Water Master Plan

SUMMARY

Board of Water Supply
City and County of Honolulu

Water for Life, Ka Wai Ola

OCTOBER 2016

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This is a summary of the Water Master Plan prepared by the City and County of Honolulu Board of Water Supply in October 2016. To see the full Water Master Plan, you are encouraged to visit the Board of Water Supply website.

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Board of Water Supply
City and County of Honolulu

THE **VALUE** OF A WATER MASTER PLAN

The Honolulu Board of Water Supply (BWS) takes to heart the significance of its role as a steward of O'ahu's precious water supply. Each day carrying out the vision *Ka Wai Ola* – Water for Life, the BWS provides approximately 145 million gallons of drinking (potable) water to roughly one million people, supporting the well being, quality of life, economic stability, and promising future of O'ahu.

To secure O'ahu's water future, the BWS has prepared a long range Water Master Plan. This Plan is a comprehensive, broad-based technical program that includes the data, investigations, assessments, and projections necessary to make decisions about O'ahu's water system for the next few decades.

Water master plans are a best management practice of water utilities. O'ahu's water system is particularly complex, with some components of the island's water infrastructure nearing the end of their expected service life. In addition, as an island state, Hawai'i faces unique challenges to water supply reliability. Based on these special factors, the BWS set its planning horizon to 30 years, a full generation and longer than the forecast used by most water master plans. The BWS also incorporated an in-depth analysis of the physical condition and operating capabilities of the current water system, to gain a clear picture of what needs attention and how critically.

The BWS Water Master Plan was prepared by a multidisciplinary team whose members combine staff's exceptional knowledge of the BWS water system and conditions on O'ahu, with extensive global experience in water system planning and analysis. Sharing knowledge, expertise, and insights specific to O'ahu, the team collaborated to complete on-site tests, computer modeling, projections of water demand, assessments of water sources, and evaluation of potential solutions to ensure water needs of the future can be met.

The following components form the core of the water master planning process.

Facilities Condition Assessment

The most extensive and detailed condition assessment ever conducted by the BWS examined the entire potable water system — all potable-water storage reservoirs, treatment facilities, pump stations, select critical pipelines, and tunnels — to help identify renewal and replacement needs of the existing infrastructure.

Water System Analysis

Focusing on the need to serve a growing population, this system-wide analysis used computer capabilities to combine thousands of data points. The analysis looked at population forecasts, customer water use around the island, current water use patterns, and current infrastructure data. The results indicate what additional facilities will be needed to meet future customer needs, precisely where, and a good idea of when.

Project Prioritization

Results of the Facilities Condition Assessment and Water System Analysis are the basis of a 30-year Capital Improvement Program, the next step in the long range planning process. The Capital Improvement Program translates the Water Master Plan findings into projects and initiatives, scheduled over the coming decades. The projects are prioritized based on risk, including impacts on the public, condition assessment findings, historic performance, resource sustainability, and engineering judgment.

The BWS Stakeholder Advisory Group

The BWS engaged a Stakeholder Advisory Group to provide input to the Water Master Plan's development and implementation. Established in early 2015, the group comprises nearly 30 highly respected local residents, civic organization leaders, and business professionals with a sustained interest in water issues, with representation covering all City Council districts.

These volunteers have participated in regularly scheduled meetings and tours of BWS facilities, to enhance their understanding of the complexities of water service. They have openly shared their perspectives and the values of the communities of interest they represent, and collaboratively developed objectives for the Water Master Plan and its implementation. The Stakeholder Advisory Group functions in an advisory capacity. Integral to their role, members have agreed to share their knowledge and ideas about the Water Master Plan within their communities.

Members will continue their engagement through the development of the Capital Improvement Program, Financial Plan, and Rates Study. The group will play a pivotal role in these efforts, providing recommendations to the BWS management and Board on best options to achieve a balance of water service adequacy and dependability, with infrastructure costs and rate affordability.

The Stakeholder Advisory Group prepared the following preamble and objectives for the Water Master Plan, reflecting values of the customers that the BWS serves and the importance of this Water Master Plan to the health and prosperity of the island of O'ahu.




OBJECTIVES OF THE WATER MASTER PLAN

The Honolulu Board of Water Supply Stakeholder Advisory Group has developed the following objectives for the BWS Water Master Plan 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.

Water Quality, Health, and Safety

- Potable water is consistently safe to drink.
- All water supplied, including potable and non-potable water, meets or is better than applicable regulatory standards and suitable for its intended 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 Oʻahu'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 operations and maintenance.
- Conservation planning.
- Providing information, education, and incentives to achieve behavioral change.

Water Resource Sustainability

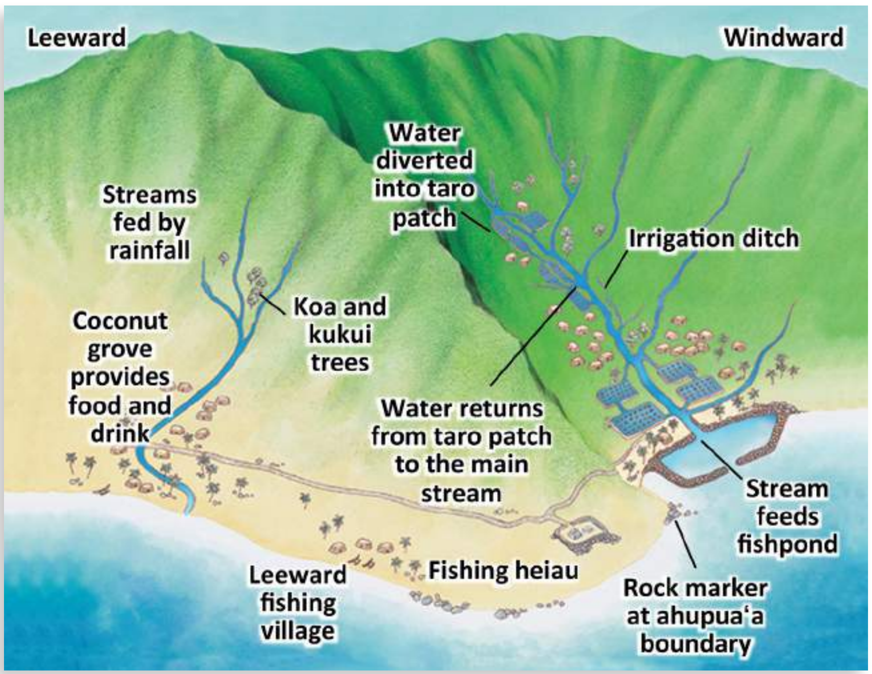
Water sources are protected and available now and into the future by:

- 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 ensuring 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).

A **LEGACY** OF WATER SUSTAINABILITY

Managing Water on O'ahu

From Hawai'i's earliest days of settlement, water was held in high regard as the key to life and prosperity. Water was a gift from the gods, thus could not be individually owned.



In pre-contact Hawai'i, ahupua'a were formed, providing a framework for communities. Land was divided following the contours of the natural terrain. Each ahupua'a stretched from the mountain top, through uplands, to flatlands, and to the sea. Everyone within an ahupua'a shared resources, including water.

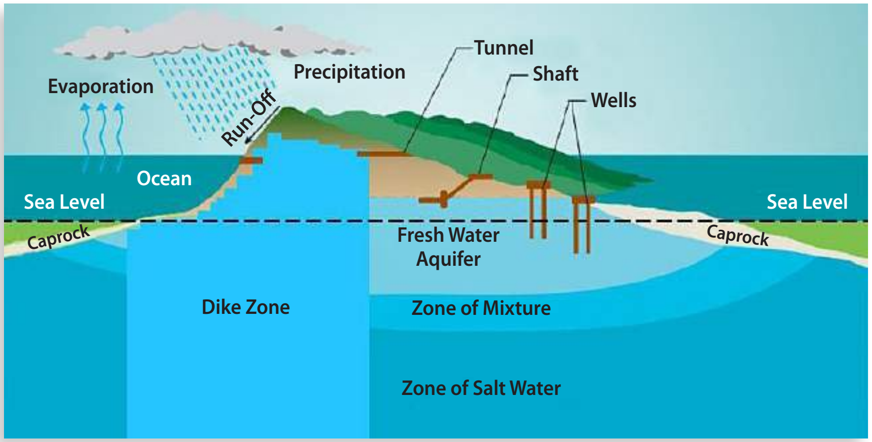
Each resident could take what they needed while making responsible use of the resource.

The Honolulu Board of Water Supply (BWS) continues this legacy of prudent, shared water use today. The BWS was created in 1929 in response to public outcry for effective water management following years of wasteful water use and droughts that led to reduced aquifer levels and water shortages. The BWS was formed by the territorial legislature as a semi-autonomous agency, free from political influence, and remains so today.

The BWS's governance structure was established by State law. Each member of a seven-member board serves a five-year staggered term, 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 Director and Chief Engineer of the City Department of Facility Maintenance.

Under the direction of the first BWS Manager, Fred Ohrt, effective water management was established in short order. The new Board capped wasteful artesian wells, sealed leaky wells, installed water meters, and billed customers for their water use.

Extraordinary demand for water during the defense build-up preceding World War II necessitated increasing the BWS's groundwater source capacity. Post-war expansion of air travel brought waves of people to the island. In 1959, the Suburban Water System, which supplied water in rural areas, was merged with the BWS.



To our great benefit, O'ahu is ideal for catching and storing water. Trade winds blow from the northeast most of the year and bring warm moist air from the ocean onto the land. As the air is deflected up along the mountains, the air cools, forms clouds, and releases rain onto the land below.

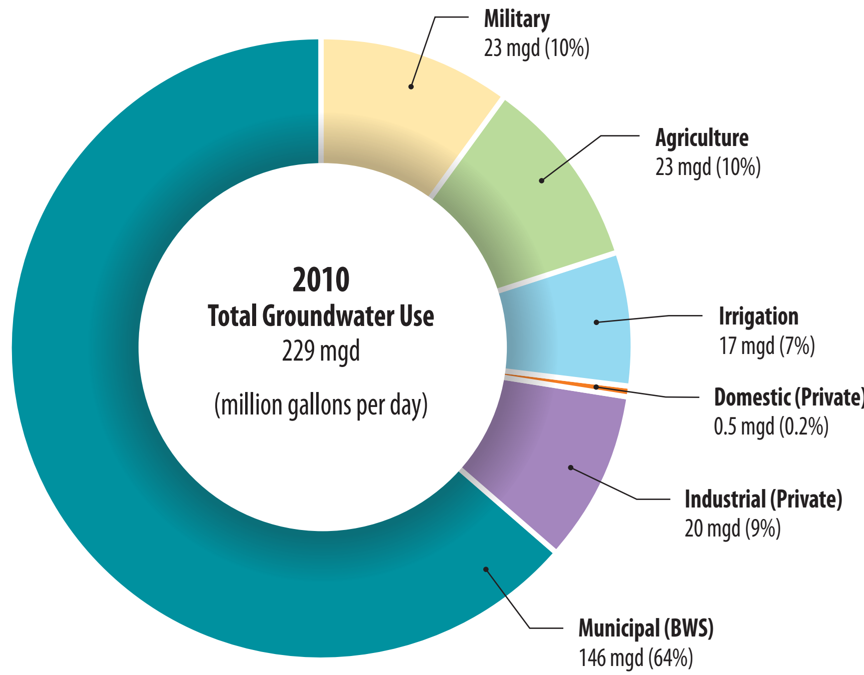
In 1987, the State Legislature established protections for water use throughout the Hawaiian Islands with passage of the State Water Code. The State Commission on Water Resource Management was established and made responsible for setting policies for all water users throughout the Hawaiian Islands, among them the Honolulu Board of Water Supply.

