Final Report

CROSS-CONNECTION CONTROL AND BACKFLOW PREVENTION SURVEY

Joint Base Pearl Harbor-Hickam, Hawaii

Naval Facilities Engineering Systems Command Pacific

Contract Number: N62470-19-D-4001 | Task Order Number: N6274222F0110

October 2022

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CROSS-CONNECTION CONTROL AND BACKFLOW PREVENTION SURVEY
Joint Base Pearl Harbor-Hickam, Hawaii

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APPENDICES

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ACRONYMS AND ABBREVIATIONS

”	inch(es)
%	percent
AFB	Air Force Base
AG	air gap
AH/BC	AH/BC Navy JV, LLC
Air Force	United States Air Force
Army	United States Army
ASME	American Society of Mechanical Engineers
ASSE	American Society of Sanitary Engineering
AVB	atmospheric vacuum breaker
AWWA	American Water Works Association
BFP	backflow prevention
BMS	Business Management System
Camp Smith	United States Marine Corps Base Hawaii Camp H. M. Smith
CCC	cross-connection control
CCC/BFP	cross-connection control and backflow prevention
CFR	Code of Federal Regulations
DCDA	double check valve detector assembly
DCVA	double check valve assembly
Director	Director of Health of the State of Hawaii Department of Health
DOD	United States Department of Defense
DOH	Department of Health
EPA	United States Environmental Protection Agency
FCCCHR	Foundation for Cross-Connection Control and Hydraulic Research
GIS	geographic information system
HAR	Hawaii Administrative Rules
HBVB	hose bibb vacuum breaker
HQ	Headquarters
IAPMO	International Association of Plumbing and Mechanical Officials
IBC	*2021 International Building Code*
IBM®	International Business Machines Corporation
IPC	*2021 International Plumbing Code*
JBPHH	Joint Base Pearl Harbor-Hickam
M14	Manual of Water Supply Practices M14
Maximo®	Maximo® Application Suite

Microsoft®	Microsoft Company
N/A	not applicable
NAVFAC	Naval Facilities Engineering Systems Command
Navy	United States Navy
NFESC	Naval Facilities Engineering Service Center
no.	number
OPNAV	Office of the Chief of Naval Operations
PAC	Pacific
POU	point of use
PVB	pressure vacuum breaker
PVC	polyvinyl chloride
PWC	Public Works Center
PWS	public water system
RP	reduced pressure zone assembly
SDWA	Safe Drinking Water Act
SDWB	Safe Drinking Water Branch
SEAL	Sea, Air, and Land Team
SOW	statement of work
SUBASE	Submarine Base
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
UPC	*2018 Uniform Plumbing Code*
US	United States
USC	University of Southern California
USMC	United States Marine Corps
USPACFLT	United States Pacific Fleet

EXECUTIVE SUMMARY

The Joint Base Pearl Harbor-Hickam (JBPHH) water system is a public water system (PWS). As such, it must comply with the Safe Drinking Water Act (SDWA) promulgated by the United States (US) Environmental Protection Agency (EPA) and enforced via primacy by the Hawaii Department of Health (DOH) Safe Drinking Water Branch (SDWB). Cross-connection control (CCC) and backflow prevention (BFP) (CCC/BFP) is a vital program that serves to protect the drinking water distribution system from the introduction of pollutants and/or contaminants through cross-connections.

Regulations that apply to JBPHH include, but are not limited to, the following:

- The Hawaii DOH SDWB adopted Hawaii Administrative Rules (HAR), Title 11, Chapter 21 (*Cross-Connection and Backflow Control*) on 26 December 1981.
- The Office of the Chief of Naval Operations (OPNAV) *Environmental Readiness Program Manual* (M-5090.1, 25 June 2021) requires that US Navy (Navy) drinking water systems be constructed, operated, and maintained to comply with SDWA standards, including implementation of a CCC/BFP program per Paragraph 21-3.10.b.

Furthermore, the Navy has issued guidance concerning implementing and conducting CCC/BFP programs:

- Naval Facilities Engineering Systems Command (NAVFAC) Headquarters (HQ)'s *Cross-Connection and Backflow Prevention* (Business Management System [BMS] B-24.10, 19 April 2022)
- The Naval Facilities Engineering Service Center (NFESC)'s *Cross-Connection Control and Backflow Prevention Program Implementation at Navy Shore Facilities* (UG-2029-ENV, May 1998)

AH/BC Navy JV, LLC (AH/BC) conducted a containment-level CCC/BFP survey of facilities at JBPHH in accordance with the statement of work (SOW) and facility and BFP device inventories provided by JBPHH personnel. A containment-level survey focuses on protection of the entire public water distribution system at JBPHH against contamination emanating from within a facility. Main use, fire protection, and irrigation were the most common facility service connections at JBPHH associated with this approach. This survey did **NOT** involve isolation protection, which focuses on protection of the occupants/users within a facility from cross-connections inside that facility.

AH/BC personnel collected the audit information presented in this report and conducted field surveys from 7 February to 5 August 2022. The survey encompassed 1,703 facilities. Survey personnel identified potential cross-connections and inventoried BFP devices as required by UG-2029-ENV. This report summarizes the results of these surveys and provides recommendations for corrective actions to (1) address unprotected and under-protected high and low hazard connections to the water system; (2) bring the existing devices into compliance with all federal, state, and local requirements; and (3) encourage JBPHH to adopt practices and conduct follow-up surveys to further ensure safe drinking water. AH/BC entered the collected device information into a Microsoft Company (Microsoft®) Access® database that exports the data into a formatted Microsoft® Excel® inventory to be integrated into an existing inventory stored in an International Business Machines Corporation (IBM®) Maximo® Application Suite (Maximo®) database.

This report prioritizes recommendations for cross-connection corrective actions into five groups. Priority Groups 1 through 3 are from the highest to lowest water service hazards. Priority Group 4 focuses on reinstalling, removing, relocating, documenting, and/or replacing BFP devices to meet manufacturer and/or regulatory requirements. Priority Group 5 includes repairing defective and/or leaking devices and removing unneeded devices where overprotection/redundancy is identified. The five groups are further summarized as follows:

- **Priority Group 1:** Install BFP devices on unprotected high hazard service connections.
- **Priority Group 2:** Install BFP devices on under-protected and improperly protected high hazard service connections.
- **Priority Group 3:** Install BFP devices on under-protected and unprotected low hazard service connections.
- **Priority Group 4:** Relocate, replace, or modify BFP devices according to federal, state, and/or local code.
- **Priority Group 5:** Remove, replace, or repair abandoned, leaking, damaged, and/or redundant BFP devices.

Table ES-1 summarizes the total findings at JBPHH for each of these groups.

Table ES-1 Summary of Survey Findings

Hazard/BFP Device Finding	Total
Unprotected High Hazards (Priority Group 1)	[redacted]
Under-Protected High Hazards (Priority Group 2)	[redacted]
Unprotected Low Hazards (Priority Group 3)	399
Total Unprotected and Under-Protected Hazards (Priority Groups 1 to 3)	[redacted]
Inappropriately Installed BFP Devices (Priority Group 4)	211
Damaged and/or Unnecessary BFP Devices (Priority Group 5)	151

Table ES-2 summarizes all existing BFP devices encountered during this survey, organized by device type.

Table ES-2 Summary of Existing Backflow Prevention Devices

BFP Device Name	BFP Device Acronym	Applicable Standard(s)*	Survey Database Count
Air Gap	AG	American Society of Mechanical Engineers (ASME) A112.1.2	7
Reduced Pressure Zone Assembly	RP	American Society of Sanitary Engineering (ASSE) 1013 American Water Works Association (AWWA) C511	1,855
Pressure Vacuum Breaker	PVB	ASSE 1020	222
Double Check Valve Assembly	DCVA	ASSE 1015 AWWA C510	573
Double Check Valve Detector Assembly	DCDA	ASSE 1048	24
Atmospheric Vacuum Breaker	AVB	ASSE 1001	644
Hose Bibb Vacuum Breaker	HBVB	ASME A112.21.3 ASSE 1011	1
Total			**3,326**

* Per Table 603.2 of the International Association of Plumbing and Mechanical Officials (IAPMO) *2018 Uniform Plumbing Code* (UPC) and Table 608.1 of the *2021 International Plumbing Code* (IPC) (excluding Canadian Standards Association)

Table ES-3 summarizes proposed new BFP devices for existing or potential cross-connections discovered during the CCC/BFP survey, organized by device type. The majority of these proposed devices are testable devices.

Table ES-3 Summary of Proposed Backflow Prevention Devices

BFP Device Name	BFP Device Acronym	Applicable Standard(s)*	Survey Findings
Air Gap	AG	ASME A112.1.2	[redacted]
Reduced Pressure Zone Assembly	RP	ASSE 1013 AWWA C511	[redacted]
Pressure Vacuum Breaker	PVB	ASSE 1020	[redacted]
Double Check Valve Assembly	DCVA	ASSE 1015 AWWA C510	[redacted]
Hose Bibb Vacuum Breaker	HBVB	ASME A112.21.3 ASSE 1011	[redacted]
Other**	Not Applicable (N/A)		[redacted]
Total			[redacted]

* Per Table 603.2 of the IAPMO UPC and Table 608.1 of the IPC (excluding Canadian Standards Association)

** Relocation of existing BFP device to where it protects entire facility plumbing system instead of partial

The following recommendations are made to implement an effective CCC/BFP program at JBPHH that complies with HAR (Title 11, Chapter 21):

- Develop a written instruction that comprises the CCC/BFP program policies and clearly defines the roles and responsibilities to govern and sustain the program. This instruction should apply to all CCC/BFP assets operated and maintained by JBPHH in Navy, US Air Force (Air Force) (active duty and reserve), Hawaii Air National Guard, and US Marine Corps (USMC) facilities.
- Assign a local CCC/BFP program manager who will administer the program base-wide and have access to all BFP devices, regardless of their location.
- Maintain a list of certified testers/inspectors.
- Review plans and specifications for impending projects that contain changes or new connections to the JBPHH system.
- Inspect and test all BFP devices at least once annually.
- Survey the entire JBPHH system for new cross-connections every five years.
- Maintain an accurate inventory of existing BFP devices and inspection/field test reports for at least five years.

- Develop a public education and outreach initiative to inform customers of the dangers and risks posed by cross-connections.

To ensure the program aligns with Navy policy, including BMS B-24.10, the following is required:

- Inspect and test all BFP devices installed at high hazard locations every six months.
- Maintain the inventory for all BFP devices in one location for JBPHH (i.e., Maximo®). Update the inventory of BFP devices with the findings from this survey.
- Geographic information system (GIS) is a complementary tool that can be used to help manage the CCC/BFP program (e.g., locate BFP devices in the field and plan out routes for testing). Reaping the full benefit of GIS use requires improved coordination between the GIS and Maximo® databases (including updates based on the findings from this survey). When combined for this survey, approximately one-third of the total device entries could be linked to both databases. It is critical to maintain one complete master database using Maximo®. Meanwhile, the GIS database is a tool which can be used to pinpoint the location of existing devices; however, it can only be effective if all entries are linked to entries in the Maximo® database.

Based on the results of the field survey for this project, AH/BC recommends the following additional items:

- Tag all BFP devices installed in the field to identify their unique asset number (no.), manufacturer, model no., serial no., size, and type. Use of metal "dog tags" is highly recommended.
- Whenever a BFP device is replaced, provide a new asset no. instead of keeping the asset no. of the previous device. This is crucial if asset nos. (instead of serial nos.) will be the main identifiers of devices. If multiple devices share an asset no., it is difficult to establish a proper tracking history of each unique device (Process Step 5 of BMS B-24.10 requires records to be maintain for a minimum of 5 years).
- Install PVBs at all future irrigation systems. They are testable devices (compliant with the University of Southern California [USC] Foundation for Cross-Connection Control and Hydraulic Research [FCCCHR]) and are less expensive to install and maintain than RPs.
- Fire suppression water storage tanks located on or near the Hickam Air Force Base (AFB) flight line (identified via GIS as demolished Structure 84310H at Building 1052H and Structure Primary Key Identifiers S-3163 and S-3164 at Building 2127H) were supplied with AGs to separate the fire suppression systems from the potable water system. Install proper fall protection on the storage tanks to enable routine inspection of the AGs.
- Establish a uniform color code to paint all devices:

- Main service (i.e., drinking water): Blue
- Freshwater fire system: Red
- Saltwater fire system: Red with black stripes

AH/BC developed cost estimates for the corrective actions required to address the findings summarized in Table ES-2; these are summarized by Priority Group in Table ES-4 below. Based on the no. of devices and total cost estimates, the areas of Hickam, Shipyard, and SUBASE are identified as the most concerning (see Table 5-6).

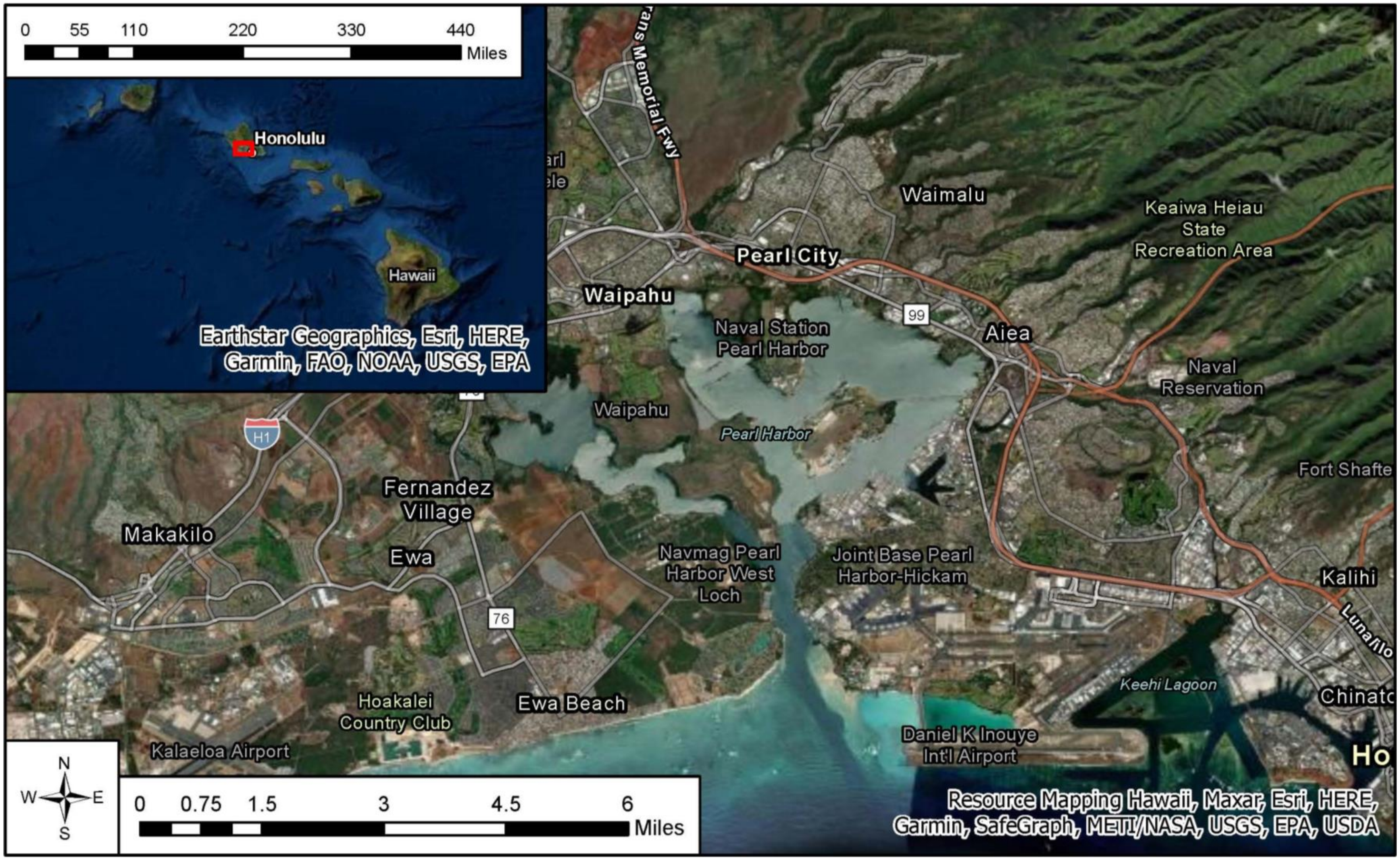
Table ES-4 Summary of Corrective Action Cost Estimates

