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CAPE TOWN WATER AND SANITATION DESIGN

A Major Qualifying Project Proposal

submitted to the Faculty

of

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Degree of Bachelor of Science

By

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1. Water
2. Sanitation
3. Monwabisi Park

Abstract

Monwabisi Park is an informal settlement in Cape Town, South Africa. Poor water and sanitation services in the area cause diarrheal diseases and negatively impact the quality of life. A facility was designed to expand access to clean water and toilet services in Monwabisi Park and also provide community interaction through public washing stations and gardening. The facility conserves water through waterless toilets, rainwater collection and recycling. The design is easily modified and can be replicated across Monwabisi Park.

Acknowledgements

We would like to thank our advisors, Jeanine Plummer and Scott Jiusto for their continued guidance and support throughout our project. We would also like to acknowledge Marcella Granfone, Christopher Lizewski, and Dan Olecki for their hard work collecting the preliminary water and sanitation data while in Monwabisi Park, Cape Town, South Africa. Special thanks is also given to Dianne Womersley with the Shaster Foundation for her enthusiasm and help with the design of our water and sanitation facility.

Capstone Design Statement

The purpose of this Major Qualifying Project was to design a Water and Sanitation Facility to be installed in Monwabisi Park, Cape Town, South Africa. Located on the urban fringe, Monwabisi Park is an informal squatter camp with limited water and sanitation services. A preliminary study conducted in the fall of 2008 recommended correcting the shortfall in water and sanitation services through community facilities. This project designed such a facility.

An analysis of possible facility components, including types of toilets, water taps, and laundry stations was completed. Each component was evaluated to ensure it improved current water and sanitation services in Monwabisi Park, added to the likelihood of community acceptance of the facility, and promoted social interaction within the community. In particular, each component was assessed on water conservation, removal of standing water in the area, improvements to public hygiene, and reduction of vandalism, theft, and facility misuse. Design of each component also focused on sustainability, either through the production of useful byproducts like compost or through minimizing water and energy consumption and maintenance costs. After evaluation, components were selected for inclusion in the facility.

A 10 meter x 12 meter site was identified to house the water and sanitation facility. Facility components were arranged to fit in the small space, while preserving a community-building atmosphere. Water and wastewater loads were estimated through discussion with the local community. A garden leaching field was designed to treat effluent and limit standing surface water. The design is also easily replicable, for installation across the community. Possible variations of the design were made to assist with implementation at other sites.

This project addressed the following ABET design considerations:

- Economic
  - Cost analyses provided for various toilet options and for entire facility design.
- Environmental
  - Design minimizes unsafe discharge to the surrounding environment.
- Ethical
  - Design balances cost efficiency against individual user services.
- Health and Safety
  - Facility design strives to reduce disease transmission and provide a save atmosphere for users.
- Political
  - Design satisfies basic service requirements as established in South African national law.
- Social
  - Design responds to various social challenges, including crime, vandalism and poverty.
- Sustainability
  - Design maximizes water and energy conservation and also includes composting producing toilets.

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1 Introduction

There are over one billion people worldwide without a safe water source. More people are without adequate access to toilet facilities. A lack of adequate water and sanitation services is particularly apparent in developing countries in Africa. Even near modern cities, like Cape Town, South Africa, water provisions and sanitation services are in great demand. Though progress has been made to remedy these problems, they still exist.

The goal of this Major Qualifying Project (MQP) was to design a water and sanitation facility to expand access to clean water and sanitation services in Monwabisi Park, Cape Town, South Africa. This MQP followed the work of an Interactive Qualify Project (IQP) team, which conducted an in-depth investigation of water and sanitation services currently available in the informal settlement. The IQP team found that there is an insufficient number of water taps and toilets in this impoverished area, many of which are unusable due to vandalism and misuse. Though the City of Cape Town is required by national law to provide one water tap for every 125 people, the actual ratio of working taps to people is 1:442. Similarly, the legal ratio of toilets to families is 1:5, yet in Monwabisi Park it is 1:69 (Granfone *et al.,* 2008).

