THESIS

APPLYING THE THEORIES OF SUSTAINABLE WATER AID

Submitted by

Caleb B. Douglas

Department of Civil and Environmental Engineering

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2010

Master's Committee:

Department Chair: Luis Garcia

Adviser: Ken Carlson

Sybil Sharvelle

Evan Vlachos

Stephen Mumme

ABSTRACT OF THESIS

APPLYING THE THEORIES OF SUSTAINABLE WATER AID

A lack of accessibility to safe water has always been one of the greatest challenges to the rural developing world. This issue has resulted in the deaths of countless millions of people, as well as the underdevelopment of many nations. The developed world has always recognized the necessity of providing water aid to these developing nations. However, this water aid has had limited success in providing sustainable water solutions and in alleviating this crisis.

Recognizing this lack of effectiveness, the theories of water aid and community development have been studied and scrutinized. This has resulted in great strides in the science of providing sustainable aid to developing nations. Yet, while much has been learned about the proper theories, little increase in success has been seen in the developing world.

This study seeks to determine if one of the reasons for this lack of translated success is due to a lack of summarized and unified development principles. Therefore, this thesis attempts to collect a representative sample of literature on water aid and community development and develop a singular theory for implementing water aid. This developed procedure will serve as a step-by-step guideline that covers water aid from the community selection process to the necessity of following up with the community.

This thesis will then apply this developed procedure in four communities and monitor the successes and failures. Based on this analysis, observations can be made on the viability of the new standard operating procedure. If successful, perhaps this plan could be utilized by aid organizations to provide replicable results. Additionally, observations can be made on whether a lack of collated development theories is one of the reasons for a lack of success amongst water aid. All this is done with the intention of furthering the progress of water aid, with the hope of provided greater lasting success in the developing world.

ACKNOWLEDGEMENTS

I would like to thank several people who have been instrumental in the completion of this thesis. First, I must give thanks to God. Without Him, none of this could have been possible. He is my inspiration and the reason for this thesis. I would also like to thank my wife, Morgan, who supported me by allowing me to focus on my thesis rather than her. I would like to especially thank my parents, who financially supported me throughout my undergraduate and graduate school. I would have never had the opportunity for advanced education without them. I would like to thank my adviser, Dr. Carlson, for his years of support and inspiration. His unique outlook on life and education is what kept me in school. Lastly, I would like to thank my entire committee. Each of you helped shape my worldview in some way. Also, each of you has put forth effort into making this thesis reach its full potential. Thank you all!

Table of Contents

List of Tables and Figures

Page

"Success is the ability to go from one failure to another with no loss of enthusiasm."

-Winston Churchill

CHAPTER 1.0- INTRODUCTION

Safe water is essential for human life; necessary for drinking, cooking, sanitation and hygiene. It is estimated that over 1.1 billion of the world's most impoverished people lack access to safe water [1]. The health effects caused by a lack of clean water are grim. Approximately 3.8 million people die every year from a lack of clean water, including the deaths of 6,000 children every day [2].

Besides the attributed negative health effects, studies show that a lack of safe water directly contributes to the perpetuation of underdevelopment for many countries. A lack of safe water has been linked to lower literacy rates [3], an oppression of women's and children's rights, the hindrance of local businesses [4], increased mortality of HIV/AIDS victims [5], and the exacerbation of violent conflicts [6]. All of these effects have been shown to stymie national development.

Since the times of industrialization, the developed world has been committed to alleviating the water crisis and promoting development in the Third World. This social consciousness and moral imperative has most often come in the form of water aid. Since the advent of water aid, its priority on the international agenda has grown with every passing year, culminating with the United Nation's Millennial Development Goals in 2005 [7].

However, for as long as water aid has existed, the developed world has systematically failed to provide successful and sustainable water treatment systems to the developing world. Success and sustainability rates for water aid have consistently hovered around 10% to 12% [8, 9]. Countless monies have been inefficiently used for water aid projects like the UN's first water decade [8], El Cajon dam [10], the Red Cross' Central American water tank program [11] and bio-sand filters [9].

Due to these recognized failures, research on proper water aid has exploded in both the private and the public sector. From this research, much progress has been made in developing principles of sustainable and successful water aid. The emerging philosophy places greater emphasis on the proper assessment of technology and community development by holding paramount the independent variables of participation, anticipation, education, community trust, economy and governance.

While a great deal has been learned about the science and philosophy of international water development, the success rates have not been drastically increased. One reason could be that the suggested practices and principles are quite dispersed in literature and policy. In order to follow suggested protocol in community water development, it is necessary to consult large amounts of literature.

If this is the case, making the principles of water aid more applicable and practical requires summarization and organization of the principles of water aid into a cumulative standard operating procedure. If this standard operating procedure were successful at quantifying water aid philosophy, it could serve as a stand-alone guide for implementing water aid. These conclusions could greatly help any philanthropist or aid agency attempting international water development.

1.1 Objectives of the Study

This study's ultimate objective is to examine whether greater success and sustainability in water aid is possible by combining what has been learned about the theory of international water development and creating a standard operating procedure. Then, the developed plan can be applied to developing communities. Finally, conclusions may be drawn on the success and viability of the current water aid principles through monitoring and analysis. The sub-objectives and key results of the study are listed below in chronological order:

1. Conduct a cumulative literature review on the principles and science of proper water aid and community development
2. Create a procedure for proper water aid and community development using the knowledge gained from the literature review
3. Implement water aid in various communities using the developed procedure
4. Monitor each community's water aid for success and sustainability

The cumulative literature review can only be successful by recognizing the two variables to water aid. These variables are technology and community development. While each variable is of vital importance, water aid cannot be successful without paying due diligence to both. Therefore, these variables are co-dependent on each other for successful water aid. These two variables allude to several of the critical variables for water aid, including: population, governance, water quality, ecology, water quantity, education, conservation, participation, etc. Using this knowledge, the literature review can be conducted in a manner that seeks out each variable in the philosophy of international water development. Furthermore, recognizing that a procedural plan is one of this thesis' main objectives, the literature review should include theories for every phase of the water aid process. This includes the planning and selection process, the implementation process and the follow-up process. By honing the literature review, the process will be more efficient and pertinent.

After the literature review has been conducted, the water aid plan needs to be created. This plan should serve as a stepwise procedure that can be followed to implement successful water aid. During this plan's development, special care must be given to every detail to ensure that no important principle or step is left out. The plan must include every aspect of water aid that the literature review deems important. This plan is the culmination of this thesis and could potentially serve future aid organizations in their water aid efforts.

The created plan will then be tested by applying it to various rural developing communities. By applying the plan in various communities with a range of people groups, more insight can be gained on the plan's ability to translate and account for geographical and anthropological differences. For the prudency of the study, the plan must be followed rigidly in each case to eliminate extraneous variables.

To complete the study, the results of the test must be monitored in each case. In this study, success must be defined since the study's main objective seeks a more successful and sustainable method to water aid. In this study, success will be defined as the cumulative effect of the duration of the water system's operational life, the quality of water throughout the life of the system, the continuous amount of the community served, continuous community satisfaction and increased public health. This data will then be compared to success rates of previous water aid efforts. The entire methodology of this study can be summed up by Figure 1.1

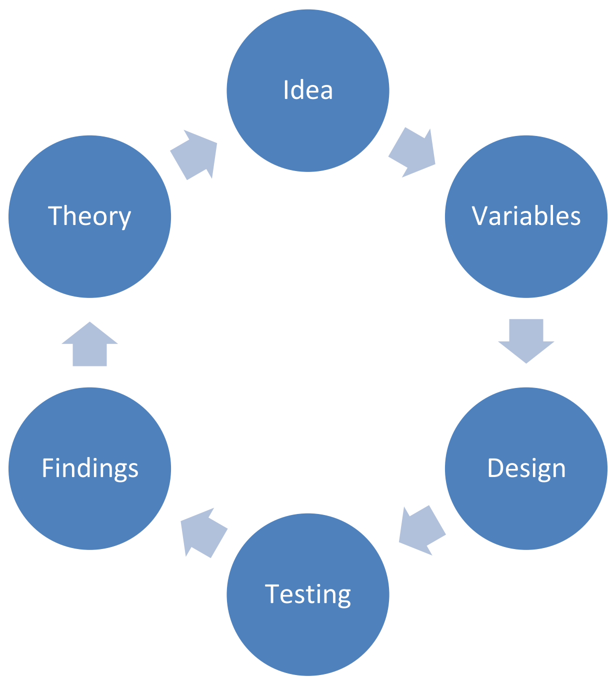

Figure 1.1 The methodology of the study

The researcher developing this plan and conducting this study has provided water systems to rural developing communities in Latin America and West Africa for the last ten years. The researcher has implemented seven water treatment systems and planned many others, thereby gaining experience in community development and several water treatment technologies. The researcher has also maintained relationships with all the communities he has served through local contacts and personal visits. Through the literature review, numerous interviews, and the data collected in this study, the researcher feels qualified to offer expertise and guidance in the realm of water aid in the rural, developing world.

In summary, the water crisis among developing nations is dire, and projected to get worse. Approximately 1.1 billion of the world's population still does not have access to clean water, which results in millions of deaths every year [2]. Besides the negative health effects, a lack of access to clean water has been demonstrably shown to hinder national development, thereby subjecting affected populations to greater poverty and lower quality of life [12].

The industrialized world has recognized its role in aiding the developing world through the provision of clean water. However, in spite of good intentions, water aid has not consistently provided the developing world with lasting and sustainable solutions to their water needs. To combat this, researchers have studied the principles of community development and water aid extensively and great strides have been made in the science.

Unfortunately, the large amount of knowledge that has been learned about international water development has not directly translated to increases in the effectiveness of water aid. Some of this blame might be associated with the disorganization of the various theories. If a single document attempted to summarize water aid principles as a whole, the causality of the aid failures may be better understood and great strides in the science of community water development may be fully realized.

The intent of this thesis is to create a version of this standard operating procedure for allocating and implementing water aid by thoroughly examining available literature. Then, this thesis will examine if greater success is achieved by reason of a cumulative, organized document that effectively summarizes the principles of water aid. Through this study, conclusions may be made on the validity of the current water aid paradigm. Also, this study may provide insight to the reasons of past water aid failures. Finally, all this will be done with the intent of positively impacting the theory of water aid and the quality people's lives.

CHAPTER 2.0- REVIEW OF WATER AID PRINCIPLES

The first step towards the completion of this study requires the summation of a variety of literature on the proper methodology of water aid. This literature review will cover both proper assessment of technology and community development for the developing world while maintaining focus on the critical variables of water aid. Studies that analyze past water aid failures and draw conclusions on proper water aid practices will be especially useful. Additionally, what has been learned from aid agencies (like the UN and World Bank) and NGOs on the theory of water aid should be considered. The end goal of this literature review is to provide unbiased and cumulative insight into the process of international water development.

2.1 Failed Water Aid

Some of the earliest failures in water aid that were documented by mass media were during the United Nation's (UN's) first water decade (1981-1990). With a self-proclaimed goal to provide everyone in the world with water of adequate quality and quantity [13], the UN set their bar high. During the first water decade, initial solutions to the water and sanitation problems of the developing world were thought to be intricate centralized distribution systems for water and wastewater [14]. Although using urbanization for public health engineering is commonplace in the industrialized world, it lacked success in developing world applications. The solutions were not technologically relevant to rural, developing countries because of the high initial capital costs, the operational complexities of high-tech solutions and the scatter of communities within the developing world [14].

By the mid-1980's, the focus shifted away from urbanization towards simpler hand pumps and wells [14]. The initial results were successful. Communities across sub-Sahara Africa were using the systems and the costs of installation and operation were low. However, when the hand pumps started breaking down, the systems were quickly abandoned by the communities rather than fixed [14]. When the aid agencies saw a number of their systems broken and abandoned, they set out to find the most sustainable and durable hand pump they could find. However, the problem was not the lack of a better technology. Instead, the failure occurred because the communities felt no responsibility to maintain the systems, nor knew how to maintain the system in the first place [14]. These failures during the first water decade perfectly demonstrate the two pitfalls of global water development; irrelevant technologies and inadequate community involvement and participation.

The United States Agency for International Development (USAID) was one of the main agencies that installed water systems for the UN during the first water decade. In a survey of the USAID water systems that had been installed during the water decade, it was found that by 1995 only 30% of the water systems were still being operated. By 2000, only 12% of the water systems were still being used [8]. These results were not uncommon for other international aid agencies associated with the UN's water decade either. With an average project lifespan of less than 5 years, it is easy to see why the issues of clean water and sanitation have continued to persist [8,9,16].

Another example of misappropriated water aid is El Cajon dam [10]. El Cajon dam was built in Honduras in 1985 by the World Bank and Intra-American Development Bank. The hydroelectric dam was built to supply Honduras with more energy and greater water resource. Since the dam was largely designed and built by international engineers, El Cajon was designed like similar monolith dams found in the developed world.

El Cajon dam represents failed water aid in several ways. First, it lacked emphasis on the relative economics of the dam (which had been identified as a critical variable). Hondurans were very concerned about undertaking a project as large and expensive as El Cajon, but their concerns were disregarded by the international developers. El Cajon ended up costing the Honduran government $774 million, through loans from USAID, World Bank, the International Development Bank, etc [10]. For context, El Cajon dam cost approximately 50% of Honduras' entire annual economic output [15]. However, the international engineers thought nothing of the dam's cost considering that in the United States the same dam would only account for a fraction of a percent of its yearly economic output. Ultimately, the technology's disproportionate costs doomed Honduras to years of debt and limited their resources used to tackle other development problems [16].

Similarly, El Cajon dam was an overly complicated technology, deeming it irrelevant in a developing country such as Honduras. Specialized engineering expertise and sophisticated equipment were required for the high-tech project [10]. These necessities are scarce in the developing world. Due to a lack of locally trained engineers and operators, the project became dependent on international engineers and supplies [10]. Without the constant oversight of international engineers and the provision of specialized supplies, the project was doomed to fail. If the technological solution was able to be locally operated and maintained, the outcome of El Cajon dam may have been very different.

Lastly, El Cajon dam failed to utilize anticipatory and participatory water aid practices. In the initial design of El Cajon, many locals expressed concern about undertaking such a large project with associated massive debt. Other locals suggested that five smaller dams be built on the river's tributaries to minimize the inherent risks. Others expressed concern about the loss of land, the relocation of locals and deforestation. Ultimately, most of these concerns were given little regard by the "humanitarian" developers [10].

When Honduras experienced an unprecedented drought spanning in the 1990's, El Cajon did not produce nearly enough electricity to provide for Honduras. During this time, several smaller dams would have negated some of the effects of the drought. Also, approximately 2,000 people were displaced by the dam and thousands of acres of forest and farm land were lost due to El Cajon [10]. Additionally, the environmental impacts of large dams are now well documented. Finally, the locals were right to express concerns about the cost, which ended up incurring massive debt on the Honduran people, who were not being adequately compensated with electricity, given the lengthy drought [10]. If the developers had listened to the concerns of the locals and worked to mitigate those concerns, how much negative impact from El Cajon could have been averted?

Non-governmental organizations (NGOs) have experienced the same lack of sustainability in water aid due to irrelevant technologies and a lack of community involvement. The meteoric popularity and widespread use of the bio-sand filter is another example of international water aid agencies failing to apply anticipatory principles to technology. In theory, bio-sand filters seem to be one of the most pertinent water treatment solutions for rural, developing countries. NGOs like Samaritan's Purse and International Aid Inc. have installed approximately 100,000 bio-sand filters worldwide [9]. Yet, one study shows that bio-sand filters have only a 10% chance of sustained use beyond one year [9]. That same study cites an unacceptable and foreign technology and a lack of local education on maintenance and operation as the primary causes of failure for the bio-sand filter.

In another study, a student group from the University of Virginia implemented these bio-sand filters in a community in South Africa. Their conclusions of the technology were that it was unreliable, high in maintenance and was admittedly implemented due to a bias towards the bio-sand filtration technology [16]. The summation of an unacceptable technology, a lack of education, unreliability and bias resulted in 90% failure rate [16].

Some water aid agencies' failures simply stem from a lack of understanding the developing country's needs and resources. The Red Cross' allocation of water tanks is an example of one such failure. In an effort to alleviate water shortages, the Red Cross donated and erected water towers in rural villages throughout Central America. However, these water towers were not allocated with *a priori* knowledge of the communities. Hence, hundreds of water towers were given to communities that lacked water quantity, lacked water of sufficient quality or simply lacked a means to get water up into a tower. Consequently, nearly all of the towers were never used [11]. To this day, red water towers loom derelict across the Central American landscape (Figure 2.1).

Figure 2.1 Donated Red Cross water tower in Guatemala

Water aid agencies have had less than optimal success in part due to having too little regard for the technology's local acceptance or ease of operation and maintenance. Much of water aid has also been unsuccessful at empowering communities to become independent and self-sufficient. Without educating and enabling each community to take responsibility of their own water system and circumstances, water projects are doomed to fail. A misunderstanding of the critical variables of water aid has bred a misguided approach from the industrialized world, thereby negating many of the good intentions. In order to reverse the lack of sustainability in water aid, a change in focus must occur in the developed world.

2.2 The Theory of Water Aid

For as long as failures in water aid have existed, science has been intent on devising more successful philosophies on water aid and community development. Fresh off the failures of the UN's first water decade (1981-1990), the Global Consultation of Safe Water and Sanitation for the 1990's was held in New Delhi, India to refocus the misguided efforts of the first water decade [17]. The consultation, comprised of the UN and 115 participatory countries, vowed to prioritize more focus on those in greatest need. The credo from New Delhi was “Some for all, rather than more for some.” [17]

In 1992, the International Conference on Water and the Environment took place in Dublin, Ireland. During the forum, the participating countries came up with four principles that have now become cornerstones when considering global water development [18]. These four principles became known as the Four Dublin Principles (they became further defined in various publications and manuals). The first principle states that fresh water is a finite resource that is essential to sustain life, development and the environment. The second principle states that all water development and management should stem from a participatory approach. This principle emphasizes the need for communities to desire and ask for help, as well as their inclusion in the solution. The third principle recognizes that women play a central role in the development and management of water. This principle, along with the second principle, is an essential lesson in the application of community water development. Finally, the fourth principle recognizes that water has economic value. This principle is important because it places emphasis on the need for water in business and local economy. The success of this forum came through recognizing the importance of community participation, the importance of women and the importance of water’s effects on business and economy. All of which are vital pieces of the community water development puzzle.

Integrated Water Resource Management (IWRM) sought to embody the Dublin Principles and put them into practice. The IWRM was developed as a comprehensive participatory planning and application method for the development of water resources.

IWRM seeks to manage resources (including water) in a socially and economically equitable manner. IWRM strove to include all stakeholders in the decision-making process and recognized the many uses of water (agricultural, drinking, healthy ecosystems and livelihoods) [19].

Several other forums and conferences on international water development helped continue to shape the new paradigm of water aid. In 1997 the first World Water Forum, in Marrakech, Morocco, was held [18]. At this forum, nations discussed the risk of water causing wars and possible solutions to avert those consequences. In 2000, at the second World Water Forum, the focus was on the proper governance of water resources. It was here that a need to include all stakeholders in the management of water resources was emphasized again [18]. Additionally in 2000, the UN created Millennial Development Goals (MDGs) aimed at eliminating global poverty, increasing global health and education and promoting equality and global partnership. One of these millennial goals was stated “to halve, by 2015, the proportion of people who are unable to reach or to afford safe drinking water.”[7]

Spurned by the MDGs, the UN decided to give the water decade idea another try and proclaimed that 2005-2015 would be the International “Water for Life” decade. This decade would focus on community involvement and education, with specific priority placed on Africa’s needs. Lastly, in 2006 the fourth World Water Forum was held in Mexico City. At this forum, a need for local solutions was publicly recognized again. It was here that the focus of community water development continued the shift towards a more local, enabling approach [18].

In conjunction with the emerging philosophies of water aid by large-scale international aid organizations, community development and water aid has also been elaborated on through grassroots movements. Topics such as community participation, listening, governance, education and proper assessment of technology have all experienced great reform in the private sector.

