Developing a Sustainable Water Management Model: Addressing Water Pollution in the Khlong Toei Slum in Bangkok, Thailand.

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Submitted By:

Meghan Goodwin

Elia Perez Luna

Julia Truong

Adrienne Weishaar

bkk15khlongwater@wpi.edu

Project Advisors:

Prof. Robert Kinicki, WPI

Prof. Fabienne Miller, WPI

Authorship

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Abstract

Lack of access to water fit for human consumption negatively affects the health and quality of life for those living in slum communities. The Khlong Toei Slum, restricted by its high density population, poverty, land tenure issues, and damaged water pipelines, exemplifies this issue with its severe water pollution. To address the water pollution in the Khlong Toei Slum, this project investigates the root causes of poor potable water quality by conducting interviews with local water management companies and residents of the Khlong Toei Slum, administering surveys, and forming focus groups to determine solution feasibility. This project can be the stepping stone for future implementation of a water management system for the Khlong Toei Slum community.

1 Introduction

Access to water fit for human consumption is an essential component for the health and livelihood of all people (Grey, Grey, & Sadoff, 2007). However, more than 3.4 million people worldwide die each year from substandard water quality, poor sanitation, and hygiene-related causes such as excreta left in water and open space (Wiwanitkit & Suwansaksri, 2008). The Water Environment Partnership in Asia (WEPA) classified one third of the surface water in Thailand as poor quality (Suwal, n.d.).Untreated domestic sewage, industrial wastewater, and solid hazardous wastes pollute the water.

Twenty percent of the 6.2 million people living in Bangkok reside in slums, such as Khlong Toei, that have limited access to quality water (Murray, 2014). To promote good health of the Khlong Toei residents, the Duang Prateep Foundation (DPF), which acts as a liaison between the Thai government and the slum-dwellers, installed drinking water vending machines. However, the quality of the water obtained from these machines does not meet drinking standards. Moreover, according to DPF, damaged underground pipelines cause inaccessibility to in-home piped water for the residents of the Khlong Toei Slum. Therefore, many slum-dwellers rely on polluted communal taps. Studies by the Environmental Health Perspectives claim that polluted water can negatively affect the health of communities by transmitting bacteria, protozoa, and viruses (Ford, 1999). To tackle the health issues that arise from the consumption of polluted water, this project will investigate sources of pollution and recommend a water management model that could be implemented in the Khlong Toei Slum.

To recommend a water management model that effectively handles, directs, and controls the use of water resources in the Khlong Toei Slum, this project explores Khlong Toei's land tenure issues, current water networks in the slum, water pollution sources, and water management models. First, the Thai government does not legally recognize the slum because the residents do not own rights to the land they inhabit. Consequently the government does not provide the slum with standard utilities such as waste collection and a supply of clean water (Duang Prateep Foundation, 2004). Second, the Metropolitan Waterworks Authority, a state enterprise under the Thai Ministry of Interior, distributes water to the Khlong Toei District. However, the Khlong Toei Slum, similar to slums globally, exhibits a random and haphazard development pattern, which limits the ability to incorporate utility networks (Dagdeviren & Robertson, 2011; Metropolitan Waterworks Authority, 2010). Third, there are two main types of water pollution sources found throughout the world: point and nonpoint sources such as waste water discharge and agricultural runoff. Lastly, water management methods, such as water vending machines, rainwater harvesting, and solar water disinfection, serve as possible solutions that the team could recommend to the Khlong Toei Slum to improve water quality.

Recommending a water management model that could serve as a means to improving water quality requires more extensive research. There is a gap of information regarding transmission of water into the slum, root causes of pollution, water usage of slum-dwellers, waste disposal methods, and preferences of the Khlong Toei slum-dwellers. The team will conduct research to understand how water arrives in the slum and the reason the water quality differs from the water distributed to the Khlong Toei District water facilities. Also, research will help the team understand where slum-dwellers collect water, the reasons for which they use the water, and whether their choice in water source is due to the water quality. In addition, observing habits of waste disposal may lead to the recognition of water pollutants. Furthermore, understanding the slum-dwellers' needs and preferences is crucial in recommending a

sustainable water management system compatible with local needs. Although in past years various teams have performed different projects in the Khlong Toei Slum, none have effectively addressed the poor water quality in the Khlong Toei community.

The goal of the project is to recommend a water management model that will serve the community's needs. The objectives of the project are to determine the water network of the Khlong Toei Slum, to determine the pollutants of the water, to analyze the water usage, to develop a criteria and assessment method based on the communities needs and preferences, to assess potential water management systems, and to determine the feasibility of the potential solutions in the Khlong Toei Slum. The team's approach will be to conduct observations, interviews, surveys, and focus groups in order to collect the data needed. These methods will lead to the production of a water quality report and will allow the team to recommend viable options for a water system in the Khlong Toei Slum. This project serves as a cornerstone for future establishment of a water management rehabilitation program for Khlong Toei.

2 Background

There are many challenges in recommending a solution for water pollution in the Khlong Toei Slum. Section 2.1 explores the history of the slum's land tenure issues, current land tenure issues in utility implementation, and the water network of the Khlong Toei District. Section 2.2 reviews water pollution, types of pollution sources, and section 2.3 investigates possible solutions that the team could use to recommend a sustainable water management system. Considering these topics of land tenure and the causes of water pollution can help the team effectively recommend a water management model specific to the Khlong Toei Slum.

2.1 Khlong Toei Slum

Bangkok, while known as the thriving urban center of Thailand with its many skyscrapers, is also home to thousands of impoverished residents living in makeshift shanties in the Khlong Toei Slum. Bordering central Bangkok, as seen in Figure 2-1, the Khlong Toei Slum resides on a network of wooden boardwalks covering three-meter-deep beds of swampland. Governmental authorities reclaimed and paved over the land with varying degrees of success (Elliott, 2003).

Figure 2- 1: Khlong Toei Slum Bordering the City Life of Bangkok, Thailand (London & London, 2013)

The Khlong Toei Slum, known for its high density population, falls within the United Nations' slum definition. A slum is a heavily congested and often poorly built temporary

settlement, which is characterized by the lack of one or more of the following five amenities (Pokhariyal, 2005; UN-Habitat, 2008):

1. Housing infrastructure resistant to extreme climate conditions
2. Access to drinkable and affordable water in a sufficient amount
3. Access to sanitation facilities such as a private or public toilet shared with a reasonable number of people
4. Access to living areas where no more than three people share a room
5. Presence of medical and social facilities that serve the community's needs.

This list describes the identifying characteristics of slums throughout the world.

Slums have limited access to urban services such as proper water management systems, which are basic rights for every urbanite (Rana, 2009). Water management is the activity of managing, handling, directing, or controlling the use of water resources (Management, n.d.). According to UNICEF (2014), slum dwellers perform unhygienic practices due to lack of adequate education on safe water practices, exposing themselves to health risks associated with their unsanitary behavior. For example, in Bangladesh, a large number of people leave excreta in the water and open space, use unsafe sources of water for personal and domestic needs such as cooking, bathing, and washing utensils (Rana, 2009). Unsafe water supply, lack of hygiene, and poor sanitation, lead to health issues such as diarrhea, malaria and cholera outbreaks, which cost slum-dwellers 2.2 million lives every year (UN-Habitat, 2008).

Besides overcrowding, bad sanitation, poor water infrastructures, crime, and poor access to health care, the lack of land tenure is one of slum resident's biggest problems. The purpose of this project in the Khlong Toei Slum relates closely to the lack of amenities 2 and 3 described above in the UN-Habitat's list. In Khlong Toei, residents receive limited recognition from public authorities. As a consequence, basic utilities such as water and electricity are not up to municipal standards (Angel & Boonyabancha, 1988). Subsections of 2.1 discuss the history of the slum's land tenure issues, land tenure issues that affect utility implementation, and the water utility network that services the Khlong Toei District.