Beyond quantifying the water and sanitation services in Monwabisi Park, the IQP team surveyed community members to identify their current preferences and practices regarding water and sanitation. The team also interviewed officials from the Cape Town Water and Sanitation Department (CTWSD) and the Shaster Foundation, a non-profit organization formed to better the community of Monwabisi Park, to gather their ideas to improve water and sanitation.

After considering the shortfalls in water and sanitation provisions in Monwabisi Park along with the recommendations from the community and public officials, the IQP team proposed a comprehensive plan to improve the water and sanitation services in order to promote a healthy environment while embodying sustainability. The plan included a communal water and sanitation facility, which would be replicable to other locations within the community. Eventually, with enough of these communal water and sanitation facilities installed across Monwabisi Park, the backlog in providing water and sanitation services will disappear.

The focus of this MQP was to formalize the design of the proposed water and sanitation facility. Recommendations for success listed in the IQP report were strongly considered to ensure the success of the facility. The design is intended for a site near the Indlovu Community Center in Monwabisi Park. It includes water taps, toilets, and public laundry stations. Because of the scarcity of water and the difficulty of removing wastewater, the site operates waterless toilets. Other services requiring water drain to a community garden. The design is easily modified, maintaining the intent to replicate this facility across Monwabisi Park. The facility will help the community achieve basic levels of water and sanitation services. Implementation of this facility, which will be supervised by another MQP team, is slated to begin in October 2009.

The following report details the process that led to the development of the design for the facility. Chapter 2 provides background information about South Africa with a focus on the city of Cape Town. This background section continues with Chapter 3, which focuses specifically on the community of Monwabisi Park and the availability of water and sanitation services there.

Chapter 4 includes a review of the methods and evaluation techniques used to design the water and sanitation facility, and Chapter 5 details that design. The report concludes with a list of recommendations for the future. These recommendations are discussed in Chapter 6.

2 Background

Water is an invaluable resource. Unfortunately, many people worldwide do not have a reliable, safe water resource or adequate wastewater treatment. In 1996, the World Health Organization (WHO) stated that “there remained a total of 1015 million people without safe water and 1764 million without adequate sanitation” (World Health Organization, 1996).

Water and sanitation issues are more pronounced in developing countries in Africa and Asia. Though Africa’s “share of global fresh water resources, at ten per cent, closely matches its share of world population, at 12 per cent… the distribution of this resource is uneven – from areas of severe aridity like the Sahara and the Sahel in the North, and the Kalahari in the south, to the Congo Basin, which is estimated to have fifty per cent of Africa’s fresh water” (Donkor, 2003). With this vast inequity in water distribution, people in the more arid areas struggle to find adequate supplies of clean water. According to G.O.P. Obasi, the Secretary-General of the World Meteorological Organization, “it is estimated that more than 300 million people in Africa live in a water-scarce environment. By 2025, 18 African countries are expected to experience water-stress” (Obasi, 2003). Unless a solution is found, these problems will continue to worsen as the population of Africa grows.

Due to inadequate sanitation and water services, waterborne diseases are very common throughout Southern Africa. “Public institutions […] suffer from a lack of access to safe water and sanitation services: 59 percent of all schools (over 16,000) and clinics (over 2,500) lack access to acceptable sanitation facilities, while 27 percent of all schools (over 7,500) and 48 percent of all clinics (over 2,000) lack access to safe water supply” (UNESCO, 2008). Some of the most common diseases found in these communities include cholera, dysentery, hepatitis, malaria and schistosomiasis (UNESCO, 2008). Two of these diseases are discussed in Section 3.3.1.

The following sections describe the risks associated with unclean water and highlight the importance of having reliable, clean water sources. Background information is provided about water and sanitation services in South Africa. The chapter gradually narrows its focus from a nationwide view of South Africa to a view of Cape Town, South Africa. The chapter concludes with a description of water and sanitation services in the informal settlements surrounding Cape Town.

