7-5-2012

Sustainable water supply for the Village of Kpandu Dafor, Volta Region, Ghana

Amy Louise

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By

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A Professional Project Submitted in Partial Fulfillment of the Requirements
For the Degree of
Master of Water Resources
Hydroscience Concentration
Water Resources Program
The University of New Mexico
Albuquerque, New Mexico
December 2004

Committee Approval

The Master of Water Resources Professional Project Report of **Amy Louise** is approved by the committee:

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Acknowledgements

I would like to thank Dr. Vannetta Perry, for reaching out to Michael Campana to find a graduate student interested in a professional project in Africa. Dr. Perry and Dr. Kodzo Gavua, Professor of Anthropology at University of Ghana, suggested designing a water distribution system for Kpandu Dafor. Dr. Perry introduced me to her village, Wusuta, a few miles north of Kpandu Dafor, and her contact, Dr. Gavua, who opened his home to me in Accra for a few days during my trip in March 2004. I would like to thank Dr. Gavua for helping me gather data from the village and for his encouraging words. Dr. Perry introduced me to other friends of hers in Africa and has encouraged me.

Dr. Michael Campana helped me financially by allowing the Water Resources Program to purchase an airline ticket to travel to Ghana in March 2004 and for encouraging me to apply for a RPT grant with Office of Graduate Studies (OGS). I thank the OGS for approving the grant. Also, I would like to thank the U.S. Department of Agriculture for the paid internship I received during the spring 2004 semester.

Thanks go to Dr. Bruce Thomson for his kindness and design expertise.

I would like to thank my family and friends for their emotional support while pursuing this degree.

I would also like to thank New Mexico Office of State Engineer, Water Rights Division, especially Nancy Cunningham, because I was allowed to work part time while I attended college full time.

Also, I would like to thank the people of Kpandu Dafor for their hospitality, openness, and celebrations. I express thanks to Ghana, Africa, for an adventurous journey.

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Abstract

This report describes the design of a water distribution system for the village of Kpandu Dafor. The water distribution system consists of the source of water, four designs of the distribution system, water-storage tank, septic tank systems, and chlorination system. The source of water was one of the three boreholes that can provide water at 70 or 80 liters per minute (Lpm). EPANET was used to develop the four different pipe designs for the water distribution system. The pipes were designed to be 24.5-, 32-, 50-, 63-, and 90-millimeter (mm) polyvinyl chloride (PVC) with flow of 0.225 liters per second (Lps) for each tapstand and stubout. Three of the designs consist of twenty tapstands with approximately five homes per tapstand and six stubouts and one design with ten tapstands with approximately ten homes per tapstand and six stubouts. There were six stubouts located at Togbe Debresu VIII's (Chief of Kpandu Dafor) home, four community flushing toilet facilities, and one at the new Catholic church. Currently there is only one building with indoor plumbing, the Chief's home. The village is currently seeking funding for the new Catholic church that will have indoor plumbing.

For sanitation purposes, septic tank systems were located at the locations of the six stubouts. The septic tank systems were not designed. The one existing septic tank system is located at the Chief's home. Also, four roofed concrete washing table stations for washing clothes were designed for sanitation purposes. The four community-flushing toilet facilities were designed to have four flushing toilets each and two sinks each and will be located at the school grounds and the existing community toilet facilities. A water chlorination system was necessary since the water would be stored in the tank. The water

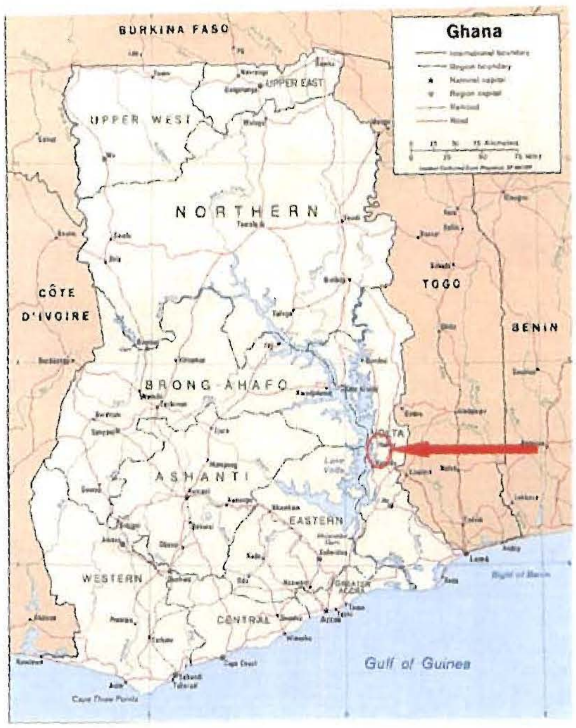
storage tank's capacity of 60,000 liters was based on a 1.8% per year growth rate for twenty-year design period.

A geographic information system was used for the visual representation of the water distribution system. The capital cost of the water distribution system is approximately $72,000 United States (US) dollars or 720,000,000 Cedis for a 20-tapstand system or approximately $61,000 US dollars or 610,000,000 Cedis for a 10-tapstand system with an exchange rate of 10,000 Cedis per one US dollar. A water committee design was provided so there would be guidance for system operation, maintenance and access to water. A list of potential funding agencies was also provided for the village, so the village can seek money to build the water distribution system.

Introduction

The country of Ghana (Figure 1), located in West Africa, is bounded by the Gulf of Guinea on the south, Cote d'Ivoire on the west, Burkina Faso on the north, and Togo on the east. Kpandu Dafor (Figure 2) is located within the Volta Region in eastern Ghana between Lake Volta, the largest reservoir in the world, and the country of Togo. There are approximately 500 people living in the village of Kpandu Dafor. Currently there is no water distribution system for this village. Lake Volta and three boreholes are the source of water. Women who cannot afford to buy the water from the boreholes use Lake Volta for drinking and domestic purposes.

Figure 1: Ghana, West Africa



http://www.cnmat.berkeley.edu/~ladzekpo/maps.html

Figure 2: Ghana, showing Kpandu Dafor on the eastern shore of Lake Volta north of Kpandu

The United States Geological Survey (USGS) Africa Data Dissemination Service (USGS, 2004) indicates that in 2000 the life expectancy was 57 years, the education level was one year, and literacy rate was 65%. The 2000 Population Census indicates Ghana had population of 18,412,247. The ethnic groups include the Akan (49.1%), Mole Dagbani (16.5%), Ewe (12.7%), Ga-Dangme (8%), and the remaining (13.7%) are not Ghanaians. The Volta Region's population was 1,612,299 and predominantly Ewe (Gavua, 2000; Ghana Home Page, 2004). There are approximately 500 people living in the village of Kpandu Dafor and the language is Ewe and English.

The currency in Ghana is the Cedi. The exchange rate was 10,000 Cedis per one US dollar in March 2004. According to IRIN (2004), a United Nations humanitarian information unit, the minimum wage is approximately 10,000 Cedis or one US dollar per day.

Predominantly, the people in the Volta Region are farmers. The occupations in the village of Kpandu Dafor include farmers, business owners, seamstresses/tailors, barbers, fishermen, fishmongers, and teachers. The women are typically farmers and fishmongers.

The village council is made up of Togbe Debresu VIII (Chief of Kpandu Dafor, Figure 3), elders, sub-elders, and three women leaders. One of the women is the Queen Mother who represents all the women in the village. The Queen Mother makes the ultimate decision over who the Chief of the village will be, so the role is very important (Perry, 2004, personal communication). There are no other organizations in the village.

Figure 3: Togbe Debresu VIII

The objectives of this report are to design a water distribution system and a committee or governance structure to provide system operation, maintenance and access to water. The sustainable water supply will decrease the workload on the women and provide good quality water for domestic purposes at low to no cost. When good quality water at low to no cost is used, health, sanitation, and hygiene are increased.

History of Water Supply

During the pre-colonial era, sources of water supply were dug wells, ponds, streams, and rainwater harvesting from roofs. Even though colonial rule began in 1844, the colonial government assumed responsibility in 1900 for public water supply in urban and rural areas because of droughts, population growth and large communities. The Public Works Department was formed to investigate issues of water pollution that led to health problems in urban areas. In 1920, the Geological Survey Department was requested by the government of Ghana to offer assistance in locating the optimum location for wells. A water supply division was developed in the Geological Survey Department in 1937 to investigate new sources of water supply, well digging, lining, and maintenance, and sanitation issues. The Department of Rural Water Supply was created in 1944 to manage rural water supply issues. The department helped develop water from small sources and trained and supervised "native administration staff" (Gyau-Boakye, 2001). Mechanically drilled boreholes with piped supplies were provided to large communities. The Department of Community Development of the Ministry of Social Welfare and Community Development and the Department of Agriculture also assisted with rural water supply. "The technology used were mainly hand-dug wells, with or without hand pumps, Henderson Boxes for the development and protection of springs, rainfall harvesting from roofs, infiltration galleries, dug-outs, and small dams" (Gyau-Boakye, 2001).

Independence in 1957 created the impetus to improve water supply by establishing the Ghana Water and Sewerage Corporation (GWSC) in 1965. The GWSC

is responsible for supplying potable water to rural communities mainly from ground water sources. Ground water is the most economical source of rural potable water supply based on a 1975 study, due to the poor quality of the surface water. Developing potable water from surface water costs twice the amount (Gyau-Boakye, 2001). "According to the 1984 population census approximately 40.7 percent of the rural population, depend on boreholes and wells for their water supply needs" (Gyau-Boakye, 2001). In March 1998, approximately 52 percent of the rural population depended on ground water for their water supply.

Social Aspects

Water and Gender Roles

Gender perspectives are not always taken into account due to the power dynamics in communities. Experience has shown that project effectiveness is increased if both women and men (rich and poor) are involved (United Nations Development Program (UNDP), 2003). "Traditional gender roles assigning different responsibilities to women and men have resulted in political, cultural and economic barriers that restrict women's access to natural resources. For example, women are frequently excluded from decision-making" (Pearl, 2003). Gender roles are different for men and women in the management and use of water. "In most parts of the world, women and girls are responsible for collecting water for cooking, cleaning, health and hygiene, and if they have access to land, growing food" (Pearl, 2003). Since men's work is paid labor, men are not involved in fetching water. Due to the amount of time it takes to access water, females do not have time to be involved in activities such as "education, income generation, cultural and political involvement, and rest and recreation" (Khosla and Pearl, 2003). A *woman's*

"water-related work is taken for granted and denied its economic and social value" (Bulajich, 1992). However, men are involved if there is paid labor such as infrastructure for irrigation.

