

- Bottomfish: water column down to 400 meters from shoreline out to the 200-mile U.S. Exclusive Economic Zone (EEZ) boundary (for eggs and larvae); and water column and all bottom habitat from shoreline to a depth of meters (for juveniles and adults)
- Pelagics: water column down to 200 meters (for eggs and larvae) and 1,000 meters (for juveniles and adults) from shoreline out to EEZ boundary
- Coral Reef Ecosystem: Water column and all bottom substrate down to 100 meters depth from shoreline out to EEZ boundary
- Crustaceans (lobsters/crab): Water column down to 150 meters depth from shoreline out to EEZ boundary (for eggs and larvae); and bottom from shoreline down to 100 meters depth (for juveniles and adults)

5.7.2 Impacts and Mitigation

Effects on biological resources were considered significant if implementation of an alternative plan would result in any of the following:

- Result in a substantial loss of native species;
- Reduce habitat availability or degradation of habitat suitability of a magnitude and/or duration that could substantially affect a native species population;
- Substantially interfere with the movement of migratory species; or
- Introduction or contribute to the substantial spread of an invasive species.

The potential effects to biological resources that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.7.2.1 No Action Alternative

Under the No Action Alternative, no flood risk management measures would be implemented and as such, project-related impacts to biological resources would not occur. In the absence of flood reduction measures, it is anticipated that areas adjacent to the stream (including forested areas in the upper watershed and other vegetated areas in the urbanized zone) would be subject to periodic flooding.

In general, future climate changes are expected to result in habitat loss and degradation, decreased biodiversity (including extinction of endangered species and migration and loss of native species), and spread of invasive species. However, these conditions are already prolific within the watershed; therefore, it is expected that the future without-project conditions would be commensurate with existing conditions. Specifically, it is expected that the measure sites would continue to be characterized by a suite of non-native (including invasive) species that typically occur in disturbed urban environments. While there may be some slight changes in localized conditions, the overall species composition and habitat structure is not expected to change dramatically over the period of analysis.

Based on the extent of existing urbanization and development within the Ala Wai Watershed, and more specifically along the streams, it is expected that further development would be minimal. Some degree of redevelopment may occur in the neighborhoods throughout the watershed, however this is not expected to substantially affect biological resources. With respect to instream habitat, it is assumed that there would be no significant changes in the extent and degree of channel hardening or modifications.

5.7.2.2 Recommended Plan (Alternative 3A-2.2)

Vegetation

Implementation of the proposed action would involve clearing and trimming of vegetation within the construction limits (including any associated staging and access roads) at each of the structural measure sites. Of this area, vegetation would be permanently displaced within the footprint of the structural feature (e.g., detention berm, floodwalls, etc.) and access road (as needed to provide long-term O&M). Following construction, temporarily impacted areas would be revegetated, with landscaped vegetation replaced in-kind and non-native species replaced with suitable native species (where practicable). The approximate areas that would be impacted are summarized in Table 25.

Table 25. Summary of Disturbance Areas for the Recommended Plan

	Total Construction Area (acres)	Permanent Footprint (acres)	Vegetation Management Area for O&M (acres)	Inundation Area During Flood[a] (acres)
Forested Area (Upper Watershed)	9.8	4.1	3.1	8.55
Park Area	33.11	5.1	15.0	142.66
Other Urbanized Area	11.99	0.3	0.11	0
TOTAL	**54.88**	**9.5**	**18.22**	**151.11**

Note:

[a] The inundation area is based on a 1-percent ACE flood event; the maximum duration of flooding for any given site is expected to be no more than 10 hours at any given time.

The vegetation that would be impacted is predominantly comprised of non-native species, many of which are considered invasive. Native species present within the measure sites are commonly occurring throughout Hawai'i; no Federally listed plant species are expected to be present.

In general, impacts to non-native vegetation are not considered to be significant. However, some of this vegetation may provide habitat for aquatic and other wildlife species within the watershed, such that impacts to the vegetation could affect the wildlife species. Specifically, riparian vegetation, even if non-native and/or invasive, still provides shade and cover that contributes to habitat quality for native stream species. Similarly, non-native tree species may still provide habitat for native birds or bats.

Although impacts to vegetation are generally expected to be less than significant, construction of the project could affect a few concentrations of native species. Specifically, this includes a *kukui* copse at the Makiki detention basin site, and a series of *niu* and *milo* trees planted along the Ala Wai Canal. To the extent possible, these trees would be avoided during construction. Where impacts cannot be avoided, the individual trees would either be replaced in-kind following construction or relocated to a suitable location near the project area (**MM BIO-1).** The exact location and total number of trees to be affected and replaced/relocated would be determined as part of pre-construction surveys.

Following construction, long-term operation and maintenance of the project would require ongoing vegetation management, including clearing and trimming in select locations (**IMP BIO-2**). Specifically, a 20-foot-wide buffer around the perimeter of the detention structures would be revegetated with a suitable grass species; vegetation management would involve mowing the grass and removing any woody vegetation. Vegetation along the access roads would also be periodically trimmed, as needed to maintain adequate clearance for access. The estimated area in which vegetation will be maintained is provided in Table 25. As the areas to be maintained are within the construction limits, they will have been previously disturbed as part of construction (and revegetated, as appropriate); no sensitive species are expected to colonize in these areas. Therefore, maintenance of these areas is not expected to result in more than minimal vegetation-related impacts.

During flood conditions, the detention basins would occasionally be used to store flood waters, and vegetation within the inundation zone could be temporarily impacted by the floodwaters (**IMP BIO-3**). The approximate extent of vegetated areas that would be inundated (based on the 1-percent ACE event) is summarized in Table 25. The inundation period would be relatively short (in general, less than 10 hours at any given time) and would occur very infrequently (based on the return interval of large scale flood events). Given the infrequent nature and short duration of inundation, coupled with the lack of sensitive vegetation resources in these areas, operation of the detention basins is not expected to significantly affect vegetation resources.

Invasive plants, such as Java plum, strawberry guava, swamp mahogany, and albizia, are widespread within the project area. Given the prevalence of these species, implementation of the project is not expected to result in a significant increase in the distribution or spread of invasive plant species within the site. However, construction of the project could potentially result in the introduction of new invasive species to the project site **(IMP BIO-4)**. To minimize this potential impact, the following BMPs would be implemented **(MM BIO-2)**:

- All construction equipment, materials and vehicles arriving from outside of the island of O'ahu would be washed and/or visually inspected (as appropriate) for excessive debris, plant materials, and invasive or harmful non-native species before transportation to the project site; import of materials that are known or likely to contain seeds or propagules of invasive species would be prohibited.
- Offsite sources of revegetation materials (such as seed mixes) would be certified as weed-free or inspected before transport to the project area.
- All areas that are hydroseeded would be monitored for six months after hydroseeding to identify invasive plants that establish from seeds inadvertently introduced as part of the seed mix; all invasive plants identified within the hydroseeded areas would be removed.
- At the end of the construction period, areas impacted by construction of the project would be surveyed to confirm that no problematic and/or invasive species had been introduced and become established. Appropriate remedial actions would be undertaken to facilitate containment or eradication of the target species as soon as reasonably possible.

Based on the prevalence of non-native species and lack of sensitive vegetation resources, coupled with the mitigation measures to replace/relocate native species and minimize the introduction of invasive species, impacts to vegetation resources are expected to be less than significant.

Fauna

Faunal resources that occur (or could potentially occur) within the watershed include a suite of native aquatic and terrestrial species, some of which are Federally and State listed as endangered. Impacts to these resources are specifically addressed in the subsections below. In general, other wildlife is comprised of non-native and/or invasive species, although a limited number of non-listed native species could occur (e.g., native birds). Potential effects to non-listed native terrestrial species could include both direct impacts (e.g., disturbance, collision with project vehicles) and indirect impacts associated with habitat loss (**IMP BIO-5**). However, non-listed native terrestrial species that occur in the project area are generally common and widespread on O'ahu, such that direct impacts would not significantly reduce the local population. The proposed project would reduce the amount of habitat available for these species, which could also result in the displacement of some individuals. However, the amount of affected habitat represents a very small part of the total range available to each species. Consequently, impacts to non-listed terrestrial species are not considered significant.

Potential impacts to non-native wildlife species are not considered significant. Many of the potentially impacted species have been identified as invasive, which are species that are considered likely to cause economic or environmental harm or harm to human health (EO 13112). For example, feral pigs are generally considered to be a threat to ecosystems as they often consume or trample native flora and fauna, accelerate erosion, alter soil properties, and promote the invasion of non-native plants (Stone et al., 1992; Courchamp et al., 2003). Invasive bird species aggressively chase and outcompete native species for food and space; they also spread the seeds of invasive plant species. As such, adverse impacts to invasive species could be considered a positive effect, although given the scale of the project, any actual change in local populations is likely to be so low as to be insignificant.

Aquatic Species

As previously described, the majority of the aquatic species in the watershed are non-native species, many of which are considered invasive. Similar to non-native terrestrial species, potential impacts to non-native aquatic species are not considered significant. As many of the potentially impacted species have been identified as invasive (meaning they are considered likely to cause economic or environmental harm or harm to human health), adverse impacts could be considered a benefit. However, given the scale of the project, any actual change in local populations is likely to be so low as to be insignificant.

Although not abundant, native aquatic species have been documented in all of the streams and Canals in the watershed (including four gobiid species [*o'opu nakea (Awaous stamineus), o'opu nopili (Sicyopterus stimpsoni), o'opu naniha (Stenogobius hawaiiensis), and o'opu akupa (Eleotris sandwicensis)*], two shrimp species [*'opae kala'ole (Atyoida bisulcata)* and *'opae 'oeha'a (Macrobrachium grandimanus)*] and a mollusk species [*hapawai; Neritina vespertina*]). Construction of the measures which involve work within the streams could directly impact these native aquatic species (**IMP BIO-6**). Specifically, potential impacts to aquatic species as a result of in-stream construction activities could include injury, death or possible entrainment. To minimize potential impacts to species, each measure area would be dewatered prior to construction, with proper fish exclusion protocols and other standard BMPs implemented, such that construction-related impacts to native aquatic species are expected to be less than significant (**MM BIO-3**). Recommended protocols and BMPs are expected to include the following:

- The extent and duration of instream work would be minimized to the extent possible.
- Construction activities within the stream channels would be limited to low-flow conditions. In addition to minimizing the extent of dewatering required, this would also serve to minimize the potential to disrupt migration of native species.
- Proper dewatering techniques would be implemented, as needed. For example, sand bags or a cofferdam would be used to isolate the work area and to concentrate upstream flows into a large-diameter pipe. The pipe would extend downstream, thus allowing the stream flow to bypass the construction area and maintain downstream flows. The outfall of the pipe would be carefully sited to avoid the potential for erosion. Given the temporary nature of construction, and the timing to avoid peak migration events, routing of stream flows through the pipe is not expected to significantly affect migration of native species.
- If needed, a pump would be used to dewater the construction area, once the pipe is effectively bypassing stream flows. The pump would be properly screened to preclude entrapment of fish, and the area would be adequately inspected to ensure no fish are stranded.

As part of the long-term project operations, O&M activities would be required to keep the flood risk management structures in proper working order; in-stream O&M activities would include periodic sediment/debris removal from the in-stream debris and detention basins. This work would generally be limited to the area upstream of the detention berm, and the above-listed BMPs would be implemented (as appropriate), such that impacts are expected to be less than significant.

Aquatic Habitat

In addition to the direct impacts to fauna, the project would also impact aquatic habitat, which could indirectly affect native aquatic species (**IMP BIO-7**). Habitat loss is primarily expected to occur as a result of the in-stream detention basins, as these would involve the greatest extent of in-stream work. The debris catchment structures and multi-purpose detention basins would also displace a small amount of stream habitat. The Ala Wai Canal floodwalls are not expected to affect any aquatic habitat. As previously described, the measures in the recommended plan would disturb approximately 3503 linear feet of streams within the watershed; of this, approximately 1898 linear feet of stream would be within the permanent footprint of the flood risk management structures, while the remaining area would only be temporarily impacted (Table 19).

The design process incorporated efforts to avoid and minimize potential impacts to the extent practicable. These efforts include reduction of the project footprint to the extent practicable, and design features to minimize habitat impacts and maintain passage for native species. For example, the scour protection riprap features and box culvert inlet/outlet transitions would be designed to avoid or minimize barriers to aquatic migration. However, even with avoidance and minimization efforts, the proposed project would still result in some unavoidable impacts to aquatic habitat. As detailed in the Mitigation and Monitoring Plan (Appendix E), the HSHEP model was used to quantify the loss of aquatic habitat; the results of this effort indicate the recommended plan would result in a total loss of 295 HUs. As such, the project incorporates compensatory mitigation to offset the anticipated loss of aquatic habitat function (**MM BIO-4**). As described in Section 3.10, the compensatory mitigation measures involve in-stream improvements to eliminate two existing migratory passage barriers for native aquatic species in Mānoa Stream (Figure 11). Implementation of these measures is expected to offset the impact to aquatic habitat to a less-than-significant level. Recognizing that the purpose of the mitigation measures is to improve passage for native species, there is the potential they could also allow increased movement of non-native species. However, the results of the stream surveys indicate that non-native species are already present above these in-stream barriers.[34] Furthermore, based on input from the resource agencies, the measures have been designed to incorporate a near-vertical surface, which is believed to promote native species passage, while discouraging increased movement of non-native species. Based on this approach, the project is not expected to significantly contribute to the spread of invasive aquatic species.

Protected Species and Critical Habitat

Several ESA-listed species have the potential to be affected by the project; these are Hawaiian hoary bat, O'ahu elepaio, Hawaiian waterbird species (Hawaiian stilt, coot and moorhen), and blackline Hawaiian damselfly. Potential impacts to these species are summarized below, with further detail provided in the Biological Assessment (Appendix E). The project area does not contain critical habitat. ESA compliance is discussed in Section 5.7.3.

Hawaiian hoary bat (ESA status – Endangered): Hawaiian hoary bat could possible roost in tall trees within the measure locations in the forested portions of the upper watershed. Although species occurrence is relatively unlikely, should they occur, Hawaiian hoary bats could be directly or indirectly impacted by the project (**IMP BIO-8**). Direct effects could include mortality or other forms of take (e.g., harm or harassment) to individual bats as a result of heavy equipment used to clear the site and construct the flood risk management structures. The use of heavy equipment would also generate noise, which could disrupt bats that are present. To avoid and minimize the potential for these impacts, removal of any woody vegetation that exceeds 15 feet in height would be conducted outside the season when lactating or non-volant bats could be present (July through August). In addition, all construction activities would be scheduled to occur during daytime hours, thus avoiding potential bat foraging activities, which typically occur in the evening hours (**MM BIO-5**). With implementation of these measures, impacts to Hawaiian hoary bats are expected to be insignificant, such that the proposed action may affect, but is not likely to adversely affect the species.

Other effects could include permanent loss or temporary impacts to habitat. However, tree clearing within the action area is not expected to measurably decrease the amount of forest available to the local population of bats for roosting. As the total population of bats on O'ahu is believed to be small (USFWS, 1998) and trees are plentiful, roost trees are not expected to be a limiting factor for the species on O'ahu. The forest habitat in the upper portions of the watershed is fairly homogenous, and does not vary significantly in composition or

[34] As the non-natives are true freshwater species, they do not migrate to and from the ocean. Therefore, once introduced in the upper reaches (e.g., through intentional or unintentional releases), they reproduce and become established (in many cases, at high densities), irrespective of downstream barriers. In contrast, each generation of native species must migrate to and from the ocean, thus needing to pass whatever barriers are in place. As such, the in-stream barriers result in heavy selection against native species (and for introduced species).

structure between adjacent patches. For these reasons, it is expected that any bats displaced by the project would readily find alternate roost sites in surrounding undisturbed forest.

Oʻahu elepaio (ESA status – Endangered): The portions of the action area within Mānoa Valley (i.e., Waihi and Waiakeakua detention basins) contain suitable habitat; however, as described above, the species is no longer believed to occupy any portion of Mānoa Valley. The portions of the action area within Pālolo Valley (i.e., Pūkele and Waiʻōmaʻo detention basins) also contain suitable habitat, but these areas are considerably downslope from the lower edge of the species' current geographic range. Although species occurrence within the measure locations is unlikely, should they occur, Oʻahu elepaio could be directly or indirectly impacted by the project (**IMP BIO-9**). Direct effects could include mortality or other forms of take (e.g., harm or harassment) to individual birds or destruction of their nests as a result of heavy equipment used to clear the site and construct the flood risk management structures. The use of heavy equipment would also generate noise, which could disrupt birds that are present within the action area. To minimize the potential for these impacts, trimming or clearing of vegetation in areas of suitable habitat would be restricted during the elepaio nesting season (January through June) (**MM BIO-6**). With implementation of seasonal restrictions, the proposed action may affect, but is not likely to adversely affect Oʻahu elepaio.

Other effects could include permanent loss or temporary impacts to habitat. However, vegetation clearing within the action area is not expected to measurably decrease the amount of forest available for elepaio habitat. The total population of elepaio in this region is small, and forested areas are readily available, such that habitat is not expected to be a limiting factor for the species. In addition, the forest habitat in the upper portions of the watershed is fairly homogenous, and does not vary significantly in composition or structure between adjacent patches. Therefore, in the unlikely event that elepaio were to occur in the project area, it is expected that they would readily find alternate habitat in the surrounding undisturbed forest.

Hawaiian waterbirds (Hawaiian coot, Hawaiian stilt, and Hawaiian moorhen; ESA status - Endangered): The only suitable habitat for these species are very small pockets of isolated wetland features within the Ala Wai Golf Course and possibly along Hausten Ditch and/or the upper edges of the Ala Wai Canal. The extent and quality of potentially suitable habitat for Hawaiian waterbirds within the project area is very limited, and is likely to only be used as resting habitat (if at all). In the unlikely event that Hawaiian waterbirds are present within the project area, it is expected that they would readily disperse to nearby areas with higher quality habitat (e.g., Pearl Harbor National Wildlife Refuge) in response to disturbance. As such, the potential effects of the proposed action are expected to be limited to temporary construction-related disturbance (e.g., noise) (**IMP BIO-10**); these impacts are considered to be less than significant, such that no conservation measures would be required. Injury or mortality of Hawaiian waterbirds (or their nests) is not expected.

Following construction, the extent and quality of habitat is expected to be commensurate with the existing condition. During large-scale flood events, the detention basins would be inundated for short periods (i.e., less than 24 hours) which could temporarily increase the extent of potential habitat. Although increased habitat may be viewed as a benefit, in heavily urbanized areas (such as the Ala Wai Watershed), it can also create an attractive nuisance for waterbird species. Specifically, areas of increased habitat may attract waterbirds, which are then vulnerable to predator species that are prevalent in an urban environment (e.g., feral cats, mongoose). However, given the low probability of species occurrence and the infrequent recurrence and short-term duration of flooding, these conditions are not expected to significantly affect Hawaiian waterbirds. Based on the minimal extent and quality of suitable habitat coupled with the nature of the proposed activities, impacts to Hawaiian waterbirds are expected to be insignificant, such that the proposed action may affect, but is not likely to adversely affect the species.

Blackline Hawaiian Damselfly (ESA status – Endangered): This species occurs in the slow sections or pools along mid-reach and headwater sections of perennial upland streams and in seep-fed pools along overflow channels bordering such streams. Although previously thought to be restricted to higher elevations of the watershed (and therefore not having the potential to occur within the project area), on July 28, 2015, the USFWS identified blackline Hawaiian damselflies within the proposed footprint of the Waihi debris and detention basin (D.

Polhemus, personal communication, July 29, 2015). If constructed in this location, the flood risk management structure could impact the blackline Hawaiian damselfly (**BIO-11**). Potential effects could include mortality or other forms of take (e.g., harm or harassment) as a result of heavy equipment used to clear the approximately four acres construction site for the Waihi and Waiakeakua debris and detention structures; other effects could include permanent loss of or temporary impacts to habitat. Initial survey information was provided by USFWS, and concludes that the proposed action is likely to adversely affect the blackline Hawaiian damselfly. In accordance with Section 7 of the ESA, consultation with USFWS has identified actions to avoid and minimize potential impacts to the blackline Hawaiian damselfly. Negotiated actions range from relocating ESA protected species prior to construction to implementation of other measures to minimize impacts (**MM BIO-7**). The objective would be to reduce impacts to the blackline Hawaiian damselfly, such that the project would not be likely to adversely affect the species.

Essential Fish Habitat

Pursuant to the Magnuson-Stevens Act, an adverse effect is defined as any impact that reduces quality and/or quantity of EFH; this includes direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to species and their habitat, and other ecosystem components.

As described in Section 5.7.1.2, no portion of the project area has been designated as EFH, such that the proposed action is not expected to directly affect the quality and/or quantity of EFH. The nearshore waters downstream from the Ala Wai Canal (i.e., Māmala Bay) include EFH for various lifestages of bottomfish, pelagics, coral reef ecosystem, and crustaceans. In general, conditions that could indirectly affect EFH include increased delivery of sediment and associated contaminants, which could smother bottom substrate and degrade water quality. However, as described in Section 5.6.2.2, the project is not expected to result in significant water quality impacts, either within the streams or nearshore waters (including EFH). Rather, it is possible that some degree of benefit could be realized over the long-term through the capture and removal of sediment from the debris and detention basins. As such, the project is not expected to adversely affect EFH, either directly or indirectly.

An overview of the proposed project and a discussion of potential project-related impacts was the subject of a meeting with NMFS on June 29, 2015; based on this discussion and the analysis contained in this document, USACE determined that there would be no adverse effect to EFH, such that consultation is not required. NMFS requested consultation under the Magnuson-Stevens act in March 2016, based on concerns that the project had the potential to generate suspended sediment within the watershed that could affect EFH. The USACE prepared an EFH assessment for the NMFS (provided in Appendix E), in which it again determined that the project would have no adverse effect on EFH.

5.7.2.3 Alternative 2A

Although a different suite of flood risk management measures would be implemented as part of Alternative 2A, the measures would generally involve work within areas with a similar suite of biological resources as those described for the recommended plan. As such, implementation of Alternative 2A has the potential to affect the same resources as the recommended plan, although to varying degrees. The key differences in the potential impacts of Alternative 2A versus the recommended plan are as follows:

- The measures in Alternative 2A involve less disturbance in the upper portion of the watershed (a total of approximately 4.7 acres within the construction limits), and more disturbance in the urbanized portion of the watershed (a total of approximately 62.0 acres within the construction limits). As such, construction, ongoing vegetation management (**BIO-2**), and inundation during large flood events (**BIO-3**) associated with Alternative 2A would involve less impact to forested vegetation and more impacts to urban/landscaped vegetation, as compared to the recommended plan. As these vegetation communities are predominantly comprised of non-native species (many of which are considered invasive), these impacts are considered to be less than significant. Impacts to the *kukui* copse at the Makiki detention basin site, and a series of *niu* and *milo* trees planted along the Ala Wai Canal (**BIO-1**) would not differ from the recommended plan.

- Alternative 2A would include a slightly greater length of stream within the construction limits as compared to the recommended plan (approximately 1,742 feet), but would include less stream within the permanent project footprint (a total of approximately 527 linear feet). In particular, this difference is attributed to a 600-foot-long culvert that would be installed along the length of Mānoa Stream (from the Poelua debris catchment feature to the Mānoa District Park detention basin); this feature would involve construction disturbance but would not result in a permanent in-stream footprint. Overall, it is anticipated that direct impacts to native aquatic species would be similar to those described for Alternative 2A (**BIO-7**), and would be minimized to a less-than-significant level with implementation of the listed mitigation measures (**MM BIO-3**). Given the slightly greater extent of disturbance yet smaller permanent in-stream footprint of Alternative 2A, the loss of aquatic habitat function is expected to be similar to that for the recommended plan. Although the exact loss of HUs was not modeled, it is expected to be within a similar range as that for the recommended plan, such that the same compensatory mitigation measures would be incorporated as part of Alternative 2A (**MM BIO-4**).
- The same suite of Federally listed species has the potential to occur within the measure locations associated with Alternative 2A, as those described for the recommended plan. However, based on the differences in the amount of each habitat that would be affected (as described above), the extent of potential impacts to listed species could vary. In particular, Alternative 2A involves less disturbance within the forested vegetation in the upper watershed, such that the potential to affect Hawaiian hoary bat, O'ahu elepaio, and blackline Hawaiian damselfly is less than for the recommended plan. With implementation of avoidance and minimization measures (**MM BIO-5**, **MM BIO-6**, and **MM BIO-7**), implementation of Alternative 2A may affect, but is not likely to adversely affect, Federally listed species.

5.7.3 ESA Section 7 Consultation

Pursuant to Section 7 of the ESA, the USACE has been informally consulting with the USFWS and NMFS regarding potential impacts to threatened and endangered species (including candidate species) and designated or proposed critical habitat. Based on this ongoing consultation, the USACE evaluated the potential impacts of the proposed project and summarized the results in a Biological Assessment. As documented in the Biological Assessment, USACE determined that the project may affect but is not likely to adversely affect the Hawaiian hoary bat, O'ahu elepaio, and Hawaiian waterbirds (Hawaiian coot, Hawaiian stilt, and Hawaiian moorhen), with no effect on all other Federally listed/candidate species or designated critical habitat. As the blackline Hawaiian damselfly was initially thought to be restricted to higher elevations of the watershed (and therefore have no potential to occur within the project area), the Draft Biological Assessment included a no effect determination for this species. However, on July 28, 2015, USFWS identified blackline Hawaiian damselflies within the proposed footprint of the Waihi debris and detention basin (D. Polhemus, personal communication, July 29, 2015). An updated Biological Assessment was prepared in December 2015 and USACE initiated formal consultation under ESA, Section 7. On August 16, 2016 USACE received a final Biological Opinion from USFWS. Consultation resulted in a non-jeopardy opinion for blackline Hawaiian damselflies in the vicinity of the proposed Waihi and Waiakeakua detention basins. USACE has provided written acknowledgement of its understanding of the terms and conditions of the Biological Opinion received from USFWS.

A copy of the updated Biological Assessment, the USFWS Biological Opinion and ESA Section 7 correspondence is contained in Appendix E.

5.8 Cultural Resources

5.8.1 Affected Environment

5.8.1.1 Regulatory Framework

Regulations and policies that protect archaeological, historic, and cultural resources and are being considered as part of the proposed project include the following:

- National Historic Preservation Act (NHPA)

- HRS Chapter 6E
- HRS Chapter 343

Compliance with NHPA Section 106 is discussed in Section 5.8.3. Supporting documentation is contained in Appendix F; this content is also being used for compliance with HRS Chapter 6E.

5.8.1.2 Environmental Setting

A historic property is defined under Federal law (36 CFR 800.16(l)(2)) as any archaeological site, building, structure, or object included (or eligible[35] for inclusion) on the National Register of Historic Places (NRHP). The term includes properties of traditional religious and cultural importance to a Native American tribe or Native Hawaiian organization (NHO) and that meet the NRHP criteria. Under Hawai'i State law, similar criteria are considered (as well as additional criteria relating to environmental quality and cultural values) for listing eligibility on the Hawai'i Register of Historic Places.

As established by 36 CFR Part 60, an historical property (generally a property over 50 years of age) is eligible for listing in the NRHP if it possesses "integrity of location, design, setting, materials, workmanship, feeling, and association," and it meets at least one of four criteria:

A. It is associated with events that have made a significant contribution to the broad patterns of our history; or

B. It is associated with the lives of persons significant in our past; or

C. It embodies the distinctive characteristics of a type, period, or method of construction, or it represents the work of a master, or it possesses high artistic values, or it represents a significant and distinguishable entity whose components may lack distinction; or

D. It has yielded, or may be likely to yield information important in prehistory or history.

Similarly, to be significant under HAR Section 13-275-6, a historic property shall possess integrity of location, design, setting, materials, workmanship, feeling, and association and shall meet one or more of the following criterion:

1) Criterion "a." Be associated with events that have made an important contribution to the broad patterns of our history;

2) Criterion "b." Be associated with the lives of persons important in our past;

3) Criterion "c." Embody the distinctive characteristics of a type, period, or method of construction, represent the work of a master, or possess high artistic value;

4) Criterion "d." Have yielded, or is likely to yield, information important for research on prehistory or history; or

5) Criterion "e." Have an important value to the native Hawaiian people or to another ethnic group of the state due to associations with cultural practices once carried out, or still carried out, at the property or due to associations with traditional beliefs, events or oral accounts—these associations being important to the group's history and cultural identity.

An assessment of archaeological and historic resources, including traditional Hawaiian and post-Contact sites, was conducted to provide an understanding of the existing resources within the project area that are listed (or eligible for listing) on the NRHP or Hawai'i Register of Historic Places. In addition, a Cultural Impact Assessment was conducted to identify cultural resources, practices and beliefs that relate to the project area.

[35] The term eligible for inclusion in the National Register includes both properties formally determined as such in accordance with regulations of the Secretary of the Interior and all other properties that meet the National Register criteria.

Area of Potential Effect

Consistent with the requirements of NHPA Section 106, the Area of Potential Effect (APE) was defined for each of the measures that would be constructed. In consultation with the State Historic Preservation Officer (SHPO), the Direct APE was defined as the area that would be directly affected by construction, and includes the measure footprint, as well as any staging areas, access roads, or other areas within the construction limits. The Indirect APE is defined to include those areas within a one-half-mile radius extending from the outer edge of the Direct APE.

Archaeological Resources

As part of the assessment of archaeological resources within the watershed, archival research was conducted to identify the background history, *wahi pana* (place names), *mo'olelo* (traditional stories), and previously recorded archaeological sites within the watershed. Specifically, the archival research included a review of previous archaeological studies, cultural history documents, historic maps and photographs, and Land Commission Awards (LCAs). This information was compiled and used to identify potential localities within the watershed where archaeological resources may exist, and the type and potential significance of those resources. In addition, a field investigation was conducted to identify additional surface archaeological features.[36] Archaeological survey was not conducted within the entirety of the direct APE. Provisions for additional archaeological survey, if needed, are in the programmatic agreement.

Additional discussion of the various resources is contained in the *Cultural Resources and Ethnographic Study for the Ala Wai Watershed Project, Vol I and II* (Cultural Surveys Hawai'i, 2010).

Historic Structures

An inventory was conducted to identify structures and open spaces within the study area (watershed) that are listed or appear to meet the criteria for listing on the NRHP or Hawai'i Register of Historic Places. The inventory identified a variety of structures dating from 1965 or earlier, including bridges, culverts, channel modifications, dams, and water supply structures. Those structures that are within the Direct APE and which are listed (or were determined to be eligible for listing) on the NRHP or Hawai'i Register of Historic Places are listed in Table 26. A detailed description of the various structures is contained in the *Historic Structures Inventory for the Ala Wai Watershed* (Mason Architects, 2010).

Traditional Cultural Uses and Practices

As part of the preliminary planning efforts, ethnographic interviews were conducted with persons knowledgeable about cultural practices in the study area, with a focus on *kupuna* (elders), to gain an understanding of traditional land use activities and to identify and describe relevant cultural resources, practices, and beliefs. Several themes emerged during the interviews, including those related to education and natural resource protection. Education was identified as an important component of fostering an appreciation for natural resources and preserving watershed resources. The participants described the extensive *lo'i* (irrigated agricultural terraces) that were once present within the watershed, noting that *lo'i* could serve as a valuable tool for teaching younger generations about traditional Hawaiian practices, as well as providing natural filtration and improving water quality. They described the role of agriculture within the community, explaining the value of living off natural resources as part of the traditional Hawaiian culture, and protecting the land as a source of life.

Relative to flood risk management, the participants discussed the importance of keeping the streams clean (e.g., through community efforts) to maintain channel capacity. The transcripts and a more detailed summary of the

[36] The field investigation was conducted within 10 meters of either side of Makiki, Mānoa, and Pālolo streams. It included the entire length of Makiki Stream and its tributaries, Mānoa Stream up to the junction with its tributary streams, and Pālolo Stream and the lower reaches of its tributaries. It also included the following open space areas: Archie Baker Park/Tantalus State Park, Mānoa District Park, Noelani Elementary School, the Woodlawn Ditch area, Kānewai Field, the University of Hawai'i Athletic Field, Pālolo District Park, Fort DeRussy, Ala Wai Park, Ala Wai Golf Course, Kaimukī High School, and Kapi'olani Regional Park.

interviews are contained in the *Cultural Resources and Ethnographic Study for the Ala Wai Watershed Project, Vol III* (Cultural Surveys Hawai'i, 2010).

Building on this effort, a Cultural Impact Assessment (CIA) was subsequently conducted as part of the plan formulation process to understand the cultural resources relative to the proposed project. The CIA was prepared in accordance with the State of Hawaii Environmental Council "Guidelines for Assessing Cultural Impact." The CIA identified cultural resources in the study area (watershed). Additional interviews were conducted; information provided as part of these interviews included specific references to activities and resources provided by the waterways in the project area. Relative to stream-based activities, many of the participants recalled swimming in the streams during their childhood; this includes two deep ponds downstream of Woodlawn Bridge and areas along Pālolo stream. They also discussed various forms of sustenance, including *o'opu*, crayfish, *'ōpae*, and *pipipi* collected from the streams, as well as fruits and other plants. The participants referenced multiple *lo'i* use to grow *kalo* (taro), including Ka Papa Lo'i o Kanewai and 'Aihualama Lo'i in Mānoa. The interviewees also referenced other resources that were gathered, including *laua'e* in Pālolo Valley, *lā'au* in Mānoa and Makiki Valleys, and *limu* along the shoreline. These resources were not only used for food consumption, but also for ceremonial purposes. Other stream-based resources identified include water used for ceremonial purposes and rocks used for multiple purposes (rock wall building, *imu* [underground oven] use, and pounding poi). The interviewees noted that the areas along the streams and waterways were inhabited by native Hawaiians, and indicated the potential for encountering burials (particularly in the Waikīkī area). As a result of these investigations, a variety of cultural resources were identified. Those sites that were identified within the Direct APE and which are listed (or were determined to be eligible for listing) on the NRHP or Hawai'i Register of Historic Places are presented in Table 26.

5.8.2 Impacts and Mitigation

Effects on NRHPNRHP eligible cultural resources were considered to be significant if implementation of an alternative plan would result in any of the following:

- Alter, directly or indirectly, any of the characteristics of a resource that qualifies it for the NRHP or State Register of Historic Properties so that the integrity of the resource's location, design, setting, materials, workmanship, feeling, or association is diminished;
- Isolate cultural resources, practices or beliefs from their setting (or otherwise limit access to areas that support those resources, practices or beliefs); or
- Introduce elements that substantially alter the setting in which cultural resources, practices, or beliefs occur.

The potential effects to cultural resources that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.8.2.1 No Action Alternative

Under this alternative, no flood risk management features would be implemented by USACE. Historic properties that occur within the existing floodplain could be affected by future flood-related events (e.g., through inundation, scouring of the ground surface, or deposition of debris).