2.1 South Africa

South Africa lies at the Southern tip of Africa. It is surrounded by Botswana, Lesotho, Mozambique, Namibia, Swaziland, Zimbabwe, and 2,798 km of coastline on the Indian and South Atlantic Oceans. With a total area of 1,219,912 sq. km, South Africa has a plethora of natural resources, including diamonds, gold and nickel. This area has a semi-arid climate, making water a precious resource. South Africa has a population of 48,780,000 people, 79% of whom are black African, 9.6% of whom are white, 8.9% of whom are colored and 2.5% of whom are Indian or Asian (Agency, 2009).

Though once colonized by the British and the Dutch, South Africa gained independence in 1934 (About.com, 2008). Following independence, the National Party of South Africa passed several laws with the intent of solidifying white supremacy and further segregating different races. These laws included the classification of each person into three categories: white, black (African) and coloured (mix of different races). "White-only" jobs were created. This time of segregation is known as the Apartheid. Table 1 shows the unequal distribution of wealth, land, and other services between races during the Apartheid around 1978 (Stanford, 2008).

Table 1: Apartheid and the People of South Africa circa 1978 (Stanford, 2008)

Statistic	Blacks	Whites
Population	19 Million	4.5 Million
Land Allocation	13%	87%
Share of National Income	< 20 percent	75 percent
Ratio of Average Earnings	1	14
Minimum Taxable Income	360 rands	750 rands
Doctors/Population	1/44,000	1/400
Infant Mortality Rate	20% (urban) 40% (rural)	2.7%
Annual Expenditure on Education per Pupil	$45	$696
Teacher: Pupil Ratio	1:60	1:22

During the Apartheid, blacks were also prohibited from living in cities across South Africa. From 1960 to 1983, "the Apartheid government forcibly moved 3.5 million black South Africans in one of the largest mass removals of people in modern history" (Wiley & Kornbluh, 2006). The Apartheid continued until 1993, when it was abolished after many negotiations.

Subsequently, in 1994, the first multi-racial elections in South Africa took place, putting the African National Congress in power for the first time since the beginning of the Apartheid. Shortly after, the Reconstruction and Development Programme was implemented, which laid the groundwork for improving living standards in South Africa. This was the newly-elected national government's first attempt at improving quality of life in South Africa, including water and sanitation services.

2.2 Water and Sanitation Services

In 2001, the national government adopted a policy under the Reconstruction and Development Programme in which basic water and sanitation services would be provided to all residents of South Africa free of charge. Funding to provide these services is made possible through national grants and revenue from local governments. One such grant the national government provides is the Municipal Infrastructure Grant (MIG). The purpose of this grant is to improve the infrastructure for poor households and ultimately reduce and eliminate the backlog of sanitation improvements (City of Cape Town, 2008). Between the financial years of 2003/04 and 2008/09, MIGs made up 60 percent of the total funds transferred directly from the national government to local municipalities (Josie, 2008).

Another subsidy known as the Equitable Share transfers funds from the national government to local governments to alleviate the costs of services to the poor (City of Cape Town, 2008). The

Equitable Share allocates funds according to the percentage of the population that cannot pay for basic services. However, the Equitable Share is not sufficient to provide basic services for everyone, and therefore municipalities must turn to cross-subsidization for further funding. In some cases, this can leave the cities with an enormous deficit (Loots, 2004).

2.2.1 Basic Water and Sanitation Services

In 2003, the Department of Water Affairs and Forestry (DWAF) released the Strategic Framework for Water Services, which implemented the concept of the water ladder. The first step of the water ladder is to provide basic water services to everyone living in South Africa. The next goal is to assist communities to an intermediate level of service, which would include a tap in their yard. Ideally, communities would reach the highest level of service with indoor plumbing and flushing toilets (City of Cape Town, 2008). The basic level of water service is defined as at least 25 liters per person per day of potable water delivered to a tap or standpipe. These need to be located within 200 meters of a household, with no more than 25 households serviced by each tap. The water ladder is summarized in Table 2.

