Appendix F - Groundwater Hydrology Assessment

Groundwater Hydrology Assessment of the Waiawa Correctional Facility

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Introduction

The Hawaii Department of Public Safety has been notified by the Honolulu Department of Planning and Permitting that it must comply with the Plan Review Use (PRU) and State Special Use Permit requirements to bring the Waiawa Correctional Facility (WCF) into compliance. In support of the PRU application, this report provides a groundwater hydrology assessment of the potential effects of the WCF on the Zone of Contribution (ZOC) of the US Navy's Waiawa Shaft. A portion of the WCF site is within the ZOC.

Description of the Groundwater Occurrence Beneath and Downgradient of the Waiawa Correctional Facility

The WCF overlies a portion of the largest and most important groundwater aquifer on the Island of Oahu. It is known as the Waipahu-Waiawa Aquifer System and it encompasses an area of about 60 square miles (Figure 1). Groundwater in this aquifer system occurs as a robust basal lens in contact with saline groundwater beneath it and with seawater offshore. Beneath the WCF site, the top of the basal lens is approximately 20 feet above sea level based on measurements in Well Nos. 2658-004 and -005 which are located just outside the entrance to the WCF.

The State Commission on Water Resource Management (CWRM), the entity with regulatory authority over the development and use of groundwater, has designated the Waipahu-Waiawa Aquifer System as a Groundwater Management Area (GWMA) and has established its sustainable yield at 104 million gallons per day (MGD). Water Use Permits (WUPs) are required to operate wells in the GWMA. Currently, the CWRM has issued 50 WUPs for a total authorized use of 85.465 MGD in the Waipahu-Waiawa Aquifer System. As shown on Figure 2, actual use decreased dramatically with the closing of Oahu Sugar Company in the early 1990s and has averaged about 50 MGD over the last 15 years.

The Aquifer System is a major source for the Honolulu Board of Water Supply (BWS). It has 22 WUPs with a total authorized use of 54.702 MGD. Its pumpage over the last 15 years has been relatively constant and has averaged about 33 MGD (Figure 3). Use of the Navy's Waiawa Shaft, which has an authorized use of 14.977 MGD, has averaged 13.7 MGD over the last 15 years (Figure 4).

The U.S. Navy's Waiawa Shaft and its Delineated Zone of Contribution

Configuration of the Shaft. The U.S. Navy's Waiawa Shaft, also identified as State Well No. 2558-010, was completed in 1951. It consists of a 30° inclined shaft from ground level down to a pump room, an unlined pump sump excavated to 20 feet below sea level, and a 1700-foot long infiltration tunnel which runs directly to the north.

Vulnerability of the Shaft to Contamination. As an infiltration tunnel, the Shaft's particular vulnerability to contamination was dramatically illustrated by the trends of the salinity of its pumped water in response to irrigation of sugarcane fields nominally upgradient of the Shaft (from Oki et al, 1990):

- Water pumped from Oahu Sugar Company's (OSCO) Pump 6, a battery of 14 wells manifolded together (State Nos. 2459-001 to -014), had been irrigating fields inland of Waiawa Shaft for about 50 years prior to completion of the Shaft in 1951.

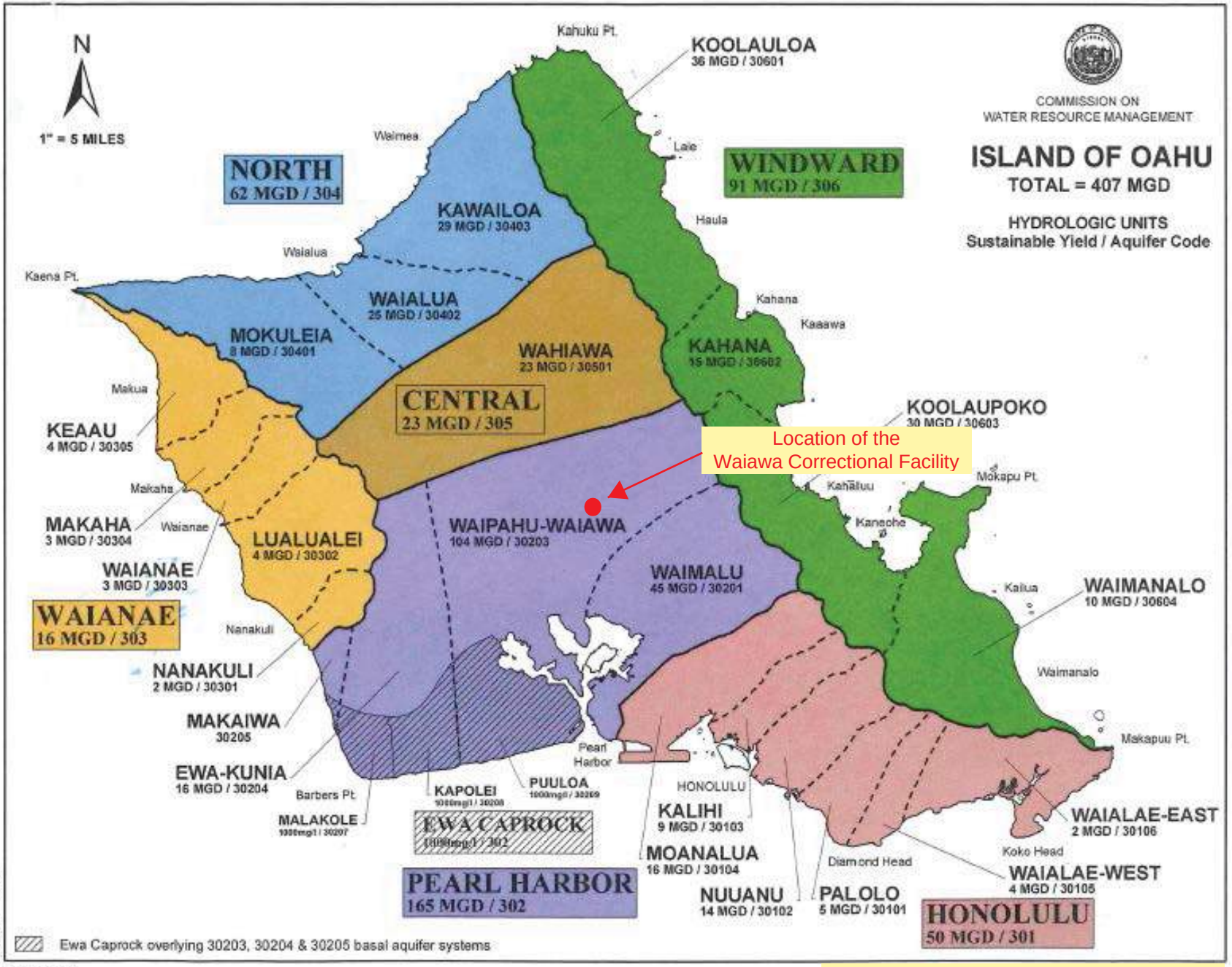


Figure 1

Location of the Waiawa Correctional Facility in the Waipahu-Waiawa Aquifer System

