TECHNICAL, ORGANIZATIONAL, AND SOCIAL CHALLENGES OF PROJECT DEVELOPMENT IN RURAL LATIN AMERICA: A HONDURAN CASE STUDY

By

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This report “Technical, Organizational, and Social Challenges of Project Development in Rural Latin America: A Honduran Case Study,” is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING.

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Preface

While I worked in Honduras as a Peace Corps volunteer (PCV) for two years from 2002 through 2004, I was welcomed into the community and developed many warm relationships. I also worked with many different organizations and communities, and completed several system designs. Many of these were for communities with which Peace Corps water and sanitation technicians had developed relationships and evaluated the feasibility on both social and technical levels. I also completed designs for sewer expansions for two municipalities, which I expect to be built and maintained successfully.

My focus and time while in Honduras was divided between many projects, which is more typical for other development agencies than for PCVs. In most Peace Corps projects, a volunteer works with a small number of communities, most specifically the one in which they are living. This allows the volunteer time to know a community well, through informal development of personal relationships. Perhaps this is the best way of addressing community development, but I explore the possibility and the liability of collecting social information more directly through surveys as a way of addressing needs through a wider geographical area.

While my relationship with various organizations is described in this paper, I chose to focus on one particular village, Sabanetas, about an hour journey by automobile or bus from the small city where I resided. I chose Sabanetas for a variety of reasons, mostly because it was a technically complex and interesting project. As it turned out, it became even more socially and organizationally difficult, as this village is a community with many obstacles to development. While I entered the situation with excellent technical training and abilities, I had a limited amount of personal experience and training in rural international development. I struggled with my role and relationship with this community, in a large part because I neither developed a close personal relationship with the community nor collected the social information though good quality surveys.

The message that I hope to deliver with this paper is that working with a community, especially as a PCV, is a learning process. I hope that the reader improves understanding of the challenges that can be encountered in the field. Organizational and financial readiness of communities must be evaluated early on, and reevaluation is a continuing process. In the end, these challenges of the Sabanetas project have made a much more interesting topic for this paper than if the project had gone forth in a straightforward manner, with only technical issues to deal with.

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Too many to list them all by name, many Peace Corps volunteers in Honduras must be thanks for both social and technical support. I do want to make a special note of Lauren Candia, Mark Jackson, and Ben Hildner. They are great friends with whom I shared some of the best experiences in Honduras. Additionally, Lauren helped me to organize my thoughts on the paper, and Ben supplied some valuable details about the community of Sabanetas. In addition to volunteers, the program manager of the water and sanitation sector of Peace Corps Honduras, Martin Rivera, was always a good source of technical information as well as personal support.

Likewise, there were too many Honduran friends and good neighbors to thank them all by name. I would like to make a note of Mildred Garcia, who has been both a great friend and also a source of information about the inner working of the development agency where she was a manager. And a special thanks to the Hernandez Vazquez family who made me feel at home, and who became my Marcala family.

List of Abbreviations

AHJASA – Asociación Hondureña de Juntas Administradoras de Agua

ENEE – Empresa Nacional de Energía Eléctrica (National Electric Energy Company)

FHIS – Fondo Hondureño de Inversión Social

O&M – Operation and Maintenance

PCV – Peace Corps Volunteer

SANAA – Servicio Autónomo Nacional de Acueductos y Alcantarillado (National Autonomous Water and Sewer Service)

UNICEF – United Nations Children's Fund

WHO – World Health Organization

Abstract

Developing a rural infrastructure project in a developing country involves much work beyond the technical aspects of the project. Understanding and knowledge of the community is essential for long-term success of a drinking water system. My experience in a Honduran village provides a case study, illustrating the necessity of collecting social and technical information before embarking on extensive topographic surveys and hydraulic design work.

A development agency also needs to recognize the implicit power relationship implied in giving aid. Once this unequal balance of power is accepted, the agent should use care and discretion to listen to the community members' wants and needs and to guide them in choices and responsibilities for operation and maintenance of a water system. This is assuming a common goal of better health and improved economic status of the community. Many authors advise extensive questioning and training of villagers as the first step in project planning.

When I arrived in the village, previous Peace Corps volunteers had already completed some work on the project. While making technical changes to the existing plans, I never reevaluated the basic assumption that the community needed a drinking water system with a pump and private household connections. While working on the topographic survey and other preparations, I repeatedly encountered difficulties surrounding the organization of the water board. I disregarded these warnings and continued with the study and design.

I quickly learned that many technical features needed to change from their original plan. I changed the location of the water intake to a location that would suffer from less contamination. I also elaborated two different designs based on differing storage tank configurations. One design included a surface tank, and the other had a water tower at a different location. Detailed cost analysis is given to compare these two choices.

After all of this study and design work, I realized that the community did not have the necessary unity or economic resources (even with agency aid) to build and maintain an expensive and complicated pump system. Thus, I recommend further work with the community to evaluate interest in improved drinking water quality. If the interest is present, I suggest two possible technical solutions, but more importantly, that the villagers be surveyed on an individual basis to confirm the usefulness of the plan and widespread support.

1 Introduction

When working with a rural community on an engineering development project in a developing country, the engineer or technician encounters challenges that extend beyond technical issues into the areas of social preferences and organizational abilities of the beneficiaries. Additionally, development agencies frequently have organizational, temporal and budget constraints that need to be considered. The objective of this paper is to explore both the challenges of working with both the beneficiaries and development agencies on infrastructure projects in rural Latin America. I use my personal experience in designing a small drinking water system in the agrarian community of Sabanetas, Marcala, La Paz, Honduras as a case study. Chapter 2 introduces briefly the case study village, Sabanetas, and the country of Honduras.

Change and growth in the community leadership and organization are essential to long-term development. However, the question of the legitimacy of bringing and imposing outside values to a local community comes with any effort to create social change. There remains a continuing tension between paternalism and local control when considering the appropriate relationship of development agencies and communities that they seek to serve. The best project would impose some external values that are necessary for long-term project success, while accepting and working with local values and beliefs as much as possible, and always maintaining the goal of community independence. A community survey is an essential first step, both to impose some necessary outside values and knowledge, and so that the agent can learn about the local values and needs. Chapter 3 discusses the general points of development, first considering the abstract and theoretical literature, then proceeding with practical principles, specifically community surveys, which can be used in the field.

Chapter 4 presents the organizational aspects of development in Honduras, specifically as they apply to the drinking water project for Sabanetas. Several stories illustrate the organizational difficulties in working with this particular community, as work on the project progressed. Some of these might have been avoided had I familiarized myself more thoroughly with the community before elaborating the technical design. After each story, there is a commentary on how a greater familiarity with the community might have supplied the opportunity to avoid or prepare for these difficulties.

The technical requirements to develop a small-scale water system for a small rural community include the initial community investigations, topographic survey, design, funding, construction, and planning for operation and maintenance (O&M). Because the case study that is detailed in this paper also included an electric pump as part of the design, an introduction to pump sizing and selection is also covered. The general principles of engineering design in Honduras are discussed in Chapter 5.

These principles are illustrated in detail in Chapter 6 for the case study of Sabanetas, where two design alternatives are presented and compared. This chapter parallels the events in Chapter 4, but with an emphasis on the technical aspects of the project. In the first part of this chapter, the design on which the community had already been working was shown to be unfeasible (both the water source and the surface storage tank location). A new topographic survey and design give much better results using a different water source and a different surface based storage tank location. Also considered and evaluated was an elevated storage tank tower at the same site as the unfeasible surface storage tank. At the end of this chapter, an optimal design is presented, within some limiting parameters of the community and the funding agency.

The conclusion reevaluates the appropriateness of the design that is presented in Chapter 6. Because I did not first conduct a community survey, but instead proceeded directly to the study and design phase of the project much of the work on the project was misdirected. While working with the villagers, I learned much of the information that should be gathered in the community survey. This information forms a foundation for reevaluation of the entire project. The final design decisions must not always reflect a purely technical analysis, but need to consider the appropriateness of the technology for the individual community. Thus, I conclude that the complicated pump design presented in Chapter 6 is not appropriate, and recommend additional community survey work to discover what other alternatives might be appropriate.

2 Introduction to Sabanetas, Honduras

2.1 National Statistics

Honduras is one of the poorest countries in the Western hemisphere (CIA 2002). It has the lowest average income in Central America, including neighboring Guatemala, El Salvador, and Nicaragua (Figure 1), but has lower infant mortality and longer life expectancy than Guatemala (Population Reference Bureau 2003). Most of the people living in rural areas have sufficient food and adequate shelter, but some suffer from malnutrition, for lack of variety. The poorest live almost entirely on corn tortillas, with some dry red beans and occasionally some dairy. To receive any cash at all, they must work for very low wages, usually during the four-month coffee-cutting season. There are few wage labor jobs available the rest of the year.

Figure 1. Map of Honduras

The World Health Organization (WHO) and United Nations Children's Fund (UNICEF) report that the current rural coverage of potable water is 82% (2000). It is not clear how they arrive at this number. To survive, everyone must have access to some water. The more important questions always revolve around the quality and quantity of the available water. Many of the drinking water systems in the department of La Paz, where I lived, were contaminated with fecal coliforms, agricultural chemicals, or high levels of iron. Additionally, if access was difficult, the small quantity of water available at the home negatively influenced the levels of personal hygiene, especially hand washing.

2.2 Physical Characteristics of Sabanetas

In Sabanetas, there are approximately 60 houses or locations with pending construction within the expected service area. About 30 houses form the center of the community, near the highway that follows one of the highest ridges for miles around. In addition to the 30 houses grouped near the center, there are approximately another 60 houses in the more outlying areas, but only about half of these were included in the final design, some because they were very far away and at elevations where water from the system would not reach. Other households that could have been well served by the water project needed to be asked why they have chosen not to participate.

Table 1 shows the current and estimated future population for the design period. The basic design parameters are listed in Table 2. The calculations used for both of these tables are detailed in Appendix C. A map of the community (Figure 3) shows the locations of the houses, public buildings, and proposed dam and storage tank locations.

Table 2. Estimation of future population of Sabanetas for the design period.

