Collection and Representation of GIS Data to Aid Household Water Treatment and Safe Storage Technology Implementation in the Northern Region of Ghana

By

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B.S. Civil and Environmental Engineering
University of Washington, 2005

Submitted to the Department of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree of

MASTER OF ENGINEERING IN CIVIL AND ENVIRONMENTAL ENGINEERING
at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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ABSTRACT

In 2005, a start-up social business called Pure Home Water (PHW) was begun in Ghana to promote and sell household water treatment and safe storage (HWTS) technologies. The original aim of the company was to offer a variety of products, allowing customers to choose the technology which best fit their individual needs. This differed from the typical implementation of HWTS promoters to date, in which an organization often distributes a single technology for the population to use. Instead, Pure Home Water wanted to give users a choice. PHW is also unique because they are attempting to sell their products without any subsidy. The goal is to create a sustainable business that will both bring better quality water to the population and be financially self-supporting.

Because the company is new, a need existed to gather data on the demographic, health, and water and sanitation infrastructure within the region. Due to the geographic nature of the project, it was decided that a Geographic Information System (GIS) would be the best tool to store, analyze and represent the data. The system could be used to help plan relevant business strategies, and maps could be created to visually communicate important information among the Pure Home Water team and other interested parties.

The final database did achieve the goal of collecting and bringing together important regional information in a form hopefully useful to PHW, future MIT teams and others. However, the use of the database for long-term planning is currently too advanced for the small company.

Thesis Supervisor: Susan Murcott
Title: Senior Lecturer, Civil and Environmental Engineering Department

Acknowledgements

This thesis has benefited from the support of numerous people and organizations. First I would like to thank Susan Murcott for her continual guidance. She provided inspiration when I was faltering, and her passion for improving water and sanitation in the developing world proved contagious.

Throughout my stay in Ghana, I was constantly surprised by the willingness of people and organizations to freely share their data. This thesis would not have been possible without the shared knowledge from the Ghana Statistical Service, World Vision, the Community Water and Sanitation Agency, the Rural Water and Sanitation Agency and the Guinea Worm Eradication Program. All of these organizations are doing important work throughout Ghana and I appreciate the time taken to assist me. Thanks are also given to the Conrad N. Hilton Foundation for their generous financing of the project.

The thesis also heavily relied on the work and companionship of all Pure Home Water team members. Hamdiyah Alhassan and Wahabu Salifu's daily work and enthusiasm keep Pure Home Water moving forward. Their warm hearts and welcoming spirits also made the stay in Ghana highly enjoyable. My fellow engineering team members, Rachel Peletz and Claire Mattelet, have been great friends throughout our travels as well as through the long process of writing and presenting. It would not have been as enjoyable without sharing the experience with you. The business students, Brendon Monaghan, Casey Gordon, Kenichi Honna and Rachel Lawson, all added a new perspective to the project as well as entertainment throughout the trip.

I would also like to thank the MIT Civil and Environmental Engineering Department and the MEng program, particularly Dr. Eric Adams and Dr. Peter Shanahan for their help and support throughout the entire year. The MIT GIS lab also provided value help in initially familiarizing me with the necessary software.

And finally thanks goes to my parents for their continual love and support.

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List of Abbreviations

CWSA – Community Water and Sanitation Agency
GIS – Geographic Information System
GPS – Global Positioning System
HWTS – Household Drinking Water Treatment and Safe Storage
NORRIP – Northern Region Rural Integrated Program
OIC – Opportunities Industrialization Centers
PHW – Pure Home Water
RWSA – Rural Water and Sanitation Agency
UNICEF – United Nations Children's Fund
WAWI – West African Water Initiative
WHO – World Health Organization

Chapter 1 - Introduction

1.1 Worldwide Water Crisis

The World Health Organization has estimated that approximately 1.8 million deaths occur each year due to a lack of access to safe water, sanitation and proper hygiene. Of these deaths, 99.8% occur in developing countries and 90% are children (Nath, Bloomfield, Jones, 2006). These deaths could be virtually eliminated if proper infrastructure and educational programs were put in place. The United Nations Millennium Development Goals have set a target to "halve by 2015 the proportion of people without sustainable access to safe drinking water" (UN, 2005). Currently nearly one-sixth of the world's population does not have access to an improved source of drinking water and are instead drinking from rivers, streams, ponds or unprotected springs and hand dug wells. Access to safe drinking water is a basic human right and its provision has the capability of saving millions of lives

1.2 Household Water Treatment and Safe Storage (HWTS)

Household water treatment and safe storage (HWTS) systems allow people to continue using their traditional water sources while waiting for improved access. However, even if a person has access to an improved water supply, HWTS technology may still be a wise purchase. The distribution systems in many developing countries are far from perfect. Dangerous contaminants find their way into drinking water systems through groundwater infiltration, cross connection with sewer lines and overburden of the treatment processes. If groundwater is used, contamination can occur between fetching the water and its consumption. Possible contamination routes include: the use of contaminated fetching buckets or storage containers, debris falling inside the containers, children dipping their hands into the containers, and insects entering the water containers. Safe storage is meant to eliminate these risks by providing a container for water storage which is enclosed and has a spout, allowing water to be accessed without compromising its safety. Beyond protecting the integrity of the current water source, many household water treatment technologies go beyond safe storage to improve the quality of the water prior to drinking.

HWTS technologies come in a variety of forms but most rely on the water treatment principles of particle removal and disinfection. Microbes often attach themselves to particles in water, so removing the particles is equivalent to removing a large portion of the microbes. An added benefit is that particle removal makes the water more aesthetically acceptable for drinking. One common method for particle removal is filtration. This is typically accomplished by running water through ceramics, or properly treated and layered sand. Coagulation is another particle removal method in which a chemical is added that causes small particles to clump together and form larger particles. These larger flocs will then settle out, if the water is left undisturbed.

Disinfection is the other essential treatment technique and it kills or inactivates the remaining bacteria. One of the most common methods used is chlorine disinfection.

Chlorine damages the cell structure of the bacteria, effectively destroying them. Other simple low cost disinfection methods involve using UV light to destroy bacteria or to use a biological means of disinfection whereby bacteria are removed by biological predation as well as natural die-off.

Besides producing a water of higher quality, other key features required of HWTS technologies include being low cost, easy to use and socially acceptable. Without these features, the new technologies will not be adopted by low income populations in developing or developed countries, and the health benefits will go unrealized.

1.3 Ghana

This thesis addresses HWTS implementation in Ghana, but before turning to the specific subject some basic facts and figures about Ghana are presented. Ghana is located in West Africa, bordered to the north by Burkina Faso, to the west by Cote d'Ivoire, to the east by Togo and to the south by the Gulf of Guinea. Its land area is 238,537 square kilometers which puts it at approximately the size of Oregon (CIA Factbook, 2006). The most notable geographical feature is Lake Volta which is one of the world's largest artificial lakes and takes up 3.6% of Ghana's land area (Encyclopedia Britannica, 2006).

Figure 1: Map of Ghana (CIA World Factbook, 2006)

There are three major ecological zones within Ghana. The first is the coastline and associated coastal plains. The second zone is heavily forested land which covers the middle and western portions of the country. The final zone is savannah which stretches across northern Ghana. These regions vary widely in weather patterns with the south receiving an average of 80 inches of rainfall a year, while the north typically only experiences 40 inches (GSS, 2004).

The current population of Ghana is just over 22 million residents (CIA Factbook, 2006). Most people reside in the southern part of the country, with Accra, at a population of around 2 million, being the largest city and the country's capital. Amongst the population, there are a variety of ethnic groups. The largest are the Akans which make up 49 percent of the population. The Mole-Dagbon tribe is next comprising 17 percent of the population, followed by the Ewe at 13 percent and the Ga/Dangme at 8 percent (GSS, 2004).

1.4 Pure Home Water (PHW)

Pure Home Water is a company set up in Ghana to promote and sell HWTS technologies. The original aim of the company was that a variety of HWTS products would be offered. This would allow all customers to choose the product which contains the level of treatment, cost and features to fit their specific needs. This differed from the typical implementation of HWTS promoters to date, in which an organization often distributes a single technology. Pure Home Water is also unique compared to other implementers because they are attempting to sell their products without a subsidy. Instead PHW is trying to create a sustainable business which will both bring better quality water to the population and be financially self-supporting.

1.5 CT Filtron

A ceramic filter known as the CT Filtron is the best seller and currently the main water treatment product of Pure Home Water (Figure 2). The filter is produced by combining terracotta clay with sawdust sieved to a particular size. This mixture is then pressed into the shape of a large flower pot and left to dry for a few days. When it is ready, the pots are fired in a kiln at 900°C. The elevated temperature causes the sawdust to burn off, leaving pores for water to pass through. Once cooled, the pots are dipped in a bath of colloidal silver. This potentially acts as a disinfectant, as well as keeps microbes from growing within the pores. The filters then go through a testing process to ensure their flow rate is within an acceptable limit, with the target flow rate at 2 liters per hour. After passing the test, the filters are ready for sale. The complete system also includes a plastic container, ensuring that water is safely collected and stored once it has passed through the ceramic filter element. This container has a spigot to allow access to the treated water as well as a lid to keep the system fully enclosed.

Figure 2: Complete CT Filtron System (Picture by Rachel Peletz)

1.6 Thesis Objective

This past January was the first time that the MIT branch of Pure Home Water had traveled to the Northern Region of Ghana. Thus, there was the need for a data gathering effort to learn as much as possible about the demographic, health, and water and sanitation infrastructure status within the region. Because of the geographic nature of the project, it was decided that a Geographic Information System (GIS) would be the best tool to store, analyze and represent the data. More than just simple maps, GIS allows for geographic locations to be connected to relevant information about the features shown on the map. For example, a point feature representing a village could have information on the population, number of boreholes and percentage of the population practicing proper sanitation. Separate features can then be layered on top of each other to show interrelations which may have not been otherwise apparent. Querying of the data can also be done to answer questions concerning the spatial relationships between features as well as the linked statistical information. In terms of this project, the GIS system was envisioned as an organizational tool to collect all relevant project information into a single database. The system could be used to help plan relevant business strategies and maps could be created to visually communicate important information among the Pure Home Water team and other interested parties.

Chapter 2 - Methods

2.1 Data Gathering

On a previous trip to Ghana in June 2005, the project's principal investigator, Susan Murcott, visited both the national and Northern Region office of the Ghana Geological Survey Department as well as the Northern Region Town and Country Planning Department in search of paper maps of the region. Unfortunately, all maps found were from the 1970s and 1980s which contained basic information but were too outdated and general for our intended uses. However, in January 2006 it was discovered that the Ghana Statistical Service (GSS) has a wealth of statistical information pertinent to the project and which they were very generous in sharing. This information is gathered through the census and other surveys of the population. Of particular interest to our project was the 2003 Health and Living Standards Survey. This document along with the year 2000 Census gave an abundance of information on the demographic, economic, cultural and health aspects of the population. The information was all in tabular form, but through GIS could be displayed visually. Some GIS work has been started within Ghana, especially by a group called the Centre for Remote Sensing and Geographic Information Services (CERSGIS) at the University of Ghana. However, the majority of this work is currently focused in the southern portion of the country and particularly around the capital of Accra. The GIS work which was obtained for the Northern Region included borehole mapping done by World Vision, the Community Water and Sanitation Agency (CWSA) and the Rural Water and Sanitation Agency (RWSA) as well as mapping of disease incidence by the Guinea Worm Eradication Program. For more information on the data used, please see the bibliography which contains further descriptions of each data source.

Data creation was accomplished using an eTrex Venture GPS device manufactured by Garmin. The data points marked included the locations of various businesses and organizations within downtown Tamale, the location of households where Pure Home Water members conducted epidemiological surveys (Peletz, 2006), and the location of water sources tested for microbial contamination (Mattelet, 2006). Some boreholes, rivers and roads were also marked to check the accuracy and completeness of datasets which had been received from other organizations.

2.2 Tools Used

The system used to store, analyze and display all of the GIS data was ArcView 9.0 from ESRI. ESRI is the world's leading producer of GIS software and ArcView is the most basic form of their DesktopGIS package. To run this software the minimum requirements for a computer are 512 MB of RAM memory, a 1 GHz processor and a Windows 2000 or Windows XP operating system.

The GPS device used was the Garmin eTrex Venture. Some of its features include simultaneous tracking of up to 12 satellites, one megabyte of storage space and PC compatibility for easy transfer of data. The accuracy within Ghana tended to be 15-20 meters; however, when used in the United States, accuracy can approach 3 meters.

2.3 Field Experiences

Data collection within the Northern Region was difficult because it is unclear who stores geographical information and who does not. Before arriving, it was assumed that there would be little GIS data available, but fortunately this was not the case. However, time constraints meant that not all the organizations possibly possessing data were visited. Besides World Vision, CWSA and RWSA other organizations which may have borehole data for the region include Oxfam, Terrahydro Associates, Community Partnership for Water & Sanitation, the Northern Region Rural Integrated Program (NORRIP) and Opportunities Industrialization Centers (OIC) Ghana. However, some of the data from these organizations may already be incorporated into the World Vision dataset. When UNICEF was visited, they said their GIS coordinates were sent to World Vision since UNICEF did not have the capabilities to maintain their own database. However, UNICEF and World Vision are both part of the West Africa Water Initiative partnership and thus have a relationship in place to share data. This may not be the case with other organizations.

Besides borehole and stream data, data concerning the location of other water sources such as hand dug wells, springs and dugouts[1] appears non-existent. This should be researched further; however, the information is unlikely to be present because these sources are either natural unimproved sources or created by villagers themselves and not by outside agencies. In order to get an idea about the prevalence and pattern of these sources, a small trial area could be chosen and all the water sources manually marked. While this would take time, it would give a more complete picture of the water source landscape.

While in Ghana, some dugouts were located with the GPS device for water testing (see Figure next page). The specific locations were chosen based on the local knowledge of a taxi driver and do not represent all dugouts within the area. When traveling to water source locations, it should be noted that a quick trip is not to be expected. The dugouts are communal places where women and children come to fetch water, do laundry and play. Travel to the sight will attract attention and curiosity. If the water source belongs to a specific village, it is also culturally necessary and common courtesy to first visit the chief of the village to ask permission to visit the water source.

[1] A dugout is a depression created in the ground that collects water during the raining season and stores it for use throughout the year.

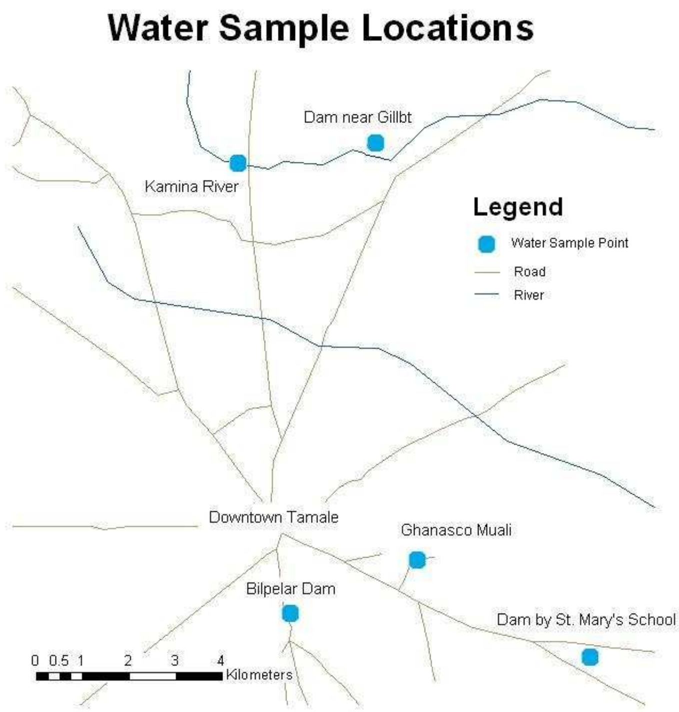

Figure 3: Water Sources Manually Marked in Tamale District

Another useful data set which was not actively pursued is the coverage of piped supply within Tamale district. There should at least be paper maps showing the locations of water lines and public connections. Because the system is intermittent in its supply, it would also be useful to know which areas received water on specific days.