2.1.1 History of the Khlong Toei Slum's Land Tenure Issues

Irrigated by canals since the 18th century, Bangkok became known as the "Venice of the East" during much of the 19th century (Bodry, 2012). Bordering the Chao Phraya River, Khlong Toei's name originates from Bangkok's canal history (Elliott, 2003). The word "*khlong*" is Thai for canals while "*toei*" is the name of the trees that ran along the side of the waterways (DiNino, 2006).

In the late 1940s, workers, brought in by the government to build one of Bangkok's major shipping ports, founded the Khlong Toei District (Elliott, 2003). Since the workers were brought in from northeast Thailand and were not financially capable of other options, the workers set temporary shanties beside the construction zone, which is now known as the Khlong Toei Slum. During this time, the workers had full rental authority over the land. When the construction of the port completed in 1947, the government reclaimed the land and gave operation rights to the Port Authority of Thailand (PAT) (Elliott, 2003). Although the workers had full rental authority during the time of construction, the workers became illegal squatters after the completion.

Due to the need for additional storage space, many illegal squatters surrounding the port faced eviction (Asian Coalition for Housing Rights, 2003). The thousands of workers and their families, having no place to go, continued illegally settling on the land. This population continued to grow and experienced a dramatic increase around 1960 when a severe drought left

many rural families in need of work (Asian Coalition for Housing Rights, 2003). The Khlong Toei Slum population continued to grow with rural families looking for work in the city. As of 2014, the one square kilometer slum consists of over 100 thousand migrants (Duang Prateep Foundation, 2004).

2.1.2 Disputed Land Tenure Issues in Utility Implementation

Slum-dwellers in Thailand, including residents of the Khlong Toei Slum, generally have secure housing tenure,[1] but many do not have secure land tenure (Asian Institute of Technology, 2008).[2] Lack of secure land tenure is an issue because under no land tenure contract, the Thai government is not responsible for providing basic utilities. Thus, many slum communities lack basic facilities such as water supply and waste removal. In the few slums that do have secure land tenure and basic water supply, utility regulations are largely ignored by the Thai government. Water sources are left undrinkable because of the slum's haphazard development pattern that restricts construction and constrains the residents ability to pay for such utilities (Angel & Boonyabancha, 1988).

One of the main problems associated with obtaining land tenure for the slum residents is Thai citizenship. Many slum communities are made up of a majority of refugee migrants from countries like Burma. According to Thailand land tenure regulations, the government restricts foreigners from owning land (Boonyabancha, 2005). Although secure land tenure may be helpful for slum-dwellers in securing basic utilities, non-Thai slum residents would not be able to own land by Thai law.

Eviction is not a feasible option for the Thai government due to the large slum population. To aid in land tenure issues, the Thai government signed land-sharing agreements.[3] In these land sharing agreements the slum-dwellers living on government property had to condense their housing into a smaller section of the disputed area so that the government could use the rest of the land for city development (Pacione, 2005). In 1985, the Thai government signed five land-sharing agreements in different Thai districts, including Khlong Toei (Hardoy & Satterthwaite, 2014).

Despite continuing efforts, land tenure continues to be a key issue, and in the context of a clean water supply, a major issue. As the Khlong Toei Slum resides on property owned by the Port Authority of Thailand and its residents are only issued land-sharing agreements, accessibility to potable water is also a legal challenge.

2.1.3 Water Utility Network Serviced to Khlong Toei

The Khlong Toei district receives water through distribution by the Metropolitan Waterworks Authority (MWA). The MWA, a state enterprise under the Thai Ministry of Interior, is responsible for clean, disinfected water production, transmission, and distribution to people living in three provinces: Bangkok, Nonthaburi and Samut Prakan. The Bangkhen Water Treatment Plant (Bangkhen WTP) serves as the center for water filtration and transmission for

[1] "In residential real estate, the legal arrangement for the right to occupy a dwelling is most commonly known as the housing tenure." (Gonzales, 2010)

[2] "Land tenure is the political, economic, social, and legal structure that determines how individuals and groups access and use land and related resources—including trees, minerals, pasture, and water. Land tenure rules define how rights to use, control, and transfer land and resources are allocated within societies." (US Aid, 2013)

[3] A land-sharing agreement is "a negotiated agreement between landowner/developers and land occupants to partition and share a plot of land" (Rabe, 2005)

the city. The MWA follows the World Health Organization (WHO) standards to control its water quality, ensuring that the water treated is drinkable (Metropolitan Waterworks Authority, 2010).

Figure 2-2 shows the path of water traveling from the Chao Phraya River to Khlong Toei. The water process encompasses six steps: raw water extraction, clarification, filtration, water storage, transmission, and distribution. The water network starts in the Chao Phraya River where the Sam Lae Pumping Station takes raw water, meaning untreated, into the East Canal until it reaches the Bangkhen WTP. The water pumping stations transport raw water through the influent channel to the clarification section. The clarified effluent channel then delivers the water to rapid sand/anthracite coal filters. Water storages, called reservoirs, collect filtered water. To meet the MWA drinking water standards, the water receives doses of post-lime and chlorine, disinfecting substances. Pumping stations transmit and distribute the treated water from the Bangkhen WTP to the majority of MWA customers through water tunnels and conduits. Transmission Pumping Station No.2, which is part of the East Pumping Stations, distributes water to many pumping stations including the Khlong Toei Distribution Pumping Station (Khlong Toei DPS). Once in Khlong Toei, water reaches the customers through the MWA branch offices of the district (Metropolitan Waterworks Authority, 2010).

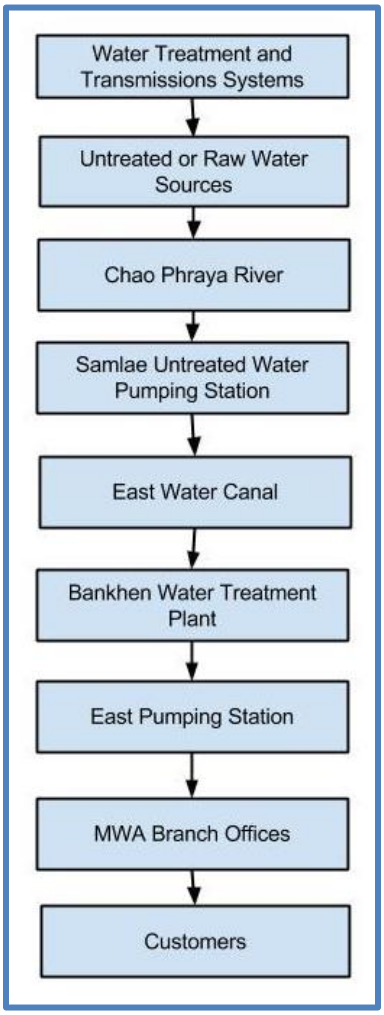


Figure 2- 2: Route of Water from the Chao Phraya River to Khlong Toei (Metropolitan Waterworks Authority, 2010)

This information supports that water comes from the Chao Phraya River and arrives to the Khlong Toei District. There is a knowledge gap in the transmission of water from the Khlong Toei District to the Khlong Toei Slum. According to DPF, damaged underground pipelines and leakage lead to poor water quality. Following this assumption, the root cause of pollution could be poor maintenance of the water networks.

2.2 Water Pollution

"A water pollutant can be defined as a physical, chemical, or biological factor causing aesthetic or detrimental effects on aquatic life and on those who consume the water" (Goel, 2006). Pollution occurs through different pathways and can be classified into different categories: point and nonpoint sources. Point sources are easily identifiable and come from one place while nonpoint sources "are often termed 'diffuse' pollution and refer to those inputs and impacts which occur over a wide area"(EPA Victoria, 2012).