Priority Group	Total
1	$[redacted]
2	$[redacted]
3	$5,211,870
4	$86,440
5	$177,350
Total	**$[redacted]**

1. INTRODUCTION

Joint Base Pearl Harbor-Hickam (JBPHH) is a United States (US) military installation situated along the shoreline of Pearl Harbor on the island of Oahu, Hawaii, approximately 6 miles northwest of Honolulu (see Figure 1-1). This joint installation was established following the integration of Naval Station Pearl Harbor with Hickam Air Force Base (AFB) on 1 October 2010. JBPHH's mission is "to enable maximum mission readiness of [its] tenant commands and activities by providing the highest quality installation services, facilities support and quality of life programs." It has a total population of over 107,000 and hosts more than 270 tenants including commanders of the US Pacific Fleet (USPACFLT); Submarine Force, USPACFLT; US Navy (Navy) Region Hawaii; Naval Surface Group, Middle Pacific; and Naval Facilities Engineering Systems Command (NAVFAC) Pacific (PAC) (Commander, Navy Region Hawaii, https://cnrh.cnic.navy.mil/Installations/JB-Pearl-Harbor-Hickam/About/).

Figure 1-1 Location and Vicinity Maps



1.1 BACKGROUND

JBPHH owns and operates a drinking water system that serves approximately 70,000 people at the main installation, US Marine Corps (USMC) Base Hawaii Camp H. M. Smith (Camp Smith), and a consecutive system owned and operated by the US Army (Army). It is identified as a public water system (PWS) that requires regulation under the following:

- The Safe Drinking Water Act (SDWA), a federal law that authorizes the US Environmental Protect Agency (EPA) to establish minimum drinking water standards, requires that each federal activity with jurisdiction over a PWS comply with applicable federal, state, and/or local requirements, whether substantive or administrative. The SDWA and requirements specified in the *National Primary Drinking Water Regulations* and *Other Safe Drinking Water Act Regulations* (Code of Federal Regulations [CFR], Title 40, Parts 141 and 143, respectively) are designed to ensure that every user of a PWS receives water that is safe to consume.
- The EPA has delegated primacy for implementing and enforcing the SDWA to the Hawaii Department of Health (DOH) Safe Drinking Water Branch (SDWB); which established Hawaii Administrative Rules (HAR); Title 11; Chapters 19 to 21, 23, 25, and 65; to identify regulations that PWSs and other drinking water-related entities must follow. The Hawaii DOH SDWB identifies the JBPHH system under PWS Number (No.) 360 (Hawaii DOH SDWB, https://health.hawaii.gov/sdwb/files/2022/02/RegulatedPWSHawaii.20220208.pdf).
- The Office of the Chief of Naval Operations (OPNAV) *Environmental Readiness Program Manual* (M-5090.1, 25 June 2021) requires that Navy drinking water systems be constructed, operated, and maintained to comply with SDWA standards. Additional US Department of Defense (DOD) guidelines are discussed in Section 2.

1.2 OBJECTIVE

The objective of this project was to conduct a cross-connection control (CCC) and backflow prevention (BFP) (CCC/BFP) survey of the drinking water distribution system at both the main JBPHH installation and outlying areas. The survey will assist JBPHH with maintaining a CCC/BFP program in alignment with Hawaii DOH SDWB requirements (specifically under HAR, Title 11, Chapter 21) and OPNAV M-5090.1 (2021), which states that all Navy installations that own or operate a PWS shall develop and implement a CCC/BFP program (Paragraph 21-3.10.b, 25 June 2021). NAVFAC

PAC contracted AH/BC Navy JV, LLC (AH/BC) to perform this work under Contract No. N62470-19-D-4001, Task Order No. N6274222F0110.

The statement of work (SOW), dated 29 December 2021, specified that this survey primarily covered facilities served by the JBPHH system and sourced from the system's Waiawa, Halawa, and Red Hill shaft water sources (largely based on provided inventories of facilities and BFP devices, dated 17 and 29 December 2021, respectively). Main service lines to individual family housing units were not considered part of this project scope. It is assumed that construction of these private residences followed state codes, including BFP of plumbing. Inspections in housing areas mainly focused on fire service (if present), non-housing facilities, and irrigation. In addition, the SOW clarified that this survey covers the water systems of additional facilities at and associated with Camp Smith, which are owned and operated by JBPHH. An Army housing area, located southwest of the Red Hill shaft, receives water from the JBPHH but is a consecutive system owned and operated by the Army. This survey covered only the two interconnections to this area. In total, 1,703 facilities were identified as served by the JBPHH system and surveyed as part of this project.

In accordance with the SOW, the focus of this survey was "utility-level," otherwise known as ***containment*** protection (or ***service*** protection by the University of Southern California [USC] Foundation for CCC and Hydraulic Research [FCCCHR]). This type of survey focuses on protection of the main water distribution system at-large against contamination emanating from within a facility. This is primarily achieved by protecting service lines to facilities (e.g., main use, fire protection, irrigation) based on the degree of hazard corresponding to the water use of the entire facility. This survey did **NOT** involve ***isolation*** protection (also called ***internal*** protection by the USC FCCCHR), which focuses on protection of the occupants/users within a facility against contamination within that facility. Isolation protection is primarily achieved by protecting points of use (POUs) throughout the facility based on the degree of hazard corresponding to the water use at each POU. See the Naval Facilities Engineering Service Center's (NFESC's) *Cross-Connection Control and Backflow Prevention Program Implementation at Navy Shore Facilities* (UG-2029-ENV, May 1998) for further details on these protection strategies.

Using industry-established and best management practices, AH/BC personnel identified cross-connections at JBPHH where BFP devices did not exist. For each of these cross-connections, AH/BC documented the degree of hazard posed, the reason the cross-connection existed, and whether or not it could be eliminated. If it could not be eliminated, AH/BC also provided a recommendation for the proper type of device to install to mitigate the hazard. Recommendations were also provided for removal of unnecessary or redundant devices. An inspection checklist was completed for each device documenting the type, location, current status, proposed inspection frequency, serial no., model no., and pipe size and material. AH/BC entered the collected device information into a Microsoft Company (Microsoft®) Access® database that exports the data into a formatted Microsoft® Excel® inventory to be integrated by NAVFAC PAC and/or JBPHH personnel into an existing inventory stored in an International Business Machines Corporation (IBM®) Maximo® Application Suite (Maximo®) database.

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2. REGULATIONS

Federal, state, and local regulations, rules, and codes and Navy policies, criteria, and guidance establish BFP requirements for Navy activities. The SDWA of 1974 and the SDWA Amendments of 1986 and 1996 are the basis of the federal regulations. OPNAV M-5090.1 (2021) requires that Navy drinking water supplies be constructed, operated, and maintained to comply with SDWA standards. The regulatory basis (requirements) and guidance for the JBPHH CCC/BFP survey and program are listed below:

State and Local Requirements and Guidelines:

- HAR, *Rules Relating to Public Water Systems*, Title 11, Chapter 20
- HAR, *Cross-Connection and Backflow Control*, Title 11, Chapter 21
- HAR, *Hawaii State Plumbing Code*, Title 3, Chapter 183
  - Adopted a revised version of the International Association of Plumbing and Mechanical Officials (IAPMO) *2018 Uniform Plumbing Code* (UPC)

Federal and DOD Requirements and Guidelines:

- SDWA (1996)
- CFR, *National Primary Drinking Water Regulations*, Title 40, Part 141
- CFR, *National Primary Drinking Water Regulations Implementation*, Title 40, Part 142
- CFR, *Other Safe Drinking Water Act Regulations*, Title 40, Part 143
- EPA, *Cross-Connection Control Manual*, EPA 816-R-03-002, February 2003
- International Code Council, *2021 International Building Code* (IBC), September 2021
- International Code Council, *2021 International Plumbing Code* (IPC), September 2021
- American Society of Sanitary Engineering (ASSE), *Guide to Cross-Connection Protection Devices and Assemblies – Application and Selection*, 2018 (3rd Edition)
- ASSE, *Cross-Connection Control Professional Qualifications Standard*, Series 5000, March 2022
- NFESC, *Cross-Connection Control and Backflow Prevention Program Implementation at Navy Shore Facilities*, UG-2029-ENV, May 1998

- USC FCCCHR, *Manual of Cross-Connection Control*, October 2009 (10th Edition)
- USC FCCCHR, *List of Approved Backflow Prevention Assemblies*, 6 September 2022
- American Water Works Association (AWWA), *Backflow Prevention and Cross-Connection Control: Recommended Practices*, Manual of Water Supply Practices M14 (M14), 2015 (4th Edition)
- American Society of Mechanical Engineers (ASME), *Plumbing Supply Fittings*, ASME A112.18.1, October 2018
- NAVFAC Headquarters (HQ), *Cross-Connection and Backflow Prevention*, Business Management System (BMS) B-24.10, 19 April 2022
- OPNAV, *Environmental Readiness Program Manual*, OPNAV M-5090.1, 25 June 2021
- DOD, *Plumbing, General Purpose*. Unified Facilities Guide Specifications (UFGS) 22 00 00, May 2021 (Change 4)
- DOD, *DOD Building Code*, Unified Facilities Criteria (UFC) 1-200-01, 1 September 2022
- DOD, *Operation and Maintenance: Water Supply Systems*, UFC 3-230-02, 1 April 2021 (Change 1)

Many PWSs require users to have BFPs at (typically metered) service connections and an internal CCC program. An internal CCC program protects not only the public water distribution from actual or potential contamination hazards but also the water users at that location; however, it can be compromised without the knowledge of the PWS, which is one reason a PWS may require both. As stated previously, the focus of this CCC/BFP survey for JBPHH was on *containment* protection related to service connections to facilities. A survey focused on *isolation* protection should also be conducted in the near future.

Per the SDWA, individual states are responsible for the enforcement of national CCC/BFP standards established by the EPA and supervision of PWSs. Water purveyors are responsible for guaranteeing that provided water quality meets these standards at the source and throughout their distribution systems.

Hawaii's CCC/BFP regulations (HAR, Title 11, Chapter 21), initially adopted on 4 November 1948 and revised on 26 December 1981, serve to (1) protect the PWS from possible contamination caused by backflow (backpressure or backsiphonage), (2) promote CCC or elimination, both actual or potential, and (3) provide for the maintenance of a continuing CCC/BFP program that will effectively prevent contamination of all PWSs. They are included in Appendix A.

The Hawaii DOH SDWB has specifically identified the following as key components of an effective CCC/BFP program (Miyahira, 1996):

- An inventory of BFP devices, including details on location/address, manufacturer, model no., and installation date
- Annual BFP device test records
- A list of certified testers
- Educational materials for consumers, updated at least annually
- Adequate access to all BFP devices for inspection, testing, maintenance, and replacement

UFGS specify construction requirements for military services. The specification for *Plumbing, General* Purpose (Division 22, Section 22 00 00, May 2021 [Change 4]) essentially implements the requirements of the IPC. Part 2 of this specification provides the technical requirements for BFP devices, piping materials, and plumbing fixtures, including lead content requirements. In addition, UFC 1-200-01 and UFC 3-230-02 require permanent DOD facilities to follow the IBC and IPC with noted modifications.

UG-2029-ENV provides information for Navy activities regarding preparation and implementation of CCC/BFP programs. This document provides technical guidance; establishes administrative authority; delineates the responsibilities of personnel; and outlines requirements for surveys, approved equipment, recordkeeping, testing, inspection, training, and certification. Within this guidance document, the Navy references AWWA M14 and the USC FCCCHR's *Manual of Cross-Connection Control* for specific backflow installation, operation, and maintenance requirements.

Table 2-1 compares hazard classifications for water system cross-connections identified in AWWA M14, the USC FCCCHR, and the HAR (Title 21, Chapter 21). The definitions closely compare and require no adjustments for existing BFP device installations due to conflicting definitions. While the HAR does not explicitly define a non-health hazard, it can be reasoned to mean any cross-connection that doesn't meet its definition of a health hazard.

Table 2-1 Definitions of Degrees of Hazard

Hazard Terms	Definitions		
	AWWA M14	**USC FCCCHR**	**HAR (Title 21, Chapter 21)**
High Health/ Health/ Contaminant	A cross-connection or potential cross-connection involving any substance that could, if introduced into the potable water supply, cause death or illness, spread disease, or have a high probability of causing such effects Substance Example: Any one of the National Primary Drinking Water Standards	Any substance that shall impair the quality of water, in such a way as to create an actual hazard to the public health through poisoning, the spread of disease, etc.	Any condition, device, or practice in the water supply system and its operation which creates, or in the judgment of the Director of Health of the State of Hawaii Department of Health (Director) may create, a danger to the health and well-being of the water consumer Example: A structural defect in the water supply system, whether of location, design, or construction, that regularly or occasionally may prevent satisfactory purification of the water supply or cause it to be polluted from extraneous sources
Low Health/ Non-Health/ Pollutant	A cross-connection or potential cross-connection involving any contaminant that if introduced into the potable water system as a result of a backflow situation may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water	An impairment of the quality of the water to a degree which does not create a hazard to the public health but which does adversely and unreasonably affect the aesthetic qualities of such waters for domestic use	None

Table 603.2 of the IAPMO UPC, adopted as the *Hawaii State Plumbing Code* (HAR Title 3, Chapter 183) with minor modifications, and Table 608.1 of the IPC, adopted by the DOD with minor modifications per UFC 1-200-01 and UFC 3-230-02, list air gaps (AGs), reduced pressure zone assemblies (RPs), pressure vacuum breakers (PVBs), double check valve assemblies (DCVAs), double check valve detector assemblies (DCDAs), atmospheric vacuum breakers (AVBs), and hose bibb vacuum breakers (HBVBs), among others, as approved BFP devices for low hazard applications. Of these devices, only DCVAs and DCDAs are not approved for high hazard applications. These devices and hazards are discussed further in Sections 3.3 to 3.5.

