Designing a Model Water and Sanitation Centre Prototype for Monwabisi Park, Cape Town

An Interactive Qualifying Project proposal to be submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Chapter 1: Introduction

The World Health Organization recognizes unsafe water supply and poor sanitation as one of the most common "preventable risks" leading to mortality across the globe. Unsafe water and inadequate sanitation and hygiene are the leading contributors to the transmission of a wide variety of illnesses, including schistosomiasis, trachoma, hepatitis, worm infestations, cholera, and the particularly devastating diarrhoeal diseases. As of 2006, there were 54 countries in which more than half of the population lacked access to satisfactory sanitation facilities, while 14% of the global population remained without access to improved drinking water. Together, these two statistical categories total to over 2 billion people without improved sanitation and close to one billion people without improved water supplies (World Health Organization, 2009).

Cape Town, South Africa may be considered one of the most beautiful cities in the world (SA-Venues.com, 2009), but it is not exempt from this global epidemic of inadequate water infrastructure. The unique city draws in thousands of tourists annually for attractions ranging from culinary curiosities to breathtaking beaches, however it also holds the appealing prospect of employment for its indigenous population. As the Apartheid era came to a close, South African natives began to migrate to the major cities in order to exercise their hard earned rights for equal opportunity. This massive influx of people led to an over-saturated job market, which directly resulted in the swell of "squatter camps" - temporary dwellings for migrants in pursuit of jobs. Over time, these squatter camps have gradually evolved into permanent domiciles due to the absence of any significant efforts to formally accommodate their residents (Granfone *et al*, 2008).

The abandonment of official planning during the erection of squatter camps like Monwabisi Park, located in the Khayelitsha Township, resulted in inadequate provision of even the most basic services. The City of Cape Town has since installed 92 pour flush toilets in the park, yet these toilets are located on the outskirts of the park and over three quarters of them are now nonfunctioning. In response, many residents have constructed rudimentary pit latrines in order to achieve some form of local, private, and semi-structured toilet facility. However, these facilities are generally unsanitary and often contribute to the contamination of the region's ground water supply. The City of Cape Town also provides free, clean water to Monwabisi Park via municipal water taps. Many of these taps, however, are broken due to vandalism and misuse, leading to the overuse of the remaining functional taps and promoting leakages that cause erosion and further tap failure. Contamination of the clean city water due to unsanitary practices at the taps is also a problem. Personal hygiene practices, such as hand washing, are not

frequently advocated or applied. When coupled with the lack of proper sanitation provisions, unsanitary practices have led to a proliferation of diarrhoeal diseases. In Khayelitsha alone, 80 children die per year from diarrhoea-related illnesses. New standards of hygienic practices as well as a proper form of waste control must be implemented in Monwabisi Park in order to deter the spread of disease (Granfone *et al*, 2008).

The problems faced by the people residing in Monwabisi Park and other informal settlements have been recognized by preceding project groups, outside aid organizations such as the Shaster Foundation, and the City of Cape Town. The basis of this project is itself an expansion of the work performed by previous researchers. Through the exploration of case studies, we will evaluate past successes and failures in similar situations. We will specifically look at examples of effective community-led redevelopment in Pakistan (Hasan, 2002), infrastructure after rapid urbanization in Cambodia (Chen & Solon, 2004), and wastewater treatment through constructed wetlands in Italy (Masi &Martinuzzi, 2007). We will use research conducted by last year's WPI Major Qualifying Project and Interactive Qualifying Project teams in conjunction with the University of Cape Town and the local government for information specific to Monwabisi Park. These students worked with city officials and current residents of Monwabisi Park to document many of its current problems and offer ideas for redevelopment. They devised a preliminary plan to install communal water and sanitation facilities in the park, which could later be implemented throughout the community to alleviate the distress caused by current conditions (Granfone *et al*, 2008). This research and planning has provided our project group with a robust framework to build upon.

Despite the work that has already been done in Monwabisi Park, there is still a desperate need for immediate water and sanitation services. Thousands of citizens continue to follow unsafe sanitation practices, largely due to the lack of available alternatives. The law requires a family-to-toilet ratio of 5:1, and yet even if all toilets are assumed functional, 69 families must still share a single toilet. Water contamination still exists within the park, and the alarming 2005 infant mortality rate of 34.72% indicates that hygiene practices have not sufficiently improved to prevent the spread of disease. Previously gathered information on the conditions of Monwabisi Park and possible methods of providing clean water and sanitation to its residents may have set the stage for improvement, but has provided little to date in terms of tangible change for the community.

The goal of this project is to devise an integrated and sustainable plan that will promote proper water sanitation and hygienic health practices and improve the general availability of toilets in

Monwabisi Park. We will model this plan in the “Redevelopment Seed” by researching and interacting with community members to find the best solutions for reducing waterborne diseases and helping the community to achieve a cleaner, safer, and more convenient lifestyle. We will complete this goal by first investigating and documenting possible options for structured sanitation systems and determining what will adapt best to the Community Centre and the neighboring housing of the Redevelopment Seed. Among the priority considerations of these alternatives are the sanitation of grey water, disposal of wastewater, and protection of drinking water. We will also collaborate with members of the community as well as project sponsors to determine the desires of the residents and the feasibility of our selections. We will create a final proposal for the City of Cape Town to use as a model in future redevelopment planning. Finally, we hope to take part in the actual construction of the sanitation systems and water facilities during our brief stay in Cape Town.

Chapter 2: Background

In order to model a facility that will improve upon the water and sanitation situation plaguing Monwabisi Park, the evolution, current state, and previously attempted solutions for the problem must first be fully understood. The following chapter thus outlines the impact of the region's transition from apartheid oppression to post-apartheid privileges on its water and sanitation circumstances. Primary concerns for health and well-being within Monwabisi Park's current conditions and practices are then identified, and preceding efforts to address them both directly in the park and in other areas of the globe are highlighted. Finally, the water facility designs and sanitation system suggestions provided by the previous two years' WPI teams will be described as the strong foundation from which our work will expand.

2.1 Water and Sanitation in South Africa

South Africa is a country that continuously struggles to provide basic water and sanitation services to its citizens. The complications involved in this quandary are not new to cities like Cape Town; however the recent turnover in the region's politics has challenged this issue with a national initiative (Hattingh *et al*, 2007).

2.1.1 South Africa during the Apartheid Era

The national government of South Africa played no role in providing public water or sanitation services during the apartheid era. The government was a largely centralized power dominated by the wealthy white minority. Therefore a new government was required before the people of South Africa, in particular the black population, would see any changes to their municipal support (Hattingh *et al*, 2007).

2.1.2 Post-Apartheid South Africa

In 1996, as the apartheid era came to a close in South Africa, the new national government drafted a constitution depicting their vision of a novel free country. Contained within this constitution was a Bill of Rights that provided South Africans with their first environmental liberties, including the right to free water and sanitation services (Appendix II). For the first time in South African history, its citizens were legally entitled to "an environment that is not harmful to their health or well-being" (RSA 1996) - a provision already commonplace to most of the developed world. However, there is a considerable difference between "human right" and "service rendered". Of the 40 million people living in South Africa at the time, more than a third were still denied access to a basic water supply while more than half lacked basic sanitation (Hattingh *et al*, 2007).

As a result of the new political stance of the government and the newly drafted constitution, the state set out to develop new policies targeting these water and sanitation problems. Among these policies were the National Environmental Management Act (NEMA) of 1998, the Water Services Act (WSA) of 1997, and the National Water Act (NWA) of 1998 (Preambles recorded in Appendix II). Now, the government faced the challenge of working backwards to institute a water and sanitation system into an already developed and inhabited land (Hattingh *et al*, 2007).

2.1.3 Responsible Parties

In 1994, the government took formal ownership of all water and sanitation services by assigning the Department of Water Affairs and Forestry (DWAF) the daunting task of assuring that all South Africans had "equitable access to water supply and sanitation" (Muller 2003). DWAF started the Community Water Supply and Sanitation (CWSS) Program in 1994, which targeted key areas for instituting a water and sanitation system. In 1997, the National Sanitation Program was established to increase the rate of distribution of water and sanitation services (City of Cape Town, 2008).

DWAF's vision for the management and delivery of water services in South Africa is as follows:

"Water is life, sanitation is dignity.

All people living in South Africa have access to adequate, safe, appropriate and affordable water and sanitation services, use water wisely and practice safe sanitation.

Water supply and sanitation services are sustainable and are provided by effective and efficient institutions that are accountable and responsive to those whom they serve.

Water is used effectively, efficiently and sustainably in order to reduce poverty, improve human health and promote economic development. Water and wastewater are managed in an environmentally responsible and sustainable manner" (City of Cape Town, 2008).

The City's Role

In 2000, the Municipal Systems Act (Preamble recorded in Appendix II) moved the accountability for water services onto the local government, making it the city's responsibility to provide basic water and sanitation services for all of its citizens. In order to fund the water and sanitation improvement efforts, local governments were permitted to receive money from the national government using the Municipal Infrastructure Grant (MIG) or Equitable Shares, or to use money that has been collected locally (City of Cape Town, 2008).

The Water Ladder

In 2003, the national government released a three phase policy known as "the water ladder" to systemize their work and its progress. In the first phase or "step", a basic level of water service would be provided to all citizens. This first step is the government's priority and an objective that they wish to accomplish within the next few years. The second step would then introduce an individual tap to each citizen's property, raising their status to an intermediate water service level. Finally, the projected result would see all residents reach a full level of water service, including running water in individual homes (City of Cape Town, 2008). Table 1 summarizes the definitions of the water service categories.

Table 1: Water Service Latter (City of Cape Town, 2008)

Category	Water Service Definition
Inadequate	No access to basic water supply as defined below.
Basic	a) The provision of potable water: • 25liters per person per day • within 100 meters of a household • less than 25 households per tap • less than 7 days interruption of supply to any consumer per year b) The provision of appropriate education with respect to effective water use
Intermediate	Yard tap
Full	House connection

The water ladder policy can also be adapted for a sanitation system. The first step would provide a basic level of sanitation service to all citizens, which would once again constitute the government's first priority. The second step would supply communal bathroom facilities for clusters of residents that are located close to their homes. The final step ultimately presents all residents with a toilet in the home that connects to a municipal waste management system (City of Cape Town, 2008). Table 2 shows what each of these service categories entails.

Table 2: Sanitation Service Ladder (City of Cape Town, 2008)

Category	Sanitation Service Definition
Inadequate	No access to basic sanitation as defined below.
Basic	a) Access to a toilet which is: • safe • reliable • environmentally sound • easy to keep clean • provides privacy and protection against the weather • well ventilated • keeps smells to a minimum • prevents the entry and exit of flies and other disease-carrying pests b) The provision of appropriate health and hygiene education c) Maximum of five families per toile
Intermediate	Communal toilet facilities in close proximity to homes
Full	On-site, water-based conservancy tank or suitable waterless technology

2.2 Current Conditions within Monwabisi Park

Currently, the City of Cape Town provides free water to many of its residents, including those within Monwabisi Park. All of this water, however, is not being distributed at a "basic" service level as discussed previously. Water is carried into the park from the city by a main line that runs along Mew Way. Underground plastic piping directs this water to fire hydrants and water taps throughout the settlement. Granfone *et al* (2008) describes first-hand the current conditions of the park, which are summarized in the following paragraphs.