Table 2: Water Services Ladder (City of Cape Town, 2001)

Category	Water Services Definition
Inadequate	No access to basic water supply as defined below.
Basic	a) the provision of appropriate education in respect of effective water use; and b) a minimum quantity of potable water of 25 liters per person per day: • at a minimum flow rate of not less than 10 liters per minute • within 200 m of a household; and • with an effectiveness of not more than 7 days interruption of supply to any consumer per year.
Intermediate	Yard tap, Yard Tank
Full	House Connection

Through the Water Service Act, the DWAF also guaranteed basic sanitation services. The DWAF has delegated the task of providing these services to local municipalities. Therefore, each city is responsible for providing free basic water and sanitation services to all of its citizens through its water and sanitation department, including those living in informal settlements (City of Cape Town, 2008). However, any services beyond the definition of basic services are still paid for by the resident directly. Table 3 shows the DWAF interpretation of basic, intermediate and full sanitation services. A basic level of sanitation is to provide one toilet for every five families (City of Cape Town, 2008).

Table 3: Sanitation Services Ladder (City of Cape Town, 2001)

Category	Sanitation Services Definition
Inadequate	No access to basic sanitation as defined below.
Basic	a) the provision of appropriate health and hygiene education; and b) 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 and prevents the entry and exit of flies and other disease-carrying pests. This service includes VIPs, Formal black bucket, Container and Chemical Toilet usually provided as a communal service.
Intermediate	Communal Toilet (Ablution Facilities)
Full	On-site Waterborne, Septic Tank, or French Drain

The DWAF has delegated the task of providing these services to local municipalities. Therefore, each city is responsible for providing free basic water and sanitation services to all of its citizens through its water and sanitation department, including those living in informal settlements (City of Cape Town, 2008). However, any services beyond the definition of basic services are still paid for by the resident directly.

2.3 Cape Town, South Africa

Cape Town lies on the southwestern most point of the African continent and is the capital of South Africa's Western Province. Figure 1 shows Cape Town's location in South Africa. It is the second largest city in South Africa with about 3.4 million people (City of Cape Town, 2008). Cape Town has yet to completely overcome the effects of the Apartheid and struggles with high poverty. In 2005, 38.8% of households were living below the poverty line (households earning less than R1600 or $163 per month). The lack of financial resources currently available and social challenges have prevented the city from overcoming significant issues with providing basic water provisions and sanitation services.

2.3.1 <u>Growth</u>

Cape Town continues to grow, both economically and with regards to population. According to the City of Cape Town (2001), "the economic growth rate [in Cape Town] was 2.6% during 1991-2000 compared to the national economic growth rate of 1.8% for the same period. Also, the City of Cape Town contributed 11% to South Africa's gross domestic product, which included 86 billion South African Rand (R86 billion or $8.7 billion) in goods and services produced in 2000" (City of Cape Town, 2001). Cape Town's current growth rate is expected to decline from 1.6% to 0.6% by 2021. This decrease in growth is attributed to high death rates due to HIV/AIDS. Cape Town's population is expected to grow only by 300,000 people, or 0.09%, by 2021 (Morris, 2006).

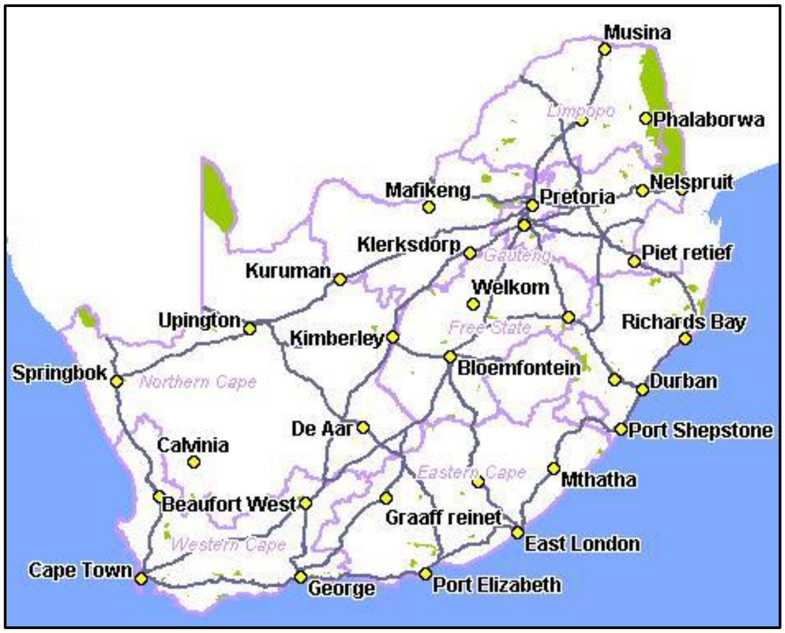

Figure 1: Map of South Africa (South African Map, 2008)