Chapter 3 - Regional Statistics

Much of the pertinent information collected from the Ghana Statistical Service is presented in this section. Before beginning an implementation project, it is important to know the current state of affairs within a community. This way appropriate options can be selected and effects of the implementation can be tracked. This section lays out some of the current demographic, economic, health and infrastructure conditions in Ghana, particularly for the Northern Regions and the districts of Tamale, Savelugu-Nanton and Tolon-Kumbungu where Pure Home Water is currently focusing.

3.1 Geographical Orientation

In order to understand the area of Ghana where the project takes place, the following two maps were created. The map on the left shows the ten regions of Ghana along with major cities and large rivers. The map on the right spits up the Northern Region into its 13 districts and highlights the three districts of Tamale, Savelugu-Nanton and Tolon-Kumbungu where Pure Home Water is currently focusing.

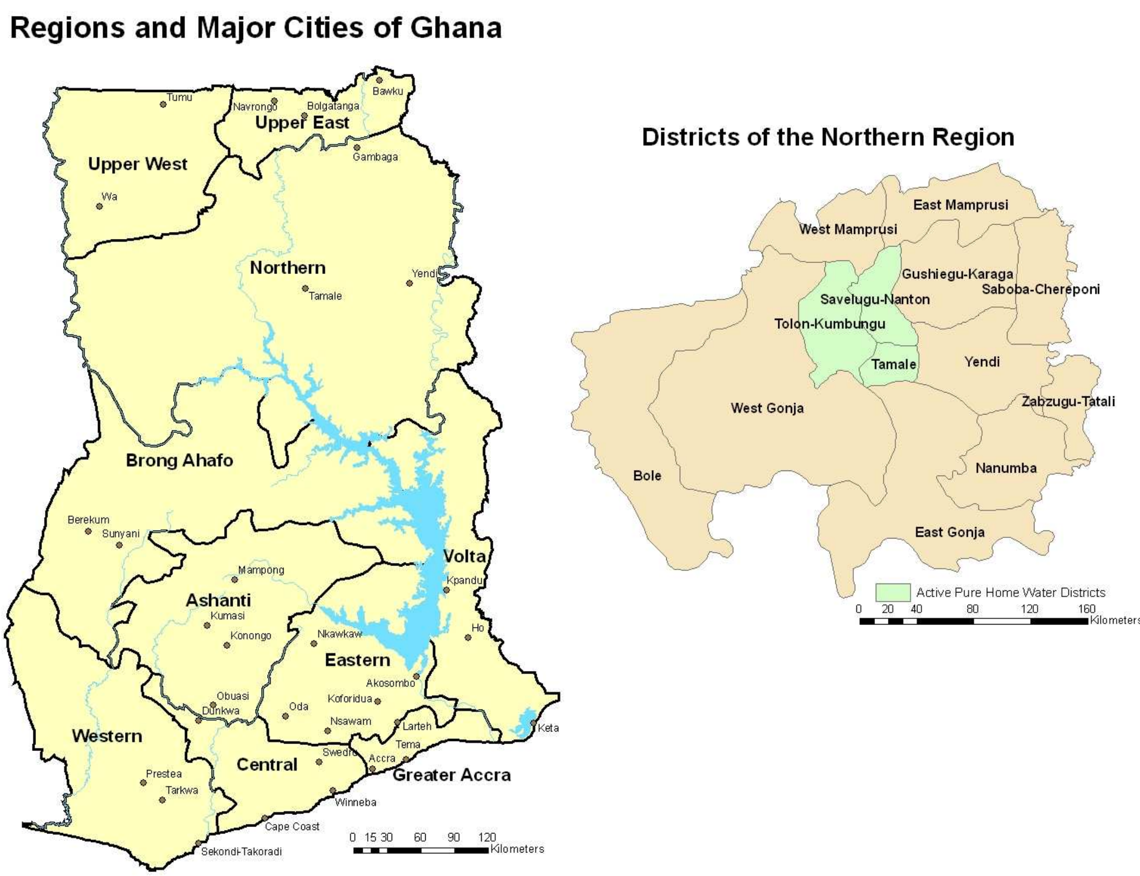

Figure 4: Regions and Major Cities of Ghana & Districts of the Northern Region

According to the year 2000 census, the three districts where PHW is currently focusing have a population of 517,000 people (GSS, 2005). The original business plan of Pure

Home Water was to have six target districts which also included West Mamprusi, Gushiegu-Karaga and Saboba-Chereponi. This would have given a target population of 851,000 people. However, due to transportation restraints, the target area needed to be decreased to its current three districts. To solve the transportation issue, a motorbike is being purchased to allow easier travel throughout the project area. Pure Home Water holds the rights to distribute the CT Filtron throughout all of the Northern Region as well as the Upper West and Upper East Regions. Thus, solutions of how to scale up the project are of great interest.

3.2 Demographics

According to the 2000 Population and Housing Census, 1.8 million people live in the Northern Region (GSS, 2005). Tamale municipality which contains Tamale, the third largest city within Ghana, accounts for 16% of the population, while the rest is spread evenly throughout the remaining 12 of the 13 districts. Within the Tamale municipality, 67% of the population is considered to be urban, while the average for the region is only 26.6% (GSS, 2005). The increased urbanization of Tamale compared to other Northern Region districts means that many services such as piped water, sanitation, electricity, waste disposal, education and health care are more available within Tamale than in the surrounding districts.

The major ethnic group in the Northern Region is the Mole Dagbon which makes up 52.2% of the population. Other large groups include the Gurma at 21.8% and the Akan and Guan each accounting for 8.7% (GSS, 2005). Each of these groups has their own indigenous languages which vary between districts. The Dagbani language, however, is the most prevalent in the region and is spoken in nine of the thirteen districts (GSS, 2005). The predominant religion of the region is Islam with 56.1% of the population being Muslim, while 21.3% follow traditional religions and only 19.3% are Christian. This is vastly different than the country as a whole in which Christianity is largest religious group, accounting for 68% of the population (GSS, 2005).

Education in the region is low with only 22% of the population being literate and only 7.9% of the population, 15 years and older, having been to secondary or tertiary school. The population is also young with 46.2% under the age of fifteen (GSS, 2005). This is due to there being both high fertility and mortality rates, with the average woman giving birth 6.7 times (GSS, 2004).

3.3 Economics

If Pure Home Water is going to be a sustainable business, the HWTS technologies must be economically feasible for the population to purchase. Within the Northern Region, 71.2% of the economically active population is employed in agriculture. This means that the income of these families is seasonal and that money for the purchase of a Pure Home Water filter or other product may only be available after a harvest. Some of these workers may, in fact, not be paid at all. In the region, 23% of the economically active population is classified as unpaid family workers while 68% are self-employed and 6%

are employees (GSS, 2005). It is only the employees who are likely to have a regular and reliable paycheck and this must be a consideration when promoting the HWTS technologies.

The cost of the HWTS technologies must also be a consideration. In 1999, 69% of the Northern Region population was classified as living below the poverty line of 900,000 cedis a year or around US$100 (Gyan-Baffour, 2003). Currently the CT Filtron is selling for 150,000 cedis (US$18) which makes it beyond the price range for the majority of the population. To address this issue, Pure Home Water offers to sell their filters on credit. This way poorer households can pay over the course of three months, instead of a single lump sum.

3.4 Health

The driving force behind implementing HWTS technologies is improvement of health through the reduction of waterborne disease. This section gives current health statistics for Ghana applicable to HWTS implementation. It is important to know which types of diseases the population suffers from, so that the proper interventions can be made and improvements can be tracked.

3.4.1 Diarrhea and Mortality Rates in Children under Five

Children have an increased susceptibility to waterborne diseases because their immune systems have yet to develop resistance to many common pathogens. They also bear an increased chance of death because their bodies are small, allowing the effects of dehydration to come about quickly. Children thus carry the overwhelming majority of the disease burden and many health indicators focus on them specifically.

One common health indicator is mortality rate. Mortality is measured as the number of children under the age of five who will die for every thousand children born. Currently the average in Ghana is that 111 deaths occur for every 1000 live births, or that 1 out of every 9 children will not make it past their fifth birthday (GSS, 2004). By contrast in a developed country like the United States, the under five mortality rate is 8 deaths out of 1000 live births (UNICEF website). The mortality rate is not uniform throughout Ghana. In the following map, it can be seen that the under five mortality rate is significantly higher in the Northern and Upper West regions than in the rest of the country. Even within a specific region, the mortality rate can be variable within districts and even from village to village depending on the current health and sanitation conditions.

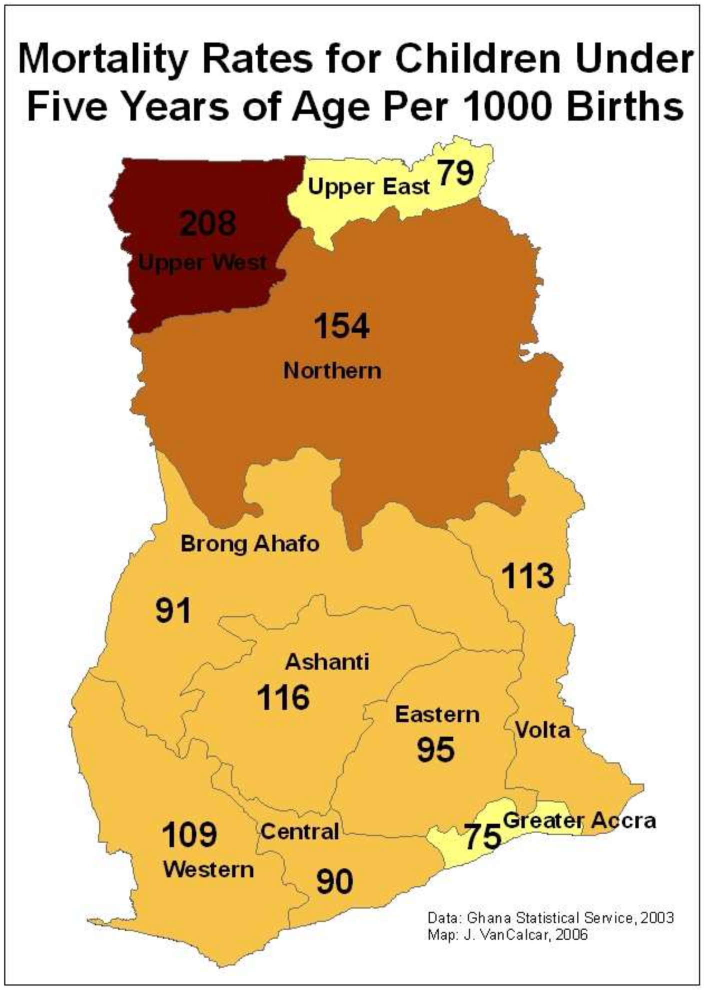

Figure 5: Mortality Rates for Children Under Five Years of Age

While the mortality rates are high in the Northern Region, the good news is that the rate has been dropping. The Demographic and Health Surveys of 1993 and 1998 showed the mortality rate of the Northern Region to be 237 and 171 respectively (GSS, 2005), so progress is being made.

Another common health indicator is the prevalence of diarrhea in children under the age of five. While there are a large variety of waterborne diseases, diarrhea is one of the most common and widespread illnesses. It causes dehydration and also necessitates that the caretaker of the family put time and resources into helping the sick child. Thus, diarrhea can place a significant burden on families and communities. The following map shows the percentage of children who had diarrhea in the period two weeks prior to the 2003 Health and Living Standards survey.

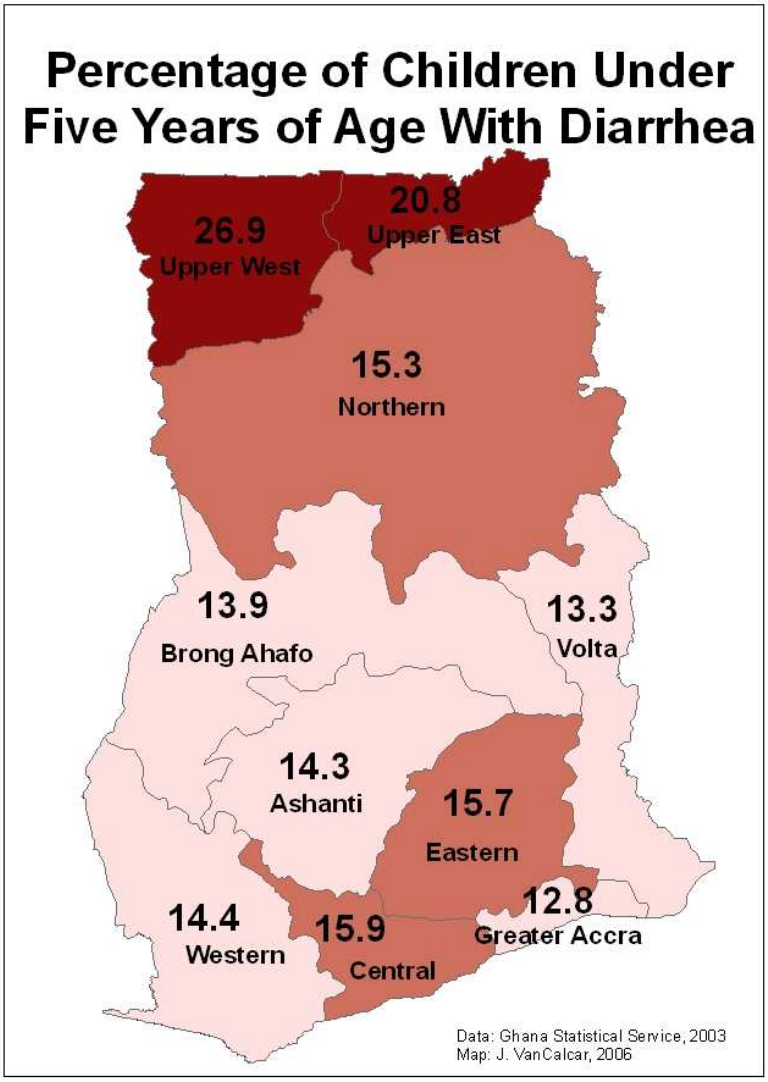

Figure 6: Percentage of Children Under Five Years of Age with Diarrhea

Diarrhea rates are high throughout Ghana with the largest problem occurring in the Upper East and Upper West Regions. One issue affecting this trend is that these regions are both poor and rural, two factors which often lead to a lack of water and sanitation infrastructure. The regions also have a largely uneducated population and thus may not know proper hygiene techniques. In the Upper West Region, 72.3% of the population six years and older has never been to school. This is the highest regional percentage in the country of never having attended school, with the national average at 38% (Ghana Statistical Service, 2005).

To get an idea how cultural factors are related to the disease indicators, Pearson's correlation coefficients were determined. Pearson's correlation reflects the degree to which two variables are linearly related. The value can range anywhere between +1.0 to -1.0. A value of +1.0 means that the two variables have a perfect positive linear relationship, as one variable goes up, so does the other. A value of -1.0 indicates a perfect negative relationship; as one variable goes down, the other goes up. A value of

0.0 signifies no linear relationship at all. Values in between zero and one indicate how strong the relationship is; it should be noted that a correlation does not indicate causation, only that the two variables are interrelated. The following table shows the correlation between a variety of factors with mortality rates and the prevalence of diarrhea. The calculations were done by the author using data from the Ghana Statistical Service (GSS, 2004).