2.1 OPERATOR CERTIFICATION AND BACKFLOW PREVENTION DEVICE TESTING

The JBPHH drinking water system is regulated by the state under the SDWA and, as such, is required to comply with all state and local CCC/BFP requirements as well as federal and DOD policy requirements for maintenance and testing of BFP devices.

Section 11-21-8 of the HAR lists the following requirements for BFP device maintenance and testing:

- The water user is responsible for the maintenance of all BFP devices on their premise(s). No bypassing of devices is permitted.
- Periodic testing of BFP devices and inspection schedules shall be established by the Director and are not to exceed 1 year. Newly-installed devices should be inspected frequently after initial installation to ensure that the installation did not compromise the device. Inspection and testing shall be performed by certified testers approved by the Director. Records of tests, repairs, and overhauls shall be maintained and made available upon request by the Director. If the water user fails to properly test their device(s) and/or maintain proper records, the Director may perform the necessary testing, repairs, and/or replacement and charge the user for these services.

Process Step 4 of BMS B-24.10 requires BFP devices protecting high hazards to be tested every 6 months, at a minimum, and non-testable BFP devices (e.g., AVBs) to be replaced every 5 years.

UFC 3-230-02 requires new BFP device inspections to be conducted by a certified backflow inspector or qualified installation personnel to ensure the following:

- Approved AGs are maintained
- The BFP device is in good condition
- The BFP device is properly installed and debris from the installation does not interfere with functioning of the device (inspection to be completed within 1 week after acceptance and 3 months after installation)

A BFP device must pass certification requirements by a certified tester before water service is turned on.

OPNAV M-5090.1 (2021) requires Navy installations to establish and implement a CCC/BFP program that includes, at a minimum, procedures and mechanisms to accomplish the following:

- Find and eliminate existing cross-connections by conducting CCC surveys of all facilities at least every 5 years, and prevent new cross-connections
- Install, inspect, and test BFP devices when cross-connections cannot be eliminated or as required by state or local regulations
- Keep an inventory of all existing BFP devices, including the degree of hazard and hydraulic condition against which the device provides protection (backsiphonage or backpressure)
- Certify all BFP devices as required by the regulatory agency
  - If there is no regulatory requirement, all BFP devices should be certified at least once every 6 months for high hazards and once every 12 months for low hazards by a state or local water authority certified tester

Promptly repair or replace defective BFP devices, and retain cross-connection and inspection and maintenance records for at least 5 years.

The USC FCCCHR's *Manual of Cross-Connection Control* notes that records must contain specific information that is detailed enough to support the actions of the administrative authority (e.g., the PWS) and be defensible.

3. METHODOLOGY

3.1 SITE AUDIT AND DATA COLLECTION

AH/BC personnel collected the audit information presented in this report and conducted field surveys from 7 February to 5 August 2022. Prior to arriving at JBPHH, AH/BC prepared a schedule for surveying facilities using geographic information system (GIS) mapping. AH/BC surveyed each water service connection to identify existing BFP devices and under-protected/unprotected cross-connections. The survey included inspection of exterior water service lines, associated vaults, mechanical rooms, and exposed interior water piping, where necessary.

Each AH/BC survey team included two members with at least one member having successfully completed a certified CCC/BFP training program. Each team took field notes, completed inspection reports, and photographed existing BFP devices and cross-connection deficiencies, where permitted. The Microsoft® Excel® database deliverable ultimately incorporates all this information.

Each survey team performed the following tasks, based on UG-2029-ENV and BMS B-24.10 and modified to conform with the requirements of the SOW (i.e., containment):

- Reviewed relevant installation and facility maps and existing IBM® Maximo® database entries prior to the audit to gain familiarity with the installation
- Traced water piping systems in and throughout each facility, when necessary, to verify the presence of internal BFP devices on service lines where external BFP devices were not identified
- Identified external non-potable water systems, uses, equipment, and fixtures
- Identified existing and potential interconnections (cross-connections) between the JBPHH distribution system and external non-potable systems, equipment, and fixtures
- Determined the risk (e.g., degree of hazard) of each cross-connection or the non-potable water use presented to the JBPHH distribution system in the event backflow should occur
- Selected the particular type of BFP device required to properly protect the JBPHH distribution system from existing or potential hazards

- Identified previously-installed BFP devices and inspected those devices for adequacy according to the potential class/degree of hazard and compliance with regulations, plumbing codes, standards, and technical guidelines
- Inspected all existing BFP devices for any visible malfunctions and discrepancies (e.g., leakage, mislabeling)

Each survey team collected and recorded the following information for each containment-level BFP device:

- Asset no. (assigned internally by JBPHH)
- Facility no.
- BFP device location (e.g., inside/room, outside, nearby features)
- Service type (e.g., main, fire protection, irrigation)
- Tag/plate condition
- Pipe material
- BFP device type (e.g., AVB, DCVA, PVB, RP)
- BFP device manufacturer
- BFP device model no.
- BFP device serial no.
- BFP device size (i.e., pipe diameter)
- Degree of hazard

3.2 DATABASE

The existing IBM® Maximo® database used for JBPHH is designed with the capability to store specified information on BFP devices and facility/operational considerations. AH/BC entered all devices identified in the survey into a Microsoft® Access® database along with identified under-protected/unprotected cross-connections requiring improvements. This data was ultimately formatted into a Microsoft® Excel® inventory to be integrated into the existing JBPHH Maximo® database. Quality assurance/quality control review of the database included a comparison of the information from the field test reports and the data collected in the field survey to identify data gaps. AH/BC investigated and resolved/corrected any identified conflicts and/or discrepancies as needed.

3.3 BACKFLOW PREVENTION DEVICE DESCRIPTIONS

Table 3-1 lists each type of BFP device encountered during this CCC/BFP survey. A description of each device and its usage is provided below.

Table 3-1 List of Backflow Prevention Devices

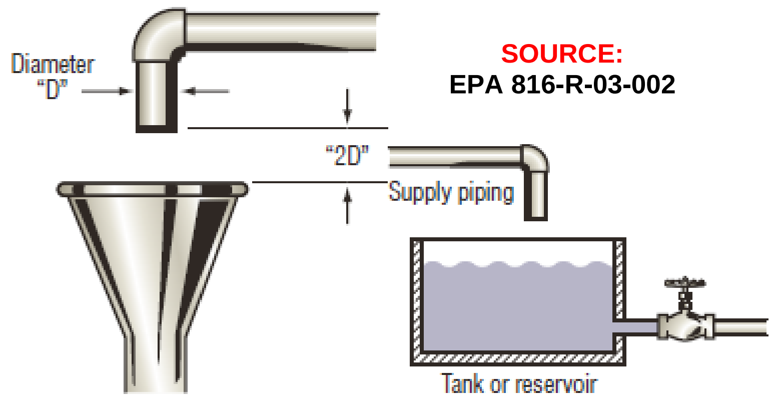
BFP Device Name	BFP Device Acronym	Applicable Standard(s)*
Air Gap	AG	ASME A112.1.2
Reduced Pressure Zone Assembly	RP	ASSE 1013 AWWA C511
Pressure Vacuum Breaker	PVB	ASSE 1020
Double Check Valve Assembly	DCVA	ASSE 1015 AWWA C510
Double Check Valve Detector Assembly	DCDA	ASSE 1048
Atmospheric Vacuum Breaker	AVB	ASSE 1001
Hose Bibb Vacuum Breaker	HBVB	ASME A112.21.3 ASSE 1011

* Per Table 603.2 of the IAPMO UPC and Table 608.1 of the IPC (excluding Canadian Standards Association)

3.3.1 Air Gaps

AGs (ASME A112.1.2) are unobstructed vertical distances through the free atmosphere between the lowest opening of a supply pipe to the flood level rim of the receiving receptacle. The AG distance should be at least twice the effective diameter of the supply pipe but not less than 1 inch ("). Figure 3-1 shows examples of AGs.

Figure 3-1 Air Gaps

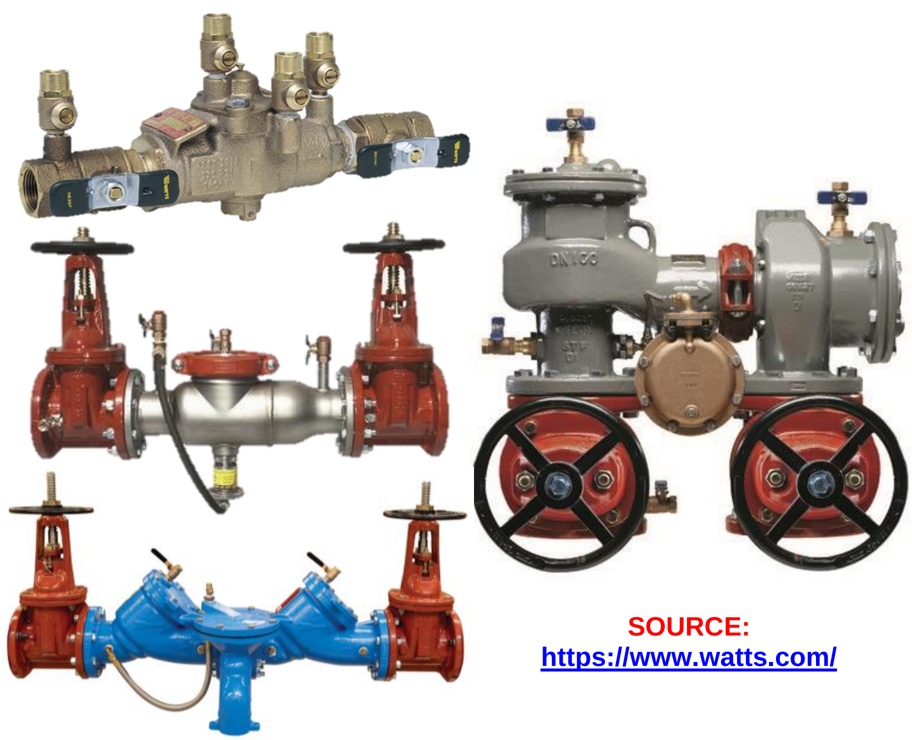


SOURCE:
EPA 816-R-03-002

3.3.2 Reduced Pressure Zone Assemblies

RPs (ASSE 1013/AWWA C511) consist of two independently-acting check valves force-loaded closed and separated by an intermediate chamber and four test cocks. The intermediate chamber has a hydraulically-operated relief valve for venting. Figure 3-2 shows examples of RPs.

Figure 3-2 Reduced Pressure Zone Assemblies



SOURCE:
https://www.watts.com/

3.3.3 Pressure Vacuum Breakers

PVBs (ASSE 1020) are BFP devices that contain an independently-acting check valve force-loaded to the closed position, an independently-acting air inlet valve located downstream of the check valve that is force-loaded to the open position, and two test cocks. Figure 3-3 shows an example of a PVB.

Figure 3-3 Pressure Vacuum Breaker

SOURCE:
https://www.zurn.com/

3.3.4 Double Check Valve Assemblies

DCVAs (ASSE 1015/AWWA C510) consist of two independently-acting check valves force-loaded closed, two tightly closing shutoff (isolation) valves, and four test cocks. Figure 3-4 shows examples of DCVAs.

Figure 3-4 Double Check Valve Assemblies

SOURCE:
https://www.watts.com/

3.3.5 Double Check Valve Detector Assemblies

DCDAs (ASSE 1048) consist of two independently-acting check valves force-loaded closed, two tightly closing shutoff (isolation) valves, and four test cocks (same as DCVAs). The assemblies also include a bypass line that provides a visual or audible indication of system leakage or unauthorized use of water. Figure 3-5 shows examples of DCDAs.

Figure 3-5 Double Check Valve Detector Assemblies

3.3.6 Atmospheric Vacuum Breakers

AVBs (ASSE 1001) consist of an air inlet valve to prevent the backsiphonage of contaminants or pollutants into the potable water system. These BFP devices cannot be subjected to any type of backpressure and are typically limited to isolation application only (included in this report due to being encountered during this containment survey). Figure 3-6 shows examples of AVBs.

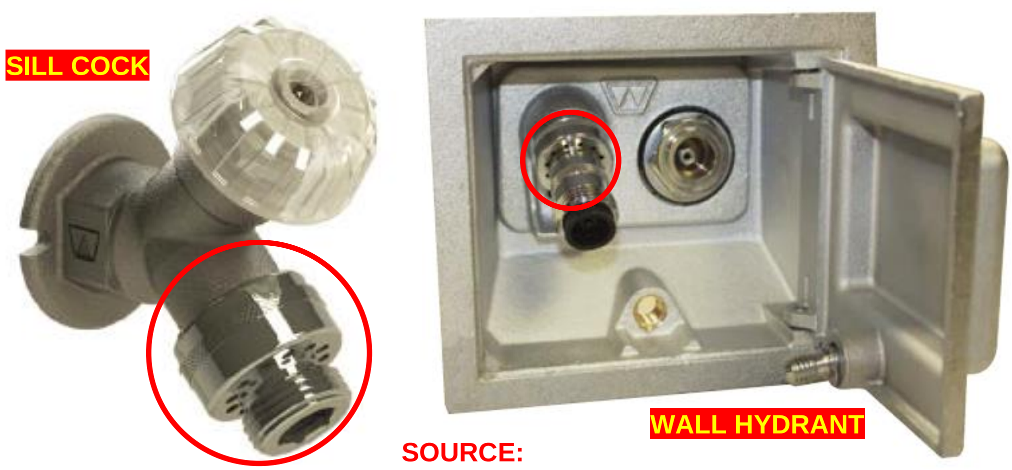
Figure 3-6 Atmospheric Vacuum Breakers

SOURCES:
https://www.watts.com/
https://www.zurn.com/

3.3.7 Hose Bibb Vacuum Breakers

HBVBs (ASME A112.21.3/ASSE 1011) are vacuum breakers mounted on freeze resistant, automatic draining-type hose connections. The BFP device is installed downstream of the last control valve and can be either a wall hydrant or sill cock that contains the integral vacuum breaker component. These devices cannot be subjected to any type of backpressure and are typically limited to isolation application only (included in this report due to being encountered in select cases during this containment survey). Figure 3-7 shows examples of HBVBs.