Houses of participants	61
Present Population	298
Design Period	20 yr
Growth Rate	3.5%
Estimated Future Population	506

Table 1. Basic design parameters for the Sabanetas water system.

Average daily requirement per capita	25 gal
Inflow required for design (MDC)	13.2 gpm
Required tank size	5000 gal

The people of Sabanetas established the community in a location where access to potable water, and even positioning a storage tank, is difficult. People build communities in certain locations for a variety of reasons sometimes without prioritizing easy access to potable water. This location offers fantastic vistas or prospects, and convenient access to a primary transportation route, but water needs to be hauled up to 500 meters by hand from wells, which are typically located at an elevation seventy meters below many of the houses. These sources are frequently contaminated, and according to local public health officials, cause illness in the community. Infiltration of agricultural chemicals is suspected to cause much of this illness (Hildner 2004). They clearly need to have an improved water source for health reasons.

Figure 2. Picture of Sabanetas from near the center of town. The highest hill in the area is shown near the right of the picture, behind the foreground bush.

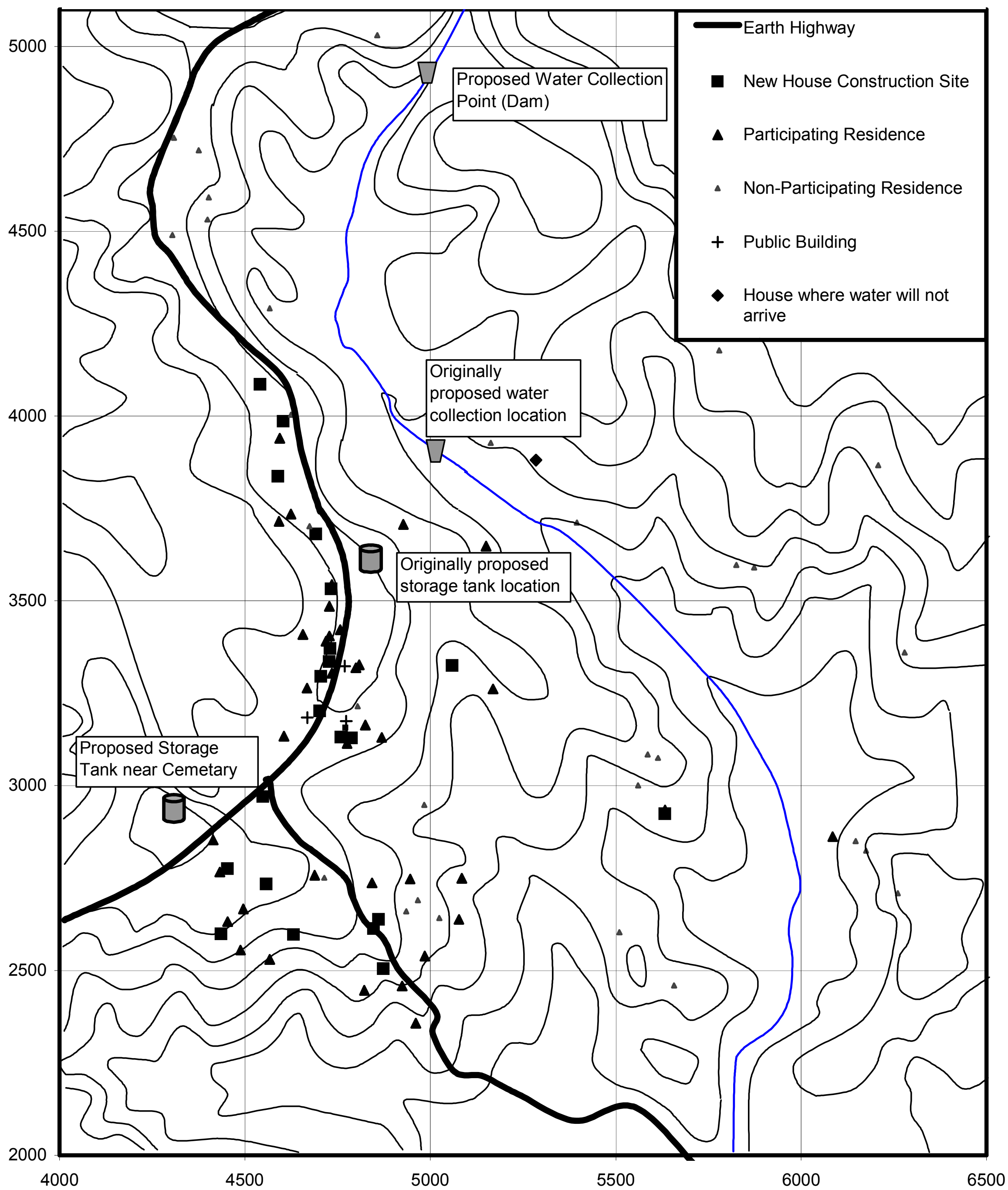

Figure 3. Houses, potential tank and potential dam locations in Sabanetas. Contours were taken from the USGS 1:50000 series. They represent 20-meter intervals. Feature locations were recorded using the Global Positioning System. (UTM Zone 16, units in meters, easting –380000, northing –1550000).

During my time there, the wells that they used for drinking water were not tested. However, the location where the community had been planning to construct an intake for the water system failed to meet quality standards. The results showed high, but passable levels of total coliform bacteria, but also showed the presence of fecal coliforms. Servicio Autónomo Nacional de Acueductos y Alcantarillado (SANAA), the Honduran national water company, will not construct a drinking water system if there is any fecal coliform contamination in the source, which indicates pathogenic bacteria, specifically *E. coli* (Reents 2003, C-22 – C-23).

3 Development Theory and Social Survey

To create a successful project in the developing world, an understanding of the role of the development agent and potential tools for learning about the community should be considered first. The agent must have an understanding of the community in order to create good quality objectives for both the community and the agency. This chapter first considers the most general aspects of the activities and roles of the agent in the development process, and advocates an initial acknowledgement of an imbalance of power between a rural community, such as Sabanetas, and the agency. From this position, the agency can foster development within the community with the goal of increasing independence for the community. Secondly, this chapter presents some research tools, namely surveys, which can be used by the agency to learn about the community. With knowledge of the community, the agency can then customize a development strategy and evaluate the appropriate level of technology that is appropriate for the community. Chapter 4 will show, in retrospective, how using these tools would have contributed to the effectiveness of work with the community of Sabanetas.

3.1 Aid and Power - Paternalism

"Since the leftist 1970s and liberal 1980s, paternalism has become a notion regarded with great disdain" (Tonkens 2003). It is important to note, Tonkens continues, that "community workers cannot rid themselves of paternalism", regardless of political ideals. "Attempts to eliminate paternalism are not only fruitless, but also undesirable."

One form of neo-paternalism "creates a group of people who are considered to be hopeless. And because damage is the only reason for intervention, this intervention becomes predominately negative; focusing on penalties and punishment" (Tonkens 2003). This is only slightly different from the paternalism of the 1950s, where "community workers knew what was best for their client." In the more contemporary form, intervention happens only if there is a request for help, or in response to bad behavior. National and international aid have traditionally followed this 1950s model, which served to maintain a particular power structure.

To empower villagers requires much more work than to provide handouts, as many of them are fatalistic or passive with no vision for themselves to change their own lives or position. Quite possibly this passiveness is a learned behavior resulting from generations of receiving aid. In contrast, what Tonkens calls "caring neo-paternalism" requires criticism of the professional and outreach into the community.

While avoiding the word "paternalism", probably for the reasons given above, Macdonald (1995) makes a similar observation: "Dominant approaches to the growing role of non-governmental organizations in the delivery of development assistance tend to overlook the implicit power relations which shape and restrict NGO action." By first acknowledging that some groups are subordinate, a NGO can make an effective plan for eventual local control. "NGOs are most likely to contribute to long-term democratization if they support both real participation at the grassroots level and the construction of alliances of subordinate groups seeking to challenge the balance of national political forces in their favour."

Often community members need clear requirements and goals that they must meet in order to receive assistance with a project. At what level can the community meet this? Is there someone who can organize a census, for example? If not, then it is best to take the time to explain how in detail and to work with a local person on every step of the process. Thereby the person learns, and increases power within the community. Of course, in the beginning, this is much more challenging than using aid as a lever to demand some kind of behavior. In the long term, with improved education, hope, and social organization, a community may eventually become more independent and stronger.

3.2 Miscast Roles in Development Projects

In addition to power relationships between the development agency and the community, the roles that are cast and the associated expectations need to be considered. Honduras is no exception to the typical miscast roles of agency and community as described by Cairncross (1980: 107):

> A public agency is designed to carry out routine activities, while villagers can be stirred into an occasional generous contribution toward self-help projects. These roles cannot readily be reversed. Bureaucracies may be very bad at one-off project where officials are most exposed to local influence and a routine approach is difficult to establish; while on the other hand village communities are generally unable, through voluntary effort, to organize themselves on a sustained basis for routine management tasks. So the financially convenient arrangement often adopted by a water agency, whereby it does the

initial construction job and then leaves maintenance to the people in the village, coincides with the greatest organizational weakness of both the agency and the village.

Continuing support by agencies is instrumental to good long-term use of a water system. Unfortunately, as Cairncross (1980) implies, there is a lack of agency funding and presence for long-term support. For example, the Asociación Hondureña de Juntas Administradoras de Agua (AHJASA) office in the small city of Marcala, La Paz, whose sole purpose was to support O&M in surrounding rural communities, lost funding and closed their office. Without some form of continuing support, any project in Sabanetas is likely to fail, so part of project planning must account for how this support would be maintained.

3.3 Factors Relating to O&M Failure

Both the dependency-fostering type of paternalism and the miscast roles of the players contribute to the failure in operation and maintenance (O&M) of water system and other infrastructure projects. "The following factors relating to centralized management often contribute to O&M failure:

- an overdependence on government agencies who do not have the resources to keep supplies functioning
- user expectation that government provides all the necessary services and funding required to maintain supplies
- user non-payment for water services, and
- a lack of user involvement in decisions concerning their own water supply" (Davis 1995: 52).