Figure 2. Reported Pumpage of Wells in the Waipahu-Waiawa Aquifer System

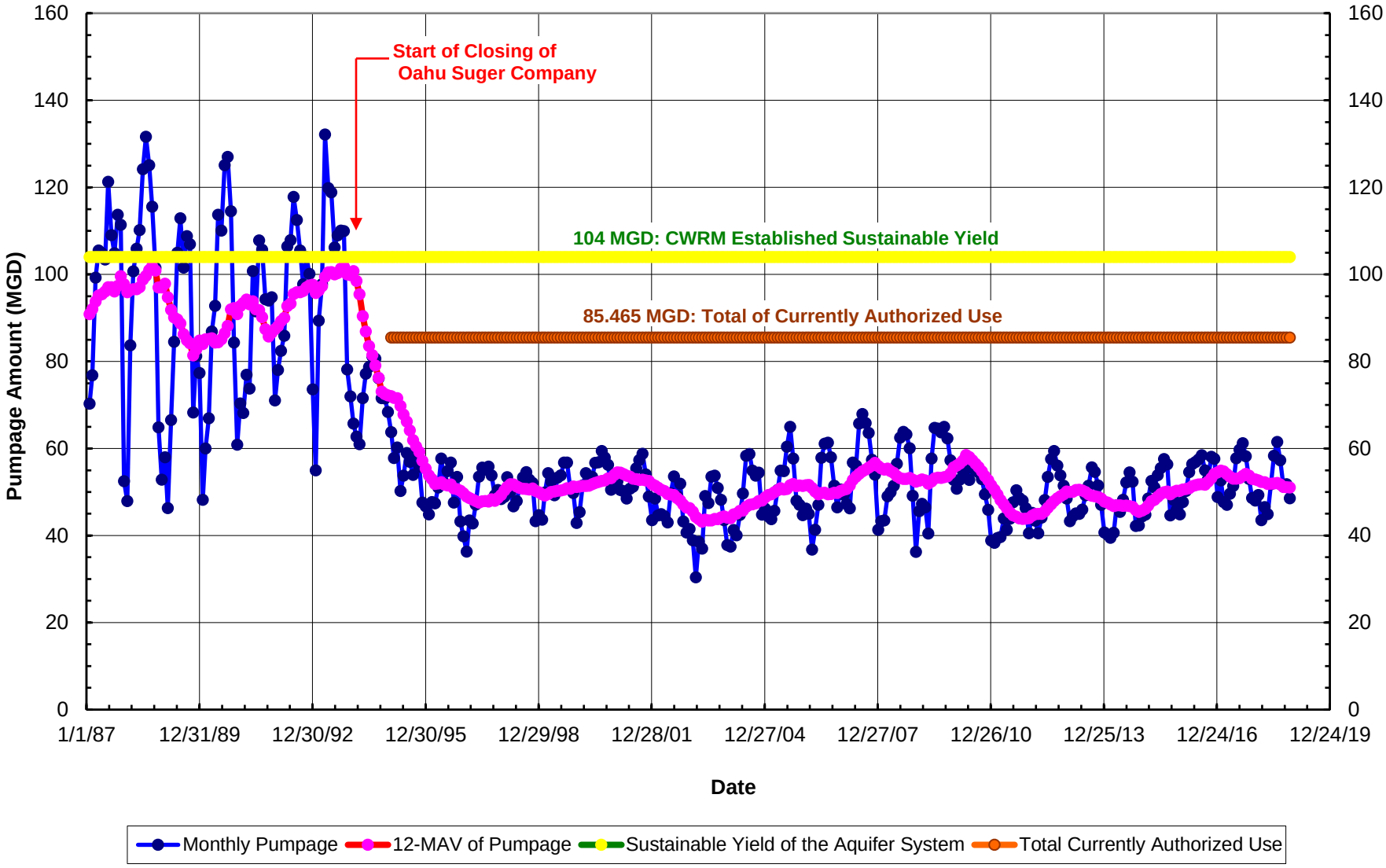


Figure 3. Pumpage of BWS Wells in the Waipahu-Waiawa Aquifer System

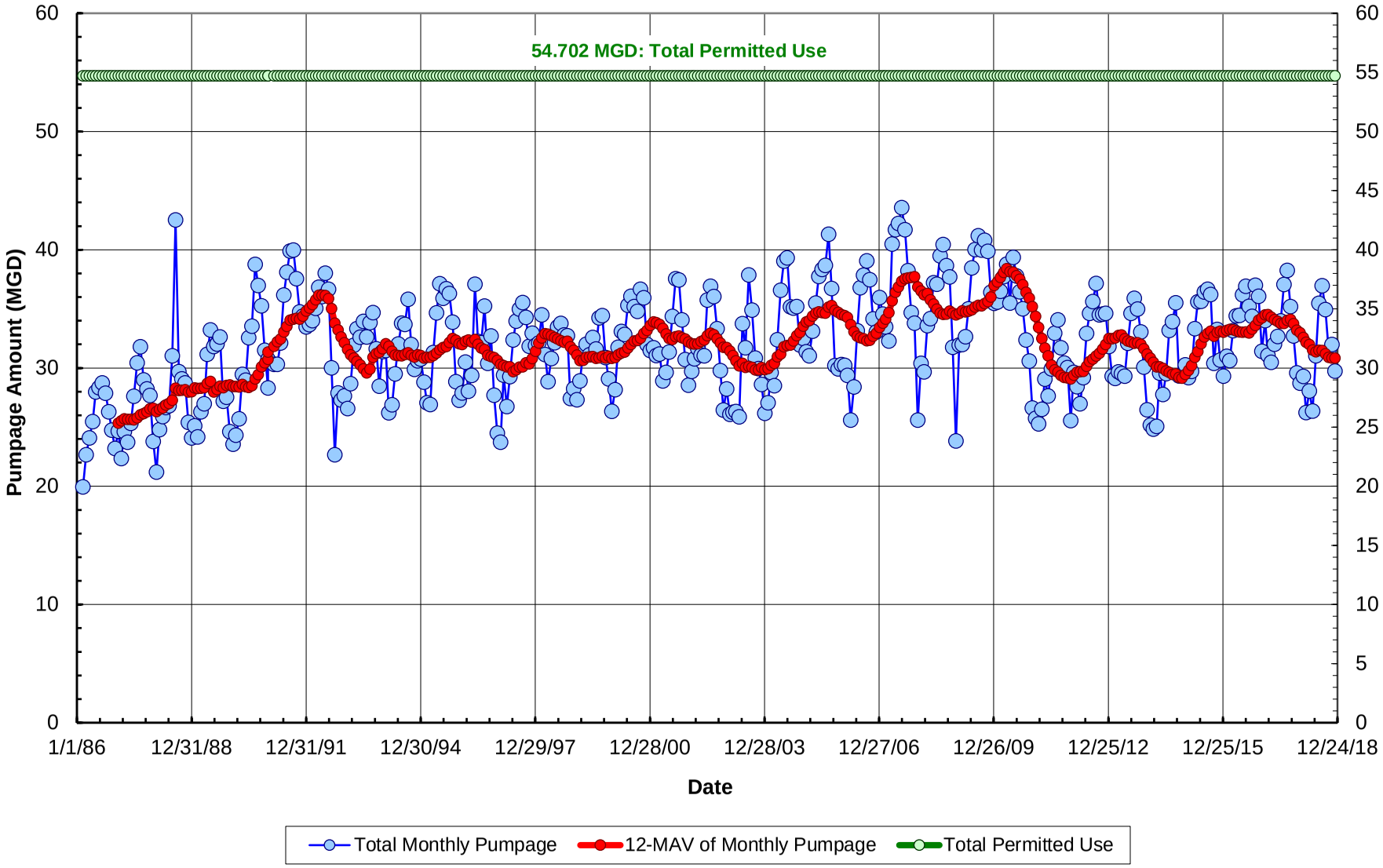
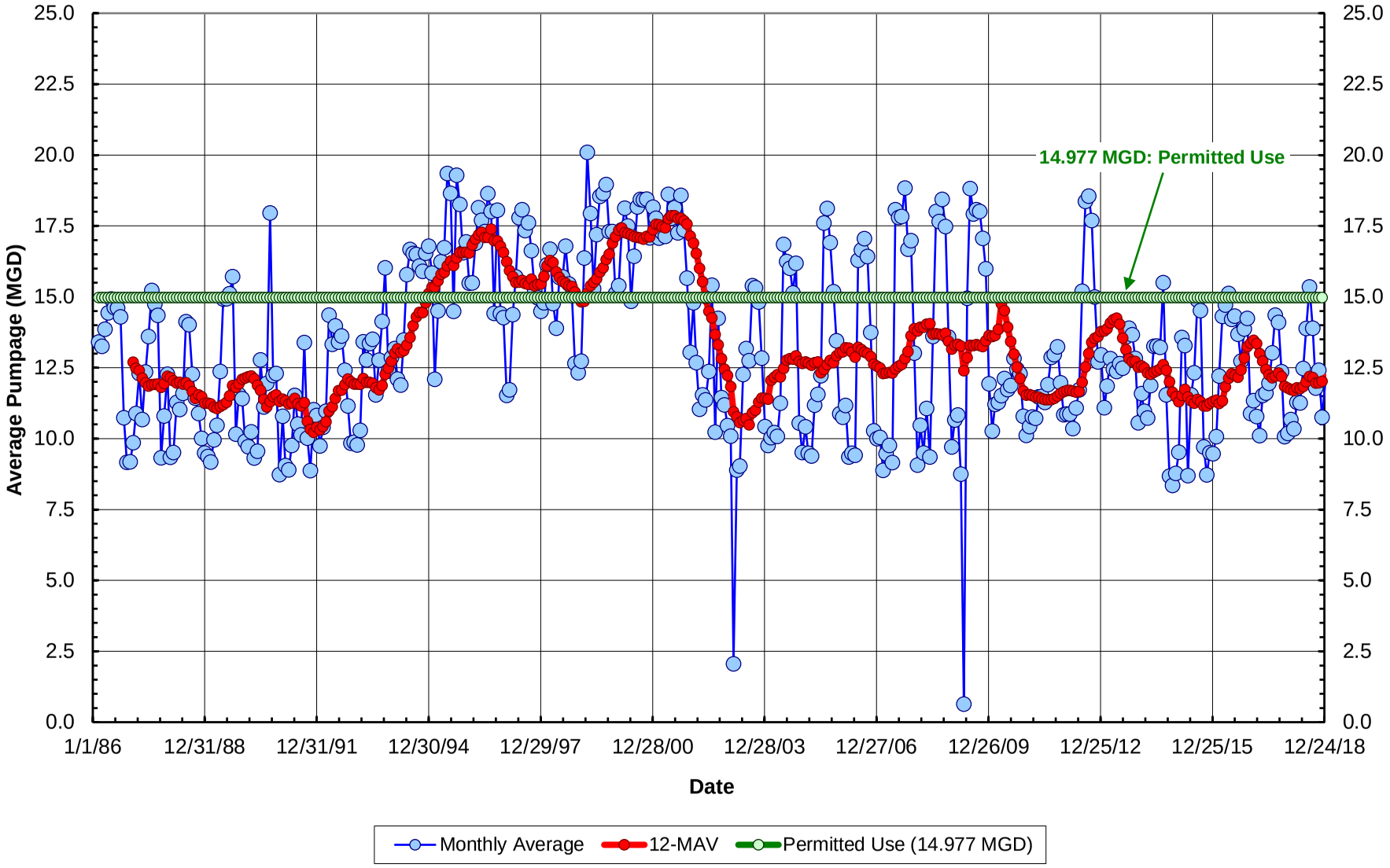