For example, Slim and Thomson's book Listening For A Change [20], explores the necessity of listening to make lasting changes in community development. They say, "It is not enough for the development 'expert' to summarize and interpret the views of others-the 'others' must be allowed to speak for themselves." Listening For A Change goes on to mention that listening to the community's needs may require seeking out "hidden voices" or the voices that may be lost in the shuffle. These "hidden voices" may not have much sway in the community, but they may be very important stakeholders in the project. In many male-dominated cultures, women or children may be key candidates for "hidden voices". It is important to identify all stakeholders in the project and hear their opinions.

Community participation has also been discussed at length. The Development Dictionary states, "The long-term 'sustainability' of projects is closely linked to active, informed participation by the poor." [21] It continues that, "Present obstacles to people's development can and should be overcome by giving the populations concerned the full opportunity of participating in all the activities related to their development." [21] Ramaswami also stresses the importance of community participation when he says, "Participatory planning builds local trust and independence." [22] Abell draws a direct connection between the sustainability of water aid and participation when he says, "The effectiveness (of aid) is increased if…the people on the receiving end of new technology and other programs are *enfranchised* in the process." [23]

Ramaswami also speaks on the issue of water resource governance in his paper Integrating Developed and Developing World Knowledge into Global Discussions and Strategies for Sustainability. He states that any shared common resource (like drinking water) must be communally governed in the developing world. He also stresses the need to have all stakeholders represented by the authority. Ideally, the governing contingency would be made up of several community nominated leaders, representing all demographics, with the best interest of the community in mind [22].

Maggie Black sums up the issues of proper assessment of technology and education in water aid in her review of the UN's first water decade. Of water systems provided by the UN, she says, "Where such installations had been provided in the name of public health as a free public good, there was no sense of community ownership. Consequently, when they broke down the community did nothing. They neither knew how to mend their system nor perceived the breakdown as 'their' problem." [14] This statement implicates the need for easily maintained technologies, as well as education of maintenance.

Black also argues the necessity of educating locals on the importance of water quality and its effect on hygiene and health. She says, "The health effects of safe water were not well understood by most poor communities. However, improved health was the driving force behind water and sanitation development co-operation. Thus, the 'lesson learned' was that there was a great need for health and hygiene education." [14]

Due to the great strides in the theory of water aid and community development, some water aid efforts have been quite successful. A water aid project, undertaken by students at the Colorado School of Mines, to bring drinking water and graywater systems to the community of Colinas de Suiza, Honduras took great care in following the principles of proper international water development. Instead of applying extraneous technological solutions, the group was focused on providing locally available technologies [24].

Additionally, listening to the locals was a high priority. The students sought out the opinions of the community for support. "We also held town meetings where its atmosphere of consensus-building provided inclusive transfer of information and ideas…This kind of consensus and informational meeting consistently occurred during each visit." [24] The team from the Colorado School of Mines also sought out the "hidden voices" of the community. Even after an attentive planning process, they did not feel like the entire community had the opportunity to voice their opinion. "Despite the participation in the larger town meetings, we still felt that we had not heard from everyone or had ample opportunity to educate all about the proposed water project. Therefore, smaller consensus meetings were established." [24] This team exemplified listening to their community. They identified the "hidden voices", created an atmosphere of openness and gave the "hidden voices" an opportunity to be heard. "The villagers too seemed more relaxed; they easily engaged in dialogue surrounding the logistics of the proposed projects and shared more ideas to improve their community." [24]

Lastly, the team from the Colorado School of Mines was able to integrate community involvement into the project. The team worked within the confines of the local governance [24]. They also predetermined (with the community) how the community would participate in the installation of the projects. They decided on a fiscal responsibility of $80-$100 per family, as well as labor requirements [24]. By paying special attention to listening, community participation, education, economics, governance and technological relevance, water aid principles dictate that this project has been given every possible chance to be sustainable and successful.

From the many water development conferences and grassroots research, the new water aid paradigm began to form. From the new philosophies on water aid, greater emphasis was placed on the need for proper technology and community development. Also, the new theories uncovered some of the critical variables of water aid: community participation, listening, trust, education, governance, an anticipatory approach, economics, community responsibility, etc. Using all that has been learned about proper water aid principles and their critical variables, a standard operating procedure for international water development can begin to take shape.

CHAPTER 3.0- THE DEVELOPED TECHNIQUE OF WATER AID

In order to adequately determine if the lack of water aid success is due to a lack of collated and organized theories, a development plan needs to be created that provides guidance for implementing water aid. This created plan, therefore, must strive to be inclusive of the great majority of current water aid principles. The plan must also include a focus on the variables of technology and community development, in addition to the several independent variables that have been outlined in *Chapter 2*. Finally, this plan must have a broad spectrum to ensure proper testing for the causality of the failures of water aid.

Based on past experience and logical methods, there are three stages in the implementation of water aid. First, the planning stage takes water aid from entrance into the country to the final design choice of the water technology solution. The second stage is the implementation stage which takes water aid from the technology's installation through leaving the country. Finally, the last stage is following up with the community, which includes opening communication pathways and follow-up visits with water quality and community satisfaction surveys. Following all three stages chronologically should enable the water aid project to have its best chance for success.

Before the plan can be applied and tested in the rural, developing world, the scope of study must be defined. This study will operate under the premise that community welfare takes precedence over individual welfare. Also, the study will strive towards the goal of sustainable solutions. Therefore, the procedure will be tested within the scope of a rural developing community and success will be measured on positive community impact and sustainability for an indefinite amount of time.

To assess how well the procedure functions, indices will be developed to define success. In the quest for sustainability, the ultimate indicator of success is the time for which the water treatment system operates properly. Additional indices should include; water quality, the quantity of people served, the decline in water-borne illness and overall community satisfaction. To obtain this categorical information, surveys will be utilized community-wide during each follow-up visit (These surveys are included in the Community Enablement Plan in Appendix A).

The water quality data analysis technique will consist of before-treatment and after-treatment water samples. The before-treatment samples will be used to determine the background quality of the water being treated. The after-treatment samples will be taken at the nearest available location (at the cistern or first tap) to eliminate any effects on water quality from the distribution system. This is done so that only the performance of the water treatment system is characterized. All samples will be taken to a local analytical chemistry lab that follows the "Standard Methods for the Examination of Water and Wastewater" as defined by the American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF). This water quality analysis allows for a physical/chemical water characterization, as well as a biological characterization. Finally, this water quality sampling should occur during each follow-up visit.

Water was determined to be safe if the lab showed that the water met both biological and physical/chemical criteria. Biologically, safe water had to have very few pathogens (less than 1.8 MPN/100ml) as total coliforms, fecal coliforms and E. coli. Physically, the water was deemed safe if all criteria fell within accepted and pasted ranges (seen in the reports in Appendix C). Only when water met both facets of quality was it considered safe to drink.

Using the water quality data, the duration each system has operated and the community satisfaction surveys, success can be defined. Since the goal of the study is to provide greater success than past water aid efforts, those past success rates need to be taken into account. While water quality and years of operation are quantitative data and are easy to compare to past values, satisfaction data is often categorical and difficult to compare. Therefore, discretionary predefined benchmarks of community satisfaction have been developed and will be utilized as a comparison for the communities of the study. All these facets will be used when considering success.

3.1 The Planning Stage

- **Develop social network**
- **Select a community**
- **Learn about the community**
- **Establish community-wide trust**
- **Unequivocally assess their need**
- **Selection of technology**
- **Define community contributions**

Figure 3.1 The planning stage

The first question that begs to be asked when starting a water project is how to find and select the benefitting community (Figure 3.1). To answer that question, a community's needs, willingness to cooperate and feasibility all factor into the prioritization. To determine these characteristics, inherent local knowledge of many communities (both on a broad country-wide scale and on a focused community-wide scale) is necessary. Therefore, a social network should first be in place before international water development can occur.

This social network should consist of local contacts on several levels. It will be beneficial to obtain a country-wide contact that knows the needs of several communities across the country. This person is typically more educated and worldly, and is probably devoted to national philanthropic efforts. A good place to find these broad types of contacts is through local NGOs. The directors of these local NGOs can make excellent candidates for these types of contacts.

The "broad picture" contacts can relay information to communities to inform them of the aid agency's services. Similarly, this contact can help determine which communities would be optimal candidates for water aid. Once a community is selected, the country-wide contact can help initiate contact with a local community-wide contact. This localized contact can serve as a liaison between his or her community, the country-wide contact and the humanitarian engineer. The local contact can offer site specific knowledge and an invitation to the village. See Figure 3.2 for a clarification of the social network hierarchy.

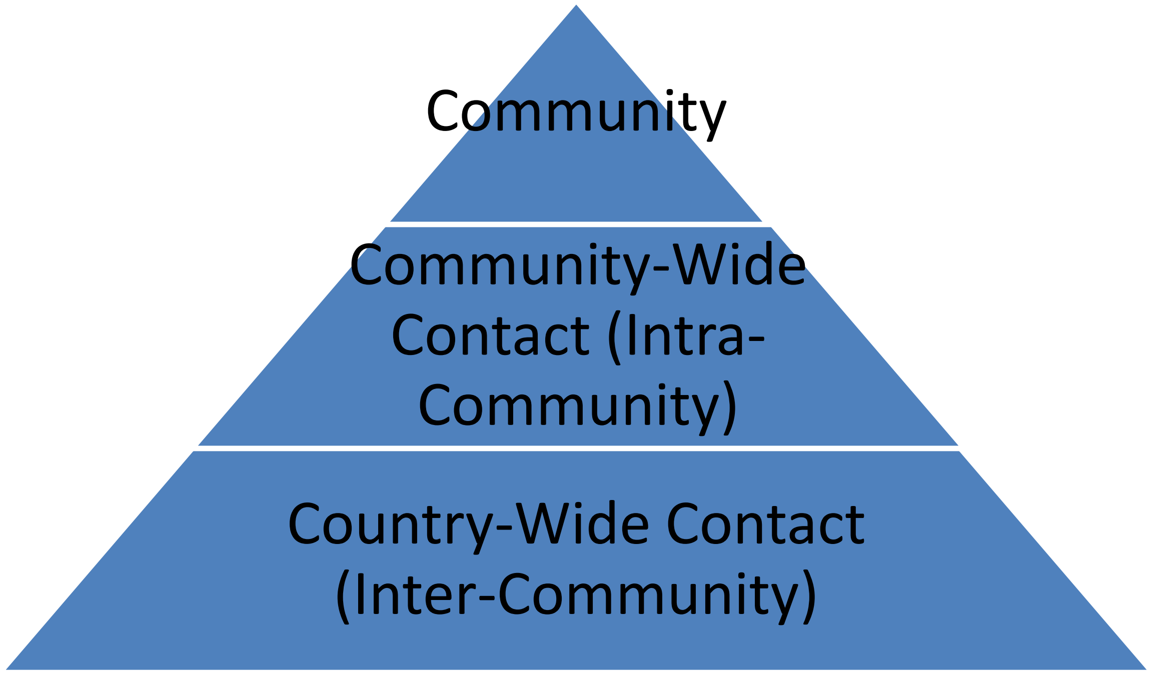

Figure 3.2 Social network hierarchy

Creating a social network of locals with varying scales of focus is essential when undertaking a successful international water project. This network can aid in the community selection process. Additionally, it can offer unique insight into specific communities. A social network is also a great way to maintain contact. While a philanthropist who is out of the country may have difficulty contacting villagers, a country-wide contact (often located in a more urban setting) can often be contacted by telephone or email. Likewise, villages can relay messages back through the network to the philanthropist. Finally, a social network offers an aid organization credibility in a country or village. While villagers tend to be leery of help from international strangers, they are more willing to listen to a fellow local. This credibility is essential when coming into a village for the first time.

When choosing a prospective community, it is important to remember that anyone who needs help should first take the initiative. It is suggested that a community to approach the aid organization for help, not vice-versa. This is based on the belief that one must recognize his own problems first, and then take initiative to mitigate them. This also ensures the community's willingness and desire for help. From the example of El Cajon dam in Honduras, a community's willingness and desire are required for a successful project.

By using the developed social network, a community can be chosen based on need, existing social infrastructure and feasibility. Like the humanitarian team from the Colorado School of Mines, it is important to determine if the community truly needs and desires the project. By being deliberate in the community selection process, there is greater potential for a successful system.

Once a community is chosen, it becomes necessary to learn as much as possible about the selected community. By using both local contacts from inside and outside the village, one can learn about the community's culture, beliefs, language, philosophies and habits. Learning about the community's history is also a good idea before undertaking a water development project. If a community has had prior experience with aid organizations, then they may have certain existing views on aid. If a community has warring factions, then the community may have difficulty sharing a water system. Finally, learning about locally available materials can provide direction for water aid technology solutions.

Through learning about the community and its resources, much insight can be gained about potential pitfalls. By understanding how the community views development and risk, a more tailored technology can be selected. If a community is steeped in tradition, with conservative views on development, only low-tech solutions should be considered. Another pitfall may occur if all the stakeholders are not properly recognized. These stakeholders could be involved politically, economically, socially or religiously. By identifying the "winners" and "losers" of the water project, mitigation may be possible and the issue could be squelched [25].

One anecdotal example, in Honduras, a water system was nearly complete when several integral valves disappeared. The water truck drivers had sabotaged the system by taking the valves, fearing for their livelihood of delivering water to the community. If all the stakeholders had been properly identified and a solution was developed that was more inclusive of the water truck drivers, there may have been a more positive outcome to the water system.

Finally, learning about the community can help to indentify the "hidden voices" that were discussed in *Chapter 2's* section on the importance of listening. By learning which demographics in a community are given less credence to, the "hidden voices" can be identified. As demonstrated earlier by the team from CSM, seeking out these "hidden voices" is very important when assessing the entire community's needs (sometimes it may be necessary to be creative to give them a voice).

Aside from learning about the community, spending time in the village can also help nurture trust between the villagers and the humanitarian developer. Trust is essential between the two entities during the entire water project process. Ignoring the need for trust could result in an unaccepted water treatment technology or a mismanaged water system, ultimately resulting in failed water aid. This trust can be built by following these guidelines.

First, trust is built when the aid agency takes time to listen to the community. Try to hear what their perspective is on the system, their needs, their desires and their issues with any system. Listening will help the community to know that the aid agency has their best interests in mind. Second, local contacts can help build trust. The word of a fellow countryman or friend can mean more than all the good intentions of a philanthropic stranger. Third, site visits help to build trust. When a community sees the aid organization spending time in their village, true commitment is demonstrated. This commitment will help ensure the village of the organization's good intentions. Fourth, the *a priori* knowledge learned about the community (discussed above) demonstrates devotion to the community. When an organization takes the time to learn the ins and outs of the community, the trust is perpetuated. Fifth, when possible, speaking the local language can certainly help nurture the trust of a community. Even when it is not possible to speak the language, try to obtain local contacts that can serve as translators. Finally, when an aid agency is open with the community, full trust and inter-dependence is demonstrated. This openness may entail describing the projects potential benefits and costs, indentifying any contingencies, identifying potential "winners" and "losers" of the project and asking for feedback and potential solutions. When open communication is garnered, both the community and humanitarian developer are totally honest with each other and the best solution can be found. All these guidelines can help lead to a mutual trust between the community and philanthropist, which is necessary for any water aid project.

The next step in this community development approach, after sufficient trust has been built, is to unequivocally assess the water and sanitation needs of the community. An improper assessment or a poor assumption of need is one of the largest reasons for failure in water aid [8,10,11,26]. Understanding the community's needs requires surveying the entire community on their water needs and desires. Culturally, this survey may be difficult. As mentioned earlier, "hidden voices" may need to be identified and sought out. Even when such "hidden voices" are identified, it is important to remember the social context of surveying them. Community members that can be identified as "hidden voices" may not be comfortable speaking in a community-wide forum; they may only be comfortable with fellow members of the same demographic.

In rural Latin America for instance, a woman's place is often in the home. In some villages, woman may appear nonexistent because they are taught to stay at home. These women are often not allowed a voice in public hearings. However, women are a large stakeholder in any water project since it is often their chore to collect water, do laundry, cook and clean. Therefore, the women of these communities must be sought out. They may only be comfortable sharing their water needs and desires in a "women only" context. However, their opinions and perspective are vital for the success of any water project.

After assessing the community's needs, a water aid technology can be chosen. The suggested approach to select the proper technology follows a stepwise procedure to that is provided in the Community Enablement Plan in Appendix A. After obtaining various local contacts, from both inside and outside the village, and performing the initial site visit, a relationship has ideally been formed with the given community. From what has been learned about the community, based on personal observations, community meetings and the local contacts, the associated needs and challenges become more well-known to the aid organization. This intimate understanding of a community is the basis for this technology selection.

By understanding the given community's inherent challenges and needs, an accurate and tailored technology can be prescribed. Using seven criteria as a guideline, the community's assets and liabilities can be categorically prioritized and scored. These criteria are:

- Ease of operation
- Ease of maintenance
- Reliability
- Ease of travel
- Ease of installation
- Upgradability
- Safety

As an example of scoring based on community characteristics, if a community is inherently technologically savvy, ease of operation and maintenance might not need to hold such high priority simply because the community is more capable. Similarly, if a community's system needs to be located near lots of children, safety becomes a higher priority. All scores will be allocated as whole number 1 through 10, with higher numbers holding more significance. Every community will have differing priorities for each criteria and these differences will help determine the community's correct technology.

After determining the community's unique needs and challenges through the criteria weighting in the technology selection process, relevant water treatment technologies need to be researched and considered. The possibilities are numerous, some water treatment technologies include: chlorination, drilled well, ozone disinfection, UV disinfection, sand filtration, ultra-filtration, flocculation/sedimentation or combinations thereof. However, it is important to only consider technologies that are relevant to the community in question.

After researching and determining approximately four alternative technologies, weigh each technology's strengths and weaknesses using the same seven criteria, using the scores of 1 through 10. Perhaps, one technology involves the addition of a dangerous chemical (i.e. chlorination), this technology would score lower on safety. Likewise, if a technology is high-tech with a complex user interface, it might score lower in ease of operation and ease of maintenance. Each of the considered technologies will have specific qualities and detriments.

Upon scoring each of the considered technologies, decision analysis software can be utilized to match the best technology with the community's needs. Decision software, like Criterion Decision Plus®, can determine the best technology and perform sensitivity analyses. Ultimately, the software can score the alternatives from best to worst.

After determining the scores of all the alternatives, a cost analysis should be performed for each considered technology that includes both capital and maintenance expenditures. While the cost has been proven to be vital to the success of a system (demonstrated in *Chapter 2*), it should not be considered in the preliminary decision analysis. Rather, it is more unbiased to first determine the best technology based solely on its intrinsic qualities and merit, and then consider its cost. From the cost analysis, the cost-to-benefit ratio for each considered water treatment technology can be determined. By coupling the initial decision analysis and the cost analysis, the best technology alternative can be selected. For instance, if they best technology determined by the decision analysis software scores an 89% and the cost estimate is $2000, the cost-to-benefit ratio is $22.50 per 1% scored. If the next best alternative scores an 85% and only costs $1500, the ratio is $17.65 to 1%. In this case, the second best alternative may prove to be a more efficient and better choice. In any case, determine the rank of alternatives based on their initial criteria analysis and their cost-benefit ratio.

After ranking the considered water treatment technologies for their “bang for the buck”, it is important to report the findings to the community. Modeled after the team from the Colorado School of Mines, it is important to educate the community on the available technologies and then let them aid in the decision process. Try to present the available technologies and discuss each technology’s *modus operandi* and the reasoning for initially considering it. Strive to present the logic and methodology for determining the best and most cost effective alternatives. After offering suggestions, it is important to let the community select the technology that is best for them. Allowing the community to choose their technology is based on the belief that community participation in the decision and planning stage is necessary. Additionally, allowing the community to choose allows for a potentially more relevant and accepted technology to be selected. Both the participation and relevancy have been historically shown to directly impact the success of a system.