There were a total of 117 taps initially installed in Monwabisi Park. In light of population growth and the rapid failure of taps, however, this number quickly proved inadequate. Assuming that every one of these taps worked properly, the ratio of taps to families in the park would still only reach about half of the legally required ratio. Furthermore, this generalization is an overestimation of services for certain areas of the park. In C-section alone, the tap situation is much worse than the statistics suggest. Many of the installed taps are now broken or unusable, requiring families to travel to the remaining working taps that are in turn becoming crowded

and overused. Table 3 compares the legally required ratio with the actual ratio (assuming generalized figures). Table 4 shows the actual figures specific for C-section.

Table 3: Ratio of Installed Taps to People/Households (Granfone *et al*, 2008)

	Monwabisi Park			C-Section		
	Number	Legally Required Ratio	Actual Ratio	Number	Legally Required Ratio	Actual Ratio
Population	20,000	1:125	1:171	6629	1:125	1:246
# Households	5785	1:25	1:49	1510	1:25	1:56
# Taps	117			27		
Projected figures if all taps functioned as installed						

Table 4: Ratio of Currently Working Taps to People/Households (Granfone *et al*, 2008)

	C-Section			
	Number	Legally Required Ratio	Actual Ratio	# of Taps Needed for Ideal
Population	6629	1:125	1:442	53
# Households	1510	1:25	1:101	61
# Taps	15			
Actual figures accounting for current tap conditions				

The issue does not end at the taps, either. The park has several problems with wasted water, insufficient fire hydrants, and unsanitary toilets. These are summarized by table 5.

Table 5: Major Water and Sanitation Concerns

Condition	Cause	
74% of taps failing	• Vandalism • Improper use • Improper drainage	• Underground leaks • Placement of tap • Overuse of taps
77% of toilets failing	• Vandalism • Placement (no repairs)	• Lack of proper toilet paper • Overuse
Thousands of kilolitres of water wasted	• Improper education • Lack of regulation • No easily accessible water data	• Water pressure wasted on broken pumps • Leaks not fixed in timely fashion
Frequent fires difficult to fight	• Hard to find hydrants	• Rerouting of water from hydrants

2.3 Current Practices within Monwabisi Park

Informal settlements in South Africa were hastily erected to accommodate the high influx of people seeking job opportunities in the urban centers of post-Apartheid era. The immediate need for shelter drove people into settlements, such as Monwabisi Park, where homes were built with little official planning for water pipes, toilets, or waste disposal. The lack of planning led to a lack of consideration for essential practices in procuring water, disposing of waste, and personal hygiene (Granfone *et al*, 2008).

2.3.1 Transportation of Water

In general, Monwabisi Park residents have managed to develop daily routines around their necessary trips to the nearest functional water tap. Disease and infection are being spread through the water transportation process, which can largely be attributed to the common use of unclean, uncovered buckets. The water that the residents of Monwabisi Park are receiving from their taps is clean water, but the buckets used for its transportation often contain stagnant pools - prime breeding grounds for waterborne pathogens. Many of these buckets are also produced by machinery that has been exposed to automotive fumes and chemicals. The people of Monwabisi Park do not necessarily associate the use of these buckets with the illnesses of their men, women, and most often, children (Granfone *et al,* 2008). Unsafe water and inadequate sanitation and hygiene, however, are the leading contributing factors to the transmission of diarrhoeal diseases, schistosomiasis, trachoma, hepatitis, worm infestations and cholera. In a country where 41% of the population does not have access to adequate sanitation, these illnesses

can be severe enough to cause the death of children who do not receive proper medical attention (World Health Organization, 2009).

2.3.2 Pit Latrines

A pit latrine is a common type of toilet found in Monwabisi Park, particularly within the center of the park where formal facilities are less common. While the 92 pour flush toilets provided by the city comprise the majority of the park's documented facilities, resident-constructed pit latrines still account for roughly 31% of overall disposal methods for excretory waste (Granfone *et al,* 2008). These primitive toilet facilities consist of a hole in the ground that is sheltered by three walls and some sort of door. When the hole fills with waste, it is covered with sand and the overlying structure relocated to a new pit. Over time, the buried waste begins to leach out into the ground and contaminate the ground water. Some pit latrines have been minimally improved to include ventilation systems and other modern elements, however they are generally unsanitary and often contribute to the spread of diseases (Granfone *et al,* 2008).

2.3.3 Toilet Paper

There is also a serious lack of acceptable toilet paper in the Monwabisi Park. Toilet paper is not often regarded as a necessity to sanitation systems, however it prevents direct hand-to-feces contact while removing residual excrement from the body – two particularly important contributions to a society that does not wash regularly. In place of traditional toilet paper, various other paper products are used which often clog the toilets or the systems beneath them. This creates further health risks because it damages drains and backs up the system, exposing waste to human contact and the open air (Carbonneau *et al*, 2009).

2.3.4 Hand Sanitation Procedures

Currently, the people of Monwabisi Park are not upholding the necessary hygiene standards to deter the spread of disease in their day-to-day routines, particularly when it comes to hand washing. Commutable diseases can easily be spread by a single infected person contaminating an open water tap with his or her hands, and just as easily contained by the cleansing of those hands prior to contact. The neglect of this sanitary step can be partially contributed to both the lack of available wash stations and insufficient education on healthy practices. Therein lay the problem's complications, as well, as it is difficult to inform a population about their substandard hygienic habits without offending them (Granfone *et al*, 2008).

Because of a severe lack of general knowledge on concepts of hygiene in the informal settlements, the nurse who ran the Indlovu Centre clinic, Glenn Vondo, used to inform the residents about the importance of hygiene and its relation to disease by distributing pamphlets. Also, during his regularly scheduled appointments, Glenn tried to inform his patients about the importance of proper hand sanitation. Unfortunately, it was very difficult to communicate these points because the people of Monwabisi Park are a rather proud community, and dislike receiving instruction on how to wash their hands or suggestions that their hygiene practices need to be improved. Hygiene awareness has further dwindled in the past year after the 2008 fire forced the clinic to cease operation (Granfone *et al,* 2008).

2.3.5 Vandalism at Facilities

Finally, unacceptable conditions at toilet and water exchange facilities extend beyond a simple lack of sanitation procedures. The locations and composition of communal toilet facilities and water taps make them a large target for crime and theft, especially late at night. Some residents will venture to the taps after dark, especially those located away from lighted streets, and steal the metallic portion of the taps. The stolen pieces are then sold for money. This is rendering a large number of the taps useless by preventing them from functioning properly. In addition, the removal of tap components causes them to leak. The pooled water around their base becomes yet another supply of standing water to further spread waterborne diseases. Monwabisi Park was originally provided with 27 taps throughout the community. Theft and vandalism have rendered 11 of these taps useless, leaving only seven fully functional taps for the community to survive on (Granfone *et al,* 2008).

2.4 Monwabisi Park as a Model for Redevelopment

One of the main goals of our project is to model a prototype that can both address current issues and be effectively replicated throughout other informal settlements. In doing this, we must adhere to certain ideals, including those of sustainability and permaculture, in order to mesh our efforts with those of the Shaster Foundation and other contributors already working to develop environmentally friendly solutions.

2.4.1 A Sustainable Future: Permaculture and the "Eco-Village"

"Permaculture" is a design theory developed by the Australian naturalist Bill Mollison that encourages populations to "work with, rather than against nature" (Jungck, 73). This idea is embodied by the "eco-village" concept, which entails full employment and reuse of available natural resources by a community in order to achieve the highest possible level of sustainability

and independence from importation. Approaching a project from a permacultural standpoint includes working "with what is already there: firstly to preserve what is best, secondly to enhance existing systems, and lastly to introduce new elements" (Whitefield, 8). For example, this project is looking to recycle "grey water", which is the non-sewage byproduct of water used for activities such as washing hands and doing laundry. This grey water would then be recycled back into the system where appropriate in order to maximize the conservation of resources. The Methodology will further explain how this project seeks to exemplify these permacultural principles in its proposed solutions.

2.4.2 The Shaster Foundation and the Indlovu Centre

The Shaster Foundation for Community Development is an organization founded in Cape Town by Dianne Womersley. Womersley has been involved in community work within the informal settlements for over 15 years (Shaster Foundation, 2008). The foundation bases its work on the aforementioned principles of sustainability, permaculture, and the conservation of natural resources. The objectives of the Shaster Foundation are stated:

- Improve the health and well-being of impoverished communities in a sustainable way
- Enable communities to grow food and create shelter for all
- Stimulate economic development and much needed job creation
- Revive a sense of pride in traditional and indigenous culture
- Encourage self-sufficiency and conservation of natural resources
- Encourage volunteers to contribute their skills to the community
- Protect the environment
- Eliminate waste
- Create a world that works for everyone - no one is left out

  (Shaster Foundation, 2008)

WPI students and professors have worked very closely with the Shaster Foundation since the Cape Town Project Centre's inception in 2007, and hope to continue to do so into future years. The foundation will aid the effort as a whole by upholding sustainable values in their contributions towards the overall goal of creating an "eco-village" within Monwabisi Park. The

foundation's greatest achievement thus far toward that end is the Indlovu Project, a comprehensive development plan "made of several different elements worked into an integrated and cohesive whole that forms the heart of the Monwabisi Park informal settlement" (Shaster Foundation, 2008). The people of the Shaster Foundation are currently focusing most of their time and energy towards this facet of the redevelopment, which includes a Community Centre, a laundry centre (designed by WPI students in 2007), and a crèche.

2.4.3 Previous WPI Project Teams

The WPI Cape Town Project Centre was piloted in 2007 by a group of four IQP students and advisors Scott Jiusto and Stephen Weininger. The team collaborated with the Shaster Foundation and the local community to design and construct a communal laundry facility for Monwabisi Park. In the fall of 2008, another group of four IQP students under the guidance of advisors Scott Jiusto and Robert Hersh began further research on possible solutions to the water and sanitation shortcomings of Monwabisi Park. They provided a strong base for our own work by observing and quantifying the various problems in the water and sanitation conditions across the entire park. Their research included determining the number of working taps in the park, the types of toilets used within the park, and the public health of the community. After a thorough assessment of these conditions, the team started researching possible methods and devices to fix them. A WPI MQP team led by advisors Jeanine Plummer and Scott Jiusto continued to expand on this conservationist foundation into 2009 from American soil, designing a comprehensive water facility as a model for implementation across Monwabisi Park. The information these groups have collected and the design concepts conceived from it have been a great resource in our investigation into possible toilet and sanitation options, with particular attention paid to the laundry centre, tap design, and the water facility.

Laundry Centre

The laundry station proposed and constructed by Alex *et al* (2007) represented WPI's introduction to the Monwabisi Park scene and established the working relationships between WPI and the key players in the park's redevelopment efforts. The station's design reduced the labor involved in clothes washing while embodying sustainable practices through its provisions for rainwater collection and effluent reuse as irrigation. The small adjacent grove of fruit trees fed by the station's grey water effluent also provided a comfortable and safe venue for the social congregations that are often integrated into the laundry process (Alex *et al*, 2007). The completed laundry station is pictured in Figure 1 below.

Figure 1: Completed Laundry Station (Alex *et al*, 2007)

Taps

The taps at Monwabisi Park are currently operated by a valve system, however these taps have been vandalized by people who steal the metallic parts and sell them for rand. Granfone *et al* (2008) investigated a new approach to attaining tap water, which involved the usage of a foot pedal instead of a twistable valve. The implementation of a foot pedal tap offers many advantages and would be a very fitting solution to the main problems that surround current tap usage. It would deter on-site contamination of water, because there would be little hand-to-tap contact. Residents also hang buckets on the taps which often causes them to warp and break. To remedy this, the team suggested that a concrete stand be installed underneath the tap to place buckets on, alleviating the physical stress of their weight and reducing the probability of tap damage (Granfone *et al*, 2008). Figure 2 below depicts a CAD model of this design.

