Evaluation of Hand-dug Wells in Rural Haiti

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ABSTRACT

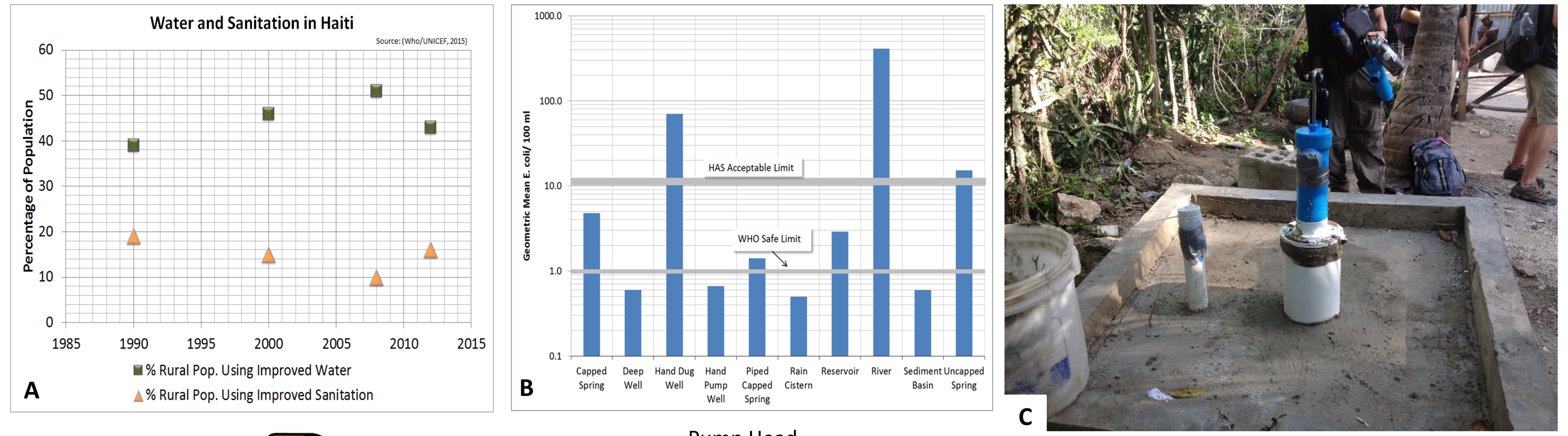
Water resources are limited for many Haitians, especially safe potable water. In areas where shallow groundwater is available many household water needs such as laundry, bathing, and cooking are supplied by hand-dug wells. In order to better understand the water quality and prevalence of these household wells, 20 wells were surveyed and sampled in a small community in Borel, Haiti. Borel has approximately 590 homes and 3,000 people and is situated roughly 65 km northwest of the capital; Port au Prince, Haiti. Some of these hand-dug wells, which are common throughout Haiti, may be suitable for conversion to a new well type called an In-Situ Filtration (ISF) well. ISF wells are installed with an internal sand filter system, PVC piping, pump, and are sealed from surface contamination. Previous installations have reduced E. coli to safe drinking water levels within 90 day of installation.

Data was collected from 20 hand-dug wells in the Borel area on June 6th, 2016. Each well was given an identification number, and measurements of elevation, depth, static water depth, and collar type were recorded. Water samples were collected and tested for fecal coliform and E. coli using the Colilert-18 method which reports a MPN (most probable number) for both coliform and E. coli. These wells had an average depth of 2.6 meters and an average static water depth of 0.88 m, 95% of the samples were unsafe to drink based on the World Health Organization (WHO) standard for E. coli in potable water. Average E. coli for the 20 wells was 817.8 (MPN) (geometric mean of 218.8 (MPN)), which exceeds the standard of 1 E. coli per 100 mL based on the WHO.

A hand-dug well density of 823 wells per km² was estimated in Borel. Based on this value, there are approximately 280 hand-dug wells similar to those sampled in the entire Borel community. Given an approximate cost of ISF well conversion of $300 per well. Conversion of all the wells in the community would cost approximately $84,000.