Drinking polluted water is very harmful to humans and there are a multitude of water-related diseases that are caused by poor water quality. When bacteria, protozoa, and viruses are present in drinking water, people consuming these contaminants are at risk. Common ailments include diarrhea, amoebiasis, typhoid, cholera, giardiasis, and dracunculiasis (Ford, 1999).Some of these diseases are fatal and others cause severe side effects to people.

Governments regulate drinking water standards to protect people from becoming ill (World Health Organization, 2011). Many studies of water quality test for pH, heavy metals, fecal coliforms, conductivity, temperature, and dissolved oxygen because they are governmentally regulated and there is equipment available to use for testing (Collivignarelli et al., 2008). Section 2.2 outlines which sources of pollution fall into the categories described and offers further insight into the water pollution in slums.

2.2.1 Point Sources

Point sources "discharge pollutants into receiving waters at identifiable single- or multiple-point locations" (Chin, 2006). Common examples of these sources include combined-sewer overflows, stormwater discharges, and animal feeding operations.

Domestic wastewater discharges, industrial discharges, and spills contribute to surface water pollution (Chin, 2006). Stormwater discharges control rainwater and snowfall on paved roads such as highways as well as on building and home roofs. These management systems collect water that can contain contaminants such as acids, salts, or sediments that may negatively affect water sources (Utah State University, n.d.). Industries discharge dangerous contaminants that may leak into water. Researchers found toxic chemical compounds, heavy metals, and sometimes nutrients in point sources caused by an industrial facility (Chin, 2006). In addition, industrial discharge may change the natural temperature of a water body depending on what process it goes through. Spills sometimes have serious consequences for surrounding bodies of water even though the spills are not always intentional. Freight trucks carrying various chemicals get into car accidents, causing leaks onto roadways that may seep into water sources. An additional point source of contamination is bursting underground pipes which are left undetected for long periods of time, thus increasing the flow of contaminants. This allows their contents to seep into surface and groundwater (Chin, 2006). Point sources are often regulated with laws that require treatment, but these standards are not always followed.

2.2.2 Nonpoint Sources

Nonpoint sources are much different than point sources and are harder to manage. These sources "of contamination generally occur over large areas" and are "a direct result of land-use patterns" (Chin, 2006). Some prevalent types are agricultural runoff, livestock, urban runoff, landfills, and recreational activities such as swimming in lakes and camping.

Different types of nonpoint sources affect bodies of water in different ways. Agricultural runoff leads to multiple contaminants including pesticides, herbicides, and fertilizers. Some techniques in the agriculture industry can lead to erosion which in turn changes the turbidity, color, and sediment levels of water (Chin, 2006). Livestock "feedlots" cause microorganism pollution (Chin, 2006). Urban runoff, the process of contaminants being washed off of roadways, causes high levels of petroleum and salt found in water. Governmental researchers classify landfill waste as a nonpoint source. Landfills emit leachate, a solution of soluble constituents and contaminants which pollutes groundwater through percolation (Dictionary.com Unabridged). Not all landfills have systems in place to prevent this type of groundwater pollution (Chin, 2006; Conserve Energy Future; Environmental Protection Agency, 1994). Human activities such as "swimming, boating, and camping" contribute other pathogenic microorganisms (Chin, 2006). Nonpoint sources typically result from human actions and are still detrimental to bodies of water.

2.2.3 Common Causes of Pollution in Slums

Overcrowding is a main cause of water pollution globally (Dagdeviren & Robertson, 2011; Islam, Chou, & Kabir, 2011; Kimani-Murage & Ngindu, 2007; Rana, 2009). Slum communities develop quickly and many residents inhabit them in a short time period. In these instances, the government and community members do not have sufficient time to develop, build, or implement an adequate waste, water, or filtration management system while keeping up with the rapid population growth. Unless an organization or governmental agency steps in, water used by slum-dwellers frequently remains polluted thus leaving the community without a management system.

Another fundamental cause of pollution is the lack of effective sanitation practices, which are point sources. Poor sanitation practices lead to human pollution of water sources. Examples include waste management, human defecation too close to bodies of water, and inadequate and/or contaminated storage containers used for water transportation and storage.

Overcrowding and poor sanitation methods affect, in short- and long-term, the water quality in slums. Examples include disposing of food waste and trash into bodies of water. Residents in these communities consume contaminated water and cause further pollution by lack of proper techniques and education about safe water practices in their communities.

In addition to overcrowding and sanitation practices, the current waste management system may be a contributor to the water pollution. In 2014, a team of Worcester Polytechnic Institute (WPI) and Chulalongkorn University Bachelor of Science in Applied Chemistry (BSAC) students conducted a project about the waste management system in the Khlong Toei Slum (Poompat Aroonsri, 2014). Their report outlines how the slum-dwellers prefer using communal dumping grounds rather than a central location or collection service. As mentioned previously, these dumping grounds (which are similar to landfills, just on a smaller scale) cause water pollution. If the slum-dwellers are dumping waste close to bodies of water used for drinking water, leachate and other contaminants like bacteria and microorganisms may be found in the water.

2.3 Water Management Methods

Globally, there have been efforts in slum communities to improve the access to quality water and overcome the challenges of overcrowding, poor sanitation practices and the lack of waste disposal systems, through the implementation of different water management methods. This section discusses the current water vending machines in Khlong Toei, rainwater harvesting and solar water disinfection as possible sustainable water management systems for the Khlong Toei Slum.

2.3.1 Water Vending Machines

Water vending machines intake water from a previous source much like a faucet or spout. The water travels through a filtration system to improve the water quality at a minimal fee. The water filtration system is composed of a four stage pre-filtration, a reverse osmosis, and a two stage post-filtration systems. The pre-filtration system consists of two screen filters, a sediment filter, and a carbon filter. The post-stage filtration system consists of a carbon block filter and a UV sterilizer. The water pumps through the vending machine and dispenses at a flow rate of 3-3.5 gallons per minute. Users bring their own containers and can fill them at the water vending machine. The price of the water depends on the quantity of water and the location of the vending machine (Water Invention Company Limited, 2014).

The Thai Interior Ministry installed water vending machines, Figure 2-3, in four provinces of Bangkok to improve the quality of life of its inhabitants in 2013 (Asian News Monitor, 2013). The Duang Prateep Foundation installed water vending machines in the Khlong Toei Slum. However, the water is contaminated by bacteria and heavy metals, leading to diarrhea and typhoid. According to Thailand's Health Department, only 70% of drinking water from vending machines pass water quality standards (The Nation, 2011).

Figure 2- 3: Water Vending Machines in Thailand (Leo Vending, 2013)

If working properly, water vending machines should deliver filtered, purified water. However, in the case of the vending machines in the Khlong Toei Slum, the dispersed water is not meeting drinking standards. Table 2-1 displays the advantages and disadvantages of water vending machines (Bragulla, 2014).

Table 2- 1: Advantages and Disadvantages of Water Vending Machines

Advantages	Disadvantages
• Provides filtered water at a low price • No staff required • Little maintenance	• High installation fee • Users need to provide their own bottles

The advantages and disadvantages of water vending machines may influence the effectiveness of the machines application. Although, water vending machines have a high installation fee, slum-dwellers pay a small price for quality water. Water vending machines require minimal maintenance, however this does not mean the machines do not require maintenance at all. In the case of water vending machines in the Khlong Toei Slum our team does not know how regularly the vending machines are serviced, but perhaps the machines are malfunctioning. Users supply their own containers which may not be clean and could hold contaminants. Therefore, even if the vending machines are dispersing clean water, the containment methods of the slum-dwellers may be polluting the water.