5.8.2.2 Recommended Plan (Alternative 3A-2.2)

Based on the studies conducted to date, it was determined that construction and operation of the project could impact historic properties within the Direct APE. Potential impacts include modifications that may affect the integrity and/or characteristics of historic properties. Table 26 lists the effect determination for each historic property identified within the Direct APE (**IMP CUL-1**). For those properties with an adverse effect determination, treatment recommendations have been identified. The intent of these recommendations is to identify conditions that can be placed on the design and construction to mitigate impacts to the resource (**MM CUL-1**). Historic buildings, bridges, and walls affected by construction would undergo appropriate historic documentation, and design input would be solicited from SHPO and interested consulting parties, and incorporated into the final design where feasible. Where possible, impacts to archaeological resources would be avoided. Where avoidance is not possible, data recovery would be performed. Where practicable, construction measures would be microsited either up or downstream to minimize the impacts to features of Native Hawaiian cultural significance (TCPs) that could be disturbed by project actions. Considering that the project is still in the feasibility phase and that there are still a number of unknown variables that may result in adverse effects through the future planning, design, and construction phases, a Programmatic Agreement is being developed. The Programmatic Agreement establishes a process for further resource identification and effects determinations, resolving adverse effects, and expands upon the treatment recommendations listed in Table 26. The Programmatic Agreement was coordinated with the Advisory Council on Historic Preservation (ACHP), SHPO, and other consulting parties. A copy is included in the Appendix F of this report. Implementation of the treatment recommendations developed through consultation and as per the Programmatic Agreement is expected to reduce potential impacts to a less-than-significant level.

Based on input obtained through the CIA process, impacts that are of particular concern include those associated with the Ala Wai Canal, as this is a prominent feature in the Waikīkī District. Specifically, construction of the floodwalls and pump stations could affect viewplanes associated with the Canal, which could diminish the characteristics that qualify its listing on the Hawai'i Register of Historic Places (**IMP CUL-2**). As per the PA, design input to minimize visual impacts to the greatest extent possible will be solicited from SHPO and interested consulting parties, and incorporated, as feasible, into the final design and construction of the floodwalls and pump stations. In addition, the appropriate level of historic documentation of the Ala Wai Canal will be developed with SHPO and other consulting parties (**MM CUL-2**). Impacts are expected to be less than significant with the implementation of agreed-upon measures.

The CIA also identified a variety of cultural resources, practices, and beliefs that relate to the project area. These include gathering native plants and animals and other resources (e.g., water and rocks) from the streams. Overall, gathering of resources and other cultural practices that occur within and immediately adjacent to the project area may be temporarily disrupted during construction, as access within the various measure locations would likely be restricted during ground-disturbing activities (**IMP CUL-3**). However, as discussed in Section 5.7.1.2, the specific areas where the measures would be located are overwhelmingly dominated by non-native species; furthermore, there would still be abundant opportunities to gather resources along streams throughout the upper watershed. Following construction, none of the measures are expected to limit access to cultural resources or practices. Construction of the flood risk management measures, particularly the in-stream debris and detention basins in the upper watershed, could result in removal or destruction of rocks from the stream bed (**IMP CUL-4**). In response to input received during the CIA process, and as per the PA, the USACE will slightly adjust the location of the measure upstream, or downstream (micrositing) to avoid significant cultural resources, and re-use significant rocks within the streambed during construction (**MM CUL-3**). As such, impacts are expected to be less than significant.

Table 26. Historic Properties Potentially Affected by the Ala Wai Canal Project

Measure Location/Description	Site ID	Criteria	Effects Determination	Treatment Recommendation
1) Makiki: <u>Makiki D&D Basin</u>				
Mounds/Platforms/Walls	50-80-14-6734	D,e	adverse effect	follow PA
Archie Baker Park	Inventory No. 92	A,C	no adverse effect	minimize temporary impacts
Makiki Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
2) Manoa: <u>Waihi D&D Basin</u>				
Waihi Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
3) Manoa: <u>Waiakeakua D&D Basin</u>				
Waiakeakua Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
Waaloa Way Bridge 2	Inventory No. 51	C	adverse effect	historic documentation / mitigation plan as needed
Waaloa Way Bridge 1	no inventory number	none	adverse effect	historic documentation
4) Manoa: <u>Woodlawn Ditch</u>				
Open Space at Park	No SIHP Assigned	none	not historic	not historic
5) Manoa: <u>Manoa In-Stream Debris Catchment</u>				
Manoa Stream Channel	Inventory No. 41	A,C	adverse effect	historic documentation
6) Manoa: <u>Kanewai Field Multi-Purpose Detention Basin</u>				
Kanewai Field	Inventory No. 94	C	no adverse effect	avoid architecture & trees, seed the new berm
7) Palolo: <u>Pukele D&D Basin</u>				
Pukele Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
8) Palolo: <u>Waiomao D&D Basin</u>				
Waiomao Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources

Table 26. Historic Properties Potentially Affected by the Ala Wai Canal Project

Waiomao USGS Gaging Station	No SIHP Assigned	none	not historic	not historic
9) Ala Wai: <u>Hausten Ditch Detention Basin</u>				
Ala Wai Canal	50-80-14-9757	A	adverse effect	mitigation plan/ historic documentation/ consulting party design input & review
Alanaio Stream Channel (Hausten Ditch)	Inventory No. 82	A,C	this section not historic	none
Ala Wai Park	No SIHP Assigned	none	not historic	not historic
10) Ala Wai: <u>Ala Wai Golf Course MPDB</u>				
Ala Wai Golf Course	No SIHP Assigned	none	not historic	monitoring during construction
Manoa-Palolo Canal	Inventory No. 36	A,C	adverse effect	historic documentation
Ala Wai Canal	50-80-14-9757	A	adverse effect	mitigation plan/ historic documentation/ consulting party design input & review
11) Ala Wai: <u>Ala Wai Canal Floodwalls/Pump Stations</u>				
Kalakaua Ave Bridge	Inventory No. 02	A,C	adverse effect	match design with existing walls
McCully Street Bridge	Inventory No. 03	A,C	adverse effect	match design with existing walls
Kapahulu (Ala Wai Golf course) Drainage	No SIHP Assigned	none	not historic	not historic
Ala Wai Canal	50-80-14-9757	A	adverse effect	mitigation plan/ historic documentation/ consulting party design input & review
Ala Wai Clubhouse (C&C Art Deco Parks)	50-80-14-1388/ No.90	C	adverse effect	historic documentation / consulting party design input
12) Watershed: <u>Flood Warning System</u>				
Manoa Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources

Table 26. Historic Properties Potentially Affected by the Ala Wai Canal Project

Makiki Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
Palolo Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
Waiomao Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
Ala Wai Canal	50-80-14-9757	A	adverse effect	mitigation plan/ historic documentation/ consulting party design input & review
Other Locations To Be Determined				follow PA
13a) <u>Aquatic Habitat Mitigation, Proposal A (Falls Repair)</u>				
Waihi Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
Waiakeakua Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
Manoa Stream	No SIHP Assigned	e	adverse effect	micrositing to avoid significant resources
Waaloa Way Bridge 1	no inventory number	none	no adverse effect	historic documentation
Waaloa Way Bridge 2	Inventory No. 51	C	adverse effect	historic documentation / mitigation plan as needed
Waihi Gaging Station	Inventory No. 53	A,C	no effect	avoidance
Waihi Stream Stone/Mortar Dam	50-80-14-6736/ No.54	A	adverse effect	create more natural stream bed appearance
Waiakeakua Gaging Station	Inventory No. 55	A,C	adverse effect	create more natural stream bed appearance
13b) <u>Aquatic Habitat Mitigation, Proposal B (Manoa Stream)</u>				
Manoa Stream Channel	Inventory No. 41	A,C	adverse effect	historic documentation
Lowrey Avenue Bridge	Inventory No. 45	C	no effect	avoidance

Also as discussed in the CIA, the proposed measures at Waihī Stream and Kānewai Stream are located *makai* (oceanward) of ‘Aihualama Lo’i and Kānewai Lo’i, respectively. The proposed measures are not expected to directly affect the integrity of the *lo’i*. Inundation associated with the Kanewai detention basin would be entirely contained within Kanewai Field, and would not extend to the *lo’i*. Inundation behind the Waihī detention basins during and after heavy storms could extend to the Aihualama Lo’i. However, as previously described, flood-related inundation would occur infrequently and for a short duration. As flooded conditions are already experienced in the *lo’i* under existing conditions, it is expected that infrequent inundation would not significantly impact the *lo’i*.

There is a high possibility that *iwi kūpuna* (ancestral bones), may be present within the project area and that land-disturbing activities during construction may uncover presently undetected burials or other cultural materials (**IMP CUL-5**). The Programmatic Agreement stipulates measures that the USACE will undertake to address the potential for burials. Should burials or other cultural finds be identified during ground disturbance, the construction contractor would immediately cease all work in the area, and the appropriate agencies would be notified pursuant to applicable laws, including NHPA and HRS Section 6E (**MM CUL-4**). Implementing procedures regarding burials as stipulated in the Programmatic Agreement and following legislative protocols for inadvertent discovery of remains would mitigate impacts to a less-than-significant level.

5.8.2.3 Alternative 2A

Although a different suite of flood risk management measures would be implemented as part of Alternative 2A, the measures would generally involve work within areas with similar cultural resources as those described for the recommended plan, although the specific resources and extent of disturbance would vary. Specifically, Alternative 2A would involve substantially less ground disturbance in the upper Mānoa and Pālolo watersheds, as the flood risk management measures in these locations would consist of debris catchment structures (as opposed to the larger debris and detention basins). Given the scale of the debris catchment structures, it is anticipated that they could be sited so as to avoid impacts to historic properties. However, Alternative 2A would include the Mānoa District Park Detention Basin (including the 600-foot-long culvert from the Poelua debris catchment feature); project-related activities could affect historic properties in these areas. In addition, the floodwalls along the Ala Wai Canal would be approximately one foot higher (on average). Potential impacts to archaeological and historic properties would be mitigated in the same manner as described for the recommended plan, through a combination of avoidance, historic documentation, data recovery and development of a PA.

Similar impacts to cultural resources could occur as described for the recommended plan, including temporary limitations on access (e.g., for gathering of resources and other cultural practices) and/or removal or destruction of cultural resources (e.g., rocks from the stream bed). However, given the small extent of disturbance in the upper watershed, where many of these resources are located, cultural resource impacts associated with Alternative 2A would likely be less pronounced than those associated with the recommended plan.

5.8.3 NHPA Section 106 Consultation

In compliance with Section 106 of the NHPA, consultation with SHPO was initiated in a letter dated August 21, 2014. Ongoing consultation has been conducted with SHPO, ACHP, NHOs and other consulting parties, with input sought relative to definition of the APE, identification of historic properties, and determination of potential effects to those properties. A copy of the Section 106 consultation documents is contained in Appendix F. Consistent with the summary of impacts and mitigation described above, the USACE determined that there would be an adverse effects to historic properties. Measures have been proposed to mitigate adverse effects. A Programmatic Agreement has been developed to further identify resources, determine effects and establish the process for resolving adverse effects that may arise throughout the remaining planning, design, and construction phases of the project. Responses to consultation letters, as well as the Final Programmatic Agreement are included as part of this report. The Programmatic Agreement will be used to ensure that the USACE satisfies its responsibilities under Section 106 of the NHPA and other applicable laws and regulations.

5.9 Land Use

5.9.1 Affected Environment

5.9.1.1 Regulatory Framework

Regulations and policies that relate to land use and are being considered as part of the proposed project include the following:

- Coastal Zone Management Act
- EO 11988 (Floodplain Management)
- HRS Chapter 205 (Hawai'i State Land Use Law)
- HRS Chapter 205A (Coastal Zone Management)
- HRS Chapter 183C (Conservation District)
- HRS Chapter 183 (Forest Reserves, Water Development, Zoning)
- ROH Chapters 21 (Land Use Ordinance) and 25 (Special Management Area)

5.9.1.2 Environmental Setting

A variety of different land uses are present in the watershed, both in urban and undeveloped areas. Land uses are primarily controlled by State Land Use designations, and further by County zoning designations. A summary of the existing land uses, as well as the land use districts and zoning for each of the measures in the recommended plan are listed in Table 27, with additional detail provided below.

State Land Use Districts

Three State Land Use districts occur within the watershed: urban, conservation, and agriculture. The majority of the study area (approximately 11 mi^2 or 59 percent of the watershed) is within the Urban District, which encompasses nearly all of the developable land in the watershed, extending from the shoreline to the steep slopes of the upper watershed (LUC, 2015). It is one of the most heavily urbanized areas in the State, and supports a variety of residential, commercial, and industrial uses.[37] Waikīkī, a prime tourist destination and the major economic engine for the State, is a particularly important component.

The upper watershed is entirely within the Conservation District (approximately 7.5 mi^2 or 40 percent of the watershed), with the exception of a small area in Pālolo Valley that is designated as an Agricultural District (1 percent of the watershed) (OCCL, 2015). The purpose of the Conservation District is to protect watersheds and water supplies; preserve scenic areas; conserve endemic plants, fish, and wildlife; prevent floods and soil erosion; forestry; and other related activities. A large portion of the upper watershed is part of the Honolulu Forest Reserve, one of fourteen reserves in the State Forest Reserve System. Originally created in 1903 to protect recharge of the groundwater supply, the Forest Reserve System is now managed by DLNR DOFAW to protect, manage, restore, and monitor natural resources (DOFAW, 2015).

County Zoning

The County zoning designations generally correspond with the State district boundaries, with preservation lands located in the upper watershed and mixed residential and industrial uses located in the lower portions of the watershed (Townscape and Dashiell, 2003). Many of the parks in the Urban District are also zoned for preservation. In addition to the zoning boundaries, there are additional designations overseen by the County, including a Special Management Area (SMA) and special districts, both of which trigger additional development standards and restrictions. The SMA is intended to facilitate compliance with the objectives of the State's Coastal Zone Management (CZM) program, and generally extends from the shoreline inland, ranging from 100

[37] A study of metropolitan densities indicated that Honolulu, of which the urbanized portion of the Ala Wai Watershed is a part, is the densest metropolitan area in the United States, with 12.36 persons per urbanized acre (Fulton et al., 2001).

yards to several miles in width. Special districts within the watershed include Waikīkī, Diamond Head, Punchbowl, and Kaka'ako (DPP, 2015).

Table 27. Land Use Designations of Measure Sites

Measure[b]	Existing Land Use	State Land Use	County Zoning	SMA and Other Special Districts
Waihi Debris and Detention Basin	Open space in forested upper watershed	Conservation (Resource Subzone)	P-1[a]	Not in SMA
Waiakeakua Debris and Detention Basin	Open space in forested upper watershed; adjacent to residential homes	Conservation (Resource Subzone); partially within Forest Reserve	P-1[a]	Not in SMA
Woodlawn Ditch Detention Basin	Open space in residential neighborhood; adjacent to agricultural operation	Urban	P-2	Not in SMA
Mānoa In-stream Debris Catchment	Open space within Mānoa Stream, at edge of Mānoa District Park; adjacent to residential properties and an elementary school	Urban	P-2	Not in SMA
Kanewai Field Multi-Purpose Detention Basin	City & County Park; adjacent to residential properties, an elementary school and the UH campus	Urban	P-2	Not in SMA
Wai'ōma'o Debris and Detention Basin	Open space associated with Wai'ōma'o Stream; adjacent to residential properties	Conservation (Resource Subzone) and Urban	P-1[a] and R-5	Not in SMA
Pūkele Debris and Detention Basin	Open space associated with Pūkele Stream; adjacent to residential properties	Urban (staging and access on Conservation)	R-5 (staging and access on P-1)	Not in SMA
Makiki Debris and Detention Basin	Open space associated with Makiki Stream, Makiki Tantalus Recreation Area and Archie Baker Mini Park; adjacent to residential properties	Conservation (Resource Subzone) (staging/ access on Urban)	P-1[a] (staging and access on R-10)	Not in SMA
Ala Wai Canal Floodwalls	Open space associated with Ala Wai Canal, Ala Wai Promenade and Ala Wai Community Park; adjacent to commercial and residential properties and an elementary school within Waikīkī District	Urban	Public Precinct	Not in SMA; in Waikīkī/ Diamond Head Special District
Hausten Ditch Detention	Open space associated with Hausten Ditch and Ala Wai Community Park	Urban	P-2	Not in SMA; in Diamond Head Special District
Ala Wai Golf Course Multi-Purpose Detention	City & County Golf Course	Urban	P-2	Not in SMA; in Diamond Head Special District
Mitigation Measures (Falls 7 and Falls 8)	Open space associated with Mānoa Stream; adjacent to residential properties	Urban	R-7.5	Not in SMA

Notes: [a] Pursuant to ROH 21-3.40-1, regulatory authority within the County P-1 zoning district is delegated to the appropriate State agency.
[b] The new gage locations associated with the flood warning system are not listed as they have not yet been sited; however, it is assumed they would be located along the streams in the upper watershed (State Conservation District, County P-1 zoning district).

5.9.2 Impacts and Mitigation

Effects on land use were considered to be significant if implementation of an alternative plan would result in any of the following:

- Preclude use of an area for its intended purposes, or displace an existing land use;
- Substantially conflict with the objectives any applicable land use regulation, plan, or policy; or
- Directly or indirectly induce a substantial degree of development in a floodplain.

The potential effects to land use that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.9.2.1 No Action Alternative

Under the No Action Alternative, no flood-risk management measures would be implemented and as such, significant portions of the watershed would continue to be at risk of flooding, thus threatening existing land uses (particularly in the urbanized watershed).

Over the 50-year period of analysis for the future without-project condition, the boundaries and intended uses of the various land use designations are expected to be maintained. In particular, no portion of the Conservation District is expected to be rezoned to allow development.[38] Within the Urban District, nearly all available land is already developed, leaving very little area for future development. As is already occurring, future development activities are expected to primarily consist of redevelopment of existing lots (CCH, 2009b).

5.9.2.2 Recommended Plan (Alternative 3A-2.2)

Overall, construction of the project would involve disturbance of approximately 54 acres of land (see Table 25), which would disrupt existing and adjacent land uses, including open space and parks, as well as adjacent residences and other development (**IMP LU-1**). However, the majority of this disturbance would be associated with temporary construction-related activities, and measures would be implemented to reduce the potential impacts to a less-than-significant level. Measures to be implemented include phasing of construction to minimize the extent of disturbance at any given time, and restoration of temporarily disturbed areas to pre-project conditions. In addition, for work on privately-owned land, easements would be obtained, and would include fair compensation for loss of use by landowner during construction (**MM LU-1**).

Once constructed, the measures are generally not expected to conflict or otherwise preclude existing or future land uses. To the extent possible, the measures have been designed to allow for the continuance of existing land uses (e.g., County park or golf course), except under flood conditions; as these areas already flood during large-scale events, this is not considered to be a significant impact. Similarly, the measures that are in or adjacent to residential areas would generally occupy the stream/Canal and would not preclude residential use of the property. Consistent with USACE regulations, the non-Federal sponsor would be responsible for securing all necessary lands, easements, and rights-of-way. The measures are expected to be consistent with the land use and zoning designations for each site, as further described below; no changes in land use or zoning designations are anticipated.

- Several of the measures are entirely (or partially) within the State's Conservation District (Table 27), where land use is regulated by the State Office of Conservation and Coastal Lands (OCCL), including the in-stream debris and detention basins on Waihi, Waiakeakua, Makiki, and Pūkele and Waiʻōmaʻo streams. These are all in the Resource Subzone. The objectives of this subzone is to ensure, with proper management, the sustainable use of the natural resources of those areas. HAR 13-5-24 specifies the land uses that apply to the resource subzone, which incorporate land uses also listed for the protective and limited subzones (HAR 13-5-22 and 13-5-23). It is expected that the proposed measures would quality as Public Purpose Uses (D-1), which are defined as "not for profit land uses undertaken in support of a public service by and agency of the county, state, or federal government…[including but not limited to] flood or erosion control projects" (HAR 13-5-22); this use is permitted with issuance of a Conservation District Use Permit (CDUP). As such, these measures are expected to be consistent with the objectives of the Conservation District; a CDUP will be

38 Over the past 35 years (since 1975), the total area within the Conservation District on Oʻahu has not decreased and has in fact increased by approximately 1,700 acres, indicating that areas within the Conservation District are rarely, if ever, rezoned for development (CCH, 2009).

obtained prior to construction. The CDUP for public purpose uses (D-1) requires approval by the Board of Land and Natural Resources. It is expected that this approval process would also address work within the Forest Reserve area (approximately 0.75 acre of the Waiakeakua debris and detention basin).

- The remainder of the measures are located within areas where land use is regulated by CCH; these are generally either located within the preservation (P-2), residential (R-5/10) or Public Precinct zoning districts (see Table 27). It is expected that the proposed measures would meet the definition of Public Uses and Structures, which means "uses conducted by or structures owned or managed by the federal government, the State of Hawai'i or the city to fulfill a governmental function, activity or service for public benefit and in accordance with public policy" (ROH 21-10.1). Public Uses and Structures are permitted across all zoning districts (ROH, Table 21-3). It is anticipated that permits would be required for work in the Waikīkī and Diamond Head Special Districts.

Under EO 11988, the USACE is required to avoid or minimize adverse impacts associated with use of the base floodplain and avoid inducing development in the base floodplain unless there is no practicable alternative. As the objective of the proposed project is to reduce riverine flooding, work within the floodplain is unavoidable. However, the vast majority of the floodplain is already developed, and the proposed project is not expected to induce further development of the base floodplain. Additional discussion of compliance of EO 11988 is contained in Section 8.6.

5.9.2.3 Alternative 2A

Alternative 2A would include the same type of uses as the recommended plan, but would involve less disturbance in the upper portion of the watershed (a total of approximately 4.7 acres within the construction limits), and more disturbance in the urbanized portion of the watershed (a total of approximately 62.0 acres within the construction limits). Overall, the impacts to land use as a result of implementation of Alternative 2A (and the measures that would be implemented to address those impacts) are expected to be commensurate with those described for the recommended plan.

5.10 Recreation

5.10.1 Affected Environment

5.10.1.1 Regulatory Framework

Regulations and policies that relate to recreation and are being considered as part of the proposed project include the following:

- HRS Chapter 183 (Forestry and Wildlife; Recreation Areas; Fire Protection)
- HRS Chapter 198D (Hawai'i Statewide Trail and Access System)
- ROH Chapter 10 (Rules, Regulations, Charges and Fees for Public Parks and Recreation Facilities)

5.10.1.2 Environmental Setting

A wide range of recreational opportunities are available within the Ala Wai Watershed, ranging from hiking in the upper watershed, organized sports at the numerous parks in the urban neighborhoods, and water-based activities in the coastal areas. Many of these recreational opportunities are an integral part of the tourism industry, which is a critical component of the State's economy.

The State's Comprehensive Outdoor Recreation Plan (SCORP) includes an inventory of recreational facilities throughout the State. A wide range of recreational facilities are available within the Ala Wai Watershed, including Federal, State and County parks; hiking trails; a golf course; boating facilities; and the Ala Wai Canal itself. These are briefly described below, with the specific facilities at each measure location listed in Table 28. Although it is recognized that recreation activities can generally occur anywhere, the focus of this analysis is on designated recreational facilities.

Park Facilities

Over 400 acres of CCH parks are located within the Ala Wai Watershed, including two regional parks (Kapi'olani Regional Park and Ala Moana Regional Park), two beach parks, four district parks, eight community parks, five neighborhood parks, ten mini-parks, eight urban parks, and several miscellaneous facilities.[39] State park facilities within the study area include Makiki Tantalus Recreation Area, Pu'u 'Ualaka'a State Park, and Wa'ahila Ridge State Recreation Area; the Honolulu Forest Reserve also offers recreational opportunities. The only Federal park facility within the Ala Wai Watershed is the Fort DeRussy Armed Forces Recreation Center (Fort DeRussy Park), located in Waikīkī.

Trails

Administered by DLNR DOFAW, Na Ala Hele is the State of Hawai'i's Trail and Access Program. Developed in response to concerns over decreasing public access to trails and development threats to historic trails, Na Ala Hele is responsible for inventorying, constructing, maintaining and regulating activities within their network of trails. A total of 15 Na Ala Hele trails are located within the Ala Wai Watershed (DLNR, 2009c). Average use varies between trails, but is highest for the Mānoa Falls Trail, which is a popular tourist destination.

Ala Wai Golf Course

The Ala Wai Golf Course is one of six municipal golf courses managed by CCH (Department of Enterprise Services, Golf Course Division). It is located along the Ala Wai Canal on land owned by the State, and is approximately 146 acres in size. It is the only public golf course located in the Honolulu area. The 18-hole course has been distinguished as the busiest golf course in the world, with about 500 rounds played per day (or 180,000 rounds annually).

Boating Facilities

Several boating facilities are located within the Ala Wai Watershed, including the Ala Wai Small Boat Harbor and Kewalo Basin, as well as moorings off Waikīkī Beach. Located between Waikīkī and Ala Moana beaches, the Ala Wai Small Boat Harbor is the only recreational harbor in the Ala Wai Watershed. Located on the west side of Ala Moana beach, approximately one mile west of the Ala Wai Small Boat Harbor, Kewalo Basin is a mixed-use harbor that provides berthing for commercial fishing and recreational vessels. In addition to these two facilities, DOBOR provides temporary anchorage immediately offshore of Waikīkī, from Fort DeRussy to Diamond Head (Kapua Channel moorings) (DLNR, 2009a).

Ala Wai Canal

The Ala Wai Canal offers a variety of recreational opportunities, including outrigger canoe paddling, kayaking, and fishing; it supports the single largest concentration of canoe clubs in the State (Belt Collins, 1998). In addition, the promenade and other pathways along the Ala Wai are heavily used for walking, running and biking. Overall, the Ala Wai Canal System (including the contributing streams) has been identified as a regionally outstanding recreational resource, as defined based on the diversity of high quality experiences, unique characteristics, or unique combination of recreational attributes (Hawai'i Cooperative Park Service Unit, 1990). The Canal is the most heavily used inland waterway in the state for recreational activities, and is in almost constant use nearly every day of the year (Belt Collins, 1998). Access into the Canal is primarily via the following seven sites: Waikīkī–Kapahulu Library, Mānoa–Pālolo Drainage Canal, Ala Wai Neighborhood Park, Ala Wai Community Park, Magic Island, Ala Wai Small Boat Harbor, and the Ala Wai Channel.

Despite significant human health issues associated with poor water quality, fishing is another common recreational activity in the Canal. Fishing activities include pole fishing, throw netting, fay netting, and crabbing

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39 Each type of park is specifically designed to serve an approximate population size. Regional parks serve the entire island (or a region of the island), with a standard of 8 acres for every 1,000 people. Community-based parks include district parks, community parks and neighborhood parks, with a standard of 2 acres of park space for every 1,000 people. These standards are considered flexible, especially in communities where the amount of open land is limited (CCH, 1997). All of the parks, particularly the regional parks, are heavily used by both residents and tourists. The only facility for which recreational use estimates are available is Mānoa District Park. Between fall 2006 and summer 2007, average daily use of the park was 174 people. Annual visitation was estimated to be 63,120 users (Townscape, 2008).

(Belt Collins, 1998). The Ala Wai Canal is regulated as a Fisheries Management Area (FMA), under which fishing or taking of aquatic life is restricted to the conditions established by DLNR DAR (DLNR, 2009b).

Waikīkī Beach

In addition to the designated beach parks managed by the CCH, Waikīkī Beach itself offers some of the most popular recreational opportunities in the Ala Wai Watershed. Waikīkī Beach is the best known and most visited beach in the state (CCH, 2009a). Recreational opportunities at Waikīkī Beach include sailing, outrigger canoe paddling, kayaking, snorkeling and scuba diving, body boarding, surfing, swimming, fishing, walking, and sunbathing (DOT, 1981).

Table 28. Recreational Facilities and Activities At or Near Each Measure Location

Measure[a]	Recreational Facility
Waihi Debris and Detention Basin	No designated recreational facilities/activities at or adjacent to measure location
Waiakeakua Debris and Detention Basin	Partially within Honolulu Forest Reserve (State)
Woodlawn Ditch Detention Basin	No designated recreational facilities/activities at or adjacent to measure location
Mānoa In-stream Debris Catchment	Adjacent to Mānoa District Park (CCH Park)
Kanewai Field Multi-Purpose Detention Basin	Within Kanewai Community Park (CCH Park)
Waiʻōmaʻo Debris and Detention Basin	No designated recreational facilities/activities at or adjacent to measure location
Pūkele Debris and Detention Basin	No designated recreational facilities/activities at or adjacent to measure location
Makiki Debris and Detention Basin	Partially Within Makiki Tantalus Recreation Area (State Park); staging area within Archie Baker Mini Park (CCH Park)
Ala Wai Canal Floodwalls	Within Ala Wai Promenade (CCH Park) and Ala Wai Community Park (CCH Park); adjacent to Ala Wai Canal
Hausten Ditch Detention Basin	Within Ala Wai Community Park (CCH Park)
Ala Wai Golf Course Multi-Purpose Detention Basin	Within Ala Wai Golf Course
Mitigation Measures (Falls 7 and 8)	No designated recreational facilities/activities at or adjacent to measure location

Notes:

[a] The new gage locations associated with the flood warning system are not listed as they have not yet been sited; however, it is assumed they would be located along the streams in upper watershed areas that do not support designated recreational facilities.

5.10.2 Impacts and Mitigation

Effects on recreation were considered significant if implementation of an alternative plan would result in any of the following:

- Substantially disrupt activities that occur at a institutionally-recognized recreational facility
- Substantially reduce availability of and access to designated recreational or open space areas

The potential effects to recreation and open space that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.10.2.1 No Action Alternative

Over the period of analysis for the project, the type and extent of recreational opportunities are expected to be consistent with the existing condition. Given the extent of development within the watershed, little to no open space is available to support new recreational facilities.

Under the No Action Alternative, recreational facilities and activities within the watershed would not be affected by construction of flood-risk management measures. However, in the absence of these flood risk management measures, significant portions of the watershed would remain within the 1-percent ACE floodplain and would continue to be subject to flood conditions, including the Ala Wai Golf Course, Ala Wai Community Park, and

Kanewai Community Park (see Figure 15). It is expected that these sites would not be available for recreational use during and immediately following flood events (to allow for post-flood clean-up and recovery).

5.10.2.2 Recommended Plan (Alternative 3A-2.2)

As detailed in Table 28, several of the flood risk management measures would be located either within or adjacent to a designated recreational facility. For those measures located within a recreational facility, construction would result in a temporary loss of access and/or recreational use within the construction area (**IMP REC-1**). Specifically, it is expected that recreational activities would be restricted within the construction limits for the duration of construction, thus temporarily limiting the range and/or accessibility of recreational opportunities. Designated recreational facilities that could be affected (at least in part) include Honolulu Forest Reserve, Kanewai Community Park, Makiki Tantalus Recreation Area, Ala Wai Golf Course, Ala Wai Community Park, and Ala Wai Promenade. In addition, portions of Mānoa District Park and Archie Baker Park would be used for staging and access. Construction activities at Honolulu Forest Reserve and Makiki Tantalus Recreation Area, as well staging at Mānoa District Park and Archie Baker Park would involve a very small portion of each facility, and would not significantly impact recreational activities. Similarly, construction of the floodwalls would not preclude recreational use of the Ala Wai Canal, but certain access points may be temporarily unavailable during the construction phase. Overall, these impacts would be temporary and would be mitigated to less-than-significant levels by providing adequate notice to inform recreational users of the construction activities and alternative locations and/or access for recreational activities (**MM REC-1)**. Recreational activities that occur in areas adjacent to the construction limits could be indirectly affected by construction, including increased levels of dust and noise. As discussed in Sections 5.13 and 5.14, standard BMPs would be implemented, such that these impacts are expected to be less than significant.

Over the long term, berms for the multi-purpose debris and detention basins would occupy a portion of Kanewai Community Park, Ala Wai Community Park and Ala Wai Golf Course (**IMP REC-02**). To the extent practicable, the flood risk management features have been designed to have the smallest footprint possible, and to minimize impacts to recreational activities during non-flood conditions. For example, the berm for the Ala Wai Golf Course detention basin has been designed to accommodate the existing golf cart path, such that the layout and use of the golf course would not be significantly affected over the long-term. Similarly, the berms at Kanewai Community Park and Ala Wai Community Park would be located around the outer perimeter of the park.[40],[41] The Waiakeakua and Makiki debris and detention basins, which would be located in the Honolulu Forest Reserve and Makiki Tantalus Recreation Area (respectively), would also displace potential recreational area. These measures are not designed for multi-purpose use; however, no established recreational activities are known to occur at these sites and sufficient area surrounding each feature would still be available for use. As such, recreational use of these sites is not expected to be significantly affected during non-flood conditions.

In the event of a flood, when the various debris and detention measures would detain floodwaters and capture debris/sediment, the inundation zone would be temporarily unavailable for recreation (**IMP REC-03**). As listed in Table 17, the projected inundation period for a 1-percent ACE flood is project to be less than 10 hours. Following a flood event, post-flood maintenance would be conducted to remove accumulated debris/sediment; this could require several days. Potential recreational impacts associated with post-flood maintenance could occur at those sites with multi-purpose detention basins, where established recreational activities regularly occur (e.g., Kanewai Community Park, Ala Wai Community Park, and Ala Wai Golf Course). However, project analyses indicate that these sites already flood (thereby impacting recreational uses) under without-project conditions. Furthermore, O&M activities would be programmed as part of the standard flood response activities to

[40] In 2011, CCH obtained Land and Water Conservation Fund (L&WCF) Act grant funds to renovate Ala Wai Community Park. DLNR is coordinating with the National Park Service's Pacific West Region to determine whether L&WCF assisted property would be affected by any of the proposed project features.

[41] Design details related to park functionality (such as compliance with Americans with Disabilities Act (ADA) requirements, maintenance of utilities, etc.) would be addressed as part of PED during the detailed design phase (see Section 8.11).

minimize post-flood maintenance response time. As such, impacts to recreational activities are expected to be less than significant.

5.10.2.3 Alternative 2A

As described in Section 3, one of the fundamental trade-offs considered in the planning process related to impacts associated with maximizing detention in urbanized open space areas versus upper watershed areas. Based on the resulting plan formulation strategy, Alternative 2A includes the Mānoa District Park multi-purpose detention basin, with only small debris catchment features in place of the Waihi, Waiakeakua, Waiʻōmaʻo and Pūkele debris and detention basins.

The general nature and severity of the potential recreational impacts (and the measures implemented to mitigate those impacts) would be similar to that described for the recommended plan, but instead of construction-related impacts and displacement of recreational activities in the Honolulu Forest Reserve, Alternative 2A would impact recreational activities at Mānoa District Park. However, as described for the plan, construction-related impacts would be temporary and adequate notice would be provided to inform recreational users of the construction activities and alternative locations for recreational activities. Similar to the multi-purpose detention sites included in the recommended plan, these areas would not be available for recreational purposes during or immediately following a flood, during which time post-flood maintenance would be conducted to remove accumulated debris/sediment. However, portions of the park already flood under the without-project condition, and post-flood maintenance activities would serve to restore recreational access in a timely manner. As such, recreational impacts associated with Alternative 2A are expected to be less than significant.