2.3.2 Weather

Cape Town experiences a Mediterranean climate with little rain. Cape Town has an average annual rainfall of 515 mm (20.2 inches) (South African Weather Service, 2003). As a point of reference, the average annual rainfall in Boston, Massachusetts, is 1080 mm (42.5 inches). The rainiest month in Cape Town is June, with an average of 93 mm (3.6 inches). Rain is much heavier during June, July, and August than other times during the year. Almost half of the annual rainfall (49%) falls during these three months. Because of this, standing water can be an issue, especially where the topography or soil conditions prevent the excess water from running off or infiltrating the soil.

In the summer months from December to March, temperatures usually range from lows around 15°C (60°F) to highs around 27°C (80°F) (Ritztrade International, 2008). Temperatures can reach as high as 40°C (104°F), but this is a rare extreme for Cape Town (South African Weather Service, 2003). In the winter months from June to August, temperatures average between 7°C (45°F) and 20°C (70°F). Extreme lows approach 0°C (32°F) (Ritztrade International, 2008).

2.3.3 Water Resources

Cape Town receives its water from five surrounding rivers: Theewaterskloof, Voëlvlei, Wemmershoek, Steenbras, and Berg. The dams at Theewaterskloof and Voëlvlei account for two thirds of the water supply to Cape Town. The Steenbras dams (upper and lower) supply 11% of the water provided to the city. To supplement the water supply, the Berg Water project constructed a dam on the Berg River in 2008. This added an additional 18% to the region's available water resources (Matthews, 2005).

2.3.4 Water and Sanitation Services

As adopted into the Constitution of Cape Town, South Africa in 1996, socio-economic rights that were once denied were now guaranteed. These rights include access to clean water and basic sanitation services. In Cape Town, while larger amounts of water are used for gardens (35%), bathing (20%), flushing (29%), and dishwashing and laundry services (13%), only a small percentage (3%) of water is used for drinking or cooling (Smith, 2008).

While progress has been made in providing these basic water and sanitation services, the goal of providing it to everyone is still not complete. There is still an unequal distribution of water services throughout Cape Town. Figure 2 shows the distribution of water services, while Figure 3 displays the distribution of sanitation services in Cape Town as of 2001. As seen in these figures, the central region and some areas to the north and west of Cape Town suffer the most. The areas in dark blue found in these regions represent 88 to 100 percent of people without water and 86 to 100 percent without sanitation. The eastern parts of Cape Town have much better conditions both with water and sanitation. These are the areas of Cape Town that are the most highly urbanized and developed.

Each year the City of Cape Town drafts an Integrated Development Plan, which outlines local revenue sources and how they will be allocated to improve the city and its services (City of Cape Town, 2008). As part of the Water Services Development Plan in 2005/06, 13,905 households were provided basic, non-emergency level sanitation, but the backlog still remains at 44,000. The estimated costs of eradicating these backlogs are much higher than the Department of Water and Sanitation's actual budget. In order to accommodate the growing population as well as to eradicate the enormous backlog in sanitation, the city has provided an emergency level of service by distributing black buckets to 95% of the residents in the 195 informal settlements. Through the "black bucket system," buckets are provided to each household in place of a toilet or proper sanitation service. This emergency level of service is only considered a basic service until the sanitation backlog can be eliminated.