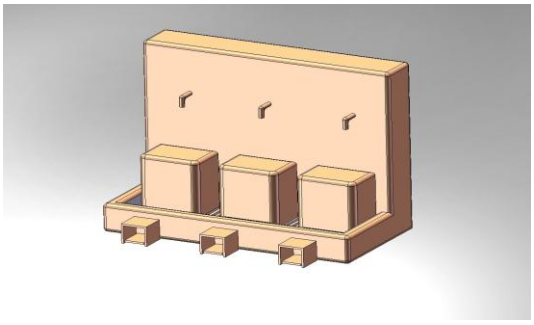


Figure 2: Tap Station Design with Bucket Support and Foot Peddle Operation (Granfone *et al*, 2008)

The Water Facility

The Carbonneau *et al* (2009) further elaborated on the plans proposed by Granfone *et al* (2008), including the design of a water and sanitation facility that "would give the community

access to basic water and sanitation features including water taps, a laundry station, and toilets" (Carbonneau *et al*, 2009). Their proposed facility is a structure that is integrated with sustainable, environmentally friendly, and sanitary elements that, if implemented, would alleviate some of the water and sanitation issues present in the park. It would be equipped with features including rain collection tanks, hand washing stations, bathing areas, and a public toilet facility (Carbonneau *et al*, 2009). A blueprint of the water facility is shown in Figure 3 below.

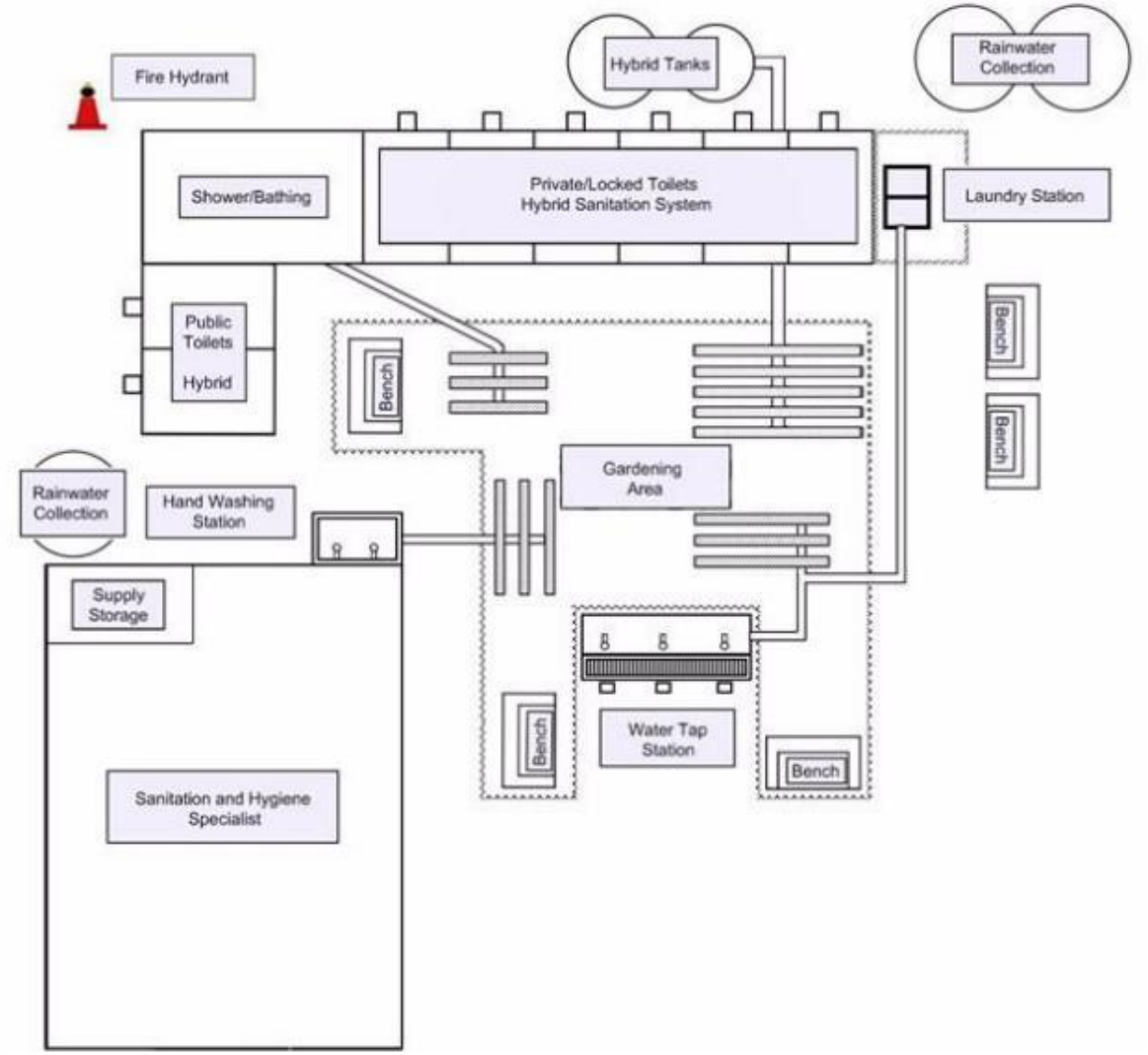


Figure 3: Comprehensive Water Facility (Granfone *et al*, 2008)

Within the center of the facility, the team suggested establishing a gardening area with an irrigation system contingent on grey water run-off from the laundry, bathing, and hand washing stations. The rainwater collection tanks are also suggested to emphasize conservation practices and lighten the demand on the municipal water system. The rainwater collection tanks would

be primarily used for the hand washing stations and laundry facility. Among the implantation of structures that promote sanitation and hygiene, the team also suggested a fire hydrant to be located at the water facility. Access to fire hydrants is a recently highlighted issue after a devastating fire that occurred in 2008 (Carbonneau *et al*, 2009).

The team also investigated waterless toilet options due to the continuing emphasis on water conservation. The types of toilets suggested included the Hybrid Toilet and the Enviro-Loo, which will be explained in detail in a later section. The proposal was that each toilet would be exclusive to a few families, and privately enclosed and locked. There would also be one or two public toilets for passerby and occasional visitor use (Carbonneau *et al*, 2009).

Water and Hygiene Specialist

Granfone *et* al (2008) also recognized that a centralized water facility cannot be managed and maintained by an untrained citizen. A water and hygiene specialist would have to be selected and educated on how to manage the facility, as well as have the responsibility to educate the residents of Monwabisi Park on health and sanitation procedures. The other responsibilities of the job would include the distribution of medication for diarrhoea, and, if necessary, revoking privileges for failing to practice the mandated sanitation procedures or vandalizing the facilities. The specialist would also have the responsibility of handling the transfer of water from the taps to the buckets, to further prevent the contamination contributing to the spread of disease. There would be a container for every resident's house and another in the water facility, all with sealable lids to prevent possible contamination during transport from the water facility to household. The person who would take up this job would also ideally live on the premises of the facility to be present in case any issues arise.

Along with the sanitation benefits, this position would also provide a job opportunity in the community. The water specialist position would be appointed by the local leaders in the street committee, and the selected resident would need training by the Cape Town Water and Sanitation Department before he or she would be qualified to operate such a facility.

2.5 Alternate Sanitation Options

The water and sanitation needs of the people living in Monwabisi Park are not being met. The availability of suitable toilets and hand-washing facilities is extremely low, and the contamination and misuse of water taps has aided the spread of waterborne diseases (Granfone *et al,* 2008). There has been extensive research conducted on the possible solutions to these

problems, and several plans have been partially developed. It is the goal of this project to bring together the best solutions from each plan into a single cohesive proposal to be implemented at the earliest possible time. Sanitation needs have been identified as the most pressing issue, but there are several key decisions that need to be made prior to the formation of any recommendations.

2.5.1 Framework for Sanitation Decisions

The prospect of not having a toilet in one's home is a foreign thought to most Americans. Almost 99% of American homes are, in fact, equipped with full plumbing facilities (U.S. Department of Housing…, 2008). Therefore the first choice to be made is whether the new facilities will be individual or communal. This is a socially charged issue because the people feel it is more appropriate and civilized to have individual toilets next to or within their homes (Granfone *et al.*, 2008*)*, but that may not be feasible. The additional space needed to add a sanitation system to each home is a concern, but a single system with multiple pipes may be a possibility. A community facility could be placed in a central location abutting the new housing development. This system may require more space than is available. Our project currently provides for one shared facility to be located outside the new Community Centre as well as an additional facility to accommodate the housing development. Due to the fact that the housing development will not be built during our time in Africa, this additional facility will be based on a temporary communal design with the option for future adaptation to in-home systems.

The second key question to be answered is whether a dry or water-based sanitation system would be better suited for this situation. Dry systems are beneficial in areas with little or no access to mass quantities of water. Although the residents of Monwabisi Park have water supplied by the City of Cape Town, the taps are in very poor condition. As described in the Background, 74% of the existing taps are malfunctioning and some people have reported traveling nearly two kilometers to find a working tap (Granfone *et al*, 2008). A dry system could also support multiple toilets and produce compost to be used for garden fertilization. On the other hand, the benefit to water-based systems is that they generally require less maintenance and are considered to be more socially acceptable (Granfone *et al,* 2008*)*. If we determine that a water-based system proves to be most suitable, however, closed loop options will be explored in order to limit the effluent produced. Variations of both systems can be installed underground and can have several toilets feeding into a single tank or vault.

2.5.2 Sanitation System Options

There are many different sanitation systems available, but not all are well suited for the conditions in Monwabisi Park. Based on the research of Carbonneau *et al (*2009*)*, the Enviro-Loo and Hybrid systems will be considered. A biodigester system and the AGAMA system will be evaluated due to sponsor recommendation, as well. We also researched the MineARC system, but this system was ruled out upon communications with the vendor. Each system has its own advantages and disadvantages which will be discussed and thoroughly examined before a final recommendation is made.

The Enviro-Loo Toilet System was designed to treat human waste without the use of water. It was conceived in the 1980s and 1990s in response to the lack of sanitation services in Africa (Enviro Options, 2009). The system uses dehydration and pasteurization to decompose and sterilize human waste. When waste enters the system, the liquids and solids are separated by gravity. The solids remain on a drying plate while the liquids are drained to the bottom of the vault (Carbonneau *et al,* 2009). A wind powered fan pulls air through the vault, evaporating the liquid and accelerating the dehydration and decomposition of the solids. As the solid waste dries, it can be reduced to as little as 5% of its original volume (Enviro Options, 2009). After the solids have been dehydrated, they can be scraped off the drying plate and added to a compost pile for further digestion. Once this is complete, the solids are fit to be reused and sold as compost (Carbonneau *et al,* 2009).

The cost of the Enviro-Loo system is roughly R5300 ($716) and has a lifetime expectancy of more than 20 years. Although it is a simple system with few moving parts, it does require regular maintenance. The drying plate needs to be scraped clean regularly and the vault must be emptied once every 6 months to three years depending on the amount of usage. The dry waste is then stored for another several weeks to finish decomposing. Each toilet that feeds into the vault is designed for 20 users per day, but several toilets may be placed in parallel to support more users (Carbonneau *et al,* 2009).