2.3.2 Rainwater Harvesting

Rainwater harvesting systems are a water management method that does not use the community's current water sources. Instead, water is collected from rainfall. Rainwater harvesting provides nearly the cleanest naturally accessible water that is available, at various quantities, around the world (WaterAid, 2013). Rainwater harvesting gathers and collects water, at the household level, and stores the water in a ferro-cement tank.

In the city of Dhaka, Bangladesh, the Bangladesh University of Engineering Technology (BUET) installed rainwater harvesting systems to utilize rainfall as an alternative source of safe drinking water. This city suffers from shortages of water during the dry seasons and from arsenic-contaminated groundwater. During the monsoon season, Bangladesh has an adequate amount of rainwater. The system collects rainwater and users of the tank can consume the water directly. The rainwater harvested during the monsoon season can be stored in the tank for a four month period time to satisfy the demands of water during the dry season (M. M. Islam, Chou, Kabir, & Liaw, 2010).

Rainwater harvesting has three main components: the roof or catchment, a ferro-cement tank and an initial flushing device at the intake. Figure 2-5 displays a schematic drawing of the rainwater harvesting system installed in Dhaka, Bangladesh. In order to provide adequate supply of contaminant-free rainwater, the system requires a roof made of unpainted sheets of corrugated iron, tile or fiberglass as well as a sufficient area. BUET opted to use a non-toxic waterproof cloth for the catchments in Bangladesh as opposed to roofs because most were not suitable to use. The rainwater drains from the catchment into the initial flushing device. The initial flushing device disposes of the first 6-8 mm of rainfall to prevent sediment and debris from contaminating the storage water. After the initial flush of rainwater, the remaining rainwater collects in a storage tank. The calculations of the storage tank are based on water variables such as drinking,

cooking, and dishwashing. Producers manufactured the tank using cement, sand and wire mesh. The Bangladesh team then installed inlet and drainage pipes as needed. The residents in the construction area then used the rainwater collected in the storage tanks as a source of quality water (M. M. Islam et al., 2010).

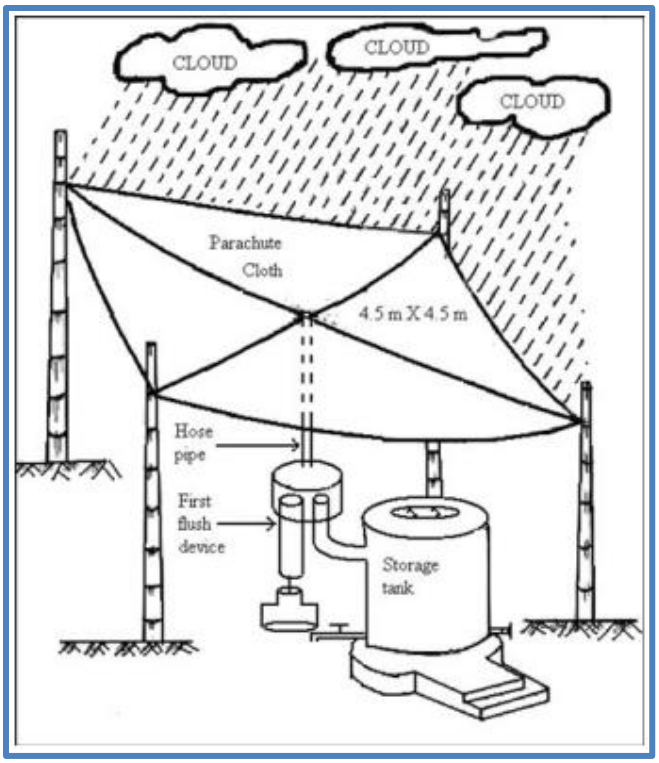


Figure 2- 4: Schematic Drawing of the Rainwater Harvesting System in Dhaka, Bangladesh (M. M. Islam et al., 2010)

BUET concluded from their research that the rainwater harvesting system was a useful and acceptable potential source of safe drinking water for the Dhaka, Bangladesh area. The BUET team found the initial flushing device to be effective and test results showed that the quality of the stored rainwater was an acceptable alternative as safe drinking water (M. M. Islam et al., 2010).

Rainwater harvesting has advantages and disadvantages. Table 2-2 organizes these concepts (Dos Anjos, 1998; WaterAid, 2013).

Table 2- 2: Advantages and Disadvantages of Rainwater Harvesting (Not Listed in Order of Importance)

Advantages	Disadvantages
• If using a clean collecting surface, consumers can drink the collected water without treatment. • Installers can use relatively cheap materials for the construction of storage tanks and collecting surfaces. • Low maintenance costs • Provides a supply of safe water close to homes, schools or clinics • Increases independence from the domestic supply network • Collecting rainwater reduces the amount of water that can flood the slum.	• Rainfall is not a reliable source during droughts. • Poorly constructed storage tanks can cause algal growth and invasion by insects and rodents, and can act as a breeding ground for disease if not properly maintained. • High initial costs • Requires space for storage tanks • Requires regular maintenance

The advantages and disadvantages directly relate to the effectiveness rainwater harvesting could have in the Khlong Toei slum. The high density of the Khlong Toei slum limits the area for storage tanks and restricts their size. For the system to be effective, the volume of the storage tanks needs to satisfy the water demands of the residents throughout the dry season. In Thailand, the climate is dry between November and May and is rainy July to October. Yearly, Thailand gets around 95 inches of rain (Tourism Authority of Thailand, 2014). Reducing the size of the storage tanks will limit the amount of rainwater harvested and may not supply a sufficient quantity of water to last throughout the dry season. Rainwater harvesting has high construction costs, however, the relatively low expenses of maintenance of the system are important to consider since most slum dwellers are impoverished (Dos Anjos, 1998; WaterAid, 2013). These low costs might contribute to the success of rainwater harvesting in Khlong Toei.

2.3.3 Solar Water Disinfection (SODIS)

Solar Water Disinfection is a water system that kills microorganisms in the current water supply simply through exposure of sunlight. The SODIS system only requires two resources: sunlight and polyethylene terephthalate (PET) plastic bottles. Research institutions conducted tests to determine whether substances in PET bottles can cause cancer through extended exposure to heat and sunlight. The studies concluded that when the SODIS method is applied properly with PET bottles, there is no danger to human health (SODIS, 2014). Table 2-3 identifies the recycling symbol that classifies PET bottles and also common uses of these bottles (PET, 2014). Contaminated water is poured into PET bottles and exposed to direct sunlight for a minimum of six hours or increased to eight hours if the weather is overcast. Although SODIS is not sufficient in eliminating all contaminants that may be present in the water, the UV-A radiation from sunlight and minor heating kills microorganisms. SODIS is a low-cost and simple

method for treating water and therefore is a suitable option for the poorest segments of developing countries to obtain safe water depending on the water contaminants (Jürg Graf, 2008).

Table 2- 3: PET Identification

Symbol	Type of Material	Common Uses
	Polyethylene Terephalate (PET or PETE)	• Soft Drinks • Juices • Single serve water bottles • Beer

In Kenya, specifically the slum of Kibera, many organizations have trialed solar water disinfection (SODIS) as a potential water management system. Kibera inhabits roughly 700 thousand people in 0.97 square miles, making it one of the largest populated slums in Sub-Saharan Africa. In this slum there is an onset of diarrhea in young children. A research project conducted by the Swiss Federal Institute of Aquatic Science and Technology studied the application of SODIS and its effectiveness in reducing diarrheal diseases (Jürg Graf, 2008).

If used properly, SODIS destroys pathogens that could cause diarrhea. In recent years, researchers have carried out studies in many continents and results show the reducing effects of SODIS on the incidence of diarrhea in children by 40%. In the Kibera slum in Kenya, the first controlled field trial of SODIS had promising results (Jürg Graf, 2008).

