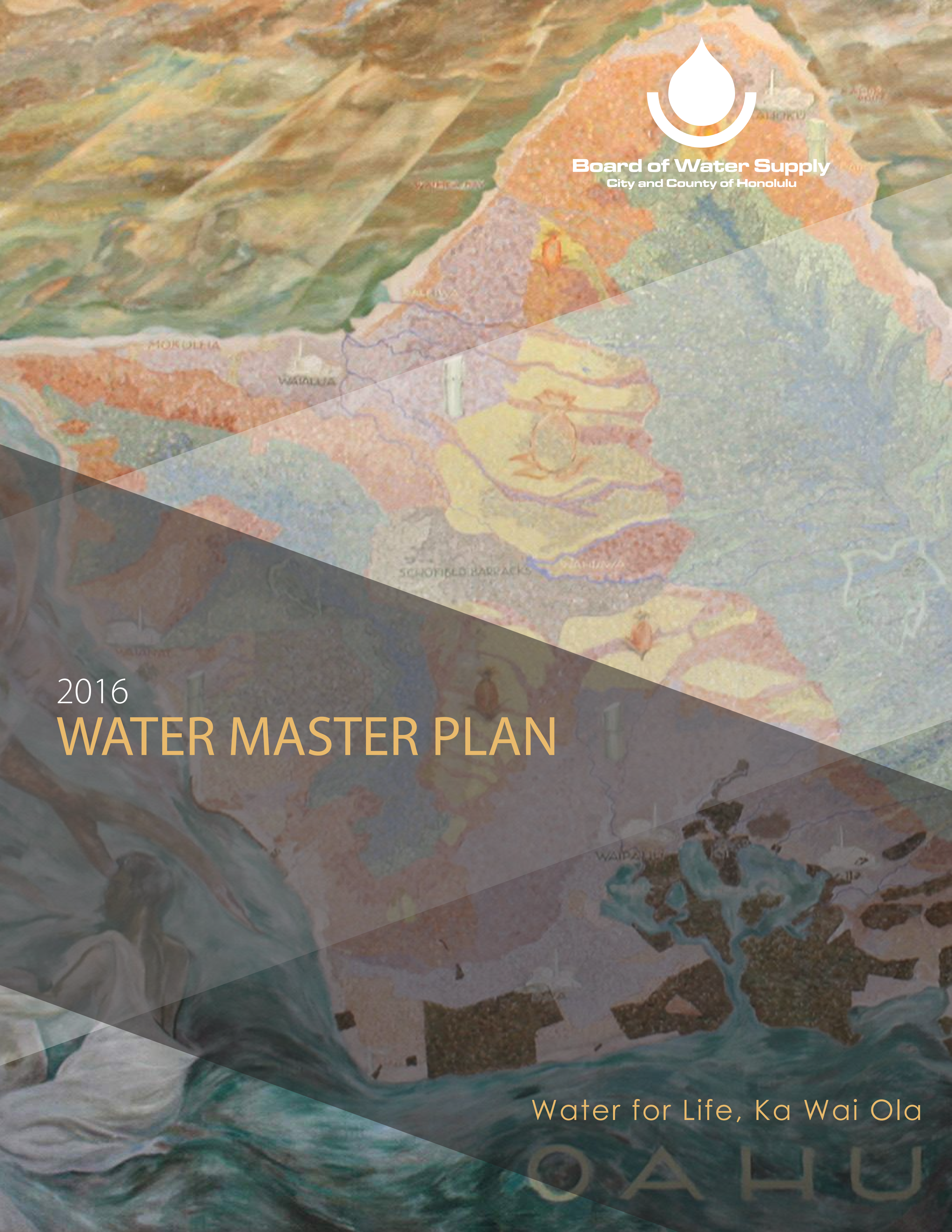

Board of Water Supply
City and County of Honolulu

2016

WATER MASTER PLAN

Water for Life, Ka Wai Ola

BOARD OF WATER SUPPLY
CITY AND COUNTY OF HONOLULU

RESOLUTION NO. 870, 2016

RESOLUTION ADOPTING THE BOARD OF WATER SUPPLY
WATER MASTER PLAN

WHEREAS the Board of Water Supply, City and County of Honolulu takes to heart and is committed to its mission to provide safe, dependable, and affordable water on Oahu now and into the future;

WHEREAS a sound, appropriately sized, operational water system to sustain, capture, treat, move, store, and deliver water to customers is fundamental to that mission;

WHEREAS the water system of the Board of Water Supply, City and County of Honolulu, is aging and in need of targeted investment in renewal and replacement to reduce risk and meet future needs;

WHEREAS long-range water master plans are a best practice of modern water utilities which, when periodically updated to reflect changing conditions can guide sound, well thought out decisions for decades to come;

WHEREAS a multi-disciplinary team has crafted a comprehensive, long term Water Master Plan for Oahu that assesses the current condition of facilities, analyzes and projects water system requirements over a 30-year planning horizon, and recommends improvements prioritized according to risk;

WHEREAS a Stakeholder Advisory Group comprising of diverse community leaders has represented the perspectives and priorities of stakeholders in forming goals for and guiding development of the Water Master Plan;

WHEREAS, following publication of the draft Water Master Plan, the Board of Water Supply, City and County of Honolulu, has informed the public of the Plan's purpose and content, and invited questions and input through presentations, publications, web postings, information distribution directly to customers and through neighborhood boards, as well as soliciting and collecting comments and questions, and responding to all commenters;

WHEREAS the Water Master Plan is intended to be a living document, allowing for flexibility in implementation through periodic updates and adjustment of projects as conditions and needs change, and providing a roadmap for long-term water system planning on Oahu for the next 30 years that supports the mission of the Board of Water Supply, City and County of Honolulu;

WHEREAS the findings of the Water Master Plan will be combined with research to anticipate and adapt to climate change and other emerging impacts;

WHEREAS a financial plan, rate study, and Capital Improvement Programs will be developed to support implementation of Water Master Plan findings; now, therefore

BE IT RESOLVED by the Members of the Board of Water Supply, City and County of Honolulu, that the Water Master Plan dated October 2016 be adopted, thus institutionalizing its findings and direction and embedding them into the Organization, institutionalizing its guidance for decades to come; and

BE IT FURTHER RESOLVED that the Board of Water Supply proceed with implementation of the Water Master Plan and empower the Manager with flexibility for non-substantive adjustments, e.g. does not affect WMP Section 12 recommendations. The Manager shall report to the Board on an annual basis any updates to Water Master Plan, and also the Health of the Water System Scorecard contained in Section 13 of the WMP.

ADOPTED:

BRYAN P. ANDAYA
Chair

Honolulu, Hawaii
October 24, 2016

APPROVED

RESOLUTION NO. 870, 2016, ADOPTING THE BOARD OF WATER SUPPLY WATER MASTER PLAN, ADOPTED ON OCTOBER 24, 2016			
	AYE	NO	COMMENT
BRYAN P. ANDAYA	X		
ADAM C. WONG			ABSENT
DAVID C. HULIHEE	X		
KAPUA SPROAT	X		
KAY C. MATSUI	X		
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2016

Water Master Plan

Honolulu Board of Water Supply

October 2016

Prepared by:

CDM Smith

About the Cover:

Oʻahu Mural, 1940 - Juliette May Fraser

Located in the Board of Water Supply, Engineering Building Lobby, between Lisbon and Alapai Streets, this oil on canvas painting mounted on a panel depicts a map of Oʻahu that shows how and where water is conserved, by whom, and for what purposes the water is used.

According to the 16th Biennial Report of the Board of Water Supply:

"The story of the mural tells The Rainfall Cycle – Kāne, the Life-Giver, incarnate in the Sun as well as the rain, draws the water of life from the sea with the rays of Lā, the Sun.

Supreme in his sea realm lives the great shark god, Kamohoaliʻi.

This water pours from the clouds as rain upon Papa, the Earth Mother, who sits attended by Lono, God of cultivated crops, and Laka, goddess of the wildwood. Circling around the Earth Mother is Moʻo, the lizard, god of fresh water and inshore tides.

In the sky the tradewinds sweep the billowing white clouds, the men dancers in white. The dancers whirl their arms in a motion which is the hula symbol for "wind." As the tradewinds dance, Mahina, the moon, queen of the night and the goddess who governs planting, rides in the heavens in all her effulgence.

And as the drizzle intensifies into a thunder squall, the southerly wind, Kona, stormy and gray hulamaster that he is, thunders and keeps time with his gourd drum in ever-increasing tempo.

The tempest soon passes, Kona silences his gourd drum, and the Earth Mother is left refreshed and reinvigorated, clean and purified by the rain waters, the waters of Kāne."

Acknowledgements

The Water Master Plan (WMP) process was commissioned in 2013 through the vision of the Honolulu Board of Water Supply. Critical to the development of the WMP was a diverse, collaborative team of contributors and reviewers. The following organizations and their staff have dedicated significant time and effort to shaping a reliable, sustainable water future for the people of Oʻahu.

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Abbreviations and Acronyms

µg/L	micrograms per liter
ACI	American Concrete Institute
ADD	average day demand
AL	Action Level
ASCE	American Society of Civil Engineers
AWWA	American Water Works Association
Board	BWS Board of Directors
BWS	Board of Water Supply
CCL	Contaminant Candidate List
CIP	Capital Improvement Program
City	City and County of Honolulu
CoF	consequence of failure
CPD	Capital Projects Division
Cr^{6+}	hexavalent chromium
CWRM	State of Hawaiʻi Commission on Water Resource Management
D/DBPR	Stage 1 Disinfectant/Disinfection Byproducts Rule
DBP	disinfection byproducts
DCP	1,2-dichloropropane
DCR	demand-capacity ratio
DNLR	Department of Land and Natural Resources
DOH	Hawaii State Department of Health
DPP	City and County of Honolulu Department of Planning and Permitting
EPA	United States Environmental Protection Agency
EPS	extended period simulation
EST	Engineering Support Technicians
fps	feet per second
FSMA	Food Safety Modernization Act
FY	fiscal year
GAC	granular activated carbon
GIS	Geographical Information System
gpcd	gallons per capita per day
gpd	gallons per day
gpd/acre	gallons per day per acre
gpd/unit	gallons per day per unit
gpm	gallon per minute
Group	Stakeholder Advisory Group
GWR	Ground Water Rule
KMWP	Koʻolau Mountain Watershed Partnership
LBP	line booster pump
LCR	Lead and Copper Rule
LF	linear feet
LLC	Limited Liability Company
LoF	likelihood of failure

LRP	BWS Long Range Planning group
M	million
MCL	maximum contaminant level
MDD	maximum day demand
MG	million gallons
mg/L	milligram per liter
mgd	million gallons per day
NP	nonpotable
OISC	O‘ahu Invasive Species Committee
OWMP	O’ahu Water Management Plan
PCE	tetrachloroethylene
PDR	Project Definition Report
PFB	probability of future breaks
PMIS	Project Management Information System
PRV	pressure reducing valve
psi	pounds per square inch
PVC	polyvinyl chloride
PWA	pipe wall assessment
QUINCI	Quality Infrastructure Conservation Initiative
R&D	research and development
R&R	renewal and replacement
RO	reverse osmosis
RTU	remote telemetry unit
SCADA	Supervisory Control and Data Acquisition
SOP	Standard Operation Procedure
Standards	2002 State of Hawai‘i Water System Standards
State	State of Hawai‘i
SY	sustainable yield
TCE	trichloroethylene
TCP	1,2,3-trichloropropane
TCR	Total Coliform Rule
TDH	total dynamic head
TOD	transit-oriented development
TTHM	total trihalomethane
UH	University of Hawai‘i
U.S.	United States
USGS	United States Geological Survey
WMP	Water Master Plan
WMWP	Wai‘anae Mountains Watershed Partnership
WRF	Water Recycling Facility
WUP	Water Use Permit
WWTP	wastewater treatment plant

Glossary

ahupuaʻa – Ancient Hawaiian land division roughly following the contours of watersheds.

Aquifer – A water bearing geological formation that stores and/or transmits water, such as to wells and springs.

Aquifer sector area – A large region which reflects broad hydrogeological similarities yet maintains traditional hydrographic, topographic, and historical boundaries where possible. Oahu is divided into seven aquifer sector areas: North, Waiʻanae, Central, Windward, Pearl Harbor, Honolulu, and ʻEwa Caprock.

Aquifer system area – An area within an aquifer sector area showing groundwater hydraulic continuity.

Average day demand – The average daily water volume delivered to the system over the course of one year.

Booster pump station – A water pump station that moves water along a transmission system or lifts water into a higher pressure zone. The BWS has both potable and nonpotable booster pump stations.

Capacity analysis – An evaluation to determine the ability of the water system to meet Water System Standards under current and future demand conditions.

Capacity expansion project – Projects needed to serve existing or future demands as identified by Standards or evaluation of system capabilities.

Capital Improvement Program – Identification and schedule of capital projects needed to maintain the BWS infrastructure. The BWS capital improvement program identifies funding requirements for renewal and replacement (R&R), research and development (R&D), and capacity expansion projects.

Capital cost – A capital cost represents the total cost to bring a project to operable status. It can therefore include the cost of planning, permitting, environmental assessment, design, construction, construction management, and startup. As used in the Water Master Plan, capital costs estimates do not include the cost of land.

Condition assessment – An objective evaluation of infrastructure (e.g., pipelines, reservoirs, pump stations, etc.) by qualified professionals to determine deficiencies and identify potential repair or replacement needs.

Construction cost – The anticipated cost to build a project by hiring a responsible, qualified contractor selected through a public low bid process.

Consequence of failure (CoF) – The impact of a potential failure of a water system infrastructure component, for example the failure of a particular pump station. CoF is one part of the equation to determine risk.

Dike – In the higher elevations, where rainfall is concentrated, groundwater is restrained by impermeable vertical rock structures called "dikes" formed by lava flows that intrude into existing, permeable rocks.

Distribution main – A smaller size water pipeline, typically less than 16 inches in diameter. See also Transmission main.

Domestic use – Water for household purposes such as drinking, bathing, heating, cooking, and sanitation. Domestic water use also includes non-commercial outdoor purposes such as watering lawns and gardens.

Groundwater – Water found below the surface of the ground, filling the porous spaces in soil, sediment, and rocks. Groundwater originates from rain and is the source of water for aquifers, springs, wells, and tunnel supplies.

Hydraulic model – A computer-based, mathematical model that is used to analyze the behavior of the BWS piping, pumping, and water storage system under existing and future conditions.

Kuleana – A cultural concept meaning responsibility.

Likelihood of failure (LoF) – The probability that a component of the infrastructure will fail.

Line booster pump station – A type of booster pump station that moves water along a major transmission main. See also Booster pump station.

Main break – A common measure of pipeline condition. Whereas most agencies only count major blow-outs or catastrophic pipe ruptures as breaks, the BWS includes the identification and repair of pipe leaks in its main break count, if the leak is on a pipe that is four inches in diameter or larger.

Maximum day demand – The maximum water use in a 24-hour period during the year, which generally occurs during the maximum month of usage in summer. Maximum day demand occurs around August or September for the BWS system.

Municipal use – The domestic, industrial, and commercial use of water.

Nonpotable water – Water that does not meet State Department of Health drinking water standards. The BWS has separate nonpotable systems that are used only to provide water for industrial and irrigation purposes.

Peak hour demand – The peak one-hour period of flow on the day of maximum demand.

Peaking supply – Supplementary supplies used to meet peak hour demands in certain areas.

Potable water – Water fit or suitable for drinking.

Pressure zone – An area of service within a water distribution system that is served by a source(s) or booster pump station(s) that provides the same range of hydraulic gradient.

Renewal and replacement project – A type of capital improvement project that provides for improvements to existing infrastructure.

Research and development project – A type of capital improvement project that provides for development of data or consultant services. Recent examples of R&D projects are Red Hill Groundwater Monitoring Wells and Waikele Gulch exploratory well.

Stakeholder Advisory Group – A diverse group of volunteer community leaders who provide a community perspective to the Water Master Plan.

Risk – Risk equals the likelihood of failure times the consequence of failure.

Standards – See Water System Standards.

Surface water – Water in streams or lakes.

Sustainable yield – The withdrawal rate of groundwater that could be sustained indefinitely from an aquifer without reducing either the quality of the pumped water or the volume of the aquifer. Meant to be a guide for planning.

Transmission main – A larger size water pipeline, 16 inches or larger in diameter. See also Distribution main.

Water Management Area – A geographic area which has been designated pursuant to Hawaiʻi Administrative Rules Title 13 Chapter 171 as requiring management of the ground or surface water resource, or both. Designated by the Commission on Water Resource Management when it is determined that water resources in the area may be threatened by existing or proposed withdrawals or diversions of water.

Water pumpage – The volume of water pumped, generally from a groundwater source.

Water source – A place where water comes from. The BWS potable water sources include groundwater aquifers and tunnels. Its nonpotable water sources include recycled water, and brackish and nonpotable wells.

Water System Standards – The State of Hawaiʻi Water System Standards with amendments. The current Standards are dated 2002, but are updated with amendments that are considered part of the Standards. The Standards cover planning, materials, construction, approved material list and standard details for Board of Water Supply, Department of Water Supply - County of Hawaiʻi, Department of Water – County of Kauaʻi, and Department of Water Supply - County of Maui.

Watershed – An area of land that is defined by ridgelines and drains into a distinct stream.

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Part I

Background and Approach

Section 1

Water Master Plan Background and Approach

The City and County of Honolulu Board of Water Supply (BWS) for the City and County of Honolulu (City) serves approximately 145 million gallons per day (mgd) of potable water and 10 mgd of nonpotable water to roughly one million customers on Oʻahu. The municipal potable water system provides dependable service through a complex system of 2,100 miles of pipe, 386 source and booster pumps, 212 water sources (wells, tunnels, and shafts), and 171 water storage reservoirs. The BWS provides nonpotable water for irrigation and industrial uses through a water recycling facility and several separate brackish sources. Groundwater is the only source for the BWS potable water supply, coming from naturally filtered aquifers that can withstand periods of drought. The BWS water system delivers high quality water at quantities to provide for the health and safety of the community and has built-in redundancies and resiliency, but, as is typical with water systems of this size, some of the infrastructure is aging and needs attention.

The BWS is committed to providing the people of Oʻahu with safe, dependable, and affordable water now and into the future. To ensure that commitment is met efficiently and effectively, the BWS proactively undertook this Water Master Plan (WMP), a comprehensive program that looks ahead 30 years to evaluate the entire water system, quantify future demands and source options, identify necessary improvements, and balance needs and costs of providing water to residents and visitors. This WMP provides an updated, comprehensive understanding of Oʻahu's water supplies, water needs, and the water system, giving the BWS a roadmap to meet future needs, establish priorities, and adopt sustainable financing strategies.

The BWS engaged in a rigorous three-year process to develop the WMP. The work effort integrated multiple elements in formulating the plan recommendations, including consistency with watershed management plans and development of strategies to ensure long-term sustainability in the face of growth, climate change, and other challenges. The analysis included performing a thorough condition assessment of the BWS's infrastructure, developing hydraulic models for the entire BWS system, performing hydraulic evaluations of the water systems, and assessing necessary system improvements. The WMP also provides the basis for identifying and prioritizing Capital Improvement Program (CIP) projects and a sustainable financial program. The BWS Board of Directors (Board) will be adopting the WMP as the comprehensive "living" document for future water system improvements.

1.1 BWS History

The BWS was created in 1929 in response to public outcry for effective water management that would be free from political influence. In the years prior, multiple years of wasteful water use, droughts, and ineffective management led to reduced aquifer levels and water shortages. The BWS was formed by the territorial legislature as a semi-autonomous agency, thus separating water management on Oʻahu from political influence, which had been destructive over the past decades. The BWS's responsibilities include the undertaking of investigations, surveys, and compilation of data relating to Oʻahu's water resources and their development, utilization, and conservation. The BWS has continued to strive for far-sighted planning and more efficient management of the water system.

The BWS's governance structure was established by State law and continues to date. Each member of a seven-member board serves five-year staggered terms, to retain depth of understanding for the complex issues that are common to water service management. Five members are appointed by the Mayor with confirmation by the City Council. The remaining two members are ex-officio: the Director of the State Department of Transportation and the Engineer of the City Department of Facility Management. Among their responsibilities and powers, the Board appoints the Manager and Chief Engineer of the BWS, sets important policies, approves budgets, fixes water rates and charges, issues revenue bonds, acquires real property, and prescribes and enforces rules and regulations having the effect of law.

1.2 WMP Approach

The BWS's water master planning process involved extensive research and analysis to arrive at recommendations for improvements over the next 30 years. The WMP approach included efforts to:

- Assess existing conditions of pipes, pumps, reservoirs, wells, treatment plants, and other facilities;
- Develop and compare projections of future (2040) needs with existing water supplies and infrastructure;
- Identify needs for future supplies and improvements to existing facilities;
- Develop CIP projects and a prioritized 30-year CIP (with a more detailed focus of the first 10 years) based on risks to the system and providing reliable service to customers; and
- Develop a comprehensive plan to implement improvements, including priorities, schedules, costs, financing, and rates, in conjunction with the CIP.

The methodologies for the main work elements of condition assessment, system evaluation, and improvement projects development are discussed below.

1.2.1 Facility Condition Assessment

Approximately 10 percent of the BWS pipelines and reservoirs are over 70 years old, with 2 percent of each older than 85 years. As facilities age and approach the end of their useful lives, they begin showing signs of wear and tear, sometimes failing outright. The BWS was aware of the system's age and decided to undertake the most comprehensive condition assessments ever conducted for O‘ahu's water system to provide data that would help determine where to spend funds based on criticality and condition. The BWS evaluated all of its potable water storage reservoirs, granular activated carbon (GAC) treatment facilities, and pump stations, and the physical condition of selected critical pipelines, tunnel facilities, and Base Yards. The condition assessments were an important source of information for the WMP's identification of significant infrastructure risks to O‘ahu's water system and prioritization of necessary repair, rehabilitation, and replacement projects.

Evaluation methods varied depending upon the type of facility, accessibility, potential problems, and information desired. They ranged from physical evaluation to analyzing data gathered using state-of-the-art technology.

1.2.2 System Capacity Evaluation

The BWS developed hydraulic models of its water system to evaluate the existing system under both current and future demand conditions, identify deficiencies, and evaluate capital and/or operational improvements to address these deficiencies. The water system was divided into 13 separate sub-systems (10 potable and 3 nonpotable) and a hydraulic model was developed for each, covering different geographic areas.

The hydraulic models simulated how each water system works, using inputs of water demands, daily demand patterns, and locations and operational characteristics of pipelines, pump stations, reservoirs, wells, tunnels, and valves. The model outputs included flows at wells and pump stations, water pressure, and reservoirs levels. Each system was evaluated for its ability to meet operational standards during average conditions, peak demand periods, and firefighting flow conditions.

1.2.3 System Improvements Development

In identifying projects for system improvement, the BWS develops projects in three primary categories: renewal and replacement (R&R); capacity expansion; and research and development (R&D). R&R and capacity expansion are the two largest categories of projects included in the annual and rolling six-year BWS CIPs. Within those categories, the system improvements projects are evaluated and placed within five major groups, consisting of pumps, reservoirs, pipelines, treatment facilities, and operating facilities.

The condition assessment efforts discussed in Section 1.2.1 resulted in the development of the majority of the R&R projects included in the 30-year CIP. Capacity expansion projects included expansion or enlargement of existing facilities (i.e., pump stations, reservoirs, pipelines, or treatment facilities), or development of new projects to meet the existing and future needs of the BWS system. Capacity expansion projects were identified by the hydraulic models and driven by existing and future water demands and the need to provide additional infrastructure in order to meet those demands. These projects were developed by evaluating the existing and future system needs against specific criteria and standards. The BWS uses water system standards applicable to all of the Hawaiian Islands with specific amendments for its system.

Some projects identified, particularly alternative supply or major infrastructure expansions, will require additional studies or planning to determine the most feasible alternative before moving them forward into design phases. These study/planning R&D projects include items such as exploratory groundwater wells, feasibility studies to optimize water systems, facility siting studies, and environmental documentation. Climate change research on impacts to resource sustainability and sea level rise vulnerability are ongoing, but are funded by the BWS Operating budget.

1.3 WMP Report Organization

This report highlights the key findings from the WMP process. Important findings in Sections 4 through 11 are summarized at the beginning of each chapter and identified with a code (for example, DMND-1 for the first finding in the section on water demands). These codes are repeated in Section 12 to easily tie findings from each section to the recommendations for BWS action listed in Section 12.

The WMP has 13 sections organized into 3 parts. These parts group together similar types of sections to help guide readers to relevant information.

Part I – Background and Approach

- Section 1, *Water Master Plan Background and Approach*, describes the purpose of the WMP and summarizes the methodology used to develop the report.
- Section 2, *Related BWS Work*, connects the WMP efforts to programs and initiatives that are guiding BWS actions and presents the WMP objectives.
- Section 3, *Stakeholder Advisory Group Recommendations,* describes the purpose and process behind the Stakeholder Advisory Group.
- Section 4, *Water Supply Sustainability*, discusses BWS efforts to ensure that water supply is managed in a sustainable way, consistent with the principles of *conserve*, *recharge*, and *reuse*.
- Section 5, *Water System Planning Standards,* presents the planning criteria used to define operating performance of the water system infrastructure.
- Section 6, *Description of BWS Water System*, presents an overview of the island-wide system and characteristics of the 10 individual modeled water systems.

Part II – Technical Evaluation

- Section 7, *Historical and Future Water Demands,* provides recent water demand trends, the demand projection methodology, and the projected future water demands by each water system.
- Section 8, *Current and Future Water Supply Sources,* addresses the existing water supply sources in the BWS service area, water use and facilities, trends, and uncertainties related to these supplies, and potential future supply sources.
- Section 9, *Water Quality, Regulations, and Treatment,* reviews current and future water quality regulations and potential water quality issues that may affect the BWS water system.
- Section 10, *System Capacity Evaluation*, provides the results of the hydraulic evaluation of each water system.

- Section 11, *Facility Condition Assessment,* summarizes the condition assessments conducted on the BWS's pipelines, reservoirs, pump stations, wells, base yards, and treatment facilities, and presents recommendations for improvements.

Part III – Findings and Implementation

- Section 12, *Findings and Recommendations,* provides the findings drawn from the planning and assessment efforts and a high-level summary of the CIP projects recommended over the 30-year planning horizon.
- Section 13, *Implementation,* reviews the range of issues, in addition to infrastructure planning and prioritization, that are necessary for successful implementation of the WMP and the approach and rate of CIP implementation.

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Section 2

Related BWS Work

Over the past several years, the BWS has further defined its mission and vision, the principles that are the basis of the BWS's management of Oʻahu's water supplies. The WMP supports the multi-tiered planning effort of Oʻahu's General Plan, regional watershed plans, and City plans and policies. The BWS also embraced input from outside the utility by creating the Stakeholder Advisory Group (Group). Section 2 discusses the water management framework and introduces the WMP's objectives developed by the Group. Additional information on BWS programs is described in more detail in Section 3, Stakeholder Advisory Group, and Section 4, Water Supply Sustainability.

2.1 Guiding Principles

2.1.1 Vision

The BWS's vision is Ka Wai Ola, Water for Life. This vision, the motivating force behind BWS planning policies and actions, captures the critical need of water – that water is the basis for life. With this vision comes the responsibility of the BWS's stewardship of and the duty to manage our natural water resources for both present and future generations. The ancient Hawaiians valued water as one of nature's greatest gifts and they lived in harmony with water. Land divisions (ahupuaʻa) mirrored the natural ecosystem – land was divided according to watershed boundaries, spanning from the mountain tops through upland forests to flatlands and the shore. Formal rules governed the use of water and regulations were established and enforced in order to cultivate the resources in each ahupuaʻa, to conserve as much as possible to lower the stress on the resources, and to ensure that a pure supply was available to everyone whether they lived in the mountains or close to the sea.

2.1.2 Mission

In Hawaiʻi, water is a public trust and the BWS serves its customers with this trust in mind. The mission of the BWS is to provide a safe, dependable, and affordable water supply now and into the future.

Safe addresses the multiple areas of individual and community needs. Water must meet all statutory and regulatory compliance standards in providing water for consumption and other uses. Water must provide for public health and safety such as for firefighting and sanitation needs.

Dependable relies upon three factors:

- Sources of water must be sufficient and available now and into the future. The BWS ensures this through management of the watershed and groundwater supply, long-range planning, and possible development of alternative sources of water.
- A water system that is designed, constructed, and operated with system redundancy that continues delivery of water even with disruptions in the system.
- Employees of the BWS who are committed to providing their customers with high quality water and excellent service.

Affordable water delivery is primary. The BWS establishes programs for efficiency in water use through conservation, infrastructure installation, and water system operations and maintenance. The BWS continually implements changes to its systems to deliver water at the most responsible cost to the customer.

2.1.3 Strategic Plan

To continue to efficiently and effectively fulfill this important mission, the BWS developed a 3-year Strategic Plan[1] in 2014. The Strategic Plan provides an internal and external perspective of the commitment of the BWS employees to deliver its mission through focus on three strategic goals – resource, operational, and financial sustainability. These three strategic goals are interrelated and coordinated with the three main points of the BWS's mission. The WMP's evaluations and recommendations are direct efforts to support the BWS's goals of resource sustainability and operational sustainability and to inform sustainable financial planning.

Resource Sustainability
Protect and manage our groundwater supplies and watersheds through adaptive and integrated strategies.

Operational Sustainability
Foster a resilient and collaborative organization utilizing effective and proactive operational practices consistent with current industry standards.

Financial Sustainability
Implement sound fiscal strategies to finance our operating and capital needs to provide dependable and affordable water service.

For each goal, the Strategic Plan established the specific objectives presented in Table 2-1, each of which is relevant to and informs this WMP.

Table 2-1 BWS Strategic Plan Goals and Objectives

Strategic Goals	Category	Strategic Objectives
Resource Sustainability	Climate Change	We will adapt to climate change to manage O'ahu's water resources and protect the limited water supply.
	Water Quality	We will protect, preserve, and collaborate to ensure the safety and quality of O'ahu's fresh water resource.
	Communication	We will communicate the value of water to engage the community in a shared stewardship of O'ahu's water resources.
Operational Sustainability	Organization	We will ensure the necessary workforce and competencies to support the BWS needs.
	Infrastructure	We will renew and improve the water system to ensure water system adequacy, dependable service, and operational efficiency.
	Customer Service	We will proactively and consistently provide a quality experience in every customer interaction.
	Technology	We will ensure that our technology systems are current and leverage opportunities in technology to effectively support current and future BWS needs.
Financial Sustainability	Financial Management	We will pursue and leverage financial opportunities and implement strategies to affordably meet our financial and regulatory requirements.

[1] BWS. Strategic Plan 2014 – 2017. Available at: http://www.boardofwatersupply.com/files/BWS%20Strategic%20Plan%202014-2017.pdf. August 25, 2014.

To achieve these objectives, a variety of initiatives are underway that align with the Strategic Plan. Among them are the WMP, development of watershed management plans (discussed in more detail below), the BWS's Water Conservation Plan (described in Section 4), and its Energy Savings Program (not discussed in this WMP), as depicted in Figure 2-1.

Figure 2-1
BWS Plans and Programs that Relate to the WMP

2.2 Programs and Initiatives Guiding the WMP

A number of island-wide and BWS initiatives and partnerships helped to guide and inform development of the WMP.

2.2.1 O'ahu General Plan

The City's General Plan is a statement of O'ahu's long range objectives for the welfare and prosperity of the people of O'ahu by describing social, economic, environmental, and design policies to guide land use and development decisions. The General Plan guides land use and development for 11 areas of concern: population; economy; natural environment; housing; transportation and utilities; energy; physical development and urban design; public safety; health and education; culture and recreation; and government operations and fiscal management.

The General Plan is the top tier in a three-tier planning system. Under the O'ahu General Plan are the regional Development Plans and Sustainable Communities Plans. Implementing ordinances and regulations are then developed to put into effect the policies set forth through the plans. The General Plan establishes objectives for population distribution by considering limited natural resources and efforts to minimize social, economic, and environmental disruptions. As such, it sets the stage for where future growth will occur, focusing on areas that are best suited to accommodate sustainable growth.

2.2.2 Watershed Planning

In pre-contact Hawai‘i, the land was divided into ahupua‘a which mirrored the lines of natural watersheds and ecosystems. Their boundaries extended from the mountains, through upland forests, streams and lowlands, and to the coral reefs. There was access to upland forests for timber, stream water for drinking, agricultural lands for crops and the ocean for fishing and travel by sea. Cultural concepts like kuleana (responsibility), pono (fairness and morality), and kapu (code of conduct of laws) governed the ahupua‘a. No one could take more than what they could use, and stiff penalties existed. The ahupua‘a principle ensured natural systems were kept in balance and acknowledged inherent relationships between land and sea (mauka and makai), natural resource management and cultural practices (which are one and the same), and between water and life. Rules guided people’s behaviors. The ahupua‘a principle is more than a division of land; it also embodies resource management through a balance of environmental, economic, and social/cultural values.

The BWS continues the ahupua‘a principle through its watershed planning processes. Chapter 30, Water Management, of the Revised Ordinances of the City established the O‘ahu Water Management Plan (OWMP), which is a resources management plan, unlike the infrastructure planning of the WMP. The OWMP is required by State law (Hawai‘i Revised Statute 174c, the State Water Code) and becomes a part of the Hawai‘i Water Plan. Each county is required to develop its own plan that is adopted by ordinance by the respective county council.

The OWMP has evolved into a framework of eight regional watershed management plans, one for each City land use district, prepared by the City Department of Planning and Permitting (DPP) and the BWS to provide short-, mid-, and long-range guidance for the sustainable management and use of O‘ahu's valuable and finite surface and groundwater resources in meeting demands consistent with City land use plans. The OWMP goal is to formulate an environmentally holistic, community based, and economically viable watershed management plan that will provide a balance between: 1) the protection, preservation and management of O‘ahu’s watersheds; and 2) sustainable groundwater and surface water use and development to serve present users and future generations. Five major objectives are common to all watershed management plans[2]:

- Promote sustainable watersheds;
- Protect and enhance water quality and quantity;
- Protect native Hawaiian rights and traditional and customary practices;
- Facilitate public participation, education, and project implementation; and
- Meet future water demands at reasonable cost.

The BWS began the development of the district-wide watershed management plans in 2004. The plans are developed with input from community stakeholders and neighborhood boards, and

[2] BWS. 2015. *North Shore Watershed Management Plan, Public Review Draft.* Prepared for BWS. Prepared by Group 70 International. Available at: http://www.boardofwatersupply.com/files/NSWMP_PublicReviewDraft_11.3.15.pdf. November 2015.

align with State and City policies. The plans contain district-specific policies, watershed and water supply projects, programs, and strategies to address a range of surface water, groundwater, land management, cultural resources, and water supply issues. Implementation of the plans is a long-term, ongoing process involving many project champions from public agencies, non-profit entities, community groups, and private land owners and businesses. Funding of these projects will potentially be provided by various federal, state, and city programs and agencies, and by private foundations and businesses.

The BWS's long-term planning incorporates this watershed approach and information from the watershed management plans because water systems must be designed to align with land use plans and provide available water supplies where demand for water is located. The siting of new sources needs to explicitly account for the complexities of watersheds including available sustainable yields in areas that do not impact stream flows and their associated habitat, traditional and customary practices, water rights, and near shore waters. Siting of new sources must also account for the long-range water needs of agriculture and should not detrimentally affect existing sources of water supply.

The Waiʻanae, Koʻolauloa, and Koʻolaupoko watershed management plans are complete. The ʻEwa, Central Oʻahu, and North Shore watershed management plans are under development, with the North Shore submitted for adoption. The Primary Urban Center's plan will begin shortly, and the East Honolulu watershed management plan will be the final plan to be developed.

2.2.3 Hawaiʻi Fresh Water Initiative

The Hawaiʻi Fresh Water Initiative was launched in 2013 to bring multiple, diverse parties together to develop a forward-thinking and consensus-based strategy to increase water security for the Hawaiian Islands. Organized by the independent, nonprofit Hawaiʻi Community Foundation, the Initiative relied on the Hawaiʻi Fresh Water Council, a blue ribbon advisory panel of individuals with deep knowledge of water and a collaborative spirit, to articulate a vision for a more secure and sustainable water future based on shared values and shared sacrifice. Their "Blueprint for Action" is the result of this work and provides Hawaiʻi policy and decision-makers with a set of solutions that have broad, multi-sector support in the fresh water community that should be adopted over the next three years to put Hawaiʻi on a path toward water security. The Blueprint presents a state-wide goal of 100 mgd in additional fresh water capacity and focuses on three aggressive water strategy areas and individual targets that the public and private sectors must work together to achieve by 2030[3]:

- Conservation: Improve the efficiency in how water is transported and used so that each Hawaiʻi resident requires 15 percent less water per capita to meet our needs.
- Recharge: Increase Hawaiʻi's ability to capture rainwater in key aquifer areas by improving stormwater capture and nearly doubling the size of our actively protected watershed areas. By 2030, this goal will provide 30 mgd in increased water availability.

[3] Hawaiʻi Community Foundation. 2015. *Hawaiʻi Fresh Water Initiative, A Blueprint for Action: Water Security for an Uncertain Future, 2016 – 2018*. Available at: http://www.boardofwatersupply.com/files/Fresh_Water_Blueprint_FINAL_062215_small.pdf.

- Reuse: More than double the amount of wastewater currently being reused in the Islands to 50 mgd. By 2030, this goal will provide an additional 30 mgd in increased water availability.

The BWS is a partner in the Fresh Water Initiative and has worked to incorporate the three water strategy areas into its resource planning. The BWS has a long and successful track record of promoting water conservation, as evidenced by the reduction in per capita water use in the last 30 years (conservation efforts are further discussed in Section 4 and Section 7, Historical and Future Water Demands). The BWS has developed a recycled water system that provides eight mgd of supply for irrigation needs in ʻEwa (recycled water is further discussed in Section 4 and Section 8, Current and Future Water Supply Sources). The BWS is also investigating stormwater capture in the Nuʻuanu Valley and, if successful, will add critical supply to the Honolulu aquifer system (see Section 4).

2.2.4 BWS Stakeholder Advisory Group

In April 2015, the Board of Directors of the BWS approved the formation of a Stakeholder Advisory Group whose purpose is to provide important feedback on the WMP, rate study, and other important initiatives. The Group is one of many BWS initiatives that demonstrate its commitment to increase the consistency, responsiveness, and transparency of the BWS's communications and public engagement. The Group, described in more detail in Section 3, is helping the BWS obtain valuable feedback from respected professionals and community representatives to ensure their needs are considered as the WMP is developed. The Group consists of approximately 28 highly respected local residents and community leaders with expertise in many disciplines and who have an active and ongoing interest in issues relevant to the BWS. The Group represents diverse communities, interests, and geographies across Oʻahu.

The Group has provided feedback related to the WMP, as well as other BWS issues, including but not limited to water conservation, customer services, field services, outreach and education, and future rate adjustments. They also provided input on the objectives for the WMP planning process. Although the Group functions in an advisory capacity and does not have decision-making authority, it will make recommendations to the BWS management and Board, which have expressed their intent to consider and implement, if appropriate, the Group's recommendations.

2.3 WMP Objectives

The BWS Stakeholder Advisory Group has developed the following objectives shown in Table 2-2 for the WMP using a consensus-based process. These plan objectives support the BWS's water resource planning efforts and the ahupuaʻa model of sustainable resource management. In a world of limited resources, meeting these objectives will require fiscal prudence, balance, sensitivity, and shared kuleana. These objectives enable the BWS to fulfill its roles and responsibilities in a larger system of agencies contributing to the management of water resources.

Table 2-2 Water Master Plan Objectives

Main Objective	Detailed Objective
Water Quality, Health, and Safety	▪ Potable water is consistently safe to drink. ▪ All water supplied, including potable and nonpotable water, meets or is better than applicable regulatory standards and is suitable for its intended water use. ▪ Water system facilities are secure as well as structurally and operationally sound, protecting the public, employees, and the community. ▪ The exceptional natural quality of O'ahu's source water is sustained.
System Reliability and Adequacy	▪ Water service is uninterrupted and at proper pressures, when and where it's needed. ▪ Water system is designed, constructed, and maintained to consistently support vital emergency services, such as hospitals and fire protection, and withstand long-term impacts of climate change. ▪ System protections support basic functions during natural disasters.
Cost and Affordability	▪ Infrastructure project expenditures integrate system needs, community values, innovation, and affordability for current and future ratepayers. ▪ Water system is designed and operated to deliver water at the most responsible cost to the customer. ▪ The price of water is transparent and reflects the whole cost of providing water to present and future generations (e.g., watershed protection, infrastructure investment, sufficient financial and staff resources, maintenance, planned management, and long-term water sustainability). ▪ Achieve water and energy efficiency and conservation via infrastructure design and construction, system operations and maintenance, and consideration of renewable energy options.
Water Conservation	▪ Achieve water conservation to optimize resource sustainability via: using and promoting best management practices and policies; infrastructure design and construction; system operation and maintenance; conservation planning; and providing information, education, and incentives to achieve behavioral change.
Water Resource Sustainability	▪ Water sources are protected and available now and into the future by: proactively managing and improving the watershed and groundwater supply; conducting long-range planning and taking action to address risks, and adapting to climate change; engaging in and supporting long-term watershed partnerships, and ensure consultation with regard to the effect of land use on water sources; pursuing alternative sources of water where reasonable and practicable (e.g., stormwater, recycled water, brackish water and seawater).

These WMP objectives are similar to those of the watershed management plans, touching on the same important areas of responsibility. These alignments are depicted in Figure 2-2.

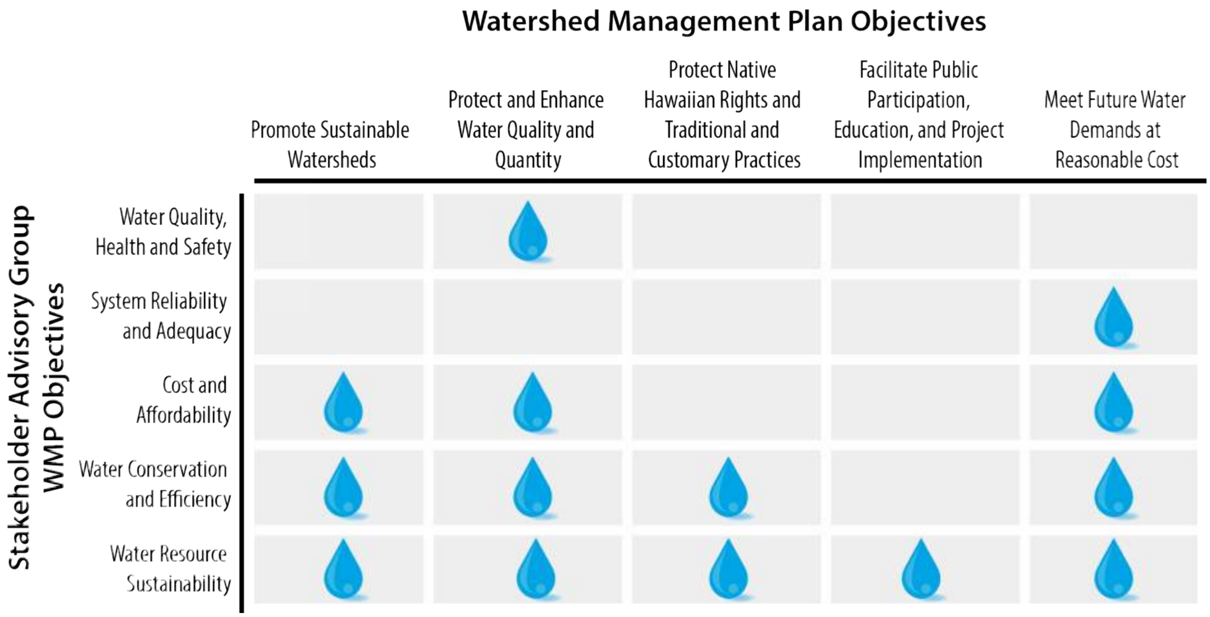

Figure 2-2
Alignment of the WMP Objectives and Watershed Management Plan Objectives

Section 3

Stakeholder Advisory Group

This section describes the purpose and process behind the BWS's convening of a Stakeholder Advisory Group (Group) to contribute a community perspective to the WMP. The stakeholder group also is providing guidance on other BWS initiatives and will develop recommendations to the BWS management and Board regarding both the amount and structure of water rates to support the findings of the WMP.

Section 3 **provides information that addresses the following WMP objectives:**

- Water Quality, Health, and Safety
- System Reliability and Adequacy
- Cost and Affordability
- Water Conservation
- Water Resource Sustainability

3.1 Key Findings

The Group has been an important element in the WMP development, providing input on the priorities, objectives, and contents of the WMP. Their continued involvement through the rate setting process will provide the BWS with perspectives as a new rate structure is developed that provides for sufficient infrastructure reliability while balancing costs and affordability.

3.2 Purpose and Background

Concurrent with early development of the WMP, the BWS faced an intensive period of challenges, including issues with implementation of a new electronic customer information system, public fall-out from a long-overdue rate increase, and confusion over a change to monthly billing. As it successfully addressed and resolved these issues, significantly improving service to customers, the BWS also committed to strengthen contact and communication with its customers, communities, and stakeholders to be more responsive to the community and to increase public involvement in its functions, plans, and programs. The resulting public engagement strategy included a new customer newsletter, additional publications explaining the scope and complexities of the water system and its operations, a continued presence at Neighborhood Board meetings and public events, and establishment of the Group. By establishing and meeting regularly with this Group, the BWS sought to share information and, most importantly, to hear directly from community leaders the perspectives, values, and ideas of diverse interests across O'ahu.

Understanding the intensity of commitment that would be asked of Group members, the BWS determined it would be best to engage the Group at a point in the WMP process when technical study results would be available. Efforts to form and launch the Group began in January 2015, allowing time for careful decision-making related to the scope of topics it would address, organizations and communities of interest to involve, meeting format, meeting documentation, public sharing of meeting notes, and myriad other details that would provide for timely and smooth implementation.

Through the Group's on-going participation, the Board seeks to learn more about the water-related perspectives and concerns of varied constituencies. Through the Group's links with organizations and communities of interest, the BWS seeks to strengthen the public's understanding of Oʻahu's complex water issues and enhance public confidence of the BWS's commitment and ability to provide safe, dependable, and affordable water now and into the future. As the BWS has completed the WMP and now moves forward with the CIP, Financial Plan, and Rate Study, the Group is expected to play a pivotal role by providing recommendations to the BWS on best options to achieve the critical and delicate balance between water service adequacy and dependability, and infrastructure costs and rate affordability.

3.3 Formation

At its regularly scheduled meeting on April 27, 2015, the BWS Board authorized formation of the Stakeholder Advisory Group to provide diverse perspectives and input in development of the WMP and other BWS initiatives, eventually extending into the upcoming Financial Plan and Rate Study. Initial roles of the Group were to:

- Meet with BWS staff over the course of two years to consider a broad range of water-related topics and issues;
- Provide feedback on a 30-year WMP and other initiatives on the balance of needs and costs, water conservation, customer service, outreach and education, and rates;
- Contribute to a WMP that meets the needs and interests of the people of Oʻahu; and
- Share information with their communities and help build understanding of Oʻahu's complex water system.

Considerable work and attention went into forming an active group of a manageable size for interactive sessions. Equally significant was assuring representation of diverse interests with a high stake in water policies, as well as coverage of all Council Districts. An additional requirement was participants' willingness to devote the necessary time and effort for sustained active and meaningful participation.

A diverse and balanced group was formed of 28 individual stakeholders representing the following interests.

- Agriculture
- Community organizations
- Developers
- Environment
- Every Council District
- Financial
- Golf
- Hawaiian culture
- Homeowner associations
- General contractors
- Large water users
- Military
- Realtors
- Restaurants
- Seniors/low income
- Travel/tourism industry
- Small businesses
- Utilities

3.4 Engagement

3.4.1 Interviews

To establish a framework for participants and provide a strong start for their input to the BWS, individual face-to-face interview/discussions were held with each person joining the Group. Two people representing the BWS (typically, one BWS employee and one member of the consultant team) attended each interview to facilitate clearer understanding and allow for note taking. Most interviews ran about an hour. All of these interviews demonstrated high interest in water issues and in sharing ideas with the BWS, as demonstrated by these stakeholder quotes.

> *"When the Water Master Plan is completed and as it is implemented over the next 30 years, we stakeholders may not be here, but we were chosen to have our voices heard."*
>
> *"The Water Master Plan should have tangible solutions. Making the right decisions today is our responsibility and our legacy to continue from now forward."*
>
> *"I believe the Water Master Plan will benefit all of us if we commit to being a part of it."*
>
> *"Agreement across the different interest areas represented by the stakeholders and the planning group is a sign of success for the Stakeholder Advisory Group."*
>
> *"We have a chance to plan for our water future the right way and not like it was done in the past."*
>
> *"It is apparent that everyone involved with planning the Stakeholder Advisory Group really cares; you can't fake that."*
>
> *"These aren't the usual players, and it is refreshing because I know we are all invested in O'ahu's future."*
>
> *"It will be a success if the stakeholders and planning team can really take the different views of the stakeholders into account while working on the Water Master Plan, and keep working until we get to the serendipity moment where we know we have a plan that really works."*

3.4.2 Commitment to Open and Public Meetings

While Group meetings may not be subject to Hawai'i's Sunshine Law, to maximize openness and transparency these meetings have followed the Law's intent. Meetings are announced and posted in advance, are open to the public, include time for public comment, and are followed by posting of meeting presentations, notes, and materials on the BWS web site[1].

3.5 Topics and Stakeholder Input

Early meetings focused on building a foundational understanding of the scope and challenges of the BWS's complex water system. This will help the Group to consider and balance funding and rate options. Print material, including infographics and fact sheets, were developed to help build understanding and enable Group members to share information within their organizations and communities.

[1] The BWS Stakeholder Advisory Group materials can be found at http://www.boardofwatersupply.com/cssweb/display.cfm?sid=125077.

3.5.1 Topics Presented or Discussed

Each meeting included a standing topic where the BWS Manager provided an update of current and emerging issues, as presented in Table 3-1.

Table 3-1 Stakeholder Advisory Group Meetings and Topics

Meeting	Date	Topics
1	May 5, 2015	▪ An overview of the BWS, its mission, staffing, strategic plan, and six key functions: sustain; capture; treat; move; store; and deliver ▪ Oʻahu's water system, historic and current ▪ Water quality overview ▪ WMP overview - condition assessment processes and challenges ▪ WMP benefits ▪ Top priorities of the Stakeholder Advisory Group - In a group exercise, participants identified the top three topics most important to them. Topics were generated from stakeholder interviews and input during the meeting
2	July 21, 2015	▪ Outcomes of the top priorities exercise at Meeting 1 ▪ Refining WMP objectives - group input to revise or verify draft objectives and definitions ▪ Customer survey and focus groups outcomes - results of a benchmark survey of 685 Oʻahu residents, as well as focus groups, to ascertain their satisfaction with and impressions of the BWS and its services
3	September 16, 2015	▪ How the WMP builds upon and aligns with other BWS initiatives ▪ Supply and demand – how the WMP analysis is helping the BWS to balance where water is needed and where it is available ▪ Climate change – anticipated effects and mitigation ▪ Water conservation – overview and interactive session to solicit ideas based on individual background and experience of Stakeholder Advisory Group members
4	November 18, 2015	▪ Water conservation – continued stakeholder input ▪ Fresh Water Council Blueprint for Action – strategies for a secure and sustainable water future for Hawaiʻi ▪ Role of the BWS in implementing the Fresh Water Blueprint – discussion and input by group members ▪ WMP objectives – continuing discussion and refinement
5	January 12, 2016	▪ WMP objectives – continuing discussion and refinement ▪ Water quality and treatment program ▪ WMP reservoir condition assessment – assessment process and findings
6	March 16, 2016	▪ WMP objectives – continuing discussion and refinement ▪ WMP water system analysis – initial results
7	May 17, 2016	▪ Tour of the BWS Headquarters ▪ WMP objectives – finalize objectives and preamble
8	July 12, 2016	▪ WMP condition assessment – assessment process and findings for pipelines, wells, pump stations, and treatment systems ▪ Overview of the WMP ▪ Introduction to the 30-year CIP
9	September 14, 2016	▪ Overview of the WMP ▪ Draft WMP Discussion and Recommendations

Moving forward through 2016, the group continued meeting every other month. The Group explored how the consensus-adopted WMP objectives led to policy recommendations made to the Board. Topics included:

- Technical analysis results;
- Understanding risk-based prioritization;
- CIP, Financial Plan, and Rate Study; and
- BWS updates on emerging issues.

Prior to Meeting no. 8, the Draft WMP was made available for public comment, and presented to the Group at the meeting. At Meeting no. 9, the public comments were reviewed, and the Group was given the opportunity to discuss and make recommendations on the WMP. At the conclusion of Meeting no. 9, the Group made a recommendation to forward the WMP to the BWS Board for adoption.

Rates will be the dominant topic for 2017, as the Group explores options to achieve a balance between water service adequacy and dependability, and infrastructure costs and rate affordability. Meetings will be held monthly, with the Group applying their understanding of water issues developed through the prior years' activities. Through a facilitated consensus process, the Group will advise on important choices about O'ahu's water future, with recommendations to the Board to address:

- What is an appropriate level of reliability?
- How should the BWS support non-infrastructure initiatives?
- What are the community values that influence how and to what extent costs will be distributed among customer types?

3.5.2 Stakeholder Advisory Group Input and Ideas

Members of the Group have provided significant input, both in terms of quality and quantity. Group members have openly shared their ideas during interactive sessions and in response to presentations. A sampling of their more formal contributions is provided below.

3.5.2.1 Top Priorities

The Group exercise at Meeting 1 rated the significance of a range of water-related topics. While not empirical, these results provide a general sense of the water issues deemed most significant by stakeholders, shown in Figure 3-1.