Figure 4. Pumpage of the Navy's Waiawa Shaft from January 1986 through November 2018



- Over that 50-year period, chlorides of the Pump 6 wells were generally in the range of 200 to 400 milligrams per liter (MG/L).
- Up until the mid-1960s, chlorides of the water pumped from the Shaft were generally in the range of 70 to 100 MG/L.
- As the basal lens tapped by the Pump 6 well battery, the Waiawa Shaft, and other wells began to shrink in response to increased pumping in the 1960s, chlorides in the very deep Pump 6 wells (to depths between 540 and 700 feet below sea level) increased to in excess of 1000 MG/L.
- From the mid-1960s to the end of the 1970s, chlorides in the Waiawa Shaft Steadily increased, reaching 280 MG/L at the end of 1978.
- OSCO ended its use of Pump 6 in 1983 when the sugarcane fields being irrigated with its water were abandoned.
- Since 1983, chlorides of the Shaft decreased to 40 to 50 MG/L, a lower level than when the Shaft was initially put into service.

Reason for the Delineation of the Shaft's Zone of Contribution. In 1987, Gentry-Pacific Ltd. petitioned the State Land Use Commission (LUC) to reclassify 1395 acres of land in Waiawa from Agriculture to Urban. Most of this land was former Oahu Sugar Company (OSCO) fields located around and upgradient of the Navy's Waiawa Shaft. Gentry's intent was to develop a master planned residential community. Based on the salinity history of the Shaft in response to OSCO's irrigation with water from Pump 6 and on the subsequent finding of DBCP and TCP in the Shaft's water that was attributed to pineapple cultivation, concern was raised by the Department of Health (DOH), the State Office of Planning, and the U.S. Navy regarding potential contamination of the Shaft's water by the proposed Gentry project.

In granting Gentry's request for the redesignation of the land from Agriculture to Urban, the LUC included a condition that a study funded by the U.S. Navy be conducted regarding the potential for groundwater contamination resulting from the land's urbanization. The study was to be completed prior to any development or construction on the Gentry site. That Navy-funded study was undertaken by the UH Water Resources Research Center in 1987 and its results were published in 1990 (Oki et al, 1990).

Another condition imposed by the LUC was for DOH to define the area of the Gentry project site which does not contribute to the Zone of Contribution (ZOC) of water which is pumped by the Shaft. To do this, DOH formed an Ad Hoc Committee of technical experts from the U.S. Geologic Survey, University of Hawaii, BWS, State Department of Land and Natural Resources, and the Safe Drinking Water Branch (SDWB) of DOH. The methods and results of this work were presented in Safe Drinking Water Branch (1990) and are described in the section following.

Delineation of the Zone of Contribution. The three equations used by the Ad Hoc Committee to construct the Shaft's parabolic-shaped ZOC were as follows:

(1) Downstream Stagnation Point, r:

$$r = \frac{Qw \times 5280}{2\pi \left(b / 41h\right) Q / L}$$

(2) Maximum Width of the ZOC, W:

$$W = 2\pi r$$

(3) Perimeter of the ZOC

$$\frac{Y}{X} \equiv \pm \tan\left[\frac{2\pi \times Q/L \times b \times y}{41h \times Qw}\right]$$

where the argument of the tangent is in Radians

Parameter definitions and values used in these equations were as follows:

- b = depth of the groundwater flow moving to the Shaft in feet, taken to be 415 feet based on a mixing cell model;
- h = freshwater head at the Shaft, taken to be 18 feet;
- Qw = pumping rate in MGD, taken to be 22 MGD; and
- Q/L = Groundwater flowrate in the aquifer in MGD/mile, taken to be 47 MGD/1.5 miles based on Hufen et al, 1980

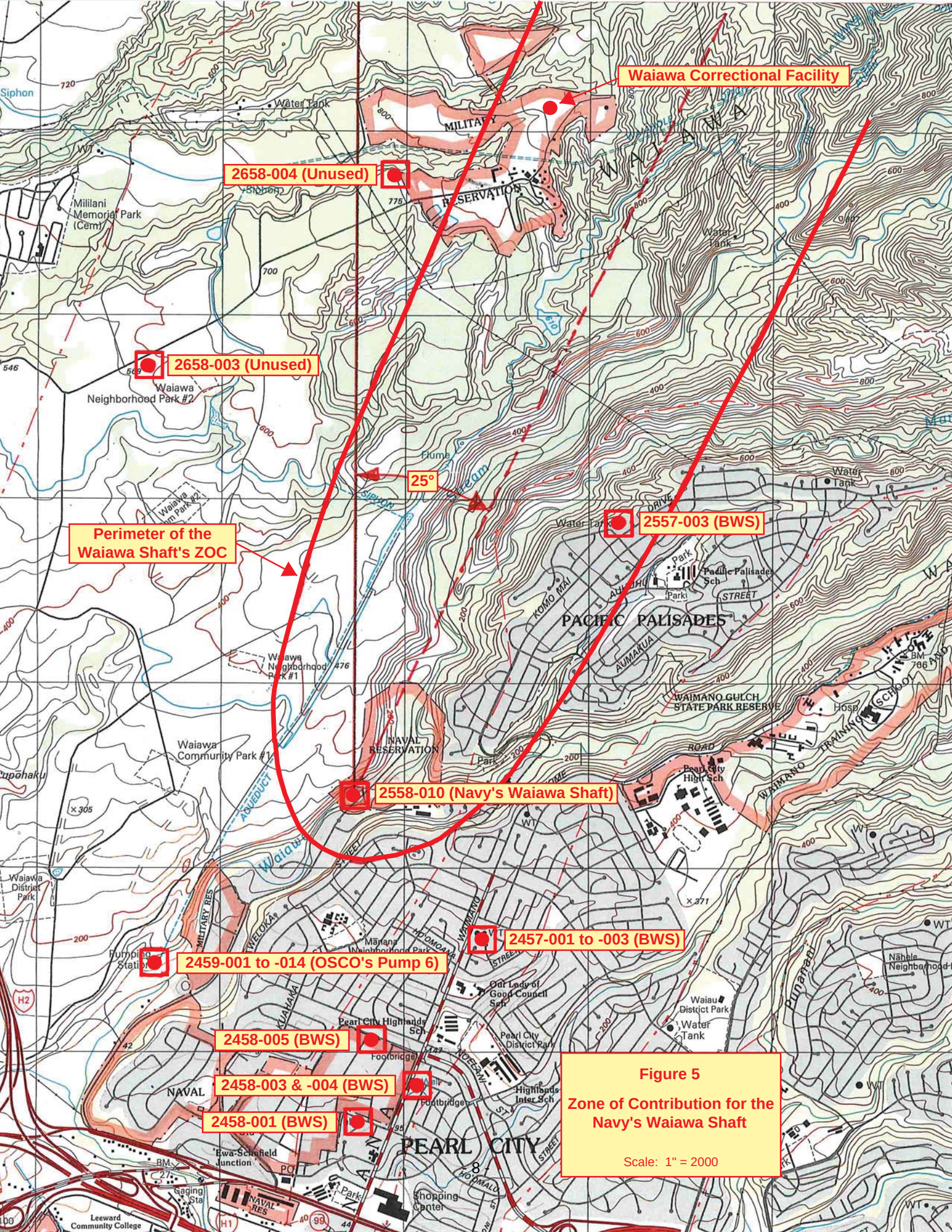
The foregoing equations and parameter values allow the calculation of the parabolic-shaped ZOC, but not its orientation to the direction of groundwater flow. Based on a USGS groundwater flow model that was then being developed; this direction was taken to be from 25 degrees east of north. Figure 5 depicts the resulting perimeter of the ZOC. Also shown are BWS wells in the vicinity, the location of the no longer used OSCO Pump 6 well battery, and two of the four wells developed for the Gentry Waiawa project that remain unused. The west perimeter of the ZOC bisects the hyacinth lagoon at the makai end of the WCF. New development within the ZOC is not prohibited, but it is subject to approval by DOH.

It is instructive to examine the sensitivity of the parameter values used in creating the shape and orientation of the ZOC. The three most critical parameter values are as follows:

- Pumping Rate, Qw, of 22 MGD. The Ad Hoc Committee's report used 22 MGD for the value of Qw based on 18 MGD as the well's "preserved" use, an additional 2 MGD for "emergencies", and another 10 percent for "tolerance". In fact, the Shaft's authorized use has always been 14.977 MGD (not 18 MGD) and the 12-month moving average of pumpage, the Qw value that should be used in the equations, has never exceeded 18 MGD. An earlier, September 2019 version of the Committee report used 18 MGD for the value of Qw. With 22 MGD, the width of the ZOC at the makai end of the WCF site is 5960 feet. At 18 MGD as the value for Qw, the width would be 1000 feet narrower at 4960 feet.

