Alternative Analysis – Report

Community:	La Cuchilla
Country:	Dominican Republic
Chapter:	Kansas City Professional
Submittal Date:	01/01/2018
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1.0 DESIGN REQUIREMENTS

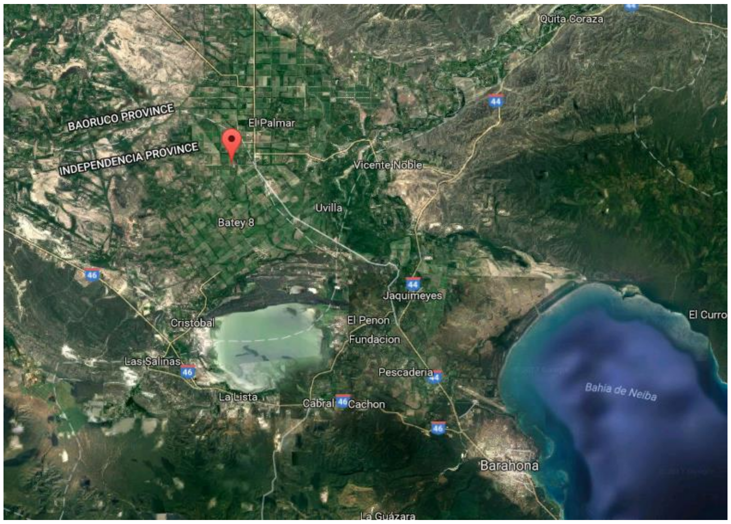
1.1 COMMUNITY

The goals and composition of the community are vitally important to the success of any project. This project is focused on the community's goals and needs by taking into account the social, historical, and economic situation of the community of La Cuchilla.

1. La Cuchilla GPS: 18.386673, -71.270847

Figure 1-1 – La Cuchilla Aerial View

Figure 1-2 – La Cuchilla Location (18.386673, -71.270847)



1.1.1 PROJECT MOTIVATION AND GOALS

During the assessment trip the EWB-KC chapter had multiple meetings with the leadership of the community. EWB-KC asked them the open-ended question of what type of project would you like to see happen. Around the room the answer was a clean and reliable drinking water system. For this reason, the alternative analysis will focus on improving and repairing the drinking water system.

Figure 1-3 – Meeting with Community Leadership

The community’s water source has become contaminated due to near-by agricultural practices, irrigation channels, and failing infrastructure. The existing well was tested and found to be contaminated with fecal bacteria. In addition, the well is not yielding enough water to match the community's needs with the likely cause determined to be that it is approximately 2/3 full of fine sediment. There are many low pressure and low flow issues with the existing water distribution network as well. This report will evaluate alternatives to improve the water system with the goal of increasing water availability.

About three weeks prior to the March 2017 assessment trip the solar panels powering the existing well pump were stolen. During the trip, the EWB team re-wired the pump and connected it to the electrical grid, as a temporary measure to restore service. The resulting material cost amounted to about $200 USD, of which the community was asked to pay 5%. Community leadership went to each household and collected a payment towards this 5% and explained in detail what the money was going towards and why we were asking them to pay. The community then paid this 5% in full to the EWB team, which amounted to about 450 pesos (US$10).

Figure 1-4 – Community Members Filling Bottles at Well Overflow

1.1.2 DEMOGRAPHICS

This community includes a total of about 450 people. There is also a grade school which includes about 120 students, many from the community. A new school is being built in the community by the government which will add an additional 120 students. There are a large number of women and children in the community, with the women typically filling community leadership roles. The men of the community work in the sugar cane fields. Average daily income per household is roughly 180 pesos per day or US$4.

Table 1-1 – Community Demographics

Description	Number of Households	Number of People
Existing Community	145	456
Future Community (~10% Growth)	15	60
Total	**160**	**516**

1.1.3 COMMUNITY ORGANIZATION AND NGO PARTNERSHIPS

The community of Cuchilla has proven themselves to be very driven and great self-starters. Historically they have formed committees to accomplish tasks or initiatives for the community. One of the current standing committees is the sanitation and hygiene committee made up of about 15 men and women. Their responsibilities include educating children and parents about the best sanitation practices like hand washing, taking shoes off before entering the home (lots of livestock around), and they also educate on point of use water treatment. The main water treatment strategy they teach is to add a few drops of "chloro", or bleach, per gallon of water. The chloro is available at the local store. The community has also organized a school bus system that all families who use it pay about 100 pesos/month per household. There are about 4 other committees and organizations within the community and the leadership of all of these was represented during initial project meetings with the EWB team. To quote from one leader, "I don't care if I have to stand outside the (president's) palace, we will find the money needed for this water project." The community has proven themselves able to organize towards goals and initiatives as well as able to collect money to pay for services. We will build on their frameworks to create the local water board.

The main NGO partner is World Water Relief (WWR). They maintain staffed employees near the community and support this project with regular communication between EWB and the community at least once a month. WWR also supports our chapter during travel with logistics, lodging, and translation. WWR also helps coordinate the community hygiene committee that is comprised of community members. This committee educates people about sanitation practices.

A second NGO relationship with Water at Work has been developed since the assessment trip. They have installed a water treatment facility in the community. Both EWB and Water at Work are coordinating resources so that this project represents the best investment for the community.

In addition to these NGOs, EWB has been in communication with hydrogeological engineers in Santo Domingo and well contractors in Barahona. These relationships have been used to gain subsurface data, water quality data, and well logs for the area that have assisted in the new well design. We will continue to use these relationships to help with identifying contractors, materials, and equipment for construction.

1.1.4 NEW SCHOOL CONSTRUCTION ISSUES

A new school is currently under construction adjacent to the existing community school. The school, school buildings, and land are all owned by the Ministry of Education. About 5 years ago the new school started construction in La Cuchilla. However, construction was halted about 2.5 years ago. The contractor and engineers pulled all resources and drawings, essentially liening the project, until they received payment for design and construction services from the government. It is an unfortunate situation for the students, however this political situation is not expected to impact our project. An additional 120 students are expected to occupy the school and this project will plan to supply drinking water to the new school as well.

Figure 1-5 – New School

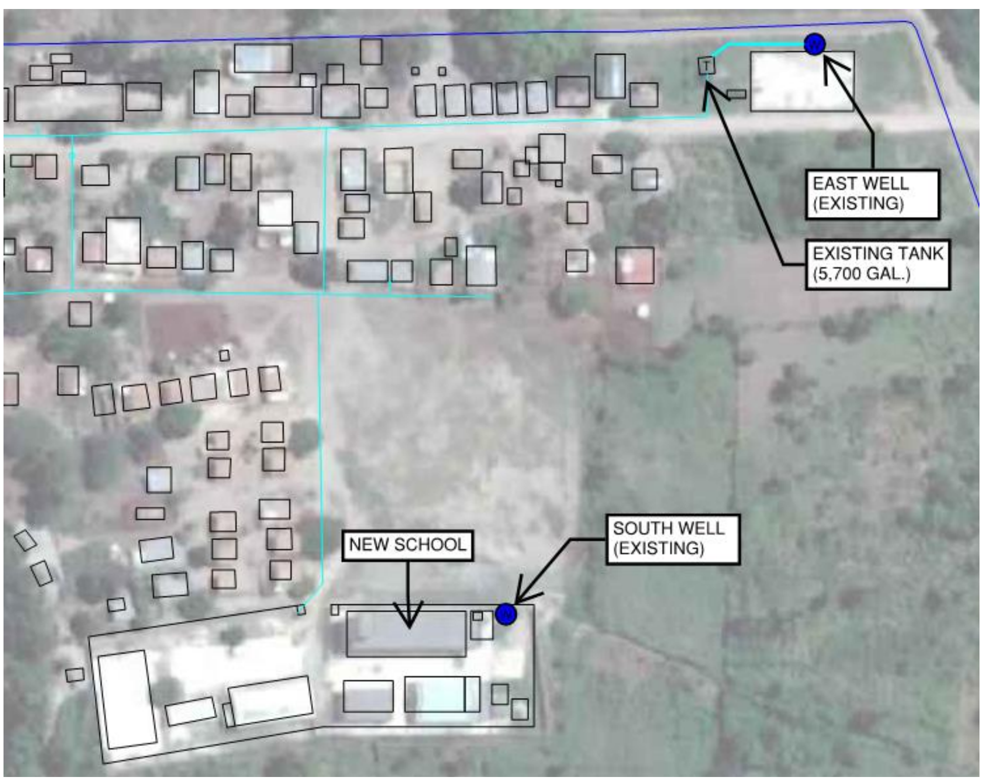
1.2 EXISTING INFRASTRUCTURE

The community has an existing water system with supporting infrastructure which includes two wells, pumps, distribution piping, elevated storage tanks, and a treatment facility. There are several issues with the existing infrastructure which will be defined in this report. As much as possible this infrastructure will be reused in the new design. Reusing existing infrastructure will help to minimize construction cost and construction time.

1.2.1 WELLS

The community has two existing wells. There is the east well located near the east entrance to the community as well as a newer south well that was constructed for the new school. The east well is the only well currently serving the community. This well fills the main storage tank connected to the water distribution network. The south well was built only for the new school and is not currently operational or connected to any distribution network.

Figure 1 – Map of Community Wells



East Well

Based on the community's recollection, the east well was constructed in the early 1990's. This well has multiple issues which were investigated during the assessment trip including:

1. Well depth and infiltration
2. Surface contamination
3. Flooding

The well depth was measured during the assessment trip and found to be 34'-0". After reviewing typical well construction types for the region and talking with community operators, it is assumed that the original well depth was much deeper. The original well depth is believed to be 100' or greater. The well has been filling up with sediment and dirt over the years. This could be explained if the well screen or well casing had been compromised or damaged, which could have occurred during construction with improper installation or settlement of the surrounding subsurface. This well is expected to continue to fill with sediment over time and will shorten the operational lifetime of the well. The stagnant column of sediment inside the well casing is also a breeding ground for bacteria.

The east well is also seeing surface contamination due to its proximity to the irrigation canal. The section of the canal nearest the well does not have a full concrete liner which allows the contaminated canal water to saturate the subsurface near the well. The irrigation practices vary during the year but sometimes the irrigation canals are flooded to send as much water to the sugar cane fields as possible. This results in significant flooding in the community that can last for days or weeks. The well house structure is not water tight, and during the flooding the canal water can freely enter the well and contaminate it.

Figure 1-6 – East Well House Structure and Irrigation Canal

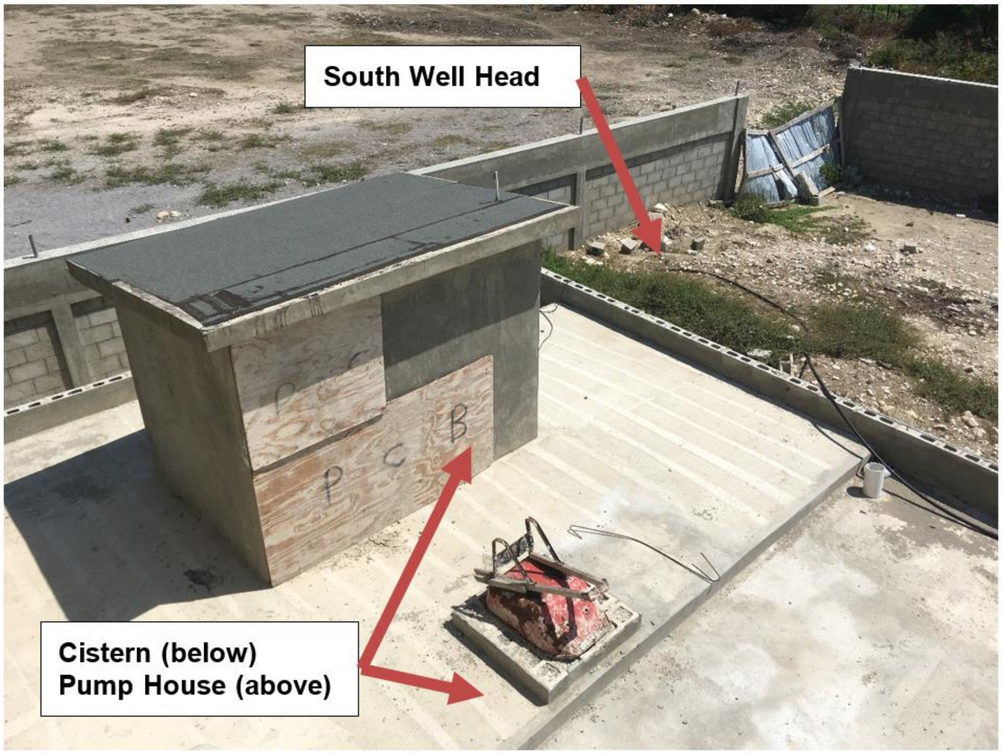
Figure 1-7 – East Well Opening and Pump Discharge Piping

South Well

The south well was constructed within the last 3 years and was installed specifically for the new school. The well is discharged to a cistern and pumps are used to send the water to school kitchens and bathrooms. The well pump design flow is known to be 55 gpm according to the contractor who installed the pump. This well also has multiple issues which were investigated:

1. Perforated well casing
2. Ownership

Figure 1-8 – South Well, Cistern, and Pump House



During the assessment trip, EWB members met with the construction superintendent for the school project and asked how the well was installed and constructed. He indicated that the well casing was made of five 20 feet (ft) sections (100 ft deep well) of 8-inch metal pipe and that each casing pipe had two holes drilled into it every 60 ft. It is unknown why holes were drilled into the well casing pipe as that is not a typical construction practice in the US. This allows near-surface water to enter the well which increases risk for well contamination, but can be explained if the well was only intended to be used for mixing cement.

The school well is also within the walls of the school which is owned by the Ministry of Education. Currently the school ownership is conflicted, with a lien being held by the engineering and construction companies working on the project due to the government having not paid them. It is unknown if the engineering company will allow the well to be used for the community for the immediate future, or if the government will allow this for the long-term future.

1.2.2 WELL PUMPS

Two submersible well pumps are owned by the community, one manufactured by Grundfos and one manufactured by Myers. The Grundfos pump is currently installed in the East Well serves the communities water supply. The Myers pump is not installed in any well and is not currently used; its operational condition has not been determined. Another pump was installed in the South Well which is a part of the new school and owned by the Ministry of Education.

Table 1-2 – Well Pump Schedule

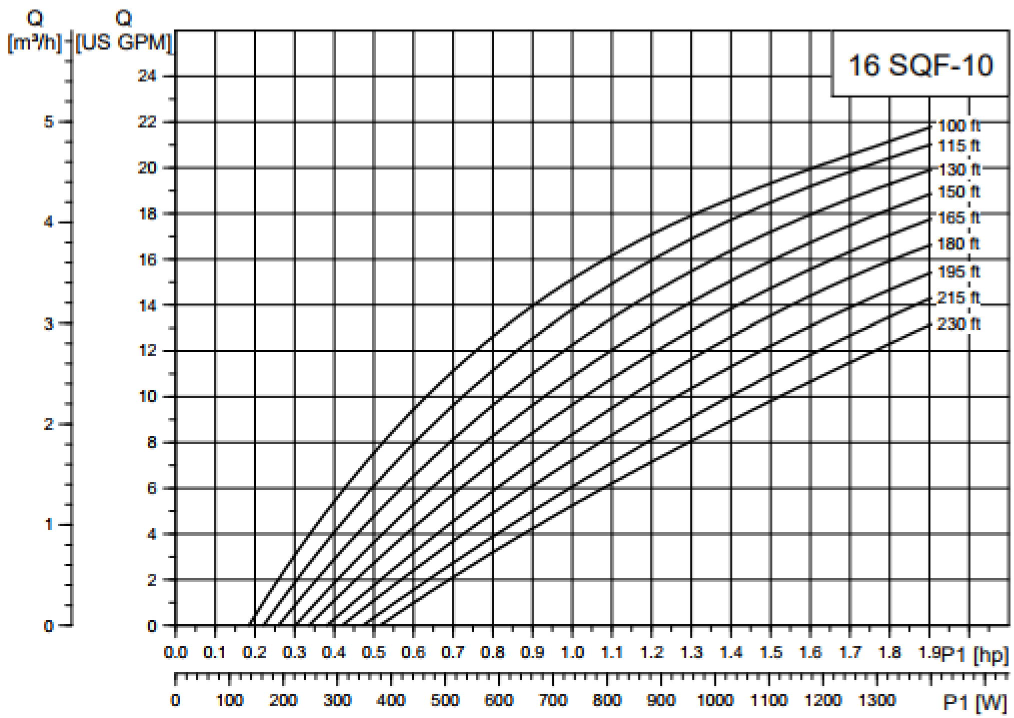
Pump Name	Manufacturer	Model No.	Design Flow (GPM)	TDH (ft.)	Max. Power Input (W)	Max. Current Input (A)
East Well Pump	Grundfos	16SQF10	16	130	1400	8.4
Unused Pump	Myers	3ST102-20	-	-	-	-
South Well Pump	Unknown	Unknown	55	-	-	-

Figure 1-9 – Grundfos Pump Nameplate

Figure 1-10 – Myers Pump – Not Used

Figure 1-11 – East Well Grundfos Pump Curve

16 SQF-10



1.2.3 WATER STORAGE TANK

The community has one elevated concrete water storage tank which has an effective volume of 5,700 gallons. The tank is cleaned regularly by the operator named Papito. He has been the water system operator for 10-15 years. He stated that he regularly cleans the tank by washing the interior walls and removing any sediment in the tank.