Finally, after a water treatment technology is mutually decided upon, steps to ensure community participation and responsibility in the implementation stage should be taken. Near the end of the planning stage, try to discuss and mutually decide with the community what contributions they should be expected to make. These contributions can be financial and/or in the form of labor. By allowing the community to participate and take responsibility, ownership of their project can be fully realized. If a community is able to contribute financially to the system, even nominally, they are that much more invested in their new system. Likewise, by contributing with labor, “sweat equity” can build ownership of their system. Perhaps the community could be put in charge of building parts of the water system’s infrastructure (i.e. a cistern or the distribution system). From Maggie Black’s assessment of the failures of water aid, she mentions that systems were not properly cared for because the community did not understand that the system was their responsibility. By making the water project cost the community something, ownership and responsibility for their system will be fostered.

3.2 The Implementation Stage

- **Follow through with community contributions**
- **Community participation**
- **Fellowship with community**
- **Establish governance of water system**
- **EDUCATE!!**
- **Operate the system with the community**

Figure 3.3 The implementation stage

Once the planning stage is finished and a water treatment technology has been decided upon, the system must be installed. The focus on community development during the implementation stage must not be neglected. It is during this stage that much of the community's true enablement takes place through education and participation.

Once the water treatment technology has been purchased and brought to the community ready for installation, the first step towards community development requires following through with the community's previously discussed contributions (Figure 3.3). Whether the community had imposed labor obligations, financial obligations or both, it is essential that they complete their end of the bargain. If a community is unable to complete their predetermined tasks, first it is important to attempt to understand why. Then, a restructuring of what is expected of them may be necessary. If the community does not follow through with responsibilities after several attempts, it is best to search for a more feasible community to help. A community that cannot help themselves is not capable of maintaining a water system. As such, progressing a water project in that case would simply be a waste of time and money. By following through on the community's responsibilities, the unsuccessful current water aid paradigm of a dependence on aid and the industrialized world is being challenged.

During the installation of the water system, community participation should be encouraged by all possible means. It is suggested to allow community members to watch the work or let them help with installation (Figure 3.4). Many of the community members may not have seen power tools or certain technologies, it could be useful to let them try the tools out. During the installation process, try to take time to explain each process and its purpose. By encourage questions during the entire process, greater education can occur. Another important focus needs to be including the entire community. While including women and children in the hard labor may not be culturally acceptable, attempt to come up with creative ways to involve the entire community while working within the bounds of their culture. Perhaps the women could prepare a mid-day meal for the laborers or children could help decorate for the festivities after the project's completion.

Figure 3.4 Local participation during drilling

The benefits of encouraging community-wide participation during the installation are numerous. First, the relationship between the aid organization and community members grows. Second, "hands on" participation and education gives the community the confidence and knowledge necessary to maintain and operate the system. If they were present during the installation, they should be better equipped to handle future maintenance issues. Lastly, the community-wide participation continues to build an ownership of the project among the entire community.

Another step towards community development during the implementation stage of the project is to spend quality time with the community. While North Americans and Europeans (and most aid organizations) typically value hard work over relationships, it is often the opposite in rural underdeveloped communities. While the humanitarian developer may believe that he or she can best serve the community through quality hard work, he may unknowingly be hurting his relationship with the community. Likewise, an ill-informed humanitarian developer may be frustrated at a seeming lack of work ethic by locals who prioritize relationships over productivity. Try to prioritize spending time with the community members away from the job site. By eating lunch with them or playing soccer with the children, a deeper bond can be formed. Also, emphasizing celebration can strengthen the bond between philanthropist and community (Figure 3.5). By spending time with the community and developing a lasting relationship, the project is given a much greater chance to succeed.

Figure 3.5 Celebrating with a community in Guatemala

During the installation process, another integral aspect of community development is establishing proper governance of the water system. Although the manner of governance should be decided upon by the locals, given the complex cultural structure of their government, proper aid should attempt to ensure that the governing authority is organized and fair. The governing authority should consist of a group of locally nominated community members that make up the water committee. This committee should represent every stakeholder in the project and have the community's best interest in mind. This committee needs to be developed to oversee the daily operations of the system, as well as the maintenance and welfare of the water system. In addition, the water committee needs to choose some responsible, educated (literate), mechanically- and technically-minded individuals to serve as operators of the water system. By offering input to the development of the water committee, the aid agency can ensure that proper steps have been taken to govern the system in a fair and organized manner.

After the installation is complete, it is important that the aid agency engage in several facets of education. These facets include water resource protection, the need for water aid, community health practices, technology operations and maintenance and system expectations. First, community-wide education needs to take place. This education should detail the system, including the mechanism, daily operation requirements, maintenance requirements and what to expect with the system. Additionally, the community-wide education needs to cover the importance of water resource conservation. It is enticing for a community armed with a new water purification system to excessively use water. Therefore, it is important to educate the community that pure water is a finite resource and the long-term performance of their water system depends on conservation. Finally, community-wide education should include proper sanitation and hygiene. Try to focus on watershed protection like eliminating livestock presence in source water or building proper latrines. Also, focus on the need to use pure water for cooking and hand washing. Simply by educating a community on proper sanitation and hygiene, huge gains can be made in community health (even without any infrastructure!). Therefore, it is essential that any humanitarian water engineer places great emphasis on community-wide education.

Besides community-wide education, a more focused education needs to be provided to the operators and water committee. In-depth maintenance and operation education should take place. When possible, create a manual in their language to aid in operation and maintenance. See Appendix B for an example manual created for one Guatemalan community. Treat this education as a training course, since these men and women will be the future operators. If possible, provide necessary tools and parts to properly maintain the system. Depending on the system, there may be some essential part that needs to be replenished or replaced (i.e. UV bulbs, filters, chlorine). Otherwise, when applicable, try to give instructions on how the essential part can be acquired locally. By choosing a system that has replacement parts available locally, sustainability and self-sufficiency are promoted. By preparing the operators and governing authority adequately, the system has greater potential to succeed, even after the aid organization leaves.

By educating the entire village, total community health is prioritized. Similarly, when the entire community is educated on the system and what to expect, a check and balance is formed between the operators, the water committee and the public. This education, both community-wide and to the operators, is essential for a properly governed water system. By educating and adequately preparing the community, the aid organization has taken the right steps to achieve lasting success for the water project.

Once the system has been completed, it is important to operate the system with the community for the first time. This is another integral step in community development. By operating the system with the community, the humanitarian developer has a chance to see firsthand if the system works properly. The system should be run for a day or two by the humanitarian to see if problems arise. Also, by operating the system with the community, they are able to see the system correctly operated by the humanitarian engineer for the first time. This aids in the operational education of the system. Lastly, prioritize celebrating the joint success of the functioning water system. Much like the benefits of spending quality time with the community, celebration promotes a lasting relationship and community ownership and excitement of the system. All of these incurred benefits give the system a much greater chance for lasting success.

After operating the system with the community, if possible, the humanitarian developer should remain in the country for a few days. Typically, technical problems arise within the first few days. Similarly, operational questions and concerns also arise within the first few days of operation. By remaining close by, the humanitarian is able to fix technical problems or answer essential system questions more easily. After those few days, the system must be left in the care of the community. The system is now completely theirs and the fate of the system is their responsibility. But the efforts of aid cannot stop there.

3.3 The Follow-Up Stage

- **Open communication pathways**
- **Follow-up visits**
- **Follow-up surveys**
- **Continue encouraging the community**

Figure 3.6 The follow-up stage

The actions of the aid worker after the implementation of the water system greatly affect the rate of success for the water project. Learning from unsuccessful water aid case studies where it was common to sever ties with the community after the projects were completed, the aid workers should strive to maintain contact with the community to continue to assess the functionality of the system and the ongoing needs of the community. Looking back to this thesis' defined goal of providing sustainable water systems, the idea of sustainability cannot be achieved without continuous support.

The first step in maintaining contact with the community is to provide communication pathways (Figure 3.6). Recognizing that a rural developing community does not always have access to email or long distance calls, it is essential that the aid agency provides methods to enable communication. Using the previously developed social network is a great option to create a communication hierarchy. When the social network is operating properly a community can contact their local community-wide contact/liaison, this intra-community contact can communicate with the broader spectrum contact, this inter-community contact typically has the means (email, long distance phone access) to contact the aid agency. Likewise, the reverse method can be utilized to pass on information from the agency to the village. See Figure 3.2 for the social/communication hierarchy. Another benefit of this hierarchy is that issues can be resolved in a hierarchical manner. While an agency or philanthropist may need to be contacted for queries on the system, many times the local contacts can answer the questions. This self-reliance combats the paradigm of dependence on international humanitarians, while still maintaining the option to seek help abroad. Maintaining open communication pathways is essential in the development of a truly sustainable water system.

Another necessity of community development in the follow-up stage is to conduct follow-up analyses. These analyses are useful for quantifying the amount of success for the system, which can be used to better serve the given community or future communities. These follow-up analyses will also provide valuable data towards the verification or contradiction of this thesis.

These follow-up surveys should be done routinely throughout the length of the relationship between the community and the aid organization. With the goal of sustainability in mind, these follow-up surveys should ideally be carried out indefinitely. While that time scale is not possible, the aid organization should still strive to accurately portray the success of the system over a great length of time in order to adequately assess the system's true sustainability.

These follow-up surveys should include a water system satisfaction survey for the entire community, remembering the need to seek out all sects of the community to gain the holistic perspective (included in the Community Enablement Plan in Appendix A).

This satisfaction survey directly asks the community if they are happy with the system. Perhaps some demographics are happier than others. This portion of the survey should also question what percentage of the community is being served by the system. This quantification is used to determine if the assessment of need was successful. Finally, this portion of the survey should ask if the community is satisfied with the governance of the system. If dissatisfaction in any way is harbored, the system may not reach its full potential. Given the openness that has been established and encouraged throughout the project, the community should feel at ease to be honest with the aid organization. One should work to mitigate issues that breed discontent.

The second piece of the follow-up survey is a water quality test before and after treatment immediately after installation, then several months later. These tests ensure that the water system is continuing performing and the community is still receiving water of adequate quality. This water quality test can be completed through the use of local analytical chemistry labs (available in almost any country). See Appendix C for some of these water quality reports.

Third, the philanthropist should ask the community if they require additional supplies or training. Often, a community may run out of a necessary supply or have persistent questions about the system. Conducting follow-up analysis allows the aid agency to directly address the community's specific needs.

Finally, a community health survey needs to be done to complete the follow-up survey. This can be achieved by surveying the community to see if health has generally increased, decreased or remained constant. It may be useful to bring along doctors to help with this assessment.

Ideally, all these follow-up surveys should occur at least once a year. If a personal assessment is not possible, trained local contacts can also be utilized to perform the surveys. Either way, follow-up surveys help perpetuate the success and satisfaction of any water system. These follow-up surveys are necessary when considering the importance of all the measured factors. If a community is not holistically satisfied or served and if the community is not holistically receiving cleaner water and greater health, then the system can never be truly successful.

In this study, in order to assess whether the four given community’s systems are successful they must be compared to other values. Since the purpose of this thesis is to improve water aid, based on the lack of success of past efforts, it makes sense to compare these results with past water aid success rates. Since the UN’s first water decade had a 30% success rate after five years and a 12% success rate after ten years, those values will serve as a comparison to estimate, with limited data, whether this thesis’ design is more sustainable.

Besides the length of operation, benchmarks need to be created on the percent of the community served, the percent of the community that is satisfied, the percent that is satisfied with the water committee and the percent of perceived increase in community health. These benchmarks have been implemented as a tool for the measurement of success because of the recognition of their impact on the success and sustainability of a water system. A water treatment system can only be successful if the great majority of the community is served. Likewise, a system must be satisfactory to a large majority of the community to promote a strong sense of ownership and responsibility. Lastly, the community's recognition of increased health benefits is necessary for the perpetuation of a system. If the community recognizes the system's benefits, the system will be maintained steadfastly. The values of each benchmark success rate can be found in Table 3.1. While these benchmark values may seem arbitrary, they are based off past experiences and can be changed at the prerogative of the practicing humanitarian developer.

Table 3.1 Benchmarks for success among water treatment systems

	Benchmarks
# of systems operational after 5 years	30% [1]
# of systems operational after 10 years	12% [1]
% of community served	80% [2]
% of community satisfied	70% [2]
% satisfied with governance	70% [2]

1- UN and USAID success rates
2- Personal benchmarks based on experience

The final responsibility of the aid agency is to continually encourage the community in their pursuit of development and community health. This can only be done through direct support and a lasting relationship. As demonstrated by the countless failures at development, enabling a community to change their circumstances is very difficult. Therefore, constant encouragement and support is essential when trying to help a community.

3.4 Community Enablement Plan

A comprehensive "stand-alone" document for community water development guidance has been created using the principles discussed in *Chapter 2* and the previous sub-sections. The Community Enablement Plan, found in Appendix A, offers a holistic approach to international water development and creates a step-wise method to undertake any rural developing community water project. This Community Enablement Plan is the culmination of this thesis. Using this Community Enablement Plan, several water systems will be implemented so that the plan can be tested and assessed.

In this study, the Community Enablement Plan was utilized to install water treatment systems in four communities. The four communities are Cruz de Piedra, Guatemala, Los Encuentros, Guatemala, La Nueva Cajola, Guatemala and Harbel, Liberia. These four communities and their respective systems were monitored and analyzed with the hope of providing conclusive evidence supporting or refuting this study's developed standard operating procedure.

CHAPTER 4.0- ANALYSIS OF DATA

This thesis recognizes the shortcomings of current water aid and theorizes that the reason for the shortcomings may stem from a lack of organization among learned water aid principles. Therefore, this thesis attempts to summarize the developments of water aid into a single standard operating procedure. Then, after thorough application of the procedure, conclusions may be drawn on the plan's effectiveness at improving water aid sustainability.

Success for a water project has been defined in this thesis as a system that provides clean water to a satisfied community sustainably. Through education and nurtured ownership and empowerment, the community is ideally able to maintain and operate their system indefinitely. This success can be measured by each system's length of operation in the given community. Additionally, success will be measured through water quality delivered by the chosen treatment technology, as well as the number of community members served, the number of satisfied community members and the observed increase in community health. By attempting to quantify the success of each system, a bolder conclusion on the plan can be deduced. Therefore, the analysis of each system and each community is essential in the validation of this thesis.

To accomplish this, the next step in this thesis' methodology is to implement the developed water aid approach to analyze its performance while making observations on the effectiveness of the created plan. The community water development guidelines discussed in *Chapter 3* have now been implemented by the author in four communities in the rural, developing world. Some of these communities have operated their water treatment systems for almost ten years, while other communities have only operated their systems for approximately one year. This section will attempt to analyze the data collected for four specific communities which received water aid following this thesis' design.

4.1 Los Encuentros, Guatemala

Los Encuentros is a small community in the rainy, highlands of central Guatemala. It is located several hours northeast of Guatemala City near the town of Salama. Los Encuentros was selected for water aid with the help of several local contacts and the developed social network. With one of the local contacts, Dr. Jacobo Pineda, a site visit was conducted in Los Encuentros in the summer of 2006.

During the site visit all the necessary tasks suggested in the Community Enablement Plan and the technology selection process were attempted. In the watershed survey, it was observed that the only water source for the community was a large river running alongside the village. Besides the obvious uses of drinking and cooking, the river also served as the communal laundry, bathing and livestock watering site. Since there were no wells in the community, it was assumed groundwater was inaccessible. Lastly, several communal pit latrines were observed. According to the locals, the pit latrines were all dug 1.5 meters deep and the newer pit latrines were concrete lined. From this watershed survey, it was concluded that the river must be an integral part of any proposed water treatment system and the system should not inhibit the community's many other uses of the river.

From asking the locals, it was determined that the population of Los Encuentros was approximately 35 families or 200 people. There were a large portion of children in the community (typical of the rural developing world). These children attended the one school in town, which teaches through 9th grade. The school also doubles as a community center and clinic when doctors like Jacobo come to visit. Additionally, there were two churches in the community (one Protestant, one Catholic). From the observations drawn during the population and demographic analysis, the estimated daily water use was between 1000 and 2000 gallons, using the provided equation in the Community Enablement Plan. It was also concluded that taps would be beneficial at the school/community center/clinic, as well as at the nearby church.

Finally, after observing the local infrastructure and supply availability, it was realized that the community had no electricity or prior water system. Evidently any design would require solar power. Furthermore, a large local hardware store only 1 hour away in Salama was observed. After a tour of the hardware store with Dr. Jacobo, a solid grasp of supply availability was gained. After being reassured of the availability of supplies, confidence was instilled that most building supplies required for the water system could be purchased in Salama.

After dialogue with the community members of Los Encuentros, it was found that river contamination was destroying their quality of life through diarrhea and other gastrointestinal diseases (specifically in the children). The community said that the river flows all year, but does fluctuate. With local help, the seasonal low and high flows were noted. Lastly, from observations and discussions, their main goal was for centralized taps at the school and churches, where the entire community could gather water.

Before leaving, the humanitarian team reiterated what it had learned from the community. The team also took the opportunity to stress water resource protection, through limiting livestock activity in the river and lining their latrines. Communication lines remained open, through Jacobo, and a return date was set for the next year.

From what was learned about Los Encuentros, their priorities for a water treatment technology were able to be weighed. Given their lack of electricity and technological experience, they needed a system that was rudimentary and simple to operate and maintain. Furthermore, safety needed to be heavily prioritized, given the treatment system would be located at the school/community center. After weighing all the categories outlined in the technology selection process, a decision matrix was developed comparing UV, ozone and ultra-filtration (a drilled well was not applicable or pertinent for this community given a lack of groundwater and wells).

Table 4.1 Los Encuentros' weighted technologies

		ABS(Community Score-Tech. Score)		
	Los Encuentros	Ozone	UV	UF
Ease of Operation	8	1	0	1
Ease of Maintenance	9	1	1	0
Reliability	7	3	0	0
Ease of Travel	9	2	1	0
Ease of Installation	10	2	1	1
Upgradability	7	0	2	1
Safety	10	2	1	0
Difference		11	6	3
		3rd	2nd	1st
Capital Cost		$6,200	$3,500	$3,700
Yearly Maintenance		$50	$110	$100

Cost after 10 years		$6,700	$4,600	$4,700

The technology of ultra-filtration (UF) had the highest score, while UV came in second (see Table 4.1 and Appendix E for the technology scores' justifications). Also, the differences in cost (capital and maintenance) were not drastic enough to merit automatic disqualification. See Appendix F for cost analysis [27]. After bringing the options to the community and educating them on each technology's pros and cons, the community decided on using ultra-filtration for their water purification needs.

The water treatment technology of UF offers excellent treatment while maintaining a simple design. UF's intrinsic simplicity implies easy operation and maintenance for the community while remaining easy to install for humanitarian developers. While there are several means to the same end in ultra-filtration, the system this researcher has used with success is a three filter approach (see Figure 4.2). The first filter excludes particles larger than 5 microns and serves as preliminary treatment. The second filter is a silver-impregnated ceramic filter that disinfects pathogens and excludes particles greater than .25 microns [28]. Lastly, the water passes through a granular activated carbon filter to remove any trace organics. The water is able to pass through these using the pressure supplied from the pump in either the groundwater or surface water source. The design also needed to include consideration of the confines of the given community: solar power, using the river as a source, limited river disturbance, centralized taps at the school and church and 1000 to 2000 gallons per day.

Figure 4.1 Alluvial well in Los Encuentros (note the perforated tank sides)

The final implemented design consisted of an alluvial well near the river. The purpose of this alluvial well was to limit the obtrusion in the river (Figure 4.1). The untreated river water was then pumped up to the school, using solar power, through a series of three filters (see Figure 4.2). After treatment, the finished water was stored in a tank on the roof of the school and gravity fed to the two centralized taps (Figure 4.3).