- Depth of Groundwater Moving to the Shaft of 415 Feet. No details of the mixing model used to estimate the depth of flow were given in the Committee report. As a skimming-type well, a shallower depth for the value of b in the equations is quite plausible. If 315 rather than 415 feet was used for this depth, the width of the ZOC at the makai end of the WCF site would be almost 2000 feet wider at 7640 feet for Qw = 22 MGD, encompassing almost all of the WCF. If both the lower pumping rate (Qw = 18 MGD) and the lesser depth of flow (b = 315 feet) were used, the ZOC at the makai end of the WCF would be 6380 feet, moving the west side of the ZOC to bisect the smaller lagoon adjacent to the hyacinth lagoon.

- Direction of Groundwater Flow from 25° East of North. The actual direction of groundwater flow is very sensitive to the anisotropy in lava flows and the amount of inflow from the Wahiawa (high


Waiawa Correctional Facility
2658-004 (Unused)
2658-003 (Unused)
25°
Perimeter of the Waiawa Shaft's ZOC
2557-003 (BWS)
2558-010 (Navy's Waiawa Shaft)
2457-001 to -003 (BWS)
2459-001 to -014 (OSCO's Pump 6)
2458-005 (BWS)
2458-003 & -004 (BWS)
2458-001 (BWS)
Waiawa Neighborhood Park #2
Waiawa Neighborhood Park #1
Waiawa Community Park #1
Waiawa District Park
Mililani Memorial Park (Cem)
MILITARY RESERVATION
NAVAL RESERVATION
PACIFIC PALISADES
WAIMANO GULCH STATE PARK RESERVE
PEARL CITY
Pearl City High Sch
Pearl City Highlands Sch
Pearl City District Park
Waiau District Park
Our Lady of Good Council Sch
Highlands Inter Sch
Pacific Palisades Sch
Ewa-Schofield Junction
Leeward Community College
Shopping Center
Gaging Sta
Water Tank
Siphon
Flume
Aqueduct
Figure 5
Zone of Contribution for the Navy's Waiawa Shaft
Scale: 1" = 2000

level) Aquifer System into the mauka end of the Waipahu-Waiawa Aquifer System. Groundwater contours based on measured water level suggest a more north to south flow direction rather than the direction used by the Ad Hoc Committee. Flow direction based on these contours would put the entire WCF in the ZOC. It is also of interest to note that less than 20 percent of the OSCO fields identified as having been irrigated by Pump 6 water, which had caused a sharp increase in Waiawa Shaft salinity in the 1970s, are within the ZOC. The remaining 80 percent of the irrigated fields are to the west of the ZOC (Figure 6 based on Eyre, 1983).

The ZOC as specified in the Ad Hoc Committee report is correctly shown on Figures 5 and 7, the latter taken from Wilson Okamoto & Associates, Inc. (1997) which clearly and correctly shows various onsite uses in the WCF with respect to the ZOC boundary. However, the 2017 Due Diligence Report (HHF Planners, 2017) shows an alternative interpretation which puts the ZOC boundary about 950 feet further to the east and at an angle of about 30° east of north (Concept Site Plans on pages A-3 and A-4 in the Due Diligence Report). This interpretation would move a large portion of the WCF outside of the ZOC. However, no basis for the alternative interpretation is given and it is definitely not correct.

WCF's Potential Impacts on Groundwater Within and Outside the Zone of Contribution of the Navy's Waiawa Shaft

Use of Water from Waiahole Ditch. All of the water used for potable consumption and irrigation at the WCF comes from the Waiahole Ditch which is now owned and operated by the State's Agribusiness Development Corporation (ADC). The CWRM regulates use of Waiahole Ditch water as its own Aquifer System. It has issued 14 WUPs for withdrawals from the Ditch totaling 12.241 MGD for various agricultural and other uses on the leeward side of the Koolau mountain. ADC reports water use for all 14 of these WUPs on a monthly basis to the CWRM, including the use by the WCF.

The WCF's permitted use is 0.150 MGD (equivalent to 150,000 gallons per day [GPD]) based on WUP No. 630 issued on December 28, 2001. The Ditch daylights upstream of the WCF at Adit 8, passes beneath the WCF in a tunnel, and daylights again downstream of the WCF. At this downstream point, water is pumped up to the WCF for potable use after treatment by a Memcor filtration plant and for agricultural irrigation, the latter using the Ditch water without treatment. The schematic on Figure 8 illustrates the water system from its point of withdrawal on Waiahole Ditch to its delivery into the WCF distribution system, with the locations of three flow meters highlighted in red and yellow: (1) on the inflow pumped through the Memcor filter units; (2) on the line delivering the filtered and chlorinated water to the 0.5 million gallon (MG) storage tank; and (3) on the line delivering water from the storage tank into WCF's distribution system.

ADC reports WCF's monthly water use as the amount measured by the Raw Water Flow Meter at the treatment plant. Using data provided for that meter by Pural Water Specialty Co., Inc. and incorporating corrections for obvious meter errors, Figure 9 illustrates this reported use in comparison to WCF's authorized use of 150,000 GPD. The reported use averaged about 60,000 GPD over this period. The problem is that the actual withdrawal from Waiahole Ditch is not measured and the location of the Raw Water Flow Meter does not measure the following amounts of water actually withdrawn for WCF from the Ditch:

- Losses enroute from the point of diversion on the Ditch to the 2,400 Gallon Raw Water Tank near the Memcor treatment plant;