Figure 1-12 – Well Tank

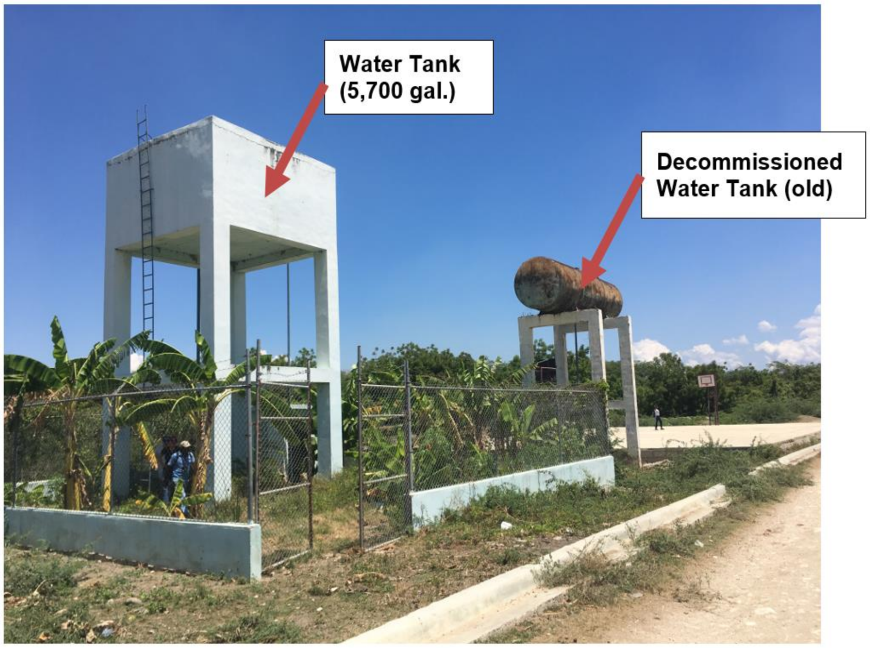


Figure 1-13 – Well Tank Top View

The condition of the tank is in good working order. There are some issues that could use addressing.

1. Clogged drain pipe
2. Broken chlorination system
3. Rusty top hatch

The tank drain pipe has been clogged for many years. Since the drain valve is located near the ground, this leaves a vertical section of pipe free to fill with solids. The only way to empty the tank currently is to wait for the community to consume the water.

A recirculating chlorination system appears to have been used with this tank. This would have recirculated and dosed the water in the tank with chlorine, per good practice. This system has been abandoned and disassembled with little of the original components remaining, other than a broken pump and some piping. There is an in-line tablet based chlorine unit on the tank discharge line.

Figure 1-14 – Abandoned Tank Circulator Pump

The maintenance access hatch located on the top of the tank has some noticeable corrosion as well as holes on the hatch. These are minor, but they are points of possible contamination for the tank. Patches and repairs to the access hatch may be beneficial.

Figure 1-15 – Tank Access Hatch

1.2.4 WATER DISTRIBUTION AND TREATMENT

The only water treatment in the current drinking water supply is a small in-line chlorinator. It was noted that the chlorinator is in need of cleaning, which can be seen in the following figure. According to the community, they keep this unit full of chlorine tablets when they have the tablets available. As observed on the assessment trip, there were not any chlorine tablets in the unit. Before the end of the trip, chlorine tablets were left with the community to keep this unit full for a few months. It is not known how effective this type of chlorine treatment is to provide a residual within the distribution system.

Figure 1-16 – Chlorinator Unit

1.2.5 BOTTLING FACILITY

A bottling facility is connected to the water distribution network. This facility was originally built by the NGO Water at Work. There is a local family which operates the bottling facility and are responsible for maintenance and operations. This facility includes a raw water tank, water treatment equipment, and a clean water tank. The water treatment at this facility includes:

1. Chlorination at the raw water storage tank
2. 3-stage filtration
3. Ultraviolet treatment

Figure 1-17 – Bottling Plant Treatment Equipment

During the assessment trip, many issues were found with the bottling facility. The clean water tank was extremely contaminated with insect and biological growth. There were a lot of mosquitos around the tank and it is suspected that the mosquitos have a way to enter the tank. Community members have commented that they believe people have become sick from the water from this bottling plant and some have been hospitalized.

Figure 1-18 – Bottling Tank Contamination

After the assessment trip, Water at Work was contacted about the current state of the facility. They were very responsive and thanked us for bringing this to their attention. Within a week they sent a team to Cuchilla to address the issues we found. They mentioned that the system installed in Cuchilla is a legacy treatment facility that had since redesigned. Their current 10 bottling plants include reverse osmosis treatment and clean water tanks inside the treatment building. Since then the EWB-KC chapter has developed a partnership with Water at Work.

1.2.6 POWER

Prior to the 2017 assessment trip, the east well pump operated by 4 polycrystalline solar panels rated for 250W each. With the pump being the sole load on the panels, a conservative estimate for peak power delivered is around 470W. This was untested, as just prior to travel one of the panels was stolen, taking the pump out of service. Two of the remaining panels were then removed by the community and stored in locked location for safe keeping. The fourth panel remained mounted and was observed to be badly damaged by rock impacts. Use of the two undamaged panels stored in community center may be considered for future projects.

To get the pump back into service, the controller, which accepts a wide range of DC voltages or up to 240 VAC, was wired directly to the power grid. After coordinating the reduction of some load from the local grid, the AC supply provides the max 1.4kW that the pump will draw, with the grid operating on a schedule delivering power up to 6 hours a day. This is not considered a sustainable configuration for the pump operation, and was only done to get the community water supply back into service until the EWB team could return.

Future power supply installations for pump should consider the long-term reliability, which includes consistent operational performance, required power availability, and the security of the supply from theft or tampering.

1.3 WATER QUALITY

To assess the water supply options available to the community and complete the alternatives analysis, limited water quality data was obtained by testing several sources in and around the community. The following locations in the community were tested:

- Water at Work Bottling Plant (treated water)
- East Well
- South Well
- West Canal
- East Canal

Figure 1-19 below shows the sampling locations within the community. The water sampling was performed on August 18, 2017 by Water at Work.

Figure 1-19 – Water Sampling Locations

The first sampling location was at the Water at Work Bottling Plant located in Batey 3. A treated water sample was taken at the bottling plant from the sampling port inside the water house. A sample was then taken from the clean water tank that is filled directly from the East Well. This water tank appeared to be dirty.

The South Well, located at the community school that is currently under construction, was sampled next. The South Well has a pump house and a cistern. At the time of sampling, a pump was not located in the pump house. Members from the community stated that they will bring a pump to the well, hook it up to the hose, and then pump water into the cistern. Without a pump available at the time of testing, a water sample was taken from the cistern at the well. Water was drawn up from the cistern using a rope a bucket. There is a high chance this water was contaminated with bacteria since the cover to the cistern was open to the elements (animals, rain, dust, etc.). This sample may not be representative of the South Well water quality.

Water samples were then taken from the east and west canals. Children were playing in the canals, and the water appeared to be very high in sediment. Runoff from agricultural fields, livestock, and the communities nearby flows into these canals.

1.3.1 WATER TESTING RESULTS

The following water quality parameters were tested for each of the water samples in order to get an idea of the overall water quality for each water supply option:

- pH
- Turbidity
- Total Dissolved Solids (TDS)
- Iron
- Nitrate
- Hardness
- e. Coli
- Total Coliforms

Water at Work had the capability to perform only these water tests at the time at the time of testing. The results of this testing compared to applicable standards is shown in Table 1. World Health Organization (WHO) health-based guidelines were compared to water quality parameters of health concern. United States Environmental Protection Agency (US EPA) secondary standards were used for parameters of aesthetic concerns such as taste, color, odor, or water treatment considerations.

Table 1-3 – La Cuchilla Water Quality Results

Water Parameter[a]	East Well	South Well	Bottling Plant	West Canal	East Canal	Drinking Water Standard	Normal Water Quality Range
pH	8.88	7.18	7.44	7.19	7.43	6.5 -8.5[c]	--
Turbidity (NTU)	12	6	6	63	31	5[b]	--
TDS (ppm)	546	23	182	373	354	500[c]	--
Iron (mg/L)	0.02	0	0	0.43	0.1	0.3[c]	--
Nitrate (mg/L)	0.9	0.7	0.5	0.4	0.6	50[b]	--
Hardness (mg/L)	222	171	154	274	274	--	Very hard water > 180
Silica (mg/L)	26	37	--	--	--	--	0-200[d]
E. coli (CFU/100 mL)	>1	>1 CFU	>1 CFU	>1 CFU	>1 CFU	0 CFU/100mL[b]	--
Total coliforms (CFU/mL)	>1	>1 CFU	>1 CFU	>1 CFU	>1 CFU	0 CFU/100mL[b]	--

(a) NTU = nephelometric turbidity units; ppm = parts per million, mg/L = milligrams per liter; CFU/100 mL = colony forming units per 100 milliliters
(b) World Health Organization Guidelines for Drinking Water Quality (WHO, 2004)
(c) US EPA secondary drinking water standard
(d) High silica concentrations can cause membrane fouling used for water treatment

1.3.2 REQUIREMENTS AND STANDARDS

The results of the water quality testing show that the main area of concern is bacterial contamination. Water samples from all locations in the community exceeded the WHO health based standards of zero colony forming units (CFU) of Escherichia coli (E. coli) or total coliforms per 100 milliliters (mL) of water. All potential drinking water sources show bacteriological contamination, therefore treatment for bacterial removal will be required for the selected water source. Some type of filtration will also be required to reduce turbidity since all sources exceeded the WHO turbidity guideline of 5 Nephelometric Turbidity Units (NTU). Nitrates and nitrites are a concern due to the presence of agriculture in the area, however the water quality sampling did not show high levels of nitrate. The well samples contained lower levels of iron than the canal samples, however the levels of iron in the canals are not high enough to be of health or aesthetic concern.

The water testing results showed that the South Well had the overall best water quality with regards to the parameters tested. This indicates that groundwater is likely the best option in terms of water quality, however there is some uncertainty with this sample since it came from the South Well cistern.

It is recognized that these analyses were limited in determining presence or absence of possible agricultural and industrial water contaminants. Analysis of a broader list of contaminants will be done in the future, prior to selecting a treatment technology.

1.4 WATER DEMAND REQUIREMENTS

Increasing access to water is an important goal of this project. The community currently uses about one 3/4 full tank of water per day, which is about 4,300 gallons. Among the 456 community members, this is about 9 gallons/person/day (gpcd). There are multiple standards and comparisons for recommended daily water consumption for developing communities, but to meet typical recommendations the water availability needs to be increased. The World Health Organization (WHO) recommends at least 13-26 gpcd to meet water consumption and hygiene needs for a community as shown in the Figure below.

As can be seen, the current system is not providing enough water for the community on a daily basis. This project will aim to achieve at least 20 gpcd for the new water system.

Table 1-4 – Water Demand Requirements

Demand Case	Number of People	Daily Water Access (gal.)	Water Availability (gpcd)
Current System	456	4,300	9.4
Design Usage (w/future of 10% growth)	516	10,320	20

Figure 1-20 – WHO Water Demand Guidelines

Source: WHO, 2003, *Domestic Water Quantity, Service, Level, and Health*

Service level	Access measure	*Needs met*	Level of health concern
No access (quantity collected often below 5 l/c/d)	More than 1000m or 30 minutes total collection time	Consumption – cannot be assured Hygiene – not possible (unless practised at source)	Very high
Basic access (average quantity unlikely to exceed 20 l/c/d)	Between 100 and 1000m or 5 to 30 minutes total collection time	Consumption – should be assured Hygiene – handwashing and basic food hygiene possible; laundry/ bathing difficult to assure unless carried out at source	High
Intermediate access (average quantity about 50 l/c/d)	Water delivered through one tap on-plot (or within 100m or 5 minutes total collection time	Consumption – assured Hygiene – all basic personal and food hygiene assured; laundry and bathing should also be assured	Low
Optimal access (average quantity 100 l/c/d and above)	Water supplied through multiple taps continuously	Consumption – all needs met Hygiene – all needs should be met	Very low

1.5 ELECTRICAL DEMAND REQUIREMENTS

Prior to considering the quantity of power or the supply source, some basic criteria for the well pump must first be established. Assuming acceptable maintenance, the following criteria must be met:

1) Power source must be reliable. It must produce consistent results over the design life of the system (15 yrs+).
2) Power source must be available. It must regularly produce power within design parameters on regular schedule.
3) Power source must be secure. Factors such as theft or tampering by unauthorized personnel must be mitigated as much as reasonable.

The well pump must be able to operate at least 8 hours per day in order to deliver enough water to the community to meet water demand requirements. Losses from the power source such as inverters will need to be considered.

2.0 DESCRIPTION OF ALTERNATIVES

The following section contains a description of Supply, Storage and Distribution, and Power Supply alternatives which were considered in our design process.

2.1 SUPPLY ALTERNATIVES

Four options were identified as potential water supply alternatives, including:

1. Reusing Existing Wells
2. Existing Irrigation Canals
3. Water Delivery Service
4. Construct a New Well

2.1.1 REUSE EXISTING WELLS

Either the east well or the south well could be reused as the community's water supply. Using the south well would require adding distribution lines and pump controls (at a minimum) since it is currently only set up to supply the new unfinished school. As we currently do not have permission to use this well, we would need to acquire that before designing for this option.

2.1.2 EXISTING IRRIGATION CANALS

Water could also be supplied from the existing irrigation canals which surround the community on several sides. These irrigation canals are also owned by the sugar cane companies and are exposed to contamination via surface water runoff.

2.1.3 WATER DELIVERY SERVICE

A water delivery service could supply water to the community by setting up a reliable scheduled delivery of pre-treated water, from a service such as those that deliver drinking water to stores for resale. Water delivery services are currently active in La Cuchilla as water is delivered both to the school and the convenience store. The water quality of these operations is also concerning as they have historically been inconsistent in delivering contaminant-free drinking water. During the 2017 site visit EWB-KC noticed suspended solids and biological organisms in the delivered drinking water.

2.1.4 CONSTRUCT NEW WELL

A new well could be constructed. The well would need to be located far enough away from irrigation canals, flood areas and other potential sources of surface contaminants. It would be on community property and owned by the town after completion.

2.2 STORAGE AND DISTRIBUTION ALTERNATIVES

Currently the school and homes at the far end of the community receive inadequate water flow and pressure. The school in particular receives very little flow while taps near the tank and main road have a plentiful supply.

The following supply and distribution alternatives address flow, pressure and storage issues contributing the observed lack of water availability in some areas of the community.

2.2.1 DISTRIBUTION ALTERNATIVES

Distribution alternatives exist which address the current pressure issues and reuse the existing water tank. While these options do not increase the system storage capacity, they do address pressure issues. The options include:

1. Install Distribution Pump
2. Install Hydro-pneumatic Tank
3. Scheduled Water Service

Distribution Tank

The distribution pump option entails installing a supply pump at the discharge of the existing storage tank, which would pressurize the distribution lines. The use of a supply pump to maintain pressure (with start/stops controlled by a pressure gauge) would result in an excessive number of pump starts per hour, as the pump would start nearly every time someone opened a tap, and stop when all or most of the taps are closed. The frequent start/stops would create pressure spikes and valleys as taps were opened and closed.

Hydro-Pneumatic Tank

A hydro-pneumatic tank located after the elevated storage tank would pressurize the distribution lines while reducing the number of pump starts per hour. It is likely that a large hydro-pneumatic tank or several smaller tanks would be needed to maintain pressure throughout the system. These tanks require maintenance and would need to be replaced after their useful life.

Both of these options would increase the pressure in the distribution system from a relatively low-pressure gravity-fed system to a higher pressurized system. They would require additional equipment and may create a number of leaks in the existing distribution system. These options may require a significant replacement of the distribution piping to handle the increased pressure.

Scheduled Water Service

Another option is to maintain the current low-pressure gravity-fed system and to schedule the water service at different times within the community. This would require the community to be sectioned of into water service zones by installing new piping to supply each zone and installing shutoff valves to isolate each zone. With this option, water would be provided to one section of the community by opening/closing the appropriate series of valves. This approach would reduce the number of taps open at one time which would reduce the total flow demand on the system. Thus, it would provide better water supply and pressure to those areas of the community currently receiving little or no water service.

2.2.2 NEW STORAGE ALTERNATIVES

Options to increase water storage include a new centralized tank and new decentralized storage tanks.

New Centralized Tank

One alternative is to replace the existing 5,700-gallon tank with a new centralized storage tank that is taller and has a larger storage volume than the existing tank. The storage volume of the new tank would be sized to meet a full day supply of water for the community. This new tank would also be higher in order to increase the system pressure. It is estimated that this tank would need to be about 20-30 ft tall and 10,000 gallons.

New Decentralized Storage Tanks

Another alternative is to add additional storage tank(s) (probably 1 to 3 tanks, each 1,000-3,000 gallons). constructed at strategic locations in the community. The purpose of these tanks would be to provide a more even distribution of water pressure and quantity throughout the community. They would be used in conjunction with the existing 5,700-gallon storage tank.

Secondary storage, or “booster” tanks, would be at a lower elevation than the existing tank and would fill sequentially from the existing “main” tank by gravity or by a small supply pump. Water pipes feeding these booster tanks would ideally be dedicated solely to this function and would not have service taps. Secondary tank volume and height would be sized based on water demand in the area they serve, the system’s ability to fill them, and structural limitations.

2.3 POWER SUPPLY ALTERNATIVES

When considering alternatives for the power supply, both wind and diesel generation were ruled out. Low wind density is known to be present in the area, that and the addition of higher costs and higher maintenance led us to rule it out as an option. Diesel generators were also ruled out due to the additional maintenance and operational cost.

The use of batteries as backup during periods of source unavailability was ruled out due to the short lifespan and additional maintenance. After these considerations, the following three configurations remained as options.