Because women are responsible for the management of the household, it is necessary for women to be part of the decision-making, so their needs and concerns are addressed. "If women are to be integrated in the work on a water project, the starting point must be that women should participate in public matters on equal terms with men" (Jorgensen, 1984). Although the women leaders were involved in the first water system meeting, women were not treated equally. Simon (Figure 4), my guide, took me to the location of the proposed water reservoir (top of the hill), three boreholes, three community toilets, lakeshore, Catholic church, primary and secondary schools, and location of the proposed pipeline. Togbe paid him. On the other hand, I do not know if Georgina (Figure 5, on the left) got paid when she accompanied me to the market in Kpandu and the Catholic church on Sunday.

Figure 4: Simon

Figure 5: Georgina, Amy, and Naomi

In Kpandu Dafor, the women pump attendants do not get paid, but they do get water for working. Older women are selected as pump attendants (Figures 6, 7, and 8) because they do not work in the fields during agricultural periods. "The duties of a pump attendant include preventative maintenance, minor repairs and reporting breakdowns to headquarters" (Hannan-Anderson, 1985). The attendants also collect the 100 Cedis per 19 liters of water. It is interesting that "a male worker who installs water pipes in a house in the city is considered 'economically active,' whereas a woman who fetches 40 liters of water once or twice a day, is only doing 'household work'" (Hannan-Anderson, 1985).

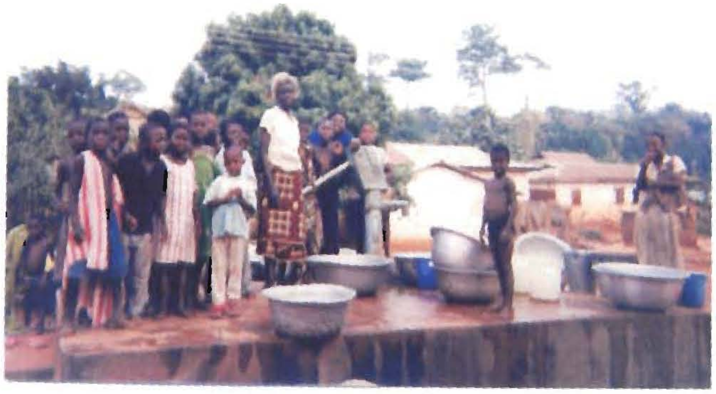


Figure 6: Pump attendant for Borehole 1

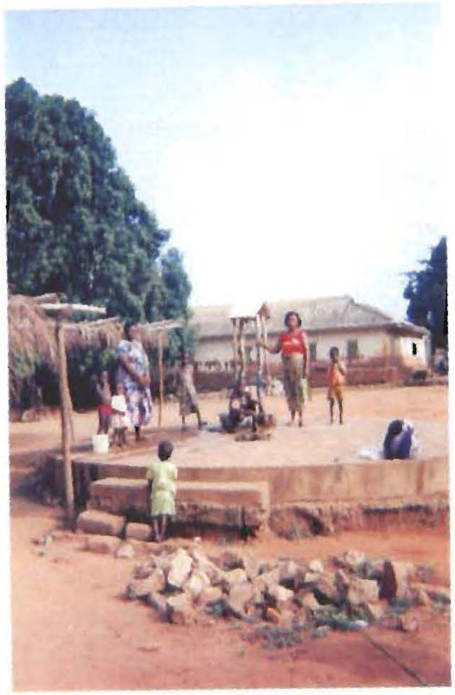


Figure 7: Pump attendant for Borehole 2

Figure 8: Pump attendant for Borehole 3

Safe, sufficient amounts of water and sanitation are "essential to health and well-being, and to empower people, especially women, through a participatory process of water management" (Khosla and Pearl, 2003). "By involving women, particularly in the planning, design, operation, and maintenance stages as well as in health education programs, water and sanitation projects could more effectively achieve the ultimate goals of more and safer water, resulting in better health" (Bulajich, 1992).

Women and Participation

"If women are to be integrated in the work on a water project, the starting point must be that women should participate in public matters on equal terms with men" (Jorgensen, 1984). Women were present at the first meeting when I arrived at the village of Kpandu Dafor. It was essential I ask the Chief, elders, sub-elders, and three women leaders if I could design a water distribution system for the village. The representative for the Queen Mother and two other women leaders were present. Women's needs and concerns such as distance for carrying water from tapstands, distribution and number of washing table stations, and number of community flushing toilet facilities were included in the design. It was recommended women be involved in all aspects of the development of the water distribution system. However, practically, it will be the funding agency that decides if the gender equality recommendations will be implemented. The agency should involve women in the entire process of development and maintenance. Women need to be trained on the maintenance of the water distribution system for the system to remain functional. Women should be encouraged to participate in the in-kind labor when the system is built and be trained in repairing the system.

With a decrease in amount of time spent fetching water, more time can be spent on other activities such as education and production. "The water project should include a job and education component which could be offered to women who are interested" (Jorgensen, 1984). "Thus, for more than 25 years global UN conferences have repeatedly recognized that effective sustainable water resources management depends on the involvement of women in decision-making and on mainstreaming gender at all levels" (Women's Environment & Development Organization (WEDO), 2004).

The Kugeria Women's Group has learned how to build and maintain a water system for 300 families. Because of the system, sanitation has improved with a reduction in waterborne diseases. Also, the additional time spent looking for water is now used for agricultural production. The system is also used for irrigation, so the people no longer have to beg for food during drought. According to Pearl (2003) the women have "become leaders, moving from bare survival to contribution. Project management training for women's groups has helped to ensure the sustainability of this venture and it has resulted in further community development initiatives, including the building of a clinic and the provision of family planning services to their community."

Health, Sanitation, and Hygiene

"Women carrying water are frequently exposed to malnutrition, anemia and water-related diseases" (Dufaut, 1988). Women experience health hazards such as skeletal problems due to carrying heavy loads of water. Animals are usually not used for carrying water because poor families cannot afford them or the male heads of household claim the animals. A water distribution system will reduce the burden on women. "By reducing energy requirements, women will be less vulnerable to malnutrition; by providing safe water the incidence of water-related diseases will decrease; by reducing walking distances the skeleton will not suffer as much, and one of women's many carrying tasks will be considerably reduced" (Dufaut, 1988). Also, with introduction of an improved water supply, diarrhea cases have decreased (Jorgensen, 1984).

"Water is essential to human beings and all forms of life. But pollution and lack of access to clean water is proliferating the cycle of poverty, waterborne diseases, and gender inequities" (Khosla and Pearl, 2003). Family health is considered female's

responsibility. However, women are not included in the decision-making on sanitation and hygiene issues. Toilets (Figures 9, 10, and 11) are usually placed at a distance where it is a safety risk for women and there may not be privacy. In Kpandu Dafor, clapping hands before entering the vicinity is used to allow for privacy. If someone is present, they also clap their hands (Simon, 2004, personal communication). Proper hygiene and sanitation practices can reduce common water-borne diseases with education. According to the World Health Organization, 80 percent of all sickness is attributable to unsafe water and sanitation. Waterborne diseases kill approximately 3.4 million people, mostly children, each year. Diseases such as diarrhea, malaria, schistosomiasis, and hepatitis sicken millions of people, but are preventable with clean water and education.

Figure 9: Community toilet 1

Figure 10: Community toilet 2

Figure 11: Community toilet 3

"In their roles as caregivers and household and natural resource managers, women are most affected by the current global water crisis" (Khosla and Pearl, 2003). Women and girls are infected with schistosomiasis when they stand in infested water while washing clothes or fetching water. Boys obtained schistosomiasis while swimming in the infested water. Typhoid is common, and cholera is rising with women and children being most vulnerable (Amenga-Etego, 2001).

Elimination of All Forms of Discrimination against Women (1979) and the Convention on the Rights of the Child (1989)" (Amenga-Etego, 2001). Disconnection from a water supply would be a violation of international law (Amenga-Etego, 2001). Everyone should have a right to water, especially the poor. However, the World Bank is defining water as an "economic rather than social good" (WEDO, 2003).

Defining water as an economic good rather than a social good encourages privatization. Privatization has a negative impact on health and safety. Some entrepreneurs are interested in making a profit while supplying water to poor people. Women are forced to choose between buying good quality water and buying food for their families. According to IRIN News Organization (2004), private owners sell water to the poor for three times as much. When women have to travel greater distances to search for water, this decreases the time required to grow and prepare food and increase income. Neoliberalism has affected both men and women adversely. The needs of the poor are not met when selling water on the open market. The poor cannot afford to build the water systems necessary to provide good quality water; however, the government of Ghana provides assistance to communities that can contribute 5 to 7% of the capital costs needed for a water system. Many communities cannot afford to contribute 5 to 7% towards a water system.

The active financiers for privatization are the Department for International Development (DFID) of the United Kingdom and United States Agency for International Development (USAID). The government of Ghana relies on the World Bank and International Monetary Fund (IMF) for policy direction because it does not have a water sector policy of its own. Water rates will continue increasing until a market rate is

achieved under the IMF and World Bank policy prescriptions for Ghana. Water meters limit access of the poor to water systems as described above in Wusuta. If people are unable to pay, they will drink contaminated water. According to Amenga-Etego (2001), "the Information Memorandum prepared for donors by Stone & Webster stipulates that the prospective investors will not be responsible for providing water to low-income communities in the urban areas. This remains the responsibility of the Government of Ghana." A study conducted by an economics consultant, London Economics, projects that with privatization, poor communities spend 8% to 25% of their monthly incomes on water and the non-poor spend 4.6% of their monthly incomes on water (Amenga-Etego, 2001).

Geography

Ghana lies between latitude 4.5°N and 11.5°N and longitude 3.5°W and 1.5°E and has a total area of 238,533 km^2. The highest elevation of 880 meters above sea level is at Mount Afadjato in the Akwapim-Togo Ranges. The five distinct geographical regions include the Low Plains (southern Ghana), Ashanti Uplands (north of the Low Plains), Akwapim-Togo Ranges (north of the Low Plains), Volta Basin (north of the Low Plains) and the High Plains (north and northwest Ghana) (Gyau-Boakye, 2001).