The Hybrid Toilet system was designed in the 1990's for Aboriginal communities with limited water access (Carbonneau *et al,* 2009). The system is a combination of a traditional septic system and a composting toilet. The primary tank is filled with water and when waste enters, anaerobic bacteria begin to break it down into sludge that collects at the bottom of the tank. This activity reduces the waste to 5% of its original mass (SA Biotech, 2008). The tank is aerated by a

solar or battery powered fan. As the water level in the primary tank rises, it is diverted through a separation chamber into the secondary tank for further degradation. This tank contains plastic media baffles which host microorganisms that further digest the organic material remaining in the water (Carbonneau *et al*, 2009). Once the water has passed through both tanks, it is discharged into the ground. The sludge in the primary tank only needs to be removed once every four to seven years, and the tanks may be buried just beneath ground level or kept visible for easier maintenance access. The basic unit cost of a hybrid system with a user capacity of about 25 people is R14,150 ($1,900), however larger systems are also available to support more users (Hybrid Toilet System, 2007). We are currently working with SA Biotech, as well, to adapt their system to function on a closed loop. The cost of this unit may vary depending on required parameters.

The concerns associated with the Hybrid sanitation system revolve around the quality of the effluent. This is waste water that has been treated and will then be discharged into the ground or recycled through the system. If the pathogens within the waste are not properly digested by the bacteria in the system, they will contaminate the leech field and produce an odor. The contamination of ground water is a particular concern due to the high level of the water table (Granfone *et al,* 2008). There have been case studies documenting the effectiveness of this system and it is shown that under close monitoring the system produces a consistently safe effluent. The second byproduct is the sludge that forms in the primary tank. This is not a major health concern as long as the system is functioning properly. This sludge is removed by a licensed authority and disposed of. We believe the biodigester systems have very similar health risks, but we plan to research this further upon arrival by meeting with an AGAMA representative.

A bio-digesting system uses agitators in a large tank to mix wastewater as microorganisms break down the organic material. Simultaneously, the gas that is released is captured and can be used to fuel a generator that powers the agitator inside the tank (Biogas Plants, 2009). This closed loop system is sustainable with minimal costs aside from the initial installation. The AGAMA and WELtec options are both examples of biodigester systems.

The MineARC Hybrid system is a self contained single unit that is approximately 2 meters by 2 meters and stands 2.8 meters high. The MineARC is a completely closed system that keeps all waste entirely separated from the surrounding environment. It recycles the purified waste water back into the system therefore preventing it from being discharged to the ground. After working with the MineARC Sales representative, we discovered that the unit employs gasses specific to

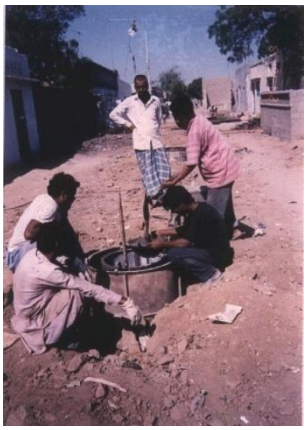
mines that will not be available in Monwabisi Park. Thus we determined that this system is poorly suited for the park's challenging environment and therefore will not pursue it further.

2.6 Learning by Example: Case Studies

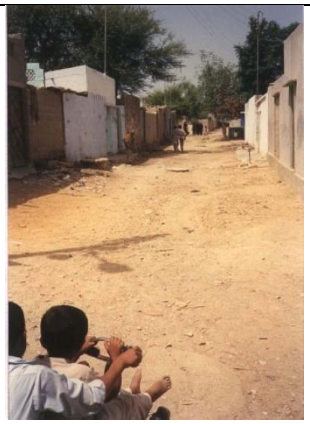
In addition to the wealth of information gathered by the previous WPI IQP and MQP teams, efforts to redevelop water and sanitation infrastructures beyond South Africa's borders are also a valuable source of considerations for our project. We recognize that progress is made most efficiently by learning from the successes and failures of previous endeavors, and will continue to consult a variety of case studies, as we have with the three outlined here, in order to apply their lessons to our own research and design.

2.6.1 Effective Community-Led Redevelopment: Karachi, Pakistan (Hasan, 2002)

"Typical conditions in Orangi before OPP-RTI began working in the settlement".



"Manholes being cast".



"…and after. Over 6,675 Orangi lanes containing 100,244 houses have built their lane sewers and latrines in their homes".

Figure 4: Photographs from Orangi Pilot Project (Orangi Pilot Project (OPP) - Institutions and Programs, 2009).

The Orangi Township, located in the District West of Karachi, Pakistan, consists of a diverse population numbering greater than one million, all clustered onto approximately 8,200 acres of land. While a small fraction of the township was formally developed by the city's Development Authority division, the majority consists of "katchi abadis", or illegal, unplanned, and informal divisions of state territory into settlements with generally "substandard infrastructure" (Hasan,

2002) much like that of Monwabisi Park, particularly in regard to sewage systems. The Katchi Abadi Improvement and Regularization Programme (KAIRP), a local government aid initiative, was created to provide infrastructure and land leases to katchi abadi residents. However, though the programme displays sporadic success, major roadblocks have generally slowed any significant progress. Photographs taken throughout the progression of the Orangi Pilot Project are shown in Figure 4 above.

The Orangi Pilot Project was thus established in 1980 in response to these conditions, with the OPP-Research and Training Institute's Sanitation Programme as one of its primary focuses. They designed an "internal-external sanitation concept" that outlines the four levels of the community's sanitation system according to where their financial, managerial, construction and maintenance responsibilities lie within the community or among outside institutions. Thus far, the Project's efforts have produced latrines and sewage systems for 6,082 out of 7,256 lanes, as well as 409 collection sewers, from a community investment of Rs 80.664 million (US $1.5 million) – an expenditure seven times less than that estimated for government-led efforts. Furthermore, analysis of the successes and failures in Orangi and similar situations has led to improved emulations of the project across the globe.

To date, cumulative review of the Project and its global offshoots has produced a few core conclusions for consideration in our own planning for Monwabisi Park:

- "Communities are already trying to solve their problems and if they are supported by technical advice and managerial guidance, their solutions will improve… Development does not take place with funds. It takes place through the development of skills, self-reliance and dignity." (Hasan, 2002). Therefore NGOs, support agencies, and trained professionals are primarily educators, and must have a deep understanding of the community and knowledge of the context, particularly though mapping and documentation of physical conditions. In addition, plans should provide for feasibility (especially financial) first and the ideal later, while maintaining transparency within the community.

  In light of these lessons, we should make full use of last year's detailed surveying on water and sanitation conditions within the Park, as well as collaborate with this year's Mapping and Communications teams to be as completely educated on the Park and its residents' efforts and expectations as possible. We should then design our project so that our implementations may be ably maintained by the community after our departure. This includes a practical approach with heavy community involvement and education throughout.

- Many local governments are ready and willing to change, however they and other outside agencies must learn to participate within the community's structure and not the other way around. Therefore, in collaborating with the government and professionals, we must keep an open mind to their equally difficult position on Monwabisi Park affairs while still encouraging a willingness to adopt new relief strategies.

2.6.2 Infrastructure after Rapid Urbanization: Phnom Penh, Cambodia (Chen & Solon, 2004)

Figure 5: Aerial Photograph of Phnom Penh. (Chen, 2004).

Cambodia, a coastal country in Southeastern Asia, is currently suffering the effects of mass urban immigration after nearly a decade of national civil unrest in the 1970s. Due to limited space and resources, hastily constructed informal settlements with little to no water or sanitation infrastructure have become a predominant temporary-turned-permanent home for the migrants. Further complicating this precarious situation is the capital's location at the convergence of four rivers amid the larger region's affinity for damaging weather patterns, as well as its archaic water and sanitation conventions.

In the face of such obvious need, most of the current infrastructural improvement efforts are merely "band-aids" due to their approaches to the situation. What is shown to be effective for areas like Cambodia is quite the opposite of the norm: infrastructural planning with an emphasis on locality and simplicity – supported by what this study deems "intermediate technology". The study specifically cited the treadle water pump introduced to the rural Prey

Veng Province of Cambodia as a positive example of this concept, as well as the more pervasive Ros Reay Project in Cambodia's Capital, Phnom Penh (pictured in Figure 5 above), which was modeled from the aforementioned Orangi Pilot Project of Pakistan.

The Cambodian study highlights a few main concluding considerations for our own work from the perspective of a nation whose history and current condition are fairly analogous to that of South Africa:

- All of the provided examples included land tenure – a lack of permanency may prevent some communities from investing in infrastructure.
- Partnership between community and state is essential before improvement efforts can begin. Friction between them could lead to the state uprooting developing projects or the community misusing or casting off government provisions. Therefore, one desirable consequence of our work would be the establishment of a better working relationship between the Monwabisi Park community and their local government.
- Technologies should be introduced as a "building process" – start simple and be patient. In that spirit, the sanitation systems we consider must be simple enough to be easily understood, maintained, and repaired by the community, possibly with the intervention of nearby professionals. Further advances in system complexity can be made upon the success of these early implementations.
- Multifaceted approaches to the situation with careful consideration of the culture and existing framework have a better chance for success. Thus the emphasis on "integration" and teamwork between the WPI Projects should be fully exploited to address Monwabisi Park's sanitation situation from all angles, as should partnerships with the government, the Shaster Foundation, the University of Cape Town, sanitation system vendors, and especially the community itself. The results of this collaboration should first and foremost take into account the lifestyles and current practices of the project's ultimate patrons – the Park residents.

2.6.3 Wastewater Treatment through Constructed Wetlands: Florence, Italy (Masi &Martinuzzi, 2007)

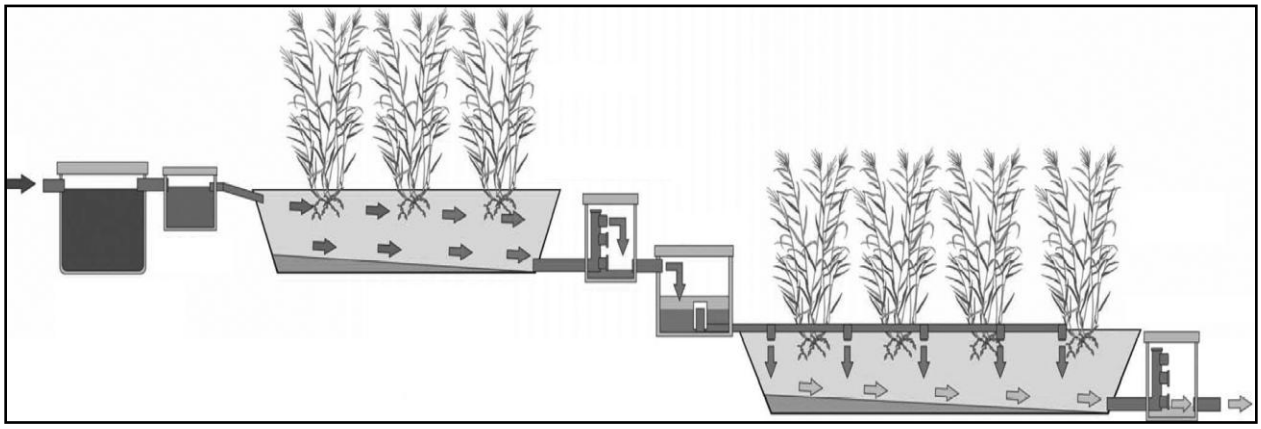


Figure 6: Schematic representation of the hybrid constructed wetland at the Italian hotel (Masi & Martinuzzi, 2007).