Nearly a century after its formation, the BWS continues as a semi-autonomous, self-supporting agency. The BWS is authorized by the City Charter and is part of the City and County of Honolulu, but has the authority and independence necessary to ensure timely, science-based, operationally sound plans and decisions relative to current and future water management. This Water Master Plan is one example.

Sustaining Nature's Bounty

The island itself is like a stone sponge; rainwater percolates through ancient volcanic dike zones and also into underlying aquifers. Over 1 billion gallons of rain fallson O'ahu every day. About one third is lost to evapotranspiration. Another third runs off into the ocean. The last third seeps into the aquifers if the watersheds are healthy.

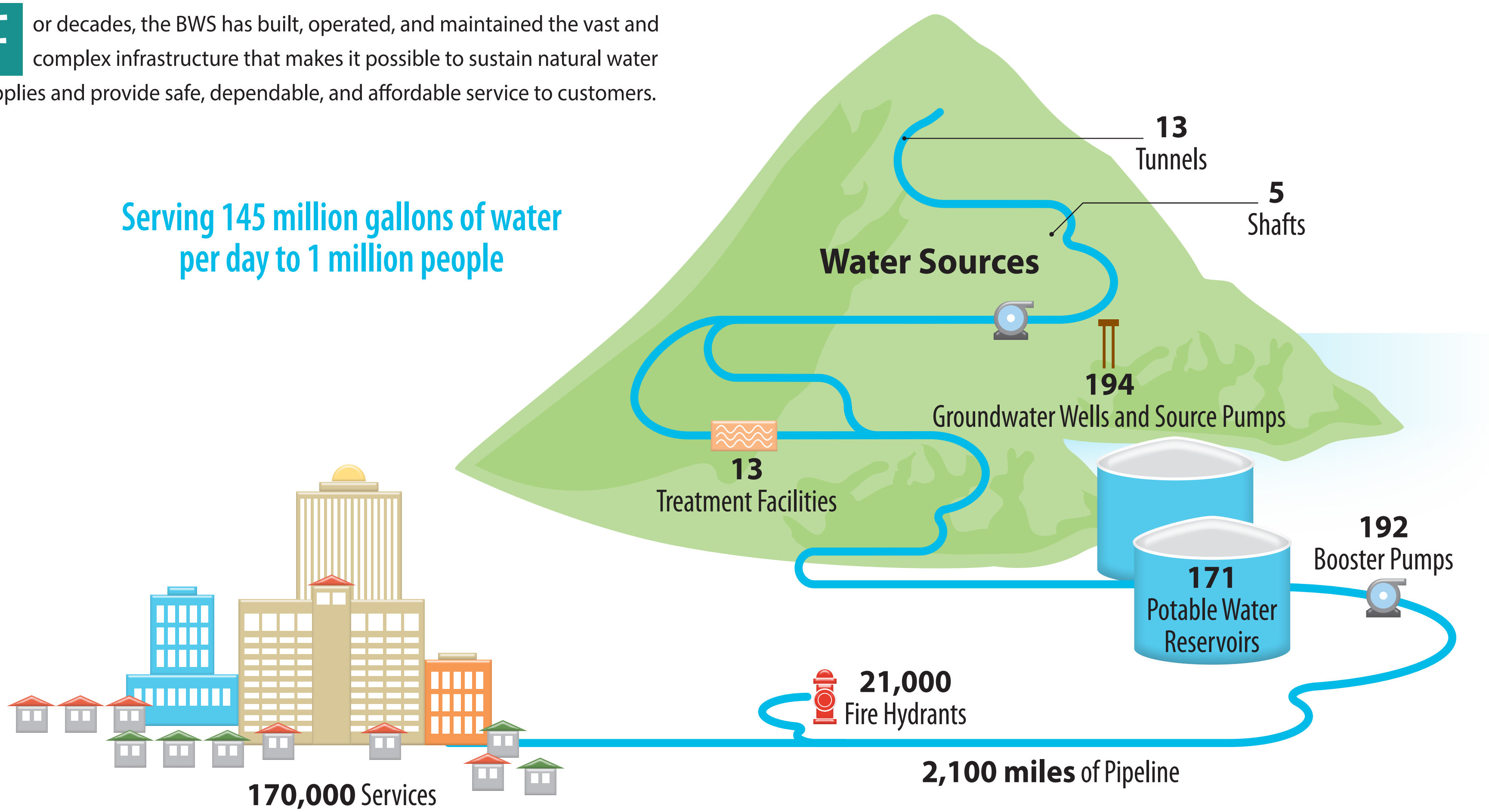
The source of BWS's drinking water supply is groundwater. Unlike surface water, groundwater stored in aquifers is more resilient to drought and of higher, more consistent water quality, requiring less treatment. It is naturally filtered through basalt rock, providing high-quality drinking water.



To sustain O'ahu's aquifers for this and future generations, the amount of groundwater pumped is strictly limited by the State Commission on Water Resource Management. The State Commission establishes the sustainable yield for each aquifer and issues permits to the BWS and other groundwater users to pump up to defined amounts. The current sustainable yield for all O'ahu aquifers combined is 407 million gallons per day. Total groundwater use, island-wide, is about half of that: 229 million gallons per day in 2010.

THE BWS'S **LARGE** AND **COMPLEX** WATER SYSTEM

For decades, the BWS has built, operated, and maintained the vast and complex infrastructure that makes it possible to sustain natural water supplies and provide safe, dependable, and affordable service to customers.



Operating the water system on O'ahu presents special challenges unique to this island setting. Many BWS facilities (particularly pipelines) are subject to high salinity groundwater, corrosive soils, and other conditions that can impact infrastructure lifespan. O'ahu's dramatic landscape requires that water supplies be pumped up steep mountainsides. The freshwater/seawater interface in the island's aquifers must be carefully monitored and balanced. Water is transferred throughout the island, from where it is most abundant to where water is needed. Following on page 9 is a description of the six primary steps to providing water from source to tap.

SUSTAIN

Groundwater is O‘ahu’s only current supply source for potable water, coming from high quality, naturally filtered, reliable aquifer storage. The BWS manages **thousands acres of watershed area** on O‘ahu to protect and preserve underlying water sources. Efforts to manage and protect the watersheds include limiting access and development, combatting invasive plants and animals, promoting healthy forests, and encouraging customer water conservation. The BWS also owns and maintains **5 dams or open reservoirs**, 4 of which currently provide flood control and the other storing non-potable water for irrigation.

CAPTURE

Several approaches are used to capture groundwater. The BWS operates **194 groundwater wells**. Each well requires drilling into the ground, sometimes hundreds of feet below the surface. In addition, **5 water shafts** provide access to groundwater. Unlike wells that penetrate deeply with small-diameter holes, shafts are dug out of rock to reach groundwater. The BWS also maintains and operates **13 tunnels**, dug horizontally into the mountains to access stored groundwater.

TREAT

The majority of the island’s groundwater is exceptionally pure, requiring treatment only to assure it remains ready to drink as it travels through the distribution system that takes it from source to use. Some sources, particularly in Central O‘ahu, require treatment primarily to address legacy agricultural contamination. The BWS operates **13 granular activated carbon facilities** to remove these contaminants. The BWS also operates the Honouliuli Water Recycling Facility that treats and supplies non-potable recycled water for industrial and irrigation uses.

MOVE

Water sources on the island are sufficient, but are not always located where the supply is needed. Large transmission pipelines have been installed by the BWS to carry water from the source to the general area where it will be used. The **360 miles of transmission pipelines** vary from 16 to 42 inches in diameter. The BWS maintains **192 booster pumps** that keep the water moving through the piping system. This is in addition to **194 pumps, one at each well.**

STORE

Reservoirs (large covered tanks) have been built by the BWS at varied locations throughout the system to store water close to the point of use. The reservoirs store water for high demand periods and fire protection, and add dependability to the system. There are **171 potable water reservoirs** across O‘ahu, together capable of storing about 196.5 million gallons. In addition, **7 non-potable reservoirs** can store approximately 15 million gallons of recycled or brackish water, used for irrigation or industrial purposes.

DELIVER

Once the water has been carried to the general area where it is needed, it moves into the distribution system to be delivered to its point of use through distribution pipelines that are less than 16 inches in diameter. In total, the BWS system includes **2,100 miles of pipeline**, necessary to serve water to nearly 1 million people across O‘ahu through about **170,000 services**. The BWS’s customers include residential, commercial, and industrial users. In addition to these potable water customers, the BWS serves non-potable water for use in golf course irrigation and industrial processes.

EXAMINING THE **EXISTING** WATER SYSTEM

A condition assessment is a full examination and evaluation of the physical and operating state of individual components of a water system's infrastructure. Sometimes compared to a personal physical exam, these investigations study and test the health of the system's parts. The examination can determine how well components are functioning and whether there are leaks, irregularities, or other signs of wear. This is a good way to catch irregularities that, over time, could lead to a major failure. Like a doctor's exam, condition assessments apply technologies that provide great detail and accuracy, indicating what portions of the system warrant attention.

The BWS has previously performed condition assessments, however this is the most broad-based and rigorous investigation to date. This current assessment involved the entire potable water system, used new technologies, and examined fine details. The result is a wealth of information, new insights, and hard data that defines areas of concern to be addressed.

The BWS wells and pump stations can be found both outdoors and indoors.

Pump Stations

Responsible for maintaining flow throughout the service area, pumps can be thought of as the "heart" of the water system. Every one of the BWS's 184 pump stations was evaluated, including examination of the site, structure, roads, and fencing. Most BWS pump stations include multiple pumps to provide "back up" in the event of operational failure. All 386 pumps were inspected for noise, vibration, and corrosion, as well as the condition of insulation, wiring, and other items. Pumps were tested and valves were checked to determine whether they opened and closed fully and correctly. In addition, a desktop evaluation was conducted to determine the priority of each facility for sustaining water flow throughout the system.

FINDINGS

The BWS has sufficient capacity to meet all current flow conditions, however there is the need for additional backup pumps (redundancy) and refurbishment.

Pipelines

Some of the features we love most about Hawai'i – the tropical climate, the ocean, the mountains, the lush vegetation – are really hard on water infrastructure.

The BWS water system includes pipelines of varied materials, sizes, and ages. Most pipelines are buried and all are pressurized, making it challenging to evaluate their condition. As a result, multiple approaches were applied for pipeline condition assessments:

- Analytical tools were used to identify which stretches of pipeline are most critical for dependable service as well as which are more likely to fail. Statistical analyses included information on lifespan, water-main break history, and factors that contributed to failure.
- State-of-the-art pipeline-wall analysis tools were applied to test selected pipelines under normal conditions. While expensive and difficult to implement, these in-pipe electromagnetic and acoustic tools can locate leaks (even small ones), as well as air pockets and localized corroded areas that could lead to breaks, all while the pipeline remains in service.

Advanced pipeline condition assessment requires traffic control, excavation, construction of a vault, tapping into water-filled pressurized pipe, and installation of a valve. The testing team tracks a probe inserted into the pipeline, propelled by the moving flow of water, up to a distance of ½ mile.