Figure 3-7 Hose Bibb Vacuum Breakers



SOURCE:
https://www.woodfordmfg.com/

3.4 HAZARD RANKING RATIONALE

Each drinking water cross-connection must be characterized as either a high hazard or low hazard to determine appropriate protection. As defined by the USC FCCCHR, high hazard cross-connections present the potential to allow the introduction of a contaminant that could cause illness or death if consumed by humans. The contaminant may be toxic to humans from a chemical, bacteriological, or radiological standpoint. Low hazard cross-connections may adversely affect aesthetic quality, such as taste, odor, or color, through the introduction of a pollutant and must be non-toxic and non-bacterial in nature with no significant health effect. Hazard ranking is critical to the selection of appropriate BFP devices because some types of devices are only rated to protect against low hazards, while other devices provide adequate protection against high hazards. Table 3-2 summarizes appropriate applications for different devices.

Table 3-2 Backflow Prevention Device Applications

BFP Device	High Hazard	Low Hazard	Backpressure	Backsiphonage	Continuous Pressure
AG	Yes	Yes	Yes	Yes	No
RP	Yes	Yes	Yes	Yes	Yes
PVB	Yes	Yes	No	Yes	Yes
DCVA	No	Yes	Yes	Yes	Yes
DCDA	No	Yes	Yes	Yes	Yes
AVB	Yes	Yes	No	Yes	No
HBVB	Yes	Yes	No	Yes	No

As shown in Table 3-2, the following are important factors in selecting appropriate BFP devices:

- RPs are the only mechanical BFP devices allowed for use in high hazard applications with backpressure.
- DCVAs and DCDAs are restricted for use in low hazard applications only.
- PVBs, AVBs, and HBVBs must not be subjected to backpressure.
- AVBs and HBVBs must not be subjected to continuous pressure.
- AVBs and HBVBs are typically limited to isolation applications as they are not testable devices. If not downstream of a testable device, installation of a testable device is recommended.

To assign hazard rankings, AH/BC developed a rationale for the identified cross-connections using a combination of available industry publications, including UG-2029-ENV, AWWA M14, the USC FCCCHR's *Manual of Cross-Connection Control*, EPA 816-R-03-002, and the ASSE's *Guide to Cross-Connection Protection Devices and Assemblies – Application and Selection*. Table 3-3 presents the hazard ranking rationale used to develop all hazard ranking recommendations in this project (containment protection only). Different backflow equipment types are rated to protect against high (health) hazards or low (non-health) hazards, backpressure or backsiphonage, or both backpressure and backsiphonage. Backpressure exists when pressure at a cross-connection exceeds the pressure within the potable water distribution system. Backsiphonage is a reversal of flow that occurs when the supply line pressure falls below atmospheric pressure. In many cases, a cross-connection can have the potential to exhibit both backpressure and backsiphonage.

Table 3-3 Assessment of Containment Hazards and Selection of Backflow Prevention Devices

Description	Assessment of Hazard	Required BFP Device(s)
Facilities		
Aircraft and Missile Plants	High	AG or RP
Barracks/Quarters	Low*	DCVA or DCDA
Commercial Car Wash Facilities	High	AG or RP
Commercial Laundry Facilities	High	AG or RP
Cold Storage Facilities	High	AG or RP
Docks and Dockside Facilities	High	AG or RP
Hospitals, Morgues, Mortuaries, Medical Clinics, Dental Clinics, Veterinary Clinics, Autopsy Facilities, Sanitariums, and Medical Laboratories	High	AG or RP
Metal Manufacturing, Cleaning, Processing, and Fabrication Plants	High	AG or RP
Offices	Low*	DCVA or DCDA
Petroleum Processing and Storage Facilities	High	AG or RP
Plating and Chemical Plants	High	AG or RP
Pleasure Boat Marinas	High	AG or RP
Private, Individual, and Unmonitored Wells	High	AG or RP

Table 3-3 Assessment of Containment Hazards and Selection of Backflow Prevention Devices (continued)

Description	Assessment of Hazard	Required BFP Device(s)
Facilities (continued)		
Rainwater Harvesting Systems	High	AG or RP
Reclaimed Water Systems	High	AG or RP
Restroom Buildings	High	AG or RP
Restricted, Classified, or Other Closed Facilities	High	AG or RP
Sewage Lift Stations	High	AG or RP
Sewage Treatment Plants	High	AG or RP
Tall Buildings or Elevation Differences Where the Highest Outlet Is 80 Feet or More Above the Water Meter	Low	DCVA or DCDA
Equipment		
Cooling Towers with Chemical Additives	High	AG or RP
Firefighting Systems (backpressure)	Low	DCVA or DCDA
Firefighting Systems (backsiphonage)	Low	DCVA or DCDA
Firefighting Systems (toxic liquid foam concentrates)	High	AG or RP
Heating Equipment	Low*	DCVA or DCDA
Hose Bibbs	Low or High	HBVB
Irrigation Systems	High	AVB**, RP, or PVB
Ornamental Fountains	High	AVB**, RP, or PVB
Swimming Pools (public)	High	AG or RP
Wash Racks	High	AG or RP

* Where a greater hazard exists (due to toxicity or other potential health impact), additional protection with an RP is required.

** While AVBs are technically applicable, they are non-testable devices and must be replaced (including proper recordkeeping of replacement) every 5 years per BMS B-24.10. They are not recommended for installation at JBPHH.

3.5 INSTALLATION REQUIREMENTS FOR BACKFLOW PREVENTION DEVICES

For proper operation, BFP devices must be installed according to specific requirements. Testable devices should be physically located where they can be safely, efficiently, and adequately tested and serviced without having to reach for the device and/or having the device obstructed by walls, equipment, or utility appurtenances. A testable device cannot be installed less than 12” or more than 60” from the floor or a permanent platform. The following sections specify the recommended practices for installing certain devices. The AH/BC survey teams used these criteria to evaluate the installation procedures for each individual device encountered.

3.5.1 Air Gaps

AGs are non-mechanical BFP devices that meet ASME A112.1.2 and are used to protect against backpressure and backsiphonage. In general, AGs must be twice the diameter of the supply pipe but never less than 1”. Industry standards recommend using AGs for swimming pool makeup water feed lines, chiller makeup water feed lines, sink faucets, drain lines from potable water-fed equipment, and water storage tanks.

3.5.2 Reduced Pressure Zone Assemblies

RPs are testable BFP devices that meet ASSE 1013/AWWA C511. These devices are used to protect against backflow, due to backpressure or backsiphonage, of pollutants and contaminants from high hazard facilities. Industry standards recommend RPs for certain facilities, such as dental and medical clinics, high-rise buildings, aircraft hangars, vehicle and aircraft maintenance shops, restaurants, water and wastewater treatment plants, and sewage pump stations. High hazard equipment includes boiler feeds, heat exchanger and chiller makeup water feeds, cooling towers, hot water re-circulation systems, humidifiers, chemical storage and feed systems, fire sprinkler systems that use chemical additives, irrigation systems, water cooled equipment, sterilizers, and other dental and medical equipment that connect to the water system. RPs are available in ¼”, ⅜”, ½”, ¾”, 1”, 1¼”, 1½”, 2”, 2½”, 3”, 4”, 6”, 8”, and 10” sizes. Lead-free models are available. Figure 3-8 illustrates examples of RPs at JBPHH with bronze, ductile iron, and stainless-steel bodies.

Figure 3-8 Reduced Pressure Zone Assembly Examples

To operate properly, RPs must be installed horizontally unless they are approved for vertical installation. The bottom of the RP should be placed with a minimum of 12” and a maximum of 36” clearance underneath the BFP device. Clearance from walls should be a minimum of 12” on both sides. A drain is required to direct the RP discharge to a floor drain. There must be an AG between the bottom of the RP relief valve and the drain or where the drain pipe discharges to the drain. RPs located in underground vaults or pits require gravity drainage to the atmosphere. Industry standards recommend installing a strainer immediately upstream of the device to prevent fouling from grit and debris in the water. In-line union fittings for services up to 2" should be used for ease of removal and reinstallation of the device. RPs should be located where they are protected from freezing and flooding. Thermal water expansion and/or water hammer downstream of the RP can cause excessive pressure. Excessive pressure should be eliminated to avoid possible damage to the device in accordance with the manufacturer's recommendations.

3.5.3 Pressure Vacuum Breakers

PVBs are testable BFP devices that meet ASSE 1020 and protect against backsiphonage of pollutants and contaminants from high and low hazard facilities. These devices can be utilized under constant pressure. Recommended uses for PVBs include industrial facilities, cooling towers, laboratories, laundry facilities, swimming pools, lawn sprinkler systems, and hot water recirculation systems. PVBs are available in ½", ¾", 1", 1¼", 1½", and 2" sizes. Lead-free models are available. Figure 3-9 illustrates an example of a PVB at JBPHH.

Figure 3-9 Pressure Vacuum Breaker Example

PVBs must be installed horizontally to operate properly. The BFP device should be placed at least 12” above the highest piping and downstream outlet elevations to preclude backpressure. PVBs should be installed where easily accessible for maintenance and testing and where the device discharge will not be objectionable.

3.5.4 Double Check Valve Assemblies

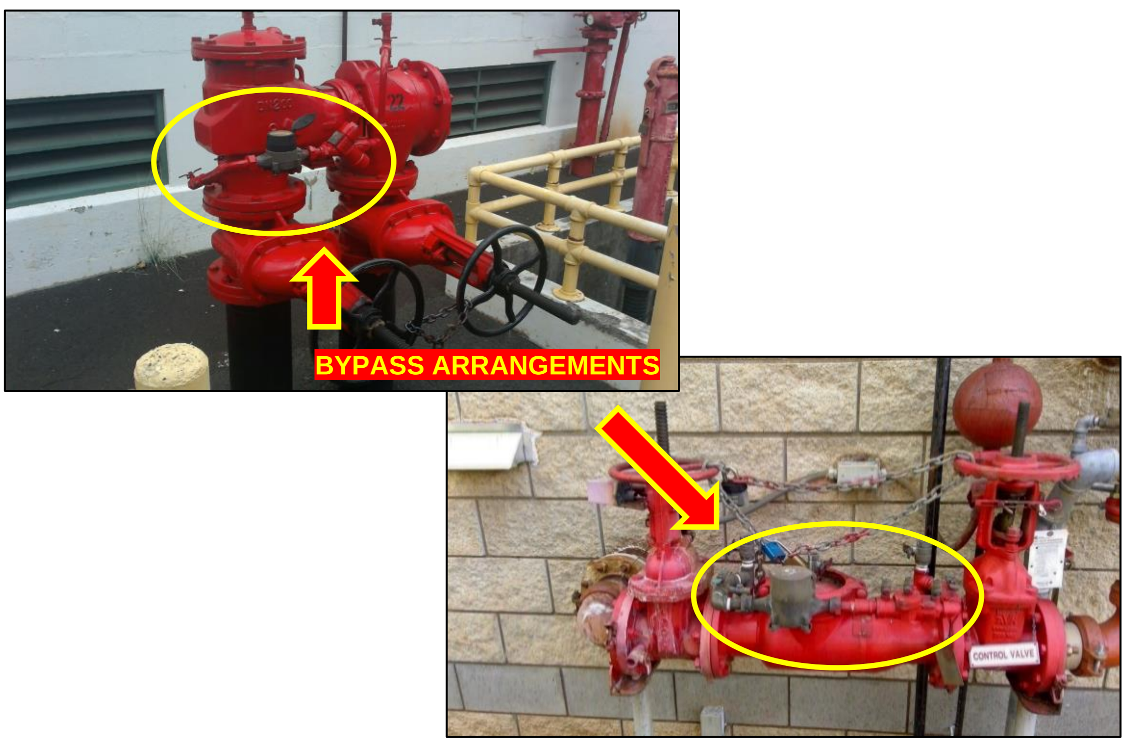
DCVAs are testable BFP devices that meet ASSE 1015/AWWA C510. These devices are used to protect against backflow, due to backpressure or backsiphonage, of pollutants and contaminants from low hazard facilities, such as office spaces and housing. They are also recommended for fire sprinkler systems that do not use chemical additives. DCVAs are available in ½”, ¾”, 1”, 1¼”, 1½”, 2”, 2½”, 3”, 4”, 6”, 8”, and 10” sizes. Lead-free models are available. Figure 3-10 illustrates examples of RPs at JBPHH with bronze, ductile iron, and stainless-steel bodies.

Figure 3-10 Double Check Valve Assembly Examples

DCVAs can be installed horizontally or vertically with the flow direction pointing up. The bottom of the DCVA should be placed with a minimum of 12” and a maximum of 30” clearance underneath the BFP device. Clearance from walls should be a minimum of 12”. Industry standards recommend installing a strainer immediately upstream of the device to prevent fouling from grit and debris in the water. In-line union fittings for services up to 2” should be used for ease of removal and reinstallation of the device. Thermal water expansion and/or water hammer downstream of the DCVA can cause excessive pressure. Excessive pressure should be eliminated to avoid possible damage to the device in accordance with the manufacturer’s recommendations.

DCDAs are BFP devices that meet ASSE 1048 and consist of a mainline DCVA with a bypass (detector) arrangement around the DCVA that contains a water meter and a second DCVA. They are designed for fire protection systems in which a mainline water meter is not used but leaks or unwanted usage need to be detected. DCDAs can protect against backpressure and/or backsiphonage and can only be used to protect both low hazard applications. Installation criteria are the same as for DCVAs. These devices operate like DCVAs, except the bypass is engineered to detect the first 2 gallons per minute (7.6 liters per minute) of flow through the assembly. This low flow is registered by the water meter in the bypass and is used to show any unauthorized usage or leakage in the system. The bypass arrangement may bypass the mainline DCVA second check valve only and contain a water meter with a single check valve. This is commonly referred to as a Type II DCDA. It provides the same level of backflow protection as a standard DCDA but uses a shared first check valve for both the mainline and bypass arrangements. Figure 3-11 illustrates examples of DCDAs at JBPHH.

Figure 3-11 Double Check Valve Detector Assembly Examples



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4. SITE SURVEY

The following section summarizes the CCC/BFP field survey, conducted from 7 February to 5 August 2022.