While reducing diarrheal disease, Solar Water Disinfection has other advantages along with disadvantages. Table 2-4 outlines these concepts (Center for Disease Control, 2008).

Table 2- 4: Advantages and Disadvantages of SODIS (Not Listed in Order of Importance)

Advantages	Disadvantages
• Proven reduction of viruses, bacteria, and protozoa in water • Reduction of diarrheal disease incidence in users • Simplicity of use • No cost to user after purchasing PET bottles • PET plastic bottles are widely available.	• Water with higher turbidity will need pretreatment. • Limited volume of water that can be treated at once • Many hours required to treat water • The need for a large supply of intact, clean, suitable plastic bottles is required. • Weather dependency

The effectiveness of SODIS in the Khlong Toei Slum has a direct relationship to the advantages and disadvantages. The amount of time it takes to treat a small volume of water is

rather inefficient. A day's worth of water is the outcome of water being treated in many PET bottles for numerous hours. However, the simplicity and the low costs of the SODIS water system could be huge selling points for impoverished, uneducated Khlong Toei slum-dwellers and increase the participation and success of this system (CDC, 2008).

2.4 Summary of Background

Lack of access to water fit for human consumption negatively affects the health and quality of life for those living in many slum communities. The Khlong Toei Slum, restricted by its high density population, poverty, land tenure issues, and damaged water pipelines, exemplifies this situation. Serious consequences have led researchers to investigate solutions such as rainwater harvesting and solar water disinfection. By researching the history of the slum's land tenure issues, present land tenure challenges, the water network that serves the district, and different kinds of contaminants of water pollution, the team can better assess water management systems to fit the Khlong Toei Slum community.

3 Methodology

This project addresses the lack of accessible potable water in the Khlong Toei Slum by investigating the root causes of poor water quality in Khlong Toei and recommending to the Duang Prateep Foundation a sustainable water management model for the Khlong Toei slum-dwellers. To accomplish this goal, the team will carry out the following objectives: (1) to determine the water network, (2) to determine the pollutants of the water, (3) to analyze the water usage, (4) to develop a criteria and assessment method based on the communities needs and preferences, (5) to assess water management systems, and (6) to review this project with residents of the Khlong Toei Slum to validate results.

By achieving the above objectives, the team will be able to produce a water quality report that identifies the types and levels of water pollution in the Khlong Toei Slum, as well as recommend a sustainable water management model for the community.

This chapter serves as a guideline for how the team plans on achieving our goals. Figure 3-1 outlines the scope of the methodology for the project. The team will deliver a water quality report and recommend a water management model to the Duang Prateep Foundation. By first observing the routines and cultural practices in the Khlong Toei Slum, the team will develop semi-structured interviews with specific questions for the slum-dwellers to answer. From these results, the team will develop a survey for the slum-dwellers. This survey will show the areas of importance to the slum-dwellers in regards to a water management model. The observations will allow the team to determine possible sources of point and nonpoint pollution sources in the slum. To validate the obtained results, the team will conduct focus groups formed by different individuals from the slum, DPF, and Water Management Companies. The sample size of the community that the team will be interviewing and surveying does not meet the significance level necessary to generalize results to the whole community because the number of responses will vary depending on accessibility.

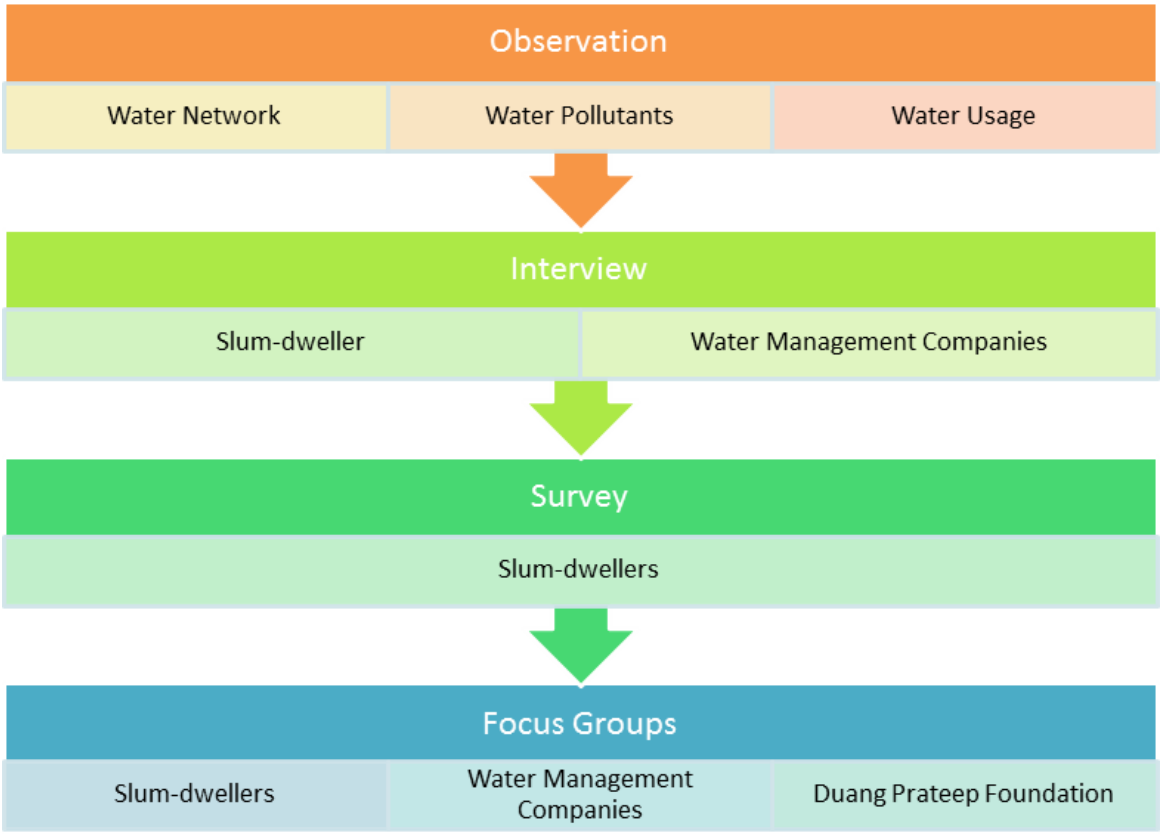


Figure 3- 1: Scope of Methodology

3.1 Observation

Observations are needed for the team to become aware of cultural habits, to identify waste habits, to locate gathering places (i.e. local market), and to locate sources from which the slum-dwellers obtain their water. Observing waste habits may allow the team to gain insight about pertinent pathways of potential human sources of pollution. Observing local gathering places will identify possible locations where surveys can have a high response rate. Observing possible water sources will give the team possible locations to test the water. The team will also use observations to identify daily schedules. Observations will address all of the team's objectives and fill knowledge gaps between the research presented in the background chapter and the actual application within the Khlong Toei Slum.

The team will make observations by taking several full-day visits to the Khlong Toei Slum and taking photos of items in the slum throughout our entire duration in Thailand. Making several visits will allow slum-dwellers to adjust to the team's presence. Making observations within the first week will help the team format interview questions. The team will use observations following the interviews to compare validity of answers. Each team member will take individual, in-depth notes through the application of the five senses. The team will split notebooks for observations into two columns: one for what is directly observed and another for the team member's interpretation of the observation. An example of this would be "Observation: The resident offers the team tea. Interpretation: The resident wants the team to feel welcome." (Purdue OWL, 2010). The purpose is to separate literal observations from the perspectives of the

observer. The observer will also make sure to write the time of day the notes were taken to consider if the time of day affects habits.