5.11 Visual Resources

5.11.1 Affected Environment

5.11.1.1 Regulatory Framework

Regulations and policies that protect visual resources and are being considered as part of the proposed project include the following:

- National Historic Preservation Act
- Coastal Zone Management Act
- HRS Chapter 205A (Coastal Zone Management)
- HRS Chapter 183C (Conservation District)
- Hawai'i Scenic Byways Program
- General Plan for the City and County of Honolulu
- Primary Urban Center Development Plan

5.11.1.2 Environmental Setting

Visual resources refer to the natural and constructed features that give a particular environment its aesthetic qualities. In undeveloped areas, landforms, water bodies, and vegetation are the primary components that characterize the landscape. These components are characterized in terms of form, color, texture, and scale. They also may be described in terms of the extent to which they are visible to surrounding viewers (i.e., whether they are considered foreground or background). In developed areas, the natural landscape often provides a background for constructed features, which are often characterized in terms of the size, form, materials, and function of buildings, structures, roadways, and associated infrastructure. The combination of these characteristics defines the overall landscape, thus determining the visual quality of an area. Attributes used to describe visual quality include significant views or vistas, landscape character, perceived aesthetic value, and uniqueness. Visual quality is also described in terms of sensitive receptors, which include areas with high scenic quality (such as designated scenic corridors or locations), areas where concentrations of people may be present (such as residential or recreation areas), and important historic or archaeological locations.

In general, the visual landscape within the Ala Wai Watershed is characterized by sweeping views of the mountains and ocean, the broad distribution of developed features within the urban corridor, and a series of significant geologic landforms (such as Diamond Head and Punchbowl). The Koʻolau Mountains serve as a visual backdrop for the watershed, with prominent views of its steep ridges and slopes from locations throughout the watershed and nearshore waters. In addition to the mountains, other natural features that contribute to the overall visual character of the Ala Wai Watershed include Māmala Bay and the broader Pacific Ocean. Although the ocean is the most prominent feature of views from the shoreline, it is less visible than the mountains from central portions of the watershed, as the low-lying views are more readily obscured by urban development. Urban development (including residential buildings, commercial structures, and roadways) covers nearly the entire surface of the coastal plain and adjacent valleys, with the tallest structures clustered in the Waikīkī area. Although these structures often block views of the ocean, they form a visually distinct skyline, which is a significant component of the visual landscape of this region. From within the urban corridor, views of the mountains and ocean are often most prominent along established *mauka-makai* corridors (i.e., perpendicular from the mountain to the ocean), particularly those along major roadways. Geologic landforms are also important components of the visual landscape, serving as a focal point of particular viewsheds. Punchbowl is an important component of views to the west. Views to the east capture Diamond Head, arguably the most widely recognized landmark in Hawai'i. In addition to these large-scale components of the visual landscape, there are a variety of smaller scale features which contribute to local viewsheds. These include the stream and canal corridors, natural vegetation, and cultural sites (such as *lo'i* terraces).

The visual landscape of the proposed debris and detention basins locations along Waihi, Waiakeakua, and Waiʻōmaʻo streams and Woodlawn Ditch are dominated by the natural stream corridor and forested habitat, with a relatively closed tree canopy. The proposed measure locations along Pūkele and Makiki Stream are similar in nature, but are more exposed based on their proximity to adjacent residential properties and roads. The Mānoa in-stream debris catchment, as well as the proposed mitigation measures, are also in areas characterized by the natural stream corridor, with adjacent residential and park environments. The visual landscape of the Kanewai detention basin location is dominated by the open space associated with the park setting and adjacent stream corridor, and the surrounding residential properties and UH campus. The measure locations in Waikīkī (including the Ala Wai Canal floodwalls, Hausten Ditch and Ala Wai Golf Course detention basins) are characterized by broad views of the Ala Wai Canal and the adjacent parks and walkways, as well as the surrounding urbanization, including multi-story buildings and apartments.

Given the population density of the watershed, combined with the overall quality of the visual landscape, there are a variety of potentially sensitive receptors throughout the watershed, including adjacent residential properties, recreational facilities and commercial operations. In addition, the Waikīkī District is a particularly important receptor, as it is the State's prime tourist destination (thus, an important component of the State's economy) and visual quality contributes to the overall visitor experience. Specific components of the Waikīkī District include the Canal itself, which is listed as a historic property on the Hawai'i Register of Historic Places. In addition, two scenic byways have also been established in this area under the Hawai'i Scenic Byways Program: the Diamond Head Scenic Byway and the Waikīkī–Kauhale O Hookipa Scenic Byway (DOT, 2015). The Diamond Head Scenic Byway spans from Kapiʻolani Park to Diamond Head Crater. The Waikīkī–Kauhale O Hookipa Scenic Byway includes the major thoroughfares through Waikīkī, including Ala Wai Boulevard.

Significant views and potentially sensitive receptors for each measure location are summarized in Table 29.

Table 29. Established Viewplanes/Potentially Sensitive Receptors Associated With Management Measures

Measure[a]	Significant Views and Established Viewplanes	Potentially Sensitive Receptors (and Distance from Proposed Measure Location)
Waihi Debris and Detention Basin	Panoramic view of the Koʻolau Mountain Range is identified as significant view that should be preserved (DPP, 2004)	• Mānoa Falls trailhead (~200 feet northwest) • Lyon Arboretum (~200 feet northwest) • Agricultural operation (~300 feet east) • Treetops Restaurant (~ 500 feet southwest) • Residential properties (~0.25 mile southwest)
Waiakeakua Debris and Detention Basin	Panoramic view of the Koʻolau Mountain Range is identified as significant view that should be preserved (DPP, 2004)	• Residential properties (~200 feet southwest) • Agricultural operation (~1,000 feet north)
Woodlawn Ditch Detention Basin	None identified	• Residential properties (~50 feet south) • Mānoa Chinese Cemetery (~200 feet northeast)
Mānoa In-stream Debris Catchment	None identified	• Residential properties (immediately adjacent) • Mānoa District Park (immediately adjacent) • Elementary School (adjacent)
Kanewai Field Multi-Purpose Detention Basin	None identified	• Residential properties (immediately adjacent) • Kanewai Community Park (immediately adjacent) • Elementary School (adjacent)
Waiʻōmaʻo Debris and Detention Basin	None identified	• Residential properties (immediately adjacent)
Pūkele Debris and Detention Basin	None identified	• Residential properties (immediately adjacent)
Makiki Debris and Detention Basin	None identified	• Residential properties (immediately adjacent)
Ala Wai Canal Floodwalls	Panoramic views of the Koʻolau Mountain Range from the Ala Wai Canal promenade identified as a significant view (DPP, 2004)	• Ala Wai Canal (Listed as Historic Property on the Hawaiʻi Register of Historic Places) • Waikīkī - Kauhale O Hookipa Scenic Byway • Ala Wai Canal, Ala Wai Community Park, Ala Wai Promenade, and Ala Wai Golf Course • Residential properties (immediately adjacent) • Elementary School (adjacent)
Hausten Ditch Detention Basin	None identified	• Ala Wai Community Park (immediately adjacent) • Residential properties (immediately adjacent)
Ala Wai Golf Course Multi-Purpose Detention Basin	None identified	• Ala Wai Golf Course (immediately adjacent) • Residential properties (immediately adjacent)
Mitigation Measures	None identified	• Residential properties (immediately adjacent)

Note:

[a] The new gage locations associated with the flood warning system are not listed as they have not yet been sited; however, it is assumed they would be located along the streams in the upper watershed.

As a means to maintain visual quality, many urbanized areas prescribe standards or design guidelines related to scenic resources. The General Plan for the City and County of Honolulu contains the following objectives with respect to scenic resources: (1) Retain the island's streams as scenic, aquatic and recreation resources (Objective A, Policy 2) and (2) Protect Oʻahu's scenic views, especially those seen from highly developed and heavily traveled areas (Objective B, Policy 2). More specific to the Ala Wai Watershed, the County's Primary Urban Center Development Plan (DPP, 2004), which implements the objectives and policies of the general plan and guides the long-range planning for the area, specifies the following policy: "*Preserve panoramic views of natural landmarks and the urban skyline: Preserve views of the Koʻolau and Waianae Mountain Ranges, Punchbowl, Diamond Head, Pearl Harbor and other natural landmarks. Maintain important view corridors within and across urban Honolulu and keep Downtown as the most prominent feature of the urban skyline*." The plan identifies specific views that should be preserved, including panoramic views from the Ala Wai Canal promenade and Ala Moana Beach Park toward the Koʻolau Mountains, as well as *mauka-makai* view corridors along major roadways. Figure 19 illustrates the views that are called out for preservation in the plan.

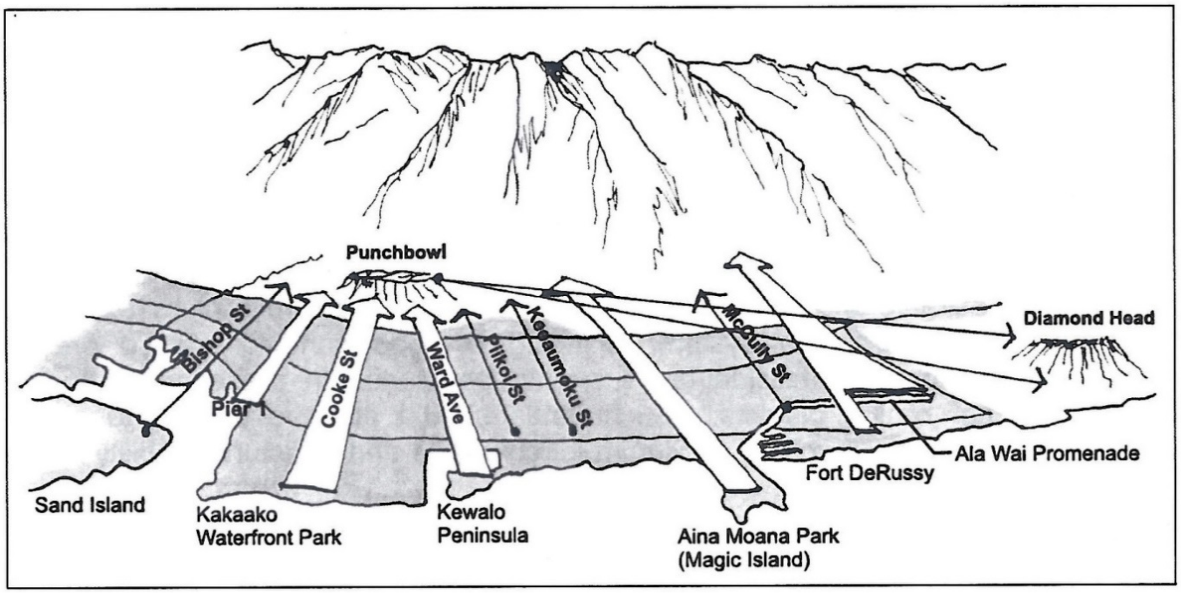

Figure 19. Significant Panoramic and *Mauka-Makai* Views Identified in the Primary Urban Center Development Plan *(DPP, 2004)*

The importance of the scenic resources throughout the Ala Wai Watershed has generally been affirmed by stakeholders, based on input received through the scoping and stakeholder involvement process. In particular, stakeholders have emphasized the importance of local views of the stream and canals, especially the more natural reaches, as these help to maintain a landscape connection within the community.

5.11.2 Impacts and Mitigation

Effects on visual resources were considered significant if implementation of an alternative plan would result in any of the following:

- Development that substantially conflicts with the surrounding landscape (i.e., a form, line, color, or texture that contrasts with the visual setting)
- Obstruction of established viewplane, significant view corridor, or other public views of important environmental resources and/or landscapes
- Substantial reduction of the views or aesthetic values associated with a historic property, scenic byway, or other important landmark

The potential effects to visual resources that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.11.2.1 No Action Alternative

Under the No Action Alternative, the flood-risk management measures would not be constructed and therefore would not affect visual resources. Over the period of analysis, the natural features within the watershed (including Māmala Bay, the Koʻolau Mountains, and other geologic landforms) are not expected to significantly change in form, color, texture, or scale. As such, the visual characteristic of these features are expected to be consistent over time. As previously noted, the urbanized portions of the watershed may be subject to redevelopment, which could affect the overall visual landscape. However, it is assumed that the existing development guidelines and standards would continue to be implemented, thus maintaining significant views and other important visual qualities.

5.11.2.2 Recommended Plan (Alternative 3A-2.2)

Construction of the proposed project would involve the use of large construction equipment, exposed soils, and staged materials, which could temporarily reduce the overall aesthetic quality at each of the measure locations (**IMP VIS-1**). However, these activities would be temporary in nature; in addition, the construction sites would be kept free of litter and excess equipment and materials, and generally maintained in a clean and organized condition, such that impacts are expected to be less than significant.

Once constructed, the measures would introduce built elements to the natural environment, which could alter the visual landscape to some degree. These impacts are generally expected to be limited to the detention basins and floodwalls; the in-stream debris catchment and the mitigation measures are low-profile features that are generally expected to blend with the natural stream and are not expected to substantially affect visual resources. Recognizing the effect that the remaining measures could have on the visual landscape, project siting and design were conducted in a manner so as to best integrate each measure with the natural characteristics of the site and minimize visual impacts to the extent possible. In particular, this effort focused on using the natural topography to minimize the overall size and obtrusiveness of the proposed structures.

In the case of the Waihi, Waiakeakua, and Woodlawn debris and detention basins, these measure locations are not readily accessible by the public and the dense vegetation surrounding each site is expected to screen views from adjacent areas. The other detention basins in the upper watershed (Pūkele, Waiʻōmaʻo, and Makiki) are also set amongst dense vegetation, but are adjacent to residences and/or roadways. In the case of Waiʻōmaʻo, the berm would be approximately 50 feet lower in elevation than the nearby residences, and therefore views from the adjacent residences are expected to be screened by the surrounding vegetation. The Pūkele and Makiki measures would be visible from the adjacent residences and roadways (**IMP VIS-2**). However, the berms for these measures have been designed to sit within the existing stream channel to the extent possible, such that they would not significantly extend above the elevation of the surrounding ground surface and would not be substantially visible from locations beyond the immediately adjacent areas. As such, none of the detention basins in the upper watershed are expected to substantially diminish important environmental or landscape views from readily accessible viewing locations, nor are they expected to affect significant view corridors, including broader views of the respective valleys or the Koʻolau Mountains. As such, impacts to visual resources associated with the debris and detention basins in the upper watershed are expected to be less than significant. Renderings of the Waiakeakua, Woodlawn, Pūkele and Makiki debris and detention basins (which are expected to also be representative of the features at the Waihi and Waiʻōmaʻo sites) are contained in Appendix E.

In the case of the Kanewai, Hausten and Ala Wai Golf Course detention basins, the measure would introduce a built element to existing open space areas (i.e., Kanewai Community Park, Ala Wai Community Park, and Ala Wai Golf Course, respectively), and would also be visible from adjacent areas including surrounding residences (**IMP VIS-3**). However, in each case, the detention basin would be comprised of an earthen/grass berm designed to be a multi-purpose feature, which once constructed, is expected to blend and be visually commensurate with the existing park or golf course facilities. None of the multi-purpose detention basins are expected to substantially diminish important environmental or landscape views from or toward the open space areas, nor are they expected to affect significant view corridors, including *mauka* views of the Koʻolau Mountains. As such, impacts to visual resources associated with the multi-purpose detention basins are expected to be less than significant. Renderings related to the Hausten and Ala Wai Golf Course detention basins are contained in Appendix E.

In addition to the detention basins described above, the project would also include floodwalls along the majority of the Ala Wai Canal, from Kapahulu Avenue to Ala Moana Boulevard on the *makai* side, and from the confluence with the Mānoa–Pālolo Drainage Canal to Ala Moana Boulevard on the *mauka* side. The floodwalls would include several pump stations (which could be several stories tall): (1) at the Kapahulu end of the Canal, (2) on the Ala Wai Golf Course near the Kapahulu storm drain, and (3) at Ala Wai Community Park, near the *makai* end of University Avenue (**IMP VIS-4**); renderings related to the floodwalls and pump stations are contained in Appendix E. Based on the conceptual designs, the floodwalls along the Ala Wai Canal are currently expected to be approximately 4 feet high (on average); the wall heights are expected to decrease as the wall gets closer to Ala Moana Boulevard. They would partially obstruct views of the Canal from cars along Ala Wai Boulevard and from pedestrians along both sides of Canal, and would also obstruct views from within the Canal (e.g., those of paddlers and others using the Canal for recreation). Neither the floodwalls nor the associated pump stations are expected to substantially obstruct broad landscape views (including those of the Koʻolau Mountains), but could diminish localized views, including those along the Ala Wai Canal. In addition to these views being an important resource for the Waikīkī District in general, they are also significant in terms of the Ala Wai Canal as a historic property on the Hawai'i Register of Historic Places, as well as the Kauhale O Hookipa Scenic Byway (which includes Ala Wai Boulevard). As detailed in Section 3, the feasibility analysis determined that the floodwalls (and associated pump stations) would be a necessary feature to provide adequate flood protection for this area. Efforts throughout the planning process would minimize the impacts to the extent possible, particularly as related to the overall floodwall heights. Further refinements would be made during the design phases, and would further evaluate opportunities to reduce the dimensions of the floodwalls and pump stations, as well as incorporate design details that may otherwise minimize potential visual impacts, such as use of construction materials and/or landscaping to blend the structures into the surrounding environment (**MM VIS-1**). This effort would incorporate design input solicited as part of the NHPA Section 106 consultation process, as described in Section 5.8. Implementation of these measures is expected to reduce potential visual impacts to a less-than-significant level.

5.11.2.3 Alternative 2A

Alternative 2A would include the same impacts to visual resources as described for the recommended plan relative to the Kanewai, Hausten, and Ala Wai Golf Course detention basins. In comparison to the recommended plan, the key differences would be smaller debris catchment structures (in lieu of the debris and detention structures) on Waihi, Waiakeakua, Pūkele, and Waiʻōmaʻo streams, but the addition of the Mānoa District Park multi-purpose detention basin and higher floodwalls along the Ala Wai Canal.

Although the debris catchment structures would introduce a built element to the natural environment, these would be substantially smaller than the detention basins. Even in areas where views are not fully screened by existing vegetation (e.g., along Pūkele Stream), the structure is expected to be relatively unobtrusive and blend with the surrounding environment, such that it would not substantially diminish important environmental or landscape views.

In the case of the Mānoa District Park detention basin, visual impacts are expected to be similar to those described for the other multi-purpose detention basins as part of the recommended plan. Specifically, the measure would introduce a built element to the existing environment, and would be visible from within the park and surrounding residential properties. However, the detention basin would be comprised of earthen/grass berm designed to be a multi-purpose feature of the park, and once constructed, is expected to blend and be visually commensurate with the existing park facilities. As such, the structure is not expected to substantially diminish views from any readily accessible viewing locations, including potentially sensitive receptors, nor is it expected to affect broader views of Mānoa Valley or the Koʻolau Mountains.

The floodwalls along the Ala Wai Canal would be in the same location as the recommended plan (and would include the same pump stations), but would be approximately one foot higher (with an average height of 5 feet). These would not substantially diminish broad landscape views (e.g., those of the Koʻolau Mountains), but in comparison to the 4-foot-high floodwalls included in the recommended plan, would be expected to block views of the Canal for a substantially greater percentage of pedestrians and other users along Ala Wai Boulevard.

5.12 Hazardous and Toxic Waste

5.12.1 Affected Environment

5.12.1.1 Regulatory Framework

Regulations and policies that relate to hazardous and toxic waste and are being considered as part of the proposed project include the following:

- Resource Conservation and Recovery Act (RCRA)
- Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)
- HRS Chapter 342J

5.12.1.2 Environmental Setting

Similar to other heavily urbanized environments, the Ala Wai Watershed is expected to include areas with hazardous and toxic waste. To identify sites that could affect the project, a hazardous, toxic and radioactive waste (HTRW) assessment was conducted; this information was used both to inform the alternatives formulation process as well as to identify potential project-related impacts. As part of the assessment, information about potential HTRW sites was collected from a number of sources, including Federal and State databases, aerial photographs, historical documents, Federal and State agencies, CCH departments, and non-governmental organizations. In addition, a visual survey was conducted, with a focus on areas adjacent to the streams. Sites identified during data collection were evaluated to determine if HTRW contaminants are present in the environment in concentrations and conditions that could, under typical conditions, negatively impact surface water, groundwater, storm water, or proposed project elements. A site was considered an HTRW site where a release of hazardous, toxic, radioactive, or petroleum materials or waste has been identified but not yet cleaned up. In some cases, it was not possible to determine the status of a site because of limited available information; sites whose status was unclear were identified as possible HTRW sites. All sites for which adequate geographic information was available were compiled into a geodatabase and mapped.[42]

The assessment identified a variety of HTRW sites within the Ala Wai Watershed; however, no HTRW sites were found to occur within the construction limits for any of the measure locations. Potential sites were identified within the footprint of the Makiki debris and detention basin and the Ala Wai floodwalls, but were determined to be non-HTRW sites.

Additional information regarding the assessment results is provided in the *Final Reconnaissance Phase Hazardous, Toxic, and Radioactive Waste (HTRW) Assessment for the Ala Wai Watershed Project* (Myounghee Noh and Associates, 2009).

5.12.2 Impacts and Mitigation

Effects relative to hazardous and toxic waste were considered to be significant if implementation of an alternative plan would result in any of the following:

- Uncover or expose an existing hazardous, toxic or radioactive waste into the environment
- Accidentally release a hazardous material or other contaminant

The potential effects relative to toxic and radioactive waste that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.12.2.1 No Action Alternative

Under the No Action Alternative, the flood-risk management measures would not be implemented, such that no project-related actions would affect HTRW. Although some of the existing HTRW sites within the watershed may

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[42] Some of the potential HTRW sites that were identified were unmappable because of incomplete street addresses. These sites were included if they had street names or zip codes indicating they were within the watershed.

be remediated on a case-by-case basis, the timing and extent of remediation activities generally cannot be predicted. Additional HTRW sites are not expected to be generated to a significant extent, as there are existing regulations designed to prevent future contaminant releases. As such, the number, extent and influence of HTRW sites on aquatic habitats in the watershed are not expected to significantly differ from existing conditions.

5.12.2.2 Recommended Plan (Alternative 3A-2.2)

Given that no HTRW sites are known to occur within the construction limits based on the reconnaissance assessment, implementation of the recommended plan is not expected to uncover or otherwise expose hazardous, toxic or radioactive waste within any of the measure locations. To confirm the reconnaissance findings, a detailed Phase I Environmental Site Assessment would be performed during the project design phase. In the event the Phase I assessment indicates the presence of HTRW, a Phase II Environmental Site Assessment would be performed, including chemical analysis for hazardous substances and/or petroleum hydrocarbons. If HTRW is detected, appropriate mitigation measures would be implemented, including proper characterization, transport and disposal in accordance with the appropriate local, State, and Federal laws and regulations. In accordance with USACE regulations (ER 1165-2-132), the non-Federal sponsor would be responsible for HTRW response actions as a non-project cost.

Construction and O&M activities would require the use of some hazardous materials, including fuels (e.g., gasoline and diesel fuel) and lubricants, which could adversely affect the environment if accidentally released (**IMP HAZ-1**). However, only a limited amount of these materials would be present onsite, and construction personnel would follow BMPs, including use of proper handling procedures and daily inspection of equipment for leaks, as needed to prevent spills or releases of hazardous materials during construction activities. As previously described, the project will be subject to regulation under the NPDES stormwater program, which requires preparation of a SWPPP to obtain permit coverage; it is expected that the permit requirements will also specify effluent limitations guidelines (ELGs) and new source performance standards (NSPS) to control the discharge of pollutants from the project site. With implementation of these measures, potential HTRW-related impacts are expected to be less than significant.

5.12.2.3 Alternative 2A

Similar to the conditions described for the recommended plan, the HTRW reconnaissance assessment did not identify any HTRW sites within the measure locations included in Alternative 2A. A detailed Phase I Site Assessment would be performed to confirm these findings; in the event HTRW is detected, appropriate response actions would be implemented by the non-Federal sponsor. Under Alternative 2A, similar types and quantities of hazardous materials (e.g., fuels and lubricants) would be used during construction and O&M activities. As described for the recommended plan, BMPs (including use of proper handling procedures and daily inspection of equipment for leaks) would be implemented as needed to prevent spills or releases of hazardous materials; in addition, an SWPPP would be prepared and implemented as part of the NPDES permit program. With implementation of these measures, potential HTRW-related impacts associated with Alternative 2A would be less than significant.

5.13 Air Quality and Climate Change

5.13.1 Affected Environment

5.13.1.1 Regulatory Framework

Regulations and policies that protect air quality and are being considered as part of the proposed project include the following:

- Clean Air Act
- HRS Chapter 342B (Air Pollution Control)
- EO 13514 (Federal Leadership in Environment, Energy and Economic Performance)

5.13.1.2 Environmental Setting

Air Quality Standards

Under the authority of the Clean Air Act, the U.S. Environmental Protection Agency (EPA) has established nationwide air quality standards to protect public health and welfare. These Federal standards, known as National Ambient Air Quality Standards (NAAQS), represent the maximum allowable atmospheric concentrations for the following criteria pollutants: carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), lead (Pb), and particulate matter (respirable particulate matter less than or equal to 10 micrometers in diameter [PM_{10}] and respirable particulate matter less than or equal to 2.5 micrometers in diameter [$PM_{2.5}$]). The NAAQS are based primarily on evidence of acute and chronic (or short-term and long-term) health effects, and apply to outdoor locations to which the general public has access. Based on measurements of ambient criteria pollutant data, EPA designates areas of the United States as having air quality equal to or better than NAAQS (attainment) or worse than NAAQS (non-attainment). Areas previously designated as non-attainment, which receive no NAAQS violations over an extended period, may be re-designated as a maintenance area. Federal agencies are required to perform a general conformity analysis on activities within non-attainment and maintenance areas to ensure that actions they undertake are consistent with air quality management plans for those areas.

The Clean Air Branch of the DOH is responsible for implementing air pollution control in the State and has established Hawai'i Ambient Air Quality Standards (HAAQS), which in some cases are more stringent than the comparable Federal standards or else address pollutants that are not covered by the Federal standards. The HAAQS are based primarily on health effects data, but also reflect other considerations, such as protection of crops, protection of materials, or avoidance of nuisance conditions (such as objectionable odors).

In general, air quality in the State of Hawai'i is some of the best in the nation, primarily because of consistent trade winds and limited emission sources. DOH and EPA maintain a network of air quality monitoring stations throughout the islands. The closest air quality monitoring station to the Ala Wai Watershed is the Honolulu Station, located on the roof of the DOH building, which is located in a busy commercial, business, and government sector of Honolulu. This station is intended to provide data relative to population exposure, and collects measurements for CO, SO_2, PM_{10}, and $PM_{2.5}$. The most recent measurements reported by DOH for this station were recorded in 2013. All of the measurements were well below the Federal and State standards (DOH, 2014). Based on these latest data, the area is currently in attainment of all criteria pollutants established by the Clean Air Act and the HAAQSs. With the exception of exceedances of SO_2 and $PM_{2.5}$ associated with the volcano on Hawai'i Island, the entire State of Hawai'i was in attainment in 2013 (DOH, 2014).[43] As such, conformity analysis procedures do not apply to this project (EPA, 2013).

Greenhouse Gas Emissions

In addition to criteria air pollutants of direct concern for human health, other air emissions are produced as a result of natural processes and human activities. Specifically, greenhouse gases (including carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O)) are chemical compounds which trap heat in the atmosphere, thus affecting the earth's temperature. Scientific evidence indicates a trend of increasing global temperatures (i.e., global warming) over the past century due to an increase in global greenhouse gas emissions.

EO 13514 (Federal Leadership in Environment, Energy and Economic Performance) first introduced greenhouse gas emissions management requirements for the Federal government. On December 18, 2014, the Council on Environmental Quality (CEQ) released *Revised Draft Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in NEPA Reviews* (CEQ, 2014), which provides guidance for Federal agencies in considering climate change in their decision-making process. Relative to the need to disclose projected quantitative greenhouse gas emissions, the guidance provides a

[43] The volcano is considered a natural, uncontrollable event and therefore the State is requesting exclusion of these exceedances from attainment/non-attainment determination (DOH, 2014).

reference point of 25,000 metric tons of CO_2 [carbon dioxide] -equivalent emissions on an annual basis, below which a greenhouse gas emissions quantitative analysis is not warranted (unless quantification below that reference point is easily accomplished) (CEQ, 2014).

5.13.2 Impacts and Mitigation

Effects on air quality were considered significant if implementation of an alternative plan would result in any of the following:

- Exceed Federal or State air quality standards established for criteria pollutants
- Substantially contribute to an existing exceedance of a Federal or State air quality standard (for pollutants in non-attainment)
- Generate greenhouse gas emissions that would significantly contribute to climate change

The potential effects to air quality and climate change that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.13.2.1 No Action Alternative

Under the No Action Alternative, no Federally funded flood risk management improvements would be implemented in the project area, such that no emissions of criteria pollutants would occur. The existing range of air pollution sources within the project area would not be expected to change substantially over the period of analysis. With continuing trade wind patterns, air quality levels are expected to remain relatively constant and would continue to be in compliance with Federal and State standards.

5.13.2.2 Recommended Plan (Alternative 3A-2.2)

Construction of the project would involve a variety of ground disturbing activities, including site preparation, excavation, and grading. Use of heavy equipment and earthmoving operations conducted as part of these activities would generate internal combustion engine emissions and fugitive dust; potential air pollutants associated with these emissions include hydrocarbons; carbon monoxide; nitrogen, carbon, and sulfur dioxide; and PM_{10} and $PM_{2.5}$ (**IMP AQ-1**). In general, these emissions would be temporary and localized in nature. In comparison to overall emissions in the region, the contribution by the proposed action is relatively small; this contribution would only negligibly affect regional air quality and would not be expected to affect attainment of the Federal or State ambient air quality standards. Furthermore, construction would be conducted in compliance with HAR Title 11 Chapter 60.1 (Air Pollution Control), which specifies that the best practical operation or treatment be implemented such that there is not discharge of visible fugitive dust beyond the property lot line. BMPs that would be implemented to reduce construction-related impacts to air quality are expected to include use and proper maintenance of diesel power equipment, minimizing the extent of exposed soils at any given time, stabilizing soil as quickly as possible (e.g., soil binders, jute netting, and revegetation), use of water trucks or sprinkler systems to minimize dust, covering loose material hauled in trucks, and limiting number of vehicles and speed on unpaved surfaces. With implementation of these BMPs, construction-related impacts to air quality are expected to be less then significant; no mitigation would be required.

Over the long term, the project would also result in air emissions from use of vehicles for operations and maintenance activities (**IMP AQ-2**). In addition to the maintenance equipment and vehicle emissions, operation of the pump stations would result in indirect emissions as a result of fossil fuel energy use for electricity. However, these emission levels would be very low, and similar to those associated with construction, would be expected to have a negligible impact on air quality.

Specific to greenhouse gases, a limited amount of emissions would be associated with construction of the project resulting from the use of heavy equipment. Published EPA data indicate that 22 pounds of carbon dioxide are produced for every gallon of diesel fuel burned, and 19.4 pounds are produced for every gallon of gasoline used (EPA, 2008). Given the scale of the project, the total amount of emissions resulting from construction would be insignificant at a regional scale; further, the emission levels would be significantly under

Federal reporting thresholds. As such, the project would be expected to have a negligible impact on greenhouse gas emissions and climate change.

5.13.2.3 Alternative 2A

Air quality emissions that would occur with implementation of Alternative 2A are expected to be within the range of those described for the recommended plan, and as such, impacts to air quality are expected to be less than significant; no mitigation would be required.

5.14 Noise

5.14.1 Affected Environment

5.14.1.1 Regulatory Framework

Regulations and policies that relate to noise and are being considered as part of the proposed project include the following:

- Noise Control Act
- HRS Chapter 342F (Noise Pollution)

5.14.1.2 Environmental Setting

In general, ambient noise levels vary with land use throughout the watershed. In the forested portions of the upper watershed, ambient noise levels are relatively low, with the majority of sounds associated with environmental factors such as wind, rain, and animals (particularly birds). In locations that interface with low density development (i.e., residential areas and recreational facilities), sounds associated with human activity generally increase ambient noise levels. Within the Urban District, ambient noise levels range from relatively quiet residential neighborhoods to commercial and industrial areas, which typically generate higher levels of noise. Sources of noise include commercial and industrial operations, construction activities, intermittent aircraft flybys, and traffic, especially along the major arterial roads and freeways.

Although they may contribute to ambient noise levels, some of the uses within and surrounding the project site are also considered to be sensitive to high levels of ambient noise; these include residences, schools, hospitals, and open space areas. Table 30 summarizes the ambient noise conditions and potential noise-sensitive noise receptors at each of the flood risk management measure locations.

Table 30. Ambient Noise Conditions at Proposed Measure Locations

Measure[a]	Ambient Noise Conditions	Potentially Sensitive Noise Receptors (within 500-foot radius)
Waihi debris and detention basin	Low levels of noise generated by environmental factors (e.g., wind, rain, birds), with intermittent increases from vehicles on Mānoa Rd.	Wildlife, hikers, users at Lyon Arboretum, adjacent agricultural operators
Waiakeakua debris and detention basin	Low levels of noise generated by environmental factors (e.g., wind, rain, birds) and adjacent residential community	Wildlife, hikers, nearby residents
Woodlawn Ditch detention basin	Moderately low levels of noise, primarily associated with agricultural operations and surrounding residences	Nearby residents, agricultural operators, Mānoa Chinese Cemetery
Mānoa in-stream debris catchment	Moderately low levels of noise, mostly associated with adjacent residences, as well as recreational users at Mānoa District Park	Nearby residents, users of Mānoa District Park, adjacent elementary school
Kanewai Field multi-purpose detention basin	Moderately low levels of noise, mostly associated with adjacent residences, UH student housing and nearby roads, as well as recreational users at Kanewai Field	Nearby residents (including UH student housing), users of Kanewai Field, adjacent elementary school
Wai‘ōma‘o debris and detention basin	Low levels of noise generated by environmental factors (e.g., wind, rain, birds) and adjacent residential community	Wildlife, nearby residents
Pūkele debris and detention basin	Low levels of noise generated by environmental factors (e.g., wind, rain, birds) and adjacent residential community	Wildlife, nearby residents
Makiki debris and detention basin	Moderately low levels of noise, mostly associated with adjacent residences and roadways, with some environmental factors	Nearby residents, wildlife
Ala Wai Canal floodwalls	Moderate levels of noise associated with urban district, including dense apartments and other development, and relatively heavy traffic along Ala Wai Boulevard.	Nearby residents, users of the Ala Wai Canal; Iolani School; Ala Wai Elementary School
Hausten Ditch detention basin	Moderate levels of noise associated with urban district, including apartment buildings and other development, and users of Ala Wai Community Park	Nearby residents, users of Ala Wai Community Park and Canal, Ala Wai Elementary School
Ala Wai Golf Course multi-purpose detention basin	Moderate levels of noise associated with urban district, including apartments/residences and other development, and relatively heavy traffic along Kapahulu Boulevard.	Nearby residents, users of the Ala Wai Golf Course, Iolani School, Kaimuki High School
Mitigation measures	Moderately low levels of noise, mostly associated with adjacent residences	Nearby residents

Note:
[a] The new gage locations associated with the flood warning system are not listed as they have not yet been sited; however, it is assumed they would be located along the streams in the upper watershed.