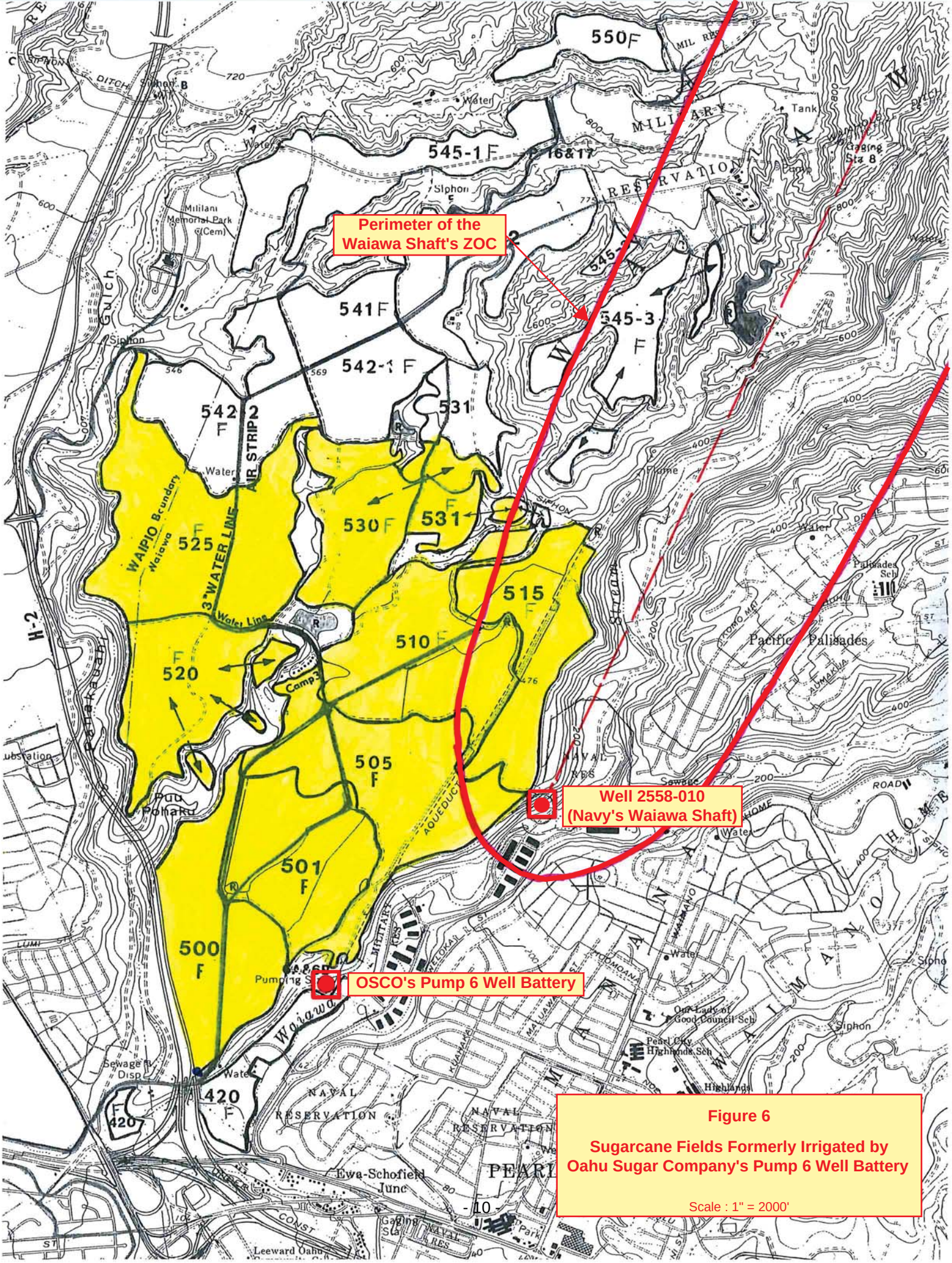
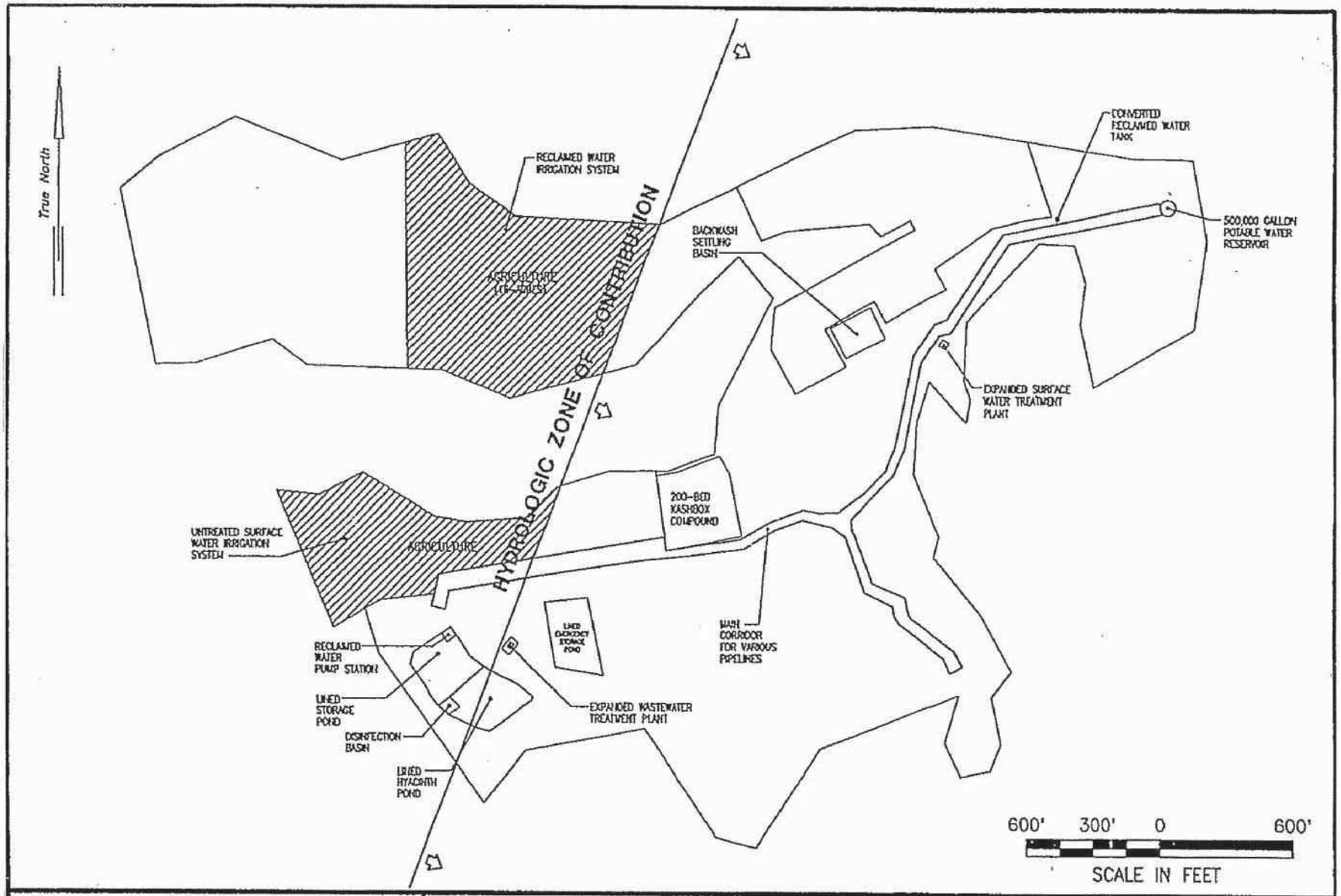


Figure 6

Sugarcane Fields Formerly Irrigated by Oahu Sugar Company's Pump 6 Well Battery

Scale : 1" = 2000'



WAIAWA CORRECTIONAL FACILITY IMPROVEMENTS

Fig. 14

HYDROLOGIC ZONE OF CONTRIBUTION

Prepared for:
DEPARTMENT OF ACCOUNTING AND GENERAL SERVICES, STATE OF HAWAII

Prepared by:
WILSON OKAMOTO & ASSOCIATES, INC.