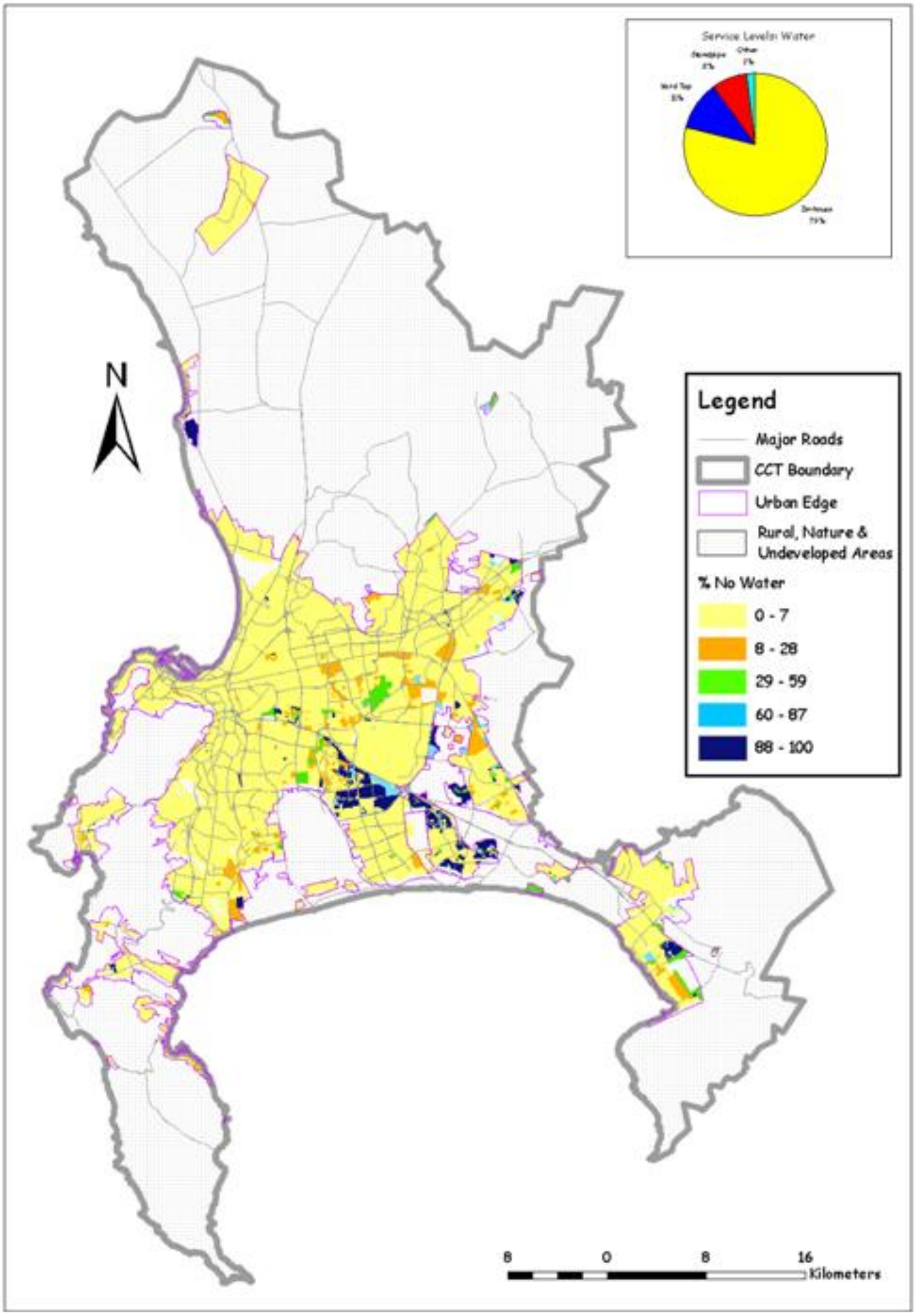

Figure 2: Cape Town Water Distribution as of 2001 (City of Cape Town, 2001)