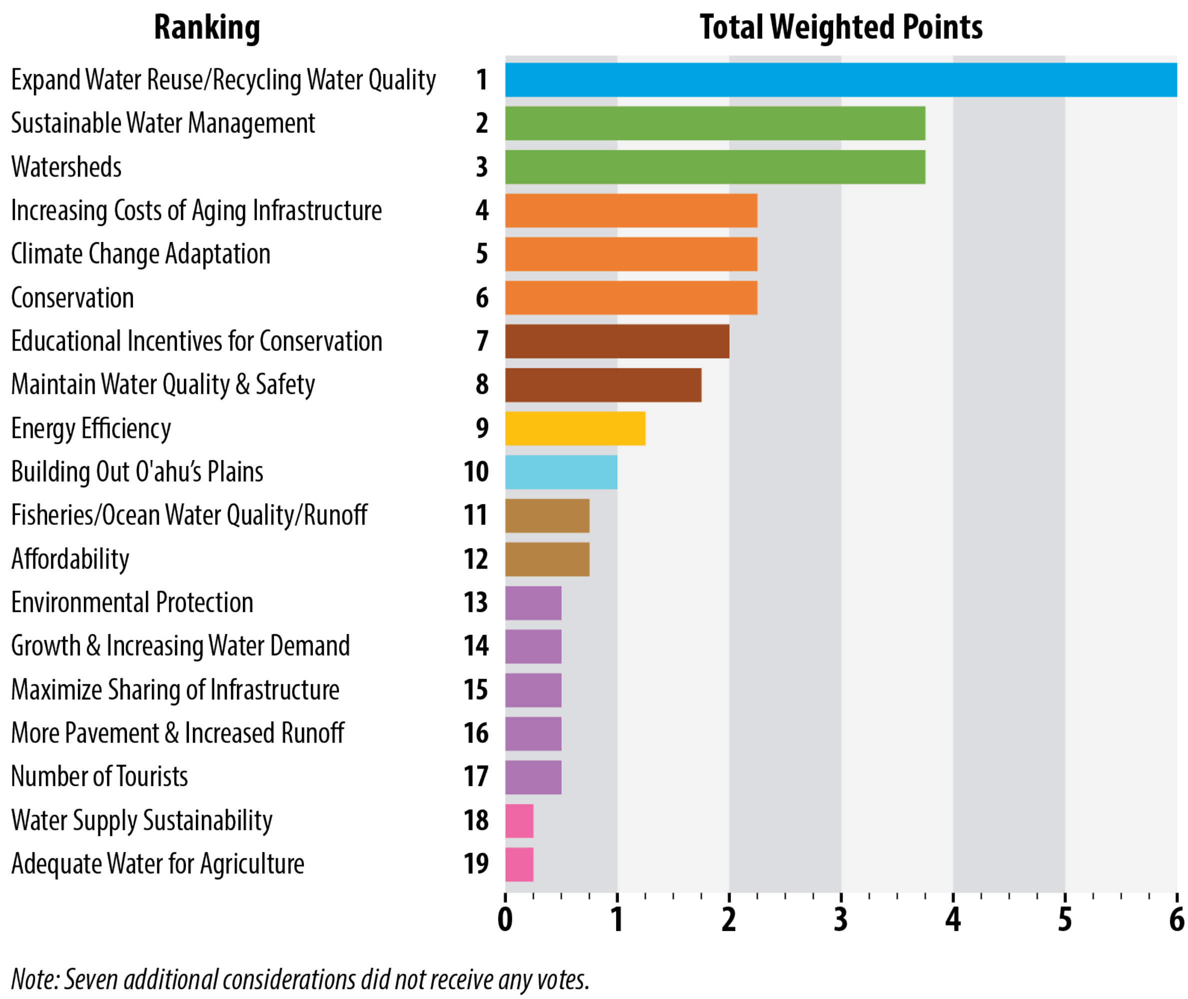

Figure 3-1
Stakeholder Advisory Group Ranking of Water Issues

3.5.2.2 WMP Organization

New sections were added to the WMP based on comments by the Group during discussion of these priorities. The top three topics on Figure 3-1 would not typically be part of a Water Master Plan. The group made clear that a sole focus on water infrastructure in the WMP was not sufficient to address their view of O‘ahu’s water future. In response, the WMP team added two sections to the plan – one on water supply sustainability (Section 4) and the other on implementation (Section 13). The BWS believes these additions have made the WMP better reflect community values the stakeholders have voiced. The Group also dedicated significant effort to developing the WMP objectives, presented in Section 2.3.

3.5.2.3 Water Conservation Concepts

Using brainstorming, the Group shared their thoughts and ideas to bolster water conservation on O'ahu, framed around a series of four questions. Table 3-2 summarizes the responses from the Group. The BWS will consider these suggestions as part of its ongoing conservation program.

Table 3-2 Summary of Stakeholder Advisory Group Water Conservation Suggestions

Question	Suggestions
What insights do Group members have for water conservation? What's needed? What will the impacts be over the next 30 years?	▪ Need more opportunities to use recycled water and/or gray water. ▪ Consider that the overall population is older and many are moving here from the mainland. ▪ Make use of new types of low-flow toilets. ▪ Save water with recirculation pumps that can deliver hot water to the shower faster. ▪ Capture more stormwater.
What incentives should the BWS use to advance water conservation?	▪ Offer incentives for hot water recirculation pumps. ▪ Renew incentive for low-flow plumbing. ▪ Look into the potential for "time of use" incentives, similar to those offered by power utilities. ▪ Develop an informational menu of incentives, such as is done for solar power. ▪ Develop directed incentives towards specific types of water users. ▪ Set up a certification program for water conserving homes, similar to what is done for green homes, as a marketing advantage.
What research or pilot programs should the BWS conduct or partner in?	▪ Partner with the University of Hawai'i to continue their study of crop water use requirements. ▪ Create pilot program with a whole community for a period of time to determine how much water can be saved in a year through conservation. ▪ Conduct research and engineering studies on improving metering, leak detection, and technology advancements to help promote water use efficiencies. ▪ Use high-level modeling to show the optimum mix of incentives, disincentives, and types of rates related to water use and water conservation.
How do businesses make decisions to invest in water conservation?	▪ Balance costs of investment with other business costs and whether the investment would bring other benefits (e.g., brand enhancement for being environmentally responsible). ▪ Consider whether there are other efficiencies to be gained, such as reduced preparation and clean-up when nurseries use drip irrigation over other watering methods.

3.5.2.4 Ideas for the *Fresh Water Initiative*

As discussed in Section 2.2.3, through the Hawai'i Fresh Water Initiative, the Hawai'i Community Foundation established the state-wide goal "to achieve 'no net loss' for our current aquifer stores by creating 100 mgd in additional, reliable, fresh water capacity by 2030" in its plan "A Blueprint for Action"[2]. The Blueprint focuses on conservation, recharge, and reuse as the strategic areas necessary to achieve this goal. Through facilitated discussion and idea exchanges, the Group

[2] Hawai'i Community Foundation. 2015. *Hawai'i Fresh Water Initiative, A Blueprint for Action: Water Security for an Uncertain Future, 2016 – 2018*. Available at: http://www.boardofwatersupply.com/files/Fresh_Water_Blueprint_FINAL_062215_small.pdf.

framed the appropriate role for the BWS in working to achieve the Blueprint goals. The Group concurred that the BWS should take a lead in water conservation. BWS will collaborate with willing partners, the City Department of Environmental Services, City administration, and developers to expand water reuse opportunities that arise. For recharge, the BWS is an important player and a direct beneficiary of forestry management activities and projects in priority watersheds that sustain large BWS pumping stations within the watershed. The BWS also owns large dams that can capture stormwater and be used to recharge the aquifer, directly supplying downgradient BWS pumping stations.

Section 4

Water Supply Sustainability

This section describes the BWS's proactive efforts to ensure that the water supply sources used to serve its customers are used in a sustainable way to safeguard their quantity and quality into the future. The BWS uses a multi-pronged approach that includes protecting the island's watersheds and underlying groundwater aquifers and developing alternative water supplies and conservation programs that help to save potable water sources.

Section 4 **provides information that addresses the following WMP objectives:**

- Water Quality, Health, and Safety
- System Reliability and Adequacy
- Cost and Affordability
- Water Conservation
- Water Resource Sustainability

Information in Section 4 provides input to Section 12, Findings and Recommendations. A number of the programs discussed here have been part of the Stakeholder Advisory Group discussions described in Section 3, Stakeholder Advisory Group.

4.1 Key Findings

The BWS is involved in many programs to protect its watersheds and maintain its sustainable water supplies (SUST-1). Working together with the State of Hawaiʻi (State) Commission on Water Resource Management (CWRM) and Department of Health (DOH), the BWS monitors and protects Oʻahu's groundwater resources, as groundwater is the predominant supply source for its service area. The BWS is a partner in the Freshwater Initiative (discussed in detail in Section 2, Related BWS Work), which includes goals for conservation, groundwater recharge, and water reuse. To support these goals, the watershed management plans provide coordination of land use planning with watershed protection efforts.

The BWS's water conservation strategies have lowered water usage over the last several decades (which is discussed in more detail in Section 7, Historical and Future Water Demands), and the BWS is counting on a continued, comprehensive conservation program to provide further savings (see Section 4.4). Furthermore, to provide greater supplies and protect their water quality, the BWS focuses on developing alternative water supplies such as recycled water and desalination, reducing pressure on groundwater basins.

4.2 Watershed Management and Protection

A watershed is defined as a drainage basin that catches, collects, and stores water that travels from the mountains toward the ocean via rivers, streams, or through subterranean springs or seepages. In addition, a critical function of watersheds is allowing this collected water to recharge the groundwater aquifers below it, which is especially important for the BWS because over 90 percent of its supply is groundwater.

4.2.1 Watershed Management Plans

As discussed in detail in Section 2, the BWS is in the process of developing watershed management plans for each of Oʻahu's eight land use districts through a planning process that emphasizes:

- Community participation and consultation;
- Holistic management of watershed resources;
- Alignment with important State and City policies and programs;
- An action orientation: implementation of important watershed management programs; and
- Ahupuaʻa principles.

The goal of the watershed management plans is to develop environmentally holistic, economically viable, and community-based plans that balance the protection of groundwater and surface water resources with managed use and development. A key factor integrating land use and water planning is the maintenance of a healthy watershed. Land use plans and water use and development plans that support growth and existing communities on Oʻahu must ensure that watersheds remain healthy through sustainable planning practices, watershed protection projects, and best management practices that minimize impacts.

4.2.2 Watershed Partnerships

Healthy watersheds sustain the quality and quantity of Oʻahu's streams and groundwater supplies and the BWS has a responsibility to care, protect, and preserve these areas for future generations. One of the ways the BWS is protecting forested watersheds, and encouraging community involvement which is a key part of the watershed management plan process, is by participating in watershed partnerships that protect and enhance the watersheds through resource management. The BWS has partnered with government agencies (both local and Federal), private landowners, and school and community groups. The current watershed partnerships that the BWS is involved in include the following.

- Koʻolau Mountain Watershed Partnership (KMWP): The BWS helps fund KMWP projects which protect priority watershed forests in the Koʻolau Mountains that will enhance watershed function, such as pig control, fence enclosures, and restoration projects; partners include Department of Land and Natural Resources (DLNR), Agribusiness Development Corporation, Department of Hawaiian Home Lands, United States (U.S.) Army, Queen Emma Foundation, Kamehameha Schools, Dole Food Company, Inc., Hiʻipaka Limited Liability Company (LLC, doing business as Waimea Valley), ʻOhulehule Forest Conservancy LLC, University of Hawaiʻi (UH) Mānoa/Lyon Arboretum, U.S. Fish and Wildlife Service, Tiana Partners, Bishop Museum, Kualoa Ranch, Hawaiʻi Reserves Incorporated, and Oʻahu Country Club.
- Waiheʻe Ahupuaʻa Initiative: Restore and protect Waiheʻe/Kahaluʻu watershed. Completed a fish passage project in Waiheʻe Stream to allow Oʻopu (Hawaiian gobi) to travel upstream;

working on a riparian learning center near the trail head to the upper valley; partnering with Kualoa-Heʻeia Ecumenical Youth Project and Hui O Koʻolaupoko.

- Waiʻanae Mountains Watershed Partnership (WMWP): The BWS is working with WMWP to protect priority watershed areas in the Waiʻanae Mountains. The BWS helps fund WMWP natural resource management projects that control threats and restores forested areas to enhance groundwater recharge, including fire presuppression, reforestation, and weed mapping and control; partners include DLNR, Gill-Olson Joint Venture, MAʻO Organic Farms, U.S. Army Garrison Hawaiʻi, Navy Region Hawaiʻi, and Kaʻala Farms Incorporated.
- Mohala I Ka Wai: Projects include stream monitoring, rainfall data collection, and restoration of archeological sites. Mohala I Ka Wai also has a land license with BWS to restore loʻi in Mākaha Valley, which will help revitalize the land and educate a new generation on land stewardship; partners include members of Mohala I Ka Wai and Kaʻala Farm, Incorporated, Waiʻanae High School, Nānākuli High School, Mākaha Elementary School, and Hoa ʻĀina o Mākaha.
- Makua Implementation Plan with U.S. Army: On-going efforts to install fences in Mākaha to protect endangered species from pigs and goats and on the bog on Kaʻala to keep out pigs; other projects include rodent control, vegetation monitoring, rare plant, and snail conservation; partners include the Oʻahu Army Natural Resource Program along with other land owners in the Waiʻanae mountains.
- Oʻahu Invasive Species Committee (OISC): OISC is a voluntary partnership of private, state and federal agencies that work together to control incipient species of concern that may significantly impact the watershed. The BWS provides funding to OISC to control their target species on BWS lands and other priority watershed areas, the main target being Miconia calvescens.
- Oʻahu Plant Extinction Prevention Program: The BWS works with this program to survey, monitor and maintain their target species – endangered plants with less than 50 individuals left in the wild on Oʻahu.
- Hawaiʻi Snail Extinction Prevention Program: The BWS works with this program to survey and monitor rare and endangered snail species on BWS lands.

4.3 Groundwater Protection

Activities above ground, such as using pesticides or fertilizers, can impact the water quality below ground. Because of the porous soils overlying the fractured and porous basalt groundwater aquifers that underlie much of Oʻahu, organics and chemicals that are not consumed biologically or absorbed chemically can pass through the top layers of soil and into the groundwater aquifer. Leaking fuel storage tanks, pipelines, and chemical spills are also major threats to groundwater aquifers. To protect the groundwater aquifers that provide water supply, the BWS recognizes that all people on the island have a responsibility to use chemicals, fertilizers, and pesticides responsibly and to dispose of wastes properly to avoid potential contamination.

On a larger scale, the BWS and DOH work together to monitor and protect the island's groundwater resources. Their approach includes:

- Understanding the impact of activities above and below ground on groundwater supply wells: The BWS works to provide safe water to the community that meets all State and Federal drinking water standards. The DOH established source water protection boundaries for public water systems that identify capture zone areas (using 2- and 10-year contaminant travel times) where contaminants could reach drinking water sources to determine the susceptibility of public water systems.
- Continually monitoring the health of groundwater sources, which is critical to ensuring a sustainable water supply: The BWS uses a network of shallow and deep monitoring wells to track the quality of its groundwater supply, ensuring that the water provided to customers meets all State and Federal drinking water standards.
- Educating customers about the quality and safety of drinking water: The BWS believes that keeping the public informed about the quality and safety of its drinking water is an important part of its mission. Protecting the island's water resources begins with protecting the environment and everyone has a role in protecting the watersheds that provide water supply.

In September 2015, the Board adopted Resolution 860 recognizing that pristine aquifers are a critical public trust resource that should be protected and defended. The Board resolved that BWS should take necessary measures to protect the groundwater, and that the groundwater around Red Hill should be restored by the Navy, and that the Navy should prevent future leaks.

4.4 Conservation

Historically conservation has reduced water demands, thereby conserving natural water resources, and can offset the need for new water supplies and infrastructure needed to meet demands. Water conservation is less expensive than the construction of traditional system infrastructure for capacity expansion and could defer costly system improvements. It will also be important to continue and increase these water conservation efforts into the future.

The BWS's conservation program, developed over a number of years and guided most recently by the comprehensive Water Conservation Program Plan[1] finalized in May 2011, uses a multi-faceted approach to promote water conservation both within the distribution system and with its customer base. Elements of the BWS's conservation program are detailed below.

- **Leak Detection, Repairs, and Maintenance Program** – Preventing water loss system-wide involves vigilant efforts of BWS crews to detect and fix leaks. Improving distribution system efficiencies reduces operations and maintenance costs and reduces water loss. Infrastructure water loss and efficiency measures include leak detection, repair of existing pipelines, and the renewal and replacement of water system facilities (e.g., pipelines, pump stations, reservoirs, and treatment systems). The BWS Leak Detection Team was tasked to

[1] BWS. 2011. *Water Conservation Program Plan*. Prepared for Honolulu Board of Water Supply. Prepared by Brown & Caldwell. May 4, 2011.

proactively survey and identify leaks in the BWS system using a combination of digital correlating loggers to record pipe vibrations as water flows through the pipes and toning equipment to pinpoint the location of the leak. The data collected is used to prioritize and schedule planned repairs to the water system, which resulted in the prevention of potential emergency main breaks equating to even more water savings. Better data collection and validation, pressure management evaluation and the expansion of the District Metered Areas program can help continue to reduce the volume of lost water (called non-revenue water). The Leak Detection Team intends to survey the entire water system on a two-year cycle, or 87.5 miles per month.

- **Large Water Users Program** – The BWS helps O‘ahu businesses save water and money through water audits and partnerships. Proposed conservation incentives will be tailored for large water users in collaboration with energy conservation programs. Commercial, government, hotel/motel/resorts, multi-family residential, and large landscape water surveys help identify ways large water users can conserve water. Promoting demand-side management programs supports hardware and behavioral modifications of customer water use. Water conservation tips, public service announcements, and specific programs tailored to distinct user categories will effectively reduce water use and defer development of new water sources.

- **Water Conservation Regulatory Program** – Drought plans, wasteful water use enforcement, and low-flow fixture requirements all help increase conservation. The BWS is considering expanded conservation requirements (measures or performance metrics) for new development such as Transit Oriented Development.

- **Developing New Conservation Opportunities** – Capturing stormwater, using recycled water for irrigation, new green infrastructure plumbing codes, and research are all contributing to new opportunities for conserving more potable water. The BWS Rain Barrel Program provides workshops throughout the year that promote rain barrel water catchment as an alternative and effective educational tool for conserving water outdoors. Gray water reuse for outdoor irrigation can also reduce the demand on potable water. The BWS will continue to evaluate opportunities for the use of recycled water for industrial customers, e.g., cooling towers, industrial processes, and other non-drinking water uses.

- **Education and Outreach** – The BWS has many programs to inform the public about conserving water. In 2016, the BWS held its 38th annual water conservation poster contest and its 8th annual poetry contest, helping to educate students to be life-time water conservationists. The Hālawa Xeriscape Garden displays a series of xeric (dry) plants in a residential-scale setting to demonstrate species capable of providing a visually attractive garden, while using less water than most currently popular plants. The garden opened to public in September 1989 as a way to educate O‘ahu residents on ways to save water in lawns, gardens, and landscaped areas. Among the water-efficient irrigation systems demonstrated in the Hālawa Xeriscape Garden are automatic timers, moisture sensors, rain shutdown devices, and low output irrigation equipment such as spray sprinkler heads, micro-spray sprinkler heads, emitters, and dripper lines.

Implementation and expansion of these programs is key to the assumptions that the BWS per capita water demands will continue to decrease through the 2040 planning horizon. The Stakeholder Advisory Group provided input on a number of ways that the BWS can enhance its water conservation efforts (see Section 3.5.2.3). Section 12, Findings and Recommendations, calls out the need to continue the BWS's investment in conservation.

4.5 Alternative Supply Sources

As discussed in Section 8, Current and Future Water Supply Sources, encouraging supply diversity is a critical planning principle for the BWS. The BWS invests in the development of alternative supplies to potable groundwater to protect and conserve that important resource or to provide supply in areas where potable water is not available in sufficient quantities to meet local demand. Some of these alternative supplies have the benefit of being drought resistant, meaning the yield from these supplies is not reduced during droughts, which further decreases the stress on groundwater sources which are affected by drought. BWS alternatives supplies include:

- Recycled Water Projects – Expansion of the capacity of the Honouliuli Water Recycling Facility (WRF) will be used to meet future demands for irrigation and industrial process water in ʻEwa, freeing up potable water for domestic uses. There are a number of relatively new project areas that are planned to be added to the existing recycled water distribution system. As ʻEwa develops, there will be additional opportunities to expand recycled water use. Recycled water will provide almost 40 percent of the total water needs of ʻEwa at full build-out. Continued and increased use of recycled water will help to preserve potable groundwater resources and could also be used to recharge the aquifer in the future. There are also recycled water membrane bioreactor projects being considered for the Ala Wai golf course (0.5 mgd) and Mililani Wastewater Treatment Plant (WWTP) for Central Oʻahu Regional Park (1.0 mgd).

- Desalination Projects – The Kalaeloa Seawater Desalination Plant is currently anticipated to be designed in 2018 to 2019 and constructed in the 2020 to 2022 timeframe, and will bring an additional 1 mgd of potable water supply to the ʻEwa and Waiʻanae land use districts. As ʻEwa demands increase in the future towards build-out, the plant capacity could be increased as needed. In addition, BWS acquired the State's demonstration brackish water desalination plant land and facilities in Kapolei Business Park, which will be reconstructed to produce 0.7 mgd of potable water supply for Kapolei.

Section 5

Water System Planning Standards

Section 5 provides information that addresses the following WMP objectives:

- Water Quality, Health, and Safety
- System Reliability and Adequacy
- Cost and Affordability
- Water Conservation
- Water Resource Sustainability

Water utilities use planning criteria to define the allowable operating performance of their water system infrastructure and improve the level of reliability in the design of water facilities. These planning criteria vary depending on the size, location, and specific characteristics of water utilities, but the types of parameters are similar across utilities related to the sizing of pipelines, reservoirs, and pump stations.

The BWS has standards and criteria that are used in the planning and design of the BWS facilities and affect the sizing of both existing and future facilities. The BWS used the 2002 State of Hawai‘i Water System Standards (Standards) as the basis for its system planning criteria. The purpose of the Standards is to provide guidelines for planning and designing of water systems at a fundamental level. This section describes the current BWS standards and criteria and how they were used for the purposes of the WMP analyses. The planning system standards were applied to the individual pressure zones, and the combination of pressure zones, making up the 10 model systems for the hydraulic model analyses described in Section 10, System Capacity Evaluation. The analysis of existing and future 2040 facility requirements is also presented in Section 10.

5.1 Key Findings

The key findings related to system planning criteria are listed below. These findings are identified with a code (an abbreviation for the section name) and number (for example, STND-1). These codes are repeated in Section 12, Findings and Recommendations, to easily tie the findings in this section to the recommendations for BWS action listed in Section 12.

STND-1 Some Standards were found to be insufficiently defined for the various and complex configurations of the BWS water systems, where the objectives of the Standards may be met by different combinations of facilities and operation. Because these details are not spelled out in the Standards, the BWS has added clarification in how the Standards were applied and/or adapted to evaluating overall system requirements and not just the individual components of the system. The application of these adaptations is explained in more detail in Section 10. The BWS should formalize adaptation of Standards where appropriate.

STND-2 Some Standards may no longer be appropriate for a water system the size and complexity of the BWS's. The BWS should review the Standards to determine if updates are required. The BWS should modify current Standards as appropriate and install or improve infrastructure where appropriate to meet Standards.

STND-3 The maximum day demand (MDD) and peak hour factors given in the Standards may not be appropriate for systems with historical data. The BWS should utilize actual historical MDD and peak hour factors where available, and utilize the Standards where insufficient data exists.

5.2 Standards and Criteria

The BWS uses the Standards for its system planning criteria, with specific applications made for the individual BWS systems. As discussed in the Standards[1], "These standards of planning are not intended to limit the initiative and resourcefulness of the engineer in developing water system plans but they shall be viewed as the minimum limits in design criteria." Some of these applications are discussed in Section 5.3 and also later in Section 10.

The primary planning criteria from the Standards (Division 100 Planning, Section 111 Water Requirements) that affect the BWS are presented in Table 5-1, and adaptations that BWS has made to the Standards.

The main Standards sections used in the WMP evaluation include:

- Domestic Consumption Guidelines (Standards Section 111.02);
- Fire Flows, Duration, and Hydrant Spacing (Standards Section 111.03, Table 100-19);
- System Capacity (Standards Section 111.04);
- Demand Factors (Standards Section 111.05 and Table 100-20);
- Pipeline Sizing (Standards Section 111.06, Table 100-21);
- Reservoir Capacity (Standards Section 111.07); and
- Total Pump Capacity (Standards Section 111.08).

[1] State of Hawai'i. 2002. Water System Standards, Division 100 Planning, Section 111 Water Requirements, 111.01 General. Available from http://www.boardofwatersupply.com/files/With%20Amendments%20Final%20Complete%20Copy%20of%20Water%20System%20Standards%202002.pdf.

Table 5-1 Key State of Hawaiʻi Water System Standards that Affect the BWS System and BWS Adaptations

System	Criteria	BWS Adaptations
Fire Flows		
Residential single family, duplex	1,000 gallons per minute (gpm) for 1 hour	None
Residential multiple family (townhouse, low rise apartment)	1,500 gpm for 1 hour	None
Schools, neighborhood commercial, hotels and high rise apartment	2,000 gpm for 2 hours	None
Light industrial, downtown business, large commercial, hospital	4,000 gpm for 3 hours	None
Heavy industrial, hotels	Subject to special review and control by the BWS Manager	None
System Capacity		
Distribution system	Distribution system shall deliver the maximum day demand simultaneously with the required fire flow.	None
	Distribution system shall also deliver the peak hour flow (without fire flow).	None
Pipeline Sizing		
Maximum velocity, non-fire conditions	6 feet per second (fps)	Initial indicator, then evaluate downstream head loss
Hazen-Williams "C" factor (diameter-based[1])	4-inch to 6-inch diameter: C =100	None
	8–inch to 12-inch diameter: C =110	None
	16-inch to 20-inch diameter: C =120	None
	24-inch diameter and larger: C =130	None
Reservoir Capacity		
Maximum Day Demand (MDD)	Reservoir full at beginning of 24-hour period with no source input to reservoir	When total storage not available, utilize excess peaking capacity from sources and pump stations or from transfers from storage in other pressure zones
Fire flow	Fire flow with reservoir ¾ full at start with credit for incoming flow from pumps with one maximum size pump out of service.	None
Minimum size reservoir	0.1 million gallons (MG)	None
Multiple reservoirs	Sizing based on combined protection provided by all facilities available.	None

Table 5-1 Key State of Hawaiʻi Water System Standards that Affect the BWS System and BWS Adaptations

System	Criteria	BWS Adaptations
Pump Capacity		
MDD (Based on largest capacity calculated from the 3 criteria)	MDD over 16 hours per day plus fire flow independent of reservoirs. Standby unit may be used.	Apply to residential systems with one reservoir
	MDD plus fire for duration of fire less ¾ of reservoir storage.	Apply to systems with significant commercial and industrial developments
	MDD over 16 hours per day.	Apply to systems with multiple reservoirs
Distribution System Pressures		
Minimum pressure for peak hour demand	40 pounds per square inch (psi)	None
Minimum pressure for MDD plus fire condition	20 psi @ flowing hydrant	Maintain 20 psi in entire zone
Maximum pressure (maximum static or modeled pressure)	125 psi	Evaluate based on hydraulics and elevation
Demands		
MDD	1.5 x Average Day Demand (ADD)	Based on consistent historical data, MDD is different than 1.5 x ADD. MDD ranges from 1.15 to 1.61 x ADD, depending on the size of the system.
Peak Hour	3.0 x ADD	Based on consistent historical data, peak hour demands vary from 3.0 x ADD. Peak hour demand ranges from 1.6 to 2.5 x MDD, depending on the size of the system.

[1] "C" factor is a function of pipe age, material, and condition.

5.3 BWS Application of Standards and Criteria for the WMP

The BWS compared the Oʻahu standards to those of Maui, Kauaʻi, and Hawaiʻi and found the criteria are very similar across the Hawaiian Islands, with slight variations in criteria between all the islands for pipeline velocities, pumping capacities, fire flow, and demand peaking factors. The BWS also compared its standards to those of mainland communities with similar service populations.

In some instances, physical and operational limitations may constrain the ability of the BWS to comply with the direct application of the Standards. In these cases, different combinations of facilities may be used to meet the same system objectives as intended in the Standards, while accounting for the operational needs of the water system. For example, the Standards require sizing reservoirs such that peak hour demands are met by the volume of water in storage. However, if it is not feasible to install large reservoirs, the intent of those Standards can be met by looking at the system as a whole and utilizing not only storage, but also pumping capacity to meet peak demands. This may be an option within the individual model systems, as well as between systems to share capacity. The following sections describes the BWS criteria's differences from the Standards.

Several of the criteria are based on meeting certain levels of demand. Average day demand (ADD) refers to the average daily water use over the course of the year. MDD is the maximum water use in a 24-hour period during the year, which generally occurs during most of the maximum month of usage in summer. Peak hour demand is the peak flow during a one-hour period on the day of maximum demand. Where available, historical MDD and peak hour factors were used in the analysis with the exception of pipeline sizing, which retained 1.5 multiplied by ADD to be conservative.

5.3.1 Pipeline Sizing

Criteria: Maximum velocity in a distribution main (without fire flow) is 6 feet per second (fps).

Pipeline flows exceeding the six fps velocity criterion provide an initial indication of potential operational or capacity issues, but do not necessarily result in the need for parallel pipelines. Areas with velocities in excess of six fps were assessed in conjunction with other key evaluation criteria, such as low pressure or excessive head loss causing operational problems, to determine whether improvements are necessary to meet the hydraulic requirements of the system efficiently and economically. Pipelines that exceed 10 fps, regardless of excessive head loss, were considered for improvements. This evaluation and application is typical of large metropolitan water systems.

Oʻahu does not have criteria for maximum velocity with fire flow. Some mainland agencies do have a criterion for maximum flow of 10 to 12 fps; however, this criterion was not applied to the sizing of BWS pipelines.

5.3.2 Reservoir Capacity

There are four criteria associated with sizing the system reservoirs:

- Criteria: Meet MDD with the reservoir full at beginning of a 24-hour period, with no source input.
- Criteria: Meet fire flow with reservoir three-quarters full at start with credit for incoming flow from pumps, with one maximum size pump out of service.
- Criteria: Minimum size reservoir is 0.1 million gallons (MG).
- Criteria: Where there are two or more reservoirs serving the same system, sizing shall be based on combined protection provided by all available facilities.

Historically, the BWS has not been able to meet all of the storage requirements for some of the pressure zones, particularly in the Metro Low system. Currently, this is primarily due to lack of sites to place large reservoirs at appropriate elevations. To compensate for the limited storage, the BWS has met peak hour demands with well sources. This is a typical application for large metropolitan water systems where excess peaking supply capacity is used to meet the objectives of the Standard.

Where adding storage is feasible, recommendations for new storage are included in Section 10, System Capacity Evaluation, and Section 12, Findings and Recommendations. Where implementation of multiple large reservoirs to fully meet the calculated storage requirements (e.g., the Metro Low system) is either not feasible or very costly, alternatives were presented combining additional storage, local peaking wells, and installation of transmission facilities to convey the needed maximum day and peak hour needs into these systems.

5.3.3 Pump Station Capacity

There are three criteria associated with sizing pump station capacity, with the most restrictive criteria providing the planning-level sizing. The primary intent of these criteria is to provide redundancy in the initial sizing of facilities. However, as discussed in Section 10, where these criteria are applied in initially identifying sizing, engineering judgement and operational flexibility may also provide similar levels of redundancy. Also, a key part of the capacity analysis in Section 10 is the appropriate sizing of these facilities.

Criteria: Meet MDD with an operating time of 16 hours simultaneously with maximum fire flow required independent of the reservoir. The standby unit may be used to determine the total flow required.

The BWS applies this to residential systems with one reservoir because the pump station will need to meet fire flow if the reservoir is out of service during a fire. In the case of multiple reservoirs and pump stations, the multiple supply sources and reservoirs provide the redundancy.

Criteria: Meet MDD over the duration of fire plus fire demand less 75 percent of reservoir storage. The largest pumping unit shall be considered out of service (standby).

The BWS applies this to systems with significant commercial and industrial developments, which tend to have large fire flows and durations (e.g., 4,000 gallons per minute [gpm] for 3 hours).

Criteria: Meet MDD with an operating time of 16 hours. The largest pumping unit shall be considered out of service (standby).

The BWS applies this to systems with multiple reservoirs. Having enough pump capacity to deliver the MDD within 16 hours, as opposed to 24 hours, gives the BWS the operational flexibility to turn off the pumps and not have to operate for the full day. It also allows flexibility as water demands increase or some pumping capacity is offline for maintenance.

The requirement for pump stations to have a standby unit (largest unit) out of service during certain operations is designed for pump stations that may have multiple pumps, allowing for redundant capacity for maintenance operations and some additional capacity for unforeseen situations. This requirement may be overly conservative for groundwater systems, where a local well field may have from one to seven independent wells (independent units pumping from the same well field), or multiple wells and well fields that can meet the supply needs within the pressure zone or model system (combined pressure zones). The individual well systems were evaluated to meet the level of service goal with 75 to 90 percent of the active well sources available/operational at all times. This percentage varies depending on the size of the well pumping units, and whether they can be operated at the rated capacity continuously for at least 24 hours. The lower the percentage, the more excess capacity that is available from the combined system of wells. A greater number and diversity of sources (excess capacity over that needed to meet MDD or peak hour conditions) reduce the level of service percentage required. This level of service goal is similar to that used by mainland systems in which the primary source of supply is groundwater wells. This level of service goal is being reviewed by the BWS.

5.3.4 Demand Factors

Criteria: MDD = 1.5 x ADD

The ratio of the MDD to the ADD is the seasonal peaking factor, or the MDD factor. Maximum day demand occurs around August or September for the BWS system. The Standards define MDD as 1.5 x ADD. However, for the purposes of the systems analysis, the actual MDD factor calculated with historical data from the previous 4 years was used for all analyses with the exception of the pipelines, which retained the Standard MDD ratio to be conservative.

Figure 5-1 presents an example of how the daily demand across a typical model system varies throughout the year. The seasonal demand multiplier was calculated from production data for 2010 through 2013 for each model system as shown in Table 5-2. Average seasonal demand multipliers vary by model system, ranging from a low of 1.15 for Metro Low to a high of 1.61 for Kahuku. These factors also vary annually, with the factors in 2013 higher than in 2012 for almost every model system. Rainfall is the primary determining factor in annual water demand variation. In this case 2013 had lower total rainfall than 2012. Based on these calculations and review with BWS staff, it was ag0reed that the historical model system MDD would be used where available.

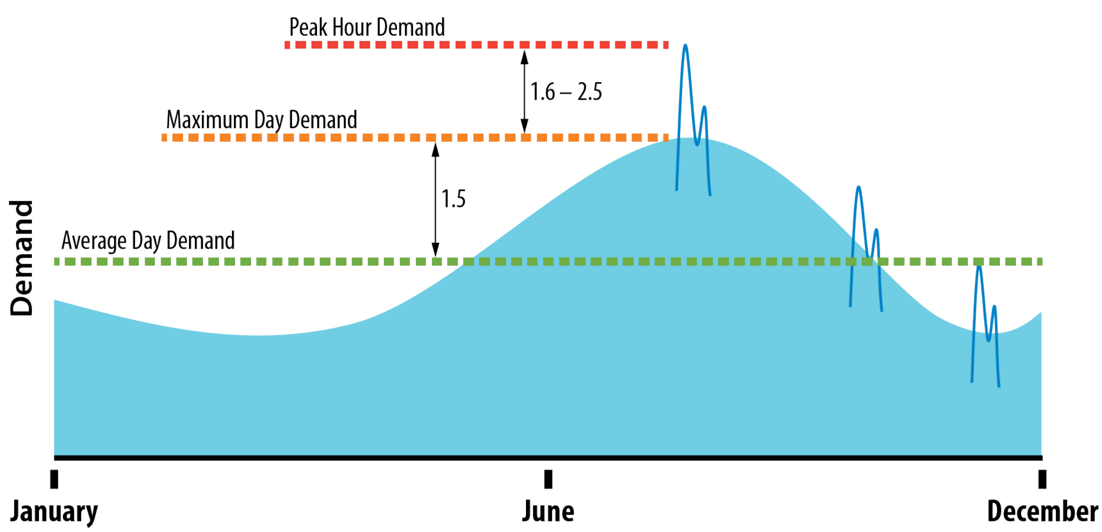

Figure 5-1
Typical Seasonal Variations in Maximum Day and Peak Hour Demand

Table 5-2 Historical Production Data and Seasonal Peaking Factors

Model System	2012 ADD (mgd)	MDD/ADD Factor				
		2010	2011	2012	2013	Average
Metro Low	55.6	1.20	1.14	1.11	1.15	**1.15**
Metro High	12.3	1.20	1.16	1.16	1.26	**1.20**
Leeward (Waiʻanae - Mākaha)	10.1	1.32	1.35	1.28	1.31	**1.31**
ʻEwa-Waipahu	27.7	1.18	1.17	1.18	1.24	**1.19**
Pearl City	5.1	1.26	1.25	1.23	1.22	**1.24**
ʻAiea- Hālawa	3.3	1.54	1.46	1.66	1.73	**1.60**
Windward	15.6	1.28	1.21	1.25	1.27	**1.25**
Kahuku	0.4	1.49	1.88	1.48	1.57	**1.61**
North Shore	3.8	1.44	1.37	1.37	1.43	**1.40**
Central (Wahiawā - Mililani)	7.9	1.28	1.34	1.28	1.30	**1.30**
Total	141.7	1.23	1.20	1.19	1.23	**1.21**

Criteria: Peak Hour Demand = 3.0 x ADD, or 2.0 x MDD

The peak hour ratio is defined as the peak hour demand divided by the ADD over the course of the entire year. The Standards define this ratio, or factor, as 3.0. Therefore, peak hour demand is equal to 3.0 multiplied by ADD. The peak hour demand can also be expressed as 2.0 multiplied by MDD, because the Standards ratio of MDD to ADD is 1.5.

As a comparison to the Standards, peak hour factors were calculated for each of the model systems based on 15-minute incremental data collected by the SCADA system. These factors were calculated from the 24-hour period of August 28, 2013, and compared with data from several other years. Though the peaking factors changed from year to year, they were generally consistent in their range. The August 28, 2013 factors were used as the operational data for the BWS system for the verification of the hydraulic models.

A trend was observed in the peak hour factors that were calculated from 2013 MDD verification data – pressure zones with lower ADD had higher peak hour to MDD factors compared to pressure zones with higher ADD. Figure 5-2 presents an example of how the peak hour demand varies based on the size of the pressure zones. Therefore, instead of applying a peak hour multiplier to MDD factor of 2.0 for all zones as indicated in the Standards, three tiers of peak hour factors were applied in the hydraulic model evaluation based on the volume of demand in the pressure zone, as indicated below:

- Peak hour = 1.6 x MDD for zones with ADD demands > 3,500 gpm;
- Peak hour = 2.0 x MDD for zones with ADD demands between 350 gpm and 3,500 gpm; or
- Peak hour = 2.5 x MDD for zones with ADD demands < 350 gpm.

This range of peak hour factors is also indicated in Figure 5-1.

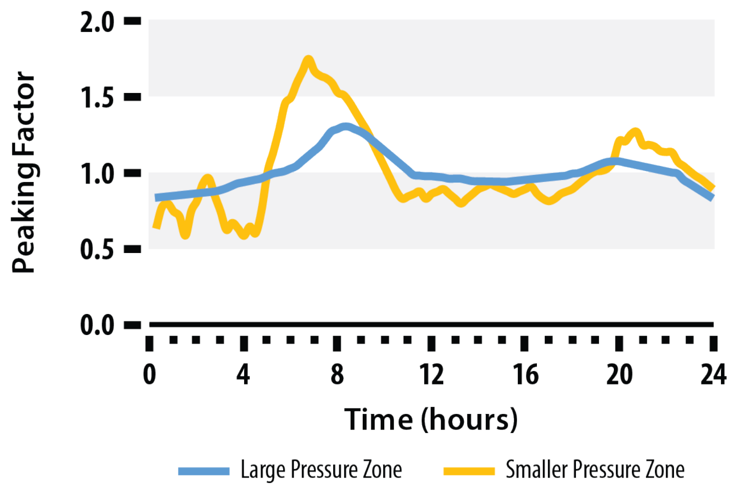

Figure 5-2
Typical Peak Hour Factor Variations Between Large and Small Pressure Zones

5.3.5 Domestic Consumption Guidelines

The domestic consumption guidelines listed in the Standards provide recommendations for water use consumption by different land use zoning designations when better data is not available. They were developed before the BWS implemented conservation programs that led to reduced consumption over the last several decades. For this WMP, updated consumption rates were calculated from BWS 2012 meter data and used to calculate future demands. Year 2012 was a low rainfall year resulting in more conservative water use. Table 5-3 presents the water consumption guidelines listed in the Standards and the calculated consumption based on the 2012 meter data.

Table 5-3 Domestic Consumption Guidelines: Oʻahu Standards versus 2012 Usage Data

Zoning Designation Per Standards	Domestic Consumption Guidelines Per Standards	BWS Guidelines Accounting for Recent Trends in Conservation	Calculated Rates Based on 2012 Customer Usage Data
Single family or duplex	500 gallons per day per unit (gpd/unit) or 2,500 gallons per day per acre (gpd/acre)	400 gpd/unit	2,500 gpd/acre
Multi-family low rise (3 stories and lower)	400 gpd/unit or 4,000 gpd/acre	300 gpd/unit	5,000 gpd/acre
Multi-family high rise (4 stories and higher)	300 gpd/unit	200 gpd/unit	15,000 gpd/acre
Commercial only	3,000 gpd/acre		Low commercial: 1,500 gpd/acre
			High commercial: 3,000 gpd/acre
Commercial/industrial mix	100 gpd/1,000 sq. ft.		Not calculated because the Standards did not list a gpd/acre value
Commercial/residential Mix	120 gpd/1,000 sq. ft.		Not calculated because the Standards did not list a gpd/acre value

Table 5-3 Domestic Consumption Guidelines: O‘ahu Standards versus 2012 Usage Data

Zoning Designation Per Standards	Domestic Consumption Guidelines Per Standards	BWS Guidelines Accounting for Recent Trends in Conservation	Calculated Rates Based on 2012 Customer Usage Data
Resort	350 gpd/unit or 4,000 gpd/acre		15,000 gpd/acre
-	-		High rise hotel: 51,000 gpd/acre
Light industry	4,000 gpd/acre		Light industry: 1,500 gpd/acre
			Heavy industry: 4,000 gpd/acre
Schools, parks	4,000 gpd/acre or 60 gallons per student		2,500 gpd/acre
Agriculture	4,000 gpd/acre		2,500 gpd/acre

Section 6

The BWS Water System

The BWS builds, operates, and maintains an infrastructure network across Oʻahu to capture, treat, move, store, and deliver water to its customers, while sustaining the water resource for future generations. Section 6 describes the BWS facilities through the lens of these six functions. The hydraulic analysis, which evaluated pumping, storage, and how water moves through this system, can be found in Section 10, System Capacity Evaluation.

Section 6 **provides information that addresses the following WMP objectives:**

- Water Quality, Health, and Safety
- System Reliability and Adequacy
- Cost and Affordability
- Water Conservation
- Water Resource Sustainability

6.1 System Overview

The BWS was established in 1929 by the Legislature of the Territory of Hawaiʻi to modernize the water system, meter all water distributed, seal leaking artesian wells, and protect the groundwater resource. In 1959, the BWS incorporated the Suburban Water System, bringing the majority of Oʻahu's water under a single entity. As Oʻahu has grown, the BWS has expanded to ensure safe, dependable, and affordable water supply. Figure 6-1 illustrates the growth of the system in two ways: 1) the population served by the BWS (and pre-1959 Suburban Water System) is shown as the height of the blue area, using the scale on the left axis; and 2) the total demand over the last 80 years, with the total demand (in million gallons per day [mgd]) as the orange line and the average demand per person (in gallons per capita per day [gpcd]) as the green line, using the scale on the right axis.

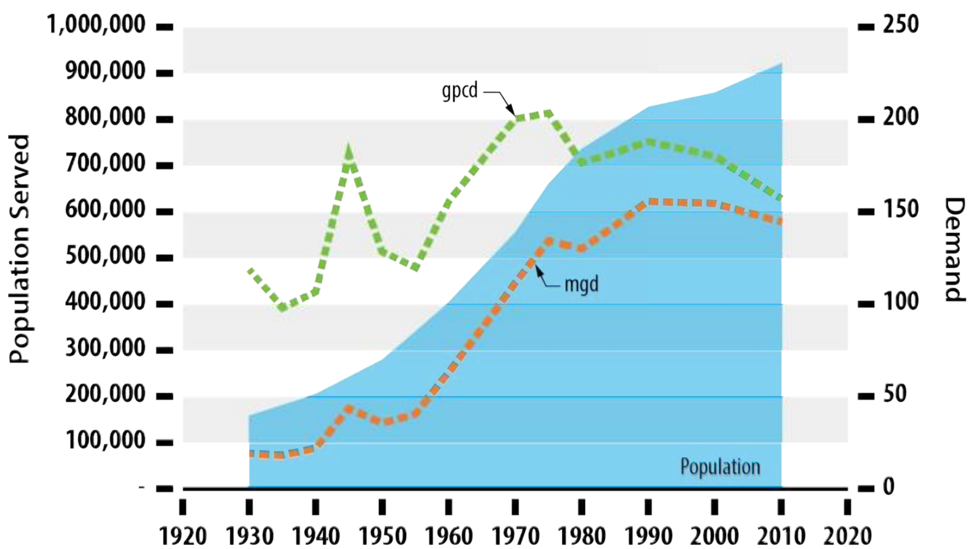

Figure 6-1
Historical Population and Demand Served by BWS

Figure 6-2 provides an overall view of the BWS potable water infrastructure across Oʻahu, covering the sources, pumps, reservoirs, and pipelines that are discussed in the sections below. Throughout this WMP, the water infrastructure is presented grouped into hydraulic model systems. These model systems were created to facilitate the hydraulic modelling, but they also allow for geographical reference for various parts of the water system. The 10 model systems are illustrated in Figure 6-2.

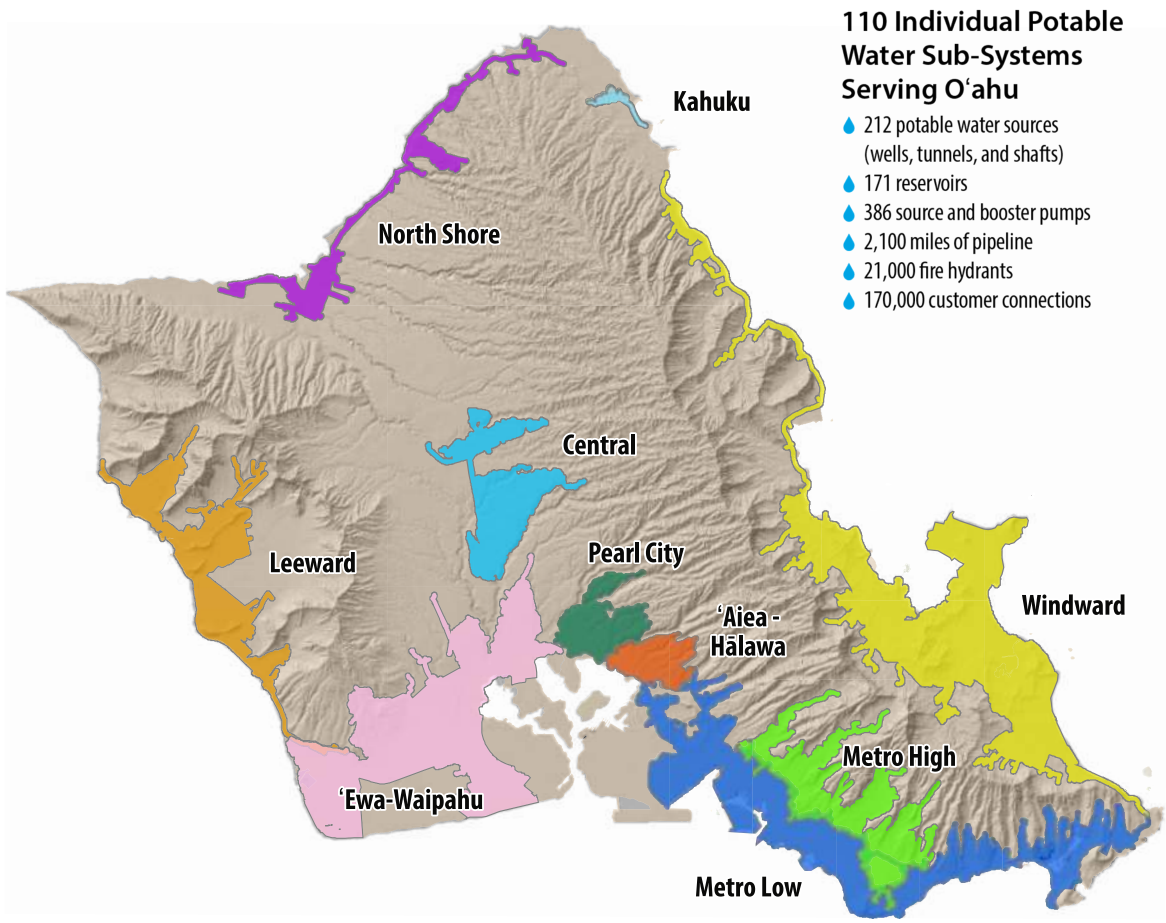

Figure 6-2
Overall BWS Infrastructure

6.2 Sustain

The BWS manages thousands of acres of watershed area on Oʻahu to protect and preserve 212 separate potable water sources, the combination of 194 individual groundwater wells, 13 active potable water tunnels, and 5 shafts. The BWS's proactive efforts to manage and protect the watersheds include limiting access and development, combatting invasive animals and plants, promoting healthy forests, and encouraging customer water conservation to reduce the amount of water withdrawn from the environment. These BWS efforts are discussed in more detail in Section 4, Water Supply Sustainability.

To ease the demand on the groundwater supplies, the BWS also operates brackish and recycled water nonpotable water systems for irrigation and industrial use in ʻEwa, Mākaha, and Hālawa-Airport. The BWS owns and maintains five dams or open reservoirs. Four reservoirs in Nuʻuanu are now used solely for flood control, and the fifth, Mauna ʻOlu reservoir, stores nonpotable water used for irrigation. The four Nuʻuanu reservoirs may be used for stormwater capture, infiltration, or hydropower in the future.

6.3 Capture

The BWS captures groundwater to serve the needs of Oʻahu's people using several different strategies. Groundwater wells on the coastal plains are the largest number of sources, and the BWS currently operates 194 individual wells located throughout the island. Wells penetrate the ground and tap groundwater sometimes hundreds of feet below the surface. The majority of the BWS groundwater supplies are located in the Honolulu and Pearl Harbor aquifers.

The BWS uses five shafts to access the plains groundwater. Unlike a well that penetrates into the groundwater aquifer with a small diameter hole, shafts are dug out of water-bearing rock near the water table or the top of the saturated portion of the aquifer. As such, shafts are able to supply significantly greater amounts of water than an individual well can.

Tunnels are another source of supply for Oʻahu. The BWS has 13 active, potable water tunnels in the Waiʻanae and Koʻolau mountains, dug horizontally into the mountain to penetrate the dike layer and access stored water. A full discussion about sources can be found in Section 8, Current and Future Water Supply Sources.

Table 6-1 Water Supply Sources by Model System

Model System	Number of Sources			Source Pumps
	Wells	Tunnels	Shafts	
Potable	**194**	**13**	**5**	**194**
Metro Low	52	-	2	44
Metro High	6	2	-	14
Leeward	11	4	1	11
ʻEwa-Waipahu	49	-	1	49
Pearl City	12	-	1	14
ʻAiea-Hālawa	9	-	-	9
Windward	27	7	-	25
Kahuku	2	-	-	2
North Shore	9	-	-	9
Central	17	-	-	17
Nonpotable	**6**	**1**		**12**
TOTAL	**200**	**14**	**5**	**206**

Note: The 7 nonpotable sources include 4 wells, 1 spring, 1 tunnel, and the Honouliuli WWTP.

6.4 Treat

The majority of the BWS groundwater supplies are pristine and require no treatment other than addition of chlorine for residual disinfection in the distribution system. Some sources, particularly in Central and North Oʻahu, do require treatment for legacy agricultural contamination of the groundwater. These sources are treated using granular activated carbon (GAC) to remove the contaminants to meet safe drinking water standards.

The BWS also operates the Honouliuli WRF that supplies nonpotable recycled water for industrial and irrigation uses. A full discussion on potential future supplies and regulations and their effect on treatment can be found in Section 9, Water Quality, Regulations, and Treatment.

6.5 Move

While Oʻahu has sufficient freshwater supply to meet the needs of the population, the sources are not always located near the water demands. Therefore, water must be moved from sources across the island through pipelines and pump stations to where it is needed.

The BWS systems can be thought of as being split into a transmission system and a distribution system (discussed in Section 6.7, Deliver). The transmission system moves water long distances from where excess supply is available to where unmet demand is located. The transmission system uses larger sizes of pipes (16 to 42 inches in diameter), but makes up only 19 percent of the total number of miles of pipeline (approximately 385 miles). Over 200 booster pumps keep the water moving along the transmission system and lift water into higher pressure zones. Table 6-2 presents the number of booster pumps, pump capacity, and miles of transmission line in each model system.

Table 6-2 Booster Pumps and Transmission Lines by Model System

Model System	Number of Booster Pumps	Nameplate Pump Capacity (mgd)	Transmission Lines (miles)
Potable	**192**	**465**	**364**
Metro Low	53	114	103
Metro High	45	44	20
Leeward	12	31	30
ʻEwa-Waipahu	25	112	71
Pearl City	15	27	6
ʻAiea-Hālawa	14	22	1
Windward	18	95	88
Kahuku	0	0	0
North Shore	4	5	16
Central	6	17	28
Nonpotable	**16**	**-**	**20.6**
TOTAL	**208**	**465**	**384.5**

Note: The booster pump count does not include source or shaft pumps. Some booster pumps are located on the same site as sources. There is a total of 414 pumps in the BWS system, which includes 28 nonpotable pumps.

6.6 Store

Reservoirs store water throughout the BWS system to provide adequate water for high demand periods and fire protection, improve the dependability of the system, and ease stress from fluctuating pumping pressures and demands. In total, there are 171 potable water reservoirs across Oʻahu capable of storing 196.5 million gallons (MG). In addition, 7 nonpotable reservoirs have a total capacity of 15.3 MG. The distribution and volume of reservoirs across Oʻahu are presented in Table 6-3.

Table 6-3 Reservoirs by Model System

Model System	Number of Reservoirs	Reservoir Volume (MG)
Potable	**171**	**196.5**
Metro Low	37	35.8
Metro High	31	18.9
Leeward	11	18.3
ʻEwa-Waipahu	26	56.0
Pearl City	11	10.3
ʻAiea-Hālawa	12	7.5
Windward	22	31.3
Kahuku	1	0.5
North Shore	6	6.0
Central	14	18.0
Nonpotable	**7**	**15.3**
Total	**178**	**211.8**

6.7 Deliver

Once the water has been moved to the general area it is needed (through the transmission mains discussed in Section 6.5, Move), water moves into the distribution system for delivery to each and every BWS customer and fire hydrant. The BWS currently maintains service to over 170,000 customer connections and 21,000 fire hydrants.

The distribution system pipelines include distribution mains that are less than 16 inches in diameter and laterals, the pipes that go from the street to an individual home, that range from 1 inch to 4 inches in diameter. The total pipeline length in each model system is presented in Table 6-4. Figure 6-3 depicts the age range of both distribution and transmission pipelines, from the most recently installed in 2013 (latest data) to over 100 years in service.

Table 6-4 Distribution Pipelines by Diameter

Model System	Pipeline Length (miles)		Total Miles
	≤ 8 inches in diameter	10 to < 16 inches in diameter	
Potable	**1,223**	**424**	**1,647**
Metro Low	261	116	377
Metro High	199	36	235
Leeward	84	35	118
‘Ewa-Waipahu	182	85	267
Pearl City	65	21	86
‘Aiea-Hālawa	44	14	57
Windward	228	72	300
Kahuku	2	3	5
North Shore	44	12	56
Central	115	30	145
Nonpotable	**13**	**23**	**36**
TOTAL	**1,236**	**447**	**1,683**

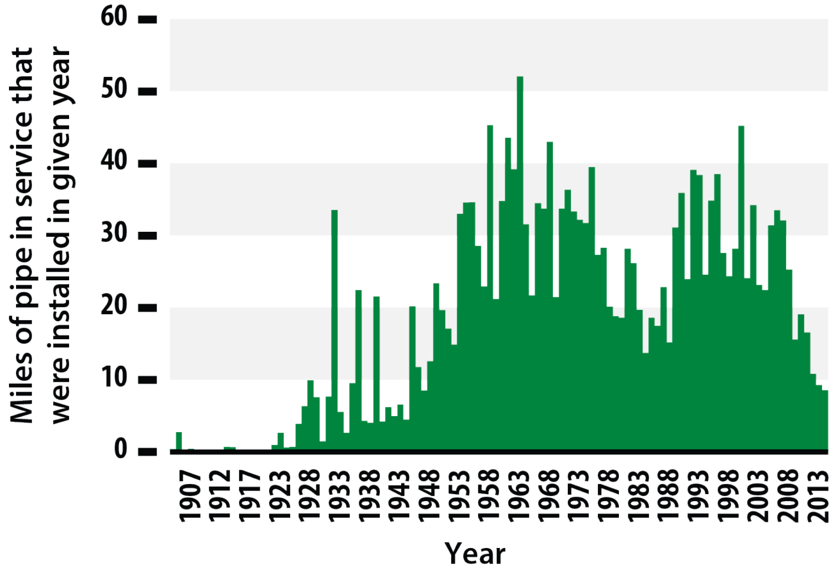

Figure 6-3
Age Profile of Potable Pipelines

Together, the BWS system pipelines are made of materials as diverse as asbestos-cement, steel, cast and ductile iron, and polyvinyl chloride (PVC). The distribution of pipes by type of material is presented in Figure 6-4.