2.3.1 EXISTING ELECTRICAL GRID

The electrical grid into the community is intermittent and provides power for a ~6 hours a day on a predetermined rotating schedule. In addition, load issues have been observed within the community, which is served by only three transformers. Usage of the grid by the community is completely unregulated, with most taps being from the closest distribution point using methods and materials available on-hand. The voltage is irregular and other communities in the region have reported pumps burning out when connected to the AC electrical grid. In this region of the country, dependence on the electric grid is generally considered to be unsustainable due to future power availability and usage being unknown.

2.3.2 NEW SOLAR PANELS

The key benefits to solar are reduced O&M costs and reliability, though the installation cost would be higher than other options. With an average insolation incident that remains at or greater than 0.52 kW/m^2 throughout the year, this region in particular benefits from consistent sunshine for a relatively large number of hours a day. It has been observed that solar has been utilized in similar situations throughout the region, and the EWB chapter has successfully installed similar operations in other regions of the DR. Solar panels could be placed on top of the school for greater security, and be directly tied to the new well pump minimizing losses. Solar could be used as the primary power source during the day, with the AC electric grid providing backup in cases where the pump needs to be run at night or during prolonged periods of cloudy weather Install Backup Generator Connection

A portable generator could be used to power the new school well but would need fuel purchased on a continual basis, which could be a significant burden for the community. In addition, it would require more time from someone in the community to operate than would solar or connecting to the electrical grid. The use of a generator as backup has its drawbacks, but depending on the success of using the grid as a backup source, a backup generator may need to be used for backup.

3.0 ANALYSIS OF ALTERNATIVES

3.1 PROJECT GOAL

The project team has had extensive debates and analysis into whether the goal of this project should be to provide clean water or to focus on increased access to water. A phased approach has been agreed to be the best path forward, which includes focusing on increasing the water supply first and addressing the water quality issues in a second phase.

This first phase will provide increased access to water which will positively impact water consumption and hygiene practices. Consideration of water treatment is recommended for a second phase for a number of reasons. The water quality of the new water supply is currently unknown and that makes it difficult to determine appropriate water treatment technologies. More extensive water quality tests will be conducted on the new water supply to determine if or what type of water treatment is required. A review of water treatment options is provided in Attachment 4.

Further details on the project alternatives and project approach are discussed in the following sections.

3.2 SUPPLY ALTERNATIVES

Four options were identified for the water supply including reusing one of the existing wells, the existing irrigation canals, water delivery service, and constructing a new well.

3.2.1 REUSE EXISTING WELLS

The existing wells both have complications. The east well was observed to be only 34 ft deep when it was originally much deeper. Overtime this well has been filling up with sediment and is suspected that either the well casing or well screen was installed incorrectly or has been damaged overtime. It is anticipated that this well will continue to fill with sediment as water is drawn from the well. This well also is regularly flooded and contaminated by the adjacent irrigation canal.

The south well is not operational and also is technically owned by the engineering and construction company that worked on the school. Once this well is operational, the well will be owned by the school and/or Ministry of Education. Since the community does not own this well, relying on it for the source of water for the community is risky. The south well casing was also reported to be perforated the entire length of the well which may lead to contamination from the surface water.

These reasons make reusing the existing wells a poor option for the new water supply for the community.

3.2.2 EXISTING IRRIGATION CANALS

Using the existing irrigation canals as the water supply was also ruled out as an option due to the agricultural and biological contamination of the water, the very irregular water flow throughout the year, as well as these canals being owned by the sugar cane companies. These irrigation canals are very extensive and are generally believed to be contaminated by agricultural practices and runoff from a wide area. The contamination and ownership issues make this a poor option for the new water supply for the community.

3.2.3 WATER DELIVERY SERVICE

Delivery of treated water is common in the developing world and specifically the Dominican Republic. Water would be delivered by municipal or private treatment operations is bottled and delivered via truck at a cost to cover the added expense. Water delivery services are available but also were determined to be a poor long-term solution. These services are known by the community for having poor water quality and typically are more expensive per gallon of water. Use of this service would also make the community dependent on when trucks can deliver water. Likewise, dependency on the service also makes the community susceptible to inordinate price increases.

There are multiple private water delivery services that sell water in 5-gallon bottles commercially. There are also services where a water tanker truck will come and deliver water to a storage tank. Both of these types of commercial operations may have higher water costs to the community and prices may increase over time. These reasons make water delivery a poor option for the long-term water supply of the community.

3.2.4 CONSTRUCT NEW WELL

The goal of constructing a new well for the community is to provide cleaner water in greater qualities for the community. A new well would be constructed in a location and in a manner that minimizes surface contamination. This well would also be deeper than any well in the community currently, which will help deliver cleaner water. More extensive water quality tests will be done to determine the water quality from this new well and to determine if and what type of water treatment is required.

Constructing a new well requires knowledge of the subsurface to determine well depth and well construction types. A review of geological and subsurface investigations of the area was conducted and is documented in Attachment 1. It was judged that the subsurface is composed of an unconsolidated sediment down to about 200 ft to 250 ft. Below that is a confined aquifer which is suspected to be limestone. Well construction types were analyzed for drilling into either of these geologic features.

Unconsolidated Sediment – 0-200 ft. below surface

This option includes drilling into the shallow unconsolidated lacustrine sediments aquifer (USACE map unit 4) and setting an 8-inch diameter casing from ground surface to approximately 50 ft below ground surface (bgs), screening the well from approximately 50-150 ft bgs, and placing a sump portion to allow for well sedimentation from approximately 150-170 ft bgs.

The two existing wells in the Batey were each originally drilled to a total depth of approximately 100 ft into the unconsolidated sediment formation. Another well immediately south of the Batey has a total depth of 192 ft (according to well logs obtained by EWB). The yield and geologic information pertaining to these wells are unknown at this time. A literature review of the area indicates a potential for low yields in shallow marine muds and sediments with the exception of unmapped and irregular lenses consisting of sand and gravel (Vaughan et al, 1921).

High yield segments of the formation such as sand or gravel lenses would have the highest water yields. The well screen would need to be located near these intervals and may require field decisions based on the soil removed from the borehole during drilling. It is also recommended that a series of in-the-field measurements of water quality be determined prior to final well installation (specific conductance and pH should be considered at a minimum). Well screens would be placed in geologic conductive zones below zones of lower permeability. Drilling would be terminated if bedrock was encountered. Ideally, this will place the capture zone of the well at a depth where both contaminated surface recharge and deeper potential brackish water would be hydraulically isolated from the well.

The proposed location of the drilled well is located near the school at approximately 18.3862° N by 71.2696° W. After careful consideration, this location was chosen because of the reduced potential of surface flooding from the nearby canal system, and due to the physical separation from other potential sources of contamination (i.e. sewage or agricultural runoff). The exact location of the well is subject to change due to accessibility, property boundaries, and above requirements for additional plumbing and treatment equipment.

The major potential risks and unknowns involved in this option are listed below:

1. A risk of future groundwater contamination from sources at the surface. This risk is potentially mitigated by drilling to depth and/or below low permeability zones and ideally by locating the well up gradient from contaminant sources. The gradient in this area is not well understood at this time.
2. A risk for fine particulates to infiltrate the well, causing pump issues and eventually plugging the well. This risk will be mitigated by using proper well construction techniques including a proper sump, a site-specific-designed gravel pack, a bentonite-cement grout, good well development, and a properly located screen.
3. Water quality at this depth is relatively unknown; however, field tests on the surrounding wells at a depth of 100 feet have indicated the potential for bacteriological contamination. Other water parameters that were measured at the 100-ft wells did not violate primary drinking water standards as currently stated by the EPA (Correspondence with Water at Work).
4. Due to the unmapped, varied, and localized nature of the site geology, there is a potential that sand or gravel lenses may not be encountered during drilling. Missing these water-bearing zones could result in a water yield less than is required by the community. This risk will be minimized by hiring a well-drilling contractor with experience in the region, having them and the EWB team monitor the bore hole output in real time during drilling and adapting to these observations.

5. A risk of water rights issues with neighboring sugar cane plantations. Reportedly, the plantations ignore water rights violations for public use like drinking water, but this may change in the future.
6. Impact to the water yield of the South Well. Care would need to be taken to ensure the new well is located outside the well's radius of influence.

Confined Aquifer – 200-300 ft. below surface

This option includes drilling the well deeper into the shale and gypsum below the unconsolidated lacustrine sediments discussed previously. A 6-inch diameter casing would be installed from the ground surface to approximately 100-200 feet bgs (depending on in-field geologic observations recorded during drilling). A screened casing would extend 100 feet beyond the unperforated top section, resulting in a well with a final depth of 200-300 feet. A literature review of the area indicates a limestone aquifer at depth (USACE and Gilbo); however, the community may be located too far from this confined limestone aquifer or alluvial deposits which formed adjacent to mountains to the community's north and south.

Well installation depths and screen intervals are subject to change, dependent on geologic site conditions being logged by the field geology team. It is also recommended that a series of in-the-field measurements of water quality be determined (specific conductance and pH should be considered at a minimum) prior to finalizing well installation details of total depth and screen location.

Ideally, this will place a well deep enough to significantly reduce the risk of surface and agricultural contamination. This would potentially minimize the amount of water treatment required to be installed and maintained in perpetuity. The proposed location of the drilled well is located near the school at approximately 18.3862° N by 71.2696° W. After careful consideration, this location was chosen because of the reduced potential of surface flooding from the nearby canal system, and due to the physical separation from other potential sources of contamination (i.e. sewage or agricultural runoff). The exact location of the well is subject to change due to accessibility, property boundaries and above requirements for additional plumbing and treatment equipment.

The major potential risks and unknowns involved are listed below:

1. A high risk of significantly increased drilling costs to reach the greater depths proposed.
2. A risk of limited yield within the shale and gypsum layers previously described. The yield of this layer is unknown, and may be potentially limited (Vaughn et al., 1921).
3. A risk of higher salinity groundwater at depth based on Vaughn's findings in 1921.
4. A risk of high concentrations of calcium and sulfate in groundwater from the solubility of gypsum ($CaSO4 \cdot 2H2O$).
5. A risk that the aquifer has been historically impacted by irrigation practices. It is reported that there are 1500+ wells in the nearby area that may be pumping out of this formation (Correspondence with Jesus Medina).
6. A risk of water rights issues with neighboring sugar cane plantations. Reportedly, the plantations ignore water rights violations for public use like drinking water (Correspondence with Jesus Medina), but this may change in the future.
7. A risk of very hard water. Limestone aquifers can leech sodium and chloride into the water, making it very hard water, and requiring softening which, will add to the community's responsibilities and treatment costs.
8. Impact to the water yield of the South Well. Care would need to be taken to ensure the new well is located outside the well's radius of influence.

3.3 STORAGE AND DISTRIBUTION ALTERNATIVES

Storage and distribution alternatives were analyzed for addressing pressure, flow, and water storage issues for the water system.

3.3.1 DISTRIBUTION ALTERNATIVES

Distribution alternatives analyzed included installing either a new distribution pump or a hydro pneumatic tank, and creating a scheduled water service.

Distribution Pump

While the distribution pump provides a simple means of increasing pressure in the line, it presents several disadvantages.

1. The number of pump starts per hour would be excessive and would tend to burnout the motor.
2. The pump may over-pressurize the system, causing leaks at fittings, which may require a substantial replacement of system piping
3. Pump has potential to dead-head which would quickly burn out the motor.
4. The pump is another draw of electricity on already-stressed power supply.

This alternative seems infeasible.

Hydro-pneumatic Tank

Similar to the supply pump, a hydro-pneumatic tank would pressurize the distribution lines, but presents many of the same disadvantages as the supply pump, save the effects of dead-heading and being a significant draw of electricity. The tank would be installed after the existing storage tank. Multiple hydro-pneumatic tanks may be required throughout the distribution network, since doing a single one may require a large sized tank. A small air compressor would be required to intermittently re-inflate of the tank's internal bladder. The NGO representative remarked that from his experience in-country, these tanks were more often broken then operational.

This alternative seems less desirable.

Scheduled Water Service

Implementing a water supply schedule presents construction challenges and requires us to consider the social implications of a "separate and distribute" methodology. For the supply schedule to function, the community must first be divided into independent distribution zones. Each zone district would have approximately the same number of residents, so that if we had 3 zones, each would contain approximately a third of the community's population. To make each zone independent of the others, new water pipe would need to be installed. An operator would be responsible for opening and closing the valves to each of these districts according to a schedule.

The purpose of the schedule is to provide a more even distribution of water than currently exists. With fewer residents pulling from the supply at once, everyone in the "open" zone receives higher water pressure. Some disadvantages of the system: This will require a new water pipeline, a preliminary estimate being ~1,200 ft. Along with the installation of new pipeline, multiple new valves would need to be installed.

This approach will allow the existing system to serve smaller zones of the community at a time while still increasing access to water for all members of the community. For example, the community would consist of three sections having a service schedule as follows:

1. Zone #1: 7:00 am - 10:00 pm
2. Zone #2: 11:00 pm - 1:00 pm
3. Zone #3: 3:00 pm - 6:00 pm

In this example all members of the community get access to water for 3 hours per day and only 1/3 of the community is ever being served at a time. This reduces both the flow and pressure demands on the water system and will increase the flow available for each individual water tap. To make this scheduling option work, an operator would be required to go around to the isolation valves of each zone and open/close them at each interval. The capacity to do this will be integrated into the water board and monthly water payments may contribute towards an operator's salary.

3.3.2 NEW STORAGE ALTERNATIVES

Storage alternatives reviewed include a new centralized storage tank and new decentralized storage tanks.

Centralized Storage Tank

This option includes the construction of a new centralized storage tank. This tank would be elevated high enough to supply all the distribution pressure needed and would be large enough to store enough water volume for the community. Building a structure such as this presents cost and construction challenges. The structure's height and weight, coupled with extremely high wind and seismic loads in the area, would necessitate reinforced concrete or steel construction, in lieu of the CMU block construction used nearly exclusively for all low-rise construction in the region.

Reinforced concrete construction requires formwork, rebar cages, and consistent high-quality concrete in large quantities. Concrete construction is prevalent enough that procuring a concrete contractor with the necessary tools and skills is not a prohibiting concern. However, La Cuchilla's semi-rural location prompts us to consider quality issues due to procurement logistics. If the concrete manufacturing facility is far from our site, workability additives – likely of an unknown and inconsistent quantity – may be added to the concrete, decreasing its compressive strength. Knowing this may be a factor, we can reduce the concrete's design strength, but without being able to predict the manufacturer's (or delivery person's) actions, we cannot know if this reduction is conservative or appropriate. In addition to concerns about workability additives, lack of (or unenforced) quality standards and unskilled labor, among other reasons, means overall concrete quality and consistency is questionable. Again, we can make an educated attempt to conservatively address these issues accordingly.

The use of steel introduces corrosion considerations, which can be mitigated by initial painting, regular repainting, and regular monitoring for excessive oxidation. Steel water tank support structures were observed in nearby communities. Welding will likely be necessary in the case of steel construction, but can be kept to a minimum by using bolted braced-frame construction.

Regardless of structure material, a substantial concrete foundation will be needed to support this tall, heavy tank. Also with the tall structure come concerns about construction safety. Safe scaffolding and fall protection equipment would need to be acquired if not provided by the concrete contractor.

In the event of failure of the tank support structure, a 30 ft structure with (potentially) 10,000 gallons of water atop represents a greater risk to human life and property than does the existing tank. To mitigate this safety concern, the new tank would be fenced and located away from existing structures and populated areas.

New Decentralized Storage Tanks

This option includes constructing multiple decentralized storage tanks throughout the community. These tanks would be smaller and would store 1,000-3,000 gallons each. Estimates are for 1-3 of these tank structures. The addition of these tanks in the community would add storage and solve pressure issues. Water pipes feeding these booster tanks would ideally be dedicated solely to supplying the decentralized storage tanks and would not be intermediately tapped. Doing this reduces the likelihood of contamination in these tanks, and makes the flow into them more predictable.

These secondary tanks increase the storage capacity of the system – and subsequently the volume of water available per person – assuming both the main and secondary tanks can be filled every day. This approach relies on power being available, since these tanks do include small booster pumps to fill the tank.

While these lower-elevation structures may allow the use of cheap and readily available CMU, special detailing may be required to achieve required strength, driving back up construction costs and complexity. Preliminary designs indicate deeper blocks (or possibly multi-wythe wall construction), and fully or partially grouted, reinforced walls will be required to resist design loads. Reinforced concrete slabs (roof and foundation) would be used support the water tank and structure, introducing concrete quality concerns similar to those discussed in the previous section.

3.4 POWER ALTERNATIVES

In order to increase to community's access to water, the system will also need increased access to electricity. Currently the electrical grid delivers power at unreliable and irregular times and also irregular voltages. A more sustainable and reliable source of power is needed to operate the well pump to meet the water demand requirements. Solar power has proven to be a way to reliably integrate a new power supply into the community for these applications.

A new solar panel system will be installed on the roof of the new school. In order to prevent theft a welded steel structure will surround the solar panels and will be anchored to the concrete roof. The roof of the new school is approximately 25' and covers a large surface area. This is the tallest structure in the community. Locating the solar panels back far enough from the edge of the building will prevent anyone from seeing them and keep them out of site. The electric wiring will be concealed as best as possible. The school is also supposed to have a night guard who patrols the school grounds regularly. These measures should prevent theft as best as possible.

It has been determined that the power requirements necessary to meet projected future water demand growth are a regular supply of around 1.3 hp (0.97 kW) at least 8 hours per day (>7.76 kWh/day). An array of six 340W modules has been calculated to provide the necessary requirements. Any larger number of panels has been assumed to create too large of a failure point.

Maximum and minimum assumed operational parameters for this region are outlined in the table below.