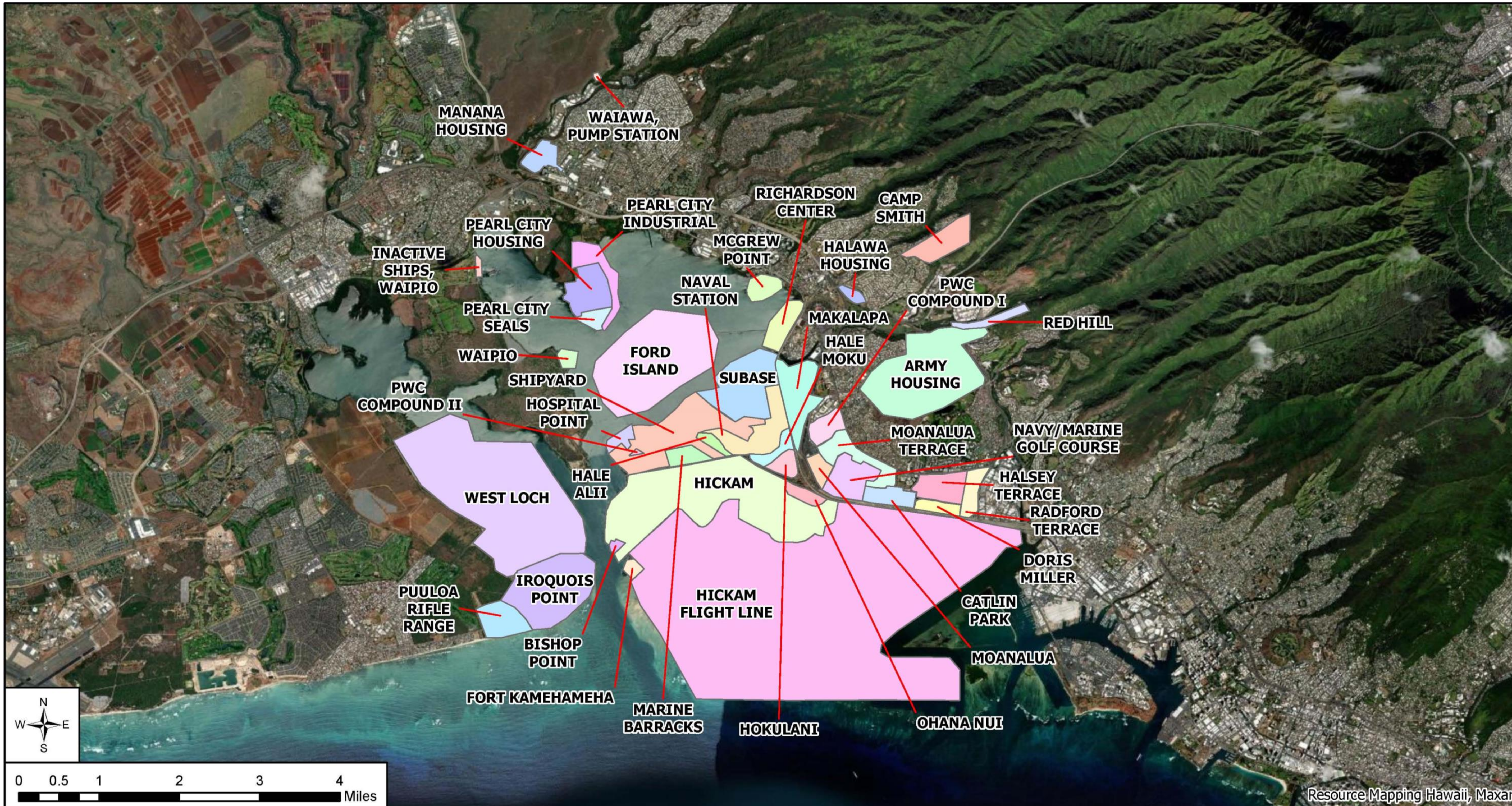
4.1 FACILITIES SURVEYED AND INSPECTED

Prior to the site survey, JBPHH personnel provided AH/BC an inventory of facilities, dated 17 December 2021. Using this database, available GIS mapping files, and other guidance from NAVFAC and JBPHH personnel, AH/BC selected 39 areas on which to focus the survey (see Figure 4-1):

- Army Housing
  - Identified as a consecutive system owned and operated by the Army; only the two interconnections were covered as part of this survey
- Bishop Point
- Camp Smith
- Catlin Park
- Doris Miller
- Ford Island
- Fort Kamehameha
- Halawa Housing
- Hale Alii
- Hale Moku
- Halsey Terrace
- Hickam
- Hickam Flight Line
- Hokulani
- Hospital Point
- Inactive Ships, Waipio
- Iroquois Point
- Makalapa
- Manana Housing
- Marine Barracks
- McGrew Point

- Moanalua
- Moanalua Terrace
- Naval Station
- Navy/Marine Golf Course
- Ohana Nui
- Pearl City Housing
- Pearl City Industrial
- Pearl City Sea, Air, and Land Teams (SEALs)
- Public Works Center (PWC) Compound (I and II)
- Puuloa Rifle Range
- Radford Terrace
- Red Hill
- Richardson Center
- Shipyard
- Submarine Base (SUBASE)
- Waiawa, Pump Station
- Waipio
- West Loch

Figure 4-1 Survey Areas



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In total, 1,703 facilities were identified as served by the JBPHH system and surveyed as part of this project. Note that surveys of main service lines to individual family housing units were not part of this project scope. It is assumed that construction of these private residences followed state codes, including BFP of plumbing. Surveys in housing areas mainly focused on fire service (if present), non-housing facilities, and irrigation.

4.2 SURVEY FINDINGS

All findings of the CCC/BFP survey were entered into a Microsoft® Access® database and exported into a formatted Microsoft® Excel® inventory. A copy of the database file developed by the AH/BC survey teams, including pictures of BFP devices, deficiencies, and locations (where photography was allowed), is contained on a digital video disc included with this report.

Appendices B through D provide reports summarizing all observations during the survey. Appendix B summarizes all existing devices encountered by the survey teams, regardless of protection adequacy. Appendix C lists all locations where installation of a new device is proposed (whether for an unprotected connection or to replace an existing device that is under-protecting the connection). Appendix D presents existing devices that were in the original databases provided and were removed from the survey database (device removed/replaced based on survey observations).

Table 4-1 summarizes the total cross-connection corrective actions identified by the survey teams. They are prioritized into five groups:

- **Priority Group 1:** Install BFP devices on unprotected high hazard service connections.
- **Priority Group 2:** Install BFP devices on under-protected and improperly protected high hazard service connections.
- **Priority Group 3:** Install BFP devices on unprotected low hazard service connections.
- **Priority Group 4:** Relocate, replace, or modify BFP devices according to federal, state, and/or local code.
- **Priority Group 5:** Remove, replace, or repair abandoned, leaking, damaged, and/or redundant BFP devices.

Table 4-1 Summary of Survey Findings

Hazard/BFP Device Finding	Total
Unprotected High Hazards (Priority Group 1)	[redacted]
Under-Protected High Hazards (Priority Group 2)	[redacted]
Unprotected Low Hazards (Priority Group 3)	399
Total Unprotected and Under-Protected Hazards (Priority Groups 1 to 3)	[redacted]
Inappropriately Installed BFP Devices (Priority Group 4)	211
Damaged and/or Unecessary BFP Devices (Priority Group 5)	151

Table 4-2 lists all BFP devices found during the CCC/BFP survey. Of these [redacted] devices, [redacted] were testable devices. The table also shows a side-by-side comparison between the survey results and original Maximo® database records. A secondary GIS database was incorporated as part of this survey (not included in original count in Table 4-2); however, the databases were not well synchronized and only shared roughly one-third of the entries. In addition, a significant portion of the GIS database consisted of entries with no data that were identified as removed or a duplicate of another entry in the Maximo® database.

Table 4-2 Summary of Existing Backflow Prevention Devices

BFP Device Name	BFP Device Acronym	Applicable Standard(s)*	Original Maximo® Database Count	Survey Database Count
Air Gap	AG	ASME A112.1.2	[redacted]	[redacted]
Reduced Pressure Zone Assembly	RP	ASSE 1013 AWWA C511	[redacted]	[redacted]
Pressure Vacuum Breaker	PVB	ASSE 1020	[redacted]	[redacted]
Double Check Valve Assembly	DCVA	ASSE 1015 AWWA C510	[redacted]	[redacted]
Double Check Valve Detector Assembly	DCDA	ASSE 1048	[redacted]	[redacted]
Atmospheric Vacuum Breaker	AVB	ASSE 1001	[redacted]	[redacted]
Hose Bibb Vacuum Breaker	HBVB	ASME A112.21.3 ASSE 1011	[redacted]	[redacted]
Total			[redacted]	[redacted]

* Per Table 603.2 of the IAPMO UPC and Table 608.1 of the IPC (excluding Canadian Standards Association)

Table 4-3 summarizes proposed BFP devices for potential cross-connections discovered during the CCC/BFP survey. The majority of these proposed devices are testable devices.

Table 4-3 Summary of Proposed Backflow Prevention Devices

BFP Device Name	BFP Device Acronym	Applicable Standard(s)*	Survey Findings
Air Gap	AG	ASME A112.1.2	[redacted]
Reduced Pressure Zone Assembly	RP	ASSE 1013 AWWA C511	[redacted]
Pressure Vacuum Breaker	PVB	ASSE 1020	[redacted]
Double Check Valve Assembly	DCVA	ASSE 1015 AWWA C510	[redacted]
Hose Bibb Vacuum Breaker	HBVB	ASME A112.21.3 ASSE 1011	[redacted]
Other**	Not Applicable (N/A)		[redacted]
Total			[redacted]

* Per Table 603.2 of the IAPMO UPC and Table 608.1 of the IPC (excluding Canadian Standards Association)

** Relocation of existing BFP device to where it protects entire facility plumbing system instead of partial

5. RECOMMENDATIONS

This section provides recommendations for BFP device deficiencies at JBPHH. These recommendations are prioritized into five groups, as previously identified in Section 4.2. Priority Groups 1 through 3 are from the highest to lowest water service hazards. Priority Group 4 focuses on reinstalling, removing, relocating, documenting, and/or replacing devices to meet manufacturer and/or regulatory requirements. Priority Group 5 includes repairing defective and/or leaking devices and removing unneeded devices where overprotection/redundancy is identified.

For the purposes of this *containment-level* CCC/BFP survey, it is crucial to note that the focus was on protection of all service lines to JBPHH facilities. Without a thorough *isolation-level* survey (i.e., thorough review of all internal facility uses), a device must be considered for every service line in order to protect the JBPHH system from all possible cross-connections that could be within each facility. These instances were typically noted with “NO PROTECTION” comments on the forms. If a future isolation-level survey of a facility identifies no unprotected potential cross-connections, then the recommended device for the service line is not necessary.

Typically, recommended device selections for unprotected lines were based on whether the general nature of the facility could present high/health (Priority Group 1) or low/non-health (Priority Group 3) hazards and backpressure and/or backsiphonage backflow conditions. In general, RPs were recommended for main service lines to facilities deemed high/health hazards and fire service lines connected to systems using chemicals additives, PVBs were recommended for irrigation systems, and DCVAs were recommended for main service lines to facilities deemed low/non-health hazards and fire service lines connected to systems that do not use chemical additives.

5.1 PRIORITY GROUP 1: INSTALL BACKFLOW PREVENTION DEVICES ON UNPROTECTED HIGH HAZARD SERVICE CONNECTIONS

Recommendations in this group include required high hazard BFP devices, as detailed in Table 5-1, for unprotected high hazard connections. A total of [redacted] devices are included in Priority Group 1. Figures 5-1 to 5-4 show examples of Priority Group 1 deficiencies. Appendix E provides lists each Priority Group 1 finding with corresponding building nos., location descriptions, sizes, recommended devices, and types of service.

Table 5-1 Priority Group 1 Findings

Recommendation	Total
AG Installation	[redacted]
RP for Unprotected Service Connection	[redacted]
PVB for Unprotected Service Connection	[redacted]
HBVB for Unprotected Service Connection*	[redacted]
RP Relocation	[redacted]
Total	[redacted]

* Unprotected service connections requiring HBVBs were identified as Priority Group 1 if a high hazard was identified (e.g., located on pier, used for irrigation).

Figure 5-1 Priority Group 1 Example – Air Gap Installation

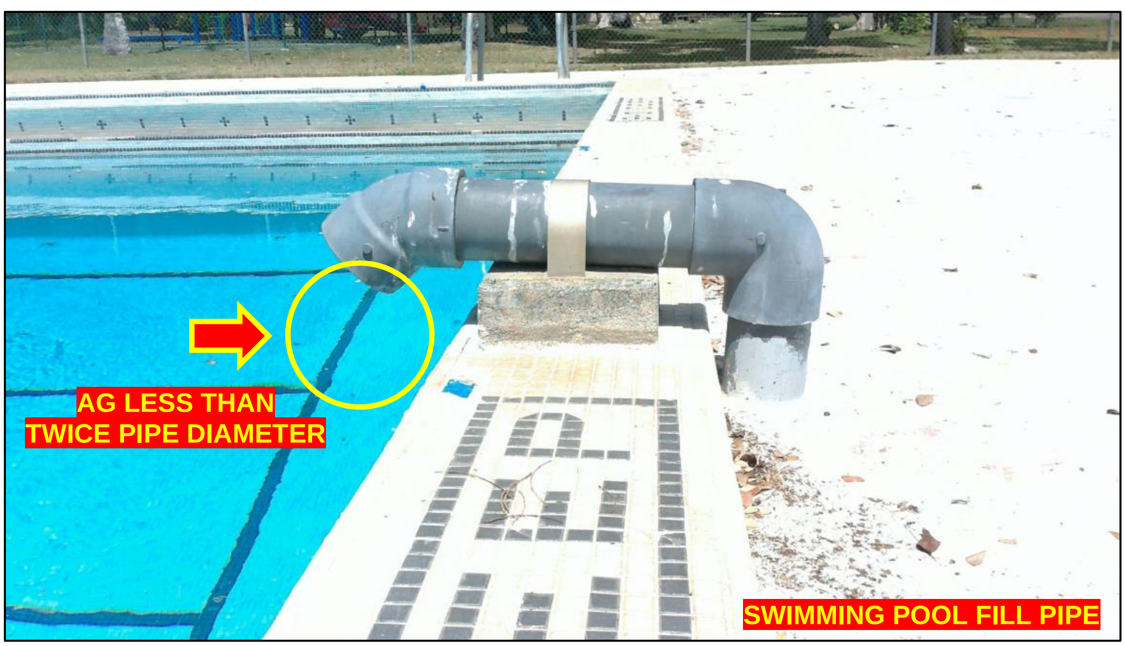


Figure 5-2 Priority Group 1 Example – Reduced Pressure Zone Assembly for Unprotected Service Connection

Figure 5-3 Priority Group 1 Example – Pressure Vacuum Breaker for Unprotected Service Connection

Figure 5-4 Priority Group 1 Example – Reduced Pressure Zone Assembly Relocation

5.2 PRIORITY GROUP 2: INSTALL BACKFLOW PREVENTION DEVICES ON UNDER-PROTECTED AND IMPROPERLY PROTECTED HIGH HAZARD SERVICE CONNECTIONS

Recommendations in this group include replacement of existing BFP devices, as detailed in Table 5-2, for under-protected high hazard connections. A total of [redacted] devices are included in Priority Group 2. Figures 5-5 and 5-6 show examples of Priority Group 2 deficiencies. Appendix F lists each Priority Group 2 finding with corresponding building nos., location descriptions, sizes, recommended devices, and types of service.

Table 5-2 Priority Group 2 Findings

Recommendation	Total
Replace DCVA with RP	[redacted]
Replace AVB with PVB*	[redacted]
Total	[redacted]

* While AVBs are technically applicable, they are non-testable devices and must be replaced (including proper recordkeeping of replacement) every 5 years per BMS B-24.10. They are not recommended for installation at JBPHH.