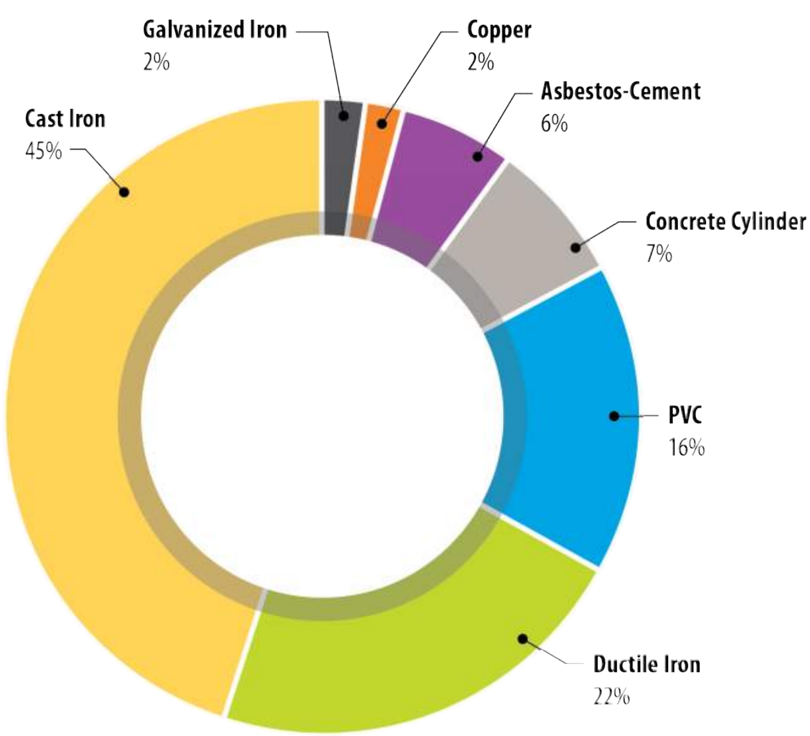

Figure 6-4
Summary of Potable Pipeline Materials

The BWS regularly maintains these pipelines to minimize both the number of and damage from main breaks. To support logistics of these maintenance activities, the BWS has six Base Yards located across Oʻahu. From these yards BWS crews are dispatched, materials and equipment are stored, and vehicles are stocked and repaired. The Capital Projects, Water Systems Operations, Water Quality, Finance, Customer Care, Water Resources, and Information Technology Divisions, Office of the Manager and Chief Engineer, and staff offices are located at the Beretania Complex.

Part II

Technical Evaluation

Section 7

Historical and Future Water Demands

This section describes historical annual demands in the BWS service area, the demand projection approach, and estimated annual demands for the future planning periods of 2025 and 2040 for two growth scenarios. There are several areas, including military installations, on O'ahu that are not served by the BWS; the population and demands in these areas are not included in this WMP.

Section 7 provides information that addresses the following WMP objectives:

- Water Quality, Health, and Safety
- 💧 System Reliability and Adequacy
- Cost and Affordability
- 💧 Water Conservation
- 💧 Water Resource Sustainability

The water demands developed in this section were used to develop the hydraulic system models and factor into the system analysis presented in Section 10, System Capacity Evaluation.

7.1 Key Findings

The key findings of the WMP's analysis of the BWS water demands are listed below. These findings are identified with a code (an abbreviation for the section name) and number (for example, DMND-1). These codes are repeated in Section 12, Findings and Recommendations, to easily tie the findings in this section to the recommendations for BWS action listed in Section 12.

DMND-1 From 1980 to 2010, population served increased from 737,000 to 922,000. The BWS system is anticipated to see continued population growth reaching 1,055,000 by 2040 (about 0.5 percent per year). Population growth will be focused in transit-oriented development (TOD) areas in 'Ewa, Central O'ahu, and the Primary Urban Center, while other land use districts will experience stable populations or marginal decreases.

DMND-2 Although projections in the early 1990s predicted demand growth, Island-wide demand has decreased by 11 mgd in the last 25 years due to per capita demand decreasing by 31 gallons per capita per day (gpcd) freeing up existing capacity. Reduction in per capita demand was due to BWS conservation initiatives, changing land use that increased population density and reduced irrigation, and economic incentives from higher water and sewer rates. With additional conservation programs and further reductions in potable water irrigation, additional per capita demand reductions are possible. The BWS should continue investment in conservation with a goal of reducing per capita demand from 155 gpcd to 145 gpcd by 2040. These continued water conservation programs and declining per capita consumption are anticipated to moderate future system demand growth.

DMND-3 A range of demand projections was developed to address uncertainties in planning assumptions. Water demand is projected to increase from 145 mgd in

2012 to between 153 mgd (for the most probable demand projection) and 167 mgd (for the high range projection) by 2040. This represents a demand increase of 8 mgd, or 5 percent, for the most probable demand projection, and 22 mgd, or 15 percent, for the high range demand projection. ʻEwa has the largest estimated increase in future demand, with Central O'ahu having the second largest increase.

DMND-4 In the 5-year average centered on 2010, BWS estimates that water loss (also referred to as unaccounted for water or non-revenue water) was approximately 10 percent. The BWS should identify areas of highest percentage of non-revenue water to focus meter calibration, leak detection, addition of new meters if necessary, and water conservation efforts, with the goal to reduce non-revenue water (real and apparent losses) to less than 8.1 percent[1].

7.2 Historical Demands

Over the past three decades from 1980 to 2010, the BWS-served population on Oʻahu increased by about 24 percent, from 737,000 to 922,000. However, the BWS water systems saw only an 11 percent water supply production increase during that same period due to increased water conservation measures, more efficient fixtures, system improvements, increasing water and sewer rates, and changing land use. Historical trends for demand and per capita use are discussed below.

7.2.1 Historical System Demand

The BWS water systems serve the majority of the water users in the eight land use districts of Oʻahu defined in the City General Plan. Table 7-1 presents the historical water demand of each land use district, the total BWS demand for each decade from 1980 to 2010 (in mgd), and the overall water demand growth over that period. Figure 7-1 depicts the historical demands for each land use district and for the entire BWS system.

Table 7-1 BWS Demand by Decade and Land Use Districts

Land Use District	1980 (mgd)	1990 (mgd)	2000 (mgd)	2010 (mgd)	30-Year Growth (%)
Primary Urban Center	77.1	88.6	76.5	69.5	-10%
ʻEwa	7.8	10.6	15.3	17.1	119%
Central Oʻahu	11.5	15.0	19.4	17.8	55%
Waiʻanae	7.7	9.1	9.3	9.2	19%
North Shore	2.3	3.2	2.8	2.9	26%
Koʻolauloa	1.5	2.9	1.5	1.4	-1%
Koʻolaupoko	16.0	17.7	19.6	15.9	-1%
East Honolulu	6.2	8.7	10.1	9.3	50%
Total	**130.1**	**155.6**	**154.5**	**143.1**	**10%**

[1] American Water Works Association (AWWA). 2014. *2012 Benchmarking Performance Indicators for Water and Wastewater Utilities: Survey Data and Analyses Report.* AWWA Catalog No.: 20761. Available at: http://www.awwa.org/store/productdetail.aspx?productid=39837461.

Almost half of the total demand in 2010 is in the Primary Urban Center, 67.7 mgd, while the next two largest land use districts, ʻEwa and Central Oʻahu, have a demand of 17 and 18 mgd respectively. These three largest districts combined represent 73 percent of the total BWS demand.

ʻEwa had the highest overall percentage of growth at 119 percent, with an increase in demand of almost 9 mgd from 1980 to 2010, followed by Central Oʻahu with growth of 55 percent and a demand increase of almost 6 mgd. While the Primary Urban Center had the highest water demand of any land use district, it experienced a 10 percent decrease in demand, equivalent to an approximately 8 mgd decrease. Koʻolauloa and Koʻolaupoko experienced very low negative growth.

Total demand decreased from 156 mgd in 1990 to 143 mgd in 2010. This decrease is attributed to the BWS conservation program and other factors such as economic drivers that occurred during the same time period, as described in Section 7.2.3.

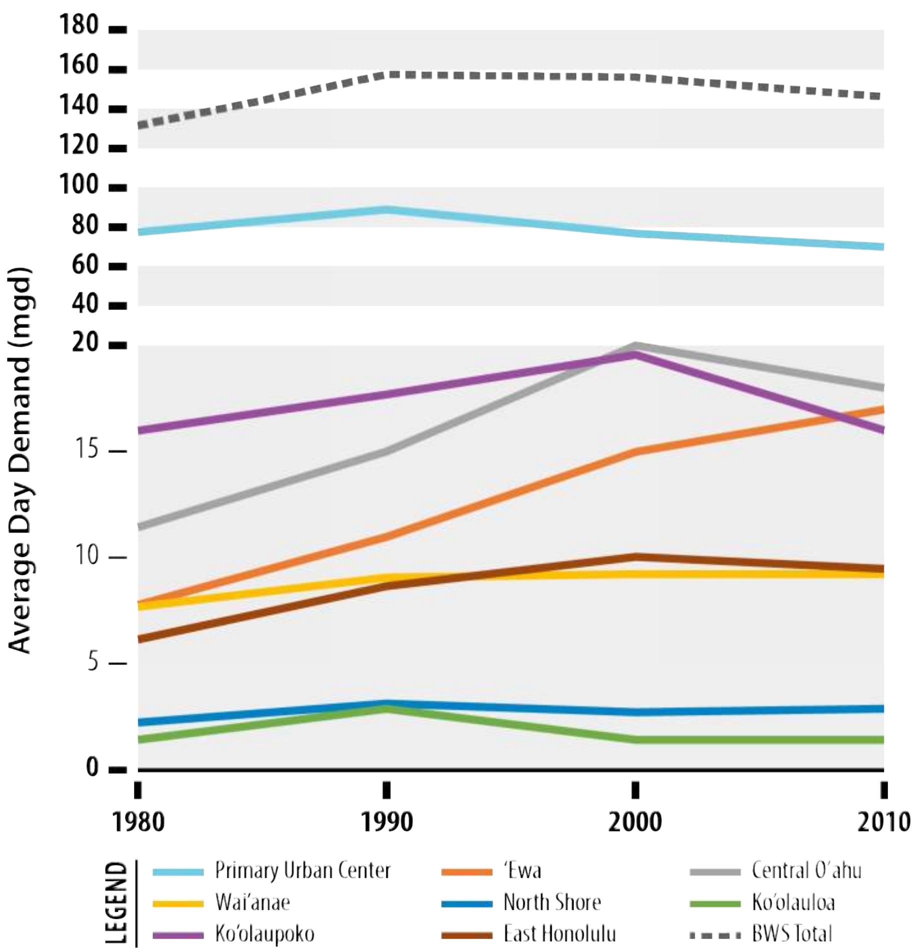

Figure 7-1
Historical Water Demand by Land Use District

7.2.2 Historical Per Capita Demand

As BWS supply system improvements and water conservation programs were implemented, per capita water demand decreased over the past 30 years. Table 7-2 presents the historical demand by land use district in gallons per person (also known as per capita) per day (gpcd). The per capita estimates are based on total production (residential, agricultural, commercial, industrial, system losses) by area or land use district, divided by the BWS served population in those corresponding areas. The importance of these metrics is that the per capita use has varied significantly between planning areas. Understanding these trends and differences is a key element in the estimation of future water demands.

Table 7-2 BWS Historical Per Capita Demand by Land Use District

Land Use District	1980 (gpcd)	1990 (gpcd)	2000 (gpcd)	2010 (gpcd)
Primary Urban Center	177	190	171	151
ʻEwa	317	281	224	185
Central Oʻahu	149	142	156	126
Waiʻanae	235	239	224	196
North Shore	195	217	195	202
Koʻolauloa	192	254	141	149
Koʻolaupoko	149	151	173	146
East Honolulu	145	190	221	194
Total	**176**	**188**	**180**	**155**

The BWS average per capita demand declined from 176 gpcd in 1980 to 155 gpcd in 2010, a 12 percent decrease. As shown in Figure 7-2, while there is variation in the trends for per capita demand between 1980 and 2000, all but two land use districts experienced decreasing per capita demand from 2000 to 2010. The two remaining land use districts, North Shore and Koʻolauloa, experienced increased per capita demand of 4 and 6 percent, respectively, from 2000 to 2010. These increases in per capita demands are likely due to decreasing population served with corresponding smaller decreases, or slight increases, in total demand, primarily from agricultural water use.

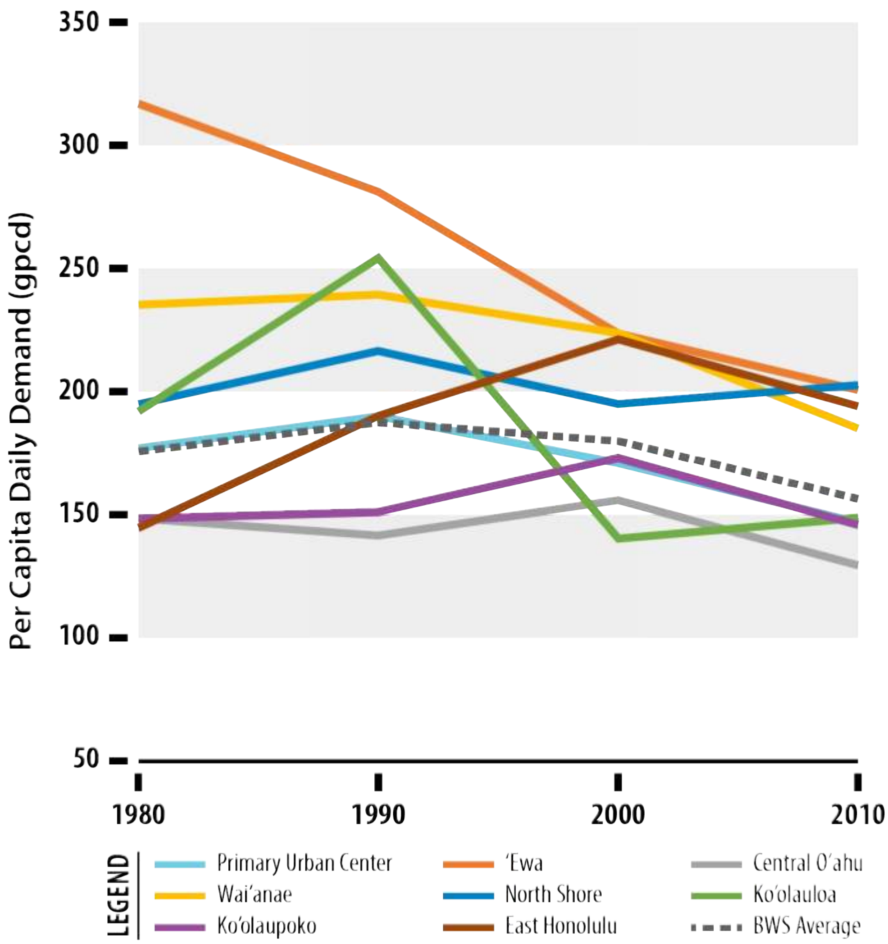

Figure 7-2
BWS Historical Per Capita Demand Trends

The BWS average per capita demand tracks closely with that of the Primary Urban Center because it has the highest demands and the largest population. The per capita daily demand for ‘Ewa was over 300 gpcd in 1980, but dropped to less than 200 gpcd by 2010. The per capita demand in the district was high in 1980 because there was only a small population compared to the industrial demand. From 1980 to 2010, residential population almost tripled, while corresponding industrial demand continued to decline due to water conservation and increased recycled water use that replaced potable water, thus reducing the per capita demand significantly. The per capita daily demand for Ko‘olauloa fluctuates the most out of the land use districts because this district has the smallest population and the smallest overall demand.

7.2.3 Effects of Water Conservation

In the late 1980s, O‘ahu’s water demand was reaching system capacity. This increasing demand trend changed in the 1990s, fueled by the collapse of the Japanese real estate investment bubble, leading to a local economic downturn. Also, the BWS’s Water Conservation Program started in 1990, and the O‘ahu Sugar Company, a large user of groundwater, closed in 1995 freeing up agricultural supply for potable uses.

Although the population served by the BWS has steadily increased from 740,000 in 1980 to 922,000 in 2010 (25 percent increase), per capita demand decreased system-wide from 1990 to 2010 from 176 gpcd to 155 gpcd (12 percent decrease). It is anticipated that the downward trend will continue, although at a slower rate (estimated additional 10 percent decrease by 2040). This continued decrease will only occur with dedicated conservation programs going forward. See Section 4, Water Supply Sustainability, for more information on future water conservation efforts.

As part of the conservation program, the City Council passed the low flow toilet ordinance in 1993 which mandated the immediate change out of all non-residential toilets from the 3 to 5 gallons per flush type to 1.6 gallons per flush type. The BWS and the City Department of Environmental Services also created a $100 rebate for residential toilets to support the mandate. This rebate program extended from 1994 to 2007 with just under 60,000 toilets in single-family homes replaced. Conservation also helped to mitigate drought conditions caused by a strong El Niño event and following drought from 1997 to 2003.

Starting in 2005, water rates increased for the first time in 11 years, and at the same time the City sewer rates increased to address the U.S. Environmental Protection Agency (EPA) consent decree. These water and sewer rate increases encouraged additional conservation.

7.2.4 Effects of Water Loss

The water demands for existing conditions were established based on the BWS customer meter and water supply production data. The production data includes water loss, also referred to as unaccounted for water or non-revenue water. Water loss is made up of two components – real and apparent losses.

1. Real water loss is the water lost through leakage, main breaks, and tank overflows.
2. Apparent water loss is water not accounted for due to unauthorized consumption or uncalibrated customer and/or source meters. In addition, some uses may not be metered including irrigation in some areas, water used to fight fires, or use of fire hydrants for construction.

For the BWS system, the total water loss including the two components is calculated as the difference between the total water production (based on flow meters at sources) and the amount of water billed to customers (metered consumption), and is estimated to be about 10 percent island-wide as of 2010. The median water loss estimate from an American Water Works Association (AWWA) survey in 2012 was 8.1 percent[2].

In order to help reduce water loss. the BWS Leak Detection Team continues to survey water pipelines and meter boxes for leaks, and repairs are conducted by the BWS Field Operations. The CIP will include projects to reduce apparent water loss, such as adding additional meters in the transmission system, performing maintenance on the retail meters and master meters to improve meter accuracy, and investing in automatic meter reading upgrades. As that data is developed, it will be used to modify future demand projections.

[2] AWWA. 2014. 2012 Benchmarking Performance Indicators for Water and Wastewater Utilities: Survey Data and Analyses Report. AWWA Catalog No.: 20761. Available at: http://www.awwa.org/store/productdetail.aspx?productid=39837461.

7.3 Demand Projection Approach

7.3.1 Oʻahu Water Management Plan

A key element in the Oʻahu Water Management Plan (OWMP) is the development of island-wide water demand estimates utilizing population forecasts provided by the Department of Planning and Permitting (DPP), developer master plans, and subdivision development information. DPP developed forecasts by transportation analysis zones and census tracts, providing discrete land use coverages within the eight land use districts. For the OWMP, the BWS applied its water use data to DPP's population forecast data to derive BWS-served populations, per capita demands, and water demand forecasts by land use district for long-range planning of source development and water system infrastructure sizing.

As with all long-range forecasts, variation occurs due to uncertainties in changing economic climate, jobs, tourism, zoning, development starts, population distribution, and water conservation. To address these variations, the OWMP developed up to four water demand scenarios up to year 2040 for each of the land use districts: low; most probable; high; and ultimate scenarios. The low-growth scenario reflected slower growth in urban development. The most probable was based on the most likely assumptions and grounded on City policies. The high growth scenario reflected a faster rate of urban growth than the City and County policies. The ultimate growth scenario identified demands where the land use districts are fully built-out.

7.3.2 WMP Annual Demand Projections

The OWMP demand projection scenarios were developed to determine the extent of water use and source development. For the Water Master Plan, that level of broad BWS-wide water demand projection was too coarse for the necessary water system analysis, especially for appropriately sizing pipelines to accommodate growth in the TOD areas. More detailed demand projection methods were utilized to provide a finer level of detail for the WMP. Some of the other information used to develop the estimates of future BWS annual demand, included:

- U.S. Census data for 2010;
- Island-wide population projections from DPP;
- The BWS served population[3] projection from the BWS Long Range Planning (LRP) Branch;
- Historical customer meter data and pumping production data from the BWS;
- Year 2012 and 2013 operational data;
- The BWS projected per capita demand projections for 2015 to 2040;
- Neighborhood TOD Plans published in 2015;
- Private development master plans, not approved by the BWS; and,
- Land use information from the City's geographical information system (GIS) zoning layer.

[3] Served population is defined as those served by the BWS water system, which takes into account residential population and visitors.

This information was used to develop future annual water demand projections that were then applied in the hydraulic models to evaluate the water system's capacity needs. Two scenarios were developed to account for potential uncertainties, and variability in many of the planning assumptions. Demands were developed through the planning horizon of 2040, and include the most probable demand estimate and a high range demand estimate. The demand estimates for years between 2010 and 2040 were based on linear interpolation.

These demand scenario calculations are depicted in Figures 7-3 and 7-4. Both the most probable and high range demand estimates were based on population projections and per capita demand projections. The most probable demand estimate assumed that the downward trends seen in per capita demands (shown in Figure 7-2) would continue in both the existing water use and new demands from incremental population growth from 2010 to 2040. The high range demand estimate assumed that the existing population's per capita demand would hold steady at 2010 levels throughout the planning period, while only the incremental increase in population from 2010 to 2040 would reduce its per capita demands to the projected 2040 rates (discussed in Section 7.4). The high range demand projection assumes that the level of conservation for existing customers has reached saturation and little additional water savings will be possible without a major rebate incentives program to compel existing users to retrofit low flow fixtures with more efficient fixtures.

Figure 7-3
Most Probable Demand Projection Approach

Figure 7-4
High Range Demand Projection Approach

7.4 Population and Per Capita Demand Projections

The City plans for the future population growth in a manner that is consistent with O'ahu's natural resources to minimize social, cultural, economic, and environmental disruptions. U.S. Census data for 2010 was the starting point for the population forecasts, with DPP population estimates for 2040 as the end point. Intermediate year populations between 2010 and 2040 were developed using linear interpolation. The BWS LRP Group processed the DPP projections to determine the population served by the BWS water supply systems, which is approximately 97 percent of the total population of Oʻahu. The population projections are presented in Table 7-3 and are consistent with the various economic development plans of Oʻahu, providing an indicator and magnitude of future trends of the BWS water system demands in the land use districts.

Table 7-3 BWS-Served Population Estimates

Land Use District[2]	2010 Population	Projected Population[1,2]						30-Year Growth	30-Year Growth Rate
		2015	2020	2025	2030	2035	2040		
Primary Urban Center	461,000	465,900	470,800	475,700	480,600	485,600	490,500	29,500	6%
ʻEwa	92,100	104,600	117,100	129,600	142,100	154,600	167,100	75,100	81%
Central Oʻahu	141,000	145,000	148,900	152,900	156,800	160,700	164,700	23,600	17%
Waiʻanae	47,200	48,000	48,900	49,700	50,600	51,400	52,300	5,100	11%
North Shore	14,500	14,800	15,100	15,400	15,700	16,000	16,300	1,800	12%
Koʻolauloa	9,500	9,700	10,000	10,200	10,500	10,700	11,000	1,500	16%
Koʻolaupoko	108,500	108,000	107,600	107,100	106,600	106,200	105,700	-2,800	-3%
East Honolulu	48,100	48,000	48,000	47,900	47,900	47,800	47,800	-300	-1%
Total	**921,900**	**944,000**	**966,400**	**988,500**	**1,010,800**	**1,033,000**	**1,055,400**	**133,500**	**14%**

[1] The BWS-served population excludes the military, private water systems, and absent residents but includes visitors.
[2] Projections have been rounded to the nearest 100.

The 2040 estimates show a wide range of population growth between the different land use districts. The 30-year population growth rates range from 81 percent in ʻEwa to -3 percent in Koʻolaupoko. The Primary Urban Center, ʻEwa, and Central Oʻahu will account for 96 percent of the total increase in population, while Koʻolaupoko and East Honolulu are anticipated to experience negative growth as the population ages. During the 30-year WMP planning period, the overall BWS-served population was projected to increase at a rate of 14 percent, which is less than 1 percent per year.

Based on the historical per capita demand trends by land use districts (shown in Table 7-2) and future implementation plans for water conservation programs, the BWS projected per capita demands by land use districts. As shown in Table 7-4, all the land use districts future per capita demand rates are projected by the BWS to decrease during the WMP planning period as the BWS conservation programs expand to ensure the per capita demands continue to decrease.

Table 7-4 BWS Per Capita Demand Estimates

Land Use District	2010 Per Capita Demand (gpcd)	Projected Per Capita Demand (gpcd)					
		2015	2020	2025	2030	2035	2040
Primary Urban Center	151	150	145	140	140	140	140
ʻEwa	185	182	168	160	160	160	160
Central Oʻahu	126	125	125	123	123	121	120
Waiʻanae	196	197	191	185	180	174	170
North Shore	202	203	203	203	203	203	200
Koʻolauloa	149	145	140	140	140	140	140
Koʻolaupoko	146	146	145	145	145	145	145
East Honolulu	194	179	180	180	180	180	180
Total	**155**	**154**	**150**	**146**	**146**	**145**	**145**

7.5 Future Annual Water Demands

As discussed in Section 7.3, the BWS future demands over the planning period have been developed for both a most probable demand and a high range demand scenario. These demands were calculated using population projections and estimated per capita water demand, with adjustments incorporated to reflect higher growth occurring in certain land use districts over others based on local development plans.

The BWS's average system production in 2012 was considered the existing system, or base year, demand. The following subsections present the base year, 2025, and 2040 projected demand by land use district and by model system. Figure 7-5 presents the system-wide historical demands from 1980 to 2010, and the two demand projection scenarios for 2010 through 2040. The difference between the most probable and high range scenarios is about 13.5 mgd by 2040. The BWS promotes the use of nonpotable water to conserve potable water resources. The water demand projection scenarios have taken nonpotable system expansion into consideration in ʻEwa only.

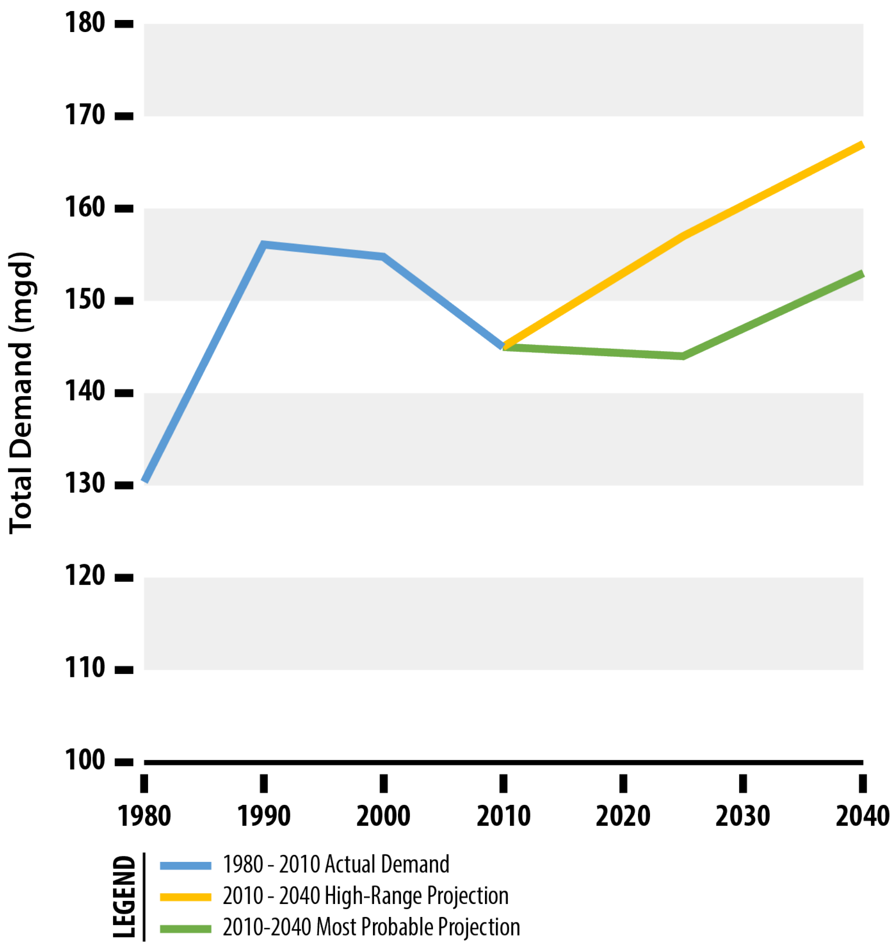

Figure 7-5
BWS Historical and Projected System-Wide Demands

7.5.1 Most Probable Demand Projection

Table 7-5 presents the most probable demand projections by land use district.

Table 7-5 Most Probable Demand Projection by Land Use District

Land Use Districts	2012 Actual Demand (mgd)	2025 Projected Demand (mgd)	2040 Projected Demand (mgd)	Change in Demand from 2012 to 2040 (mgd)	% Change in Demand 2012 to 2040
Primary Urban Center	67.4	67.0	68.7	1.3	2%
ʻEwa	18.7	20.7	26.7	8.0	43%
Central Oʻahu	17.2	18.8	19.8	2.6	15%
Waiʻanae	9.7	9.2	8.9	-0.8	-8%
North Shore	3.4	3.1	3.3	-0.1	-4%
Koʻolauloa	1.2	1.4	1.5	1.2	28%
Koʻolaupoko	18.4	15.5	15.3	-3.1	-17%
East Honolulu	8.9	8.6	8.6	-0.3	3%
Total	**144.9**	**144.4**	**152.8**	**7.9**	**5%**

The increase in total demand is just over 8 mgd, an approximately 5 percent increase from 2012 to 2040. Total demand is flat between 2012 and 2025, with a decrease of less than 1 mgd. There is a wide variation in land use district water demand growth from 2012 to 2025 (-16 to 19 percent) and from 2012 to 2040 (-17 to 43 percent). ʻEwa has the largest increase in demand from 2012 to 2040 at approximately 8.0 mgd (43 percent). Central O'ahu has the second largest increase in demand, 2.6 mgd for 2012 to 2040. Waiʻanae, Koʻolaupoko, and East Honolulu are projected have negative growth in demand (-8, -17, and -3 percent, respectively) through the planning period under the most probable demand projection.

7.5.2 High Range Demand Projection

Table 7-6 presents the high range water demand projections by land use district.

Table 7-6 High Range Demand Projection by Land Use District

Land Use District	2012 Base Year (mgd)	2025 Projected Demand (mgd)	2040 Projected Demand (mgd)	Change in Demand from 2012 to 2040 (mgd)	% Change in Demand 2012 to 2040
Primary Urban Center	67.4	72.2	74.4	7.0	10%
ʻEwa	18.7	22.9	28.2	9.5	51%
Central Oʻahu	17.2	19.4	20.8	3.6	21%
Waiʻanae	9.7	10.2	10.6	0.9	9%
North Shore	3.4	3.6	3.8	0.4	12%
Koʻolauloa	1.2	1.3	1.4	0.2	17%
Koʻolaupoko	18.4	18.4	18.4	0.0	0%
East Honolulu	8.9	8.9	8.9	0.0	0%
Total	**144.9**	**156.9**	**166.5**	**21.6**	**15%**

The increase in total demand is just under 22 mgd, an approximately 15 percent increase from 2012 to 2040. There is a wide variation in the land use district demand growth from 2012 to 2025 (0 to 22 percent) and from 2012 to 2040 (0 to 51 percent). ‘Ewa has the largest increase in demand from 2012 to 2040 at approximately 9.5 mgd (51 percent). The Primary Urban Center has the second largest increase in demand, 4.8 mgd for 2012 to 2025 and 7 mgd for 2012 to 2040. More than 75 percent of the total increase in demand occurs in ‘Ewa and the Primary Urban Center. Both Koʻolaupoko and East Honolulu are projected to have no growth in demand through the planning period.

7.6 Nonpotable Demands

The BWS promotes the use of nonpotable water to conserve potable water resources. The BWS water systems consist of four existing nonpotable (NP) water systems:

- Barbers Point 215 NP (Brackish water wells);
- Mauna ‘Olu 530 NP (Glover Tunnel);
- Honouliuli WRF (tertiary disinfected R-1, and reverse osmosis demineralized recycled water); and
- Hālawa 245 NP (Brackish water springs).

The Barbers Point 215 NP and Honouliuli WRF water systems serve the nonpotable water users in ‘Ewa land use district. Both systems are planned to expand their service capacities as shown in Table 7-7. Glover Tunnel supplies nonpotable water to Mauna ‘Olu 530 NP Reservoir, which is used for irrigation. The Hālawa 245 NP water system is located in the Primary Urban Center land use district and is supplied by Kalauao Springs.

With increasing availability and accessibility, nonpotable water will be more commonly used by future golf courses, parks, development landscaping, and industrial users. Some existing large users on the potable water system may also be converted to nonpotable water use when nonpotable water becomes available. As the nonpotable supplies are expanded and take the place of potable supply with the applications above, the unit potable water demand of ‘Ewa land use district will decrease.

The BWS has taken this NP system influence into consideration in the projection of the future per capita water demands. Future nonpotable demands have been accounted for by offsetting the increase in future demands of the potable water system.

Table 7-7 Existing and Future Demands by Nonpotable Users in ʻEwa

Project Area Name	Existing Demand (mgd)	Ultimate Demand (mgd)	Source of Projection
Kapolei Business Park	0	0.52	Total of 3.22 mgd ultimate NP demand[1]
Kapolei Harborside	0	0.46	
Maritime Industrial Park	0	0.09	
Kapolei West	0	1.19	
City of Kapolei	0.12	0.96	
Ko Olina Resort	1.00	1.00	Total of 13.03 mgd ultimate NP demand[4]
Ko Olina Golf Course	0.70	0.70	
Campbell Industrial Park	1.50[2]	1.88[2]	
	0[3]	1.33[3]	
Villages of Kapolei	0.34	0.60	
East Kapolei (UH–West Oʻahu)	0.40	1.02	
ʻEwa Gentry	0.57	0.57	
Ocean Pointe	0.60	1.0	
ʻEwa Beach	1.10	1.32	
ʻEwa Villages	0.75	0.75	
West Loch	0.75	0.75	
Hoʻopili	0	2.11	
Total	**7.83**	**16.25**	

Notes:
[1] Source: Engineering Concepts, Inc. 2012. *Draft Kapolei Regional Non-Potable Water Master Plan*. Prepared for Kapolei Property Development LLC. July 2012.
[2] Reverse osmosis (RO) water – recycled water that is oxidized, filtered, disinfected, and demineralized, and used for industrial purposes at refineries and power plants
[3] R-1 water – recycled water that is oxidized, filtered, and disinfected, and used for landscaping and irrigating crops
[4] Source: BWS Water Resources data, 2016.

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Section 8

Current and Future Water Supply Sources

Section 8 **provides information that addresses the following WMP objectives:**

- Water Quality, Health, and Safety
- 💧 System Reliability and Adequacy
- Cost and Affordability
- 💧 Water Conservation
- 💧 Water Resource Sustainability

This section addresses the existing water supply sources for the BWS service area, trends and uncertainties related to these supplies, and potential future supply sources. Planning for, and sustainable use of, Oʻahu's water supplies are important functions and responsibilities of the BWS. As the largest user of the island's water resources, the BWS recognizes the importance of understanding the interrelationship between the overall island resources and the other uses and users of water on Oʻahu.

The information in Section 8 is used in conjunction with the data in Section 7, Historical and Future Water Demands, to evaluate the BWS model systems, as presented in Section 10, System Capacity Evaluation.

8.1 Key Findings

The key findings of the WMP's analysis of the BWS water supply sources are listed below. These findings are identified with a code (an abbreviation for the section name) and number (for example, SUPP-1). These codes are repeated in Section 12, Findings and Recommendations, to easily tie the findings in this section to the recommendations for BWS action listed in Section 12.

SUPP-1 Water users on Oʻahu have access to multiple sources of water to meet their needs. Domestic, industrial, and agricultural users may access a variety of surface water, groundwater, recycled water, and brackish water supplies depending on what is available to them.

SUPP-2 The sustainable yield from Oʻahu's groundwater aquifers adopted by the Commission on Water Resource Management (CWRM) is 407 mgd[1]. Of the estimated sustainable yield of 407 mgd from Oʻahu's aquifers, less than half was used in 2010. However, demand is not always co-located with available supply so supplies can be stressed in areas of high population density and high water use.

[1] State of Hawaiʻi Commission on Water Resource Management. 2008. *Hawaiʻi Water Plan: Water Resource Protection Plan.* Prepared by Wilson Okamoto Corporation. Available at: http://files.hawaii.gov/dlnr/cwrm/planning/wrpp2008update/FINAL_WRPP_20080828.pdf. June 2008.

SUPP-3 The BWS customers form the largest user base on the island making the BWS is the largest user of water. As of 2010, the BWS's supply was comprised of groundwater (93 percent), recycled water (5 percent), and brackish nonpotable water (2 percent).

SUPP-4 The BWS has sufficient supply during normal and drought conditions to meet the high range demands in 2040 for average day conditions.

SUPP-5 There are several issues that could potentially affect O'ahu's water supply reliability, such as water quality concerns and climate change. The BWS is actively addressing these concerns by continuously monitoring its system, maintaining operation flexibility, investing in alternative supply sources, and researching the implications of climate change adaptation (see Section 4, Water Supply Sustainability, for more information).

SUPP-6 Well casings are aging, some approaching 100 years old, which could cause water quality issues and reduced yield. Wells should have maintenance completed every 25 years as pumps are replaced. Casings are expected to last at least 100 years before needing replacement.

SUPP-7 The structural condition of source tunnels and shafts and sanitary seals need to be periodically evaluated. Sanitary surveys are conducted periodically. Tunnel condition should be reevaluated every 20 years (currently due), and tunnel and shaft rehabilitation projects as identified should be implemented.

SUPP-8 Potable water sources are entirely drawn from groundwater. Climate change is forecast to make dry areas drier, cause more frequent and severe droughts, and increase chloride levels in 'Ewa, Kunia, and Wai'anae sources. Reliability could be improved through diversification of sources. Invest in diversified (nonpotable groundwater) sources working toward the FWI goal of doubling such supply by 2040. Projects include increased reuse and Kalaeloa and Kapolei desalination plants.

8.2 O'ahu's Water Resources

In order to support the balance between the demands of its customers and the needs of the island's other water users in a sustainable way, the BWS adheres to the following planning principles when operating its system and planning for future supply:

- Operate groundwater sources within sustainable yields;
- Move water from where it is to where it is needed, take only what is needed, without causing harm, and do not waste it;
- Develop new groundwater sources for growth and reliability;
- Protect and maintain the quality of drinking water groundwater resources;
- Plan for sufficient water for agricultural uses;

- Diversify supply to address uncertainty; and
- Monitor trends and adjust as necessary.

With these principles in mind, the BWS utilizes its water supply to meet the demand of its customers efficiently and with a high level of quality. The WMP provides information on how to best use Oʻahu's water resources to meet the service area's water demands in a sustainable manner, while meeting the goals of the BWS's planning principles.

8.2.1 Hydrology

In ancient times, Oʻahu's earliest inhabitants, the native Hawaiians, drew their water supplies from freshwater springs, lakes, streams, and wells. When the first artesian wells were developed in the late 1800s, residents of Oʻahu increasingly relied on groundwater for industrial and municipal water supply. Groundwater sources are fed by rainfall and healthy watersheds that collect and recharge the underground aquifers, and are dependent on three essential natural elements:

- Tradewinds from the northeast drive clouds, hydrated by evaporation from ocean waters, inland towards the Koʻolau Mountains.
- The Koʻolau Mountain range captures and forces the moisture-laden clouds to higher elevations, resulting in condensation and rainfall on the land below. The direction of the prevailing winds causes the windward (northeast) side of Oʻahu to be generally wetter than the leeward (southwest) side, with most of the rainfall occurring over the Koʻolau and Central Oʻahu. The distribution of rainfall across Oʻahu is presented in Figure 8-1. Annual precipitation ranges from less than 25 inches in ʻEwa and leeward coastal areas to 240 inches along the northern end of the Koʻolau Mountains.
- As rainwater slowly percolates into the earth, the water is naturally filtered by volcanic soils and stored in groundwater aquifers. These aquifers are a natural, freshwater reservoir from which the BWS eventually extracts groundwater to supply their customers. In the higher elevations, where rainfall is concentrated, groundwater is restrained by impermeable vertical rock structures called "dikes" formed by lava flows that intrude into existing, permeable rocks. In the valleys and middle elevations, groundwater exists as extensive reservoirs of freshwater that float on sea water under much of the southern and northern portions of the island. Where the fresh and salt waters merge, a brackish water mixing zone forms. Caprock formations comprised of sediments and corals deposited along Oʻahu's coast line effectively dam the freshwater from freely discharging to the ocean, creating a thick basal freshwater lens upgradient. The caprock aquifer is brackish and supplies many small wells used for irrigation. Figure 8-1 shows the areas of the island where dike-impounded, fresh basal, and brackish caprock water are typically found.

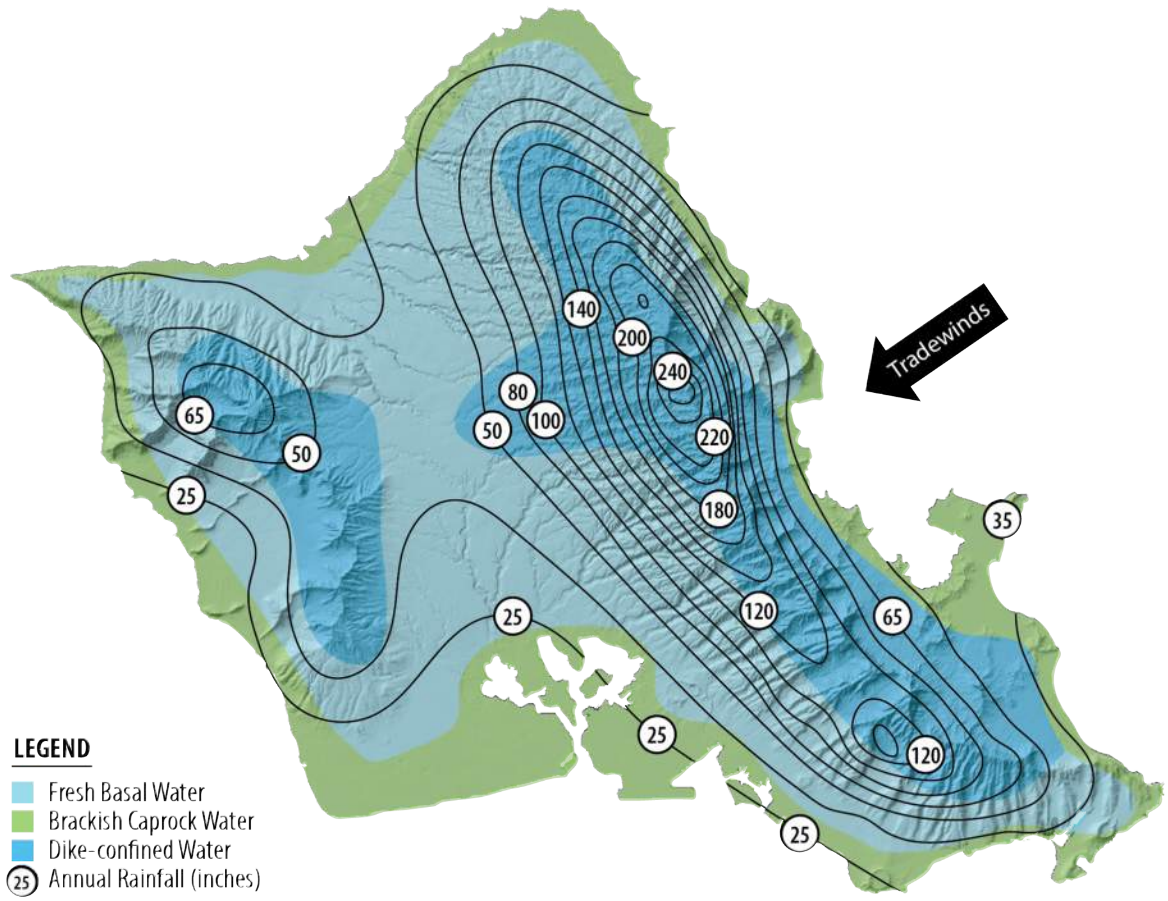

Figure 8-1
Oʻahu Mean Annual Rainfall in Inches[2]

The average volume of rainfall falling on Oʻahu's watersheds is approximately 1.4 billion gallons per day. Of this total, approximately one-third is lost through evapotranspiration (loss of water through evaporation and plant transpiration), one-third recharges the groundwater aquifers, and one-third becomes runoff and streamflow. As water moves from the mountains to the sea in streams, recharge to groundwater aquifers can also occur from seepage through streambeds.

Some streamflow is used by farmers to irrigate crops. Figure 8-2 shows the agricultural zoned lands on Oʻahu with the four major irrigation systems: Waiāhole Ditch; Wahiawā; Waimānalo; and Punaluʻu. The majority of the agricultural land is located on the leeward coast, the north shore, and in central Oʻahu. The system of irrigation ditches was developed over time to more efficiently convey streamflow to agricultural lands.

[2] Source: Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte. 2013. Online Rainfall Atlas of Hawaiʻi. *Bull. Amer. Meteor. Soc.* 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1. Available at: http://rainfall.geography.hawaii.edu/.

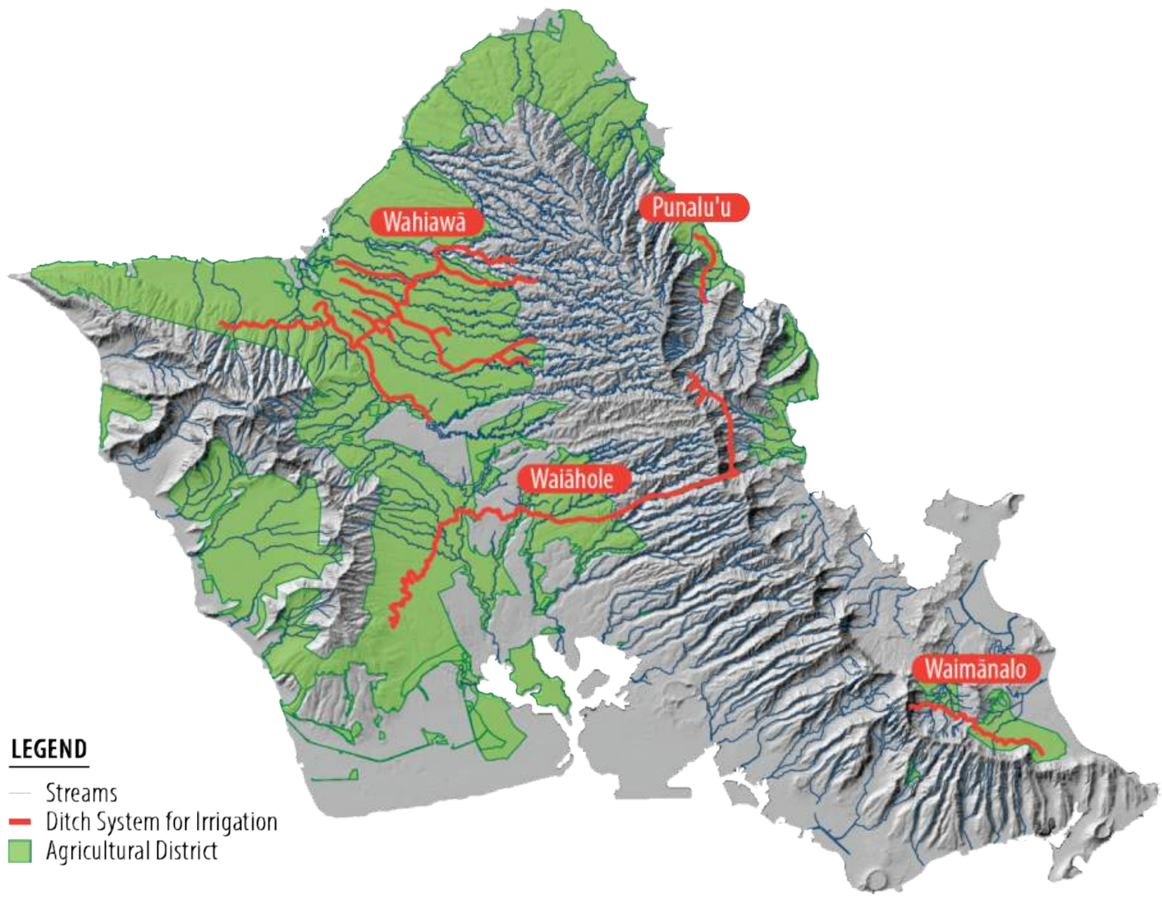

Figure 8-2
Oʻahu Streams and Irrigation Ditches

Maintaining a healthy watershed requires a balance between the supply of water in the streams (surface water used by agricultural interests and environmental needs) with the supply of water in underground aquifers (groundwater used by the BWS and other users) to meet municipal and agricultural demands. The BWS understand the importance of maintaining healthy watersheds, and therefore operates its groundwater sources within the sustainable yields of the aquifers they pump from. Additionally, the BWS sites new sources to not impact streams, habitat, water rights, stream users, or other water users.

8.2.2 Groundwater Resources

On Oʻahu, the major freshwater groundwater aquifers are either freshwater lens or dike-impounded systems. Minor perched systems, or pockets of groundwater sitting on impermeable soils such as volcanic ash, can also exist above the lowest water table level. Normally, dike-impounded groundwater is tapped using horizontal tunnels. Once a dike compartment holding water is accessed, water flows by gravity through the tunnel and into transmission mains for delivery to customers. Vertical wells, using pumps to lift groundwater from below the ground surface, are used to tap the basal freshwater lens groundwater that is located in lower elevations and provides the majority of supply for the island.

In the freshwater lens, illustrated in cross section in Figure 8-3, the ratio between the respective densities of the freshwater and salt water is such that theoretically for each foot of freshwater that stands above sea level, 40 feet extend below sea level. In the Honolulu and Pearl Harbor Aquifers, where the average water table (groundwater elevation) is approximately 20 feet above sea level, there is approximately 800 feet of freshwater aquifer thickness below sea level. More important to understanding the sustainability of a groundwater aquifer than the volume of stored freshwater available is the rate at which it recharges. Based on the estimates of rainfall that becomes runoff, evapotranspiration, and groundwater recharge presented above, about 470 mgd of water percolates into the ground in an average day on Oʻahu. However, the net contribution to groundwater can be less after accounting for groundwater contributions to streamflow (stream base flow) and leakage to nearshore waters.

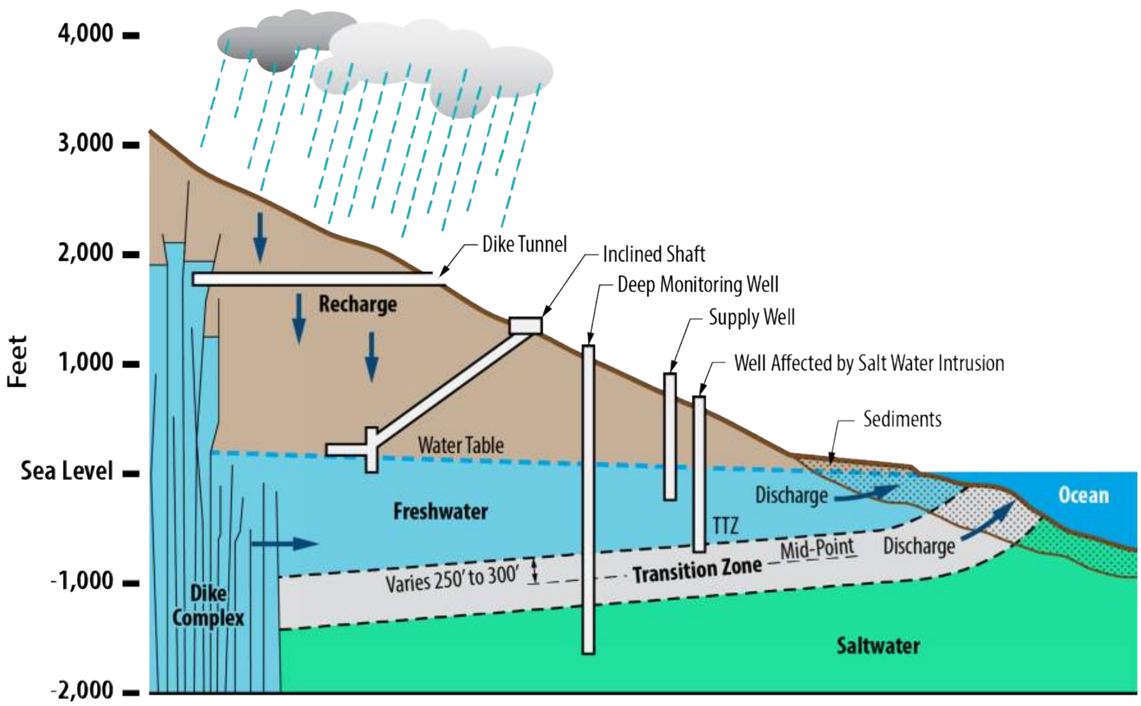

Figure 8-3
Aquifer Zones – Freshwater, Transition Zone, and Saltwater

Two of the critical responsibilities of the Commission on Water Resource Management (CWRM) are the determination of Oʻahu's aquifers sustainable yields, which is the maximum rate at which water may be withdrawn from a water source without impairing the source's utility or quality, and the administration of Water Use Permits (WUP) for designated water management areas. Figure 8-4 presents the sustainable yield CWRM developed for each groundwater aquifer. A total of 407 mgd is estimated to be available from Oʻahu's aquifers for use by the BWS and other permitted groundwater users.

The aquifer sustainable yields are determined by CWRM and updated periodically. The aquifer sustainable yields have been reduced in the past, largely due to changes in land use from the closing of sugar plantations and the associated reduction in recharge from irrigation, and may be again in the future based on updates to the CWRM water balance calculations. Any reductions in sustainable yield could affect water supplies if users are directed to reduce pumping.