	July	December
Insolation Incident (kW/m^2)[1]	0.68	0.52
Insolation Incident ($kWh/m^2/day$)[2]	5.94	4.20
Power at Midday (kW)	1.25	0.955
Daily Average Energy Supplied (kWh)	10.9	7.71

1. Monthly Averaged Midday Insolation Incident on A Horizontal Surface (kW/m^2). Source: https://eosweb.larc.nasa.gov/
2. Monthly Averaged Insolation Incident on A Horizontal Surface ($kWh/m^2/day$). Source: https://eosweb.larc.nasa.gov/

Redundancy should be designed into the system given the time limited availability of the AC electric grid, and the inherent limitation of solar panels due to available sunlight requirement. To facilitate this, the electric grid would also be tied into the well head structure through a transfer switch, to provide electricity at night if needed. The community could be encouraged to purchase a generator for a 3rd backup in the event that the panels and grid are both down, such as extended periods of heavy cloud cover during the daily timed-outages of the grid.

4.0 COMMUNITY INPUT AND SELECTIONS

4.1 COMMUNICATION

Refer to Attachment 2 for the full letter sent to the community which summarizes the options and provides recommendations for the project. Questions were asked to the community and a written response and signature was requested for the community's approval of the proposed project.

4.2 RESPONSE SUMMARY

The community was send a questionnaire in order to get their input on the proposed design. The questions and answers to these questions are described below. Signatures of the community leaders and the NGO were also collected to acknowledge receipt of the proposed design and approval to move forward.

Q1: How many gallons per day does each typical household use currently? How much water per day would you like to have per household?

A1: A typical home uses 200 liters per day and we would like to have 350 liters.

Q2: What concerns do you have with the proposed water schedule system? What would be the community's preferred schedule for each service zone?

A2: No worries with the plan made by EWB. Our preferred schedule is 7 to 12pm & 4 to 6 pm.

Q3: We are concerned about theft of the solar panels. Are there any additional anti-theft measures you would recommend for the area?

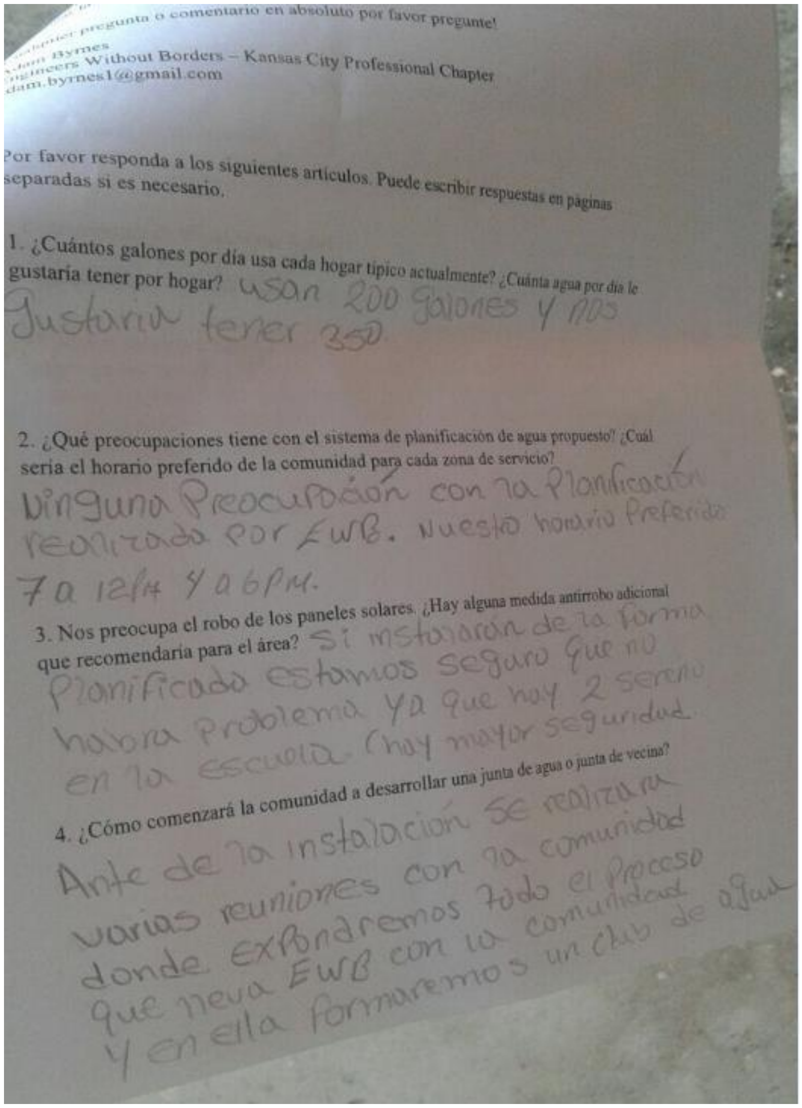
A3: If they are installed in the manner planned, we are sure there wouldn't be a problem since there are 2 night-watchmen at the school (there is better security).

Q4: How will the community begin to develop a water board or junta de vecina?

A4: Before the installation, there will be multiple meetings with the community where we explain the process EWB is putting in place and where we will form a water club.

Q5: In general, is this the project the community wants to be designed and built? Do you approve of the project plans outlined in this letter?

A5: Yes, this is the project we would like to construct and we approve everything said in the letter.


...pregunta o comentario en absoluto por favor pregunte!

...dam Byrnes
...ngineers Without Borders – Kansas City Professional Chapter
...dam.byrnes1@gmail.com

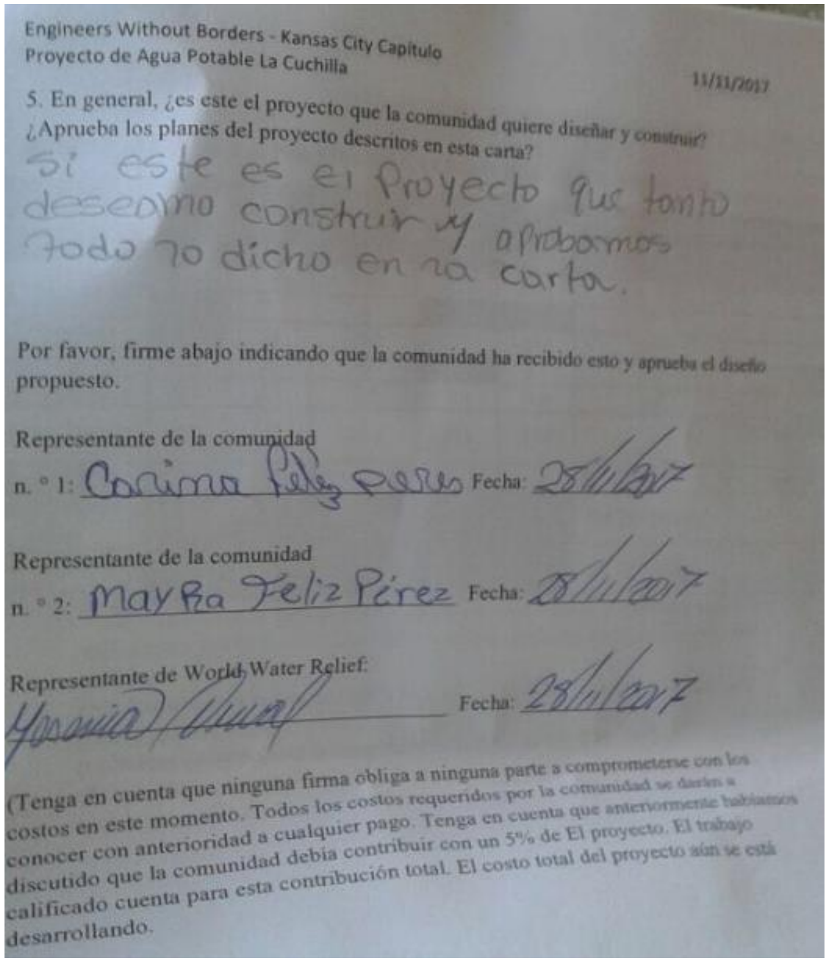
Por favor responda a los siguientes artículos. Puede escribir respuestas en páginas separadas si es necesario.

1. ¿Cuántos galones por día usa cada hogar típico actualmente? ¿Cuánta agua por día le gustaría tener por hogar? usan 200 galones y nos gustaria tener 350.

2. ¿Qué preocupaciones tiene con el sistema de planificación de agua propuesto? ¿Cuál sería el horario preferido de la comunidad para cada zona de servicio? Ninguna Preocupación con la Planificación realizada por EWB. nuestro horario Preferido 7 a 12M y a 6PM.

3. Nos preocupa el robo de los paneles solares. ¿Hay alguna medida antirrobo adicional que recomendaría para el área? Si instalarón de la forma planificada estamos seguro que no habra problema ya que hay 2 sereno en la escuela (hay mayor seguridad

4. ¿Cómo comenzará la comunidad a desarrollar una junta de agua o junta de vecina? Ante de la instalación se realizara varias reuniones con la comunidad donde expondremos todo el proceso que lleva EWB con la comunidad y en ella formaremos un club de agua



Engineers Without Borders - Kansas City Capitulo
Proyecto de Agua Potable La Cuchilla

11/11/2017

5. En general, ¿es este el proyecto que la comunidad quiere diseñar y construir? ¿Aprueba los planes del proyecto descritos en esta carta?

Si este es el Proyecto que tanto deseamo construir y aprobamos todo lo dicho en la carta.

Por favor, firme abajo indicando que la comunidad ha recibido esto y aprueba el diseño propuesto.

Representante de la comunidad n. ° 1: Corina Feliz Peres Fecha: 28/11/2017

Representante de la comunidad n. ° 2: MayRa Feliz Pérez Fecha: 28/11/2017

Representante de World Water Relief: Fecha: 28/11/2017

(Tenga en cuenta que ninguna firma obliga a ninguna parte a comprometerse con los costos en este momento. Todos los costos requeridos por la comunidad se darán a conocer con anterioridad a cualquier pago. Tenga en cuenta que anteriormente habíamos discutido que la comunidad debía contribuir con un 5% de El proyecto. El trabajo calificado cuenta para esta contribución total. El costo total del proyecto aún se está desarrollando.

5.0 DESCRIPTION OF THE PREFERRED ALTERNATIVE

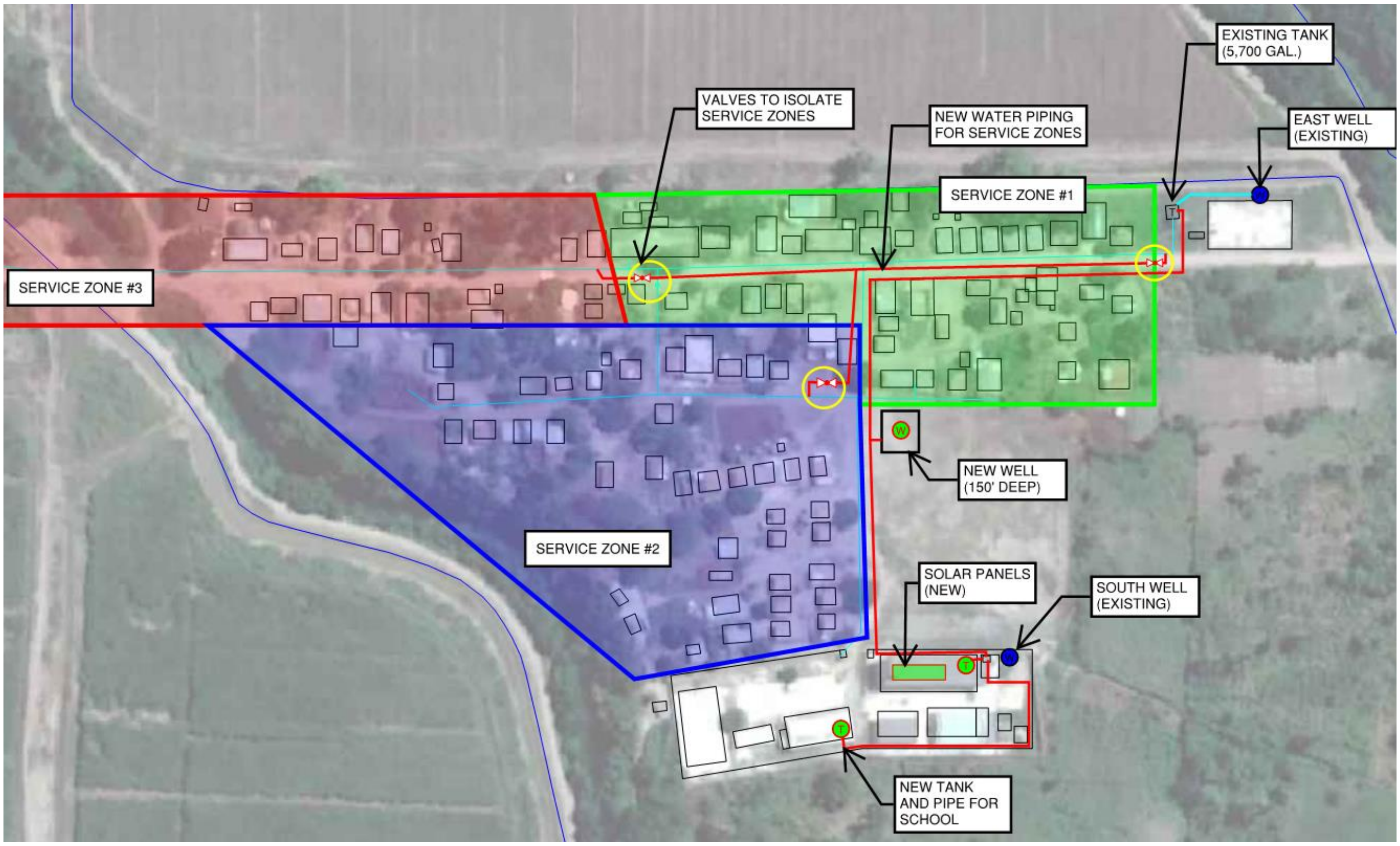
5.1 PROJECT PHASE #1

After review of the alternatives and discussions with the community, the following alternatives were selected.

- Supply Alternative Selection
  - Construct new well, 150 ft. deep.
- Storage and Distribution Alternatives Selection
  - Water zones and scheduled water service to each zone
- Power Alternatives Selection
  - Install solar array and connect to existing electrical grid for backup power

A high-level schematic of the proposed plan is detailed in the Figure below.

Figure 2 – Project Phase #1 Schematic



A new well was decided as the best option to provide the community a reliable and clean water supply to last generations. This will also increase the amount of water accessible to the community. The well will also be owned by the community, not by the government or the local sugar cane companies. After reviewing the geological data, it was decided that the well should be drilled into the unconsolidated sediment to about 150 ft below the surface. The well will include a 20-inch borehole with an 8-inch well casing pipe. Gravel screens and a well cap extending at least 50 ft below the surface will prevent a majority if not all surface water contamination. Expanded water samples and tests will be conducted to determine the water quality and the need for water treatment

To improve the water distribution to the community, the water distribution network will be split into three water service districts. Each district will have separate, scheduled hours of water delivery every day so that only one district is receiving water at a time. This will alleviate the current issue of low flow to homes at the end of the distribution network by decreasing the instantaneous water demand. This water district will require an operator to go to each valve station and turn on and off each water service district according to the water schedule. This will require the community to develop a water board to organize and maintain the water system. The community has a successful history of developing committees and has already begun developing this water committee.

The schools will also be connected to the new well. The new school (currently not in operation) has its own well (South Well). In the case that the South Well is not in operation, new piping will be run from the new community well to the school cistern to provide a backup water supply. New storage tanks and piping will also be added to the existing school

A new electrical system will be installed to supply power to the new well pump. A new solar array will be installed and will be the primary source of power. The existing electrical grid will also be able to power the well pump through automatic transfer switches. This will serve as backup power to operate the well pump at night or on very cloudy days. There will also be the ability to easily plug in an emergency generator to operate the well pump in emergency situations when the electric grid is down or the solar panels are damaged, like a hurricane for example.

The first phase of construction can be summarized into discipline specific scope items as follows:

- School Scope
  - Install new storage tank for existing school
  - Install piping connecting new school cistern to new storage tank for existing school
- Mechanical Scope
  - Install new submersible well pump
  - Install new piping from well to existing tank
  - Install new distribution piping to section off community into districts
- Civil/Structural Scope
  - Construct well head structure and enclosure
  - Construct new steel support structure for solar panels
- Well Scope
  - Install new, deeper well
  - Conduct water quality testing
- Electrical Scope
  - Install solar panels on roof of new school
  - Install conduit and cabling from solar panels to well head structure
  - Install transfer switch, electrical disconnect, and breaker box in well head structure
  - Install hookup for backup generator in well head structure

5.2 PROJECT PHASE #2

A potential second phase of construction may include the addition of water treatment technologies and/or pumping and storage improvements to the distribution system. These aspects of the water system require further evaluation after the new well is installed to determine the appropriate path forward.

This will be assessed after detailed water quality tests are done on the new well water supply.

Again, water treatment is recommended for a second phase because the water quality of the new well will be unknown until the well has been drilled. This well will be about 100’-0” deeper than the existing well, so it is expected that there will be cleaner water with less surface contamination.

However, this will be evaluated with detailed water quality tests as soon as the well is drilled. The water quality will determine if any levels of water treatment are required.

There is also a possibility that the proposed water districts and schedule will need to be modified. This project will monitor how the community and the water board make decisions on how they use the water with the new water district plan. If additional storage or increased distribution pressures are required, then the other storage and distribution alternatives defined previously may be considered for implementation.