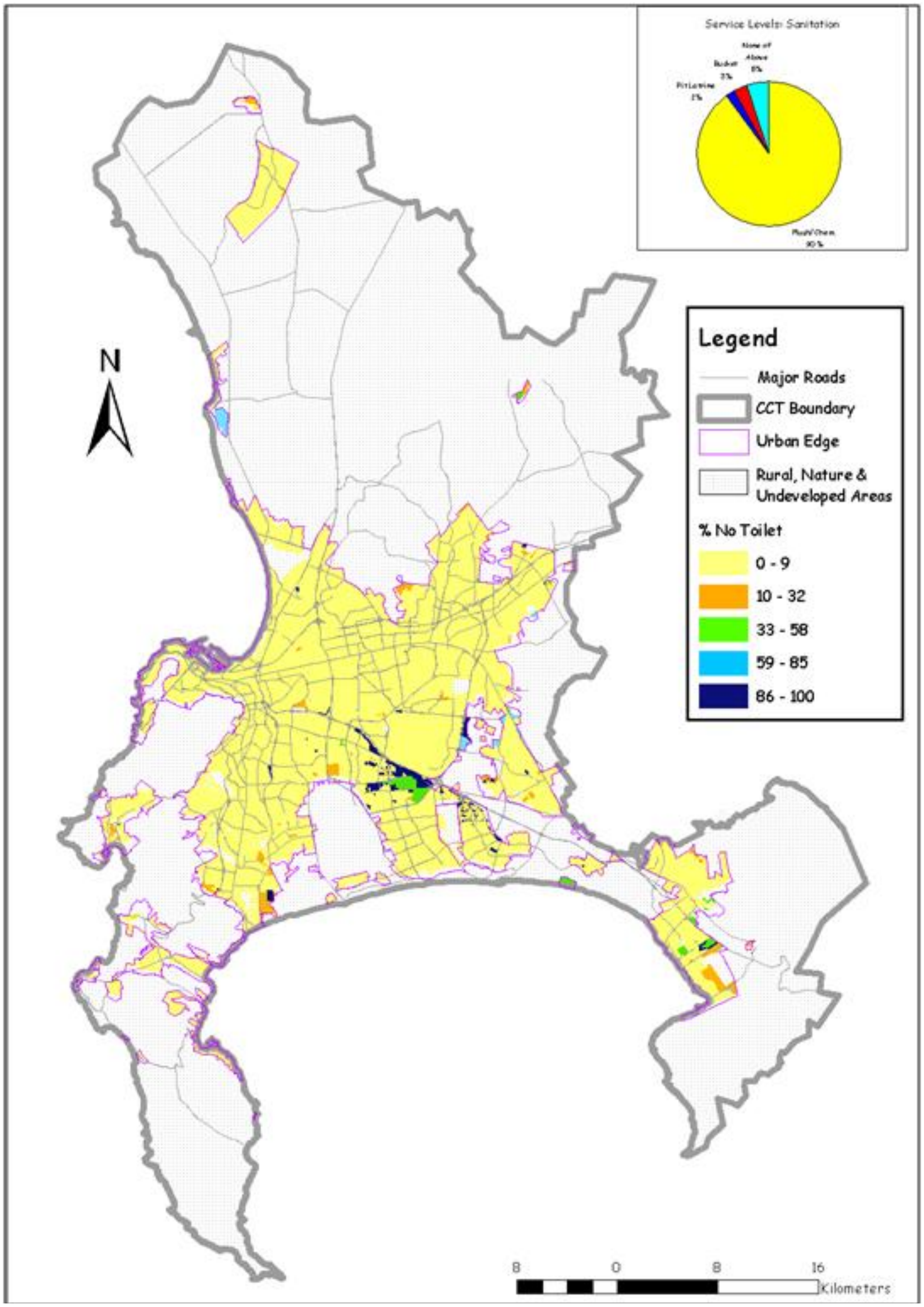

Figure 3: Cape Town Sanitation Services Distribution as of 2001 (City of Cape Town, 2001)

In the 2006/07 financial year, R8 million was spent on installing toilets; however, as of 2008, 2,880 black buckets still needed to be replaced. The Water Services Development Plan indicates that in the 2008/2009 financial year, R34.5 million will be needed to address the backlog in sanitation, yet the budget for the Department of Water and Sanitation is only R18.1 million. It is projected that in 2009/2010, the department's budget will increase to R40.5 million and only

R38.9 million will be required for backlog. However, in the year 2010/2011 the budget will be back down to R17.0 million and R45.7 million will be required for the sanitation backlog (Amanzi Obom Consulting cc, 2008). These data are summarized in Table 4. The city projects that it will eliminate all sanitation backlogs by the year 2012 (Amanzi Obom Consulting cc, 2008).