Climate

Ghana is influenced by three air masses, i.e., the Southwest Monsoon, Northeast Trade Winds, and Equatorial Easterly. The Southwest Monsoon is warm and moist and originates from the Atlantic Ocean. The Northeast Trade Winds (Tropical Continental Air Mass) originates from the Sahara Desert (Gyau-Boakye, 2001). The *Harmattan (*Figure

Basic Right versus Economic Good

Access to water, sanitation and hygienic conditions is a fundamental human right. Appleton (2000) indicates there is a strong link between "water, sanitation and hygiene improvements and human development as a whole." Health is improved if basic needs are met and income can be used for other activities. Poorer people pay as much as 12 times more for water than wealthier people with water piped (Appleton, 2000; Amenga-Etego, 2001). Neoliberalism economic policies and privatization, i.e., free trade and government deregulation have impacted many countries severely. "Privatization of water, and indeed all other natural resources, is increasingly infringing on people's rights and livelihoods around the world, most severely on poor women and girls. Water privatization perpetuates gender inequalities by relying on traditional gender roles that have made women and girls responsible for and the main suppliers of water to their families and households" (WEDO, 2003). Privatization has resulted in decreased water quality, enormous price hikes, reduced water availability, and health and sanitation dangers (WEDO, 2003). However, some organizations consider women in sustainable development.

"WEDO is an international advocacy organization that seeks to increase the power of women worldwide as decision-makers at all levels to achieve economic and social justice, democratic governance, and sustainable development" (WEDO, 2003). Under the international human rights law (International Covenant on Economic, Social and Cultural Rights), "all people have the right of access to the amount of water required to sustain life and fulfill basic needs" (WEDO, 2003). "The right to water is also explicitly mentioned in two existing international treaties, the convention of the

12) causes poor visibility from November to March because it blows sand from the Sahara in North Africa towards the Atlantic (Neufeldt and Guralnik, 1991). The Southwest Monsoon and the Harmattan flow towards each other into a low-pressure belt called the Inter Tropical Convergence Zone (ITCZ). The ITCZ causes wet and dry seasons.

Northern Ghana experiences one rainfall season, and southern Ghana experiences two rainfall seasons. Southern Ghana receives more than 2000 mm of rainfall a year. The southeast coastal plains are the driest part of the country with precipitation of 800 mm (Gyau-Boakye, 2001). The annual precipitation varies between 1000 to 1140 mm (Ocasney, 2003). "The total annual runoff is on average 41.6 billion m^3" (Andah et al., 2003). Humidity ranges between 20 to 100 percent, highest on the coast and lowest in northern Ghana (Gyau-Boakye, 2001).

Figure 12: Poor visibility caused by the Harmattan

Hydrogeology

The Basement Complex and the Paleozoic consolidated sedimentary formations are the two main hydrogeologic formations in Ghana, covering 54 percent and 45 percent of the country, respectively. One percent of the country is made up of Cenozoic and Mesozoic sediments consisting of "unconsolidated alluvial sediments, beach sand, red continental deposits of mainly alternating limonitic sand, sandy clay gravels, marine shale, limestone, and glauconitic sandstone" (Gyau-Boakye, 2001). The Basement Complex comprises the Precambrian crystalline igneous and metamorphic rocks. It is subdivided into the Birimian, Dahomeyan, Togo, and Tarkwaian Formations and consists mainly of gneiss, phyllites, schists, migmatites, granite-gneiss, and quartzites. The Paleozoic consolidated sedimentary formation or Voltaian Formation consists mainly of sandstones, shale, arkose, mudstone, sandy and pebbly beds, and limestones.

Ground water in the Basement Complex and the Voltaian Formation occur with secondary porosity from jointing, shearing, fracturing, and weathering since they have no primary porosity. The weathered zone and fractured zone are the two main types of aquifers. The Cenozic sediments are associated with three aquifer formations known as the unconfined aquifer, intermediate aquifer (semi-confined or confined) and limestone aquifer (artesian). According to Driscoll (1986), an artesian well is "a well deriving its water from a confined aquifer in which the water level stands above the ground surface."

Recharge is through "direct infiltration precipitation through fracture and fault zones and through the sandy portions of the weathered zone. Some recharge also occurs

through seepage from ephemeral stream channels during the rainy seasons" (Gyau-Boakye, 2001).

Source of Water

Each of the three boreholes was drilled in 1982 by Danish International Development Agency (DANIDA) with yields of 70 and 80 Lpm. Borehole 2, closest to the Chief's home, was used for the source of supply (Figure 7). It is unknown if the well's yield is 70 Lpm or 80 Lpm. The pertinent borehole record information is shown in Table 1 below. A 3 horsepower electric submersible pump with 1.26 Lps flow and 122 m of head will pump the water from the well to the reservoir. The pump will operate no more than 12 hours per day. Pipe can be laid easily near the schools and the borehole is closest to the water storage tank. A locked pump house will be necessary to protect the borehole and pump because the villagers are accustomed to using the borehole to fill up their pans for their water supply.

Table 1: Borehole records

BOREHOLE RECORDS			
FACILITY LOCATION CODE	**KPBO8B11**	**KPBO8B12**	**KPBO8B13**
DATE	09/07/1982	12/07/1982	10/07/1982
YIELD (Lpm)	80.00	70.00	80.00
STATIC WATER LEVEL (m)	3.40	7.70	10.57
SPECIFIC CAPACITY (Lpm/meter)	4.33	4.17	9.67
AQUIFER ZONE (m)	40 - 49	43 - 49	40 - 49
BOREHOLE DIMENSION (m)	0.215 (0 – 28 m)	0.215 (0 – 24 m)	0.215 (0 – 29 m)
BOREHOLE DIMENSION (m)	0.615 (28 – 49 m)	0.615 (24 – 49 m)	0.615 (29 – 49 m)
CASING (m)	0.100	0.100	0.100

(Water Research Institute, 1982)

Water Distribution and Storage System

Initially there will be six buildings with indoor plumbing connected to the water system: three community flushing toilet facilities, one school flushing toilet facility, the Chief's home, and the Catholic church. The community flushing toilet facilities will be where the existing community toilets are located. Each of the facilities will have four flushing toilets and two sinks each. The village inhabitants do not want community showers. The six buildings are indicated as stubouts in maps of the water distribution systems in Figures 13, 14, 15, and 16.

Pipe Designs

Pipe designs 1, 2, and 3 incorporates twenty tapstands, and pipe design 4 incorporates only ten tapstands. Pipe design 4 was included because the potential funding agency may install only ten tapstands instead of twenty. The pipeline designs were based on the approach in EPANET (United States Environmental Protection Agency (USEPA), 2004) and shown in Figures 17, 18, 19, and 20. Tables 2, 3, 4, and 5 show the nodes, pressures, demands, elevations, and heads for each of the four designs.

Gate valves (Figure 21) were used at the branch points to serve as on/off control valves for repairs. Globe valves (Figure 22) were used at the discharge points to dissipate residual head. A valve box will be used at one location to control the gate valves except for the one at the reservoir. Tees were used at the branch points, and elbows were used at the end of a pipeline to stop the flow.

The elevations for the designs were determined by referring to the GPS points taken in March 2004, shown in Table 2, and the 2nd Edition 1952 British Directorate of Overseas Surveys map (Figure 23). Khalid Mehboob of Earth Data Analysis Center

(EDAC) at University of New Mexico assisted me in projecting the GPS points to the 1952 contour map (Mehboob, personal communication, 2004).