INTRODUCTION

- According to the World Health Organization (WHO), 663 million people worldwide use unimproved drinking water sources, including springs, surface water, and unprotected wells (WHO, 2015).
- In 2012, Only 62% of Haitians had access to improved drinking water sources, 75% in urban areas and 42% in rural areas (Figure 1A) (UNICEF, 2015).
- Karst development in Haiti results in unsafe water in shallow aquifers and dissolving bedrock (www.gvsu.edu/haitiwater).
- In the Artibonite Valley, 71-100% of the fresh water springs are unsafe to drink based on the WHO safe limit (Figure 1B). (Wampler and Sisson, 2011).
- Safe water interventions include cement and plastic biosand filters (BSF), Sawyer filters, chlorination, drilled wells, and boiling of water.
- BSF, Sawyer filters, and chlorination have proven less effective due to cultural practices and education (Sisson et al., 2013).
- A new intervention has been implemented called an In-Situ Filtration (ISF) well. Theses wells use a sand pack to filter water slowly as it is drawn through the well. The materials required are commonly found in Haiti and cost approximately one tenth the price of a traditional drilled well (Figure 2B, Figure 9).
- ISF wells can provide safe drinkable water and have proven to be more efficient and sustainable. ISF wells may contain beneficial biological activity within the outer layer of the well similar to the Schmutzdecke layer of a BSF (Figure 2A).



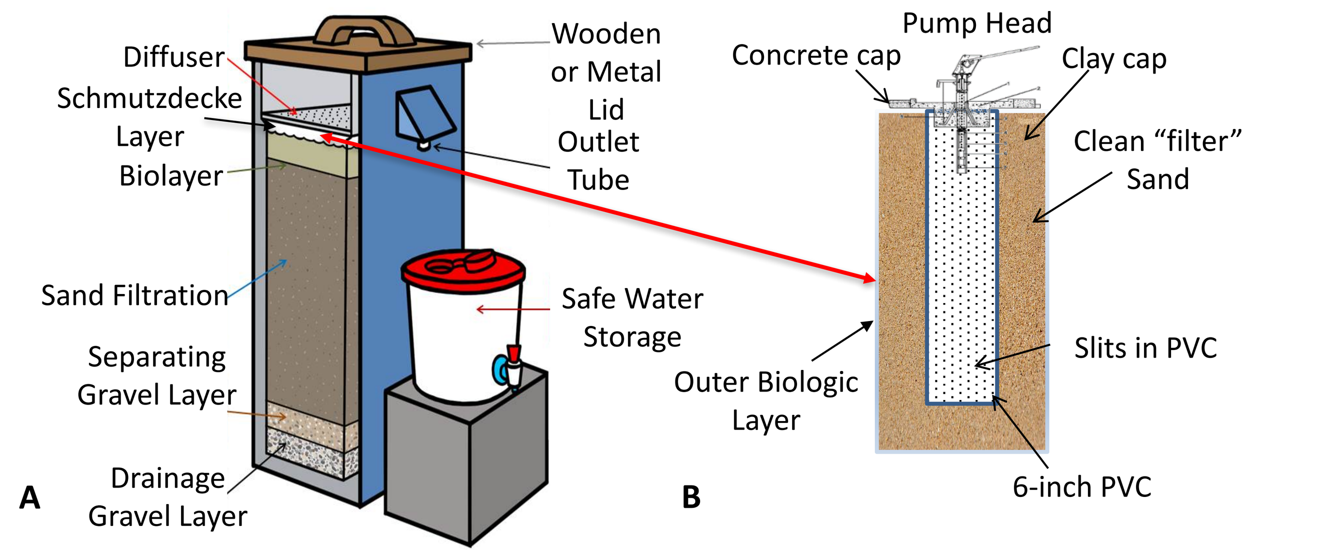


Figure 2. (A) A diagram of a biosand filter (BSF) which uses different sediment sizes as layers to remove pathogens and suspended solids (Stevens, 2013). (B) A typical In-situ filtration (ISF) well.