- Forensic analyses were conducted at main breaks, in an effort to identify common factors among the sites. Remnants of broken pipes were carefully examined, including sandblasting to reveal underlying conditions, as well as laboratory testing of material properties.
- The BWS's dedicated Leak Detection Team surveys about 360 miles of pipe each year, proactively searching for leaks.

FINDINGS

Water main breaks in the BWS system, overall, have been on the decline for several years. This reduction of water main breaks, from about 500 down to about 300 per year, is due largely to the BWS's proactive efforts, including changes in operational practices, pressure management, leak detection, and renewal and replacement of selected sections of pipes. Breaks in large pipelines 16 inches or more in diameter are relatively small in number, but the break rate has been trending upward. Causes are being studied.

The analyses identified several factors that make pipelines more prone to breaks: age of the pipes, corrosion, smaller diameters with thinner pipe walls, higher pressures, placement in certain soil types or in areas of dredged fill, and location in coastal zones or near stream crossings.

State-of-the-art pipeline assessment technology including closed-circuit television, acoustics, and electromagnetic sensors has a role in future decision-making about pipeline renewal and replacement, if used selectively. These technologies are currently too costly to assess all of the BWS pipes, however they can be of significant value when used to confirm where and when to make major investments in replacing sections of larger water mains that have high consequence of failure.

The BWS leak detection program contributes system-wide assessment information to decision making about pipeline renewal and replacement. The team inspects the entire 2,100-mile pipeline system over a 6-year cycle.

5-million gallon reservoir at Barber's Point.

Reservoirs

All of the BWS's reservoirs were inspected from top (the roof) to bottom (seals near the ground). In addition to these visual examinations, a remote-operated underwater vehicle was used to provide interior inspection of 30 reservoirs more than 40 years old. Reservoirs of different designs were analyzed for their ability to withstand hurricanes and earthquakes.

Treatment

Water treatment facilities on O'ahu include 13 granular activated carbon facilities to remove legacy agricultural contaminants from water sources. These treatment systems have provided excellent water quality since their installation, and they continue to serve this critical function of effectively removing contaminants to below water quality limits. The facilities were inspected for general condition and efficiency.

Granular activated carbon water treatment facilities are located throughout Central O'ahu.

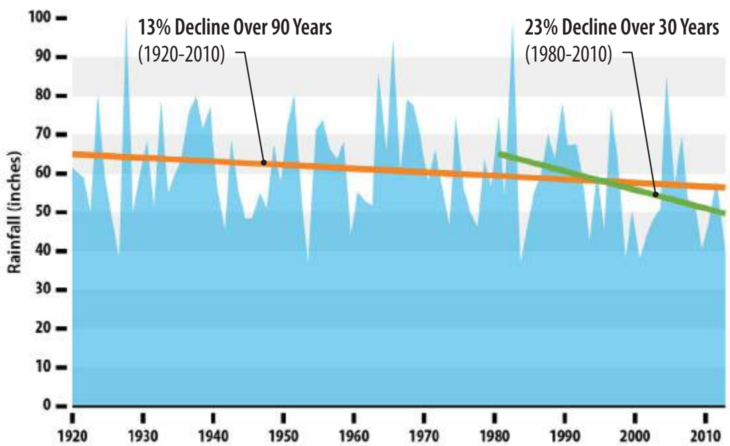
CLIMATE CHANGE **ADAPTATION** AND OTHER TRENDS

Decades of detailed records tell the story of O'ahu's water supply: how much water was available, how much water would be needed, where supplies would be found. Information was based in large part upon historical trends and inherent knowledge.

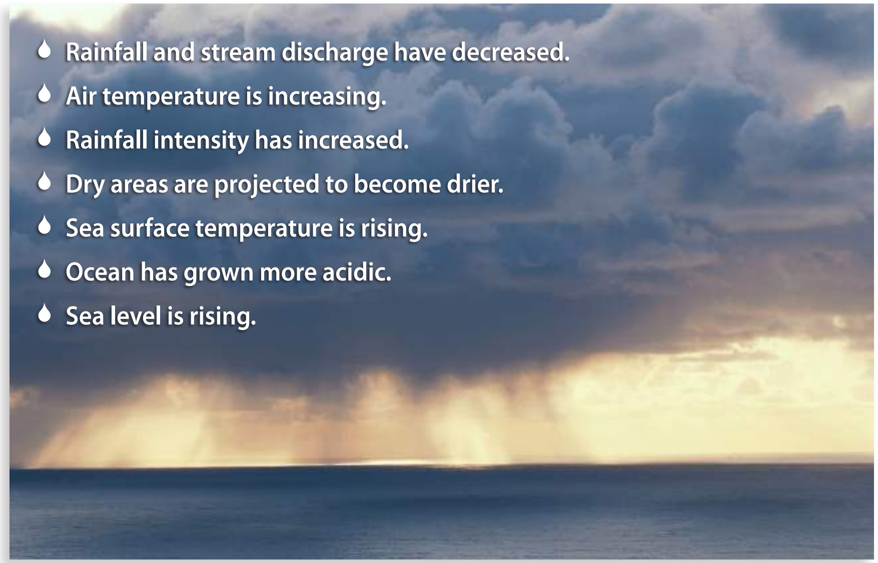
In today's accelerated world, dramatic new trends are emerging, with growing technology and tools to track and mitigate impacts. The BWS is following these trends closely and collaborates with others to anticipate and prepare for their effects. These trends and uncertainties are considered in the Water Master Plan recommendations.

Climate Change

Rainfall trends on O'ahu have been in steady decline since the 1920s. In the last 30 years, the downward trend has been even more dramatic. Dry areas of the island are forecast to get drier. Rainstorms are expected to become more intense, which will increase the amount of water that runs off into the ocean, resulting in less water going to deep aquifer recharge.



Historical annual average rainfall for O'ahu (data from the Rainfall Atlas of Hawai'i).

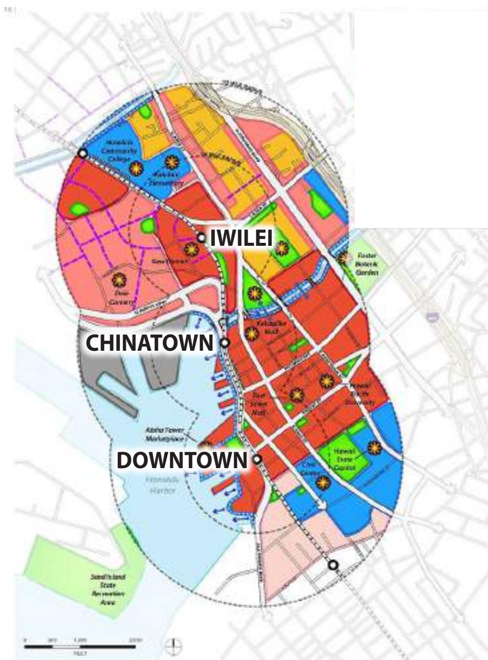


As global temperatures increase and polar ice melts, sea level is projected to rise three to six feet by the end of the century. The island's fresh water is protected from seawater intrusion by a miracle of geological good fortune. O'ahu is surrounded by caprock built up over thousands of years, forming a dam that retains the fresh water from leaking into the ocean.

Coastal communities on O'ahu that are close to sea level, such as Waikīkī, Kaka'ako, Iwilei, and Mapunapuna, will feel the effects of projected sea rise the most. This includes the water infrastructure that serves those communities. Metallic pipelines are expected to corrode faster in soils that absorb the encroaching seawater. Coastal erosion and inundation may threaten the stability of water pipelines along the coast, especially pipes suspended on bridges. The BWS has commissioned targeted studies of impacts on the coastal water infrastructure and will integrate the findings with those of the Water Master Plan.

Looking to better understand and adapt to climate change impacts, the BWS has joined with organizations such as the U.S. Geological Survey and University of Hawai'i (UH) to track changes in climate, as technology evolves and more accurate predictions are formed. This data will be factored into future capital investments and maintenance requirements. UH rainfall models will help the BWS to better anticipate changes in rainfall patterns and the effects on the island's surface water and groundwater supplies.

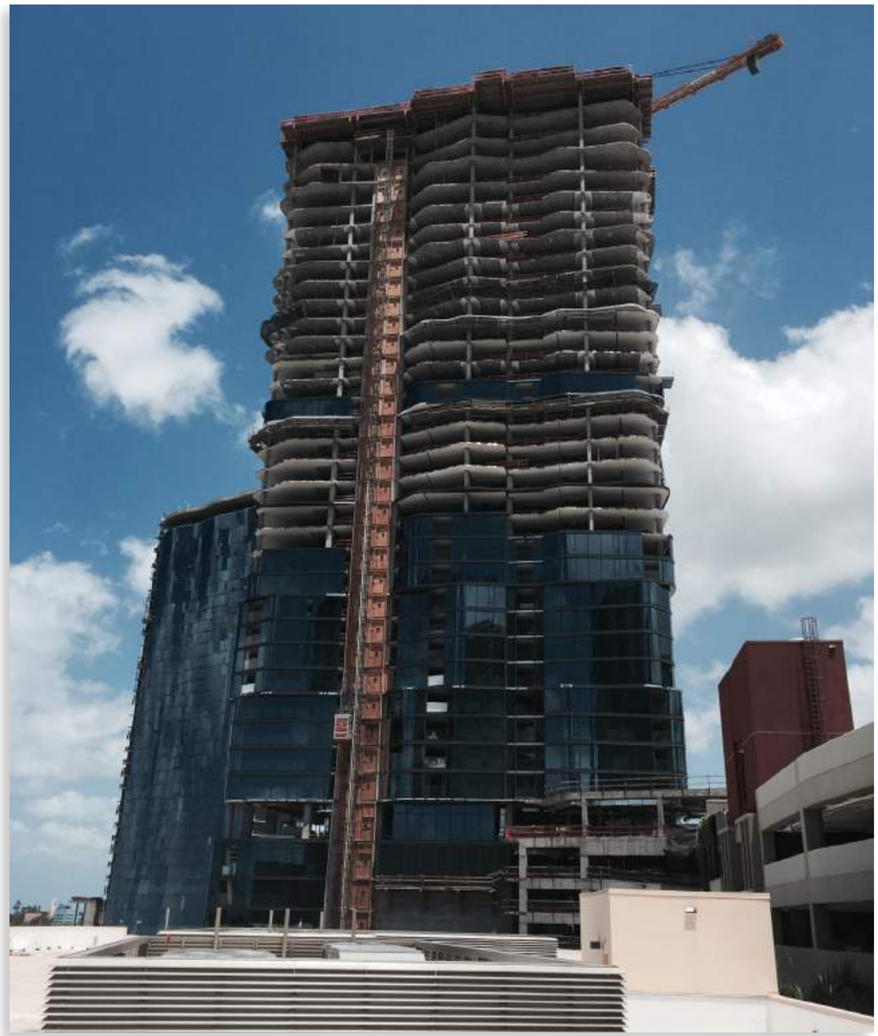
Growth Areas and Transit-Oriented Development



Downtown neighborhood TODs. Each TOD is about a 1/2 mile radius around a transit station. City and County of Honolulu Downtown Transit Orientation Development Plan, May 2015.

Population growth and new developments create the need for increased water supplies and added transmission pipelines to get the water where it is needed. New development is underway in ʻEwa and Honolulu especially around Transit-Oriented Developments (TODs). Together, this will account for about 75 percent of Oʻahu's anticipated population increase from the 2010 census to 2040. Serving these new demands will require significant additional water infrastructure.