5.14.2 Impacts and Mitigation

Effects related to noise were considered to be significant if implementation of an alternative plan would result in any of the following:

- Exceed maximum permissible levels established by local noise ordinances
- Cause long-term exposure of noise-sensitive receptor(s) to a substantial increase in noise levels over the ambient condition

The potential effects to noise that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.14.2.1 No Action Alternative

Under the No Action Alternative, the flood risk management improvements would not be implemented, such that no increase in ambient noise levels would occur. As previously described, land uses under the future without-project condition are expected to be reasonably consistent with the existing land uses. Given that the types of noise and maximum permissible noise levels are linked to the various land uses districts, the general range of ambient noise levels across the watershed is not expected to measurably change over the period of analysis.

5.14.2.2 Recommended Plan (Alternative 3A-2.2)

Construction of the recommended plan would require operation of heavy equipment for various activities, including clearing, site preparation, excavation, grading, and installation of the structures. Typical sound levels produced by this type of construction equipment are listed in Table 31; these sound levels are based on an inventory of equipment noise emissions that were compiled by the Federal Highways Administration (FHWA) as part of their Construction Noise Handbook (USDOT, 2006).

Table 31. Example of Typical Sound Levels Emitted from Construction Equipment

Type of Equipment [a]	Lmax at 50 feet (dBA, slow) [b]	Type of Equipment [a]	Lmax at 50 feet (dBA, slow) [b]
Backhoe	80	Excavator	85
Compactor (ground)	80	Flatbed truck	84
Concrete saw	90	Front end loader	80
Drill rig truck	84	Grader	85
Dozer	85	Pick-up truck	55
Dump Truck	84	Tractor	84

SOURCE: USDOT, 2006 (http://www.fhwa.dot.gov/environment/noise/construction_noise/handbook/handbook09.cfm)
Notes:
[a] This is an abbreviated list for example purposes; a more complete list of construction-related equipment is available at the above-referenced source.
[b] The sound levels shown are specification limits for each piece of equipment expressed as a maximum sound level (L_{max}) in dBA "slow" at a reference distance of 50 foot from the loudest side of the equipment.
dBA = A-weighted decibels

The State of Hawai'i has adopted statewide noise standards, set forth in HAR Section 11-46 ("Community Noise Control"); these are administered by DOH. The stated purpose of the standards is to "provide for the prevention, control, and abatement of noise pollution in the state from the following noise sources: stationary noise sources (such as air-conditioning units, exhaust systems, generators, compressors, and pumps) and equipment related to agricultural, construction, and industrial activities" (HAR Section 11-46). The noise standards are the maximum permissible sound levels (as measured from the property line) and vary according to land use district. The maximum permissible sound levels for each class of land uses are listed in Table 32. With the exception of the Ala Wai floodwalls, all of the measure sites are zoned for preservation or residential (Class A). The Ala Wai floodwalls would be located within in a public precinct, as part of the Waikīkī Special District (assumed to be a Class B).

Pursuant to HAR Section 11-46-7, a permit may be obtained for operation of an excessive noise source beyond the maximum permissible sound levels. Factors that are considered in granting of such permits include whether the activity is in the public interest and whether the best available noise control technology has been incorporated into the activity.

Table 32. Maximum Permissible Sound Levels By Zoning District

Zoning District	Maximum Permissible Sound Levels (dBA)[a,b]	
	Daytime (7am—10pm)	Nighttime (10pm—7am)
Class A: All areas equivalent to lands zoned residential, conservation, preservation, public space, open space or similar type	55	45
Class B: All areas equivalent to lands zoned for multi-family dwellings, apartment, business, commercial, hotel, resort, or similar type	60	50
Class C: All areas equivalent to lands zoned agriculture, country, industrial, or similar type	70	70

NOTES:
[a] The maximum permissible sound levels apply to any excessive noise source emanating within the specified zoning district, and at any point at or beyond (past) the property line.
[b] The maximum permissible sound level for impulsive noise is 10 dBA above the maximum permissible sound levels shown.

Based on the typical noise levels emitted by construction equipment (as listed in Table 31), construction noise levels would be expected to exceed the State's maximum permissible property line noise levels at each of the measure locations (**IMP NOI-1**). Pursuant to HAR Section 11-46-7, a permit would be obtained from DOH to allow the operation of construction-related equipment (**MM NOI-1**). It is expected that the permit would restrict the times of day when construction activities may emit noise in excess of the maximum permissible sound levels. The DOH may also require the incorporation of noise mitigation into the construction plan and/or community meetings to discuss construction noise with the neighboring residents and business owners. BMPs that would be implemented to reduce noise levels, particularly for noise-sensitive receptors including nearby residents, are expected to include:

- Proper tuning and balancing of construction equipment, and maintenance in accordance with the manufacturer's specifications
- Use of noise barriers and/or mufflers on diesel and gasoline engines
- Restriction of construction activities to typical working days/hours
- Keeping unnecessary noise to a minimum

During construction, it is expected that noise levels would exceed the maximum permissible noise levels and would be significantly higher than ambient noise levels for sensitive noise receptors. However, given the short duration and temporary nature of the construction activities, and with approval of a Community Noise Permit (including implementation of noise-reduction measures), construction-related noise impacts would be reduced to a less-than-significant level.

Over the long term, the flood risk management measures are not expected to substantially affect ambient noise levels. There would be some noise generated during O&M activities (e.g., maintenance vehicles and debris-removal equipment) (**IMP NOI-2**), but these would be very short-term increases that occur on a periodic basis (e.g., once per year), such that the impact on noise levels is expected to be insignificant.

5.14.2.3 Alternative 2A

Noise levels that would occur as a result of construction and O&M activities for Alternative 2A would be within the range of those described for the recommended plan. Pursuant to HAR Section 11-47, a noise permit would be obtained to allow the operation of construction-related equipment, and would include measures for reducing project-related noise levels. Similar to the recommended plan, implementation of these measures would reduce construction-related noise impacts to a less-than-significant level.

5.15 Transportation and Traffic

5.15.1 Affected Environment

5.15.1.1 Environmental Setting

A variety of roadways occur within the watershed, ranging from one of the State's primary freeways, to major thoroughfares and collector streets, to local access roads (see Figure 1). H-1 (Lunalilo Freeway) is one of four freeways on the island of O'ahu, providing access between the 'Ewa district and Hawai'i Kai, which constitutes the island's primary urban corridor. It is approximately 27 miles long, of which approximately 4 miles occurs within the watershed. The number of lanes varies throughout the corridor, but within the watershed there are typically three lanes in each direction, not including ramps and auxiliary lanes. The only State Route (SR) within the watershed is SR 92, more commonly referred to as Ala Moana Boulevard, which parallels the shoreline in the western portion of the watershed (DOT, 2008). Other major thoroughfares within the watershed include Beretania Street, King Street, Kapi'olani Boulevard, Ward Avenue, Kalakaua Avenue, University Avenue, Waialae Avenue, and Kapahulu Avenue. Most of these roadways serve as collector roads, carrying traffic between areas of activity within the urban district. These roadways are generally oriented in either an east-west direction (Beretania Street, King Street, Kapi'olani Boulevard, and Waialae Avenue) or a *mauka-makai* direction (Ward Avenue, Kalakaua Avenue, University Avenue, and Kapahulu Avenue). The remainder of the transportation network within the Ala Wai Watershed is comprised of smaller, local roads, such as those providing access into the residential neighborhoods. With the exception of H-1 and SR 92, all of the roads within the watershed are under the jurisdiction of the CCH Department of Transportation Services (DTS). Traffic conditions vary by location, but in general, many of the major roadways are over capacity during morning and afternoon peak hours, resulting in significant traffic delays.

The O'ahu Bike Plan (DTS, 2012) was developed to guide bikeway planning for the entire island of O'ahu. It identifies the existing bicycle network, and provides recommendations for new facilities as part of a strategy for better integrating bicycling into the transportation system. Relative to the proposed project, the plan identifies an existing bike lane along the *mauka* side of Ala Wai Boulevard; it also includes recommendations for a proposed bike route along Makiki Road (adjacent to the Makiki detention basin) and a proposed bike path along Mānoa Stream (adjacent to Kanewai detention basin).

5.15.2 Impacts and Mitigation

Effects on transportation and traffic were considered to be significant if implementation of an alternative plan would result in any of the following:

- Substantially increase vehicle travel times due to increased congestion, delays in traffic movement and circulation, and/or reduced roadway capacity
- Substantially reduce availability, quality and/or safety of roadways or other transportation resources (e.g., sidewalks, bicycle lanes, etc.)
- Substantially decrease access to businesses, residences or public facilities
- Substantially displace parking and/or cause other significant changes in parking supply

The potential effects to transportation and traffic that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.15.2.1 No Action Alternative

Over the period of analysis for this project, it is anticipated that traffic levels could increase, but the transportation resources within the watershed are not expected to substantially change. Under the No Action Alternative, none of the proposed flood risk management measures would be implemented and the anticipated reductions in potential flooding within the watershed would not be realized. As such, none of the construction-related impacts to traffic and transportation resources would occur, but nor would the benefits associated with protecting important roadways during flood conditions.

5.15.2.2 Recommended Plan (Alternative 3A-2.2)

Construction of the proposed project would require the delivery of construction equipment and materials, as well as the transportation of construction workers to each of the measure locations, which is expected to impact traffic and transportation resources (**IMP TRN-1**). Specific impacts that are anticipated include the following:

- Increased traffic congestion and/or reduced circulation when trucks are hauling material to/from the site
- Reduced roadway capacity (e.g., lane closures) when construction vehicles or equipment are required within the public right-of-way
- Temporary closure of sidewalks, walkways, crosswalks and/or bicycle lanes
- Degradation to existing pavement/condition of roadways, curbs, or intersections from large, heavy construction vehicles and equipment
- Decreased driver safety because of reduced sight-distances or increased visual hazards associated with construction vehicles
- Temporary changes in access to businesses, residences or public facilities in areas adjacent to construction zones
- Temporary reduction in availability of public, on-street parking because of construction activities

An overview of the roadways and other transportation resources that are expected to be affected at each measure location is provided in Table 33.

Table 33. Roadways and Other Transportation Resources Affected by recommended plan

Measure	Summary of Roadways Affected	Other Transportation Resources Affected
Waihi debris and detention basin	Major thoroughfares (e.g., Punahou Street and/or University Avenue); collector streets (e.g., Mānoa Road and/or Oʻahu Ave.)	Temporary reduction in access to residences, Treetops Restaurant, Lyon Arboretum and/or Mānoa Falls Trail
Waiakeakua debris and detention basin	Major thoroughfares (e.g., Punahou Street and/or University Avenue); collector streets (e.g., Mānoa Road and/or Oʻahu Ave.); local residential roads (e.g., Waaloa Place, Waaloa Way)	Temporary reduction in access to residences
Woodlawn Ditch detention basin	Major thoroughfares (e.g., Punahou Street and/or University Avenue); collector streets (e.g., East Mānoa Road)	Temporary reduction in access to Mānoa Chinese Cemetery and/or adjacent agricultural operations
Mānoa in-stream debris catchment	Major thoroughfares (e.g., Punahou Street and/or University Avenue); collector streets (e.g., East Mānoa Road); local residential roads (e.g., Kahaloa Drive)	Temporary reduction in access to residences and/or Mānoa District Park
Kanewai Field multi-purpose detention basin	Major thoroughfares (e.g., University Avenue); collector streets (e.g., Dole Street)	Temporary reduction in access to residences and/or Kanewai Community Park
Waiʻōmaʻo debris and detention basin	Major thoroughfares (e.g., Waialae Avenue); collector streets (e.g., Pālolo Avenue, 10th Avenue); local residential roads (e.g., Waiʻōmaʻo Road)	Temporary reduction in access to residences
Pūkele debris and detention basin	Major thoroughfares (e.g., Waialae Avenue); collector streets (e.g., Pālolo Avenue, 10th Avenue); local residential roads (e.g., Jasmine Street, Ipulei Place)	Temporary reduction in access to residences
Makiki debris and detention basin	Major thoroughfares (e.g., Punahou Street, Keeaumoku Street); collector streets (e.g., Makiki Street, Nehoa Street); local residential roads (e.g., Makiki Heights Drive)	Temporary reduction in access to residences

Table 33. Roadways and Other Transportation Resources Affected by recommended plan

Measure	Summary of Roadways Affected	Other Transportation Resources Affected
Ala Wai Canal floodwalls	Major thoroughfares (e.g., Kapahulu Avenue, University Avenue, and/or Kalakaua Avenue); collector streets (e.g., Ala Wai Boulevard, McCully Street); local residential roads (e.g., adjacent to Ala Wai Boulevard)	Temporary reduction in access to residences, pedestrian walkways and bike lanes along Ala Wai Canal, parking along Ala Wai Boulevard
Hausten Ditch detention basin	Major thoroughfares (e.g., University Avenue, Kapiʻolani Boulevard); local residential roads (e.g., Hihiwai Street)	Temporary reduction in access to Ala Wai Community Park, canoe club facilities, and impacts to school traffic (Ala Wai Elementary)
Ala Wai Golf Course multi-purpose detention basin	Major thoroughfares (e.g., Kapahulu Avenue); collector streets (e.g., Date Street); local access roads (e.g., golf course entrance road)	Temporary reduction in access to businesses and other facilities (e.g., Waikīkī-Kapahulu Public Library, Library for the Blind and Physically Handicapped)
Mitigation Measures	Major thoroughfares (e.g., Punahou Street and/or University Avenue); collector streets (e.g., Mānoa Road, Oʻahu Avenue); local residential roads (e.g., Pawaina Street)	Temporary reduction in access to residences

These impacts could significantly increase travel times and/or affect other transportation resources. However, these impacts would be limited to construction, such that they would be temporary in nature. In addition, the contractor would be required to prepare and implement a Transportation Management Plan (**MM TRN-1**); measures to be included in the plan are expected to include the following:

- Institute time-of-day restrictions for large, oversized construction vehicles to minimize interference with peak-hour or commute traffic.
- Maintain at least one travel lane on roadways to the extent possible; if complete lane closures are required, post adequate signage for potential detours or possible delays, or conduct full lane closures at night.
- Establish temporary increases in lane capacity, as needed (e.g., widen existing shoulders for bypass traffic).
- Provide advance warning and proper roadway signage along potential construction routes to warn motorists, residents, businesses of changes in roadway and traffic-related conditions (e.g., potential vehicles entering and exiting the roadway, etc.).
- Identify safe and reasonable detours, including those needed for pedestrians and bicyclists, and provide adequate notification.
- Provide written, advanced notice to property owners and businesses adjacent to construction areas.
- Use pilot vehicles when slow or oversized/wide loads are being hauled.
- Use flaggers, as necessary, to direct traffic when large equipment is exiting or entering public roads to minimize risk of accidents.
- Provide temporary parking in nearby locations to the extent possible.
- Repair surface damage to local roads used for construction haul routes to pre-construction conditions.

Preparation and implementation of the plan would be coordinated with the relevant transportation agencies, including DOT and DTS. With implementation of the plan, including the measures listed above, it is anticipated that impacts to traffic and transportation resources would be reduced to a less-than-significant level.

Once constructed, the flood risk management measures would not permanently displace any transportation facilities, including roadways, bicycle lanes, pedestrian pathways and/or parking. The project would function to substantially reduce the extent of flooding within the watershed, and would effectively remove many major thoroughfares and collector roads (as well as smaller access roads) from the floodplain, including Kapiʻolani Boulevard, Kapahulu Avenue, Kalakaua Avenue, and Ala Wai Boulevard. By decreasing the potential for flooding within these roadways, the project would provide important benefits, including improved access within and out of the watershed during flood conditions, including routes used for evacuation and flood response activities (**IMP TRN-2**). During non-flood conditions, operations and maintenance of the proposed measures would require the use of trucks and other vehicles (e.g., to remove and dispose of debris, etc.). However, only a minimal number of vehicles would be required and these activities would occur on a periodic basis, such that traffic and transportation resources are not expected to be significantly affected.

5.15.2.3 Alternative 2A

Impacts to traffic and transportation that would occur as a result of implementation of Alternative 2A would be similar in nature to those described for the recommended plan, but with varying degree of impact to the different roadways and transportation resources (based on the type and location of measures). As described above, construction-related impacts could include increased congestion; delays in traffic movement and circulation; reduced capacity/availability of roadways and other transportation resources (including sidewalks and bike lanes); decreased access to adjacent businesses, residences and public facilities; and displacement of parking. These impacts could significantly increase travel times and/or affect other transportation resources, but would be mitigated to the extent possible through preparation and implementation of a Traffic Management Plan, such that construction-related impacts are expected to be less than significant. Similar to the recommended plan, flood reduction benefits associated with implementation of Alternative 2A would include removal of important roadways from the floodplain, thereby improving access within and out of the watershed during flood conditions, including routes used for evacuation and flood response activities.

5.16 Public Health and Safety

5.16.1 Affected Environment

5.16.1.1 Regulatory Framework

Regulations and policies that protect public health and safety and are being considered as part of the proposed project include the following:

- HRS Chapter 127A (Emergency Management)
- ER 1110-2-1156 (Safety of Dams – Policies and Procedures)

5.16.1.2 Environmental Setting

In the event of catastrophic flooding, potential safety threats include loss of life, injury, and post-flood health hazards. Elevated and/or high-velocity floodwaters can threaten physical health and safety (e.g., risk of drowning and injury from movement of debris and other large objects), as well as mental health (e.g., stress and anxiety). Other health and safety hazards that could occur as a result of flooding include potential contamination of floodwaters (e.g., including sewage, fuel oil, pesticides, and solvents); in addition, flood conditions can increase exposure to bacteria and/or mold (e.g., leptospirosis).

Currently, the affected population within the 1-percent ACE floodplain includes approximately 54,000 residents, of which more than 20 percent are over the age of 65 or under the age of 5 (and are thus more vulnerable to flood-related safety hazards). In addition to permanent residents, there are an additional estimated 79,000 visitors in Waikīkī on any given day, plus an influx of students to the schools located within the floodplain, as well as workers to the Waikīkī District and other centers of employments (e.g., UH).

Critical Infrastructure

Critical infrastructure includes emergency facilities or other assets that are essential for functioning of a community, and can directly affect public health and safety; these include fire and police stations, hospitals and medical clinics, and evacuation shelters. Access to these facilities can be limited during and after flood events; in some cases, critical infrastructure may need to be evacuated (e.g., temporary closure of medical facilities would interrupt normal public health operations, as well as trauma care). Much of the critical infrastructure within the watershed is in the 1-percent ACE floodplain. This includes 4 of 7 fire stations, 1 of 2 police stations, 2 of 9 hospitals, 2 of 14 nursing facilities, and 9 of 21 emergency shelters.

Flood Warning and Evacuation

The presence of a flood warning system, including the amount of warning provided, can directly affect injury and fatality rates (Doocy et al., 2013). The watershed currently includes a warning system that includes multiple real-time rain and stream gages. These are sponsored by the CCH Department of Environmental Services (ENV); however, sponsorship is not expected to continue over the long-term.

In some areas, evacuation planning is also an important contributor to flood-related safety. Given the geography and development patterns in Hawai'i, there are generally no designated evacuation routes for riverine flooding; recommendations are to avoid streams and other low-lying areas (seek higher ground). In general, the ability to evacuate is linked to sufficient warning time.

Natural Disaster Planning and Response

Natural disaster planning and response in Hawai'i is provided by multiple entities, and includes proactive efforts to focus on hazard mitigation and community resilience. In general, responsibility for disaster planning and response starts at the County level, which for the island of O'ahu is the CCH Department of Emergency Management. Each county conducts their own mitigation planning and coordinates with State Civil Defense (Hawai'i Emergency Management Agency), which provides operational infrastructure and procedures when additional support is needed. State Civil Defense also formed the State Hazard Mitigation Forum, which includes participants from State and local government and public and private sectors; this group oversees recommendations for hazard mitigation planning and public awareness.

At the Federal level, FEMA provides hazard mitigation and disaster recovery support, pursuant to the Disaster Mitigation Act of 2000. Eligibility for FEMA funding requires development of a State hazard mitigation plan. The State of Hawai'i's Multi-Hazard Mitigation Plan was originally approved in 2004, and was most recently updated in 2013 (State Civil Defense, 2013). The plan provides the State's strategy to reduce the risks from natural hazards, and incorporates hazard mitigation planning conducted by each of the counties. The Disaster Mitigation Act also provides for preparation of local hazard mitigation plans; local plans that apply to the Ala Wai Watershed include the UH's System-wide Multi-hazard Mitigation Plan (UH, 2009).

The State's Flood Control Program (authorized under HRS Chapter 179) is overseen by DLNR, who is responsible for coordinating all Federal and State flood control projects, as well as for maintaining compliance with the NFIP. The NFIP is a Federal program managed under FEMA that allows property owners to purchase insurance protection against losses from flooding. Insurance rates are determined based on FIRMs; the current FIRMs for the island of Oahu were updated in 2014 to reflect new coastal surge analyses.[44] To participate in the NFIP, a community must adopt and enforce a floodplain management ordinance to reduce future flood risks to new construction and improvements in flood hazard areas.

5.16.2 Impacts and Mitigation

There is no metric for life-safety within this evaluation. Assessments are qualitative, relying on quantitative data where possible. Effects on public health and safety were considered to be significant if implementation of an alternative plan would result in any of the following:

- Increased health and safety risks to residents and/and visitors
- Decreased access to or functionality of critical infrastructure, or other public facilities including schools
- Conflict with or impair implementation of an adopted plan or policy, including applicable hazard mitigation plans

[44] The inundation maps prepared by USACE for this study do not supersede the FIRMs. If the project moves forward into construction, CCH may choose to adjust the FIRM to account for improved protection in the watershed.

The potential effects to public health and safety that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.16.2.1 No Action Alternative

Under the No Action Alternative, the flood risk management measures would not be implemented and public health and safety would continue to be threatened by large-scale flood events. The currently affected population of approximately 54,000 residents, 48,000 students and approximately 79,000 visitors to the Waikīkī area would remain in the 1-percent ACE floodplain, and could potentially grow as the population increases over time.

As evidenced by past flooding events, there is some potential for life loss because of flooding in the watershed. The existing flood warning system is expected to significantly reduce the potential for life loss by providing residents and visitors with sufficient warning to evacuate; however, the long-term funding and support of the flood warning system is uncertain. Regardless, the potential flood characteristics are not projected to be of a depth and velocity that imminently threaten life safety. Rather, the more prominent health and safety threats are expected to be injuries associated with movement of debris and/or health concerns related to contaminated floodwaters.

Much of the watershed's critical infrastructure would remain within the floodplain, which elevates the risk associated with these health and safety threats. Critical infrastructure that is within the existing 1-percent ACE floodplain would remain subject to flooding, including 4 fire stations (McCully, Waikīkī, Ala Moana, and Makiki), 1 police station (Waikīkī), 2 medical clinics (both in Waikīkī), and 9 emergency shelters (3 in Waikīkī, 2 in McCully/Mō'ili'ili, 3 in Mānoa, and 1 in Kaimuki).

5.16.2.2 Recommended Plan (Alternative 3A-2.2)

Overall, the project would function to decrease health and safety risks associated with potential flooding in the watershed, consistent with the objectives and approaches adopted in the applicable flood hazard mitigation plans. As described throughout this document, implementation of the recommended plan would significantly reduce the potential extent of flooding in the watershed, thus reducing the number of people subject to flood-related health and safety risks, including the majority of the watershed's residents and most (if not all) of the daily visitors to Waikīkī (**IMP SAF-1**). As discussed in Section 3.6, it is not possible to entirely eliminate the potential for flooding in the watershed; there would still be some degree of health and safety risks associated with movement of debris and health concerns from contaminated floodwaters in areas still subject to flooding. However, the depth and velocities of flooding would be reduced (see Table 10) and the overall risks to health and safety from flooding would be greatly improved, such that these residual impacts are expected to be minimal in comparison to the benefits provided across the watershed.

In addition to reducing health and safety risks to the affected population, critical infrastructure and other public facilities would be removed from the 1-percent ACE floodplain, thus contributing to health and safety through increased resiliency in response to flood events (**IMP SAF-2**). Specifically, the project would provide protection for 2 of the 4 fire stations, the police station, both medical clinics, and 6 of the 9 emergency shelters that are currently in the 1-percent ACE floodplain. Critical infrastructure that would remain in the floodplain includes 2 fire stations (the Makaloa station in Ala Moana and the Wilder station in Makiki), and 3 emergency shelters (Lunalilo Elementary, Hokulani Elementary and Washington Intermediate in McCully/Mō'ili'ili). In addition to the three schools that serve as emergency shelters, the only other school that would remain in the 1-percent ACE floodplain would be a portion of Iolani School; the other 7 schools that are currently in the floodplain would be protected by the project.

Another beneficial impact associated with implementation of the project is heightened awareness of the flood-related risks, including both an increased understanding of the overall potential for flooding based on dissemination of project-related information, as well as increased communication of imminent flood events via improvements to the flood warning system. This is expected to translate to increased levels of preparedness (thus improving health and safety) (**IMP SAF-3**).

Despite the protection afforded by the flood risk management measures, there are potential safety concerns associated with the detention basins. These concerns relate to both the risk of failure, as well as increased potential for water-related safety hazards (e.g., drowning) during times when the detention basins contain standing water (**IMP SAF-4**). Water-related safety hazards generally relate to the multi-purpose detention basins (as these are sited in parks and other areas readily accessed by the public). However, as previously described, these measures are in areas that would otherwise flood in the absence of a flood risk management project (thus posing similar health and safety risks). In addition, they would only be periodically inundated during large-scale flood events (at which times, the public is not expected to be in these areas). The risk of a structural failure would be more of a concern in locations where the detention basin would be upstream of residential or other developed uses. For the purposes of this project, it is expected that the proposed detention structures would be regulated under both the Federal and State Dam Safety Programs, and subject to the safety requirements (**MM SAF-1**).[45] The USACE has adopted a risk-informed approach to manage its portfolio of dams, with a priority focus on public safety. Likewise, DLNR manages the State of Hawai'i's Dam Safety Program, which includes inspections, maintenance of a statewide inventory, risk assessment, emergency planning and training. With implementation of these measures, the inundation of floodwaters in these detention features is a managed risk that is outweighed by the flood reduction benefits throughout the watershed, such that the impacts are considered to be less than significant.

5.16.2.3 Alternative 2A

Overall, implementation of Alternative 2A would provide similar benefits to public health and safety as described for the recommended plan. The extent of floodplain reduction would differ slightly, but Alternative 2A would still provide protection for a majority of the watershed's residents and most (if not all) of the daily visitors to Waikīkī. Most of the critical infrastructure within the existing 1-percent ACE floodplain would no longer be subject to flooding; infrastructure remaining in the floodplain would include 2 fire stations (the Makaloa station in Ala Moana and the Wilder station in Makiki), 2 nursing facilities (Hale Nani in Makiki and Mānoa Cottage in Kaimuki), and 2 emergency shelters (Lunalilo Elementary and Washington Intermediate in McCully-Mō'ili'ili). Both Hokulani Elementary and Iolani School would be protected under this alternative which would reduce flood risk for an additional 2250 students at these schools during daylight hours.

This alternative would also include similar safety concerns with the detention basins as described for the recommended plan. However, the degree and location of the concerns would differ, based on the absence of debris and detention basins in the upper reaches of Mānoa and Pālolo streams, and the inclusion of inclusion of Mānoa District Park as a multi-purpose detention basin. These differences contribute to additional safety-related concerns at Mānoa District Park. As the inlet would be located several hundred feet upstream and would not be visible to park users, a flood warning system would be provided and would activate when water enters the basin (**MM SAF-2**). Similar to the recommended plan, the detention structures would also be regulated under the Federal and State Dam Safety Programs, such than the potential health and safety impacts are considered to be outweighed by the flood reduction benefits and would be less than significant.

[45] The USACE defines a dam as "*an artificial barrier, including appurtenant works, constructed for the purpose of storage, control, or diversion of water, and which (1) is twenty-five feet or more in height from the natural bed of the stream or watercourse measured at the downstream toe of the barrier or from the lower elevation of the outside limit of the barrier if it is not across a stream channel or watercourse, to the maximum water storage elevation or (2) has an impounding capacity at maximum water storage elevation of fifty acre-feet or more. Any such barrier which is under six feet in height regardless of storage capacity, or which has a storage capacity at maximum water storage elevation not in excess of fifteen acre-feet regardless of height is not considered a dam. This lower size limitation should be waived if there is potentially significant downstream hazard. This definition applies whether the dam has a permanent reservoir or is a detention dam for temporary storage of floodwaters. The impounding capacity at maximum water storage elevation includes storage of floodwaters above the normal full storage elevation.*" (ER 1110-2-1156)

5.17 Public Services and Utilities

5.17.1 Affected Environment

5.17.1.1 Regulatory Framework

Regulations and policies that relate to public services and utilities and are being considered as part of the proposed project include the following:

- HRS Chapter 46-11.5 (Maintenance of Channels, Streambeds, Streambanks, and Drainageways)
- ROH Section 41-26.3 (Maintenance of Channels, Streambeds, Streambanks and Drainageways)

5.17.1.2 Environmental Setting

Public services and utilities that are available within the Ala Wai Watershed include police, fire, and emergency medical services and infrastructure for electricity, telecommunications, solid waste, and water and wastewater. Other services include stream channel maintenance. Following is a brief overview of each of these services and utilities.

Police, Fire Protection and Emergency Medical Services

Police services on the island of O'ahu are provided by the Honolulu Police Department (HPD). HPD's headquarters are located in downtown Honolulu, just within the western boundary of the watershed. The island is divided into eight patrol districts; the Ala Wai Watershed includes three of these districts, including most of District 1 (Central Honolulu), all of District 6 (Waikīkī), and the western half of District 7 (East Honolulu).

In general, fire protection services for the island of O'ahu are provided by the Honolulu Fire Department (HFD). The HFD is responsible for multi-mission emergency response for events including fire, emergency medical situations, hazardous material incidents, search and rescue (i.e., for mountain and ocean), motor vehicle accidents, and natural disasters. The island is divided into five battalions containing 44 fire stations. The Ala Wai Watershed includes portions of Battalion 1 and 2, with a total of 7 stations.

DOFAW also has a Fire Management Program, which provides protection for wildlands, including forest reserves, natural area reserves, wildlife and plant sanctuaries, and public hunting areas. Portions of the upper watershed are designated as DOFAW primary response areas. In addition, DOFAW will cooperate with HFD for the protection of other wildlands not within their primary response area, to the extent needed to provide for public safety (DOFAW, 2010).

Emergency medical facilities within the Ala Wai Watershed include Straub Hospital and Kapi'olani Medical Center for Women and Children. Straub Hospital is a full-service hospital, located near the western boundary of the watershed, in the Ala Moana/Kaka'ako neighborhood. Kapi'olani Medical Center for Women and Children is located in lower Makiki, near the border with the Mānoa neighborhood. Specializing in care for women and children, it offers a full array of medical services, including a pediatric emergency services and intensive care facilities. Queen's Medical Center, considered to be the primary trauma hospital on the island, is located just outside the western boundary of the watershed.

Electricity and Telecommunications

HECO is the primary electrical utility provider for the island of O'ahu. None of the power plants on the island of O'ahu are located within the Ala Wai Watershed. HECO's island-wide transmission and distribution system is comprised of a various substation facilities and a broad network of power lines (some of which are located underground), with capacities ranging from 12 kV to 138 kV.

Telecommunication services that are provided throughout the watershed include various radio, cell phone, and internet technologies.

Solid Waste

Solid waste services for the island of O'ahu are provided by the CCH ENV. Specific services include drop-off facilities, curbside collection, and recycling. Most residential and general commercial trash is disposed at

H-POWER, the City's waste-to-energy plant (located at Campbell Industrial Park). H-POWER processes over 600,000 tons of waste annually, producing approximately 7 percent of O'ahu's electricity. Noncombustible construction and demolition (C&D) debris and industry waste is disposed of as landfill (ENV, 2005). The island's two landfills are located approximately 35 miles west of the watershed.

Water and Wastewater

CCH BWS manages the municipal water supply and distribution system on the island of O'ahu. BWS is responsible for providing water service for consumers, regulating water availability for new developments, and protecting, developing, and conserving the island's water resources. In 2006, municipal water use for the island of O'ahu totaled approximately 140140 mgd (CWRM, 20142014). Of this, approximately 36 mgd was consumed within the Ala Wai Watershed (BWS, 2009a).

CCH ENV is responsible for management of wastewater on the island of O'ahu. There are a total of nine wastewater treatment plans in operation; the Ala Wai Watershed is services by the Sand Island wastewater treatment plant, located approximately 2 miles west of the watershed. The Sand Island WWTP is the largest plant on O'ahu and receives approximately 85 percent of the island's wastewater, processing more than 60 mgd (ENV, 2010).

Stormwater Drainage

CCH ENV is also responsible for the island's storm drain system. This system, which is referred to as the Municipal Separate Sewer System (MS4), captures storm water and conveys it directly to streams, canals and/or the ocean to prevent flooding in developed areas. Certain segments of the storm drainage system do not have the capacity to handle the design storms under their current conditions (Oceanit, 2008b).

Stream Channel Maintenance

HRS Section 46-11.5 mandates that "each county shall provide for the maintenance of channels, streambeds, streambanks, and drainageways, whether natural or artificial, including their exits to the ocean, in suitable condition to carry off storm waters; and for the removal…(of) any debris which is likely to create an unsanitary condition or otherwise become a public nuisance." However, the statute specifies that waterways that are owned by the State or by a private entity shall be maintained by their respective owners.[46] A large percentage of the streams are privately owned, with an estimated 150 private landowners along Mānoa Stream alone (Oceanit, 2008a). Section 41-26.3 of the ROH dictates that private owners are responsible for maintaining, dredging, and clearing the stream of any debris, vegetation, silt, or other items of any kind that may interfere with the natural flow of water.[47] However, many private landowners are not aware of this responsibility or the scope of activities that are entailed (Townscape, 2008).