6.0 LIST OF ATTACHMENTS

6.1 GEOLOGIC AND SUBSURFACE INVESTIGATION

6.2 COMMUNITY LETTER AND RESPONSES

6.3 PROJECT SCOPE DRAWING

6.4 PHASE #2 WATER TREATMENT ALTERNATIVES

Engineers Without Borders-USA
Kansas City Professional Chapter

Memorandum

Date:	August 29, 2017
Author(s):	Mike Rawitch Max Wood Jacob Berger Jacob Taylor Ricardo Gamarra Luca DeAngelis Joshua Bragg Adam Byrnes
Project Location:	Batey Cuchilla, Indepencia Province, Dominican Republic
Project Title:	Cuchilla Water Supply Facility
Memo Title:	**Subsurface Characterization**
Memo Sub-Title:	Literature Review & Site Conceptual Model

Overview

The Batey Cuchilla resides in the Hoya De Enriquillo physiographic region (USACE, 2002) at an elevation of approximately 39 feet above mean sea level. Annual rainfall is approximately 850 mm with a mean annual temperature of *25* ° C. The topography of the Batey is generally flat with surface drainage to several canals on the east and west side of the village. The Batey falls at the borders the Rio Yaque del Sur and Lago Enriquillo hydrogeologic basins (USACE, 2002), an area used extensively for sugarcane and agricultural production. A review of aerial photographs taken between 2003 through 2013 showed no historical industrial activity, but does demonstrate a consistent agricultural presence in the area of the community. The historical aerial photos also demonstrate that the Batey sits in a heavily cultivated area where most of the where most of the surface water features are irrigation canals. An existing community well is the primary source of water for the village, and an additional well was installed at the school in recent years. Both wells were drilled to 100 feet below ground surface (bgs), are powered by six solar panels, and use a Grundfos pump. The community stores its' water in a 15,000 storage tank. Within the community there are 145 households consisting of approximately 600 – 1,000 people who use septic systems for wastewater disposal.

Geology

A literature review identified three documents which contained useful information regarding the geology, physiography, and water resources in the DR. These documents are:

- Water Resources Assessment of the Dominican Republic
  - USACE 2002
- A Geological Reconnaissance of the Dominican Republic
  - Vaughn et al. 1921
- The Aquifer Systems of the Dominican Republic
  - Gilboa 2009

Additionally, a detailed geologic map of the region produced by the SGN (Servicio Geologico Nacional) was identified and reviewed. A summary of these document displaying pertinent text and figures along with the geologic map is provided at the end of this report (see A-13).

Batey Cuchilla is located within the Hoya de Enriquillo, or the Enriquillo structural basin in southwestern Dominican Republic. This basin resides between two mountains, the Sierra de Neiba to the North and the Sierra de Baoruco to the South. The basin was below sea level until recent tectonic activity resulted in an uplift of the region estimated at 115 feet. Prior to the uplift the shallow marine bay extended and encompassed Lake Enriquillo. The uplift, combined with sediment deposition at the mouth of the Yaque River closed off the bay and created the saline lake, whose surface now sits approximately 140 feet below sea level. The uplift is noted to have occurred relatively recently, and quaternary marine fossils can be found at ground level within the basin.

Vaughn et al. 1921 notes of the Enriquillo Basin:

"The general aspect of the lower valley of the Yaque suggests that its delta deposits may have separated Lake Enriquillo from the Bay of Neiba, the lake having been in comparatively recent geologic time an arm of the sea. The actual separation probably took place during the regional elevation that formed one of the latest diastrophic movements. The east end of Lake Enriquillo is bordered by a broad mudflat that gently rises eastward to a barren waste of sandy "Saladas" or salt covered plain."

These "saladas" are easily visible on an aerial photo on the east side of the lake, and it is interpreted that agriculture in the basin begin/ends where the saladas become overlain by the deltaic sediments (see A-1).

Locally, around the project site, delta deposits formed from the river Rio Yaque del Sur overly shallow marine lacustrine deposits. The lithology of these sediments is described as primarily silt and clay with localized lenses of sand and gravel. The depth of the unconsolidated sediments is unknown, though it is thought to be 100-300 m below ground surface.

Stratigraphic sequences in bedrock range from early Miocene to Pleistocene in age. These include the Angostura Formation, Las Salinas Formation and the Jimani Formation with each having their own unique lithology, as described by Mann et al.; the oldest, being the Angostura Formation, is comprised predominantly of siltstones with massive interbedded and recrystallized gypsum and halite; the Las Salinas Formation consists of shallow-marine to marginal-marine sediments, especially sandstones, limestones, and siltstones; the youngest, Jimani Formation, is made of siltstones, mudstones, and fossil-bearing limestones (Mann et al. 1991).

Hydrogeology

The USACE (USACE 2002) summarizes groundwater resources in the Indepencia Provence as:

"Map unit 2 covers about 60 percent of the province and is in the northern, western, and southern parts of the province. Very small to very large quantities of ground water are available from Tertiary to Quaternary age limestone at depths ranging from 5 to 25 meters for low-lying areas and 100 to 200 meters for mountainous areas. Ground water quality is generally fresh and very hard. Within or near urban areas, shallow ground water may be contaminated with biological and/or chemical wastes. Major aquifers include the karstic limestone in the La Toca, The Cevicos, the Arroyo Blanco, the Higuerito, the Arroyo Seco,

the Sombrieto, the Lemba, the Florentino, the Abuillot, the Plaisance, and the Neiba Formations. A reef limestone unit, the Villa Trina Formation, is also present.

The rest of the province lies in map units 4 and 6 where ground water exploration is not recommended during military exercises without site-specific reconnaissance."

La Cuchilla is interpreted to reside in map unit 4, which USACE describes as:

"Fresh water is scarce or lacking in areas containing recent age lacustrine deposits (clay with some sand and gravel). Very small to small quantities of ground water may be available from these low-permeability aquifers. Small yields of ground water may exist in the sand and gravel lenses. These aquifers are primarily in the north-central, northeastern, and south-central parts of the country. Depths to these aquifers range from less than 1 to 10 meters below ground surface.

Gilboa 2009 notes that the primary aquifer(s) used in the agricultural valley to be recent lacustrine deposits, which he/she describe as:

"Unmappable thin lenses of sand and gravels, deposited along river courses and within fine sediments of lacustrine origin, form irregular, elongated, thin and limited aquiferous beds. The 10-30 m thick lenses occupy an insignificant segment of the lacustrine sequence. Generally, the permeability is low as shown by the poor yields of the 30 operating wells. Exceptionally high rates of 200 m3/h, gauged in four wells, result from a combination of high local permeability with a well-developed sand lens, and are not typical of this remote aquifer."

Locally, within the surficial aquifer, conductive horizons located in the quaternary sediments are recharged by precipitation, surface water infiltration, and the springs of the vast limestone aquifers which are located on the outskirts of the basin (Gilboa, 1980). Groundwater is thought to be 1 to 10 m below ground surface. Groundwater quality and flow direction may be influenced by surface canals and irrigation. Recently, water quality sampling was performed on two wells in the Batey along with water from the irrigation canals the pass by. A summary of the data collected from these sources is provided below:

Water parameter	Well at Entrance	Well at School	Purified Water	West Canal	East Canal	Drinking Water Standard	Normal Water Quality Range
pH	8.88	7.18	7.44	7.19	7.43	6.5 -8.5[b]	--
Turbidity (NTU)	12	6	6	63	31	1[a]	--
TDS (ppm)	546	230	182	373	354	500[b]	--
Iron (mg/L)	0.02	0	0	0.43	0.1	0.3[b]	--
Nitrate (mg/L)	0.9	0.7	0.5	0.4	0.6	10[a]	--
Hardness (mg/L)	222	171	154	274	274	--	Very hard water > 180
Silica (mg/L)	26	37	--	--	--	--	0 -200[c]
e. Coli (pass/fail)	fail	fail	fail	fail	fail	0 colonies[a]	--
Total coliforms (pass/fail)	fail	fail	fail	fail	fail	0 colonies[a]	--

(a) EPA primary drinking water standard (for protection of health)
(b) EPA secondary drinking water standard (for aesthetic considerations such as taste, color and odor, or water treatment considerations)
(c) High silica concentrations can cause membrane fouling used for water treatment

Current Groundwater Uses

The drinking water at Batey Cuchilla is acquired from a groundwater well (entrance well) in the northeastern portion of the town that neighbors an irrigation canal. The groundwater well itself has lost its integrity as a drinking source. According to Adam Byrnes, project manager for the EWB-KC/Batey Cuchilla Partnership and engineer at Burns & McDonnell Engineering Firm, the well was originally constructed with a depth of 100 feet and was measured at only 34 feet in March 2017 indicating the well casing has deteriorated and the well has filled with sediments. Secondly, the quality of the water is failing the community as well. Brynes says that the water is likely contaminated and has visual signs of contamination apparent (April 2017). Recent samples indicate the pH, turbidity, and total dissolved solids failed EPA primary or secondary drinking water standards. Additional, the water sample taken from this well failed tests for e. coli and total coliform bacteria.

In addition to the entrance well in La Cuchilla there is another well located at the newly developed school (school well) drilled to a depth of 100 feet with an 8 inch diameter casing. More than 10 other wells have been drilled in the vicinity of La Cuchilla which are said to range from 15-25 cm in diameter and 165 to 215 feet in depth (Correspondence with Jesus Medina). The water quality parameters determined during the recent sampling effort showed much better water quality than the entrance well, but also failed the bacterial test. There are no known existing water permitting issues for existing wells.

Sources of Potential Contamination

The main threats to groundwater potability at the Batey include biological and chemical contamination of the shallow aquifers from human refuse and agricultural fertilizer use. This can occur from infiltration through the vadose zone or by localized flooding around a well pad where the disturbed ground and/or poor well seal can act as a conduit to introduce surface water contaminants to groundwater. That later is thought to be a primary cause of the deteriorated conditions seen in the entrance well. Garbage disposal remains a secondary issue due to limited population size. Industrial pollution or seawater intrusion are not of any significant threat to the potability of water in the village. There is some concern that groundwater may become increasingly saline with depth. It is interpreted that marine lacustrine deposits underlie the delta deposits of the Yaque River, and the description of these sediments where exposed at ground surfaces (the “saladas” described above), along with their marine origin and elevation below sea level suggests these sediment may harbor brackish waters or may become increasingly brackish with depth.

Batey Cuchilla is a community that is surrounded by agricultural land that consists of a system of irrigation canals that run through the community. Notably, nitrates are commonplace in the Batey Cuchilla water supply. These contaminants are likely derived from fertilizers, as indicated by Mishimi et al., “The main nitrate sources in groundwater are fertilizer applications on cultivated land…” (2010). In the process of runoff, the fertilizer chemicals enter the surface water system and, subsequently, recharge the aquifer.

Biological contaminants, such as E. coli, represent a threat to water resources in the Independencia Province. This is demonstrated by the USACE’s warning, “All surface water should be considered biologically contaminated...” (2002). Such contamination has led to epidemics, “…a widespread 2006 disease outbreak associated with Escherichia coli (E. coli) O157-H7 to spinach irrigated by pumping wells that may have been impacted by surface water–groundwater exchange” (Mellor and Cey, 2015). Significant biological contamination is also possible from waste generated in overflowing or broken septic systems throughout the Batey.

Data Gaps

The information gathered to date indicates a heterogeneous system where groundwater yield and quality can vary significantly within relatively short distances. The description of the lacustrine sediments by Gilboa above provides a good indication of the uncertainty in what will be found when drilling is performed. If a thick interval of sand is encountered, water of good yield and quality may be produced. On the contrary, if only fine grained sediments are found then the yield may be lower. Vaughn et al. also describes groundwater as more or less saline throughout the "lowlands", indicating potentially poor water quality. Despite these obvious cons, it is known that groundwater wells are used as water supplies at other bateys and the sample collected from the school indicates decent water quality at this location. The location of the school well is on the outskirts of the village and installing an addition in this vicinity may be the safest bet to obtain decent quality water.

Design Considerations

The project has an objective to provide 7000-7500 gallons per day of clean water to La Cuchilla. Using a solar powered pumping system, this equates to producing approximately 20 gallons per minute (gpm) for 6 hours every day. An estimate of aquifer properties in order to evaluate the required well construction details is difficult because of the heterogeneity discussed above but the following recommendations represent a reasonable estimate of the final design and may be sufficient to proceed to towards installation. Further discussions with the well drilling contractor may provide useful information about how we can improve the design and a re-evaluation of the design details should be performed again when new information becomes available and/or before finalizing. The design is intended to meet the project water objectives (rates) and these details are very likely to be able to do so, and may produce significant more water than is required. Given the uncertainty and heterogeneity, this is expected to be a safe design although the transmissivity of the sediments near the Batey remains an unknown. If it is determined that these well dimensions will be financially difficult to achieve (a larger drill rig/augers will cost more), it may be possible to obtain the objective rates with smaller diameter well and/or a well drilled to a shallower total depth.

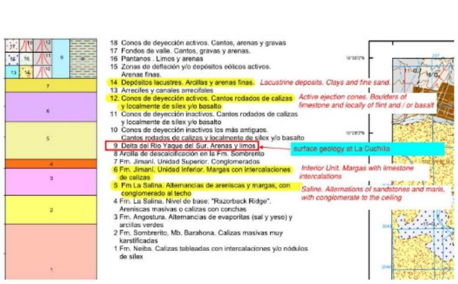
We would propose the following well construction parameters to best meet project goals:

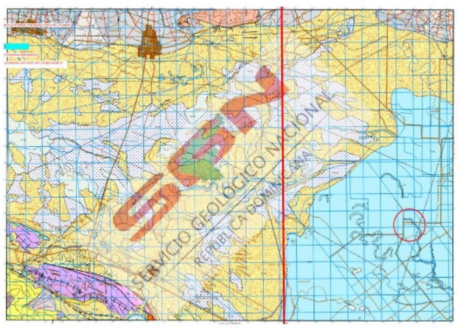
- 20” Borehole diameter
- 8” Casing diameter
- 0’ – 100’ Casing interval
- 100’ – 150’ Screen interval
- Screen slot size (approximately 0.02” to 0.03”)
- 95’ – 155’ Filter pack (depends on final slot size, generally 0.03” to 0.07”)
- 85’ – 95’ Bentonite seal
- 0’ – 85’ Grout
- Pump (20 GPM w/ 50 ft of head should be near the middle to low end of pump capability)
- 5’ x 5’ Concrete well pad, sloping away from the well to prevent surface water infiltration

Summary

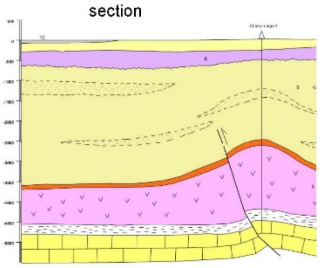
A relatively clear understanding of the hydrogeology within the basic has been put together following a review of literature and information obtained from local sources, however that understanding is that the system is heterogeneous and there is significant uncertainty in the condition at the site. This uncertainty does not preclude moving forward with plans to drill a water supply well and groundwater appears to be a viable source of water for the Batey. The water quality at the school well is of decent quality and an 8 inch diameter well drilled to 150-170 feet below ground will likely provide water of similar quality and is a safe bet to be able to 20 gpm for 6 hour daily. Flexibility as more data is obtained and discussions begin with a drilling contractor will enhance Engineers Without Borders ability to make a properly informed decision about using groundwater as a supply of drinking water.