These points all have a common thread running through them. They indicate subservience, and an expectation of a dependent relationship with NGO or governmental organizations. These first two points are already obviously issues with the community of Sabanetas. It would require significant effort to break historical inertia. These issues must be addressed so that the second last two points listed do not become issues if a water system is built in the community.

3.4 Payment Issues in O&M

Frequently in rural water systems, there are significant problems with delinquent accounts, which could easily occur in a community such as Sabanetas. This can start the downward spiral where lack of funds leads to lack of maintenance, so the system works poorly, so fewer people pay. This is why it is so important that there "be sanctions on those who do not pay" (Davis 1995).

Throughout Honduras, it is common for communities to use the statutes recommended by the Asociación Hondureña de Juntas Administradoras de Agua (AHJASA) (Appendix B). Article 33 states that delinquents will have their water supply cut off. This is harsh and punitive, like the "bad" form of paternalism discussed above. Often, with reason, it is a statute that a water board is unlikely to uphold.

> [I]t should be stressed that there is no evidence of significantly increased levels of nonpayment of bills where there is no threat of disconnection. It should also be stressed that disconnection from a public water supply represents a significant health risk to the whole community and not just the disconnected household. Significant increases in disease are noted in areas where disconnections have taken place.
>
> Where household resources are limited and non-payment becomes problematic, other solutions should be identified. These may include a minimum amount of water provided effectively free of charge, employing large-scale subsidization from wealthier domestic users and industry or installing flow limiters on households with a history of persistent non-payment. (WHO no date)

Therefore, it is important to develop and customize the water board statutes specifically for the community that is involved. There needs to be a discussion with the water board concerning the consequences for delinquent accounts, addressing both the potential effectiveness of sanctions, and the willingness of the water board to carry them out.

3.5 Community Survey

By learning about a village, specifically though a survey, the agent or the Peace Corps volunteer (PCV) can learn about the needs, preferences, beliefs, strengths and weaknesses of the community. In this way, the agent can avoid some problems entirely, and be prepared for others. The communication skills of the interviewer are very important. "Training must be given in how to ask questions, *and how to listen to the answers.* The manner of asking is as important as the contest of the questions. Interviewers should be sensitive when asking questions of a personal nature such as questions about defaecation habits. Training interviewers from within the community will help to overcome some of the difficulties. There should be a system of cross-questioning, that is, asking the same question in different ways more than once, to check the reliability of answers" (Davis 1993: 66). Davis goes on (69-79) to recommend gathering the following socio-economic information for planning a water system:

- Level of support – It is important to try to estimate the level of [community] support
- How many people [and which ones] might benefit from an improved water supply

- The health of the community and existing sanitation practices
- People's awareness of the connection between water and health
- Time spent collecting water, and the quantity and quality of the water collected
- Money matters
- Community structures

In Sabanetas, I collected very little information on any of these items, which significantly influenced the outcome of the project. Chapter 4 discusses issues of the Sabanetas project, and refers to the information listed above, and how it could have made a positive difference in the project's progress.

3.6 Contingent Valuation Survey

In may be difficult to discover the market preference of the community if they receive free materials through an agency, as is typical in many development projects. As a village water board or any other village organization generally does not have strong credit to receive a low interest loan, nor are they likely to be responsible in repaying the loan, rural communities need assistance, but this assistance can obscure the true values of the village.

A typical remedy for this problem is to "assume that so long as financial requirements do not exceed 5% of income, rural consumers will choose to abandon their existing water supply in favor of the "improved" system. Several reviews by the World Bank, bilateral donors, and water supply agencies in developing countries have shown, however, that this simple model of behavioral response to improved water supplies has usually been proved incorrect. In rural areas many of those 'served' by new systems have chosen to continue with their traditional water use practices" (Whittington 1990a). However, a well-constructed simple survey can yield good results.

A survey of the village can be well suited to establish preferences, needs, and interests of all the members of the community. "[G]oing into a village and conducting a relatively simple household survey can yield reliable information on the population's willingness to pay for improved water services." The contingent valuation survey, "where the interviewer poses question in the context of a hypothetical market", that Whittington (1990a) tested in Haiti did "not appear to have a major problem with either starting point or hypothetical bias. The evidence with regard to strategic bias [was] less conclusive." This means that, at least in Haiti, there was statistical value in devising a "bidding game" questionnaire. "Most attempts to incorporate willingness-to-pay considerations into project design have, however, been *ad hoc*, in large part because of the absence of validated, field-tested methodologies for accessing willingness to pay for water in the context of rural communities in developing countries" (Whittington 1990a).

There is a substantial volume of literature that contests the validity of contingent valuation (Portney 1994). However, a vast majority of this debate falls within the field of natural resource and environmental economics. Even when applied to other fields, contingent valuation is usually used to measure "passive use value", such as reduced risk of respiratory disease (Portney 1994, Carson 2001). There is a relative dearth of literature regarding the use of contingent valuation to establish the willingness-to-pay for delivery of hypothetical goods or services. Clear, concrete hypothetical outcomes can be presented in a questionnaire, substantially reducing the risk of hypothetical bias that may be common with more abstract or difficult-to-observe values, such as biodiversity of a forest or cleanliness of a lake. Strategic bias could be reduced by introducing the questionnaire with an explanation of how the most honest responses would serve the interests of the community, so that the project will best serve the communities needs throughout the life of the project.

While in Honduras, I was not familiar with contingent valuation studies. I believe that part of the problem that developed with the project in Sabanetas was that, even with agency support, the proposal exceeded the willingness-to-pay of many villagers, but this was not established beforehand. A good quality contingent valuation survey would require significant research and preparation beforehand. Contingent valuation can yield useful results when it is done right (Carson 2001). As with the more general social survey questions that were presented in the previous section, Chapter 4 discusses the potential application of a contingent valuation survey in the Sabanetas project.

3.7 Value Placed on "Free" Materials

Concerning construction costs, when free materials are available, such as piping, the community is not motivated to limit the amount of that resource that they use. If paying the true economic cost, they might prefer to simplify the system, use less of the available tubing, and instead use the value of the tubing toward other projects. While it is clear that the average household needs some assistance to improve access to potable water, it remains difficult to make designs and plans that meet their economic preferences.

An ideal solution might involve an increase in wages, so that the community could afford to buy their own system. This would make for more rational decision-making on the part of the community, and greatly enhance the sense of ownership. If the community had paid their own money for the materials, they would likely have much more interest in doing an excellent construction job, such as excavating the ground to a sufficient depth to protect the expensive tubing.

Additionally, a cost recovery scheme could possibly help to assign values to the materials, even if the community cannot afford to purchase the supplies upfront. Whittington (1990b) provides an example where villagers were not interested in paying in advance, but were happy to pay substantial money for water on demand through a kiosk system, in which vendors sell water to carry away by the unit. The point is not that kiosks are necessarily what Sabanetas needs, but rather any cost recovery options could be explored with quality survey questions.

4 Development in Honduras

4.1 The Players

A variety of organizations, with different agendas and working styles, must all work together to build a successful community infrastructure. Regarding drinking water projects in particular, a development organization such as SANAA, Fondo Hondureño de Inversión Social (FHIS, a large Honduran national development organization) or a non-governmental organization (NGO) commonly supply the technical expertise, O&M training, and many of the material components of a project. The local community contributes unskilled labor, locally available materials, and the organization and funding for O&M. The PCV can act as an intermediary between the community and development organizations, organize community training, and supply the technical expertise to design and build a project. This section elaborates on the activities of each type of player, first of the development or funding organization, then of the local community, and finally of a PCV.

4.1.1 Development and Government Agencies

Currently, there are large amounts of money going toward Honduran development. This is one of the largest aspects of the economy, forming 6.9% of the gross domestic product, following only merchandise exports and maquiladora (Orozco 2000). Monies from industry go primarily to the owners, while the workers are not paid enough to establish themselves as a middle class. In contrast, professional employees of development agencies form a very visible part of the local middle class, most conspicuously in small cities near rural areas.

Ironically, there seems to be a shortage of money and aid workers, or more need than there is help to go around. Sometimes this may be a result of poor prioritization, or ineffective administration. In other cases, priorities are divided so many ways that motivated individuals within agencies may not have the time to know communities well and to estimate the greatest capability of any individual rural community.

4.1.2 The Local Community

The ownership arrangement most frequently endorsed by development agencies for rural water projects in Honduras is "ownership by a water users' association for which non-subscribers may be excluded." Cairncross (1980: 108) lists several other possibilities, but of these, the only other arrangement that is seen in Honduras is municipal ownership by larger towns and small cities. There was a legislative initiative in 2003 to privatize these larger systems, which was very controversial in the media. However, for a system the size of Sabanetas, ownership by the water board is the arrangement of choice.

For the success of any local water delivery system, the water board must execute the duties laid out in statutes that are supplied or recommended by the funding agency. Appendix B provides an example of the statutes that AHJASA recommends. The water board then in turn organizes the community to complete necessary work on a project and establish a tariff for future O&M.

4.1.3 The PCV

According to the Peace Corps Act signed by Congress in September 1961, the goals of the Peace Corps are:

- To help the people of interested countries meet their needs for trained workers;
- To help promote a better understanding of Americans in countries where Volunteers serve; and
- To help promote a better understanding of people of other nations on the part of Americans.

These ideas make a good starting point, but in practice, the goals become more complicated. The first goal, especially, becomes modified in the field. As implied earlier in this chapter, there are many Hondurans who are trained workers. Sometimes these trained workers are in organizations that have management, strategy, or financial difficulties. Working at this level requires administrative capacity that may be beyond the expectations and abilities of a PCV.

A PCV develops relationships with local communities. In the Honduran water and sanitation (W&S) sector, the PCV usually works as a liaison between the community and other organizations. The W&S volunteers frequently do the technical tasks that are explained in detail in Chapter 3. The ideal, however, is to render the post obsolete, eventually. The volunteer should be training and working with people through the entire process, so that dependency is eliminated. In my experience, this rarely happens, as the local Hondurans that are best able to learn the technical work of a W&S volunteer are usually extremely busy with their own projects. The immediate needs of the rural villages often lead the volunteer to work independently of agency representatives, to try to get a system in place as soon as possible.