Figure 5-5 Priority Group 2 Example – Replace Double Check Valve Assembly with Reduced Pressure Zone Assembly

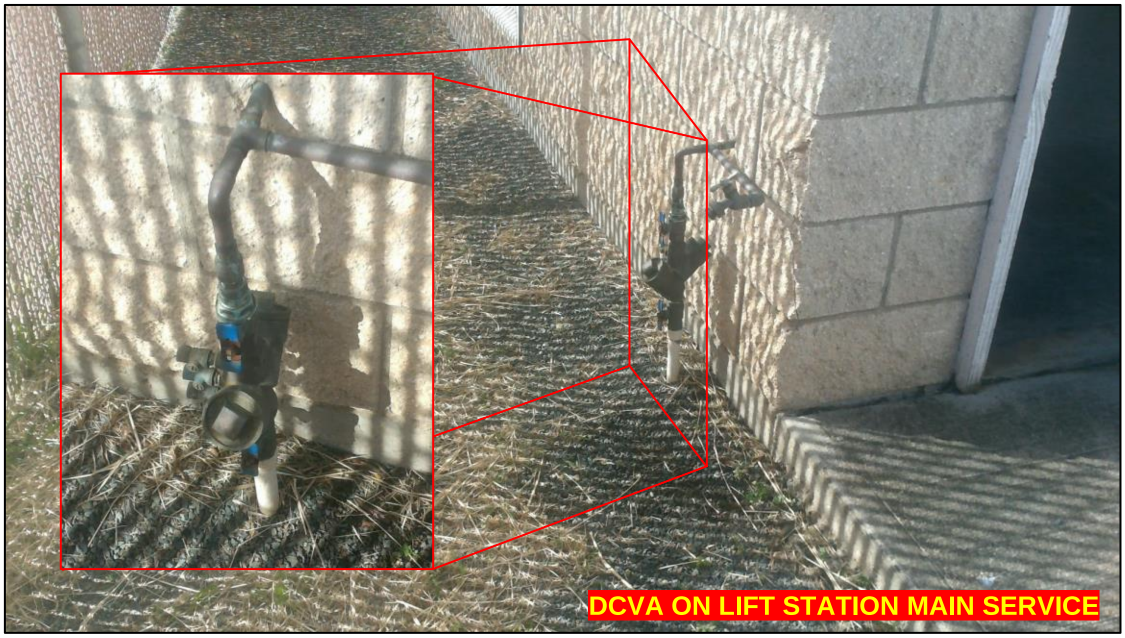
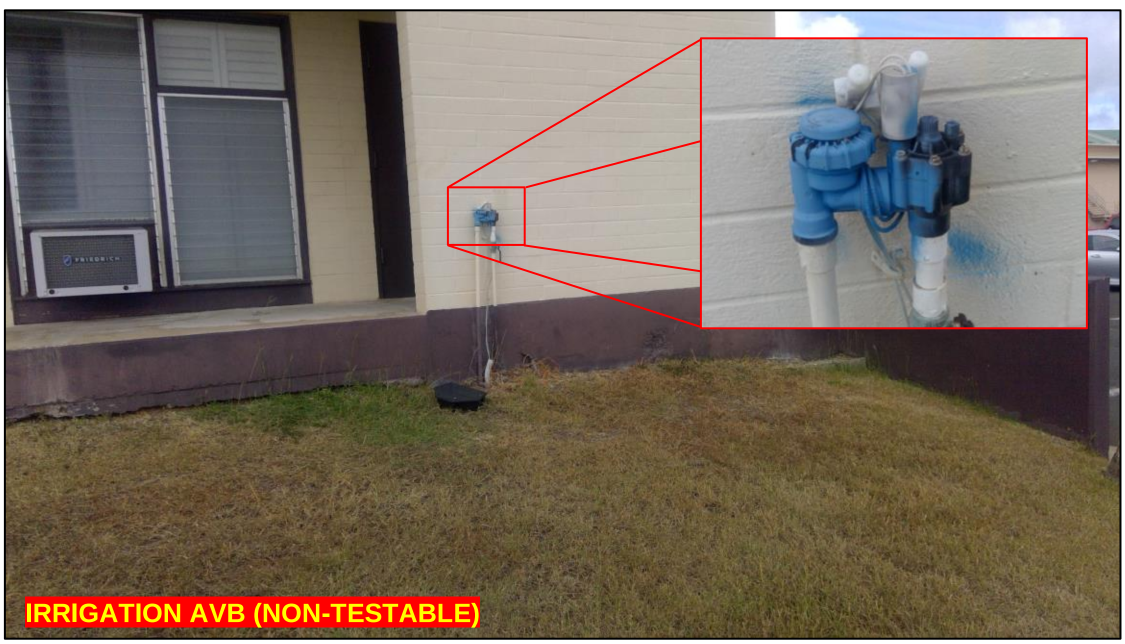


Figure 5-6 Priority Group 2 Example – Replace Air Vacuum Breaker with Pressure Vacuum Breaker



5.3 PRIORITY GROUP 3: INSTALL BACKFLOW PREVENTION DEVICES ON UNPROTECTED LOW HAZARD SERVICE CONNECTIONS

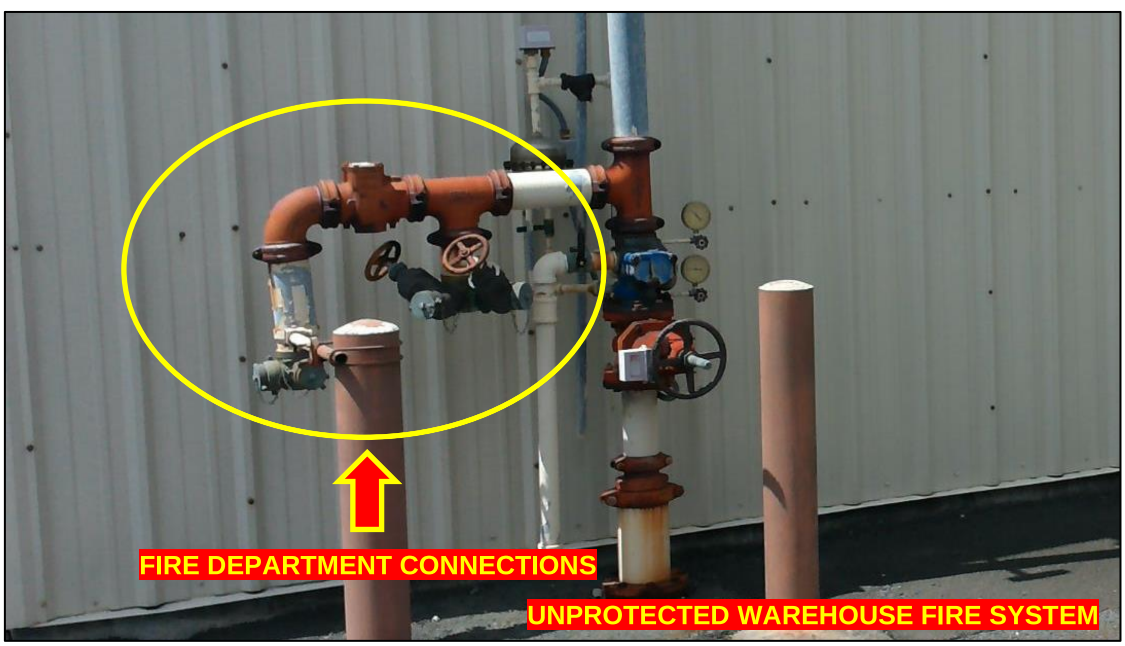
Recommendations in this group include required low hazard BFP devices, as detailed in Table 5-3, for unprotected low hazard connections. A total of 399 devices are included in Priority Group 3. Figure 5-7 shows an example of a Priority Group 3 deficiency. Appendix G lists each Priority Group 3 finding with corresponding building nos., location descriptions, sizes, recommended devices, and types of service.

Table 5-3 Priority Group 3 Findings

Recommendation	Total
DCVA for Unprotected Service Connection	396
HBVB for Unprotected Service Connection*	1
DCVA Relocation	2
Total	**399**

* Unprotected service connections requiring HBVBs were identified as Priority Group 3 if no high hazards were identified.

Figure 5-7 Priority Group 3 Example – Double Check Valve Assembly for Unprotected Service Connection



5.4 PRIORITY GROUP 4: RELOCATE, REPLACE, OR MODIFY BACKFLOW PREVENTION DEVICES ACCORDING TO FEDERAL, STATE, AND/OR LOCAL CODE

Recommendations in this group call for relocation, replacement, or modification of BFP devices that do not meet cross-connection and backflow code requirements. A total of 211 devices are included in Priority Group 4, as detailed in Table 5-4. Figures 5-8 to 5-13 show examples of the Priority Group 4 deficiencies. Appendix H lists each Priority Group 4 finding with corresponding building nos., location descriptions, device manufacturers, device model nos., device serial nos., sizes, device types, types of service, and descriptions of the deficiencies.

Table 5-4 Priority Group 4 Findings

Recommendation	Total
Install "Non-Potable" Signage on Hose Bibb	4
Lower BFP Device Position	3
Make BFP Device Easily Accessible	77
Raise BFP Device Position	13
Reinstall Removed RP Relief Valve	1
Replace Unreadable/Missing Plate and/or Tag	26
Reposition RP from Vertical to Horizontal Position	1
Remove Improper Connections to Device	17
Resolve Inconsistent Information Between Device Plate, Tag, and/or Maximo® Entry	69
Total	**211**

Figure 5-8 Priority Group 4 Example – Lower Backflow Prevention Device Position

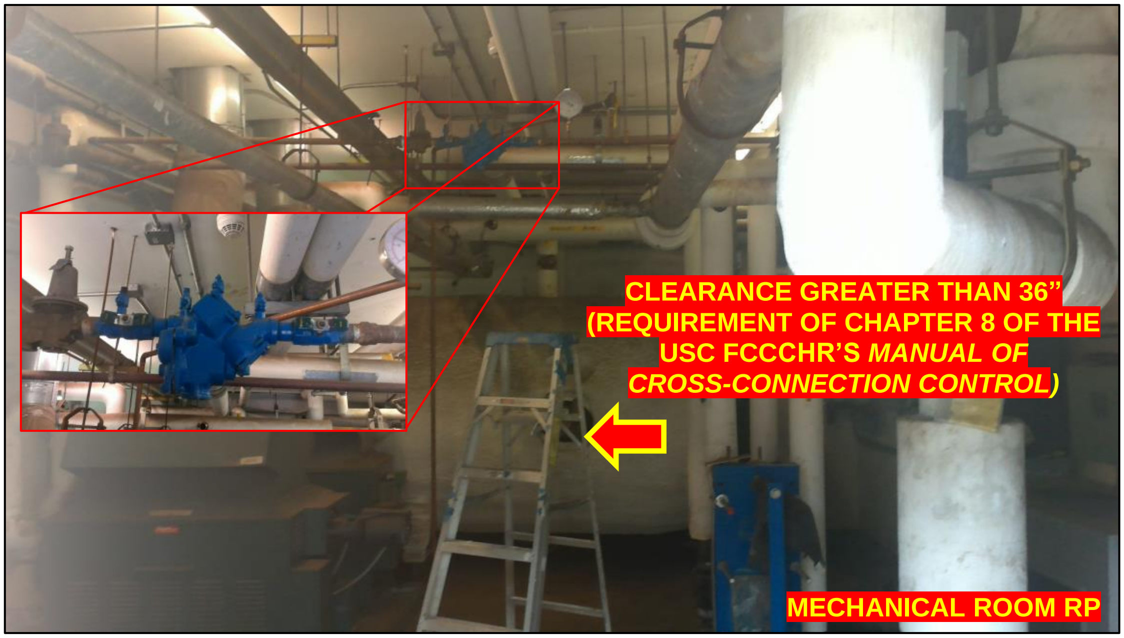


Figure 5-9 Priority Group 4 Examples – Make Backflow Prevention Device Easily Accessible

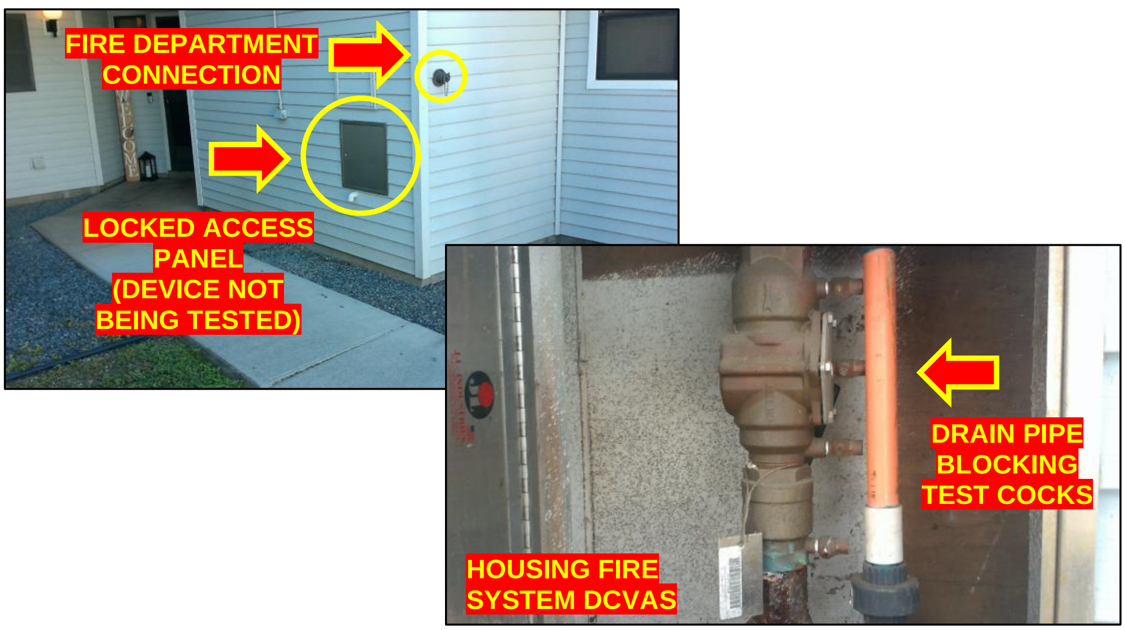


Figure 5-10 Priority Group 4 Example – Raise Backflow Prevention Device Position

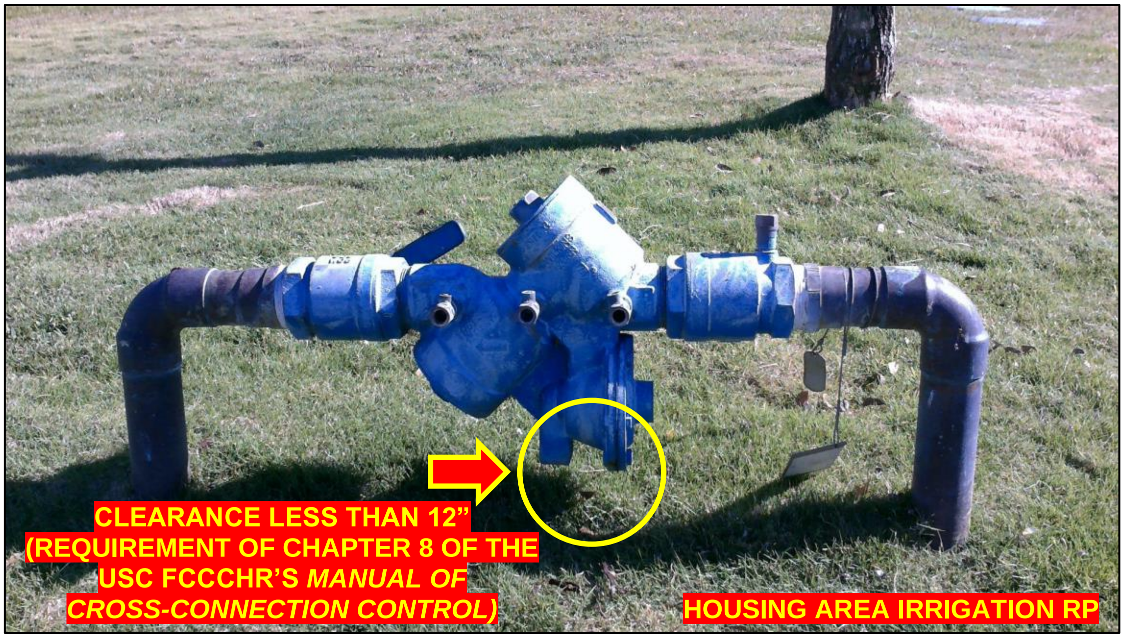


Figure 5-11 Priority Group 4 Example – Replace Unreadable/Missing Plate and/or Tag