Advanced conservation practices in the new developments could translate to less infrastructure required, less community disruptions for pipeline installation, and reduced costs. Aggressive water conservation measures could include advanced conservation measures such as smart-irrigation control, reuse of air conditioning condensate, retention of stormwater for outdoor irrigation, ultra-low flow water fixtures, and more.



New developments on Oʻahu, like the high rises planned as Transit-Oriented Developments, can include advanced conservation technologies to help keep water use in line with sustainable supplies.

Potential for Groundwater Contamination

The quality of the island's groundwater is influenced by activities that take place on the surface. The Federal Safe Drinking Water Act, a set of regulations that apply to water utilities to ensure that water is safe to drink, specifies requirements for drinking water standards, monitoring, treatment, enforcement, and public notification. The BWS is ever vigilant in following these requirements. The BWS carefully tracks conditions likely to affect the water system and goes beyond what is required to stay ahead of new trends that could impact water quality. With over 30,000 chemical and microbiological tests conducted by the BWS every year, this continuous surveillance can provide an early warning of potential contaminants.

There are additional ways the BWS works to protect the sources of O'ahu's water, including collaboration with watershed partners. The BWS pays close attention to prevent contamination of groundwater aquifers. It is the State Department of Health's responsibility to monitor and regulate these activities. Education plays an important role, as much of the island's population literally lives above its water supply. What gets poured onto the ground – whether from pesticides, cesspool seepage, chemical spills, motor oil, or other toxic substances – has the potential to percolate into aquifers used for drinking water.

Signs of such contamination can be found on O'ahu. Treatment is in place at several locations on the island to address legacy groundwater contamination from historical agricultural practices. Cesspools — construction of which has only recently been prohibited — pose on-going potential for water contamination. And, as scientific capabilities are refined, there is the possibility for currently unknown and unregulated contaminants to be identified.

Evidence of such uncertainty is being closely watched at the Red Hill Bulk Fuel Storage Facility in Hālawa, a group of 20 fuel storage tanks built during World War II, each capable of holding up to 12.5 million gallons. In 2014 the Navy reported a 27,000-gallon leak at the site, which is located 100 feet above two irreplaceable groundwater aquifers. These aquifers contain two water sources the BWS uses to provide 25 percent of the water served to residents from Moanalua to Hawai'i Kai.

The location of underground tanks are illustrated in this aerial photo of the U.S. Navy's Red Hill Bulk Fuel Storage Facility in Hālawa. Ref. Red Hill Bulk Fuel Storage Facility Final Technical Report, 2007, Fig. 1-3, p. 1-15.

To date, samples collected and tested by the BWS have been found to be safe to drink and not to contain contaminants above allowable levels. The BWS continues to track this situation very closely and is monitoring water quality at nearby wells to determine the potential need for remedial actions.

Contamination often can be mitigated, but treatment usually is very expensive and takes considerable time to implement. If treatment is too costly or not possible, the water source will need to be shut down, reducing water supply. Sometimes it's possible to establish new wells, but this is very costly and takes time. Prevention is the most reasonable and cost-effective solution to guard precious water supplies from contamination.

SUSTAINABILITY OF OʻAHU'S WATER

Sustainability is a planning framework that guides the actions of many government agencies, communities, volunteers, agriculture, organizations, businesses, and other interests. Sustainable practices allow limited resources to be protected for current use and for those who will follow.

Healthy watersheds are better able to sustain the water supply over the ages, through droughts and effects of climate change. Increased conservation – consuming less water and reserving the existing supply – can enable the BWS to delay spending limited funds to construct new infrastructure or perhaps even eliminate the need to construct new wells or larger facilities.

The BWS has invested deeply in the sustainability of Oʻahu's water through initiatives that protect the natural sources, diversify the source of supply, and encourage wise water use. The BWS's planning and decision making are informed by an alignment of protection of the environment, economic stability, the island's current ideals, and cultural values. Following are a few of the resulting initiatives.

Coordination with Other Agencies and Programs

The BWS is involved in many inter-agency programs to protect watersheds and maintain sustainable water supplies. Working together with the State of Hawaiʻi Commission on Water Resource Management and the Department of Health, the BWS monitors and protects Oʻahu's groundwater resources. Looking forward, the BWS anticipates coordinating with transportation, energy, environmental, and other utilities, as well civic and community organizations, to advance climate change adaptation.

Watershed Partnerships

The BWS has responsibility to care for, protect, and preserve watersheds for future generations. Integral to fulfilling this responsibility, the BWS continues to develop strong and diverse partnerships that protect and enhance Oʻahu's watersheds

Partnership efforts include reforestation, elimination of invasive species, restoration of streams, wildlife and fire protection, and more to protect the watersheds, surface water, and groundwater aquifers. Photo by Tom Anderson.

through resource management. Partners include local and Federal government agencies, private landowners, schools, and community groups. These partnerships have brought to reality programs that restore and protect watersheds, provide stream monitoring, collect watershed hydrology data, protect endangered species, and restore archaeological sites.

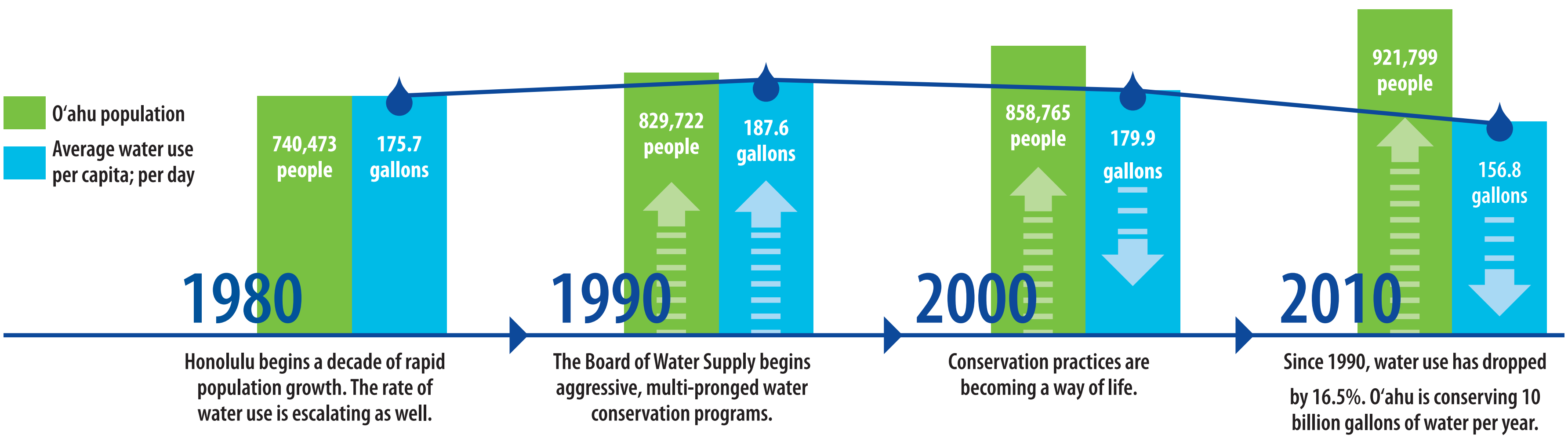
Conservation

Since 1990, as people have made water conservation a daily habit, water use on Oʻahu has dropped 16.5 percent, conserving 10 billion gallons of water per year. This graph shows that reduction in water use in terms of gallons per capita per day (gcpd) even as population continued to increase. The BWS supports conservation through leak detection, repairs, and maintenance; a large water users program; a water conservation regulatory program; ongoing conservation initiatives; and developing awareness and changing behavior patterns with education and outreach.

Conservation trends have a saturation point, however. Early efforts capture water savings that are simpler and lower cost. Looking forward, the BWS is preparing to ramp up its water conservation program to counter-balance the demands of a growing population.

Collaborative Water Sustainability Initiatives

The BWS has been an active partner in the Hawaiʻi Community Foundation's Fresh Water Initiative, which brings together multiple parties to develop forward thinking, consensus driven strategies to increase water security on the Hawaiian Islands. The initiative has set an ambitious statewide goal of securing 100 million gallons per day of additional fresh water capacity through conservation, recharge, and reuse. The BWS plays a key role in achieving this goal through its conservation initiatives, ongoing leak detection, water recycling, educational program, and commitment to watershed sustainability and partnerships.



Gallons per capita per day (gcpd) is the quantity of all water used in a day (including business, agriculture, and others) divided by population served.

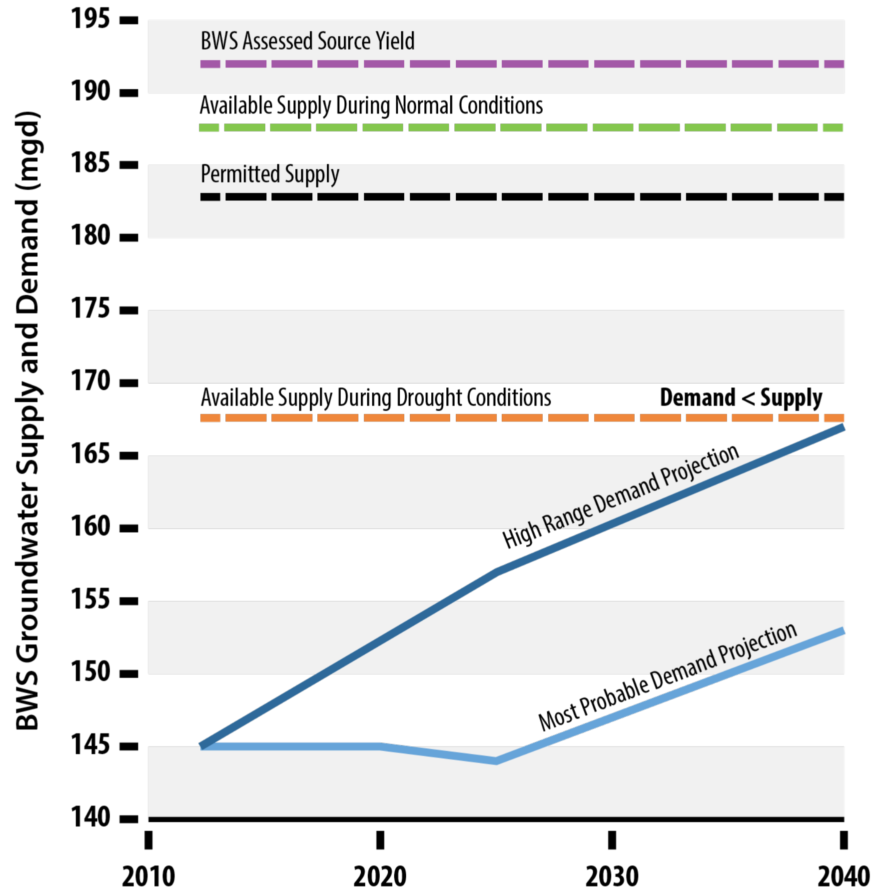
WILL THERE BE **ENOUGH** WATER?

The question of having enough water is, in large part, about having sufficient supply to meet the demands of a growing population. It is also a question of having the right quality of water for the island's diverse needs: drinking, agriculture, industry, irrigation, and more.

The Water Master Plan determined that, yes, the supply of water is enough to meet the demands, but there are many things to be done to secure sustainability for the long term. The BWS's total water supply consists of potable groundwater (93 percent), non-potable recycled water (5 percent), and brackish non-potable water (2 percent). Water Master Plan analyses comparing projections of future populations and the island's supply sources confirmed that there is sufficient water to meet even the highest projected demands in 2040.