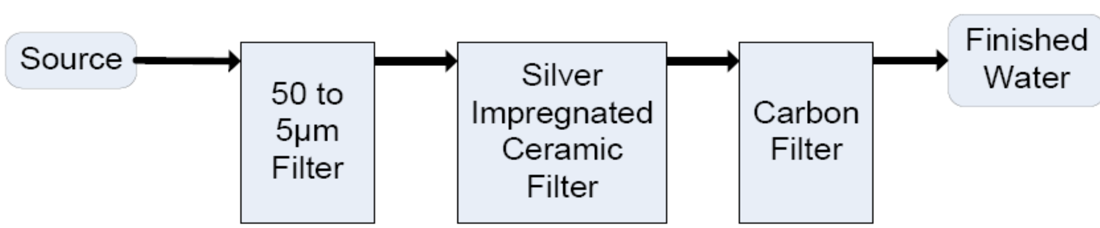

Figure 4.2 Schematic of 3-stage ultra-filtration process

Figure 4.3 Finished water cistern and gravity fed tap at the school in Los Encuentros

Initial testing of the water before and after treatment showed the technology's treatment prowess and demonstrated that the water treatment system supplied safe water for community use (Table 4.2). Since the ultra-filtration system in Los Encuentros was only installed in 2007, only one follow-up water quality report has been collected. However, another report would be very useful at this juncture.

Table 4.2 Water quality analysis for the implemented system in Los Encuentros

		Los Encuentros, CA	
		Pre-Treatment	Post-Treatment
Biological	Total Coliform (MPN/100ml)	4900	4.5
	Fecal Coliform (MPN/100ml)	4900	<1.8
	E. coli (MPN/100ml)	4900	<1.8
Chemical/Physical	Chlorine Residual (mg/L)	0	0
	Color (Pt-Co)	80	14
	Turbidity (NTU)	250	7
	Conductivity (µS/cm)	98	392
	pH	7.81	7.95
	Total Dissolved Solids (mg/L)	40	159
	Alkalinity @ pH=8.2 (mg/L	0	0

	$CaCO_3$)		
	Alkalinity @ pH=4.3 (mg/L $CaCO_3$)	45	200
	Calcium (mg/L)	20	40
	Total Hardness (mg/L)	68.8	206.4
	Total Iron (mg/L)	0.31	0.06
	Manganese (mg/L)	<.5	<.5
	Nitrate (mg/L)	<.5	<.5
	Nitrite (mg/L)	0.09	0.07

The last step in the installation process was to supply the water committee with a sufficient number of replacement filters and instructions on where to obtain future filters in Salama or Guatemala City.

The first follow-up survey was conducted in 2007 and one other survey was personally conducted in 2010 to determine whether the system was still meeting the community's needs (Table 4.3). Los Encuentros' water system is still operating after nearly three years of sustained use. However, in this community's case, the water system was polarizing to the community. The water system could only serve the school and one of the two churches via centralized taps (one of the churches was Protestant, the other was Catholic). The lack of service simply stemmed from the fact that the second church was too far away. The system would not be capable of providing sufficient pressure head to the second church. Due to the omission of service to the second church, satisfaction and usage of the system was relatively low in the 2007 initial follow-up survey, as well as governance satisfaction. Although the system was never intended to be polarizing along religious lines, the system began to appear that way. However, the trend of all these factors seems to be increasing from the 2010 follow-up survey. This probably implies that the community has better assimilated the portion of the community that was originally left out. Hopefully this increasing trend will persist and the community will continue to seek out the remainder that remains unaffected.

Table 4.3 Follow-up surveys of water system in Los Encuentros, Guatemala

	Los Encuentros, Guatemala	
	2007	2010
Years in Operation	<1	2.5
Currently Operating?	Yes	Yes
% of Community Served	73%	79%
% Satisfied with System	64%	72%
% Satisfaction with Governance	70%	70%
% Who Noticed Public Health Increase	Results Pending	66%

One bright aspect of the water system in Los Encuentros is the notable increase in community health since the inception of the system. Anecdotally, the author witnessed several children from los Encuentros who were examined by doctors from Guatemala City (of which, Dr. Jacobo was one). The doctors proclaimed that these children had a marked difference in health when compared to children of similar circumstance [29].

One observation during the personal follow-up survey of 2010 showed that the community was operating the filtration system backwards. Instead of using the finest exclusion filter last, the operators were using it first. While the system still performed, the operational error would have negatively impacted the project's lifespan if the mistake persisted. With proper correction and education, the operators better understood how to operate the system correctly. This small example shows how essential follow-up surveys are. If there were no follow-up, the system would have surely failed within the year. It is no wonder why so many systems fail without a complete relationship between the aid organization and the community.

4.2 La Nueva Cajola, Guatemala

La Nueva Cajola is a small community on the dry, coastal plains of Guatemala's west coast, about an hour from Retalhuleu. La Nueva Cajola was selected using the developed social network in Guatemala and a series of local contacts. A site visit of La Nueva Cajola was first conducted in November of 2008 with a local contact, Dr. Hugo Gomez, whom the researcher has known for several years. During this initial visit to La Nueva Cajola, a team was able to conduct the recommended site visit, as per the Community Enablement Plan, in order to properly allocate water aid for this community.

When conducting a watershed survey, it was observed that the main source of water for the community was a series of wells. While a river was approximately 800 meters away, the entire community used the wells. There were three communal wells, two of which were hand dug. Aside from the two hand-dug wells that were 35 and 20 meters deep, the community had one drilled and cased well that was 240 feet deep. This drilled well had been supplied by an international NGO, however, a pump was not included. Therefore, the cased and sealed well had been sitting dormant for several years. The general consensus of the community was that the two hand dug wells were severely contaminated and caused widespread illnesses. Additionally, the community conveyed that the hand dug wells were sufficiently deep to provide yearlong water supply. A quick survey of latrines showed that communal lined pit latrines were most prevalent, but there were also a set of very progressive composting and urine separation latrines.

From these observations, several deductions were made. First, the source water for any water treatment system must be groundwater. Second, the community is more progressive than most, given their lined pit latrines, composting toilets and a drilled well.

The population of La Nueva Cajola was estimated to be around 500 families, which translates to between 2500 and 3000 people. Additionally, the community had six schools, a clinic, a community center and a local jail. From this population, a daily water demand of 13,750 to 27,500 gallons was forecasted using the equation provided in this thesis' Community Enablement Plan.

While the large size of the community would pose difficulties in the storage and distribution of the water, a survey of existing structures offered hope. Already in place were two water towers, each capable of holding 15,000 gallons (these water towers were installed by the Red Cross and were discussed previously). Additionally, a distribution system was already set up to deliver water to every home. Furthermore, the two hand dug wells both had relatively new 7.5 hp pumps. Lastly, the community was already supplied with continuous 240V electricity.

Several conclusions were drawn from these observations. First, it would be beneficial to utilize all existing structures like the tanks, distribution system and pumps. Second, the available 240V electricity allowed for a larger sized pump in the drilled well. From conversations with the locals, it became evident that water quantity and quality were both issues. The two hand dug wells were contaminated and couldn't supply a sufficient quantity of water. The drilled well had sufficient quality, but could not yield enough quantity to be used alone. Therefore, it was deemed that using multiple wells would be necessary.

After the team conveyed their admiration for La Nueva Cajola's progression, a desire to find a technological solution that would satisfy both their water quality and quantity needs was reiterated. The team also communicated that it would need the community's help and participation throughout the project, which was especially critical given the large size of the community.

After leaving La Nueva Cajola, their technology priorities were weighed out and potential designs were considered (Table 4.4). It became apparent that the drilled well needed to be utilized, but given its lack of adequate quantity, it would need to be supplicated by one of the contaminated hand dug wells. From those initial constraints, it was realized that the best system would require a pump for the drilled well and an adequate disinfection technology for one of the contaminated hand dug wells.

Table 4.4 Weighted technologies for La Nueva Cajola

		ABS(Community Score-Tech. Score)		
	La Nueva Cajola	Ozone	UV	UF
Ease of Operation	8	1	0	1
Ease of Maintenance	9	1	1	0
Reliability	7	3	0	0
Ease of Travel	7	0	1	2
Ease of Installation	9	1	0	0
Upgradability	5	2	0	1
Safety	9	1	0	1
Difference		9	2	5
		3rd	1st	2nd
Cost		$5,000	$2,150	$2,350

Yearly Maintenance	$50	$110	$100
Cost after 10 years	$5,500	$3,250	$3,350

From the initial site visit, it was recognized that this community was comparatively more progressive and technically adept. Therefore, ease of operation and maintenance did not require such high prioritization. However, ease of installation became a huge priority since there were essentially two systems that needed to be installed. From a decision matrix comparing disinfection technologies to the community's priorities, two systems stood out. The recommended choices were UV or ultra-filtration (See Appendix E for the technology scores' justifications). After a cost analysis ensured both recommendations were tenable, the decisions were brought before the community's water committee and the choice of UV disinfection was made (See Appendix F for detailed cost analysis).

Ultraviolet disinfection is based on the premise that UV radiation kills most bacteria, parasites and viruses [30]. Through passing water by a UV source, disinfection can take place. In order to do this, the water treated must have very low turbidity. As such, the water may need to be pre-filtered using a passive 5 micron filter [31,32,33]. UV systems are an attractive proposition in the Third World due to their inherent simplicity, only requiring a UV light bulb (similar to a fluorescent tube) and ballast (See Figure 4.4). UV's simple and capable design allows for quick installation and easy operation and maintenance.

However, UV disinfection is not without caveats. UV bulbs last approximately one year and are very difficult to find in most of the developing world. As such, in order to not hinder sustained usage, a stock of bulbs would need to be provided until the bulbs become available locally. Additionally, the quartz sleeve housing the bulb requires cleaning once a month. Taking these concerns into consideration, the UV system is still a very tenable technological option for developing world water treatment.

Figure 4.4 A UV disinfection system in Nueva Cajola, Guatemala

The final design first required the installation of a 5 hp pump into the drilled well. This pump, when run for 12 hours, supplied approximately 14,400 gallons per day. Additionally, a UV system was installed on the higher yield hand dug well. The system was run off the community's existing pump and consisted of a preliminary 5 micron filter and the UV system (see Figure 4.5 and 4.6). Each system was designed to flow to one of the two water towers. The gravity-fed effluent leaving the two water towers then combined in the distribution system.

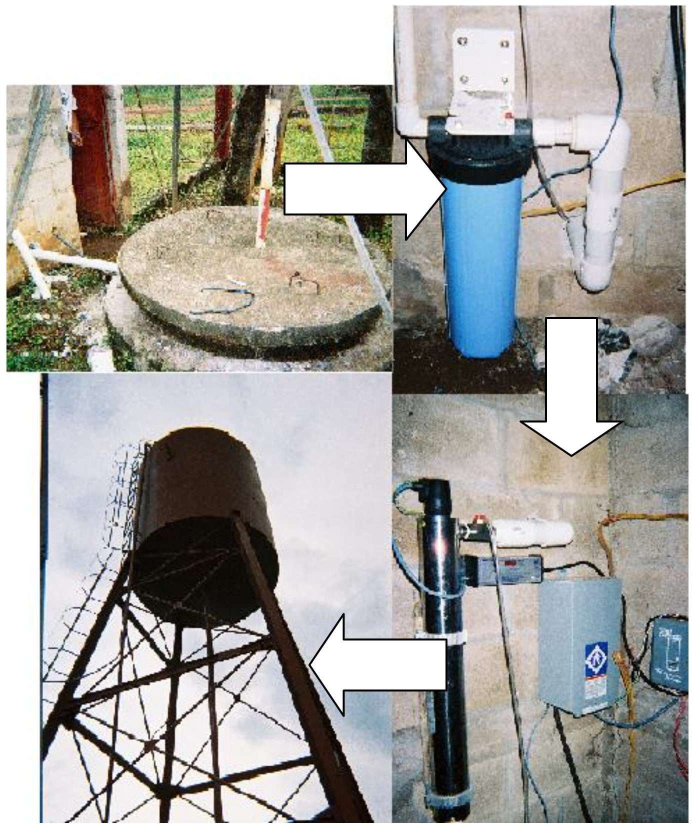

Figure 4.5 The water treatment process for La Nueva Cajola

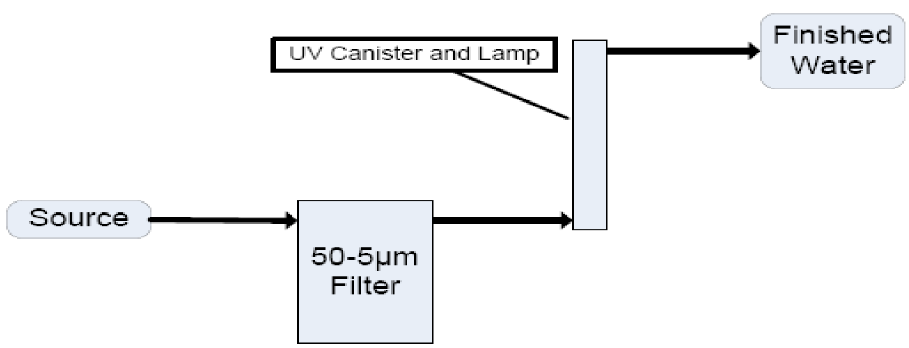

Figure 4.6 A schematic of La Nueva Cajola's UV disinfection system

To confirm adequate treatment from the UV system, samples were tested prior to treatment and after treatment (Table 4.5). Since the UV disinfection system in La Nueva Cajola was only installed in 2009, only one water quality report has been generated so far. However, from these results, it was verified that pure, pathogen-free water was being supplied from both the drilled well and the UV system, thereby satisfying La Nueva Cajola's water quality and quantity needs.

Table 4.5 Water quality analysis for the implemented system in La Nueva Cajola

		La Nueva Cajola, CA	
		Pre-Treatment	Post-Treatment
Biological	Total Coliform (MPN/100ml)	920	<1.8
	Fecal Coliform (MPN/100ml)	920	<1.8
	E. coli (MPN/100ml)	14	<1.8
Chemical/Physical	Chlorine Residual (mg/L)	0	0
	Color (Pt-Co)	<2	<2
	Turbidity (NTU)	0	0
	Conductivity (µS/cm)	483	507
	pH	7.14	7.4
	Total Dissolved Solids (mg/L)	195	204
	Alkalinity @ pH=8.2 (mg/L $CaCO_3$)	0	0
	Alkalinity @ pH=4.3 (mg/L $CaCO_3$)	250	210
	Calcium (mg/L)	78	80
	Total Hardness (mg/L)	206.4	223.6
	Total Iron (mg/L)	<.05	<.05
	Manganese (mg/L)	<.5	<.5
	Nitrate (mg/L)	1.8	4.3
	Nitrite (mg/L)	<.07	<.07

The final step in the installation process was to supply La Nueva Cajola with a three year supply of UV bulbs and maintenance instructions. Through our local contact, Dr. Hugo Gomez, future bulbs may be supplied if they cannot be found locally.

Table 4.6 Follow-up surveys of water system in La Nueva Cajola, Guatemala

	La Nueva Cajola, Guatemala	
	2009	2010
Years in Operation	<1	1
Currently Operating?	Yes	No
% of Community Served	92%	0%
% Satisfied with System	90%	0%
% Satisfaction of Governance	74%	0%
% Who Noticed Public Health Increase	Results Pending	0%

.

An initial follow-up survey was conducted a few months after implementation by Dr. Gomez (Table 4.6). In La Nueva Cajola, the UV disinfection system was operated for one year before its demise. While initial service and satisfaction numbers were promising, certain members of the community were unsatisfied with the water committee. The committee was headed by a woman, who was locally elected to serve in the leadership capacity. Two men in the community were especially upset that a woman was allowed to lead the water committee. In a drunken rage, they chose to sabotage the system. This case shows how integral every facet of community satisfaction is. While the community appreciated the system, a lack of trust in the water committee ultimately led to the system's permanent failure.

4.3 Harbel, Liberia

This project concerned an orphanage near Harbel, Liberia (Figure 4.6) which is approximately one hour from Liberia's capital city of Monrovia. The orphanage was selected from a string of local contacts, starting with the orphanage's director to a good friend of many years, Tony Weedor. While the site visit was completed in January 2010, implementation was completed in March 2011. Therefore, since the system is relatively new, limited data will be available.

Figure 4.6 Myself and a fellow humanitarian engineer at the orphanage in Liberia

During the site visit in January with a local contact, Tony, the necessary analyses and surveys to properly prescribe relevant water aid for the orphanage were completed. In the watershed survey, it was found that the orphanage only used wells for water supply and there was one hand pumped, drilled well on campus and one shallow hand dug well. The well was installed by the international NGO Living Water International®. This drilled well was only 30 feet deep, but supplied water of adequate quality. Another well on the campus was hand dug and only 10 feet deep. From observations, it seemed that Liberia as a whole only used wells as water sources. From these observations, another drilled well seemed like a viable option.

The orphanage's population was approximately 125 children and 10 staff. However, the campus is flourishing with the scheduled completion of a new hospital, school, cafeteria and two dorms within the next two years. The director estimates that the population of the orphanage will double every year. For the current circumstances, a daily water use of 1500 gallons was estimated. However, given the high projected growth, it was determined that the system would need to be readily upgradeable.

The existing structures were limited. The only water system currently in place was the hand pumped well. Additionally, taps had already been installed in all the nearly-completed buildings. There was no electricity available. Evidently, the system would need to be almost entirely new and operated on solar power.

A survey of the availability of local supplies was also grim. While hardware stores were readily accessible, the quality of their goods was laughably poor. It became clear that most tools and supplies would need to be brought from the United States. There were two pieces of good news however. First, an accessible drilling rig was found through an international NGO, Water of Life®. Second, the local contact Tony was certain that he could find quality PVC pipe, which would be required for any chosen system.

Before leaving, a realistic timeline for the system was decided upon with the help of Tony and the orphanage director. Additionally, financial and labor obligations were discussed with the director. It was conveyed that they would be expected to provide the labor and financing for the distribution system and the cistern.

After visiting Liberia and seeing the orphanage, their technological priorities were considered. They would require a system that is very simplistic to operate and maintain, given their inexperience with technology. Secondly, they would require a technology that is easily upgradeable given their projected population growth. Furthermore, the technology would need to be safe since it would be operated in an orphanage. Lastly, it would be beneficial to mirror similar local technologies to harvest familiarity and allow for similar technological experiences. After all things were considered, a drilled well seemed like the only technological option.

Drilled wells are a great option, but can be complicated by drilling. All drilled wells require a drill rig and an experienced driller (see Figure 4.7). However, even if a drill rig or experienced driller is not available, all hope is not lost. Several international NGOs (i.e. Living Water International, Water of Life, Samaritan's Purse) offer local assistance drilling wells. If a drill rig and a driller are not available, either privately or from an NGO, a drilled well may not be possible.

Figure 4.7 Drilling a well in Guatemala

Following approval from the orphanage's director, the planning began and a cased well was drilled by Water of Life® in March of 2010. A water tower is also scheduled to be built by locals in the summer of 2010, which will help mitigate the fluctuating demand for water throughout the day.

After the completion of the well, a water quality analysis was conducted (Table 4.7). Since the drilled well in Harbel utilizes groundwater, a pre-treatment sample of water was neither available nor pertinent. Also, since the well in Harbel was drilled in the early spring of 2010, only one water quality sample has been collected. However, from the data, it is seen that the newly tapped groundwater is safe to drink based on the physical and biological standards. This implies that the aquifer is sufficiently pure and the well is adequately deep, provided that proper water resource protection continues to take place.

Table 4.7 Water quality analysis for the implemented system in Harbel, Liberia

		Harbel, Liberia Post-Drilling
Biological	Total Coliform (MPN/100ml)	<1.8
	Fecal Coliform (MPN/100ml)	<1.8
	E. coli (MPN/100ml)	<1.8
Chemical/Physical	Chlorine Residual (mg/L)	0
	Color (Pt-Co)	<2
	Turbidity (NTU)	0
	Conductivity (µS/cm)	177
	pH	10.42
	Total Dissolved Solids (mg/L)	72
	Alkalinity @ pH=8.2 (mg/L $CaCO_3$)	70
	Alkalinity @ pH=4.3 (mg/L $CaCO_3$)	70
	Calcium (mg/L)	28

	Total Hardness (mg/L)	86
	Total Iron (mg/L)	<.05
	Manganese (mg/L)	<.5
	Nitrate (mg/L)	2.1
	Nitrite (mg/L)	<.07

Lastly, a follow-up survey was conducted a few weeks after installation (Table 4.8). Since the follow-up was conducted very early and the system was young, the system has not yet been given ample chance to withstand the test of time. However, the system in Harbel is already successful at targeting the community and its needs since the entire community uses the system, as well as neighboring villagers. This successful targeting is also exemplified by the 94% satisfaction rating. Finally, while community health and its perception are vital to any water system's success and longevity, it is impossible to draw conclusions on the impact of community health in this short of a time scale.