Figure 7

West Perimeter of the ZOC Crossing the Waiawa Correctional Facility

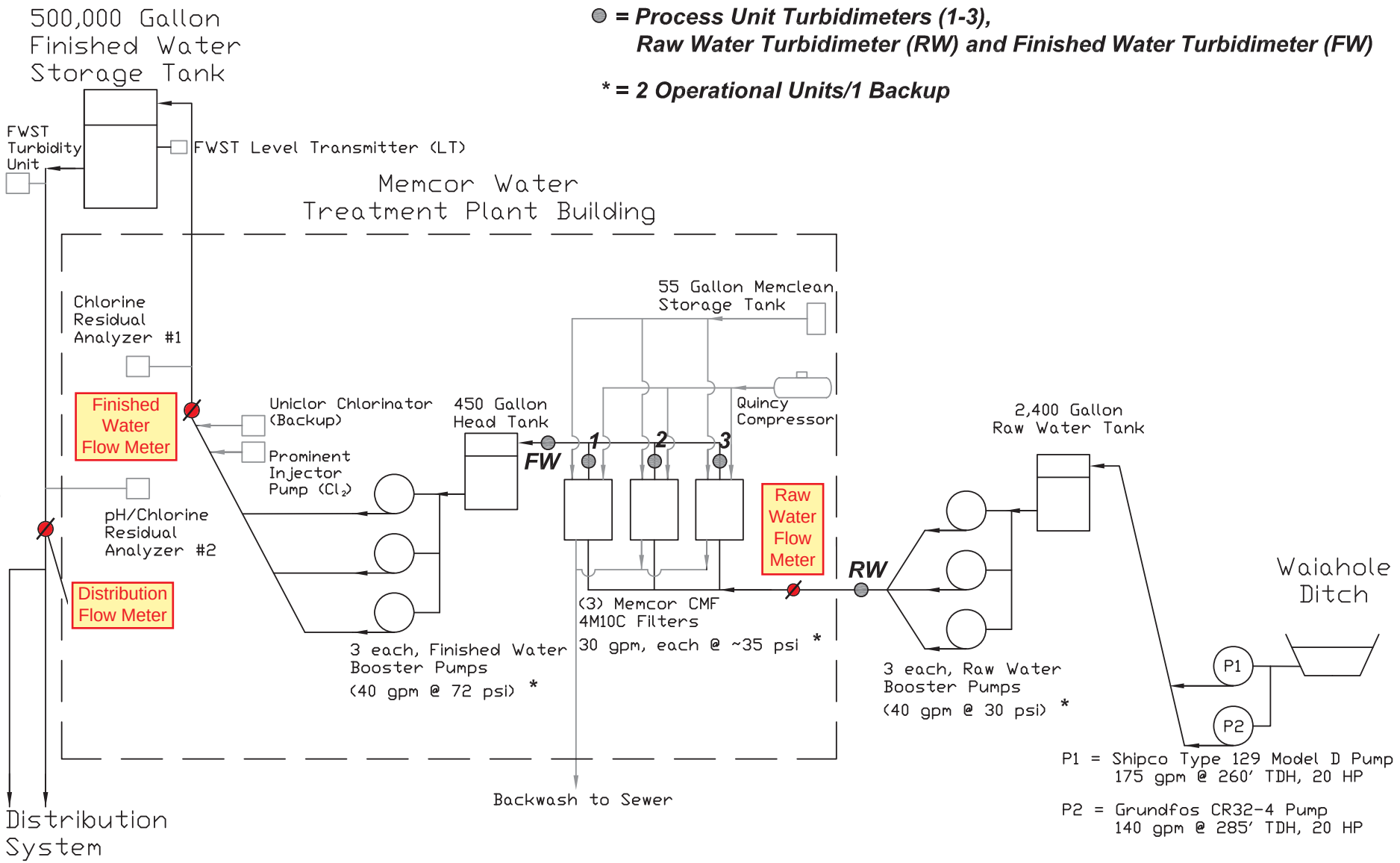


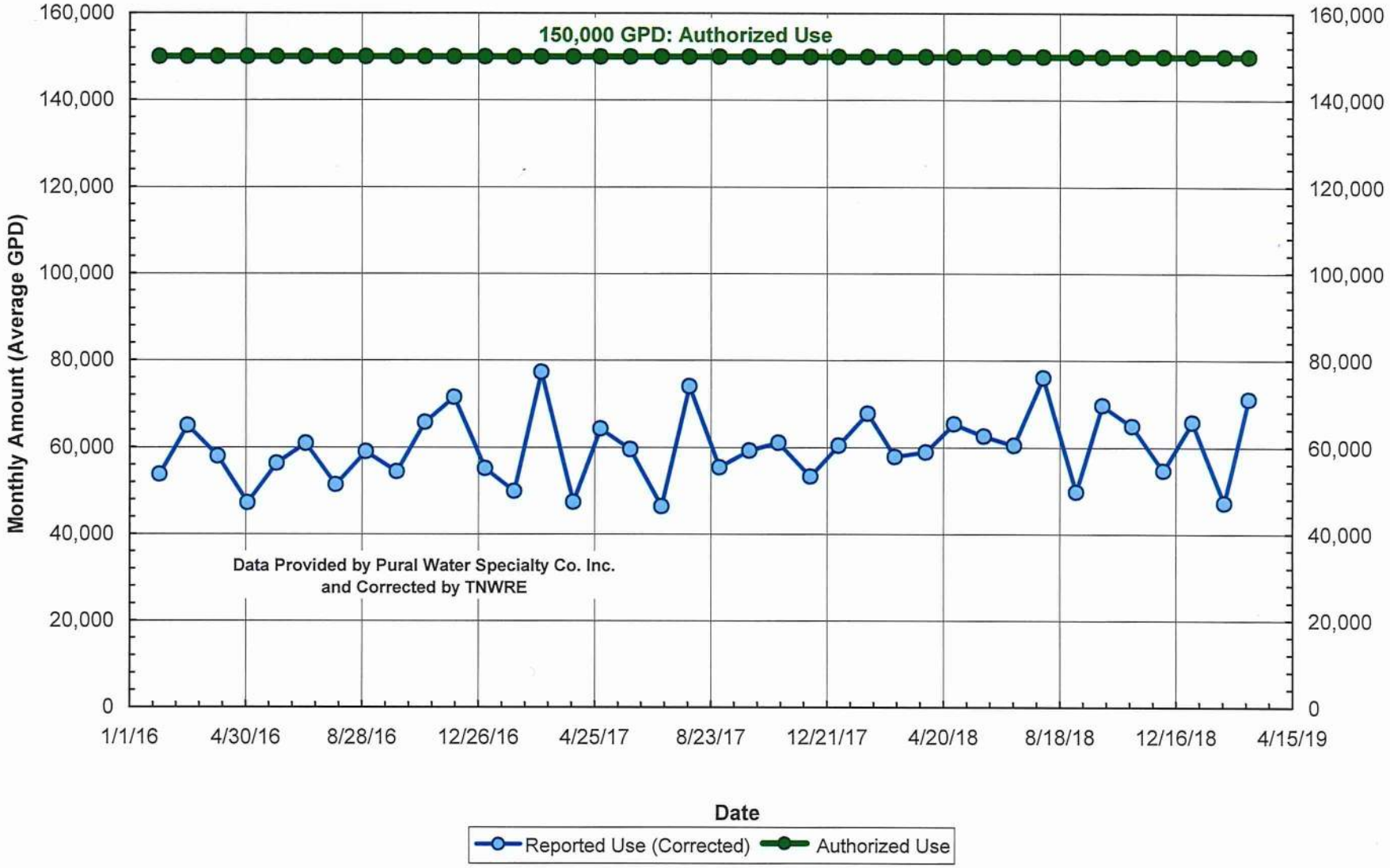
Figure 8

WCF Water System Schematic

Page 1 of 1	Date: 12/03/13

Pural Water Specialty Co., Inc.
Waiawa Correctional Facility
Water System
Water Distribution Schematic

Figure 9. Comparison of WCF's Corrected Reported Use with its Authorized Use



- Overflows from the Raw Water Tank which occur because the tank is too small for pump capacities and system supply requirements; and
- Use of untreated Ditch water for irrigation on the 10-acre site identified on Figure 7 and outside of the ZOC, by far the largest component of unmetered use or loss.

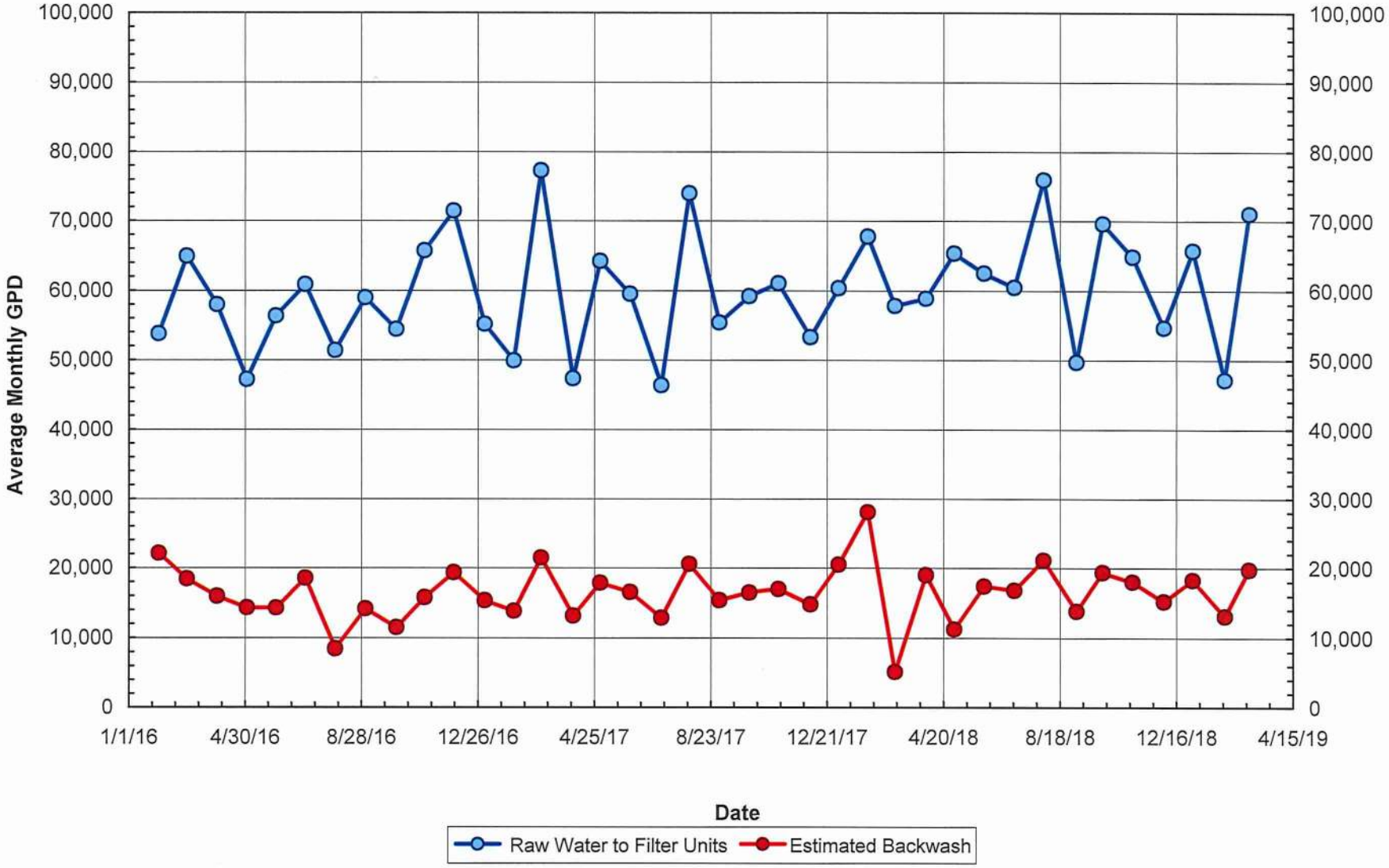
The connection for irrigation use is not shown on Figure 8. It consists of gravity flow from the 2400-gallon Raw Water Tank into an adjacent and buried 96,000-gallon concrete storage tank. Delivery for irrigation use is by gravity from the buried tank. There is no way to accurately approximate the unmeasured amounts identified in the bullet points above, but it is likely that the actual withdrawal from the Ditch is about 100,000 GPD, still below WCF's 150,000 GPD permitted use.

Potential Impact of the Treatment, Storage, and Backwash Disposal of WCF's Drinking Water System. The WCF's drinking water system is regulated by the SDWB of DOH as Public Water System No. 348. Operation of the system is done by Pural Water Specialty Co., Inc. under contract to WCF. As shown previously on Figure 8, the Ditch water is pumped through one or more of the three Memcor filtration units, is chlorinated, and is then pumped up to the 0.5 million gallon (MG) bolted steel tank located at the mauka end of the WCF site. Backwash of the Memcor filtration units occurs automatically at timed intervals and/or in response to back pressure on the filter units. The backwash water flows by gravity to an unlined "silting basin" that is now quite overgrown and has standing water in an area of about 0.15 acres (disposal of the backwash is shown incorrectly on Figure 8 as being delivered into the "sewer system"). Locations of the treatment plant, 0.5 MG storage tank, and silting basin are shown on Figure 7. All, including the unlined silting basin, are within the ZOC. The amount of the filter backwash can be approximated as the difference between the Raw Water and Finished Water flow meters. These amounts are shown on Figure 10 and averaged about 17,000 GPD over this period, amounting to about 28 percent of the water sent into the Memcor filters. Disposal of the backwash in this manner was previously approved by DOH and its potential impact on the groundwater beneath the WCF at depth is deemed to be inconsequential. The quantity is small, contains no chemicals of concern, and is subject to substantial natural filtration through the silt bottom of the basin and the soil below the basin.