Figures and Excerpts





Delta deposits absent in cross section



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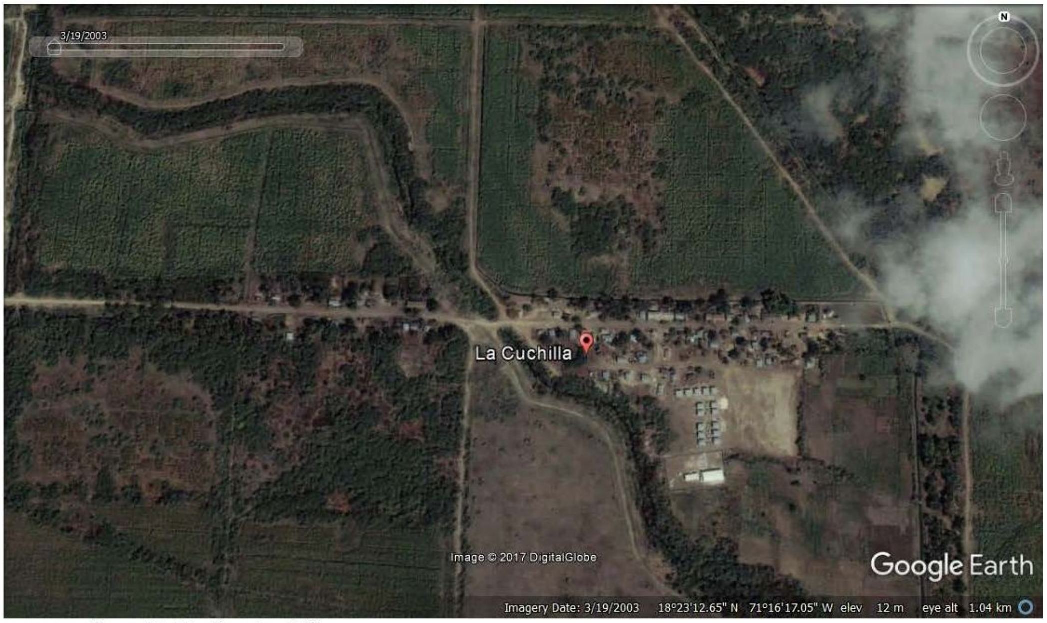
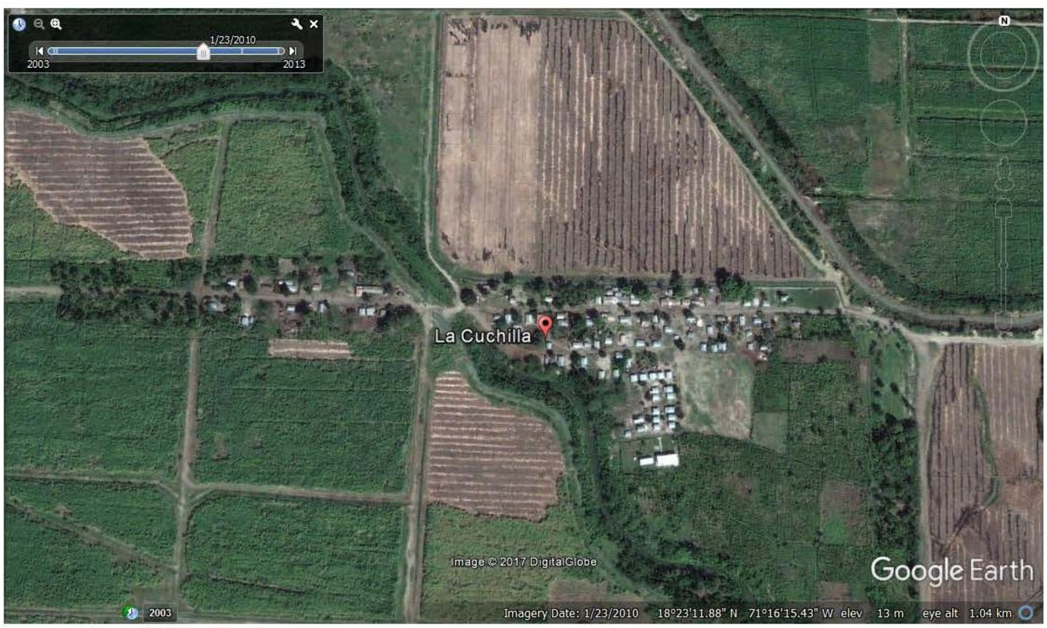
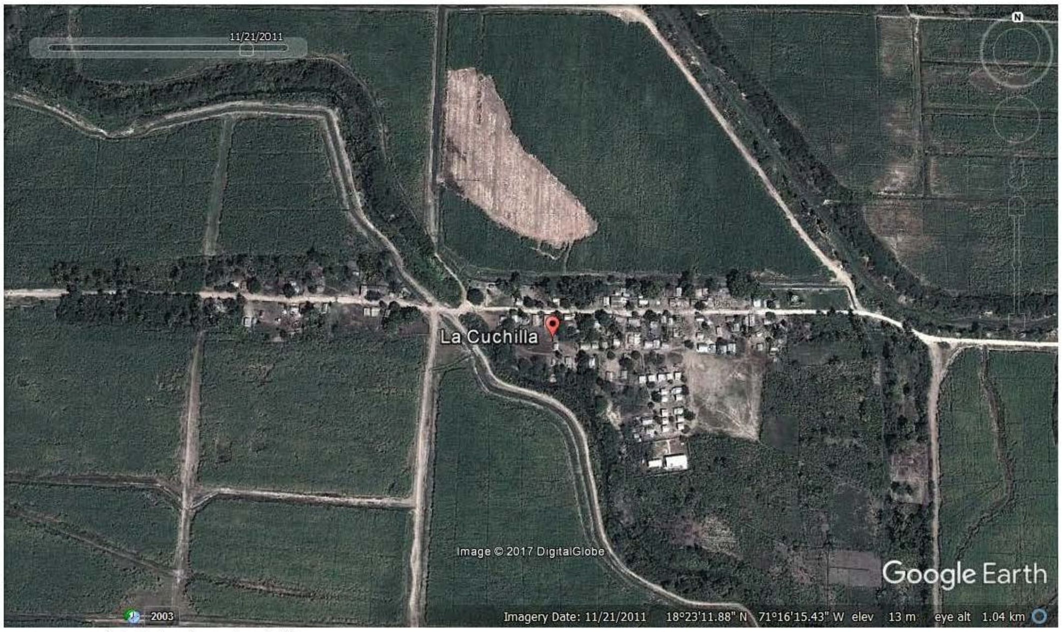


Imagery from 2003 of La Cuchilla.

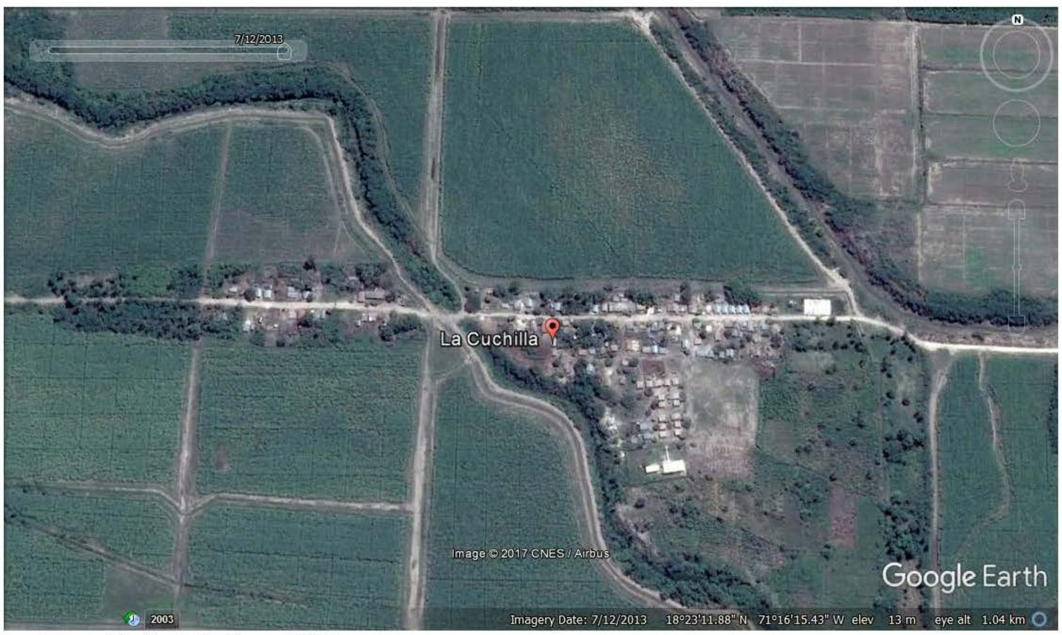


Imagery from 2010 of La Cuchilla.

A-2



Imagery of 2011 of La Cuchilla



Imagery of La Cuchilla from 2013

A-3

The aquifer systems of the Dominican Republic

Y. GILBOA The Israel National Oil Co. Project, 80 Shenkin Street, Tel Aviv, Israel

Recent lacustrine sediments

Unmappable thin lenses of sand and gravels, deposited along river courses and within fine sediments of lacustrine origin, form irregular, elongated, thin and limited aquiferous beds. The 10–30 m thick lenses occupy an insignificant segment of the lacustrine sequence. Generally, the permeability is low as shown by the poor yields of the 30 operating wells. Exceptionally high rates of 200 m^3/h, gauged in four wells, result from a combination of high local permeability with a well developed sand lens, and are not typical of this remote aquifer.

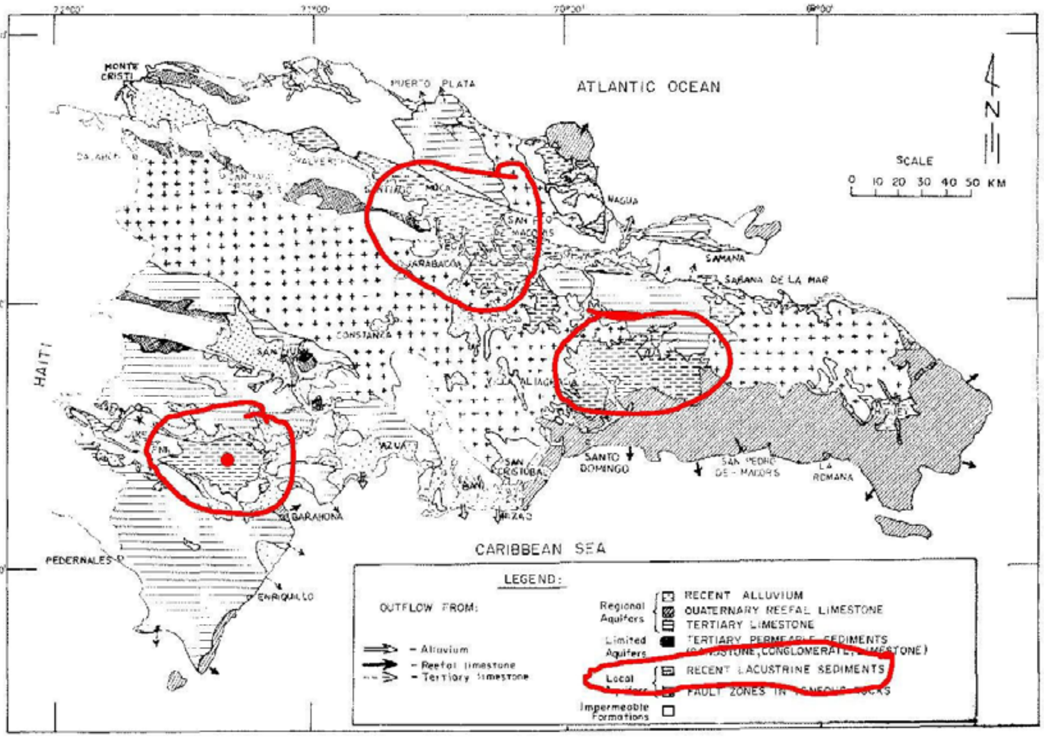


FIG. 4. The aquifers of the Dominican Republic.

Local	Recent lacustrine sediments	North of S. Domingo, Cibao and Neiba Valleys, beaches	5 030	lenses of beach sand and gravels within clay and loam	5–10	Rainfall, Rivers	50	5–25	10–100	Good–acceptable
	Faults in igneous rocks	Central and Oriental Cordilleras	14 130	faulted zones in volcanic, intrusive and metamorphic rocks	---	Rainfall, Rivers	150	5–25	25–200	Good

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The aquifer systems of the Dominican Republic

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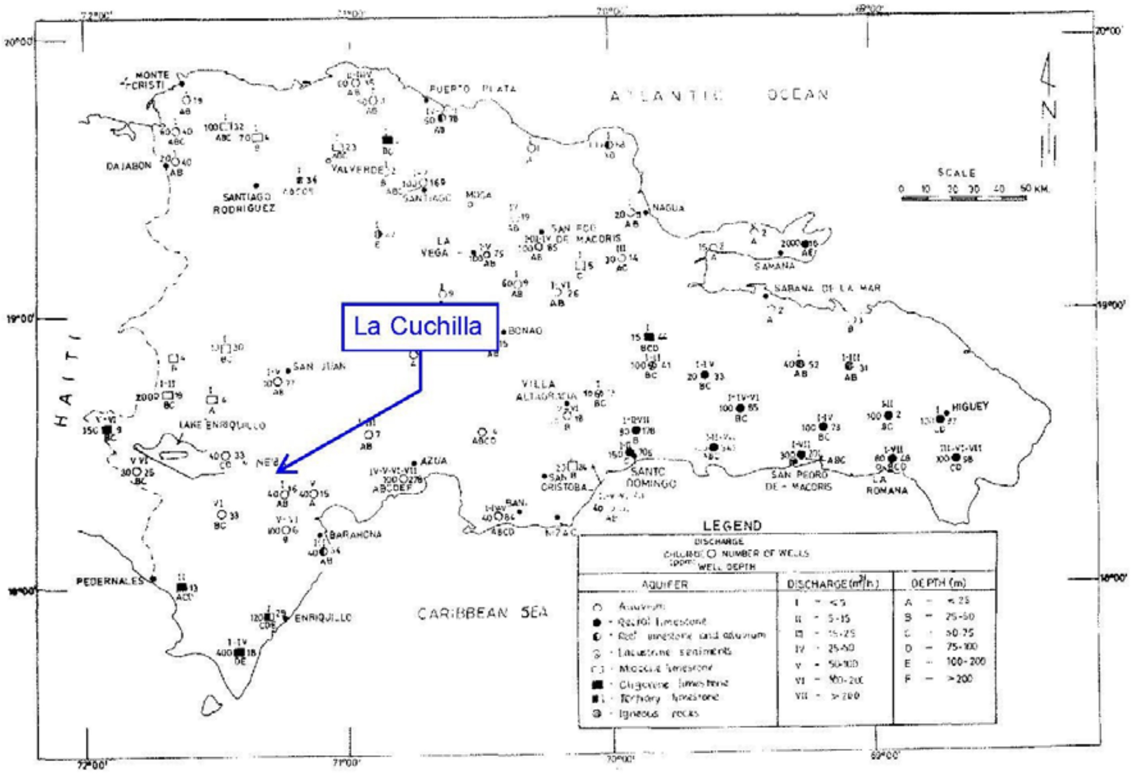

FIG. 5. Water wells distribution in the Dominican Republic.

Aquifer systems of Dominican Republic 387

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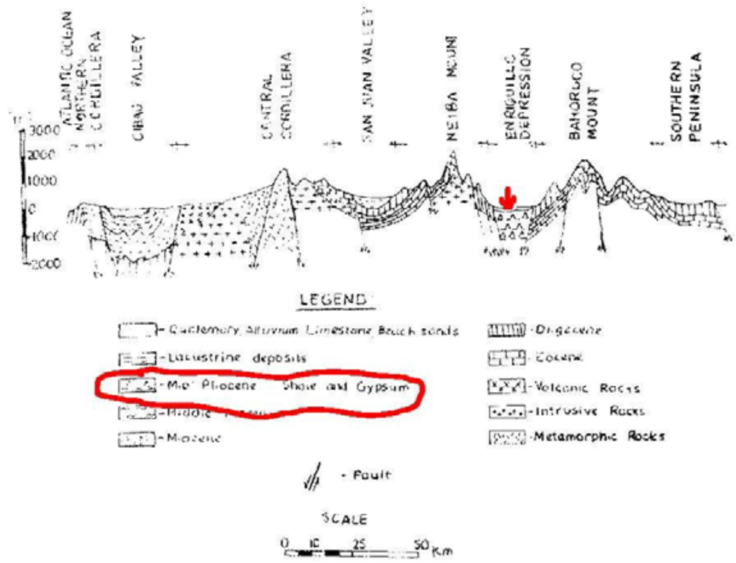


FIG. 3. Schematic geological cross section between the Atlantic Ocean and the Caribbean Sea (Western Dominican Republic).

The aquifer systems of the Dominican Republic

Y. GILBOA The Israel National Oil Co. Project,
80 Shernkin Street, Tel Aviv, Israel

A-6

WATER RESOURCES
ASSESSMENT
OF THE
DOMINICAN REPUBLIC

2. Hydrogeology

Variations in the geological structures, geomorphology, rock types, and precipitation contribute to the wide variety of ground water conditions in different parts of the country. The primary aquifer systems in the Dominican Republic are as follows:

- Quaternary to Recent age alluvium (map unit 1);
- Tertiary to Quaternary age limestone (map unit 2);
- Tertiary differentiated and undifferentiated sedimentary rocks with minor inclusions of metamorphic rocks (map unit 3);
- Quaternary age lacustrine deposits (map unit 4);
- Cretaceous to Eocene age igneous and metamorphic rocks with minor inclusions of sedimentary rocks (map unit 5); and,
- Recent age marsh or swamp deposits and minor pockets of Cretaceous age metamorphic/igneous rocks in small areas (map unit 6).

Ground Water:

Map unit 2 covers about 60 percent of the province and is in the northern, western, and southern parts of the province. Very small to very large quantities of ground water are available from Tertiary to Quaternary age limestone at depths ranging from 5 to 25 meters for low-lying areas and 100 to 200 meters for mountainous areas. Ground water quality is generally fresh and very hard. Within or near urban areas, shallow ground water may be contaminated with biological and/or chemical wastes. Major aquifers include the karstic limestone in the La Toca, The Cevicos, the Arroyo Blanco, the Higuerito, the Arroyo Seco, the Sombrieto, the Lemba, the Florentino, the Abuillot, the Plaisance, and the Neiba Formations. A reef limestone unit, the Villa Trina Formation, is also present.

The rest of the province lies in map units 4 and 6 where ground water exploration is not recommended during military exercises without site-specific reconnaissance.

d. Other Aquifers (Map Units 4, 5, and 6)

Fresh water is scarce or lacking in areas containing Recent age lacustrine deposits (clay with some sand and gravel). Very small to small quantities of ground water may be available from these low-permeability aquifers. Small yields of ground water may exist in the sand and gravel lenses. These aquifers are primarily in the north-central, northeastern, and south-central parts of the country. Depths to these aquifers range from less than 1 to 10 meters below ground surface.

A-7


DOMINICAN REPUBLIC
International boundary
Provincia boundary
National capital
Provincia capital
Railroad
Road
0 20 40 Miles
0 20 40 Kilometers
ATLANTIC OCEAN
CARIBBEAN
La Cuchilla
SANTIAGO
LA VEGA
SAN JUAN
INDEPENDENCIA
BARAHONA
PEDERNALES
SANTO DOMINGO
WATER RESOURCES ASSESSMENT OF THE DOMINICAN REPUBLIC
A-8

ENRIQUILLO BASIN.