Table 4.8 Follow-up survey of water system in Harbel, Liberia

	Harbel, Liberia
	2010
Years in Operation	<1
Currently Operating?	Yes
% of Community Served	>100%
% Satisfied with System	94%
% Satisfaction with Governance	100%
% Who Noticed Public Health Increase	Results Pending

4.4 Cruz de Piedra, Guatemala

Cruz de Piedra is a small urban community in the rainy, mountainous highlands of central Guatemala, about an hour west from Guatemala City. Once again teaming up with the Guatemalan friend and contact, Dr. Jacobo, this community was selected. A site visit to Cruz de Piedra was first conducted in November of 2000.

When Cruz de Piedra was first visited, the community had only one hand dug well for the community. According to local knowledge the groundwater was approximately 20 feet deep. While the single well provided adequate quantity for the small community, the water quality was of concern. Contributing to the groundwater contamination was the widespread use of unlined pit latrines, which allow human waste to seep into the groundwater. From the watershed survey it was concluded that the current well would be sufficient for supply, but would require disinfection.

The population of Cruz de Piedra was small, comprised of only 120 people. There was a single church in the community, but no school, clinic or community center. Children would walk to a neighboring community for school. The daily water usage, using the equation provided in the Community Enablement Plan, was estimated to be 1000 gallons.

A survey of Cruz de Piedra’s existing infrastructure found that 110V electricity was available. Additionally, a water distribution system was already in place to provide each house with a personal tap. Furthermore, a 2 hp pump in good condition was salvageable from the existing well. By utilizing the existing infrastructure and well, a system could be planned that minimized waste and was properly tailored to Cruz de Piedra's circumstances.

During a community meeting to assess need, it was reiterated that Cruz de Piedra's water needs were strictly of quality. Community members, specifically children, had been getting sick for several years. The community members conveyed an idea to use ozone disinfection, which they had seen in a neighboring community. Ozone was attractive to them because it provided disinfection without the taste of chlorine. Before leaving, ozone systems were discussed in length. Additionally, water resource protection education was taught, stressing the importance of lining pit latrines.

While weighing the priorities of a technology for Cruz de Piedra, several conclusions were made. First, the community would be sufficiently technically advanced to operate and maintain an ozone system, given their comparatively urbane experiences. Second, the community's opinion of technology was of highest importance. If proper education and training was provided, Cruz de Piedra could operate an ozone system. Finally, it was decided that ozone would be Cruz de Piedra's best option, remembering the importance of community ownership and desire.

Ozone disinfection is based on the chemistry of using the strong oxidant ozone to kill most pathogens and cysts [34]. The attractive quality of ozone is that it is completely uninhibited by resources. While filters need to be replaced in filtration systems, bulbs need to be replaced in UV systems and chlorine needs to be continually added for chlorine disinfection, ozone is a stand-alone treatment alternative without any necessary additives. An ozone generator works by taking atmospheric oxygen (O_2) and electrolytically catalyzes the O_2 to ozone (O_3). From there, the ozone is diffused or mixed into the raw water where nearly instantaneous disinfection takes place. Ozone's independence from other variables is one of the reasons why this technology has demonstrably proven long-term sustainability [35].

However, ozone systems are inherently complex and may be intimidating to certain communities (see Figure 4.8). Additionally, much like chlorine, ozone is a very dangerous gas that requires caution (although ozone dissipates very quickly and operates in a closed system). Given the right circumstances in a community where these issues would be minimized, an ozone system offers excellent treatment while promoting longevity and freedom from dependent resources.

Figure 4.8 An ozone system near Quetzaltenango, Guatemala

The planned ozone system in Cruz de Piedra was designed to take raw water from the existing well, using the existing pump, to a preliminary tank. From the preliminary tank, the raw water would be pumped to the ozone unit located inside the church (to maximize protection and limit human contact). The generated ozone would be distributed into the raw water via Venturi suction. Then, the ozone infused water would enter a baffled mixing tank for a four hour retention time. After proper mixing and retention, the treated effluent was pumped through a final carbon filter (to remove trace organics and disinfection by-products) into the distribution system. After emptying the finished water tank, a switch reset to treat a new tank full of raw water (Figure 4.9).

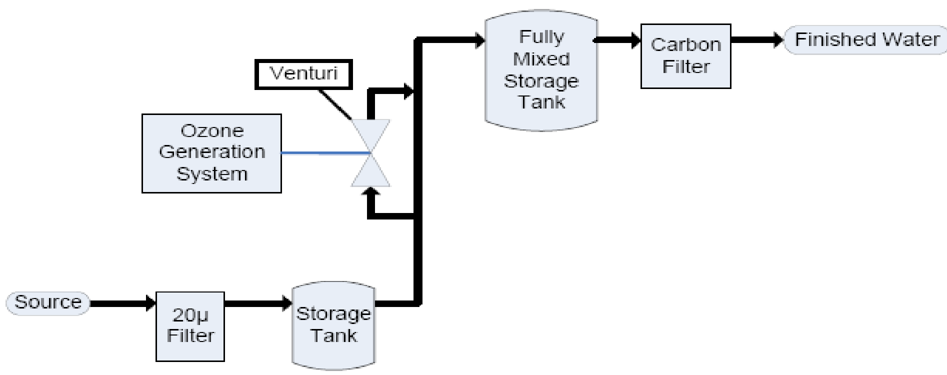

Figure 4.9 A schematic of Cruz de Piedra's ozone system

The system was installed in the spring of 2001. After completion, water samples were taken in 2001 and 2009 to confirm adequate water quality (Table 4.9). From the data it can be seen that the water provided by the system has been safe for both tests, using the predetermined guidelines, concluding that this ozone system has performed successfully since its inception.

Table 4.9 Water quality analysis for the implemented system in Cruz de Piedra

		Cruz de Piedra, CA		
		Pre-Treatment 2001	Post-Treatment 2001	Post-Treatment 2009
Biological	Total Coliform (MPN/100ml)	920	<1.8	<1.8
	Fecal Coliform (MPN/100ml)	540	<1.8	<1.8
	E. coli (MPN/100ml)	220	<1.8	<1.8
Chemical/Physical	Chlorine Residual (mg/L)	0	0	0
	Color (Pt-Co)	<2	<2	<2
	Turbidity (NTU)	3	<1	1
	Conductivity (µS/cm)	287	272	284
	pH	6.65	7.44	8.25
	Total Dissolved Solids (mg/L)	116	116	114
	Alkalinity @ pH=8.2 (mg/L $CaCO_3$)	0	0	45
	Alkalinity @ pH=4.3 (mg/L $CaCO_3$)	100	90	90
	Calcium (mg/L)	50	50	50
	Total Hardness (mg/L)	137.6	137.6	137.6
	Total Iron (mg/L)	<.05	<.05	<.05
	Manganese (mg/L)	<.5	<.5	<.5
	Nitrate (mg/L)	4.8	4.9	5.2
	Nitrite (mg/L)	<.07	<.07	<.07

Several follow-up surveys were conducted, in 2001, 2005, 2007 and 2009 (Table 4.10). Due to the longer time scale, this community may offer the best insight into the sustainability of water projects implemented using the Community Enablement Plan, and the verification of the hypothesis. From these surveys, several conclusions were drawn. First, the ozone disinfection system has been operated successfully for nine years (as of 2010). Second, the percent of the community served, satisfied and content with the governance of the system all have remained relatively consistent throughout the system's nine year life. During the second follow-up survey, in 2005, the system required its first major repair. A circulation pump broke, causing a slight decrease in satisfaction of the system and trust in the water committee, but through the community's enablement and education they were able to fix the system quickly and restore confidence and satisfaction.

Table 4.10 Follow-up surveys of water system in Cruz de Piedra, Guatemala

	Cruz de Piedra, Guatemala			
	2001	2005	2007	2009
Years in Operation	<1	4.5	6.5	8
Currently Operating?	Yes	Yes	Yes	Yes
% of Community Served	95%	92%	91%	92%
% Satisfied with System	95%	84%	91%	91%
% Satisfaction with Governance	91%	81%	91%	89%
% Who Noticed Public Health Increase	Results Pending	66%	74%	89%

Additionally, the citizens of Cruz de Piedra have perceived an increase in community health in every follow-up survey. This positive trend shows that as the community starts to grow new children have been raised on pure water. While a child born in Cruz de Piedra in 1995 received pure water at the age of six, a child born in 2002 has received pure water throughout the gestation period and his entire life. This causes an overall increase in the public health of the community. This promising trend should be reciprocated in other water systems given ample time.

CHAPTER 5.0- SUMMARY AND CONCLUSIONS

This study recognizes the need for a standard operating procedure in water aid. Without a summary of the philosophies of community development and water aid, practicing proper water aid practices is a daunting task. This could be the reason that international water development has not seen marked increases in success and sustainability. Therefore, this study sought to create a plan that reviewed what has been learned about proper international water development and translated it into a singular stepwise process. The result of that summary is the Community Enablement Plan.

After the plan was created, this study sought to test the viability of the standard operating procedure by implementing it in four communities. By using these four communities, this study attempted to represent multiple parts of the developing world and multiple water treatment technologies. These four communities have been monitored throughout their operational lives for water quality data, community usage and community satisfaction. All these results were then compared to past success rates of water aid in order to determine if creating a standard operating procedure is beneficial to water aid.

5.1 Findings

- 50% of this study's water systems have lasted over five years, with the potential for another two (Harbel and Los Encuentros)

- The ozone system in Cruz de Piedra has lasted over nine years
- The large majority of people in each of the four communities have used the provided systems with great satisfaction
- Increases in public health have been observed in cases with sufficient history
- The Community Enablement Plan leads to greater success in water aid

While the analyses of these four communities are ongoing, initial data suggests that the Community Enablement Plan does promote greater success and sustainability than aid implementation without a summary of theories.

While the sample size is very small and the time scale considered has been limited, promising trends have been noticed. Currently, 50% of the systems have lasted over five years with the potential for two other systems (which would make a 75% success rate). The success rate after five years among UN designed projects in the first water decade achieved only a 30% success rate. Although the UN's sample size and time scale were much larger, current data suggests that the Community Enablement Plan promotes greater sustainability than the methods used by the UN.

While none of the systems have existed for ten years, the ozone disinfection system in Cruz de Piedra has lasted over nine years and looks to easily last many more years. The UN experienced a 12% success rate after ten years on water systems built in the first water decade. Although none of the considered systems have been given the chance the last ten years, already the first system implemented using the Community Enablement Plan looks promising.

Other trends also appear successful and begin to validate the plan. For the self-imposed benchmark of an 80% rate of usage of the water system by the community, two of the three remaining systems achieve greater than 80% community-wide usage. The only community not meeting the standard is Los Encuentros, which is currently operating at 79% usage (nearly the benchmark). Also, before the demise of the water treatment system in La Nueva Cajola, they achieved a usage rate of 92%.

For the self-imposed, predetermined benchmark of 70% for community satisfaction of the water treatment system, initial results were also successful. While in operation, all four of the communities achieved greater than 70% community satisfaction. Although it took several years to cultivate sufficient community satisfaction in Los Encuentros, they currently operate at a 72% approval rating. Additionally, while the system in La Nueva Cajola is no longer in existence, before its destruction, the system was achieving 90% satisfaction.

Along the same line, the benchmark for community satisfaction with the governance of the water system (at 70%) has also been met in all cases. While in operation, all four of the communities achieved this benchmark. Although the system in La Nueva Cajola is not longer operational, initial governance satisfaction results were good.

Finally, for the benchmark success rate of 60% of the community that recognizes an increase in public and community health, there are also promising signs of success among the four considered communities. Of the two systems that have been operated long enough to notice health benefits, both communities have sufficiently recognized an increase in community health. Cruz de Piedra is an especially successful case with the trend of community health continuing to increase over the nine year lifespan. Similarly, the greater health effects have been noticed by medical doctors in both Los Encuentros and Cruz de Piedra. While the drilled well in the orphanage in Harbel, Liberia has not operated long enough to notice drastic health benefits, a high success rate in the area of public health is expected, given the large demographic of susceptible and easily affected children.

Clearly, the four systems that were installed following the Community Enablement Plan were successful at being widely used, predominately satisfactory and effective at increasing public health. Similarly, although the sample size is small and the data is limited by time, initial early results point to greater sustainability than water aid practices without a summarized plan. While the quantity of samples and data is not large enough to make a bold statement about the success of the Community Enablement Plan, the initial results hint at success.

Therefore, while the standard operating procedure cannot be statistically accepted as better than past methodologies, it can also not be rejected. Through longer datasets on existing systems and a greater sample size, more conclusive significance can be gained. Until then, the Community Enablement Plan can be considered a viable alternative in water aid.

5.2 Limitations of the Study

- This study needs more communities in more parts of the rural, developing world

- This study needs more time to monitor the systems in each of the four communities
- The Community Enablement Plan is not all-encompassing

Clearly there are many limitations in this study that affect the outcome. There were limitations of data, limitations of the design, limitations of assumptions, limitations of time and limitations of the researcher. All of these limitations impacted the conclusions of the study in various ways.

In an ideal study, many more communities would have been considered. However, due to time and resources, only four water treatment systems were able to be installed in the given time. In any case, drawing conclusions on the Community Enablement Plan using a sample size of four is not ideal. This study was also limited by data in the spatial scale. Ideally, communities and water projects from all over the developing world would be included. However, only communities in Latin American and West African regions were able to be included. Additionally, community satisfaction surveys were not all-encompassing. While the surveys would be ideally given to everyone in the community to determine total satisfaction, time and resources limited the number of surveys. Oftentimes, only a portion of the community would be surveyed (Appendix D). Finally, the data was limited in its time scale. With the goal of sustainability, the time scale should approach infinity. Clearly, that is impossible. However, it would have been beneficial to have systems that had operational lives of greater than ten years to serve as a comparison to the UN's systems. However, in the scope of a typical Master's thesis, any portion of the study that includes nine years is fortunate. Clearly, all these limitations on data minimize the study's conclusions on the viability of a standard operating procedure for water aid principles.

There were also limitations in the design of this study. While the Community Enablement Plan sought to summarize all philosophies of proper water development in the developing world, inevitably the Community Enablement Plan could not have possibly been all-inclusive. A great deal of care was taken in the literature review and research of international water development. But accounting for every new theory in community water development would have been impossible. Likewise, although the Community Enablement Plan sought to create a stepwise program for water development, inevitably extra steps may be required and improvisation will be necessary. Given the limitations of the Community Enablement Plan, the hope of the researcher is that the plan serves merely as a thought-provoking guide, promoting independent and alternate thinking among philanthropists.

Additional limitations occurred in this study in the form of assumptions. While the goal of this thesis was to create a plan summarizing water aid philosophy and apply it throughout the developing world, the spatial scale was limited. Three of the communities considered were in Guatemala and one was in Liberia. Therefore, this thesis assumes that the results of this study (and plan) would be translated to any other developing country. It is up to the reader to determine if the Community Enablement Plan would have the same success in India, Ethiopia, Honduras, etc. However, it is the researcher's belief that the principles of the Community Enablement Plan outline universal truths in human nature and ensuing development.

This study was also limited by time. As stated previously, several of the communities have not been given ample time to determine long-term success and sustainability. If this study was conducted for ten more years, then a weighty conclusion could be made about the validity of the plan's effectiveness. However, the difficulties associated with a 19 year study are not within the scope of a Master's thesis. Nevertheless, in an ideal study without limitations of time, a much clearer conclusion could be made.

Finally, this study was impacted by limitations of the researcher. Although the researcher attempted to gather information from various experts, only a small portion of the total available resources on international water development were utilized. Also, while personal follow-up visits are best, time and finances prevented the researcher from personally conducted every follow-up survey. Instead, the researcher often placed the responsibility and trust in his local contacts. Lastly, although the researcher always strived to understand the given community's culture and assimilate its considerations into the Community Enablement Plan, it is impossible to fully know the culture of another people group. Therefore, the researcher relied on locals to interpret local customs and behaviors. All these limitations of the researcher may have skewed the Community Enablement Plan, thereby affecting the results of the study.

With all these limitations in mind, it is necessary to attentively discern their effects on this study's conclusions. Due to the fact that all these limitations hindered the study in some way, the results of the study can only be taken at face value. The designed Community Enablement Plan was a successful alternative for these four considered communities. Further conclusions, such as the translation of the plan across borders or through time, can only be made on assumptions and trend analysis.

5.3 Lessons Learned

- The system in Los Encuentros was greatly impeded due to a lack of identifying all stakeholders
- The system in La Nueva Cajola failed due to a lack of attention on developing proper water resource governance

Several lessons have been learned by the researcher throughout this study that can be applied to future projects. As stated earlier, the failures of the past can help refine the methods of the future. By observing these failures and learning from them, failures may be avoided in the future.

In the case La Nueva Cajola, the system failed. While most pragmatic observers would argue that the failure of La Nueva Cajola was simply due to a few “bad apples”, there were still failures on the part of the humanitarian engineer. The Community Enablement Plan stresses the importance of establishing local governance of the water system, in the form of a water committee. Furthermore, the Community Enablement Plan stresses the need for community-wide representation of the various demographics and stakeholders in the water committee. The system in La Nueva Cajola failed because of a lack of attention to the governance.

While the community voted the woman into the position of leadership in the water committee, there were still some very dissatisfied community members. Although it is not the aid organization’s place to interfere with the formation of the water committee, greater steps in education of proper governance could have been taken. Perhaps a completely republic water committee (one without any defined leader) could have been suggested. Regardless, if the community's true feeling were better understood and better documented, this failure could have been avoided.

In the case of Los Encuentros, the system is not a failure. However, great mistakes were made by the researcher. The system in Los Encuentros was widely polarizing because of the inadvertent exclusion of a portion of the community. While the system was physically unable to distribute water to the farther church, steps could have been taken to prepare the community and mitigate the response among all the stakeholders.

The Community Enablement Plan stresses the process of identifying potential "winners" and "losers" of any system. In Los Encuentros' case, the "losers" were the members of the farther church. If due diligence was given to identifying that a second church of another denomination would be excluded, thereby unintentionally excluding community members because of denomination, the system could have prioritized a more central tap that draws no distinction based on denomination.

However, from Los Encuentros' satisfaction and usage data, it appears that the community is attempting to become more inclusive. This inclusion will promote a greater chance for success and sustainability. In this case, the system has succeeded in spite of the misguided efforts of the researcher.

While many other lessons have been learned throughout the researcher's seven years of water development work, they are too numerous to be written here. Instead, the emerging philanthropist should learn from their own experiences and mistakes, which will continue to refine them.

5.4 Final Reflections

- There is a need to summarize and quantify all the principles of water aid and community development
- Current water aid principles are on the right track
- The theories need to be implemented and applied more often
- This study needs to be continued to draw more weighty conclusions on the Community Enablement Plan

There are various connections and conclusions to this study. These conclusions have varying scopes of relevance, from as broad as the theory of water aid to as narrow as the focus of this specific ongoing study. However, the conclusions are unified as a call to action to relentlessly pursue global access to pure water.

This study recognized that there is a wealth of information in the realms of community development and water aid. However, the great gains in the knowledge of water development have not translated to increased success and sustainability in the developing world. This lack of effect could be due, in part, to the fact that the large amount of information on development philosophies has not been summarized effectively in a cumulative or organized manner. Therefore, in the spirit of the scientific method, a standard operating procedure was developed in this thesis, using the large quantities of literature available on water development theory. To draw conclusions on the effects of a standard operating procedure and its relation to sustainable water aid, the plan needed to be applied and monitored in several locations.