Potential Impact of the Generation, Treatment, and Irrigation Reuse of Wastewater Generated at the WCF. Wastewater generated at the WCF is delivered to an extended aeration treatment plant in the southwest corner of the WCF site. From there it flows by gravity into a lined, hyacinth-filled lagoon for nutrient removal. "Polished" water from the hyacinth lagoon is then chlorinated in a contact chamber and then flows into the adjacent smaller lagoon. Water in this lagoon is classified as R-2 quality treated effluent. Its disposal is by drip irrigation of the vegetation in the 16-acre area outside of the ZOC shown on Figure 7. As a matter of completeness, it should be noted that there is an unlined, emergency overflow spillway on the mauka side of the extended aeration treatment plant.

The wastewater system, including disposal of the R-2 effluent by irrigation, is operated under contract by Aqua Engineers. On Figure 11, monthly average wastewater inflow rates as measured by the weir at the extended aeration plant are plotted against the plant's stated 56,100 GPD rated capacity. Average wastewater inflow over this period was 53,300 GPD. Figure 12 is a plot of the R-2 effluent pumped for drip irrigation on the 16-acre designated area shown on Figure 7. The R-2 amounts are measured on the discharge pipeline of the two pumps at the finished water lagoon. For the months shown on Figure 12 for which the amount of R-2 pumped for irrigation are available, the R-2 volume averaged 34,500 GPD, amounting to about 65 percent of the influent wastewater to the extended aeration treatment plant. The difference reflects the amount of evapotranspiration from the hyacinth lagoon, evaporation from the open water surface of the R-2 lagoon, possible leakage loss from the lined lagoons, and potential flow meter inaccuracy. As shown on Figure 13, meter inaccuracy is a very real possibility.

Figure 10. Portion of the Raw Water Pumped to the Memcor Filters that Becomes Filter Backwash



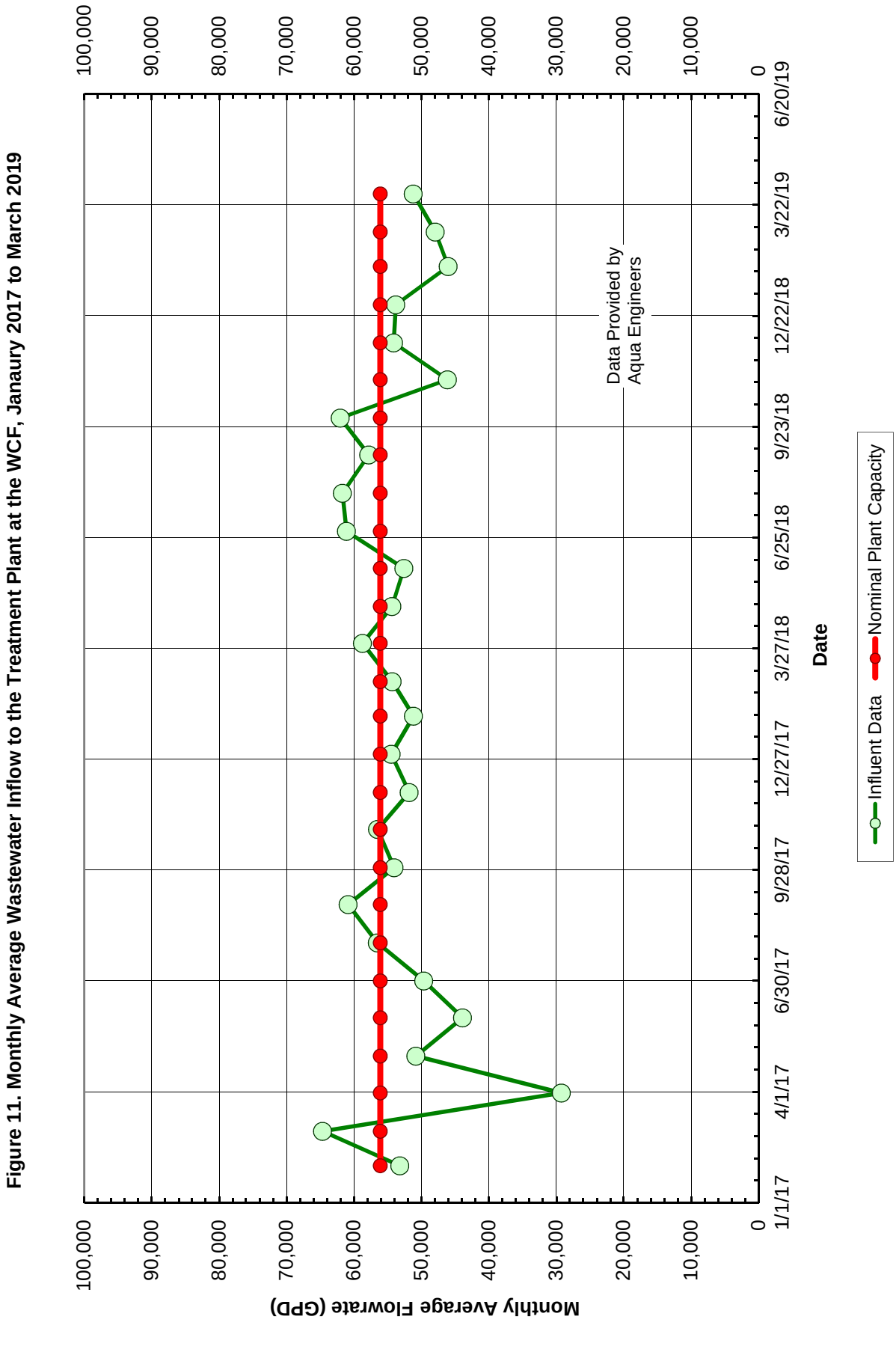


Figure 11. Monthly Average Wastewater Inflow to the Treatment Plant at the WCF, Janaury 2017 to March 2019
Monthly Average Flowrate (GPD)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1/1/17
4/1/17
6/30/17
9/28/17
12/27/17
3/27/18
6/25/18
9/23/18
12/22/18
3/22/19
6/20/19
Date
Data Provided by
Aqua Engineers
Influent Data
Nominal Plant Capacity

Figure 12. Comparison of the Influent Flowrate to the R-2 Effluent Pumped for Irrigation