Figure 1. (A) Water and Sanitation data from 1990 to 2012 for Haiti. (B) E. coli levels in different water sources in rural Haiti. (C) Belanger converted ISF well. (D) An example of an in-home BSF.

KARST AQUIFERS AND LOCAL GEOLOGY

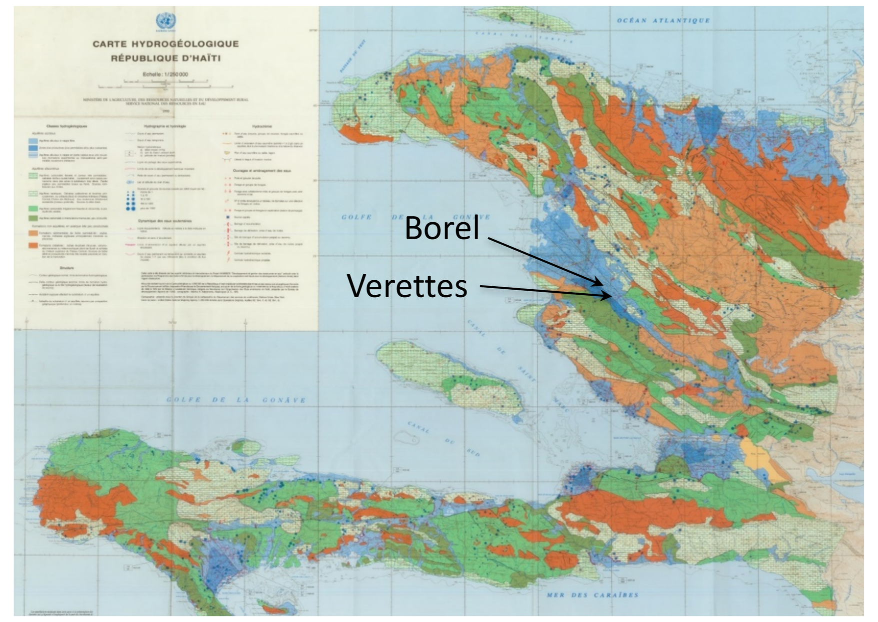


Figure 3. Hydrogeological map of Haiti. Area of study is located in a confined aquifer (colored blue) (Ministère De L'Agriculture, 1990).