"CWs", or "constructed wetlands", upscale the natural principles of soil substrate filtration for the treatment of black water, grey water, rainwater, landfill leachate, and sludge contaminated by point-source pollution, as well as the treatment of water that has been diffusely polluted by various run-off sources. There are two overarching divisions of the CW concept: surface-flow (FWS) or subsurface-flow/ "reed bed" (RBTS) treatment systems. The "optimized" hybrid constructed wetland discussed in this study on a Resort Hotel in Florence, Italy, combines both Horizontal Flow (HF) and Vertical Flow (VF) subsurface wetlands in a design that minimizes both operational issues and dimensional requirements. Successful CW applications in France, Syria, and Morocco were specifically cited in by this study, however many other regions were reported to have followed suit due to the systems' low maintenance requirements and prospective potential to recycle water resources. A schematic representation of the hybrid system used at the Italian hotel is pictured in Figure 6 above.

After extensive sampling and analysis, the final effluent of this hybrid system has exhibited levels of performance "at the highest level for CW technology" (Masi & Martinuzzi, 2007). Purification levels were substantial enough to earn the hotel's recently acquired permission to redirect the hybrid effluent into irrigation for its gardens, with the only additional recommendation being to install a UV lamp in the "reuse tank" for ensured *E. coli* control.

The Florence hybrid system study presents a few key aspects of wastewater treatment systems that promise potential in our own project:

- The effectiveness of this reasonably straight-forward system in wastewater filtration is encouraging both as a direct option for Monwabisi Park and in the affirmation that simplistic systems can still produce satisfactory results.
- The hybrid system "could be adaptable to hot climate countries" (Masi & Martinuzzi, 2007), particularly due to its control of evapotraspiration through minimized surface area. North African applications of hybrid systems have already been explored according to the paper, and appear to be attractive wastewater treatment options for the area. The intra-continental conversion of the system to South Africa, then, would be expected to entail fewer adaptations and complications than directly imitating the Italian example.
- The study provides methodical sampling and analysis procedures for determining the effectiveness of wastewater treatment systems that could be applied to the system options outlined within our own project.
- The approximately 15mg/L average remaining nitrogen content annually of the final effluent "provides a useful nitrate concentration in the outlet for reuse in irrigation" (Masi & Martinuzzi, 2007) that is within the WHO and Italian regulations. Grey water reuse in agriculture is one avenue of resource conservation our project aims to explore, and the sanctioned example of this study provides a prime launching point for our understanding of how this capability is applied and approved by the necessary institutions.

Chapter 3: Methodology

The ultimate goal of this project is to design a sanitation and water use station for the Community Centre currently being reconstructed in the Redevelopment Seed of Monwabisi Park. We intend the system to be sustainable and well integrated into the community. Our design will take into consideration the cost, size, availability, and complexity of each system in order to best meet the needs of the community while providing a proper sanitation facility. The structure will fit within the physical constraints of the area while supporting all necessary facilities. We will also research grey water recycling options with the intent of including hand-washing and laundry stations in our final facility design.

3.1 Exploring Existing Water and Sanitation Options

A good first step upon arrival in Cape Town will be to familiarize ourselves with the current water and sanitation conditions. Granfone *et al* (2008) has provided much of the preliminary research on conditions of the park. Our goal, however, is more specifically to learn about what water options exists in the new Community Centre and what else is happening in Cape Town

with regard to water and sanitation. We will do this by communicating with community members and city officials as well as conducting first-hand observation. This will be an important step in determining what systems we can implement, what has been successful in the past, and what resources we already have available.

3.2 Defining the Scope of this Project

After we have explored the current conditions, we must define the scope of this project. This will allow us to understand who will be served through the implementation of a water and sanitation centre as well as what services we will be able to provide. This information will become extremely valuable to our understanding of the needs of our target population and hopefully allow for their involvement in the planning process. Our approach to defining the scope of this project is primarily rooted in collaboration with community leaders. They will help us identify the specific individuals within the community that will be directly affected by the new centre so we may seek their input as to which services to include. We presently believe that the services needed are toilets, improved taps, sinks, and a laundry station. We will determine a level of priority for each of these services, as well as determine a feasible strategy for their integration.

3.3 Developing a Water Centre Model

In order to build a water centre, we must first create a plan that details what design we will use and what the facility will include. This will allow us to have constructive input on the designs of the water centre and make suggestions that reflect the views of city officials as well as residents of Monwabisi Park. This will involve piecing together work from city planners, architects, and prior researchers into a developed “blueprint”. We will also need to look at our constraints, such as what space we have available, soil conditions, etc. The design of the physical structure will need to include areas for all the necessary facilities while meeting the requirements of the city and community.

3.4 Defining the Upgrading of Taps and Provision of Sinks

Closely related to the planning for the water centre is the upgrading of the taps and provision of sinks. We must define what the sinks and tap stations will look like, who will make them, and how they are going to fit into the water centre as a whole. These designs will draw upon the ideas of last year’s project teams as well as input from city planners and residents of the community.

3.5 Determining the Most Appropriate Sanitation Systems for the Community Centre and Housing Development

We must then proceed to take on the challenging task of selecting the sanitation systems that best fit the Community Centre and housing development locations. There are many possible solutions to the sanitation problem and finding one that can be adapted, both socially and physically, to the location is a daunting decision that must be made in order to construct a toilet facility in the park. We will do this by weighing certain criteria and assessing the community's reaction to our prioritized possibilities. These key system criteria include spatial requirements, financial investment, maintenance expectations, and health risk control, which will be evaluated based on system descriptions and vendor responses to our "Request for Proposal" , or RFP (Appendix V).

3.6 Creating a Plan for Health Education

In order for improvements to health and sanitation to be observed, the community must be educated on how to maintain sanitary conditions as well as how to properly use new equipment. We must identify the key points that we would like to pass on to the community and create a plan that will allow us to effectively communicate these points. This will involve close collaboration with the co-researchers. We will also cooperate with the Communications Team in order to make this information available to the community. Our plan is to provide information through the health clinic, Community Centre, and Indlovini TV in the form of pamphlets, posters, and television segments. The issues we believe need to be targeted most are hand washing practices and the proper use of the new facility.

3.7 The Role of a Caretaker in the Water Centre

In order to maximize the effectiveness of the water centre, a caretaker role should be identified and instituted. It is vital to the survival of the facility for a specific person to be in charge of its cleaning and maintenance, but there should be an incentive or stipend attached to this position. We will need to seek the advice of the co-researchers in order to establish the most appropriate method of payment and to develop the criteria for determining who will hold this position. The caretaker will also need to be thoroughly educated on the proper upkeep and routine repair of the systems. This will involve collaboration with the Building and Economics Teams.

3.8 Implementing a Sanitation System in the Community Centre and Redevelopment Seed

One of our goals is to leave behind tangible evidence of our work for the community. We will do this by building, or beginning to build, a sanitation system for the Community Centre and the neighboring housing development. We have neither the skills nor the time required to build and install this system so we must define who will manage the construction, who will provide the physical labor, and how the community will be involved. We must also define other details such as pipes, pumps, and toilets. These details will be documented during our time in Cape Town and left with the co-researchers in order to provide the community with a detailed plan for completing the water centre.

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Appendices

Appendix I: Preliminary Annotated Bibliography

Background & Current Conditions

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This is a case study of Khayelitsha that contains a lot of useful information about the area. It also describes some proposals for redevelopment. We could use this source to reference any details about the park's current conditions.
Submitted by Joshua Matte

[2] Carbonneau, M., Elbag, M., & Krasinskas, J. (2009). *Cape Town Water and Sanitation Design* (MQP No. JYP-0804).

This is an excellent source of information on water and sanitation in Monwabisi Park. They explored the current conditions of the water facilities in the park and made recommendations for Water and Sanitation Facilities. They explored details such as Water Taps, Public Sinks, a Public Laundry Station, Fire Hydrants, Waterless Toilets, Site Layout, and a Water Services Specialist. They also researched several commercially available toilets that would be feasible for use in the park.
Submitted by Joshua Matte

[3] City of Cape Town. (2001). Retrieved December 3, 2008, from: http://www.capetown.gov.za/en/Water/WaterservicesDevPlan/Documents/chapter3_Custom_Profile.pdf.

This report details the water laws in Cape Town. It also describes the current water usage and future service level strategy for supplying and sanitizing water.
Submitted by Joshua Matte

[4] *City Visiting Informal Settlements at Khayelitsha*. (2008). Retrieved November 19, 2008, from Khayelitsha Struggles: http://www.khayelitshastruggles.com/2008/10/city-visiting-informal-settlements-at.html.

Describes several of the current problems with water and sanitation (as well as others) in Khayelitsha. Also includes good pictures of destroyed toilets.
Submitted by Joshua Matte

[5] Mara, D. D., & Feachem, R. G. A. (1999). Water- and excreta-related diseases: Unitary environmental classification. *Journal of Environmental Engineering, 125*(4), 334-339.

Journal article talks about water and excreta-related diseases. Journal not available online but is in Library. This may be a useful source to understanding waterborne diseases.
Submitted by Joshua Matte

[6] Steding, A. *Water Resource Management* in AccessScience@McGraw-Hill. http://www.accessscience.com, DOI 10.1036/1097-8542.YB990920.

This article focused more about the scientific facts on how much water needs to be consumed daily on a per person basis as well as taking environmental, agricultural, and unpredictable needs into consideration. They conclude by touching briefly on methods of efficiently saving and managing water, which we would need to investigate more thoroughly. It might help us if we ever need to do some math and come up with some practical figures on how much water would be ideal to use daily. We can formulate these numbers and apply them to the Cape Town population.
Submitted by Blake Kelly

Sanitation Facilities

[1] Hardoy, A. & Schusterman, R. (2000). New models for the privatization of water and sanitation for the urban poor. [Electronic Version]. *Environment and Urbanization*, 12, 63-76.

Useful- This article addresses the privatization of sanitation resources in informal settlements in Buenos Aires. It is understood that this is a different region with different cultural issues, but the success of different models for sanitation is useful to our research. The author has experience establishing healthier sanitation alternatives in areas of very little income and infrastructure.
Submitted by Katherine McKenna

Water Provision

[1] Lundqvist, J., Appasamy, P., Nelliyat, P. (2003). *Dimensions and Approaches for Third World City Water Security*. Unavailable. The Royal Society.

The authors talk about the increase of population in cities and how this might affect water resources. There is also a discussion about the "security" of water and how it can be accessed and purified in these cities. The conclusion was comprised of a couple of solutions on how to purify water which might be a little bit too advanced for the amount of time we have, but we could possibly explore their ideas on a smaller scale. Also, we can look at the expected population increases in this article and what problems they bring so we can also plan for the future.
Submitted by Blake Kelly

Waste Water Production & Control

[1] Armitage, N.P., Winter, K., Spiegel, A. & Kruger, E. (2009). Community-focused greywater management in two informal settlements in South Africa. [Electronic Version]. *Water Sci Technol (PubMed), 59*(12), 2341-2350.

Very Useful- This paper dives into the immediate need for proper removal or management of greywater. Work was carried out in three different settlements with different conditions. This research could be extremely helpful in ruling out possible solutions that have already been proven not to work. It could also guide our thinking towards possible solutions we may not have thought of otherwise.
Submitted by Katherine McKenna

[2] Carden, K., Armitage, N., Winter, K., Sichone, O., Rivett, U., & Kahonde, J. (2007). The Use and Disposal of Greywater in the Non-Sewered Areas of South Africa: Part 1 - Quantifying the Greywater Generated and Assessing its Quality. [Electronic Version]. *Water SA, 33*(4), 425-432.