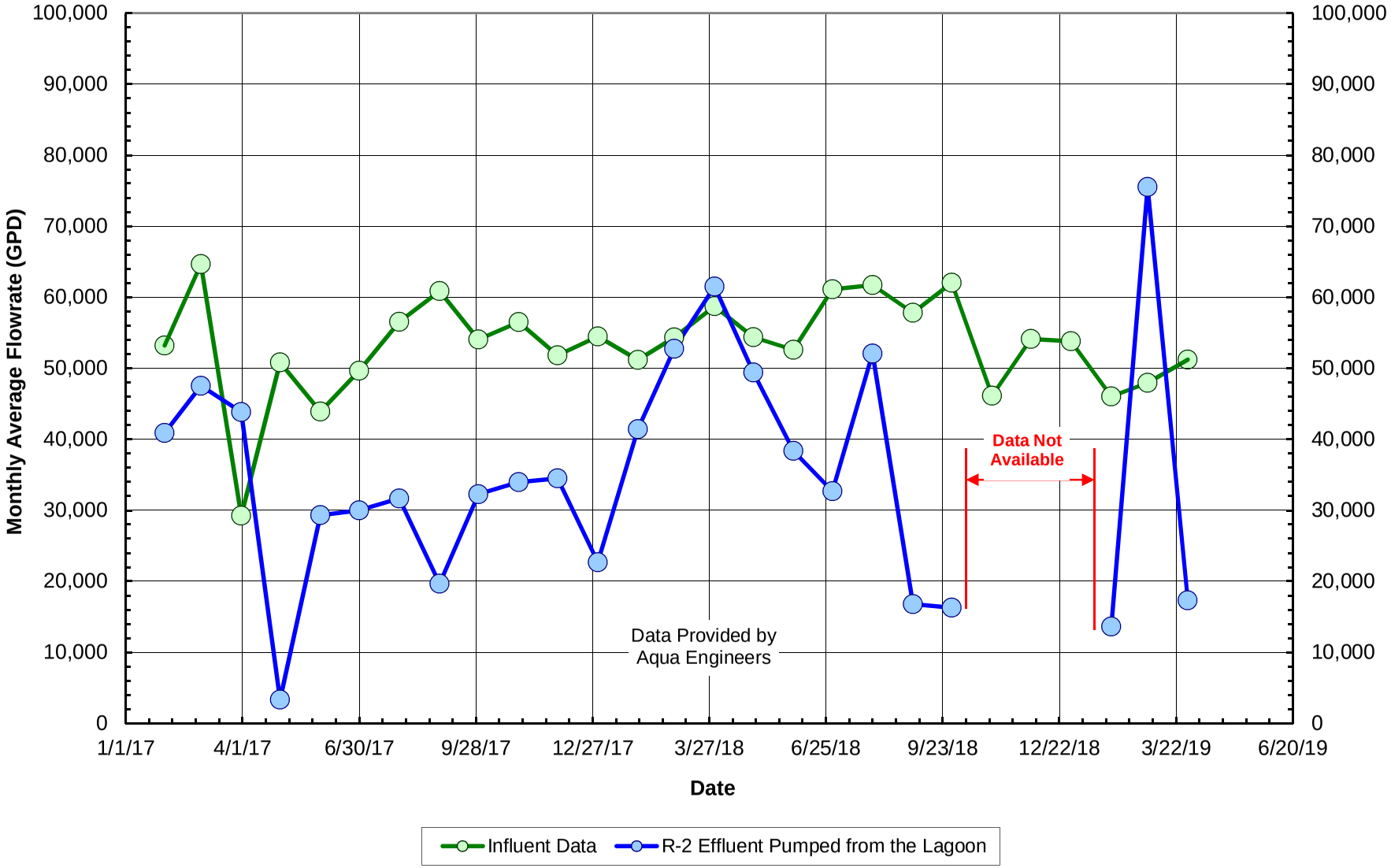
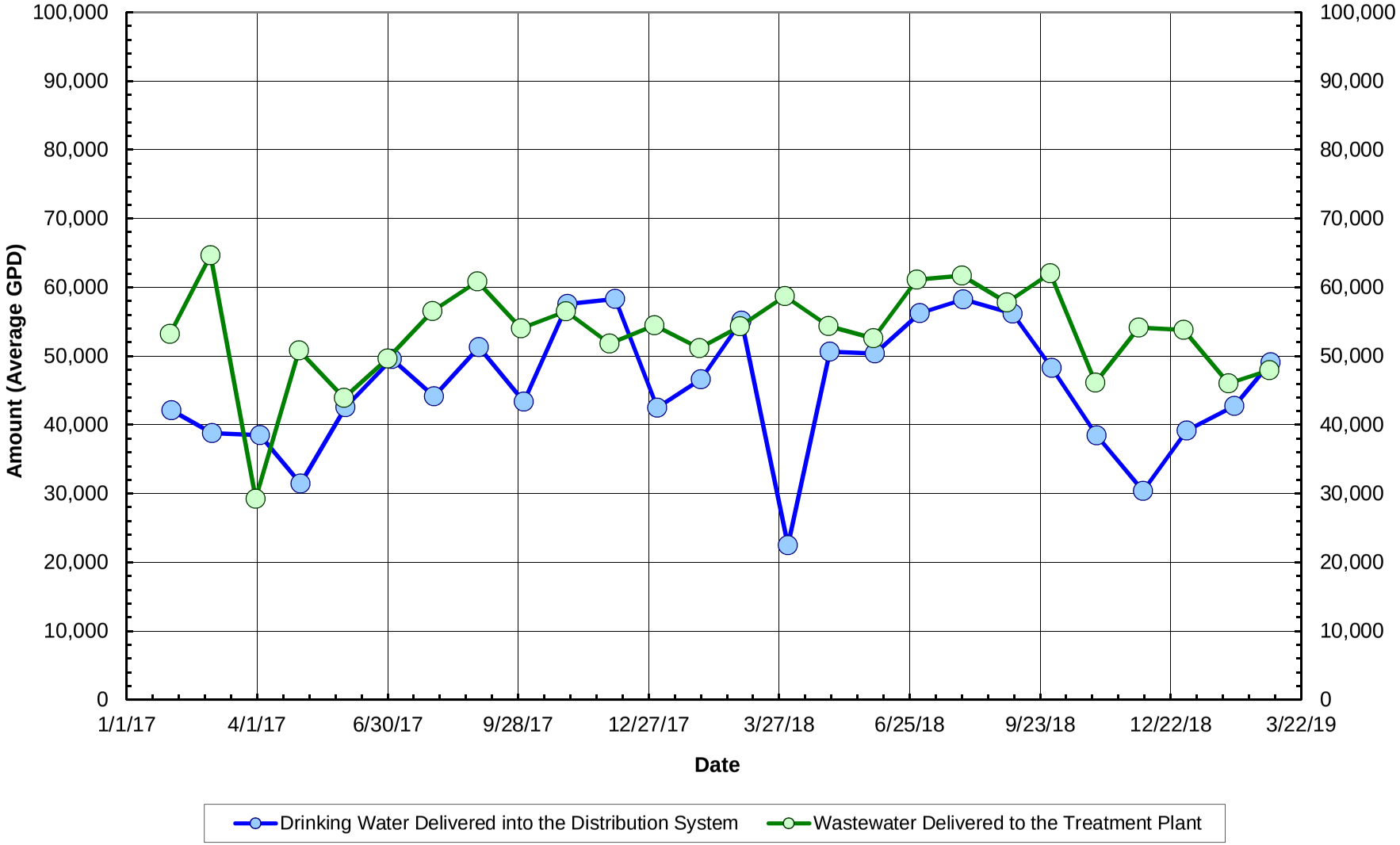


Figure 13. Comparison of Drinking Water Delivered into the Distribution System and Wastewater Delivered to the Extended Aeration Treatment Plant



The measured amount of wastewater into the extended aeration treatment plant is consistently shown to be greater than the amount of drinking water delivered into the distribution system. Over this 26-month period, the metered average drinking water amount was 45,500 GPD. In comparison, the metered average wastewater flow was 17 percent higher at 53,400 GPD. It is unlikely that infiltration into the sewer lines accounts for this difference.

Application of the R-2 effluent using drip irrigation on the 16-acre area identified on Figure 7 must be in accord with DOH's Reuse Guidelines and have the prior approval of DOH. By letter of May 18, 1998 from Lawrence Miike, Director of the DOH, to Keith Kaneshiro, State Director of Public Safety, the WCF was authorized to operate its wastewater facility and irrigation reuse of the R-2 treated effluent outside the Waiawa Shaft's ZOC. On a quarterly basis thereafter until 2005, the SDWB of DOH sampled the Waiawa Shaft and three other BWS wells in the vicinity (Waipio Heights I, II, and III) for nitrate, nitrite, and TDS to track water quality changes that might be attributable to activities at the WCF, including its irrigation reuse of the R-2 effluent. By letter of February 11, 2005, from William Wong, Chief of the SDWB, to Harold Yee, Chief of the Wastewater Branch, the SDWB indicated that it would no longer conduct the quarterly sampling. The reason given was that "…. no notable change has occurred." Based on the data collected, it is reasonable to conclude that the impact of the irrigation reuse of the R-2 effluent is inconsequential.

Potential Impact of Irrigation with Untreated Ditch Water. A portion of the 10-acre area outside of the ZOC identified on Figure 7 is irrigated with untreated Waiahole Ditch water. Delivery of the water is by gravity from a buried 96,000-gallon storage tank. As stated previously, this use is not metered. However, it is likely to be in the range of 20,000 to 30,000 GPD. A portion of this, perhaps on the order of 10 to 15 percent, may pass below the root zone of the irrigated crops and ultimately reach the groundwater below. The quantity is small and considered to be of inconsequential impact to the quality of groundwater in the aquifer.

Summary of Findings, Conclusions, and Recommendations

1. The ZOC of the Waiawa Shaft is correctly shown on Figures 5 and 7 of this report.

2. Activities within the ZOC which have a potential to impact the underlying groundwater are percolation from the unlined silty basin on the drinking water system and possible leakage of treated wastewater from the system's two lined lagoons. Their potential impact on the underlying groundwater are considered to be insignificant.

3. All irrigation is taking place outside of the ZOC. It consists of drip irrigation of R-2 treated wastewater on a 16-acre area and irrigation using untreated Waiahole Ditch water on a separate 10-acre area. Their potential impacts on the underlying groundwater are also considered to be insignificant.

4. The draw of water from Waiahole Ditch is incorrectly being reported as the amount measured by the Raw Water Flow Meter at the Memcor filtration plant. This fails to include irrigation with untreated Ditch water, overflows of the 2400-gallon Raw Water Tank, and other losses. A flow meter should be installed on the discharge line of the pumps that draw water from the Ditch. It would be useful if a meter was also installed on the pipeline from the Raw Water Tank to the buried irrigation tank to document the irrigation use.

5. The 2400-gallon Raw Water Tank is too small for its intended function. It should be replaced with a tank appropriately sized for the manner and rate of pumping from Waiahole Ditch.

6. Inflow to the extended aeration wastewater treatment plant is measured with a weir. It appears to be overestimating the actual rate of inflow. Calibration to check or adjust its accuracy should be undertaken.

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