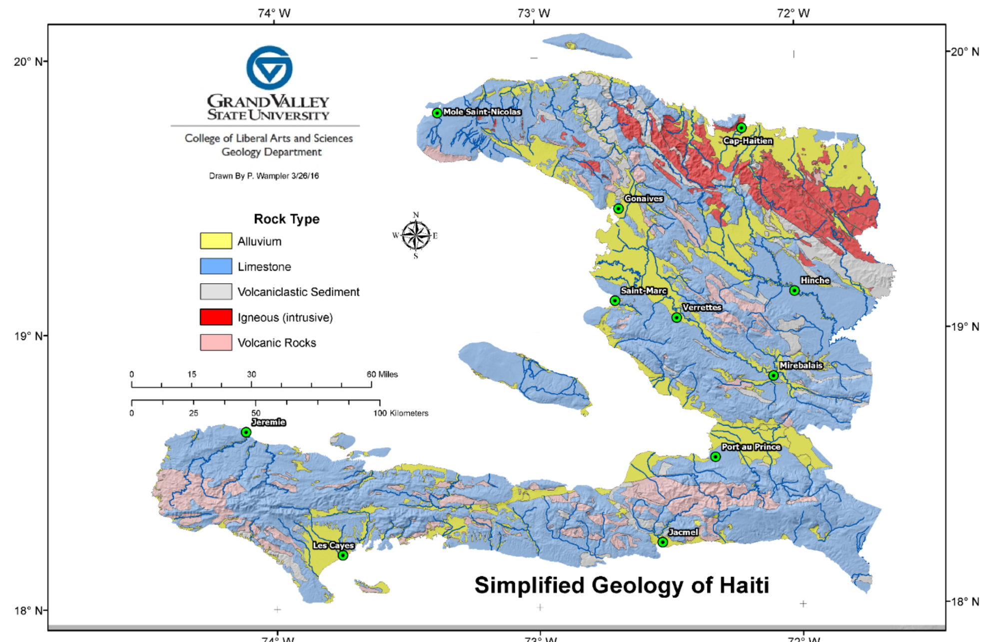


Figure 4. Simplified bedrock map of Haiti, overview of our study area.

METHODS

Hand-dug Well Data:

- Wells were selected by pseudo-randomized convenience sampling.
- Data was collected for each of the 20 hand-dug wells including GPS coordinates, geotagged photos, top width, total depth, static water depth, and collar type (Table 1).

Water Quality Data:

- Water samples were collected in 100 mL sterile Whirl-Pak bags.
- Most Probable Number (MPN) of E. coli and coliform bacteria were determined using the IDEXX Colilert-18 method.
- A nutrient indicator was added and allowed to dissolve into the sample, and then was poured into a 97-cell Quanti-Tray and sealed using a Quanti-Tray sealer. The sample was then incubated at 35 degrees Celsius for 18-24 hours.
- Coliform bacteria content was determined by counting cells colored yellow (Figure 5A) E. coli MPN was determined by counting cells that fluoresced in ultraviolet light (Figure 5B).

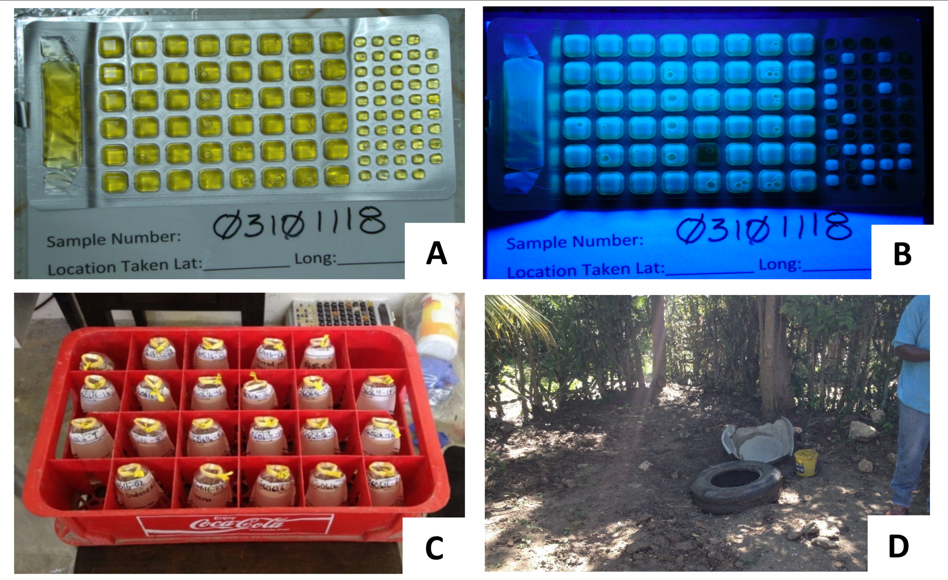


Figure 5 (A) Sample from a hand-dug well showing coliform at >2419.6/100mL MPN. (B) The same sampler under UV light E. coli 238.2/100 mL MPN. (C) Samples from every well tested in this study. (D) Example of a typical hand-dug well.

RESULTS

Figure 6. Map of Borel showing locations of hand-dug wells and their corresponding E. coli MPN.