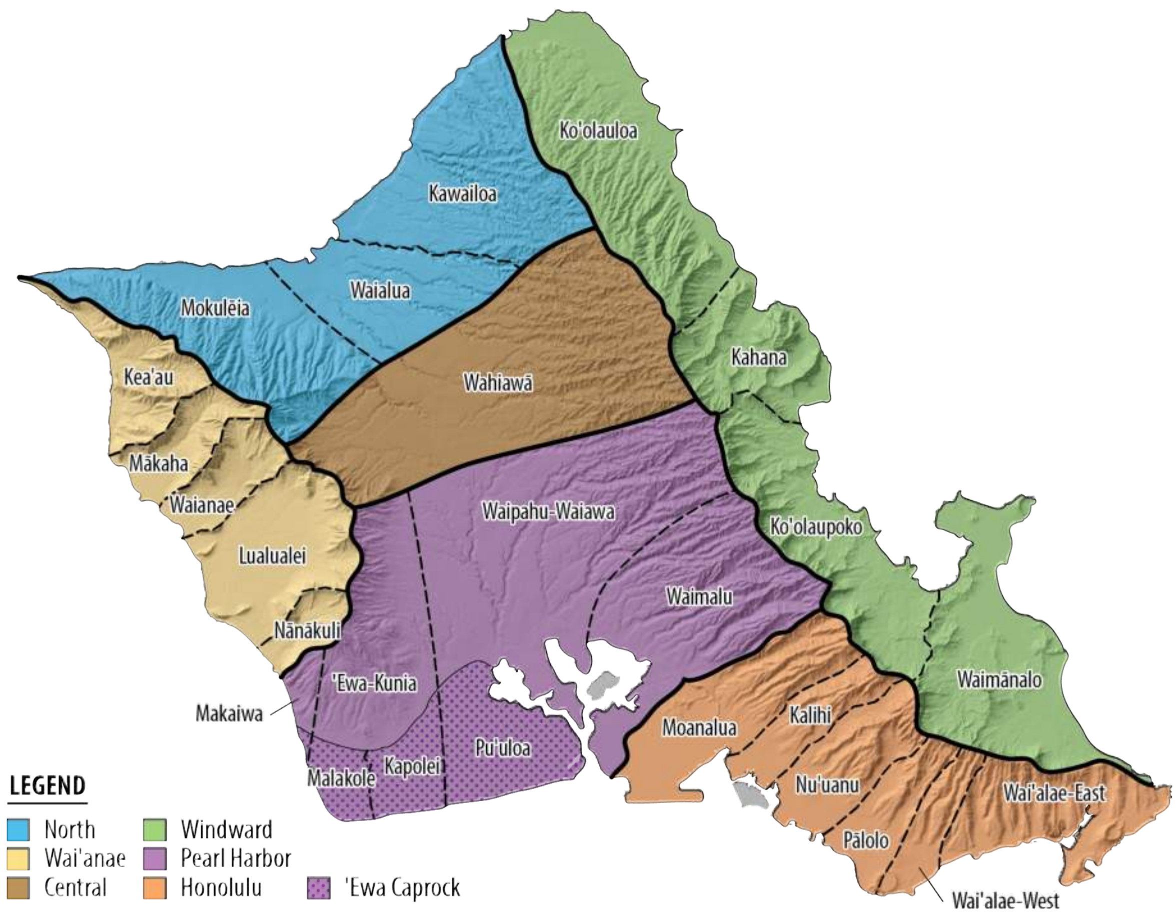

Figure 8-4
Oʻahu Aquifers[3]

8.3 Water Use and Supply Availability

Water users on Oʻahu are fortunate to have access to multiple sources of water to meet their demands. Domestic, industrial, and agricultural users may use a mix of supplies depending on what is available to them. For example, in a 2015 study of agricultural land use on Oʻahu[4], 13 agricultural areas identified around the island used a mixture of surface water sources (e.g., Wahiawā Reservoir, Maunawili and Punaluʻu streams), private groundwater sources (e.g., Waiāhole Ditch), and the BWS groundwater sources where connectivity to the BWS's system was available. In accordance with its planning principles of "Moving water from where it is to where it's needed, take only what we need, without causing harm, and don't waste it" and "Planning for sufficient water for agricultural uses," the BWS does not use surface water for drinking water

[3] Source: CWRM. 2008. *Island of Oʻahu, Hydrologic Units*. Available at: http://files.hawaii.gov/dlnr/cwrm/maps/gwhu_oahu.pdf. August 28, 2008.

[4] Hawaiʻi Department of Agriculture. 2016. *Statewide Agricultural Land Use Baseline 2015.* Prepared by UH at Hilo. Available at: http://hdoa.hawaii.gov/wp-content/uploads/2016/02/StateAgLandUseBaseline2015.pdf.

supply. Island-wide groundwater use and other sources of water (recycled and nonpotable water) that the BWS utilizes are provided below.

8.3.1 Island-wide Groundwater Use

The BWS is the largest user of groundwater on the island, accounting for 64 percent (146 mgd) of the groundwater use in 2010, as shown in Figure 8-5. Other major users include the military (23 mgd), agriculture (23 mgd), and landscape irrigation (17 mgd). Private domestic and industrial users account for 0.5 mgd and 20 mgd, respectively. The groundwater use shown in Figure 8-5 includes freshwater aquifers, Waiāhole Ditch, and ʻEwa Caprock brackish groundwater.

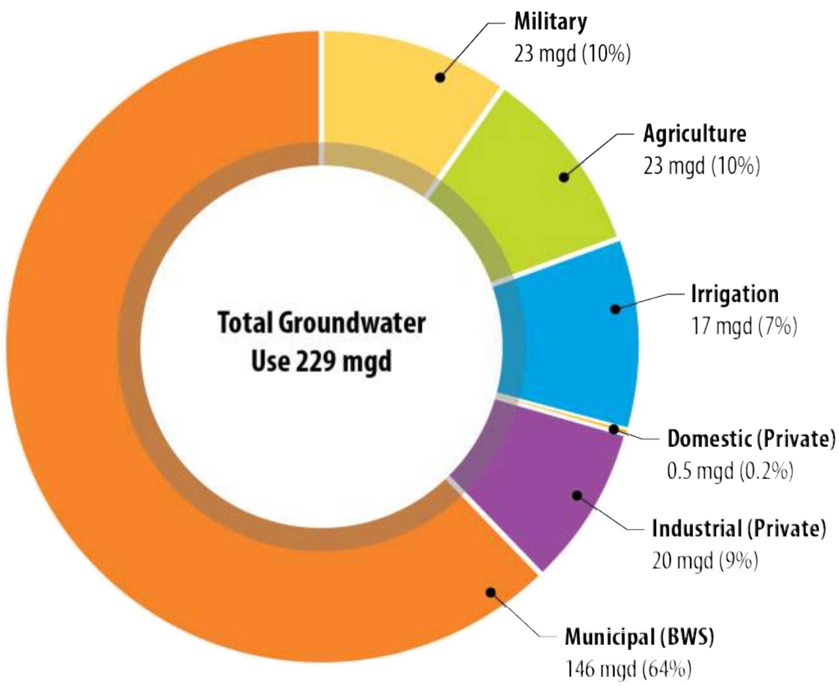

Figure 8-5
2010 Oʻahu Groundwater Use

Table 8-1 summarizes the sustainable yield, water use permits, and usage for each of the major freshwater aquifers based on CWRM's aquifer sectors shown in Figure 8-4. Approximately 294 mgd of the total sustainable yield of 407 mgd is permitted for use by the BWS and other users. The Waiʻanae aquifer is not a "Designated Water Management Area," so it does not have water use permits assigned to it. The remaining 113 mgd is unallocated, but, except for the Waipahu-Waiawa aquifer, much of this potential yield is located in basins where it is either difficult to access the underground supplies or expensive to convey the water to areas where additional supplies are needed. For example, the sustainable yields in Waiʻanae and Windward aquifer sectors (Kahana, Koʻolaupoko, and Waimānalo) are not readily recoverable due to their many dike systems. The BWS exploratory wells in these areas experienced low yields or affected streams.

Table 8-1 Summary of Oʻahu's Aquifers

Aquifer Sector	Sustainable Yield (SY) (mgd)	WUP Issued[1] (mgd)	Unallocated SY (mgd)	2010 Water Use[2] (mgd)	SY Less 2010 Water Use (mgd)
Honolulu	50	53	-3	45	5
Pearl Harbor	165	147	18	99	66
Central	23	22	1	8	15
Waiʻanae	16	0[3]	16	5	11
North	62	40	22	4	58
Windward	91	32	59	29	62
Total	**407**	**294**	**113**	**190**	**217**

Notes:
Source: BWS. 2015. North Shore Watershed Management Plan, Public Review Draft. Prepared for BWS. Prepared by Group 70 International. Available at: http://www.boardofwatersupply.com/files/NSWMP_PublicReviewDraft_11.3.15.pdf. November 2015.
[1] WUP includes the BWS and non-BWS supplies.
[2] Does not include Waiāhole Ditch or ʻEwa Caprock Aquifer.
[3] The Waiʻanae aquifer does not have WUP assigned.

In the Honolulu aquifer, the total permitted use is greater than the estimated sustainable yield of the aquifer due to recent CWRM reductions in sustainable yields and water use is close to the sustainable yield. The Pearl Harbor aquifer has available sustainable yield, due to reductions in agricultural demands (e.g., the closing of the Oʻahu Sugar Company in 1994). There is also available sustainable yield in the North and Windward aquifer sectors that could be used for additional agriculture because the City General Plan does not plan major urban growth in those areas.

8.3.2 BWS Water Use

As shown in Figure 8-6, the BWS's supply is comprised of groundwater (93 percent), recycled water (5 percent), and brackish nonpotable water (2 percent). The planning principle of encouraging diversity of supplies in order to address uncertainties like drought, climate change, and water quality issues drives the BWS to develop and utilize alternative sources that may prove more resilient than the existing groundwater wells. In ʻEwa, recycled water has been developed to reduce reliance on transfers from Central Oʻahu (specifically the Pearl Harbor aquifer) to provide sufficient groundwater supplies for urban and agriculture in Central Oʻahu and in Honolulu.

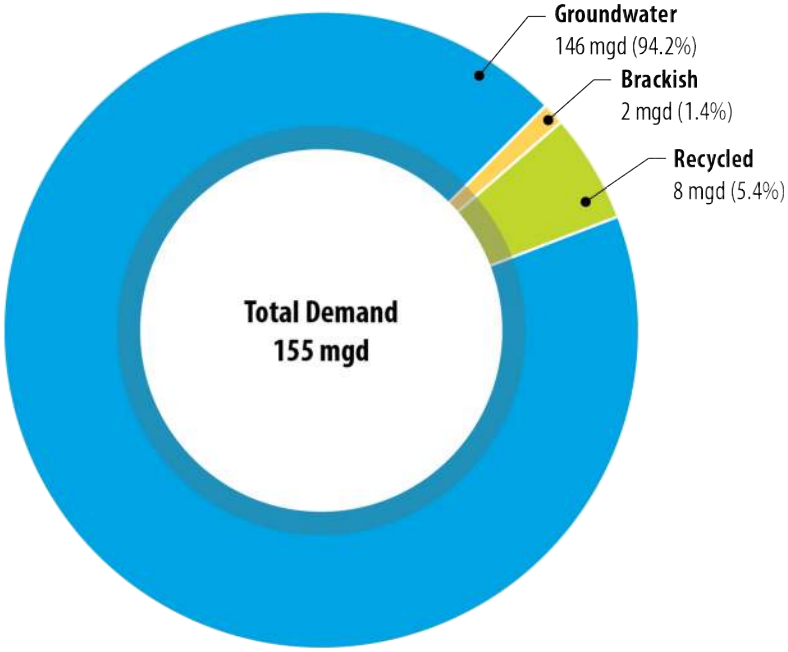

Figure 8-6
BWS Source Water Used in 2010

8.3.2.1 Groundwater

The BWS potable supply wells have a total permitted use of 182.6 mgd, although this does not include supplies in the Waiʻanae land use district because Waiʻanae is not a designated water management area and, therefore, water use permits are not assigned for this aquifer. The total BWS-assessed source yield and State permitted use, which includes the Waiʻanae sources and other spring sources, is 192 mgd. Actual pumping varies year-to-year and throughout the year, based on the demands of BWS customers. In general, demand is higher in the summer and higher overall in drier years due to greater irrigation needs. For the period of 2010 to 2014, annual average pumping from BWS supply wells ranged from 135.8 mgd to 144.5 mgd and averaged 142.4 mgd. Table 8-2 summarizes the BWS assessed source yields and permitted use for BWS supply for each land use district.

Also included in Table 8-2 is an estimate of how much yield is available from each of the BWS's facilities during a period with normal (average) amounts of rainfall, and during a drought (period with below average rainfall). Based on the BWS's Strategic Plan Vision of "Water For Life" and mission – to provide safe, dependable, and affordable water now and into the future - the "Water for Life" drought estimates were developed by the BWS based on sustainable pumpage goals for each groundwater source. Normal rainfall and drought estimates were developed by the BWS based on an assessment of historical source pumpage, head levels, deep monitor well data, and chloride trends. The difference between the normal rainfall and drought yield estimates is approximately 20 mgd. The estimates represent sustainable pumpage goals for each groundwater source to be used as guidance for operating BWS sources during average rainfall conditions and where pumping must be reduced during extended drought periods. Where assessed and permitted use exceeds the normal rainfall estimate, such as in Honolulu and Windward, the BWS goal is to reduce average day pumping to allow the source to recover so more water can be available during drought. Where assessed and permitted use is less than normal rainfall estimates, such as in Pearl Harbor, the BWS is intending to apply for more permitted use when growth occurs and more water is needed.

Table 8-2 BWS Groundwater Average Annual Supplies by Aquifer Sector

Aquifer Sector	BWS Assessed Source Yields (mgd)[1]	BWS Permitted Use (mgd)	"Water For Life" Normal Rainfall Well Yield (mgd)	"Water For Life" Drought Well Yield (mgd)
Honolulu	44.9	44.9	39.3	32.2
Pearl Harbor	108.5	108.5	113.2	102.7
Central (Wahiawā)	4.3	4.3	4.5	4.5
Wai'anae[2]	4.3	0.0	4.3	4.3
North	4.1	4.1	4.9	4.9
Windward	25.8	20.8	21.3	19.0
Total	**192.0**	**182.6**	**187.6**	**167.6**

[1] BWS adds source yields that do not have a permitted use.
[2] The Wai'anae aquifer is not a designated water management area and therefore does not have a permitted use.

8.3.2.2 Recycled Water

In 2003, the BWS acquired the state's largest water recycling plant, the Honouliuli WRF. The plant is next to the city's Honouliuli WWTP and can produce up to 12 mgd. Average production is currently approximately 8 mgd. The facility produces two grades of recycled water, one for irrigation and the other for industrial use. The Honouliuli WRF is capable of producing 10 mgd of R-1 water (recycled water that is oxidized, filtered, and disinfected), used for landscaping and irrigating crops, and 2 mgd of reverse osmosis (RO) water (recycled water that is oxidized, filtered, disinfected, and demineralized), used for industrial purposes at refineries and power plants. The RO water is pumped to Campbell Industrial Park and Kahe Power Plant. The R-1 water is pumped to users throughout 'Ewa including most golf courses and the City of Kapolei. Recycled water is delivered to users through pipes that are separate from the drinking water distribution system. Recycled water with this level of treatment is not intended for drinking. Recycled water is regulated by DOH to the highest levels of safety based on the intended use.

8.3.2.3 Brackish Water

Brackish supplies are used to meet demand for landscape irrigation in various locations in Central, Wai'anae, and the Primary Urban Center and averaged 2.0 mgd of supply in 2010. These supplies include Glover Tunnel in Mākaha, a Barbers Point nonpotable well, and Kalauao Spring in Pearlridge.

8.3.3 BWS Supply Availability

Figure 8-7 compares the average annual demand projections for 2020 to 2040 for the high range and most probable demand scenarios (see Section 7.5) to two assumptions about groundwater supply: 1) well pumping capacity during normal conditions; and 2) well pumping capacity during drought conditions. The results show that the BWS has sufficient supply during normal and drought conditions to meet the high range of demands in 2040 for average day conditions. These are island-wide totals and individual water system source capacities will vary. The BWS will monitor and update water demand projections so that if the higher projection of demands occurs, the BWS will begin work on developing more aggressive conservation measures or additional capacity to meet the demand increases. However, based on current use it appears unlikely that the high range demand projection will actually occur.

The supply needed during a maximum day or peak hour demand period would be higher for a short period of time, and the same existing groundwater sources can be operated in a way to maximize peak supply by utilizing available aquifer storage in the short-term while maintaining long-term average pumping within the permitted rates. The maximum day and peak hour demands, and the need for additional supplies to meet these demands, are discussed in Section 10.

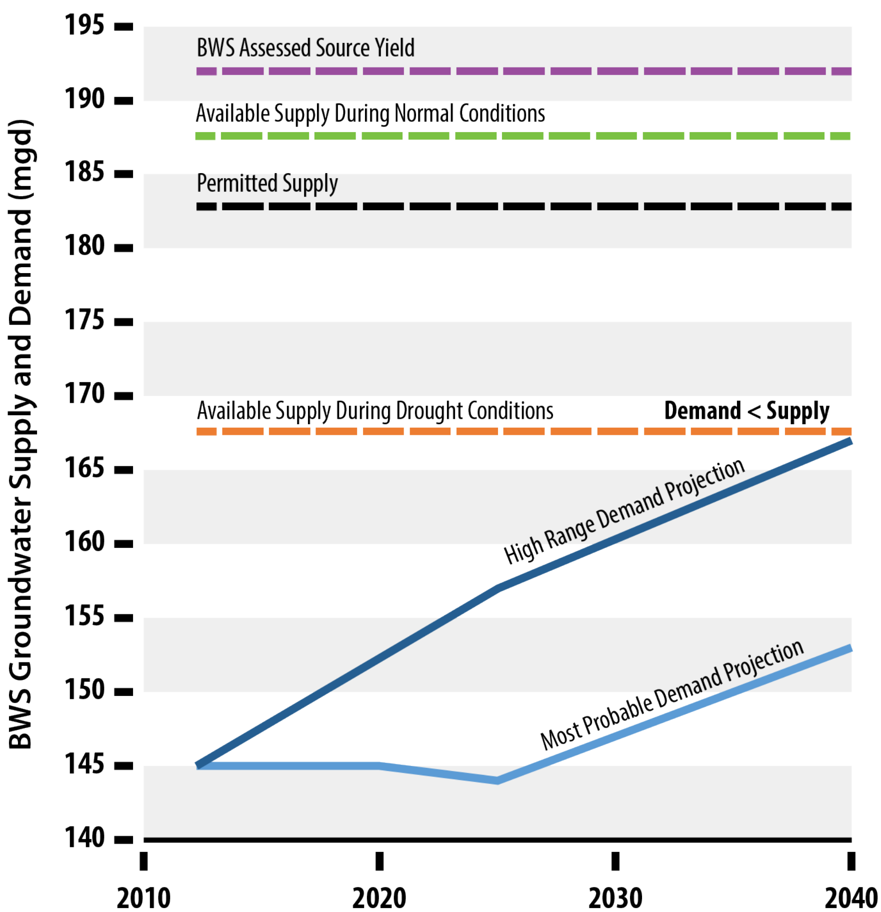

Figure 8-7
Comparison of BWS Average Annual Demand Projections and Currently Planned Supplies

8.4 Trends Affecting O‘ahu’s Water Supply Needs

Because the BWS heavily relies on groundwater to serve its customers, any conditions that impact the availability of groundwater affect the BWS’s overall supply reliability. This section highlights several conditions that affect O‘ahu’s water supply reliability, such as water quality concerns and climate change, and offers contingency planning to address uncertainties.

8.4.1 Climate Change

Climate change has the potential to affect the availability of water supply as rainfall and temperature patterns change in the future. Many studies are underway to quantify future climate change in Hawaiʻi. Both the future climate predictions and the datasets they are based on have been improving with advancements in climate change research. Modeling completed for the 2012 Pacific Islands Regional Climate Assessment predicts mean annual temperature increases for Oʻahu ranging from three to five degrees Fahrenheit by the end of this century[5]. Predictions for changes in precipitation are more variable, ranging from a two-percent decrease to a four-percent increase in rainfall by the end of the century, based on the two models used in the study. Even in the scenarios with an overall increase in rainfall, the dry areas of the island are forecasted to get drier and the wet areas will get wetter.

Other climate and environmental changes are predicted to occur due to these potential changes in temperature and rainfall, as illustrated in Figure 8-8. Sea surface temperature and ocean acidity is increasing due to sequestration of carbon dioxide, which will impact ocean organisms including coral. Rainstorm intensity is predicted to increase, which will increase runoff to the ocean and reduce deep aquifer recharge. However, one of the most important impacts of increased global temperatures is the melting of polar ice with a subsequent rise in sea level. Sea level rise is particularly important for an island like Oʻahu because there are several low-lying communities such as Waikīkī, Kakaʻako, Iwilei, and Mapunapuna, and coastal erosion and inundation could affect water pipelines and other facilities along the coast, especially on bridges. BWS pumping facilities are also reliant on power supplies that are currently generated at power plants located near sea level.

In June 2014, the UH Mānoa Sea Grant College Program released "Climate Change Impacts in Hawaiʻi: A summary of climate change and its impacts to Hawaiʻi's ecosystems and communities." There is a range of climate change impacts predicted that echo global threats, including sea surface temperature increases, ocean acidity increases, and sea level rise, but there are several predicted impacts that have the potential for affecting Hawaiʻi's water supply on a local scale[6]. The key water supply impacts included the following.

- A change in the prevailing northeasterly trade winds, which drive precipitation in mountain areas on windward coasts, has been recorded in Hawaiʻi over the last 40 years.
- Hawaiʻi has seen an overall decline in rainfall of 13 percent in the last 90 years, and an even steeper decline of 23 percent in the last 30 years (see Figure 8-8), with widely varying precipitation patterns on each island. Due to higher temperatures that drive weather patterns, it is projected that Hawaiʻi will see more drought and heavy rains causing more flash flooding, damage to infrastructure, runoff, and sedimentation.

[5] Keener, V. W., Marra, J. J., Finucane, M. L., Spooner, D., & Smith, M. H. (Eds.). (2012). *Climate Change and Pacific Islands: Indicators and Impacts*. Report for The 2012 Pacific Islands Regional Climate Assessment. Washington, DC: Island Press.

[6] University of Hawaiʻi at Mānoa Sea Grant College Program. 2014. Climate Change Impacts in Hawaiʻi - A summary of climate change and its impacts to Hawaiʻi's ecosystems and communities. Available at: http://seagrant.soest.hawaii.edu/sites/default/files/publications/smfinal-hawaiiclimatechange.pdf. June 2014.

- Declining precipitation trends have caused a decrease in stream base flow over the last 70 years and could reduce aquifer recharge and freshwater supplies and influence aquatic and riparian ecosystems and agriculture.

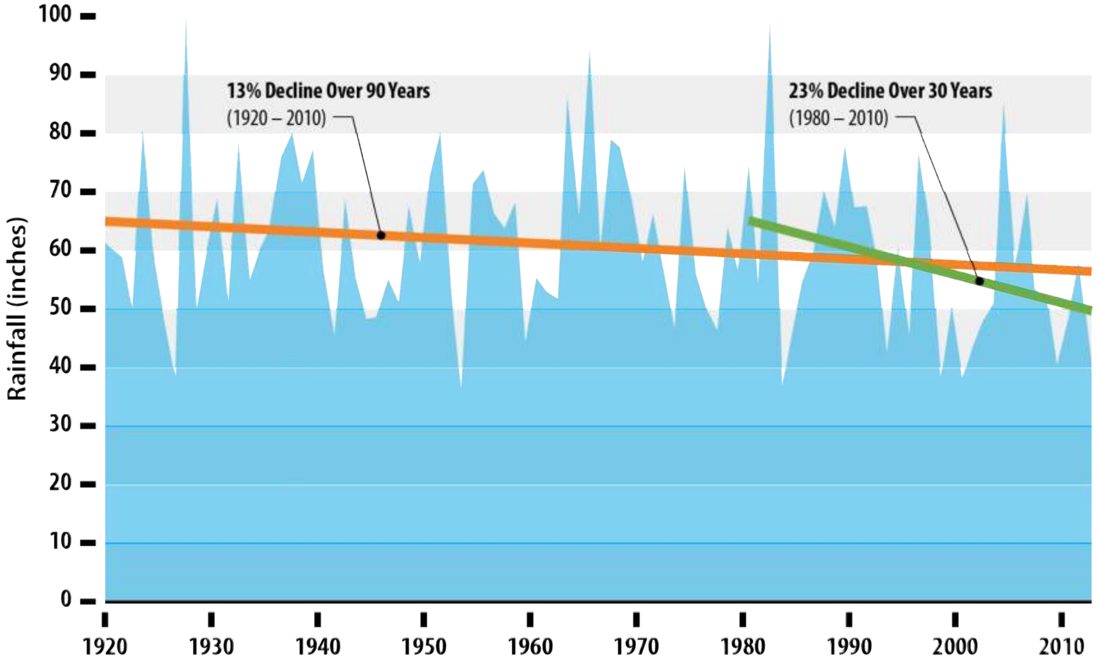

Figure 8-8
Historical Annual Average Rainfall for O'ahu[7]

8.4.2 Water Quality

The fresh groundwater lens that the BWS relies on for most of its water supply sits above a mass of denser, more saline water. If a supply well is pumped at a high enough rate, the freshwater lens in the localized area could be depleted so that water with higher salinity is drawn into the well, increasing the chloride levels in the supply water. Normally supply wells are operated to keep chloride concentrations from rising and protect the quality of water delivered to BWS customers. Source chlorides are tested regularly to inform pump operations of significant changes or trends.

The groundwater levels in the different freshwater aquifers used for supply are monitored carefully using a series of groundwater index wells. Section 3-318 of the BWS's Rules and Regulations summarizes the response to low groundwater level conditions as measured in the BWS's 14 index wells around the island. Actions could include promotion of voluntary reductions in irrigation, mandatory restrictions in water use, or progressive actions to reduce water use through increased rates, reduced allocations, flow restrictors on meters, or civil actions.

In addition to the groundwater elevation thresholds for caution, alert, and critical conditions, there are water quality thresholds associated with the intake of increasingly saline water when the freshwater groundwater elevations decrease. Water level measurements are collected weekly

[7] Source: Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte. 2013. Online Rainfall Atlas of Hawai'i. *Bull. Amer. Meteor. Soc.* 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1. Available at: http://rainfall.geography.hawaii.edu/.

at the index wells and if water levels fall into an alert or critical range, the BWS may respond by reducing pumping rates at supply sources nearby to protect its viability. It is important during a response to declining water levels at these index wells to carefully monitor water levels and water quality at supply wells nearby.

Potential over-pumping is also controlled on a longer-term basis through the CWRM-defined sustainable yield for the groundwater aquifers. In general, the current production from the groundwater aquifers is significantly below the CWRM-defined yield. In some aquifers, recent short-term production is greater than the sustainable yield, although chloride levels remain low suggesting no long-term impacts to the aquifer as long as production is reduced. In evaluating production versus yields, the permitted use is usually compared to a 12-month moving average of production. In the case where there is a long-term overage, production may have to be reduced or shifted to other aquifers that are not over the defined yield. Because the island's distribution system is designed to be flexible, where water can be moved from different parts of the island to areas of need, production shifts are usually accomplished without interruptions in supply delivery.

8.4.2.1 Agricultural and Industrial Activities

Some BWS groundwater supply may be affected by the activities of entities outside of the BWS's control, including government agencies and private sector customers. Monitoring the impact of these external forces is critical to the protection of the BWS supplies.

Legacy Agricultural Chemicals

Due to past agricultural application of pesticides, trace (very low) concentrations of ethylene dibromide, 1,2-dibromo-3-chloropropane, and 1,2,3-trichloropropane (TCP) have been observed in groundwater beneath areas in South Oʻahu where these chemicals were historically used. The BWS includes these chemicals in their regular monitoring effort and uses GAC treatment if needed, to ensure that water is safe to drink and meets all Federal and State drinking water requirements.

U.S. Navy Red Hill Fuel Storage

In January 2014, the U.S. Navy reported a 27,000-gallon leak of jet fuel from a storage tank at its Red Hill Bulk Fuel Storage Facility in Hālawa. The Navy owns 20 fuel tanks, built during World War II, in the Red Hill area each able to contain up to 12.5 MG of fuel. These tanks are located 100 feet above the underlying groundwater aquifer. This irreplaceable aquifer contains two water sources that the BWS uses to provide 25 percent of the water to residents from Moanalua to Hawaiʻi Kai. The BWS is conducting regular testing of its wells in the area. To date, no petroleum contaminants have been detected and the water is safe to drink. The BWS will continue to encourage the Navy to retrofit the fuel tanks to double walls with state-of-the-art alarms and also remediate the leaked fuel.

8.4.3 Future Changes in Agricultural Demand

The U.S. Food and Drug Administration's Food Safety Modernization Act (FSMA) establishes, for the first time, science-based minimum standards for the safe growing, harvesting, packing, and holding of fruits and vegetables grown for human consumption. More stringent water quality standards for water supply used to irrigate food crops may make existing surface water supplies unusable for certain irrigation and related agricultural practices. The reduction in the use of surface supplies would require more reliance on the BWS potable supplies. Because the FSMA was only recently finalized, the impact on Hawaiʻi's farmers is still uncertain. The BWS will monitor the trends, including new meter requests for agricultural customers, and assess whether new source capacity should be installed when more information is available,

8.5 Addressing Supply Uncertainties

As described in Section 8.2, the BWS coordinates with other entities to plan for future water supply and address future supply uncertainty. This coordination includes supporting research in understanding and mitigating climate change impacts, monitoring the health of groundwater aquifers, and adjusting operational strategies to ensure they meet customer demands in a sustainable manner.

8.5.1 Research Efforts

Although the average atmospheric and land surface temperature trends in Hawaiʻi have risen and are projected to continue rising, the rates will vary spatially depending on land uses, topography, and trade wind and precipitation patterns.

The BWS is working with entities such as the U.S. Geological Survey (USGS) and UH to track the changes in climate as technology evolves and more accurate predictions are formed. The impacts of these changes will be factored into future capital investments and maintenance requirements. UH is developing climate models to forecast rainfall trends out to 2061, including quantifying the contribution of cold front-generated rainfall to dry areas of Oʻahu. This research will help improve the understanding of how rainfall patterns will evolve and directly affect the amount of surface water and groundwater supply available in Hawaiʻi.

The BWS, CWRM, UH, and USGS are advancing research and modeling tools to increase understanding of recharge, groundwater aquifers, and streams. The BWS and USGS are working collaboratively to fund, construct, and utilize three-dimensional, solute transport groundwater modeling calibrated with new deep monitor wells in basal aquifers to:

- Evaluate individual source yields to prevent up-coning and salt water intrusion during normal rainfall and drought events;
- Optimize existing source pumping to meet water system demands and avoid detrimental impacts to the aquifer's utility (quality and quantity);
- Ensure adequate aquifer recovery after long drought periods;
- Evaluate aquifer sustainable yields as allocations and pumping approach sustainable yield limits to ensure sources are sustainable; and
- Site and size new wells to develop remaining groundwater and minimize impacts to adjacent and down-gradient sources and surface waters.

8.5.2 Monitoring

Monitoring the health of groundwater sources is critical to ensuring sustainable water supply. In addition to a network of shallow monitoring wells, the BWS also utilizes a number of deep monitoring wells that provide information on the aquifer's salinity profile ranging from the shallow freshwater lens, through a transition zone, and into the deeper saline aquifer. The deep monitoring well data is shared with CWRM.

8.5.3 Operational Flexibility

The BWS balances the operation of its systems to be able to provide high quality and reliable service to its customers. As discussed in Section 8.3, supply sources can be affected by a number of issues and future planning should account for potential loss of supply. The BWS water supply system is designed to provide flexibility in how demands are met, whether by utilizing multiple sources to serve a specific demand area or transferring water from a neighboring area during high demand periods. The BWS will continue to enhance their supply system operational flexibility in order to provide a reliable service to its customers.

8.5.4 Supply Diversification

Potential future supply sources are being considered to both increase supply in high demand areas and to diversify types of supplies available to meet demands to provide alternative sources where existing supplies face some degree of uncertainty. These alternative supplies include additional potable groundwater sources where available, increased recycled water, and desalination projects that are currently under development, as shown in Table 8-3. The BWS will balance the need for development of new supplies with the cost of doing so to provide value to their customers.

Increases in potable and nonpotable demand are offset by water conservation, released agricultural groundwater from the close of the sugar plantations, seawater desalination, and the development of brackish and recycled irrigation water systems.

Groundwater will be developed utilizing available sustainable yield. Groundwater supply evaluations will be conducted to refine available groundwater estimates especially as permitted use approaches sustainable yields. New sources of supply will be developed in locations that do not impact streams or other sources.

Recycled water facilities in ‘Ewa and Central Oahu are planned for expansion to continue to offset additional groundwater development.

- BWS has been operating the 12 mgd Honouliuli Water Recycling Facility for over a decade to supply irrigation and industrial process water for ‘Ewa. The recycled water distribution system can be supplemented with brackish water.

In the mid-term, seawater and brackish water desalination plants will be constructed to provide for future demand and offset additional groundwater development and provide a cost competitive alternative to increasing inter-district transfers.

- The Kalaeloa Seawater Desalination Plant is currently planned for construction in the early 2020 timeframe and will bring an additional 1.0 mgd minimum of potable water supply to the ‘Ewa districts. The plant will be capable of further expansion as needed.

- The Kapolei Brackish Water Desalination Plant in Kapolei Business Park is currently being master planned adjacent to a new operations base yard. The brackish desalination plant is expected to produce approximately 0.7 mgd of potable water supply for Kapolei.

Table 8-3 Potential Additional Water Sources

Name	Estimated ADD Yield, mgd	Land Use District(s) Supplied	Aquifer System Groundwater Management Area	Notes
POTABLE GROUNDWATER SOURCES				
Kunia Wells IV	4.5	ʻEwa, Waiʻanae	Waipahu-Waiawa	Will pump into Honouliuli 440 Reservoir
Waikele Gulch	4.5	ʻEwa, Waiʻanae	Waipahu-Waiawa	Will pump into Waipahu Wells IV GAC system
Kalawahine Well	2.0	Primary Urban Center	Nuʻuanu	Will pump into new Kalawahine 180 Reservoir
Ewa Shaft	10.0	ʻEwa, Waiʻanae	ʻEwa-Kunia	Will pump into Honouliuli 228 Reservoir
Total Conventional Sources	**21**			
POTABLE SALINE SOURCES				
Kapolei Brackish Desal	0.7	ʻEwa, Waiʻanae	Malakole	Will pump into Ewa 215
Kalaeloa Seawater Desal	1.0	ʻEwa, Waiʻanae	Malakole	Will pump into Ewa 215
NON-POTABLE SOURCES				
Honouliuli WRF Expansion	12 - 20	ʻEwa	Puuloa	Will produce R1 and RO
Ala Wai MBR	0.3	Primary Urban Center	Palolo	Decentralized reclamation plant
Mililani WWTP MBR	1.0	Central	Waipahu-Waiawa	
Total Alternative Sources	**15 – 23**			

8.5.4.1 Desalination Projects

Seawater and brackish water desalination plants may be constructed to provide for future demand, offset additional groundwater development, and provide an alternative to increasing inter-district transfers. The BWS owns 20 acres of land in Kalaeloa from the Barber's Point base closure and is subject to Federal land conditions that require the development of a desalination plant on the land or the land reverts back to Federal ownership. The Kalaeloa Seawater Desalination Plant is currently planned for construction in the 2018-2020 timeframe and will bring an additional one mgd of potable water supply to the ʻEwa and Waiʻanae land use districts. The plant will be capable of further expansion as needed. The BWS acquired the State's demonstration brackish water desalination plant facilities in Kapolei Business Park, which could be reconstructed to produce approximately 0.7 mgd of potable water supply for Kapolei. Although brackish desalination is more cost effective than seawater desalination, there are insufficient quantities of stable chloride brackish water supply in ʻEwa.

The BWS has selected brackish water and seawater desalination as long-range sustainable water supply options rather than pursuing indirect potable reuse to meet the large increase in demand as the ‘Ewa land use district approaches full build-out. Although the cost of indirect potable reuse is likely less than seawater desalination, there is a community acceptance challenge to drinking indirect potable water that would need to be addressed. Desalinated water can also be an important drought mitigation strategy. The use of desalinated water during periods of drought with a corresponding reduction in groundwater pumping would allow groundwater sources to stabilize and be conserved.

8.5.4.2 Recycled Water Projects

The recycled water facilities in ‘Ewa are planned for expansion to continue to offset the need for additional potable groundwater development. In 2003, the BWS acquired and now operates the 12 mgd Honouliuli WRF supplying irrigation and industrial process water for ‘Ewa. As shown in Figure 8-9, there are a number of relatively new project areas that are planned to be added to this recycled water system. As ‘Ewa develops, there will be additional opportunities to design for recycled water use. The Honouliuli WRF will need to be expanded as the demand for recycled water increases in the ‘Ewa land use district. The upcoming BWS and Veolia Disk Filter and Ultra Violet project will increase the plant’s R-1 capacity to 14 mgd and increase its energy efficiency. According to the terms of the “2010 Global Consent Decree” between EPA and the City, the Honouliuli WWTP will be upgraded to full secondary treatment by 2024. The WWTP upgrade will produce higher quality effluent that will increase the opportunity for expanded water reuse.

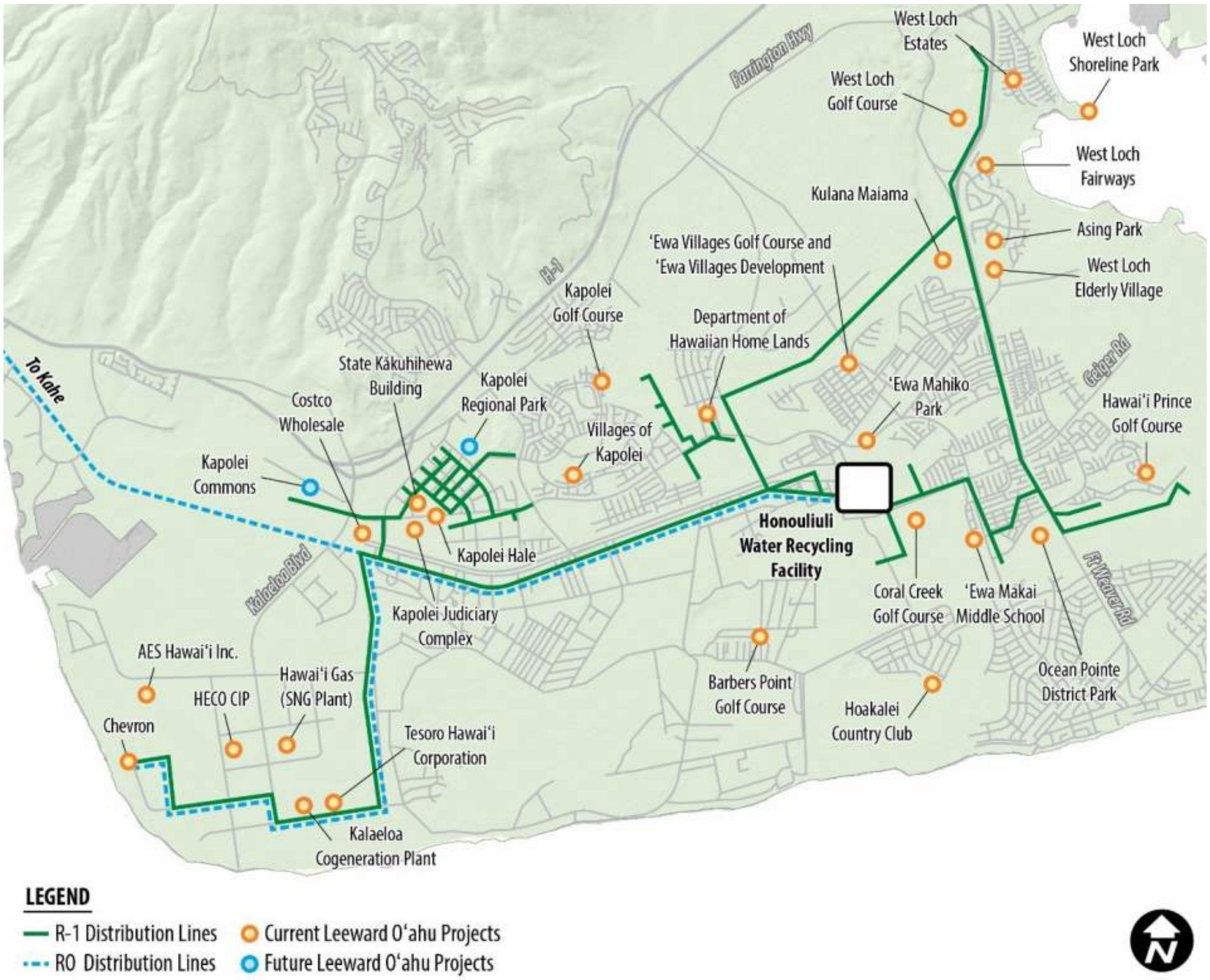

Figure 8-9
Existing Recycled Water Infrastructure and Projects – Leeward O'ahu[8]

The 'Ewa caprock aquifer is getting saltier due to continuous pumping and less recharge than when the sugar plantations were irrigating and recharging it. If the aquifer becomes too saline to be used for irrigation, R-1 recycled water could be used to replace the caprock irrigation supply.

Recycled water could eventually meet almost 40 percent of the total water demands of the 'Ewa land use district at full build-out. Continued and increased use of recycled water will help to preserve potable groundwater resources and will also help to recharge the caprock aquifer.

[8] Source: The Limtiaco Consulting Group. 2013. *2013 Update of the Hawaii Water Reuse Survey and Report*. Prepared for Department of Land and Natural Resources, Commission on Water Resources Management. Available at: http://files.hawaii.gov/dlnr/cwrm/planning/hwrsr2013.pdf. July 2013.

Section 9

Water Quality, Regulations, and Treatment

Section 9 provides information that addresses the following WMP objectives:

- Water Quality, Health, and Safety
- System Reliability and Adequacy
- Cost and Affordability
- Water Conservation
- Water Resource Sustainability

The BWS provides high quality water to its customers and is in full compliance with all regulatory requirements. This section provides a broad overview of current and future water quality regulations and potential water quality issues that may affect the BWS water system. No significant current or future issues were identified.

The BWS demonstrates its compliance to customers through the Consumer Confidence Report. This document, sent annually to all customers, documents pertinent regulatory requirements and the corresponding BWS water quality values.

Information in Section 9 provides input to the risks discussed in Section 12, Findings and Recommendations, including recommendations for future studies.

9.1 Key Findings

The WMP's key findings for issues of water quality and treatment are listed below. These findings are identified with a code (an abbreviation for the section name) and number (for example, WQTR-1). These codes are repeated in Section 12, Findings and Recommendations, to easily tie the findings in this section to the recommendations for BWS action listed in Section 12.

WQTR-1 The water that the BWS delivers meets all federal and state requirements.

WQTR-2 Current and legacy activities and groundwater recharge can potentially affect source water quality. The BWS identified several strategies to maintain compliance for these water quality issues, and these projects are continually monitored and reviewed by the BWS so that they can be implemented should the need arise.

9.2 Current and Potential Regulations

This section provides a brief overview of regulations and requirements. These include current regulations, regulations under development, other water quality issues being considered by regulators, and internal BWS water quality goals.

9.2.1 Current Regulations

The Hawai‘i State Department of Health (DOH) received approval from EPA to administer the federal water quality regulations under primacy. These federal regulations have primarily focused on source monitoring and protection, treatment, and distribution system water quality monitoring and protection. Specific risks that these regulations aim to minimize include: microbiological (treatment techniques based on source water quality and maintenance of water quality throughout the distribution system); chemical (disinfection byproducts, corrosion byproducts, synthetic organic compounds, inorganic compounds, and other organic compounds); and radiological. More recent regulations have focused on managing water quality throughout distribution systems with respect to the control of microbial activity, and the formation of disinfection byproducts (DBPs) and corrosion byproducts. The main regulations are summarized below.

9.2.1.1 Ground Water Rule

The Ground Water Rule (GWR) was promulgated by EPA in 2006 to reduce the risk to potential pathogens that may be present in public water systems using ground water. The GWR has four major components.

1. Periodic sanitary surveys evaluating eight critical elements and identification of significant deficiencies.
2. Source water monitoring to test for the presence of one of the following: *E. coli*; enterococci; or coliphage in the sample. There are two monitoring provisions:
    a. *Triggered monitoring* for systems that do not already provide treatment that achieves at least 99.99 percent (4-log) inactivation or removal of viruses and that have a total coliform-positive routine sample under the Total Coliform Rule sampling in the distribution system.
    b. *Assessment monitoring* – As a complement to triggered monitoring, a State has the option to require systems, at any time, to conduct source water assessment monitoring to help identify high risk systems.
3. Corrective actions required for any system with a significant deficiency or source water fecal contamination.
4. Compliance monitoring to ensure that treatment technology installed to treat drinking water reliably achieves at least 99.99 percent (4-log) inactivation or removal of viruses.

Currently, the BWS operates under the "Triggered Source Monitoring" provision that requires testing the source waters for *E. coli* (a direct indicator of fecal contamination) any time a sample in the distribution system tests positive for coliforms (the testing required for the Total Coliform Rule). If the source tests positive for *E. coli* then corrective measures must be taken that might include installing disinfection for 4-log inactivation of viruses. Implementing these corrective measures is cost and time intensive, and could lead to a loss of use of certain supply sources while the system is under repair.

9.2.1.2 Total Coliform Rule

The Total Coliform Rule (TCR) was promulgated by EPA in 1989 and updated with the Revised Total Coliform Rule in 2013. These regulations govern microbiological water quality in the distribution system based on the analysis for total coliform organisms, which serves as an indicator for the presence of potentially pathogenic organisms. Compliance with the maximum contaminant limit (MCL) is based on the presence or absence of total coliforms in a sample, rather than on an estimate of coliform density, and/or confirmation of the presence or absence of fecal coliforms or *E. coli* which would indicate contamination by potentially pathogenic organisms in the system. The MCL for water systems analyzing at least 40 samples per month is no more than 5 percent of the monthly samples may have a positive total coliform result. Samples are collected from representative sites in the distribution system, including high, medium, and low water age areas. Currently the BWS fully meets the TCR.

9.2.1.3 Disinfection Byproducts Rule

EPA promulgated a revised standard for total trihalomethanes (TTHMs) and a new standard for other DBPs in 1998 in the Stage 1 Disinfectant/Disinfection Byproducts Rule (D/DBPR). This rule applies to all water systems that use a disinfectant for water treatment. The Stage 1 D/DBPR lowered the previous MCL for TTHMs to 0.08 milligrams per liter (mg/L) and established the MCL for the five haloacetic acids at 0.06 mg/L. The Stage 2 D/DBPR modified how compliance is calculated by changing from a system-wide running annual average of quarterly samples to a location-specific running annual average. Currently the BWS fully meets the Stage 1 and Stage 2 D/DBPR.

9.2.1.4 Lead and Copper Rule

In 1991 EPA promulgated the Lead and Copper Rule (LCR) and established Action Levels (ALs) for lead and copper at 0.015 mg/L and 1.3 mg/L, respectively, for water samples at locations where consumers are most likely to be exposed to increased lead levels. If ALs are exceeded, then the water provider must conduct corrosion control studies in the distribution system and implement treatment programs and additional monitoring to assess continued corrosion control performance. EPA published minor corrections and clarifications to the LCR in 2004 and short-term revisions in 2007. The revisions were intended to enhance implementation in the areas of monitoring, treatment, customer awareness, and lead service line replacement; enhance public education requirements; and ensure drinking water consumers receive meaningful, timely and useful information. Currently the BWS fully meets the LCR.

9.2.2 Future Regulations

There are revisions under way to several Federal water quality regulations that may or may not affect the BWS system. If implemented, effects could include limitations on uses of some sources, addition of treatment, or operational modifications:

- Long-Term LCR revisions: These revisions may include elimination of partial lead service line replacements, additional guidance on water quality targets, changes in sampling protocols, and potential inclusion of new sampling locations that have distribution system lead components, including lead gooseneck connections.
- Perchlorate: EPA has been considering regulatory action for perchlorate, though this action has been delayed. California has set its own MCL for perchlorate at 6 micrograms per liter (µg/L) and Massachusetts at 2 µg/L.

- Carcinogenic volatile organic compounds: EPA is considering aggregating a number of contaminants for a single regulatory limit. Included in this set of compounds are: 1) trichloroethylene (TCE); 2) tetrachloroethylene (PCE); 3) other currently regulated compounds, such as benzene, carbon tetrachloride, 1,2-dichloroethane, 1,2-dichloropropane (DCP), chloromethane, vinyl chloride; and 4) eight currently unregulated compounds, including aniline, benzyl chloride, 1,3-butadiene, 1,1-dichloroethane, nitrobenzene, oxirane methyl, TCP (currently regulated by DOH), and urethane. This rule is important as it sets a direction for future regulations.

- Hexavalent Chromium: Total chromium is currently regulated by EPA with an MCL of 100 µg/L; however, EPA has not yet established an MCL for hexavalent chromium (Cr^{6+}). Because Cr^{6+} is more toxic than trivalent chromium, a lower MCL is anticipated than for total chromium. Hawai‘i has established an AL of 13 µg/L. Future chromium regulations could potentially be more stringent, as observed in California where a Cr^{6+} public health goal of 0.02 µg/L in finished water and an MCL of 10 µg/L became effective July 1, 2014.

- Distribution system reservoirs: EPA is considering developing a rule governing distribution system water storage facility inspection and cleaning, and other risk management approaches to help maintain facility integrity and finished water quality.

9.2.3 Issues on the Regulatory Horizon

EPA periodically evaluates additional constituents for potential regulation. EPA reviews these by developing Contaminant Candidate Lists (CCLs) and collecting data for the Unregulated Contaminant Monitoring program, which studies constituents that may be present in drinking water but do not yet have standards under the Safe Drinking Water Act. Potential constituents for future regulation that are not yet being developed include the following:

- Microbiological quality in the distribution system: The water industry has increased its attention on disease outbreaks that occur not due to source water quality or treatment deficiencies, but due to breaches in the integrity of the distribution system. Large systems, particularly those in warm climates, present unique challenges with respect to maintaining disinfectant residuals, limiting water age, controlling microbial regrowth, and preventing the proliferation of opportunistic pathogens when contamination occurs. EPA continues to evaluate all aspects of distribution systems, and such efforts may lead to future regulations that address more stringent water quality protection to the customers' taps.

- Emerging DBPs: Disinfectants react with naturally occurring material in water and other treatment chemicals to produce DBPs. More than 600 separate DBPs have been identified, with more DBPs being discovered as analytical methods improve. Some DBPs pose possible human health risks and thus are a cause for concern, including nitrosamines, other nitrogenous DBPs, and brominated and iodinated DBPs. The organic content of the BWS water sources suggest there is low formation potential for these DBPs.

- Strontium: Strontium's human health risks are being evaluated by EPA and it is being considered for the CCL.

9.2.4 Internal Water Quality Goals

The BWS has several water quality considerations that are not strictly regulatory driven, but are based on the operations of its specific water systems. Three examples include: 1) granular activated carbon (GAC) facilities are operated to ensure that TCP levels remain comfortably below the 0.6 μg/L limit; 2) efforts are made to manage chloride/salinity concentrations to avoid customer complaints; and 3) changes to chlorine residual concentrations are minimized to limit customer objections to chlorinous tastes and/or odors.

The BWS water system has been primarily designed to provide water supply reliability. The use of different water sources to provide this reliability can lead to different water quality depending on which sources are used. The current limitations on mixing in the system and the sensitivity of customers to both chlorine and mineral content need to be considered in development of any water system improvements. For example, a 10 to 1 ratio is required when mixing well water at Makakilo and Honouliuli due to taste considerations. When water from the Kunia wells is blended, customers notice the change in taste.

Customer sensitivity to distribution system water quality is also important when considering new supply sources. If desalination is implemented, special attention would need to be paid to stabilizing water corrosivity prior to its introduction in the distribution system. Red-colored water incidents have been noted on the mainland when water of substantially different water quality is introduced into pipes that had been balanced to a specific water chemistry.

9.3 Source Water Quality

Both changes to source water quality and new regulations could trigger the need for BWS actions to maintain treated water quality, such as supplementary monitoring, source protection measures, treatment optimization, or new water treatment.

9.3.1 Parameters that May Trigger Action and Potential Compliance Issues

A number of watershed and water system issues can potentially affect source water quality and trigger changes in water treatment.

- Legacy activities: Both agricultural and urban use of pesticides, herbicides, and solvents may be related to the presence of TCP, heptachlor epoxide, ethylene dibromide, dieldrin, DCP, dibromochloropropane, atrazine, chlordane, and simazine in soils and water sources. Cesspools, while being phased out, can pose some risk to aquifers as noted by DOH.
- Current activities: While agricultural practices have changed, the impacts of different chemicals, application methods, and best management practices (to the extent implemented) are unknown, as are the impacts of treatment and potential application of genetically modified organism crops. Leaking underground storage tanks, whether small-scale (e.g., gas stations) or large-scale (e.g., Red Hill[1]), also pose a risk to water quality. Commercial activities can lead to the presence of PCE, TCE, methyl tert-butyl ether, carbon

[1] Fuel leaks from the Red Hill Navy tanks could impact Hālawa Shaft, Hālawa Wells, ʻAiea Wells, ʻAiea Gulch Wells, and Moanalua Wells.

tetrachloride, and chlorodifluoromethane. As noted above, cesspools do exist, and, while the BWS has mitigated effects near drinking water sources, monitoring continues.

- Aging infrastructure: The potential for microbial contamination increases for older infrastructure such as tunnels, shafts, and pipes. Aging galvanized and cast iron pipes are potentially susceptible to tuberculation which can affect turbidity, chlorine residuals, and other water quality characteristics.

- Degree of groundwater recharge: Groundwater recharge occurs through the natural processes of rain water infiltration and percolation, though this could decrease during drought conditions. Over pumping groundwater can also result in higher chloride levels, which may be caused by lowering groundwater levels to depths with higher salinity levels or causing increased refilling of the lower aquifer layers with saltier water. Changes in rainfall patterns due to climate change may reduce or increase rainfall, groundwater infiltration, and the transport of contaminants.

9.3.2 Potential Water Quality Compliance Strategies

Several strategies have been identified by the BWS to maintain compliance for the water quality issues identified above. The principal issues for the BWS to consider are microbiological risks, TCP, hexavalent chromium, and chlorides.

9.3.2.1 Microbiological Risks

Potential microbial risks have been identified for groundwater sources and treated waters (in the distribution system). To avoid triggering a requirement for 4-log treatment for virus inactivation of groundwaters at risk of microbial contamination (i.e., if *E. coli* is detected in the source), the BWS should:

- Renovate source water tunnels and shafts (as needed) to improve sanitary seals and address drainage issues.

To enhance disinfection throughout the distribution system and reduce positive coliform detections in monthly (TCR) samples, the BWS should:

- Improve chlorine feed systems through process control:
  - Early detection of chlorine feed interruptions through remote chlorine residual monitoring; and
  - Avoid unanticipated chlorine feed loss through the use of level sensors.
- Repair/replace chlorine feed equipment as identified in the condition assessments.

9.3.2.2 TCP

GAC treatment is currently in place for the BWS's sources impaired by TCP. Potential alternatives/modifications to the current treatment process are being evaluated and include:

- Reconfigure plants to increase treatment efficiency: piping modifications to allow serial rather than parallel treatment, as the existing system is configured for and operates as single pass;
- Implement activated carbon adsorbents (i.e., coconut shells); and
- Plant improvements identified in the condition assessment.

Condition assessment of the GAC facilities has been completed, while the evaluation of alternative GAC media are currently being performed, including pilot testing of different types of granular activated carbon.

9.3.2.3 Hexavalent Chromium

Monitoring data has identified one source where Cr^{6+} levels are close to 10 μg/L, the current California MCL, which EPA and the State of Hawaiʻi are considering as a future MCL. Options to address Cr^{6+} include:

- Ion exchange, coagulation-filtration, or RO;
- Boosting water from an adjacent water system; or
- Alternative supplies instead of treatment: The BWS could develop a replacement source, assuming sufficient yield is available.

9.3.2.4 Chlorides

Chloride concentrations vary among the BWS aquifers, and the primary approach to management has been controlling the amount of pumping and some blending. Potential changes to the current sustainable yields and permitted pumping quantities are periodically reviewed by CWRM.

Three potential projects include:

1. Right-sizing pumping at each of the most affected wells consistent with its yield: It is recommended that the evaluation of appropriate pump sizes be made as each well comes up for replacement according to the condition assessment analysis.
2. Re-operation: This approach encompasses any needed modifications to existing infrastructure to allow demands to be met when certain sources are off-line due to high chloride levels. It also includes improvements required to facilitate blending of low chloride water with higher chloride water to achieve water quality goals.
3. New source development: One proposed project is to drill a new well in the Koʻolau formation (which would require GAC treatment) for blending with Honouliuli Wells supply.

