HAINA WELL WATER ANALYSIS FOR PRESENCE OF HUMAN ENTERIC VIRUSES AND OTHER WATER QUALITY PARAMETERS, ISLAND OF HAWAI'I

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BASIS AND PURPOSE FOR ANALYSES OF HAINA WELL WATER

The Haina Well (DLNR Job No. 22-HW-26) is located in a sugarcane field approximately 644 m (0.4 miles) makai (downgradient) of the town of Honokaa and at an elevation of 260.6 m (855 ft) above sea level (Fig. 1). The well taps a basal lens. At the well site, the water table is approximately 1.8 m (5.75 ft) above sea level. The well water is intended for domestic drinking use. The origin of the fresh water is believed to be principally rain water which had percolated through the soil column and the underlying rock formations. The quality of groundwater is generally very good. However, the geological structure within the Honokaa area is characterized by lava tubes which may transport water a long distance without subjecting the water to natural purification by such processes as filtration, adsorption, degradation, and plant uptake. In this regard, sewage in that area is generally discharged untreated into cesspools or directly into underground lava tubes. Of particular concern is the discharge of untreated sewage from the Honokaa Hospital into a subterranean lava tube approximately 241 m (0.15 miles) makai of Honokaa town and 402.25 m (0.25 miles) mauka of the Haina Well site. Under these conditions, there is a reported concern that the source of fresh water from the Haina Well may be contaminated with sewage. Moreover, since sewage is a source of infectious human enteric pathogens, such as bacteria, viruses, and protozoa which may be transmitted by ingestion, it is essential that the Haina Well water be determined to be free of human enteric pathogens. To determine the presence or absence of human enteric pathogens, water sources are currently tested for coliform bacteria. However, due to the relative instability of coliform bacteria as compared to human enteric viruses, the usefulness of the coliform test is limited under conditions of long storage or even treatment with chlorination. Under these conditions,