Given the diverse ownership of land, management responsibilities for the waterways are divided amongst many agencies and individuals. Many stakeholders have expressed frustration with the lack of adequate stream channel maintenance, which stems from the complexity of land ownership, with issues including fractured or inconsistent approaches to maintenance by different landowners, limited accessibility, limited resources, and excessive costs.

5.17.2 Impacts and Mitigation

Effects on public health and safety were considered to be significant if implementation of an alternative plan would result in any of the following:

[46] Under HRS Chapter 179, the Board of Land and Natural Resources (BLNR) is designated as the agency responsible for flood control and flood water conservation. BLNR has the authority to coordinate drainageway maintenance problems with the appropriate State or County agency. For waterways with undetermined ownership, BLNR is responsible for coordinating the resolution of maintenance problems with the appropriate State agencies.

[47] CCH is authorized to enforce stream maintenance on private properties and fine the property owners for non-compliance. ROH 41-26 gives the City the power to enter any property to inspect the streams to ensure maintenance. The City is then authorized to notify the stream owner of maintenance violations. Upon failure of the stream owner to comply with the notification, the City may clear and maintain the stream at the owner's expense. However, in general, this authority is not exercised because of permitting hurdles and resource limitations (Townscape, 2008).

- Substantially interfere with, or increase the response time of police, fire or emergency medical services
- Permanently disrupt or decrease the level of service for any public utility
- Significantly burden any public service or utility, including the water, wastewater, or stormwater drainage system

The potential effects to public services and utilities that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.17.2.1 No Action Alternative

Under the No Action Alternative, the Federal flood risk management measures would not be constructed, and as a result, there would be no construction-related impacts to public services and utilities. However, large portions of the watershed (and the associated public services and utilities) would remain vulnerable to increased levels of flooding. Flood-related impacts include increased emergency response requirements by police, fire and medical teams during flood events; as discussed in Section 3.6, many of the emergency response facilities in the watershed are located within the 1-percent ACE floodplain. In addition, portions of the utility infrastructure may be subject to flooding (including the sewer and stormwater drainage systems, as well as electrical substations), which could cause widespread service disruptions.

Given the current extent of development and the extensive network of utilities within the watershed, it is assumed that the distribution and scope of public utilities and services would remain relatively constant over the duration of the period of analysis.

5.17.2.2 Recommended Plan (Alternative 3A-2.2)

Police, Fire Protection and Emergency Medical Services

Construction of the project is not expected to affect police, fire protection or emergency medical services. As part of the Traffic Management Plan described in Section 5.15.2, planning and coordination would be conducted with these service providers relative to construction-related road closures, detours, and other potential traffic delays, as needed to maintain adequate response times and levels of service.

Over the long term, reduction of flood risk resulting from project implementation would be expected to provide some degree of benefit by decreasing the flood-response burden on these service providers (**IMP UTL-1**). In addition, as described in Section 3.6, some of the infrastructure for these emergency services would be removed from the 1-percent ACE floodplain, thus improving flood-response capabilities.

Electricity and Telecommunications

Construction of the recommended plan would require removal/relocation of onsite utilities, where they occur within the construction limits. In general, these are expected to generally be limited to the measures located in developed portions of the lower watershed – that is, Kanewai Field Multi-purpose Detention, Hausten Ditch Detention, Ala Wai Golf Course Multi-purpose Detention, and the Ala Wai Canal Floodwalls.

The specific locations of existing utility lines and detailed relocation plans would be identified as part of the design phase. There may be some temporary interruptions in service, as needed to accommodate utility removal/relocation (**IMP UTL-2**), but the interruptions would be minimized to the extent practicable and adequate notification would be provided, such that these impacts are expected to be insignificant. The existing utilities would be replaced/relocated such that following construction, there is not expected to be any reduction in the extent or level of service provided. Planned utility relocations (e.g., HECO's 46-kV Cable Protection Project; see Table 1) would be coordinated and accommodated through the final design phase, to the extent practicable.

The only utility requirements that are expected for operation and maintenance of the project is electricity to operate the pump stations; however, these would only be used periodically (as needed in response to a flood event). As such, the proposed project is not expected to significantly impact public utilities.

Solid Waste

Construction and operation of the proposed project is not anticipated to generate a significant amount of solid waste. During construction, all waste would be stored and periodically carried out and properly disposed of in a permitted landfill. Some solid waste may be recycled; these materials would be stored and hauled separately to the appropriate recycling company. Operations and maintenance would involve periodic removal of sediment and debris; other maintenance activities (e.g., pump maintenance) would generate minimal amounts of solid waste. All materials generated during operation and maintenance would be properly disposed of in an approved landfill. No hazardous solid waste is expected to be generated as a result of construction or operation of the proposed project. Because only a small amount of solid waste is expected to be generated during construction and operation, and appropriate management practices would be implemented, impacts to solid waste disposal or processing are expected to be minor.

Water and Wastewater

Some water would be needed to support construction activities (e.g., mixing concrete, providing dust control, etc.). This water would be obtained from the municipal water supply; the required quantities are expected to be well within the current water supply. The proposed project would not involve discharge to the wastewater treatment facilities. As such, no impacts to water or wastewater are anticipated.

Stormwater Drainage

As described in Section 5.5.2, the project is not expected to affect the quantity of stormwater runoff, nor would it otherwise burden the stormwater drainage system. Overall, the project would reduce the extent of the stormwater drainage system that is subject to flooding. In addition, the design includes features to maintain the functionality of the stormwater drainage system during flood conditions, including a series of gates and pumps to prevent floodwaters in the Ala Wai Canal from backing up into the stormwater drainage system.

Stream Channel Maintenance

The proposed flood risk management structures would require ongoing maintenance, beyond the existing maintenance that is conducted for the stream channels; specific O&M activities are listed in Table 9. As previously described, the non-Federal sponsor is responsible for fulfilling all O&M requirements for the project. A detailed O&M manual would be developed as part of the final design phase, and O&M costs would be specified as part of the Project Partnership Agreement (PPA), which must be executed before construction. Although the O&M requirements would require expenditure of non-Federal sponsor resources, the development and implementation of detailed O&M practices is considered to be beneficial to the overall maintenance of the stream channel infrastructure in the watershed (**IMP UTL-3**).

5.17.2.3 Alternative 2A

Changes relative to public services and utilities that would occur with implementation of Alternative 2A are expected to be within the range of those described for the recommended plan, and as such, impacts are expected to be less than significant and/or beneficial; no mitigation would be required.

5.18 Socioeconomics and Environmental Justice

5.18.1 Affected Environment

5.18.1.1 Regulatory Framework

Regulations and policies that relate to socioeconomic and environmental justice issues are being considered as part of the proposed project include the following:

- EO 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations)
- EO 13045 (Protection of Children from Environmental Health Risks and Safety Risks)

EO 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations) requires Federal agencies to identify and address the disproportionately high and adverse human health or environmental effects of their actions on minority and low-income populations, to the greatest extent practicable. The objective of EO 13045 (Protection of Children from Environmental Health Risks and Safety Risks) is to make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children.

5.18.1.2 Environmental Setting

Demographic and economic variables can be used to define the socioeconomic conditions within a study area, thus providing a baseline that can be used to evaluate whether a proposed project would have a large or disproportionate impact on any one social or economic class of the population. Following is a basic overview of the existing demographic and socioeconomic conditions relative to each of the neighborhoods in the watershed; the data were obtained from various sources including past U.S. Census datasets (primarily the most recent available data based on the 2012 American Community Survey [ACS]).

Population Statistics

As of 2012, the neighborhoods that comprise the Ala Wai Watershed had a total permanent population of approximately 200,000 persons (U.S. Census Bureau, 2012), which represents approximately 20 percent of the population of Oʻahu (as governed municipally by CCH). Table 34 lists the population by neighborhood.[48] In addition to the resident population in the watershed, a majority of the visitors that travel to Oʻahu visit the Waikīkī District. In 2012, Oʻahu hosted more than 5 million visitors; on any given day, there were approximately 79,070 visitors in the Waikīkī District (Hawai'i Tourism Authority, 2013; DBEDT, 2013).

As shown in Table 34, the population within the watershed has increased an estimated 7.4 percent since the 2000 census. This is less than the increase for CCH (9.0 percent), the State of Hawai'i (12.5 percent), and the entire U.S. (9.9 percent) over the same time period. Among the neighborhoods in the watershed, Ala Moana has the smallest population, but had the greatest growth (33.8 percent). Waikīkī had the next highest rate of growth, with a 13.7 percent increase. Overall, Kaimuki/Pālolo has the largest population, followed by Mānoa.

Table 34. Population by Neighborhood

Neighborhood	Year			Percent Change (2000-2012)
	1990	2000	2012	
Ala Moana	14,328	13,906	18,601	33.8
Kaimuki/Pālolo	49,212	48,839	51,067	4.6
Makiki	23,118	21,435	23,134	7.9
Mānoa	39,558	43,921	44,980	2.4
McCully/Mō'ili'ili	33,636	31,187	31,619	1.4
Waikīkī[a]	28,656	27,507	31,274	13.7
TOTAL	**188,508**	**186,795**	**200,675**	**7.4**

Source: U.S. Census Bureau. 2012. American Fact Finder. Available online at: http://factfinder.census.gov.
NOTES:
[a] In addition to residents, there are also approximately 79,070 visitors in the Waikīkī District on any given day (DBEDT, 2013).

According to the 2012 ACS data, the national median age is approximately 37.2 years, while the median age in the State of Hawai'i is 38.4 years. Within the Ala Wai Watershed, the median age ranges from 39.6 years in McCully/Mō'ili'ili to 45.2 years in Ala Moana (Table 35). As indicated by these data, the neighborhoods in the watershed all have a relatively high median age, which is indicative of a high percentage of elderly residents. The

48 The population of each neighborhood was estimated based on zip code tabulation area. Although the zip code areas correspond relatively closely with the boundaries of the watershed, there are portions of two neighborhoods (Kaimuki/Pālolo and Ala Moana) that are not within the watershed; this may result in a slight overestimation of total population.

percentage of the population that is 65 years and older ranges from 17.3 (McCully/Mō'ili'ili) to 19.7 (Kaimuki); these values are all higher than the national average of 13.2 percent. Aging of the population is one of the most prominent population trends in Hawai'i. While growth in the elderly population is higher is areas outside of the study area, the basin contains elderly care facilities such as twelve adult residential care facilities and five nursing facilities.

Table 35. Median Age by Neighborhood

Neighborhood	Median Age
Ala Moana	45.2
Kaimuki/Pālolo	44.3
Makiki	41.5
Mānoa	40.2
McCully/Mō'ili'ili	39.6
Waikīkī	41.4

Source: U.S. Census Bureau. 2012. American Fact Finder. Available online at: http://factfinder.census.gov.

All of the neighborhoods that comprise the watershed are predominantly occupied by people of Asian descent, which is fairly consistent with the overall distribution within the state (Table 36). The next most prevalent ethnicity is Caucasian. Representation of Native Hawaiians and other Pacific Islanders is highest in Makiki (24 percent), McCully/Mō'ili'ili (19.8 percent) and Kaimuki/Pālolo (18.9 percent), which is within the general range for the state (25.5 percent); representation is significantly lower in Waikīkī (9.1 percent), Ala Moana (10.3 percent) and Mānoa (14.6 percent).

Table 36. Representation of Race by Neighborhood[a]

Neighborhood	White	Black or African American	American Indian and Alaska Native	Asian	Native Hawaiian and Other Pacific Islander	Other Race
Ala Moana	28.8	4.3	1.4	72.8	10.3	1.8
Kaimuki/Pālolo	34.1	1.6	2.0	70.0	18.9	1.1
Makiki	32.5	3.7	1.3	63.9	24.0	1.2
Mānoa	36.6	2.6	1.9	66.6	14.6	2.2
McCully/Mō'ili'ili	28.0	1.3	2.5	72.0	19.8	1.1
Waikīkī	52.7	2.9	1.8	48.2	9.1	1.9
CCH	37.3	3.6	2.1	61.6	23.6	2.3
State of Hawai'i	42.2	3.0	2.4	57.1	25.5	2.6
United States	76.5	13.6	1.6	5.6	0.4	5.3

SOURCE: U.S. Census Bureau. 2012. American Fact Finder. Available online at: http://factfinder.census.gov.
Note:
[a] The percentages include both those persons who reported a single race alone and those who reported a combination with one or more other races.

Unemployment within the watershed ranges between 4.7 percent (Kaimuki) and 5.7 percent in Waikīkī; these rates are all below those for CCH (5.8 percent) and the state (6.7 percent).

In 2012, the per capita income in the watershed ranged from $29,451 (McCully/Mō'ili'ili) to $36,941 (Mānoa), all of which are comparable to (or higher than) values for CCH ($30,219) and the state ($29,227). The median household income ranged from $45,209 (McCully/Mō'ili'ili) to $75,839 (Kaimuki). The median household incomes in several of the neighborhoods (Ala Moana, Waikīkī and McCully/Mō'ili'ili) are significantly lower than that for CCH and the state; however, these neighborhoods are also those with smaller than average household sizes.

The highest median household income was reported for Kaimuki/Pālolo (Table 37). However, this includes residents in Kahala, one of O'ahu's wealthiest areas; although considered part of Kaimuki, Kahala is not actually part of the Ala Wai Watershed. Mānoa had the second highest per capita income and median household income. The lowest per capita income neighborhood was McCully/Mō'ili'ili; Ala Moana had the lowest median household income.

In 2012, the percentage of people within each neighborhood with incomes below the poverty level were in the general range of that for the state (10.8 percent), with the exception of the McCully/Mō'ili'ili and Waikīkī neighborhoods, where the percentages are significantly higher (16.4 and 14.4 percent, respectively).

Table 37. Income Statistics by Neighborhood

Neighborhood	Per Capita Income	Median Household Income	Percentage of People with Income Below the Poverty Level
Ala Moana	$36,857	$49,995	10.8%
Kaimuki/Pālolo	$34,729	$75,839	7.5%
Makiki	$35,225	$61,385	10.7%
Mānoa	$36,941	$62,688	11.5%
McCully/Mō'ili'ili	$29,451	$45,209	16.4%
Waikīkī	$33,002	$46,340	14.4%
CCH	$30,219	$72,292	9.6%
State of Hawai'i	$29,227	$67,492	10.8%
United States	$28,051	$53,046	14.9%

SOURCE: U.S. Census Bureau. 2012. American Fact Finder. Available online at: http://factfinder.census.gov.

Approximately 40 public schools, private schools, and universities are present within the watershed, with a combined student body of more than 48,000 students. The majority of the students are affiliated with UH, a public university located in Mānoa. With the exception of Chaminade University, a small private university with a student body of approximately 2,700 students, the remaining schools are elementary, middle, and high schools. The largest of these is Punahou School (located in Mānoa), with approximately 3,760 students. The majority of the schools are public institutions.

Social connectedness refers to the degree in which communities are able to instill a shared sense of belonging and purpose among residents; contributions to social connectedness include access to civic infrastructure (e.g., schools, libraries, community centers, and religious establishments). In addition to the public and private schools and their facilities, the study area includes a total of four State public libraries (Makiki, Mānoa, McCully-Mō'ili'ili, and Waikīkī-Kapahulu) and two community centers (Mō'ili'ili and Waikīkī). Of these facilities, 11 schools (including UH), 2 libraries (Mānoa and Waikīkī-Kapahulu), and 1 community center (Waikīkī) are within the existing 1-percent ACE (100-year) floodplain. In addition, a large number of churches and other religious establishments are located throughout the watershed, both within and outside the existing floodplain. Other areas that facilitate social connectedness within the community include parks and recreation facilities, which support a wide range of recreational opportunities and sports events, as further described in Section 5.10.

5.18.2 Impacts and Mitigation

Effects related to socioeconomics and environmental justice were considered to be significant if implementation of an alternative plan would result in any of the following:

- Induce substantial population growth (either directly or indirectly)
- Displace substantial numbers of existing people or housing
- Substantially reduce employment opportunities or income levels in the area
- Significantly affect the social connectedness of the community

- Disproportionately affect any particular low-income or minority group
- Disproportionately endanger children in areas within or near the project site

The potential effects related to socioeconomics and environmental justice that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.18.2.1 No Action Alternative

As discussed in Section 5.18.1, the demographics of the project area generally reflects that of the island-wide and state-wide population, except that the McCully/Mō'ili'ili and Waikīkī neighborhoods contain a substantially greater percentage of people with an income below the poverty level (16.4 and 14.4 percent, respectively, as compared to 9.6 and 10.8 percent for O'ahu and the state). In addition, the median age throughout the watershed is greater than that of the island or state, which is indicative of a high percentage of elderly residents; this trend is expected to continue in the future, as Hawai'i's population continues to age. Without implementation of the proposed flood risk management project, a large portion of the Ala Wai Watershed (including the lower income population in much of the McCully/Mō'ili'ili and Waikīkī neighborhoods, as well as a percentage of the elderly population) would remain within the 1-percent ACE floodplain and would continue to be within at risk of catastrophic flooding. In addition, a total of 11 schools (including UH), as well as libraries, community centers and other social facilities would continue to be at risk. These conditions are not expected to significantly change over the period of analysis.

5.18.2.2 Recommended Plan (Alternative 3A-2.2)

In general, it is expected that the area directly affected by the project would be those areas within the immediate vicinity of the proposed measures, with benefits extending throughout the existing floodplain and watershed as a whole. Given the potential magnitude of economic damages associated with a large-scale flood, the benefits of the project are expected to extend to the entire island, state, and nation.

Given the current extent of urbanization within the project area, the proposed project is not expected to induce population growth or otherwise affect the overall population within the watershed, nor is the project expected to displace any portion of the population/housing, reduce employment opportunities or income levels, or otherwise adversely affect socioeconomic conditions in the watershed. Rather, the project is expected to increase the level of flood protection within the watershed, thereby reducing the potential for displacement of people/housing and impacts to employment/income as a result of flooding (**IMP SOC-1**). As part of the increased level of protection, the recommended plan would reduce the risk of flooding of community facilities, including 7 of the 11 schools (including UH) and all of the libraries and community centers within the 1-percent ACE floodplain; it would also provide protection for various churches, religious establishments, recreational facilities, and other areas that serve as community gathering areas. As such, the project is expected to have a positive influence on social connectedness.

Environmental Justice

Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no racial, ethnic, or socioeconomic group should bear a disproportionate share of the negative environmental consequences resulting from an action, including the execution of Federal, State, local, and tribal programs and policies. Factors considered in determining whether the proposed project would significantly affect environmental justice include the extent or degree to which its implementation would (1) change any social, economic, physical, environmental, or health conditions so as to disproportionately affect any particular low-income or minority group or (2) disproportionately endanger children in areas within or near the project site. These factors are consistent with the requirement for compliance with EO 12898 (Environmental Justice) and EO 13045 (Protection of Children from Environmental Health Risks and Safety Risks).

As described above, the racial composition of the population within the watershed is relatively consistent with trends across the state. All of the neighborhoods that comprise the watershed are predominantly occupied by people of Asian descent; the next most prevalent ethnicity is Caucasian. Representation of Native Hawaiians and other Pacific Islanders is highest in Makiki (24 percent), McCully/Mōʻiliʻili (19.8 percent) and Kaimuki/Pālolo (18.9 percent), which is within the general range for the state (25.5 percent); representation is significantly lower in Waikīkī (9.1 percent), Ala Moana (10.3 percent) and Mānoa (14.6 percent). Based on the available data, the project area does not appear to include a disproportionately large minority population. The percentage of people within each neighborhood with incomes below the poverty level are in the general range of that for the state (10.8 percent), with the exception of the McCully/Mōʻiliʻili and Waikīkī neighborhoods, which have a disproportionately high number of low-income residents (16.4 and 14.4 percent, respectively). Based on the presence of several nearby schools, there are also expected to be a high percentage of children present in the project vicinity.

As described in Sections 5.6 and 5.12, the project is not expected to affect human health through discharge of pollutants or contaminants. Construction activities are expected to result in impacts related to air quality, noise, and traffic, which could affect the local population, including children that may be present in the area. However, these impacts are expected to be temporary and the measures described in Sections 5.13, 5.14, and 5.15 would be implemented to minimize these impacts, such that they are expected to be minor. None of these impacts or any other project-related changes are expected to disproportionately affect children, or the economically disadvantaged population in the McCully/Mōʻiliʻili and Waikīkī neighborhoods. As described in Section 5.16, the project would involve the ponding of water within the detention basins, which could pose an increased safety hazard to children (especially for measures located near schools, including the Kanewai and Hausten Ditch detention basins). However, these conditions would occur infrequently and for a short duration; furthermore, these conditions would only occur during large-scale flood events which would otherwise pose similar safety risks. As such, the proposed project is not expected to pose human safety risks that would disproportionately affect children.

Furthermore, the project is expected to reduce the potential for flooding throughout the watershed, thus serving to protect as much of the watershed as possible. Although it is not possible to fully protect all neighborhoods, the project is not expected to provide unequal treatment of minority or economically disadvantaged populations. In fact, much of the area that would be protected from the 1-percent ACE flood is within the McCully/Mōʻiliʻili and Waikīkī neighborhoods, which includes a higher percentage of economically disadvantaged residents.

Overall, implementation of the recommended plan is not expected to disproportionately affect children or any low-income or minority group within or near the project site, and may provide long-term benefits associated with reduced flood hazards. As such, the proposed project is not expected to result in an environmental justice impact, and is in compliance with EOs 12898 and 13045.

5.18.2.3 Alternative 2A

Similar to the recommended plan, Alternative 2A would increase the level of flood protection within the watershed, thus providing socioeconomic benefits through reduced displacement of people/housing and impacts to employment/income due to flooding. Alternative 2A would eliminate the risk of flooding for 9 of the 11 schools and all of the libraries and community centers that are currently located within the existing 1-percent ACE (100-year) floodplain, including the UH.

Consistent with the analysis provided for the recommended plan, implementation of Alternative 2A would not disproportionately affect children or any low-income or minority group within or near the project site, and may provide long-term benefits associated with reduced flood hazards. As such, the proposed project is not expected to result in an environmental justice impact, and is in compliance with EOs 12898 and 13045.

5.19 Other Required Analyses

Under the NEPA and HRS Chapter 343 review processes, analysis of the significance of potential environmental effects should consider the sum of the effects on the quality of the environment; in addition to direct impacts, the analysis should also consider indirect impacts, cumulative effects, and short-term and long-term effects of the proposed action.

5.19.1 Secondary and Cumulative Effects

In addition to direct impacts, projects may also result in secondary and induced effects. The interrelationships and cumulative impacts of the proposed project and other related projects should also be discussed.

Secondary effects are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable; they may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems (40 CFR 1508.8 and HAR Section 11-200-2). As described throughout this document, the proposed project would significantly reduce the potential for flooding throughout the watershed. It would not lead to secondary changes in land use and/or development patterns, as the areas to be protected from flooding are already so densely developed, there is little opportunity for increased development. Nor would the project create conditions that would induce population growth, or have any other related secondary effects on the environment. While the proposed project's construction and operation expenditures would provide a direct benefit to the local economy, the amounts are relatively too small to cause significant secondary effects in the local economy. No other secondary impacts are anticipated as a result of project implementation.

Cumulative effects are defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR Section 1508.7). Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. As described throughout this document, large-scale changes have occurred within the Ala Wai Watershed over time. It has been estimated that the area comprising the Waikīkī District once supported approximately 2,000 acres of coastal wetlands. The streams emerging from Mānoa, Pālolo, and Makiki valleys flowed parallel to one another before dispersing into multiple smaller waterways which meandered through the coastal wetlands before entering the ocean. The Ala Wai Canal was constructed in the 1920s (due to health concerns over mosquitoes and a desire to more fully develop the Waikīkī District); dredged material was used to fill the wetlands, thus allowing these areas to be developed for residential and commercial purposes. Over the next several decades, various stream channelization projects were completed in response to flooding; these included joining and channelization of Mānoa and Pālolo streams to form the Mānoa–Pālolo Drainage Canal, as well as channelization of extensive lengths of Makiki and Pālolo streams. Upper portions of the watershed, which historically supported a dense forest with a variety of native species, were also significantly altered. Harvesting of native woods for trade and cattle grazing in the late 1800s led to deforestation of the upper valleys (Griffith, 1902). Subsequent reforestation efforts, first in an effort to protect Honolulu's water supply and later, in an attempt to establish a timber supply, replaced the once native forest with a patchwork of fast-growing, introduced species (Ziegler, 2002). The introduction of pigs also had a deleterious impact on many endemic species and the biological composition of the forest ecosystem (Mueller-Dombois, 1981). These changes over time provide context for the consideration of cumulative impacts.

Principles of cumulative effects analysis in the CEQ guide *Considering Cumulative Effects under the National Environmental Policy Act* (CEQ, 1997) states: "for cumulative effects analysis to help the decision maker and inform interested parties, it must be limited through scoping to effects that can be evaluated meaningfully." The potential for cumulative impacts to the environment from the proposed action was evaluated by reviewing other projects and activities in the Ala Wai Watershed that could directly or secondarily affect the same environmental resources as the proposed action. The analysis generally includes actions that were recently completed, are currently underway, or are programmed to occur in the foreseeable future,[49] and are directly related to flood risk management, are located within or proximate to the proposed measure sites and/or would directly or secondarily affect the streams or canals in the watershed. Based on a review of the related actions presented in Table 1, this analysis incorporates the following projects and activities.

- Ala Wai Elementary School Drainage Improvements
- Sewer Pipe Replacement
- AWWA Riparian Restoration Pilot Project
- Ala Wai Dredging and Improvement Project
- HECO Cable Protection Project
- Woodlawn Bridge Flood Mitigation Project

The effects of these actions were considered in combination with the degree and timing of the potential adverse and beneficial effects of the proposed alternatives to determine the types and significance of potential cumulative effects. For this analysis, implementation of the project is considered cumulatively significant if, in concert with other past, present, or reasonably foreseeable future actions, it would exacerbate the declining status of an identified resource (a resource that is already adversely affected) or create a condition in which an effect is initially minor but is part of an irreversible declining trend.

Based on an analysis of the potential impacts, these actions could cumulatively impact a variety of resources including hydrology and hydraulics, surface water resources, biological resources, recreation, and visual resources. Each of these are briefly described below.

- **Flood Reduction and Public Safety:** As described in Section 5.5, the recommended plan (and its alternatives) would function to detain floodwaters and/or improve conveyance, thus providing benefits associated with a reduced risk of flooding and increased safety for residents and visitors within the watershed. Several of the related actions would also provide flood-reduction benefits, primarily the Woodlawn Bridge Flood Mitigation Project; this action would involve construction of a drop structure to increase the conveyance capacity under Woodlawn Bridge. It is intended to address potential flooding associated with overtopping along this reach of Mānoa Stream (such as what occurred in October 2004). The Ala Wai Elementary School Drainage Improvements (currently incomplete) would involve installation of drainage swales to the Ala Wai Canal as a means to restore positive drainage to the Ala Wai Canal; this action would also help to reduce the potential for flooding, although on a localized level (i.e., internal drainage at the school) rather than riverine flooding. Regardless of the fact that these projects would be implemented at different times and would provide different types of flood protection in varying locations, they would provide cumulative benefits by reducing potential flooding and increasing public safety within the Ala Wai Watershed over the long term. None of the actions are expected to increase flooding or flood-related safety risks.
- **Waters of the U.S. and Loss of Aquatic Habitat:** The proposed project would involve placement of dredge or fill material within Waters of the U.S., both during construction and O&M of the flood risk management structures. Standard BMPs would be implemented to avoid and minimize potential effects to the extent practicable; in addition, compensatory mitigation would be implemented to offset the potential loss of aquatic habitat associated with unavoidable impacts to Waters of the U.S. Several of the related actions would also involve work within Waters of the U.S., although most would only involve temporary impacts and would not result in the loss of aquatic habitat functions and values. For example, both the Ala Wai Canal Dredging and Improvement Project and the HECO Cable Protection Project would involve movement/ removal of accumulated sediments within the Canal; however, once complete, these actions are not expected to result in a long-term impact to aquatic habitat. A minor

[49] A guidance document issued by the CEQ titled "Considering Cumulative Effects" states, "Commonly, analysts only include those plans for actions which are funded or for which other NEPA analyses are being prepared" (CEQ, 1997). This guideline was expanded to include actions that are believed likely to occur, have an identified source of funding, and have been defined in enough detail to allow meaningful analysis.

amount of dredge and fill may also occur in the upper reaches of Mānoa Stream as part of the AWWA Riparian Planting project, but this is expected to be incidental to replanting effort.

The only project that is expected to adversely affect aquatic habitat over the long-term is the Woodlawn Bridge Flood Mitigation Project. Exact quantities are not known, but it is expected that the proposed rip-rap drop structure would displace aquatic habitat along several hundred linear feet of Mānoa Stream. Based on input provided by DLNR, it is understood that the footprint has been minimized to the extent practicable. In addition, compensatory mitigation would be implemented to offset the unavoidable impacts using the same approach as is being used as for the Ala Wai Canal Project. These mitigation efforts are being coordinated such that the proposed measures are expected to be complementary (though not inter-dependent), with a combined focus on improving passage and in-stream habitat for native aquatic species. As such, from a cumulative perspective, the projects are not expected to contribute incrementally to the loss of aquatic habitat functions and values. It is possible that the compensatory mitigation efforts may in fact synergistically contribute to improved habitat functions and values.

- **Recreational Facilities:** As described in Section 5.10, the project would impact recreational resources, including both temporary loss of access and use within the construction limits, as well as permanent displacement of recreational areas within the footprint of the detention basins. None of the related actions are expected to permanent displace recreational areas, but several involve reduced access and availability along the Ala Wai Canal (and the adjacent parks and walkways) during construction; these include the Ala Wai Sewer Pipe Replacement, Ala Wai Dredging and Improvement Project, HECO Cable Protection Project. It is possible that construction of the proposed flood risk management measures along the Ala Wai Canal (including the Hausten detention basin and Ala Wai Canal floodwalls) could contribute to a significant cumulative impact on recreation along the Ala Wai Canal, were these actions all to occur at the same time. However, the Ala Wai Canal Project and each of the related actions would be implemented at different times, with access and availability restored following construction, such that the cumulative impact is expected to be insignificant.
- **Visual Resources:** The proposed project involves construction of flood risk management measures, including debris catchment features, detention basins and floodwalls, which would introduce new built elements to the existing viewshed, thus resulting in visual impacts. Several of the related projects would also affect visual resources (Ala Wai Sewer Replacement Project, Ala Wai Dredging and Improvement Project, HECO Cable Protection Project, and Woodlawn Bridge Flood Mitigation Project); however, it is expected that these would primarily be temporary impacts during construction (e.g., use of heavy machinery, equipment staging, etc.). The only structure that would be substantially visible is the Woodlawn Bridge chute structure. Given that the Ala Wai Canal Project is not expected to be constructed at the same time as any of the related actions (such that the temporary constructed-related visual impacts would not occur simultaneously), nor would any of the measures be located in the vicinity of any other new structures (e.g., Woodlawn chute structure), the project is not expected to contribute to significant cumulative visual impacts.

In addition to the above-listed impacts, the project would result in a range of temporary construction-related impacts, including increased potential for erosion and sedimentation, air quality emissions, increased noise and traffic. Most (if not all) of the related actions are expected to result in similar construction-type impacts. As described throughout this document, measures would be implemented to avoid and minimize the impacts of the proposed project; it is expected that the other projects under consideration include similar measures to minimize and mitigate potential impacts. As such, it is not expected that these temporary construction-related impacts associated with the proposed project would combine with those of other projects in the vicinity to create substantial adverse cumulative impacts. Based on this analysis, the recommended plan is not expected to result in any significant cumulative impacts to the human environment when considered with other known past, present, and foreseeable future actions.

5.19.2 Relationship Between Short-term Uses of the Environment and Maintenance and Enhancement of Long-term Productivity

The analysis of short-term uses versus long-term productivity considers the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity. This should include a discussion on the extent to which the proposed project involves tradeoffs among short-term and long-term gains and losses, as well as whether future options are foreclosed, whether the range of beneficial uses of the environment are narrowed, and whether the proposed project poses long-term risks to health and safety.

As described throughout this document, the proposed project would involve construction and operation of measures that would function to reduce the risk of flooding throughout the Ala Wai Watershed. Implementation of these measures would result in environmental impacts, including the loss of habitat for native aquatic species, cultural resources, and modification of visual resources. Given the efforts to avoid, minimize and mitigate potential environmental impacts, the project is not expected to substantially narrow the range of beneficial uses of the environment or foreclosure future options. Overall, the project is designed to minimize flood-related risk, thereby reducing health and safety hazards, as well as protecting housing units, commercial structures, and public facilities from flooding. By decreasing flood risk, the project would reduce the potential for incurring costs associated with clean-up, debris removal, and building and infrastructure repair as a result of flood events, thus maintaining productivity and increasing the potential for long-term growth opportunities throughout the watershed. Given the extent of area and the affected population protected from flood hazards relative to the anticipated environmental impacts, the project-related efforts to enhance long-term productivity are expected to outweigh the short-term uses of the environment.

5.19.3 Irreversible or Irretrievable Commitments of Resources

The analysis of irreversible and irretrievable commitments of resources includes a description of the extent to which the proposed project makes use of non-renewable resources (including labor, materials, and natural and cultural resources) or irreversibly curtails the range of potential uses of the environment.

Construction and operation of the proposed project would consume non-renewable resources, such as construction labor, materials (e.g., concrete), fuel for vehicles, and electricity to run the pumps. Commitment of construction materials, manpower expended, and fuel/electricity consumed is considered an irreversible use of resources. In addition, the project would result in unavoidable impacts to environmental resources, including habitat for native aquatic species. As described in Sections 3.6and 5.7.2, these impacts have been avoided and minimized to the extent possible; in particular, the berms for the in-stream detention basins have been designed to incorporate an arch culverts where feasible, which would function to maintain the natural stream bed. Although construction of these features would result in adverse impacts to aquatic habitat, to the extent that the materials could be removed from the stream bed, the impacts are not necessarily considered irreversible. In addition, compensatory mitigation measures designed to improve native species passage would be implemented to offset the habitat loss. As such, the project is not expected to substantially contribute to irreversible loss of environmental resources.

5.19.4 Unavoidable Adverse Effects

Both Federal and State regulations [40 CFR 1500.2(e) and HAR Section 11-200-17(L)] require a description of probable adverse effects that cannot be avoided and the rationale for proceeding with the proposed project. Unavoidable impacts are those effects remaining after incorporation of mitigation measures that minimize, rectify, or reduce impacts of the proposed project.

Descriptions of the anticipated impacts and proposed mitigation measures are described in Section 5 (and are summarized in Table ES-2). Potential adverse impacts include those related to biological resources (aquatic habitat), cultural resources, recreation, and visual resources; however, measures to avoid, minimize, and mitigate these impacts have been incorporated to the extent practicable. Although some degree of impact would occur, the analysis has not identified significant, unavoidable adverse impacts that would remain after implementation of proposed mitigation measures. Implementation of the proposed project is expected to protect a large portion of the watershed (including its residents and visitors) from flooding and flood-related safety hazards. These benefits are expected to outweigh any remaining adverse impacts.