9.4 Potential Water Quality Improvements

Table 9-1 presents several projects that have been identified by the BWS to improve water quality and regulatory compliance in the BWS system. Some of these are in the current six-year CIP, while others are still being evaluated and/or may be addressed through the BWS operations budget.

Table 9-1 Summary of Potential Issues and Projects for Water Quality Improvement and Regulatory Compliance

Potential Issue	Project
Microbial intrusion	Waiʻanae Tunnel 3 (remove collapsed boulder and structurally enhance tunnel portal)
	Waimānalo Tunnel 1 & 2 (rainwater drainage issues)
	Pālolo Tunnel (extend intake pipe further into the tunnel and repair the portal doors)
Disinfection reliability	Continuous residual monitoring at treatment facilities – in process
	Level sensors on chlorine storage tanks
	Waiheʻe Chlorinator
	Mākaha Well V (checking chlorinator pumps)
	Waipiʻo Heights Wells II Pump
	Kaʻahumanu Wells (chlorine booster pumps)
	Waialua Wells (electrical system)
	Waiʻanae Well III (chlorine booster pumps)
Organic contaminant removal via GAC	Re-plumbing facilities to improve efficiency (series versus parallel operation)
	Mililani Wells I renovation
	Improvements at select facilities (repair/replacement of GAC vessels) and blending storage
	Waipiʻo Heights Wells and Waipiʻo Heights Wells I
Chloride management under 165 mg/L	Right-size pumps to limit chloride intrusion based on sustainable yield. Reduce average annual pumping at Kaimukī, Beretania, Punanani, and Kalauao Wells. Build blending facilities (i.e., Honouliuli I). These strategies may result in the need to develop additional supplies.
Future supply needs	Desalination of new brackish or saline sources
	New wells to offset reduction in pumping capacities at existing wells
Water supplies vulnerable to Red Hill contamination	Work towards ensuring U.S. Navy fuel tanks do not contaminate the aquifer. If the source becomes contaminated, install appropriate treatment at the U.S. Navy's expense.
Fluoridation	Implement if mandated by state legislature
Dieldrin	Changes in regulatory requirements, and/or groundwater concentrations might trigger the need to install treatment.

In addition, there are other identified, potential CIP projects that could be triggered by changes in regulations or deterioration of source waters. These projects may include:

1. Addition of treatment or development of additional sources and appropriate conveyance if the Red Hill Navy contamination reaches the Hālawa Shaft and/or Moanalua Wells.

2. Cr^{6+} exceeds regulation of 13 µg/L triggering need for treatment or blending.

3. A new chlorate regulation triggering need for changes in storage and/or supply of hypochlorite.

4. *E. coli* positive detections triggering need for 4-log inactivation at various sources.

The need for the potential projects listed above are monitored by the BWS, and the need for system modifications or additional treatment are reviewed as part of annual review and the identification of potential CIP projects.

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Section 10

System Capacity Evaluation

Section 10 provides information that addresses the following WMP objectives:

- Water Quality, Health, and Safety
- 💧 System Reliability and Adequacy
- 💧 Cost and Affordability
- Water Conservation
- Water Resource Sustainability

This section describes the hydraulic modeling tools used to evaluate the ability of the existing BWS water system facilities (i.e., supply, pipelines, reservoirs, and pump stations) to meet existing and future water demands. The capacity evaluation also addressed the water system's ability to meet criteria described in Section 5, Water System Planning Standards, including:

- Maximum day demand (MDD);
- Peak hour demand;
- Fire flow;
- Reservoir capacity;
- Pump capacity; and
- Pipeline capacity.

These evaluations, and resulting infrastructure needs identified in this section, helped define the capacity projects necessary to mitigate these needs. These capacity projects, along with the recycled water and desalination supply projects discussed in Section 8, Current and Future Water Supply Sources, and the renewal and replacement (R&R) projects presented in Section 11, Facility Condition Assessment, are key projects to be included in the BWS 30-year CIP.

10.1 Key Findings

The key findings of the WMP's system capacity analysis are listed below. These findings are identified with a code (an abbreviation for the section name) and number (for example, CPCY-1). These codes are repeated in Section 12, Findings and Recommendations, to easily tie the findings in this section to the recommendations for BWS action listed in Section 12.

CPCY-1 The system capacity projects to serve both existing areas and future demands or to transfer supply from one area to another will be a significant and critical part of the 30-year CIP. These capacity projects are needed island-wide, but predominantly in the Metro Low, ʻEwa-Waipahu, and Leeward model areas. Facilities needed within the 30-year CIP horizon are summarized in Figure 10-2.

CPCY-2 The Metro Low model system has the most significant current and future storage and supply needs. The West Side Supply Project addresses supply deficiencies and includes a new 10-MG reservoir at Waiawa 228, a 10-mgd booster pump station and a control valve downstream of the reservoir to flow into the west side of Metro 180 West, and a 36-inch Stadium transmission main. For storage deficiencies, an alternatives analysis incorporating feasibility and life cycle cost is recommended to develop solutions to mitigate this issue. Alternatives include:

- New storage within Honolulu where demands are concentrated;
- New peaking wells between downtown Honolulu and Kāhala could reduce some of the anticipated transfers from west to east, improving local system reliability, and may reduce some of the identified transmission capacity;
- Due to limitations in siting new reservoirs and constructing new wells in Metro Low, a large portion of the infrastructure could be located west of the Metro 180 service area; or
- A combination of the options above.

CPCY-3 Source yields in existing select large pumping stations need to be reduced to stabilize rising chloride trends and allow the aquifer to recover after drought periods. This will result in a reduction of pumping in large Metro Low sources by 8 mgd during average day demand conditions to meet Water for Life sustainable pumping goals. This reduction will be offset with transfers from Waipahu and other sources.

CPCY-4 Some data weaknesses were found during hydraulic modeling. Prior to the next round of data collection and verification for the hydraulic modeling, data sources should be improved including: calibrating or repairing Supervisory Control and Data Acquisition (SCADA) equipment where data was found to be inaccurate or questionable; installing water level gauges at wells; installing flow meters at major control valves; and installing flow meters and pressure gauges at unequipped tunnels.

10.2 Water System Analysis

This section presents the approach and results of the hydraulic analysis for the BWS water distribution and transmission systems. The water system analysis assessed distribution and transmission system performance, identified capacity needs, and developed capital improvements for the BWS water system to provide reliable service for existing and future customers. To perform this analysis, numerical hydraulic models were developed from the large amount of system information residing in the BWS GIS database and verified using the best data available from the SCADA system, historical water demands based on the BWS customer meters, and pump production data. Future water demand projections were estimated from population growth estimates by the City and historical water use in the BWS system (see Section 7, Historical and Future Water Demands). The hydraulic performance criteria used in the hydraulic analysis were based on the Standards, which are discussed in Section 5. Projects identified as part of the hydraulic analysis are presented at the end of this section.

10.2.1 Hydraulic Models

Due to the large geographic extent and complexity of the BWS water system, the hydraulic model was developed as 10 different systems (model systems). These 10 systems include the 110 individual pressure zones. Figure 10-2 shows the distribution and transmission pipelines by model system, and reservoirs, pump stations, and sources.

The hydraulic model systems were developed from the BWS pipeline database which included 2,100 miles of pipelines. The BWS desired to create the most accurate hydraulic models possible and consequently, all transmission and distribution pipelines, as small as two inches in diameter, were incorporated into the model. The additional data listed below were used to model water distribution facilities including pump stations, reservoirs, pressure reducing valves (PRVs), and sources (wells, tunnels, and shafts).

1. Manufacturers pump curves, or if available field data
2. Reservoir dimensions and locations
3. Well pump data including static and pumping water level, if available
4. Tunnel and shaft configurations
5. Honolulu Online Utilities GIS viewer which allowed access to as-built drawings for pipelines and pump stations
6. Digital elevation model to obtain pipeline elevations
7. Historical customer billing records and customer meter locations
8. Pumping records to determine total amount pumped and to calculate unaccounted-for water
9. Control valve elevations

10.2.2 Hydraulic Model Verification

After developing the 10 models from GIS and other data, the accuracy of the model was assessed and then improved by comparing the modeled outputs to available system information. The key modeling verification steps are listed below.

1. Models were verified using the best available SCADA data for two 24-hour periods, MDD, and minimum day demand, which span the typical operating range of the system.
2. Model inputs included initial reservoir levels, estimated demand and diurnal demand patterns, pump controls, and initial pump on/off settings.
3. Models were run over a 24-hour simulation period. Outputs such as reservoir levels, pump station pressures and flows, and well pressures and flows were compared to SCADA data.

4. For areas where model outputs did not match SCADA data, further investigation was performed. These investigations included confirming if pipeline intersections in GIS crossed without connecting or whether gate valves were open or closed. On a case by case basis, adjustments to factors such as pump curves, pump controls, or valve settings were made to improve model results (e.g., modeled tank levels matched field data more closely).

The validation procedure resulted in an overall high level of confidence in the models. Strengths uncovered during verification included the following:

- Detailed SCADA records for flow, pressure, tank levels, and pump on/off status for most facilities;
- User-friendly access terminal to find and plot SCADA records;
- Sufficient data to calculate diurnal patterns by pressure zone; and
- Determination of how pumps were performing relative to the manufacturers performance curves.

Weaknesses found during the verification process included:

- Inaccurate flow, pressure, or water level measurements;
- Inconsistent information, such as a pump status being off, but flow data showing a positive value;
- Absence of water level measurement in wells;
- Absence of flow meters or pressure gauges at certain tunnels; and
- Absence of flow meters at certain control valves between pressure zones.

Consequently, the following actions are recommended prior to the next round of data collection and model verification:

- Calibrate or repair SCADA equipment where data was found to be inaccurate or questionable;
- Install water level gauges at wells;
- Install flow meters at major control valves; and
- Install flow meters and pressure gauges at unequipped tunnels.

10.2.3 Hydraulic Model Analysis

After verifying the models represented current operating conditions, the existing and future scenarios were created to evaluate the system against capacity-related Standards, as described in Section 5.

10.2.3.1 Existing and Future ADD Demands

Section 7 presents the average day demand (ADD) estimates used in the system analysis. The demands presented in Section 7 were based on the eight land use districts as defined by the City General Plan. These are defined by the watershed areas of Oʻahu. However, the hydraulic model system boundaries are different from the land use district boundaries. Model systems are divided at locations where the water distribution system was either hydraulically disconnected, or connected by a pump station or control valve. Tables 10-1 and 10-2 present the 10 model systems along with the most probable demand projection and the high range demand projection.

Table 10-1 Existing and Future Most Probable ADD Projection by Model System

Model System	2012 ADD (mgd)	2025 Projected ADD (mgd)	2040 Projected ADD (mgd)	Change in Demand from 2012 to 2040 (mgd)	% Change in Demand 2012 to 2040
Metro Low	55.6	56.2	58	2.4	4%
Metro High	12.3	11.8	11.7	-0.6	-5%
Leeward	10.1	9.8	9.6	-0.5	-5%
ʻEwa-Waipahu	27.7	29	35.8	8.1	29%
Pearl City	5.1	4.9	4.9	-0.2	-4%
	3.3	3.4	3.5	0.2	6%
Windward	18.7	17.5	17.4	-1.3	-7%
Kahuku	0.4	0.4	0.4	0	0%
North Shore	3.8	3.8	4.2	0.4	11%
Central	7.9	7.6	7.3	-0.6	-8%
Total	**144.9**	**144.4**	**152.8**	**7.9**	**5%**

Table 10-2 Existing and Future High Range ADD Projection by Model System

Model System	2012 ADD (mgd)	2025 Projected ADD (mgd)	2040 Projected ADD (mgd)	Change in Demand from 2012 to 2040 (mgd)	% Change in Demand 2012 to 2040
Metro Low	55.6	60.1	62.1	6.5	12%
Metro High	12.3	12.3	12.3	0.0	0%
Leeward	10.1	10.5	10.9	0.9	9%
ʼEwa-Waipahu	27.7	34.1	40.8	13.1	47%
Pearl City	5.1	5.2	5.3	0.1	2%
	3.3	3.6	3.7	0.5	15%
Windward	18.7	18.7	18.8	0.1	0%
Kahuku	0.4	0.4	0.4	0.0	0%
North Shore	3.8	4.0	4.2	0.4	11%
Central	7.9	7.9	7.9	0.0	0%
Total	**144.9**	**156.8**	**166.4**	**21.6**	**15%**

The BWS island-wide ADD was 145 mgd in 2012. Under the high range demand projection, demand is expected to increase by 15 percent, or 22 mgd, by end of 2040. Total ADD in 2040 is estimated to be 166 mgd. Under the most probable demand projection, demand is estimated to increase by 7 percent, to a total of 153 mgd. The hydraulic model analysis, which assessed the pipeline capacity, was performed using the high range demand projection to be conservative. Systems with high growth will continue to grow past the 2040 horizon. Projects arising from the high range demand will not actually be implemented until demand is trending toward needing the improvement. Existing reservoir capacity and pump station capacity were compared with the Standards. These assessments were made using both high and most probable 2040 demands, as well as with the historical MDD peaking factors.

About 90 percent, or 19 mgd, of the island-wide growth is projected to occur in the ʻEwa-Waipahu and Metro Low model systems. This is due to developments in the master plan areas in ʻEwa-Waipahu and TOD areas that are centered at stations along the planned rail system. About two mgd of growth is projected to occur in three model systems – Waiʻanae, ʻAiea-Hālawa, and the North Shore. A year 2040 future scenario, which is the WMP planning horizon, was created for these five models with some projected growth.

Increases in demand for each of the remaining five model systems is less than 0.1 mgd or lower than existing demand. Thus, for these model systems, only an existing model scenario was created and analyzed.

10.2.3.2 Existing and Future Analysis Assumptions

The existing conditions were based on the BWS historical demands in 2012, including average and maximum day demands. The existing modeled systems were based on the GIS data for pipelines, pumps, reservoirs, and PRVs as of June 2013, and included projects that are currently under construction or design. The following 6-year CIP capacity expansion projects for fiscal year 2016/2017 were included as part of the existing system capacity analysis.

- Honolulu District 42-Inch Mains - Liliha to Moiliili, Phase I: 42-inch main along Beretania Street from Liliha Street to Richard Street, along Richard Street from Beretania Street to King Street, along King Street to Victoria Street, and along Victoria Street to Kinau Street 42-inch main; approximately 11,000 linear feet (LF).

- Ala Moana Boulevard 24-Inch Main: 24-inch main and appurtenances along Ala Moana Boulevard from Ward Avenue to Atkinson Drive; approximately 6,200 LF. The new 24-inch main replaces an existing 12-inch main.

- Kalakaua Avenue Water System Improvements: Phase III: 16-inch main along Kalakaua Avenue from Beretania Street to Kapiolani Boulevard; approximately 3,200 LF.

- Ala Moana Water System Improvements: 24-inch main along Ala Moana Boulevard from Ala Wai Boulevard to Kalakaua Avenue; approximately 2,780 LF.

- Salt Lake Boulevard 36-Inch Main - Foster Village to Āliamanu: 36-inch main along Salt Lake Boulevard (525 feet south of Maluna Street to Ala Lilikoi Street); approximately 4,275 LF.

- Farrington Highway 30-inch: Approximately 400 feet of 24-inch pipeline between Farrington Highway and Barbers Point 215-1 reservoir upsized to a 30-inch pipeline.

- Lumihoahu 16-inch: A new 16-inch pipeline along Lumihoahu Street and Kamehameha Highway from Waipiʻo Heights Wells and Waipiʻo Heights Wells I to the GAC treatment facility at Waipahu Wells III.
- Kalāwahine 180 2.0 MG Reservoir: 2.0-MG reservoir and 24-inch main along ʻAuwaiolimu Street and Pensacola Street to Kinau Street; approximately 4,700 LF.
- ʻĀina Haina 170 0.5 MG Reservoir No. 2: 0.5-MG reservoir at existing ʻĀina Haina 170 Reservoir site.

Hydraulic model simulations and spreadsheet calculations were used to assess the existing distribution system's ability to serve customer demands based on the Standards. The future conditions were based on the estimated 2040 demands.

The hydraulic model was used to identify pipeline capacity improvements and incorporated only the high range demand estimate and not the most probable estimate. For the system capacity hydraulics, primarily affecting the sizing of pipeline, these more conservative demand numbers identify the largest facility sizing that may be required by 2040. Although the recommended infrastructure resulting from the high demand scenario would be conservative, the higher demand scenario allows the BWS to look beyond 2040 as growth continues. In addition, the additional infrastructure costs above the most probable future demands provide an alternative investment target for more aggressive water conservation to defer portions of the larger infrastructure projects.

The calculations for required storage, pumping capacity, and supply used the most probable and high range demand estimates, based both on the Standards as well as the historical MDD factors. The potentially needed supply, reservoir storage, and pumping facilities could be built more quickly than large diameter pipelines, and their capacities could be phased for future growth, so less conservativism is warranted. For instance, a larger pump can replace an existing pump to increase pump station capacity. However, a larger pipeline cannot easily replace an existing pipeline that does not have enough capacity.

Recommended capacity expansion projects are divided into three categories:

- Near-term improvements needed to be operational within the 30 year CIP planning period (by 2040) to meet anticipated MDD projected using historical MDD factors for each system;
- Intermediate improvements needed to meet growing demands, likely beyond the planning period depending on actual demands; and
- Long-term improvements to meet the letter of the Standards, but, with historical data and experienced engineering judgement, would most likely not be needed within the planning period.

Pumping standards, which were applied to both well pumps from source aquifers and booster pumps from one zone to another, require enough capacity to deliver MDD over a 16-hour pumping period, or 1.5 times the 24-hour pumping rate. Standby pump capacity was either included or excluded depending on the type of zone being served as specified in the Standards. The 16-hour requirement is intended to provide redundancy in pumping capacity.

Many of the booster pumps, which boost water from a lower pressure zone to higher pressure zone, operate for 16 hours or less. However, many of the well pumps, especially in the larger zones such as Metro 180 West, are smaller in capacity and have to operate on a 24-hour basis, which is sufficient to meet customer needs but does not meet the Standards.

Thus, near-term improvements highlight the necessary capacity expansion needed to meet the increasing demands of the system under current operation, between now and 2040, using historical data. Intermediate improvements are those needed to meet growing demands likely beyond the planning horizon. These are the next priority of improvements after the near-term improvements are implemented. This may or may not occur within the WMP planning horizon, depending on whether the actual MDD tracks the estimated future demand. Long-term improvements represent the capital expansion projects to meet the design requirements stated in the Standards; however, available historical data suggest this will likely occur after the WMP planning horizon.

Figures 10-1A through 10-1J illustrate the future demand projections (both the most probable and high range demand projections for maximum day) using historical MDD factors for each model system, respectively, compared to the available supply for each system. If MDD trends in the future begin to approach the available supply, additional supply will need to be moved forward in the CIP.

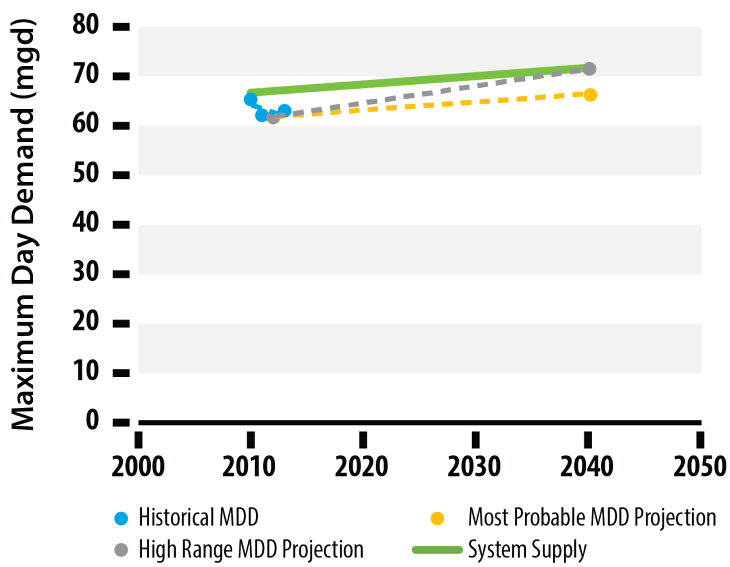

Figure 10-1A
Historical and Projected MDD Compared to Available Supply, Metro Low System

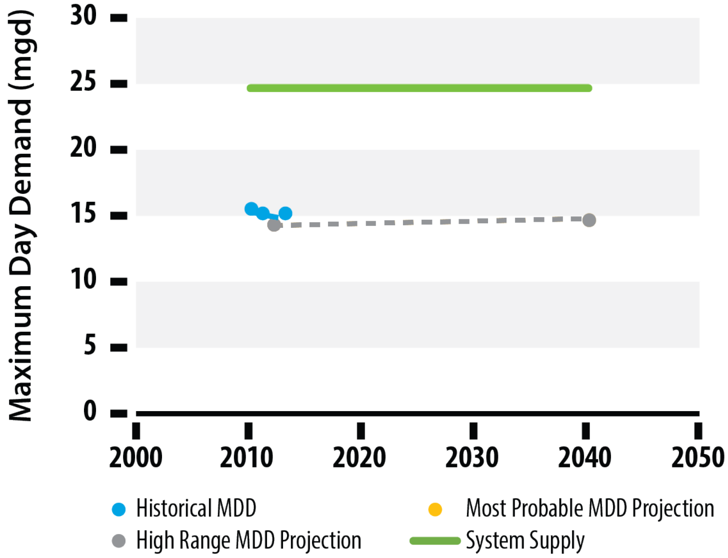

Figure 10-1B
Historical and Projected MDD Compared to Available Supply, Metro High System

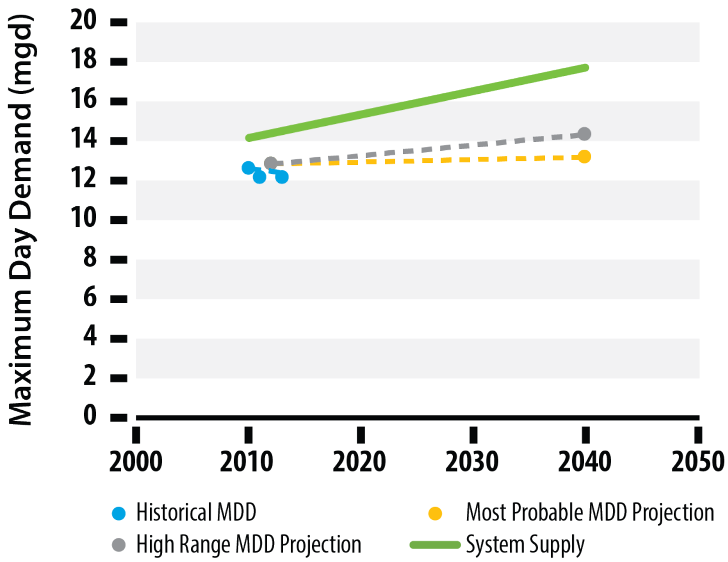

Figure 10-1C
Historical and Projected MDD Compared to Available Supply, Leeward System

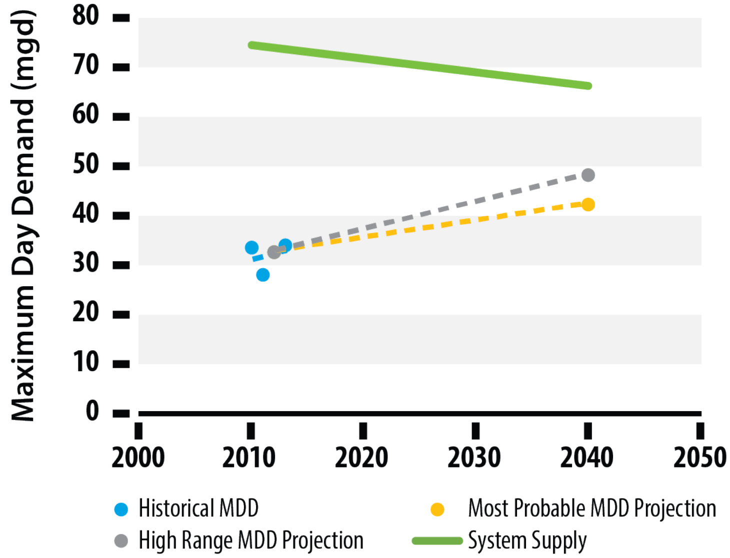

Figure 10-1D
Historical and Projected MDD Compared to Available Supply, ‘Ewa-Waipahu System

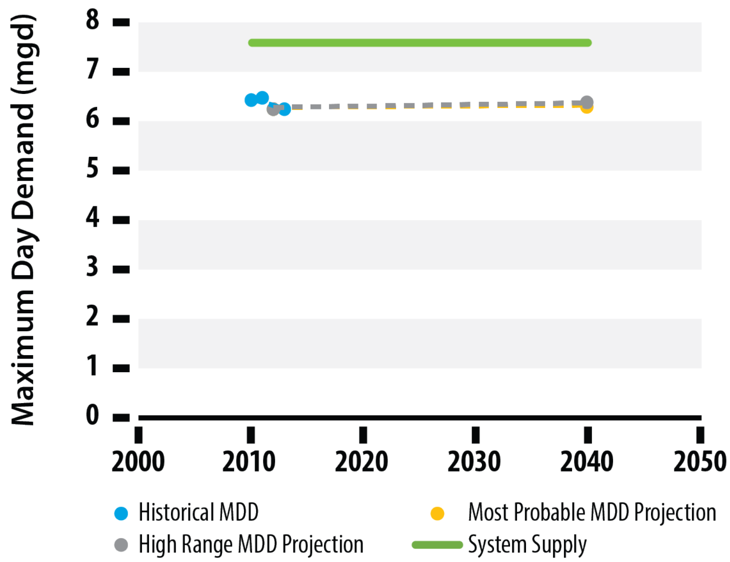

Figure 10-1E
Historical and Projected MDD Compared to Available Supply, Pearl City System

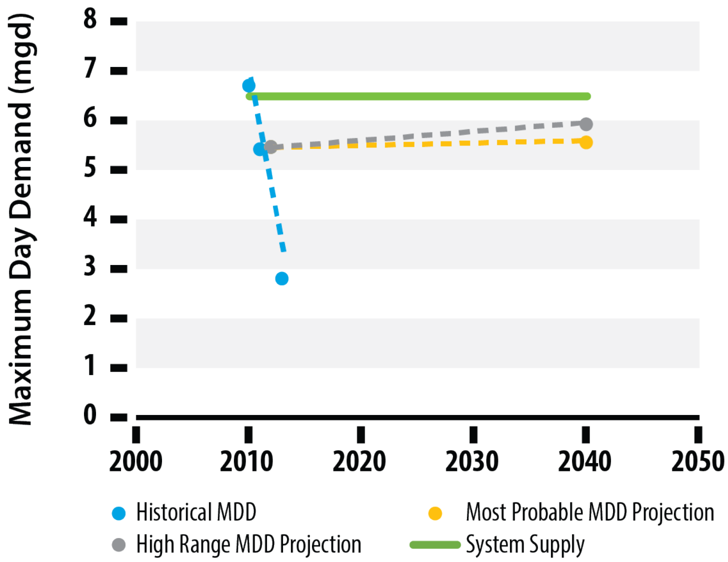

Figure 10-1F
Historical and Projected MDD Compared to Available Supply, ʻAiea-Hālawa System

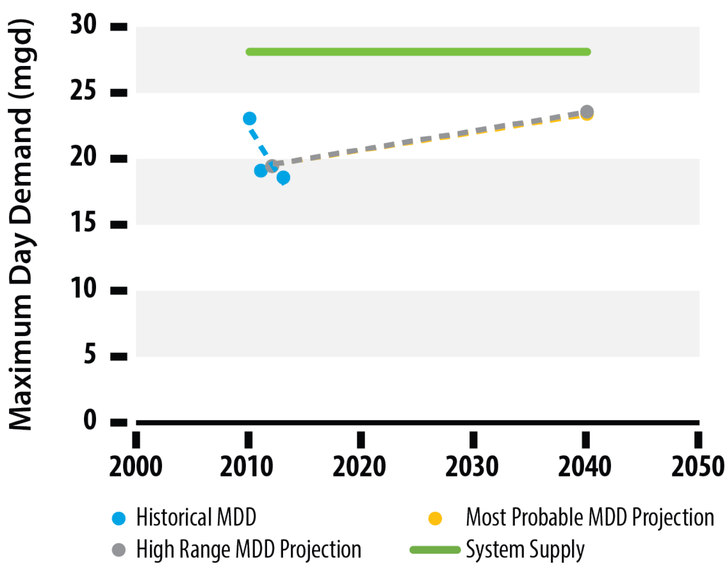

Figure 10-1G
Historical and Projected MDD Compared to Available Supply, Windward System

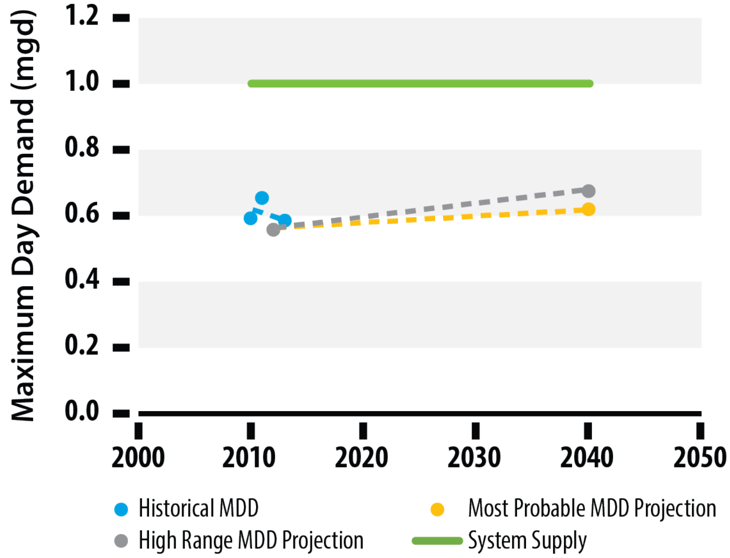

Figure 10-1H
Historical and Projected MDD Compared to Available Supply, Kahuku System

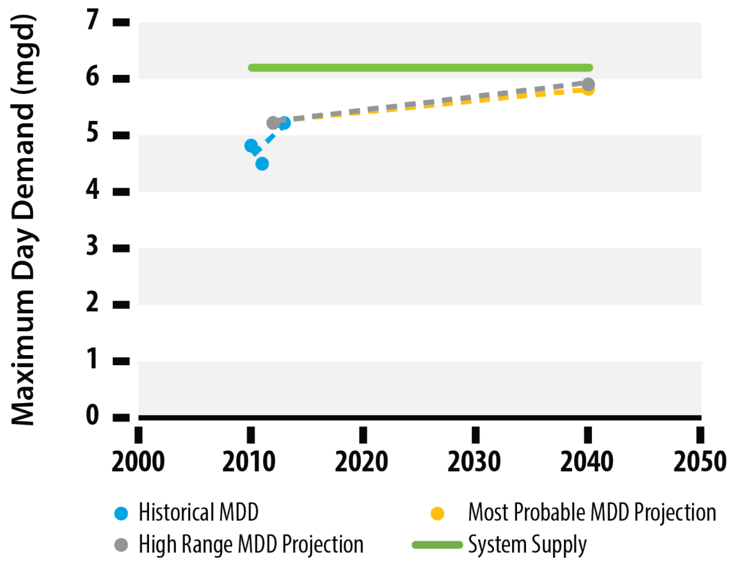

Figure 10-1I
Historical and Projected MDD Compared to Available Supply, North Shore System

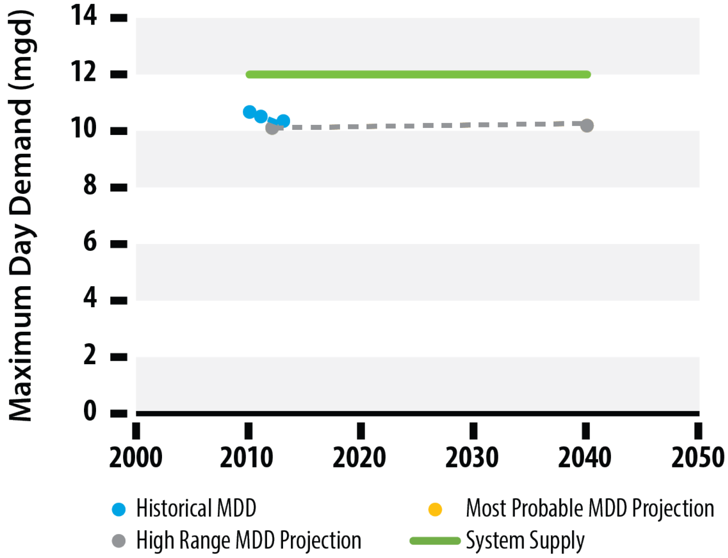

Figure 10-1J
Historical and Projected MDD Compared to Available Supply, Central System

10.2.3.3 Pipeline Capacity Evaluation

To evaluate pipeline capacity, hydraulic model simulations were conducted for three main types of conditions:

1. MDD, both steady state simulation and extended period simulation (EPS);
2. Peak hour demand; and,
3. Fire flow with MDD.

Maximum Day Demand

The ratio of MDD to ADD is referred to as a seasonal demand multiplier. Maximum day demand typically occurs in August or September for the BWS system. As described in the Section 5, the Standard MDD to ADD factor of 1.5 was used for pipeline analysis. A 48-hour EPS simulation was checked that it was representative of actual operations such as:

1. Reservoir operating levels within about the top 25 percent of the reservoir level and refill by the end of the day. The ability to refill reservoirs may be an indicator that sufficient transmission capacity exists to meet maximum day demands.
2. Wells are providing supply within allowable levels. Supply pumped from the wells were bound by the lowest of three types of constraints:
    a. Permitted levels established by CWRM. Permitted supply at wells and tunnels were based on average day demands. To determine actual supply available during MDD, the same seasonal demand multiplier (1.5 x ADD) was used for permitted supply (1.5 x permitted amount);

b. Pumping restrictions established by the BWS operations staff based on electrical, mechanical, hydraulic, or operational constraints; and

c. Pumping restrictions established by the BWS based on limiting long-term water quality impacts in the wells.

Pipelines identified by the model analysis as having capacity constraints, indicated by high velocities in the pipelines in the MDD EPS model simulation, were recommended for upsizing as identified in Section 10.3.

Peak Hour Demand

The peak hour demands used in this analysis are described in Section 5. Rather than the Standard factors, peak hour factors were calculated from the historical data to better represent the actual systems. A steady state peak hour scenario was modeled to identify low pressure areas below 40 pounds per square inch (psi) and high headloss pipelines that may be undersized for the amount of flow being conveyed. Where high headloss occurs, adding pipelines may be required to meet the operational pressures within the system.

Pipes with a velocity greater than 6 feet per second (fps) and that resulted in downstream pressure below 40 psi were recommended for a CIP project. Pipes with velocities greater than 10 fps were recommended for a CIP project, regardless of downstream pressure. Pipes with a velocity between 6 and 10 fps that did not have downstream pressures below 40 psi were recommended for upsizing during the R&R program priority, but not as a separate CIP project.

Areas that had low pressures (less than 40 psi) due to high headloss pipelines supplying the area are an indication of inadequate pipeline capacity. There are no Standard limits for headloss, In the evaluation, as a general guideline, pipelines with greater than 15 feet of headloss per 1,000 feet of pipeline length were investigated further to determine if they should be recommended for upsizing. Other areas had low pressures due to high ground elevations relative to the pressure zone. In this case pipeline capacity was not deficient, but other improvements such as rezoning to a higher pressure zone may mitigate the low pressure.

High pressure areas above 125 psi were also identified, which were mostly due to very low ground elevations compared to the pressure zone grade line. These areas were considered for either reconfiguring pipelines such that customers are serviced by an adjacent pressure zone with a lower operating grade line or creating a new pressure zone with PRVs. Pressure management using PRVs will reduce water loss and damage from leaks and main breaks over the life of the pipeline. These results are summarized in Section 10.3.

Fire Flow

The BWS owns over 21,000 fire hydrants island-wide. The fire flow available at each hydrant was calculated using the hydraulic model and compared to the required fire flow, which is based on zoning designations such as Single Family, Multi-Family Low Rise, Commercial, or Light Industry. Hydrants that did not meet the standard were evaluated further to identify possible pipeline or other improvements needed to mitigate the fire flow shortfall. Available fire flow was calculated by the model as the flow available at a hydrant while maintaining a minimum pressure of 20 psi throughout the pressure zone, with MDD demands, and with the reservoirs at 50 percent full.

Hydraulic modeling results were reviewed to identify pipelines leading up to the hydrants that experienced high head losses, greater than 15 feet per 1,000 feet, during the fire flow simulation. These pipelines were then upsized by two standard pipe sizes (i.e., 6 inches and 8 inches to 12 inches, 10 inches and 12 inches to 16 inches, 16 inches and 18 inches to 24 inches) to simulate the increase in fire flow available at the particular hydrant and evaluate if that change adequately addressed the low fire flow. This method offered a good basis for an initial estimate of improvements that may be needed to meet fire flow. As a planning level estimate, these pipelines became the recommended projects for fire flow related capacity improvements. These results are summarized in Section 10.3.

10.2.3.4 Capacity Evaluations for Supply, Pumps and Reservoirs

Supply Capacity Evaluation

The supply need for each model system was calculated for both existing and 2040 demands. See Section 8 for information on how supply capacity and the other capacity evaluations were applied or modified. The supply needs are summarized in Section 10.3.

Reservoir Capacity Evaluation

The reservoir capacity in each pressure zone was compared against the Standards. The volume of storage in each zone should be equivalent to the MDD of that zone. Storage should also have the volume to meet a maximum day flow rate plus fire flow for the duration of a fire with the reservoir three-quarters full at the start of the fire. As an example, Makakilo 1230 has an estimated 2040 most probable ADD of 679 gallons per minute (gpm) and a 2040 MDD of 842 gpm (or 1.24 multiplied by ADD), which is equivalent to 1.2 MG of storage needed. With an existing storage of 2.0 MG, the pressure zone has a surplus storage of 0.8 MG (2.0 MG less 1.2 MG).

Storage shortages by pressure zone were identified for existing conditions and for future conditions, using both most probable and high range demands. These results are summarized in Section 10.3.

Pump Capacity Evaluation

Pumping capacity requirements are different depending on the type of pressure zone being supplied. The three pressure zone types (zones with a single reservoir, multiple reservoirs, or commercial and industrial demands) and their respective pumping requirements are described in Section 5.3.3. As an example, Makakilo 1230 has a single reservoir with 2040 most probable MDD of 842 gpm over a 24-hour pumping period. To deliver the same amount of supply over a 16-hour pumping period, the pumping rate is 1.5 multiplied by the 24-hour rate, or 1.5 x 842 gpm = 1,263 gpm. The required highest fire flow in the zone is 1,500 gpm for townhouse and low rise apartments. Thus, the pumping requirement is the sum of 1,263 gpm and 1,500 gpm, for a total of 2,763 gpm. The total capacity of Makakilo Booster 4 is 3,900 gpm per pump nameplate capacities. Thus, there is a surplus pumping of 1,137 gpm (3,900 gpm less 2,763 gpm). A similar calculation was performed for each pressure zone to identify the surplus or shortage. These results are summarized in Section 10.3.

10.3 Capacity Analysis Results

The purpose of the capacity analysis is to identify the existing and future capacity needs, and develop projects to mitigate these needs. While the capacities for pipelines, reservoirs, and pump stations were evaluated separately, they all make up the water delivery system for the BWS. Limitations affecting the sizing and construction of specific types of facilities (for example, a lack of usable land at the correct elevation or location for large reservoirs) can require increasing supply needed to meet peak hour demands and pipeline capacity. In general, the supplies must be able to meet the average day and maximum day demands. Normally the peak hour demands are met from reservoir storage, with water being pumped into the reservoirs during the lower demand periods of the day. In the existing BWS systems that may not have sufficient storage to meet these peak hour demands, the peaking capacity comes from wells within that particular system or from supply transferred through transmission mains from areas further away that have either excess storage capacity or excess peaking wells to meet these shortfalls. This will also be true for some of the future system improvements and operations.

10.3.1 System Wide Overview

10.3.1.1 Projects Planned Within the 30-Year CIP

The identification of capacity needs for reservoirs, pump stations, and sources, as well as the hydraulic analysis determining distribution and transmission pipe capacity needs, result in a series of recommended projects. These projects represent near-term improvements that are needed to be operational within the 30 year CIP planning period (by 2040), intermediate improvements that are needed to meet growing demands, likely beyond the CIP planning period, and long-term improvements that are needed to meet Standards and would most likely not be needed before 2040. Figure 10-2 provides an island-wide view of the major future improvements identified for each model system. As indicated in Figure 10-2, there are major transmission pipeline, pump station, well, and storage projects required across the island to meet the future infrastructure capacity needs for the BWS.

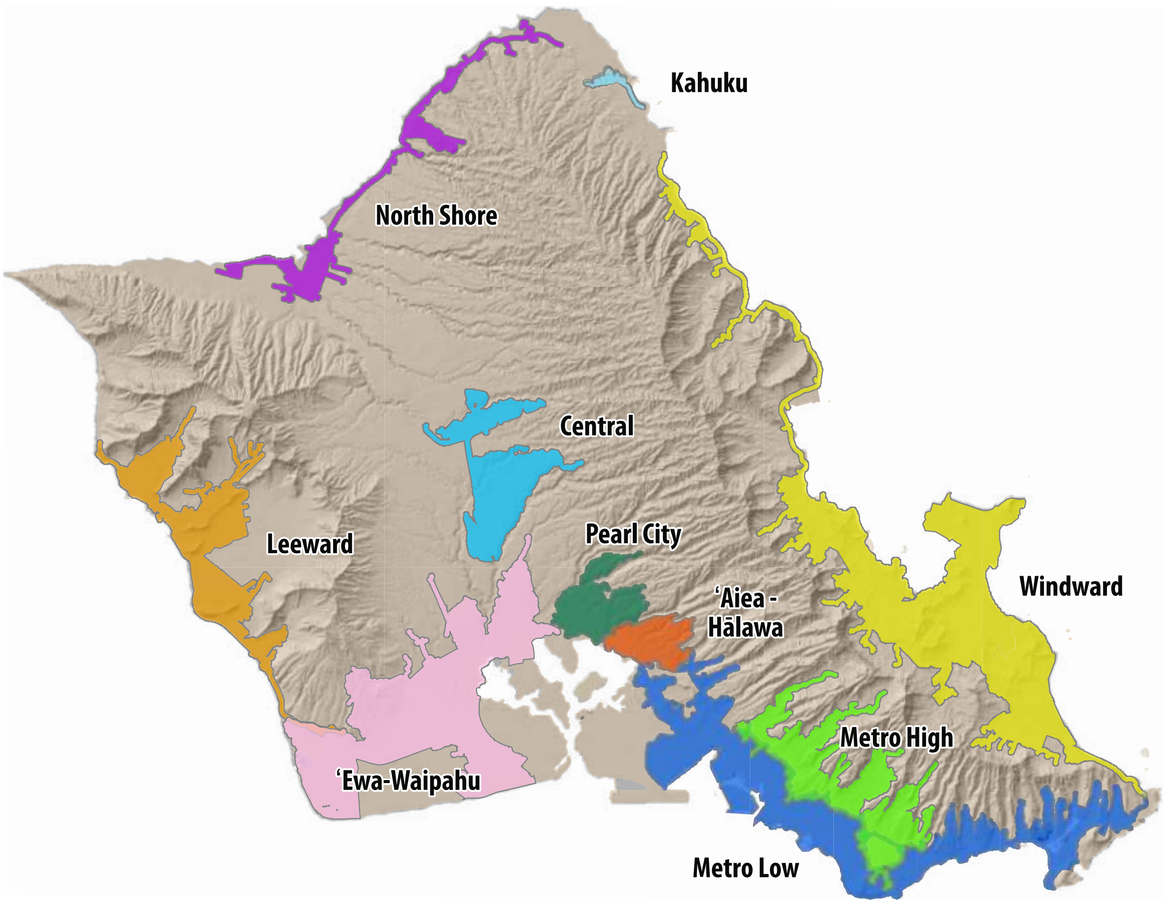

Figure 10-2
Summary of Major Recommended Capacity Improvements Within the 30-Year Planning Period (Near-term)

Model System	Pumps/Reservoirs	Pipes
Metro Low	▪ 10 MG Waiawa 228 Reservoir for capacity expansion. This is part of the West Side Supply Project ▪ 10 mgd variable speed booster pump station and control valve that draws from the new 10-MG Waiawa 228 Reservoir into Metro 180 West for capacity expansion. This is part of the West Side Supply Project. ▪ 2.0 MG Kalawahine 180 Reservoir ▪ Kalawahine Well with a MDD capacity of 2 mgd near the Kalawahine 180 Reservoir for capacity expansion	▪ 2.5 miles of 36" Stadium pipeline to connect from Moanalua Road 36" to the 42" pipelines for capacity expansion (for West Side Supply Project) and redundancy ▪ 4 miles of 42" pipeline, phases I and II (under design) from Liliha Street, along Beretania Street, Richards Street, King Street, and Victoria Street, to Isenburg Street, for redundancy
Metro High	▪ 0.1 MG of additional storage in 605 zone. ▪ 14.6 mgd of additional pumping in various zones	▪ 0.1 mile of 8" to 20" pipe to meet peak hour needs
Leeward (Wai'anae -	▪ Rezone into separate 242 zone ▪ 4.0 MG reservoir at Kuwale Road, near Waianae 242 Reservoir ▪ 5 mgd additional pumping capacity at Lualualei Line Booster Pump (LBP) ▪ 4 mgd additional pumping capacity at Barbers Point LBP	▪ No major facilities required for capacity
	▪ Sources planned at Kunia IV Well (4.5 mgd) and Waikele	▪ 0.3 miles of 24" pipeline from Waikele

Model System	Pumps/Reservoirs	Pipes
Waipahu	Gulch Well (4.5 mgd) ▪ Desalination plants at Kalaeloa (1.0 mgd) and Kapolei (0.7 mgd) as part of the BWS effort to diversify its supplies for drought mitigation ▪ Storage at Honouliuli 228 totaling 11 MG ▪ Additional pump capacity of 10,500 gpm (15 mgd) at Kapolei LBP to increase capacity from Waipahu toward Barbers Point LBP	Gulch Well to Waipahu Well IV GAC ▪ 1.5 miles of 24" pipeline from Kunia IV Well to Honouliuli 440 Reservoir. Kunia IV Well supply will be blended with Honouliuli Wells I and II which have high chlorides. ▪ New 0.8 miles of 16" pipeline from Kalaeloa desalination plant to Kalaeloa Blvd.
Pearl City	▪ Rezoning lower half of Pearl City 640 zone to lower pressure ▪ New pump station (1.8 mgd) and reservoir (0.3 MG) at Waiau 850 for reliability improvements ▪ 1.1 mgd of additional pumping in Pearl City 385 zone ▪ 0.6 mgd of additional pumping in Pearl City 865 zone ▪ 0.1 mgd of additional pumping in Pearl City 1050 zone	▪ No major facilities required for capacity
‘Aiea-	▪ Rezoning of ‘Aiea 497 and Pearl Harbor 277 near ‘Aiea Heights Drive and Kanaloa Street to alleviate high and low pressures ▪ 1.0 MG of additional storage in Pearl Harbor 277 zone ▪ 8.6 mgd of additional pumping in various zones	▪ No major facilities required for capacity
Windward	▪ Calibrated flow meters at Waihe‘e LBP	▪ No major facilities required for capacity
Kahuku	▪ 2 mgd additional pump capacity ▪ 0.2 MG of additional storage	▪ No major facilities required for capacity
North Shore	▪ 3.0 mgd of additional pumping into North Shore 225 zone ▪ 0.5 mgd of additional pumping into 600 zone ▪ 2.0 MG of additional storage in North Shore 225 zone	▪ 1.3 miles of 8" pipeline along Farrington Highway from Olohio Street and Puuiki Street ▪ Upsized 12" pipelines along Kaukonahua Road between Waialua Beach Road and Kaamooloa Road (0.6 miles), and along Goodale Avenue from Waialua Beach Road to Nauahi Street (0.4 miles)
Central - Mililani)	▪ Reconfigure pipelines and control valves around Melemanu 808 Reservoir ▪ 0.2 MG of additional storage in Mililani 685 zone	▪ No major facilities required for capacity

10.3.1.2 Projects Planned Beyond the 30-Year CIP

Tables 10-3 through 10-7 summarize the supply, storage capacity, and pump station capacity needs, respectively, for all 10 model systems. These needs were based on the Standards, including calculations based on the most probable and high range ADD and MDD projections using the 1.5 seasonal peaking factor. Projects addressing these needs may be constructed beyond the 30-year CIP planning period or, depending on actual demand trends, may never be needed.

Table 10-3 presents the supply needs at MDD for each model system. Supply needs were estimated by comparing the amount of well pumping capacity available against the estimated MDD. The BWS is evaluating and developing new supplies in the ‘Ewa-Waipahu model system which include 2 mgd of MDD supply from desalination plants, and 7 mgd from new wells in Waipahu and Kunia, or a total of 9 mgd in 2040. The Metro Low system has a MDD supply shortage of 26 mgd in 2040 and 20 mgd for the existing scenario. These supply requirements were based on the 48-hour MDD EPS model run using the Standard MDD/ADD factor of 1.5. The current factor is about 1.2, for which the BWS has sufficient supplies and storage to meet operational requirements.

In the future, the BWS will develop new supplies to meet the more conservative MDD/ADD factor requirement of 1.5, providing additional flexibility, redundancy, and capacity for future growth in the system beyond 2040. New supplies proposed in the 'Ewa-Waipahu model system can offset the Metro Low supply need by about seven mgd. Depending on the actual demand increase and observed MDD/ADD factors in the future, some of the identified projects may be accelerated or deferred beyond the 30-year CIP planning period. It is recommended that BWS continue to evaluate the actual MDD/ADD factors to accurately reflect the system needs now and into the future.

Table 10-3 Supply Needs for MDD (Based on Standards)

Model System	2012 (1) (mgd)	2040 High Range (mgd)
Metro Low	20	26
'Ewa-Waipahu	-	9
Total	**20**	**35**

Note: Based on 1.5 MDD factor. The BWS will expand supply over time to meet the 2040 need.

As indicated in Table 10-4, the existing Metro Low system needs approximately 50 MG of additional storage as identified by the Standards. By 2040, this increases to just over 60 MG. Finding appropriate and large sites in the Metro Low system service area to meet the storage need will be difficult. It is preferred to locate as much of the storage in the service area as possible; however, it is possible to locate storage further away and provide peak hour pumping. An alternatives analysis would need to be completed to determine the most feasible alternative for addressing this deficiency.

Table 10-4 Storage Capacity Needs (Based on Standards)

Model System	Additional Storage Needed Compared to Existing System		
	2012 (MG)	2040 Most Probable (MG)	2040 High Range (MG)
Metro Low	50.5	55.4	60.18
Metro High	2.6	2.6	2.6
Leeward	3.3	3.4	4.5
'Ewa-Waipahu	7.3	-	-
Pearl City	-	-	-
	0.5	0.5	0.5
Windward	-	-	-
Kahuku	.1	.1	.1
North Shore	0.9	1.3	1.4
Central	-	-	-
Total	**65.1**	**62.1**	**68.1**

Note: Based on 1.5 MDD factor. The BWS will expand storage capacity over time to meet the 2040 need.

The pumping capacity needs identified in Table 10-5 include well pumps, booster pumps operating between pressure zones, and in-line booster pumps. A large portion of the pumping capacity required in the ‘Ewa-Waipahu System is to be able to deliver MDD over a 16-hour period as per the Standards. As with the supply requirements, the 1.5 ratio of MDD to ADD specified in the Standards drives the pumping capacity needs for Metro Low. The BWS is looking to meet the pumping needs over time as it expands pumping capacity to meet the Standards for 2040 demands. Over the next several years, the BWS will review those factors and their impact on costs and rates to determine the correct balance for the system.

Table 10-5 Pumping Capacity Needs (Based on Standards)

System Model	2012 (mgd)	2040 (mgd)
Metro Low	24	29
Metro High	21	21
Leeward	11	12
‘Ewa-Waipahu	14	36
Pearl City	3	3
	8	8
Windward	-	-
Kahuku	2	2
North Shore	3	4
Central	-	-
Total	**85**	**114**

Note: Based on 1.5 MDD factor. The BWS will expand pumping capacity over time to meet the 2040 need.

The pipeline capacity needs indicated in Table 10-6 include capacity requirements identified from the hydraulic model to move water between and within model systems for MDD and peak hour demand conditions.

Table 10-6 Pipeline Capacity Needs (Based on 48-Hour EPS MDD and Peak Hour Scenarios)

Model System	2012		2040		Total Miles of New Pipeline Needed
	Miles	Pipe Diameters (inch)	Miles	Pipe Diameters (inch)	
Metro Low	0.2	8	5.0	36-42	5.2
Metro High	0.1	8-20	-		0.1
Leeward	0.8	8	-		0.8
‘Ewa-Waipahu	-		5	12-36	5
Pearl City	-		-		-
	0.1	8	-		0.1
Windward	-		-		-
Kahuku	-		-		-
North Shore	1	12-16	-		1
Central	-		-		-
Total	**2.1**		**10.1**		**12.2**

Note: n/a = not applicable

The pipeline capacity needs presented in Table 10-7 are based on meeting MDD plus fire. These are the pipelines that were upsized by two standard pipe sizes where modeled hydrants had low fire flows. Only the future 2040 high demand condition was analyzed for this evaluation. The timing of these improvements will most likely be tied to pipeline replacement as part of the BWS R&R program.

Table 10-7 Pipeline Capacity Needs Related to Meeting Fire Flows (Based on Standards)

Model System	2040	
	Miles	Pipe Diameters (in)
Metro Low	8.3	12-16
Metro High	14	8-12
Leeward	1.8	12-16
ʻEwa-Waipau	-	
Pearl City	-	
	2.0	6-12
Windward	20.0	8-24
Kahuku	-	
North Shore	2.0	12
Central	0.3	12
Total	**48.4**	**6-24**

A summary of the specific needs and identified improvements for each of the 10 model systems is included in the following sections.

10.3.2 Summary of Recommended Facilities by Model System

This section provides a more detailed summary of the issues and recommended facilities associated with each of the 10 hydraulic model systems.

10.3.2.1 Metro Low Model System

Metro Low is the largest model system by demand and system complexity. It includes Honolulu and Hawaiʻi Kai and represents about 38 percent of the total island-wide demand. Metro Low includes Metro 180 West, Metro 180 East, Metro 170, and Kamehame pressure zones, and others that pump out of the Metro 180 West, Metro 180 East, and Metro 170.

This system has the largest length of pipelines and highest demand of the 10 model systems. The average day demand in 2012 for the Metro Low system was 55.6 mgd. The largest pressure zone in this model system is Metro 180 West, which had an average day demand of 42.9 mgd or 77 percent of the Metro Low system demand in 2012.

About 70 percent of Metro Low supply originates from aquifers on the west side of Metro 180 West or near the Pearl Harbor area. There are 3 major sources of supply in Honolulu that have historically contributed up to 20 percent of total Metro Low supplies: Kalihi; Beretania; and Kaimukī Wells. These have also been essential in meeting peak hour demands.

A total of 38 MG of storage exists for the entire Metro Low system. Most of the storage is in the upper zones. However, Metro 180 West, the largest zone in the Metro Low model system, has a relatively small volume of storage, 13 MG, compared to the amount of demand served by the zone. This has been adequate because of reliance on wells in the area to supply peak demands.

The subsections below summarize the issues associated with meeting the existing and future needs for Metro Low, as well as the recommended projects to address these needs.