Table 1: Correlation Coefficients between Cultural Factors, Mortality and Diarrheal Prevalence

	Correlation with Mortality	Correlation with Diarrhea
% of the population which is rural	0.46	0.58
% of the population with no education	0.52	0.65
% of the population with no access to media	0.73	0.71
% of households without hand washing material	0.25	-0.01
% of children under five with fever	0.36	0.41
% of children age 12-23 months with no vaccinations	0.49	0.08
% of children under five with diarrhea	0.65	

Some caution should be noted when looking at this table since the correlations are only based on ten data points, corresponding to the ten regions within Ghana. The low number of data points leaves room for uncertainty. When a 95% confidence interval was calculated for the correlation between diarrhea prevalence and mortality, the range was 0.04-0.90. This means that it is 95% certain that the true correlation coefficient is between this range of values; there is no guarantee that it is actually 0.65.

3.4.2 Guinea Worm Prevalence

Guinea worm is a disease that nowadays is largely limited to Ghana, Sudan and a few other countries. It is contracted when a person drinks water containing microscopic water fleas that have guinea worm larvae living inside them. Inside the stomach, the water fleas are digested and release the guinea worm larvae to mate, mature and grow. After a year, the mature female worm, up to 3 feet in length, travels through the body to typically the foot or lower leg of her host. The worm then breaks through the skin and slowly emerges in the form of a painful blister. To soothe the pain the host will often immerse their foot in water; when this happens, the female worm releases her larvae which can then infect more fleas. Fortunately, the cycle can be stopped if people drinking from surface water use a cloth or another material to filter their water. This retains the water fleas and stops their ingestion. Using this technique and other eradication methods, guinea worm is close to being eradicated completely.

The disease is debilitating to communities because people with guinea worm are unable to walk, much less harvest their crops or take care of household duties while the worm emerges. In 1986 the Carter Center began a campaign to stop the disease and has accomplished a 99.5% reduction with only 10,674 cases reported worldwide in 2005. This number is down from 3.5 million cases when the program first began. The remaining cases are concentrated in Sudan and Ghana with 3,981 cases being reported in Ghana during 2005. To see where the problem is focused, the map below shows the number of villages within each district that have endemic guinea worm.

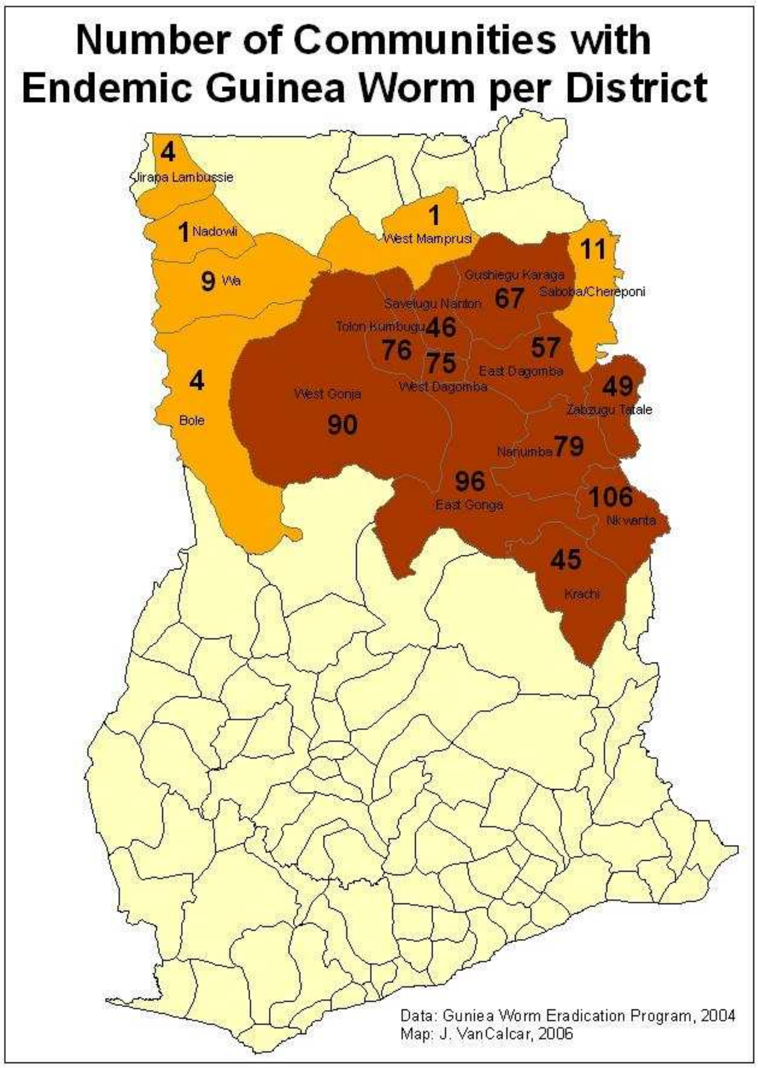

Figure 7: Number of Communities with Endemic Guinea Worm per District

To get an idea where the individual villages are, the Guinea Worm Eradication Program has created the following map of the Northern Region. This map differentiates between villages where guinea worm is endemic and those villages which have an imported case of the disease. This means that someone in the village has guinea worm but it is not prevalent throughout the whole community, rather it was picked up during travel.

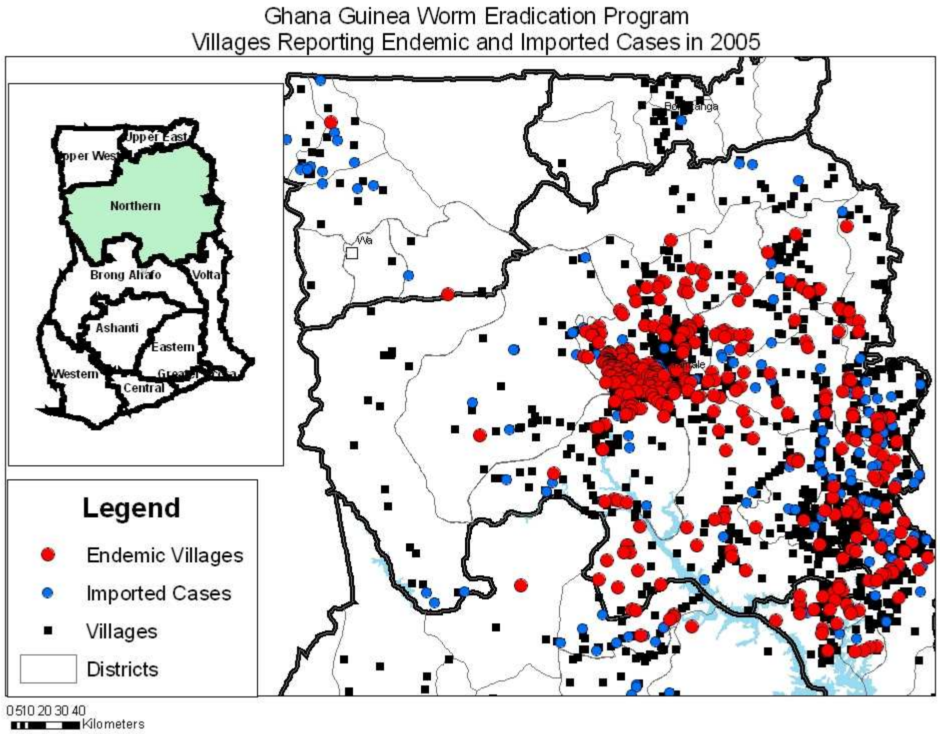

Figure 8: Villages Reporting Endemic and Imported Cases of Guinea Worm in 2005 (Guinea Worm Eradication Program, 2005)

3.5 Infrastructure

Knowing the water sources and sanitation approaches communities use gives valuable information about the need for HWTS technologies and other forms of water and sanitation intervention.

3.5.1 Water Infrastructure

In the developed world, most people receive the water they need for drinking, cooking and washing from a piped supply or a private well. This water is generally always available, abundant, and of a high quality. However, this is not the case in most of the world. Piped supplies do exist in developing countries, but they are prone to breakdown, intermittent delivery and potentially poor water quality. Another issue is that distribution systems typically only serve people within the immediate urban areas, leaving most of the population to rely on alternative sources.

The alternative sources available include surface water, hand dug wells, boreholes, springs, rain water harvesting and tanker trucks. Surface water sources are the most dangerous and unfortunately the most commonly used. Streams, lakes and ponds are all open to contamination through human and animal fecal material as well as chemicals picked up from overland runoff. In Ghana, dugouts are a common surface water source.

They are created by forming depressions in the ground which collect water during the rainy season and store it throughout the dry season (see Figure 9).

Figure 9 left: Local Dugout in Ghana (Photo by C. Mattelet) right: Women Using a Hand Dug Well (Photo by R. Peletz)

Groundwater is a safer source than surface water since it is protected from direct contamination and filtered through the soil. One way to access groundwater is through hand dug wells. These wells are low cost and can be a wise choice if the water table is not far below the ground surface. However, to prevent contamination they need to be protected. This includes placing a cover over the well along with a headwall and drainage apron to stop surface water from running into the well. A system should also be in place so that it is not necessary to touch the rope or bucket when retrieving water. If people are using their hands to raise and lower buckets, then contamination may transfer from hands, to the bucket and then to the water. Figure 9 shows an example of a hand dug well that has a cover but no fetching system.

Boreholes are another way to access groundwater. They must be installed by professional drillers and are thus more expensive then hand dug wells. However, they can reach deeper groundwater and have pumps to bring the water to the surface (see Figure 10). One drawback to boreholes is that the mechanized parts need to be maintained. Typically villagers do not have the knowledge for proper maintenance and must be trained if the borehole is going to operate successfully in the long term.

Groundwater can also be accessed where it naturally comes to the surface and seeps out in the form of a spring. Analogous to the hand dug well, for a spring source to remain pristine it should be protected. The area around the spring should not be developed and a box should be built around the spring to collect water and store it safely. Figure 10 shows a spring source which has not been protected.

Figure 10 left: Girls Using a Borehole in Ghana (Photo by J. VanCalcar) right: Unprotected Spring (Photo by S. Murcott)

Besides surface water and groundwater, rain water can be collected and stored for drinking. Rain water is of a high quality but must be stored carefully to insure enough supply and prevent contamination. One concern with this technique is that if not enough water can be stored, lesser quality water sources must be relied on. Metal roofs are typically the surface used for water collection; however, in Ghana most roofs are thatch and thus rain water harvesting is currently uncommon.

Another drinking water option is tanker truck delivery. These trucks are typically run by the government or private companies and deliver water to households or communities for a fee. However, there is no guarantee of where the water has come from. In an ideal situation it would come from a water treatment plant in a clean truck; however, in many cases it simply comes from a large surface water source (see Figure 11).

Figure 11 left: Rain Water Harvesting Container from Bangladesh (Photo by S. Murcott) right: Tanker Truck Refilling from a Dugout in Ghana (Photo by J. VanCalcar)

The map below shows the percentage of households within the three districts where Pure Home Water is currently focusing which use the various water sources mentioned above along with piped supplies.

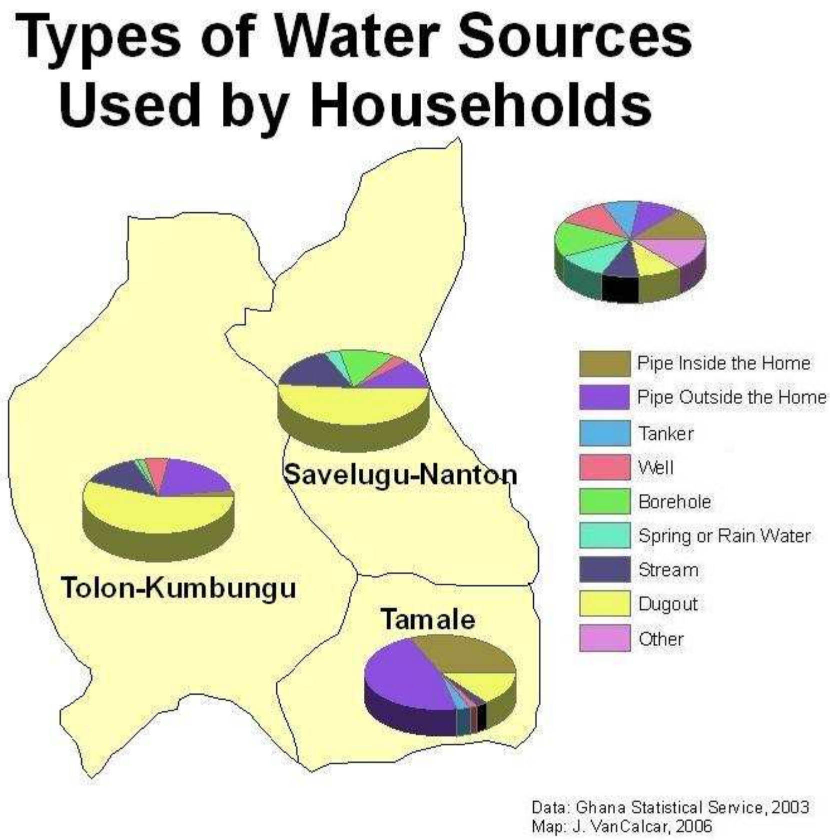

Figure 12: Types of Water Sources Used by Households

It can be seen that the majority of people in the rural districts of Savelugu and Tolon are using surface water sources, particularly dugouts. These sources are not safe. Water samples taken from dugouts within Tamale district showed total coliform levels between 757 and 25,000 CFU/100 mL (Mattelet, 2006). Ideally, drinking water should have no coliform present since it is an indicator of fecal contamination.

The World Health Organization and UNICEF Joint Monitoring Program have categorized drinking water sources into improved and unimproved sources. Examples of improved water sources include household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater harvesting (WHO/UNICEF Joint Monitoring Program, 2005). Examples of unimproved water sources are any surface water source, unprotected wells, unprotected springs and tanker trucks. If the distinctions between improved and unimproved sources are used, the following map shows the percentage of the population which has access to these sources throughout the Northern Region.