The volunteer also works with the villagers, both instrumentally, getting their help with tasks, and organizationally, to prepare them to operate their water system. Often volunteers organize workshops. The best workshops have a majority of the presentations given by other Hondurans, because language and cultural gaps might inhibit understanding. This also works toward the goal of encouraging local and national independence, *i.e.* to avoid fostering dependency on the presence of the Peace Corps. If strong networks can be established, then when the volunteer leaves, the network could continue to survive.

4.2 Working with Sabanetas

When working with a small village, such as Sabanetas, it is necessary to set expectations and goals that are appropriate for that particular community. Every community has unique characteristics, abilities, and shortcomings, akin to those of any individual person. When a community lacks experience, expectations must be set at the level that can best improve and expand that community's abilities. This requires more time, experience, and patience than perhaps any other aspect of development work.

Cairncross (1980: 108) claims "water users' associations may avoid the factionalism and conflict that is often found in rural communities." However, in the case of Sabanetas, deliberately excluding the established community leaders from the water board seemed to create a power vacuum, into which entered people with less ability to form a village consensus. I continued to find that the official village leader, even though he had no official position on the water board, was more reliable and easier to work with than the president of the water board. The democratic system of decision making by majority or plurality voting, exemplified in the AHJASA water board statutes (Appendix B), may not be sufficiently consistent with, or appropriate to, the traditional modes of decision-making and the existing power structure.

In a case like Sabanetas, it can be a good starting point to observe how the current "natural" organization of water delivery is functional, *i.e.* to investigate the existing "water collection patterns" (Davis 1993). A more sophisticated system of piped and pumped water is not necessarily equally suitable or sustainable. In the case of Sabanetas, the town has plenty of labor resources to do the necessary handwork to move the water. Under the current system of bucket potage, some of the relatively wealthy households can even afford to pay other community members, usually children looking for snack money, to make water deliveries. A more complicated and expensive water system may be beyond the means of the average household, especially with the additional expenses associated with the operation of an electric pump. For each household in Sabanetas, it was estimated that a water system with the electric pump would cost the equivalent of one day of work per month for operation and maintenance. It is important to discover if this is a price that community members are willing to pay, perhaps using a contingent valuation survey.

When considering a system with an electrical pump, a very important thing to do early on would be to calculate the monthly fee for the electricity, on a per household basis. A pump size and pump line size could then be chosen, based on the original number of interested households and the desired level of service. Using the electricity price given, a contingent valuation study would reveal willingness and ability to continue with the project. Adjustment could then be made to the plan, until the configuration that people are willing and able to pay for can be devised. The challenge here may be in making a simple sketch of a plan, that could easily be changed, but still offer a realistic estimate of costs.

4.2.1 Level of Support and Interest

Before beginning any topographic study, it is important to establish which households in the area are committed to work on the project. In Sabanetas, after we had done much of the topographic study, I found out that some branches went to houses of people who were not interested in participation in the project. I then asked the water board to make a list of all of the interested households. I had already recorded the locations of all of the houses in the community using a GPS, so I just needed to know the names of the families that were "in". Getting the list of participants took over two months, and much more of my energy then should have been necessary. The water board kept showing me a list of names that did not answer the simple question that I put to them. They listed whether or not residents had been to the most recent water board meeting, or if they were up to date with dues. They had a list with a column that was supposedly the participants, but then people would tell me that some of the people marked as "out" were actually interested, and *vice versa*. The list also sometimes used a different name to indicate the same household. This then required much conversation to establish clearly which households these were. This case was the first indication of disorganization, and perhaps lack of strong, widespread support for the project. Instead of trying to manage and understand inaccurate and unwieldy lists, organizing an initial survey could have been a much more effective use of everyone’s time.

4.2.2 Economic Strata within the Community

Establishing a financing plan for the operation and maintenance that considers the economic status of each household in the community may be sensible, but difficult to implement. Some households have a modest, but substantial cash flow, and can afford to pay their share of expenses, but many other households may not be able to do so. These more impoverished households operate almost entirely on a non-cash basis. They grow enough corn to feed themselves, but have little cash income. When there is work available, normally in the coffee cutting season, the pay is less than three dollars per day. So only if one of these poorest households has a person that can cut coffee would they be able to pay the bill, and this would be for only the four or five months of the season. Despite the differences in income and assets, in rural Honduras it is not customary to establish a pricing structure based on capacity to pay, but instead costs are divided equally between all participating households.

There are many cultural examples of mechanisms where the rich and powerful recycle money back to the poor, which often serve to maintain the existing power order and structure. Scott's (1985: 169-78) discussion of the Malaysian village where he lived and worked illustrates this point. "There have traditionally been three major forms of ritual gift giving joining the rich and poor in a Sedaka. They include the 'private' Muslim tithe, gifts, and ritual feasts to which other villagers are invited." Scott goes on to point out how these practices serve to maintain power relationships. At the same time, these traditions are breaking down in the face of modern agricultural practices.

Sabanetas does not appear to have any ritualized practice of this type. Reasons for this may include:

- It is a newly established community, established after the 1969 "Soccer War" with El Salvador. Remnants of earthen battlements remain in the immediate area.
- Honduras may not have this type of cultural tradition.
- Even the better-off villagers do not have sufficient income for substantial gift giving.

A community valuation survey might help to acknowledge different levels of income within the community. If different prices can be established for different levels of service, then the greatest number of people can be included in the system.

4.2.3 Public Tapstands

Due to hydraulic limitations, there are approximately five outlying houses that cannot possibly receive water from any ground-level tank in the community. For these houses, public tap stands would be a necessity. While the other houses in the community would have water pressure sufficient to reach the house, people in these locations would have to retrieve the water from 200-300 meters away, at 30-40 meters lower elevation.

This then raises a question about the amount of monthly payment for this less convenient level of service. SANAA recommends that households that access water at a tapstand pay a fraction, perhaps half, of the full monthly tariff. Again, the contingent valuation survey could establish a more appropriate tariff for this level of service, whether the price be higher or lower.

As a point of caution, if some households near a tapstand elect not to participate, there would be no easy solution to regulate access to water at the tap stand. This would also introduce additional design questions, for if many households collect water from the system illicitly, then there would eventually be inadequate water available based on the original design calculations. It is important that participants monitor for illicit usage, but this involves complex social relations and ethical considerations. These issues could be at least partially resolved through surveys and training, but continued monitoring might be necessary.

4.2.4 Communication and Planning Abilities

When I first arrived in Sabanetas, I overestimated the focus and ability of the community to work independently. I assumed that the leadership of the community could delegate tasks, and organize activities, without explicit instructions in every detail. Several examples show the types of activities that needed to have the requirements clearly stated.

4.2.4.1 Community Inertia

While working toward a design of the Sabanetas water system, I left some tasks in the hands of the community. I had expected them to finish these before we continued with the project. One of the tasks that I put to the water board was to attend a meeting with AHJASA, an NGO that assists community water boards in organization and operation and maintenance of their water systems. Making this connection could have strengthened their organization, connected them with other water boards, and given the project a greater chance of long-term success.

Another job that I had required them to do was to negotiate with the Empresa Nacional de Energía Eléctrica (ENEE), the state owned electric company, for the rate they would pay for electricity. This was extremely important, both so that the community could know how much they would have to pay per month, and more immediately, so that I could complete that evaluation and pump selection process.

A representative from the community did go to the AHJASA meeting. This was good news, but no one had gone, nor had any plans to go to ENEE to negotiate the price for electricity. Moreover, most of the community members left the most recent water board meeting when the directors changed the venue. The new venue made practical sense, but apparently there was some political reason that a large part of the community refused to go to the new location. This indicated disunity and instability that boded badly for success of the project.

I considered several potential responses to this inaction:

- A pep talk, saying how close they are to having a design;
- A threat, saying that I will not return until they are better organized and motivated, maybe including new elections for the executive board ; or
- A long talk, to find out where the organizational problems were, and work toward solutions so that most people could be satisfied and happy to continue with the project

Initially, I merely ignored the problem. This was not a good strategy, but I had not developed confidence in my language skills, at this early stage of my service, for the complexity of the "long talk". This, however, might be similar to the approach taken by other organizations, unable or unwilling to deal with the biggest challenges.

The best choice would have been to meet with people, from leaders to non-participants, to have that long talk. The community and I still needed to gather the "[s]ocio-economic information for planning" that Davis (1993) laid out so clearly, as provided in Chapter 3 of this report. These actions or inactions seem to follow the reasons given for O&M failure in Section 3.2

4.2.4.2 Other Instances of Poor Planning

Another instance I encountered illustrates the same inaction and lack of preparedness. Just as we were about to start the topographic survey, we encountered vandalism. It seems that some residents who live near the site that we had been exploring were not fully informed, nor in full agreement with our activities. The day we returned to the proposed dam location to begin the study, we found that several small trees had been chopped down around the site, deliberate and apparently pointless damage. Apparently, this was meant as a message to the water board that the landowner at this location was not happy with their plans.

We did not proceed with the study on that day. The community members had *not* gotten all of the necessary authorization to pass through people's land, as I had instructed them during our previous meeting. A week later, they assured me that everything was resolved and that all of the neighbors were in agreement with our work. I proceeded on faith even though this seemed an all too simple resolution to what appeared to be a very contentious situation.

4.2.5 Democratic Process and Decision Making

After completing a design for a water system for the community, using a surface based storage tank, I learned from engineers at SANAA that a water tower technically *was* an option, contrary to my previous understanding (see Section 6.5 for technical details). Therefore, I devised another design, with the water tower on top of a slightly lower hill, in a much more convenient location. Total costs for the two designs were nearly the same, but the new "tower" option delivered significantly better pressure to many houses.

After I completed the alternative design, I called a meeting with the Sabanetas water board to present the alternatives. I limited the technical explanations, and tried to show just the factors that were relevant to them. The main costs relevant to them were additional lumber, sand and gravel, and the labor for construction. The benefits were the improved water pressure at many houses, with four or five houses going from below to above minimum recommended pressure.