The team will assess observations by performing a content analysis on the notes taken. Content analysis is a technique for making inferences by systematically and objectively identifying characteristics within the text. The team will assign different colors to the different types of observations (i.e. [Red] cultural habits, [Orange] waste habits, [Blue] local gathering places, and [Green] water sources). These different colors will be the code that the team will use to analyze the text and identify keywords. The team will then use these keywords to structure the interviews and surveys.

3.2 Water Testing

Testing the water in the Khlong Toei Slum is important to determine the contaminants. If the team understands the pollutants, the root cause or causes of pollution may be found. Knowing where the pollutants are coming from will help the team to recommend a water management model that may fix the core water issue of the slum.

The team will take samples of water in locations throughout the slum where residents collect water or where there are any potential sources of pollutants such as vending machines, water taps, and water sources near markets and businesses. The samples will be collected twice a day for comparison; the time of day may help determine the sources of pollution. If there are higher percentages of pollutants in the evening compared to the morning, this may offer a clue as to the source. Different activities in the slum will take place during different times of the day, which could affect the water quality (i.e. market throwing waste in the afternoon). The team will determine the locations for taking samples after an initial walk through of the slum. Walking along the current water network, near sanitation facilities, and where waste is collected will help the team in identifying specific point and nonpoint sources of pollution in the Khlong Toei Slum.

Examining the water for contaminants will include several different tests. The team will test for pH, heavy metals, fecal coliforms, conductivity, temperature, and dissolved oxygen. To examine the pH level of the drinking water, the team will use litmus paper and the universal indicator. As for the other categories, the team will develop strategies in concordance with lab equipment available for the team's use at the Chulalongkorn University BSAC. Data collected will produce a water quality report.

3.3 Interviews

The team will conduct semi-structured interviews with the Khlong Toei Distribution Pumping Station (Khlong Toei DPS) and slum-dwellers. The interviews will be conducted in the following way: two BSAC students accompanied by two WPI students will meet with the interviewee in the determined location (i.e. Pumping Station or Foundation Headquarters). One of the BSAC students will ask the questions to the interviewee, and will take notes on the answers, while the other BSAC student will be explaining briefly in English to the WPI students what the context of the answers is and one of the WPI students will take notes. The interview will be recorded by a tape recorder to serve as support when the team transcribes the responses. After the interview is conducted, the BSAC student will read the answers to the participant to assure the information written down is correct.

3.3.1 Pumping Station Interview

According to the Bangkhen Water Treatment Plant (Bangkhen WTP), the plant receives raw water from the Chao Phraya river and distributes it to the Khlong Toei District through the

Khlong Toei DPS (Metropolitan Waterworks Authority, 2010). The team lacks information on the transmission of water from the Khlong Toei District to the Khlong Toei Slum. Interviewing the manager of the Khlong Toei DPS will allow the team to fill the knowledge gap regarding the transmission of water into the slum. The team will request a map of the current water network in order to identify possible water sources from which the Khlong Toei residents obtain the water and to identify the path water follows to leave the slum. Furthermore, the team will collect information regarding the maintenance of the pipes that serve the Khlong Toei slum. One of our assumptions is that the Pumping Station doesn't provide recurring maintenance to the pipelines leading to damage and leaking.

To conduct these interviews, the team will contact the company representative via email or phone to obtain consent to conduct and record an interview. If the company manager agrees to an interview, the team will set an appointment to visit the facility and conduct the interview. The team will follow an interview protocol that is located in Appendix B.

The team will utilize the information obtained to understand the current status of the water networks and to assess whether deteriorating pipes are in fact a source of pollution.

3.3.2 Slum-Dweller Interviews

Obtaining information about the residents' daily routines, practices and preferences will lead the team to understand how water is utilized, collected, and disposed in the slum. The team will interview five slum-dwellers identified by the Duang Prateep Foundation to obtain information regarding their perspectives on the water quality issue, water usage, water collection practices, drinking water sources, hygiene habits, health issues related to polluted water, disposal methods of food and waste, and needs and preferences. These responses will serve as a guideline to create the survey questions.

To conduct the interviews, the team will contact the individuals identified by DPF to obtain consent to conduct and record the interview. If the slum-dwellers agree to an interview, the team will set an appointment with them to interview at DPF. The team will assemble the different responses by analyzing the content of the interviews and classifying and grouping the answers into categories. The team will determine a list of answers for each question that will serve as the backbone of the survey responses. Understanding the needs and preferences of the slum-dwellers is crucial for the team to develop a solution that fits the communities' needs. The team will follow an interview protocol that is located in the Appendix C.

To know if the quality of the water affects consumption patterns within the Khlong Toei Slum, this project will establish the criteria slum-dwellers use in assessing the water they drink. The way slum-dwellers perceive water quality may affect the water they consume. Refer to Appendix D for more details on the criteria.

The team will assess the slum-dweller interviews by performing a content analysis on the interview text. The team will assign different colors to the different keywords established. These different colors will be the code that the team will use to analyze the text and identify criteria. The team will then use these keywords to structure the surveys.

3.4 Survey

Surveys will give the team quantitative data and responses that are straightforward. With anonymity, surveys can provide avenue for more honest and unambiguous responses. Surveys will also allow the team to receive numerous responses, identify common responses on the survey topics, and classify responses according to demographics of the interviewees (i.e: female,

male, thai). By identifying the criteria slum residents consider to be more important, the team will determine the weight of the criteria.

The team will make surveys with pre-selected answers by using common keywords found through the few initial interviews and observations. For example, if the question is "Where do you get your water?" the pre-selected answers will be "A. Water Vending Machines, B. Local Well, C. In-Home Piping, D. Chao Phraya River, E. Other: _____". The surveys will also ask the residents to rank their needs and preferences. The needs and preferences are pre-determined by answers in the initial interviews, described in Section 3.3, and together define the set of criteria. The team will list responses on a sheet of paper and ask the survey-takers to rank each on importance using a scale of 1-5. The team will average the results of this survey. Table 3-1 represents a hypothetical weighted criteria chart based on the characteristics of taste, color and odor.

Table 3- 1: Hypothetical Weighted Criteria Chart

Criteria	Survey 1 Results	Survey 2 Results	Survey 3 Results	Average Scale of Importance	Weight
Taste	4	3	5	4	4
Color	2	2	3	2.33	2.33
Odor	4	4	2	3.33	3.33

Water assessment based on pollutants will be more challenging. With the results of the water tests, the team will identify current pollutants in water sources of the Khlong Toei Slum. The pollutants will be given a risk factor which will serve as its weight. As opposed to the desired criteria, pollutants will have a negative weight. The risk factor of a pollutant will be designated based on the impact it has on human health. A negative one represents that the pollutant isn't as harmful as it is less desirable whereas a negative five suggests that this pollutant could cause serious harm to the residents of the slum if consumed. Assessment of the pollutants will be either, yes the pollutant is present, or no, there is no presence of the pollutant. If the pollutant is present, the assessment is a 1, if the pollutant is not present, then the assessment will be a 0.

The survey will also have questions for identifying gender and occupation. Refer to Appendix E for survey questions. By identifying local gathering places (i.e. local market) during observation, the team will spend a few days at the local gathering place asking residents if they would mind filling out a short survey. The WPI students will work with the BSAC students to conduct the surveys. If the person filling out the survey is illiterate, a BSAC student will aid the participant by reading and recording the survey and responses.

The team will assess the findings by tallying the result of the responses and comparing results by using visuals such as bar graphs or pie charts. The team will then add and average responses on criteria.

3.5 Assessment of Methods

With the developed criteria established about water characteristics and collection methods, our team will evaluate the water management case studies researched in Section 2.3. Water vending machines will be assessed through collecting water from the machines within the

Khlong Toei Slum. Due to the barriers of time and money, constructing a rainwater harvesting system will not be feasible. Our team will assess rainwater harvesting based on previously completed case studies and the established criteria. If time allows for the implementation of SODIS, our team will assess the water management system based on the findings from this study using the specified criteria. If the project is restricted by time, our team will assess SODIS based on case studies, similarly to rainwater harvesting.