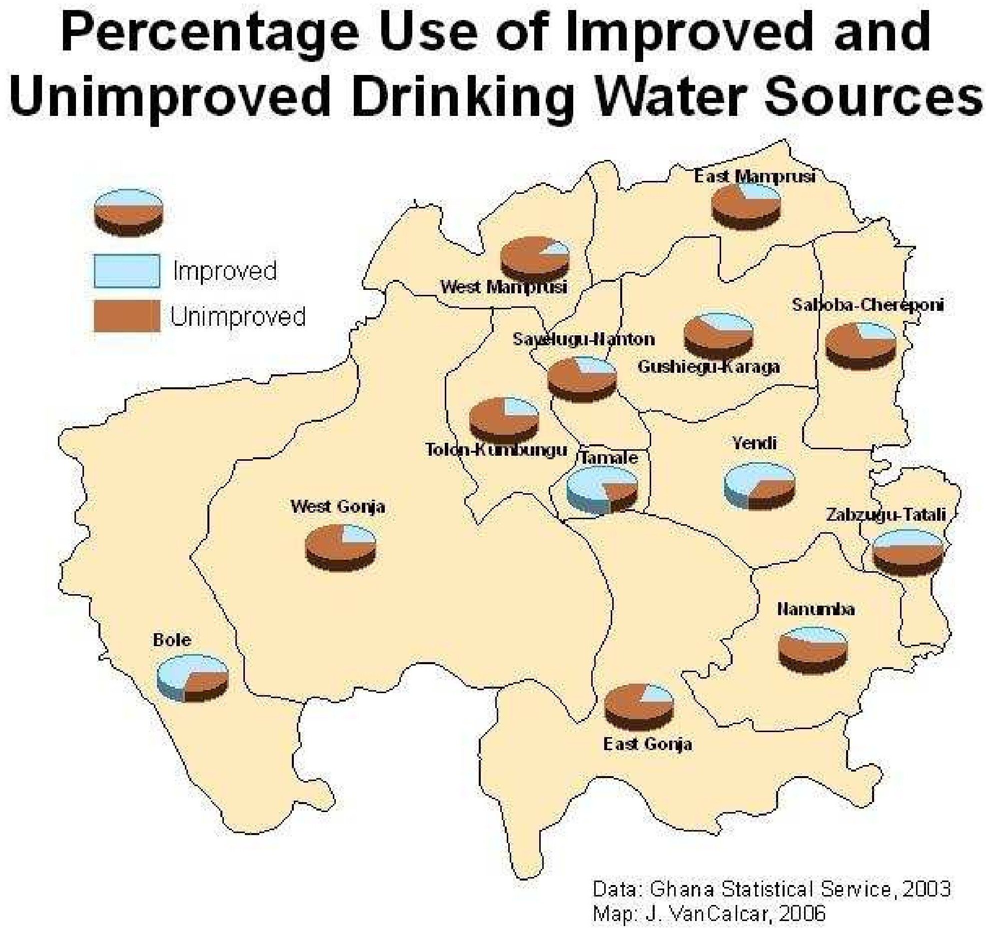

Figure 13: Percentage Use of Improved and Unimproved Drinking Water Sources

It can be seen that currently more than half of the population in each district is using water from an unimproved source. Exceptions include Tamale where there is a significant proportion of the population with a piped supply, as well as Bole and Yendi Districts which are fortunate to have good coverage through borehole drilling. Taking into account the population of each district according to the year 2000 census, the map above indicates that approximately 1 million of the 1.8 million or 56% of people living in the Northern Region are currently drinking from an unimproved source.

It is these people without a safe drinking water source who are most in need of an improved water supply and/or household drinking water treatment and safe storage. However, even the portion of the population with access to an improved source is still a potential customer. This is because contamination of water can often occur in the distribution of piped supplies or during storage of drinking water within the home.

3.5.2 Borehole Coverage

Boreholes are on the list of drinking water sources considered improved by the UNICEF/WHO Joint Monitoring Program. One of the benefits of boreholes is that they allow people to access groundwater, which is typically of higher microbial quality than surface water. If geologically feasible, boreholes can also be located within individual villages. This saves people, especially women and children, large amounts of time previously spent walking to and from water sources. Since the boreholes are closer, it also becomes easier to transport larger quantities of water. This can increase health benefits due to hygiene practices becoming easier to maintain.

However, groundwater is not available everywhere and the hydrogeologic characteristics of an area must be taken into account. The Northern Region is comprised of mainly shale and mudstone beds which tend to have a low groundwater potential yield (MacDonald et al, 2005). However, drilling rigs in the area have been successful in reaching water. The map below was created by the World Vision office in Savelugu and shows some of the borehole drilling progress throughout the Northern Region.

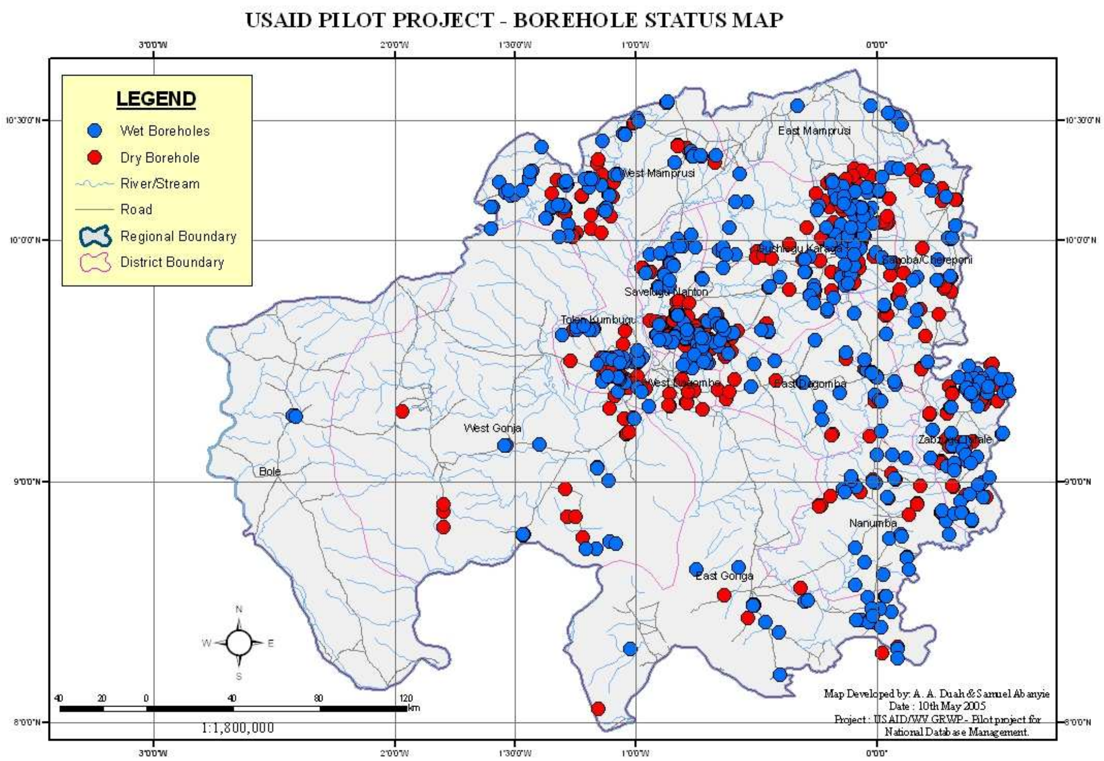

Figure 14: Wet and Dry Boreholes Drilled by the WAWI Partnership

Figure 14 shows a total of 964 boreholes being drilled of which 497 were successful and 467 turned out dry. This gives a success rate of just over 50%, which is not ideal but shows that drilling in the area is feasible.

The following map gives a more complete picture of borehole coverage throughout the region. It was created using the data points supplied by World Vision in the map above along with data sets collected from a European Union funded group known as the Rural Water and Sanitation Agency (RWSA) as well as the semi-autonomous Community Water and Sanitation Agency (CWSA), which is a government agency responsible for rural water and sanitation services.

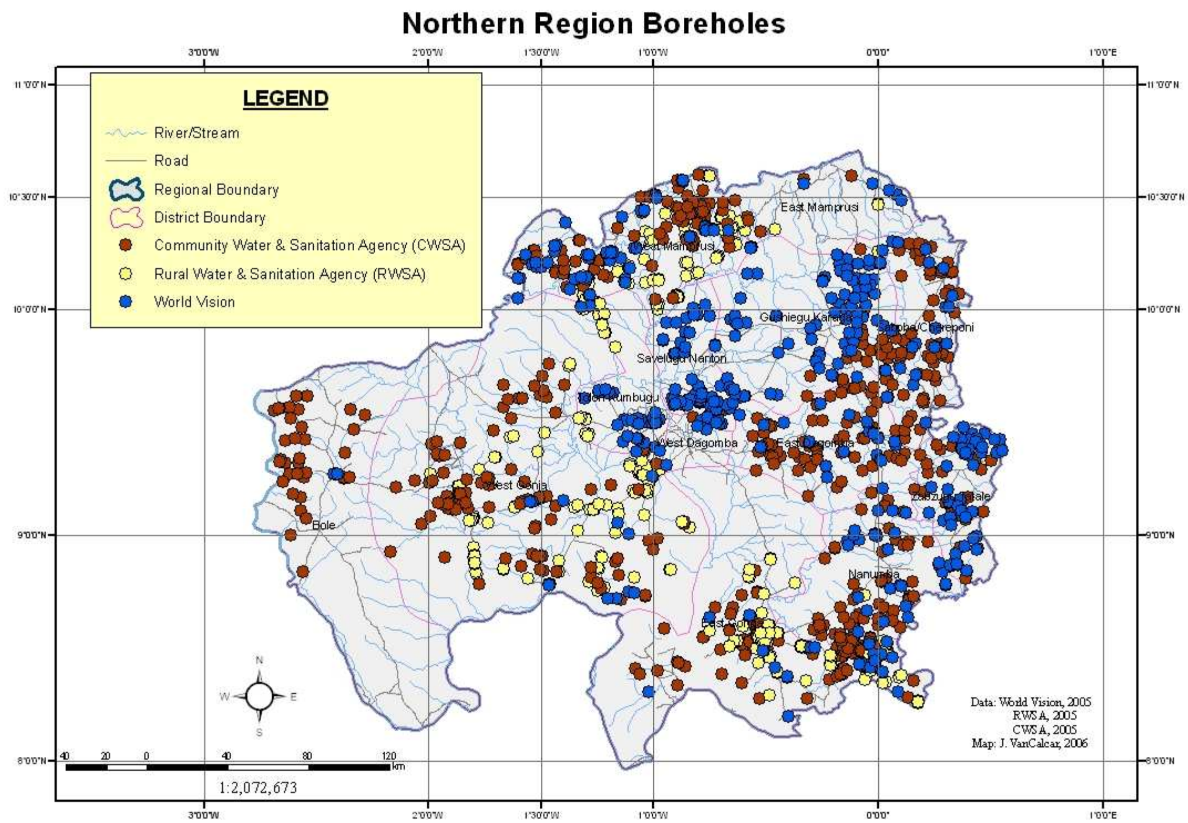

Figure 15: Northern Region Boreholes

The World Vision and RWSA data sets indicated which of the boreholes drilled were successful and which turned out dry; however this information was not known for the CWSA drilled boreholes. Since the success rate for both World Vision and RWSA were comparable at 50% and 47% respectively, a similar rate can be assumed for CWSA. This map then shows that there are slightly more than one thousand boreholes operating successfully throughout the Northern Region. However, the dataset is likely incomplete. Figure 13 showed the percentage use of improved and unimproved drinking water sources throughout the Northern Region and indicated that Bole district has a comparatively high percentage of improved water sources. This should be from borehole coverage, but is not indicated above in Figure 15.

3.5.3 Sanitation Infrastructure

Sanitation is intimately linked with water quality. Improper sanitation practices can lead to surface water sources and groundwater supplies becoming contaminated with fecal matter. But even if the drinking water of a community is protected, the disease burden may not significantly drop. This is because improper sanitation increases other disease pathways such as food contamination or disease spread through insect populations. In order to get an idea of the sanitation practices used in the Northern Region, the following map shows the types of sanitation facilities families have available to them within the districts of Tamale, Savelugu and Tolon.

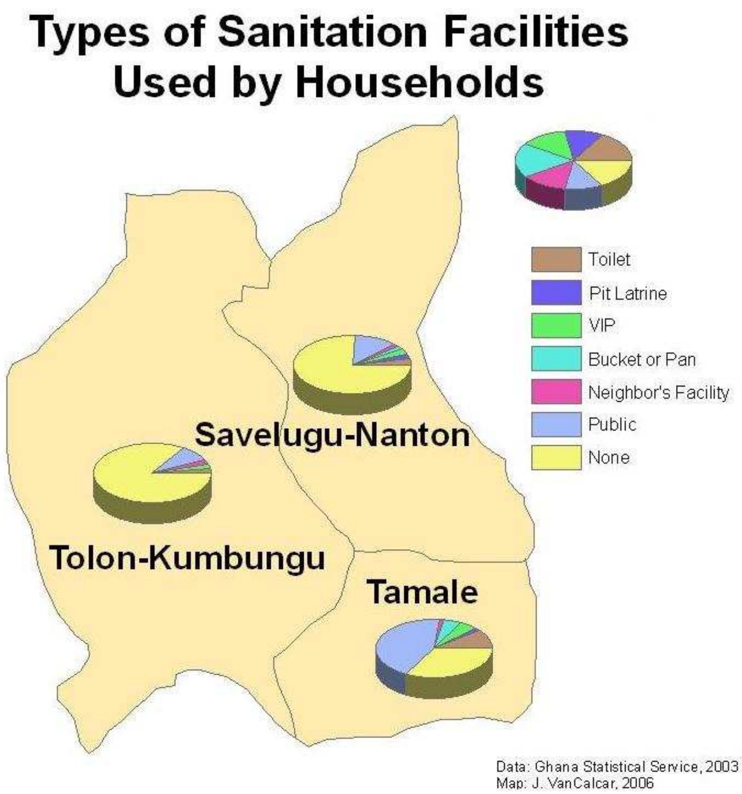

Figure 16: Types of Sanitation Facilities Used by Households

It can be seen that in the rural districts, sanitation facilities are lacking in more than three-fourths of the communities. While sanitation infrastructure is outside the scope of Pure Home Water activities, it is important to note that health benefits from an improved quality of drinking water may not be fully realized within the areas in which adequate sanitation has not been addressed.

Comparable to drinking water, the World Health Organization and UNICEF have distinctions between what is considered an improved and unimproved sanitation facility. Improved facilities include a connection to a public sewer or septic system, a pour-flush latrine, a simple pit latrine and a ventilated improved pit latrine. Unimproved facilities include public or shared latrines, open pit latrines and bucket latrines (WHO/UNICEF

Joint Monitoring Program, 2004). The key to being considered an improved facility is that privacy and hygienic use are maintained. Taking these definitions into account, the following map shows the percentage of people throughout the Northern Region who have access to improved sanitation.

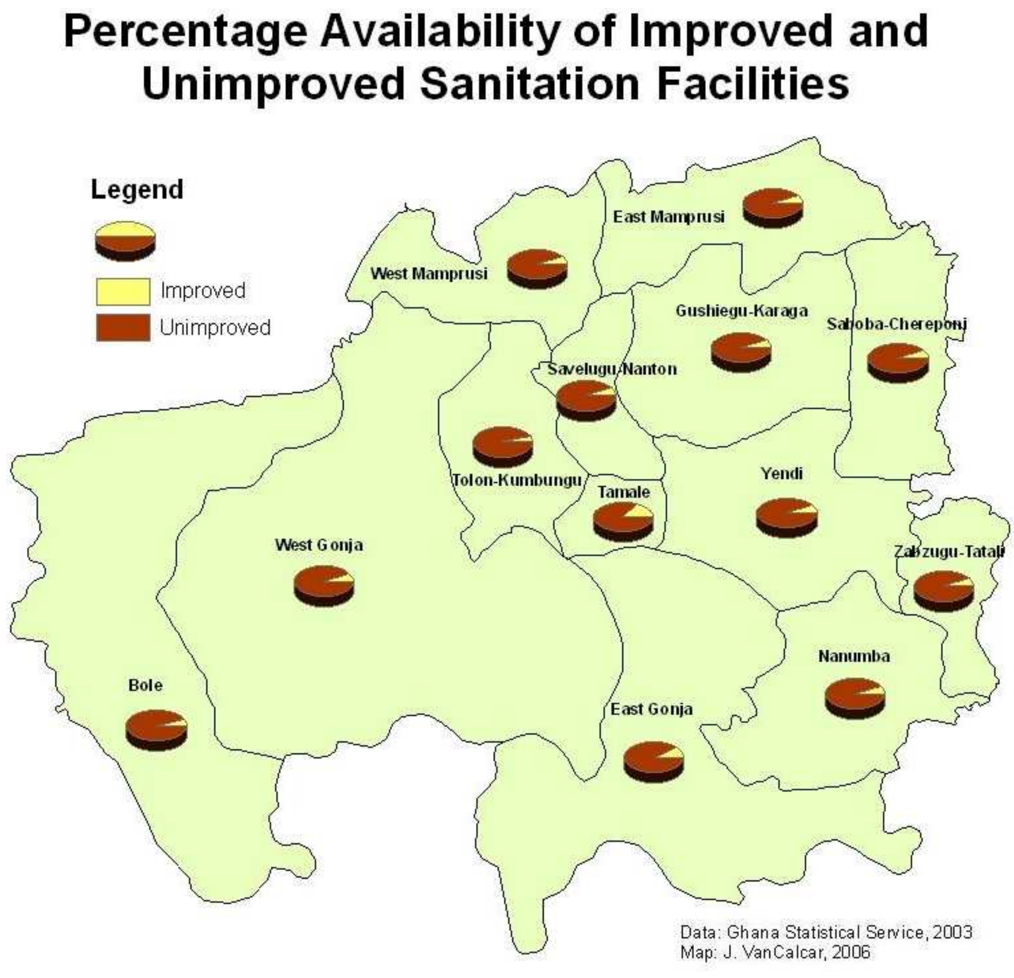

Figure 17: Percentage Availability of Improved and Unimproved Sanitation Facilities

It can be seen that throughout the whole region, the majority of the population lacks access to improved sanitation facilities. This is even the case within Tamale, where many people rely on public toilets for their sanitation needs. Since privacy and hygienic quality cannot be guaranteed in the developing world's public latrines, these facilities are not considered a suitable sanitation alternative. Taking into account the population of each district according to the year 2000 census, the map above indicates that 92% of the population does not have access to an improved sanitation facility and 71% of the population has no sanitation facility available at all.