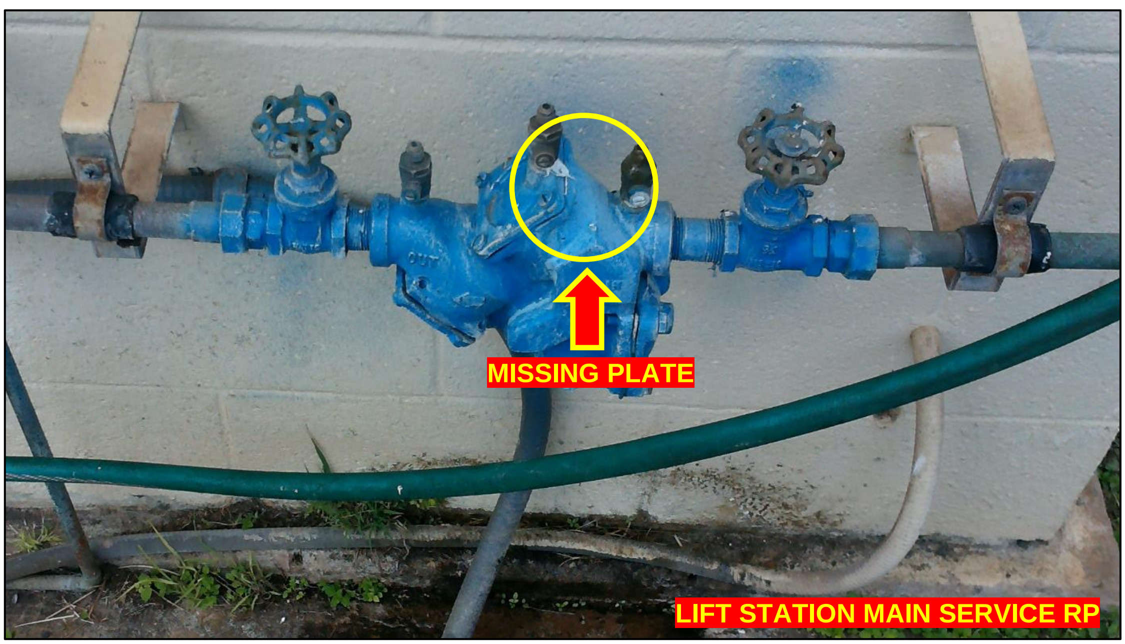
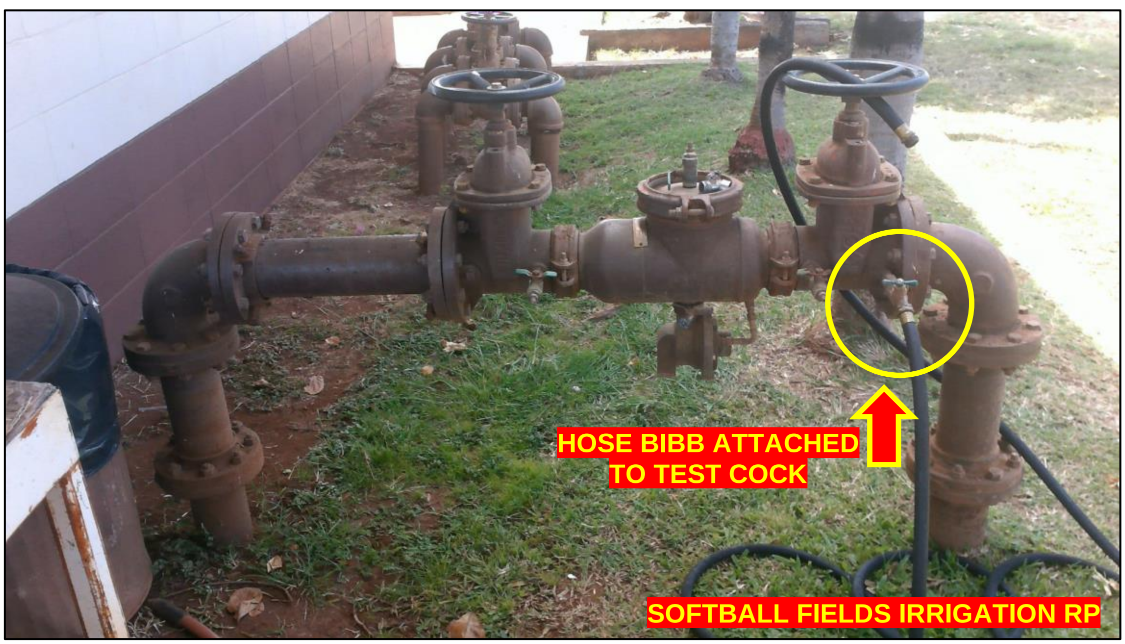


Figure 5-12 Priority Group 4 Example – Reposition Reduced Pressure Zone Assembly from Vertical to Horizontal Position

Figure 5-13 Priority Group 4 Example – Remove Improper Connections to Device



5.5 PRIORITY GROUP 5: REMOVE, REPLACE, AND REPAIR ABANDONED, LEAKING, DAMAGED, AND/OR REDUNDANT BACKFLOW PREVENTION DEVICES

Recommendations in this group call for repairing or replacing leaking or damaged BFP devices and removing unnecessary devices where either the protection is not required or the device is redundant due to another device serving the same function. A total of 151 devices are included in Priority Group 5, as detailed in Table 5-5. Figures 5-14 to 5-20 show examples of the Priority Group 5 deficiencies. Appendix I lists each Priority Group 5 finding with corresponding building nos., location descriptions, device manufacturers, device model nos., device serial nos., sizes, device types, types of service, and descriptions of the deficiencies.

Table 5-5 Priority Group 5 Findings

Recommendation	Total
Cap Pipe	2
Relocate/Remove Upstream Hose Bibb	3
Repair Bent Pipe	1
Repair Broken BFP Device	3
Repair Test Cocks	1
Replace Missing Handles	5
Replace Missing PVB Air Inlet Valve Cover	5
Replace/Repair Leaking BFP Device or Parts	127
Uncap RP Relief Valve	4
Total	**151**

Figure 5-14 Priority Group 5 Example – Cap Pipe

Figure 5-15 Priority Group 5 Example – Relocate/Remove Upstream Hose Bibb

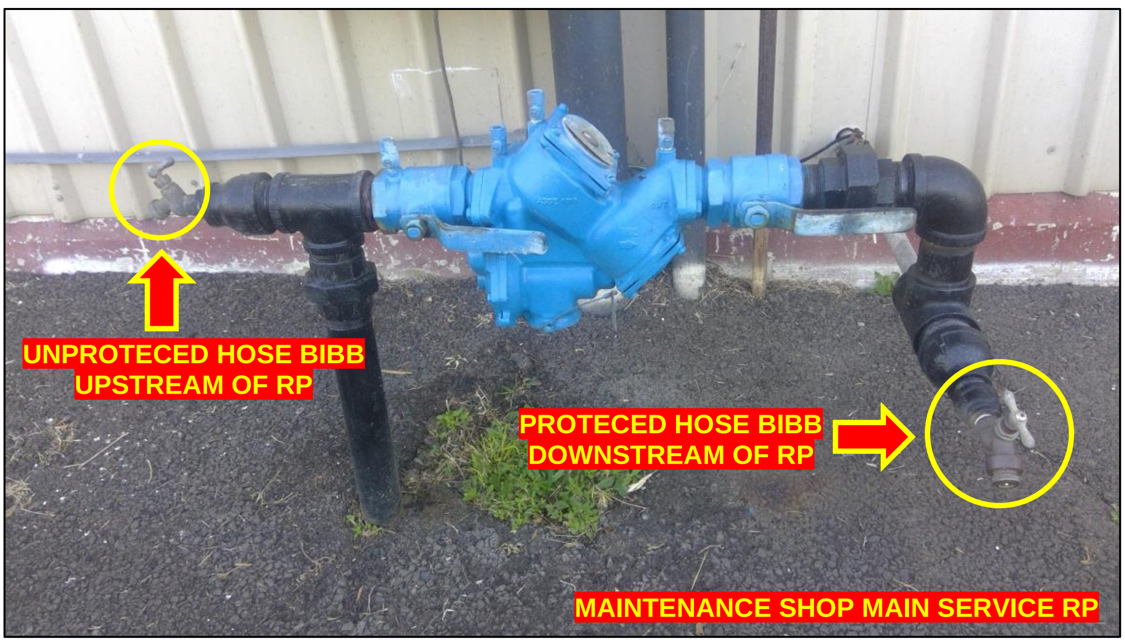


Figure 5-16 Priority Group 5 Example – Repair Bent Pipe

Figure 5-17 Priority Group 5 Example – Repair Broken Backflow Preventer Device

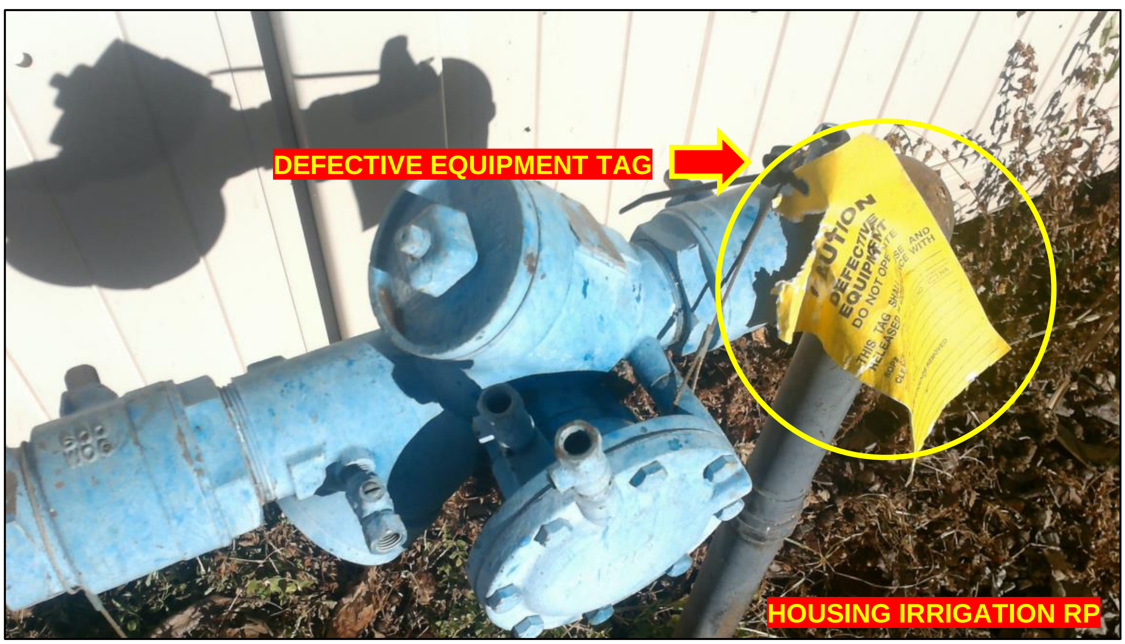


Figure 5-18 Priority Group 5 Example – Replace Missing Handles

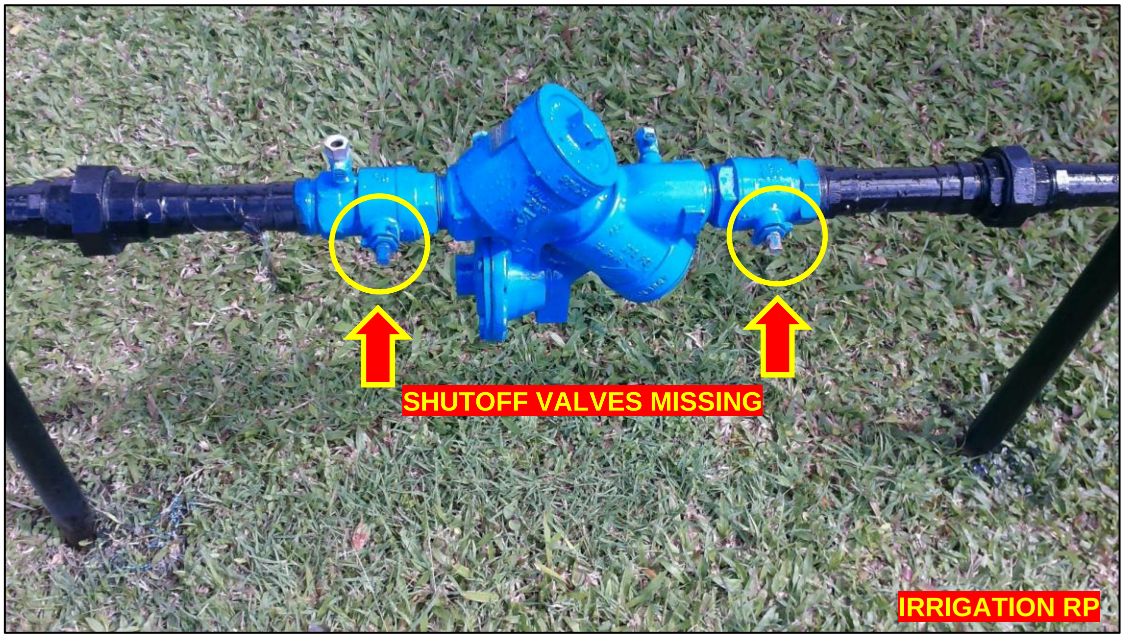


Figure 5-19 Priority Group 5 Example – Replace Missing Pressure Vacuum Breaker Air Inlet Valve Cover