Water systems will be assessed on a 0-5 point scale. A zero suggests that the system is ineffective at meeting the desired criteria, whereas a five suggests absolute compliance. The team will then weigh the results of the assessments based on the level of importance the criteria serves for the Khlong Toei residents and sum the weighted results of each criteria. Based on the criteria and the weights of each, the team will calculate a range of high, medium, and low summed values. The team will consider the water management system ranked highly as a viable recommendation for the Khlong Toei Slum.

Table 3-2 displays a hypothetical assessment of tap water versus purified bottled water. The weight scale was carried over from Table 3-1. The table below shows that the tap water tasted poorly, was discolored and had a presence of heavy metals; however, the water did not smell bad. Contrarily, water obtained from the purified bottled water met taste expectations, was not discolored and did not omit an odor. Also, the water was contaminant free. The results from weighing the assessments and taking the sum of the weighted results, justifies that drinking bottled water will most effectively supply potable water to the Khlong Toei Slum in this hypothetical case.

Table 3- 2: Hypothetical Assessment Chart

	Tap Water			Purified Bottled Water		
Criterion	**Assessment (A)**	**Weight (W)**	**Weighted Results (A•W)**	**Assessment (A)**	**Weight (W)**	**Weighted Results (A•W)**
Taste	2	4	8	5	4	20
Color	1	2.33	2.33	5	2.33	11.65
Odor	4	3.33	13.32	5	3.33	16.65
Heavy Metals	1	-5	-5	0	-5	0
Sum			18.65			**48.3**

3.6 Focus Groups

The team will form the focus groups with residents of the Khlong Toei Slum, DPF representatives, and perhaps Khlong Toei Distribution Pumping Station management. This array of people will represent the consumers, distributors, and authoritative figures in the Khlong Toei Slum. The team will conduct focus groups for each group individually to receive the most honest information. The focus group will follow a strict protocol. The focus groups will serve as a validation method for the information obtained through interviews and surveys.

First, the team will introduce the project to the participants. The team will address lack of potable water in the Khlong Toei Slum and our actions towards recommending methods to improve the system. Secondly, the team will inform the focus groups that our project conducted interviews to develop criteria of the characteristics the slum-dwellers seek in a water management system. Our project will present the criteria we established and encourage feedback from the participants. Feedback is crucial to ensure that our criterion is a good representation of the slum-dwellers. Third, the project will explain the survey that was conducted to develop the weighted criteria. The team will present the results and feedback will be encouraged.

Lastly, the team will present the assessment of water management options to the Khlong Toei slum-dwellers. Our project will outline each system, discuss the advantages and disadvantages, and display our assessments. The team will ask participants to join in on a discussion of the water management options. The opinions, thoughts, and concerns of the participants have a huge impact on the outcome of the focus group. If participants believe the criteria and weights are poor representations of their water goals, then our analysis of water management models will not be accurate. Also, the project seeks to obtain opinions on the water management models presented and whether the participants believe these are feasible options.

3.7 Summary of Methodology

A sustainable water management model must address all sources of pollution as well as the water usage practices of the community members in order to be successful. Figure 3-2 shows the scope of the project and how the team will achieve our deliverables which are a water quality report and a recommendation of viable water management models for the community. The team's approach will be conducting water quality tests, observations, interviews, surveys, and focus groups in order to collect the data needed. The team will conduct interviews with representatives of the Khlong Toei Distribution Pumping Station to obtain information regarding the current water network in the slum. Data collected through water testing supported by the information obtained from the Khlong Toei Pumping Station interview, and observations will suffice to produce a water quality report. The team will observe the slum-dwellers' practices, such as disposal and sanitation methods of slum-dwellers and local businesses. Interviews conducted with slum-dwellers will contain questions regarding their perspective of the problem, water usage practices, and their needs and preferences. After determining a set of predetermined answers for the questions, the team will create and conduct surveys for slum-dwellers to obtain numerical values and weighting of responses. To validate the information obtained through surveys and interviews, and the potential solutions, the team will conduct focus groups to present to the community the outcomes of the interviews, surveys, and the assessment of water management models in order to obtain their input on the feasibility of each option. Data collected through conducting interviews and surveys with the slum-dwellers, and assessing potential solutions will allow the team to recommend a water management model for the Khlong Toei Slum.

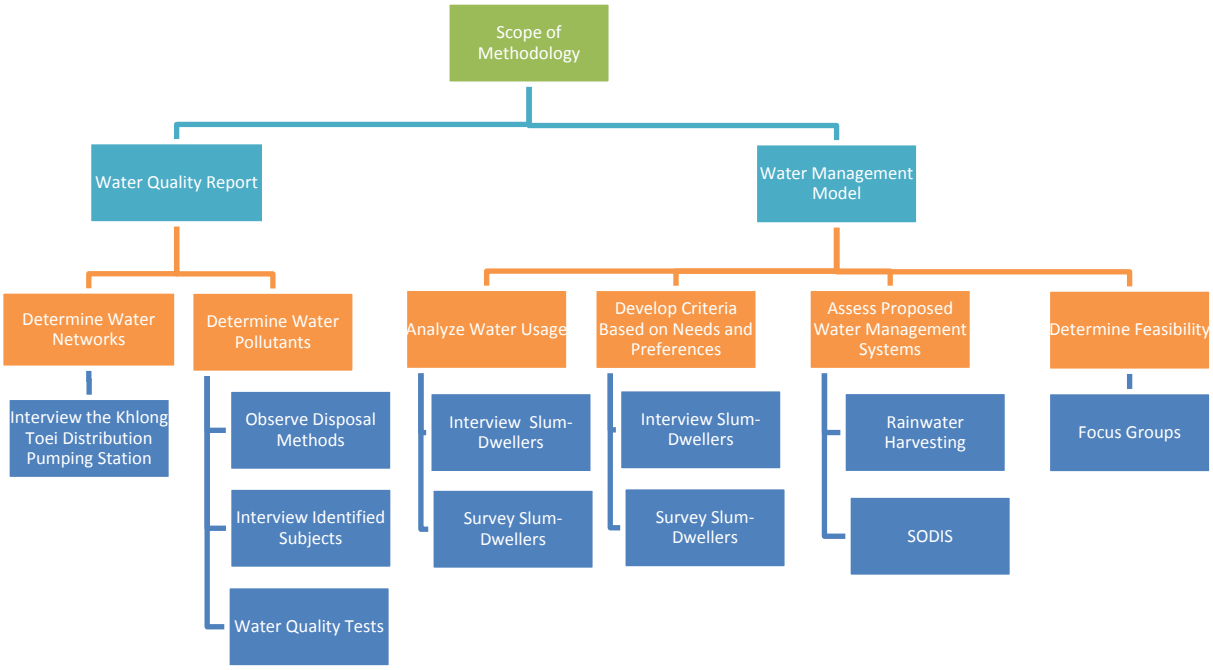


Figure 3- 2: Scope of Project

Appendix A: The Duang Prateep Foundation

The Duang Prateep Foundation is a nongovernmental organization based in Bangkok Thailand. The mission of this organization is to provide aid to the Khlong Toei Slum in three major areas. The first area is education to youth in impoverished communities. The second is to provide guidance in vocational studies and craftsmanship. Lastly, the Duang Prateep Foundation aspires to stimulate healthy living within communities (Hata, 2010).