3.6 Comparison between GSS Data and Data Collected by R. Peletz

While in Ghana during January 2006, a Pure Home Water team member, Rachel Peletz, surveyed communities as part of an epidemiological cross-sectional study. The objective of her work was to collect baseline data on the communities where Pure Home Water was actively focusing as well as to compare households with HWTS technologies to those without. The following table shows some of her results compared to what was provided by the Ghana Statistical Service.

Table 2: Comparison of Ghana Statistical Service Data to Survey Results of R. Peletz

		Tamale		Savelugu		Northern Region
		Survey Data[1]	GSS Data[2]	Survey Data[1]	GSS Data[2]	GSS Data[3]
Communities Surveyed	%Traditional/Rural	21%	33%	100%	65%	
	%Non-traditional /Urban	79%	67%	0%	35%	
Household Information	Average household size	7 people	6.5 people	24 people	6.1 people	
	Female population with no education	21%	59%	100%	83.3%	
Diarrheal Prevalence	Diarrheal Prevalence for children under 5	13%		17%		15.3%
Hygiene and Sanitation	Appropriate Hand-washing	86%		86%		37.6%*
	Adequate sanitation facility	79%	64.4% have facilities, 13.6% have improved facilities	5%	24.1% have facilities, 4.8% have improved facilities	
Water Use Practices	Tap	79%	33.2%	0%	0.4%	
	Standpipe	21%	45.6%	5%	9.6%	
	Borehole	0%	0.6%	86%	15.4%	
	Dam/surface	0%	14.1%	9%	65.5%	
	Tanker	0%	3.9%	0%	0.6%	
	Well	0%	1.7%	0%	3.7%	
	Spring/rain	0%	0.2%	0%	4.4%	
	Always Using Improved Water Source	64%	79.6%	64%	29.8%	

[1] R. Peletz, 2006
[2] Ghana Statistical Service, 2005
[3] Ghana Statistical Service, 2004
*Have hand-washing materials available

Many of the differences can be attributed to the smaller sample size of Peletz's survey. There were 28 households surveyed within Tamale district and 22 surveyed within Savelugu. All of the households surveyed by Peletz within Savelugu came from rural communities which also separates her survey results from the results for the whole district. Other differences came from the way variables were defined. Peletz defined households as everyone living within a communal circle of dwellings. This gave an average household size of 24 people in Savelugu district compared to the GSS Savelugu average of 6.1 people. Another difference was in the number of people using appropriate hand washing methods. In Peletz's survey, people were asked when they washed their hands: before cooking, before eating, after using the restroom as well as if they had soap present in the house. However, she did not check to see if the soap was actually present and available for easy use. In the GSS survey, a household having water, a basin and soap or ash available in a designated spot close to the house qualified as following appropriate hand washing techniques. Besides these differences, much of the data does coincide and supports the assumption that the data coming from the GSS accurately represents the communities with which Pure Home Water is currently working.

Chapter 4 - Tools for Implementation

The previous maps are useful in conveying important information about the region; however, another effort was made to see if GIS could be useful in the actual process of HWTS dissemination. In order to test this, two different roles for GIS were examined. The first was to create a database of villages within Pure Home Water's current area of operation. It was hoped that this database would be useful for strategic marketing purposes. The second use was to keep track of the project's progress, such as where inventory has gone and what marketing strategies have been tried.

4.1 Village Database

The village database took as a starting point the gazetteer or official list from the Ghana Statistical Service of all the villages in each district (GSS, 2005). However, the problem emerged that there was no geographic location associated with each village. To put together a map, both a name and a geographic location are needed. Going out and marking points manually throughout the district would have taken more time than was available for this thesis. So instead, a database was created by combining previous mapping efforts.

The data sources which contained both village names as well as locations included a worldwide set of populated places from the National Geospatial-Intelligence Agency, a dataset of villages which World Vision provided, and borehole data from various agencies. Each borehole often had associated with it the village for which it was drilled, thus the boreholes could be used as approximate village locations. These datasets were combined to get the most inclusive map of villages possible. However, the points on the maps were simply geographic locations. In order to get more information, the gazetteer was consulted to determine the population of each village and available facilities such as schools and health clinics. Unfortunately though, the match between the gazetteer and villages found in the database was far from perfect. Many of the names in the gazetteer did not show up on any of the location sources and thus data about them could not be included on the maps. Also, many villages on the map did not appear in the gazetteer. This could have been for a variety of reasons. One is that the name given on the map was so different from the name in the gazetteer that it could not be recognized as representing the same village. This could happen due to the variety of tribal languages with different spellings and names for villages. Another explanation is that the gazetteer list is from the year 2000, so there could be villages which may show up on older maps that no longer exist or have changed their names. There may also be new villages which have been formed since the list was created.

Despite these discrepancies, it was important that the maps provided a picture accurate enough to be useful to the Pure Home Water entrepreneurs. In an effort to ensure the largest cities were included, local students from the School of Hygiene were consulted. These students often traveled to local villages to administer surveys and teach basic hygiene. Thus, they were believed to be knowledgeable about the local geography. The students were given a list of the villages which appeared in the gazetteer but not on the map and had populations greater than one thousand people. While the students were instrumental in locating a variety of villages, there were many large villages, within their own district, of which the students had not even heard. Since these students were better traveled than the average citizen, it can be assumed that local geographical knowledge tends to be lacking and only covers immediate areas of interest. Another observation which came from interacting with the students is the unfamiliarity with written place names. One student would say the village name aloud, often trying different pronunciations until it was recognized.

Although the village database is far from perfect, it is still the most complete map of locations along with village information that I have encountered. As a gauge of how inclusive the maps are, the following table shows the number of villages listed in the gazetteer, the number displayed on the map and the percentage of the population this represents. The comparatively low percentage of the population represented on the Tolon map is due to the lack of large cities in this district. In contrast, by simply putting the city of Tamale on the map, 69% of the population was accounted for within its district.

Table 3: Percentage of the Population Accounted for in the Village Database

	Number of Villages According to the Gazetteer	Number of Villages on the Map	Percentage of the Population Accounted For
Tamale	140	85	86%
Savelugu	148	109	82%
Tolon	251	137	58%

4.1.1 Population

A basic map of villages can be useful to implementers as a planning strategy. Without knowing how many villages exist, there is no way to know when all have been visited. There is local knowledge, but this is often concentrated around a specific area, and a systematic system is better to keep track of progress and make sure there are no exclusions. Knowing the population can also be an asset to Pure Home Water in order to determine what kind of a demonstration may be appropriate or how many materials need to be brought along during visitations.

The following three maps show the villages and major connecting roadways for Tamale, Savelugu-Nanton and Tolon-Kumbungu districts. There is a separate map for each of these three districts, with symbols proportional to the village populations. It should be noted that the villages with the smallest symbols are those locations for which an entry could not be found in the gazetteer, and thus no population data is available.