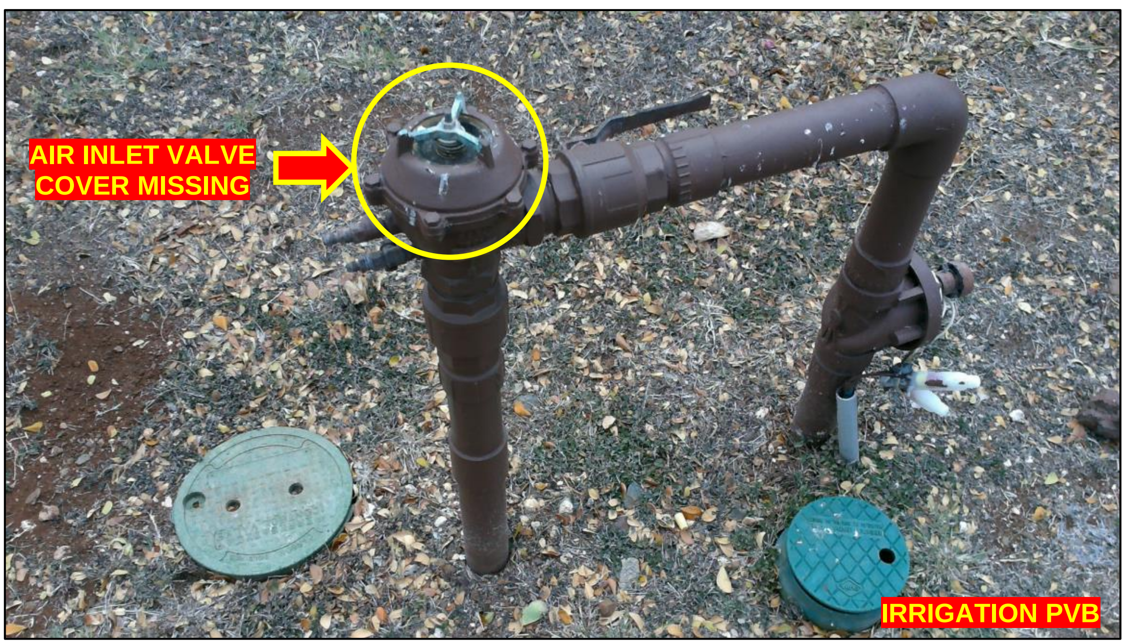


Figure 5-20 Priority Group 5 Examples – Replace/Repair Leaking Backflow Preventer Device or Parts

5.6 OTHER RECOMMENDATIONS

The following recommendations are made to implement an effective CCC/BFP program at JBPHH that complies with HAR (Title 11, Chapter 21):

- Develop a written instruction that comprises the CCC/BFP program policies and clearly defines the roles and responsibilities to govern and sustain the program. This instruction should apply to all CCC/BFP assets operated and maintained by JBPHH in Navy, US Air Force (Air Force) (active duty and reserve), Hawaii Air National Guard, and USMC facilities.
- Assign a local CCC/BFP program manager who will administer the program base-wide and have access to all BFP devices, regardless of their location.
- Maintain a list of certified testers/inspectors.
- Review plans and specifications for impending projects that contain changes or new connections to the JBPHH system.
- Inspect and test all BFP devices at least once annually.
- Survey the entire JBPHH system for new cross-connections every five years.
- Maintain an accurate inventory of existing BFP devices and inspection/field test reports for at least five years.
- Develop a public education and outreach initiative to inform customers of the dangers and risks posed by cross-connections.

Ensuring the program aligns with Navy policy, including BMS B-24.10, requires the following:

- Inspect and test all BFP devices installed at high hazard locations every six months.
- Maintain the inventory for all BFP devices in one location for JBPHH (i.e., Maximo®). Update the inventory of BFP devices with the findings from this survey.
- GIS is a complementary tool that can be used to help manage the CCC/BFP program (e.g., locate BFP devices in the field and plan out routes for testing). Reaping the full benefit of GIS use requires improved coordination between the GIS and Maximo® databases (including updates based on the findings from this survey). When combined for this survey, approximately one-third of the total device entries could be linked to both databases. It is critical to maintain one complete master database using Maximo®. Meanwhile, the GIS database is a tool which can be used to pinpoint the location of existing devices; however, it can only be effective if all entries are linked to entries in the Maximo® database.

Based on the results of the field survey for this project, AH/BC recommends the following additional items:

- Tag all BFP devices installed in the field to identify their unique asset no., manufacturer, model no., serial no., size, and type. Use of metal “dog tags” is highly recommended.
- Whenever a BFP device is replaced, provide a new asset no. instead of keeping the asset no. of the previous device. This is crucial if asset nos. (rather than serial nos.) will be the main device identifiers. If multiple devices share an asset no., it is difficult to establish a proper tracking history of each unique device (Process Step 5 of BMS B-24.10 requires records to be maintain for a minimum of 5 years).
- Install PVBs at all future irrigation systems. They are testable devices (compliant with the USC FCCCHR) and are less expensive to install and maintain than a RP.
- Fire suppression water storage tanks located on or near the Hickam AFB flight line (identified via GIS as demolished Structure 84310H at Building 1052H and Structure Primary Key Identifiers S-3163 and S-3154 at Building 2127H) are supplied with AGs to separate the fire suppression systems from the potable water system. Install proper fall protection on the storage tanks to enable routine inspection of the AGs.
- Establish a uniform color code to paint all devices:
  - Main service (i.e., drinking water): Blue
  - Freshwater fire system: Red
  - Saltwater fire system: Red with black stripes

5.7 CORRECTIVE ACTION COST ESTIMATES

This section summarizes corrective action cost estimates for the proposed findings in Sections 5.1 to 5.5. Below are key assumptions and approaches that were used in their development (see Appendix J for detailed breakdown):

- Material costs were based on prices listed on appropriate online shopping sources (e.g., USABlueBook, W.W. Grainger, Inc., U.S. Pipe, Backflow Parts USA, MyAssetTag) marked up 40 percent (%) (20% for overhead and profit, 20% for shipping to Hawaii).
- Fitting selection was based on Standard Detail P-1 from the *Standard Details for Public Works Construction* for the Departments of Public Works for the County of Kauai, City and County of Honolulu, County of Maui, and County of Hawaii (September 2000).
- Labor costs were based on wage rates published by the Hawaii Department of Labor and Industrial Relations with a 50% markup (20% for overhead and profit, 30% for insurance and taxes).
- A 20% contingency was added to total costs to account for unknown and unforeseen issues.

Table 5-6 presents cost estimate summaries broken down by priority group and area. Based on the no. of devices and total cost estimates, the areas of Hickam, Shipyard, and SUBASE are identified as the most concerning. The priority group summary tables in Appendices E through I present a further breakdown of costs per recommended device (for Priority Groups 1 through 3) or issue (Priority Groups 4 and 5). An alternate summary of cost breakdowns based on pipe sizes and materials are included in Appendix J.

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6. REFERENCES AND BIBLIOGRAPHY

104th United States Congress. *Safe Drinking Water Act Amendments of 1996*. Public Law 104-182. https://www.congress.gov/104/plaws/publ182/PLAW-104publ182.pdf. 6 August 1996.

93rd United States Congress. *Safe Drinking Water Act*. Public Law 93-523. https://www.congress.gov/93/statute/STATUTE-88/STATUTE-88-Pg1660-2.pdf. 16 December 1974.

99th United States Congress. *Safe Drinking Water Act Amendments of 1986*. Public Law 99-339. https://www.congress.gov/99/statute/STATUTE-100/STATUTE-100-Pg642.pdf. 19 June 1986.

The Air Force Institute for Operational Health. *Cross-Connection and Backflow Prevention Device Survey*. Hickam AFB, Hawaii. January 2008.

American Society of Mechanical Engineers. *Plumbing Supply Fittings*. ASME A112.18.1, October 2018

American Society of Sanitary Engineering. *Cross-Connection Control Professional Qualifications Standard*. Series 5000. March 2022.

American Society of Sanitary Engineering. *Guide to Cross-Connection Protection Devices and Assemblies – Application and Selection*. 3rd Edition. 2018.

American Water Works Association. *Backflow Prevention and Cross-Connection Control: Recommended Practices*. M14. 4th Edition. 2015.

Backflow Parts USA. https://www.backflowpartsusa.com/. Accessed 22 September 2022.

Code of Federal Regulations. *National Primary Drinking Water Regulations*. 40 CFR 141. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-141. 17 August 2022.

Code of Federal Regulations. *National Primary Drinking Water Regulations Implementation*. 40 CFR 142. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-142. 16 December 2021.

Code of Federal Regulations. *Other Safe Drinking Water Act Regulations*. 40 CFR 143. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-143. 19 July 2021.

Commander, Navy Region Hawaii. *About*. https://cnrh.cnic.navy.mil/Installations/JB-Pearl-Harbor-Hickam/About/. Accessed 2 September 2022.

Departments of Public Works, County of Kauai, City and County of Honolulu, County of Maui, County of Hawaii. *Standard Details for Public Works Construction*. https://www.honolulu.gov/rep/site/dpp/rules/standard-details-public-works-construction-2000.pdf. Revised September 2000.

Engineering Concepts, Inc. *Navy Medicine Readiness and Training Command Pearl Harbor Cross-Connection Control Survey*. November 2020.

Hawaii Administrative Rules. *Rules Relating to Public Water Systems*. HAR 11-20. https://health.hawaii.gov/opppd/files/2020/11/11-20-October-29-2020.pdf. 31 July 2020.

Hawaii Administrative Rules. *Hawaii State Plumbing Code*. HAR 3-183. https://ags.hawaii.gov/wp-content/uploads/2020/06/StatePlumbingCode_20200519.pdf. 19 May 2020.

Hawaii Administrative Rules. *Cross-Connection and Backflow Control*. HAR 11-21. https://health.hawaii.gov/opppd/files/2015/06/11-21.pdf. 26 December 1981.

Hawaii Department of Health Safe Drinking Water Branch. *Regulated Public Water Systems in Hawaii*. https://health.hawaii.gov/sdwb/files/2022/02/RegulatedPWSHawaii.20220208.pdf. 8 February 2022.

Hawaii Department of Labor and Industrial Relations. *Apprentice Schedule*. Bulletin No. 501. https://labor.hawaii.gov/wsd/files/2022/02/APPR501.pdf. 21 February 2022.

Hawaii Department of Labor and Industrial Relations. *Wage Rate Schedule*. Bulletin No. 501. https://labor.hawaii.gov/wsd/files/2022/02/WRS501.pdf. 21 February 2022.

International Association of Plumbing and Mechanical Officials. *2018 Uniform Plumbing Code*. https://epubs.iapmo.org/2018/UPC/. 6th Printing. April 2021.

International Code Council. *2021 International Building Code*. https://codes.iccsafe.org/content/IBC2021P2. 2nd Printing. September 2021.

International Code Council. *2021 International Plumbing Code*. https://codes.iccsafe.org/content/IPC2021P3. 3rd Printing. September 2021.

Miyahira, Michael. *Implementing the Federal Safe Drinking Water Act in Hawaii*. Hawaii Safe Drinking Water Branch, Engineering Section. http://www.hrwa.net/uploads/1/9/9/6/19969697/intro_background-primacy_role-regulatory_overview-expected_outcomes.pdf. 1996.

MyAssetTag. https://www.myassettag.com/. Accessed 22 September 2022.

Naval Facilities Engineering Service Center. *Cross-Connection Control and Backflow Prevention Program Implementation at Navy Shore Facilities*. UG-2029-ENV. May 1998.

Naval Facilities Engineering Systems Command Headquarters. *Cross-Connection and Backflow Prevention*. Business Management System B-24.10. 19 April 2022.

Office of the Chief of Naval Operations. *Environmental Readiness Program Manual*. OPNAV M-5090.1. 25 June 2021.

RSMeans data from Gordian. https://www.rsmeans.com/. Accessed 31 August 2022.

United States Army Corps of Engineers. *Cross-Connection Control at Army Installations*. PWTB 420-49-16. https://www.wbdg.org/FFC/ARMYCOE/PWTB/pwtb_420_49_16.pdf. 16 July 2001.

United States Department of Defense. *DOD Building Code*. UFC 1-200-01. https://www.wbdg.org/FFC/DOD/UFC/ufc_1_200_01_2022.pdf. 1 September 2022.

United States Department of Defense. *Plumbing, General Purpose*. UFGS 22 00 00. https://www.wbdg.org/FFC/DOD/UFGS/UFGS%2022%2000%2000.pdf. Change 4. May 2021.

United States Department of Defense. *Operation and Maintenance: Water Supply Systems*. UFC 3-230-02. https://www.wbdg.org/FFC/DOD/UFC/ufc_3_230_02_2019_c1.pdf. Change 1. 1 April 2021.

United States Environmental Protection Agency. *Cross-Connection Control Manual*. EPA 816-R-03-002. https://www.epa.gov/sites/default/files/2015-09/documents/epa816r03002_0.pdf. February 2003

University of Southern California Foundation for Cross-Connection Control and Hydraulic Research. *List of Approved Backflow Prevention Assemblies*. https://fccchr.usc.edu/_downloads/List/list.pdf. 6 September2022.

University of Southern California Foundation for Cross-Connection Control and Hydraulic Research. *Manual of Cross-Connection Control*. 10th Edition. October 2009.

U.S. Pipe. *Fabrication Price List*. https://www.uspipe.com/wp-content/uploads/2022/07/USPF-FAB-CEMENT-2022-02-080122-For-Website.pdf. 1 August 2022.

U.S. Pipe. *Flange Fittings P401 Price List*. https://www.uspipe.com/wp-content/uploads/2020/12/Flange-Fittings-Price-List-June-2021.pdf. 1 June 2021.

USABlueBook. https://www.usabluebook.com/. Accessed 31 August and 12 September 2022.

Watts. *Backflow Preventers*. https://www.watts.com/products/plumbing-flow-control-solutions/backflow-preventers. Accessed 25 and 26 May 2022.

Woodford Manufacturing Company. *Woodford Manufacturing Product Index*. https://www.woodfordmfg.com/Woodford/WFDIndex.html. Accessed 25 May 2022.

W.W. Grainger, Inc. https://www.grainger.com/. Accessed 30 August and 1, 12, and 22 September 2022.

Zurn Industries, LLC. *Browse Backflow Preventers*. https://www.zurn.com/products/water-control/backflow-preventers. Accessed 25 and 26 May 2022.