Existing System

The current system provides adequate and reliable water service to the customers.

Needs Based on Standards

To meet the Standards with the 2040 high range demand estimate, significant new facilities must be added in Metro Low: 55 MG of additional storage; 29 mgd of additional pumping capacity; 26 mgd of additional supply sources; and 8.3 miles of upsized pipelines for fire flow.

The 26-mgd shortfall in supply was obtained from the 48-hour MDD EPS model run which was based on the 2040 high range demand estimate with a MDD of 1.5 multiplied by the ADD. For Metro Low, the high range estimate for 2040 is 62 mgd ADD and 93 mgd MDD. Source pumping currently available per BWS Operations staff was 67 mgd, which also includes a reduction in pumping from wells in Honolulu that potentially have increasing chloride levels. The BWS intends to proactively restrict peak pumping of specific key wells in Honolulu to protect the freshwater lens of the aquifers during droughts. Thus, the difference between 2040 MDD (93 mgd) and source pumping available (67 mgd) is 26 mgd.

The drivers affecting the pumping need include:

1. Standards for pump capacity are based on a 16-hour pumping rate instead of a 24-hour pumping rate;

2. Using the more conservative high range 2040 ADD, rather than the most probable 2040 ADD; and

3. The use of an MDD to ADD ratio of 1.5 as stated in the Standards as opposed to a 1.15 ratio as seen historically.

Near-Term Improvements

The need for these additional facilities is highly dependent on whether the actual demands reach the projected demands. Thus, the recommended strategy is to monitor actual MDD relative to the projected demands. If the actual demands are not on track to reach the projected demands, many of the potential improvements can be postponed. Historical demand trends between 2010 and 2013 show that MDD has not been increasing quickly. Also, the MDD to ADD ratio has averaged 1.15 instead of the Standards ratio of 1.5. The MDD has remained below 65 mgd in the same time period.

There is currently enough source pumping capacity to meet a MDD of up 67 mgd. Future supply will not be needed until the actual MDD in Metro Low exceeds this level. When it does exceed 67 mgd, up to 7 mgd of surplus supply from ‘Ewa-Waipahu is expected to be available (as detailed in the Section 10.3.2.4), which can be transferred to Metro Low. An MDD demand of up to 74 mgd in Metro Low (sum of 67 mgd and 7 mgd) can be met with the following recommended facilities:

1. West Side Supply Project, to bring additional MDD supply into the Metro Low service area from ʻEwa-Waipahu:
    a. 10-MG reservoir in West Primary Urban Center (New Waiawa 228 Reservoir).
    b. 10-mgd variable-speed pump station that draws from the New Waiawa 228 Reservoir and pumps into Metro 180 West. The hydraulic grade line at the west end of Metro 180 currently reaches about 225 feet during MDD conditions. With higher future demands, the HGL is expected to increase above the top of the reservoir level of 228 feet.
    c. Control valve in parallel with the new variable speed pump to allow gravity flow from the reservoir into Metro 180 West during lower demand conditions.
    d. 12,700 feet of new 36-inch diameter pipeline near the Aloha Stadium to connect the existing parallel 36-inch pipelines along Kamehameha Highway near Pali Momi Street to the 42-inch transmission pipeline downstream of Hālawa Shaft. This adds transmission capacity of the source well supply in the Pearl Harbor area by connecting to the Hālawa 42-inch transmission pipeline.
2. 42-inch pipeline (11,000 feet) along Beretania Street from Liliha Street to Richard Street, along Richard Street from Beretania Street to King Street, along King Street to Victoria Street, and along Victoria Street to Kinau Street which is a planned Phase I of a project in design, and also included in the existing evaluation scenario of the hydraulic model. Phase II identifies a continuation of the new 42-inch pipeline (9,000 feet) along King Street from Victoria Street to Isenberg Street. Phases I and II will add redundant capacity to an existing 42-inch pipeline. Also note that the 42-inch pipelines near Liliha Street and Vineyard Boulevard should be connected.
3. 2-MG Kalawahine 180 Reservoir, as listed in the BWS 6-year CIP.
4. Kalawahine Well with a MDD capacity of 2 mgd near the Kalawahine 180 Reservoir.

Intermediate Improvements

MDD demands should be monitored annually. If the trend shows that MDD demands in Metro Low will exceed 74 mgd within 10 years, then the following additional facilities will be needed. This level of demand is expected to occur beyond the master planning horizon of 2040 according to current trends, and thus will not be incorporated into the CIP. If the trend begins to increase later, the CIP can be revised.

1. Replace the existing pumps at Diamond Head LBP that have a total dynamic head (TDH) of 33 feet with higher TDH pumps. A TDH of 85 feet is needed to pump to the suction side of Kuliʻouʻou due to decommissioning of Wailupe LBP.

2. Kuliʻouʻou LBP: one additional 4,000-gpm pump is needed (may be offset by the amount of supply brought over from the Windward side).

Long-Term Improvements

Potential alternative solutions for mitigating the additional supply need include:

1. Developing new groundwater wells in Metro Low system. The site locations, hydraulic capacity, and potential impact on staying within the current and potential pumping limits will need to be evaluated.
2. Increasing supply transfers from other areas (i.e., Central Land Use District, Waipahu Wells, and from the Windward area). This will require increases in transmission facilities.
3. Increasing conservation and reducing per capita usage. This may require implementing more aggressive conservation measures and developing programs to incentivize the implementation of these measures.
4. Capturing surface water for more direct recharge into the groundwater basins. The feasibility of this alternative will need to be evaluated.
5. Diversifying supplies by adding brackish or seawater desalination projects in Honolulu. Potential cost impacts of these alternatives will need to be evaluated.

If needed, the technical and financial feasibility of these alternatives will need to be evaluated.

Per the Standards, there is an existing storage need of about 51 MG, increasing in the future to about 55 MG, in the Metro 180 West zone. This can be partially offset by the new 10-MG Waiawa 228 Reservoir recommended above and the 2-MG Kalawahine 180 Reservoir. A significant amount of storage is still required by the Standards. The land required for this amount of additional storage may be difficult to identify as the area is already highly developed. There is very little vacant land at the correct elevations to build additional storage. The BWS initiated studies in 2005 and 2006 to evaluate potential locations with a 180-foot overflow elevation. The studies did not evaluate ground-level storage with pumping. In general, siting reservoirs in Metro Low is very difficult and expensive. Makiki 180 Reservoir is adjacent to a park which may accommodate an additional 2 MG of storage, but not nearly enough to meet the full storage need. If eventually needed, there are other potential ways to address the impacts of lack of storage, such as the following:

1. Additional storage near the recommended Waiawa 228 Reservoir could be developed, which builds on the recommended 10-MG Waiawa Reservoir solution described above. This alternative would require increased pumping and transmission from the west into Honolulu.
2. Pumping from new wells can be used to meet peak hour demands. For reliability, wells intended to offset the storage requirements are recommended to be equipped with standby power.

3. A reservoir that is below the operating elevation of 180 can be utilized with a pressure sustaining valve that fills the reservoir and a pump that can draw water out of the reservoir back into the system.

4. A combination of the approaches identified above.

One of the functions of a reservoir is to meet peak hour demands during the day. When hourly demands are high, the reservoir drains to meet these demands. When demand decreases at night, the pumps refill the tanks for the next day. Alternatively, well pumps can be used to meet peak hour demands. This is how Metro 180 West currently operates and is expected to continue to do so in the future. Pumping during peak hour can introduce pressure spikes that in turn can contribute to main breaks.

It is important that all well pumps being used to meet peak hour demands are equipped with standby power; just as an elevated reservoir can meet peak hour demands if power is not available, a well pump with standby power can meet the same peak hour demands.

In case demands increase at a faster rate than predicted, additional alternatives to meet the 2040 high range MDD are possible. The following potential alternatives to meeting the 2040 high range MDD conditions all meet the peak hour demand from facilities located within Metro 180 West service area as opposed to from the west side of the service area.

1. Metro 180 Alternative Storage Project: Reservoirs near Diamond Head (possible locations are buried inside Diamond Head Crater or on the outer circumference at ground level) at the proper operating grade line of 180 feet or below the grade line with booster pumps.

   A reservoir near Diamond Head might be situated at the operating grade line of 180 feet or at a lower elevation with a booster pump that draws from the tank and pumps into the Metro 180 West system. A reservoir at the operating grade line is easier to operate and maintain. However, finding suitable (size and elevation) and available property may be challenging. A possible location for additional storage is at the existing Makiki 180 Reservoir. If locations at 180 feet elevation are not available, a lower elevation location with a pump could be used to boost the reservoir supply into the zone. The trade-off between obtaining property and the cost and potential operational impacts of this type of operation will need to be evaluated.

   This reservoir will reduce the peak hour pumping of the existing well pumps located in Metro 180 West. The west side sources will continue to provide MDD, but can reduce the peak hour pumping load by the amount that the ground-level reservoirs can contribute to the peak hour demands.

   Peak hour demands will be met by pumping out of the ground-level storage reservoir during the peak demand hours. It would be filled during the low demand hours of a 24-hour period. A transmission pipeline from the reservoir or pump station discharge is needed to connect to a large transmission main within the Metro 180 West network. Benefits include increased reliability of having storage closer to the Metro 180 service area and reducing peak pumping at the existing wells including Kaimukī and Beretania pump stations.

Peak flows from existing wells on the west side through the transmission lines will also be reduced. Meeting peak demands from storage within the Metro 180 West service area will also allow the pressure to be better balanced between the west and east side of Metro 180 West during high demands.

2. Aquifer Storage at Existing Wells Alternative: Aquifer storage and recovery at Beretania or Kaimukī Wells (existing wells or new shallow injection wells).

   Recharging wells, and constructing new peaking wells within the Metro 180 service area may be an alternative to building additional reservoirs. Aquifers for Beretania Wells or Kaimukī Wells may possibly be recharged by transferring supply from aquifers near Pearl Harbor during the low demand seasons and pumping the supply through the existing Metro 180 West transmission system. Then during the high demand season, supply stored in aquifers for Beretania Well and Kaimukī Well can be used for Metro Low and/or Metro High. Benefits include: 1) during high demands, the supply is drawn from wells that are located within the service area, reducing transmission capacity needed from the west side; 2) peak demand hours during high demand days can be met from the wells; and 3) transmission mains already exist to these wells.

   Significant further study is needed to determine the feasibility of this alternative. Among the uncertainties that need further study are: the rate of injection that is possible; the rate of recovery of the injected supply; and the effect of injection on the water quality of the aquifer.

3. Aquifer Storage at New Wells Alternative: Recharge at potential new wells up-gradient in the aquifer to the wells within the service area.

   This is similar to the Aquifer Storage at Existing Wells Alternative except that the injection will occur at new wells up-gradient, but in the same aquifer as the wells that peaking supply would be drawn from. For example, Palolo Well is in the same aquifer and up-gradient of Kaimuki Wells. Similar benefits and unknowns apply. An additional cost is that new transmission pipelines are needed to connect from the existing transmission pipelines to the new wells.

Further evaluation and tracking of demands and peaking factors may result in modifying the above projects, as may future studies addressing potential future reservoir siting and feasibility constructing additional peaking wells.

Recommended Improvements for 30-Year CIP

1. West Side Supply Project:
   a. 10-MG Waiawa 228 Reservoir for capacity expansion.
   b. 10-mgd variable speed booster pump station and control valve that draws from the new 10-MG Waiawa 228 Reservoir into Metro 180 West for capacity expansion.

   c. 36-inch Stadium pipeline to connect from Punanani pipeline to Hālawa pipeline. This pipeline also improves redundancy.

2. 42-inch pipeline, phases I and II as planned in the BWS 6-year CIP, along Beretania Street, Richards Street, King Street, and Victoria Street, for redundancy

3. 2-MG Kalawahine 180 Reservoir as listed in the BWS 6-year CIP, for capacity expansion.

4. Kalawahine Well with a MDD capacity of 2 mgd near the Kalawahine 180 Reservoir, for capacity expansion.

10.3.2.2 Metro High Model System

The Metro High model system, which includes Metro 405 and the upper zones that are supplied by Metro 405, had an average day demand of 12.3 mgd in 2012. No growth is anticipated in this system. The largest zone in this model system is Metro 405, which had an average day demand of 9.6 mgd, or 78 percent of the total for this system. ʻĀina Koa 1370 in Metro High system is the highest elevation zone in the BWS system.

About 70 percent of the supply was pumped from three wells – Kalihi, Beretania, and Kaimukī Wells. Alternative supply options for this model system are limited. In addition to these three wells, there are several smaller wells that supply the system.

Existing System

The current system provides adequate and reliable water service to customers.

Needs Based on Standards

Per the Standards, 21 mgd of additional pumping capacity is needed at various pressure zones. However, for a 24-hour pumping schedule as modeled for MDD, the existing pumping capacity is sufficient to serve the system.

Recommended Improvements for 30-Year CIP

1. 0.1 MG of additional storage in Pālolo 605.

2. 14.6 mgd of additional pumping in various zones.

3. 0.1 mile of 8-inch to 20-inch diameter pipe to meet peak hour needs.

4. 14 miles of 8-inch to 12-inch diameter pipe to meet MDD plus fire.

10.3.2.3 Leeward Model System

The Leeward system had an average day demand of 10.1 mgd in 2012. The largest zone in this system is Waiʻanae 242 which had an average day demand of 8.7 mgd, or 86 percent of the Leeward system demand. The Waiʻanae 242 pressure zone is hydraulically separated into two areas by Lualualei LBP station. Storage on the suction side includes Nānākuli 242 and Lualualei 242 reservoirs. The discharge side of Lualualei LBP includes Waiʻanae 242 and Mākaha 242 reservoirs.

Needs Based on Standards

Using the 2040 most probable demands, future needs include 3.5 MG of additional storage in the Wai'anae 242 pressure zone, which is necessary to meet the Standards. Possible locations for a reservoir include Kuwale Road, which has sufficient undeveloped area and is near the existing Waianae 242 Reservoir, or near the existing Mākaha 242 Reservoirs. Because Kuwale Road is more centrally located within the Waianae 242 zone, 2.5 MG of storage is recommended at Kuwale Road, and 1.0 MG of new storage is recommended at the Mākaha site. Per the Standards, 11.6 mgd of additional pumping capacity is needed at various pressure zones.

Near-Term Improvements

For a 24-hour pumping schedule as modeled for 2040 high range demand estimate, a smaller total additional pumping capacity is recommended: 4 mgd additional at Barbers Point LBP and 5 mgd additional at Lualualei LBP.

An additional 4.0 MG of storage is needed in the Wai'anae 242 zone.

Also recommended is converting the Nānākuli neighborhood, which is currently in the Wai'anae 242 pressure zone, into a separate zone such that the pressure is regulated by the Nānākuli 242 Reservoir only. This has multiple benefits including allowing Lualualei 242 Reservoir to be filled by Barbers Point LBP and having better control of pressures at Nānākuli area.

Recommended Improvements for 30-Year CIP

1. Rezone Nānākuli into separate Nānākuli 242 zone.
2. 4.0 MG reservoir at Kuwale Road, near Waianae 242 Reservoir.
3. 5 mgd additional pumping capacity at Lualualei LBP.
4. 4 mgd additional pumping capacity at Barbers Point LBP.

10.3.2.4 'Ewa-Waipahu Model System

The 'Ewa-Waipahu model system had a total average day demand in 2012 of 27.7 mgd. The largest zone in this model system is Pearl Harbor 228 (Waipahu-Kunia-Honouliuli 228) which had an average day demand of 11.9 mgd, or 43 percent of the total demand for this system. The second largest zone is 'Ewa 215 (Barber's Point-Kapolei 215) which had an average day demand of 7.3 mgd, or 27 percent of the total demand for this system. The current facilities provide sufficient and reliable water service to the existing customers.

Needs Based on Standards

To meet the Standards with the 2040 high demand estimate, 36 mgd of additional pumping capacity, additional storage planned by the BWS, and additional sources planned by the BWS are needed to supplement Leeward and Metro Low demands. The 36 mgd of additional pumping capacity needed to meet the Standards is recommended as a long-term improvement project, which is beyond the timeframe of the 30-year CIP.

Near-Term Improvements

The ADD demand in the 'Ewa-Waipahu system is projected to increase from 27.7 mgd in 2012 to 40.8 mgd ADD in 2040 high range projection, which is the highest demand increase out of the 10 model systems. Most of this growth will be due to new developments planned in the master plan areas and also in the TODs, which are in the 'Ewa-Waipahu system.

The MDD in the 'Ewa-Waipahu system is expected to increase from 32.7 mgd in 2012 to 48.5 mgd by 2040 under the high range projection. The total existing MDD supply is 82.7 mgd under MDD conditions. This MDD supply assumes 10 mgd MDD supply is available from 'Ewa Shaft.

In order to meet its MDD demand by 2040, the Leeward system will need 11.5 mgd of MDD supply transferred from the Waipahu area via Barbers Point LBP. Possible new sources are already planned to be developed. The new sources, along with the estimated MDD supply, are listed below.

1. Kunia IV – 4.5 mgd (4 new wells at 1.5 mgd each – 3 mgd for ADD, 4.5 mgd for MDD)
2. Waikele Gulch – 4.5 mgd (4 new wells at 1.5 mgd each – 3 mgd for ADD, 4.5 mgd for MDD)
3. Kalaeloa desalination plant – 1 mgd ADD and MDD
4. Kapolei desalination plant – 0.7 mgd ADD, 1 mgd MDD

Recommended Improvements for 30-Year CIP

1. Sources planned at Kunia IV Well, Waikele Gulch Well.
2. Desalination plants at Kalaeloa (1.0 mgd) and Kapolei (0.7 mgd) as part of the BWS effort to diversify its supplies for drought mitigation.
3. 0.3 miles of 24–inch pipeline from Waikele Gulch Well to Waipahu Well IV GAC.
4. 1.5 miles of 24-inch pipeline from Kunia IV Well to Honouliuli 440 Reservoir. Kunia IV Well supply will be blended with Honouliuli Wells I and II which have high chlorides.
5. 0.8 miles of 16-inch pipeline from recommended Kalaeloa desalination plant to existing 12-inch pipeline on Kalaeloa Boulevard.
6. Storage at Honouliuli 228 totaling 11 MG, which has been identified in the BWS's long-range plans.
7. Additional pump capacity of 10,500 gpm (15 mgd) at Kapolei LBP to increase capacity from Waipahu toward Barbers Point LBP.

10.3.2.5 Pearl City Model System

The Pearl City model system had a total average day demand of 5.1 mgd. The largest zone in this model system is Pearl Harbor 285, which had an average day demand of 2.5 mgd, or 49 percent of the total demand for this system. Four reservoirs in the Pearl City 285 zone are spread across the zone. Pearl City 285 Reservoirs 1 and 2 are in an area where the majority of Pearl City 285 demands are located. Waiau 285 and Newtown 285 Reservoirs are in the central and east areas, respectively, which have smaller demands. Pearl City Wells I and Pearl City Shaft pump into the pressure zone near Pearl City 285 Reservoir.

Needs Based on Standards

Based on the Standards, an additional 3 mgd of pumping is required at various pressure zones within the Pearl City model system for existing and future conditions.

Near-Term Improvements

Capacity-related pipeline improvements are not needed. The lower elevation half of the Pearl City 640 pressure zone, including Hoona Street at a ground elevation of 290 feet, operates at pressures higher than 125 psi, which is above recommended operating pressures. Historically there have been numerous pipe breaks in this part of the pressure zone. Partitioning this area with PRVs is recommended so that it will operate at a lower pressure, decreasing pipe breaks. From the discharge of Pearl City Booster I, one pipeline feeds the northern half of Pearl City 640 via Komo Mai Drive. A branch off the discharge pipeline on Waimano Home Road feeds the southern half of the zone. This is where a PRV can be installed to reduce the high pressure experienced in the lower part of the zone.

The Waiau 850 zone serves residential neighborhoods spanning three ridges with a 16-inch pipeline crossing a valley between the northern ridge (Waiau) and the center ridge (Newtown), and a 12-inch pipeline crossing the valley between the center ridge and southern most ridge (Royal Summit). Pipelines in both valley crossings are difficult to access and maintain due to the wooded and steep terrain. Waiau Booster No. 2 is the only supply and Waiau 850 Reservoir is the only storage in the zone. Both are on the Waiau ridge, so a break on either the 16-inch or the 12-inch cross-country mains would cut off service to Royal Summit and possibly Newtown ridges.

To improve reliability, a new reservoir (0.3 MG) on Royal Summit and a new pump station (2 pumps at 625 gpm each) is recommended. The additional reservoir and pump station, provide redundancy for the Royal Summit and Newtown Ridge 850 zones.

A total of 1.8 mgd of additional pumping is needed in various pressure zones using historical MDD factors.

Recommended Improvements for 30-Year CIP

1. Rezoning lower half of Pearl City 640 zone to lower pressure.
2. 1.8 mgd pump station and 0.3 MG reservoir on Royal Summit in Waiau 850.
3. 1.1 mgd of additional pumping in Pearl City 385 zone.
4. 0.6 mgd of additional pumping in Pearl City 865 zone.
5. 0.1 mgd of additional pumping in Pearl City 1050 zone.

10.3.2.6 ‘Aiea-Hālawa Model System

The ‘Aiea-Hālawa model system had a total average day demand in 2012 of 3.3 mgd, with 60 percent of demand in Pearl Harbor 277 which serves the Pearl Ridge Center along Pearl Harbor.

The incline along Kaonohi Street, ʻAiea Heights, and the Hālawa neighborhood are included in this distribution system.

Needs Based on Standards

About 0.5 mgd of future growth is expected, and there is sufficient storage and pump capacity to meet existing demands with current operations. However, per the Standards, 0.5 MG of additional storage is needed in Hālawa 418, and 8.1 mgd of additional pumping capacity is needed in various zones within the model system.

Near-Term Improvements

A four-block square neighborhood in the ʻAiea 497 zone experiences pressure above the standard operating limit of 125 psi, while the adjacent streets served by the Pearl Harbor 277 zone experiences pressures below the standard minimum of 40 psi. Partitioning this area with PRVs such that pressures in this area are within the pressure range suggested in the Standard is recommended.

Due to the historical MDD factor being greater than 1.5, recommended improvements are actually greater than those suggested by Standards; 8.6 mgd of additional pumping is needed in various zones. There is excess storage in ʻAiea 497 and Kaʻamilo 497 to offset the storage deficit in Pearl Harbor 277 via an existing control valve at Aiea Booster No. 1, and an emergency connection point at Kaʻamilo Booster

Recommended Improvements for 30-Year CIP

1. Rezoning of ʻAiea 497 and Pearl Harbor 277 near ʻAiea Heights Drive and Kanaloa Street to alleviate high and low pressures.
2. 1.0 MG of additional storage in Pearl Harbor 277 zone.
3. 8.6 mgd of additional pumping in various zones.

10.3.2.7 Windward Model System

The Windward model system had a total average day demand in 2012 of 18.7 mgd. The largest zone in this model system is Windward 272, which had an average day demand of 14.0 mgd or 74 percent of the total demand for this system. Primary supplies into this zone include the Waiheʻe pump set which draws suction from the Waiheʻe Tunnel pipeline, the Punaluʻu pump set that draws suction from the Kahana 315 zone, Maunawili PRV that drops supply from the Windward 500 zone, and the Kāneʻohe Bay PRV that drops supply from the Luluku 500 zone.

Existing System

The majority of the Windward model system demands are south of the Waiheʻe LBP, while the majority of pumped supply is from wells north of the line booster. Because a significant amount of flow passes through the Waiheʻe LBP, it is important to have accurate flow meters at this location. This will allow more accurate calculation of supply into the system as well as more accurate water loss calculations.

The Windward 500 and Luluku 500 zones are hydraulically independent pressure zones. There is a control valve between the two zones but it is not typically operated. The larger of the two, Windward 500 zone, is supplied by two tunnels and their adjacent wells which include Kahaluʻu Tunnel and Well and Haʻikū Tunnel and Well. Some of the Luluku Tunnel and Well supply feeds the Luluku 500 zone while the majority of the supply is passed through the Kaneohe Bay PRV into Windward 272.

The Windward system demand is not expected to increase between 2012 and 2040; therefore, there are no storage or pump station capacity needs.

Historical production from the Haʻikū and Kahaluʻu Tunnels has been below the permitted amount. Because the estimated maximum day demand of 1.5 times the ADD is greater than the actual historical maximum day demand, the modeled Windward system utilized supplies greater than what was historically needed. Modeled tunnel flows were increased to be within but not exceed permitted level. For the 2013 scenarios, supply up to the permitted amount was assumed to be available from the tunnels, though the ability to produce this amount has not been tested in the past.

Recommended Improvements for 30-Year CIP

1. Calibrated flow meters at Waiheʻe LBP.

10.3.2.8 Kahuku Model System

The Kahuku model system consists of one pressure zone with one reservoir and one well station. It is the smallest model system with an existing ADD of 0.38 mgd and is hydraulically separate from other BWS systems. Demands are expected to remain the same in the future.

Existing system demands have been met under current operations. However, according to the Standards, 0.08 MG of additional storage and 1.7 mgd of additional pumping capacity are needed. However, due to the historical MDD factor being greater than 1.5, recommended improvements are actually greater than those suggested by Standards; 1.8 mgd of additional pumping and 0.12 MG of additional storage is needed.

Recommended Improvements for 30-Year CIP

1. 2 mgd of additional pumping.

2. 0.2 MG of additional storage.

10.3.2.9 North Shore Model System

The North Shore model system has an existing ADD of 3.8 mgd. The largest pressure zone in this model system is North Shore 225, which had an average day demand of 2.7 mgd or 70 percent of the total demand for this system. Operating grade lines range from 170 feet near the coast to 892 feet up the Pupukea Highlands. Most of the distribution system is situated along the coastline.

Near-Term Improvements

Waialua 225 Reservoir and Haleʻiwa 225 Reservoir serve the areas to the west of the reservoirs. About two miles of pipe improvements are recommended to improve fire flows in areas where the ground elevation is high relative to the reservoir elevations. An 8-inch pipeline along

Farrington Highway between Olohio Street and Puuiki Street is recommended for fire flow improvement and also forms a looped pipeline network on the west side of North Shore 225. About 0.4 miles of 8-inch pipeline on Goodale Avenue from Waialua Beach Road to Nauahi Street and 0.6 miles of 6-inch and 8-inch pipeline on Kaukonahua Road between Waialua Beach Road and Kaamooloa Road are recommended for upsizing to 12-inch pipelines to improve pressures during peak hour demands.

North Shore 225 has a storage need of 1.0 MG in 2040 using the most probable demand estimate and historical MDD factors. This assumes that a 0.6 MG storage surplus in Kawela 228 is able to back feed into North Shore 225 via Pupukea LBP station. The North Shore model system has a total pumping need of 3.4 mgd for the 2040 most probable demand scenario.

Recommended Improvements for 30-Year CIP

1. 3.0 mgd of additional pumping into North Shore 225 zone.
2. 0.5 mgd of additional pumping into Pūpūkea 600 zone.
3. 2.0 MG of additional storage in North Shore 225 zone.
4. 1.3 miles of 8-inch pipeline along Farrington Highway from Olohio Street and Puuiki Street, for fire flow conditions and redundancy.
5. 0.4 miles of 8-inch pipeline on Goodale Avenue from Waialua Beach Road to Nauahi Street and 0.6 miles of 6-inch and 8-inch pipeline on Kaukonahua Road between Waialua Beach Road and Kaamooloa Road, for peak hour demands.

10.3.2.10 Central Model System

The Central model system had a total average day demand in 2012 of 7.9 mgd. The largest zone in this model system is Mililani 865, which had an average day demand of 2.4 mgd or 30 percent of the total demand for this system. Wahiawā 1361 is the second highest pressure zone in the BWS system in terms of ground elevation of the customers served. Existing facilities meet the Standards for pumping and storage requirements. A PRV from Mililani 994 to Mililani 865 is needed to allow excess storage in Mililani 1150 to offset a deficit in Mililani 865 and Mililani 685 zones.

Currently, Melemanu 808 Reservoir is locked out and not used because the hydraulic grade line near the reservoir would cause the reservoir to overflow. Reconfiguration of pipelines and control valves near the reservoir are needed such that it can become fully functional and not be susceptible to overflowing. About 0.3 miles of pipeline are recommended to improve fire flow in the Wahiawā 1180 pressure zone.

Recommended Improvements for 30-Year CIP

1. Reconfigure pipelines and control valves around Melemanu 808 Reservoir.
2. 0.2 MG of additional storage in Mililani 685 zone.

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Section 11

Facility Condition Assessment

Section 11 provides information that addresses the following WMP objectives:

- Water Quality, Health, and Safety
- System Reliability and Adequacy
- Cost and Affordability
- Water Conservation
- Water Resource Sustainability

Water utilities conduct condition assessments of their facilities to identify areas of concern for further analyses or action. If the facility being analyzed is found to be in poor condition, actions may be taken to rehabilitate or replace the facility before it fails.

This section details the condition assessments conducted on the BWS's pipelines, reservoirs, SCADA system, pump stations, wells, water treatment facilities, and microfiltration/chlorination facilities. Summaries of the results of the condition assessment and recommendations are included in this section.

This assessment, the supply analysis discussed in Section 8, Current and Future Water Supply Sources, and the capacity analysis described in Section 10, System Capacity Evaluation, help form the basis for the near- and long-term improvements for the BWS, presented in Section 12, Findings and Recommendations.

11.1 Key Findings

The WMP's key findings for the facility condition assessments are listed below. These findings are identified with a code (an abbreviation for the section name) and number (for example, COND-1). These codes are repeated in Section 12 to easily tie the findings in this section to the recommendations for BWS action listed in Section 12.

11.1.1 Pipelines

COND-1 Main breaks have been on the decline for several years, and, at 312 per year (equal to about 15.2 breaks per 100 miles of pipe), are about half of the national average of 30 breaks and leaks per 100 miles of pipe as reported by the AWWA 2012 Benchmarking Report[1]. Although the average age of the piping system has been increasing, existing BWS efforts at reducing main breaks have been effective. These efforts include: replacement of failed pipes; operational changes and pressure management; and leak detection and repair. These efforts should be continued.

[1] AWWA. 2014. 2012 Benchmarking Performance Indicators for Water and Wastewater Utilities: Survey Data and Analyses Report. AWWA Catalog No.: 20761. Available at: http://www.awwa.org/store/productdetail.aspx?productid=39837461.

COND-2 Large diameter main breaks (16 inches in diameter or greater) are relatively few (averaging 11 per year), but trending upward. Prioritization of replacement of pipelines on highest risk sections is recommended.

COND-3 Main breaks tend to cluster on specific sections of pipelines. This has been observed on 10th Avenue in Pālolo, Hahaʻione Street in Hawaiʻi Kai, McArthur Street in Waiʻanae, and at other locations. Monitoring main break density (breaks per mile) on pipelines and replacing pipeline if main breaks become greater than what is considered a failed pipe (one break per 200 feet in the last ten years) is recommended. A portion of the capital budget should be dedicated to replacing these smaller pipelines with frequent breaks.

COND-4 Over the last 10 years, the BWS has awarded contracts to replace an average of 8.7 miles of pipeline per year. Pipeline break and risk metrics should be monitored, and in the event of worsening metrics, replacement rate should increase to 20 miles per year as determined by the lifespan assessment. Savings from lower interest rate State Revolving Fund loans can be utilized to increase risk-based pipe replacement miles when funding is available.

COND-5 Even at a replacement rate of 1 percent per year, it is projected that the main break rate of 312 per year will eventually begin to increase and reach about 350 breaks per year by the year 2040 as the system ages and older pipes exceed their design life. The BWS has implemented operational strategies to reduce main breaks to close to 300 per year, and future operational changes may include adding surge control at key pump stations, increasing reservoir storage where deficient, and/or reducing pressure in high pressure areas.

COND-6 The Failure Factors Analysis showed that targeted pipe replacement (replacing shorter segments of high likelihood of failure pipe, with a minimum replacement of 1,000 feet) can significantly reduce break rates and increase pipe replacement efficiency (by not unnecessarily replacing pipes with lower likelihood of failure). High quality risk and assessment data will allow more efficient and targeted pipeline replacement, reducing the break rate at any given replacement rate. These efforts are critical to maintaining the low rate of main breaks the BWS has achieved.

COND-7 Statistical evaluation of all existing BWS materials (cast iron, PVC, concrete cylinder pipe, asbestos-cement pipe, galvanized steel, ductile iron, and other materials) shows that ductile iron has the best performance considering historical main breaks per mile. Ductile iron is a reliable pipe material for the BWS and is the default standard pipe material for all new BWS pipe installations.

COND-8 To allow future generations to eventually replace pipelines at a lower rate per year, the BWS will seek to design new ductile iron pipelines for a service life of greater than 100 years. This ambitious goal will require adoption and consistent application of better-than-current industry "best practices" for design, material specifications, concurrent use of multiple methods of corrosion control, and a long-term commitment to monitoring and testing of cathodic protection systems.

COND-9 PVC pipe is the other pipe material used by the BWS in new installations. Recently, the BWS has experienced PVC pipe failures (main breaks) in pipelines that are less than 20 years old. The BWS has implemented an interim standard requiring thicker wall PVC pipe, limiting installations to lower pressure areas, restricting maximum PVC size to 16 inches in diameter, increasing trench cushion requirements, and prohibiting pipe bending and joint deflection. This interim standard will remain in place pending the results of an on-going (2016) PVC pipe study.

COND-10 To efficiently prioritize and schedule pipeline replacement, ongoing condition assessment can be helpful. Continued monitoring of condition assessment technology for improved ease of use and pipeline condition assessment on transmission pipelines as recommended by the pipeline decision framework (CapPlan) is recommended. Additionally, all new ductile iron transmission pipelines should have six-inch diameter access points installed at half mile intervals to simplify future condition assessment testing. A standard detail should be developed and adopted.

COND-11 Moanalua Tunnel may require strengthening to allow surface development. If surface development is allowed, implement tunnel rehabilitation projects as identified. Reevaluate condition of all pipeline tunnels every 10 years.

COND-12 BWS currently has a valve exercising program. Continue valve exercising program and specifically address large (16 inches in diameter or greater) valves that have not been exercised recently.

COND-13 Due to the public perception of water waste, the unidirectional flushing and hydrant testing programs ramped down several years ago. The need to reinstate unidirectional flushing and hydrant testing programs should be evaluated, beginning with public outreach to explain the needs.

11.1.2 Reservoirs

COND-14 The majority of the reservoirs are conventionally reinforced, cast-in-place concrete, and this type of structure has proven to be very durable. In larger sizes, strand-wound concrete reservoirs originally constructed to AWWA D110 standards have also performed well. Eighty-nine percent, or 152 of the 171 reservoirs are in need of only minor or no work. Continued use for cast-in-place concrete for small reservoirs, and AWWA D110 designs for reservoirs larger than 1 to 2 MG is recommended. Continued proactive maintenance and completion of needed repairs to reservoirs is recommended.

COND-15 Eighteen of the reservoirs (11 percent) have high priority projects that should be performed. These projects are included in the CIP.

COND-16 Although designed to then-current codes, one hundred twenty reservoirs (70 percent) do not meet the most current seismic code, although code level failures of most would cause only minor damage. As structural work is performed on any of these reservoirs in the future, upgrading the seismic restraint system to meet the latest codes is recommended. There are no Federal, State, or local requirements for most structures (including reservoirs) to be upgraded to meet changing codes. These costs have been included as placeholders in the CIP.

COND-17 Two reservoirs are recommended for immediate replacement due to seismic risk. One of these two reservoirs is also considered vulnerable to roof damage from hurricane-related winds. Based on extrapolation of the evaluation of representative BWS reservoirs designs, all other remaining BWS reservoirs appear to be suitable to withstand hurricane-related winds.

COND-18 Reservoir condition assessment is important to identify and schedule needed repairs. Re-inspecting the poorer condition reservoirs every 5 years and updating the reservoir condition assessment every 10 years is recommended.

COND-19 Approximately 60 reservoirs have had internal inspections in the last 10 years, and many need cleaning to remove natural sediment. A reservoir inspection and cleaning program for all reservoirs is recommended.

11.1.3 Pump Stations

COND-20 Four hundred fourteen source and booster pumps have reliably supplied water and maintained system pressure, currently meeting an average day demand of 145 mgd and a maximum day demand of 180 mgd.

COND-21 Eighteen percent of pumps are out of service and need repair, reducing redundant capacity in the system. Although only about 60 percent of pumps are needed to meet system demands, rehabilitating out of service pumps, with the goal of more than 90 percent of pumps available for service, is recommended.

COND-22 Many pump stations are in need of repair, refurbishment, or upgrade. Refitting pump stations to improve operation, reliability, and efficiency is recommended.

11.1.4 Water Treatment

COND-23 At some facilities, physical treatment equipment is in need of repair, predominantly related to corrosion. Completion of repairs to treatment equipment and an on-going painting program to extend useful lifespan are recommended.

COND-24 Treatment at some facilities may be able to be made more efficient by process modifications and new carbon filter media products, like coconut carbon. Completing modifications to treatment processes to increase efficiency is recommended.

11.1.5 Facilities

COND-25 The BWS has a comprehensive and widely used GIS system. In addition, the Water Master Plan has provided a risk-based pipeline prioritization tool called CapPlan. These tools should be regularly updated to continue to provide a benefit to BWS.

COND-26 The BWS is installing a dedicated and hardened microwave-based backbone telemetering communication system that ties in all BWS facilities island-wide. Existing remote telemetry units (RTUs) and SCADA system should be upgraded to current technology and functionality improved. A multi-year phased approach should be used to migrate SCADA data to the microwave system to avoid disruption to existing operations.

COND-27 Office and base yard buildings and facilities are in need of various repairs and functional modifications to meet their current uses. Completing high-priority repairs is recommended, but an Office and Base Yard Master Plan should be completed to coordinate with future needs.

COND-28 Office and base yard needs into the future were not evaluated in the WMP; however, planning is being completed separately for the Kapolei Base Yard. Completing an office and resource evaluation and developing a master plan for new and/or modified spaces is recommended, along with a Base Yard Master Plan for new and/or modified yard areas.

COND-29 The BWS has completed a Facility Security Study that identified a variety of intruder or damage vulnerabilities. The recommendations of that study should be implemented.

11.2 Pipelines

The pipes that carry water throughout O‘ahu were installed at different times and constructed of varied materials and varied sizes, with some as large as 42 inches in diameter (see Section 6, The BWS System). Like all constructed facilities, pipelines degrade over time due to corrosion, fatigue, land movement, or other factors. Volcanic soil and saline groundwater, like that found in some places on O‘ahu, can accelerate corrosion that externally breaks down the pipe material.

Because pipelines are buried, their condition cannot be easily assessed. Additionally, unlike sewer pipelines in which cameras can be readily inserted because the pipes are non-pressurized, assessing the condition of pressurized water pipelines poses complex challenges. The BWS used advanced tools to assess the wall condition of selected transmission pipes, collected data on breaks and leaks, conducted forensic analyses on representative pipes that have failed, and gathered information on operations and maintenance practices. A number of analytical tools were applied to relate these thousands of data points to one another, making it possible to estimate which stretches of pipeline are most critical for service dependability and which are potentially most likely to fail. The results helped determine where to invest first in repair, rehabilitation, and replacement projects.

After the analyses were complete, the entire inventory of pipelines was sorted in a decision framework to determine the needed action for each segment. This decision framework grouped pipelines into the following categories:

- Replace pipeline (add project to the CIP and complete per prioritization presented in Section 13, Implementation) – 16 percent;
- High frequency monitoring (about 10 years) – 3 percent;
- Low frequency monitoring (about 20 years) – 15 percent; and
- Reevaluate in the future – 66 percent (no current action needed).

Large diameter pipelines (greater than or equal to 16 inches in diameter) were the focus of pipeline inspections due to their critical nature and infrequent failure history (meaning little is known of pipeline condition); however, the statistical evaluations included all pipelines.

11.2.1 Pipeline Condition Assessment Methodology

Pipeline replacement needs were estimated using a Lifespan Analysis, a Failure Factors Analysis, and finally a Pipeline Risk Analysis to help prioritize the most critical pipelines to replace. In addition to the statistical analyses, forensic analysis of selected main breaks and physical condition assessment were completed on a subset. Each of these analyses is discussed below.

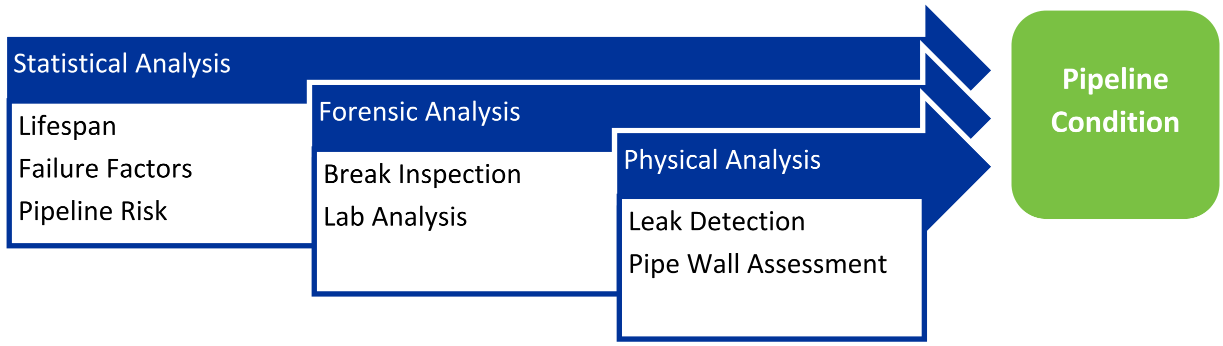
A Lifespan Analysis was completed to determine, on average, the length of pipe that should be replaced each year. This analysis considers only assumed pipe lives applied to the current inventory of pipelines in the system, and is a conservative first look at the potential replacement needs over the long-term (100 years).

To determine the order that pipes should be replaced, data on previous main breaks was reviewed, identifying and evaluating their characteristics to identify the mechanisms of pipe failure. This Failure Factors Analysis used available GIS data to suggest which pipe and environmental factors contribute the most to current failures. The Failure Factors Analysis tested the statistical significance of various factors (for example, pipe material, soil type, brackish groundwater, pressure, among others) to determine which factors are most affecting the degradation of pipelines and materials within the system.

The Pipeline Risk Analysis then took the estimated likelihood of failure scores from the Failure Factors Analysis along with a separately developed consequence of failure score to develop a risk score for every pipe in the BWS system. This analysis helped to prioritize specific pipe assets to rehabilitate or replace in order of overall risk.

Over the course of the pipeline condition assessment program a number of main breaks were investigated to identify potential causes of the failure. Pipe material from several of these breaks was analyzed by a lab to determine whether the pipe material itself was a potential cause.

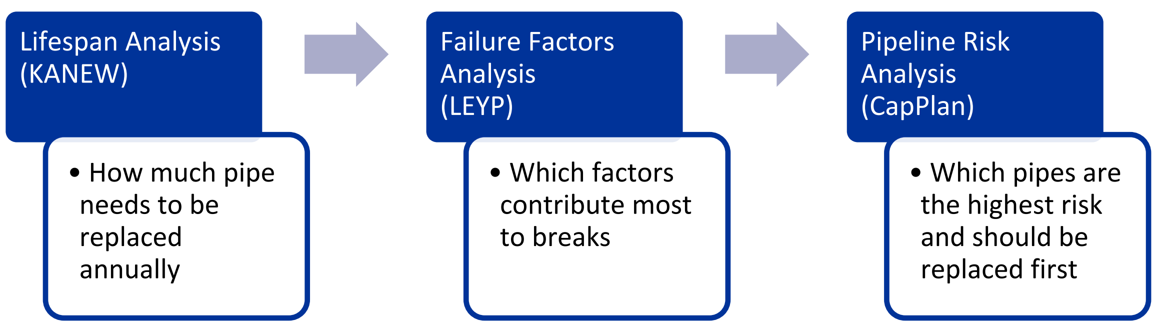
A number of (mostly transmission) pipes were selected for further physical analysis using leak detection and pipe wall assessment technologies based on the following steps. First, pilot testing was conducted to determine which testing technologies were most appropriate for BWS facilities. Next, the risk prioritized list of pipelines was used to determine the pipes with the highest potential risk. Logistics and site-specific feasibility were also considered, including pipe location, depth, traffic, accessibility, paving, and budget.



Physical analysis focused on pipes with a large diameter and high rating for consequence of failure and evaluated different pipe types and sizes. Particularly of interest were otherwise high consequence of failure pipelines that had no condition data because they have not broken. In doing so, this testing informed how pipeline replacement should be prioritized in the CIP.

11.2.2 Statistical Analysis

The Lifespan, Failure Factors, and Pipeline Risk Analyses each utilized a specific computer program (KANEW, LEYP, and CapPlan, respectively) to analyze thousands of data points gathered over many decades by the BWS. These data included pipe characteristics, location, break information, and nearby land uses. Together, the data give an indication of the condition and criticality of each pipe.



11.2.2.1 Lifespan Analysis (KANEW)

The BWS began by analyzing the current inventory of pipelines to estimate their expected service lives, and then using the installation date to estimate when in the future these pipes will begin reaching the end of their service lives. This Lifespan Analysis gives a broad indication of, on average, the pipeline renewal rate.

The Lifespan Analysis, evaluated with the KANEW software program, used estimated pipeline lifespans that were developed from industry standards[2]. The lifespan assumptions vary for each type of pipe material, but generally range from 50 years, when the first pipes of the lowest life material start failing, to over 100 years when a relatively small portion of long lived pipes remain in service.

By applying these estimated lifespans to the pipelines currently installed in the BWS system, a projection was created, depicted in Figure 11-1, showing the estimated miles of pipelines that will reach the end of their expected lifespans decades into the future. For many utilities, this analysis shows a large peak of pipe reaching the end of its expected lifespan in the future. Fortunately for the BWS, this was not the case. The peak of pipe reaching the end of its expected lifespan in the 2070s is relatively small overall. Lifespan Analysis is a conservative first look at the needed level of annual pipeline renewal. Better knowledge of and management of main break factors, such as the other condition assessment efforts as part of the WMP as well as the on-going Quality Infrastructure Conservation Initiative (also known as QUINCI[3]), can effectively increase the service life of pipes and reduce the long-term renewal amounts.

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[2] AWWA. *Buried No Longer: Confronting America's Water Infrastructure Challenge*. Available at: http://www.awwa.org/Portals/0/files/legreg/documents/BuriedNoLonger.pdf.

[3] QUINCI was formed to determine the most prevalent pipeline failure mechanisms, identify mitigation and prevention measures to reduce catastrophic pipeline breaks, and conduct pipeline condition assessments.

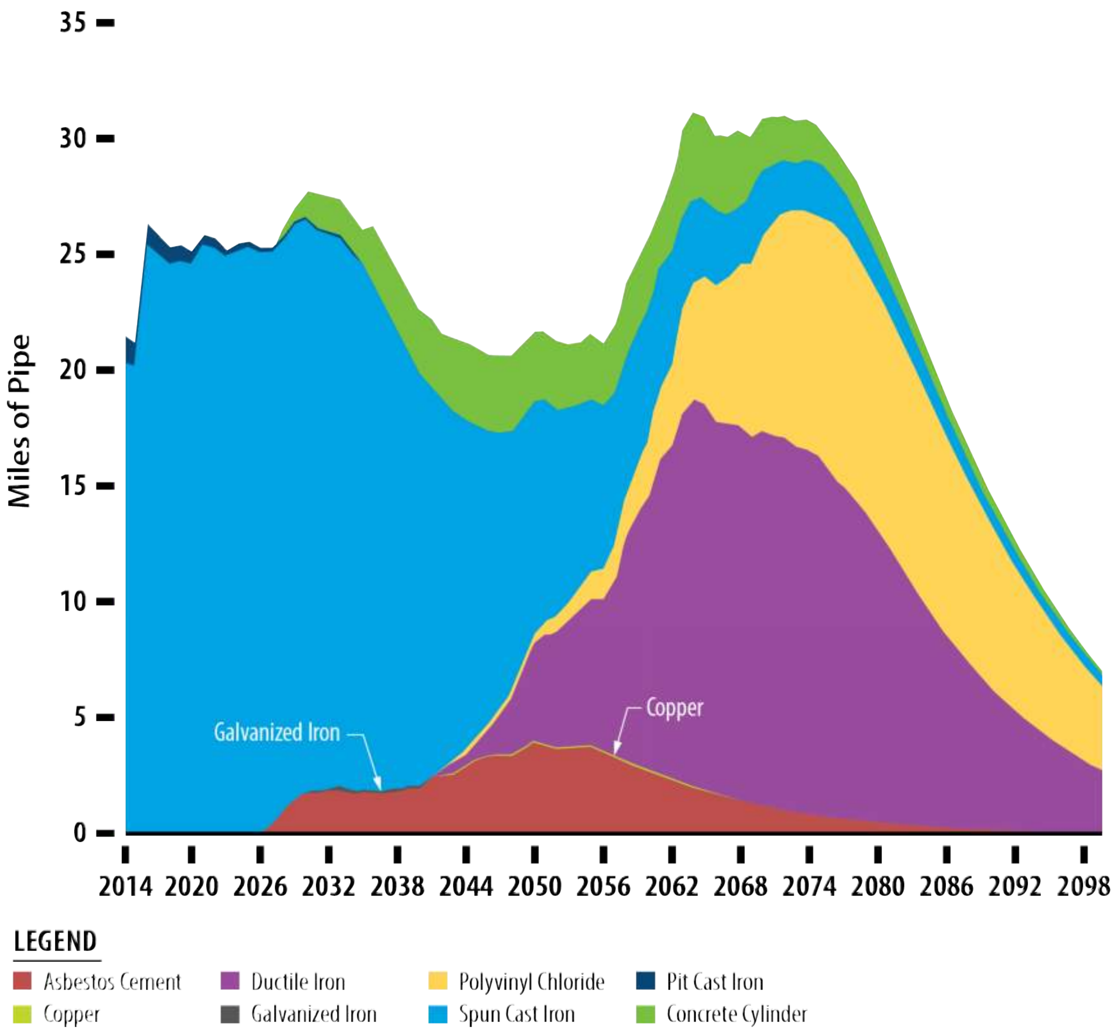


Figure 11-1
Pipe Renewal Needs Forecast Using Industry Standard Pipe Service Lives

The Lifespan Analysis suggested that approximately 20 to 25 miles of pipe per year should be renewed. Table 11-1 summarizes how variations in the miles of pipeline replaced per year affect the length of time to replace all pipelines in the BWS system and the resulting impact on average pipe age.

Table 11-1 Pipe Replacement Rate and Impact on Average Pipe Age

Miles of pipe replaced per year	Years to replace all pipes	Resulting Impact on Average Pipe Age by Year Shown[1]					
		2015	2025	2035	2045	2055	2065
5	420	40	44	49	53	57	62
10	210	40	42	45	48	51	54
15	140	40	41	42	44	46	48
20	105	40	39	39	40	41	42

[1] Assumes oldest pipes are replaced each year.

11.2.2.2 Main Breaks and Failure Factor Analysis (LEYP)

The BWS has been collecting data on main breaks since the early 1970s and now has a rich set of data. Historical main break data can be used both as a metric to assess one part of the health of the BWS water system and as an analysis tool to try and determine the causes of pipe degradation and main breaks. The BWS considers a break to be any breach of pipe greater than four inches in diameter. This definition includes what the AWWA benchmarking considers as both breaks and leaks. The BWS definition of a leak is a breach on service mains or laterals four inches in diameter or smaller. Also, damaged valves are considered "repairs" and not counted as leaks or breaks.

To date, pipeline replacement decisions have been based on institutional knowledge of the system and focused on main break hot spots that have been observed around the island. This method of replacement prioritization has worked well to reduce the number of main breaks to their current low level. Figure 11-2 illustrates the main break hot spots identified initially by staff knowledge and refined by GIS analysis.

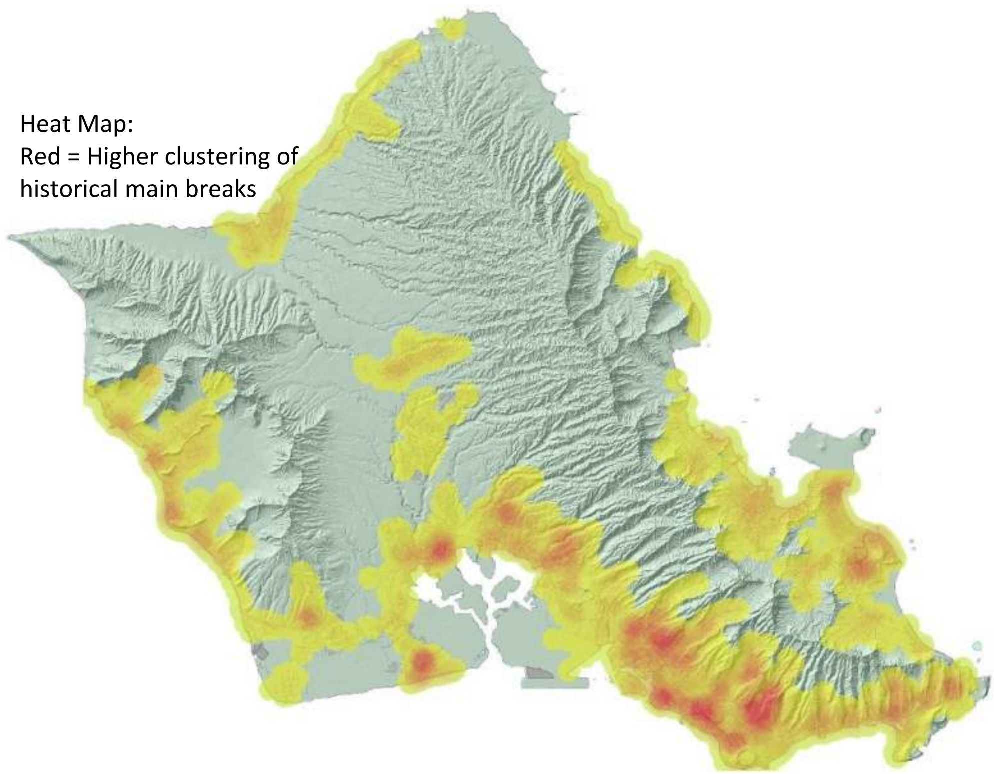


Figure 11-2
Clustering of Main Breaks in Specific Areas

As an overall trend, the total number of main breaks across the BWS system has decreased for the last 20 years to a current level of approximately 312 main breaks per year. This reduction was likely due to significant investment in the last two decades in main replacement and operational changes the BWS has adopted to minimize triggering main breaks. For context, applying the higher, national average rate of main breaks (30 breaks and leaks per 100 miles) to the BWS system would result in about 620 main breaks per year. The trend in main breaks is illustrated in Figure 11-3.

> Number of main breaks is one metric the BWS uses to assess the health of the water system. Rising main breaks over several years could indicate additional investment is needed in pipeline replacement. See Section 13 for a full discussion on metrics and adaptive management for system needs.