I realized after the fact that the people of the community were not equipped or educated enough to make this sort of technical decision. One woman asked the president of the water board how they could make a decision between the two options if they did not know which option was better. I had already presented both options, each of which had advantages and disadvantages. I felt that I was not qualified to make an executive decision on the matter, because I had incomplete knowledge of the values of the community. She, however, thought that there was only one right answer, and wanted help.

As their most basic concerns were short-term cash costs and short-term labor, they chose the option that was cheaper for the community in the present, and required less labor. It appeared that they did not have any sort of evaluative discussion about the relative merits. My Peace Corps associate who lived in the community commented that the majority of community members are afraid of making the "wrong" decision, so most of the residents just sat in the meeting and did not say or do anything, not even ask any questions.

The president of the water board made his position clear to the community, and they followed his direction without any dissent or evaluation of the possibilities. I had handed the president two maps, one representing each of the two options. After reading the legend aloud (which was hardly very important or relevant to the decision at hand), he then mistakenly described the map that he was holding up as the non-tower option. After I corrected him, he then said that the one that he was holding "doesn't work" and handed it back to me. He closed any discussion, and put it to the vote. The vote was, of course, unanimous for the option represented by the map that was still in the president's hand (*i.e.* the tower option).

The decision that the community made was not "wrong", but it was not at all an example of good decision-making processes. I now believe that it would be equally valid for me to have made the decision, and tell them how the project must be built. I had assumed that rural Hondurans had the capacity for decision-making, like that of community leaders in the Unite States. Regrettably, because of the small amount of education that they have received, a somewhat paternal approach to rural development may be necessary.

This mode of thinking may be a result of rural education extending little beyond the basics. While many of the people of rural Honduras have a basic education and are functionally literate, they generally do not advance beyond a sixth-grade level. This form of education does not advocate critical thinking skills. As the teachers themselves are not educated beyond the high school level, their curriculum emphasizes conformity and rote memorization. This must be taken into consideration, then, when presenting information or choices to people.

Hopefully, the cycle of poverty and lack of education will begin to be broken, so that future generations can grow up healthier, have a greater capacity to compare choices, and have the self-esteem to risk going against the majority. It appears that the current generation of adults expects, and even wants, to be told what to do, in order to be "rewarded" with a development project.

4.2.6 Parachute Project Problem

Apparently, there was also much talk among part of the community that Peace Corps is a joke for Sabanetas. The reason for this comment, I would guess, was because the project was progressing slowly, and they were becoming discouraged. In addition, they have been accustomed to having a development agency arrive, do the project, and leave. I do not believe that the community has ever had to organize itself, and be responsible for a project. Perhaps church buildings have been the only community projects that they have organized and built on their own.

A PCV who lived in Sabanetas for two years provides two examples of failed projects, both of which show an organization neither communicating well with the villages nor following through with training (Hildner 2004):

> Improved wood burning stoves – Rotary Club International, in the beginning of 2002, came to Sabanetas, announced that they would be building 40 improved stoves in the community, and asked the people to come to some meetings. In the meetings, it was never decided who would be the beneficiaries, but there were more than 60 houses in the community that needed stoves. In the end, by the time I arrived, Rotary Club was building the last stoves and, as far as I could tell, the people had given no input to the design of the stoves, design of the project, the identity of the beneficiaries, or even the actual construction of the stoves. From what I saw, the engineer would arrive in a pickup truck in the morning with materials for two stoves. He would go into one house in the morning and come out with the stove built in the afternoon, then proceed to another house, install another stove, then leave. Some houses received two stoves. Others (about half of the families) received none, despite their persistent attendance to the meetings. The beneficiaries of the products were not trained to use of the stoves until a year after the project was completed. By that time, many of the parts of the stoves (the clay fire pots, the iron stove tops, the chimneys) had broken due to misuse and lack of maintenance.
>
> Chicken coops – In several houses near the center of Sabanetas, a small group of villagers organized to ask for help to build chicken coops for healthier, more productive chickens. A ministry of the Honduran government provided all the materials, but no training, and several months later the materials were missing from each house or useless because of wear. The chickens roam without limits in each of the houses of the beneficiaries.

Projects like these probably lead the villages to expect failure from aid projects. To work successfully with them, then, one would have to overcome the historical inertia of these expectations.

5 Technical Engineering for Water System Design

The activities of the water and sanitation engineer focus on the technical tasks related to the construction and operation of community water and sanitation systems. The clients for whom the engineer performs these activities include host country agencies and rural communities. Summarized in this section, these topics are explored in detail by Reents (2003), Niskanen (2003), and Jordan (1980).

5.1 Site Reconnaissance and Project Feasibility

An essential first step in most infrastructure development projects is to determine the scope of the project, its feasibility, and the willingness of the community to participate. As social and economic aspects were covered in the previous section, here the focus is on the technical information for planning. Davis (1993, p79) recommends collecting the following information:

- The hydrology, geology and topography of the area
- Existing water sources
- Water quality
- The effect of the seasons
- The availability of local technical skills
- The availability of construction materials
- Local services

Investigation typically starts with preliminary interviews of community members to define the project, be it a new water system, community training or education, or investigating problems in the water system. Information gathered can include population and demographics (included here as technical data), elevation measurements with an altimeter, age of water system, water flow at the sources, visual assessment of the water source, and flows of an existing water system. "A project should be considered feasible only if both the technical factors and human factors indicate success" (Jordan 1980: 17).

According to SANAA standards, the flow must be measured at the end of the dry season, from the beginning of April until the middle of May. If any rain showers occur during that time, the measurements must be delayed for two weeks after the event. For small streams, the measurement is made using the volumetric method, building a small dam and redirecting the water through a pipe into a five-gallon bucket. The bucket is filled at least five times, and the time required to fill it each time is recorded in a notebook. If one of the data falls outside the grouping of the others, it would be good to retake that measurement. The mean of the five data is then calculated.

If the preliminary investigations indicate that the project is feasible, additional information of a more technical nature is gathered. This can include analysis of water quality, inspection of water system components, and examining any existing plans, calculations, or documents.

5.2 Topographic Survey

Topographic surveys are typically executed with an Abney level, measuring tape and compass. An Abney level "is faster to use than a theodolite, and although not as accurate, yields results that are within acceptable limits for this type of survey" (Jordan 1980: 17). Along with members of the community, the technician plans routes for the conduction line and distribution network. The technician then teaches the community members how to measure distances and hold the target. Field notes must include both the numerical data and visual observations, including landmarks, stream crossings, road crossings, and the ease of excavation. Sometimes, when the topography is not too difficult, it is possible to conduct the survey with a GPS and barometric altimeter. The altimeter must be recalibrated frequently, and readings extrapolated to correct for change of air pressure during the day.

5.3 Water System Design

Water system design includes all tasks necessary to deliver to a client the information necessary to construct a water system. In Honduras, the designs are made in essentially the same way as expounded by Jordan (1980: 58-76). Typically water is collected in a springbox or dam, then delivered by conduction line to a storage tank where it is treated with sodium hypochlorite solution. From the storage tank, the water travels though a distribution network to private domiciliary taps.

Using a spreadsheet (Appendix C), design calculations are made based on the data collected in the topographic survey. The engineer must include all necessary storage tanks, pipe sizes, break pressure boxes, other valves, and domiciliary connections. The spreadsheet shows the resulting velocity, static pressure, dynamic pressure, and other data. These data determine if the design meets standard criteria for the materials and the system design (Reents 2003, see Appendix A). Adjustments are made to the pipe sizes and tank locations until the design meets or nearly meets these criteria.

If the water system requires a pump component, the pump and pump line should be selected after all of the other components are in place. The pump must meet the flow requirements of the design, and be sized appropriately for the dynamic pressure load, to operate near its highest efficiency. The process of finding the operational flow rate and hydraulic head is iterative, as explained in detail in the Appendix A of this document.

Drawings are made of plan views for all of the system, and a profile view for the conduction line. Usually these are made by hand, but if software and plotter are available, these can be created electronically. Included in these drawings are all parts of the design, plus topographic contours and landmarks. The final proposal has a complete list of materials, construction costs, and the prices of the materials. Normally these costs are divided between the community and the development organization. The development organization supplies expertise and materials such as cement, pipes, and valves. The community supplies manual labor and locally available materials, such as sand, gravel, and lumber. Appendix E of this report shows an itemized list for a complete proposal, including how the costs are distributed between organizations.

6 Engineering Evaluation and Design for Sabanetas

There were several major decisions for the design of the Sabanetas potable water system that fall outside of the typical design. The water might have been collected in a dam, springbox, or infiltration gallery, at any of several potential locations. For all but the infiltration gallery, the water would then flow by gravity to a cistern, from which it would be pumped to a storage tank. Calculations are made for several different pumps, including the one that the community already owns, to show the estimated electrical operating cost. The storage tank had two locations that were seriously considered. For each of these storage locations, all of the costs that would be different between them are summed in a table, one table for each tank. The final pump and tank choice is then discussed, reasons are given for the choice, and some basic comparisons are made to options that were not chosen.

6.1 Status of Equipment and Design

Selecting a pump is normally the last step in a system design, but the community had already bought the pump, without the complete and final design of the pressurized pump line. They chose the pump without regard to system requirements, specifically the dynamic pressure head. Section 6.3 explains why this makes the pump inefficient.

In addition, the community had already completed a topographic study and other plans with a previous Peace Corps engineer, but the design was inadequate. The original study markers had disappeared too, making revisions difficult to impossible. Another problem with the old study was that, with all the trouble and expense of buying and operating a pump, the proposed source was a low quality surface creek, no better than the water that they are currently using. The creek had an oily film, probably from horse and cow manure, and was downstream from pasture, farmland, and many potential sources of human contamination.

6.2 Evaluation of Water Source Alternatives

I have made three significant changes to the design of the water delivery system for the town of Sabanetas. Due to time constraints, I had to make each of these as a best guess, as a cost benefit analysis of each of the alternatives would have required more time than was available.

The first change was in the water collection design. When I arrived in Sabanetas for the first time, the plans depicted a location from which to obtain the water, but no structure had been proposed. Three possible alternatives were investigated:

- Design and build a dam or infiltration gallery at the original location.
- Find contractors or an agency to site and bore a well.
- Collect water in a dam or springbox further upstream.