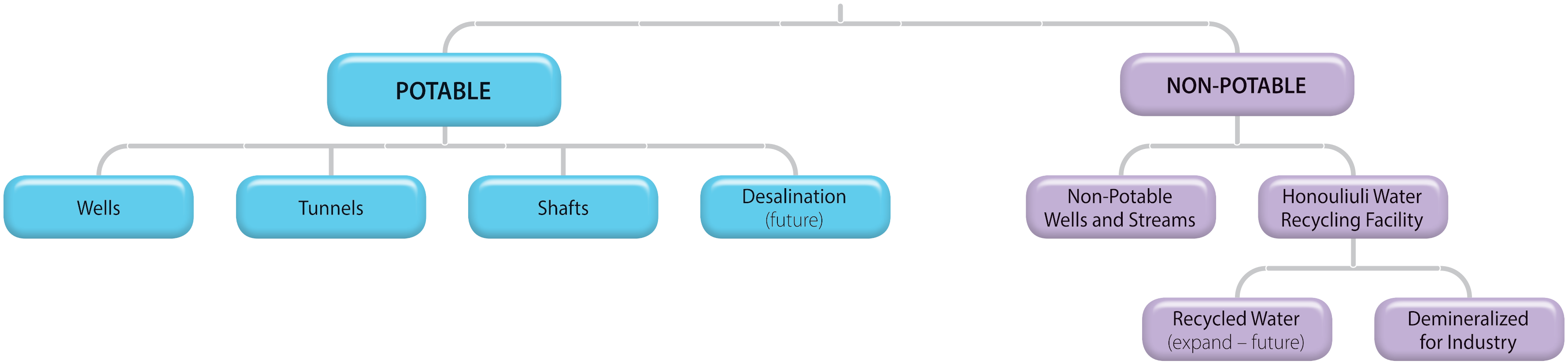
The BWS continuously tracks levels of water use compared with available supplies.

The chart below illustrates the significance of aggressive water conservation for future water supplies (most probable demand projection vs. high range demand projection), that comes to a difference of approximately 15 million gallons of water per day – enough for 100,000 water-conserving people – by the year 2025.



BWS groundwater supply and demand in million gallons per day (mgd).

BWS Potable and Non-Potable Water Sources



The BWS follows these planning principles when operating its current system and planning for future supply:

1. Operate groundwater sources (e.g. wells) within sustainable yields.
2. Move water from where it is to where it is needed, take only what is needed, without causing harm, and do not waste it.
3. Develop new groundwater sources for growth and reliability.
4. Plan for sufficient water for agricultural uses.
5. Diversify supply to address uncertainty.
6. Monitor trends and adjust as necessary.

While projections show there will be enough water for all on O'ahu, the BWS will have to transfer water from areas that have more than enough, to areas that need more than is available from nearby sources. Beyond transferring water, future local supply sources may include expanded storage, advanced conservation, more recycled water infrastructure, and development of desalination plants.

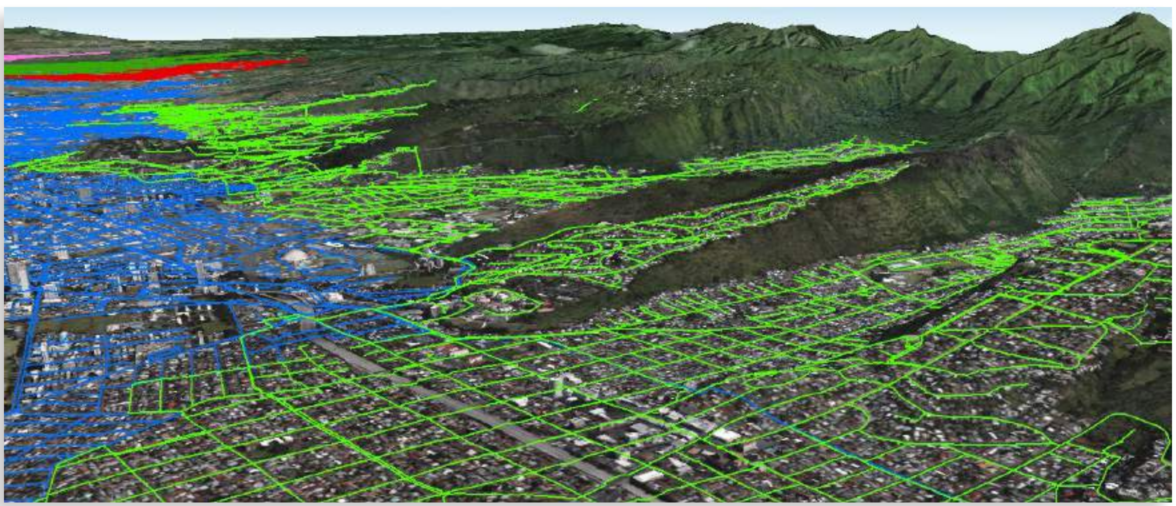
There will also be enough water for agriculture, an important part of Hawai'i's economy and quality of life.

A LENS INTO O'AHU'S **FUTURE** WATER NEEDS

The Water Master Plan included an extensive evaluation of the capacity of the entire BWS water system – everything from wells, pipes, and pumps, to treatment facilities, reservoirs, and fire hydrants – to provide safe and dependable water throughout the 30-year planning period. This evaluation identified when and where the existing system will need improvements to meet the future demands of a growing population.

Combined with technical studies, research, and engineering analysis, the evaluation of the water system provided a lens into the future. One component of the evaluation was a computerized hydraulic model that integrated these and other details to identify limitations in the BWS water system.

Hydraulic models are used to analyze the system for flows, water pressures, and reservoir tank refill cycles. The model realistically simulates how the existing water system works, and – more importantly – assesses how facilities will perform in the future under a variety of realistic scenarios. This sophisticated tool enabled the Water Master Plan team to make reliable recommendations for capital improvement projects for the near term and far into the future.



Aerial photos of different areas of the island were superimposed with computer data from the BWS's Geographic Information System (GIS) to create highly informative hybrid photos like this one of part of Metro Honolulu, showing layers of BWS pipelines. Aerial photos were provided by Google Earth.

Good Data In

The hydraulic model used extensive, detailed data about the water system as "inputs" for the model. Data inputs included accurate features of water infrastructure and their use, including:

- Tunnel and shaft configurations – location, elevation, estimated water level.
- Pump stations – size of each pump, what controls on/off e.g. pressure downstream.
- Reservoirs – locations, elevations, and sizes.
- Pipes – diameters, lengths, elevations, materials, and ages.
- Historical customer billing records and customer meter locations.
- Average water demands and daily patterns in water use (that differ by type of land use).

Good Data Out

Data "outputs" included information that demonstrated how and where the system would operate well under different future scenarios. That information included pressures throughout the entire system, reservoir levels, flow velocities, and more. Because hydraulic models were highly detailed and verified against actual conditions for accuracy, the BWS knows it can trust the data outputs as a basis for long range solutions.

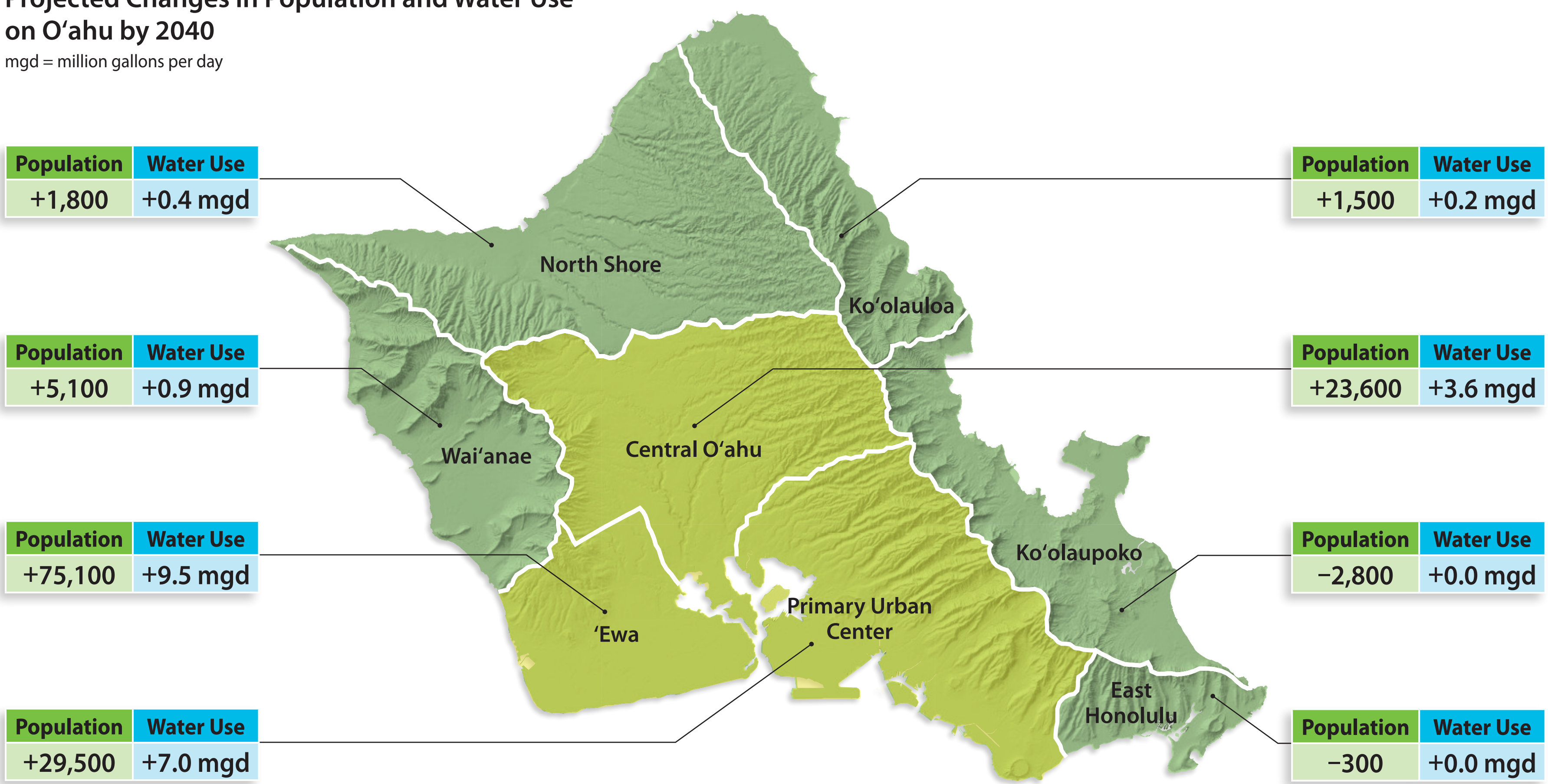
Population Projections

Population projections and estimates of water use were essential factors in evaluating the capacity of the existing water system. Population forecasts were provided by the Hawai'i Department of Planning and Permitting, other master plans, and subdivision information. Water use projections for 2040 were based on those population forecasts and the BWS's records of past water consumption by area.

As with all long range forecasts, there are several uncertainties to take into account, such as a changing economy, jobs, tourism, zoning, development starts, changing distribution of where people live and work, and the degree of future water conservation. The Water Master Planning team developed four possible future scenarios for the system evaluation. The most conservative of these is shown in this illustration of projected changes in O'ahu's population and water use, by land use district.