Carden, K., Armitage, N., Sichone, O., & Winter, K. (2007). The Use and Disposal of Greywater in the Non-Sewered Areas of South Africa: Part 2 - Greywater Management Options. [Electronic Version]. *Water SA, 33*(4), 433.

VERY useful. One possible main focus for our project has been greywater, both in its health hazards to the community and its potential recycling in the spirit of sustainability. First off, Part 1 vindicates our focus by commenting on the impending failure of further water provision improvements without addressing the waste water produced. In addition, it not only frames the problem of greywater within South Africa in both broad context and specific quantifications, but offers the conclusions that, while greywater conditions vary greatly across the region, some form of "controlled conditions" of disposal/collection are necessary in order to produce usable greywater. Part 2 of the study then continues to examine and compare methodologies already in use for the handling of greywater in multiple different circumstances of South African sanitation – including dry sanitation systems and communal facilities, both of which can be found in Monwabisi Park. The study ultimately found that current state efforts are not sustainable, and the quality of the greywater – which determines its potential reuse – seems to depend largely on the population density of the area it is produced in.
Submitted by Melanie Donahue

[3] Stander, G.J. (1966). *Water Pollution Research: A Key to Wastewater Management.* Unavailable: Water Environment Federation Stable.

This author offers information about anaerobic digestion, waste-water purification processes, utilizing wastes, and water purification. While there is a lack of conclusion to this source since there was no implementation of any of these, the ideas that are presented seem to be of good value and would have to be further investigated for advancement as this source was published over 40 years ago. Since there are primitive designs of waste water management in Monwabisi Park as it is, it might be good for us to base some of our ideas for solutions off of more underdeveloped, primitive examples.
Submitted by Blake Kelly

[4] Vlotman, W. F., Wong, T., & Schultz, B. (2007). Integration of drainage, water quality and flood management in rural, urban and lowland areas. [Electronic Version]. *Irrigation and Drainage, 56*(S1), S161-S177.

USEFUL, especially to integrated urban planning. The focus of this paper is less about the greywater problem itself than the inclusion of specifications for greywater drainage in urban planning – an idea called "water sensitive urban design". Therefore, perhaps the most valuable quality of this paper comes from its view of greywater treatment as part of the overall integrated redevelopment plan rather than a stand-alone problem – which is key to keeping the ultimate "eco-village" goal in sight.
Submitted by Melanie Donahue

[5] Winter, K., Armitage, N., Carden, K., & Spiegel, A. (2008). Why Things Fail: Greywater Management in Informal Settlements, South Africa. [Electronic Version]. Retrieved 4 Sept. 2009, from: http://www.waterinformation.co.za/literature/files/2008_081.pdf .

Again, VERY useful. This paper outlines the greywater problem in South African informal settlements, from the current statistics and system shortcomings to the evaluation of where the breakdown occurs to the introduction of possible alternatives. This particular view of the solution pays further attention to community collaboration and the willingness to assess progress throughout the implementation process – a method that the paper names the "Adaptive Decision-Making Process" or ADMP. Among the important conclusions reached were the acknowledgement of insufficient resident-municipality communication and a serious lack of understanding in the community about the dangers of greywater. However, particularly noteworthy to our efforts, the authors expressed confidence in the community's willingness to learn about those dangers.

As a side note, the paper was written at least in part by one of our project's contacts in Cape Town, Kevin Winter of the UCT's ENGEO Department, and being familiar with some of his work upon arrival can do nothing but expedite our dealings with one another.
Submitted by Melanie Donahue

Public Education

[1] Smith, M.A., Garbharran, H., Edwards, M.J., & O'Hara-Murdock, P. (2004). Health Promotion and Disease Prevention through Sanitation Education in South African Zulu and Xhosa Women. [Electronic Version]. *J Transcult Nurs, 15*, 62 - 68.

This article touches on the extreme importance of community education - for women in particular - to any potential sustained success in improving informal settlement sanitation – a factor that must be kept in mind during the planning of our project. The article also comments on the need for this education to be sensitive to the culture and history of the people, and concluded that when such sensitivities were observed while empowering local women to perpetuate a connection between sanitation and health within their own communities, marked improvements in both conditions and resident involvement were noted.
Submitted by Melanie Donahue

Case Studies

[1] Friedrich, E., Pillay, S. Carbon footprint analysis for increasing water supply and sanitation in South Africa: a case study. [Electronic Version]. *Journal of Cleaner Production (Compendex)*, 17(1), 1-12.

Useful- This is a case study of an area in Durban, South Africa researching the environmental effects of providing water and sanitation resources to in informal settlement. This may provide a baseline for us to use when evaluating the effects sanitation methods have on the environment. *Submitted by Katherine McKenna*

Appendix II: South African Legislation

Water Provisions within the Bill of Rights (RSA, 1996)

Section 27. Health care, food, water and social security

1. Everyone has the right to have access to
    a. health care services, including reproductive health care;
    b. sufficient food and water; and
    c. social security, including, if they are unable to support themselves and their dependants, appropriate social assistance.
2. The state must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of each of these rights.
3. No one may be refused emergency medical treatment.

National Environmental Management Act (NEMA) of 1998: Preamble (City of Cape Town: ERM, 2009)

ACT

To provide for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state; and to provide for matters connected therewith.

PREAMBLE

WHEREAS many inhabitants of South Africa live in an environment that is harmful to their health and well-being;

everyone has the right to an environment that is not harmful to his or her health or well-being;

the State must respect, protect, promote and fulfil the social, economic and environmental rights of everyone and strive to meet the basic needs of previously disadvantaged communities;

inequality in the distribution of wealth and resources, and the resultant poverty, are among the important causes as well as the results of environmentally harmful practices;

sustainable development requires the integration of social, economic and environmental factors in the planning, implementation and evaluation of decisions to ensure that

development serves present and future generations;
everyone has the right to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that—
prevent pollution and ecological degradation;
promote conservation; and
secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development;
the environment is a functional area of concurrent national and provincial legislative competence, and all spheres of government and all organs of state must co-operate with, consult and support one another;
AND WHEREAS it is desirable—
that the law develops a framework for integrating good environmental management into all development activities;
that the law should promote certainty with regard to decision-making by organs of state on matters affecting the environment;
that the law should establish principles guiding the exercise of functions affecting the environment;
that the law should ensure that organs of state maintain the principles guiding the exercise of functions affecting the environment;
that the law should establish procedures and institutions to facilitate and promote co-operative government and intergovernmental relations;
that the law should establish procedures and institutions to facilitate and promote public participation in environmental governance;
that the law should be enforced by the State and that the law should facilitate the enforcement of environmental laws by civil society;

Water Services Act (WSA) of 1997: Preamble (DWEA, 2009)

ACT

To provide for the rights of access to basic water supply and basic sanitation; to provide for the setting of national standards and of norms and standards for tariffs; to provide for water services development plans; to provide a regulatory framework for water services institutions and water services intermediaries; to provide for the establishment and disestablishment of water boards and water services committees and their powers and duties; to provide for the monitoring of water services and intervention by the Minister or by the relevant Province; to provide for financial assistance to water services institutions; to provide for certain general powers of the Minister; to provide for the gathering of information in a national information system and the distribution of that information; to repeal certain laws; and to provide for matters connected therewith.

PREAMBLE

RECOGNIZING the rights of access to basic water supply and basic sanitation necessary to ensure sufficient water and an environment not harmful to health or well-being;
ACKNOWLEDGING that there is a duty on all spheres of Government to ensure that water supply services and sanitation services are provided in a manner which is efficient, equitable and sustainable;
ACKNOWLEDGING that all spheres of Government must strive to provide water supply services and sanitation services sufficient for subsistence and sustainable

economic activity;
RECOGNIZING that in striving to provide water supply services and sanitation services, all spheres of Government must observe and adhere to the principles of co-operative government;
ACKNOWLEDGING that although municipalities have authority to administer water supply services and sanitation services, all spheres of Government have a duty, within the limits of physical and financial feasibility, to work towards this object;
RECOGNIZING that the provision of water supply services and sanitation services, although an activity distinct from the overall management of water resources, must be undertaken in a manner consistent with the broader goals of water resource management;
RECOGNIZING that water supply services and sanitation services are often provided in monopolistic or near monopolistic circumstances and that the interests of consumers and the broader goals of public policy must be promoted; and
CONFIRMING the National Government's role as custodian of the nation's water resources;

National Water Act (NWA) of 1998: Preamble (City of Cape Town: ERM, 2009)

ACT

10 provide for fundamental reform of the law relating to water resources; to repeal certain laws; and to provide for matters connected therewith.

PREAMBLE
Recognizing that water is a scarce and unevenly distributed national resource which occurs in many different forms which are all part of a unitary, inter-dependent cycle;
Recognizing that while water is a natural resource that belongs to all people, the discriminatory laws and practices of the past have prevented equal access to water, and use of water resources;
Acknowledging the National Government's overall responsibility for and authority over the nation's water resources and their use, including the equitable allocation of water for beneficial use, the redistribution of water, and international water matters;
Recognizing that the ultimate aim of water resource management is to achieve the sustainable use of water for the benefit of all users;
Recognizing that the protection of the quality of water resources is necessary to ensure sustainability of the nation's water resources in the interests of all water users; and
Recognizing the need for the integrated management of all aspects of water resources and, where appropriate, the delegation of management functions to a regional or catchment level so as to enable everyone to participate;

Municipal Systems Act of 2000: Preamble (City of Cape Town: ERM, 2009)

ACT

To provide for the core principles, mechanisms and processes that are necessary to enable municipalities to move progressively towards the social and economic upliftment of local communities, and ensure universal access to essential services that are affordable to all; to define the legal nature of a municipality as including the local community within the municipal area, working in partnership with the

municipality's political and administrative structures; to provide for the manner in which municipal powers and functions are exercised and performed; to provide for community participation; to establish a simple and enabling framework for the core processes of planning, performance management, resource mobilisation and organisational change which underpin the notion of developmental local government; to provide a framework for local public administration and human resource development; to empower the poor and ensure that municipalities put in place service tariffs and credit control policies that take their needs into account by providing a framework for the provision of services, service delivery agreements and municipal service districts; to provide for credit control and debt collection; to establish a framework for support,, monitoring and standard setting by other spheres of government in order to progressively build local government into an efficient, frontline development agency capable of integrating the activities of all spheres of government for the overall social and economic upliftment of communities in harmony with their local natural environment; to provide for legal matters pertaining to local government; and to provide for matters incidental thereto.