5.19.5 Unresolved Issues

The following summarizes unresolved issues that relate to the proposed project; it is anticipated that each of these issues can be adequately resolved before implementation of the project:

- Ability to acquire all the funding needed for project implementation (considering current Federal and non-Federal funding climate)
- Ability to acquire some of the key land needed for flood risk management and compensatory mitigation measures
- Extent to which residual flood risk could or would be addressed by others
- Consideration of the non-Federal sponsor's request to phase construction, which could extend the overall duration of construction phasing

6.0 Public Involvement and Agency Coordination

Recognizing the importance of involving the public in the planning process, the USACE planning guidance specifies that open channels of communication should be developed and maintained with the public in order to give full consideration of public views and information throughout the project. Critical components of the public involvement effort should include (1) disseminating project-related information, (2) understanding the public's desires, needs, and concerns, (3) providing for consultation with the public before decisions are reached, and (4) taking into account the public's views (USACE, 2000). Public and agency involvement efforts have been conducted to comprehensively address USACE policies, as well as specific regulatory requirements for consultation. In particular, NEPA and HRS Chapter 343 require public involvement as part of the environmental review process. In addition, NHPA Section 106 requires consultation with interested parties and NHOs as part of a Federal agency's consideration of the effects of their proposed undertaking on historic properties.

Based on the size of the watershed and the range of conditions, stakeholder concerns, and potential project measures and alternatives, the stakeholder involvement approach for this project incorporated a variety of different techniques, many of which are focused on addressing issues and questions in smaller-group settings rather than at a watershed-wide level. Specific techniques include interviews and small-group meetings, informational presentations, agency working meetings, neighborhood-level meetings, open house meetings, public meetings, public events, e-mail updates, and a project website and factsheet. Through implementation of these techniques, the stakeholder involvement efforts have been designed to develop awareness of specific watershed conditions and project objectives, gain stakeholder input on issues and specific project measures, and generate dialogue on project alternatives to build support for project implementation.

Following is a summary of the specific public and agency involvement efforts that have been conducted to date, the input received as a result of those efforts, and an overview of additional opportunities for public and agency involvement as the project moves forward. Additional detail and supporting information is provided in Appendix G.

6.1 NEPA and HRS Chapter 343 Scoping Meetings

Pursuant to the requirements of NEPA, an NOI was originally published on June 14, 2004 (69 FR 32996). A supplemental NOI was subsequently published on October 2, 2008 (73 FR 57339) to address the scope changes in the FCSA Amendment 1. A copy of the NOIs are contained in Appendix G.

An initial Public EIS Scoping meeting was held on June 29, 2004. A supplemental Public EIS Scoping Meeting was held on October 21, 2008, based on the revised scope in the FCSA Amendment 1. Copies of the scoping meeting reports are contained in Appendix G. Additional scoping opportunities were also afforded through other stakeholder outreach events, including a focus group meeting and open house meetings, as further discussed in Section 6.2.

As required by HRS Chapter 343, an EISPN was published in OEQC's Environmental Bulletin on October 23, 2014. Publication of the EISPN includes a 30-day comment period; no comments were received. A copy of the OEQC publication is contained in Appendix G.

6.2 Other Public and Agency Consultation Efforts

A significant number of stakeholder and agency meetings and other public involvement efforts have been conducted throughout the planning process to date. In general, the timing and focus of these events has been determined in response to project-related needs and stakeholder interests and desires. Events conducted since the Re-Scoping Charrette (October 2013) are summarized in Table 38. Copies of key stakeholder engagement materials are contained in Appendix G. A summary of all stakeholder engagement efforts since the inception of the project are described in the *Stakeholder Involvement Summary Report* (Townscape, 2010).

Table 38. Summary of Public and Agency Engagement Efforts (Between October 2012 and August 2015)

Date	Participants/Event
7/29/2015	Discussion of project impacts with USFWS, NMFS and DAR
7/8/2015	Meeting with O'ahu Island Burial Council (OIBC) to discuss project
6/29/2015	Discussion of project with USFWS and NOAA/NMFS
6/4/2015	Discussion of project impacts with USFWS
6/3/2015	Meeting with SHPO to discuss Programmatic Agreement
5/26/2015	Project update to EPA, USFWS, DAR, and DOFAW
4/14/2015	Site visit with USFWS and NFS
3/31/2015	Briefing to State Representative Calvin Say (with representatives from the Research Corporation of the UH, UH Sea Grant Program, CCH, and Department of Land and Natural Resources)
3/27/2015	Discussion of project at Ala Wai Partnership Working Group
3/25/2015	Presentation of project at Pacific Risk Management Ohana Conference
2/27/2015	Project update to USGS (specifically related to mitigation development)
2/26/2015	Meeting with SHPO to discuss effects determinations and mitigation
1/23/2015	Project update to USFWS and DAR (specifically related to mitigation development)
1/13/2015	Hawai'i Hazard Mitigation Workshop (including DLNR, CCH, and Waikīkī Businesses)
12/17/2014	Meeting with SHPO to discuss APE
11/24/2014	Briefing to DLNR, City & County of Honolulu Directors, and key Waikīkī community groups (Waikīkī Improvement Association [WIA] and Waikīkī Business Improvement Association)
11/3/2014	Briefing to DLNR and City & County of Honolulu (Managing Director's staff)
10/21/2014	Presentation of project to Waikīkī Businesses (including WIA, Hawai'i Hotel and Lodging Association, and Waikīkī BIA); WIA annual meeting
10/14/2014	Project update to USFWS and DAR
10/9/2014	Briefing on project status to State Civil Defense
8/14/2014	Presentation of project at the 10th Annual Hawai'i Floodplain Manager's Conference
6/27/2014	Project update to State Hazard Mitigation Forum
6/3/2014	Presentation of project to Hawai'i Hazard Mitigation Forum (as part of State Civil Defense presentation)
5/21/2014	Open House Meeting at Stevenson Middle School
5/20/2014	Open House Meeting at Mānoa Valley District Park
5/13/2014	Briefing to State Legislators
April - June 2014 (various)	Interviews and other consultation for Cultural Impacts Assessment (93 individuals contacted; 17 responded; five suggested referrals, 4 provided consultation and 5 participated in formal interviews)
3/27/2014	Stakeholder Focus Groups (participants included representatives from Ala Wai Watershed Association, O'ahu Hawaiian Canoe Racing Association, Na Ohana o Na Hui Wa'a, Neighborhood Boards, City & County of Honolulu DDC, Enterprise Services, ENV, DFM, DPR, and DLNR Division of Boating and Ocean Recreation (DOBOR)
3/21/2014	Stakeholder update meeting
3/20/2014	Briefing to DLNR and City & County of Honolulu (Managing Director)
2/26/2014	Briefing to DLNR and City & County of Honolulu (Managing Director)
1/2/2014	Briefing to Senator Galuteria and staff
January 2014	Project update to UH staff
11/25/2013	Briefing to DLNR (Chairperson, Engineering, Land Division, Forestry and Wildlife)
11/13/2013	Briefing to Senator Ihara

Table 38. Summary of Public and Agency Engagement Efforts (Between October 2012 and August 2015)

Date	Participants/Event
10/22/2013	Stakeholder update meeting
10/18/2013	Briefing to City & County of Honolulu, Managing Director and Department Heads (DFM, DDC, Enterprise Services [Ala Wai Golf Course], Parks and Recreation, Environmental Services)
10/17/2013	Briefing to Senator Ihara
10/14/2013	Discussion of project at public presentation regarding Mānoa Stream/Woodlawn Bridge Area
7/30-8/1/2013	Multi-day site visit to discuss conceptual project measures and approaches to avoid and minimize impacts; participants included DLNR (Engineering and DOFAW), City & County of Honolulu (ENV, DDC), and USFWS
7/23/2013	Presentation of project to Waikīkī Improvement Association (WIA)
6/17/2013	Project update to DLNR (Engineering, DOFAW, and Land Management)
5/22/2013	Presentation to the Ala Wai Watershed Association (AWWA)
10/16-19/2012	Re-Scoping Charrette (participants included USACE, DLNR (Engineering and DAR), UH Emergency Management, NRCS, City & County of Honolulu, FEMA

6.3 Input Received Prior to Public Review

A wide range of input has been provided as part of the various public and agency meetings held to date. Following is a summary of the substantive input provided by stakeholders relative to the proposed project and the proposed flood risk management measures, with particular focus on the input provided since the Re-Scoping Charrette.

- Coordination with other projects is very important and should be considered as part of the planning and design process; key projects identified by stakeholders included the Waikīkī Regional Circulator Study (which proposes a pedestrian bridge over the Ala Wai Canal), and the UH Campus Drainage Master Plan.
- Proper O&M has and will always be an issue for the stream channels. Existing stream channel infrastructure is not currently maintained; the community is losing faith in local government because of the lack of support and follow through. The community can help with maintenance, but needs support.
- Many stakeholders expressed support for the project and emphasized the need for near-term action to reduce the risk of flooding. Some stakeholders questioned the need for the project, and in some cases suggested that improved stream maintenance would adequately address the existing flooding problem.
- Ala Wai Canal is a historic property (listed on National Register of Historic Places), and there is concern that the floodwalls would cause physical and visual separation between the sidewalk and the Canal, which would impact viewplanes and open space. In addition, there is concern with the height of the floodwalls. Stakeholder questioned whether the floodwalls need to be so high and/or whether they are needed on the *makai* side of the Canal (instead, allow open spaces to flood, with berms to protect the schools).
- In addition to the floodwalls, other elements of the project could result in visual impacts along the Ala Wai Canal. The sluice gates on Hausten Ditch introduce an “industrial” element and do not fit in with the surrounding park and open space area.
- Stakeholders expressed the desire for the floodwalls to be designed to match the existing historic walls.
- In addition to the visual impact of the floodwalls, other concerns expressed by stakeholders include the potential for graffiti and congregation/loitering of homeless people. Loitering is a particular concern if the floodwalls are set back from the existing Canal edge, as this would provide a corridor that is somewhat hidden and difficult to monitor.

- The floodwalls need to allow for recreational access to the Canal, both for pedestrians and canoe paddlers. The stairs on the *makai* side of the Canal are used by fishermen; these stairs should be maintained as access. The canoe clubs primarily use three launch locations: near McCully Bridge, at the bottom of University Avenue, and near the Golf Course at Kapahulu; consider using flood gates instead of stairs or ramps to maintain adequate access in these locations.
- Canoe clubs use the corner of Ala Wai Community Park for turning their canoe trailers. The floodwalls and berm around the Hausten Ditch detention basin should be sited to maintain adequate space for the trailers.
- The amenities that are provided between Ala Wai Boulevard and the Canal (including the sidewalk, trees, landscaping and benches) are used as a linear park. Stakeholders have high expectations for this area to remain accessible and well-maintained.
- Stakeholders raised concerns about the potential of encountering pre-Contact or historic properties in the project area; there is particular concern with potential burials in the Waikīkī area.
- Flapgates have high maintenance requirements, and are a liability if they fail. It is important to use high quality products.
- Need to ensure the multi-purpose detention basins are properly maintained and provide for emergency access. In addition, need to make sure that the berms do not pose a safety concern for recreational users (e.g., baseball or softball).
- Stakeholders stressed the importance of not affecting the technical aspects of the golf course. For example, decreasing the length of the course would eliminate it as a venue for certain golf tournaments.
- Consider the possibility of locating the berm for the Ala Wai Golf Course detention basin away from the existing chain-link perimeter fence to allow for the fringes of the golf course to be used by the general public.
- Some of the detention basins in the upper reaches of the watershed are in the proximity of farms or *lo'i*; the extent to which these areas could be impacted (e.g., through detention of flood waters) needs to be considered. [Note: based on discussions with stakeholders, no farms or *lo'i* are expected to be within the inundation area of any detention basins.]
- Stakeholders requested ongoing outreach, including coordination with neighborhood boards.

As discussed throughout this document, these issues have been considered as part of the plan formulation and impact evaluation processes, and have been addressed as appropriate. A more detailed summary of stakeholder input provided at key stakeholder involvement events, including the focus group meeting, open house meetings and legislative briefings is provided in Appendix G. Input provided in previous phases of the project, which includes many of the related issues identified in Section 2.3, is summarized in the *Stakeholder Involvement Summary Report* (Townscape, 2010).

6.4 Draft Report Distribution and Public Review

Consistent with the requirements of NEPA and HRS Chapter 343, the Feasibility Report/EIS was circulated for a 45-day public review. The review period was extended by request from USEPA and occurred from August 20, 2015 through November 9, 2015. Copies of the draft document were distributed to a variety of individuals and organizations, requesting their comments on the project. In addition, a limited number of documents were provided as loan copies in libraries, as well as online through the OEQC online library and project website.

The distribution list for the Draft Feasibility Report/EIS was developed based on the recommended list provided by OEQC and was expanded to include all project stakeholders identified to date. This list includes Federal, State and local agencies; elected officials; community groups and organizations; adjacent landowners; libraries; and the news media. The complete distribution list is provided in Appendix G.

6.5 Agency and Public Comments and Responses

During the course of the public review, on 30 September 2015, USACE and the non-Federal sponsor hosted a public meeting at Washington Middle School in Honolulu, HI. Notification of the meeting was distributed in advance to all identified stakeholders, elected representatives and affected property owners. Sign-in sheets show 180 participants in attendance. A presentation was provided and participants were offered an opportunity to comment on the tentatively selected plan included in the draft Feasibility Report. Participants were notified that comments intended to be a part of the written record were required to be submitted in writing through either notecards provided at the meeting, mail submittals or e-mail.

Public review of the draft Feasibility Report/EIS produced a range of opinions from support of the study and acknowledgement of flood risks to opposition to the study by affected landowners and others concerned about environmental impacts. Overall, 64 comments were received during the review. Of those, nine voiced support for the study, sixteen highlighted concerns regarding effects on public property, twenty-three identified issues related to environmental effects, twenty-three were related to the detention basins in the upper watershed and sixteen were related to the floodwalls in the lower watershed. Of note, a school in the area stated concerns regarding the lack of protection from flooding. This area in particular did not meet economic justification, but will benefit from upstream flow management and is projected to see approximately a two-foot reduction in flood stages with the 1% chance ACE event. The PDT has determined that none of the comments received will change the planning decision on the recommended plan. Hydrologic, hydraulic, environmental mitigation and benefits models have been updated and rerun during the final Feasibility Report for the purposes of addressing technical review comments. Specific comments from review agencies included the following:

A. EPA: A rating was provided by EPA of EC-2 (Environmental Concerns – Insufficient Information). Suggested information to provide in the final Feasibility Report includes delineation of wetlands, information regarding impacts to ESA listed species, dispersal of contaminated sediments, and stormwater management. Impacts associated with the recommended plan have since been updated throughout this report.

B. USFWS: Through Fish and Wildlife Coordination Act (FWCA) coordination, USFWS identified issues related to the permanent loss of stream and riparian habitat resulting from project construction of debris detention basins, potentially lethal and sublethal exposure to contaminants for fish and wildlife resources that exist within streams and nearshore coral reefs, and the take of federally listed damselflies and destruction of their breeding habitat. In addition, USFWS requested consideration of avoidance of ESA protected species impacts through relocating the Waihi and Waiakeakua Basins further downstream and compensatory mitigation to unavoidable impacts to those areas. The PDT concluded that moving the basin further downstream would induce additional risk to surrounding homes while moving the basin upstream would potentially increase environmental impacts. For this reason, the basin was not moved to avoid the assessed impacts. USACE also evaluated the proposed mitigation plan and concluded that the plan provided adequately off-sets unavoidable impacts and provides sufficient replacement of substitute resources.

C. Resolution of Concerns: POH will continue to work with USFWS and EPA on the quantification of resources and identification of appropriate mitigation for unavoidable impacts throughout the design phase. Contamination within the watershed is a legacy issue. Through a coordination call that included USFWS and EPA on 12 JAN 2016, it was resolved that mobilization of sediments of concern resulting from construction could be addressed through proper construction sequencing and use of best management practices. Concerns regarding sediment mobilization related to maintenance could likely be addressed through the operations, maintenance, repair, replacement and rehabilitation guidelines developed during the design phase. All such concerns are addressed in Section 5 of this report. Adverse effects to ESA listed species are addressed through ESA consultation which was initiated between USACE and USFWS on 11 JAN 2016. A biological opinion was received from USFWS on 16 AUG 2016 and is included in Appendix E.

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7.0 Regulatory Compliance and Consistency with Plans and Policies

7.1 Regulatory Compliance

There are a variety of Federal and State laws and regulations that are applicable to the project, and for which compliance is required before construction. A summary of the laws and regulations (and associated permit requirements) that apply to the project and the compliance status of each is provided in Table 39. Additional detail on the requirements of each law and regulation is provided in Appendix E.

Table 39. Regulatory Compliance Status

Regulation	Form of Compliance	Compliance Status
FEDERAL		
National Environmental Policy Act	Final Feasibility Report/EIS, with Record of Decision (ROD)	Complete, with this Final EIS and ROD.
Clean Water Act, Section 404	Section 404(b)(1) Evaluation	Complete; evaluation contained in Appendix E
Endangered Species Act, Section 7	Formal consultation and a Biological Opinion	Complete; initiated with consultation letter dated April 9, 2008; Draft Biological Assessment provided to USFWS/NMFS on August 5, 2015; a final Biological Opinion was received from USFWS on August 16, 2016 and is included in Appendix E of the Feasibility Report/EIS
Fish and Wildlife Coordination Act	Section 2(b) Coordination Act Report	Extensive coordination conducted with resource agencies (see Table 38); input to date has been incorporated into the planning process; a final FWCA Section 2(b) Report was received October 31, 2016 and is contained in Appendix E
Magnuson-Stevens Fishery Conservation and Management Act	Determination of "no adverse effect" in EIS and EFH assessment; consultation with NMFS	Complete; EFH assessment contained in Appendix E
National Historic Preservation Act, Section 106	Letter from SHPO concurring with USACE effects determination; signed Programmatic Agreement	Complete; initiated with consultation letter dated August 14, 2014; an executed Programmatic Agreement is included in Appendix F
STATE		
HRS Chapter 343 (Environmental Impact Review Law)	Final Feasibility Report/EIS, with Notice of Acceptance	In progress; Draft EIS published in OEQC's Environmental Bulletin on August 23, 2015; NOA is anticipated after Final FR/EIS is provided to State.
HRS Chapter 205A (Coastal Zone Management; as required by the Coastal Zone Management Act)	Letter from Office of Planning concurring with USACE Federal Consistency Determination	Complete; conditional Consistency Concurrence Letter dated April 11, 2011 received for original scope; supplemental CZM review and concurrence complete in October 2016.
HRS Chapter 183C (Conservation District)	Conservation District Use Permit	To be obtained by non-Federal sponsor before construction[a]
HRS Chapter 183 (Forest Reserves, Water Development, Zoning)	Forest Reserve Special Use Permit	To be obtained by non-Federal sponsor before construction[a]

Table 39. Regulatory Compliance Status

Regulation	Form of Compliance	Compliance Status
HRS Chapter 174C (State Water Code)	Stream Channel Alteration Permit	To be obtained by non-Federal sponsor before construction[a]
HRS Chapter 195D (Conservation of Aquatic Life, Wildlife and Land Plants)	Concurrence/input from DOFAW/DAR	In progress (to be completed by the non-Federal sponsor) [a]
HRS Chapter 6E (Historic Preservation)	Letter from State Historic Preservation Division concurring with determination of effects, with mitigation commitments	In progress (to be completed by the non-Federal sponsor)[a]
HRS Chapter 342D (Water Pollution; as required by Clean Water Act Section 401)	Water Quality Certification	In progress; initial application for Water Quality Certification submitted; certification to be obtained during detailed design phase[b]
HRS Chapter 342D (Water Pollution; as required by Clean Water Act Section 402)	NPDES Permit	To be obtained during detailed design phase
HRS Chapter 342F (Noise Pollution)	Community Noise Permit	To be obtained by non-Federal sponsor before construction[a]
CITY AND COUNTY OF HONOLULU		
Revised Ordinances of Honolulu	Relevant zoning and construction permits	To be obtained by non-Federal sponsor before construction[a]

Notes:

[a] The USACE is not subject to regulation under these State and County regulations; therefore, compliance with the regulations would be the responsibility of the non-Federal sponsor.

[b] At the time of report drafting, USACE has applied for, but not received, Water Quality Certification from DOH.

7.2 Executive Orders

EOs that are relevant to the proposed project and have been considered in the feasibility planning process include the following:

- **EO 11514, Protection and Enhancement of Environmental Quality**: The objective of this executive order is to protect and enhance the quality of the Nation's environment to sustain and enrich human life. As summarized in this document, the potential effects of the project were assessed, with input sought from project stakeholders; compliance with all applicable environmental regulations is being obtained.
- **EO 11988, Floodplain Management**: The objective of this executive order is to avoid, to the extent possible, long- and short-term adverse impacts associated with the occupancy and modification of the base floodplain, and avoid direct and indirect support of development in the base floodplain whenever there is a practicable alternative. Compliance with this executive order, based on the procedures outlined in ER 1165-2-26 (*Implementation of Executive Order 11988 on Floodplain Management*; March 30, 1984), is discussed in Section 8.6.
- **EO 13690, Federal Flood Risk Management Standards**: This executive order builds on the existing EO 11988, above, to further evaluate the short and long term impacts of occupation of floodplains particularly in light of climate change. The Ala Wai Flood Risk Management feasibility study was conducted in compliance with this executive order in using the best available science to evaluate watershed conditions, integrating sea level rise forecasts into analyses as a climate change consideration, and additional consideration of the use of natural features and non-structural solutions towards managing hydrology and flood risk.

- **EO 11990, Protection of Wetlands**: The objective of this executive order is to minimize the loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. As discussed in Section 5.7, some small pockets of wetlands may exist within the limits of the channels, but no adjacent wetland features have been identified. Impacts to aquatic habitat within the stream channels will be mitigated so as to achieve no net loss of habitat function.
- **EO 12898, Environmental Justice**: The objective of this executive order is to make it a high priority to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of programs, policies and activities on minority and low-income populations. As discussed in Section 5.18, the project alternatives are not expected to have a disproportionate effect on minority or low-income populations in the project area.
- **EO 13045, Protection of Children From Environmental Health Risks and Safety Risks**: The objective of this executive order is to make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children. As discussed in Section 5.18, the project is not expected to involve risks that would disproportionately affect children.
- **EO 13112, Invasive Species**: The objective of this executive order is to prevent the introduction of invasive species, provide restoration of native species and habitat conditions in ecosystems that have been invaded, and promote public education and the means to address invasive species. The proposed project would include BMPs intended to address the introduction or spread of invasive species, and would incorporate native species as part of revegetation and mitigation efforts, where practicable.

7.3 Local Plans and Policies

7.3.1 County General Plan

The General Plan for the City and County of Honolulu is the policy document for the long-range development of the island of O'ahu. It describes the long-range social, economic, environmental, and design objectives for O'ahu, as well as broad policies to facilitate attainment of those objectives (DPP, 1992). Specific objectives and policies of the General Plan that are applicable to the project are listed below, along with a brief statement of how the project meets those objectives and policies.

<u>Natural Environment</u>

Objective A – To protect and preserve the natural environment

> *Policy 1 – Protect O'ahu's natural environment, especially the shoreline, valleys, and ridges from incompatible development.*
>
> *Policy 3 – Retain the Island's streams as scenic, aquatic, and recreation resources.*
>
> *Policy 6 – Design surface drainage and flood-control systems in a manner which will help preserve their natural settings.*

Objective B – To preserve and enhance the natural monuments and scenic views of O'ahu for the benefit of both residents and visitors.

> *Policy 1 – Protect the Island's well-known resources: its mountains and craters; forests and watershed areas; marshes, rivers, and streams; shoreline, fishponds, and bays; and reefs and offshore islands.*
>
> *Policy 2 – Protect O'ahu's scenic views, especially those seen from highly developed and heavily traveled areas.*

The planning process has included environmental due diligence studies and consultation with resources agencies, as needed to identify environmental resources, including native, threatened and endangered species. As discussed in Section 3.6, the project is being designed to avoid, minimize, and mitigate for impacts to these resources to the extent practicable, and incorporates environmentally sustainable design features. As discussed in Section 5.11, the flood risk management features have been sited to blend with the surrounding environment, so as to minimize impacts to scenic views. Given the need for floodwalls along the Ala Wai Canal to protect the Waikīkī District from flooding, while recognizing the importance of the views along the Canal and towards the mountains, the floodwall heights have been minimized to the extent possible; further refinements would be made during as part of the final design phase, and would consider opportunities to reduce the dimensions, as well as incorporate design details to further minimize potential visual impacts.

Public Safety

Objective B – To protect the people of O'ahu and their property against natural disasters and other emergencies, traffic and fire hazards, and unsafe conditions.

> *Policy 3 - Participate with State and Federal agencies in the funding and construction of flood-control projects.*

The objective of the project is to reduce flood risk within the Ala Wai Watershed, and involves implementation of structural and non-structural flood risk management measures. The project sponsors are the USACE and DLNR.

Culture and Recreation

Objective B: To protect O'ahu's cultural, historic, architectural, and archaeological resources

> *Policy 2 - Identify, and to the extent possible, preserve and restore buildings, sites, and areas of social, cultural, historic, architectural, and archaeological significance.*

Objective D: To provide a wide range of recreational facilities and services that are readily available to all residents of O'ahu

> *Policy 12 - Provide for safe and secure use of public parks, beaches, and recreation facilities.*

As part of the planning process, various studies have been conducted to identify archaeological, historic and cultural resources within the project area. Potential effects on these resources, and efforts to avoid, minimize, and mitigate adverse effects are being addressed through the NHPA Section 106 consultation process (see Section 5.8).

Given the heavily developed and constrained nature of the watershed, the project involves use of recreational areas. As described in Section 5.10, the flood risk management features have been designed to minimize impacts during non-flood conditions. Several recreational areas would be subject to inundation during flood conditions; however, these areas are already subject to flooding and would generally not be used for recreation during flood conditions.

7.3.2 Primary Urban Center Development Plan

Within the context of the General Plan, a series of eight regional plans provide a set of policies to help guide public policy, investment and decision-making through the 2025-planning horizon in response to the specific conditions and community values of each region. The proposed project falls within the Primary Urban Center; as there is expected to be major growth in population and economic activity in this region over the planning period, the regional plan is specified as a Development Plan (as opposed to a Sustainable Communities Plan).

Of the key elements identified as part of the vision for the Primary Urban Center, the most relevant to the project is "Honolulu's natural, cultural and scenic resources are protected and enhanced" (DPP, 2004). The following presents specific policies that relate to the project, along with a brief statement of how the project is compliant with the policies and associated guidelines:

Preserve historic and cultural sites

As described in Section 5.8, the project is being designed to avoid impacts to historic and cultural sites to the extent possible. Potential impacts would be minimized to the degree possible through treatment recommendations; in addition, a Programmatic Agreement has been executed which establishes a process for resolving adverse effects that may arise in the future.

Although the proposed project is not expected to directly affect the Ala Wai Canal, the construction of the floodwalls could affect viewplanes associated with the Canal, which is listed on the Hawai'i Register of Historic Places. Project planning and siting would be conducted in a manner so as to best integrate the project components with the natural characteristics of the site and minimize visual impacts to the greatest extent possible.

Preserve and protect natural resource and constraint areas

The proposed project would not expand urban development within the watershed. Several of the flood risk management measures would be located in the State Conservation District, but as discussed in Section 3.6, these have been designed to avoid, minimize and mitigate for impacts to natural resources to the extent practicable, and incorporate environmentally sustainable design features.

Preserve panoramic views of natural landmarks and the urban skyline

As discussed in Section 5.11, the flood risk management features have been sited to blend with the surrounding environment, so as to minimize impacts to scenic views. Given the need for floodwalls along the Ala Wai Canal to protect the Waikīkī District from flooding, while recognizing the importance of the views along the Canal and towards the mountains, the floodwall heights have been minimized to the extent possible; further refinements would be made during as part of the final design phase, and would consider opportunities to reduce the dimensions, as well as incorporate design details to further minimize potential visual impacts.

7.3.3 Revised Ordinances of Honolulu

Considered to be the third tier of the CCH systems of objectives, policies, and regulations (in addition to the General Plan and Regional Plan), ROH contains the code or set of laws that regulate land use within CCH. They include all ordinances that are general and permanent in nature, and incorporate statewide, national, and international codes (e.g., International Building Code and the State Fire Code) by reference. Multiple sections of the ROH are expected to apply to the project, including Public Works Infrastructure Requirements (Chapter 14), Building and Electrical Code (Chapters 16 - 18), Fire Code (Chapter 20), and Land Use Ordinance (Chapter 21).

7.3.4 Drainage Standards

CCH adopted rules relating to storm drainage standards in 1999, which were subsequently amended in 2013. These rules address requirements for both storm runoff quantities for flood control as well as storm runoff quality and reflect the most recent changes to Federal, State, and County requirements related to the quality of storm water discharges. For drainage areas greater than 100 acres and all streams, the design standards require the use of Plate 6 for determination of peak discharges. These discharges are roughly equivalent to a 100-year recurrence interval (1-percent ACE). Channel design standards require the use of freeboard. To the extent possible, requirements in these standards were followed, but USACE guidance does not allow the use of the same deterministic requirements as required in these standards (see Section 5.5). Therefore, hydrologic and hydraulic designs in this study were based on USACE guidance using probabilistic methods.

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8.0 Recommended Plan

Following identification of Alternative 3A-2.2 as the recommended plan, additional engineering and design work was completed, up to an approximately 35% level of design. Key refinements that were made as part of this process include refinement of the various construction limits, staging areas, and access; further detailing of the floodwall locations (and transition points at the bridges); further detailing of the slide gate and flap gate locations and designs; addition of access points along the Ala Wai Canal; and siting of the pump stations. The 35% level of design drawings are contained in Appendix A. A summary of the design features, accounting of the costs and benefits, and other key aspects of the recommended plan are briefly summarized below.

8.1 Plan Components

As described in Section 3, the recommended plan is the NED plan and consists of the following components. These are detailed in Table 17 and shown on Figure 14.

- 6 in-stream debris and detention basins in the upper reaches of the watershed
- 1 standalone debris catchment feature
- 3 multi-purpose detention basins in open space areas through the developed watershed
- Floodwalls along the Ala Wai Canal (including two associated pump stations): approximately 1.7 miles along left bank, approximately 0.9 mile along right bank (including gaps for bridges), and an earthen levee of approximately 0.9 miles in length along the perimeter of the Ala Wai Golf Course
- Improvements to the flood warning system (non-structural)
- Mitigation features

Based on the criteria set forth for the Federal and State Dam Safety Programs (ER 1110-2-1156 and HRS Chapter 179D, respectively), as described in Section 5.16.2, it is expected that the detention structures would be regulated as dams and therefore subject to safety requirements, including inspections, risk assessment, emergency planning and training. Detailed modeling would be conducted as part of the detailed design phase, as needed to determine the specific requirements.

Environmental effects resulting from implementation of the recommended plan have been assessed, as presented in Section 5. Key environmental impacts include those related to biological resources (aquatic habitat), cultural resources, and visual resources. In general, the flood risk management measures would introduce a large-scale built element to the natural environment, potentially affecting view from and toward the site. The detention features would either be screened by dense vegetation or otherwise designed to fit into the natural topography, such that they are not expected to be prominently visible from any readily accessible public locations. The proposed measures along the Ala Wai Canal, including the floodwalls, would diminish views along and toward the Ala Wai Canal. In addition to these views being an important resource for the Waikīkī District, they are also significant in terms of the Ala Wai Canal's listing on the Hawai'i Register of Historic Places (as well as a component of the Kauhale O Hookipa Scenic Byway). In spite of the visual impact of the floodwalls (and associated pump stations), the feasibility analysis determined that they would be a necessary feature to provide adequate flood protection for this area, such that some degree of impact is unavoidable. Efforts throughout the planning process would minimize the impacts to the extent possible, particularly through reduction of the overall floodwall heights. Further refinements would be made during the design phases, and would further evaluate opportunities to reduce the height of the floodwalls and pump stations, as well as incorporate design details that may otherwise minimize potential visual impacts, such as use of construction materials and/or landscaping to blend the structures into the surrounding environment.

The project would involve placement of approximately 1,234 yd^3 of fill material in jurisdictional Waters of the U.S.; in addition, excavation would also be required for construction of one of the in-stream detention basins, as well as for routine maintenance (removal of debris and sediment). Impacts to aquatic habitat would be avoided and minimized to the extent possible; however, the proposed project would still result in some unavoidable impacts to aquatic habitat. Mitigation measures to compensate for the potential aquatic habitat loss include in-stream improvements to eliminate migratory passage barriers for native species at two locations in Mānoa Stream. The Mitigation and Monitoring Plan is provided in Appendix E.

A number of known archaeological and historic resources exist in the project area and could be affected by construction and operation of the project. For those properties with an adverse effect determination, treatment recommendations have been identified and specify conditions that can be placed on the design and construction to mitigate potential impacts. Considering that the project is still in the feasibility phase and that there are still a number of unknown variables that may result in adverse effects through the future planning, design, and construction phases, a Programmatic Agreement has been executed in coordination with the ACHP, SHPO, and consulting parties. It establishes a process for further resource identification and effects determinations, resolving adverse effects, and will expand upon the current treatment recommendations; a copy of the agreement is included in Appendix F.

Suitable borrow materials (including rip-rap and fill material), as required for project construction are expected to be available from existing commercial sources on Oʻahu. Excavated materials from project construction are expected to be reusable or recyclable. Soil, rock and green waste would be hauled offsite for disposal at an approved green waste facility or other approved recycler. Haul routes are expected to consist primarily of existing public roads; some roadway improvements and localized access roads would be required. Where localized access roads are required, these would be constructed as permanent features to allow for O&M.

8.2 Project Costs and Benefits

The project first cost (October 2016 price level) for the recommended plan is summarized in Table 40; additional detail is provided in Appendix D. The project first cost (constant dollar cost) serves as the basis for providing the cost of the project for which authorization is sought; it includes costs associated with (1) PED,[50] (2) construction (including mitigation activities for impacts to aquatic habitat and cultural resources), (3) lands, easements, rights-of-way, relocations and disposal (LERRD), and (4) contingencies. In accordance with ER 1110-2-1302 and Engineering Construction Bulletin (ECB) 2007-17, a cost risk analysis was conducted to identify and measure the cost impact of project uncertainties. Contingencies were identified using a Cost-Schedule Risk Analysis.

[50] PED costs were estimated using historical and default percentages for elements including project management, planning and environmental compliance, engineering and design, document reviews, value engineering, life cycle updates, contracting and reprographics, and engineering/planning during construction. These costs will be refined as the project progresses.