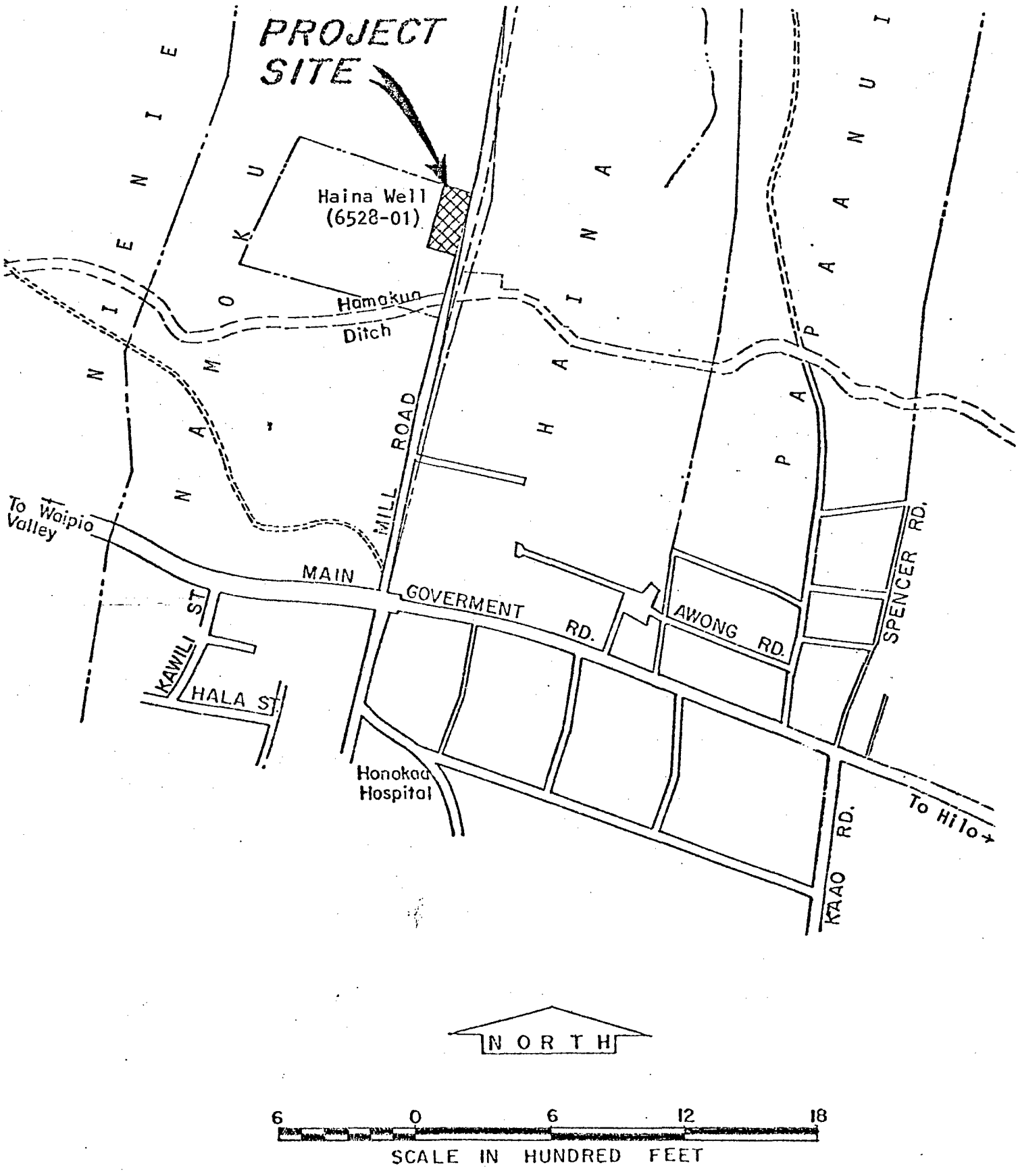

Figure 1. Haina Well (6528-01) Site, Island of Hawaii

human enteric viruses have been recovered from certain water sources which had been determined to be safe based on the coliform test.

The primary purpose for the analysis of the Haina Well water by the Water Resources Research Center of the University of Hawaii at Manoa was to determine the presence or absence of human enteric viruses in the well water. Since coliform bacteria is currently the only indicator bacteria required by law to assess the hygienic quality of water, the total coliform and fecal coliform contents of the well water were tested. In addition, the water was also tested for fecal streptococcus, the most used alternative indicator of water quality, and for *Clostridium perfringens*, the most stable of the proposed indicator bacteria. Finally, as a check on the overall quality of the well water, selected chemical analyses of the water were also done.

SAMPLING DESIGN AND PURPOSE

Pumping of the Haina Well was initiated at 10 A.M. on 28 February 1983 and continued until 4:30 P.M. with only an approximately 15-min interruption between 11:15 and 11:30 A.M. due to power failure. Although the pump was not metered, we were informed that the pump rate was 0.025 m^3/s (400 gal/min). The purpose of continually pumping the water from the well source was two-fold: first, to initially clear the water trapped in the well casing since this water may not be representative of the natural underground water; and second, to enable us to sample groundwater not only at the immediate site at the bottom of the well casing but to draw water from the aquifer surrounding that site. This sampling design should enable us to obtain water samples which would be representative of the basal water lens. A faucet attached to the well head was used to siphon off water being pumped up and was our source of sampling water.