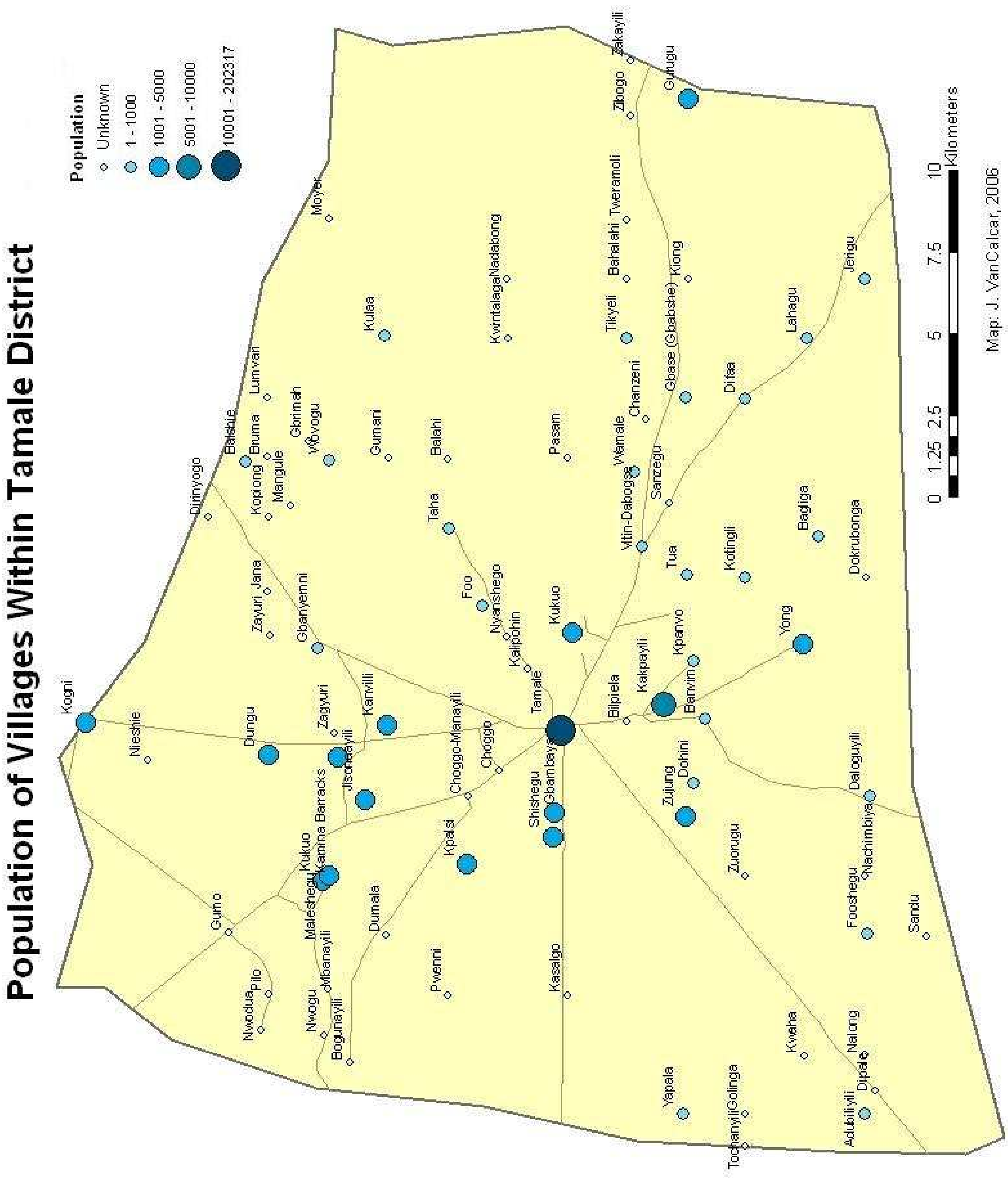

Figure 18: Population of Villages within Tamale District

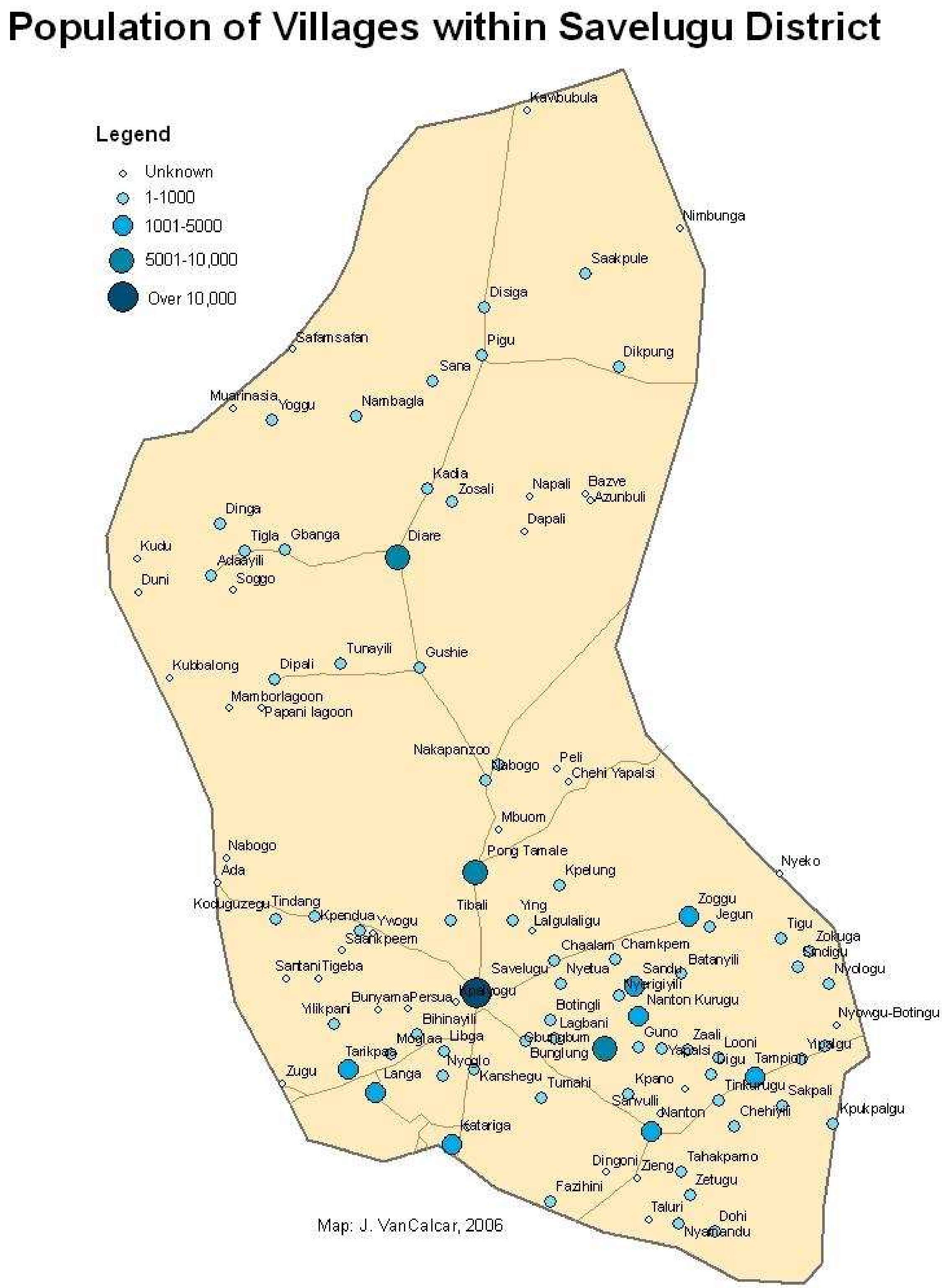

Figure 19: Population of Villages within Savelugu District

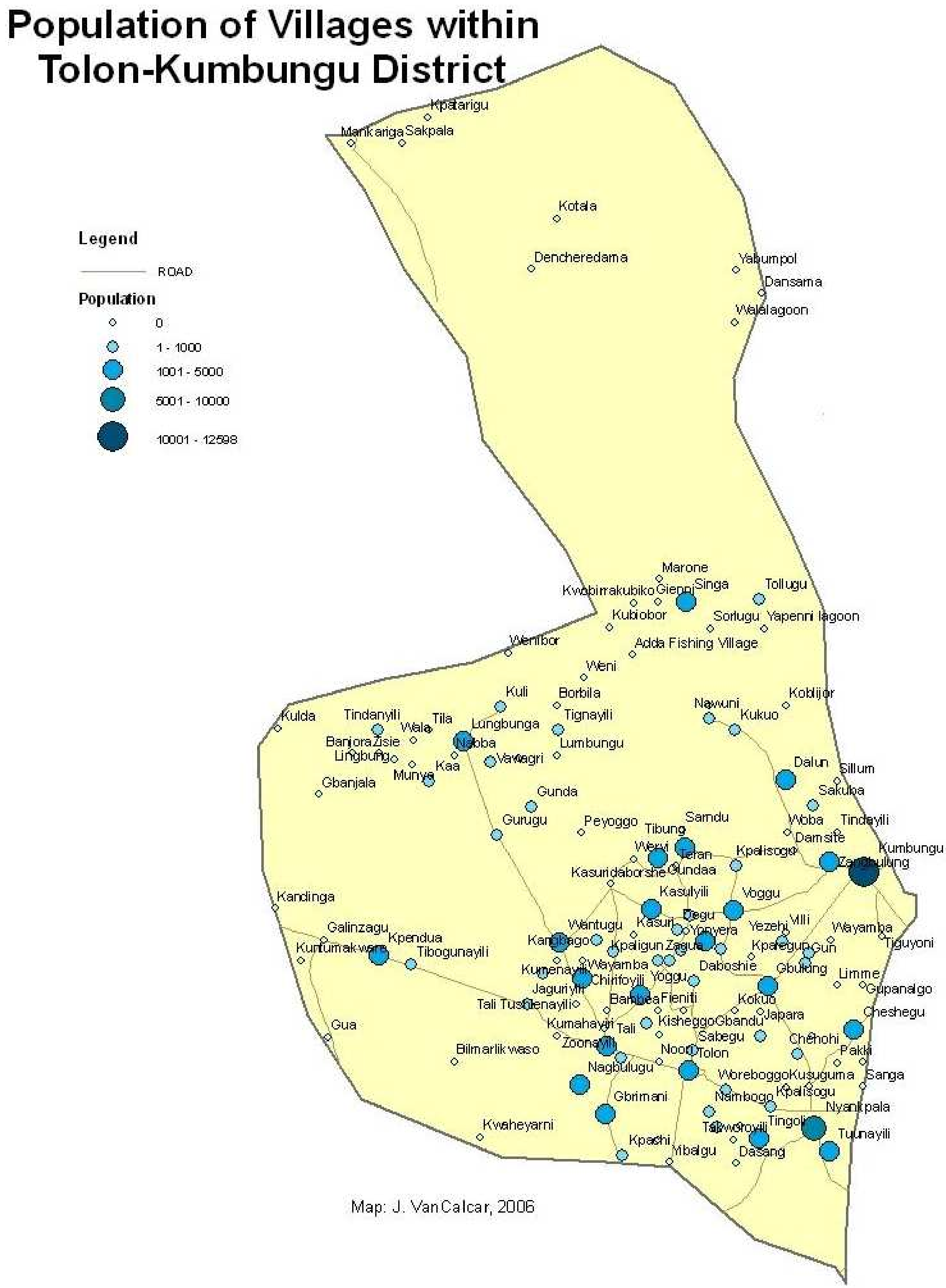

Figure 20: Population of Villages within Tolon-Kumbungu District

4.1.2 Available Facilities

One common mechanism for HWTS implementation is to work in collaboration with other organizations, allowing the technology to spread through their clients and contacts. As an example, the CT Filtron manufacturer, Ceramica Tamakloe Ltd, provided a group of midwives from Northern Ghana 150 filters to sell and distribute to their patients. This was part of an arrangement with the original filter manufacturing trainers and funders, the Stichting De Oude Boek Foundation. Another relationship currently under discussion, is to market the filters at Shell gas stations throughout the Northern Region. Similar relationships could be started among health clinics or even among schools. In an effort to see the geographical distribution of these facilities, the following maps were created. The first map shows health clinic locations within Tamale and the second map shows the schools within each community. Within Ghana, the second level of schooling is referred to as Junior Secondary School (JSS), followed by Senior Secondary Schooling (SSS). Similar maps were also created for Savelugu and Tolon districts and they can be found in Appendix A.

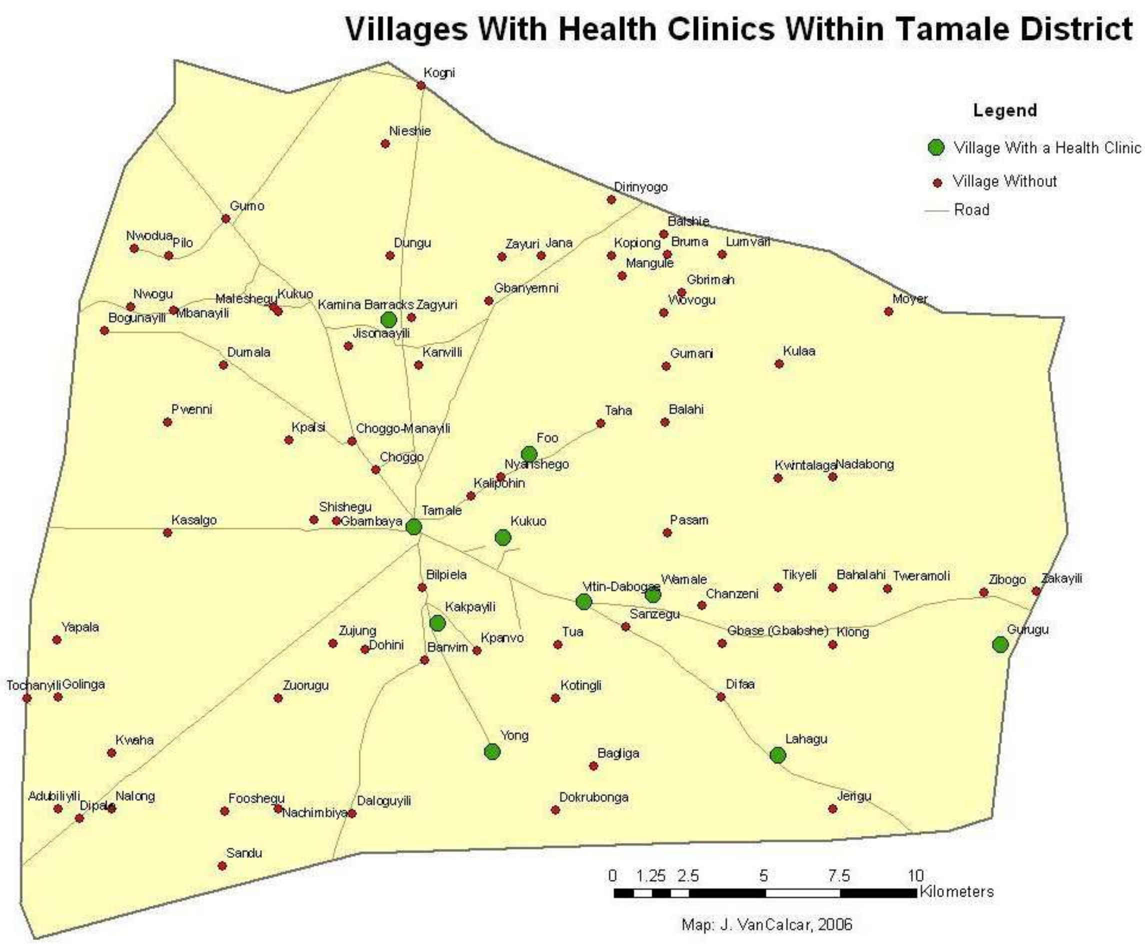

Figure 21: Health Clinic Locations in Tamale District

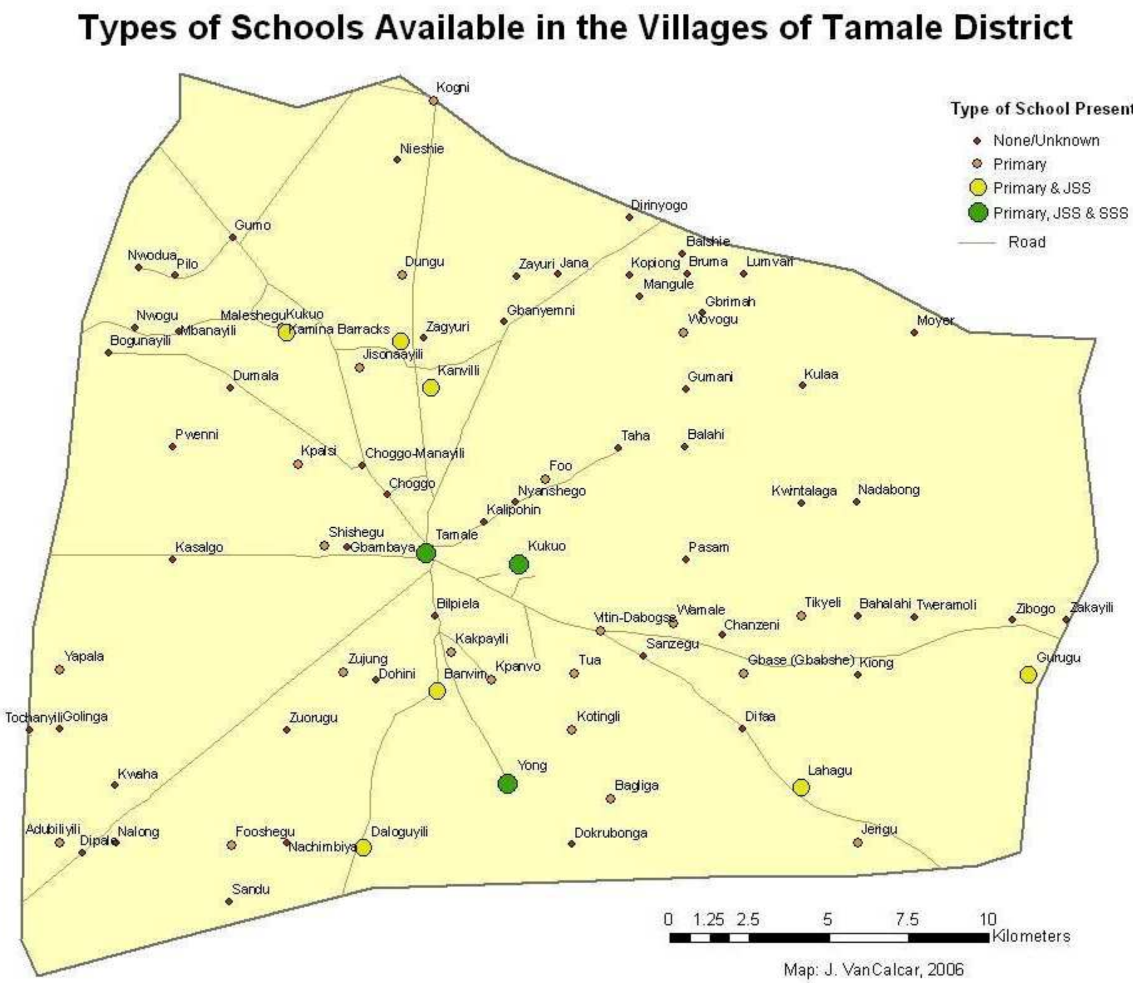

Figure 22: Types of Schools Available within the Villages of Tamale District

Looking at these maps is not only useful for Pure Home Water, but displays the coverage of essential infrastructure in the region. It can be seen that while primary school coverage is reasonable, the availability of secondary and tertiary school drops off. This lack of infrastructure is likely a contributor to the low rate of only 7.9% of the population over the age of 15 who has received education past the primary level in the Northern Region (GSS, 2005). The following figure show areas which have access to primary, secondary or tertiary schools within Savelugu district. For these maps, access was defined as within a 10 kilometer walk. This may seem far but is reasonable within a developing world setting. While coverage is not the only aspect to be considered when setting up a partnership, there is importance in making sure retail locations are available for the most customers possible. In this case, it seems that primary schools would be a good target as a partnership opportunity.

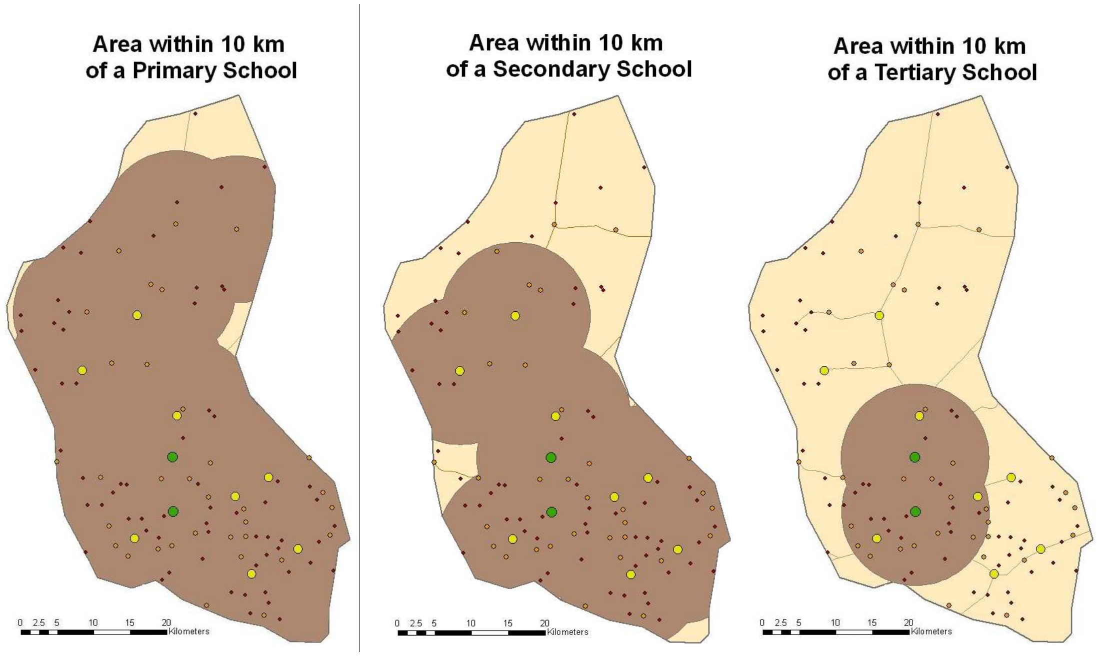

Figure 23: Access to Primary, Secondary and Tertiary Schools in Savelugu District

Another infrastructure problem is that the rural nature of the region isolates people from life outside their communities. For example, in more than 60% of communities people must travel, typically walk, more than 10 kilometers to reach a post office. And in all districts accept for Tamale, less than 2.8% of communities have access to a local phone (GSS, 2005). This lack of communication infrastructure hampers the spread of new ideas and technologies, such as household drinking water treatment. The villages which need the technologies the most will not have access to radios, newspapers or other common advertising techniques. Currently, Pure Home Water is trying to spread word of their products through market days and other outreach activities. Every six days, rural villagers come to larger urban cities to sell goods and buy supplies for their families. Pure Home Water has taken advantage of this by renting a prominent booth in the Tamale central market to display their products and raise awareness of the need for safe drinking water storage and treatment. While this effort produces few sales, the hope is that it raises awareness of the product so that future sales may be made. Currently, this effort has only taken place within Tamale; however, travel to other market locations such as Savelugu, Nanton and Diare are planned.