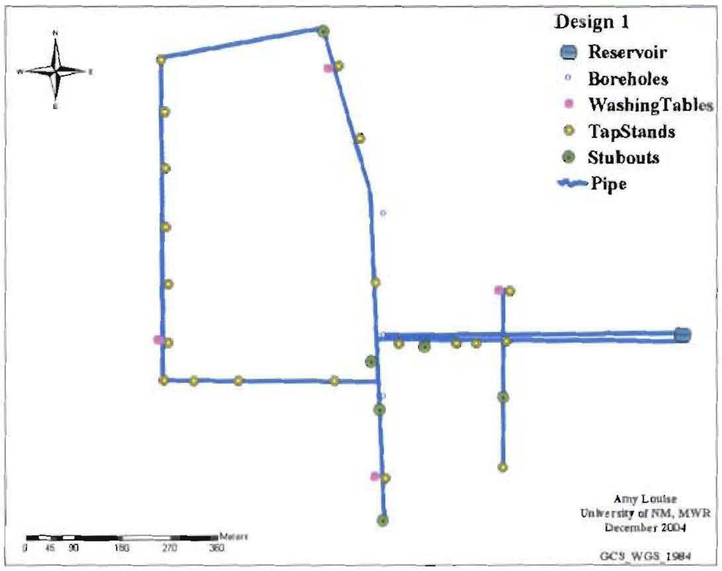


Figure 13: Pipe Design 1

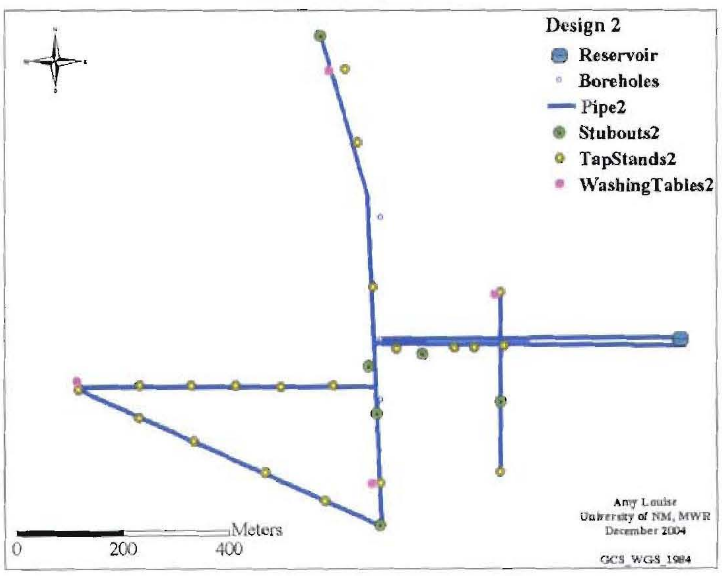


Figure 14: Pipe Design 2

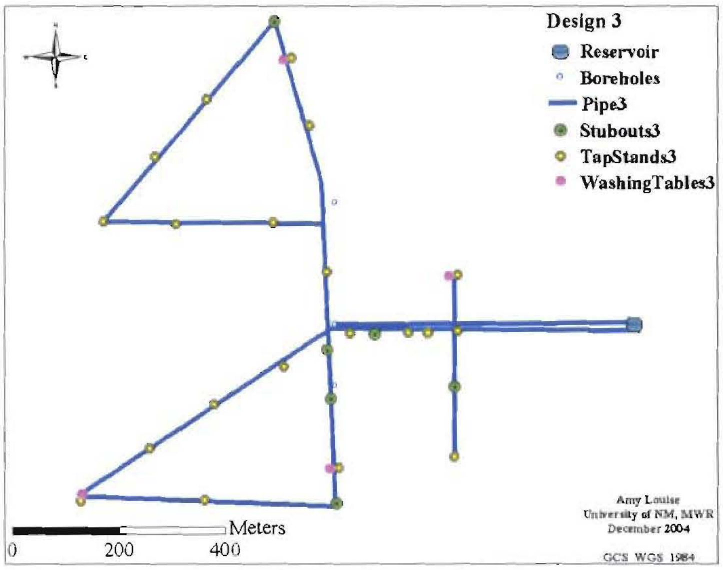


Figure 15: Pipe Design 3

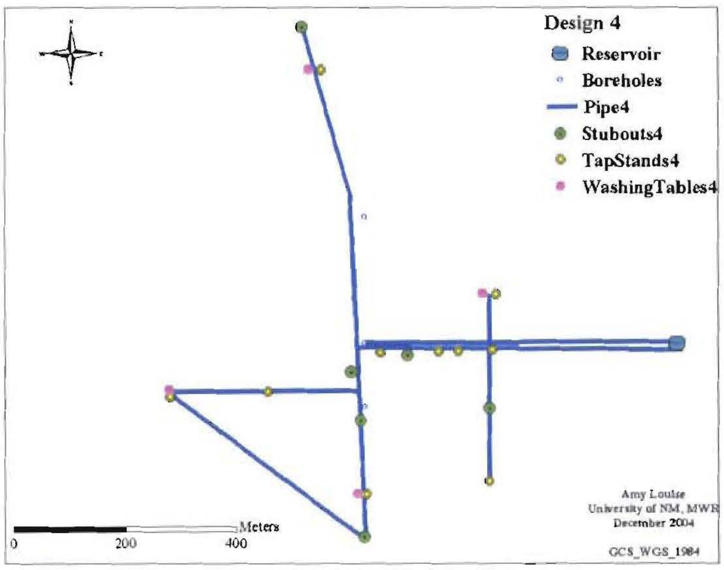


Figure 16: Pipe Design 4

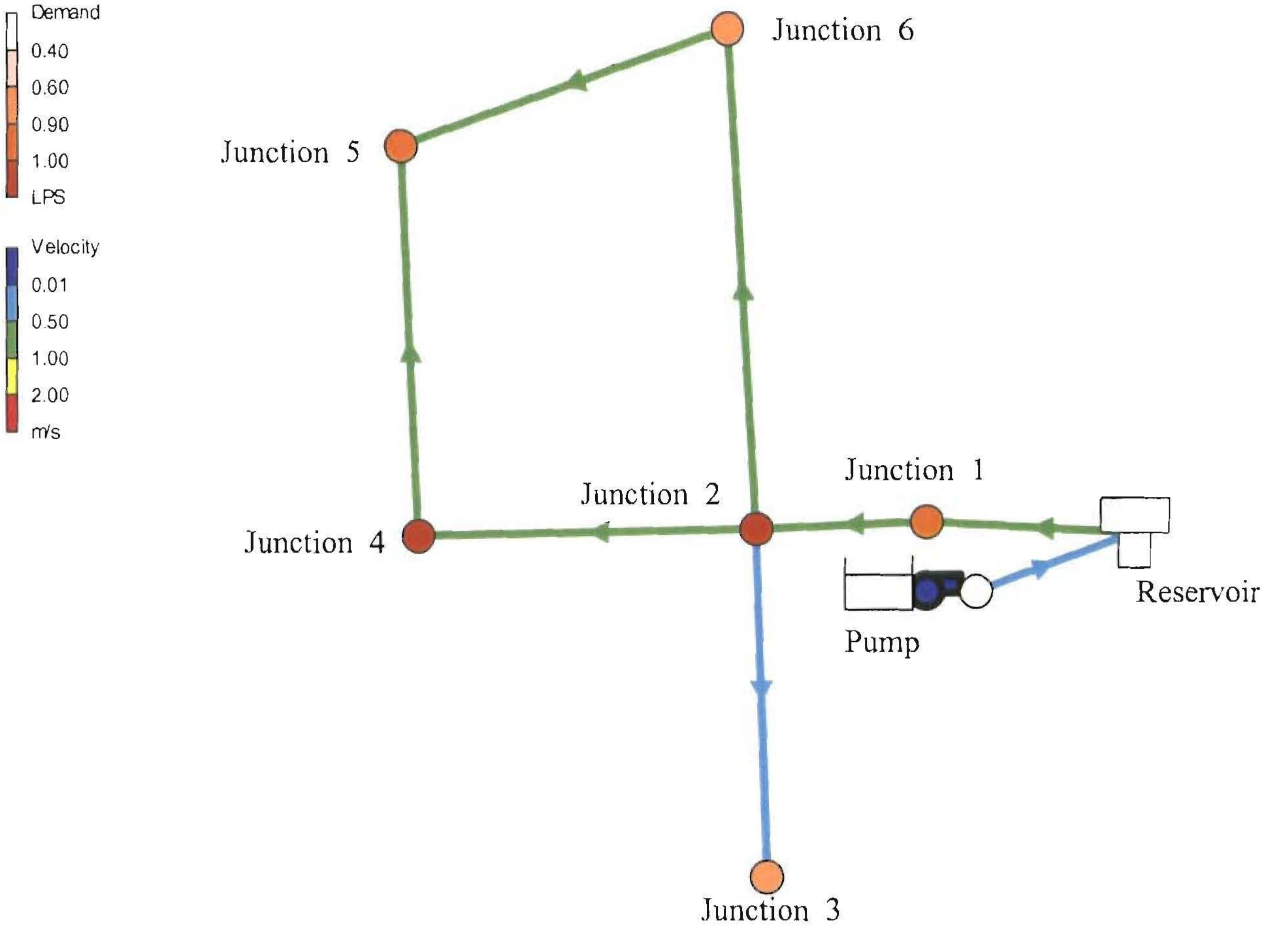


Figure 17: EPANET Pipe Design 1

Table 2: Design 1 EPANET nodes

DESIGN 1 EPANET JUNCTIONS				
NODE ID	**PRESSURE HEAD (m)**	**DEMAND (Lps)**	**ELEVATION**	**HEAD (m)**
Junction 1	28.66	0.90	163	191.66
Junction 2	59.92	1.35	130	189.92
Junction 3	62.09	0.68	127	189.05
Junction 4	96.36	1.35	85	181.36
Junction 5	87.35	0.90	85	172.35
Junction 6	89.56	0.68	95	184.56

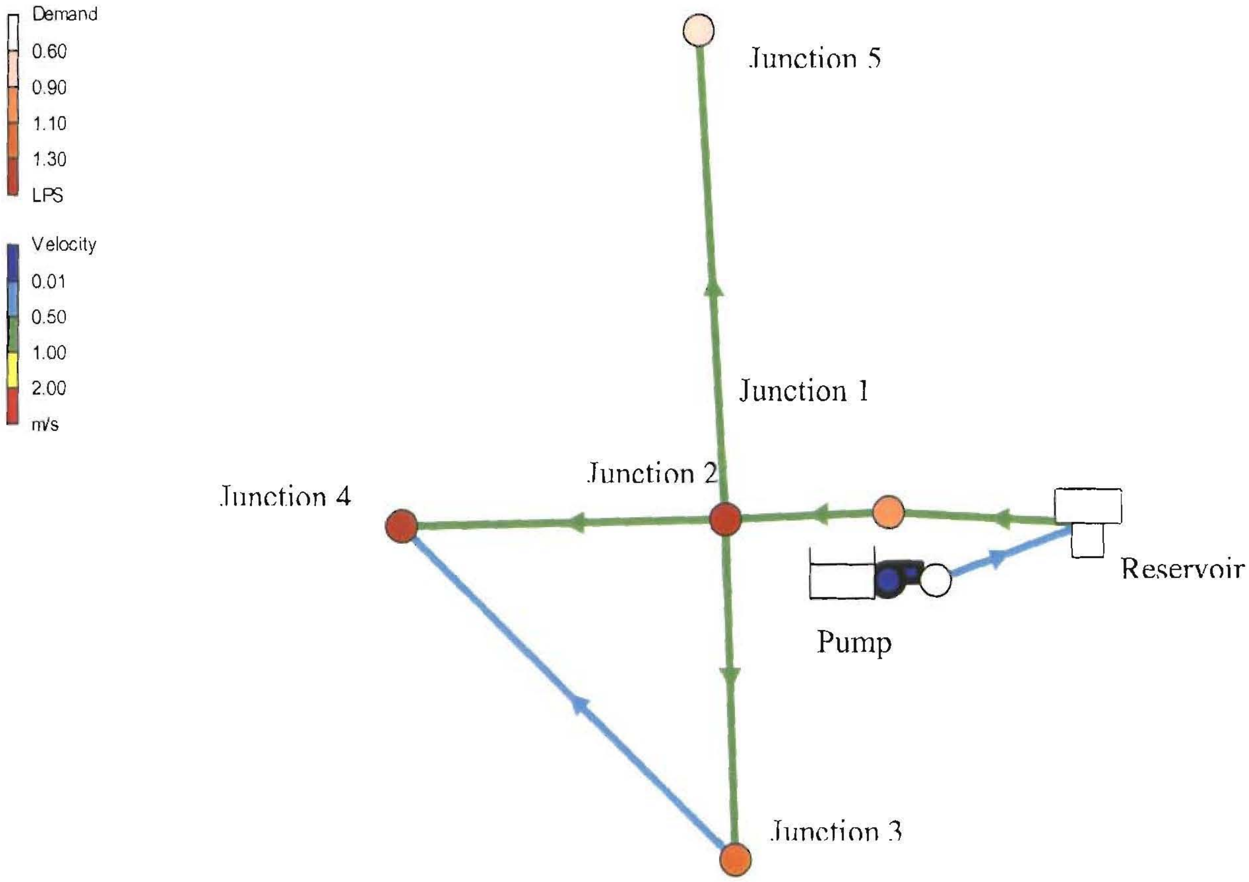


Figure 18: EPANET Pipe Design 2

Table 3: Design 2 EPANET nodes

DESIGN 2 EPANET NODES				
NODE ID	**PRESSURE HEAD (m)**	**DEMAND (Lps)**	**ELEVATION**	**HEAD (m)**
Junction 1	28.66	0.90	163	191.66
Junction 2	59.92	1.35	130	189.92
Junction 3	59.86	1.13	127	186.86
Junction 4	100.71	1.80	80	180.71
Junction 5	75.77	0.68	95	170.77