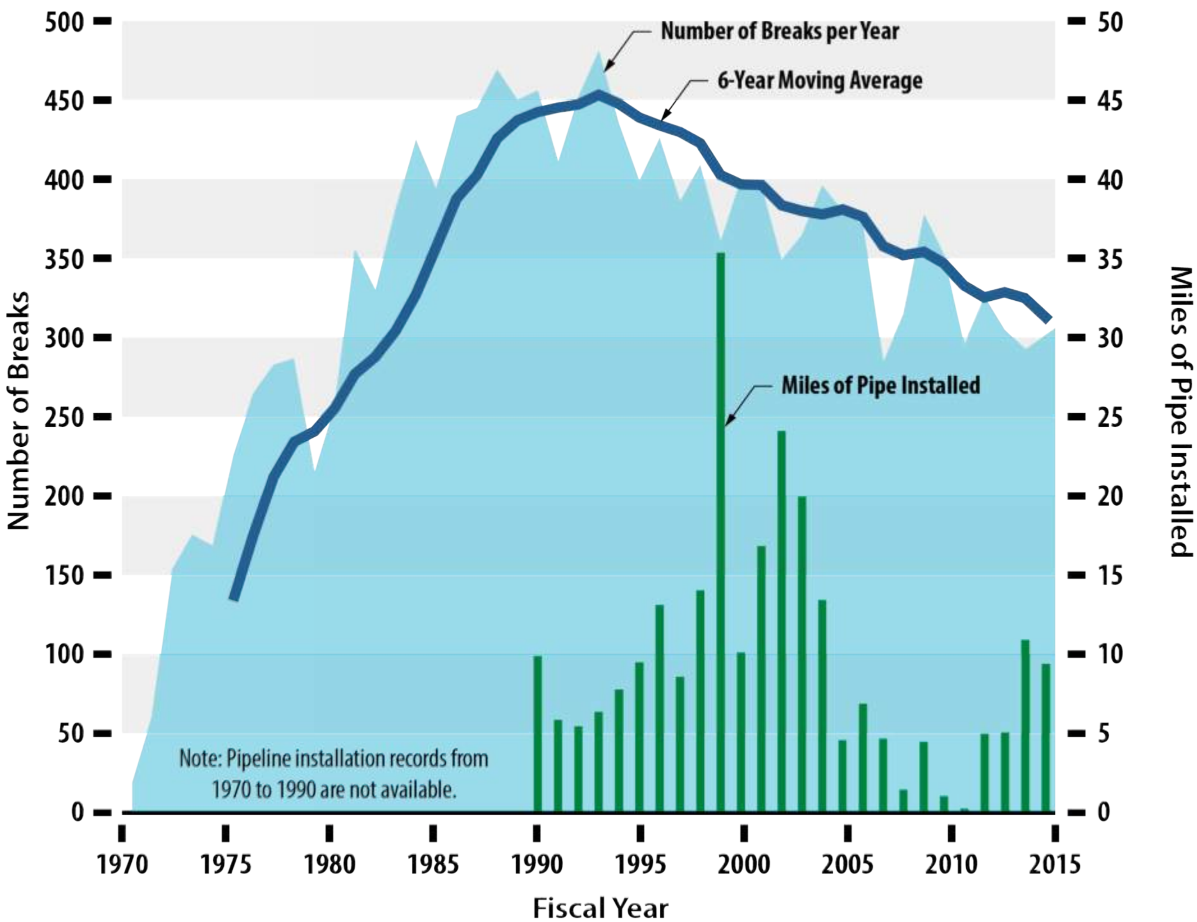


Figure 11-3
Total Main Breaks Across the BWS System

However, the number of large diameter main breaks, while still very low, has been increasing. These pipelines have the highest consequence of failure, causing larger damage and disruption than smaller diameter pipes. Figure 11-4 presents the large diameter main breaks over time.

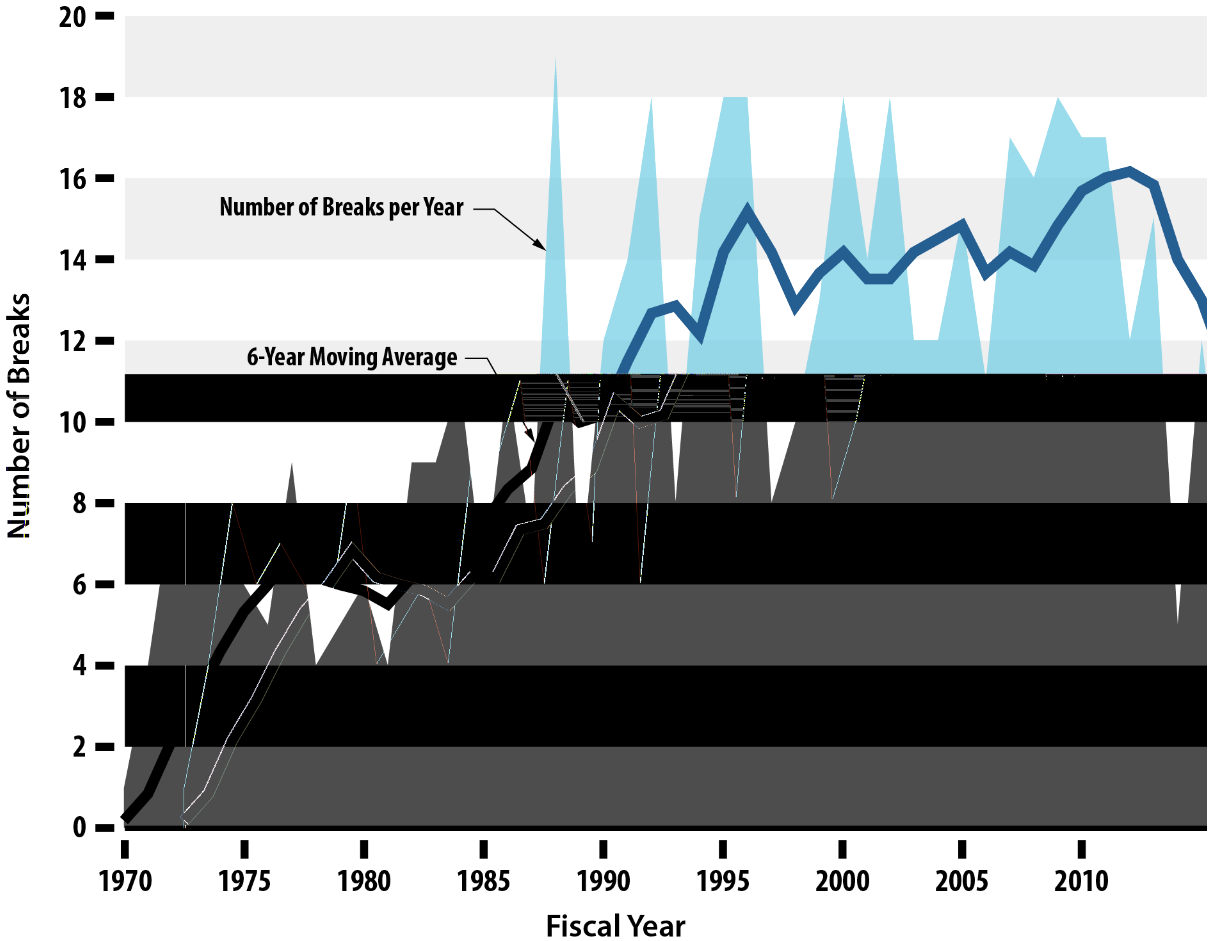


Figure 11-4
Main Breaks on Pipes 16 Inches and Larger Across the BWS System

To evaluate the factors that lead to main breaks, a Failure Factor Analysis was completed to assess all available main break data in the BWS GIS database. The LEYP statistical software program identified which factors (e.g., soil type, proximity to salt water, pipe material, etc.) most significantly correlate with the condition of pipelines and materials. The most important factors identified for main breaks were (in order of impact):

- Age – Older pipes have had longer to degrade;
- Material type;
- Coastal zone – Areas near the coast are more likely to be in groundwater, and that groundwater has higher salinity and is more corrosive;
- Pressure – Particularly above 125 psi, higher pressure pipes must contain greater force;

- Soil – Some soils are more corrosive or prone to movement than others:
  - Higher likelihood of failure includes soils with high shrink/swell potential, high plasticity, and/or high corrosivity. Also included were fill areas which can be variable, and more corrosive.
  - Lower likelihood of failure includes soils with low shrink/swell potential, low plasticity, and/or low corrosivity;
- Diameter – Larger pipes have thicker walls to withstand pressure, which also provides greater resistance to other degradation;
- Other important factors not included in Failure Factor Analysis:
  - Construction Quality – Although construction quality is an important factor in the lifespan of pipes, it is not a factor that can be evaluated using GIS data.
  - Damage Caused by Other Construction – Many breaks are caused by other contractors working in the area of BWS pipelines.

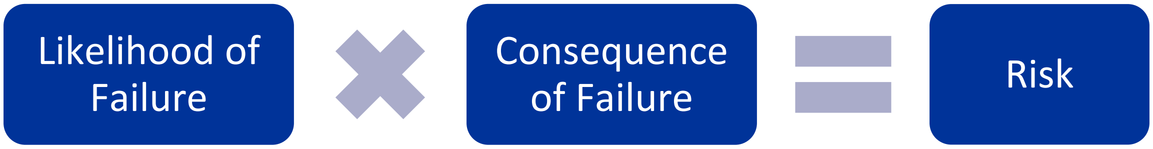
The Failure Factors Analysis was validated by holding back the last three years of main break data and assessing how well the analysis could predict where breaks would occur in those three years. The validation ratio of predicted breaks to actual breaks was 1.25 (slight over prediction), compared to a perfect model having a ratio of 1.0. Validation ratios seen from other utilities are between 0.67 and 1.44, and the BWS analysis at 1.25 is at the median, considered a good, slightly conservative model. The analysis showed that if the 10 percent of pipes with the highest predicted break rates were replaced, approximately 47 percent of main breaks would be avoided. While this level of pipe replacement would take many years and replacement of only the short segments of pipe that have high predicted break rates is not the most efficient method of pipe replacement, the analysis showed that targeted pipe replacement (shorter segments of high likelihood of failure pipe) can have a significant effect on break rate.

The data that BWS has collected since the 1970s and organized in the GIS database is what allows this analysis to be completed. The richer and longer the data set is, the better insights can be drawn from it. As such, the ongoing pipe break data collection efforts lead by the QUINCI initiative are important for future break analyses such as this and should be continued.

The information obtained from the Failure Factor Analysis provided input into the risk-based Pipeline Risk Analysis below.

11.2.2.3 Pipeline Risk Analysis (CapPlan)

The CapPlan statistical software program was used to rank pipeline segments based on the risk that each segment contributes within the entire pipeline system. For the purpose of this analysis, risk was defined as the likelihood that a pipeline will fail, multiplied by the consequence of that failure occurring.



As their names imply, the likelihood of failure (LoF) factors show the probability the pipeline segments would fail, while consequence of failure (CoF) factors show how severe an impact the potential failure would have on the entire BWS system. In a workshop setting, senior managers of the BWS selected appropriate LoF and CoF factors to input into statistical software. These factors are summarized in Table 11-2.

Table 11-2 Risk Analysis CoF and LoF Factors

CoF Factors	LoF Factors
Disruption	Probability of future breaks ("PFB," from failure factor analysis). This includes factors for:
Type of pipe cover (buried, suspended on bridge, etc.)	Age
On a bus route	Diameter
Street (versus pipe not in roadway)	Soil
Sensitive locations	Pressure
Damage	Coastal Zone
Street class (highway, major, minor, etc.)	Material Type
Diameter of pipe	Breaks (If no PFB available)
Maximum flow of water in pipe	Age of pipe (If no PFB available)
Proximity to sewer system	
Proximity to electrical system	
Proximity to gas system	
Outage	
Critical facilities and sensitive locations	
Size of isolation for repair	
Level of redundancy of pipe	
Land zoning	
Population density	

The software provided a ranking of all pipes in the BWS pipe system from highest to lowest risk. Risk values over 400 were considered high, 250 to 400 moderate, and less than 250 low. Figure 11-5 shows that the high risk pipelines in the BWS system are a relatively small portion overall (less than 170 miles, or 8 percent with risk value above 400). This ranked list was then used as the initial basis for the order of pipeline replacement.

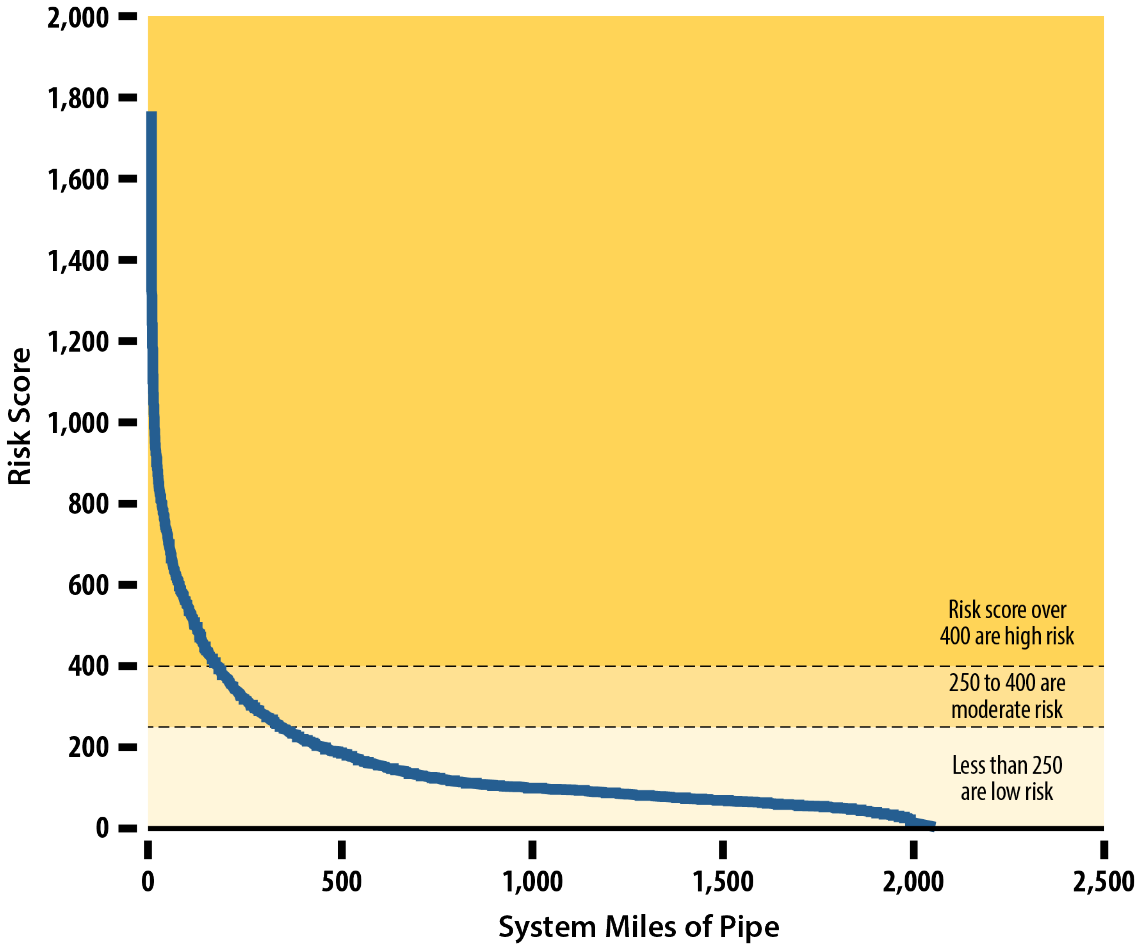


Figure 11-5
Pipeline Failure Risk by Miles of Pipeline

11.2.3 Forensic Analysis

The BWS conducted forensic analyses to better understand the reasons why water main breaks occur. These analyses are on-going, and this report includes only the analysis completed to date.

11.2.3.1 Forensic Main Break Evaluation – Cast Iron Pipe

Analysis of five 2014 main breaks was conducted to support the analysis of main break causal factors. The pipe size and locations of the analyzed main breaks included:

- May 1, 2014, 12-inch cast iron, Hahaione Street;
- May 2, 2014, 12-inch cast iron, Hahaione Street;
- May 15, 2014, 16-inch cast iron, School Street;
- June 9, 2014, 16-inch cast iron, 10th Avenue; and
- June 26, 2014, 20-inch cast iron, Dole Street.

Of the five main breaks inspected, two included material analysis and laboratory testing. Tests concluded that the iron used in that pipe met the required standards at the time of installation and the chemical properties of the pipes were similar enough to conclude that they likely were produced at the same factory. However, examination of the failed pipe segments determined that all five failures were caused by external graphitic corrosion of the pipes.

Cast and ductile iron pipes are made of an alloy of iron and carbon. If the pipes are buried in contact with corrosive soil or water, corrosion can occur. When this corrosion happens, iron is dissolved from the pipe wall into the groundwater. As the iron dissolves, all that remains is the carbon (specifically graphite, a form of carbon), which is much weaker than the iron and carbon alloy. This type of corrosion is called graphitic corrosion and is most prevalent on cast iron pipe, but can also be an issue on ductile iron pipe. The breaks inspected all suffered from external graphitic corrosion, where the soil and groundwater on the outside of the pipe start the corrosion from the outside and move inward through the pipe wall.

Because the profile of the pipe wall is left intact, graphitic corrosion is difficult to see even if the pipe is exposed. Pipe samples were sandblasted which removed the graphite but left the remaining iron pipe wall intact. This allowed assessment of the extent of corrosion. Figure 11-6 shows a section of removed pipe before and after sandblasting. It should be noted that the areas shown as holes in the pipe were not (yet) breaks or leaks because of the remaining graphite.

Figure 11-6
Excavated Pipe Showing Graphitic Corrosion Before (left) and After (right) Sandblasting

11.2.3.2 Forensic Main Break Evaluation – PVC Pipe

The BWS has commissioned a separate study to investigate PVC pipeline failures. As of 2016, that work is on-going; however, draft results suggest several reasons for the premature PVC failures that BWS has experienced recently. Material vintage, internal pressure, and the entity managing construction all showed statistically significant effects. In addition, it was found that all of the PVC breaks could be attributed to only 25 percent of the job numbers, suggesting that specific contractors perform more poorly than others.

When final results are available from this study, it is anticipated that modifications to the BWS Standard Specifications, Standard Details, locations and applications suitable for PVC, and methods of design and construction of PVC pipelines will be recommended.

11.2.4 Pipeline Inspections

Using the methodology detailed in Section 11.2.1, the BWS performed pipe inspections using both leak detection and pipe wall condition assessment. Pipeline leak detection is one screening method that attempts to correlate the presence of leaks to pipe condition. The detection of small leaks can be just as important as the detection of larger leaks. While the BWS has an existing leak detection team, additional testing was conducted using state-of-the-art acoustic equipment on a portion of the water system pipelines to detect and determine the location of leaks. Following the main break and leak detection analyses, selected high-priority pipe segments were inspected, about 17,000 feet of pipe, using sophisticated electromagnetic pipe wall assessment equipment.

11.2.4.1 Leak Detection

Pipeline leak detection is a non-intrusive (sensors are not inserted into the pipe) test method that uses sensitive microphones and data recording devices to “listen” for the presence and location of leaks in the pipeline. While recording, specifically designed software filters out ambient noise signals to focus on the acoustic signature of leaks. In good conditions, this technology is able to detect leaks less than 5 gallons per minute and pinpoint leak location within 5 to 10 feet. While the BWS maintains a leak detection team doing continuous inspections, a specialty testing company (Echologics) was used to determine if state-of-the-art technology could be useful to the BWS on some of its largest pipelines.

The joint BWS/vendor leak testing successfully located several simulated leaks in the tested mains. The vendor confirmed the location of a leak previously identified by the BWS leak detection team using different leak detection equipment, on an air valve line connected to the 42-inch cast iron transmission main on Miller Street near Queen’s Medical Center. The BWS leak detection team has since procured updated equipment, allowing for even more precise detection and location of leaks.

Leak detection provides useful information about the location and estimated size of leaks on pipelines which can be used to repair the pipelines. The presence or absence of leaks also gives information on the condition of the pipe; pipelines with several small leaks are likely to be in generally poor condition, and pipelines with no leaks should provide several more years of service before needing to be tested again. One limitation is that leak detection cannot estimate whether a non-leaking pipe is in excellent condition, or may begin to leak in the near future.

Leak detection also allows for proactive repairs to pipes, as main breaks often begin as small leaks. On many occasions, one repaired pipeline leak leads to another leak in the same area. It is not unusual over a several month period to repair multiple leaks in several hundred feet on the same pipe. The BWS leak detection team currently surveys about 30 miles of pipeline per month. Many of the leaks found by the leak detection team are coupling leaks at meters which are immediately tightened and reduce water loss and pumping energy. Reduction in water loss contributes directly to reducing costs and maintaining rate affordability.

11.2.4.2 Pipe Wall Assessment

Pipe wall assessment (PWA) is a test performed with technologies that provide an indication of pipe wall condition while the main is in place and in service. Unlike methods that provide indirect information regarding the condition of the pipe through information such as soil corrosivity, pressure, break analytics, or leak detection, PWA is considered to be a more direct method of pipe wall condition assessment.

Two different intrusive (sensor inserted into the pipe) PWA testing platforms were used (SmartBall PWA and Sahara PWA, both by Pure Technologies). The SmartBall platform is a free-swimming, ball-shaped device that is propelled by the water flow in the pipeline. The device has an electromagnetic sensor to record PWA data, and an acoustic sensor to detect leaks. The Sahara platform is a tethered (connected to a fiber optic cable) sensor that performs PWA and leak detection and also records closed circuit video. The tethered Sahara device is pulled through the pipeline by a parachute that captures the flow of moving water. One advantage of the intrusive technologies is that the sensor package passes directly through the pipeline, so the sensor is never more than one pipe diameter away from the wall or a leak, which can provide greater accuracy.

These technologies use the electromagnetic signature of pipelines to evaluate the pipe wall. The sensor measures the electromagnetic field due to the metallic pipe wall, and software analyzes the data. When the magnetic field within a cast iron or ductile iron pipe is not uniform (see Figure 11-7), the software identifies the non-uniformity as an anomaly. Anomalies due to known features of the pipe like joints, valves, outlets, and even small taps are filtered out, and the remaining anomalies are possible areas of weakness in the pipe wall. PWA was used primarily to test large diameter cast iron transmission mains due to their higher risk scores and the ability to test much longer lengths per sensor insertion. The testing resulted in the following conclusions.

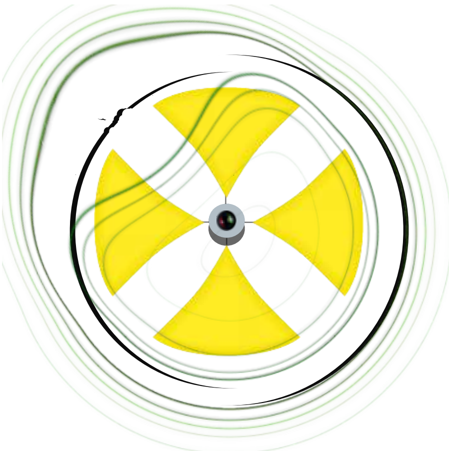


Figure 11-7
Non-uniform Electromagnetic Field Caused by Area of Weakness in Pipe Wall

Free swimming PWA testing was conducted on a 16-inch diameter, cast iron cross-country pipeline (installed circa 1952) near He'eia State Park on Windward O'ahu. The pipeline was selected for testing due to long cross-country portions that are difficult to access for maintenance. The inspection assessed 11,700 feet, identified 25 separate potential leaks, and determined that more than 50 percent of the pipeline showed signs of medium to large electromagnetic anomalies indicative of probable external corrosion. Based on these data, eventual abandonment or replacement of this pipeline is needed.

Tethered PWA testing was conducted on two separate pipelines in the Metro area – a 30-inch diameter (circa 1944) cast iron main along Date Street and a 24-inch diameter (circa 1952) cast iron main along Kāhala Avenue and into Wai'alae Golf Course. These mains were chosen to give an indication of the effects of different soil types and groundwater conditions, and were sections of the major metro transmission most accessible for testing. Inspections on these lines totaled 4,700 feet and showed no leaks. The Date Street pipe appeared to be in very good condition, showing few anomalies. The Kāhala Avenue pipe showed to be in mostly good condition, with some sections of concern that warrant further investigation and potential repair/replacement of selected segments.

These tests provided useful and actionable information for the BWS, as well as provided a baseline for possible future testing of the good condition pipes to determine the rate of degradation. Intrusive testing is, however, more difficult due to the need for increased planning, hydraulic modeling, system operational changes, and construction of pipe taps, all of which increase the cost of testing.

11.2.5 Pipeline Materials and Corrosion Control

An evaluation was performed of pipe materials and corrosion control practices used by the BWS for new installations. The work included:

- Review of 2002 Standards and amendments for pipe material and corrosion control specifications;

- Review of BWS corrosion control specifications and details;
- Review of representative design documents;
- Review of BWS break statistics (see Section 11.2.2);
- Performed forensics on failed CIP pipe segments (Section 11.2.3.1);
- Forensics and special study on PVC (Section 11.2.3.2); and
- Review and input from corrosion specialists (by V&A Consulting Engineers).

No change in the current suite of pipe material alternatives is recommended. The BWS-allowed pipe materials remain at the same two:

- Principal pipe material is ductile iron. As of April 29, 2016, the Standards for Oʻahu only were revised to increase the minimum thickness to Class 53 to provide better protection from the corrosive soils of Oʻahu.
- As of April 30, 2015, PVC pipe is allowed in selected cases, for lower pressure pipes. PVC requires DR14 wall thickness and only installations of up to 16 inches in diameter. The BWS anticipates revisiting its PVC specifications upon the conclusion of the PVC forensic study in late 2016.
- Concrete cylinder pipe is no longer approved for use by the BWS.

The BWS has indicated its desire for all new ductile iron pipe (DIP) installations to last greater than 100 years, and as a result, the following observations and recommendations are made.

- DIP has only about a 40-year history on Oʻahu. Typical life expectancy for DIP based on various industry projections is on the order of 75 to 100 years for pipes in non- or low-corrosivity soils.
- The installed cost of pipeline is particularly high in Hawaiʻi and is approximately double the cost of similar installations in the San Francisco or Los Angeles area. The disruption to customers caused by main breaks and the high replacement cost are principal reasons for achieving a long service life.
- Some soils on Oʻahu are very corrosive, particularly in coastal areas.
- Achieving a greater than 100-year life expectancy goal for DIP will require a conservative, multi-prong approach that includes potential changes in design, construction, inspection, maintenance/testing, and repairs.
- Conservative design using robust materials and corrosion protection methods is recommended for all soil types. This will result in uniformity of design and ease of implementation and inspection.

- There is no downside in pipe lasting longer than targeted as this still benefits the BWS. If conservative design and corrosion protection methods are applied on less corrosive soils and the pipe there lasts more than 100 years, this is still good value for BWS.
- The incremental cost for robust materials and potentially redundant corrosion protection methods is relatively minor.
- Increased service life for DIP will also require revised methods for repairs, regular maintenance/testing program, and additional construction inspection resources.

11.2.6 Pipeline Renewal and Replacement Recommendations

An annual renewal need for pipelines in the BWS system includes information from each of the above sources. The lifespan analysis suggests a conservative average annual pipeline replacement. The failure factors analysis suggests potential main break causal factors and pipeline risk analysis assists in prioritization of which pipelines should be replaced in which order. PWA and leak detection are used to test selected high-value transmission pipeline segments to confirm pipe condition and refine the scope and timeline for these repair or replacement projects.

The total need for pipeline renewal is approximately 20 miles per year indefinitely based on the lifespan analysis. There is potential that targeted replacement of high risk pipelines may allow for sufficient system risk and main break management while replacing a lesser amount of pipeline, reducing needed capital expenditures. Additionally, consideration of identified failure factors during design of new pipelines will extend those pipes lifespan; however, these modifications will not have an impact on pipe currently installed.

The rate of all main breaks is currently decreasing likely due to major investment in the last 20 years and operational changes that have been made in an effort to reduce main breaks. However, the number of large diameter, high consequence of failure pipes is increasing. Therefore, it is recommended that pipeline replacement shift to follow the risk based prioritization as documented above, and metrics relating to pipeline system health (see Section 13) are monitored. In the event of worsening metrics, annual pipeline replacement should be increased quickly to respond before significant increases in system risks or main breaks are encountered.

The pipeline inspections showed that condition assessment is capable of providing actionable information to refine and focus pipeline renewal to only pipelines that are in distress reducing the total miles of pipeline that need to be replaced. Testing cost per mile is similar across pipe diameters, and so is best targeted at the most critical and largest pipelines.

An assessment of Moanalua tunnel was also conducted to determine any potential impacts due to overhead development. The report found that Moanalua Tunnel may require strengthening to allow surface development. If surface development is allowed, implement tunnel rehabilitation projects as identified. In addition, the condition of all pipeline tunnels should be reevaluated every 10 years.

The BWS also has an on-going valve exercising program which should be continued. Specifically, large (16 inches in diameter or greater) valves that have not been exercised recently should be addressed.

Due to the public perception of water waste, the unidirectional flushing and hydrant testing programs ramped down several years ago. Unidirectional flushing of pipelines removes sediment and improves water quality. While the BWS already has a hydrant maintenance program to ensure hydrants are operable, hydrant testing allows hydraulic modeling assumptions to be refined, as well as confirms whether hydrants that the model suggests are deficient actually are. The need to reinstate unidirectional flushing and hydrant testing programs should be evaluated, beginning with public outreach to explain the needs.

11.3 Reservoirs

Large drinking water storage tanks (or reservoirs) are located all around the island, some holding as much as 6 million gallons, which is equivalent to a day's supply for about 40,000 people on Oʻahu. These reservoirs, critical for reliable water supplies, are subject to weather, wear, and corrosion.

11.3.1 Reservoir Condition Assessment Methodology

One hundred sixty-eight of the BWS's 171 potable water reservoirs were inspected as part of the reservoir condition assessment, with experts recording the condition of surfaces, connections, walls, and roofs; condition of underlying concrete; and other attributes specific to individual tanks. Three reservoirs were not inspected because they were either undergoing structural rehabilitation or a design project was currently active to structurally rehabilitate the reservoir. Data were reviewed on the physical site consequences of reservoir failure (e.g., downhill neighbor, type of neighbor, potential impact to BWS facilities, etc.). During the condition assessment, the following areas were examined:

- Reservoir field examinations were conducted on 168 reservoirs and their exterior walls, upper and lower seals, footings, and appurtenances.
- Internal inspections were conducted on 30 reservoirs (a number similar to previous assessments) more than 50 years old. Remote-operated vehicles inspected the interior conditions underwater. Each unit had multiple high-resolution cameras, underwater and above-water lighting, and electronic gauges that recorded the precise location of each picture taken.
- Numerical structural evaluation was conducted on 17 reservoirs. The different reservoir design types were examined to determine potential damage in code-level seismic events (earthquakes) or high-wind events (hurricanes). This representative cross section of reservoirs in the BWS's water system was used to gauge robustness of the entire reservoir inventory.
- Inlet and outlet piping connections to reservoirs were evaluated to determine susceptibility to damage caused by seismic movements.

- Consequence of failure in regards to the physical site (e.g. downhill neighbor, type of neighbor, potential impact to the BWS facility, etc.) was rated based on a scale developed for the assessment.

These inspections provided the BWS with a detailed and accurate understanding of cracks, leaks, and general physical condition of each reservoir and contributed to the prioritization of reservoir rehabilitation or replacement.

11.3.2 Reservoir Condition Assessment

The reservoirs are composed of three major structural systems: cast in place concrete; AWWA D110 strand wound post tensioned; and AWWA D115 tendon post tensioned reservoirs. The condition assessment evaluated the current condition of the reservoirs, which allows the BWS to monitor their long-term condition, provide insight to the potential lifespan of reservoir and reservoir site components, and gauge the success of repairs. There were three major tasks to the assessment: collecting and reviewing existing reservoir data; performing field inspections; and updating the BWS's database.

Collecting and reviewing the existing information on the reservoirs was critical in determining how the reservoir inspection was to be performed. Knowing the structural system for the reservoir provided direction to the inspectors as to what signs would indicate a structural concern. All inspection scoring, observations, photographs, interior inspections, maintenance recommendations, and repair or replacement tasks were recorded in the existing BWS database. Additionally, the costs for repair or replacement tasks and their prioritization were documented. The interior inspections allowed components to be viewed while the reservoirs remained in service. The interior inspections evaluated the condition of the interior coating system, foundation slab, inside face of wall, and underside of the roof slab.

11.3.3 Numerical Structural Evaluation

Wind and seismic numerical structural analyses were performed for 17 of the 171 circular reservoirs in the BWS's water system. The analyses were intended to inform the BWS of performance differences in reservoirs based on type, age, and configuration, and identify those that may be more susceptible to damage from hurricanes or earthquakes.

11.3.3.1 Reservoirs Selected for Evaluation

First, reservoirs were classified into 10 types, then 17 were selected for numerical analysis based on construction type, age, and configuration to provide a representative collection of reservoirs.

11.3.3.2 Structural Evaluation Findings

The selected reservoirs were analyzed to determine structural strength using the codes, standards, and seismic and wind criteria listed below.

- International Code Council: 2012 International Building Code
- American Society of Civil Engineers (ASCE):
    - ASCE 7-10, Minimum Design Loads for Buildings and Other Structures

- ASCE 41-13, Seismic Evaluation and Retrofit Rehabilitation of Existing Buildings

- American Concrete Institute (ACI):
  - ACI 350-06, Code Requirements for Environmental Engineering Concrete Structures and Commentary
  - ACI 350.3-06, Seismic Design of Liquid-Containing Concrete Structures and Commentary

- AWWA:
  - AWWA D100-11, Welded Carbon Steel Tanks for Water Storage
  - AWWA D110-13, Wire- and Strand-Wound, Circular, Prestressed Concrete Water Tanks
  - AWWA D115-06, Tendon-Prestressed Concrete Water Tanks

Using the current code level seismic and wind forces, the reservoirs were analyzed to determine how effectively the existing reservoirs resist those forces. Different overstress conditions for each reservoir were evaluated and a demand-capacity ratio (DCR) was determined for each of the 17 studied. DCRs are the code-level force divided by the component strength. The higher the DCR, the more stressed the reservoir is; DCRs less than 1.0 indicate that the reservoir is strong enough to resist the force while DCRs greater than 1.0 indicate that the reservoir may be overstressed. The findings from the structural numerical analysis were extrapolated to the remaining reservoirs in BWS's water system based on reservoir age, type, configuration, and specific wall-roof and wall-foundation details.

11.3.4 Reservoir Recommendations

The physical condition assessment showed the majority of the reservoirs were in good to excellent condition. Seven reservoirs, or approximately five percent, were in need of highly critical repairs or rehabilitation and will be programmed immediately into the CIP. The most significant structural issues were observed in wire-wound tanks constructed in the 1950s and 1960s, and in the post tensioned reservoirs constructed in the 1990s.

Internal inspections similarly indicated that the vast majority of reservoir interiors inspected have no major distresses. The interior inspections identified areas of spalled concrete with exposed reinforcement, a distress that would not be observable unless the reservoir was taken out of service or the failure became visible on the surface. Interior inspections also revealed that some reservoirs required cleaning.

Numerical structural analysis shows that 138 (81 percent) reservoirs would benefit from some sort of structural retrofit, however, only 11 reservoirs (in addition to the 7 above) were found to need higher priority repairs. In total, 18 reservoirs (11 percent) are in need if higher priority repair, and were added to the CIP.

An evaluation of the visible portions of reservoir pipe connections and the design drawings for each type of reservoir piping connection was performed on all reservoirs in the BWS system.

While minor changes are recommended to bring design standards current, a search of records related to reservoir and pipeline failure identified no reported issues of reservoir pipe failures. The existing BWS reservoir pipe connections appeared to be structurally sound and without issues. No further action is recommended at this time to improve the piping system at the reservoir sites.

It is therefore recommended that the high priority reservoirs identified in Table 11-3 be repaired. Additionally, reservoir design standards should be updated for current seismic code and to state-of-the-art AWWA D110 tanks for reservoirs large enough that D110 tanks are less expensive than cast-in-place. Small reservoirs should continue to use cast-in-place construction.

Table 11-3 Reservoirs Requiring High Priority Repairs

Reservoir	Inspection	Structural Repair
Barbers Point 215 No. 2		X
Barbers Point 215 No. 3		X
Honouliuli 228		X
Kahana 315		X
Kailua 272		X
Kapaʻa 272	X	X
Kapolei 215 No. 1		X
Kunia 228 No. 2		X
Mākaha 242 No. 2	X	X
Nānākuli 242		X
Pearl City 385	X	X
Waahila 180	X	X
Waahila 405		X
Wahiawā 1075	X	
Wahiawā 1361 No. 1		X
Wahiawā 1361 No. 2		X
Waiʻalae Iki 180	X	
Waimānalo 230	X	

11.4 Pump Stations

Pumps are used to draw water from underground, to move water uphill, and to keep water moving to customers. The BWS's system includes 184 pump stations, most with multiple pumps, some of which are able to move as much as 45 mgd.

Over a 4-month period between mid-October 2013 and mid-February 2014, the condition assessment team visited 170 sites, covering all pump stations, starting with an examination of structures, roads, site conditions, and security measures (such as fencing). Individual pumps were inspected for cracks, corrosion, insulation, wiring, and other conditions. Each pump was run to test if it meets requirements for flow and pressure. Chlorine treatment facilities on the pump station sites were evaluated for signs of corrosion. Valves were checked to determine whether they open and close fully and correctly, and control and instrumentation systems were tested to verify they are operational and accurate.

Based on the condition assessment site visits and a desktop evaluation of each facility's priority relative to the entire system, critical assets at each well and booster pump station were prioritized. Assets assessed included:

- Wells;
- Pumps;
- Motors and motor starters;
- Electrical distribution equipment;
- Control and isolation valves;
- Piping and appurtenances;
- Disinfection systems;
- Control and instrumentation; and
- Site facilities.

Critical assets were defined as major components that are essential to the production and distribution of water that are expensive or time consuming to repair or replace. Of the more than 400 pumping units at the 184 pump stations, 57 pump stations (31 percent) are in need of routine work, 48 pump stations (26 percent) are in moderate need of rehabilitation work, and 22 pump stations (12 percent) are in need of critical repair. Each of these projects has been included in the CIP.

In addition to the rehabilitation projects identified above, some pump stations are in need of upgrade.

11.5 Water Treatment

11.5.1 GAC Treatment Facilities

Water treatment facilities are located across Oʻahu and were evaluated as part of the condition assessment, inspected for general condition and efficiency. This assessment noted that the water treatment facility conditions were variable, from well-maintained to needing significant rehabilitation. The facilities are effectively removing contaminants below MCLs; however, some may benefit from modification to increase efficiency, maximize carbon longevity, and increase operational performance. Some sites also require high priority rehabilitation to prolong the facility life. A list of suggested repairs and anticipated needs for treatment facility replacement was compiled for inclusion in the CIP.

11.5.2 Microfiltration/Chlorination

The membrane microfiltration system in Nuʻuanu was built in 1999, but has been off-line since 2003. The facility was assessed and inspected by a team including a Memcor (the membrane equipment manufacturer) representative. The indoor equipment is likely able to be repaired, but there is some outdoor equipment that is missing, and the new process requirements of the current Memcor systems require some additional equipment.

It is possible to either have the existing system repaired, and additional process equipment added, or to replace the entire system with a modern version, which requires similar space and piping connections and may prove to be lower risk and cost. The BWS is currently formulating a scope to have the treatment system repaired.

11.6 Facilities

11.6.1 SCADA

The BWS, like many water municipalities, uses a SCADA system along with its RTUs. The SCADA system is used primarily as a supervisory system to efficiently monitor the field information at individual sites from more centralized BWS facilities.

11.6.1.1 Existing System Assessment

The BWS SCADA system was evaluated using the following steps:

1. Site visits: Site visits were conducted at approximately 20 BWS facilities including wells, reservoirs, and booster pumping station facilities to evaluate the status of RTU/SCADA hardware, software, and communication networks.

2. Review of existing documentation: A review of all available existing RTU/SCADA system documentation was performed.

3. Staff interviews: Discussions were held with key BWS staff members to obtain their input on the performance of the existing systems and their views on improvement needs.

4. Vendor discussions: Discussions were held with suppliers of the existing systems, the MOSAIC SCADA supplier (CGI Logica) and the RTU supplier (Motorola).

5. Disaster recovery review: A review was performed to evaluate the existing system's ability to withstand disaster events and the BWS's disaster recovery capabilities and system integrity.

11.6.1.2 SCADA System Findings and Recommendations

The existing RTU/SCADA system assessment developed three key findings. First, the BWS has enjoyed a long and successful operation of the existing RTU/SCADA system; however, due to the system's age, the manufacturer no longer provides maintenance support for the RTU system. Therefore, in order for the BWS to continue to provide a secure, reliable, and efficient water system operation, the BWS should continue replacing the RTUs in phases (currently 24 of 182 units have been replaced). Second, CGI Logica will need to develop and write a site-specific communication protocol that allows the BWS to communicate with the field RTUs unless/until new SCADA software is implemented. Third, the SCADA communication system is potentially susceptible to damage to overhead lines. It is recommended to complete transition to the existing microwave communication system.

11.6.2 Offices and Base Yards

A broad overview assessment of the BWS offices and base yards was conducted by a team including structural, architectural, building mechanical and plumbing, and electrical specialists. The assessment found that office and base yard buildings and facilities are in need of various repairs and functional modifications to meet current uses. Completion of high priority repairs are recommended, but additional repairs should wait for completion of office and base yard master plans to coordinate with future needs.

The office and base yard needs into the future were not evaluated in this master plan; however, planning is being completed separately for Kapolei Base Yard. Completion of an office and resource evaluation and development of a master plan for new and/or modified spaces is recommended. Additionally, a base yard master plan for new and/or modified yard areas should be completed.

11.6.3 Security

The BWS has over 300 facilities on the island of Oʻahu. Most of these facilities have chain link perimeter fencing with barbed wire on the top. The BWS also has an island-wide camera system with high resolution video cameras and motion detection systems. These systems are monitored from a centralized security center. The BWS Security Office conducted a comprehensive study of facility security and developed the findings below.

- Many facilities have been tagged with graffiti.
- Thieves have stolen wiring from a few locations.
- Some equipment is outside of buildings and is vulnerable to damage from flying debris in a hurricane or high winds.
- Electrical transformers and electrical equipment are outside of buildings at some locations.
- Building security must be maintained to protect electrical and control systems.
- Extensive vegetation growth at the BWS facilities should be removed.
- Additional security cameras will improve surveillance.

The Security Study recommends the following actions:

- Install more robust fencing;
- Remove vegetation and install weed barriers and gravel adjacent to fence lines;
- Install hurricane and intruder resistant enclosures around pumps and electrical systems;
- Add additional security camera systems;

- Prioritize projects based on consequence of a security incident (e.g., higher for large source) and likelihood of incident (e.g., where no fencing, outside pumps, etc.); and
- Based on priority, implement projects (approximately 20 sites per year) over a 15-year period.

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Part III
Findings and Implementation

Section 12

Findings and Recommendations

Section 12 provides information that addresses the following WMP objectives:

- Water Quality, Health, and Safety
- System Reliability and Adequacy
- Cost and Affordability
- Water Conservation
- Water Resource Sustainability

Summary findings and recommendations described in Table 12-1 have been drawn from the multiple planning and assessment efforts presented throughout this WMP. Detailed information on the majority of the findings and recommendations can be found in the other Sections identified below. All of these recommendations are brought together in Section 12 to present a total picture of the needs of the BWS water system.

The recommendations identify system needs, actions, operational changes, and capital improvements over the 30-year planning period; however, the actual implementation timeframe will depend on the level of available capital funding. Capital recommendations will be refined into projects and added to the 30-year CIP. See Section 13, Implementation, for additional detail on CIP prioritization. Additionally, the actual scope and implementation of these recommendations may vary once detailed planning and design is completed.

Findings are identified with a code (an abbreviation for the section name) and number (for example, DMND-1). These codes are repeated in the other sections to easily tie the findings and recommended actions here in Section 12 to their discussion within the individual sections of the WMP. Abbreviations are as follows:

- SUST: Section 4, Water Supply Sustainability
- STND: Section 5, Water System Planning Standards;
- DMND: Section 7, Historical and Future Water Demands;
- SUPP: Section 8, Current and Future Water Supply Sources;
- WQTR: Section 9, Water Quality, Regulations, and Treatment;
- CPCY: Section 10, System Capacity Evaluation;
- COND: Section 11, Facility Condition Assessment; and
- IMPL: Section 13, Implementation.

Table 12-1 Water Master Plan Major Findings and Recommendations

Finding	Recommendation
Demands	
▪ **DMND-1** From 1980 to 2010, population served increased from 737,000 to 922,000. The BWS system is anticipated to see continued population growth reaching 1,055,000 by 2040 (about 0.5% per year). Population growth will be focused in transit-oriented development (TOD) areas in ʻEwa, Central Oʻahu, and the Primary Urban Center, while other land use districts will experience stable populations or marginal decreases.	
▪ **DMND-2** Although projections in the early 1990s predicted demand growth, Island-wide demand has decreased by 11 mgd in the last 25 years due to per capita demand decreasing by 31 gallons per capita per day (gpcd) freeing up existing capacity. Reduction in per capita demand was due to BWS conservation initiatives, changing land use that increased population density and reduced irrigation, economic incentives from higher water and sewer rates. With additional conservation programs and further reductions in potable water irrigation, additional per capita demand reductions are possible.	▪ Continue investment in conservation with a goal of reducing per capita demand from 157 gpcd to 145 gpcd by 2040. Continued water conservation programs and declining per capita consumption are anticipated to moderate future system demand growth.
▪ **DMND-3** A range of demand projections was developed to address uncertainties in planning assumptions. Water demand is projected to increase from 145 mgd in 2012 to between 153 mgd (for the most probable demand projection) and 167 mgd (for the high range projection) by 2040. This represents a demand increase of 8 mgd, or 5%, for the most probable demand projection, and 22 mgd, or 15%, for the high range demand projection. ʻEwa has the largest estimated increase in future demand, with Central O'ahu having the second largest increase.	
▪ **STND-3** The MDD and peak hour factors given in the Standards may not be appropriate for systems with historical data.	▪ Utilize actual historical MDD and peak hour factors where sufficient data is available, and utilize the Standard 1.5 MDD factor where data does not exist. The MDD factors for the BWS model systems vary from 1.15 to 1.61. ▪ Monitor actual MDD for each system and use to determine when additional capacity will be needed.
Sources	
▪ **SUST-1** Source water quality has been consistently high.	▪ Continue vigilance and proactive measures to ensure highest quality possible, meeting Safe Drinking Water Standards. ▪ Maintain source and watershed protection efforts.
▪ **CPCY-3** Source yields in existing select large pumping stations need to be reduced to stabilize rising chloride trends and allow the aquifer to recover after drought periods.	▪ Reduce pumping in large Metro Low sources by 8 mgd ADD to meet Water For Life sustainable pumping goals and offset reduction with transfers from Waipahu and other sources.

Table 12-1 Water Master Plan Major Findings and Recommendations

Finding	Recommendation
▪ **SUPP-1** Water users on Oʻahu have access to multiple sources of water to meet their needs. Domestic, industrial, and agricultural users may access a variety of surface water, groundwater, recycled water, and brackish water supplies depending on what is available to them.	
▪ **SUPP-2** The estimated sustainable yield from Oʻahu's groundwater aquifers adopted by the Commission on Water Resource Management (CWRM)[1] is 407 mgd. Of the estimated sustainable yield of 407 mgd from Oʻahu's aquifers, less than half was used in 2010. However, demand is not always co-located with available supply so supplies can be stressed in areas of high population density and high water use.	
▪ **SUPP-3** The BWS customers form the largest user base on the island and the BWS is the largest user of water. As of 2010, the BWS's supply was comprised of groundwater (93%), recycled water (5%), and brackish nonpotable water (2%).	
▪ **SUPP-4** The BWS has sufficient supply during normal and drought conditions to meet the high range demands in 2040 for average day conditions.	
▪ **SUPP-5** There are several issues that could potentially affect Oʻahu's water supply reliability, such as water quality concerns and climate change.	▪ The BWS is actively addressing these concerns by continuously monitoring its system, maintaining operation flexibility, investing in alternative supply sources, and researching the implications of climate change adaptation.
▪ **SUPP-6** Well casings are aging, some approaching 100 years old, which could cause water quality issues and reduced yield.	▪ Complete maintenance on wells every 25 years as pumps are replaced. Casings are expected to last at least 100 years before needing replacement.
▪ **SUPP-7** The structural condition of source tunnels and shafts and sanitary seals need to be periodically evaluated. Sanitary surveys are conducted periodically.	▪ Reevaluate tunnel condition every 20 years (currently due). ▪ Implement tunnel and shaft rehabilitation projects as identified.
▪ **SUPP-8** Potable water sources are entirely drawn from groundwater. Climate change is forecast to make dry areas drier, cause more frequent and severe droughts, and increase chloride levels in ʻEwa, Kunia, and Waiʻanae sources. Reliability could be improved through diversification of sources.	▪ Invest in diversified (nonpotable groundwater) sources working toward the Hawaiʻi Fresh Water Initiative goal of doubling such supply by 2040. Projects include increased reuse and Kalaeloa and Kapolei desalination plants.
Pump Stations	
▪ **COND-20** In 2015, 194 source pumps at 90 source stations supplied an average of 145 mgd into the system. ▪ **COND-20** In 2015, 192 booster pumps at 94 stations supplied water and maintained system pressure with an installed capacity of 465 mgd.	

[1] State of Hawaiʻi Commission on Water Resource Management. 2008. *Hawaiʻi Water Plan: Water Resource Protection Plan.* Prepared by Wilson Okamoto Corporation. Available at: http://files.hawaii.gov/dlnr/cwrm/planning/wrpp2008update/FINAL_WRPP_20080828.pdf. June 2008.

Table 12-1 Water Master Plan Major Findings and Recommendations

Finding	Recommendation
▪ **COND-21** On average, approximately 18% of pumps are out of service undergoing repair, reducing redundant capacity in the system.	▪ Although only approximately 60% of pumps are needed for max day demand (depending on individual system), rehabilitate out of service pumps with the goal of > 90% of pumps available for service.
▪ **COND-22** Many pump stations are in need of rehabilitation and upgrade.	▪ Refit pump stations to improve operation, reliability, and efficiency.
▪ **IMPL-2** System reliability could be improved by adding temporary pump connections at critical pump stations.	▪ Add or confirm temporary pump connections on critical pump stations.
Treatment	
▪ **WQTR-1** The water that the BWS delivers meets all federal and state requirements.	
▪ **WQTR-2** Current and legacy activities and groundwater recharge can potentially affect source water quality.	▪ The BWS identified several strategies to maintain compliance for these water quality issues, and these projects are continually monitored and reviewed by the BWS so that they can be implemented should the need arise.
▪ **COND-23** At some GAC facilities, physical treatment equipment is in need of (predominantly corrosion related) repair.	▪ Make repairs to treatment equipment to extend useful lifespan. ▪ Corrosion issues at GAC facilities need to be addressed, and an on-going painting program established.
▪ **COND-24** Treatment at some GAC facilities may be able to be made more efficient by process modifications and new carbon filter media products, like coconut carbon.	▪ Make modifications to treatment process to increase efficiency.
Reservoirs	
▪ **COND-14** The majority of the reservoirs are conventionally reinforced, cast-in-place concrete, and this type of structure has proven to be very durable. In larger sizes, strand-wound concrete reservoirs originally constructed to AWWA D110 standards have also performed well. 152 of the 171 reservoirs (89%) are in need of only minor or no work.	▪ Continue proactive maintenance and complete needed repairs to reservoirs. ▪ Continue to specify cast-in-place concrete for small reservoirs, and AWWA D110 designs for reservoirs larger than 1 to 2 MG (depending on site issues).
▪ **COND-15** 18 reservoirs (11%) high priority projects which should be performed.	▪ Make structural and seismic improvements. Specific reservoirs are summarized in Section 11.3.4.
▪ **COND-16** Although designed to then-current codes, 120 reservoirs (70%) could be upgraded to meet the most current seismic code. Of these, most would sustain minor repairable damage in a code level seismic event.	▪ If major structural work is otherwise needed on a reservoir, upgrade seismic restraint system to meet latest codes. There are no Federal, State, or local requirements for most structures (including reservoirs) to be upgraded to meet changing codes.
▪ **COND-17** Two reservoirs are recommended for immediate replacement due to seismic risk. One of these two reservoirs is also considered vulnerable to roof damage from hurricane-related winds. All other remaining BWS reservoirs appear to be suitable to withstand hurricane-related winds.	▪ Replace high risk reservoirs.

Table 12-1 Water Master Plan Major Findings and Recommendations

Finding	Recommendation
▪ **COND-18** Reservoir condition assessment is important to identify and schedule needed repairs.	▪ Re-inspect selected reservoirs every 5 years ▪ Update reservoir condition assessment every 10 years
▪ **COND-19** Approximately 60 reservoirs have had internal inspections within the last 10 years.	▪ Inspect all reservoirs on a 10-year cycle. ▪ Clean reservoirs concurrent with inspection.
Pipelines	
▪ **COND-1** Main breaks have been on the decline for several years, and, at 312 per year (equal to about 15.2 breaks per 100 miles of pipe), are about half of the national average of 30 breaks and leaks per 100 miles of pipe[2].	▪ Although the average age of the piping system has been increasing, existing BWS efforts at reducing main breaks have been effective. These efforts include: replacement of failed pipes; operational changes and pressure management; and leak detection and repair. These efforts should be continued.
▪ **COND-2** Large diameter main breaks (pipes 16 inches in diameter or greater) are relatively few (averaging 11 per year), but trending upward.	▪ Prioritize replacement of pipelines on highest risk sections.
▪ **COND-3** Main breaks tend to cluster on specific sections of pipelines, causing disruption to customers.	▪ For mains that may not rank highly for risk, monitor main break density (breaks per mile), and replace pipeline when it is considered failed (1 break per 200 feet in the last 10 years, see Section 11, Facility Condition Assessment). ▪ Dedicate a portion of the capital budget to replace these smaller pipelines with frequent breaks.
▪ **COND-4** Over the last 10 years, the BWS has awarded contracts to replace an average of 8.7 miles of pipeline per year.	▪ Pipeline replacement should be based on the risk based prioritization. ▪ Pipeline break and risk metrics should be monitored, and in the event of worsening metrics, replacement rate should increase to 20 miles per year as determined by the lifespan assessment. ▪ Utilize savings in lower State Revolving Fund interest loans to increase risk based pipe replacement miles when funding is available.
▪ **COND-5** Even at a replacement rate of 1% per year, it is projected that the main break rate of 312 per year will eventually begin to increase and reach about 350 breaks per year by the year 2040 as the system ages and older pipes exceed their design life.	▪ The BWS has implemented operational strategies to reduce main breaks to close to 300 per year, and future operational changes may include adding surge control at key pump stations, increasing reservoir storage where deficient, and/or reducing pressure in high pressure areas.
▪ **COND-6** The Failure Factors Analysis showed that targeted pipe replacement can significantly reduce break rates and increase pipe replacement efficiency.	▪ High quality risk and assessment data will allow more efficient and targeted pipeline replacement, reducing the break rate at any given replacement rate. These efforts are critical to maintaining the low rate of main breaks the BWS has achieved.
▪ **COND-7** Statistical evaluation of all existing BWS materials (cast iron, PVC, concrete cylinder pipe, asbestos-cement pipe, galvanized steel, ductile iron, and other materials) shows that ductile iron has the best performance considering historical main breaks per mile.	▪ DIP is a reliable pipe material for the BWS and is the default standard pipe material for all new BWS pipe installations.

[2] AWWA. 2014. 2012 Benchmarking Performance Indicators for Water and Wastewater Utilities: Survey Data and Analyses Report. AWWA Catalog No.: 20761. Available at: http://www.awwa.org/store/productdetail.aspx?productid=39837461.