Before actual sampling, the newly purchased plastic containers which were used as our water collector were disinfected by chlorine treatment to ensure that no possible contamination from sources extraneous from the well could occur. All of the supplies (filters, hoses) which we brought were disinfected before arriving at the field site. Essentially three water samples were taken for analysis. The first sample was taken approximately at 12 noon, the second at 2 P.M. and the third at 4 P.M. In reality, each of the three sampling period occurred over a 45-min period. At each of the three sampling periods, the pH, temperature, and visual clarity of the water were assessed at the site. Sterile bottles were used to collect samples at the three stated time periods. The sample bottles were immediately stored in a closed ice chest filled with ice to keep the samples cold, and the samples were transported back to the University of Hawaii Sanitary Engineering Laboratory for chemical and bacterial analyses. In addition to these three well water samples, a sample of the Lower Hamakua Ditch water which was flowing approximately 91 m (100 yd) upgradient of the well was also collected and transported back to the UH laboratory for chemical and bacterial analyses. The ditch water was collected to serve as our reference sample which served as a quality control on our procedure of preparing sterile sample bottles, of properly transporting samples back to our laboratory and ensuring that the reagents and test procedure were working properly. All tests for chemicals and bacteria except *Clostridium perfringens* are standard tests as described in *Standard Methods for the Examination of Water and Wastewater*. The procedure to assay for *C. perfringens* is relatively new but has been recently evaluated and considered standard in our laboratory.

To assess the virological quality of drinking water sources, it is generally agreed that large volumes of water (at least 378.5 ℓ or 100 gal) be

analyzed. Since this volume of water is unreasonable to transport, the water to be tested must be processed on site. However, since the entire virus concentration procedure is complicated, only the first step of allowing viruses in the water to adsorb onto reasonably sized filters is actually performed on site. To accomplish this, well water samples are collected into clean containers and the waters are conditioned by adding appropriate chemicals and adjusting the pH. The water samples are then filtered through special 0.25 m (10 in.) cartridge type filters. Under these conditions, 378.5 ℓ of water can be processed through each filter, meanwhile allowing viruses suspended in the water to adsorb onto the filter. As a safety precaution, a backup filter was added. This filter processed all 1135.5 ℓ (300 gal) of water which were initially processed by the three separate and primary filters. Thus for virus assays, three water samples were analyzed but four filters were subsequently analyzed for virus. After the filters were transported back to our laboratory, the filters were processed to elute any virus adsorbed onto the filter, to reconcentrate the virus in the eluant to a small manageable volume, and to inoculate the final sample onto susceptible cells to allow the multiplication of viruses. It should be noted that there are no standard methods for assaying viruses from water. However our laboratory has previously evaluated a number of different methods for over ten years. Only methods which we have determined to be effective were used.

RESULTS

Chemical and Bacterial Analyses

The results of chemical and bacterial analyses of Haina Well water samples 1, 2, and 3 as well as the sample of Lower Hamakua Ditch water are summarized in Table 1. For the three Haina Well water samples, all the concentrations of chemicals and bacteria assayed met by a large margin the

standards as recommended in the primary and secondary drinking water standards. The concentrations of the measured parameters in well samples 2 and 3 were very similar to each other and substantially lower than in sample 1. The most obvious explanation for these observations is that the well casing and head were not sufficiently flushed before sample 1 was taken. However, by the time samples 2 and 3 were taken, adequate flushing had taken place and the quality of underground water appeared to have reached an equilibrium. The virtual absence of indicator bacteria, total coliform, fecal coliform, fecal streptococci and *C. perfringens* indicates that the well water is not contaminated with sewage. In this regard, the absence of *C. perfringens* from any of the well water samples is especially relevant since this enteric bacteria forms spores which are very resistant and can be expected to survive much longer than human enteric pathogens, including viruses.

For Hamakua Ditch water, all the measured chemical analyses met by a large margin the standards recommended in the primary and secondary drinking water standards. However, as in most surface water sources, substantial concentrations of total coliform were recovered. However, based on the relatively low concentrations of fecal coliform relative to fecal streptococci (FC:FS ratio of 0.5) and the very low concentrations of *C. perfringens* (2 CFU/100 mℓ) in the Hamakua Ditch water, we conclude that the source of these indicator bacteria in the Hamakua ditch water is animal and wild life and is not due to human sewage contamination.