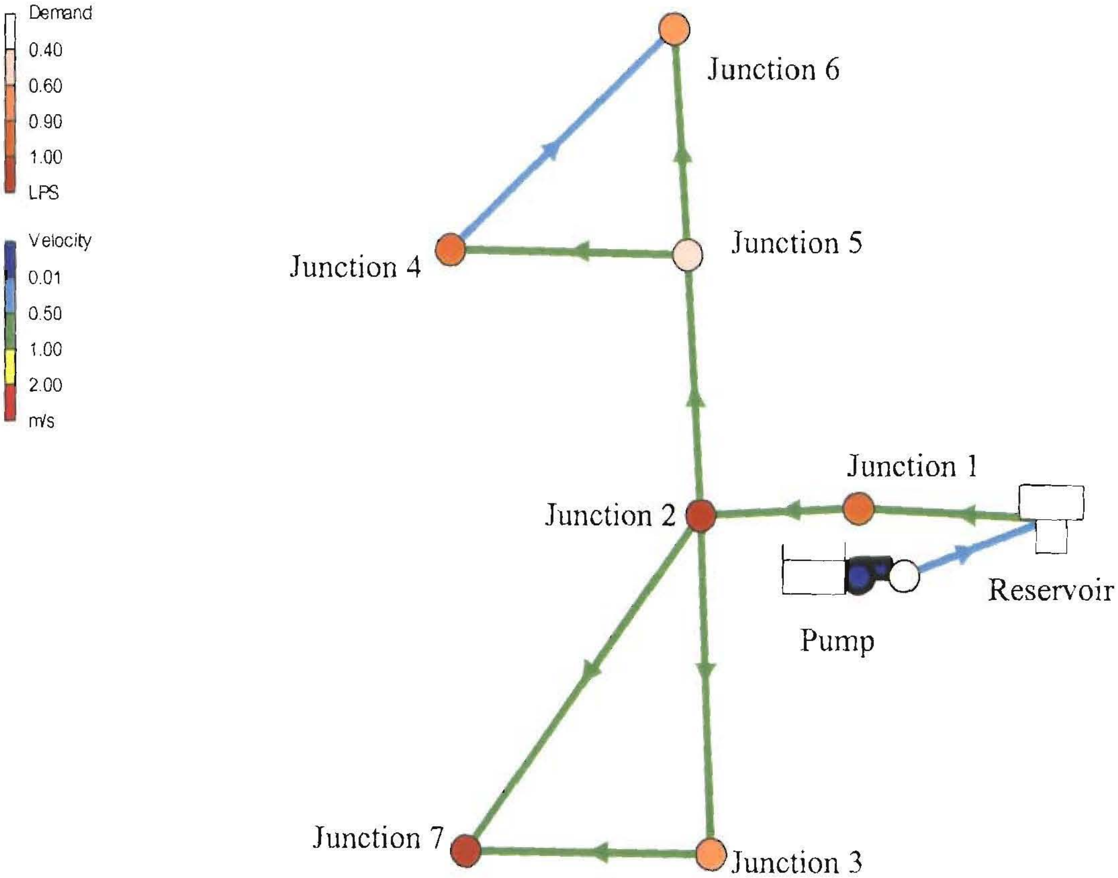


Figure 19: EPANET Pipe Design 3

Table 4: Design 3 EPANET nodes

DESIGN 3 EPANET NODES				
NODE ID	**PRESSURE HEAD (m)**	**DEMAND (Lps)**	**ELEVATION**	**HEAD (m)**
Junction 1	28.66	0.90	163	191.66
Junction 2	59.92	1.13	130	189.92
Junction 3	60.87	0.68	127	187.87
Junction 4	94.64	0.90	90	184.64
Junction 5	61.71	0.45	126	187.71
Junction 6	85.97	0.68	95	180.97
Junction 7	86.70	1.13	85	171.70

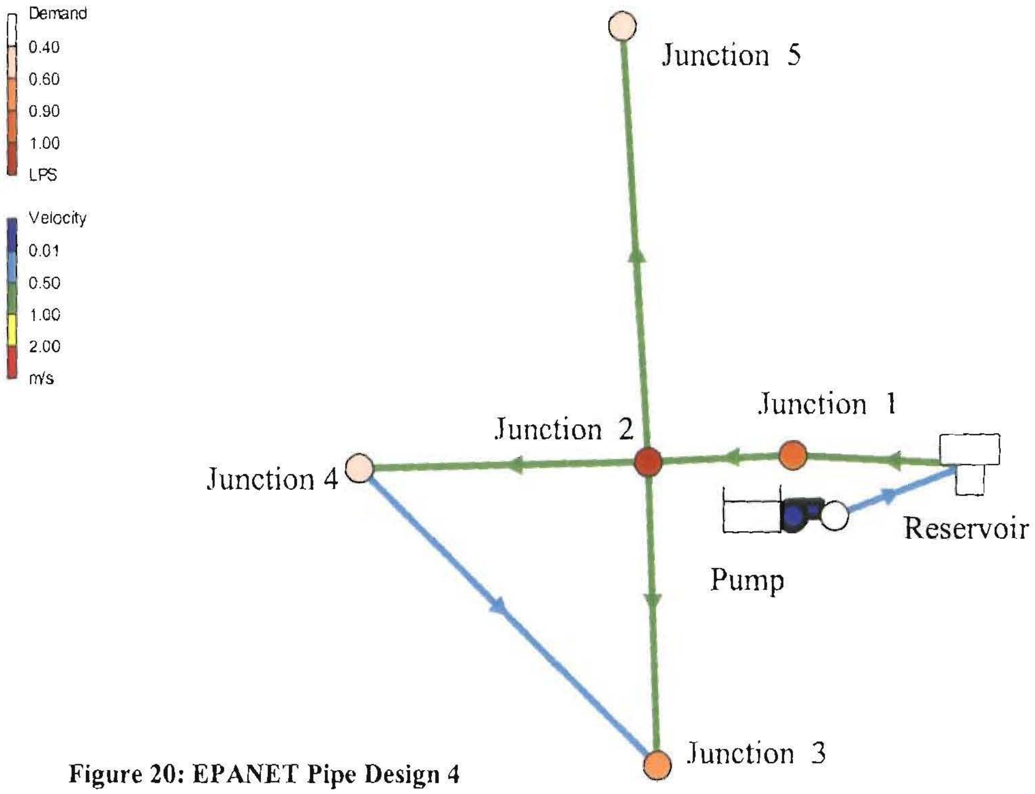
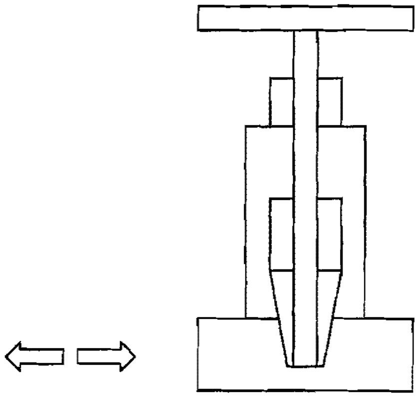


Figure 20: EPANET Pipe Design 4

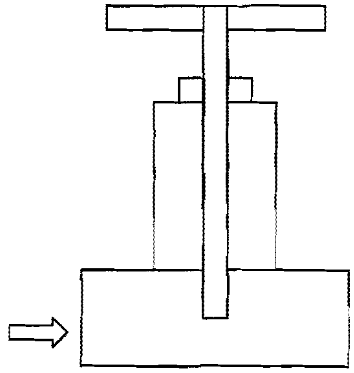
Table 5: Design 4 EPANET nodes

DESIGN 4 EPANET NODES				
NODE ID	**PRESSURE HEAD (m)**	**DEMAND (Lps)**	**ELEVATION**	**HEAD (m)**
Junction 1	30.64	0.90	163	193.64
Junction 2	60.43	1.13	130	190.43
Junction 3	59.06	0.68	127	186.06
Junction 4	99.29	0.45	90	189.29
Junction 5	86.39	0.45	95	181.39