The Enriquillo Basin is the eastward continuation of the Cul-de-sac region of Haiti. The two together form a valley about 15 kilometers wide, extending from the Bahía de Neiba, which itself is part of the same physiographic province, to Port-au-Prince, in Haiti. This valley, which in late geologic times was a strait, was uplifted so recently that it has been little modified by erosion. The visitor to the Enriquillo Basin has the unique experience of walking dry-shod on the bottom of the sea across shell-strewn sands and of wandering among forests of coral that appear so fresh that the water might have been withdrawn only yesterday. The Enriquillo Basin has been uplifted 35 meters or more, but some depressions in it stil remain considerably below sea level. Lake Enriquillo, a large remnant of the original strait, occupies one such depression. Its surface now stands 44 meters below sea level and is gradually being lowered by evaporation. In 1892, according to Wells,[1] the surface of Lake Enriquillo stood practically level with the sea. In 1900, according to Tippenhauer,[2] its surface stood 34 meters below sea level. The water in Lake Enriquillo is much saltier than sea water, owing mostly to its concentration by evaporation and partly to additions of saline matter carried by streams.

The waters of the Bahía de Neiba are kept out of the depression containing Lake Enriquillo by the delta deposits of Rio Yaque del Sur, which has built a dam across the head of the bay. During unusually high floods part of the water from Rio Yaque is diverted westward into Lake Enriquillo. Some of the flood water of Rio Yaque is stored in the Laguna del Rincón, a large fresh or slightly brackish lake connected with the Yaque by a channel near the village of Cabral.

The Étang Saumâtre, or Laguna del Fondo, occupies another depression west of Lake Enriquillo. When visited by Wells,[3] in 1892, its water was slightly brackish, but potable, and its surface stood 58 meters above sea level. According to levels run in 1900[4] the Étang Saumâtre stood 20 meters above sea level.

ENRIQUILLO BASIN.

Outline of Geology.

Between Rio Yaque and Lake Enriquillo there is a westward-sloping plain that is interrupted by the low hogback hills on the north side of Laguna Rincon. The strata exposed in the north side of the basin along Rio Yaque represent the lower division of the sandstones and shales of the Yaque group. The beds dip northward into a syncline, along the axis of which there are strata that are probably equivalent to those in the Cerros de Sal, on the south side of the basin (Cerros de Sal formation). The limestone mountains of the Neiba Range are visible in the distance to the north, and about 30 kilometers to the west the same mountain front lies close to the shore of Lake Enriquillo. The south side of the basin is bounded by the Cerros de Sal, which contain thick beds of gypsum and rock salt. These hills are locally separated from the Bahoruco Mountains, to the south, by a lowland. Similar gypseous strata appear in the ridges on the north side of Lake Rincon. Lake Enriquillo is bordered by a terrace of coralliferous limestone having an altitude of about 35 meters above sea level. This is prominently developed at Neiba and Duvergé and was recognized as a flat-lying bedded limestone at several places to the east. It is either equivalent to or somewhat younger than the conglomeratic "coast limestone" that extends from Cabral southeastward beyond Barahona.

A-10

LAND FORMS.

PROVINCE OF BARAHONA.

The surface of the Province of Barahona consists mostly of numerous hogback ridges whose trend ranges from east to southeast. Most of the rock of these ridges is hard white limestone, in beds that are generally inclined northward more or less steeply. The parallel ridges are probably in large part the result of step faulting, a type of structure known to prevail in this part of the island. The mountain tops as seen from a distance are generally of even profile, but here and there isolated peaks extend above the general summit. Some of the peaks visited consist of volcanic rock. The highest mountain ridges are generally 1,000 to 1,500 meters above sea level, and probably no peaks are as high as 2,000 meters. Between the mountains are more or less extensive valleys that include local savannas. Most of those in the interior have less rainfall than the coastal region and some are said to be poorly watered and either treeless or covered with low shrubbery of the mesquite and cactus type.

The most striking topographic feature in the Province is Enriquillo Basin, a valley 12 kilometers broad, extending from the Bay of Neiba northwestward across the Haitian border to the sea at Port-au-Prince. A part of the interior is depressed and is occupied by Lake Enriquillo, a body of salt water whose surface lies (in June, 1919) about 44 meters below sea level. To the west, in the Republic of Haiti, is the smaller Étang Saumâtre, a lake said to be less salty than Enriquillo. Extending around Lake Enriquillo is a terrace of limestone having an altitude of about 35 meters above sea level and 79 meters above the lake. The upper part of this terrace is a mass of corals underlain by marly limestone consisting largely of shells. The Quaternary age of the fossils denotes an uplift of the valley from beneath the sea in comparatively recent time. The barrier to the east against the slowly flowing waters of Rio Yaque del Sur is so slight that they are used by the inhabitants for irrigating parts of the intervening area. In times of flood the river actually overflows the country and temporarily drains into Lake Enriquillo, and the Barahona Company proposes to irrigate some 160 square kilometers of this land by water diverted from the river through a tunnel to be cut through a low hill near the village of Alpargatal.

The general aspect of the lower valley of the Yaque suggests that its delta deposits may have separated Lake Enriquillo from the Bay of Neiba, the lake having been in comparatively recent geologic time an arm of the sea. The actual separation probably took place during the regional elevation that formed one of the latest diastrophic movements.

The east end of Lake Enriquillo is bordered by a broad mud flat that rises very gently eastward to a barren waste of sandy "saladas," which

A-11

are too salty to support plant growth for a distance of several kilometers from the lake but which gradually merge into dense thickets of mesquite and cacti.

As the rainfall in all parts of the basin is more than 50 centimeters a year the somewhat desolate aspect of the region is due not to deficient rainfall alone but rather to the fact that most of the rain falls in torrents in one short rainy season and is thus of minimum benefit. Most of the bare lowlands are "saladas" caused by conditions other than scant rainfall.

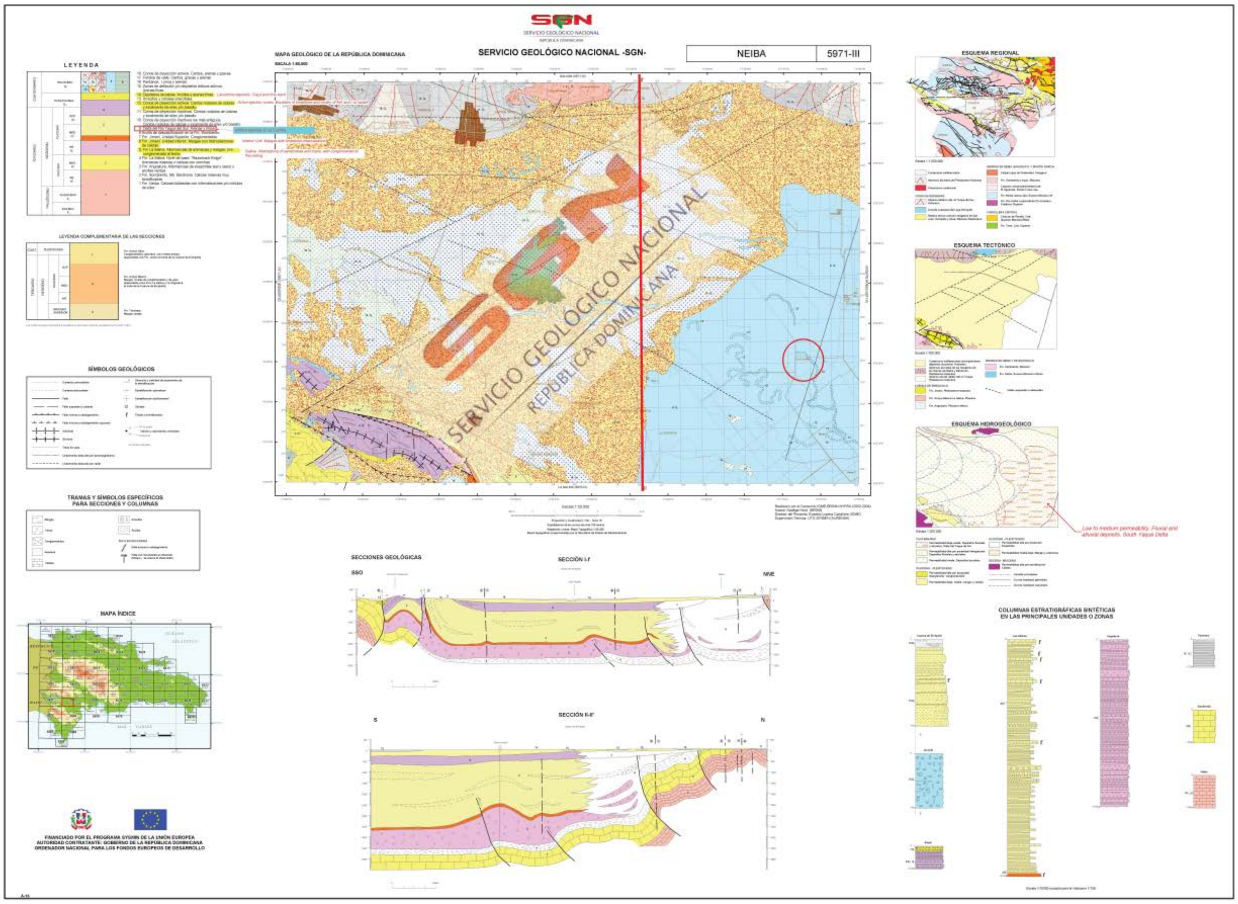
It is said that the ground-water level throughout the lowlands is within a meter or two of the surface and that the water is in most places more or less saline. The irrigation of such land will certainly raise the water table and where the ground water is saline it will render the land unfit for cultivation, but such loss may be temporary, for prolonged flooding may flush the salt water out of the ground. The success of this process will be aided by digging deep drainage ditches at rather short distances apart to carry the salt water toward Lake Enriquillo. By such means an area much larger than that included in the present project of the Barahona Company might ultimately be reclaimed. The great fertility of the soil and its prospective value for raising sugar-cane and long staple cotton seem to warrant the expenditure of a large sum of money on the project. The methods used should be similar to those employed by the United States Reclamation Service in certain parts of Arizona.

PROVINCE OF AZUA.

The Province of Azua is somewhat more mountainous than the Province of Barahona, especially in its northern part, which includes many high peaks of the Cordillera Central. The most prominent peaks are Lomas Tina, Rucillo, and Gallo, probably the highest in the islands. It is said that Loma Tina stands 3,100 meters above sea level, but it is doubtful whether the peak has ever been accurately measured or even ascended.

Spurs extend southward from the principal mountains to the great central valley of San Juan, which, like Enriquillo Valley, to the south, trends a little north of west, reaching westward into the Republic of Haiti. The Neiba Mountains, which lie south of the San Juan Valley, are 1,000 to 1,500 meters high and differ from the jagged Cordillera Central in that they consist largely of limestone and other sedimentary rocks that form hogback ridges of fairly even profile. (See Pl. XVI.)

The central valley of San Juan ranges in width from 15 to 20 kilometers and the part of it that lies within the Dominican Republic extends from east to west for about 80 kilometers. Within the valley are low hills and rolling country as well as large tracts of nearly level savannas. The most extensive savannas are near the town of San Juan and consist of flat, treeless stretches that lie only a few meters above the level of the river and slope gently southward.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LEYENDA
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MAPA ÍNDICE
SECCIONES GEOLÓGICAS
SECCIÓN I-I'
SECCIÓN II-II'
ESQUEMA REGIONAL
ESQUEMA TECTÓNICO
ESQUEMA HIDROGEOLÓGICO
SERVICIO GEOLÓGICO NACIONAL
REPÚBLICA DOMINICANA

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Correspondence with Water at Work available on Google Drive.

Correspondence with Jesus Medina available on Google Drive.

The goal of this project is to improve the water supply system for La Cuchilla and make it last for generations. This letter is meant to inform you of our progress to date as well as get your input and approval to continue with the design. All comments and questions are welcome!

The Engineers Without Borders (EWB) team visited Cuchilla in March 2017 and analyzed the existing water system. Since then EWB has been doing design, analysis, and reviewing options to improve the water system. Some options EWB developed include:

1. Supply Alternatives
    a. Existing Wells
    b. Construct New Well
2. Storage and Distribution Alternatives
    a. Scheduled Service Zones
    b. Construct New Centralized Tank
    c. Construct New Secondary Storage Tanks
3. Treatment Alternatives
    a. Bottling Plant
    b. Point of Use Treatment
4. Power Supply Alternatives
    a. Connect to Existing Electrical Grid
    b. Install New Solar Panels and Connect to Existing Electrical Grid
    c. Install Backup Generator Connection

The EWB team also tested the water for water quality and bacterial contamination in the summer of 2017 with the help of an organization called Water at Work. The results of these water tests are in the attachment. The results show high levels of bacterial contamination in the well by the basketball court, the school well, the bottling plant, and the irrigation canals.

EWB looked at several options for a new water supply including reusing one of the existing wells, water delivery, or constructing a new well.

The existing wells both have complications. The basketball court well was observed to be only 34’ deep when it was originally much deeper. Over time this well has been filling up with sediment and is suspected that either the well casing or well screen was installed incorrectly or has been damaged overtime. This well will continue to fill with sediment as water is drawn from the well. This well is also regularly flooded and contaminated by the adjacent irrigation canal.

The school well is not operational and also technically owned by the engineering and construction company who is working on the school. Once this well is operational the well will be owned by the school and/or Ministry of Education. The south well casing was also reported to be perforated the entire length of the well. This will lead to contamination from the surface water. The community may be able to use water from this well but long term it would be best to have a well owned by the community.

Water delivery services are available but determined to be a poor long-term solution. These services are known for having poor water quality and typically being more expensive per gallon of water. In the future the prices could increase and this would also make the community reliant on when trucks can deliver water.

EWB recommends that the best solution for the new water supply is to drill a new, properly constructed well in a location far from the irrigation canals to minimize contamination. This well will be about 130' – 150' deep and will be deeper than any well in the community currently which will help deliver cleaner water. However, after construction EWB will still do more thorough water quality tests in order to determine the water quality from the new well. See the attachments for maps and details on the well construction.

The distribution piping will also be addressed in this project. The main issue with the distribution network is that there are areas of significantly less water flow which results in areas of the community getting less water than others like near the school and the west side of the community.

The solution for the storage and distribution issues may be constructed in multiple phases. However, for the first phase EWB recommends new distribution piping and valves will be installed in the existing distribution piping to section off the community into separate service areas. This will allow for the existing system to serve smaller sections of the community at a time. For example, the community would consist of three sections having a service schedule as follows:

1. Section #1: 7:00 am - 12:00 pm
2. Section #2: 9:00 am - 3:00 pm
3. Section #3: 12:00 pm - 5:00 pm

This schedule can be modified to fit the community's needs. In this example all members of the community get access to water for 5 hours per day but only 2/3 of the community is ever being served at a time by the system. This will increase the flow available for each individual water tap. In order to make this scheduling option work an operator would be required to go around to the newly installed isolation valves in each section and open/close them at each time interval. The capacity to do this will need to be integrated into the water board and monthly water payments may contribute towards an operator's salary.

The water treatment for the new system is recommended to be completed in stages. The first stage is to install a new well and connect it to the water distribution piping and tanks. Then detailed water quality testing will be done to determine the water quality of the new well. It is anticipated that the deeper well will yield cleaner water with minimal bacterial contamination, however this will be confirmed. If contaminants are detected then further water treatment technologies will be considered.

In order to increase to community's access to water, the system will also need increased access to electricity. Currently the electrical grid delivers power at unreliable and irregular times and also irregular voltages. A secondary source of power is needed to reliably operate the well pump for more hours of the day.

EWB recommends a solar panel system be installed for the new well pump. EWB would install the solar panel system on the roof of the new school to prevent theft. A welded steel structure will surround the solar panels and will be anchored to the concrete roof. The roof of the new school is approximately 25’ and covers a large surface area. This is the tallest structure in the community. Locating the solar panels back far enough from the edge of the building will prevent anyone from seeing them and keep them out of site. The electric wiring will be concealed as best as possible. The school is also supposed to have a night guard who patrols the school grounds regularly. These measures should prevent theft as best as possible.

EWB will also design the electrical system so that the electrical grid will be able to power the new well pump at night or when it is too cloudy for the solar panels to produce power. An electrical connection for a generator will also be included as an emergency backup. EWB is not planning on providing a generator for this project. This way the well pump could be powered by the solar panels, the electric grid, or a generator.

Please refer to the attachment for a map of the community with locations of some of the new infrastructure the we recommend for the project. If there are any concerns with some of these locations please let us know, we are very interested in the community’s feedback on the locations of these.

You will notice on the map that there are some new pipes and tanks shown for the school. The school currently has a well but the pump is not connected to electricity. When the pump is operational we plan to install piping and tanks so that the other school can get water from that well. We also plan to install piping to be able to fill the school tanks directly from the new community well. This will give the school a more reliable water supply.

In order to operate and maintain this new water system the community will need to organize some sort of water board. This water board is very important for the long term success of the water system. This board will be responsible for collecting monthly water payments from households, fixing and maintaining broken equipment or pipes, and enforcing any rules made by the water board. There are a lot of different ways this water board can be set up in the community, one way may be to set up a “junta de vecina”. We will have continued conversations about this and World Water Relief will work with the community to develop the water board structure.

The next steps for this project include EWB making detailed construction drawings and plans. We will also be organizing different contractors and workers to construct the project. Before any money is spent EWB will show all the construction plans and projected costs of the project with Cuchilla. We anticipate being able to start construction around next summer.

Any questions or comments at all please ask!

Adam Byrnes
Engineers Without Borders – Kansas City Professional Chapter
adam.byrnes1@gmail.com

<u>Please respond to the following items. Can write responses on separate pages if needed.</u>

1. How many gallons per day does each typical household use currently? How much water per day would you like to have per household?

2. What concerns do you have with the proposed water schedule system? What would be the community's preferred schedule for each service zone?

3. We are concerned about theft of the solar panels. Are there any additional anti-theft measures you would recommend for the area?