PREAMBLE

Whereas the system of local government under apartheid failed dismally to meet the basic needs of the majority of South Africans;

Whereas the Constitution of our non-racial democracy enjoins local government not just to seek to provide services to all our people but to be fundamentally developmental in orientation;

Whereas there is a need to set out the core principles, mechanisms and processes that give meaning to developmental local government and to empower municipalities to move progressively towards the social and economic upliftment of communities and the provision of basic services to all our people, and specifically the poor and the disadvantaged;

Whereas a fundamental aspect of the new local government system is the active engagement of communities in the affairs of municipalities of which they are an integral part, and in particular in planning, service delivery and performance management;

Whereas the new system of local government requires an efficient, effective and transparent local public administration that conforms to constitutional principles;

Whereas there is a need to ensure financially and economically viable municipalities;

Whereas there is a need to create a more harmonious relationship between municipal councils, municipal administrations and the local communities through the acknowledgement of reciprocal rights and duties;

Whereas there is a need to develop a strong system of local government capable of exercising the functions and powers assigned to it; and

Whereas this Act is an integral part of a suite of legislation that gives effect to the new system of local government;

Appendix III: Case Studies

Orangi Pilot Project:

The Orangi Township is located in the District West of Karachi, one of Pakistan's major urban centers. The township itself consists of a diverse population numbering greater than one million, all clustered onto approximately 8,200 acres of land – a narrow focal point within the larger

frame of Pakistan's struggle to provide for the growing informal urban sprawl that first exploded in the 1970s. While a small fraction of the township was formally developed by the city's Development Authority division, the majority consists of "katchi abadis", or illegal, unplanned, and informal divisions of state territory into settlements with generally "substandard infrastructure" (Hasan, 2002) much like that of Monwabisi Park, particularly in regard to sewage systems. The Katchi Abadi Improvement and Regularization Programme (KAIRP), a local government aid initiative, was created to provide infrastructure and land leases to katchi abadi residents. However, though the programme displays sporadic success, major roadblocks in the forms of insufficient community involvement, excessive complexity that promotes corruption, and failure to acknowledge existing infrastructure have generally slowed any significant progress.

The Orangi Pilot Project was thus established in 1980 by the Pakistani social scientist Akhtar Hameed Khan in response to these conditions. The project's broad objectives were to understand the area's problems and their causes, develop solutions based on community management, finance, and building capabilities, and design models that consider the sociology, economics, and culture of low-income communities. The Project identified four major areas of concern: sanitation and housing quality, employment, health, and education. It then subdivided itself accordingly into a Charitable Trust, a Health and Social Development Association, a Society that channels charitable funding, and the Research and Training Institute (OPP-RTI). As "sanitation was the major problem identified by Orangi residents" (Hasan, 2002), the OPP-RTI's Sanitation Programme became one of the project's primary focuses.

The OPP-RTI Sanitation Programme outlined four "barriers" between outside aid, such as themselves, and the community: the Psychological Barrier, the Social Barrier, the Economic Barrier, and the Technical Barrier. They then developed a methodology that treated each respectively by

1. Illuminating that infrastructural development is not solely for government agencies.
2. Organizing a cohesive system of 20-40 house "lanes", each led by a local "lane manager".
3. Promoting community-based funding by whittling the necessary community contribution to an affordable Rs 900 (US $16.50) per household.
4. Ensuring the availability of appropriate designs, estimates, tools, and training.

In light of these considerations, they designed an "internal-external sanitation concept" that outlines the four levels of the community's sanitation system according to where their financial, managerial, construction and maintenance responsibilities lie. In-house sanitary latrines, underground lane sewers, and neighborhood collector sewers are all "internal", or community led, while the trunk sewer and treatment plant at the farthest end of the system requires the "external" aid of the government or NGOs. The realization of this design followed a progression which began with extensive research into the sociology, economics, and evolution of Orangi and progressed through pertinent technical study, documentation of implementation problems, causes, and resolutions, and further investigation into alternative sewage systems in the larger context of the region. Thus far, the Project's efforts have produced latrines and sewage systems for 6,082 out of 7,256 lanes, as well as 409 collection sewers, from a community investment of Rs 80.664 million (US $1.5 million) – an expenditure seven times less than that estimated for government-led efforts.

Since its commencement, the OPP model has been adopted in multiple other settings, including 46 other Karachi settlements, seven Pakistani towns and a handful of rural areas, as well as regions in Nepal, Central Asia, Sri Lanka, and South Africa, with varying success. Where the model proved fruitless, several key factors were implicated in its breakdown, including: abandonment by imported technical professionals as other opportunities arise, failure to manage large monetary donations and expand accordingly, subsidization, failure to seek advice from OPP or other parent organizations, failure to share information with the community, and lack of patience. Likewise, evaluation of productive implementations produced "keys to success" such as: community-led technical teams, community leaders who promoted effective communication between residents and government, the availability of accurate regional mapping and adequate community funding, and the maintenance of patience, transparency, and consistent communication between all parties involved.

Cambodia Infrastructure:

Located in Southeast Asia, Cambodia is a country under siege by both Mother Nature and the modern world. Framed within the broader context of unmanageable urbanization in developing countries worldwide, the Cambodian population is immigrating to urban centers en masse in search of opportunity after nearly a decade of national civil unrest in the 1970s. The combination of residual social and political instability, an outdated national infrastructural framework, and the unpreparedness of institutions to handle the sheer volume of migrants leaves the bulk of the population to fend for themselves. This is often accomplished through the hasty construction of "temporary" shelters on any available ground, leading to the exponential increase in "unchecked and unplanned informal settlements" (Chen, 2004). In the nation's capital, Phnom Penh, 374,826 Cambodians are crowded into 569 of these informal settlements, where "41,957 of these households are subject to flooding, 46,688 households have water supply problems, and 24,264 households are without a toilet" (Chen, 2004). Further complicating the situation is the capital's location at the convergence of four rivers amid the larger region's affinity for damaging weather patterns.

In terms of the importance of water and sanitation to the overall national condition, this paper says it all when it comments that "in developing countries, water infrastructure problems perpetuate extreme poverty and create harsh living environments. A safe, adequate and accessible water supply, combined with the safe disposal of human waste and drainage, is critical to the sustainability of developing cities and the health of their inhabitants" (Chen, 2004). Within the informal settlements of contemporary Cambodia, progress toward achieving these commodities is complicated by a number of factors. The communities generally obtain water through either expensive private truck import of questionable quality or arduous open-air transport from overused public pumps by the women and children of the population – which, sadly enough, are both preferable options to the third course of simply using standing fresh water. Furthermore, the region's rainy season heightens its already problematic groundwater levels, which erodes the unpaved thruways of informal settlements to the point of inaccessibility for emergency vehicles and even, on occasion, the residents themselves. In particular, the very poor are often located in flood plains with no sewage or drainage systems, forcing them to relocate whenever it rains and often causing black water to mix into the grey water that is

regularly used for washing and cleaning. Industrial waste can be found in the settlements' rivers and lakes, as well, due to their proximity to urban centers. Meanwhile, the extreme housing density forces children to play in wastewater locations and allows for the rampant spread of commutable diseases that such standing water promotes.

In the face of such obvious need, most of the current infrastructural improvement efforts are merely "band-aids" due to their approaches to the situation. Outside organizations, which wield the most funding and technology, often require quick repayment from already impoverished areas, and follow a "Western-based" philosophy of redevelopment that rarely fits their third-world targets. This implies industrialized approaches driven by monetary rather than sustainable concerns, where technologies are often employed that are too advanced to be understood or maintained locally with little consideration for the community's current conditions or involvement in their own restructuring.

What is shown to be effective for areas like Cambodia is quite the opposite of this norm: infrastructural planning with an emphasis on locality and simplicity – supported by what this paper deems "intermediate technology". The treadle water pump introduced to the rural Prey Veng Province of Cambodia serves as an example of this industrial "stepping stone" approach. The pump, developed in Bangladesh, lifts groundwater up to seven meters through a simplistic suction system. Jointly fostered by the NGO Christian Outreach and World Concern, the scheme's success was largely ascribed to its local funding and operational similarities to the Cambodian method for pounding rice, with which the water-providing women and children were already familiar. What's more, due to the benefits reaped from its implementation, further advances were able to be considered.

On a larger scale, the Orangi Pilot Project of Karachi, Pakistan was cited as a success story and the basis for Phnom Penh's own Ros Reay Project. This informal settlement within Cambodia's capital was established in 1979 on illegitimate energy and water sources with a total disregard for sewage planning. Approximately a decade later, the settlement's residents and the Urban Poor Development Fund (UPDF) NGO followed the Orangi example in using local materials and labor, community-led mapping and drainage planning, and a community contractor to provide elementary sewage provisions to a 72-house "seed". From there, the redevelopment spread throughout the surrounding community and beyond through the experience gained by volunteers from other settlements.

Mediterranean Hybrid System:

"Constructed wetlands", or "CWs", have become a new vogue in wastewater treatment techniques of late. Archetypically implemented across the European continent and replicated around the globe, these systems that upscale the natural principles of soil substrate filtration have been manipulated to suit a variety of needs. Among them are the treatment of black water, grey water, rainwater, landfill leachate, and sludge contaminated by point-source pollution, as well as the treatment of water that has been diffusely polluted by various run-off sources. This particular paper cited largely successful CW applications in France, Syria, and Morocco specifically; however many other regions were reported to have followed suit due to the systems' low maintenance requirements and prospective potential to recycle water resources.

There are two overarching divisions of the CW concept: surface-flow (FWS) or subsurface-flow/ "reed bed" (RBTS) treatment systems. In the surface-flow variety, most often chosen for tertiary treatment, lesser investment cost, or heightened wildlife habitat value, the wastewater is directed through a "shallow basin with emergent and submerged macrophytes" (Masi & Martinuzzi, 2007) in order to produce an acceptably decontaminated effluent. Subsurface or "reed bed" wetlands are further divided into Horizontal Flow (HF) and Vertical Flow (VF) varieties based on their direction of water flow. These systems consist of gravel-type substrates permeated by the roots of reeds or other appropriate plant life, making them the more effective option for filtering solids from wastewater.

The "optimized" constructed wetland design discussed in this Florence, Italy study is a combination of HF and VF subsurface wetlands, known as a "hybrid system". As illustrated in the schematic above, mixed grey and black water from the 140 p.e. load of this "medium scale tourist facility" (Masi & Martinuzzi, 2007) is fed into the initial HF bed by a loading-control pump to account for fluctuating wastewater production, and from there proceeds via two independent siphons to a secondary VF bed lined with HDPE geo-membrane. This was accomplished within a design that minimizes both operational issues like clogging and evapotranspirational water loss within the relatively low dimensional requirements of 0.9 m maximum depth and respective 160 m^2 and 180 m^2 surface areas for the HF and VF flow beds.

After extensive sampling and analysis, the final effluent of this hybrid system has exhibited mean overall removal rates of 84% TSS, 94% COD and BOD, 86% NH_4^+, 60% total nitrogen, 94% total phosphorous, and a 99.93 – 99.99% removal rate for total coliforms, faecal coliforms, faecal streptococci, and E. coli. This substantial level of purification has recently earned the hotel permission to redirect the hybrid effluent into irrigation for its gardens, with the only additional recommendation being to install a UV lamp in the "reuse tank" for ensured E. coli control.

Appendix IV: Preliminary Evaluation of Sanitation System Comparison Criteria

Spatial Requirements

The amount of space that a system will require is important to consider due to the lack of excess space within the Redevelopment Seed. The Hybrid and Enviro-Loo systems can both be placed mainly underground with only the pedestal itself remaining above. This can then be enclosed in a small room or stall for privacy. The biggest concern in placing the Enviro-Loo system is that the manhole cover should be facing the direction from which it will receive the most sunlight daily. There must also be access to the tanks of each system to allow for proper maintenance. A biodigester would require the same space for the receptacle, but additional space for the digesting tank. These tanks range in size from those designed for a single family, to large community tanks. The amount of available space next to the community center will dictate the allowable size of the biodigester which will determine if it is a viable option or not. We will

need to carefully measure the space surrounding the Community Centre to determine how big the facility can be. We also plan to collaborate with the Building and Garden Teams to design a facility for the planned housing project.

Cost

Another important consideration for any construction project is the difference in cost between products. The overall cost includes the price to purchase each system and any additional equipment needed for installation, as well as the annual maintenance fees. This information will be compiled upon arrival in Cape Town to allow ease of communication with local vendors.