Prateep Ungsongtham Hata founded the Duang Prateep Foundation in 1978. The founder lived and grew up in the Khlong Toei Slum. Realizing that the living conditions in the slum were unbearably poor, she became inspired to help this cause. Her primary goal focused on alleviating the distress these families faced and to give them hope.

The Foundation, operating for about thirty six years to date, is now working on over twenty projects to help change the lives of people living in the Khlong Toei Slum. They cover tasks such as educating the youth, running programs at the local community center, and ending drug and child abuse. The Foundation also currently runs a rehabilitation center as well as a public kindergarten school (Duang Prateep Foundation, 2014).

Appendix B: Interview Protocol- Representatives of the Khlong Toei DPS

Table B- 1: Interview Representatives of the Khlong Toei Distribution Pumping Station

Introduction	Thank you very much for agreeing to talk with us. I am _____ and I am a student working with the Duang Prateep Foundation. We are working with the DPF and your community with the goal of recommending a sustainable water management plan for the Khlong Toei Slum. We are currently assessing options, so we are most interested in talking with you about your experiences with water and your input on what you would like to see changed. All your answers will remain anonymous and your name or any identifying information will not be used in our report.

Topic: Water Networks Information	• Do you supply water to the Khlong Toei Slum?
	  ○ If not, do you know where the Khlong Toei Slum obtains water from?
	  ○ If yes, is this water tested for quality prior to distribution?
	• Do you believe there are problems with the water network in the Khlong Toei Slum?
	  ○ If yes, what are these problems and why do you consider these problems?
	  ○ How do you think these problems originated?
	  ○ What are the company's limitations for fixing these problems? (If the company supplies the slum with water)
	• When was the last time the water network pipes received maintenance? Last replaced?
	  • What was done in this last maintenance? Replacement?
	  • How often is this maintenance performed?
	• When were the pipes extending into the Khlong Toei Slum installed? (If the company supplies the slum with water)
	• Do you have water network plans we could have or copy for our project?
	• May we have permission to use any quotes from this interview as cited by your organization?

Appendix C: Interview Protocol- Khlong Toei Slum-Dwellers

Table C- 1: Interview Slum-Dwellers

Introduction	Thank you very much for agreeing to talk with us. I am _____ and I am a student working with the Duang Prateep Foundation. We are working with the DPF and your community with the goal of recommending a sustainable water management plan for the Khlong Toei slum. We are currently assessing options, so we are most interested in talking with you about your experiences with water and your input on what you would like to see changed. All your answers will remain anonymous and your name or any identifying information will not be used in our report.

Topic: Water Usage	• Where do you obtain water for general use?
	  • Why do you collect it from this location?
	  • How do you collect the water? (containment methods)
	• Do you ever use other sources of water? Keeping in mind these tasks:
	  • Cleaning/ Dishes
	  • Laundry
	  • Bathing
	  • Drinking and Cooking
	• Do you use the water vending machines that the foundation implemented?
	• Do you wash your hands after using the sanitation facilities?
	• Have you encountered health issues recently?
	  • Were they caused by the quality of the water?

Topic: Waste Disposal	• After water is used, how do you get rid of it? • Where do you dispose your trash?
Topic: Current View of the Water Issue	• Are you satisfied with the water you obtain? • Have you encountered any problems with the water? • What are your concerns about the water quality?

Appendix D: Criteria of Slum-Dwellers

Criteria based on water characteristics may include taste, smell, and color. Interviewing slum dwellers and asking why they collect water from a certain location may justify whether water characteristics are a factor. If slum-dwellers state the water from that well is ‘clean’ our interview can dig further into what makes the water clean and thus establishing a criteria for water characteristics. The prevalence of contaminants is a criterion that this project automatically establishes. The project aims to provide access to potable water that meets drinking standards, therefore this water characteristic criterion is highly required.

Criteria based on collection methods are important in the assessment of water management options for several reasons. The location slum dwellers collect water from may be affected by the prevalence of quality water. Also, slum dwellers may use different wells for different purposes such as drinking, bathing and cleaning based on the decreasing need for contaminant free water. How slum dwellers collect water may correlate to the distance they are willing to travel, potentially decreasing the quality of the water. For smaller collections, in the size of water bottles or gallon jugs, slum-dwellers may be more willing to travel to better water sources. However, if there is a larger need for water, requiring a barrel or other large container, slum-dwellers may not travel to wells with better quality water at a further distance. It is also vital that this project considers whether the price of water varies throughout the slum. If so, the price of the vending machines and taps may constrain the slum-dwellers from specific wells. Through interviews with slum dwellers, if we find that location of wells, volume of water being collected, and price effects the consumption of water for the slum-dwellers, then it will become a criteria assessed in new water management options.

Appendix E: Survey Slum-Dweller Survey (Subject to Change)

Table E- 1: Sample Survey

Introduction	Thank you very much for taking this survey. We are working with the Duang Prateep Foundation with the goal of recommending a sustainable water management plan for the Khlong Toei slum. We are currently assessing options, so we are most interested in your input about the following questions. All your answers will remain anonymous and your name or any identifying information will not be used in our report.
Topic: Water Networks Information	Sex: □ Female □ Male Nationality: □ Thai □ Vietnamese □ Other: _____ Occupation: □ _____ Age Group: □ 0-12 □ 12-18 □ 19-21 □ 22-35 □ 36-50 □ 51-65 □ 65+ Where do you get your water? (Check all that apply) □ Water Vending Machines □ Local Well □ In-Home Piping □ Chao Phraya River □ Bottled/Store Bought □ Other: _____ What do you use the water for? (Check all that apply) □ Cooking □ Cleaning Dishes □ Cleaning Your Living Space □ Drinking □ Showering □ Brushing Your Teeth □ Washing Your Face □ Washing Clothes

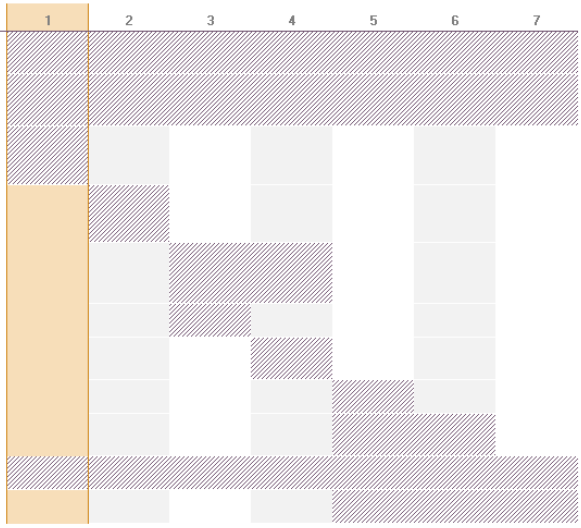
	□ Watering Plants □ Domestic Animals (Drinking and Washing) □ Other: _____ Do you collect water from different sources depending on the purpose of the usage? □ Yes □ No What is the quality of water? □ Very Clean □ Clean □ Not Clean □ Unusable

Appendix F: Research Timeline

Table F- 1: Schedule

Water Management in Khlong Toei Schedule

ACTIVITY	PLAN START (Week)	PLAN DURATION (Week)	ACTUAL START (Week)	ACTUAL DURATION (Week)	PERCENT COMPLETE
Meet with the Duang Prateep Foundation	1	7	0	0	0%
Visit Khlong Toei/Observe	1	7	0	0	0%
Contact Water Companies	1	1	0	0	0%
Visit Pumping Station/Interview	2	1	0	0	0%
Interview Slum-dwellers	3	2	0	0	0%
Collect Samples/Test Water	3	1	0	0	0%
Survey Slum-dwellers	4	1	0	0	0%
Assess Water Management Options	5	1	0	0	0%
Conduct Focus Group	5	2	0	0	0%
Write Report	1	7	0	0	0%
Final Presentation	5	3	0	0	0%



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