Gate Valve

Figure 21: Gate valve

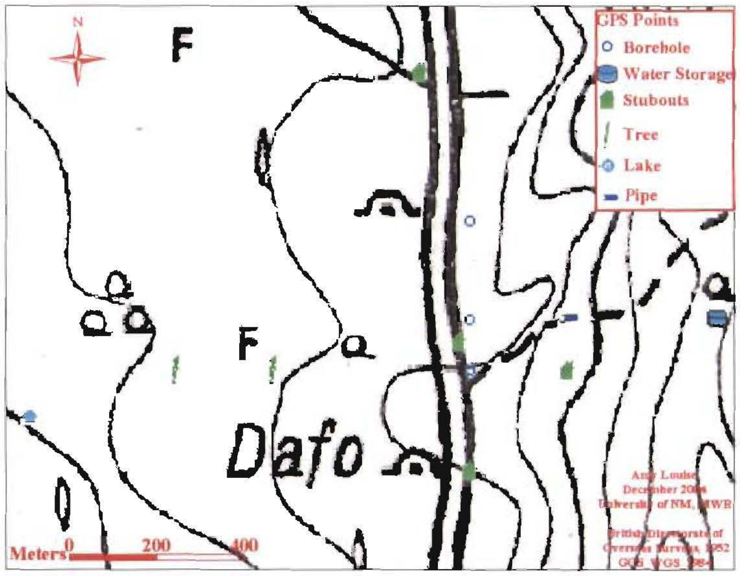


Globe Valve

Figure 22: Globe valve

Table 6: GPS points of interest

GPS Points of Interest			
Location	**Latitude (N)**	**Longitude (E)**	**Elevation (m)**
Chief's home	07° 05.014'	00° 18.468'	130
Highest point (Perimeter 1)	07° 05.014'	00° 18.763'	192
Pipeline Point 1	07° 05.019'	00° 18.612'	163
Lake Volta	07° 04.914'	00° 17.957'	71
Tree near lake (Perimeter 2)	07° 04.981'	00° 18.256'	108
Tree closest to lake	07° 04.972'	00° 18.145'	72
Borehole 1	07° 04.952'	00° 18.472'	130
Borehole 2	07° 05.016'	00° 18.478'	127
Borehole 3 (Perimeter 3)	07° 05.136'	00° 18.492'	125
Community toilet 1 (Perimeter 4)	07° 04.973'	00° 18.616'	145
Community toilet 2	07° 04.846'	00° 18.478'	129
Community toilet 3	07° 05.339'	00° 18.414'	95



(British Directorate of Overseas Surveys, 1952)

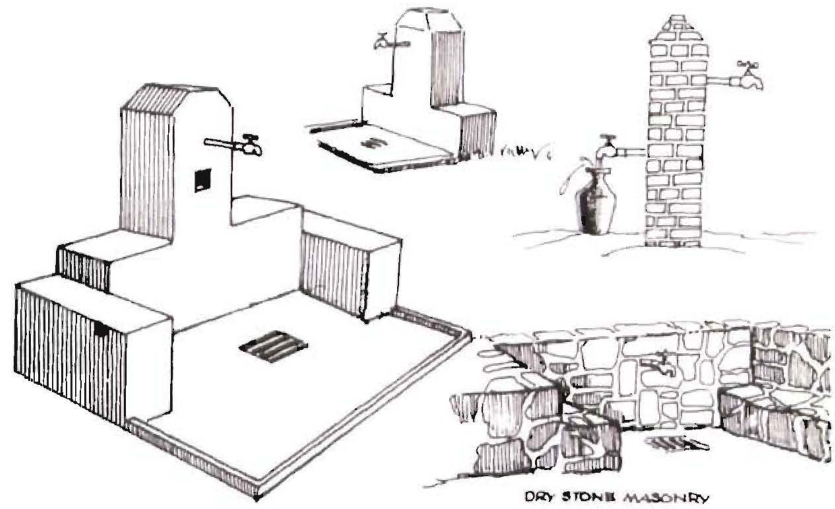
Figure 23: 1952 British contour map

Tapstands

The village inhabitants requested twenty tapstands and stubouts for every home. This design does not indicate stubouts for every home due to design complexity and location and availability for the writer to travel to the village again. There will only be six stubouts as indicated earlier.

The standard tapstand flow was 0.225 Lps that can serve a population of approximately 200 people. A 0.0127 m globe valve was used at the base of each tapstand to adjust the flow with the valve secured to avoid tampering (Figure 24). Each tapstand was designed of galvanized iron pipe and masonry around the pipe to protect it. The dimensions of the supporting column around the galvanized iron pipe were 50 centimeters (cm) by 50 cm with a footing of 30 cm below ground level. To divert the water towards the road culvert (Figure 25), garden, or watering hole for animals a drain

was used. For protection from animals and curious children fencing was around the tapstands.



(Jordan, 2000)

Figure 24: Tapstand

Figure 25: Road through village with culverts on both sides

Pump

A 3 horsepower electric submersible pump with a flow of 1.26 Lps and 122 m of head was determined to lift the water from the well to the water tank at an elevation of approximately 96.5 m depending upon the borehole (65 m ground elevation change plus pump depth of 31.5 m, 25.5 m, or 22.5 m). It is unclear the exact pump depth because clarification was not made by the Water Research Institute which borehole record corresponds to each borehole. Ninety-millimeter diameter pipe with length of 520 m will be used to carry the water from the borehole to the water tank.

Reservoir

The demand for 20 tapstands and 6 stubouts at 0.225 Lps was found to be 5.85 Lps. With 10 tapstands and 6 stubouts at 0.225 Lps, the demand was found to be 3.6 Lps. The current population was approximately 500 and the future population of 679 was determined by using population growth rate of 1.8% for 2001 (Kurian, 2003) for a design period of 20 years. The current usage was determined to be approximately 45 liters per person per day based on World Health Organization (Jordan, 2000). Future demand was estimated to be 90 liters per person per day to incorporate flushing toilets, indoor plumbing, and overall increase use of water due to accessibility. There is also a special need demand of 10 liters per student per day for the primary and secondary schools. Future daily usage was projected to be approximately 64,000 liters per day (Lpd) or 0.74 Lps for the twenty-year design period. A 60,000-liter reservoir was designed for storage. The optimum reservoir location was determined to be at an elevation of 192 meters and 325 meters east of the first junction or node. Two different schedules were used to investigate daily usage as described in Table 7.

The roof was designed to be pitched at least 5% with an overhang of 10 cm. A single-pitched roof was used because it is fast and economical. An entry with a secure cover of 80 cm by 80 cm was designed for repairs and cleaning. Corrugated galvanized

Table 7: Schedules 1 & 2 daily water needs

DAILY WATER NEEDS SCHEDULES

Schedule 1	
6 am - 8 am	2 hrs, 30% of total daily water need
8 am - 4 pm	8 hrs, 40% of total daily water need
4 pm - 6 pm	2 hrs, 30% of total daily water need
Schedule 2	
5 am - 7 am	2 hrs, 10% of total daily water need
7 am - 11 am	4 hrs, 25% of total daily water need
11 am - 1 pm	2 hrs, 35% of total daily water need
1 pm - 5 pm	4 hrs, 20% of total daily water need
5 pm - 7 pm	2 hrs, 10% of total daily water need

A brick masonry circular tank (Figure 26) will be constructed similar to the reservoirs constructed in Honduras. The dimensions of the tank are height of 2.44 meters, radius of 2.8 meters, and perimeter of 17.6 meters. The masonry walls will be plastered for waterproofing. Three coats will be added with one coat of plaster per day. The first coat will have a mortar mix of 1:4 – cement to sand; the second coat will have a mortar mix of 1:3; and the third coat will have a mortar mix of 1:2.

automatic sodium hypochlorite solution feeder will be used at the well, so the sodium hypochlorite solution will be pumped up to the reservoir. Sodium hypochlorite solution (bleach) that contains approximately 5.25 % chlorine will be used for disinfection due to its availability. I recommend 1.5 mg/L for the disinfection level for the reservoir. The amount of sodium hypochlorite solution required per day or per 60,000 liters is approximately 1.9 liters by using the formula:

Volume of Sodium Hypochlorite = [{(volume of water/1,000,000 parts per million (ppm)) * (unit weight of water) * (desired concentration in ppm)} / (0.0525)] / (unit weight of water).

It is assumed the borehole was sterilized at the time it was drilled. The borehole should be evaluated when the new pump is installed to determine if sterilization is necessary. If the borehole needs to be sterilized, the volume of sodium hypochlorite solution is calculated by using the formula:

Volume of Sodium Hypochlorite = [(volume of water) * (unit weight of water) * {(desired concentration) / (0.0525)}]/(unit weight of water).

A residual level of disinfection of water in pipelines will also be used to prevent microbial re-growth. "EPA's maximum residual disinfection levels (MRDLs) are 4 mg/L for chlorine" (Chlorine Chemistry Council, 2003). The reservoir will be monitored on a weekly basis for the first three months then monthly.

Chlorine concentration and chlorine contact time at a given temperature ensures disinfection of water. The final free chlorine concentration in mg/L is multiplied by the minimum contact time in minutes determines the CXT values. If the chlorine concentration is decreased, the contact time is lengthened; and if the chlorine concentration is increased, the contact time is reduced (Chlorine Chemistry Council, 2003). The contact time using 5.25% chlorine for chlorinating the borehole will range from 30 minutes to 24 hours depending on the organisms and organic materials within the borehole and approximately 20 minutes for the reservoir (USDI, 1981).

Disinfectants react with natural organic matter in water producing disinfection byproducts. "The health risks from these byproducts at the levels at which they occur in drinking water are extremely small in comparison with the risks associated with inadequate disinfection" (Chlorine Chemistry Council, 2003).

Washing Table Stations

The four-roofed community-washing table stations consist of four concrete washing tables each with a central water channel (Figure 28). The stations will be located at tap-stands for easy access to water, so the women will not have to haul water long distances. The tables will be 2 m^2 each. A sanitary drainage system for the wastewater will be part of the stations (El Porvenir, 2004). Gray water from station 1 will be used for gardens. The open culvert beside the road will be used for the gray water from station 2. Washing station 4's gray water will drain into the field for agricultural purposes. The gray water for washing station 3 will drain to the septic tank for community toilet 3; however, women can access the water for their gardens.

Figure 28: Washing table for washing clothes
[<http://www.elporvenir.org/what.html>]

Water Quality

I obtained levels for nitrate, dissolved oxygen, and pH for the three boreholes and Lake Volta (Table 8). Lake Volta is not used for the source of the water distribution due to microorganisms present from human and fecal animal waste and other sources such as the snail. Schistosomiasis and guinea worm are common in the area.

According to United States Environmental Protection Agency (USEPA) National Primary Drinking Water Regulations, the maximum contaminant level and maximum contaminant level goal for nitrate as N is 10 mg/L. The National Secondary Drinking Water Regulations for pH range from 6.5 to 8.5. As shown in Table 8, the boreholes do not exceed these levels. However, Lake Volta exceeds the range for pH.