Table 40. Cost Summary

Construction Item	Cost ($000)
Lands and Damages	$7,309
Relocations	$9,885
Elements[a]	
Dams (Debris and Detention Basins)	$71,288
Fish & Wildlife	$229
Levees and Floodwalls	$58,912
Pumping Plants	$67,009
Floodway Control and Diversion Structures	$6,470
Cultural Resources Preservation	$786
Buildings, Grounds and Utilities (Flood Warning System)	$356
SUBTOTAL	**$205,050**
PED	$56,627
Construction Management	$27,224
TOTAL PROJECT FIRST COST (October 2016 Price Level) [b]	**$306,095**

a Elements are based on the Civil Works Breakdown Structure as required in ER 1110-2-1302 and Engineering Manual (EM) 1110-2-1304, "Civil Works Construction Cost Index System (CWCCIS)" which is used in the Micro Computer-Aided Cost Engineering System (MCACES) software program used to develop the cost estimates. Detailed cost estimates are presented in Appendix D.

b The price level for project first cost is the date of the common point in time of the pricing used in the cost estimate.

The expected annual costs and benefits, and the resulting benefit-cost ratio are summarized in Table 41. The calculations are based on the estimated project cost[51] (October 2016 [Fiscal Year 2017] price level), and assume a 50-year period of analysis and a Federal discount rate of 2.875 percent (i.e., the Federal discount rate established for the evaluation of water resources development projects in Fiscal Year 2017).

Table 41. Expected Annual Benefits and Costs

Category	Cost ($000)
Total Estimated Cost (October 2016 Price Level)	$306,095
Interest During Construction	$13,602
Total Investment Cost	**$319,697**
Interest and Amortization of Initial Investment	$12,132
Operation, maintenance, repair, replacement, and rehabilitation (OMRR&R)	$985
Expected Annual Cost	**$13,117**
Expected Annual Benefits	$48,331
Net Annual Benefits	**$35,214**
Benefit-Cost Ratio	**3.68**

51 The estimated project cost differs from the project first cost (presented in Table 41), as the project first cost is the estimated cost brought to the effective price level (that is, the date of the common point in time of the pricing used in the cost estimate).

8.3 Project Performance

The residual 1-percent ACE floodplain for the with-project condition is shown in Figure 14. As indicated, the recommended plan provides significant flood risk management reduction throughout the watershed, as compared to the current FEMA floodzone and without-project condition (see Figure 16).

Table 42 presents three measures of project performance: annual exceedance probability, long-term risk analysis, and conditional non-exceedance probability. These values are based on the project performance target stage, where the target stage is the elevation where damages amount to 5 percent of the damage occurring at the 1-percent ACE flood elevation or the top of floodwall elevation in the case of the Ala Wai Canal Damage Reaches ALA1, ALA2, and ALA 3, or other elevation relevant to the study at that damage reach. The annual exceedance probabilities are the probability that in a given year the water surface elevation would exceed the target stage and can be interpreted as the probability that significant damages (defined subjectively) would occur. The expected or mean probability is defined as the average of the true probabilities of all magnitude estimates. At Damage Reach ALA 3, the without-project median probability is 0.98 or 98 percent chance of exceedance; with the recommended plan project, the median probability is 0.0001 or 0.01 percent. The long-term risk is the probability that the water surface elevation would exceed the target stage at least once in a given time period. The presented time periods in Table 42 are 10, 30, and 50 years. This can be interpreted as the probability of incurring significant damages within a given time period. For Damage Reach ALA 1, there is a 100 percent chance that the without-project target stage would be exceeded once in a 50-year time period; with the recommended plan, this is reduced to a 0.5 percent chance of exceedance in a 50-year time period. The CNP is the probability that a given flood event, like the 1-percent ACE flood, would not exceed the target stage. The uncertainties in the peak flow discharge frequencies and stage-flow relationships are incorporated in the computation of this probability. For Damage Reach ALA 2, under existing conditions (without-project), given that a 1-percent ACE flood occurs, there is a 0.000 probability or 0.0 percent chance that the water-surface elevation would not exceed the target stage; with the recommended plan, given that a 1-percent ACE flood occurs, there is a 0.9996 probability or 99.9 percent chance that the water-surface elevation would not exceed the target stage. Another way to look at the CNP values is to state that for the recommended plan, the target stage at ALA 2 (in this case the top of the floodwall) would provide a 99.9 percent chance of assurance against overtopping given that a 1-percent ACE flood occurs. In other words, the CNP values are conditional risk values that correspond to the reliability that particular floods can be conveyed without causing significant damages in this reach.

Table 42. Project Performance at Selected Damage Reaches

Plan[a,b]	Damage Reach	Target Stage	Annual Exceedance Probability		Long term Risk (years)			Conditional Non-Exceedance Probability					
			Median	Expected (mean)	10	30	50	10% (10-yr)	4% (25-yr)	2% (50-yr)	1% (100-yr)	0.4% (200-yr)	0.2% (500-yr)
WOP	ALA1	4.71	0.1549	0.1885	0.8762	0.9981	1.0000	0.3953	0.2251	0.1178	0.0807	0.0507	0.0264
NED	ALA1	7.9	0.0001	0.0001	0.0010	0.0030	0.0050	0.9998	0.9996	0.9996	0.9996	0.9996	0.9995
WOP	ALA2	4.44	0.6384	0.6398	1.0000	1.0000	1.0000	0.0040	0.0000	0.0000	0.0000	0.0000	0.0000
NED	ALA2	8.75	0.0001	0.0001	0.0016	0.0046	0.0077	0.9999	0.9997	0.9996	0.9996	0.9983	0.9954
WOP	ALA3	3.5	0.9841	0.9180	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NED	ALA3	9.3	0.0001	0.0002	0.0023	0.0070	0.0116	0.9997	0.9999	0.9994	0.9984	0.9969	0.9958
WOP	MPC2	14.74	0.0152	0.0206	0.1881	0.4648	0.6472	0.9981	0.8561	0.5914	0.3677	0.1294	0.0821
NED	MPC2	14.74	0.0067	0.0099	0.0946	0.2578	0.3916	0.9999	0.9629	0.8469	0.6984	0.3458	0.2366
WOP	MAK1	7.43	0.0461	0.1104	0.6896	0.9701	0.9971	0.6949	0.4440	0.2840	0.1754	0.0943	0.0682
NED	MAK1	7.43	0.0073	0.0710	0.5214	0.8904	0.9749	0.8160	0.7215	0.6430	0.5581	0.4926	0.4804
WOP	MAN6	210.35	0.0487	0.0568	0.4428	0.8270	0.9463	0.8109	0.4674	0.3029	0.1983	0.1134	0.0671
NED	MAN6	210.35	0.0138	0.0231	0.2081	0.5034	0.6886	0.9660	0.8159	0.5895	0.4287	0.2976	0.1065
WOP	PAL4	187.93	0.0047	0.0089	0.0860	0.2365	0.3622	0.9996	0.9684	0.8566	0.7089	0.4714	0.3433
NED	PAL4	187.93	0.0014	0.0014	0.0141	0.0417	0.0685	1.0000	1.0000	1.0000	1.0000	0.9924	0.7473

NOTES:

[a] As described in Section 3.9, the NED plan was identified as the recommended plan and assumes an intermediate level of sea level rise over the planning period of analysis (2025-2075). More information on additional sea level rise scenarios is found in Appendix A.

[b] Project performance statistics were calculated in accordance EM 1110-2-1619 (Department of the Army, 1996) guidelines on risk-based analysis for flood damage reduction studies. Additional detail, including sea level rise scenarios beyond the planning period of analysis, is provided in Appendix A.

WOP = without-project

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Critical infrastructure within the .2% ACE floodplain was assessed for the with-project and without-project condition. The results are summarized in Table 43 and Figure 20 below:

Table 43. Critical Infrastructure Assessment

Infrastructure	Neighborhood	0.2% ACE floodplain (without project)	0.2% ACE floodplain (with project)
Fire Station			
Kiwila Street	Palolo	no	no
Date Street Station	McCully	yes	no*
Manoa Station	Manoa	no	no
Kapahulu Station	Waikiki	yes*	no
Koko Head Station	Kaimuki	no	no
Makaloa Station	Ala Moana	yes	yes
Wilder Station	Makiki	yes	yes
7 total		**4**	**2**
Police Station			
Alapai Station	Makiki	no	no
Waikiki Station	Waikiki	no	no
2 total		**0**	**0**
Hospital/Medical Clinic			
Straub Hospital	Ala Moana	no	no
Kaiser Clinic	Ala Moana	no	no
Kapiolani Medical Center for W	McCully/Moiliili	yes (minimal)	yes (minimal)
Shriners	McCully/Moiliili	yes (minimal)	no
Urgent Care Clinic of Waikiki	Waikiki	yes	no
Straub Clinic, Doctors On-Call	Waikiki	no	no
Straub Clinic, Doctors On-Call	Waikiki	yes (minimal)	no
Waikiki Health Center	Waikiki	yes	no
Island Urgent Care	Waikiki	yes	no
Diamond Head Health Clinic	Kaimuki	no	no
Leahi Hospital	Kaimuki	no	no
11 total		**6**	**1**
Nursing Homes			
Hale Nani Rehabilitation	Makiki	yes (partial)	yes (partial)
Arcadia Retirement Residence	Manoa	yes	no
One Kalakaua Senior Living	Ala Moana	yes	yes (partial)
Living Manoa	Manoa	no	no
Manoa Cottage Care Home	Manoa	no	no
Manoa Cottage Kaimuki	Kaimuki	yes	yes
Manoa Sunshine Residential C	Manoa	no	no
Oahu Care Facility	McCully/Moiliili	no	no
Hulu Makua Senior Day Care	Kaimuki	no	no
Manoa Senior Care	Kaimuki	no	no
Palolo Chinese Home	Palolo	no	no
Mu Ryang Sa Buddhist Temple	Palolo	no	no
The Plaza Assisted Living	Makiki	no	no
Island Nursing Home	McCully/Moiliili	no	no
14 total		**4**	**3**

Infrastructure	Neighborhood	0.2% ACE floodplain (without project)	0.2% ACE floodplain (with project)
Emergency Shelter			
Waikiki Elementary	Waikiki	no	no
Paki Community Park	Waikiki	yes*	no
Jefferson Elementary School	Waikiki	yes*	no
Waikiki Convention Center	Waikiki	no	no
Lunalilo Elementary School	McCully/Moiliili	yes	yes
Washington Middle School	McCully/Moiliili	yes	yes
Kuhio Elementary School	McCully/Moiliili	no	no
Kaahumanu Elementary Schoc	Ala Moana	no	no
McKinley High School	Ala Moana	yes (minimal)*	no
Stevenson Intermediate Scho	Makiki	no	no
Roosevelt High School	Makiki	no	no
Makiki District Park	Makiki	no	no
UH Manoa	Manoa	yes (partial)	yes (partial)
Hokulani Elementary School	Manoa	yes	yes
Noelani Elementary School	Manoa	yes (partial)	yes (partial)
Manoa Elementary School	Manoa	no	no
Aliiolani Elementary School	Palolo	no	no
Kaimukī High School	Kaimuki	yes (partial)	no
Liholiho Elementary School	Kaimuki	no	no
Anuenue Complex	Palolo	no	no
Palolo Elementary School	Palolo	no	no
21 total		**9**	**5**

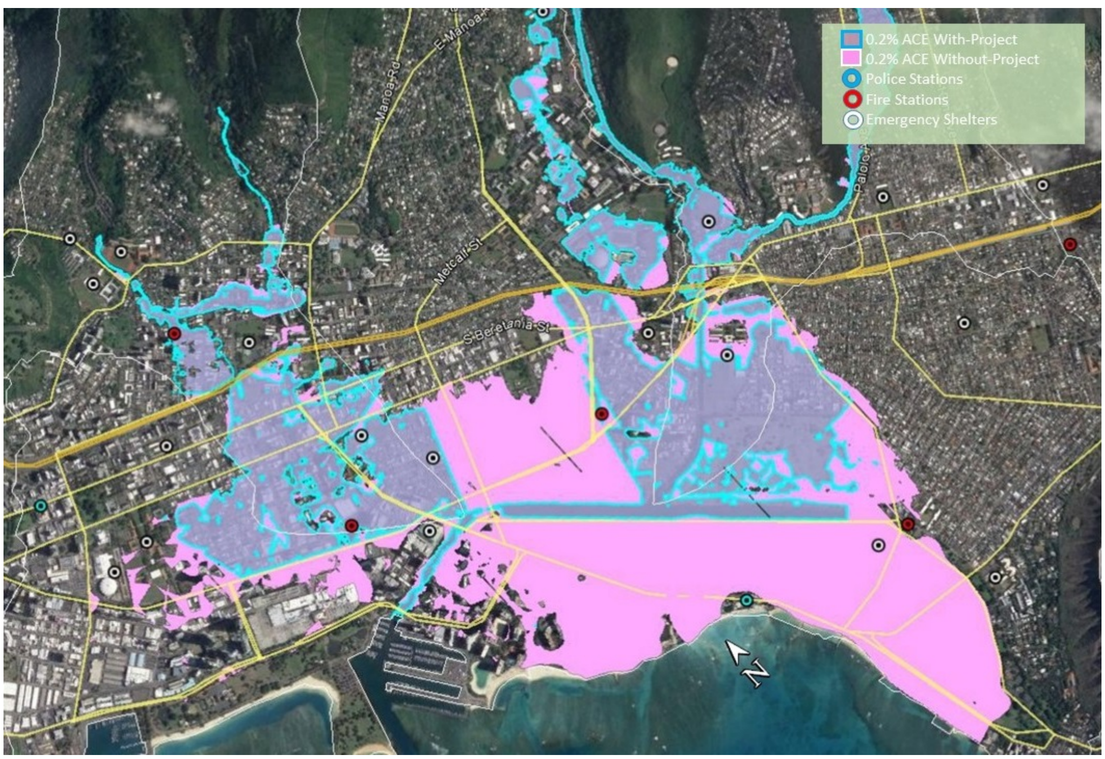

Figure 20. Critical Infrastructure within the 0.2% ACE Floodplain, With and Without-Project Conditions

Within the 0.2% ACE floodplain, per the 2010 census, the population at risk (i.e. those residing in the floodplain) is approximately 65,400 in the without project condition and 30,900 in the with-project condition. As a result of the recommended plan, the population at risk will be reduced by approximately 35,000 people. Note that this does not include transient populations of tourists, students or workers.

8.3.1 Residual Damages

Although the recommended plan reduces the 1-percent ACE floodplain throughout the majority of the watershed, it would not entirely eliminate flood risk. The without-project expected annual damages are estimated to be approximately $53.72 million; the residual expected annual damages associated with the recommended plan are estimated to be approximately $5.4 million. The residual expected annual damages are summarized in Table 44 and illustrated in Figure 21. As indicated by these data, the residual damages would be highest in the lower Makiki valley and University of Hawaii, Manoa area.

Although there are pockets of residual damages throughout the watershed, one specific area of concern is Iolani School, which is located on the right bank of Reach ALA2. With no project in place, there is potential for flooding across nearly the entire 25-acre campus, including more than a dozen large school buildings. With implementation of the recommended plan, in a 1-percent ACE event, the modeling results show floodwaters across approximately half of the campus; facilities subject to flooding would include 4 to 5 buildings, but would primarily be athletic fields, courts, and support facilities. This limited level of protection for the school is provided not by the Ala Wai Canal floodwalls, but through detention of floodwaters upstream and within the adjacent Ala Wai Golf Course.

Table 44. Residual Expected Annual Damages for the Recommended Plan

Location	Expected Annual Damages ($000)	
	No Action	Recommended plan
Ala Wai	$45,121	$487
Makiki	$2,234	$1,423
Mānoa	$6,205	$3,446
Pālolo	$159	$32
TOTAL	**$53,719**	**$5,388**

The risk of flooding Iolani School could be further reduced by extending the floodwalls to protect the school (the previously evaluated Manoa Palolo Drainage Canal floodwall), but it would induce higher water surface elevations on the Waikīkī side of the Ala Wai Canal, as well as limit the effectiveness of the Ala Wai Golf Course detention improvement. In addition, the additional increment was not economically justified (see Section 3.9.3). Site specific nonstructural solutions were evaluated as a means of providing additional protection on the Iolani campus in lieu of extending the floodwalls, but none were found to be economically feasible. A flood warning system, however, has been included in the recommended plan as a nonstructural measures which will allow the school to update its emergency planning to include use of the floodwarning system to provide an appropriate response to flood conditions.

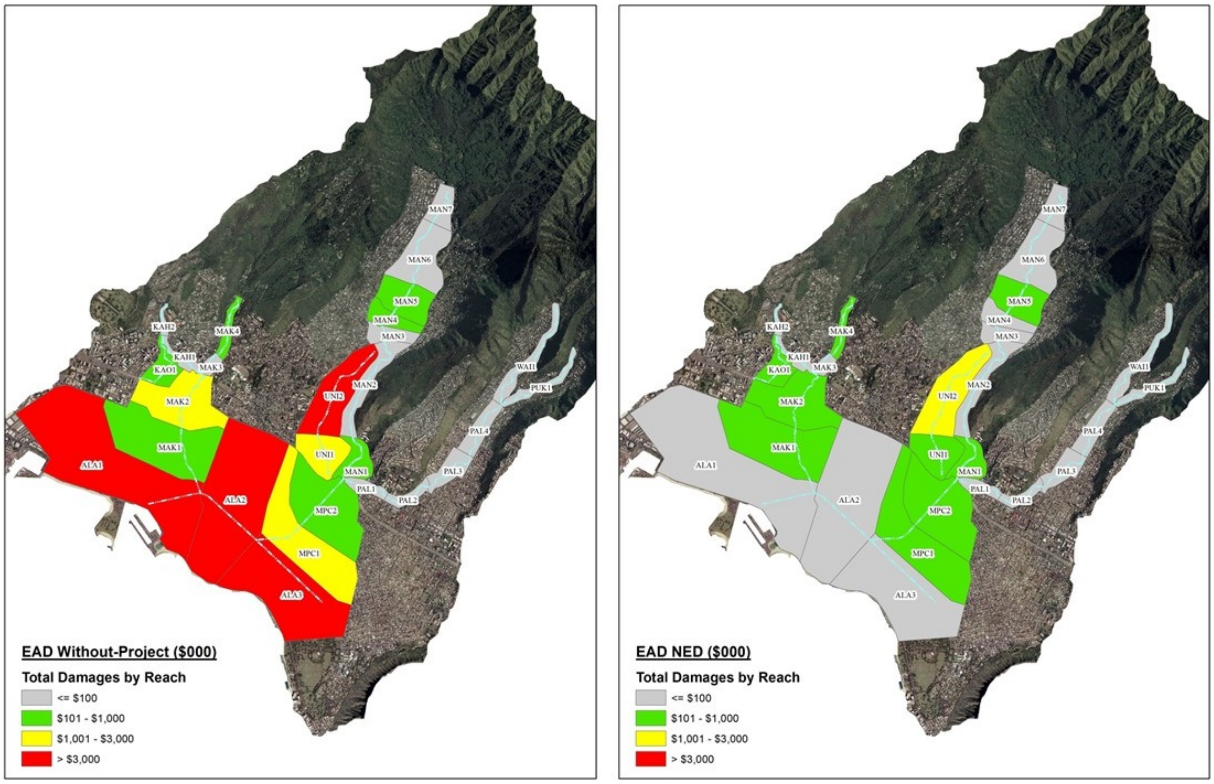

Figure 21. Expected Annual Damages By Reach, Without-Project (left) and With Implementation of the Recommended Plan (right)

8.3.2 Risk and Uncertainty

Risk and uncertainty is fundamental to all water resource planning and communication, and each aspect of a flood risk assessment must account for risk and uncertainty. USACE risk assessment procedures were followed in this study to account for uncertainty in the information to the extent practicable. However, there is some project performance uncertainty in all studies, even with the risk assessment procedures.

This study incorporated risk management framework principles and risk-informed planning into the plan formulation process. Specific examples include the following:

- Risk analysis and communication was conducted, consistent with ER 1105-2-101, Risk Analysis for Flood Damage Reduction Studies, and EM 1110-2-1619, Risk-Based Analysis for Flood Risk Management Studies. As previously described in Section 2.1.1, the probability of a hurricane or tsunami occurring at the same time as a major rain storm resulting in riverine flooding is very low (see Appendix A3 for further details). Furthermore, the FIRM, which account for hurricane coastal surge, indicate that the majority of the floodplain in Waikiki is associated with riverine flooding; the costal surge zone is mapped only along the shoreline and depending on location, extends inland to Kalakaua Avenue. The final hydraulic analysis for the study included the evaluation of sea level rise at time periods corresponding to 2025, 2075 and 2125, using a range of scenarios (low/intermediate/high) to forecast future conditions as well as evaluate project performance. In addition, the analysis evaluated the performance of the Ala Wai Canal reach flood protection under the scenario of a coincident storm surge and riverine flood event. The results of this analysis are included in Appendix A. In the event that storm surge were to occur within the Ala Wai Canal during an intense rainfall event, water surface elevations could rise above those accounted for in the hydraulic modeling, resulting in overtopping of the Ala Wai Canal floodwalls; however, the likelihood of this event is extremely small. In general, as a result of final design changes, the performance of the flood protection against a storm surge and/or flood event will protect to a minimum elevation of 7.9 feet. At this elevation, the threat of damage from coastal flooding exceeds the risk from riverine flooding due to higher coastal levels caused by relative sea level rise.

- The PDT incorporated risk-informed decision making into the planning process. An internal document (referred to as the risk register) was developed and used to document and carry forward those risk management concepts. Risks that were identified included unknowns that will be addressed in more detail during future design efforts, for example field investigations of geotechnical information, cultural resources, and biological resources, and updated of available information about construction costs and property values for economic analyses. Subsequent technical, agency, and public reviews aid in identifying and assessing the relative risks associated, and identify ways to reduce them to acceptable levels. Opportunities for value engineering will be incorporated, too, to reduce the risks of missed opportunities for identifying more effective, more cost efficient project features, designs, and/or construction.
- Uncertainty was captured through cost engineering's mandatory risk assessment process to establish cost contingencies. The economic analysis developed ranges of economic outputs with mid and mean number ranges to best capture uncertainties and identify risks in the risk register.
- Risk and uncertainty ranges were iteratively refined for costs and economics with each subsequent level of design. This analysis confirmed the conceptual numbers were still within the established ranges of uncertainty, validating assumptions and risk decisions.

8.3.3 Resiliency, Overtopping, and Interior Drainage

Under the risk-based framework, the system is expected to protect the project area up to the top of containment or, in this case, the floodwall heights along the Ala Wai Canal; resiliency refers to how well the system performs in case of capacity exceedance or overtopping on the floodwalls. Resiliency can be incorporated as a structural measure into a levee and floodwall design by constructing a scour protection apron on the protected side of the levee or floodwall for the purpose of minimizing erosion during flood events that exceed the top of wall elevation. But it also can be incorporated on how well a community can recover from an overtopping event usually by limiting the impacts from an overtopping event.

For the Ala Wai Canal floodwalls, potential impacts are based on an overtopping event on the northern, eastern, and southern sides. Figures 22 and 23 illustrate the discussion that follows.

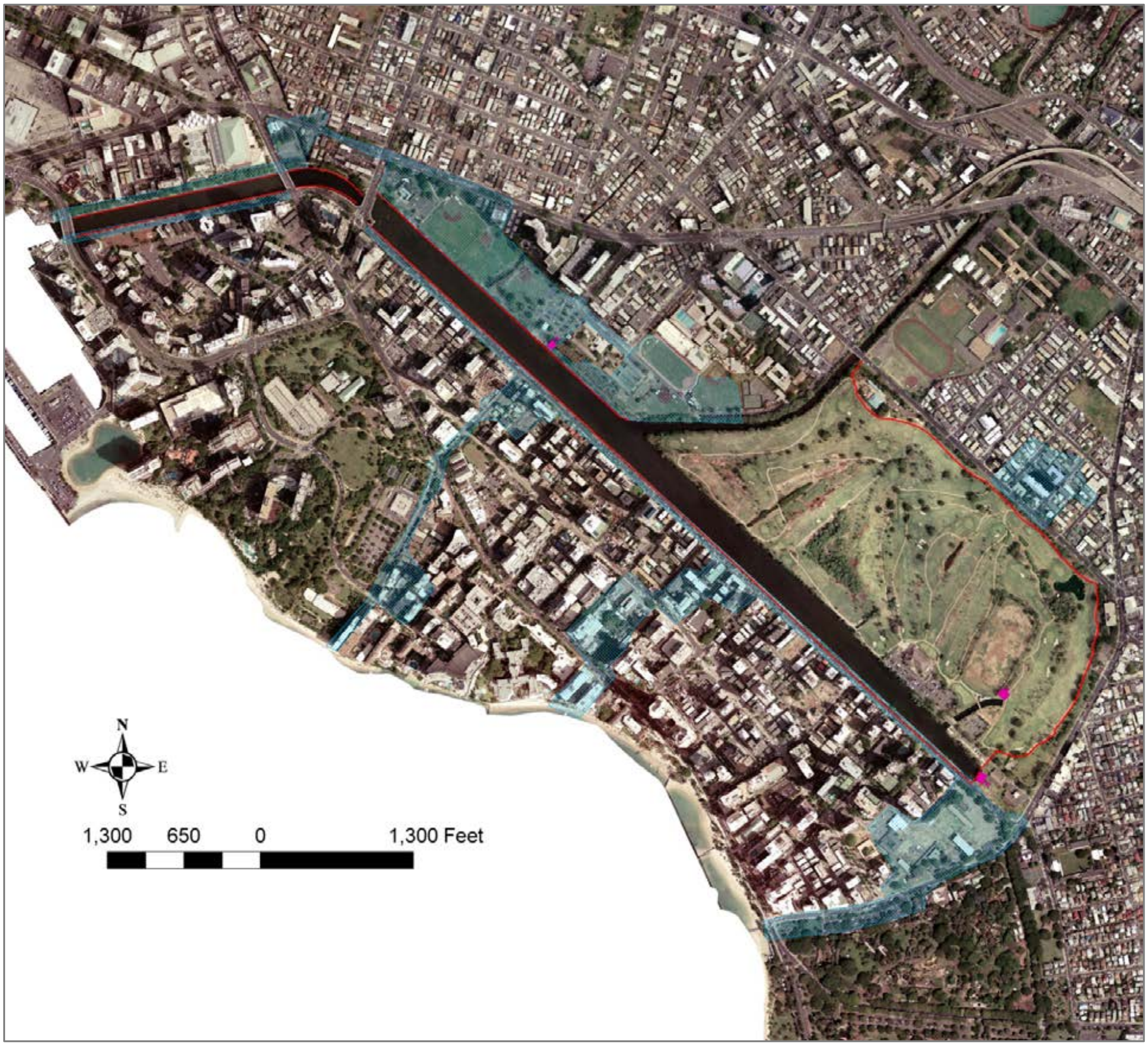

Figure 22. Potential Areas of Shallow Flooding due to Overtopping of Floodwalls/Berms

Figure 23. Potential Flooding Areas Due to Failure of Interior Drainage Systems or Residual Interior Flooding

Regardless of location of overtopping, flood peak flow events are very flashy and, in case of overtopping, the peak flow period or crest of the flood peak for a 1-percent ACE event would be between 30 minutes to 1 hour. This would limit the amount of discharge that would overtop the floodwalls or golf course berms. All areas on the landward side of floodwalls have been equipped with overtopping spill protection in the form of concrete sidewalks, to prevent scour at the base of the floodwall in an overtopping event. The duration and volume of an overtopping event is small enough that a concrete sidewalk, four inches thick, will provide sufficient scour protection. In case of overtopping on the northern or right-bank side of the Ala Wai canal, in Reach ALA1, flood waters are expected to first pond near the floodwall before flowing down the pedestrian path towards Ala Moana Boulevard and then into the ocean. In Reach ALA 2, again it would pond closest to the floodwall and in Ala Wai field before backing up onto Kapiʻolani Boulevard and flowing towards Makiki Stream or ponding at the Ala Wai Community gardens and flowing towards the Mānoa-Pālolo Drainage Canal through the Ala Wai Elementary and Iolani Schools grounds (which may inundate a few buildings, but would mostly impact their athletic fields). This would also be the potential inundation area if the University Avenue interior drainage pump station were to fail. In Reach ALA 3, along the golf course berm, flow would pond on Date Street and potentially in the residential area between Ekela Avenue and Palani Avenue. Depending on the topography and storm drain size, there would be an opportunity for overtopping flow to re-enter the Mānoa-Pālolo Drainage Canal through the storm drain system on Date Street. On the northern side, the floodwall currently is located with the sidewalk between it and the Canal, so the floodwall has no overtopping scour protection. The golf course berm also has no landside scour protection, just a paved cart path on top. Although the magnitude of the overtopping risk is low, backside scour protection can be added to these features during the PED phase of the project.

On the eastern side, Reach ALA 3, overtopping flows would pond on Kapahulu Avenue and then flow down that road towards the ocean, passing through the grounds of Jefferson Elementary school. The overtopping flow could be captured by the interior drainage system in this area and be pumped back into the Canal. Failure of the interior drainage pump station would result in a similar inundation. Overtopping on the south or left bank side of the Canal would result in flow down Ala Wai Boulevard towards the ocean in ALA 1 and flow through Waikīkī for Reaches ALA 2 and ALA 3. For the floodwalls along the Waikīkī side or left bank of the Canal, the design has the walls tied to the sidewalk; this provides the scour protection in case of overtopping.

In all cases of overtopping, the overtopping flows would result in sheet or shallow flow through park land or residential areas on the northern or right-bank side and through Waikīkī into the ocean on the southern or left-bank side of the Canal. There is a low public safety risk as such flow is not deep or fast enough to cause dangerous conditions. There is no bathtub effect in any overtopping area and ponding is expected to be in the 1- to 2-foot range. Damages would be related to those at the 2-foot depth for those overtopping areas illustrated on Figure 22.

Related to resilience is superiority, which simply means providing higher levees at all points except where initial overtopping is desired. The overtopping reach is to provide a known initial exceedance location and to provide some warning or evacuation time before total system exceedance. Because of the highly urbanized areas all around the Ala Wai Canal, no superiority reach can be safely identified.

In accordance with USACE EM 1110-2-1413, economic analysis was conducted on pump station interior drainage features to verify that the stations meet applicable guidance and that the economic benefits exceed the costs. The three pump stations proposed as a part of the tentatively selected plan intercept trunk storm sewer systems and are intended to prevent backwater flooding due to the installation of flap gates on the storm sewer outfalls.

The flood footprint for interior flooding in the absence of Pump Stations 1 and 2 partially overlaps the existing flood footprint for the without-project condition, however, this footprint extends much further to the east across Kapahulu Avenue into adjacent residential neighborhoods which would otherwise be relatively unaffected by flooding in the Ala Wai Canal (Figure 23). Water surface elevations associated with interior flooding increase above the without project condition significantly within those areas of overlap (between 0.9’-1.7’). Further, interior flooding adversely affects two emergency shelters, one fire station and evacuation routes for Waikiki including Kapahulu Avenue, Monsarrat Avenue and Kalakaua Avenue. Given the increase in water surface elevations between the without-project and interior flooding condition, the inclusion of Pump Stations 1 and 2 meet the minimum facilities criteria designated by USACE guidance and are included as an integral element to the line of protection features for the Ala Wai Canal.

In the vicinity of Pump Station 3, the flood footprint for interior flooding exists entirely within the flood footprint for the without-project condition (Figure 23). Water surface elevations associated with interior flooding decrease below the without project condition significantly within those areas (-2.28’) as a result of the recommended plan. Consequently, Pump Station 3 does not meet the minimum facilities requirement prescribed by USACE guidance and was excluded from inclusion in the recommended plan. In the absence of a pump station, a backwater effect from local drainage is expected with approximately 1-foot depths within the intersection of Date Street and University Avenue, and approximately 1.5-foot depths near Ala Wai Canal, resulting from a 10% ACE storm. Flooding associated with the backwater effect in these areas is considered residual damage. Local drainage improvements implemented in this area could improve this condition.

8.3.4 Residual Risk Management

Fundamentally, flood risk is the probability that an area will be flooded, resulting in undesirable consequences such as damage to property, disruption of public services, threats to public safety, and the potential for loss of life. This study undertakes a risk analysis approach to evaluation and decision making which, to the extent practical, incorporates considerations of risk and uncertainty. The residual risk associated with the recommended plan is the flood risk that remains once the project is implemented and functional. Figure 24 below illustrates the conceptual framework for risk analysis associated with the study, beginning with the without project condition.

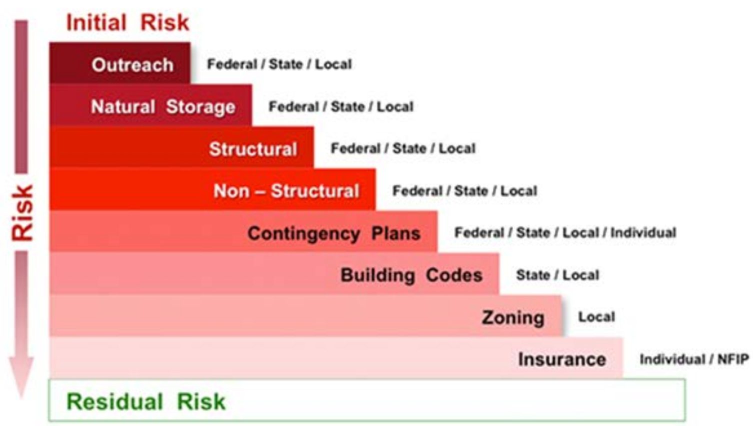

Figure 24. Conceptual Framework for Risk Management

The foundational element to the framework above is the idea that flood risk management is a shared responsibility through all levels of government down to individual property owners. Each step that is implemented in this framework reduces the cumulative risk for those who reside, visit, work or study within the watershed. This study focuses on the assessment primarily of structural and non-structural solutions to flood risk. However, it is important to recognize that while the magnitude of flood risk will be reduced as a result of implementation of the recommended plan, any solution is a partial solution and residual risks from flooding will remain. Table 45 below utilizes the framework above to summarize the work both included and not included within this report:

Table 45. Residual Risk Management

	Risk Management Category	Addressed in this Report?	Implementation Responsibility			Management Measure(s)
			Federal	State	Local	
Residual Risk ↓	Outreach	Yes	•	•		Risk communication through public review of study report
	Natural Storage	No			•	Maximized in existing channel capacity, on-going maintenance required
	Structural	Yes	•	•	•	Detention basins, floodwalls, debris catchments
	Non-Structural	Yes	•	•	•	Flood warning system, further non-structual opportunities in residual flooding areas
	Contingency Plans	No		•	•	Addressed primarily at the local level, opportunities for further risk reduction
	Building Codes	No		•	•	Addressed primarily at the local level, opportunities for further risk reduction
	Zoning	No		•	•	Addressed primarily at the local level, opportunities for management in upper watershed
	Insurance	No	•	•	•	Addressed primarily at the local level through National Flood Insurance Program

Federal justification in reducing flood risk is limited by criteria set by law and policy which includes both economic justification as well as minimal flow rates (streams must exceed 800 cfs for the 10% ACE flood). As noted in prior sections of this report, residual risks have been identified related to project performance, but areas unprotected by the recommended plan may continue to remain a concern and require consideration for additional risk reduction at the State and Local level. In such areas, compelling reasons may exist to address additional risk reduction on a local level. Strategies to reduce risk within this study and recommended plan as well as identification of additional risk reduction opportunities are detailed in the discussion below.