Identification Number	Depth (m)	Static Water Level (m)	Water Depth (m)	Coliform MPN	E. Coli MPN
060616-01	3.38	2.38	1.00	2419.6	161.6
060616-02	3	1.66	1.34	2419.6	148.3
060616-03	2.95	1.95	1.00	2419.6	143
060616-04	3.4	2.4	1.00	2419.6	2419.6
060616-05	2.9	1.78	1.12	2419.6	579.4
060616-06	2.19	1.55	0.64	2419.6	686.7
060616-07	2.83	2.33	0.50	2419.6	185
060616-08	3.02	2.36	0.66	2419.6	224.7
060616-09	2.68	2.18	0.50	2419.6	1553.1
060616-10	ND	ND	ND	2419.6	1046.2
060616-11	ND	ND	ND	2419.6	2419.6
060616-12	2.75	1.8	0.95	7.5	0.1
060616-13	2.14	1.68	0.46	2419.6	2419.6
060616-14	1.62	1.12	0.50	1986.3	83.3
060616-15	3.72	2.24	1.48	2419.6	461.1
060616-16	2.21	1.45	0.76	2419.6	727
060616-17	ND	ND	ND	2419.6	131.4
060616-18	1.93	1.32	0.61	2419.6	547.5
060616-19	2.24	1.67	0.57	0.5	0.1
060616-20	2.58	0.75	1.83	2419.6	2419.6
Average	2.7	1.8	0.9	2156.4	817.8
Geomentric Mean	2.6	1.7	0.8	1174.3	218.8

Table 1. Raw data collected on 20 hand-dug wells in Borel. Values of 2419.6 exceeded the detection limit. Values of zero are indicated as 0.1 to allow calculation of Geometric Mean.

DISCUSSION

- Homeowners using hand-dug wells need a sustainable and economical way to treat water. The most effective solution will likely be a balance between appropriate technology, cultural compatibility, and cost.
- Average E. coli exceeds the body contact standard for Michigan (300 E. coli per 100mL) (Table 1). This suggests that water from hand-dug wells is not safe for non-potable uses such as laundry, washing, and bathing.
- ISF wells appear to provide a technologically sound solution (Figure 8), however they may not be compatible with some hand-dug wells.
- In-home water treatment such BSF, Sawyer filters, and other hollow fiber membrane filters are appropriate in some cases, however, they are more susceptible to sustainability problems such as maintenance, education, and improper application.
- The best solution for many hand-dug wells may be a combination of better well protection, with or without sand filtration, and in-home treatment.

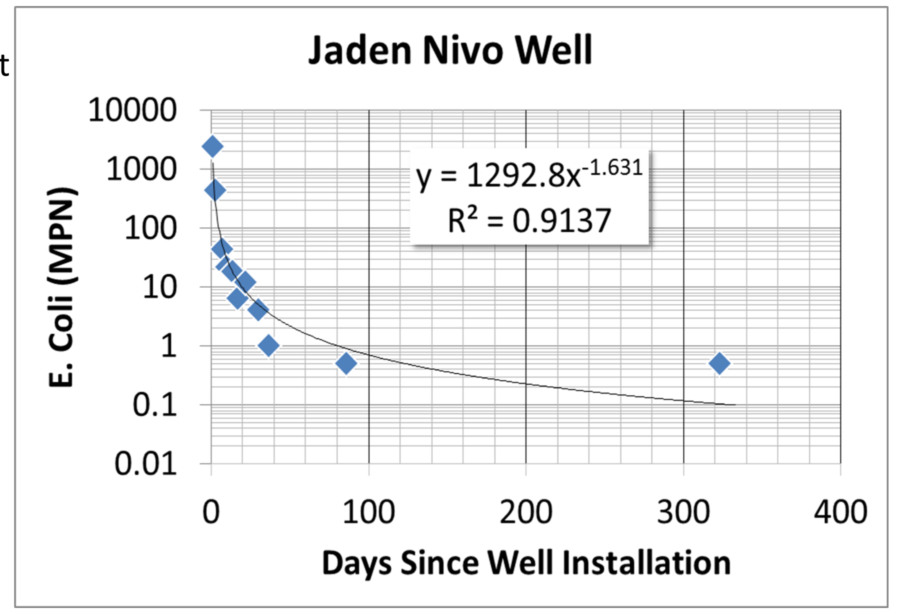


Figure 8. The Jaden Nivo well was converted to an ISF well which led to cleaner water in 90 days. Levels of E. coli decreased from >1000 to <1.0 MPN.