Table 8: Ground and surface water quality

GROUND & SURFACE WATER QUALITY			
Water Quality	**Nitrate (mg/L)**	**Dissolved Oxygen (mg/L)**	**pH**
Borehole 1	1.33	3.0	6.6
Borehole 2	1.33	2.5	6.5
Borehole 3	1.77	2.2	6.4
Lake Volta	3.54	3.9	9.8

As discussed earlier, waterborne diseases kill approximately 3.4 million people, mostly children, each year. Diseases such as diarrhea, malaria, schistosomiasis, and hepatitis sicken millions of people, but are preventable with clean water and education. World Health Organization (WHO, 2004) indicates there are fewer microbial organisms within ground water than surface water as shown in Table 9.

Table 9: Microbial aspects

MICROBIAL ASPECTS		
Pathogen or Indicator Group	**Lake & Reservoir (per liter)**	**Ground Water (per liter)**
E. coli	**10000-1000000**	**0-1000**
Viruses	**1-10**	**0-2**
Giardia	**2-30**	**0-1**
Campylobacter	**20-500**	**0-10**

(WHO, 2004)

Septic Tanks

There will be five septic tanks located at each of the community flushing toilet facilities and the Catholic church. The Chief had a block septic tank installed at his home in March while I was in the village. The design of the septic tank system will not be part of this paper. However, I recommend that the waste from the culverts on the sides of the road be piped to the septic tank systems for community toilet 2 and community toilet 3.

Economic Aspects

The capital labor costs for a 20-tapstand design were estimated to be $30,720 US dollars or 307,200,000 Cedis with an exchange rate of 10,000 Cedis per one US dollar, and the capital labor costs for a 10-tapstand design were estimated to be $22,560 US dollars or 225,600,000 Cedis as shown on Tables 10 and 11. In-kind labor includes trenching, pipe laying, pipe joining, excavating, plastering, cementing, roofing, and miscellaneous labor. The foreman and the skilled workers will train the unskilled workers, so this will benefit the inhabitants of the village.

Table 10: Capital labor costs for 20 tapstands

CAPITAL LABOR COSTS – 20 TAPSTANDS					
LABOR	**WORKERS**	**HOURS (per week)**	**WEEKS**	**WAGES (US $1.00/day)**	**WAGES (Cedi)**
MASONRY	4	40	12	1920	19,200,000
FOREMAN	1	40	24	960	9,600,000
SKILLED	4	40	24	3840	38,400,000
IN-KIND			24	24,000	240,000,000
TOTAL				30,720	307,200,000

Table 11: Capital labor costs for 10 tapstands

CAPITAL LABOR COSTS – 10 TAPSTANDS					
LABOR	**WORKERS**	**HOURS** (per week)	**WEEKS**	**WAGES** (US $1.00/day)	**WAGES** (Cedi)
MASONRY	4	40	6	960	9,600,000
FOREMAN	1	40	18	720	9,600,000
SKILLED	4	40	18	2880	28,800,000
IN-KIND	25	40	18	18,000	180,000,000
TOTAL				22,560	225,600,000

Table 12 shows the total capital costs in Cedis and US dollars, length of pipe, and features for each of the four designs. Design 4 would be the most economical because it is the least expensive, but only has ten tapstands. Ten tapstands would be sufficient for the village, but the village prefers to obtain twenty tapstands. Design 3 would be the optimum design for the village even though it is the most expensive because there are two loops; therefore, the water would not become static in the pipes.

Table 12: Capital costs

CAPITAL COSTS				
DESIGN	**CEDIS**	**US DOLLARS**	**TOTAL PIPE LENGTH (m)**	**FEATURES**
DESIGN 1	721,878,000	72,187.80	3354	20 tapstands 1 loop
DESIGN 2	714,873,000	71,487.30	3223	20 tapstands 1 loop
DESIGN 3	728,405,500	72,840.55	4016	20 tapstands 2 loops Most expensive
DESIGN 4	612,685,500	61,268.55	2808	10 tapstands 1 loop Least expensive

Tables 13, 14, 15, and 16 enumerate the capital costs for each of the four designs in US dollars and Cedis.

Table 13: Design 1 capital costs

DESIGN 1 CAPITAL COSTS					
ITEM	**AMOUNT**	**LENGTH (m)**	**UNIT PRICE**	**TOTAL COST (US dollar)**	**TOTAL COST (Cedis)**
45° elbow	26		2.40	62.40	624,000
3 hp pump	1		1740.00	1,740.00	17,400,000
Pump check valve	1		100.00	100.00	1,000,000
90 mm		1105	6.00	6630.00	66,300,000
50 mm		1334	2.00	2668.00	26,680,000
32 mm		590	1.50	885.00	8,850,000
25.4 mm		325	1.00	325.00	3,250,000
Plastic tank	1		10,000.00	10,000.00	100,000,000
Washing stations	4		700.00	2800.00	28,000,000
Reducer 90 mm – 50 mm	3		3.0	10.50	105,000
Reducer 50 mm – 32 mm	1		2.5	2.50	25,000
Reducer 50 mm – 25.4 mm	1		2.0	2.00	20,000
Reducer 32 mm – 25.4 mm	1		1.5	1.50	15,000
Gate valve	5		22.00	110.00	1,100,000
Globe valve	20		20.00	400.00	4,000,000
Septic systems	5		3000.00	15000.00	150,000,000
Tapstand parts & mortar	20		20.00	400.00	4,000,000
Chlorine feeder	1		200.00	200.00	2,000,000
Labor				30,720	307,200,000
Total Cost				72,187.80	721,878,000

Table 14: Design 2 capital costs

DESIGN 2 CAPITAL COSTS					
ITEM	**AMOUNT**	**LENGTH (m)**	**UNIT PRICE**	**TOTAL COST (US dollar)**	**TOTAL COST (Cedis)**
45° elbow	26		2.40	62.40	624000
3 hp pump	1		1740.00	1,740.00	17,400,000
Pump check valve	1		100.00	100.00	1,000,000
90 mm		1105	6.00	6630.00	66,300,000
50 mm		832	2.00	1664.00	16,640,000
32 mm		660	1.50	990.00	8,850,000
25.4 mm		626	1.00	626.00	6,260,000
Plastic tank	1		10,000.00	10,000.00	100,000,000
Washing stations	4		700.00	2800.00	28,000,000
Reducer 90 mm – 50 mm	3		3.0	10.50	105,000
Reducer 50 mm – 32 mm	1		2.5	2.50	25,000
Reducer 50 mm – 25.4 mm	1		2.0	2.00	20,000
Reducer 32 mm – 25.4 mm	1		1.5	1.50	15,000
Gate valve	5		22.00	110.00	1,100,000
Globe valve	20		20.00	400.00	4,000,000
Septic systems	5		3000.00	15000.00	150,000,000
Tapstand parts & mortar	20		20.00	400.00	4,000,000
Chlorine feeder	1		200.00	200.00	2,000,000
Labor				30,720	307,200,000
Total Cost				71,487.30	714,873,000

Table 15: Design 3 capital costs

DESIGN 3 CAPITAL COSTS					
ITEM	**AMOUNT**	**LENGTH (m)**	**UNIT PRICE**	**TOTAL COST (US dollar)**	**TOTAL COST (Cedis)**
45° elbow	26		2.40	62.40	624000
3 hp pump	1		1740.00	1,740.00	17,400,000
Check valve	1		100.00	100.00	1,000,000
90 mm		1105	6.00	6630.00	66,300,000
63 mm		270	3.00	810.00	8,100,000
50 mm		664	2.00	1,328.00	13,280,000
32 mm		938	1.50	1407.00	14,070,000
25.4 mm		1039	1.00	1039.00	10,390,000
Plastic tank	1		10,000.00	10,000.00	100,000,000
Washing stations	4		700.00	2800.00	28,000,000
Reducer 90 mm – 50 mm	3		3.0	10.50	105,000
Reducer 50 mm – 32 mm	1		2.5	2.50	25,000
Reducer 50 mm – 25.4 mm	1		2.0	2.00	20,000
Reducer 32 mm – 25.4 mm	1		1.5	1.50	15,000
Gate valve	5		22.00	110.00	1,100,000
Globe valve	20		20.00	400.00	4,000,000
Septic systems	5		3000.00	15000.00	150,000,000
Tapstand parts & mortar	20		20.00	400.00	4,000,000
Chlorine feeder	1		200.00	200.00	2,000,000
Labor				30,720	307,200,000
Total costs				72,840.55	728,405,500

Table 16: Design 4 capital costs

DESIGN 4 CAPITAL COSTS					
ITEM	**AMOUNT**	**LENGTH (m)**	**UNIT PRICE**	**TOTAL COST (US dollar)**	**TOTAL COST (Cedis)**
45° elbow	16		2.40	38.40	384,000
3 hp pump	1		1740.00	1,740.00	17,400,000
Check valve	1		100.00	100.00	1,000,000
90 mm		875	6.00	5250.00	52,500,000
63 mm		230	3.00	690.00	6,900,000
32 mm		1269	1.50	1903.50	19,035,000
25.4 mm		434	1.00	434.00	4,340,000
Plastic tank	1		10,000.00	10,000.00	100,000,000
Washing stations	4		700.00	2800.00	28,000,000
Reducer 90 mm – 50 mm	3		3.0	10.50	105,000
Reducer 50 mm – 32 mm	1		2.5	2.50	25,000
Reducer 50 mm – 25.4 mm	1		2.0	2.00	20,000
Reducer 32 mm – 25.4 mm	1		1.5	1.50	15,000
Gate valve	5		22.00	110.00	1,100,000
Globe valve	10		20.00	200.00	2,000,000
Septic systems	5		3000.00	15000.00	150,000,000
Tapstand parts & mortar	10		20.00	200.00	2,000,000
Chlorine feeder	1		200.00	200.00	2,000,000
Labor				22,560	225,600,000
Total costs				61,268.55	612,685,500

Electricity is already available to the people who can afford it. The electricity is read on a monthly basis as described in Table 17 below. The Public Utilities Regulatory Commission, Ghana, effective August 1, 2004, publishes these tariffs. The villagers who will use the tapstands and the villagers whose homes will be hooked up to the water system will pay the electricity. It is assumed the individuals with homes will use more water than individuals who will use the tapstands only because of the flushing toilets and showers. The Catholic church members will pay their portion of the electricity based on the consumption of water at the church. The tariffs will be based on the monthly consumption for residential use as stated in table below.