Outreach

One of the primary benefits of the development of this study is the identification and communication of the flood risks found within the watershed. Perceptions regarding the actual risk of flooding may vary between the general public, risk management professionals, and public officials, particularly between extended periods without a damaging flood. This study has undertaken a comprehensive risk assessment related to riverine flood risk. The overall results have been communicated to the public and policy makers through coordination with specific agencies and stakeholders, public review of the feasibility report, press releases and public meetings. As of 2017, the State is currently in the process of updating its Multi-Hazard Mitigation Plan. The information contained herein regarding both the future with and future without-project conditions will be available to local officials and the public to support future planning and risk management reduction efforts. Of particular importance is the education of the public on what to do in the event of a flood (see Contingency Plans, below).

Natural Storage

Evaluation of use of natural storage for flood flows has been assessed throughout this study. Given the flashy nature of the conveyance system, one critical problem identified (see Section 2) is the lack of channel capacity to fully convey flood flows. This problem is compounded by the presence of high debris flows, debris accumulation and flow blockages associated with flood events which further constrain channel capacities. Certain activities have been undertaken on the local level to address channel capacity concerns (e.g. the expansion of the Woodlawn Bridge in the Manoa valley), however further opportunities are likely limited given the built-out nature of the watershed. As such, storage opportunities for risk reduction with the study were explored primarily as structural alternatives.

Structural

Structural flood risk management measures focus on the direct management of the flow, timing, and storage of runoff in order to modify the floodplain and reduce the likelihood of flooding, thereby reducing economic damages and risks to public health and safety. The recommended plan relies on the dual approach of runoff detention and debris management in the upper watershed and a line of defense and creation of storage in the lower watershed. This approach will effectively reduce the magnitude, frequency, and depth of flooding and economic damages throughout the watershed. However, areas of residual flooding remain and are outlined in both Figure 14 as well as Section 8.3.1 and 8.3.3 above. Areas such as the Makiki drainage; residual flooding at the University of Hawaii, Manoa; the Iolani School and Ala Wai Elementary; as well as areas north of the Ala Wai Golf Course have been identified as residual flooding areas. While the magnitude of flooding in each of these areas has been reduced between the without-project and with-project condition, further USACE involvement in risk reduction could not be justified for inclusion in the recommended plan included in this report (see Section 3), however, consideration of additional structural measures to supplement the recommended plan may be warranted for implementation on a local level. Upstream runoff retention in small watersheds, additional line of protection in unprotected areas of the Ala Wai Canal, pump stations to address interior drainage or other drainage improvements may all help to meet local risk management goals. Regardless, the inclusion and preparation of flood response in contingency plans (see discussion below), especially in identified areas of residual risk is critical towards managing the overall risk.

Non-Structural

Non-structural flood risk management measures focus less on the actual modification of the floodplain in favor of reducing the damages associated with flooding. Examples of non-structural measures includes flood-proofing or elevating individual structures, removal or relocation of structures from the floodplain, etc. A non-structural flood risk management plan was considered as a potential study alternative (described in Section 3). Given the high density of structures within the watershed, non-structural measures become increasingly less competitive from a cost-effective standpoint versus structural protections. While the non-structural features identified above were not included in the recommended plan, strategic implementation of non-structural measures, particularly in areas where repetitive flood damages have occurred, may be viable for local implementation to further reduce risk. The recommended plan has included a flood warning system, considered a non-structural measure, which will assist in monitoring and providing warning against rising stream levels. Implementation of this feature will allow for the early warning to affected populations and execution of contingency plans (noted below).

Contingency Plans

Contingency planning is managed at the State and local level. Assistance in emergency management can be requested from the Federal government through authorities provided by the Stafford Act, but the impetus for plan development typically rests with the States. In the State of Hawaii, the State Multi-Hazard Mitigation Plan is developed and updated roughly every five years. Since 2003, local communities seeking Pre-Disaster Mitigation funds from the State must have an approved local mitigation plan. The entity charged with developing the local plan is the City-County of Honolulu, however, additional hazard mitigation plans exist that apply to entities within the Ala Wai Watershed such as public schools, as well as the University of Hawaii, Manoa. Hazard mitigation plans tend to cover a broad range of topics from man-made to natural disasters. Risk assessment, pre-planning mitigation, response to the realization of risks, and occasionally recovery and resiliency are covered. The current City-County plan considers a host of flood mitigation strategies including structural projects, non-structural projects, use of the National Flood Insurance Program (below), preventive measures (i.e. planning, zoning, building codes, discussed below), natural resource protection (i.e. natural storage), public outreach, and emergency response. The current plan proposes the following actions to reduce risk within the City-County:

- Adopt 2006, 2009, and 2012 International Building Code (IBC) and related codes per HRS 107 Part II.
- Investigate the differences between the existing and new DFIRM maps, and adapt maps so that tsunami inundation hazard is included along the south and west coasts.
- Develop rainfall and streamflow gauging system suitable to flood monitoring.
- Develop dam evacuation maps.
- Develop policies for repetitive loss structures.
- Establish additional flood and debris-flow warning systems on Oahu.
- Investigate feasibility of participating in the Community Rating System.

- Consider adopting coastal erosion setbacks per historical rates or disclosure of erosion rate during real estate transactions. Disclose hazard risks as Mandatory Seller Disclosures in Real Estate Transactions Act.

Emergency response to flood threats are coordinated by the Hawaii Emergency Management Agency (HiEMA, formerly Hawaii Civil Defense). The National Weather Service and the Pacific Tsunami Warning Center report potential flood threats to HiEMA. The information is verified, and the potential effect of the threat is evaluated. If a threat to public safety and property arises, warnings are transmitted to the public through the press, radio, and television. HiEMA coordinates warning, response, and recovery during a disaster. Strategies for managing risks includes:

- Flood threat recognition
- Warning dissemination
- Flood response
- Critical facilities protection
- Health and safety maintenance
- Post disaster recovery and mitigation

Forewarning for evacuation and emergency response within the study area will continue to rely on the National Weather Service and the Pacific Tsunami Warning Center, but will be complemented in the future by the addition of a flood warning system associated with the recommended plan. Development of the flood warning system proposed by the Ala Wai Canal FRM study recommended plan will also further integrate the goals and policies of both the State and the City-County. Consistent with Section 402 of the Water Resources Development Act of 1986, the non-Federal sponsor will prepare a floodplain management plan within one year after the date of signing a project cooperation agreement, and will implement the plan no later than one year after completion of construction of the project. Design of the flood warning system and the related contingency plans for emergency response will be closely coordinated with affected entities using cost-shared funds during the design phase of the project to ensure that residual risk areas are adequately addressed for each of the risk management strategies identified above. As noted in previous sections of the report, flood flows can materialize in the lower watershed in as little as 45 minutes of a rain event in the upper watershed. Given the short response time, the flood warning system will become a critical tool in the management of residual risks. Similar to tsunami contingency plans, vertical evacuation of the floodplain (i.e. seeking higher levels within structures with more than one floor) may serve as the most efficient response. How the warning systems translate to specific response actions will be further explored and coordinated among Federal, State and local partners as a part of the design effort for the recommended plan.

Building Codes

The City-County of Honolulu has developed building codes for structures within specific zoning districts (below) which identify flood hazard areas. Building codes are intended to reduce the structural damage associated with flooding in high hazard areas through integrating development standards. Relevant building codes include:

- Floodproofing requirements
- Structural requirements for the consideration of the effect of overturning, sliding, flotation or increased load support to structures in the event of a flood

Zoning

The City-County of Honolulu has developed a number of zoning ordinances which define floodplains and designate allowable use activities. The adoption of these zones is required for participation in the National Flood Insurance Program (NFIP, below). In theory, zoning districts dissuade development within flood hazard areas, and when development does occur, the consequences of flooding are reduced. Relevant ordinances include:

- Establishment of flood hazard districts corresponding to Flood Insurance Rate Map (FIRM) designations
- Establishment of floodway districts to elevate the hazard status of floodways and avoid encroachment
- Establishment of flood fringe districts to define allowable uses and standards outside of the floodway
- Establishment of coastal high hazard districts to define allowable uses and standards in areas of high risk of coastal flooding
- Establishment of general floodplain districts to define allowable uses and standards outside of the floodway
- Standards for development on lands adjacent to streams, rivers, drainageways outside of the flood hazard district
- Preconstruction and post-construction certification standards for new development within flood hazard districts

National Flood Insurance Program

The City-County of Honolulu is active participant in the National Flood Insurance Program (NFIP). According to the City-County Multi-Hazard Pre-Disaster Mitigation Plan, as of 2009, there were 37,000 active flood insurance policies within the County (both within and outside of the study area). The City-County of Honolulu does not participate in the FEMA Community Rating System (CRS), associated with the NFIP. CRS provides individual policyholders a premium reduction, or credit, on their flood premiums, if local governments implement additional mitigation measures approved by the NFIP. In part, participation in the program involves the dissemination of information related to flood risks, implementation of mapping and regulatory programs, preparedness for emergency actions and damage reduction targeted at repetitive losses. Several areas of repetitive flood losses exist within the study area, including several properties in the Makiki valley and along Manoa stream. As noted above in the discussion of Contingency Plans, the City-County is considering policies to address repetitive losses due to flooding as well as mitigation strategies which may allow for future participation in the CRS program. Implementation of the recommended plan associated with this study may assist the City-County in achieving some of the goals outlined in its plan.

8.4 Operation and Maintenance, Repair, Replacement and Rehabilitation (OMRR&R)

Each of the measures developed as a part of the recommended plan includes life-cycle maintenance costs, with OMRR&R performed on a routine basis. The non-Federal sponsor is aware of their responsibilities for conducting all OMRR&R; anticipated requirements are summarized in Table 9. The annual estimated cost of these requirements is approximately $985,000. A detailed OMRR&R plan will be prepared during the detailed design phase for the project.

Based on further public and technical reviews, opportunities remain during future design phases to refine designs with more detailed information about OMRR&R actions and costs.

8.5 Real Estate Requirements

As summarized in Table 46, three of the sites required for the recommended plan are either wholly or partially owned by the non-Federal sponsor. These three sites would not require acquisitions, but all the remaining sites would require acquisition from private parties and/or a provision for making the property available from CCH, who would have to either transfer the requisite interest in their ownerships to the State or would have to enter into an agreement to make their lands available for the project.

Table 46. Real Estate Requirements for the Recommended Plan

Measure	Ownership	Real Estate Requirements
Waihi debris and detention basin	CCH State of Hawai'i	2.82 acres to be acquired from the State/City-County: 2.15 acres in permanent acquisition, 0.67 temporary acquisition
Waiakeakua debris and detention basin	CCH State of Hawai'i Private	4.90 acres to be acquired from the State/City-County/one private owner: 4.18 acres in permanent acquisition, 0.72 temporary acquisition
Woodlawn Ditch detention basin	Private	3.3 acres to be acquired from the one private owner: 3.23 acres in permanent acquisition, 0.06 temporary acquisition
Mānoa in-stream debris catchment	CCH Private	0.49 acres to be acquired from CCH and one private landowner: 0.37 acres in permanent acquisition, 0.12 temporary acquisition
Kanewai Field multi-purpose detention basin	CCH	6.35 acres to be acquired from CCH: 5.48 acres in permanent acquisition, 0.86 acres in temporary acquisition
Wai'ōma'o debris and detention basin	Private	2.70 acres to be acquired from eight private landowners: 1.89 acres in permanent acquisition, 0.81 temporary acquisition
Pūkele debris and detention basin	Private	2.44 acres to be acquired from 14 private landowners: 1.51 in permanent acquisition, 0.92 temporary acquisition
Makiki debris and detention basin	State of Hawai'i	None (2.034 acres affected)
Ala Wai Canal floodwalls	State of Hawai'i	None (16.302 acres affected)
Hausten Ditch detention basin	State of Hawai'i	None (5.248 acres affected)
Ala Wai Golf Course multi-purpose detention basin	State of Hawai'i	None (23.263 acres affected)
Flood warning system	To be determined[a]	None (16.30 acres affected)
Mitigation – Falls 7 & 8	Private	0.153 acres in permanent acquisition to be acquired from 14 private landowners

Notes:

[a] The flood warning system may include both existing and new gaging stations. For existing gaging stations, it is assumed that the necessary real estate approvals are already in place. The specific location of any new stations have not yet been determined, but it is assumed that they would either be located on public land or in areas supported by private landowners, such that the real estate approvals may be easily obtained.

The fee interest is normally required for permanent structures, such as the in-stream detention basins (including the 20-foot-wide area to be maintained around the structure), pump stations, mitigation lands and debris catchment structures. For mitigation lands, easements will be acquired in lieu of fee title to accommodate the limited property interest necessary to complete the modifications to the migration areas. In addition to acquiring fee interest (approximately 5.8 acres), the project would also require flowage easements (approximately 8.6 acres), perpetual road easements (approximately 1.7 acres), flood protection levee easements (approximately 0.5 acres), channel improvement easements (approximately 1.2 acre), and temporary work area easements (approximately 5.7 acres). In addition, relocation benefits are expected to be required for at least one of the measure sites, pursuant to the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (Public Law 910646). In total, the real estate costs for the recommended plan are estimated to be approximately $7.3 million with an additional $9.52 million in relocations costs.[52] Additional detail on these requirements is provided in the Real Estate Report, contained in Appendix C.

8.6 Floodplain Management (EO 11988)

EO 11988 (Floodplain Management; May 24, 1977) requires a Federal agency, when taking an action, to avoid short- and long-term adverse effects associated with the occupancy and the modification of a floodplain. The agency must avoid direct and indirect support of floodplain development whenever floodplain siting is involved. In addition, the agency must minimize potential harm to or in the floodplain and explain why the action is proposed. Additional floodplain management guidelines for EO 11988 were provided in 1978 by the Water Resources Council and these have recently been revised as part of EO 13690, signed on January 30, 2015, which amends EO 11988. It should be noted, however that determination of the proposed floodwall heights is selected based on economic optimization of the NED Plan, not the Federal Flood Risk Management Standard released in EO 13690.

An eight-step process is used to ensure compliance with EO 11988; this process involves public review, consideration of practicable alternatives, identification of impacts and measures to minimize those impacts, and presentation of the findings. The NEPA compliance process involves essentially the same basic decision-making process to meet its objectives. Therefore, where possible, the eight-step decision-making process has been integrated into the analysis in this Feasibility Report/EIS, as listed below.

- Step 1: Determine whether the proposed action is in the base floodplain. *As described throughout this document, the proposed project is located within the base floodplain of Makiki, Mānoa, and Pālolo streams, and the Mānoa–Pālolo Drainage Canal and Ala Wai Canal.*
- Step 2: Provide early public review of any plans or proposals for action in the base floodplain. *Multiple opportunities have been provided for public and agency review of the proposed project, as described in Section 6.*
- Step 3: If the action is in the base floodplain, determine whether there is a practicable alternative to the action. *As the project is intended to provide flood risk management, there is no practicable alternative to siting the project features in the base floodplain. A variety of flood risk management measures and alternatives were evaluated, as discussed in Sections 3 and 4.*
- Step 4: Identify beneficial and adverse impacts caused by the proposed action and any expected losses of natural and beneficial floodplain values. *The Ala Wai Watershed is already highly developed, and the proposed action is not expected to induce direct or indirect land use development on the lands immediately adjacent to the streams and canals. Beneficial and adverse impacts associated with the project are identified in Section 5.*

52 These values are based on a gross appraisal dated August 2016..

- Step 5: Determine viable methods to minimize any adverse impacts of the action and methods to restore and preserve the natural and beneficial values. *Potentially adverse impacts are expected to be avoided or minimized through implementation of appropriate mitigation measures, as described in Section 5.*
- Step 6: Reevaluate the proposed action based on the information generated in Steps 4 and 5. *An iterative plan formulation process was completed, as described throughout Section 3.*
- Step 7: Prepare a Statement of Findings and advise the general public if the proposed action will be located in the floodplain. *Multiple opportunities have been provided for public and agency review of the proposed project, as described in Section 6. In addition, this Feasibility Report/EIS is being published for public review.*
- Step 8: Implement the action after completing the seven evaluation steps. *The project will be implemented after a number of further required steps are completed and all pre-construction permits are obtained, based on the implementation requirements and schedule listed in Sections 8.11 and 8.12.*

CCH addresses county-wide floodplain management and flood mitigation in their Multi-Hazard Pre-Disaster Mitigation Plan (CCH, 2012); flooding is specifically discussed in Section 10 and Appendices 10A through 10C. CCH regulations related to floodplain management include Chapter 21.9-10 of the Land Use Ordinance, which defines flood hazard districts and their appropriate uses, such as public parks, conservation, agriculture, wetlands, and planned developments that keep buildings out of the floodplain; intensive development is not permitted. This chapter was amended in 2004 by Ordinance 04-09, requiring new pre-construction and post-construction certification standards for new structures built within a flood zone. Other sections relating to the flood hazard districts were also modified to conform to the language of the NFIP. CCH does not participate in the NFIP Community Rating System (CRS), a voluntary program of the NFIP.

The DLNR maintains a Statewide General Flood Control Plan that addresses floodplain management issues for the State of Hawai'i. This plan is intended to guide the State in identifying and prioritizing areas to best focus its resources and to enhance local decision-making related to storm and flood hazard events. It is also meant to provide public awareness tools and educational information on flood risks, regulatory and preventative measures, proposed initiatives to mitigate flood risks, and an archive library for flood studies and post-flood reports.

USACE guidance requires the non-Federal sponsor to prepare a Floodplain Management Plan (FPMP) designed to reduce the impacts of future flooding in the project area. The primary focus of the FPMP is to address the potential measures, practices, and policies that will reduce impacts of future residual flooding, help preserve levels of protection provided by the USACE project, preserve and enhance natural floodplain values, and reduce the risk of future flood damages to structures within the post-project floodplain and internal drainage issues related to USACE levee/floodwall projects. To fulfill this requirement for the Ala Wai Canal Project, elements of the CCH Multi-Hazard Pre-Disaster Mitigation Plan along with information in this feasibility study would need to be used to create the FPMP.

8.7 Economic and Environmental Principles and Guidelines

As noted in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, the Federal objective of water and related land resources planning is to contribute to national economic development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Achievement of the Federal objective is measured in terms of contribution to Federal accounts intended to track the overall benefits of a given project. A comparison of contributions to the accounts utilizing a number of metrics is included in Table 14. The information below is abbreviated and summarizes the primary contributions of the recommended plan. Contributions to applicable accounts resulting from the Ala Wai Flood Risk Management Study recommended plan are as follows:

- National Economic Development (NED)

Contributions to national economic development (NED) are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation. This value is represented below by the net economic benefit of the recommended plan.

- Regional Economic Development (RED)

Regional Economic Development (RED) consists of changes in the distribution of regional economic activity that result from each alternative plan. Evaluations of regional effects are to be carried out using nationally consistent projections of income, employment, output and population. This value is represented below by the total value of the construction contract associated with the recommended plan.

- Environmental Quality (EQ)

Environmental Quality (EQ) attributes are the ecological, cultural, and aesthetic properties of natural and cultural resources that sustain and enrich human life. Evaluation of EQ in the planning process consists of the assessment and appraisal of effects. Four general actions— define, inventory, assess, appraise—are the phases of these procedures. For the Ala Wai Flood Risk Management Study, contributions to the EQ account are detailed through NEPA compliance and calculation of net ecosystem benefits. This value is represented below by the gain in habitat units provided by the mitigation plan.

- Other Social Effects

Other Social Effects (OSE) evaluates plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts. With emphasis on their incidence or occurrence, beneficial effects on social wellbeing are contributions to the equitable distribution of real income and employment and to other social opportunities. Since they are integrally related to the basic values and goals of society, these effects are usually not subject to monetary evaluation. OSE is evaluated by several metrics in Table 14, but is not represented by a single metric and therefore not included in the table below.

Table 47. System of Principles and Guidelines Accounts Credited to the Recommended Plan

Account	Contribution ($000)
National Economic Development	$35,214 (Annual)
Regional Economic Development	$211,545 (One-time)
Environmental Quality	3736 Habitat Units (Annual)
Other Social Effects	N/A

8.8 USACE Environmental Operating Principles

As part of the Department of the Army, the USACE embraces the four pillars of the Army's environmental strategy: (1) compliance, (2) pollution prevention, (3) conservation, and (4) restoration. Within this context, the USACE reaffirmed their commitment to the environment by formalizing a set of seven environmental operating principles that apply to all USACE decision-making and programs. As specified in ER 200-1-5, the purpose of the EOP is to identify the ways in which the USACE missions should be integrated with natural resource laws, values, and sound environmental practices, as well as to acknowledge the roles and responsibilities of the USACE in the sustainable use, stewardship, and restoration of natural resources (USACE, 2012b). The seven principles, and a statement of how the project complies with each, are as follows:

- Foster sustainability as a way of life throughout the organization.

- *The proposed flood risk management measures have been designed to incorporate environmentally sustainable design considerations, particularly as related to maintaining in-stream habitat and migratory pathways for native aquatic species.*

- Proactively consider environmental consequences of all Corps activities and act accordingly.
  - *The environmental consequences of the proposed project have been considered, and avoided and minimized to the extent possible, as documented in Section 5.*
- Create mutually supporting economic and environmentally sustainable solutions.
  - *As part of the feasibility planning process, the alternatives formulation process accounted for and sought to respond to both environmental and economic considerations through screening and reformulation.*
- Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the Corps, which may impact human and natural environments.
  - *The proposed project is in compliance with applicable laws and regulations related to human and natural environmental impacts, as documented in Section 7.*
- Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs.
  - *Consistent with USACE policies, the project incorporated a risk-based decision-making framework into the feasibility planning process, as discussed in Section 8.3. Risks and uncertainties were considered over the full project lifecycle, including those related to the surrounding environment; these have been (and will continue to be) addressed as part of project implementation.*
- Leverage scientific, economic and social knowledge to understand the environmental context and effects of Corps actions in a collaborative manner.
  - *The feasibility planning process incorporated relevant scientific and social information into the assessment of potential impacts, and development of appropriate mitigation measures. In particular, this process integrated the current knowledge and experience of resource agency staff relative to aquatic resources, as well as knowledge gained from project stakeholders.*
- Employ an open, transparent process that respects views of individuals and groups interested in Corps activities.
  - *A focused stakeholder engagement effort was incorporated into the planning and project development process, so as to ensure that the key stakeholder perspectives were considered as part of the proposed project.*

8.9 USACE Campaign Plan

The mission of USACE is to provide vital public engineering services in peace and war to strengthen the nation's security, energize the economy, and reduce risks from disasters. To meet this mission, the agency has developed the USACE Campaign Plan as a component of the corporate strategic management process to establish priorities, focus on the transformation initiatives, measure and guide progress, and adapt to the needs of the future (USACE, 2013). The project supports three of the four Campaign Plan goals, as follows:

- **Goal 2: Transform Civil Works (Deliver enduring and essential water resource solutions using effective transformation strategies)**
  - Modernize the Civil Works project planning program and process.
  - Enhance and refine the Civil Works budget development process through a systems-oriented watershed approach, priorities, and collaboration.
  - Improve USACE Methods of Delivery to produce quality engineering solutions and services on schedule.

- Deliver reliable, resilient, and sustainable infrastructure systems.

The Ala Wai Canal Project was one of a small handful of studies selected to be part of the USACE National Pilot Program that led the SMART planning groundwork in the transforming of the study process. As detailed in Section 3, the PDT developed and implemented a project-specific approach that incorporated SMART planning principles and improved delivery of a sustainable flood risk management project.

- **Goal 3: Reduce Disaster Risks (Deliver support that responds to, recovers from, and mitigates disaster impacts to the Nation)**
  - Enhance interagency disaster response, recovery, and risk reduction capabilities.
  - Enhance interagency disaster recovery capabilities.
  - Enhance interagency disaster preparation and mitigation capabilities.
  - Strengthen interagency support.

The PDT formulated alternative plans to meet the planning objective to reduce riverine flooding throughout the Ala Wai Watershed; project implementation would significantly contribute to interagency efforts to reduce flood-related risks in the watershed. As part of the planning process, the PDT has also increased awareness of the potential flood risks amongst the project stakeholders, and has coordinated and increased communication with other relevant agencies, thus enhancing interagency disaster capabilities and coordination relative to disaster preparation and response.

- **Goal 4: Prepare for the Future (Build resilient people, teams, systems, and processes to sustain a diverse culture of collaboration, innovation, and participation to shape and deliver strategic solutions)**
  - Maintain and advance [U.S. Department of Defense] DoD and Army critical enabling technologies.
  - Enhance trust and understanding with customers, stakeholders, teammates, and the public through strategic engagement and communication.
  - Streamline USACE business, acquisition, and governance processes.
  - Build ready and resilient people and teams through innovative talent management and leader development strategies and programs.

As part of the study process, the PDT maintained ongoing and open communication with the full range of project stakeholders. As summarized in Section 6, this effort included organization of a variety of stakeholder updates, briefings, and public meetings to achieve a balance of project goals and public concerns. The PDT also coordinated with the USACE Vertical Team and worked closely with the appropriate communities of practice to address the complexities of the project.

8.10 Non-Federal Sponsor Responsibilities (Cost-Sharing)

In accordance with the cost share provisions in Section 103(a) of the WRDA of 1986, as amended [33 U.S.C. 2213(a)], the non-Federal sponsor is responsible for providing a minimum 5 percent cash contribution, all LERRD required for the project, and any additional funds necessary to make its total contribution equal to at least 35 percent of total project costs. In addition, the non-Federal sponsor is responsible for 100 percent of OMRR&R. Table 48 summarizes the specific cost-shared amounts based on the project first cost (October 2016 price level).

The total project cost, which is the constant dollar cost (that is, the project first cost) fully funded with escalation to the estimated midpoint of construction, is estimated to be $352,204,000. This is the estimate used in the Project Partnership Agreement (PPA); these costs would continue to be refined through the detailed design phase.

Table 48. Cost-Sharing Responsibilities for the Recommended Plan

Category	Federal Cost ($000)	Non-Federal Cost ($000)	Total Cost ($000)
Project Features	$151,438	$81,544	$232,982
LERRD	$0	$19,215	$19,215
PED[a]	$42,323	$22,790	$65,113
Construction Management	$22,682	$12,213	$34,895
Subtotal	$216,443	$135,761	$352,204
5 percent Cash Contribution	($17,610)	$17,610	
Additional Contribution	$30,099	($30,099)	
TOTAL (October 2016 price level)	**$228,932**	**$123,272**	**$352,204**
Percent of Total	**65%**	**35%**	

Notes:
[a] PED costs incurred after completion of the Feasibility Report/EIS would be cost shared between the Government and the project sponsors in accordance with a Design Agreement. Upon initiation of project construction, all costs incurred under the Design Agreement would be included as part of the total project costs and subject to the project cost sharing requirements in accordance with the Construction Agreement, which will be executed before award of the first construction contract.

8.11 Views of the Non-Federal Sponsor

As the non-Federal sponsor, the State of Hawai'i DLNR is familiar with their roles and responsibilities, and is aware that would include providing all LERRD and fulfilling the OMRR&R requirements. They have expressed their full support for the proposed project and acknowledged their financial and other implementation responsibilities. These views were expressed by the Governor and the Mayor of the City-County of Honolulu in a letter of support to the USACE dated October 13, 2016.

8.12 Implementation Requirements and Next Steps

If approved by the Civil Works Review Board (CWRB), which also considers public comments, USACE will route the Feasibility Report/EIS for Washington, D.C.-level State and Agency Review. Thereafter, USACE Headquarters would prepare the Chief of Engineers Report. The Chief's Report will be submitted to the Assistant Secretary of the Army for Civil Works, who coordinates with the Office of Management and Budget for the Administration's consideration for the Federal budget and submittal to Congress.

In parallel with seeking congressional authorization and funding, the project sponsors and USACE will develop final design documents as part of the PED phase. A Design Agreement would be executed between the USACE and non-Federal sponsor, detailing the cost-sharing requirements for the development of detailed plans and specifications. Once the report is approved by the Chief of Engineers and the project is authorized by Congress, construction funds must then be appropriated by Congress, following which a PPA must be signed by the USACE and non-Federal sponsor. This agreement would define responsibilities of the non-Federal sponsor for project construction as well as OMRR&R and other assurances. Once the non-Federal sponsor has provided the cash contribution, LERRD, and assurances, consistent with the terms of the PPA, the USACE would proceed with construction of the project. As identified throughout the plan formulation process, there are additional technical studies and design considerations that would need to be addressed as part of the PED phase. Based on current information, it is not expected that any of these efforts would significantly affect the basis of the design, but rather would result in further design refinements. Following is a brief summary of list of key items that would be addressed during the PED phase:

- Topographic surveys
- Geotechnical investigation and design
- Structural analysis

- Electrical and mechanical design development for the pump stations
- Aesthetic improvements (especially along the Ala Wai Canal floodwalls)
- Unsteady flow HEC-RAS modeling
- Evaluation and relocation plans for existing utilities
- Ongoing stakeholder engagement/input

Once the report is approved by the Chief of Engineers and the project is authorized by Congress, construction funds must be appropriated by Congress, following which a PPA would be signed by the USACE and non-Federal sponsor. The PPA would define responsibilities of the non-Federal sponsor for project construction as well as OMRR&R and other assurances. Once the non-Federal sponsor has provided the cash contribution, LERRD, and assurances, consistent with the terms of the PPA, the USACE could proceed with construction of the project, if Federal funds were available.

8.13 Implementation Schedule

If approved by the Chief of Engineers, the proposed project's implementation schedule is dependent on receipt of Congressional construction authorization, appropriation of Federal funding, and availability of non-Federal cost-share funds. Upon availability of both Federal and non-Federal funding, PED activities may be initiated prior to Congressional construction authorization, with execution of a Design Agreement between the USACE and non-Federal sponsor. Once the project has been authorized and construction funds have been appropriated by Congress, the PPA would need to be signed by USACE and the non-Federal sponsor (and real estate acquisition completed), after which construction could start. A notational schedule for implementation is presented in Table 49 assuming appropriation of Federal funds and availability of non-Federal cost-sharing funds in Fiscal Year 2018.

Table 49. Anticipated Construction Schedule

Phase	Notational Schedule (Federal FY)*	2017	2018	2019	2020	2021	2022	2023	2024
Sign Design Agreement	October 2017 – September 2018								
Preconstruction Engineering & Design (PED)	October 2018 - September 2020								
Sign Project Partnership Agreement (PPA)	October 2020 – March 2021								
Real Estate Acquisition	October 2020 – September 2021								
Solicit and Award Contract	October 2020 – September 2021								
Construction	October 2021 – September 2024								

*Subject to availability of funding

Implementation of the project is anticipated through multiple concurrent construction contracts. Given the relatively large geographic distance between the various project features included in the recommended plan, for estimation purposes contracts are assumed to be structured along subwatershed boundaries. This includes the Makiki valley, the Manoa valley, the Palolo valley, and the Ala Wai Canal. Two additional contracts will follow the construction contracts for installation of the flood warning system stream flow gauges as well as monitoring for environmental mitigation features. Construction is anticipated to begin in the upper reaches of the watershed and work downstream in order to ensure that the benefits of flood risk management features are brought on-line as expeditiously as possible.

A cost-schedule risk analysis has been completed for the study and is included in Appendix D. This analysis adds time and funding to address known and unknown risks associated with project implementation. Overall, based on identified risks contingency amounts on the order of approximately 29% have been added to the budget and 78 months have been estimated as additional schedule contingency.

9.0 Recommendation

This chapter describes the Items of Cooperation for a Flood Risk Management (Single Purpose) Project that will be specifically authorized.

Based on October 2016 price levels, the estimated total project first cost of the recommended plan is $306,095,000. In accordance with the cost sharing provisions of Section 103 of the Water Resources Development Act (WRDA) of 1986, as amended [33 U.S.C. 2213(a)], the Federal share of the project first cost would be about $198,962,000 (65 percent) and the non-Federal share would be about $107,133,000 (35 percent). The non-Federal costs include the value of lands, easements, rights-of-way, relocations and disposals (LERRD). The non-Federal sponsor would be responsible for the operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) of the project after construction, a cost currently estimated at about $985,000 per year. Federal implementation of the recommended plan would be subject to the non-Federal sponsor agreeing to comply with applicable Federal laws and policies, including but not limited to:

a. Provide a minimum of 35 percent, but not to exceed 50 percent of total project costs as further specified below:

   1. Provide 35 percent of design costs allocated by the Government to flood risk management in accordance with the terms of a design agreement entered into prior to commencement of design work;

   2. Provide, during the first year of construction, any additional funds necessary to pay the full non-federal share of design costs;

   3. Provide, during construction, a contribution of funds equal to 5 percent of total project costs;

   4. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the project;

   5. Provide, during the design and implementation phase, any funds necessary to make its total contribution equal to 35 percent of total project costs;

b. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized by Federal law;

c. Not less than once each year, inform affected interests of the extent of protection afforded by the project;

d. Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;

e. Comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), which requires a non-Federal interest to prepare a floodplain management plan within one year after the date of signing a project cooperation agreement, and to implement such plan not later than one year after completion of construction of the project;

f. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the project;

g. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the project affords, hinder operation and maintenance of the project, or interfere with the project's proper function;

h. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

i. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;

j. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

k. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

l. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

m. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c et seq.);

n. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

o. Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under

CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;

p. Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

q. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

This recommendation is contingent upon such discretionary modifications as deemed necessary by the Chief of Engineers and funding requirements satisfactory to the Administration and Congress. The recommendations contained herein reflect the information available at the time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendation may be modified prior to implementation. However, the project partner, the State, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

James D. Hoyman
Lieutenant Colonel, U.S. Army
District Engineer

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10.0 List of Preparers

The primary persons responsible for contributing to, preparing, and reviewing the Feasibility Report/EIS are listed in Table 50. Those persons who participated as part of the PDT are indicated with an asterisk.

Table 50. List of Preparers and Reviewers

Name	Primary Responsibility
Michael Wyatt; USACE Honolulu District*	Planner/project manager
Michael Wong, P.E.; USACE Honolulu District*	Hydrology and hydraulics; engineering design
Jarrett Hara, P.E.; USACE Honolulu District*	Hydrology and hydraulics; engineering design
Loren Zulick; USACE Honolulu District*	Cultural and archaeological resources
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Robert Finch; USACE Honolulu District*	Economics
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Table 50. List of Preparers and Reviewers

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Michael Sakai, USACE Honolulu District	DQC Real Estate reviewer
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11.0 Index

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