Maintenance

The maintenance needs of each system will play a large role in determining the most effective solution. Although the Redevelopment Seed has road access, not all areas of Monwabisi Park do. The location of system distributors also varies and could impact the final selection.

The Hybrid Toilet system requires minimal weekly maintenance in the form of regulating the number of users and adding an appropriate amount of BioMagic and water to each pedestal. This assures that the biological breakdown of the waste is occurring properly. It is also recommended that the pedestal and stall be cleaned twice a week to prevent the growth of unwanted bacteria (Hybrid Owner's Manual). The entire system should be checked annually for any damage to the pipes or tanks, and the leech field must be monitored to guarantee the purity of the effluent. If a holding tank is used in place of a leech field, it should be checked weekly to ensure it is pumped out regularly. The sludge removal from the primary tank must be done in accordance with local regulations approximately once every four to seven years (Carbonneau *et al*, 2009). Generally, a licensed waste removal company is hired to pump out the tank and dispose of the waste properly, but we plan on requesting this service from the City of Cape Town if this system is chosen. In addition to these technical maintenance procedures, the ventilation points must be checked regularly for gaps to prevent flies from entering the system. We need to speak with the community in order to determine if this is too much maintenance for a single caretaker.

The MineARC system requires similar maintenance to the Hybrid system in terms of having sludge removed every four to six years and properly cleaning the stall area, thus we have the same concerns regarding the caretaker. It is a bacterial system so harsh chemicals should not be

used. In addition, 1 litre of bacterial chemicals must be added to the system each week to sustain the proper bacterial breakdown within the system (MineARC).

The Enviro-Loo system requires very little maintenance due to the lack of water within the system. The drying plate must be raked clean once every six months or so to expedite the dehydration process. This compost may then be placed in a drying bag for further decomposition, and then used as fertilizer (Carbonneau *et al*, 2009). The pedestal and stall should also receive cleaning on a weekly basis to ensure they remain sanitary. Our concern with this system is that it may require more than one person to clean the drying plate, but it only needs to be done every six months.

We are still investigating the maintenance needs of the WELtec and AGAMA biodigester systems. We believe it is similar to the Hybrid in terms of having sludge removed from the treatment tank after a certain period of time. This information can be gathered from AGAMA in person once we reach Cape Town.

Health Risk Control

The main focus of this project is to devise water and sanitation system that will serve as a model for waste treatment and sanitation practices. This requires us to look closely at the health risks of each system and develop alternatives where necessary.

The concerns associated with the Hybrid sanitation system revolve around the quality of the effluent. This is waste water that has been treated and will then be discharged into the ground or recycled through the system. If the pathogens within the waste are not properly digested by the bacteria in the system, they will contaminate the leech field and produce an odor. The contamination of ground water is a particular concern due to the high level of the water table (Granfone *et al,* 2008). There have been case studies documenting the effectiveness of this system and it is shown that under close monitoring the system produces a consistently safe effluent. The second byproduct is the sludge that forms in the primary tank. This is not a major health concern as long as the system is functioning properly. This sludge is removed by a licensed authority and disposed of. We believe the biodigester systems have very similar health risks, but we plan to research this further upon arrival by meeting with an AGAMA representative.

The Enviro-Loo is an extremely health conscious sanitation system. The liquid waste that enters the system is contained in a sealed vault and evaporated. The dry waste is dehydrated and

decomposed within a separate sealed vault. When this compost is scraped from the drying plate, it is sanitary enough to be used as a fertilizer (Carbonneau *et al*, 2009).

The MineARC hybrid is a completely closed system that keeps all waste entirely separated from the surrounding environment. It recycles the purified waste water back into the system therefore preventing it from being discharged to the ground. The health concerns with this system would only be the possible effects if the system broke causing a leak of unfiltered effluent to reach the ground.

Appendix V: "Request for Proposals" (RFP) for System Vendors

Indlovu Project Sanitation System
Request for Proposals
September 22, 2009

This Request for Proposals is for a sanitation system to support a new development in the Monwabisi Park informal settlement, located within the Khayelitsha township of Cape Town, South Africa.

General considerations

- The sanitation system is to be a central feature of new developments in the Indlovu Project (http://www.shaster.org.za/), a highly visible model informal settlement upgrading program in Monwabisi Park driven by the joint efforts of the Shaster Foundation, the local community, Worcester Polytechnic Institute (WPI), the City of Cape Town, and others. As such, a successful application offers proposers the opportunity to engage in collaborative learning and communication regarding how their systems address a critical need in South Africa.
- WPI faculty and students are leading water and sanitation system design and proposal review processes (see overview and preliminary "Water" report at www.wpi-capetown.org/ for more information). Final decisions on system design and providers will result from the consensus of project partners from the Shaster Foundation, WPI, the University of Cape Town, and the Monwabisi Park community.
- Informal settlement upgrading is challenging, and we expect the selected system provider to demonstrate a strong and flexible commitment to seeing the project through to successful implementation and operation.
- Proposals at this time need not be considered final – instead, we expect proposals to facilitate an intensive period of project planning and refinement leading to final decisions and commitments in the near future.

Anticipated Time Frame

- Proposal submission: as soon as possible.
- Service provider decision: by October 15, 2009
- Construction: commence by November 15, 2009 and complete by December 15, 2009.
- System monitoring and evaluation: December 15, 2009 – December 15, 2010.

Design Parameters

- Capacity:
  - Scenario 1: 20 households (80 people) + 100 additional uses/day (i.e., visits to the toilet from Community Centre)
  - Capacity Scenarios 2 & 3: 50% less and 50% greater capacity than Scenario 1
- Black water re-circulated to toilets to create a nominally closed system. Excess treated water to be released to gardens and/or soakaway lines.
- Low-flush toilets located in homes and/or ablution block.
- Grey water and other water streams managed separately from sanitation system.
- No connection to municipal sewage disposal system.
- Black water use for irrigation: Optional, on a small, experimental basis to test for health and safety concerns and whether plant growth is greater than with grey water sources, etc.
- Non-sewage wastes:
  - Waste paper: users will be instructed to use standard toilet paper, and a supply program for families is feasible, though some use of alternative paper is expected.
  - Organics (e.g., for biogas production): system must work with little to no non-sewage organic material added, though an experimental program to add organics for performance enhancement may be proposed.
  - Non-organic wastes: an educational program will seek to limit introduction of non-organics, however proposer should indicate sensitivity of system to incidental introduction of "contaminants" (solid wastes, toxic cleaning products, etc.)
- System by-products: Production of biogas for fuel and/or sewage sludge as soil amendment, etc. is desirable, but not essential, especially if such production increases complexity of system management.
- Health and safety codes: while formal approval for the system is not likely to be sought initially, proposer should design system to meet code (e.g., through use of ozone or UV technology).
- Space for system installation: tight space constraints in the area place premium on systems that can be installed below grade, with gardens above, and with minimal footprint.
- Water table: assumed to be high in region, requiring that all below-grade components be designed to prevent degradation and leakage.
- Installation: Proposer to be responsible for installation. Shaster Foundation will provide unskilled labor for digging, etc.
- System maintenance: Designs that minimize service requirements are preferred.

Requested proposal information

- General description of system design and operations.
- Technical drawings showing all key components and the system footprint.
- System operations information or manual.
- Installation services:
  - What will the service provider contribute?
  - What is needed from Indlovu Project?
- References: Contact information (email and/or telephone) from others who are using a system comparable to that proposed, whether domestically or elsewhere in the world.
- Support Services: Describe how proposer will provide support services for at least the first year of operations.

- System warranty.
- Itemized cost and payment schedule for all proposed system components, including at minimum:
    - Mechanical systems
    - Installation
    - Service
- Any additional information the proposer wishes to provide.

Proposal submission: please email proposal and any requests for further information to:

Katherine McKenna
CT09water@wpi.edu
Water and Sanitation Team
Worcester Polytechnic Institute

Appendix VI: Vendor RFP Responses

SA Biotech: Hybrid Toilet System

TEST REPORT

SABS

Your ref: Mr S Perks

Enquiries: J Strobos

Tel.: 428-6009

No: 2538/1864/MT08

Page: 1 of 7

Date: 2008-08-04

SA Biotech
Attention: Mr S Perks
P O Box 3547
HALFWAY HOUSE
1685

HYBRID TOILET SYSTEM

1 ASSIGNMENT

1.1 The client requested the SABS to assess a survey performed on whether the above mentioned toilet system is fit for the purpose of purification of waste disposal. This survey was done on the Hybrid Toilet system in Tasmania's Narawntapu National Parks by Chock Enterprises.

1.2 Furthermore the SABS was requested by the client to perform a load test on the toilet pedestal/seat to determine the safe load bearing capacity.

2. SAMPLE DESCRIPTION

Hybrid toilet system. Refer figure 1 attached.

2 DATE OF LOAD TEST

19 June 2008

3 METHOD OF TEST

3.1 Load test

Canvases filled with lead shot with mass of 10 kg each were stacked on a plank on top of the toilet seat. Deflection measurements were taken at a load of 300 kg.

3.2 Assessment of the fit for purpose of purifying waste water on the Hybrid toilet System. Refer section 1.1.

4 EQUIPMENT INFORMATION

4.1

Type:	Scale – Mettler
Capacity:	60 kg
Calibration certificate no:	2001/8043B

5 NAME OF LABORATORY

The Building and Construction Laboratory of SABS Commercial (Pty) Ltd.

AGAMA Biogas: Prefab Biodigester

PROFORMA AGREEMENT FOR THE SUPPLY AND INSTALLATION OF THE AGAMA 6m3 PREFABRICATED BIODIGESTER – WESTERN CAPE – July 2009

SUPPLY OF MATERIALS

1. 1 X Prefab Digester (6m3)
2. 1 X Two-plate Biogas Burner (Country Cooker, CF200A)
3. 10 metres of HDPE gas line with fittings/couplings
4. 10 metres of 110 mm UG sewer line with fittings/couplings
5. Operation and maintenance documentation
6. Commissioning documentation

SCOPE OF INSTALLATION

1. Transport materials to site and offload.
2. Excavate, place the digester into the ground and backfill to digester with cement-stabilized ground. Graded selected soil from the excavation will be used.
3. Spread excess soil on site (within 30 metres of tank)
4. Install sewer line between house and tank – 10 metres maximum length
5. Install gas line – 10 metres maximum length
6. Connect gas line to gas burner

PRICE

1. Total cost for the above is to be negotiated depending on numbers ordered and whether AGAMA supervises the installation.

PRICE VARIATIONS

1. Installations in unfavourable ground conditions such as rocky ground or areas with high water tables will incur additional costs, to be determined on site
2. Where graded selected soil is not appropriate for backfilling, additional costs will be incurred for importing sand to the site
3. Sites further than 100km of Cape Town will have additional mileage charged at AA rates if AGAMA does the installation.
4. For drainage and gas line lengths greater than 10 metres each, material and labour will be charged out additionally on a per-metre basis.
5. Connection to, and design and installation of, post-digester systems are excluded from the price. These will be site specific and subject to the owner's requirements, as well as environmental parameters.

NOTES

1. The installation can be undertaken by AGAMA Biogas certified specialist subcontractors as long as they are within an appropriate distance of Cape Town.
2. Digester installation to be done according to SANS 1200
3. Gas installation to be done according to SANS 087

CONTACT

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021 - 7013364
marisa.naude@agama.co.za