The results of this analysis can be found in this section’s Findings sub-section. These results statistically demonstrated that the developed Community Enablement Plan is a viable option for water aid application. The success and satisfaction rates were never low enough to merit concern on the validity of the plan’s principles. However, the study did not have sufficient data to explicitly prove the plan to be a better alternative than prior water aid attempts that did not have a qualitative plan.

Therefore, this study concludes that the Community Enablement Plan is a useful tool for administering water aid to the rural, developing world. This standard operating procedure can be utilized for future water aid projects with confidence. Based on the technical and sociological data from this study, the Community Enablement Plan offers sound water development principles that promote relevance, satisfaction and sustainability. While it cannot be said that this plan is better than past methods, it can be argued that the plan is at least as successful.

Secondly, this study concludes that current water aid paradigms are on the right track. These philosophies held paramount the need for simpler, local technologies, as well as active community development through education and participation. The Community Enablement Plan merely sought to summarize these past findings on the philosophies of water development, so any success of the plan must be credited to the tireless work and research of past scientists. As Isaac Newton once said, “If I have seen farther it is by standing on the shoulders of giants." Clearly the science and principles of water aid is making water development more successful and sustainable.

Additionally, this study connects the need to continue this research. While data has demonstrated that the Community Enablement Plan is a viable method for implementing water aid, the study did not answer the question of whether the reason for a lack of successful water aid is due to a lack of unified and organized theories. If this study is correct in assuming that part of the blame for water aid's lack of success is due to the fact that development philosophies are not in a concise and organized form, then a standard operating procedure should demonstrate greater success. This demonstration would only be possible through continued monitoring of existing communities where the Community Enablement Plan has been followed and through implementation of the plan in more communities in more parts of the rural, developing world.

Lastly, this study implores every person to take a proactive stance in alleviating the global water crisis. There is greater culpability (and responsibility) for the enlightened person. This pursuit for global access to safe water should be accomplished through innovation and a continuous quest for greater efficiency and success. Let us never be content with the *status quo*. Let us never stop questioning our methods. Let us never stop striving for the betterment of ourselves, others and the world we inhabit.

CHAPTER 6.0- REFERENCES

[1] WHO AND UNICEF Joint Monitoring Programme for Water Supply and Sanitation. Progress on Drinking Water and Sanitation: Special Focus on Sanitation. UNICEF, New York and WHO, Geneva, 2008.

[2] World Health Organization. Safer Water, Better Health: Costs, benefits, and sustainability of interventions to protect and promote health. 2008.

[3] United Nations Development Program: Beyond Scarcity: Power, Poverty and the Global Water Crisis, Human Development Report. 2006.

[4] World Business Council for Sustainable Development. Collaborative actions for sustainable water management. August 2005.

[5] UNAIDS, WHO. 2007 AIDS epidemic update. 2007.

[6] The NATO/CCMS (Committee on the Challenges of Modern Society) Pilot. Environment and Security in the International Context. January 1996.

[7] United Nations. Millennial Development Goals. Retrieved on March 3, 2009 from www.unmillenniumproject.org

[8] Niemann, Jeff. Personal interview. Spring 2008.

[9] Vanderzwaag, Jason. Use and Performance of Bio-Sand filters in Posoltega, Nicaragua. 2008.

[10] Jackson, Jeffrey. The Globalizers: Development Workers in Action. The Johns Hopkins University Press, Baltimore, MD. 2007.

[11] Gomez, Hugo. Series of personal interviews. 2001-2010.

[12] Moyo, D. Dead Aid. Farrar, Strauss and Giroux, New York. 2009.

[13] The Global Development Research Center. International Decade for Clean Drinking Water, 1981-1990. Accessed from www.gdrc.org/uem/water/decade_05-15/first-decade.html on April 20, 2010.

[14] Black, Maggie. 1978-1998 Learning What Works: A 20 Year Retrospective View on International Water and Sanitation Cooperation. September 1998.

[15] Honduras. Retrieved on March 5, 2010 from www.nationsencyclopedia.com

[16] Harshfield, E. et al. Water Purification in Rural South Africa: Ethical Analysis and Reflections on Collaborate Community Engagement Projects in Engineering. International Journal for Service Learning in Engineering. Vol. 4, no. 1, Spring 2009.

[17] United Nations Development Program. The New Delhi Statement. September 1990.

[18] Lifewater International. The Water Crisis. Accessed on December 12, 2009 from www.lifewater.org

[19] Global Water Partnership. IWRM Planning. Accessed on April 21, 2010 from www.gwp.org

[20] Slim, Hugo and Thomson, Paul. Listening for a Change. New Society Publishers, Philadelphia, PA. 1995.

[21] Sachs, Wolfgang et al. The Development Dictionary. Zed Books Ltd, London, UK. 1993.

[22] Ramaswami, Anu et al. Integrating Developed and Developing World Knowledge into Global Discussions and Strategies for Sustainability. Environmental Science & Technology.

[23] Abell, John. Fuel Efficient Stoves and Community Development in Guatemala. Information Age Publishing, Inc, Charlotte, NC. 2008.

[24] Munoz, D.R. et al. In Search of Sustainable Community Development through Practice. Colorado School of Mines. 2008

[25] Mumme, Stephen. Personal Interview. February 2010.

[26] Weedor, Tony. Series of personal interviews. January 2010.

[27] Douglas, Kirk. Series of personal interviews. 2001-2010.

[28] Doulton USA. Ceramic Candle & Cartridge Technologies. 2006. Accessed in November 2009 from http://doultonusa.com/HTML%20pages/technology.htm

[29] Pineda, Jacobo. Series of personal interviews. 2001-2010.

[30] Novotny, V. Water Quality. Second Edition. Hoboken, NJ: John Wiley & Sons, 2003.

[31] Sterilight. Sterilight Cobalt BASIC line Datasheet. Guelph, ON: VIQUA, February 2007.

[32] Sterilight. Sterilight Platinum Owner's Manual. Guelph, ON: VIQUA, 2007.

[33] WaterFilters.net, LLC. Accessed on November 2009 from http://www.waterfilters.net/culligan/wholehouse/replacement_filters/Wholehouse-20-Inch-Big-Blue.htm

[34] Asano, T., Burton, F., et al. Water Reuse. Metcalf & Eddy. New York: McGraw-Hill, 2007.

[35] ClearWater Tech, LLC. Wall-Mounted Corona Discharge Ozone Systems. San Luis Obispo, CA: ClearWater Tech, LLC, August 2008.

Appendix A

Community Enablement Plan

Planning Stage

1. Develop country-wide social network

- Find Inter-Community Local Contacts
    - These contacts should be knowledgeable, educated, reputable local contacts with a passion for community health. Ideally, an inter-community contact is familiar with the needs of many communities. Also, an inter-community contact should have means for international communication (email or long distance phone service).

Contact's Name:_____________________________

Email:_______________________________

Phone (if applicable):_______________________________

- Find Intra-Community Local Contacts

- With the aid of the inter-community contact, find intra-community contacts for all of the considered communities. Ideally, these contacts should also be educated and reputable with a devotion to their community's welfare.

Contact's Name:______________________ Community:________________________

Contact's Name:______________________ Community:________________________

Contact's Name:______________________ Community:________________________

Contact's Name:______________________ Community:________________________

Contact's Name:______________________ Community:________________________

- Convey to all local contacts the intentions and desires to aid in development through community health and water purification

2. Choose a community

- List of prospective communities (with the help of local contacts)

Community:_____________________________

Community:_____________________________

Community:_____________________________

- Visit prospective communities with inter- and intra-community contacts
    - Talk with each community about their existing water solutions, as well as their needs and expectations
    - Observe each community for potential future water solutions
    - Make note of local governance (Is the community organized? Unbiased? Willing?)
- Decide on a community based on need, ability to help, feasibility of success and community structure.
    - Take into account the input and opinions of local contacts

3. <u>Learn about the community</u>

- After selecting the community, use personal site visits and local contacts to learn everything possible about the community
    - Find out the community's culture, beliefs, language, philosophies, habits etc.
    - History of the community
    - Past experience with aid?
        - Did the aid succeed? What are the opinions on outside aid?
    - How open-minded is the community towards development and advancement? How do they handle risks?
    - Identify all potential stakeholders in the project
        - politically, socially, economically, religiously, etc.
    - Identify "winners" and "losers" of the system. Are there potential exclusions?
    - Identify "hidden voices"

4. <u>Gain the trust of the community</u>

- Speak the community's language when possible
- Utilize local contacts
- Talk with the community about their needs, desires and issues
- Spend time in the community
- Demonstrate eagerness to learn about their community
- Be open about the project
    - Describe the anticipated benefits and costs of the project
    - Identify any contingencies
    - Identify potential winners and losers
    - Allow for feedback and opposition
    - Ask for their ideas and potential solutions

5. <u>Assessing their need</u>

- Survey all sects of the community on their water needs and desires
    - Be mindful that some sects may not be vocal in certain settings (i.e. it may not be culturally acceptable for women to speak up in community wide gatherings, so meeting with a "women only" group might be necessary)
    - Be mindful of the "hidden voices" or community members that don't have a public voice (may be children or women depending on the culture), but still have a vested interest in the water project
        - Identify the vested interest of each sect in the community

6. Assessment of technology plan

- Using all the information gathered from the community, complete the Assessment of Technology Plan

Intra-Community Local Contact Information

Intra-Community Contact's Name:_____________________________

Email:_______________________________

Phone (if applicable):_______________________________

- If possible, plan a time with your contact to come perform a site visit.
- If a site visit is not possible, use your local contact to answer as many of the following questions as possible.

Conduct a Site Visit

Conduct Watershed Survey:

- What water sources are available and how close are they to the community (Rivers, Lakes, Groundwater, etc.)? Identify their seasonal fluctuations.

- If groundwater is available, how deep is the water table?

- If wells are common, survey community wells for depth, quantity and quality of water.

- Survey latrines for depth, lining and location.

- Survey livestock and agricultural uses around water bodies.

Population and Demographics Analysis:

- What is the population of the community that will be utilizing the water system?

- What portion of the population are children?

- How many schools, churches and community centers are there?

- Estimated Daily Water Use:

$$Population * 5\ to\ 10\, \frac{gallons}{person * day} = Daily\ Water\ Use$$

Survey of Existing Infrastructure:

- What electricity is available in the community and how far is the source (480V, 240V, 120V, none- 50Hz or 60Hz)?

- If applicable, what existing water treatment system is available? Are any of the parts useable for a future system (distribution system, well, pump, storage tank)?

Obtain a Community Layout:

- Map all dwellings, roads, water bodies, wells, latrines, churches, schools and community centers.

Local Equipment & Supply Availability Analysis:

- If applicable, is a drill rig available? If so, what are its specifics and cost?

- Tour local hardware stores to get a good sense of what materials may be purchased and prices. Things to consider are electrical wire, PVC and fittings, storage tanks, concrete blocks, rebar, etc.
- Explore local sources of equipment such as hand tools, concrete mixers, and motorized equipment.

Community Needs:

- Communicate with the community to hear their needs. Here are some examples of questions to convey:
    - Are the issues predominately quantity, quality or both?
    - Do they lack adequate water quantity during certain seasons?
    - Is the water making them sick? (Diarrhea is often considered normal, so explore the question from multiple angles)
    - What sort of systems do they hear about and see in other communities that are working?
    - What sort of distribution system do they envision (centralized taps, taps in the home, etc.)?
    - What are their hopes for their system?

Leave on a Good Note:

- Reiterate to the community what you have learned about them
- Convey how impressive their community's accomplishments are

- Reiterate your understanding of their needs
- Inform them of the upcoming technological decision and promise bilateral participation
- Stress that any solution will require community participation and investment
- If possible, give a timetable of the system's development
- Educate them on ill-advised practices you have noticed (latrines may need to be lined, animals may need to be kept away from water bodies, etc.)
- Promise to keep communication pathways open through your local contact

Weigh Priorities of Technology

From what you have learned from your local contact and site visit, you have established the confines for your water treatment options. Working within these community-specific confines, a best technological option must be chosen. This decision is made by prioritizing the goals of your community and their circumstances.

Using your knowledge of the community, and that of your local contact, prioritize these technological goals by weighting them from all values between 1 and 10.

<u>Score</u>

- <u>Ease of Operation</u> ________

(Score 1 if the community is technically advanced and educated, score 10 if the community fails to understand even rudimentary technology)

- <u>Ease of Maintenance</u> ________

(Score 1 if the community is highly trained to maintain technology, score 10 if the community is unable to maintain even rudimentary technology)

- Reliability ________

(Score 1 if the community is easily able to replace parts, score 10 if it is impossible to secure parts required for repairs)

- Ease of Travel ________

(Score 1 if the community is across the street, score 10 if the community requires several plane, boat and rickshaw rides to gain access)

- Ease of Installation ________

  (Score 1 if you will have unlimited time and accessible equipment to install the system, score 10 if you will only have a few days and very little available equipment to install the system)

- Upgradability ________

  (Score 1 if your community will not grow, score 10 if you predict exponential and severe population growth)

- Safety ________

  -consider open wells, power sources, ozone or chlorine gas, elevated cisterns

(Score 1 if safety has no priority in the community, score 10 if safety is of highest priority in the community).

Score Available Technologies

Score each viable technology, from 1 to 10, in each of the decided categories based on its inherent qualities. For instance, is a drilled well easier to maintain that an ozone disinfection system? Or is a chlorine system more dangerous than a UV system?

	Technology 1	Technology 2	Technology 3	Technology 4
Ease of Operation				
Ease of Maintenance				
Reliability				
Ease of Travel				
Ease of Installation				
Upgradability				
Safety				

Note: It is important to be able to justify each score for each technology

Evaluate Technologies

Using decision software, such as Criterium Decision Plus®, evaluate your community's scores and compare them with the scores of available technologies. Decision software will offer weighted scores based on higher priority categories and choose the best fit for your evaluated community.

Then perform a cost analysis on the three top-scoring technologies. Calculate the cost-benefit ratio from the equation:

$$cost\!:\!benefit\ ratio = \frac{technology\ score}{cost}$$

	Score	Projected Cost	Cost-Benefit Ratio
Highest Scoring Technology			
2nd Highest Scoring Technology			
3rd Highest Scoring Technology			

Notify the Community

Inform your local contact of your technology recommendation and inform him of your methodology for selecting the given technologies. Give him the top technology options based on your analysis, with their respective pros and cons, to take to the community. Have the local contact educate the community on the top technologies, including their mechanism, cost, required construction and other pros and cons. Then, have the local contact lead a discussion about the best available technology, while offering your guidance towards the best option. Finally, allow the community to choose which technological option they would most like.

7. <u>Define community contributions to the project</u>

With the help and input of the community, mutually decide upon the community's contributions

- Financial Obligations:
- Pre-Installment Labor Obligations:
- Installment Labor Obligations:

Implementation Stage

8. <u>Follow through with imposed community contributions</u>

- Make sure the community is held responsible for any financial, structural or labor obligations

9. <u>Encourage community participation</u>

- Let community members watch the installation process or let them participate

- Talk the observing community members through each step of the installation
    - Some community members will be very interested in what you are doing (some will observe closely and be more forward, while others will observe from a distance)
    - Explain what each part or process does and how it works
    - Answer any questions
    - Take every opportunity to educate the community members on their new system
- Include all community members in the installation process
    - Though it might not be culturally acceptable for women or children to work alongside the men, be creative in actively involving every sect of the community while operating within their cultural boundaries (perhaps the women could prepare a mid-day meal for all the laborers or children could help decorate for the festivities after project completion)

10. <u>Take time to spend with the community</u>

- While North Americans (and humanitarians) tend to value work first, it is important to recognize that many cultures prioritize relationships over work.
- Prioritize interacting with the community
    - Have lunch with your fellow workers and other community members
    - Play games with the children
    - Celebrate this experience with them (they are just honored that you would come spend time with them)
    - Enjoy fellowshipping together

11. Establish governance of the water system

- Establish a community water committee, selected by community members
  - Stress active participation and representation from all community sects
  - This committee will be in charge of the welfare of the water system
- Have the committee choose community members to operate and maintain the water system
  - Operators should be responsible, mechanically and technically minded individuals who are devoted to the success of the water system

Water Committee Members:

Operators/Caretakers:

12. Educate the community

- Include all of the community on a broad seminar of the operation and maintenance of the system, so all community members will know what to expect

- Give the chosen operators special tutorials on operation and maintenance
    - Ask them questions and give them scenarios to test their understanding
    - They will need to operate this system without help, so preparedness is paramount
- Write down any instructions on the operation or maintenance of the system in the local language (make sure the local operators or committee members are literate)
- Provide sufficient supplies for proper maintenance and operation, or provide instructions on how to obtain necessary supplies

Specifically educate the community on:

- Water resource education
    - Conserving water ensures adequate quantity
    - Water conservation ensures water system longevity
- Health Education
    - The importance of washing hands
    - The importance of using clean water for cooking
    - Health risks associated with consumption of unsafe drinking water
- Proper sanitation
    - Proper latrine design (lined pits, sufficiently far away from water bodies)
- Water resource protection
    - Don't allow livestock in water bodies
    - Don't wash clothes directly in water bodies
    - Don't defecate near water bodies

- Be mindful of upstream and downstream uses

13. <u>Operate the system with the community for the first time</u>

- Run the system for a long time during the first trial to ensure the system is functioning properly
- Celebrate the joint accomplishment of the new water system with the community
  - Celebration is often highly valued in other cultures
- Remain in the country and make yourself available for a few days after the completion of the system in case problems or questions arise
  - Typically, issues arise with the system in the first few days
  - The first few days are a critical time in the community learning to operate and accept their new technology

Follow-Up Stage

14. <u>Open communication lines to encourage feedback or offer technical support</u>

- Establish a communication hierarchy for the community
  - Direct the community first to intra-community local contacts (or other communities in the social network)
  - If the intra-community local contact cannot address the issue, direct him to your inter-community local contact (this local contact should have more formal education and more accessibility to educational resources
  - If the inter-community local contact cannot address the issues, direct him to contact you personally (He will have more access to phones or internet)

    - This hierarchy ensures that every issue has the opportunity to be addressed by local means first

15. <u>Conduct follow-up surveys</u>
    - Conduct water quality analysis
        - Take samples to certified analytical chemistry labs (available in most countries)
        - Take a pre- and post-treatment sample the first time. After that, take only a post-treatment sample
    - Conduct follow-up survey (attached on next page)
        - Survey all community members every follow-up visit, perhaps a local contact could conduct future surveys
            - This survey may need to be translated
        - Check on the system
            - Do they need more supplies?
            - Are they running the system properly?
            - Is the water committee doing a good job?
        - Check on their health and happiness
            - Has their new water system positively impacted their lives?
        - Use the collection of the surveys to complete the following table:
            - Also make note of comments

	Community
% Served	
% Satisfied	
% Satisfaction of Governance	
% Who Noticed Public Health Increase	
% Who Believe the System is Beneficial	

16. Encourage the community in their pursuit of development

Follow-Up Survey

(Allow every community member to complete this survey, then tally scores)

1. Are you currently served by the water system? Yes No
2. Are you currently satisfied with the water system? Yes No
3. Has the water committee managed the water system well? Yes No
4. Have you noticed an increase in public health since the installation of the water system? Yes No
5. Do you feel like this water system has helped the community? Yes No
6. Are there any negative effects caused by the water system?