4.1.3 Water Source Locations

Villages without access to an improved water source are those which most need HWTS technologies. Collected data concerning water source location includes a layer of stream locations received from World Vision, and borehole locations received from World Vision, CWSA and RWSA. Manual points were also taken of selected dugouts in Tamale district at which water quality testing was done. The following map shows an analysis done within Savelugu district to determine which villages have borehole access. According to the WHO/UNICEF Joint Monitoring Program, a borehole is accessible if it is within one kilometer walking distance. However, due to inaccuracies in locating villages, an error margin was incorporated and 1.5 kilometers was considered by the author to be accessible to a village. With this information, Pure Home Water could choose to specifically target those communities without access to an improved source.

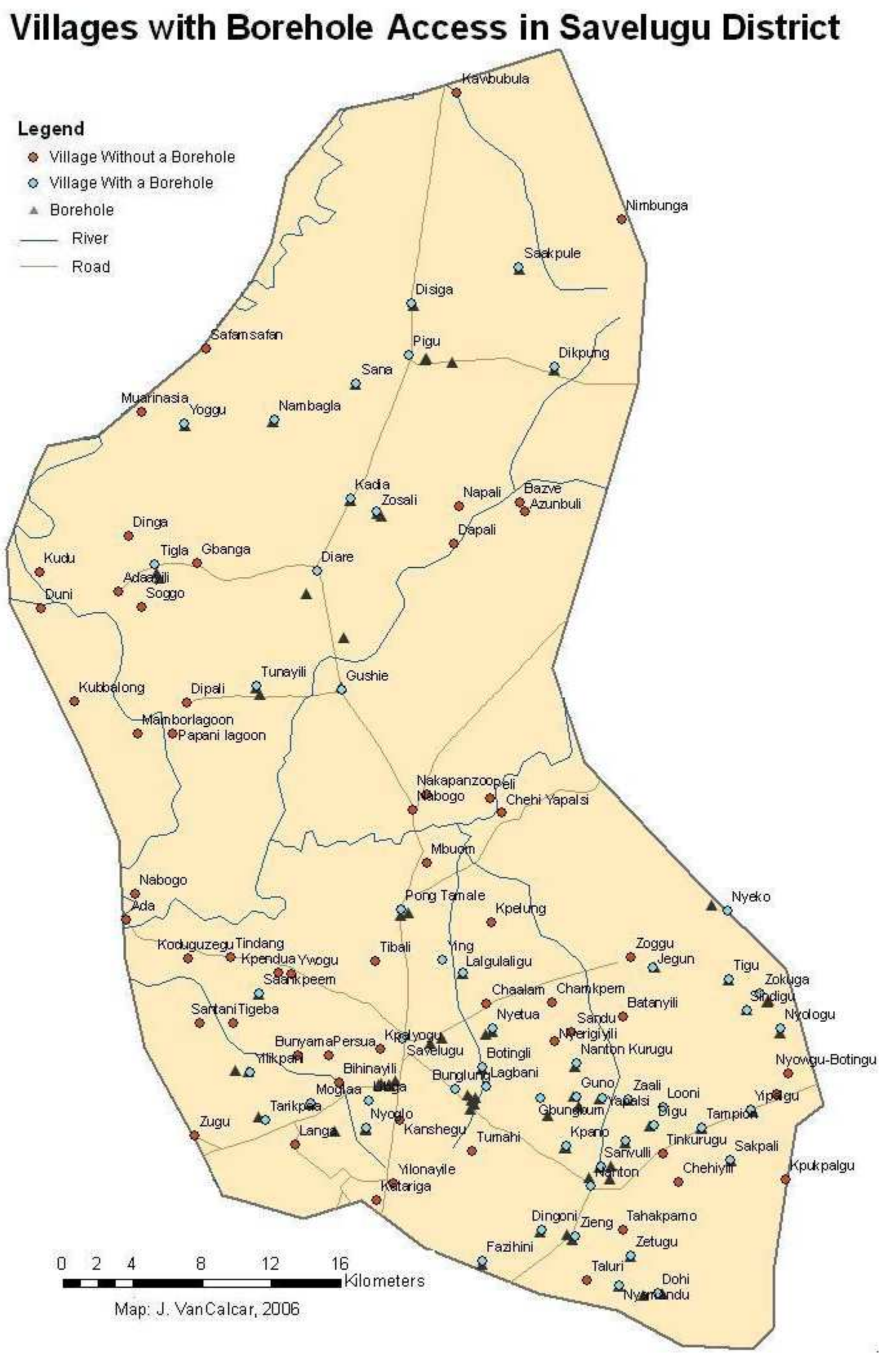

Figure 24: Villages With and Without Borehole Access in Savelugu District

4.1.4 Note Taking

Another feature of GIS is its ability to store qualitative data such as the chief's name, common issues among villagers and notes about previous trips to the village. Being able to link this information, increases the ability of the database to address the data storage needs of a community based effort, where community history and comments are likely to play as important a role as quantitative numbers like population and infrastructure coverage. The following is an example of what could be stored about the village of Saakpule. This information would pop up simply by clicking on the marker of Saakpule on the map.

Saakpule

Population: 116

Community Leaders: Ibrahim Alhassan, Zenabu Ibrahima, Alhassan Yakubu

Traditional Water Source: One dug-out pond

Local Market Day: Every six days (in Diare)

Common Health Issues:
1. Malaria
2. Diarrhea
3. Dysentery
4. Guinea worm infection

Primary Occupations: Farming

Schools: None

Organized Groups Present: Unit Committees, WATSAN committee

Ethnic Groups: Dagomba

Predominant Religion:
1. Muslim
2. Traditional worship

Community's Needs Assessment:
1. Potable Water
2. School facilities
3. Clinic

World Vision Facilities:
1. Two boreholes
2. Two laundry pads
3. Thirty VIP latrines

Figure 25: Example of Linked Information (World Vision, 2005)

4.2 Inventory Tracking

A GIS system can also be used to keep track of past sales and marketing experiences. The following map shows the businesses in downtown Tamale which have already purchased filters. The number by each business name indicates the total number of products purchased as of January 2006, with the bar graph showing the relative quantities of the CT Filtron bought verses a previous product, the Nnsupa filter.

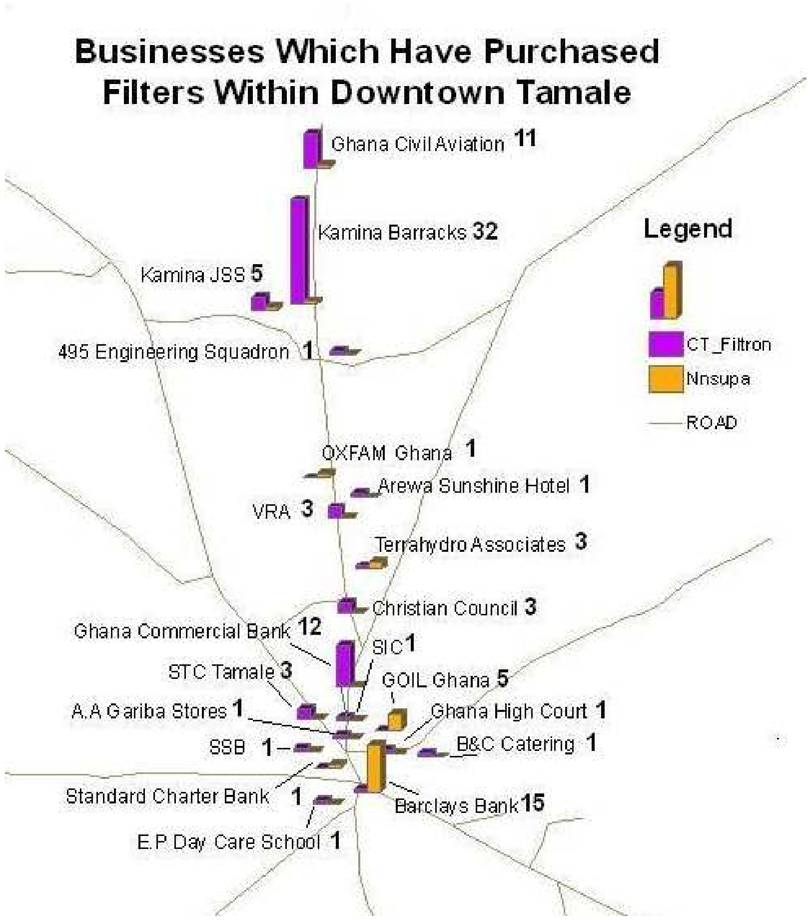

Figure 26: Businesses Which Purchased Filters in Downtown Tamale

In addition to the number of items purchased, notes could be taken and linked into the database. Thus, the type of presentation given by the PHW entrepreneurs, contacts made and other pertinent information could all be kept in a single location.

Chapter 5 - Discussion

There can be no argument about the usefulness of GIS for planning purposes and data management. However, the technical expertise and computational requirements necessary for this kind of analysis may be too advanced for typical developing country implementation projects. Just as large centralized water systems are not always the best solution in the developing world, the software and planning tools from the developed world may also not transfer effectively.

Typically it is governments which initiate the use of GIS within a country. This is because the central government has a keen interest in geographical information for planning and decision making purposes. However, more and more GIS technology is being decentralized to the district and local government arenas. It has been argued that it is these smaller and underrepresented groups which have the most to gain from GIS implementation. This is because the use of GIS can alter how knowledge is processed, displayed and discussed and thus who it preferentially favors (Elwood, 2002). For example, if the inequitable distribution of resources within a community can be clearly seen through simple visual maps, then perhaps future allocation will be based upon reducing the discrepancy rather than mainly on political influence.

The decrease in capital cost of a GIS system is one of the ways that the technology is becoming more available to community based users. It used to be that acquiring the necessary components would cost thousands of dollars. Now computers and the internet are more widely available and at costs which are sometimes within the reach of those in the developing world. The cost of acquiring data has also decreased. This used to be one of the major obstacles of a GIS system. In the past, much geographical data was digitized from old paper maps. This meant that besides a computer, a digitizer was also required. Fortunately most digitization has now been completed and geographical data is more readily available. Many online sites have basic satellite images, topography and climatology data free for download. Also, if governmental agencies already have GIS databases in place, then they may be willing to share basic data layers such as political boundaries, roadways and zoning information free of charge. GPS technology has also experienced a dramatic decrease in cost and increase in accuracy over the last decade so that manual creation of data has now become a cost effective option as well.

Besides the hardware and data issues, the availability of cheap or even free software has also done a great deal to aid the spread of GIS. While the ArcView software from ESRI is the typical tool used in the developed world, its licensing fees exceeding thousands of dollars eliminate the feasibility for community-based users, especially in developing world contexts. However, there are other options. For example, Brazil's National Institute of Space Science has created a GIS environment known as SPRING which can be downloaded from the web at no cost (see http://www.dpi.inpe.br/spring/english/index.html). Google Earth has also opened up a new pathway to share and view geographical information over the web.

A final obstacle to GIS implementation is technical expertise. This area is also improving as more universities in the developing world incorporate GIS into their class offerings. A unique offering at Vista University in South Africa combines in-class GIS theory with real world internships within the community (Ramasubramanian, 1999). This saved the university from needing to expand their own computer resources, while providing students valuable experience and organizations and companies with much needed GIS help.

Even if all the aspects needed for GIS are readily available, a system should only be adopted if it is accomplishing a specific purpose. If the major function is going to be record keeping or display of statistics, these functions can be accomplished with much simpler data management systems or even with paper and pencil. However, as the tasks get more advanced, the labor put into creating and maintaining a GIS system may prove instrumental. For example, World Vision-Ghana maintains a GIS database for their borehole drilling efforts in the Ghana Rural Water Project. If bringing together information on geologic conditions, soil types, extent of aquifers and other pertinent data can improve the success rate of borehole drilling, currently a few thousand dollars per drill attempt, GIS will likely be economical. Since the system is already running and expertise available, it then makes sense to use the system for other purposes such as storing borehole locations, water quality information and other associated data. With larger organizations like World Vision maintaining GIS databases, the hope would be that information gathered could be passed to smaller organization such as Pure Home Water.

Chapter 6 - Conclusion

The objective of this thesis was to bring together GIS data in a fashion that could benefit Pure Home Water. One benefit hopefully achieved was the display of regional statistics for the Northern Region which highlights the extensive need for an improved water supply and/or household treatment and safe storage technologies. Currently 56% of the population does not have access to an improved source of drinking water and 92% do not have access to improved sanitation. This is clearly playing a role in the high diarrhea and mortality rates throughout the region and Pure Home Water should be strengthened in their conviction to spread HWTS technologies.

As seen through the village database, the population in need of an improved water supply and/or HWTS technologies is widely dispersed in many small villages and away from important infrastructure. While this is a challenge in the effort to distribute HWTS, it is not insurmountable. Motivation should be taken from the Guinea Worm Eradication Program; this partnership organization was able to distribute cloth filters and educational information to these same villagers. Their GIS system is now tracking the final remaining endemic locations in a region which used to be overcome by the disease.

However, GIS may not currently be the most practical method of storing project information and focusing team efforts for Pure Home Water. Currently, the main objective of the entrepreneurs is to sell water filters and not to maintain a database. From the larger perspective of water and sanitation planning, a GIS system can prove extremely useful. The challenge of providing people with potable water is highly geographic in nature and knowledge concerning the location of people, water sources, technologies and diseases can encourage thoughtful planning and maximize resources.

In retrospect, the scale of this thesis straddles the two groups. The work presented is potentially too detailed and time-demanding for PHW, however, not encompassing enough for development planning. A recommendation for any further work would be to scale the collected information either down or up. A simplified system could be created with free online tools to see if its use could help the efforts of PHW in a more direct fashion. On the other hand, more information about the location of dugouts, hand dug wells, springs and other water sources could be collected along with improved village information to create a system to be used on the regional level for development planning.

With improved village information, data could be collected from agencies similar to Pure Home Water who are trying to address water, sanitation and hygiene needs. These companies are unlikely to have GIS data but should have a list of villages with whom they have worked. This data would show the types of educational material and water and sanitation programs communities have been exposed to in the past. This way adoption rates could be tracked not just of Pure Home Water's products but of numerous other health interventions. However, if this work is undertaken, there should be a specific end user in mind or specific planning purposes and goals put in place so that the database's usefulness is ensured.

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Data

Community Water and Sanitation Agency (CWSA)

Contact: Patricia Gyamfi
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CWSA provided an Excel spreadsheet of their boreholes throughout the Northern Region. The spreadsheet included the borehole ID number, project, village and location. This information was received after returning from Ghana and thus borehole locations were not checked, but they are assumed to be accurate. Data was also not provided as to whether the boreholes listed are all boreholes which had been drilled or only ones which were successfully running. It was assumed that the list contained all boreholes which had been drilled.

GEOnet Names Server – National Geospatial-Intelligence Agency

http://earth-info.nga.mil/gns/html/

This dataset was discovered through the MIT libraries. It contains names of foreign geographic features for everywhere except the United States and Antarctica. Of particular interest was a listing of populated places for Ghana. This dataset gave more detail than just major cities; however, the accuracy was suspect since villages appeared in a regular grid pattern. This is not how villages would be arranged on the ground and means that the data is meant for a basic overview and not detailed analysis.

GfK Macon

This dataset was retrieved from Rotch library on MIT campus. It contains layers of information for the whole world. Specific to Ghana were a layer of regional boundaries, major cities, major roadways, lakes and major rivers.