Projected Changes in Population and Water Use on O'ahu by 2040

mgd = million gallons per day



Results of the Evaluation of the Water System

The evaluation of the water system identified existing as well as future needs for additional capacity. Based on the results, projects will be developed to provide needed capacity and will become part of the 30-year Capital Improvement Program. These are projects to expand water system capacity where necessary, requiring new infrastructure. Major evaluation results are summarized below, by the types of capacity that will be needed in 2040: supply, pumping, storage, and pipelines for water delivery.

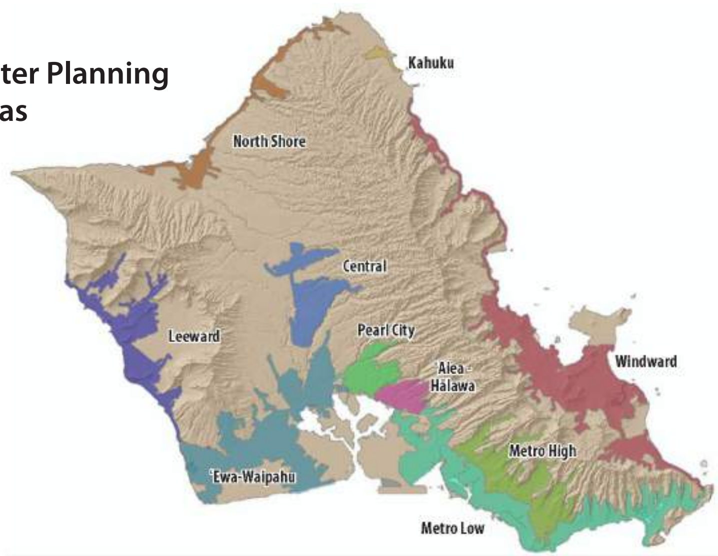
Additional Supply Needs for 2040

- Metro Low will need up to 9 million gallons per day (mgd) more supply in 2040 than today.
- 'Ewa-Waipahu will need up to 9 mgd more.

Pumping Capacity Needs for 2040

- Metro Low will need up to 10 mgd additional pumping capacity in 2040 than today.
- Metro High will need up to 14.6 mgd more.
- Leeward will need up to 9 mgd more.

Water Master Planning Model Areas



The BWS water system contains more than 100 sub-systems based on the topography, existing infrastructure, available water supplies, and population density throughout O'ahu. To facilitate analyses for the Water Master Plan and achieve greater accuracy, the island was divided into 10 "model areas". These models formed the basis for hydraulic modeling, system analyses, findings, and recommendations of the Water Master Plan.

- 'Ewa-Waipahu will need up to 15 mgd more.
- Pearl City will need up to 3.8 mgd more.
- 'Aiea-Hālawa will need up to 8.6 more.
- Kahuku will need up to 2 mgd more.
- North Shore will need up to 3.5 mgd more.

Storage Capacity Needs for 2040

- Metro Low has the most significant current and future storage needs. Alternatives to meet these needs include new storage in Honolulu, new wells between Honolulu and Kahala to meet peak demands, locating new infrastructure to the west of Metro Low due to limited availability of land, or a combination of these alternatives.
- Leeward will need up to 1.5 million gallons (MG) more.
- 'Ewa-Waipahu will need up to 11 MG more.
- Pearl City will need 0.4 MG more.
- Kahuku will need 0.2 MG more.
- North Shore will need up to 1 MG more.

Pipeline Capacity Needs for 2040

- Metro Low will need up to 6.5 miles of new pipeline, varying in size from 8 to 42 inches in diameter by 2040.
- 'Ewa-Waipahu will need up to 2.6 miles of new pipeline, varying in size from 24 to 36 inches in diameter.
- North Shore will need 2.3 miles of upsized and new pipeline, varying in size from 8 to 36 inches in diameter.

PRIORITIZING PROJECTS BASED UPON RISK

The BWS is developing a Capital Improvement Program that turns Water Master Plan recommendations into several hundred proposed and prioritized projects. Some will be new projects that add capacity and others will renew or replace parts of the existing system. Some projects are needed as soon as practical while others can wait.

Risk = **Likelihood of Failure** x **Consequence of Failure**

Prioritization of the hundreds of renewal and replacement projects is based on risk, or more specifically, the likelihood and the consequence of water infrastructure failure.

- The **likelihood of failure** reflects the condition of the pipe, pump, or other component of the system, along with other factors identified in Water Master Plan analyses.
- The **consequence of failure** varies with location along with other conditions.

For example, a break in a large water main located near a school or hospital could have severe consequences. A break in a small water main located adjacent to a parking lot would have consequences that are much less severe.

A computer program ranked all pipes in the BWS system from highest to lowest risk. The highest risk pipelines are a relatively small portion overall – less than 10 percent of the entire system. Projects with the highest risk factors are recommended for construction sooner than others.

Improved Resiliency

The Water Master Plan evaluated specific risks associated with water service on O'ahu:

- Natural disasters, such as hurricanes, floods, tsunamis, or earthquakes.
- Power outages that could impact any of the BWS's pump stations and wells, as well as the granular activated carbon water treatment facilities.
- Transmission interruptions to pipelines 16 inches in diameter or larger that are critical to move water from sources around the island to population centers and areas of high demand.
- Loss of supply, from drought, water quality changes, and other events.

Projects to minimize risks are included in the 30-year Capital Improvement Program.

Targeted pipe replacement prioritized based on highest risk can significantly reduce main break rates and increase pipe replacement efficiency.

RECOMMENDATIONS OF THE BWS WATER MASTER PLAN

The BWS Water Master Plan provides a comprehensive understanding of O'ahu's water supplies, water needs, and the water system. Recommendations of the Water Master Plan will guide the BWS over the next 30 years to efficiently add capacity to its water infrastructure and carry out renewal and replacement work at the right time and the right places to serve a growing population.

The Water Master Plan allows the BWS to:

- Increase water dependability for residents, businesses, and visitors.
- Proactively care for water quality and delivery infrastructure, and reduce costly emergency repairs.
- Prioritize investment of limited resources in infrastructure based on benefits and risks.
- Spread investments and rate changes over time.
- Improve design, construction, and maintenance practices so that infrastructure lasts longer.

Recommendations of the Water Master Plan reflect scientifically sound strategies and technologies to manage a range of challenges, from aging infrastructure to climate change adaptation. Implementation of these recommendations will reflect the objectives of the Water Master Plan, explained on page 3:

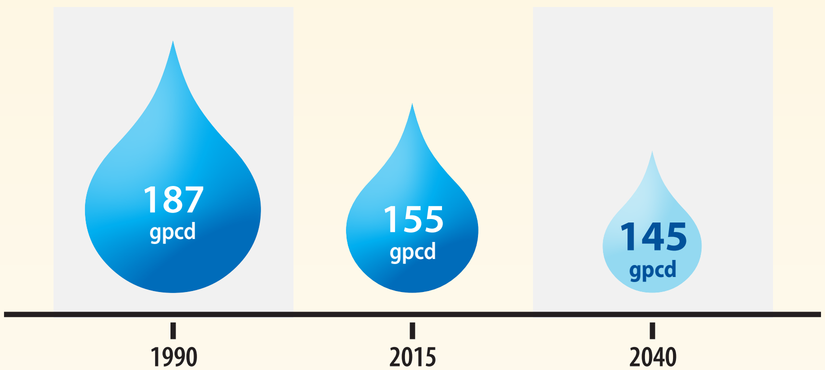
- Water Quality, Health, and Safety.
- System Reliability and Adequacy.
- Cost and Affordability.
- Water Conservation.
- Water Resource Sustainability.

Thoughtful, proactive investment in infrastructure and maintenance of the water system supports the ability to better control rates over the long run. This, in turn, supports the BWS's commitment to continue providing safe, dependable and affordable water to all of its customers, now and in decades ahead.

Recommendations of the BWS Water Master Plan described in this section identify investments, actions, operational changes, and capital improvements to be implemented over the 30-year planning period. Actual implementation timeframes will depend upon available capital funding and on how uncertainties develop over time. The timing of projects to expand the water system will be tied to actual population growth and increases in demand. Specific projects, including locations, costs, and prioritization, will be described in the BWS 30-year Capital Improvement Program.

RECOMMENDATIONS – Water Use and Conservation

- Continue investing in conservation with a goal of reducing individual water use.
- Revisit demand forecasts every 10 years, with each new census.
- Monitor changes in water demand and install necessary infrastructure in a timeframe concurrent with growth.
- Achieve a goal of no more than 8 percent non-revenue water loss.



2040 goal is to reduce water use to 145 gallons per capita per day.

Future Conservation Opportunities

New real estate development opens up opportunities for encouraging — and possibly mandating — advanced water conservation measures, such as higher-efficiency plumbing, smart-irrigation controls, sub-meters for multi-family homes, and gray water reuse. Growth in industry and the tourism/travel sectors allows the potential to advance innovations in cooling tower efficiencies, conductivity meters, water softening, rain water or recycled water supplements, and the capture and reuse of air conditioning condensate. Opportunities being researched include capturing storm water behind an existing dam in Nu'uanu to recharge the aquifer.

The Board of Water Supply's rain barrel workshops are part of its conservation program to save the precious water resource.

RECOMMENDATIONS – Supply Sources

Add to the Overall Supply, Within Sustainable Yields

- Add a new 2 mgd well in the Punchbowl area and 10 mgd from Waipahu sources via the West Side Supply Project.
- Add 9 mgd of new sources in the ʻEwa-Waipahu system including Kunia Wells, Wakikele Gulch Wells, as well as the Kalaeloa and Kapolei Desalination Plants.

Double the Amount of Water Supply from Alternative Sources

- Increase recycled water processing in the ʻEwa district to 14 million gallons per day.
- New desalination plants in Kalealoa, adding 1 million gallons per day, and Kapolei, adding 0.7 million gallons per day.
- Add recycled water plant for Ala Wai Golf Course.

Maintain the Existing Wells, Tunnels, and Shafts

- Rehabilitate wells on a 25-year cycle or as pumps are replaced.
- Reevaluate the condition of tunnels and shafts every 20 years.
- Implement tunnel and shaft rehabilitation as needed.

Protect Watersheds and Aquifers

- Maintain efforts to protect watersheds and all supply sources. Managing and protecting watersheds include limiting access and development, combatting invasive species, promoting healthy forests, and encouraging customer water conservation.
- Adjust the amount of water pumped in the lower urban center area (Metro Low) to stabilize rising chloride trends and allow the aquifer to recover after drought periods.
- New supply sources will be sited and developed, without impacting surface water for traditional and customary practices, water rights, and near shore waters. Siting of new sources will also account for the long-range water needs of agriculture, and will not detrimentally affect existing sources of water supply for non-BWS uses.

The BWS's potable water is entirely groundwater drawn from over 200 sources including wells, shafts, and tunnels. The natural quality of Oʻahu's water is very high. The BWS Hālawa Shaft offers a rare view of the pristine groundwater in this important aquifer. Not all aquifers look like this. Most hold water in smaller fractures, fissures, and pores.

RECOMMENDATIONS – Pump Stations

Increase Redundancy (Backup) Capacity

- Rehabilitate out-of-service pumps and refurbish operating pumps as needed. The goal is to have more than 90 percent of all pumps available for operations at all times. Approximately 60 percent of pumps are needed to meet demand.

Enhance Operations of Existing Pump Stations

- Refit pump stations to improve operation, reliability, and efficiency.