6.2.1 Collect Water at the Original Point

I first considered using the original point, from the old topographic study. The study had not described any proposed collection method, so I proceeded to investigate the possibilities of using a dam or constructing an infiltration gallery.

6.2.1.1 Dam

The proposed area is low and flat, immediately downstream from a wetland, and with the potential for significant sedimentation. Even more significantly, the water sample tested positive for the presence of fecal coliforms. This is not surprising considering the initial observations of the oily surface and the nearby evidence of cattle. In addition, this location is downstream of many, perhaps 20, houses that could all be sources of human fecal contamination. I quickly dismissed the possibility of building a small dam.

6.2.1.2 Infiltration Gallery

An infiltration gallery is an underground structure, built near a river, to collect the subterranean flow of groundwater that is associated with the surface river. A large rectangular pit is excavated perpendicular to the river and filled with porous material, *i.e.* sand and gravel. A submersible pump is then installed in the gallery. The pumped water is then of higher quality than surface water, due to the filtering actions of both the surrounding soil and of the sand that is inside of the structure. This should eliminate most of the particulates and the fecal coliforms that would be attached to the particles. Some surface contamination, especially chemicals from agricultural runoff, would not be eliminated. Therefore, it is possible that taking water from this location, even with the filtering action of the infiltration gallery, would not resolve one of the main health issues of the community.


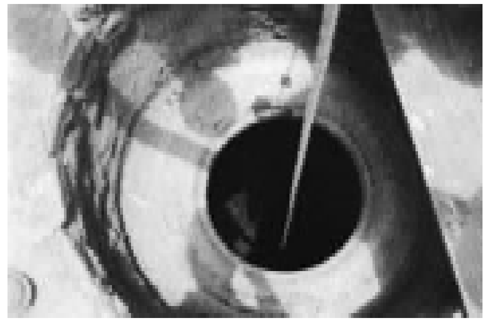

Figure 4. Raising water from a well.

6.2.2 Bored Well

The second alternative was to bore a well, where a submersible pump could be installed. Digging wells has high costs with no guarantees of meeting demand. However, this has good possibilities as the source of cleanest drinking water, without any of the contamination of the surface sources. This would also be less susceptible to the seasonal variation of flow that occurs on the surface.

Many households do use hand-dug wells in the area (Figure 4). However, the water in the one that I observed had visible sediments, and the capacity of this well was reported to be very small, just a few gallons per hour. A community well with pump would have to reach deeper to a more transmissive and cleaner aquifer.

I had hoped to find an expert that could locate and test potential well locations, but did not find any development agency that was interested in constructing a well in Sabanetas, and hiring a commercial enterprise would be an additional expense that the community could not afford.

6.2.3 Collect from Upstream Springs

The third alternative was to look for better sources farther upstream. By going farther upstream, some contamination from lower on the river course could be avoided. If a spring or springs with adequate flow could have been located, these might be one of the best sources of potable water. In addition, I also hoped to find locations that were more suitable for dam or springbox construction. It was clear that by collecting water upstream, frictional losses in appropriately sized tubing would be less than the slope of the stream, meaning that the pump inside a cistern could be located at a higher elevation than the stream surface, saving energy costs to pump water from cistern to storage tank. Most significantly, by collecting water farther upstream the water quality should be improved.

We walked upstream to investigate the possibility of collecting water from a group of four or five spring boxes. While it would be somewhat expensive to build four or five spring boxes for one small community, this may be more cost effective than the alternatives, while supplying the highest quality water. Pipes would connect all of the spring boxes to a small tank at the pump site. If the flow to this lower tank were smaller than the capacity of the pump, then some significant storage capacity would have to be built into the tank; otherwise, it would have to be no larger than what is necessary to house the pump.

These investigations revealed that most of the sources were very small, with only one of them having a flow greater than 1-2 gallons per minute, with a flow of about five gallons per minute. Piping the water from these other tiny springs to a central point was not feasible for both technical and cost reasons.

6.2.4 Selection of Water Source

Downstream from the undersized springs, there was a place where the water descended rapidly over bedrock terrain, which could be an excellent place to build a water-catchment structure. The stream flows through a narrow rocky channel, so construction at this point would be small and simple. The initial descent is steep, for rapid gain in pressure head. The immediate area is wooded, which helps with runoff contamination, but some contamination is still possible from upstream pastures. While not as ideal as collecting water in a springbox, this location is upstream from some of the contamination sources, about a kilometer from the originally proposed location.

Water piped from here would arrive at a cistern, at a higher elevation than the hypothetical nearby infiltration gallery. This configuration has the additional benefit of decreasing the required pump head, and long-term electrical cost. A submersible pump would be encased in a shroud, so that water would cool the motor as it would in a borehole. It would then be placed in a sump at the bottom of the cistern, with the intake at or below the level of cistern floor (Siirtola 2004).

I decided against the infiltration gallery for several reasons, as there were too many uncertainties. Firstly, these are uncommon in Honduras, so any construction supervisor would be unfamiliar with the kind of work that would be required. This is important because these men work based on personal experience, rather than from reading and interpreting design plans. Additionally, I was also not familiar with the site-specific design requirements for this type of structure, and did not believe that I could find the necessary resources.

On purely technical grounds, I never outright dismissed the second alternative, a bored well, but never located an organization that was excavating wells for no fee. I did dismiss the commercial approach as unfeasible for its costs and uncertain results: an unsuccessful perforation is costly, and the next attempt would be almost as expensive as the first.

6.2.5 Suitability of the Proposed Source

To verify the suitability of collecting water at this newly proposed location, the quality and quantity of water had to be measured. The mean of the five samples taken from the proposed source for Sabanetas, indicated a flow of 44 gallons per minute, more than adequate for the community needs.

A sample was sent to a laboratory for chemical testing. The sample tested high but within specifications for total coliforms, and showed no fecal coliforms. These non-fecal coliforms are of little concern, "particularly in tropical areas where many bacteria of no sanitary significance occur in almost all untreated supplies" (WHO 1997). The results for the topographic survey revealed that, with the 1100 meters of tubing that would be required, the pump can be located at about 15 m higher elevation than the hypothetical infiltration gallery location, can deliver reasonably clean water, and be much less expensive than digging a well.

6.3 Storage Tank Site and Pump Configuration

The next decision was to choose a tank site that would best serve the greatest number of residents, without incurring prohibitive additional construction costs. The tank site that had been selected by a previous PCV is of insufficient altitude to serve all of the community. This site may have been chosen for its proximity to the water source. There was, however, a better, higher site easily located about 800 meters greater distance than the original tank site, along the same ridge at the opposite end of the town center. While 800 meters is a significant distance for only eight meters of elevation, this extra elevation would significantly improve the quality of the proposal. More than half (thirty-four) of the houses in the proposal would have had severely inadequate water pressure (less than 5 meters estimated dynamic head) using the originally prescribed tank location.

After preliminary calculations, it was decided that the potential additional construction costs for the additional length of pump line would be a small percentage of the overall costs. The potential increase in the quality of household service, *i.e.* pressure at the tap, indicated that this new location warranted a

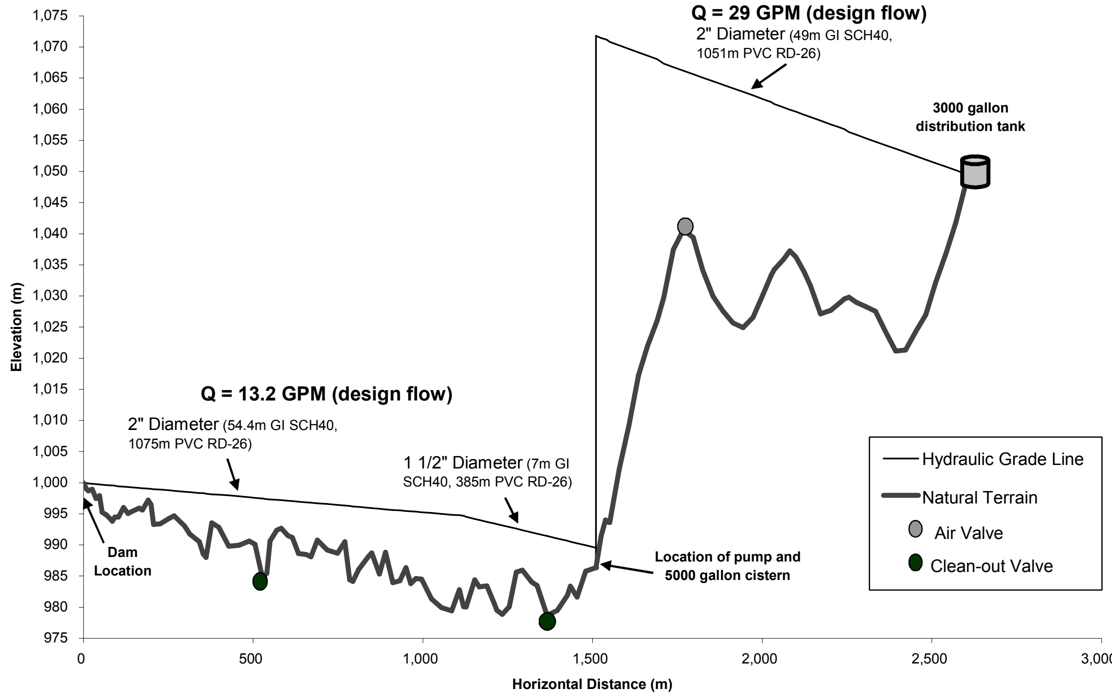

Figure 5. Hydraulic and terrain elevations of the conduction and pump lines for Sabanetas, Honduras. The elevation is based on an arbitrary datum.

complete design. The topographic survey showed that the length of pump line would be 1,110 meters and that the elevation of tank inlet would be 63.5 meters higher than the pump inlet (Figure 5).

A detailed analysis for the sizing of the pump and pump line was then completed (Table 3). The cost datum is arbitrary, since many of the common costs of the project are not included. Comparing these options is, in a way, easier than the other decisions in that it only requires research of various pump specifications, and making the corresponding calculations, rather than conducting field measurements.