4. How will the community begin to develop a water board or junta de vecina?

5. In general, is this the project the community wants to be designed and built? Do you approve of the project plans outlined in this letter?

<u>Please sign below stating that the community has received this and approves the proposed design.</u>

Community Representative #1: ______________________________ Date:_____________

Community Representative #2: ______________________________ Date:_____________

World Water Relief Representative: ______________________________ Date:_____________

(Note that no signatures here bound any party to commit to any costs at this point. All costs required by the community will be made known well in advance of any payment. Note that we had previously discussed the community being required to contribute 5% of the project. Skilled labor does count towards this total contribution. The total cost of the project is still being developed.)

WATER QUALITY TESTING RESULTS ATTACHMENT

Water Parameter[a]	East Well	South Well	Bottling Plant	West Canal	East Canal	Drinking Water Standard	Normal Water Quality Range
pH	8.88	7.18	7.44	7.19	7.43	6.5 -8.5[c]	--
Turbidity (NTU)	12	6	6	63	31	5[b]	--
TDS (ppm)	546	23	182	373	354	500[c]	--
Iron (mg/L)	0.02	0	0	0.43	0.1	0.3[c]	--
Nitrate (mg/L)	0.9	0.7	0.5	0.4	0.6	50[b]	--
Hardness (mg/L)	222	171	154	274	274	--	Very hard water > 180
Silica (mg/L)	26	37	--	--	--	--	0-200[d]
E. coli (CFU/100 mL)	>1	>1 CFU	>1 CFU	>1 CFU	>1 CFU	0 CFU/100mL[b]	--
Total coliforms (CFU/mL)	>1	>1 CFU	>1 CFU	>1 CFU	>1 CFU	0 CFU/100mL[b]	--

(a) NTU = nephelometric turbidity units; ppm = parts per million, mg/L = milligrams per liter; CFU/100 mL = colony forming units per 100 milliliters
(b) World Health Organization Guidelines for Drinking Water Quality (WHO, 2004)
(c) US EPA secondary drinking water standard
(d) High silica concentrations can cause membrane fouling used for water treatment

EXISTING TANK
(5,700 GAL.)
EAST WELL
(EXISTING)
VALVES TO ISOLATE
SERVICE ZONES
NEW WATER PIPING
FOR SERVICE ZONES
SERVICE ZONE #1
SERVICE ZONE #3
SERVICE ZONE #2
NEW WELL
(150' DEEP)
SOLAR PANELS
(NEW)
SOUTH WELL
(EXISTING)
NEW TANK
AND PIPE FOR
SCHOOL


EXISTING TANK
(5,700 GAL.)
EAST WELL
(EXISTING)
VALVES TO ISOLATE
SERVICE ZONES
NEW WATER PIPING
FOR SERVICE ZONES
SERVICE ZONE #1
SERVICE ZONE #3
SERVICE ZONE #2
NEW WELL
(150' DEEP)
SOLAR PANELS
(NEW)
SOUTH WELL
(EXISTING)
NEW TANK
AND PIPE FOR
SCHOOL

Phase #2 Water Treatment Alternatives

1.1 WATER TREATMENT ALTERNATIVES

The drinking water may require treatment depending on the water quality. Limited preliminary water quality tests were performed and are documented in the previous sections. More detailed water quality tests will be performed on the new water supply. Water treatment options include well head treatment, point of use treatment, or a bottling plant.

1.1.1 WELL HEAD TREATMENT

Treating the water at the well head is an option that is being considered. This would include adding water treatment equipment such as chlorination, filtration, ozonation, or UV treatment. Depending on the water quality one or multiple of these well head treatment options may be required. These technologies are relatively common for water treatment in developing communities since they are relatively low cost and relatively easy to operate and maintain. The treated water in this scenario would then be discharged to the storage tank and distributed to the community.

1.1.2 POINT OF USE TREATMENT

Point-of-use (POU) water treatment, also known as household water treatment, is a method of water treatment that takes place at the point of collection or use rather than at a large, centralized location. POU treatment is a viable alternative where consolidated/community treatment systems do not exist. POU treatment methods are generally simple, inexpensive technologies that allow people to treat and safely store water in their homes. Numerous studies have shown use of POU treatment interventions with an improved water source (such as a borehole well, protected dug well, protected spring, or rainwater collection) reduce diarrheal disease in developing communities. The most commonly used methods of POU treatment methods are:

- Chlorination
- Flocculation/Disinfectant Power
- Solar Disinfection (SODIS)
- Ceramic Filtration

- Slow Sand Filtration

It is important to select most appropriate treatment method for a community's specific circumstances. The most appropriate option for a community depends on existing water and sanitation conditions, water quality, cultural acceptability, implementation feasibility, availability of technology, and other local conditions.

A very important component to effective POU treatment is education of the community on proper use and maintenance of the treatment method, as well as safe storage of the water post-treatment. A long-term training approach and repeated contact with the community is needed to create awareness on the importance of treating drinking water and to establish corresponding changes in behavior. There are downsides to POU treatment. The most common of these drawbacks are as follows:

- Potential for error and treatment failure if community is not properly educated and trained on using POU treatment methods
- Users must maintain treatment equipment and/or consumables
- Some POU methods may not treat taste and odor issues
- Variability in quality of treatment equipment
- Availability of treatment equipment and consumables in remote areas
- Failure to regularly test water quality.

1.1.3 BOTTLING PLANT

A separate water treatment process may be required in order to make potable water for public use. This can be done by a bottling plant facility that would store and treat raw water to potable water standards.

The treated water would then be bottled in sanitized 5 gallon "blue jugs" and distributed to customers through truck, cart, or pick up at the facility. This facility could also have the option for customers to bring their own water container and fill up at a tap on the bottling plant. There are risks to this strategy for contamination from the water containers people would bring to the facility if not sanitized properly. If this option is selected a consideration should be made to either distribute approved water containers or have a container sanitizing station people could use before they would fill up potable water at the bottling plant or a bottle exchange program.

This bottling facility could be owned by either a community lead water board or by an organization called Water at Work. It is most preferential that if the bottling plant is located in Cuchilla that community members have an ownership stake in the facility. Great care would need to be taken to set up a sustainable organization to operate the facility, collect payments, and schedule maintenance and repair efforts.

1.2 WATER TREATMENT ALTERNATIVES

The water quality of the new water supply is currently unknown which makes it difficult to determine appropriate water treatment technologies. Detailed water quality tests will be conducted on the new water supply to determine if or what type of water treatment is required.

The current water supply for the community has not been treated for at least the last 10-20 years. There is a small chlorinator located on the discharge of the tank but this is largely unused because of the difficulty of buying the chlorination tablets. Maintaining and operating water treatment equipment is a challenge which needs to be mitigated in this system design. This is particularly noticeable in the existing bottling plant (described in Section 1.2.5) located in the community which has failed due to not changing filters, cleaning tanks, or keeping correct balances of chlorine in the water.

The water treatment for the new system is recommended to be completed in phases. The first phase is to install the new well, connect it to the water distribution piping and tanks, and conduct detailed water quality testing to determine the water quality of the new well. It is anticipated that the deeper well will yield cleaner water, however this will be confirmed. If contaminants are detected then further water treatment technologies will be considered in phase 2.

1.2.1 WELL HEAD TREATMENT

While there are many technology options available to treat water to potable water standards in the US, in the Dominican Republic water treatment technologies are limited to equipment that is relatively inexpensive, effective, and easy to operate. The water treatment technologies that will be considered for the well head treatment facility are:

1. Staged Filtration (sediment, carbon, and virus filters)
2. Reverse Osmosis
3. Chlorination
4. Ozonation
5. Ultra Violet Light

Most of these options are effective and affordable, however, it should be noted that reverse osmosis does have a high installation cost and operational and maintenance requirement but is the most effective at treating to potable water standards. More investigation should be done to identify costs and maintenance requirements for reverse osmosis equipment before it is selected. Also note that reverse osmosis membranes typically have a higher pressure drop across them which require more pumping power than normal filters. This may increase the power demand and therefore the size of the solar panels.

1.2.2 POINT OF USE TREATMENT

The following information on POU treatment methods were obtained from the Centers for Disease Control Safe Water System program.

Chlorination

The most common method for POU chlorination is to use a locally-manufactured dilute sodium hypochlorite (chlorine bleach solution). To use the chlorination method, families add one full bottle cap of the hypochlorite solution to clear water (or 2 caps to turbid water) in a standard sized container, agitate, and wait 30 minutes before drinking. Studies of the health impacts of this method have shown reductions in diarrheal disease incidence in users ranging from 22 to 84 percent. A bottle of hypochlorite solution that treats 1,000 liters of water costs about 10 US cents using refillable bottles, and 11 to 50 cents using disposable bottles, for a cost of 0.01 to 0.05 cents per liter treated. Assuming a water demand of 10 gpcd for a future estimated population of 626, the annual cost of the hypochlorite solution would range from US $865 to $4,375.

Flocculation/Disinfectant Powder

The flocculation/disinfectant powder POU method involves dosing water with a powdered ferric sulfate (a flocculant) and calcium hypochlorite (a disinfectant). This powder is available in small sachets/packets for users to add into a standard amount of untreated water. Users open the sachet, add the contents to an open bucket containing 10 liters of water, stir for 5 minutes, let the solids settle to the bottom of the bucket, strain the water through a cotton cloth into a second container, and wait 20 minutes for the hypochlorite to inactivate the microorganisms. Randomized studies have shown this treatment method to reduce diarrheal disease incidence from 90 percent to 16 percent. These sachets are manufactured by Procter & Gamble™ and are available to non-governmental agencies. The sachets and are usually sold at a cost of 3.5 US cents per packet. This equates to approximately 0.35 US cent per liter, which would translate to an annual treatment cost of US $30,270 for the future community demand.

SODIS

Using the SODIS method, the combined effects of ultra-violet light (UV)-induced DNA damage, thermal inactivation, and photo-oxidative destruction inactivate disease-causing organisms. Users of SODIS fill 0.3 to 2.0-liter plastic soda bottles with low-turbidity water, shake them to oxygenate, and place the bottles on a roof or rack for 6 hours (if sunny) or 2 days (if cloudy). In the laboratory, SODIS has been proven to inactivate the viruses, bacteria, and protozoa that cause diarrheal diseases. Field data have also shown reductions of viruses, bacteria, and protozoa in water from developing countries treated with SODIS. In randomized, controlled trials, SODIS has resulted in reductions in diarrheal disease incidence ranging from 9 to 86 percent. SODIS is a virtually zero-cost treatment method, except for the cost of the plastic bottles, which are likely already widely available in the community. SODIS treatment does not provide any filtration or methods for reducing turbidity in water, and would not be effective in removing other contaminants other than disease-causing organisms.

Ceramic Filtration

Locally manufactured ceramic filters have traditionally been used throughout the world to treat household water. Currently, the most widely implemented ceramic filter is the Potters for Peace design, which is a flowerpot shaped ceramic pot that holds about 8 to 10 liters of water, and sits inside a plastic or ceramic receptacle. To use the ceramic filters, families fill the top receptacle or the ceramic filter itself with water, which flows through the ceramic filter or filters into a storage receptacle. The treated water is then accessed via a spigot embedded within the water storage receptacle. The filters are produced locally at ceramics facilities, and then impregnated with colloidal silver to ensure complete removal of bacteria in treated water and to prevent growth of bacteria within the filter itself. Most ceramic filters are effective at removing bacteria and the larger protozoans, but not at removing the viruses. Studies have shown adequate removal of bacterial pathogens in water filtered through high quality locally-produced or imported ceramic filters in developing countries. A 60 to 70 percent reduction in diarrheal disease incidence has been documented in users of these filters. Locally manufactured ceramic PFP-design filters range in cost from $7.50-$30. The average cost of treating water with a ceramic filter ranges from 0.034 to 0.14 US cents.

Slow Sand Filtration

A slow sand filter is a sand filter adapted for household use. The version most widely implemented consists of layers of sand and gravel in a concrete or plastic container approximately 0.9 meters tall and 0.3 meters square. Users pour water into the top, and collect finished water out of the outlet pipe into a bucket. Over time, especially if source water is turbid, the flow rate can decrease. Users can maintain flow rate by cleaning the filter through agitating the top level of sand, or by pre-treating turbid water before filtration. Slow sand filter lab effectiveness studies with a mature biolayer have shown 99.98 percent protozoan, 90 to 99 percent bacterial, and variable viral reduction. Field effectiveness studies have documented *E. coli* removal rates of 80-98 percent. Health impact studies report 44 to 47 percent reduction of diarrheal disease incidence in users. The average slow sand filter's construction cost ranges from US $15 to $60, depending on whether local or imported materials are used. Assuming it lasts 10 years and families filter 40 liters per day, the cost per liter of treated water is 0.068 US cents. This would translate to an annual treatment cost of US $5,900.

The annual treatment costs of these POU methods are compared in Table 2-1.

Table 2-1 – POU Treatment Method Cost Comparison

POU Method	Cost per Liter (US cents)	Annual Treatment Cost (US dollars)
Chlorination	0.01 – 0.05	$865 – $4,375

Flocculation/Disinfectant Powder	0.35	$30,270
SODIS	No direct costs	No direct costs
Ceramic Filtration	0.034 – 0.14	$3,000 – $12,000
Slow Sand Filtration	0.068	$5,900

1.2.3 BOTTLING PLANT

Multiple aspects of a bottling plant were analyzed in order to determine water treatment effectiveness, operations and maintenance requirements, and life cycle cost requirements. A bottling plant requires significant investment by the community and all aspects of the plant should be analyzed.

The same water treatment technologies identified for well head treatment were considered for application in a bottling plant. The difference between the well head treatment and the bottling plant is in its operation and distribution. The bottling plant will not distribute water through pipes to users, but will rather bottle the water. The purpose for bottling the water is to remove any potential for contamination from a piping network due to underground pipe breaks.

Operation and Maintenance Requirements

Operation of the bottling plant would require regular and daily tasks be completed in order to treat and bottle potable water. Depending on the number of gallons bottled per day, 2-4 people may be needed to operate the facility full time. Responsibilities would include:

1. Storing sanitized 5 gallon "blue jugs"
2. Turning pumps on to transfer water from raw water storage tank, through treatment system, and into clean water holding tank
3. Filling 5 gallon "blue jugs" with potable water
4. Regular sanitization of entire bottling plant, especially any surfaces, nozzles, caps that are coming into contact with potable water
5. Loading "blue jugs" onto trucks or carts and delivering to customers
6. Collecting payments
7. Logging how many gallons are produced daily

Regular maintenance requirements would include:

1. Water quality testing.
2. Quarterly or bi-annually replace carbon and sediment filters.
3. Bi-annually replace ultra violet light bulb.
4. Monthly or bi-monthly refilling the chlorine injection system (either tablets or solution).
5. Regularly back washing the staged filters (sediment, carbon, and virus filters).
6. Regularly back washing the reverse osmosis filters and disposing of the back wash water which will contain heavy concentrations of salts and contaminants.
7. Replacing lost or missing "blue jugs".

The operation and maintenance requirement for a bottling plant are intensive. A full time staff will be required to run the operation and through planning will be required to maintain the equipment and costs for replacement of filters and other equipment.

<u>Life Cycle Cost</u>

A very rough first cost of equipment and labor is described below for a bottling plant. These figures are based on responses from NGOs in the region as well as previous experience. For reference Water at Work has indicated that it costs roughly $25,000 for them to build on of these facilities. The description below details how these first costs, annual costs, and annual profits could be broken out.

First Cost Breakdown

1.	Staged Filtration & UV	$1,500
2.	Chlorination	$500
3.	Ozination	$500
4.	Reverse Osmosis	$5,000 - $10,000
5.	Bottling Plant Structure	$5,000 - $7,000
6.	Tanks, Pipes	$1,000 - $3,000
7.	Electrical, Wiring	$3,000 - $5,000
8.	Blue Jugs (x400)	$4,000 ($10/ea.)
9.	Labor	$5,000 - $7,000
10.	**Total**	**$25,500 - $38,500**

Annual Cost Breakdown

1.	Staff Salary	$10,000 - $20,000
2.	Replacing 3 Stage Filters	$450 ($150/ea.)
3.	Replacing UV Light Bulb	$100 ($25/ea.)
4.	Replacing Blue Jugs	$200 ($10/ea.)
5.	Chlorine tablets/solution	$100
6.	**Annual Total**	**$10,950 – $20,950**

Annual Potential Profit

1.	Annual Water Revenue	$12,500 - $25,550 (35¢/jug, 100-200 jugs/day)
2.	Annual Costs	$10,950 – $20,950
3.	**Annual Profit**	**$1,550 – $4,600**

Administrative and Partnership Requirements

Payment structures and a sustainable business model would need to be implemented and maintained by the community in order for this bottling plant to work. The community would have to decide on a payment model. After reviewing other similar applications two payment models that are typically used include:

1. Pay per bottle
2. Monthly water payment

Both payment structures need to take into account the equipment maintenance and replacement costs as well as any salary paid to staff. The initial assessment above indicates that 35¢/bottle could prove profitable on an annual basis given conservative 100-200 bottles per day. For the 147 families in Cuchilla this would equate to a $7-14/month water charge which is relatively expensive on their monthly finances.

A hybrid model could combine these two models so that a flat monthly charge will get each family 25 bottles a month and it is 35¢ for every bottle after that, for example. Ultimately any payment structure would need to be thoroughly thought out and all options presented to the community as it will be their final decision what payment structure would work best.

The bottling plant would need a continuously present organization to collect payments, pay staff, buy replacement equipment, and save money for larger equipment replacements in the future if for example a pump needs replacing. This organization would need to be very consistent and trustworthy enough to handle funds this size.