Add Pumping Capacity

- Add 61 million gallons per day (mgd) pumping for growth and reliability improvements mostly in Metro Low, Metro High, ʻAiea-Hālawa, Pearl City, and Leeward, and ʻEwa-Waipahu.
- Add 2 mgd of pumping capacity in the Kahuku district.
- Add 3.5 mgd of pumping capacity in the North Shore district.

Pumps at the BWS Beretania Pump Station extract water from underground aquifers and move it to reservoirs in the area.

The BWS's pump stations move water and maintain water pressure system-wide. Pumps are so important to reliable water service that they have backups to run in times of outages for maintenance or repairs.

RECOMMENDATIONS – Treatment Facilities

- Continue routine maintenance at all granular activated carbon facilities.
- Make corrosion-related structural and mechanical repairs at two of the granular activated carbon facilities to extend their useful lifespan.
- Modify granular activated carbon treatment processes to increase their operational efficiencies.

Granular activated carbon treatment facilities remove legacy agricultural contaminants from the drinking water supply in Central O'ahu and 'Ewa-Waipahu.

Groundwater moves through volcanic aquifers on O'ahu where nature's conditions protect the very pure water. All drinking water served by the BWS is treated minimally to comply with Federal water-quality regulations. In some parts of the island, treatment facilities use granular activated carbon to remove pesticides that resulted from past agricultural activities. While the detrimental agricultural practices have been stopped, the treatment of water in these areas – Mililani, Kunia, Waipahu, Waipio, and Waialua – will continue for generations into the future.

The quality of BWS water, whether treated with small amounts of chlorine or processed in the activated carbon facilities, consistently meets or is better than water quality standards. The BWS does not add fluoride to its water supply.

RECOMMENDATIONS – Reservoirs

Repair and Maintain Existing Reservoirs

- Make needed minor repairs to reservoirs.
- Re-inspect selected reservoirs every 5 years and update reservoir condition assessments every 10 years.
- Inspect the interiors of all reservoirs on a 10-year cycle. Clean reservoirs concurrent with interior inspections.
- Reconfigure pipelines and control valves near the currently unused Melemanu reservoir to make it fully functional.

Replace and Repair Reservoirs of Concern in Seismic Events

- Replace two reservoirs and make structural and seismic improvements to 18 reservoirs in the near term.

Upgrade Reservoirs to Current Seismic Codes in Conjunction with Other Repair Work

- When major structural work is needed on any of the 120 reservoirs that do not meet current seismic codes, include an upgrade of seismic restraint systems.

Add New Storage Capacity System-Wide

- A new West Side Supply project will address a combination of supply, transmission, and storage needs, and includes a new 10 million gallon reservoir at Waiawa, a 10 mgd booster pump station, a control valve downstream of a the new reservoir to convey water into the west side of Metro Low, and a 36-inch diameter transmission main.
- A 2 million gallon reservoir near Punchbowl.
- Add 1.6 million gallons of storage capacity in the upper urban center area (Metro High).
- Add 1.5 million gallons of storage capacity in the Wai‘anae-Mākaha area.
- Add new storage in the Honouliuli area totaling 11 million gallons.

Possible locations for future storage include the Diamond Head State Monument, similar to this existing reservoir buried below ground.

The BWS's 171 reservoirs are generally in very good condition; 89 percent of them need only minor or no work. Seismic codes have been updated since many of them were built and 70 percent (120) do not meet current codes. Only minor, repairable damage would occur to most of these.

RECOMMENDATIONS – Pipelines

Repair and Replace High-Priority Pipelines

- Prioritize replacement of pipelines with highest risk sections.
- Dedicate a portion of the capital budget to replace sections of smaller pipelines that break frequently.
- Increase the number of miles of pipeline replaced annually based upon risk prioritization and the trend of water main breaks (rising or declining). In the event of worsening metrics, replacement rate should increase to 20 miles per year as determined by lifespan assessments.
- Continue to collect and use high quality risk and assessment data to allow more efficient and targeted pipeline replacement, reducing the break record at any given rate of replacement.
- Continue the leak detection program that allows for proactive repairs to pipes. The BWS leak detection team currently surveys about 30 miles of pipeline per month.

Extend the Life of the Existing Water Infrastructure

- Install and maintain corrosion protection on all new metallic pipes.
- Complete studies of PVC pipelines (underway), and implement findings such as installation methods to improve performance and lifespan of those pipelines.
- Establish the goal of achieving pipeline service life greater than 100 years.

Regularly Assess the Condition of Pipelines and Tunnels

- Continue monitoring advances in condition assessment technologies for improved ease of use.
- Perform condition assessments on selected pipelines prior to repair or replacement.
- Reevaluate the condition of pipeline tunnels every 10 years.

Install New Pipelines to Meet 2040 Needs, Increase System Reliability and Allow Transfer of Supply to Areas of Greater Need During Drought

- Install 4 miles of new 42-inch diameter pipeline along Beretania, Richards, King, Victoria, from Liliha to Isenburg streets.
- Install 2.5 miles of 36-inch diameter pipeline from Aloha Stadium to the Hālawa 42-inch pipeline (West Side Project).
- Install approximately 2 miles of pipeline in the North Shore district.
- Install approximately 2.6 miles of 24-inch pipeline in the ʻEwa-Waipahu district.
- Upsize pipes in Metro High as they reach the end of their useful life.

Efforts to reduce water main breaks have been effective, including renewal and replacement, operational changes, pressure management, and leak detection. These practices should be continued.


Recommended future pipeline construction includes installation of new pipes as well as renewing and/or replacing existing pipes.

The BWS will adopt better-than-current-industry best practices to install new pipelines that will have a service life greater than 100 years. This should provide our future generations with a water system that requires less renewal and replacement than is currently required.

Future operational changes may include adding surge control at key pump stations, increasing reservoir storage at key locations to minimize pressure spikes, and reducing pressure in high-pressure areas. In addition, risk-based pipe replacement can significantly reduce break rates and increase pipe replacement efficiency.

SUSTAINABILITY **LINKS** BWS INITIATIVES

In its Strategic Plan, the BWS expresses its core goals in terms of sustainability:

- **Resource Sustainability (Safe)** – Protect and manage our groundwater supplies and watersheds through adaptive and integrated strategies.
- **Operational Sustainability (Dependable)** – Foster a resilient and collaborative organization utilizing effective and proactive operational practices consistent with current industry standards.
- **Financial Sustainability (Affordable)** – Implement sound fiscal strategies to finance our operating and capital needs to provide dependable and affordable water service.

"Sustainability" also is the link between the BWS's Water Master Plan, which is an infrastructure based-plan, and its Watershed Management Plans and Conservation Plan.

- **The Water Master Plan** identifies the infrastructure, policies, and programs necessary to provide safe, dependable, and affordable water to BWS customers continuously through 2040 and beyond. Projections and recommendations for the water future are largely based on available supplies and projected water use.
- **The Watershed Management Plans** balance the protection of groundwater and surface water resources with managed use and development. They coordinate land use planning with watershed protection efforts. Managing healthy watersheds protects the quality and quantity of much of the island's water supply.
- **The Conservation Plan** promotes water conservation both within the BWS distribution system and with customers. The BWS's water conservation strategies have lowered water use over the last several decades. A continued, comprehensive conservation program is expected to produce further savings.

The implementation of each of these major BWS initiatives depends upon the success of the others. Actions taken to renew and expand the water infrastructure are impacted by our ability to conserve, protect, and sustain the water supply, now and in the years ahead.

The BWS will continue its present water conservation program that includes education for all ages, and will plan targeted conservation strategies to help achieve sustainability goals.

IMPLEMENTING THE WATER MASTER PLAN

The Water Master Plan's recommendations are based on maintaining the health of the BWS water system. A Scorecard system has been created, that will enable the BWS to track progress sustaining the health of the system and make necessary improvements in the critical water service steps of Sustain, Capture, Treat, Move, Store, Deliver. Each step has associated metrics (or measures) and numeric goals. A green/yellow/red rating system tracks progress toward achieving each goal: green meaning the goal has been met or exceeded; yellow indicating goal has been missed by less than 10 percent; and red showing the goal has been missed by 10 percent or more.

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting Goal?
Sustain ● (red)						
Supply from non-potable sources	% of total supply served from non-potable water system	Measures the percentage of total supply that is served by non-potable 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)	● (green)
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 withdrawal without detrimentally affecting the resource. 90% goal allows time to develop additional sources.	80%	● (green)
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	● (red)
	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	● (red)

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

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%	● (red)
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	● (red)
	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	● (green)

Capture ● ● (green)

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting Goal?
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%	● (green)

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

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%	● (yellow)
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	● (green)
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 →	● (green)
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%	● (green)
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)	● (green)

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

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%	● (green)
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%	● (yellow)
Emergency power	% of population served indoor demand (85 gpcd) 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%	● (red)
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)	● (green)

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

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 pro-portion 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 →	●

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

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)	● (red)
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%	● (red)
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 ↓	● (red)
Fire hydrant supply	Hydrants that meet fire flow standards	Measures percentage of fire hydrants meeting fire flow standards per hydraulic modeling.	> 99%	Suggested in WMP.	98%	● (yellow)
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%	● (red)
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%)	● (green)

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

Indicator	Metric	Purpose of Metric	Goal	Source of Goal	Actual (FY16)	Meeting Goal?
Tools and Planning ●●●●						
Water Master 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 hard-wired communication to the redundant microwave system.	100% (by 2023)	Transition from hardwired communication to existing microwave backbone.	13% (on-track)	●
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						

Considerations for Funding

Value of the Existing Water System

Investments in maintaining and upgrading the existing water system help retain its value, which is substantial by any comparison. The table to the right shows the approximate replacement value of the BWS's existing water infrastructure, by the type of facility.

Facility Type	Estimated Value	Percent of Total System Value
Pipelines	$12,300,000,000	77%
Pump stations	$400,000,000	2%
Supply: wells, tunnels, shafts	$1,300,000,000	9%
Water treatment facilities	$300,000,000	2%
Reservoirs	$1,250,000,000	8%
BWS operations yards	$330,000,000	2%
Total	**$15,880,000,000**	**100%**

Water Sustainability Program Budgets

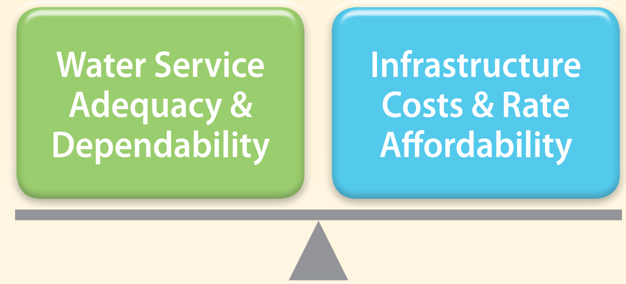
The BWS's sustainability programs – in particular Watershed Management and Conservation – are operational (non-capital) expenditures and have separate budgets for implementation (see chart below). Of high value to the future of O'ahu and its residents, and of exceptional importance to water supply sustainability, these programs do not fit neatly into the risk-based prioritization of the 30-Year Capital Improvement Program. The Water Master Plan recommends considering the establishment of a dedicated funding stream for these critical sustainability initiatives. This funding approach will be considered as part of the upcoming water rates study.