It is also necessary to estimate the prices of pipe size for the conduction line and the long-term projected electrical costs. To simplify these calculations, it was assumed that future electricity and O&M costs would be proportional to population.

It was also assumed that the discount rate for future consumption would be equal to the population growth rate. Cost-effectiveness analyses usually use a discount rate between 3% and 5% (Weinstein 1996), while population growth rate estimates for Honduras range from 2.3% to 2.9% (CIA 2002, World Bank, Population Reference Bureau 2003). For water system design, usually a slightly higher growth rate is used; while SANAA recommends a rate of 3.0%, Peace Corps volunteers in Honduras commonly use a more conservative 3.2% - 3.5%. In part, this is because it is generally thought that if an area has a good quality water system, more people will immigrate to the local area, fewer will

Table 3. Comparison of potential pumps for transporting water to a storage tank located on the ground surface, but at a farther distance from the source in Sabanetas, Honduras. Using pump characteristics and pipe diameter, along with the distance and change in elevation, other items listed in the table are calculated to provide information on the monthly electrical expense per user. Relative differences in the costs of each option are summed on the bottom line. A complete explanation of these calculations is given in Appendix A. Compare to **Table 4**.

Make and Model **Design Capacity**	**Meyers Ranger** **50 gpm**	**Meyers Ranger** **50 gpm**	**Meyers Ranger** **25 gpm**	**Jacuzzi SandHandler** **25 gpm**	**Aeromotor 25 500** **25 gpm**	**Aeromotor 25-300** **25 gpm**	**ITT-Goulds** **25 gpm**
Pump Size (HP)	**5**	**5**	**3**	**3**	**5**	**3**	**3**
Flow (Q) (gpm)	**56**	**38**	**29.4**	**28.6**	**35.3**	**29**	**27**
Pipe Diameter	**3"**	**2"**	**2"**	**2"**	**2"**	**2"**	**2"**
Velocity (m/s)	0.78	1.18	0.92	0.89	1.10	0.90	0.84
Major Losses(m)	9.99	35.09	21.82	20.73	30.61	21.27	18.63
Minor Losses (m)	0.42	0.98	0.59	0.55	0.84	0.57	0.49
Total Dynamic Head (m)	73.91	99.57	85.90	84.78	94.96	85.34	82.63
Total Dynamic Head (feet)	242.41	326.58	281.76	278.09	311.46	279.92	271.02
Estimation of Pump Efficiency (Q*CDT)/(1204*HP)	68.7%	62.9%	69.9%	67.1%	55.7%	68.5%	61.8%
Electrical Consumption by Motor (7.46*HP/0.9) (kW)	4.14	4.14	2.49	2.49	4.14	2.49	2.49
Electrical Consumption by Sensors(kW)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Average Daily Hours of operation during the first year	2.2	3.3	4.2	4.4	3.5	4.3	4.6
Total Monthly Electrical Expense	**$36.61**	**$53.95**	**$49.25**	**$50.63**	**$58.08**	**$49.93**	**$53.63**
Monthy Electrical Expense per User	**$0.60**	**$0.88**	**$0.81**	**$0.83**	**$0.95**	**$0.82**	**$0.88**
Totlal Electicity Costs (years 1-10)	$4,393	$6,474	$5,910	$6,076	$6,969	$5,992	$6,436
Total Electricity costs (years 11-20)	$4,393	$5,910	$5,910	$5,910	$5,910	$5,910	$5,910
Price to Purchace another Pump	$1,176	$1,176	$894	$1,312	$0	$0	$1,456
Price of controls and sensors	$1,471	$1,471	$1,471	$1,471	$0	$0	$1,471
Price of tubing and accessories for pump line	$11,146	$7,436	$7,436	$7,436	$7,436	$7,436	$7,436
Cost to Excavate Additional Conduction Line Length	$340	$340	$340	$340	$340	$340	$340
TOTAL (excluding costs not affected by design choice)	**$22,919**	**$22,807**	**$21,961**	**$22,544**	**$20,656**	**$19,678**	**$23,048**

emigrate, and there would be lower infant mortality. However, I was unable to find any studies that quantified the impact of quality rural water systems on the population growth within the effective area.

With these assumptions, I only had to multiply the first year's electricity cost by the projected life of the project to arrive at a comparative analysis for the different pump options, assuming that differences in the other O&M costs between these choices would be negligible. A range of electricity prices, population growth rates, and discount rates also could have been tested in a sensitivity analysis, but in the interest of simplicity, I chose to use only the best estimate for these variables. The electricity costs for the life of the pump are added to the other costs that vary between the design alternatives, to establish relative price differences between them.

6.4 Cistern/Pump Location Decision

I had anticipated that the last major decision would be where to locate the pump. As topography would have it, there were three or four potential pump site locations, each just a few meters closer to the electricity source and a few meters closer to the storage tank location, at the expense of tens of meters of additional tubing. A formal analysis would have required comparing the costs of varying lengths of both the water piping, and the electrical wiring, depending on any of two or three potential locations. This was a great cost comparison question, but under time pressure, it seemed prudent to make a best estimate, and continue with other aspects of the project. Most likely, saving 50 - 100 meters of high voltage wiring, and perhaps a wooden pole, would have been worth adding an additional 300 meters of 2" PVC tubing to the conduction line. It would be interesting to evaluate if this was the lowest cost option.

6.5 Elevated Storage Tank Site and Pump Configuration

When the design was nearly complete, I learned that a water tower could be an acceptable design option. The SANAA engineer informed me that their office would be willing to supply materials for a water tower if it were appropriate for the design. This was a surprise, because when I first started with the project, I had been given the impression that a water tower was not acceptable, so I had not been considering it. I decided to explore the possibility, and compare the results with the surface storage tank that was discussed in Section 6.3.

I prepared an alternative design for an elevated storage tank, but in the interest of expediency, without conducting any further topographic survey. The purpose at the time was to verify if it would be reasonable and advantageous to change the design. The tank would be located close to the cistern, in the same location as the old, discarded proposal suggested, but now atop a 13.5-meter tower.

In the office, I extrapolated between established points to make new connections and assumed a cistern and pump location, upstream from the design proposed in Section 6.3. Terrain and distance were estimated to connect the cistern to the elevated tank, and some network connections were reconfigured. If this option were going to be used, additional topographic study would be necessary. The detailed design for this option is presented in Appendix D. The length of pump line would be 245 meters, and the elevation of the tank inlet would be 70.5 meters higher than the pump inlet.

Table 4. Comparison of potential pumps for transporting water to an elevated storage tank in Sabanetas, Honduras. Using pump characteristics and pipe diameter, along with the distance and change in elevation, other items listed in the table are calculated to provide information on the monthly electrical expense per user. Relative differences in the costs of each option are summed on the bottom line. Compare to **Table 3**.

Make and Model **Design Capacity**	**Meyers Ranger** **50 gpm**	**Meyers Ranger** **25 gpm**	**Jacuzzi SandHandler** **25 gpm**	**Jacuzzi SandHandler** **25 gpm**	**Aeromotor 25-500** **25 gpm**	**Aeromotor 25-300** **25 gpm**	**ITT-Goulds** **25 gpm**
Pump Size (HP)	**5**	**3**	**3**	**2.5**	**5**	**3**	**3**
Flow (Q) (gpm)	**49.7**	**32.7**	**30.2**	**25.5**	**37.4**	**31**	**29.5**
Tube Diameter	**2"**	**2"**	**2"**	**2"**	**2"**	**2"**	**2"**
Velocity (m/s)	1.55	1.02	0.94	0.79	1.17	0.97	0.92
Major Losses(m)	12.84	5.91	5.10	3.73	7.58	5.36	4.89
Minor Losses (m)	1.67	0.72	0.62	0.44	0.95	0.65	0.59
Total Dynamic Load (m)	85.04	77.17	76.25	74.70	79.06	76.54	76.01
Total Dynamic Load (feet)	278.93	253.11	250.10	245.02	259.31	251.04	249.30
Estimation of Pump Efficiency (Q*CDT)/(1204*HP)	70.2%	69.9%	63.8%	63.3%	49.1%	65.7%	62.1%
Electrical Consumption by Motor (7.46*HP/0.9) (kW)	4.14	2.49	2.49	2.07	4.14	2.49	2.49
Electrical Consumption by Sensors(kW)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Average Daily Hours of operation during the first year	2.5	3.8	4.1	4.9	3.3	4.0	4.2
Total Monthly Electrical Expense	**$41.25**	**$44.28**	**$47.95**	**$50.88**	**$54.82**	**$46.71**	**$49.09**
Monthy Electrical Expense per User	**$0.68**	**$0.73**	**$0.79**	**$0.83**	**$0.90**	**$0.77**	**$0.80**
Totlal Electicity Costs (years 1-10)	$4,950	$5,314	$5,754	$6,106	$6,578	$5,605	$5,890
Total Electricity costs (years 11-20)	$4,950	$4,950	$4,950	$4,950	$4,950	$4,950	$4,950
Pump & Motor Price w/o Accessories	$1,176	$894	$1,312	$1,312	$0	$0	$1,456
Cost of controls and sensors	$1,471	$1,471	$1,471	$1,471	$0	$0	$1,471
Cost of tubing and accessories for pump line	$5,562	$5,562	$5,562	$5,562	$5,562	$5,562	$5,562
Excess Cost to Construct an Elevated Storage Tank	$4,235	$4,235	$4,235	$4,235	$4,235	$4,235	$4,235
TOTAL (excluding costs not affected by design choice)	**$22,345**	**$22,426**	**$23,284**	**$23,636**	**$21,326**	**$20,353**	**$23,564**

Table 4 shows the costs associated with the water tank tower, which can be compared with the costs in Table 3, for the surface tank configuration presented in Section 6.3. The design presented here requires a shorter pump line, and less dynamic head at the pump, to provide all of the houses in the community equal or better pressure at the tap than with the other design. The only liability is the construction costs for the water tower.

Within either of these main design alternatives, the bottom line indicates that using the pump that the community already owns, the Aeromotor 25-500 (rated at 25 gpm, 5hp), would be a better alternative than purchasing another pump, even though this pump is not the best suited for the job (*i.e.* has a low efficiency). If the cost of replacing the pump were no object, then any of the other pumps, which would use less electricity, would be the better option.