Table 12-1 Water Master Plan Major Findings and Recommendations

Finding	Recommendation
▪ **COND-8** To allow future generations to eventually replace pipelines at a lower rate per year, the BWS will seek to design new DIP pipelines for a service life of greater than 100 years.	▪ Adopt and apply better-than-current industry "best practices" for design, material specifications, concurrent use of multiple methods of corrosion control, and a long-term commitment to monitoring and testing of cathodic protection systems.
▪ **COND-9** PVC pipe is the other pipe material used by the BWS in new installations. Recently, the BWS has experienced PVC pipe failures (main breaks) in pipelines that are less than 20 years old.	▪ The BWS has implemented an interim standard requiring thicker wall PVC pipe, limiting installations to lower pressure areas, restricting maximum PVC size to 16 inches in diameter, increasing trench cushion requirements, and prohibiting pipe bending and joint deflection. ▪ This interim standard will remain in place pending the results of an on-going (2016) PVC pipe study.
▪ **COND-10** To efficiently prioritize, schedule, and define pipeline replacement projects, ongoing condition assessment can be helpful.	▪ Continue monitoring condition assessment technology for improved ease of use and efficacy. ▪ Perform pipeline condition assessment on transmission pipelines as recommended by the pipeline decision framework (CapPlan). ▪ All new ductile iron transmission pipelines 16" or greater should have 6" crown tap and valve access points installed at half-mile intervals.
▪ **COND-11** Moanalua Tunnel may require strengthening to allow surface development.	▪ If surface development is allowed, implement tunnel rehabilitation projects as identified. ▪ Reevaluate condition of all pipeline tunnels every 10 years.
▪ **COND-12** BWS currently has a valve exercising program.	▪ Continue valve exercising program and specifically address large (16" or greater) valves that have not been exercised recently.
▪ **COND-13** Due to the public perception of water waste, the unidirectional flushing and hydrant testing programs ramped down several years ago.	▪ Evaluate need to reinstate unidirectional flushing and hydrant testing programs, beginning with public outreach to explain the needs.
Facilities	
▪ **COND-25** The BWS has a comprehensive and widely used GIS system. ▪ **COND-25** The Water Master Plan has provided a risk-based pipeline prioritization tool called CapPlan.	▪ Continue to maintain and update.
▪ **CPCY-4** Some data weaknesses were found during hydraulic modeling.	▪ Prior to the next round of data collection and verification for the hydraulic modeling, data sources should be improved including: calibrating or repairing SCADA equipment where data was found to be inaccurate or questionable; installing water level gauges at wells; installing flow meters at major control valves; and installing flow meters and pressure gauges at un-equipped tunnels.
▪ **COND-26** The BWS is installing a dedicated and hardened microwave based backbone telemetering communication system that ties in all BWS facilities island-wide.	▪ Update RTUs and SCADA system to current technology, and improve functionality. ▪ A multi-year phased approach should be used to migrate SCADA data to the microwave system to avoid disruption to existing operations.

Table 12-1 Water Master Plan Major Findings and Recommendations

Finding	Recommendation
▪ **COND-27** Office and base yard buildings and facilities are in need of miscellaneous repairs and functional modifications to meet current use.	▪ Complete high priority repairs ▪ Initiate a Base Yard Master Plan for new and/or modified yard areas.
▪ **COND-28** Office and base yard future needs were not evaluated.	▪ Complete an Office and Resource evaluation and develop master plan for new and/or modified spaces.
▪ **COND-29** The BWS has completed a Facility Security Study, which identified a variety of intruder or damage vulnerabilities.	▪ The recommendations of the Facility Security Study should be implemented.
Capacity Expansion	
▪ **STND-1** Some Standards were found to be insufficiently defined for the various and complex configurations of the BWS water systems. ▪ **STND-2** Some Standards may no longer be appropriate for a water system of the size and complexity of the BWS.	▪ The BWS should review the Standards to determine if updates are required. ▪ Formalize adaptation of Standards where appropriate. ▪ Modify current Standards as appropriate. ▪ Install or improve infrastructure where appropriate to meet Standards.
▪ **CPCY-1** The system capacity projects to serve both existing areas and future demands or to transfer supply from one area to another will be a significant and critical part of the 30-year CIP. These capacity projects are needed island-wide, but predominantly in the Metro Low, 'Ewa-Waipahu, and Leeward model areas.	▪ Improvements are summarized in Figure 10-2.
▪ **CPCY-2** The Metro Low model system has the most significant current and future storage and supply needs.	▪ The West Side Supply Project addresses supply deficiencies and includes a new 10-MG reservoir at Waiawa 228, a 10-mgd booster pump station and a control valve downstream of the reservoir to flow into the west side of Metro 180 West, and a 36" Stadium transmission main. ▪ For storage deficiencies, an alternatives analysis incorporating feasibility and life cycle cost is recommended for solutions to mitigate this issue. Alternatives include: New storage within Honolulu where demands are concentrated; developing new peaking wells in the central part of Honolulu; locating storage west near the new Waiawa 228 Reservoir and peak pumping; or a combination.
▪ **DMND-4** In the 5-year average centered on 2010, BWS estimates that non-revenue water is approximately 10%.	▪ Identify areas of highest percentage of non-revenue water to focus meter calibration, leak detection, addition of new meters if necessary, and water conservation efforts. ▪ Target reduction of non-revenue water (real and apparent losses) to less than 8.1%[3].
▪ **IMPL-1** Lack of redundancy in some major transmission mains.	▪ Install parallel transmission main in selected areas.

[3] AWWA. 2014. 2012 Benchmarking Performance Indicators for Water and Wastewater Utilities: Survey Data and Analyses Report. AWWA Catalog No.: 20761. Available at: http://www.awwa.org/store/productdetail.aspx?productid=39837461.

Table 12-1 Water Master Plan Major Findings and Recommendations

Finding	Recommendation
▪ **IMPL-3** Inadequate emergency power at critical facilities to provide continuous service during long-term power outages.	▪ Install sufficient emergency power to meet essential water demands in the event of a long-term power outage. Able to serve essential supply to 89% of population with ten additional generators. May be able to install existing portable generators at these sites in the interim. Confirm whether electrical connections exist.

Section 13

Implementation

This section addresses the range of issues, beyond infrastructure planning and prioritization as part of the Capital Improvement Program (CIP) development, necessary for successful implementation of the WMP. These major areas include funding, policies, organizational capacity, monitoring and reporting progress, and updating of the WMP.

Section 13 **provides information that addresses the following WMP objectives:**

- Water Quality, Health, and Safety
- System Reliability and Adequacy
- 💧 Cost and Affordability
- Water Conservation
- 💧 Water Resource Sustainability

The WMP's key findings for implementation issues are discussed in this section. These findings are identified with a code (an abbreviation for the section name) and number (for example, IMPL-1). These codes are repeated in Section 12, Findings and Recommendations, to easily tie the findings in this section to the recommendations for BWS action listed in Section 12.

13.1 Funding

The BWS receives nearly all of its revenues from the sale of water to its customers. Water rates are established by the BWS and vary by customer class. The BWS needs to establish a revenue stream (through water rates) that is consistent with achieving the objectives of the WMP and the mission of the BWS. Of the three elements of the BWS's mission (safe, dependable, and affordable), affordable is perhaps the most subjective. As a result, like almost all utility agencies, the BWS will face the natural tension that exists in taking the actions necessary to provide safe and dependable water at an affordable cost. And, while not explicitly part of its mission statement, the concept of sustainability is fundamental to the BWS's Strategic Plan, as its three strategic goals are resource sustainability, operational sustainability, and financial sustainability. Achieving these three goals involves more than the implementation of capital projects and programs. It necessitates the dedication of resources to operational activities such as water conservation, watershed management, and infrastructure operations and maintenance. Achieving these goals also requires adequate funding to accomplish these activities in a manner that supports achieving the BWS's mission.

The BWS's water rate structure has remained virtually unchanged since 1993. Like many other water utilities, the BWS's rates are predominantly volumetric, meaning that they are based on the amount of water sold. However, the majority of an established water utility's costs are fixed and independent of the volume of water served in any given period of time. As a result, with the success of conservation programs, many water utilities have had to raise their volumetric rates and/or adjust their rate structure so that a larger portion of the charges are fixed and independent of the volume of water consumed. This trend has been affecting water utilities across the U.S., and particularly those agencies with successful water conservation programs like the BWS.

Another fundamental concept in the establishment of water rates involves the cost of service. Because of their unique water use patterns, different types of users place different demands on the water system. For example, residential users place their greatest demand on the water system during the morning and evening hours. Due to landscape irrigation, residential water use also varies seasonally, with consumption being highest during the hottest, driest parts of the year. This usage pattern requires that water supplies and infrastructure be available to meet these cumulative peak demands, even though actual volume of water used by an individual customer may be relatively low. Alternatively, water use patterns for commercial and industrial purposes are generally more stable, both daily and seasonally, despite the higher volume of water required to meet their needs. The variety in water use patterns among customer types results in differences in costs to serve different customer types. While the cost of service is an important factor in establishing water rates for customer types, there may be other considerations that warrant departures from this approach. For example, under the BWS's current rate structure, the cost to serve agricultural water users is offset by other water users to reflect the community values of locally produced, fresh produce for O'ahu and also to improve food supply security.

As a result of these types of issues, following adoption of this WMP, the BWS will be undertaking a comprehensive rate study using a transparent public process that directly involves the Stakeholder Advisory Group. As a result of this process, the BWS expects to make adjustments to both the structure and amount of its water rates in order to provide sufficient revenue to implement this WMP and maintain affordability for all of its customers.

Although this WMP looks ahead 30 years to identify system needs, it is not reasonable to establish water rates to secure revenues for such a long duration due to myriad uncertainties. Rather, revenue needs of the organization should be evaluated much more frequently, and rates adjusted accordingly, to better align both the amount and timing of revenues with actual needs. This practice minimizes the potential for underfunding and also for over-collecting from customers. The AWWA Manual of Practice M1, *Principles of Water Rates, Fees, and Charges*, recommends that water rates be reviewed in five-year cycles to adjust to the needs of the utility[1].

13.1.1 Funding Assumptions for Initial CIP Development

This WMP identifies water system needs to address a wide range of issues including existing system conditions, anticipated renewal and replacement needs, and capacity improvements to provide for anticipated growth. This WMP provides the strategy, planning, and evaluation required to meet the identified needs and forms the basis for the 30-year CIP. The 30-year CIP is complimentary to, although not a part of, this WMP report and will be developed from subsequent analysis identifying specific projects to address the needs identified in the WMP.

The projects contained in the 30-year CIP will be prioritized based on risk. For the purposes of this prioritization, risk is the likelihood of failure multiplied by the consequence of failure. Presented in Section 11, Facility Condition Assessment, this methodology provides for the highest degree of overall system reliability at the most affordable cost. The amount of money allocated to capital projects each year will influence two primary aspects of the 30-year CIP: 1) how soon

[1] AWWA. 2012. *M1 Principles of Water Rates, Fees and Charges, 6th Edition.* AWWA Catalog No.: 30001-6E. Available at: http://www.awwa.org/store/productdetail.aspx?productid=28731.

high-priority projects are implemented; and 2) how many projects can be implemented at any given time. Consequently, in order to initially establish the 30-year CIP, it is necessary to make an assumption about funding availability for capital projects. Because the rate study described in Section 3, Stakeholder Advisory Group, is not scheduled to be completed until the end of 2017, it is recommended that the first iteration of the 30-year CIP be established based on the last rate study allocating $80 million per year, but with a consumer price index adjustment for inflation. In addition, the savings from low interest State Revolving Fund loans reducing anticipated debt service payments should be allocated to increasing risk-based pipeline replacement miles to further reduce main breaks. Results should be monitored annually as well as the ramp up of the BWS's capacity to implement CIP projects at a higher rate.

With the establishment of this overall guidance, a subsequent input involves the initial allocation of funding to the different types of water system facilities, for example, pipelines, pump stations, treatment plants, and reservoirs. Although the project prioritization in the 30-year CIP will be risk-based, it is important to also distribute funding among these facility types and avoid extended peaks and valleys in the funding of any single facility type. Due to the specialized nature of many of these facilities, this distribution helps the BWS to balance internal technical resources, ensure access to specialized external resources, and support a sustainably healthy and competitive contracting and vendor/material supplier community.

Table 13-1 summarizes the replacement value of each of the major categories of BWS facilities for its potable water system, as a percentage of the total system value. Although each of these facility asset types were evaluated for condition in Section 11, and in general have different service lives, Table 13-1 provides a contextual overview to demonstrate that over 75 percent of the BWS's facility assets are pipelines and the replacement value of other asset classes is relatively small in comparison.

Table 13-1 Approximate Replacement Value of Existing Potable Water System by Facility Type

Facility Type	Estimated Value (millions)	Percent of Total System Value
Pipelines	$12,300	77%
Pump stations	$400	2%
Supplies: wells, tunnels, shafts	$1,300	9%
Water treatment facilities	$300	2%
Reservoirs	$1,250	8%
Base yards	$330	2%
Total	**$15,880**	**100%**

It is recommended that for the near-term the CIP continue at the $80 million per year level. This investment level is adequate to address high priority renewal and replacement projects in all asset classes over a 10-year window, with the exception of pipelines. Only a portion of high priority pipelines can be addressed at this funding level. Pipelines are the largest component of the BWS assets and pipeline health indicators (number of main breaks per year) are currently favorable. It should be recognized, however, that the current pipeline replacement rate will result in the average age of the pipelines increasing, meaning pipeline breaks will eventually begin to rise.

An important question that needs to be addressed is what level of service (including main breaks) is acceptable to BWS customers. The timeframe of when the CIP budget begins to increase and the annual level it reaches will be addressed in a transparent public process during the financial plan and rate study. As illustrated conceptually in Figure 13-1, the longer an increase in the CIP budget is deferred, the steeper the rate of increase in capital costs and ultimately, a higher level of investment.

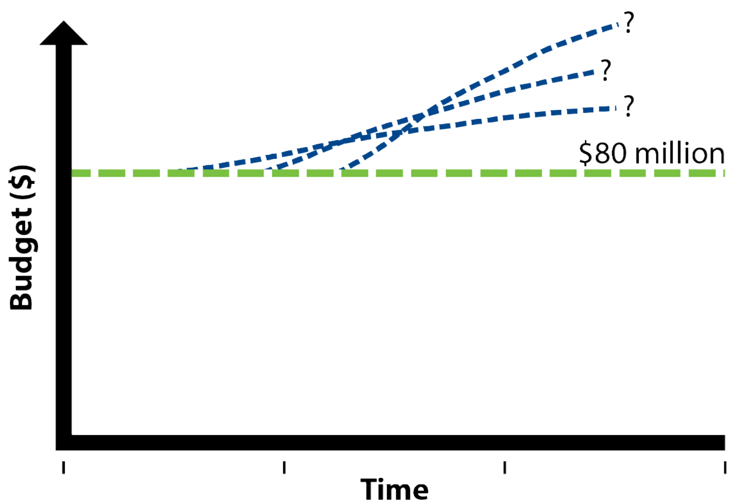

Figure 13-1
Future CIP Funding Level Scenarios

At a minimum, the rate of CIP increases should follow the rate of inflation. However, as the BWS sees in current construction bids and as other public works construction projects on Oʻahu demonstrate, the rate of increase in infrastructure cost inflation is well in excess of the general rate of inflation. These are just some of the factors that will be considered as rate makers weigh the balance of level of service and affordability.

13.1.2 Funding Assumptions for Water Sustainability Programs

As described in Section 4, Water Supply Sustainability, the three strategies of water supply sustainability are conservation, recharge, and reuse. Funding for these three strategies is derived from different sources, both internal and external to the BWS. In general, the BWS's conservation programs are funded from its operational budget and do not involve capital projects. The recharge strategy can involve a mix of expenditures: capital funds for certain projects (e.g., fencing, aquifer storage and recovery facilities); operating funds for invasive species control in BWS priority watersheds; grants from external funding organizations; and mutual collaborations with partner agencies. The water reuse strategy is primarily implemented through capital projects, such as an expansion of the recycled water treatment and distribution facilities and contributions from collaborating agencies and private developers.

Despite the importance of water supply sustainability projects and programs, these types of investments are difficult to integrate into a risk-based project prioritization strategy. For this reason, it is recommended that, as part of its upcoming water rate development process, the BWS consider in collaboration with its stakeholders the establishment of a dedicated funding stream for water sustainability programs.

For Fiscal Year (FY) 2016, the BWS's conservation program budget is $886,094, inclusive of personnel services, materials and supplies, and equipment. The BWS Watershed projects are funded in the Water Resources Hydrology-Geology budget. For FY16, the BWS resource monitoring and management and watershed partnerships program budget is $1,424,536. Of that, $689,500 is budgeted for watershed partnerships and climate change research projects. The BWS intends to continue to ramp up both programs as implementation capacity expands and until a higher level of program goals and performance metrics are attained. The FY16 budget for watershed management plans is $500,000. The BWS recycled water budget for FY16 is $6,243,590 for the contract operations and maintenance of the Honouliuli WRF. Collectively, the total BWS water sustainability program operating budget is $9,054,220 in FY16.

13.2 CIP Development

The BWS develops, manages, and prioritizes its capital project investments. This WMP describes the process of looking ahead 30 years, identifying and prioritizing system needs based on risk, and developing a 30-year CIP. The 30-year CIP represents the BWS's best look into the long-range future based on currently available information. As time goes on, conditions will undoubtedly change and the influence of uncertainties impact the accuracy of the plan in its later years. For these reasons, the BWS uses a multi-tiered CIP process, with each tier representing a different time. Those tiers are illustrated in Figure 13-2. The multi-tiered CIP planning process provides the ability to continually reevaluate conditions and needs affecting the water system and adjust the timing and scope of planned projects to balance system dependability and affordability for customers.

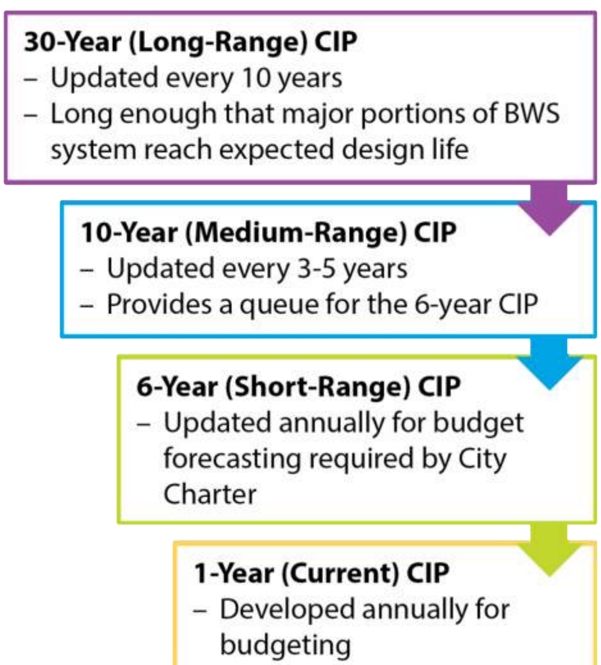

Figure 13-2
Multi-Tiered CIP Planning Process

Each tier of the CIP process feeds into the tier below it. As major needs on the horizon are identified, general placeholders are added into the 10- to 30-year time frame. As these needs approach, increased definition is added to projects. When a project enters the 10-year CIP, a more defined project description and cost estimates are developed and the project is scored for risk. When a project enters the 6-year CIP, a complete scope and cost estimate for the project are developed by the BWS and the project is prepared for planning and design. The 1-year CIP contains the projects anticipated to be contracted in the upcoming fiscal year.

13.2.1 Project Types

The BWS categorizes capital projects in three general categories: capacity expansion projects; renewal and replacement (R&R) projects; and research and development (R&D) projects. Each of these is described further in this section.

13.2.1.1 Capacity Expansion Projects

Projects that are needed to meet growing water demand are considered capacity projects. Capacity projects most commonly result from a projected increase in water demand related to population growth or changing population distribution. Capacity projects are further described in Section 10, System Capacity Evaluation. A benefit of some capacity projects is an increase in system reliability due to the provision of redundant or parallel facilities.

Facilities associated with capacity projects can include wells, tunnels, treatment, pipelines, pump stations, and reservoirs. Upsizing an existing facility (e.g., a pump station or pipeline) to meet demands or fire flow requirements is also considered a capacity project, even though this need is not necessarily due to population growth.

13.2.1.2 Renewal and Replacement Projects

Projects that are needed to renew or replace worn or aging infrastructure are R&R projects. Examples of R&R projects are repairs of an existing well, improvements to existing pump stations, structural repairs or upgrades to reservoirs and replacing aged pipelines.

13.2.1.3 Research and Development Projects

Examples of R&D projects include planning and engineering studies such as:

- Feasibility studies;
- Exploratory and/or monitoring wells;
- Special monitoring;
- Condition assessment (reservoirs, pipelines, pump stations, etc.), and;
- Planning updates.

13.2.1.4 Other Projects

The BWS also has other types of projects that technically are not classified as CIP projects because they are funded under Operations. These types of projects might include items such as watershed management work and water conservation programs.

13.2.2 Project Prioritization

This section outlines the process by which the CIP projects are prioritized. The discussion includes capacity projects and R&R projects. R&D projects are normally prioritized based on schedule (e.g., time elapsed since last plan update) or by a management decision.

Capacity projects are prioritized such that they can be planned, designed, constructed, tested, and operational by the time they are needed to meet the associated demand. As such, they are placed in the CIP based on when the system demands are anticipated to require the expansion. For this reason, the date that capacity expansion projects are needed may be moved earlier or later, or if demands grow much more slowly than anticipated they may never be needed.

R&R projects are prioritized in the following manner.

- Pipeline projects are prioritized by total risk and the decision framework presented in Section 11.2.
- Reservoir projects are prioritized by condition assessment and associated risk.
- Pump stations are prioritized by condition assessment and associated risk.
- Water treatment facilities are prioritized by condition assessment.
- Other facilities are prioritized based on risk, condition assessment, or management decisions.

As discussed previously, the overall prioritization of projects within the CIP is risk based, which considers the likelihood of failure of an asset and the consequence of that failure occurring. For pipelines, a statistical model was used to determine the likelihood and consequence of failure as presented in Section 11.2.2, Statistical Analysis of Pipelines. For reservoirs, pump stations, water treatment facilities, and other assets, each project was assigned a risk score that was calculated from metrics derived from industry standards and amended to meet the needs of the BWS.

An initial list of consequence of failure metrics was developed using AWWA M29: Water Utility Capital Financing[2]. This initial list included 26 metrics within 6 criteria categories. The BWS adopted 22 of these metrics that are appropriate for the Oʻahu water system and combined several to reduce the total number to 15. The BWS then added several metrics, as well as a new criterion (Water Resource Sustainability) suggested by the Stakeholder Advisory Group, to arrive at 24 metrics within 7 criteria. A final criterion is the estimated likelihood of failure, which is multiplied by the total of the consequence of failure criteria to produce a risk score. These metrics help the BWS to assess risk and make clear how each project will help the BWS meet its mission of provide safe, dependable, and affordable water now and into the future. The criteria and metrics are summarized in Table 13-2.

[2] AWWA. 2014. *M29 Water Utility Capital Financing, Fourth Edition.* AWWA Catalog No.: 30029-4E. Available at: http://www.awwa.org/store/productdetail.aspx?productid=43980747.

Table 13-2 CIP Prioritization: Consequence of Failure Criteria and Metrics

Criteria	Metric	Safe	Dependable	Affordable
System Reliability	Outages		💧	
	Loss of Redundancy		💧	
	Excessive Surge		💧	
System Adequacy	Fire Flows		💧	
	Low Service Pressures		💧	
	Use Restrictions		💧	
Regulatory Compliance	Regulatory Violation	💧		
	Water Quality	💧		
	Health and Safety	💧		
Cost and Efficiency	Energy Use			💧
	Outside Match Funding			💧
	Board Direct Financial Impact			💧
	Reduced O&M Costs			💧
Public Confidence	Billing or Collection Issues		💧	
	Public Support	💧	💧	
	Customer Satisfaction	💧	💧	💧
	Community Financial Impact		💧	
	Security Breach	💧	💧	
Water Resource Sustainability	Reduced Water Resource Use		💧	
	Watershed Protection	💧	💧	
	Water Resource Adequacy		💧	
Agency Coordination and Other Considerations	Coordination Benefit			💧
	Implementability			💧
	Other Considerations			

Each of the metrics was given a specific, measurable definition and scoring range from 1 to 5. These criteria and metrics were also designed to allow for detailed scoring (scoring each metric) or high-level scoring (only giving each criteria a score). Each project will be scored, giving the BWS an objective, transparent, and defensible measure of the priority of a project.

It should be noted that, while every project is given a risk score and this score serves as the initial sorting for CIP prioritization, there are several other factors that influence the timing of a project within the CIP. Additionally, there are some projects or initiatives deemed important by the Board of Directors, and policies may be made to prioritize such projects accordingly. Similarly, some projects that do not score highly may be increased in priority by senior management decisions, taking into consideration information that this framework may not sufficiently capture.

13.2.3 Development Process

The BWS maintains several CIPs that cover different lengths of time, as described below:

- 1-year CIP, for annual budgeting and contracting.
- 2- to 6-year CIP, for near-term planning, in which projects are well defined and scoped and costs are refined for financial planning.
- 6- to 10-year CIP, as a queue for the 6-year CIP, which allows projects to be defined and scoped and costs to be estimated for financial planning.
- 10- to 20-year CIP, identifying major projects, infrastructure objectives, and placeholder budget allocations for financial planning. Projects can be described, but not prescriptive, as timing, scope, and costs are subject to uncertainties.
- 20- to 30-year CIP, capturing significant portions of infrastructure reaching design lives and allows longer term projection of major projects for regional integration, economies of scale, new technologies, and extending asset design life.

The 10-year (medium-range) CIP is developed in the following manner:

1. Projects are identified for inclusion in the CIP. The subsequent prioritization process will sort projects by need. Projects from the existing 6-year CIP are included, and Table 13-2 shows how new projects are identified for the CIP.

Table 13-3 Method of Identifying Projects for the CIP

Project	Condition Assessment	Statistical Analysis	Capacity	Management Decision
Pipelines	✓	✓	✓	
Redundant transmission			✓	✓
Pump/wells	✓		✓	
Supply diversification			✓	✓
Treatment	✓		✓	
Reservoirs	✓	✓	✓	
Facilities	✓			
SCADA	✓			
Security	✓			✓
Base yard improvements	✓			✓

2. To better compare similar projects to each other, projects are divided into asset classes.

3. All potential projects in the 6- and 10-year CIP are given a risk score as described above in Section 13.2.2. The projects are sorted within their asset class for risk score. The risk scores can be used by BWS managers to review the initial 10-year CIP and compare projects between asset classes.

4. Projects are coordinated with the existing six-year CIP to smooth the transition from longer-range planning. Projects that are already being implemented (e.g., under design or construction) are listed in the six-year CIP as prior appropriations.

5. The various BWS consultants who conducted the condition assessment for pump stations, wells, water treatment plants, reservoirs, and SCADA systems have provided documentation and recommendations that the timelines for addressing the critical issues should be within the next 5 to 10 years. Therefore, the asset classes related to these functions, critical to continuing to provide safe and dependable water, will be populated first. It is anticipated that the majority, if not all, of these associated improvements can be accommodated within the 10-year CIP.

6. Other asset classes are then placed into the 10-year CIP. These projects will fill the remainder of each year's CIP budget ceiling (based on previous rate study allocating $80 million per year, as described in Section 13.1.1).

The CIP for years 11 through 30 builds on the 10-year CIP with the anticipation that there will be more budget available for pipeline R&R projects as the initial group of pump station, well, water treatment, reservoir, and SCADA projects are completed in years 1 through 10.

It is important to note that the budget allocated to each asset class is subject to additional factors:

- Constructability of the number of facilities and their function must be considered. For example, only a small percentage of BWS pump stations can be out of service at any given time, thus limiting the scheduling of improvement projects.

- The system control and monitoring improvements under a SCADA program must not interfere with the ability of the BWS to operate and control its hundreds of facilities that are connected to the existing SCADA system.

- The number of reservoirs that can be taken out of service at any given time to perform repairs or upgrades is limited, particularly if the reservoir being worked on is the only one in that pressure zone.

- Significant additional input from senior BWS managers and the Stakeholder Advisory Group is expected and will be required as the 30-year CIP is further defined. Issues they may consider could include:

    - What are the capabilities and capacity of the design and contractor community to support the project work flow?

    - What level of consistency of project type (asset class) from year to year should be considered to assure there is an able, available, and competitive construction community?

    - What level of funding for projects should be provided that achieves BWS and Stakeholder objectives such as diversification of supplies?

    - Engineering judgement and institutional knowledge.

13.2.4 Reliability

As a responsible public water utility, the BWS must evaluate the risks to its water system and how to maintain the reliability of its system if these risk events occur. Risk is one of the factors considered when prioritizing projects in the CIP, discussed earlier.

Risk integrates the potential likelihood of a facility (i.e., supply, pump, etc.) to fail with potential consequences associated with that failure. The specific method for CIP prioritization, based on risk, is discussed in Section 13.2.2.

Reliability is a measure of the adequacy of the system(s). The Standards, discussed in Section 5, Water System Planning Standards, are designed to improve the level of reliability in the design of the water facilities. The planning standards also define the need for standby pumps in a pump station in case a pump may be out of service. Redundant infrastructure is necessary to provide system reliability. This redundancy allows individual facilities to be taken out of service for maintenance and repair, or for longer-term challenges such as replacement or changes in operating strategies.

Reliability was assessed for each infrastructure category as follows:

- IMPL-1 Pipelines – Starting with a CapPlan score of the consequence of the pipeline being out of service, look for areas where single pipeline failures could affect large portions of the system. Seventeen areas were identified where significant reliability improvements can be made. These areas should be evaluated and considered for parallel pipelines.
- IMPL-2 Pump Stations – Check for pump stations where the firm capacity (total capacity with the largest unit out of service) is less than needed for MDD, and check for zones that only have one source of supply. These conditions were identified in 65 zones for a total of 16 mgd of demand. In zones with only one source of supply, determine if there are provisions for installation of temporary pumps and install if not.
- Reservoirs – Check for zones that only have one reservoir. These conditions were identified in 78 zones for a total of 21 mgd of demand. Zones should be considered for additional storage if there are other reasons for adding.
- Treatment – Check for zones where failure of treatment would eliminate only source. Four zones were identified, totaling 5 mgd of demand. This is a small proportion of the system, and is not considered critical.
- Facilities – Check for facilities that include a single point of failure for major disruption.
- IMPL-3 Electrical Supply – Identify most effective locations for additional emergency generator installation. The system is able to serve essential supply to 89 percent of population with 10 additional generators. Additionally, it may be possible to install existing portable generators at these sites in the interim. It is recommended to confirm whether electrical connections exist.

The system needs for reliability improvement were prioritized based on greatest impact and recommended projects will be included in the 30-year CIP.

The BWS continually assesses its potential risks and maintains reliability through planning, design, and developing operational responses to mitigate the impacts of these events to its customers through:

- Emergency response plans;
- Water system master planning;
- Operational plans;
- Condition assessment and infrastructure improvements; and
- Coordination with other agencies and entities at the local, State, and Federal level involved in emergency response.

The following subsections provide additional information on specific risks, including natural disasters, power outages, transmission interruption, and loss of supply.

13.2.4.1 Natural Disasters

The BWS system is susceptible to a wide range of potential natural disasters that may cause significant damage and could affect the BWS's ability to maintain service during and after events such as hurricanes, floods, tsunamis, or earthquakes. Each of these naturally-occurring events can have significant impacts on the BWS water infrastructure, as well as critical non-BWS facilities. Potential impacts of climate change on water supply, water quality, and infrastructure are discussed in Section 8, Current and Future Water Supply Sources.

Specific losses from natural disasters may include:

- Damage to BWS structures or facilities;
- Hawaiian Electric generation or transmission capacity;
- Communication systems (e.g., telephone, data, cellular);
- Road access;
- Emergency response access; and
- Limited or no access to BWS facilities.

Floods may be caused by intense rainfall events from hurricanes or other severe climate conditions. Flooding can cause not only short-term inundation damage but also erosion, damaging or limiting access to BWS facilities. In some areas (e.g., North Shore), flooding caused by storms is affecting the stability and security of bridges that support pipelines crossings, requiring relocation of those facilities.

The impact of seismic events on reservoirs was evaluated as part of the WMP reservoir condition assessment. While BWS facilities were designed to the then-current building codes, specific studies and recommendations on selected facilities are included in the CIP.

13.2.4.2 Power Outages

The BWS operates several supply sources that flow by gravity, and do not require electricity for pumping. Water storage reservoirs also provide some emergency storage of water in the case of other infrastructure failures. However, all of the BWS's 184 pump stations and well sites and 12 GAC treatment facilities are powered by electricity. An extended and wide-scale power failure would have a significant impact on the operation of the BWS facilities, the ability to meet demands, and emergency supply for fire protection.

The potential for loss of power to these pump stations, wells, and treatment facilities and the duration of the outage fall into several scenarios:

- Loss of power transmission to localized facilities (e.g., wind, flooding, or electrical system failure) – Short duration (e.g. a few hours), localized impact, high likelihood;
- Loss of power transmission to large portions of the island (e.g., hurricane, earthquake, tsunami) – Medium duration (e.g. two to three days), intermediate area impact, moderate likelihood; and
- Loss of power generation and/or transmission island-wide (e.g., hurricane, earthquake, tsunami) – Long duration (e.g. a week or more), wide-scale impact, low likelihood.

One of the approaches the BWS is applying to address risks due to power failure is to provide emergency power generators at critical facilities. The BWS currently has eight portable generators available for key pump stations. The BWS is installing fixed generators at key locations (currently three sources and the Beretania Complex). As part of the 30-year CIP, recommendations include siting additional generators in fixed locations.

Similarly, many of the BWS's pump stations include provisions for installation of temporary pumps that provide increased reliability in the case of a pump station-wide failure. The critical pump stations identified above should be confirmed to include temporary pump connections.

13.2.4.3 Transmission Interruption

Transmission pipelines (pipelines greater than or equal to 16 inches in diameter) are critical to moving supply from sources around the island to population and demand centers. For example, a large portion of the demands in the Metropolitan area are being met by sources west of downtown and conveyed several miles. The BWS has been working to construct a parallel pipeline to the large diameter transmission pipeline into the downtown area. Portions of this parallel transmission pipeline are complete, and the remaining sections are currently in planning, including the 42-inch transmission main from Liliha Street to Isenberg Street, and the 36-inch Stadium to Hālawa connection being recommended. This redundant transmission reduces the consequence of a failure of the single transmission pipeline and subsequent potential loss of supply to major portions of urban Honolulu. The increased capacity of a second pipeline also relieves existing operational constraints and provides additional capacity to meet future demand projections.

The transmission pipeline review identified over a dozen areas across Oʻahu where reliability could be improved with redundant pipelines. These recommendations will be carried forward into the 30-year CIP.

13.2.4.4 Loss of Supply

Groundwater is currently the sole source of potable water supply for the BWS customers and is captured through groundwater wells, shafts, and tunnels. These supply sources are susceptible to a number of potential impacts that could affect their ability to provide water, including:

- Temporary loss of supply due to mechanical, electrical, treatment, or other problems;
- Temporary loss due to power outage;
- Temporary or long-term concerns with potential water quality changes and impacts; and
- Reduced pumping to allow groundwater recovery between periods of drought.

As discussed in Section 8, Current and Future Water Supply Sources, the BWS is actively seeking to expand groundwater supplies to address the potential concerns listed above. In addition, the BWS is diversifying its sources to mitigate potential future reduction of potable groundwater due to climate change, including developing of desalination projects and expanding the recycled water supply.

13.3 Organizational Capacity

Organizational capacity refers to the ability of an organization to fulfill its mission with given resources. Specifically, does the BWS have an organization structure, adequate resources, business processes, tools, and training to continue to provide safe, dependable, and affordable water? To address this question, an organizational study was initiated for the agency as a whole, as well as a focused evaluation of the agency's project delivery function which is situated primarily within the Capital Projects Division (CPD). The following sections summarize these efforts and their findings.

13.3.1 Enterprise Organizational Study

The Enterprise Organizational Study supports the BWS's Operational Sustainability goal by analyzing the organizational structure and work processes, and recommending improvements to increase operational and organizational efficiencies[3]. The study is also developing an implementation plan to establish the appropriate organizational structure, work processes, span of control, staffing levels, competencies, and training programs to carry out the BWS's mission.

The study's scope of work involved twelve primary tasks:

- Task 1: Analyze current organization;
- Task 2: Document information flow and use;
- Task 3: Survey organizational structures of other similar utilities;

[3] Matrix. 2015. *Enterprise Organization Study*.

- Task 4: Conduct an employee satisfaction survey;
- Task 5: Perform an organization cultural survey;
- Task 6: Develop an organization succession, recruitment, and retention planning framework;
- Task 7: Develop incorporation plan for ongoing organizational initiatives;
- Task 8: Identify optimal organization structure;
- Task 9: Identify training requirements;
- Task 10: Recommend benchmarks and performance metrics;
- Task 11: Develop implementation plans; and
- Task 12: Develop an outreach and communication plan.

13.3.2 Capital Projects Division Study

The Capital Projects Division (CPD) supports the BWS mission of safe, dependable and affordable water now and into the future as an essential component of a robust renewal, replacement, and expansion strategy defined in the WMP's 30-year CIP. The CPD's capacity and capability to predictably deliver design and construction projects will directly drive the utility's future.

A Program Management effort to optimize the operation of the CPD was initiated in 2013. This recognized the importance of the CPD in effectively and consistently executing an expanded annual CIP. A growing CPD workload was first triggered by a two-fold increase in CPD's project delivery requirement in 2013 supported by the water rate increase in 2012. The delivery requirement is anticipated to continue and increase following the WMP. The Program Management effort can be summarized as a four-step process: assess; plan; implement; and optimize.

The initial assessment phase involved interviews with all CPD staff and selected Division leaders to evaluate current capacity, expectations, perceptions, and challenges. The needs assessment confirmed the CPD remains a dedicated and talented organization with a number of opportunities for improving efficiencies. While the CPD has been successful in meeting the requirements of an increased workload in spite of a decline in staffing, the staffing level needs to be thoughtfully increased to match the current and anticipated volumes of work and to prepare for future attrition of an aging workforce. Staff engineers regularly perform an excess of para-professional tasks. Project tracking, monitoring, and documentation are inconsistent and fragmented within CPD. Finally, project scoping and justification is best performed earlier in the budgeting process to better meet customer needs and improve schedule and budget predictability.

To chart the course for the future, Core Teams, representing a cross-section of CPD's design and construction experience and representing each CPD Branch, were formed. These teams crafted work flow diagrams for the various processes in project development and execution. These, in turn, formed the basis for Standard Operating Procedures (SOPs) and training programs for current and future staff. A project initiation, development, and prioritization process was instituted utilizing a Project Definition Report (PDR) for each proposed capital project. The PDR documents the project objectives, costs, and schedule. The PDR also confirms agreement on the scope and scale of the project with the requesting Division.

Optimized staffing is critical to CPD's future performance. Additional project administrative staff, Engineering Support Technicians (EST), will consistently and regularly monitor project performance and standardize recordkeeping and reporting. Providing EST support to the engineers and construction inspectors to perform selected, required functions will allow the engineers and inspectors to focus on higher value efforts that best utilize their experience, expertise and training. SOPs and associated training programs will bring new hires up to speed quickly. Introduction of a new entry-level class of Construction Inspector Aides in 2015 and planned new engineering hires in the coming fiscal year will begin to address future staffing needs.

A new Project Management Information System (PMIS) will consolidate all project information, improve project tracking, and guide consistent adherence to SOPs and workflows. The system will manage all project documents and facilitate project information sharing and tracking of performance metrics.

Initial implementation of CPD's strategy began in 2015 and will continue through early 2017. The SOPs, PMIS, and improved contract terms and specifications are being rolled out to CPD staff during spring 2016. All projects initiated within the CPD in FY17 will use these tools and protocols. A four-month training program, which began in April 2016, will be administered to all CPD staff to advance the changes and the best use of the new tools. During implementation, CPD and other Division leaders are identifying reporting metrics and developing tracking tools (dashboards) to monitor compliance with project execution requirements. The two consulting engineering firms that guided the development process will assist in the implementation and provide required staff support during the transition period to meet workload demands, allow for staff recruitment and provide ongoing staff training.

The BWS CPD will continue optimization of the platforms, SOPs, and other tools following an initial implementation period of approximately one year. This will include refinement of the PMIS, creation of reporting dashboards, and addition of field reporting tools to enable staff to continuously improve performance. The PMIS facilitates a more transparent view of project status and execution performance. The CPD will receive timely feedback, improve collaboration and communication, and best position itself to do its part in addressing the anticipated workload demands of the WMP.

13.4 Water System Monitoring

The WMP's recommendations are based around a core objective of maintaining the health of the water system infrastructure. In addition, timing of many of the recommendations are dependent on the needs of the system as it ages. For planning purposes an assumption has been made that existing levels of investment will be sufficient to maintain the current level of service that the water system provides. To this end, indicators are needed to be able to distinguish changes in the health of the water infrastructure.

Table 13-3 provides a proposed scorecard with detailed indicators and the metrics to be used to quantify results. The scores shown here provide for the current level of service. To the extent that a goal is not being met, it means that the BWS would like to improve the level of service in that area. Missing goals does not suggest imminent failure of the water system, but rather areas where service can be improved. Where a goal has a reference other than BWS goals, the source is referenced with the goal.

Table 13-4 Proposed Scorecard for Tracking Infrastructure Health

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting goal?
Legend	🟢(met/on track to meet, +1) 🟡(miss by < 10% of goal, 0) 🔴(miss by > 10% of goal, -1) ↓(trend arrow from previous year) All years are fiscal years.					
Sustain 🔴						
Supply from nonpotable sources	% of total supply served from nonpotable water system	Measures the percentage of total supply that is served by nonpotable sources. The purpose of the metric is to encourage the use of appropriate quality sources for the intended use, and preserve pristine sources for potable use. Excludes brackish desalination and seawater desalination.	> 12%	Fresh Water Initiative, by 2030. Goal is to double wastewater reuse. *http://www.hawaiicommunityfoundation.org/file/cat/Fresh_Water_Blueprint_FINAL_062215_small.pdf*	6% (on-track to meet goal)	🟢
Annual water resource yield	% of available water resource yield used	Measures remaining available State permitted use and BWS assessed sustainable yield island-wide. The purpose of this metric is to give an indication of when additional source will be needed.	< 90%	Sustainable yield is the maximum rate of withdrawl without detrimentally affecting the resource. 90% goal allows time to develop additional sources.	80%	🟢
Watershed management	$ budgeted for watershed management	Measures total amount budgeted for BWS priority watersheds that supply BWS sources. The purpose of this metric is to preserve the existing sustainable yield of the aquifer in the face of climate change.	4% of CIP $3.35M	Suggested by WRD based on review of other agencies, and identified need.	$1.4M	🔴
Watershed management	Acres of watershed surveyed for invasive plant species removal per year	Measures the area of BWS priority watersheds (26,085 acres) surveyed for invasive plant species per year. The purpose of this metric is to monitor invasive plant species removal, and determine if watershed management goals are being attained.	5,200 acres	OISC, WMWP, KMWP	1,691 acres	🔴

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting goal?
Watershed management	Watershed area protected by fencing	Measures watershed funding dedicated to fencing installation and restoration of fenced areas in BWS priority watersheds. In the future, a restored and maintained fenced area goal will be developed.	20% of watershed funding	OISC, WMWP, KMWP, DLNR	14%	●
Conservation	$ budgeted for conservation	Measures total amount budgeted for conservation. Efficient use of funding is managed through ROI evaluation of each project. The purpose of this metric is to protect and preserve potable water sources, minimize needed capacity expansions, and reduce costs associated with producing and supplying water.	4% of CIP $3.35M	Suggested by WRD based on review of other agencies, and identified need. Each conservation project must show positive ROI vs. installation of additional capacity.	$0.89M	●
	Per capita consumption	Measures the effect of conservation programs on per capita consumption. The purpose of this metric is to determine if anticipated reductions in per capita demands as a result of conservation programs are being realized.	< 145 gpcd (by 2040, starting at 155 gpcd in 2016)	Suggested by WRD, based on current island-based regional trends and projection for future conservation.	155 gpcd	●
Capture ● ●						
Standby source capacity	% of source capacity used at Maximum Day Demand (MDD)	Measures the total supply (pump and tunnel) capacity available to meet MDD. This metric is similar to "annual water resource yield", but instead measures the capacity of the infrastructure to meet MDD. The purpose of this metric is to give an indication of when additional pumping at existing sources or additional sources will be needed.	< 50%	Suggested in WMP. Should include enough standby for equipment redundancy and MDD variation from year to year.	44%	●

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting goal?
Water level at index wells	% of wells with stable water levels as determined by BWS	Measures the water level at the index wells, and which are stable above Low Ground Water Levels. The purpose of this metric is to monitor the health of the groundwater aquifer and prevent detrimental impact to the source.	100%	Suggested by WRD.	100%	●
Permitted or assessed sustainable yield	Number of sources exceeding source permitted use or assessed sustainable yield (12-month moving avg)	Measures the number of sources that are exceeding their permitted or assessed sustainable yield over the preceding 12 months. The purpose of this metric is to ensure individual sources are managed sustainably.	0	Suggested by WRD.	0	●
Treat ● ● ●						
Water quality regulatory compliance	Number of water quality regulatory violations	Measures compliance with water quality regulations. The purpose of this metric is to ensure supply of water that is safe for intended use.	0	Per regulations.	0 →	●
Treatment on-line	% of chlorination systems on-line	Measures the percentage of chlorination systems that are on-line. The purpose of this metric is to ensure proactive maintenance and presence of adequate standby systems to ensure sources are able to be used continuously.	100%	Suggested by WSO.	100%	●
Comprehensive treatment system condition assessment	Perform comprehensive condition assessment of all potable and nonpotable treatment systems	The purpose of this metric is to track progress toward next update.	Update every 5 years	Suggested in WMP.	On-schedule (last 2014)	●

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting goal?
Move ●						
Sufficient pump capacity	% of pressure zones where firm capacity (not counting largest pumping unit at each station) < MDD	Measures if there is sufficient pump capacity throughout the system. The purpose of this metric is to highlight areas where additional pumping capacity is needed.	< 5%	Suggested in WMP.	2.6%	●
Pumps available for use	% of pumps that are available to be put in-service	Measures the percentage of pumps that are available for service at any given time. The purpose of this metric is to ensure there is sufficient pumping capacity available for all demand conditions.	> 90%	Suggested by WSO. It is noted that 60% of the pumps will supply all demand conditions. The 90% goal recognizes the importance of standby and the long lead time necessary for pump repair and replacement.	82%	●
Emergency power	% of population served indoor demand (85gpcd) in the event of loss of power	Measures the percentage of the population that is able to receive sufficient indoor demand for basic needs in the event of a long-term, island-wide power failure. The purpose of this metric is to increase system reliability in the event of power failures.	> 85%, distributed geographically	Suggested in WMP. Based on the generator plan in the WMP, this level of service also supplies sufficient volume to meet 100% of island-wide indoor demand, but is only delivered to 85% of taps.	71%	●
Pump station condition assessment	Perform regularly scheduled condition assessment	The purpose of this metric is to track progress toward next update.	Update every 5 years	Suggested in WMP.	On-schedule (last 2015)	●

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting goal?
Store ● ●						
Reservoir restrictions	Number of reservoirs with use restrictions	Measures the number of reservoirs that have use restrictions, due to either structural or operational deficiencies. The purpose of this metric is to maximize the number of reservoirs available for unrestricted use.	< 2%		1% ↓	●
Storage deficient pressure zones	Pressure zones with less than Standard storage and without pumping or transmission equivalency to meet operating, emergency, and fire needs	Measures the number of pressure zones with less than the volume of storage required by the measured MDD Standards and without equivalency. The purpose of this metric is to ensure that sufficient storage volume is available across the system.	0%		6%	●
Reservoir condition assessment	Perform regularly scheduled condition assessment	The purpose is early identification of reservoir deficiencies	Update every 10 years	Suggested in WMP.	On-schedule (last 2015)	●
Deliver ● ●						
Pipeline breaks	Pipeline breaks and leaks repaired per 100 miles per year (3-year average)	Measures the 3-year annual average break rate across the BWS system. The purpose of this metric is to track the overall condition of the pipelines, and can be used to monitor individual zones.	< 15	"Main Breaks, Leakage, and Distribution System Evaluations", WRF (ASCE Pipelines 2016)	15.2 ↓	●
	Pipeline breaks and leaks repaired per year (3-year average)	Measures the 3-year annual average total break count across the BWS system. The purpose of this metric is to track the overall condition of the pipelines.	< 300	BWS is currently at half of AWWA median value. Even though system is aging, goal is to not let number of pipeline breaks increase.	312 ↓	●
Transmission pipeline breaks	Number of pipeline breaks for ≥ 16 inches in diameter (3-year average)	Measures the 3-year annual average large diameter break count across the BWS system. The purpose of this metric is to minimize the damage and disruption caused by transmission pipeline failures.	< 14	Transmission is 18.5% of system. This proportion of 300 breaks per year would equal 55.5 breaks. 14 breaks is 25% of this portion indicative of a lower allowable break rate on transmission pipelines.	10.7 →	●

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting goal?
Non-revenue water	% of water produced but not sold	Measures the percentage of water that is produced from sources, but not sold to a customer. The purpose of this metric is to track the amount of water lost from the system, and evaluate meter calibration and leak repair efforts.	< 8.1%	AWWA Benchmarking 2012, median non-revenue water %.	10.5% (5-year average)	🔴
High risk pipelines	Portion of pipelines with risk score > 400	Measures the percentage of pipelines that have a high risk score. The purpose of this metric is to track the reduction of overall pipeline risk as the high-risk pipelines are replaced.	< 5%	Suggested in WMP.	12%	🔴
Pipeline R&R	Miles of system pipeline renewed (3-year average)	Measures miles of pipelines renewed on a 3-year average. The purpose of this metric is to track pipeline renewal.	21 miles	Suggested in WMP based on AWWA Benchmarking and KANEW analysis.	10 miles ↓	🔴
Fire hydrant supply	Hydrants that meet fire flow standards	Measures percentage of fire hydrants meeting fire flow standards per hydraulic modelling.	> 99%	Suggested in WMP.	98%	🟡
Pipeline leak detection	% of pipes checked for leaks per year	Measures the percentage of pipelines that were checked for leaks. The purpose of this metric is to track progress toward the goal for leak detection.	25%	Suggested by FO.	18%	🔴
PWA pipeline condition assessment	Of pipelines recommended for PWA by CapPlan framework (currently 63 miles), miles assessed per year	Measures the miles of pipelines that are recommended for PWA condition assessment that were tested per year. The purpose of this metric is to track progress toward the goal for PWA condition assessment.	6.3 miles (10%)	Suggested in WMP, CapPlan decision framework.	12 miles (19%)	🟢

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting goal?
Tools and Planning ●●●●						
Water Mater Plan update		The purpose of this metric is to track progress toward next update.	Update every 10 years	Suggested in WMP.	On-schedule (last 2016)	●
Hydraulic models and CapPlan updated		The purpose of this metric is to track progress toward next update.	Update every 5 years	Suggested in WMP.	On-schedule (last 2016)	●
GIS update		The purpose of this metric is to track progress toward next update.	Annually	Suggested in WMP.	On-schedule (last 2016)	●
SCADA reliability	% of sources, pump stations, water treatment plants, and reservoirs utilizing microwave backbone for control data	Measures the percentage of core facilities (key for water service) with control data communication that utilizes the microwave backbone. The purpose of this metric is to track the conversion of facilities using hardwired communication to the redundant microwave system.	100% (by 2023)	Transition from hardwired communication to existing microwave backbone.	13% (on-track)	●

13.5 Adaptive Management

Much of the BWS's infrastructure, like much of our nation's infrastructure, was built during the middle of the 20th century. This period of development was premised on the paradigm that projects were needed primarily for economic development and human well-being, without much regard to potential environmental consequences. Since then, society's perspectives have become more enlightened. Not only is there an expectation that environmental needs will be considered during the process of infrastructure planning and development, but there is a deepening understanding that environmental conditions are closely linked to human well-being. Climate change is perhaps the most current and compelling demonstration of this recognition. However, the impacts of climate change, like many other factors that the BWS must plan for, are uncertain and beyond the control of the BWS. Population growth is another example.

Adaptive management is a strategy intended to provide for flexibility in decision making as external conditions change, project outcomes are better understood, and societal/stakeholder preferences and values evolve. According to the National Research Council's Panel on Adaptive Management for Resource Stewardship[4], "The reality of changing conditions is especially relevant to public works projects with life spans measured in decades, and to those agencies like the [U.S.] Corps of Engineers that construct and operate those projects… Adaptive management is a commonsense strategy for addressing the reality of a changing and uncertain environment." Figure 13-3 presents the sequence of activities often used to characterize adaptive management.

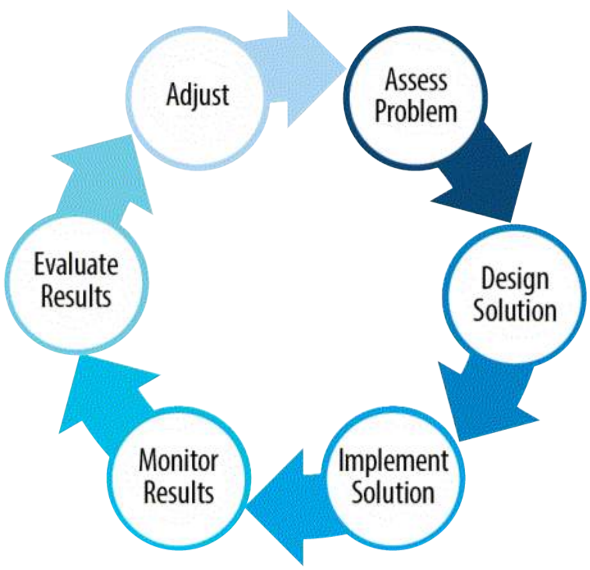

Figure 13-3
Sequence of Adaptive Management Activities

However, in the case of the WMP, which does not involve a single solution to a single problem, modification of the framework is warranted, as shown in Figure 13-4.

[4] National Research Council. Adaptive Management for Water Resources Project Planning. Washington, DC: The National Academies Press, 2004. doi:10.17226/10972. Available at: http://www.nap.edu/catalog/10972/adaptive-management-for-water-resources-project-planning.

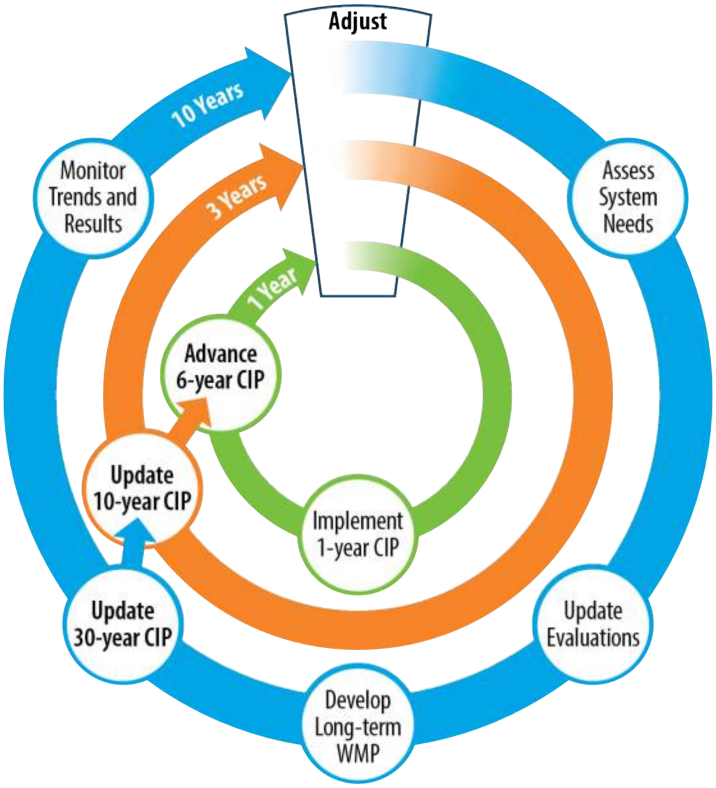

Figure 13-4
Proposed Adaptive Management Strategy for the BWS WMP and CIP

Adoption of the proposed adaptive management strategy for implementing the BWS WMP and CIP will help ensure the BWS continues to fulfill its mission of providing safe, dependable, and affordable water, well into the next century.