Analyses of Well Water for Human Enteric Viruses

The three separate 378.5 ℓ (100 gal) water samples taken from Haina Well were analyzed for human enteric viruses. The results (Table 2) show that enteric viruses were not recovered in the three samples as well as the composite of the three samples. These results indicate that the well water

TABLE 1. CHEMICAL AND BACTERIAL ANALYSES OF HAINA WELL WATER AND LOWER HAMAKUA DITCH WATER, ISLAND OF HAWAII

Parameters Tested	Haina Well Water Samples			Lower Hamakua Ditch Water
	1	2	3	
Temperature (°F)	70.5	70.5	70.5	Not Done
pH	7.1	7.1	7.1	7.1
Turbidity (NTU)	0.7	0.7	0.6	0.9
Specific Cond. (µmhos/cm)	1200	400	390	380
Total Residue (mg/ℓ)	173	83	77	101
Alkalinity (mg $CaCO_3$/ℓ)	40	14	9	37
Chlorides (mg/ℓ)	30	10	10	10
NO_2 + NO_3 Nitrogen (mg/ℓ)	1.6	0.5	0.5	0.6
Orthophosphate (mg/ℓ)	0.05	0.02	0.02	0.04
Sulfate (mg/ℓ)	10.5	14.9	12.3	2.1
Total Coliform (CFU/100 mℓ)	<1.0	<1.0	<1.0	2400
Fecal Coliform (CFU/100 mℓ)	<1.0	<1.0	<1.0	85
Fecal Strep. (CFU/100 mℓ)	1.0	<1.0	<1.0	1750
Clostridium perfringens (CFU/100 mℓ)	<1.0	<1.0	<1.0	2.0

TABLE 2. ANALYSIS OF HAINA WELL WATER FOR INFECTIOUS HUMAN ENTERIC VIRUSES, ISLAND OF HAWAII

Sample Identification	Sample Volume (gal)	Sampl. Per. (hr)	Assay for Human Enteric Viruses
Sample 1 (Filterite Filter 1)	100	1145-1230	Neg.
Sample 2 (Filterite Filter 2)	100	1345-1430	Neg.
Sample 3 (Filterite Filter 3)	100	1545-1630	Neg.
Composite: Samples 1, 2, 3 (K-27 Fiberglass Filter)	300	1145-1630	Neg.

is not contaminated with human enteric viruses. It should be pointed out that there are some limitations inherent in all virus assay procedures. However, based on the complete analysis of the well water, we conclude that the overall quality of the well water is excellent and based on our careful assessment of the well water, that it would be most unlikely for human enteric viruses to be present.

CONCLUSIONS AND RECOMMENDATIONS

The discharge of untreated sewage into cesspools and into underground lava tubes within the area of the Haina Well has been occurring for a long time. Thus, it is reasonable to assume that any contamination of the underground water by sewage should have reached a steady state condition by this time and that the samples of water collected for this series of tests are representative of the basal water supplying the well. Under these assumptions and based on the results of our own analyses of the well water for selected chemicals, several indicator bacteria and human enteric viruses, we conclude that the well water is essentially clean, fresh water that is uncontaminated with fecal matter. Since this conclusion is based on some assumptions, the following recommendations are made

1. Well water should be routinely assayed for total coliform at a frequency recommended by the Primary Drinking Water Standards.
2. Well water should be analyzed for the presence of *Clostridium perfringens* at the minimum frequency of once per month for at least six months as a conservative check on the quality of the well water.
3. If human enteric virus contamination of the well water is suspected, the following chlorination conditions as recommended by the Environmental Protection Agency to ensure that the treated water is free

of infectious viruses should be followed.

> The quality of the finished water for drinking purpose should have a turbidity of less than 1.0 NTU and a pH of less than 8.0. This water should be chlorinated with a free chlorine residual of greater than 0.5 mg/ℓ for a minimum contact period of 30 min. Moreover, a minimum of 0.2 mg/ℓ of free chlorine residual throughout the distribution system is desirable.

Although well yield and drawdown are not a part of the purpose of the analysis, we noted the technical data supplied to us. Based on these data, we suggest to limit pumping of the well, on a sustained basis, to less than 400 gpm per day in order to reduce drawdown and sea water intrusion and to preserve the freshness of the pumped water.