Current BWS sustainable program annual budgets are:	
Conservation	$890,000
Watershed Management	$1,420,000
Recycled Water	$6,240,000
Total 2016 sustainable programs budget	**$8,550,000**

Water Rates

Nearly all money to fund the BWS comes from sale of water to its customers. The BWS has four groups of customers, each with a different rate structure: residential, non-residential (commerce and industry), agricultural, and non-potable water users.

Following adoption of this Water Master Plan, the BWS will prepare a Financial Plan and conduct a Rate Study that will look at these and other factors that drive rates. This will be a year-long effort that is likely to consider adjustments to current water rates to cover costs to implement the Water Master Plan. The Water Master Plan recommends adopting the industry standard to review rates in a five-year cycle.



One of the goals of the Water Master Plan is to balance needs with costs. Funding strategies are part of the effort to achieve this balance.

The Water Master Plan includes high-level guidance toward budgeting for its implementation:

- The first iteration of the 30-Year Capital Improvement Program should be based on the current capital budget of $80 million per year, with a consumer price index adjustment for inflation.
- Initial funding should be distributed for improvements to the highest priority projects that are most critical to the system: pumps, reservoirs and treatment plants.
- Savings from use of low-interest State Revolving Fund loans to pay down debt should be used to speed up pipeline replacement based on risk assessments, to further reduce main breaks.
- Once the BWS completes its Financial Plan and Rate Study, capital budgets should focus on addressing the highest risk projects and the ability to increase the speed of implementation.

Capital Improvement Program Budgets

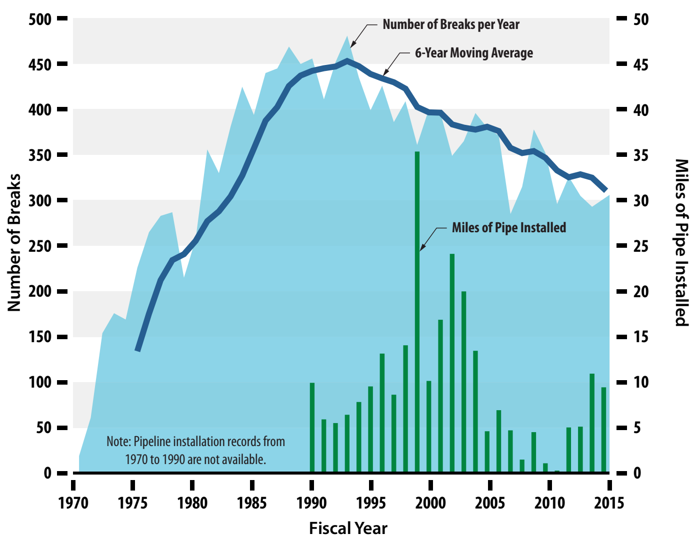
Projects in the 30-Year Capital Improvement Program are being prioritized based on risk – risk to people and property, risk to the environment, and risk to the BWS's ability to provide water services that customers can depend upon. Staging projects in this manner provides for the greatest system reliability at the most affordable cost.

Investments in the Water System Make a Difference

Water main breaks in the BWS system have decreased over the last 20 years, now numbering about 15 per 100 miles of pipeline. That adds up to an average of 312 breaks per year, well below the national average.

Water main breaks are a reality of water systems. They cannot be totally avoided, but they can be contained. Evaluations in the Water Master Plan attribute the reduction in main breaks on O'ahu largely to the BWS's investments in pipeline renewal and replacement, as well as changes in operational practices, pressure management, and leak detection.

Proactive investments in aging water infrastructure help to keep water flowing reliably and smoothly, avoiding disruptive breaks and enabling the BWS to achieve its goal of providing safe, dependable, and affordable water to its customers.

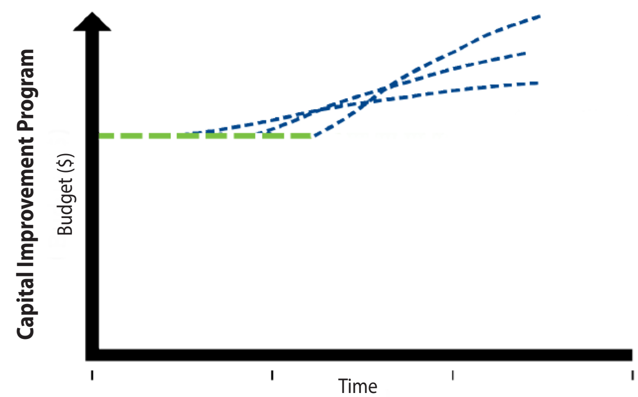


Water main breaks in the BWS system have decreased over the last 20 years, now numbering about 15 per 100 miles of pipeline, currently averaging 312 per year. This is well below the national average. This reduction is likely the result of investments in pipeline replacement over that timeframe, along with changes in system operations.

Future Capital Improvement Program Budgets

An important question related to water rates and budgets for the Capital Improvement Program is: What level of service (including water main breaks) is acceptable to Board of Water Supply customers. At a minimum, increases to the Capital Improvement Program budgets should follow the pace of inflation. However, as the Board of Water Supply sees in current construction bids and as other public works projects on O'ahu demonstrate, the inflation in infrastructure costs is well in excess of general inflation. These are just some of the factors that will be considered as Board of Water Supply water rate-makers weigh the balance of level of service and affordability.

Future Capital Improvement Program Investment-Level Scenarios



This figure shows that delaying future water rate increases may drive up overall costs to customers for the same or a lesser level of service. Deferring funding can delay the ability to implement projects, resulting in higher costs due to inflation.

Adaptive Management – Adjusting to Changing Conditions

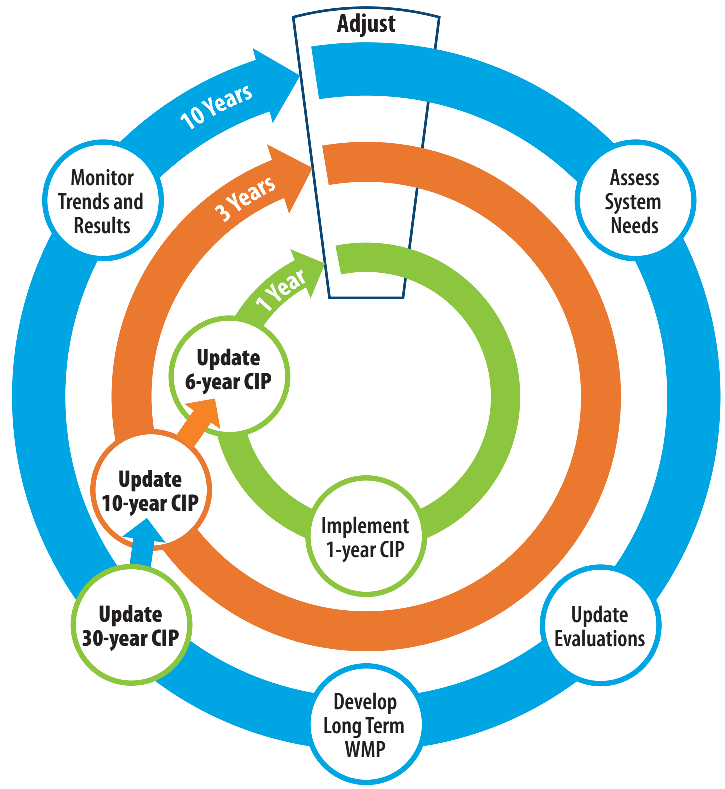
Plans for water system management and improvement are not created in a vacuum. Each finding and recommendation is set against the backdrop of conditions that are current within a specific timeframe. However, conditions change over time.

Based on uncertainties inherent in a large, complex water system, coupled with the possibility for changes in population, climate, water-use patterns, groundwater quality, and other unknowns, the BWS will apply an Adaptive Management approach to decision making and financial commitments associated with the Water Master Plan.

Adaptive Management provides for flexibility in decision making over time, as external conditions change. Decisions are revisited and analyzed every one to five years, or more frequently if significant changes have emerged.

Ongoing tracking and new information allows the BWS to adjust the timing and scope of planned projects, to maintain the balance between system dependability and affordability for customers.

As of this writing, the BWS is completing its long term Water Master Plan and is about to wrap up the 30-year Capital Improvement Plan, shown in the lower left-hand portion of the blue circle. Arrows linking the differently colored program loops show how results from each review and update feed into Capital Improvement Programs with ever-shorter planning horizons. This framework enables the BWS to apply increasing knowledge and details as projects progress toward the 1-year Capital Improvement Program, where they are positioned for funding and the start of construction in the annual Capital Budget.



This diagram illustrates the Adaptive Management process that uses continuous monitoring of trends and conditions to fine tune the scope and timing of projects. The 6-year and 1-year Capital Improvement Programs are required by City charter.

BWS Board of Directors

As defined in Hawai'i State Law, the seven-member Board sets policies and prescribes regulations for the management, control, and operation of the BWS's public water system. The BWS Board is authorized to establish and changes rates and charges, and also appoints the Manager and Chief Engineer.

As volunteers in public service, the BWS Board members receive no compensation for their time or efforts. Five members of the Board are appointed by the Mayor and confirmed by City Council. The other two members are ex-officio. Current board members are:

Duane R. Miyashiro – *Chair*
Adam C. Wong – *Vice Chair*
David C. Hulihee
Kapuaʻala Sproat
Bryan Andaya
Ross Sasamura – *Ex-Officio, Director and Chief Engineer, City Department of Facility Maintenance*
Ford N. Fuchigami – *Ex-Officio, Director, State Department of Transportation*

BWS Stakeholder Advisory Group

Current BWS Stakeholder Advisory Group members are:

Eric Au	*Sheraton – Waikīkī*
Jackie Boland	*AARP Hawai'i*
Pono Chong	*Chamber of Commerce Hawai'i*
Bill Clark	*Resident of City Council District 6*
Richard Dahl	*James Campbell Company, LLC*
Mark Fox	*The Nature Conservancy of Hawai'i*
Gregg Fraser	*Hawai'i Restaurant Association*
Neil Hannahs	*Kamehameha Schools*
Rick Hobson	*Building Industry Association of Hawai'i*
Shari Ishikawa	*Hawaiian Electric Company*
Micah A. Kāne	*Hawai'i Community Foundation*
Will Kane	*Mililani Town Association*
Ralph Mesick	*First Hawaiian Bank*
Helen Nakano	*Resident of City Council District 5*
Robbie Nicholas	*Resident of City Council District 3*
Dean Okimoto	*Nalo Farms*
Alison Omura	*Coca-Cola Bottling Company*
Kathleen Pahinui	*Resident of City Council District 2*
Dick Poirier	*Resident of City Council District 9*
Elizabeth Reilly	*Resident of City Council District 4*
John Reppun	*Kualoa-He'eia Ecumenical Youth (KEY) Project*
Cynthia Rezentes	*Resident of Council District 1*
Francois Rogers	*Blue Planet Foundation*
Josh Stanbro	*Hawai'i Community Foundation*
Cruz J. Vina Jr.	*Resident of Council District 8*
Christopher Wong	*Resident of Council District 7*
Lee Yamamoto	*Marine Corps Base Hawai'i*
Suzanne Young	*Honolulu Board of Realtors*

Board of Water Supply
City and County of Honolulu

About the Cover

O'ahu Mural, 1940 - Juliette May Fraser

Located in the Board of Water Supply, Engineering Building Lobby, this oil painting depicts a map of O'ahu that shows how and where water is conserved, by whom, and for what purposes.

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, Kamohoali'i. 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 Mo'o, 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."

Board of Water Supply
City and County of Honolulu