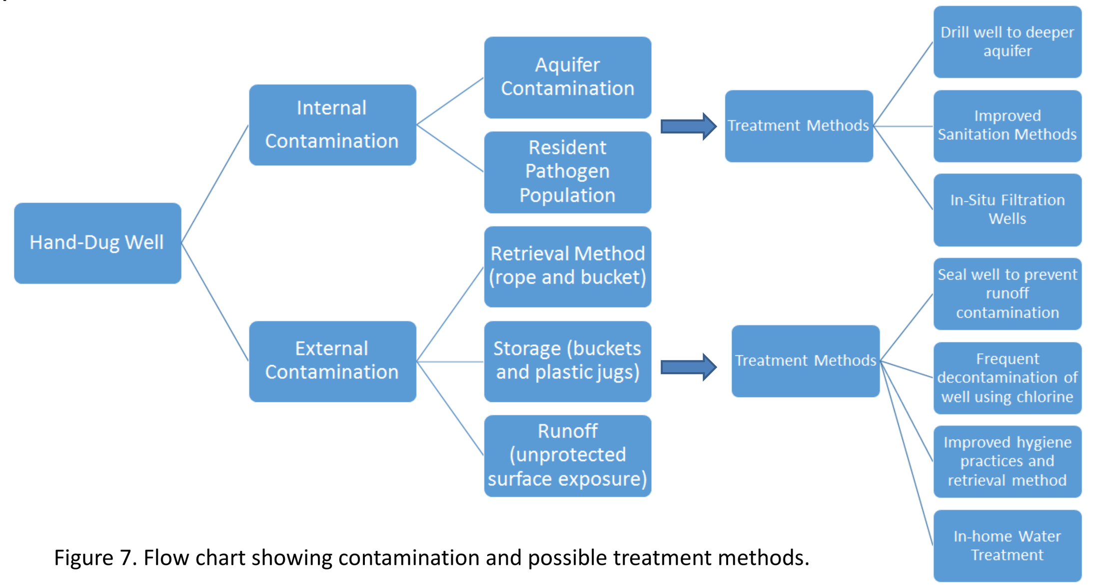


Figure 7. Flow chart showing contamination and possible treatment methods.

Figure 9. Process of converting Bwablanc #2 hand-dug well into an ISF well.

CONCLUSIONS

- 90% of hand-dug wells sampled (n=20) were not safe based on WHO standards.
- Although most hand-dug wells are not used for potable water, contamination levels suggest they should not be used for non-potable uses without treatment. Approximately 55% exceeded body contact standard for Michigan.
- Additional data is needed to evaluate the source of observed contamination (external v. internal) (Figure 7).
- Preliminary results from installed ISF wells suggest that this method is effective at reducing pathogens.
- ISF well data suggest an exponential decay in pathogen levels after installation in ~90 days. This may be a result of 1) reduction in external contamination; 2) removing internal contamination through filtration; or 3) a combination of number 1 and 2.

FUTURE STUDIES AND RECOMMENDATIONS

In order to test whether ISF wells are effective, future studies should include:

1. Sand Sterilization: Sterilizing sand prior to ISF well conversion could limit the amount of external contaminants entering and affecting the water.
2. Well Isolation: Isolating a well from surface contamination without filtration may help to determine the surface of contamination. Bacteriological data could be collected before and after isolation and compared to a nearby ISF well with a sand filter. Materials for this study would cost around $150 per well.
3. Total Well Decontamination: Once an ISF well has successfully been converted, the pump head and filter materials could be treated with bleach, to rule out internal contamination sources.
4. Collars and Water Quality: Additional well data can be collected to determine if there is a correlation between collar construction and better water quality.

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