Even better, however, is that the vendor agreed to exchange the 25-500 model for the 25-300 model, at no additional cost. This gave Sabanetas the opportunity to have an efficient pump, without incurring significant costs. The best pump for the job, then, would be the Aeromotor 25-300.

Table 5. Quality of service for each of the two storage tank locations. Ten meters of dynamic pressure is the generally accepted design criteria, so if the system were built using the surface tank near the cemetery, five houses would have substandard pressure.

Tower on the hill near pump		Surface near cemetary	
Pressure (m)	number of houses	Pressure (m)	number of houses
<18	7	<18	30
<14	3	<14	15
<9	0	<9	5

The decision between the two storage tank locations still needed to be resolved. Based on cost estimates, it would be slightly more expensive to build the water tower at the location closer to the pump. On the other hand, many issues with low dynamic pressure could be improved at several of the houses as shown in Table 5. Because these design alternatives were not purely technical, it seemed prudent to present them in simple terms to the Sabanetas water board and provide them an opportunity to choose what they deemed best for themselves.

6.6 Finished Design

In addition to design limitations imposed by community preferences, SANAA's available materials created limitations in the design. Since SANAA does not have 3" pipe on hand, this was not an option for the system, regardless of the additional long-term electricity costs that might be saved by using the larger diameter tube. The first column of Table 3 shows that this was a fairly expensive option, because of the extra cost of the hypothetical purchase of the larger pipe. It can be seen that this would have the lowest electrical usage. Since SANAA does have rebar and cement on hand, a tank tower was a good option, as far as the agency was concerned.

As previously discussed in Section 4.2.5, Sabanetas outright dismissed all options that involved the elevated storage tank, or tower. With all else staying the same, the tower option would have been more expensive than the surface-based option. This is because of the initial construction costs of the tower. There would be some savings on other areas, most notably for the pump line tubing, and in long-term electrical costs.

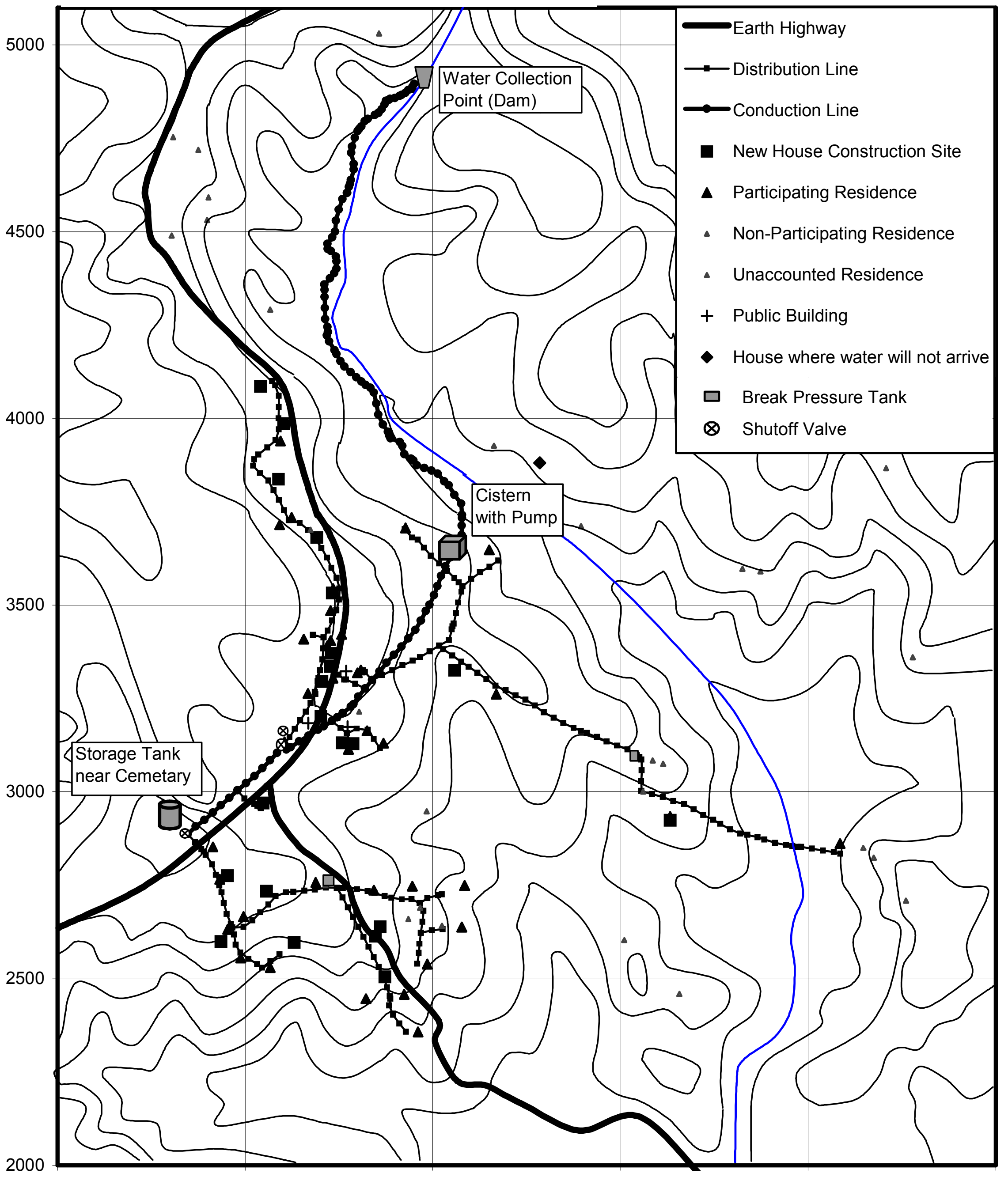

Figure 6. Map of final design of potable water system for Sabanetas, Marcala, La Paz, Honduras. All pipes are PVC except for short stretches across roadways, where GI is used. Water will flow at 13 gpm in 2" pipe from the dam to a 5000-gallon cistern. From the cistern, water will be pumped intermittently at 29 gpm, also in a 2" pipe, to a 3000-gallon distribution tank. The distribution network is composed of 2" down to ½" pipe. Note that one distribution line runs parallel, in the opposite direction, of the pump line. (UTM Zone 16, units in meters, easting –380000, northing –1550000).

Many of design options presented in the spreadsheets are then irrelevant, once SANAA and Sabanetas had made their own private decisions. Of the remaining options, all with the surface based storage tank and 2-inch pump line, the best choices utilize the brand of pump that the community already owns. Because they already own the pump, and the vendor was willing to make an exchange for the 3-Hp model, either of these would have been less expensive than buying another new pump. These calculations would be different if they were able to sell the pump that they currently own. Revenue from the hypothetical sale was not included in the spreadsheets.

Without a water tower, some of the houses would not have very good water pressure, because there is no hill high enough. The design for the distribution network was made with some tradeoffs between below-specification velocity, and below-specification pressure at the tap for several of the houses. Velocity is supposed to be at least 0.5 meters per second, and for this design, I let it drop as low as 0.3 meters per second. Five houses have less than 9 meters and as little as 5 meters of estimated dynamic pressure head, calculated at a flow rate of 1.63 liters per minute (lpm). This 1.63 lpm flow rate is the household proportion of the Community Maximum Hourly (CMH) flow, the maximum amount of water that the community is expected to use in any hour during the 20-year design period. Figure 6 shows a map of the completed design. Appendix E shows the completed project proposal.

7 Conclusions and Recommendations

There are many relevant components that must be considered for an infrastructure development project in rural Latin America: culture, education, local natural geography and community resources; agency characteristics, goals and resources; and the technical and communication abilities of all the players. Giving attention to all of these components is vital to meeting the organizational, social, and technical requirements for a successful technical community development project, such as a potable water system. It is important to start work with a community by conducting surveys of various types, including both technical information and socio-economic information. To discover more about “money matters”, a contingent valuation survey can establish economic preferences at a household level.

7.1 Further Work in Sabanetas

For the case study, I had not conducted any surveys, so in the process of working with the villagers, I eventually learned that an elaborate pump system was not appropriate. Despite the work that was involved in the pump design, I concluded that, based on organizational features and hidden preferences, it will not work for Sabanetas. The elaborate pumped water system is beyond the current capacity of the community to install and maintain. Aside from the initial expense of time and money, the long term operating costs of an electric pump may be beyond the capacity of many residents to pay. I present some alternative recommendations, with some of the basic advantages and disadvantages associated with them. Regardless of the project plan, however, it is essential that detailed communication and understanding be established before implementation.

A small gravity system could use the same proposed source, which meets health standards, with water traveling through pipes, and then ultimately hauled by bucket to the point of use. The water would be treated in a storage tank, with access at any of several public tap-stands. While the quality issues would be readily resolved, some residents might have to transport water up to one kilometer, which for some of them might be a farther distance than they haul water now. While water quality would be improved for every household, hand washing, bathing, and cleaning activities might remain limited due to quantities of available water at home. This points to important questions that a survey could help answer: Would people want to travel farther for their water than they do currently? Would they travel the extra distance for drinking and cooking water, but then use the closer sources for cleaning? Would they use laundry facilities at or near the tapstands?

Conversely, with reduced expenses, some of the poorest residents in the area may be more willing and able to participate. The proposal with the pump system has over ten households in its immediate sphere of influence, and an equal number on the periphery, which have chosen not to participate. It would be worth investigating the reason that they opted out, and if it was for financial reasons, a low cost project could be much more appealing. This could mean better health in the community and area as a whole than would be achieved by the more expensive and elaborate proposal.

Another possibility is to mitigate contamination of currently used water sources. This might involve reducing or eliminating the sources of contamination in the well that the villagers use. At an engineering level, this could achieve project goals with the lowest level of inputs. This may require relocation or closure of some of the wells, or change in agricultural practices near others. At a social engineering level this could prove to be difficult, but worth investigating, again with the recommended surveys.

Finally, it may serve well to conduct a forum with community members to find other potential solutions. The villages may have other ideas of their own. Perhaps in the right idea-generating and decision-making environment, they could imagine solutions that an outside agent would not consider.

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