Table 17: Electricity tariffs

ELECTRICITY TARIFFS BY PUBLIC UTILITIES REGULATORY COMMISSION, GHANA		
Tariff Category		**Cedi/Month**
Non-Residential		
0-300 kWh	(Cedis/kWh)	848
300+ kWh	(Cedis/kWh)	1,039
Service Charge	(Cedis/month)	21,000

The electricity tariffs for operating the 3 horsepower pump 12 hours per day for 30 days per month would amount to approximately 810 kWh hours. The cost was determined to be 805,290 Cedis per month by adding 254,400 Cedis per month for 0 to 300 kWh (848 Cedis/month * 300 kWh), 529,890 Cedis per month (1,039 Cedis/month * 510 kWh), and 21,000 Cedis per month.

The operating and maintenance labor costs for 20-year design period are indicated in Table 18 below. The skilled labor includes record keeping and technician work, and in-kind labor includes the work completed by the tapstand and toilet attendants.

Table 18: Operating and maintenance labor costs for 20-year design period

OPERATING AND MAINTENANCE LABOR COSTS – 20 YEARS					
LABOR	**WORKERS**	**HOURS (per week)**	**WEEKS**	**WAGES (US$1.00/day)**	**WAGES (Cedi)**
Skilled labor	1	2	1040	2,080	20,800,000
In-kind labor	10	2	1040	20,800	208,000,000
Bookkeeper	1	20	1040	20,800	208,000,000
Total Labor				43,680	436,800,000

It was estimated that the plastic or block water reservoir and the PVC pipes would last approximately 20 years. The pump will last approximately 5 years and the tapstands will all be replaced once in 20 years. A chlorine feeder costs approximately $200 US dollars or 2,000,000 Cedis and will last approximately 5 years, and the chlorine will cost approximately $15 US dollars per month or 150,000 Cedis per month. The total operating and maintenance costs for the 20-year design period are shown in Table 19.

Table 19: Operation and maintenance costs for 20 tapstands for 20-year design period

OPERATING & MAINTENANCE COSTS – 20 YEARS		
ITEM	**COST (US dollar)**	**COST (Cedi)**
Labor	43,680	436,800,000
Pump	6,960	69,600,000
Tapstands	400	4,000,000
Chlorine system	4,400	44,000,000
Electricity	19,327	193,269,600
Total	74,767	747,669,600

Water Committee

A community water committee is necessary for success of the system. The committee manages the operation of the system that involves performing preventive maintenance, collecting tariffs, keeping records, and guaranteeing repairs are made. An issue to consider is whether to sanction people for non-payment. The people who cannot afford to pay the tariffs will complete the required work instead.

The village residents will elect their own water committee and take responsibility for the long-term maintenance of the project. The committee of eight members will include at least four women among their members to guarantee success of the water system. Women are the ones that provide water to their families, so women are affected most if a water system is not operating. The water committee will supervise construction, monitor activities, and resolve problems (Water and Sanitation Program-Africa Region (WSP-AF), 2002)."

Some of the questions the water committee will address include:

- Who will be trained for the operation and maintenance of system?
- Who will be paid to operate, maintain, and repair water system?
- What should be the cost of using the facilities, i.e., tapstands, community flushing toilet facilities, and washing table stations?

I suggest the water system be used for domestic purposes only; however, gray water from the washing stations may be used for irrigation. The community water system committee may decide to use the system for irrigation purposes for economic reasons. The village could dig ditches to access Lake Volta for irrigation instead of using good-quality water for irrigation purposes.

All members will own the water system, not only one or a few. With a member owned water system, one or a few will not use their authority for political or financial gain. The problems associated with private ownership will be avoided if the committee is comprised of members that represent all members of the community (Katz and Sara, 1997). It was found that "willingness to pay for investment costs increased dramatically when communities have control over how funds are spent" (Katz and Sara, 1997).

The primary responsibilities of the committee include (International Water and Sanitation Center (IWSC), 2003):

- Overseeing construction and functioning of water system;
- Representing all members of the system;
- Involving community in decision-making;
- Holding monthly meetings;
- Establishing water tariff based on cost and feasibility;
- Managing finances;
- Reporting financial status to elected officials;
- Employing staff to conduct daily operations;
- Guaranteeing timely maintenance and repairs; and
- Protecting tapstands and borehole.

Daily operations will include keeping water points, community toilets, and washing stations clean, repairing, and "reporting any system malfunctions (IWSC, 2003)." Not all the committee members will be paid. The paid workers will be the record keeper and the technician who will carry out routine operation and maintenance. A constitution will be written to set out rules for governance (WSP-AF, 2002).

Cost Retrieval

The operating and maintenance cost for the 20-year design period is approximately $74,767 US dollars or 747,669,600 Cedis, so the monthly cost will be approximately 3,115,290 Cedis for the village or 6,231 Cedis per person per month. If

fewer than 500 people are members, the cost will be more per member. All public tapstands and connections will be metered and read monthly, so there are records for usage of water. The members could initially pay 6,231 Cedis (62¢ US) for tapstand and community toilet use, 7,000 Cedis (70¢ US) for private connections, and 8,000 Cedis (80¢ US) for non-domestic connections. Currently people pay 100 Cedis for approximately 19 liters (5 gallons) of water when they fill their pans at one of the boreholes. It is reasonable to assume almost everyone purchases approximately 38 liters per day, so the monthly amount paid is 6,000 Cedis. For the women who cannot afford to pay, they will work at the tapstands and toilets in exchange for water.

According to the Ghana Public Utilities Regulatory Commission, the water tariffs for tapstands is 4,031 Cedis per 1,000 liters. It was determined that the demand will be 2,700 liters per person per month, so the water tariff would be 10,883.70 Cedis per person per month under the Regulatory Commission. The recommended 6,231 Cedis per person per month is within the Regulatory Commission's tariff. Also, if a house is not metered, the flat rate per house per month is 25,000 Cedis per month. The water tariff would be 5,000 Cedis per person for 100 houses and 500 people. Metered houses are 4,031 Cedis per 1,000 liters for 0 to 20,000 liters. In the future, the water system may serve all or most of the houses within the village, so meters will be required to connect to the system. The committee will determine the cost of hooking up homes to the water system.

Sustainability

Sustainability was found to be higher if household and water committee training was available (Katz and Sara, 1997). When people are informed about potential health

benefits of a water system they are more willing to sustain the system. Training households result in people "more willing to pay the costs of maintenance, keep the system in better physical condition, and carry out better operations and maintenance. At the same time, training members of the water committee will lead to better operations and maintenance and financial management (Katz and Sara, 1997)." The funding agency will train the water committee and workers because the village will do the in-kind labor.

Recommendations

I recommend the water system be used for domestic purposes only even though the village may want to use the system for agricultural purposes. Ten tapstands may be adequate to provide water for domestic purposes for the village. However, the village wishes to have twenty tapstands and water piped to each home. Due to the design complexity of providing water to each home and the village location, the system was not designed to supply water to each home. The inhabitants may not realize the cost involved for the ten tapstands versus twenty tapstands or the cost for water to each home.

The system should include the four community flushing toilet facilities, four washing table stations, five septic tank systems, chlorination, and plastic water tank. Pipe Design 3 was recommended because it was designed to have twenty tapstands and two loops so the water does not get stagnant. Women should be involved in the entire process to ensure sustainability.

It is recommended that the village seek funding so this water distribution design can become reality. After the funding agency has completed the water system, the residents will be responsible for the repair, operation, and maintenance of the system.

Conclusions

The water system designed for the village of Kpandu Dafor assumes a 1.8% growth rate for a design period of 20 years. Kpandu Dafor Tonu is a village adjacent to Kpandu Dafor that would also like a water system. There are no boreholes in the village. Modifications can be made to the water system to include this village of 500 people. There is more than one borehole in Kpandu Dafor so the system can be expanded to include another borehole and another storage tank.

Sustainability of the system could be jeopardized if the water system was expanded without technical support. Therefore, the design is flexible to allow the village to pay the cost of higher levels of service for household connections or lower cost for lower levels of service (Katz and Sara, 1997).

List of Potential Funding Agencies for the Village

Africare, http://www.africare.org/

CARE, http://www.care.org/

Canadian International Development Agency (CIDA),
http://www.acdi-cida.gc.ca/index-e.htm

Conservation, Food and Health, http://www.grantsmanagement.com/cfhguide.html

Danish International Development Agency (DANIDA),
http://www.safemotherhood.org/smrg/agencies/bi/bi_danida.htm

Green Earth Organization, http://www.greenearth.org.gh/aboutus.htm

Living Water International, http://www.living-water.org/

United Nations Children's Fund, http://www.unicef.org/

United States Agency for International Development (USAID),
http://www.usaid.gov/policy/donor.html

Water Aid, http://www.wateraid.org.uk

Water for People, http://www.water4people.org/

United Nations Development Programme, http://www.undp.org/

World Vision International, http://www.wvi.org/wvi/home.htm

Glossary of Terms

Artesian well – A well deriving its water from a confined aquifer in which the water level stands above the ground surface; synonymous with flowing artesian well (Driscoll, 1986).

Chlorination – The process of adding a form of chlorine to water or wastewater (Chlorine Chemistry Council, 2003).

Confined aquifer – A formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric (Driscoll, 1986).

Disinfection – Destruction of harmful microorganisms, usually by the use of bactericidal chemical compounds (Chlorine Chemistry Council, 2003).

Disinfection Byproducts – Compounds created by the reaction of a disinfectant with organic compounds in water (Chlorine Chemistry Council, 2003).

Free Chlorine: The sum of hypochlorous acid and hypochlorite ions expressed in terms of mg/L or ppm (Chlorine Chemistry Council, 2003).

Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards (Environmental Protection Agency (EPA), 2004).

Maximum Contaminant Level Goal (MCLG) – The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals (EPA, 2004).

Maximum Residual Disinfectant Level (MRDL) – The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants (EPA, 2004).

National Primary Drinking Water Regulations – Primary standards protect public health by limiting the levels of contaminants in drinking water (EPA, 2004).

National Secondary Drinking Water Regulations – Non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water (EPA, 2004).

pH – A measure of the acidity or alkalinity of an aqueous solution (Chlorine Chemistry Council, 2003).

Residual – The measurement of chlorine in water after treatment (Chlorine Chemistry Council, 2003).

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