7. What would you change about the water system?

8. Additional Comments?

Follow-Up Survey Summarization

(For humanitarian's use, to summarize findings of Follow-Up Surveys)

Completed by:_______________________________

Number of surveys collected:____________________

Number of surveys that are served by the system:_____________________

Number of surveys that are satisfied with the system:_____________________

Number of surveys that are satisfied with the water committee:_______________________

Number of surveys that recognize increased public health from the system:________________

Summarize any negative effects caused by the system:

Summarize any suggestions made by community members about the system:

Additional comments:

Appendix B

La Nueva Cajola UV System Maintenance Instructions

* Cambié la luz cuando el numero dice Ø days, tambien hay un ruido de alarma
* Limpié el filtero cada mès con agua y blanceador
* Cuando el filtero es sucio despues de limpiando, cambié el filtero
* Limpié el tubo cada tres méses con agua y una esponja. ¡TEN CUIDADO!
* Traiemos tres luzes y uno extra tubo

Appendix C

Water Quality Reports

-Continued on next page-

Contro-Lab

ANALISIS MICROBIOLÓGICOS Y FISICOQUÍMICOS

La Cajola Pre UV treatment

26/08/09
Código 7204/200809/02
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA No. 2
Fecha de toma de muestras: 20/08/2009
Fecha de ingreso: 20/08/2009
Fecha de análisis: 20/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: En la Empresa
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura(durante el muestreo): Cliente
Temperatura de ingreso: 4.0 ° C

Análisis

Muestras	Cloro	Recuento aeróbico total	Coliformes totales	Coliformes fecales	*E. coli*
Agua No. 2 Retalhuleu -Xela	0.0	1,500	920	920	14
Unidades:	mg/l	UFC/ml	NMP/100ml	NMP/100ml	NMP/100ml
Método:	M1	M2	M2	M2	M2
Lugar de análisis:	In situ				

M1: Método colorimétrico
M2: Standard methods for the examination of water and wastewater 21st Edition 2005.
Para Recuento aeróbico total: Método vertido en placa, 35°C/48h Plate Count Agar.
UFC/ml: unidades formadoras de colonia por mililitro
NMP/100ml: número más probable por cien mililitros
mg/l: miligramo por litro

OBSERVACIONES: El Agua No. 2. No cumple con los requisitos Microbiológicos de la NORMA COGUANOR AGUA POTABLE 29001:99 ya que presenta contaminación por el grupo coliforme.

LIMITES DE LA NORMA COGUANOR AGUA POTABLE 29001:99:

RECUENTO DE COLIFORMES: < 2.2 o < 1.1 NMP/100 ml (Negativo).

Nota: los resultados de este informe se refieren a la muestra tal y como fue recibida en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646
LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

13 calle 10-55 Zona 11 Colonia Mariscal 2do Nivel Tel: (502) 2473-0424 Telefax: (502) 2473-3276
nq@contro-lab.com • atencioncliente@contro-lab.com • www.contro-lab.com

26/08/09
Código 7204/200809/05
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

AGUA No. 2 RETALHULEU -XELA

Muestras analizadas:
Fecha de toma de muestras: 20/08/2009
Fecha de ingreso: 20/08/2009
Fecha de análisis: 22/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: En la Empresa
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura (durante el muestreo): Cliente
Temperatura de ingreso: 4.0 ° C

Parámetro	Dimensionales	Método	Límite de detección	Resultado	*Agua Potable LMA	LMP
Temperatura	°C	Digital	-50 – 300	**4.0**	15.0-25.0	34.0
Cloro residual	mg/L	Rainbow test OTO1	0.2 – 3.0	**0.0**	0.5	1.0
Apariencia	NR/R	Visual	-	**NR**	-	-
Olor	NR/R	Organoléptico	-	**NR**	NR	NR
Sabor	NR/R	Organoléptico	-	**NR**	NR	NR
Color	Unidades Pt-Co	Espectrofotométrico	2 – 1000	**< 2**	5.0	35.0
Turbiedad	UNT	Nefelométrico	0 – 400	**0.0**	5.0	15.0
Conductividad	µSiemens/cm	Electroquímico	0 – 1999	**483.0**	-	< 1500
pH	-	Electroquímico	0 – 14	**7.14**	7.0-7.5	6.5-8.5
Salinidad	-	Electroquímico	0.0 – 70.0	**0.0**	-	-
Sólidos Totales Disueltos	mg/L	Electroquímico	0 – 1999	**195.0**	500.0	1000.0
Alc. pH=8.2	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**0.0**	-	-
Alc. pH=4.3	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**250.0**	-	-
Calcio	mg/L	Merck Aquamerck	2 – 200	**78.0**	75.000	150.000
Dureza Total	mg/L	Hach	-	**206.4**	100.000	500.000
Hierro Total	mg/L	Merck Spectroquant	0.05 – 5.00	**< 0.05**	0.1	1.0
Manganeso	mg/L	Merck Spectroquant	0.50 – 10.00	**< 0.50**	0.05	0.5
Nitratos (cómo N)	mg/L	Merck Spectroquant	0.5 – 20.0	**1.8**	-	10
Nitritos	mg/L	Merck Spectroquant	0.07 – 3.28	**< 0.07**	-	1

mg/L: Miligramos por litro (partes por millón)
NR/R: No rechazable/rechazable
Pt-Co: Platino-cobalto
UNT: Unidades nefelométricas de turbidez
LMA: Límite máximo admisible
LMP: Límite máximo permisible
* NORMA COGUANOR NGO 29 001:98 AGUA POTABLE

Nota: los resultados de éste informe se refieren a las muestras tal y cómo fueron recibidas en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab.

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

Contro-Lab

ANALISIS MICROBIOLÓGICOS Y FISICOQUÍMICOS

La Cajola Post UV treatment

26/08/09
Código 7204/200809/01
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA No. 1
Fecha de toma de muestras: 20/08/2009
Fecha de ingreso: 20/08/2009
Fecha de análisis: 20/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: En la Empresa
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura(durante el muestreo): Cliente
Temperatura de ingreso: 4.0 ° C

Análisis

Muestras	Cloro	Recuento aeróbico total	Coliformes totales	Coliformes fecales	*E. coli*
Agua No. 1 Retalhuleu -Xela	0.0	39	< 1.8 (Negativo)	< 1.8 (Negativo)	< 1.8 (Negativo)
Unidades:	mg/l	UFC/ml	NMP/100ml	NMP/100ml	NMP/100ml
Método:	M1	M2	M2	M2	M2
Lugar de análisis:	In situ				

M1: Método colorimétrico
M2: Standard methods for the examination of water and wastewater 21st Edition 2005.
Para Recuento aeróbico total: Método vertido en placa, 35°C/48h Plate Count Agar.
UFC/ml: unidades formadoras de colonia por mililitro
NMP/100ml: número más probable por cien mililitros
mg/l: miligramo por litro

OBSERVACIONES: El Agua No. 1.Si cumple con los requisitos Microbiológicos de la NORMA COGUANOR AGUA POTABLE 29001:99 ya que no presenta contaminación por el grupo coliforme.

LIMITES DE LA NORMA COGUANOR AGUA POTABLE 29001:99:

RECUENTO DE COLIFORMES: < 2.2 o < 1.1 NMP/100 ml (Negativo).

Nota: el resultado de este informe se refiere a la muestra tal y como fue recibida en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

13 calle 10-55 Zona 11 Colonia Mariscal 2do Nivel Tel: (502) 2473-0424 Telefax: (502) 2473-3276
nq@contro-lab.com • atencioncliente@contro-lab.com • www.contro-lab.com

26/08/09
Código 7204/200809/04
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

AGUA No. 1 RETALHULEU -XELA

Muestras analizadas:
Fecha de toma de muestras: 20/08/2009
Fecha de ingreso: 20/08/2009
Fecha de análisis: 22/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: En la Empresa
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura (durante el muestreo): Cliente
Temperatura de ingreso: 4.0 ° C

Parámetro	Dimensionales	Método	Límite de detección	Resultado	*Agua Potable LMA	LMP
Temperatura	°C	Digital	-50 – 300	**4.0**	15.0-25.0	34.0
Cloro residual	mg/L	Rainbow test OTO1	0.2 – 3.0	**0.0**	0.5	1.0
Apariencia	NR/R	Visual	-	**NR**	-	-
Olor	NR/R	Organoléptico	-	**NR**	NR	NR
Sabor	NR/R	Organoléptico	-	**NR**	NR	NR
Color	Unidades Pt-Co	Espectrofotométrico	2 – 1000	**< 2**	5.0	35.0
Turbiedad	UNT	Nefelométrico	0 – 400	**0.0**	5.0	15.0
Conductividad	µSiemens/cm	Electroquímico	0 – 1999	**507.0**	-	< 1500
pH	-	Electroquímico	0 – 14	**7.4**	7.0-7.5	6.5-8.5
Salinidad	-	Electroquímico	0.0 – 70.0	**0.0**	-	-
Sólidos Totales Disueltos	mg/L	Electroquímico	0 – 1999	**204.0**	500.0	1000.0
Alc. pH=8.2	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**0.0**	-	-
Alc. pH=4.3	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**210.0**	-	-
Calcio	mg/L	Merck Aquamerck	2 – 200	**80.0**	75.000	150.000
Dureza Total	mg/L	Hach	-	**223.6**	100.000	500.000
Hierro Total	mg/L	Merck Spectroquant	0.05 – 5.00	**< 0.05**	0.1	1.0
Manganeso	mg/L	Merck Spectroquant	0.50 – 10.00	**< 0.50**	0.05	0.5
Nitratos (cómo N)	mg/L	Merck Spectroquant	0.5 – 20.0	**4.3**	-	10
Nitritos	mg/L	Merck Spectroquant	0.07 – 3.28	**< 0.07**	-	1

mg/L: Miligramos por litro (partes por millón)
NR/R: No rechazable/rechazable
Pt-Co: Platino-cobalto
UNT: Unidades nefelométricas de turbidez
LMA: Límite máximo admisible
LMP: Límite máximo permisible
* NORMA COGUANOR NGO 29 001:98 AGUA POTABLE

Nota: los resultados de éste informe se refieren a las muestras tal y cómo fueron recibidas en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab.

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

Contro-Lab

ANALISIS MICROBIOLÓGICOS Y FISICOQUÍMICOS

Cruz de Piedra Pre Ozone treatment

28/08/09
Código 7210/210809/04
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA DE POZO No. 7
Fecha de toma de muestras: 21/08/2009
Fecha de ingreso: 21/08/2009
Fecha de análisis: 21/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: Comunidad Cruz de Piedra
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura(durante el muestreo): Cliente
Temperatura de ingreso: 3.0 ° C

Análisis

Muestras	Cloro	Recuento aeróbico total	Coliformes totales	Coliformes fecales	*E. coli*
Agua de Pozo No. 7 Comunidad Cruz de Piedra	0.0	260	920	540	220
Unidades:	mg/l	UFC/ml	NMP/100ml	NMP/100ml	NMP/100ml
Método:	M1	M2	M2	M2	M2
Lugar de análisis:	In situ				

M1: Método colorimétrico
M2: Standard methods for the examination of water and wastewater 21st Edition 2005.
Para Recuento aeróbico total: Método vertido en placa, 35°C/48h Plate Count Agar.
UFC/ml: unidades formadoras de colonia por mililitro
NMP/100ml: número más probable por cien mililitros
mg/l: miligramo por litro

OBSERVACIONES: El Agua de Pozo No. 7. No cumple con los requisitos Microbiológicos de la NORMA COGUANOR AGUA POTABLE 29001:99 ya que presenta contaminación por el grupo coliforme.

LIMITES DE LA NORMA COGUANOR AGUA POTABLE 29001:99:

RECUENTO DE COLIFORMES: < 2.2 o < 1.1 NMP/100 ml (Negativo).

Nota: los resultados de este informe se refieren a la muestra tal y como fue recibida en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

13 calle 10-55 Zona 11 Colonia Mariscal 2do Nivel Tel: (502) 2473-0424 Telefax: (502) 2473-3276
nq@contro-lab.com • atencioncliente@contro-lab.com • www.contro-lab.com

28/08/09
Código 7210/210809/08
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA DE POZO No. 7
Fecha de toma de muestras: 21/08/2009
Fecha de ingreso: 21/08/2009
Fecha de análisis: 21/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: Comunidad Cruz de Piedra
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura(durante el muestreo): Cliente
Temperatura de ingreso: 3.0 ° C

Parámetro	Dimensionales	Método	Límite de detección	**Resultado**	*Agua Potable LMA	LMP
Temperatura	°C	Digital	-50 – 300	--	15.0-25.0	34.0
Cloro residual	mg/L	Rainbow test OTO1	0.2 – 3.0	**0.0**	0.5	1.0
Apariencia	NR/R	Visual	-	**NR**	-	-
Olor	NR/R	Organoléptico	-	**NR**	NR	NR
Sabor	NR/R	Organoléptico	-	**NR**	NR	NR
Color	Unidades Pt-Co	Espectrofotométrico	2 – 1000	**< 2**	5.0	35.0
Turbiedad	UNT	Nefelométrico	0 – 400	**3.0**	5.0	15.0
Conductividad	µSiemens/cm	Electroquímico	0 – 1999	**287.0**	-	< 1500
pH	-	Electroquímico	0 – 14	**6.95**	7.0-7.5	6.5-8.5
Salinidad	-	Electroquímico	0.0 – 70.0	**0.0**	-	-
Sólidos Totales Disueltos	mg/L	Electroquímico	0 – 1999	**116.0**	500.0	1000.0
Alc. pH=8.2	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**0.0**	-	-
Alc. pH=4.3	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**100.0**	-	-
Calcio	mg/L	Merck Aquamerck	2 – 200	**50.0**	75.000	150.000
Dureza Total	mg/L	Hach	-	**137.6**	100.000	500.000
Hierro Total	mg/L	Merck Spectroquant	0.05 – 5.00	**< 0.05**	0.1	1.0
Manganeso	mg/L	Merck Spectroquant	0.50 – 10.00	**< 0.50**	0.05	0.5
Nitratos (cómo N)	mg/L	Merck Spectroquant	0.5 – 20.0	**4.8**	-	10
Nitritos	mg/L	Merck Spectroquant	0.07 – 3.28	**< 0.07**	-	1

mg/L: Miligramos por litro (partes por millón)
NR/R: No rechazable/rechazable
Pt-Co: Platino-cobalto
UNT: Unidades nefelométricas de turbidez
LMA: Límite máximo admisible
LMP: Límite máximo permisible
* NORMA COGUANOR NGO 29 001:98 AGUA POTABLE

Nota: los resultados de éste informe se refieren a las muestras tal y cómo fueron recibidas en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab.

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

13 calle 10-55 Zona 11 Colonia Mariscal 2do Nivel Tel: (502) 2473-0424 Telefax: (502) 2473-3276
nq@contro-lab.com • atencioncliente@contro-lab.com • www.contro-lab.com

Contro-Lab

ANALISIS MICROBIOLÓGICOS Y FISICOQUÍMICOS

28/08/09
Código 7210/210809/03
Página 1/1

Cruz De Piedra Ozone treatment

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA DE POZO No. 6
Fecha de toma de muestras: 21/08/2009
Fecha de ingreso: 21/08/2009
Fecha de análisis: 21/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: Comunidad Cruz de Piedra
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura(durante el muestreo): Cliente
Temperatura de ingreso: 3.0 ° C

Análisis

Muestras	Cloro	Recuento aeróbico total	Coliformes totales	Coliformes fecales	*E. coli*
Agua de Pozo No. 6 Comunidad Cruz de Piedra	0.0	RE: > 57,000	< 1.8 (Negativo)	< 1.8 (Negativo)	< 1.8 (Negativo)
Unidades:	mg/l	UFC/ml	NMP/100ml	NMP/100ml	NMP/100ml
Método:	M1	M2	M2	M2	M2
Lugar de análisis:	In situ				

M1: Método colorimétrico
M2: Standard methods for the examination of water and wastewater 21st Edition 2005.
RE: Recuento estimado.
Para Recuento aeróbico total: Método vertido en placa, 35°C/48h Plate Count Agar.
UFC/ml: unidades formadoras de colonia por mililitro
NMP/100ml: número más probable por cien mililitros
mg/l: miligramo por litro

OBSERVACIONES: El Agua No.6. Si cumple con los requisitos Microbiológicos de la NORMA COGUANOR AGUA POTABLE 29001:99 ya que no presenta contaminación por el grupo coliforme.

LIMITES DE LA NORMA COGUANOR AGUA POTABLE 29001:99:

RECUENTO DE COLIFORMES: < 2.2 o < 1.1 NMP/100 ml (Negativo).

Nota: los resultados de este informe se refieren a la muestra tal y como fue recibida en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

13 calle 10-55 Zona 11 Colonia Mariscal 2do Nivel Tel: (502) 2473-0424 Telefax: (502) 2473-3276
ng@contro-lab.com • atencioncliente@contro-lab.com • www.contro-lab.com

Contro-Lab

ANALISIS MICROBIOLOGICOS Y FISICOQUÍMICOS

28/08/09
Código 7210/210809/07
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA DE POZO No. 6
Fecha de toma de muestras: 21/08/2009
Fecha de ingreso: 21/08/2009
Fecha de análisis: 24/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: Comunidad Cruz de Piedra
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura(durante el muestreo): Cliente
Temperatura de ingreso: 3.0 ° C

Parámetro	Dimensionales	Método	Límite de detección	Resultado	*Agua Potable LMA	LMP
Temperatura	°C	Digital	-50 – 300	--	15.0-25.0	34.0
Cloro residual	mg/L	Rainbow test OTO1	0.2 – 3.0	**0.0**	0.5	1.0
Apariencia	NR/R	Visual	-	**NR**	-	-
Olor	NR/R	Organoléptico	-	**NR**	NR	NR
Sabor	NR/R	Organoléptico	-	**NR**	NR	NR
Color	Unidades Pt-Co	Espectrofotométrico	2 – 1000	**< 2**	5.0	35.0
Turbiedad	UNT	Nefelométrico	0 – 400	**1.0**	5.0	15.0
Conductividad	µSiemens/cm	Electroquímico	0 – 1999	**284.0**	-	< 1500
pH	-	Electroquímico	0 – 14	**8.25**	7.0-7.5	6.5-8.5
Salinidad	-	Electroquímico	0.0 – 70.0	**0.0**	-	-
Sólidos Totales Disueltos	mg/L	Electroquímico	0 – 1999	**114.0**	500.0	1000.0
Alc. pH=8.2	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**45.0**	-	-
Alc. pH=4.3	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**90.0**	-	-
Calcio	mg/L	Merck Aquamerck	2 – 200	**50.0**	75.000	150.000
Dureza Total	mg/L	Hach	-	**137.6**	100.000	500.000
Hierro Total	mg/L	Merck Spectroquant	0.05 – 5.00	**< 0.05**	0.1	1.0
Manganeso	mg/L	Merck Spectroquant	0.50 – 10.00	**< 0.50**	0.05	0.5
Nitratos (cómo N)	mg/L	Merck Spectroquant	0.5 – 20.0	**5.2**	-	10
Nitritos	mg/L	Merck Spectroquant	0.07 – 3.28	**< 0.07**	-	1

mg/L: Miligramos por litro (partes por millón)
NR/R: No rechazable/rechazable
Pt-Co: Platino-cobalto
UNT: Unidades nefelométricas de turbidez
LMA: Límite máximo admisible
LMP: Límite máximo permisible
* NORMA COGUANOR NGO 29 001:98 AGUA POTABLE

Nota: los resultados de éste informe se refieren a las muestras tal y cómo fueron recibidas en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab.

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

13 calle 10-55 Zona 11 Colonia Mariscal 2do Nivel Tel: (502) 2473-0424 Telefax: (502) 2473-3276
nq@contro-lab.com * atencioncliente@contro-lab.com * www.contro-lab.com

Contro-Lab

ANALISIS MICROBIOLÓGICOS Y FISICOQUÍMICOS

Los Encuentros source

31/08/09
Código 7217/240809/01
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA No. 8
Fecha de toma de muestras: 24/08/2009
Fecha de ingreso: 24/08/2009
Fecha de análisis: 24/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: Rio Salama - Los Encuentros
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura(durante el muestreo): Cliente
Temperatura de ingreso: 3.0 ° C

Análisis

Muestras	Cloro	Recuento aeróbico total	Coliformes totales	Coliformes fecales	*E. coli*
Agua No. 8 Rio Salama -Los Encuentros	0.0	1,600	4,900	4,900	4,900
Unidades:	mg/l	UFC/ml	NMP/100ml	NMP/100ml	NMP/100ml
Método:	M1	M2	M2	M2	M2
Lugar de análisis:	In situ				

M1: Método colorimétrico
M2: Standard methods for the examination of water and wastewater 21st Edition 2005.
Para Recuento aeróbico total: Método vertido en placa, 35°C/48h Plate Count Agar.
UFC/ml: unidades formadoras de colonia por mililitro
NMP/100ml: número más probable por cien mililitros
mg/l: miligramo por litro

OBSERVACIONES: El Agua No. 8. No cumple con los requisitos Microbiológicos de la NORMA COGUANOR AGUA POTABLE 29001:99 ya que presenta contaminación por el grupo coliforme.