Guinea Worm Eradication Program

Contact: Philip Downs
Technical Advisor
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The Guinea Worm Eradication Program provided a spreadsheet listing the villages within each district that have endemic guinea worm, along with the village population and number of households. The original version of the spreadsheet did not contain the locations of the endemic villages; however, a new version with locations as well as an associated map has now been obtained.

Rural Water and Sanitation Agency (RWSA)

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RWSA provided Excel spreadsheets of their boreholes within East Gonja, West Gonja and West Mamprusi districts of the Northern Region. The spreadsheet included the location of the borehole, village name, date drilled, pump test date and yield. Within these spreadsheet is was easy to tell which had been successful drillings through a color coded system, as well as by looking at the yield values. Like the CWSA data, this data was received after returning for Ghana and thus borehole locations could not be verified but are assumed to be accurate.

World Vision

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World Vision provided data not only on their borehole drilling efforts but on the efforts of the whole West Africa Water Initiative (WAWI) partnership. WAWI works as a partnership of many large and small non-governmental agencies and local governments to jointly address health needs, poverty reduction and sustainable development through the provision of water resources. Currently the major partners are the Conrad N. Hilton Foundation, Cornell International Institute for Food, Agriculture and Development, the Desert Research Institute, Lions Clubs International, UNICEF, USAID, WaterAid, Winrock International, World Chlorine Council and World Vision. Data associated with the boreholes included the well ID, location, community, project, funding organization, drill data, yield, status and results from chemical testing of the water.

Besides their borehole data, World Vision also provided the following shapefiles, all at a country wide scale:

Bound – Boundaries for the country, regions and districts
Climate – Average rainfall and temperature values over the country during each month
Consarea – Boundaries for game preserves and forest reserves
Geosoil – Basic geology and soil types
Hydro – Large scale basins for the country as well as large water bodies and rivers
Landcov – Land cover descriptions
Landown – State owned land
Topo – Contours and elevation data
Transp – Railways and roadways
Urban – Regional and district capitals as well as polygons of urban areas

These files had no metadata associated with them. Metadata typically gives information on who created the file, how it was created and the expected accuracy of the data sets. To insure the accuracy of the data, the shapefiles of rivers, roadways, boreholes and villages were compared with points taken using our own GPS equipment. Match ups were close but not perfect. This could have been due to inaccuracies from our GPS locations, differences in map projections or inaccuracies in the creation of the shapefiles due to them being on a country-wide scale. The errors however were small and not significant for the purposes of this project.

All electronic documents have been compiled onto a cd and left in the care of Susan Murcott, Senior Lecturer in the Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology.

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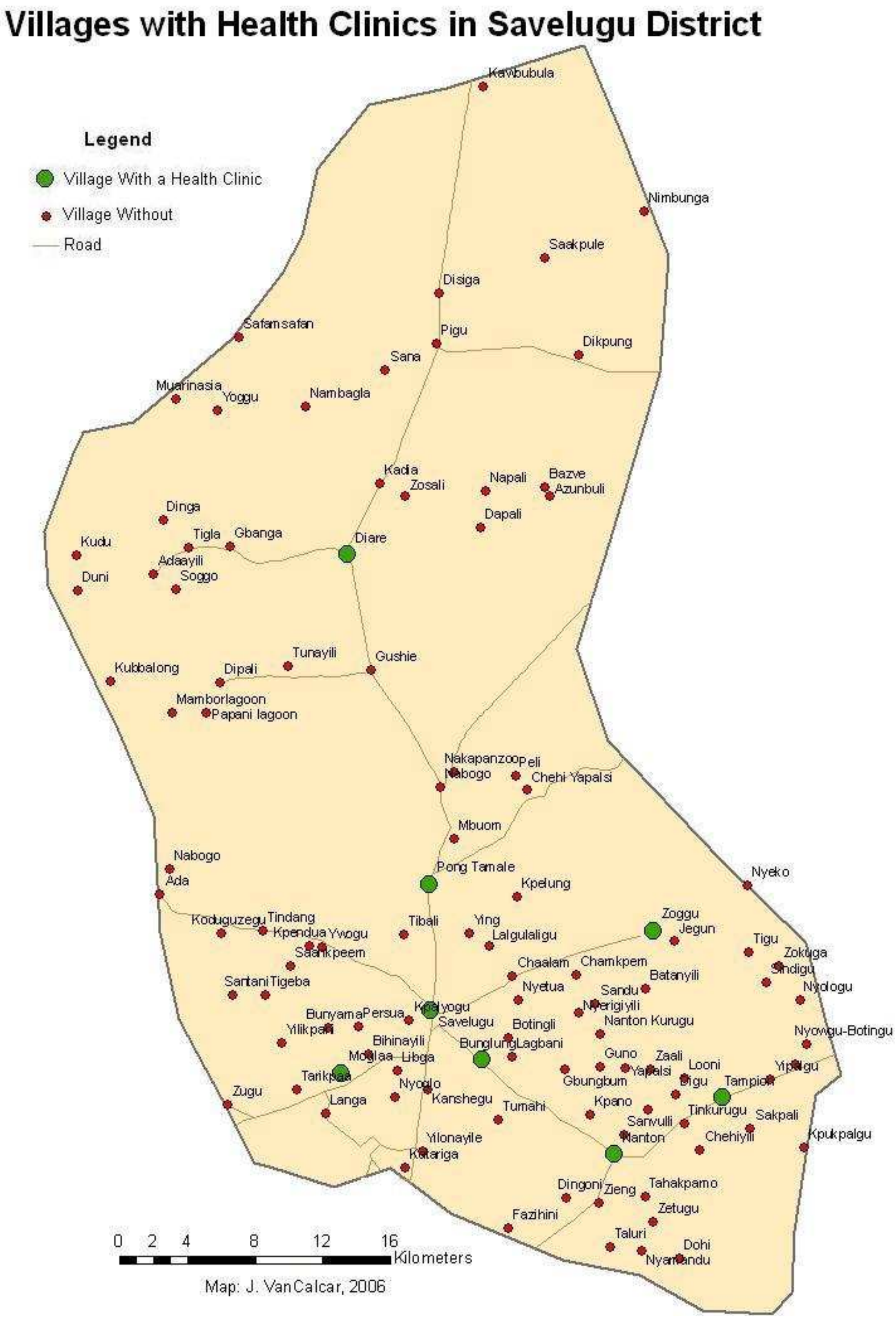
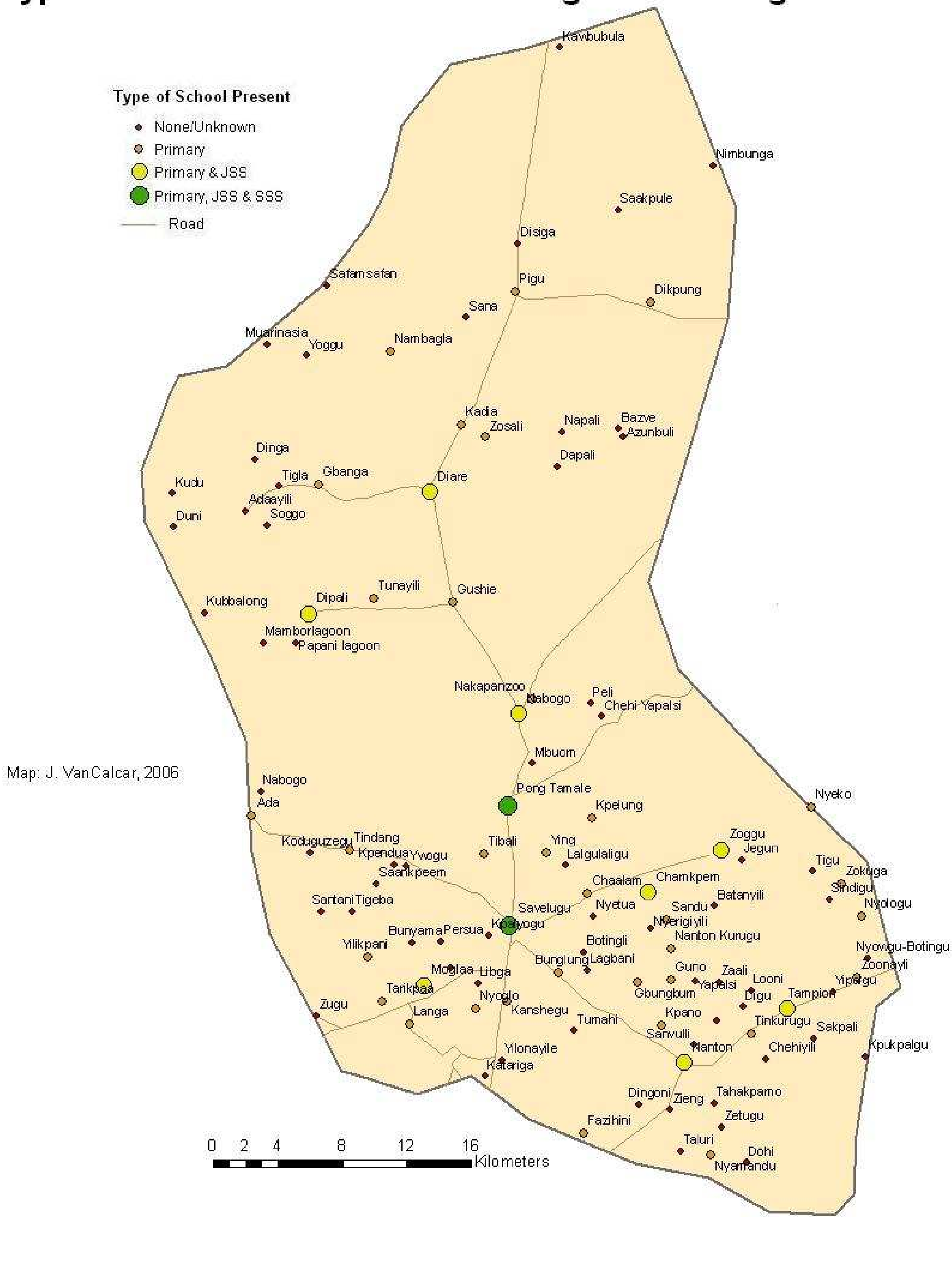
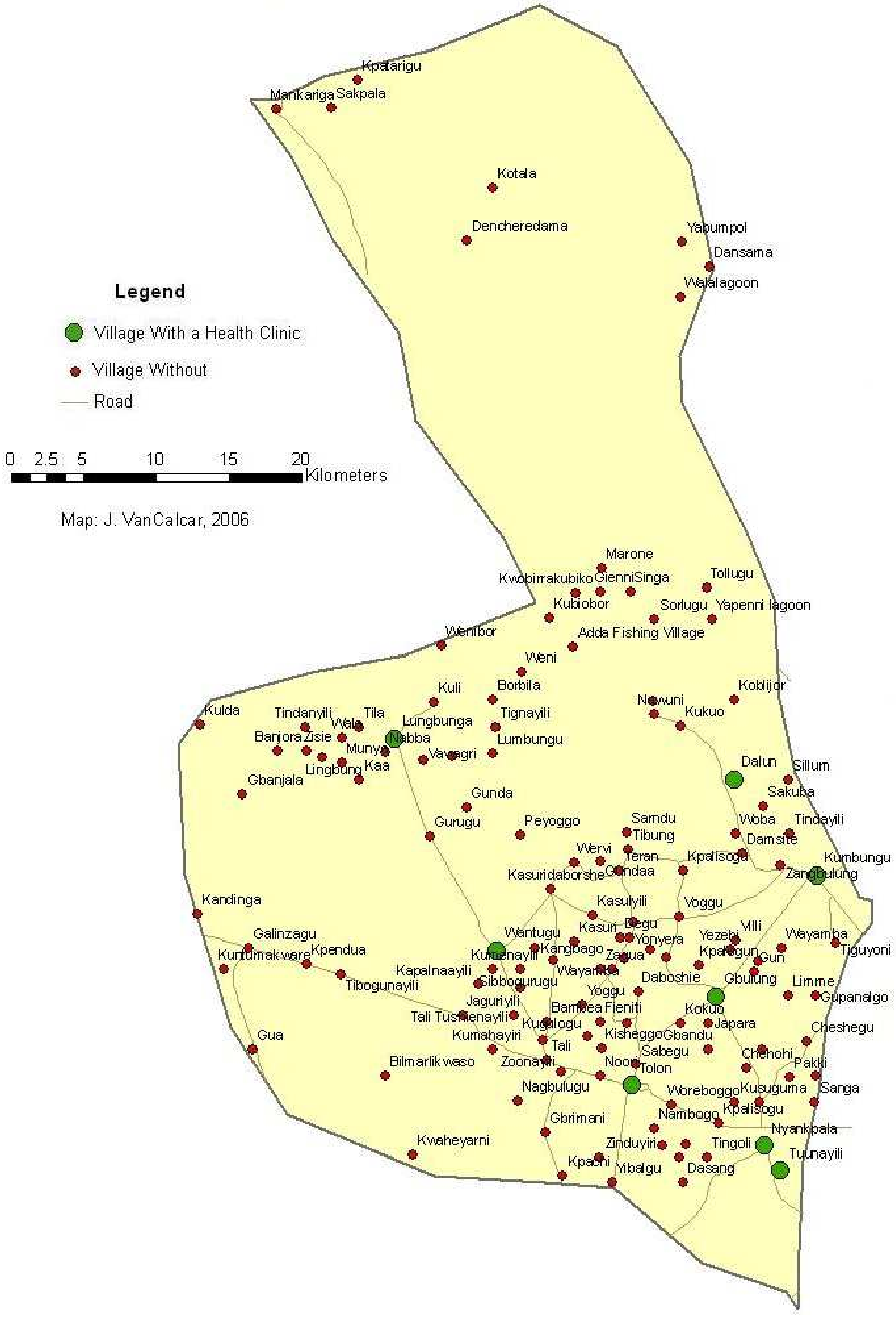
Appendix A: Facility Maps for Savelugu-Nanton & Tolon-Kumbungu Districts


Villages with Health Clinics in Savelugu District
Legend
Village With a Health Clinic
Village Without
Road
Nimbunga
Saakpule
Disiga
Safamsafan
Pigu
Dikpung
Sana
Yoggu
Nambagla
Kadia
Zosali
Napali
Bazve
Azunbuli
Dinga
Dapali
Tigla
Gbanga
Diare
Kudu
Adaayili
Soggo
Duni
Tunayili
Gushie
Kubbalong
Dipali
Mamborlagoon
Papani lagoon
Nakapanzoo
Peli
Chehi Yapalsi
Mbuom
Nabogo
Ada
Pong Tamale
Kpelung
Koduguzegu
Tindang
Kpendua
Ywogu
Saankpeem
Tibali
Ying
Lalgulaligu
Zoggu
Jegun
Nyeko
Tigu
Chaalam
Chamkpem
Batanyili
Santani
Tigeba
Nyetua
Sandu
Nanton Kurugu
Nyowgu-Botingu
Bunyama
Persua
Savelugu
Botingli
Bihinayili
Libga
Bunglung
Lagbani
Guno
Zaali
Looni
Gbungbum
Zugu
Langa
Kanshegu
Tumahi
Kpano
Sanvulli
Tinkurugu
Sakpali
Nanton
Chehiyili
Kpukpalgu
Yilonayile
Dingoni
Zieng
Tahakpamo
Zetugu
Fazihini
Taluri
Dohi
0 2 4 8 12 16
Kilometers
Map: J. VanCalcar, 2006

Type of Schools Available in the Villages of Savelugu District



Villages with Health Clinics in Tolon-Kumbungu District



Types of Schools Available in the Villages of Tolon-Kumbungu District