LIMITES DE LA NORMA COGUANOR AGUA POTABLE 29001:99:

RECUENTO DE COLIFORMES: < 2.2 o < 1.1 NMP/100 ml (Negativo).

Nota: El resultado de este informe se refiere a la muestra tal y como fue recibida en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

13 calle 10-55 Zona 11 Colonia Mariscal 2do Nivel Tel: (502) 2473-0424 Telefax: (502) 2473-3276
nq@contro-lab.com • atencioncliente@contro-lab.com • www.contro-lab.com

31/08/09
Código 7217/240809/03
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA No. 8
Fecha de toma de muestras: 24/08/2009
Fecha de ingreso: 24/08/2009
Fecha de análisis: 29/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: Rio Salama – Los Encuentros
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura (durante el muestreo): Cliente
Temperatura de ingreso: 3.0 ° C

Parámetro	Dimensionales	Método	Límite de detección	Resultado	*Agua Potable LMA	LMP
Temperatura	°C	Digital	-50 – 300	--	15.0-25.0	34.0
Cloro residual	mg/L	Rainbow test OTO1	0.2 – 3.0	**0.0**	0.5	1.0
Apariencia	NR/R	Visual	-	**R**	-	-
Olor	NR/R	Organoléptico	-	**NR**	NR	NR
Sabor	NR/R	Organoléptico	-	**R**	NR	NR
Color	Unidades Pt-Co	Espectrofotométrico	2 – 1000	**80**	5.0	35.0
Turbiedad	UNT	Nefelométrico	0 – 400	**250**	5.0	15.0
Conductividad	µSiemens/cm	Electroquímico	0 – 1999	**98**	-	< 1500
pH	-	Electroquímico	0 – 14	**7.81**	7.0-7.5	6.5-8.5
Salinidad	-	Electroquímico	0.0 – 70.0	**0.0**	-	-
Sólidos Totales Disueltos	mg/L	Electroquímico	0 – 1999	**40**	500.0	1000.0
Alc. pH=8.2	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**0**	-	-
Alc. pH=4.3	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**45**	-	-
Calcio	mg/L	Merck Aquamerck	2 – 200	**20**	75.000	150.000
Dureza Total	mg/L	Hach	-	**68.8**	100.000	500.000
Hierro Total	mg/L	Merck Spectroquant	0.05 – 5.00	**0.31**	0.1	1.0
Manganeso	mg/L	Merck Spectroquant	0.50 – 10.00	**< 0.50**	0.05	0.5
Nitratos (cómo N)	mg/L	Merck Spectroquant	0.5 – 20.0	**< 0.5**	-	10
Nitritos	mg/L	Merck Spectroquant	0.07 – 3.28	**0.09**	-	1

mg/L: Miligramos por litro (partes por millón)
NR/R: No rechazable/rechazable
Pt-Co: Platino-cobalto
UNT: Unidades nefelométricas de turbidez
LMA: Límite máximo admisible
LMP: Límite máximo permisible
* NORMA COGUANOR NGO 29 001:98 AGUA POTABLE

Nota: los resultados de éste informe se refieren a las muestras tal y cómo fueron recibidas en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab.

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

Contro-Lab

ANALISIS MICROBIOLÓGICOS Y FISICOQUIMICOS

31/08/09
Código 7217/240809/02
Página 1/1

Los Encuentros Post U.F. treatment

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA No. 9
Fecha de toma de muestras: 24/08/2009
Fecha de ingreso: 24/08/2009
Fecha de análisis: 24/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: Rio Salama - Los Encuentros
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura(durante el muestreo): Cliente
Temperatura de ingreso: 3.0 ° C

Análisis

Muestras	Cloro	Recuento aeróbico total	Coliformes totales	Coliformes fecales	*E. coli*
Agua No. 9 de Sistema de Filtración Mecánico Rio Salama – Los Encuentros	0.0	69	4.5	< 1.8 (Negativo)	< 1.8 (Negativo)
Unidades:	mg/l	UFC/ml	NMP/100ml	NMP/100ml	NMP/100ml
Método:	M1	M2	M2	M2	M2
Lugar de análisis:	In situ				

M1: Método colorimétrico
M2: Standard methods for the examination of water and wastewater 21st Edition 2005.
Para Recuento aeróbico total: Método vertido en placa, 35°C/48h Plate Count Agar.
UFC/ml: unidades formadoras de colonia por mililitro
NMP/100ml: número más probable por cien mililitros
mg/l: miligramo por litro

OBSERVACIONES: El Agua No. 9. No cumple con los requisitos Microbiológicos de la NORMA COGUANOR AGUA POTABLE 29001:99 ya que presenta contaminación por el grupo coliforme.

LIMITES DE LA NORMA COGUANOR AGUA POTABLE 29001:99:

RECUENTO DE COLIFORMES: < 2.2 o < 1.1 NMP/100 ml (Negativo).

Nota: El resultado de este informe se refiere a la muestra tal y como fue recibida en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1,646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

13 calle 10-55 Zona 11 Colonia Mariscal 2do Nivel Tel: (502) 2473-0424 Telefax: (502) 2473-3276
nq@contro-lab.com • atencioncliente@contro-lab.com • www.contro-lab.com

Contro-Lab

ANALISIS MICROBIOLÓGICOS Y FISICOQUÍMICOS

31/08/09
Código 7217/240809/04
Página 1/1

INFORME DE ANÁLISIS

Empresa: EMBAJADORES MEDICOS
Dirección: Ciudad
Remitido por: ING. CALIB DOUGLAS / DR. JACOBO PINEDA

Muestras analizadas: AGUA No. 9 SISTEMA DE FILTRACION MECANICO
Fecha de toma de muestras: 24/08/2009
Fecha de ingreso: 24/08/2009
Fecha de análisis: 29/08/2009
Lugar de análisis: Contro-Lab (Excepto donde se especifique)
Plan de muestreo: Sugerido por el cliente

Lugar de toma de muestras: Rio Salama – Los Encuentros
Muestras tomadas por: Cliente
Muestras recibidas por: Fabricio Arana
Temperatura (durante el muestreo): Cliente
Temperatura de ingreso: 3.0 ° C

					*Agua Potable	
Parámetro	Dimensionales	Método	Límite de detección	**Resultado**	LMA	LMP
Temperatura	°C	Digital	-50 – 300	--	15.0-25.0	34.0
Cloro residual	mg/L	Rainbow test OTO1	0.2 – 3.0	**0.0**	0.5	1.0
Apariencia	NR/R	Visual	-	**R**	-	-
Olor	NR/R	Organoléptico	-	**NR**	NR	NR
Sabor	NR/R	Organoléptico	-	**R**	NR	NR
Color	Unidades Pt-Co	Espectrofotométrico	2 – 1000	**14**	5.0	35.0
Turbiedad	UNT	Nefelométrico	0 – 400	**7**	5.0	15.0
Conductividad	µSiemens/cm	Electroquímico	0 – 1999	**392**	-	< 1500
pH	-	Electroquímico	0 – 14	**7.95**	7.0-7.5	6.5-8.5
Salinidad	-	Electroquímico	0.0 – 70.0	**0.0**	-	-
Sólidos Totales Disueltos	mg/L	Electroquímico	0 – 1999	**159**	500.0	1000.0
Alc. pH=8.2	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**0**	-	-
Alc. pH=4.3	mg/L $CaCO_3$	Merck Aquamerck	5 – 500	**200**	-	-
Calcio	mg/L	Merck Aquamerck	2 – 200	**40**	75.000	150.000
Dureza Total	mg/L	Hach	-	**206.4**	100.000	500.000
Hierro Total	mg/L	Merck Spectroquant	0.05 – 5.00	**0.06**	0.1	1.0
Manganeso	mg/L	Merck Spectroquant	0.50 – 10.00	**<0.50**	0.05	0.5
Nitratos (cómo N)	mg/L	Merck Spectroquant	0.5 – 20.0	**<0.5**	-	10
Nitritos	mg/L	Merck Spectroquant	0.07 – 3.28	**0.07**	-	1

mg/L: Miligramos por litro (partes por millón)
NR/R: No rechazable/rechazable
Pt-Co: Platino-cobalto
UNT: Unidades nefelométricas de turbidez
LMA: Límite máximo admisible
LMP: Límite máximo permisible
* NORMA COGUANOR NGO 29 001:98 AGUA POTABLE

Nota: los resultados de éste informe se refieren a las muestras tal y cómo fueron recibidas en el laboratorio. La reproducción parcial o total de la misma deberá ser aprobada por Contro-Lab. Muestra no captada por personal de Contro-Lab.

Licda. Nancy Quan
Químico Biólogo Colegiado No. 1646

LICDA. NANCY QUAN
Químico Biólogo
Colegiado No. 1,646

13 calle 10-55 Zona 11 Colonia Mariscal 2do Nivel Tel: (502) 2473-0424 Telefax: (502) 2473-3276
hq@contro-lab.com • atencioncliente@contro-lab.com • www.contro-lab.com

Appendix D

Follow-Up Survey Summaries

-continued on next page-

La Nueva Cajola

Follow-Up Survey Culmination

(For humanitarian's use, to summarize findings of Follow-Up Surveys)

Completed by: Hugo Gomez 2009

Number of surveys collected: 332

Number of surveys that are served by the system: 305

Number of surveys that are satisfied with the system: 299

Number of surveys that are satisfied with the water committee: 246

Number of surveys that recognize increased public health from the system: —

Summarize any negative effects caused by the system:

Summarize any suggestions made by community members about the system:

Additional comments:

Harbel

Follow-Up Survey Culmination

(For humanitarian's use, to summarize findings of Follow-Up Surveys)

Completed by: Caleb Douglas

Number of surveys collected: 30

Number of surveys that are served by the system: >30

Number of surveys that are satisfied with the system: 28

Number of surveys that are satisfied with the water committee: 30

Number of surveys that recognize increased public health from the system: N/A

Summarize any negative effects caused by the system:

Summarize any suggestions made by community members about the system:

Additional comments:

People outside the community come to the well. Everyone seems very satisfied.

Los Encuentros

Follow-Up Survey Culmination

(For humanitarian's use, to summarize findings of Follow-Up Surveys)

Completed by: Cal Douglas 2007

Number of surveys collected: 105

Number of surveys that are served by the system: 77

Number of surveys that are satisfied with the system: 67

Number of surveys that are satisfied with the water committee: 73

Number of surveys that recognize increased public health from the system: N/A

Summarize any negative effects caused by the system:

None observed

Summarize any suggestions made by community members about the system:

None made

Additional comments:

Los Encuentros

Follow-Up Survey Culmination

(For humanitarian's use, to summarize findings of Follow-Up Surveys)

Completed by: Caleb Douglas 2010

Number of surveys collected: 121

Number of surveys that are <u>served</u> by the system: 96

Number of surveys that are <u>satisfied</u> with the system: 87

Number of surveys that are <u>satisfied with the water committee</u>: 85

Number of surveys that <u>recognize increased public health</u> from the system: 80

Summarize any negative effects caused by the system:

Jacobo mentioned polarization of two churches across denominational line

Summarize any suggestions made by community members about the system:

Jacobo suggested better integration of entire community

Additional comments:

Community operators were running filter steps backwards. I corrected them and they seemed receptive. They were also running low on first-stage filters. I instructed them that they could buy them in Salama very cheap.

Cruz de Piedra

Follow-Up Survey Culmination

(For humanitarian's use, to summarize findings of Follow-Up Surveys)

Completed by: KIRK DOUGLAS 2001

Number of surveys collected: 40

Number of surveys that are served by the system: 38

Number of surveys that are satisfied with the system: 38

Number of surveys that are satisfied with the water committee: 36

Number of surveys that recognize increased public health from the system: —

Summarize any negative effects caused by the system:

NONE

Summarize any suggestions made by community members about the system:

NONE

Additional comments:

SYSTEM IS RUNNING GREAT!

Cruz de Piedra

Follow-Up Survey Culmination

(For humanitarian's use, to summarize findings of Follow-Up Surveys)

Completed by: Jacobo Pineda Ortiz 2005

Number of surveys collected: 55

Number of surveys that are served by the system: 51

Number of surveys that are satisfied with the system: 46

Number of surveys that are satisfied with the water committee: 45

Number of surveys that recognize increased public health from the system: 35

Summarize any negative effects caused by the system:

Summarize any suggestions made by community members about the system:

Additional comments:

System broke down. A pump must be replaced.

Cruz de Piedra

Follow-Up Survey Culmination

(For humanitarian's use, to summarize findings of Follow-Up Surveys)

Completed by: Caleb Douglas 2007

Number of surveys collected: 55

Number of surveys that are served by the system: 50

Number of surveys that are satisfied with the system: 50

Number of surveys that are satisfied with the water committee: 50

Number of surveys that recognize increased public health from the system: 41

Summarize any negative effects caused by the system:

None observed

Summarize any suggestions made by community members about the system:

None mentioned

Additional comments:

System is working great. Doctors (and community) recognize health increases, especially in children. Everyone seems very satisfied with the system.

Cruz de Piedra

Follow-Up Survey Culmination

(For humanitarian's use, to summarize findings of Follow-Up Surveys)

Completed by: Caleb Douglas 2009

Number of surveys collected: 70

Number of surveys that are served by the system: 65

Number of surveys that are satisfied with the system: 64

Number of surveys that are satisfied with the water committee: 62

Number of surveys that recognize increased public health from the system: 62

Summarize any negative effects caused by the system:

Summarize any suggestions made by community members about the system:

Additional comments:

Positive health trends. Kids look healthier!

Appendix E

Score Justifications for Four Considered Technologies

The scores for the ease of operation can be justified as follows: A drilled well's operation scheme simply involves turning on a pump. Similarly, UF only requires the operation of a pump, given UF's passive treatment. In comparison, UV involves the operation of a pump and the UV system. Lastly, an ozone system requires the operation of more than one pump and the ozone generator. Consequently, the scores reflect that drilled wells and UF are easiest to use, UV is next easiest, and ozone is comparatively hardest to operate.

In the methodology to score the ease of maintenance of each technology it is important to consider the extent of each technology's maintenance scheme. A drilled well may operate for several years without any maintenance, however eventual pump replacement and maintenance is difficult without a drill rig or a large amount of man power. A UF system simply requires monthly cleaning and annual filter replacement, which can usually be completed locally. Similarly, a UV system requires monthly lens cleaning and an annual bulb replacement, but its maintenance is complicated by the inaccessibility of bulbs. Congruently, an ozone system only requires maintenance every few years, but the cost of replacing one of its pumps of the ozone generator is great. Therefore, the scores reflect that drilled wells and UF are both best in terms of maintenance, although they differ in tactic. UV and ozone are comparatively more difficult and costly to maintain, thereby receiving lower scores.

When scoring reliability, historical performance is a good indicator. Ozone systems that I have installed are still currently running after 10 years of use, with only routine maintenance. This is partly due to its inherent stability, given the unlimited resource of ozone. The other technologies all experience shorter life spans. The pumps inside drilled wells typically last for 5 years, but are also complicated by unpredictable clogging and wear. A UV system can be considered reliable, but require a stock of replacement bulbs to ensure longevity. Lastly, a UF system is simple to maintain, but inadequate cleaning or care of the filters can result in an unnoticeable failure resulting in contamination. While an ozone system is by far the most reliable, the other three technologies all have similarly weighted setbacks. Therefore, the ozone scores highest, while the other three technologies will be scored equally less reliable.

When considering the ease of travel, the size and amount of equipment must be analyzed. A drilled well only requires a pump, a few tools and a few necessary pipe fittings. But it is important to note that this score is assigned with the assumption that a drill rig is locally accessible, lest this technology would not be considered for the community. A UF system requires the filters, canisters and a pump, along with required tools and pipe fittings. All of which could travel in a few suitcases. A UV system has similar bulk to the UF system, only requiring the ballast, canister and bulbs, along with a pump, the tools and fittings. However, the lenses and bulbs are fragile and more difficult to transport. Lastly, an ozone system requires a larger bulk of goods when you consider the pumps involved, the ozone generator and a larger number of required fittings. Given these justifications, the scores reflect that a drilled well and a UF system are the easiest technologies to travel with, a UV system is slightly more problematic and an ozone system is comparatively most difficult to travel with.

The methodology for scoring the ease of installation may require thinking ahead, specifically if you have not previously implemented a given technology. From previous experience I know that a UV system only requires connection to a power source and water source. Given the right circumstances, these systems can typically be installed in a few hours. From similar experience I know a UF system requires piping three filters in line with the pumped source water. This installation can also only take a few hours. Comparatively, an ozone system is more technically involved a may require a few more days of installation. However, ozone implementation still only requires following a simple schematic. Finally, a drilled well requires drilling, which can be complicated and time consuming. Drilling a 300 foot well may take several days depending on the geology. Also, several holes may be required to hit water. Drilling is typically the most grueling and time consuming of these four options, therefore it is scored lowest. While UV and UF systems are very easy to install and are scored highest.

When considering upgradeability, all four of the technologies have integral pieces that would require upsizing. A drilled well would typically require a new, larger pump. Similarly, an ozone system would probably only need a larger source pump. The ozone generator has a wide range of treatable volumes, which advocates less necessity for upgrading. In comparison, a UF system would require a new pump and would either mandate larger filters or higher loading rates (a higher loading rate implies greater risk). Furthermore, a UV system would typically require a larger pump and a larger (and expensive) UV system, due to finite treatable capacity. Therefore, the scores reflect that a drilled well is easiest to upgrade, an ozone system is nearly as easy to upgrade while some concessions are made, a UF system requires a few more inherent risks and costs and a UV system requires the greatest associated costs.

Lastly, safety can be justified for each of the technologies by examining potential pitfalls or areas of danger. An ultra-filtration system has very few dangerous aspects to its installation, operation and maintenance. The most dangerous part would be supplying the pump with power. Similarly, a UV system has very few associated dangers. However, its one exception is that UV light can be dangerous when not operated in the provided canister (while this should never happen, there is a possibility). Further declining, a drilled well requires drilling, which is a fairly dangerous aspect of installation. Congruently, an ozone system has inherent dangers to its operations, regarding ozone as a poisonous gas. While none of these factors for any of the technologies should ever pose much threat, there are risks involved with each technology. The scores reflect the justification with UF being deemed the most safe, UV being next safe and drilled wells and ozone being comparatively riskier.

Appendix F

Cost Analysis

For Los Encuentros:

Ozone system	**Cost**
Ozone system	2,400
Misc. Plumbing	500
Circulation Tank	500
Circulation Pump	400
softening unit	400
submersible supply (solar)	1600
PVC	250
wire	150
CAPITAL	6,200
10 yr Maintenance	
1 new pump/10 yrs	500
TOTAL	5500

UF system	**Cost**
UF system	1800
Misc. Plumbing	300
pump (solar)	1600
CAPITAL	3,700
10 yr Maintenance	
New filters/yr	100
TOTAL	4700

UV system	**Cost**
UV system	1,675
Misc. Plumbing	150
Pump (solar)	1675
CAPITAL	3,500
10 yr Maintenance	
New bulb/yr	100
New quartz sleeve/5 yrs	50
TOTAL	4600

For La Nueva Cajola:

Ozone system	Cost
Ozone system	2,400
Misc. Plumbing	500
Circulation Tank	500
Circulation Pump	400
softening unit	400
submersible supply (solar)	400
PVC	250
wire	150
CAPITAL	5,000
10 yr Maintenance	
1 new pump/10 yrs	500
TOTAL	5500

UF system	Cost
UF system	1650
Misc. Plumbing	300
pump	400
TOTAL	2350
10 yr Maintenance	
New filters/yr	100
TOTAL	3350

UV System	Cost
UV system	1,600
Misc. Plumbing	150
Pump	400
TOTAL	2,150
10 yr Maintenance	
New bulb/yr	100
New quartz sleeve/5 yrs	50
TOTAL	3250