Table 4: Cape Town Dept. of Water and Sanitation Budget vs. Cost Requirements (Amanzi Obom Consulting cc, 2008)

	2008/09	2009/10	2010/11	2011/12
Actual Budget	R18.1 mil	R40.5 mil	R17.0 mil	
Requirements	R34.5 mil	R38.9 mil	R45.7 mil	R36.4 mil

2.4 Informal Settlements

During the Apartheid, segregation laws forced blacks and coloured persons from cities across South Africa. Having no place to go, the displaced persons settled in the open spaces outside of the cities. The scattered shacks in the rural areas outside of the cities developed into informal townships.

These unplanned, informal settlements grew quickly without governmental support. After the Apartheid ended there was still a lack of jobs, money, and opportunities available to the blacks and coloured persons of Cape Town. As a result, the residents could not afford to move out and populations of informal settlements continued to grow rapidly.

Due to the unplanned establishment of informal settlements, the areas were developed without adequate infrastructure, including water and sanitation services. As mentioned above, the City of Cape Town has tried to provide these services, but has come across many obstacles. For instance, the lack of roads within the settlement prohibits the city from installing toilets in densely populated areas. Additionally, the services that have been installed cannot be adequately overseen, which allows for vandalism, theft, and misuse. Furthermore, the city does not possess adequate funds to accommodate the growing population.

The Cape Metropolitan Area (CMA) is an organization consisting of seven areas in Southern Africa, including Cape Town, with the goal of providing clean water to its consumers. It specifically focuses on supplying water to those in the informal settlements. The CMA pumps water into the cities from the five nearby rivers listed in Section 2.3.3. The water is then stored and pumped through the city distribution system to the user. Of all water pumped to the cities, only 30% is used. The remaining 70% of the water exits as runoff due to inadequate storage (Smith, 2008).

Table 5 displays the percentages of those living in the informal settlements in Cape Town without basic water and sanitation systems. In this table, households characterized under “Council” ownership denotes those maintained by the Cape Metropolitan Council, a program sponsored by local governments to resolve housing issues and build infrastructure (Cape Metropolitan Council, 2001).

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Table 5: Households in Informal Settlements in Cape Town without Water and Sanitation Service (City of Cape Town, 2001)

"Ownership"	Households	Without Water	Without Sanitation
Private	No. of households	10 500	1 600
	% of informal households	11.4%	17%
	% of total no. of households	1.7%	2.5%
"Council"	No. of households	7 600	37 100
	% of informal households	8.4%	41%
	% of total no. of households	1.2%	6%
Total	No. of households	18 100	53 100
	% of informal households	20%	57.7%
	% of total no. of households	2.9%	8.5%

There is a similar need for improved sanitation services in the informal settlements. An employee of the South African Municipal Workers' Union, Anna Weekes, voiced her concern about the inadequate level of sanitation: "We are still using the bucket system of toilets, which is disgusting. Our children are always sick as a result" (Weekes, 2002). Many residents have nowhere to properly dispose of the contents of their bucket and therefore empty them in the streets where children play.

The City of Cape Town has made some progress in providing these basic sanitation and water services to the people living in informal settlements, but the goal of providing it to everyone has not been achieved to date. One such informal settlement in dire need of basic water and sanitation services is Khayelitsha, which is discussed in the next section.

2.5 Khayelitsha

Khayelitsha is the third largest township in South Africa and the largest near Cape Town, with a population between 500,000 and 1,000,000 residents. Many of the residents are illegally living there, and thus the City of Cape Town has great difficulty assessing the exact population. As shown in Figure 4, Khayelitsha (highlighted in orange) is located about 40 km southeast of central Cape Town on the False Bay Coast.

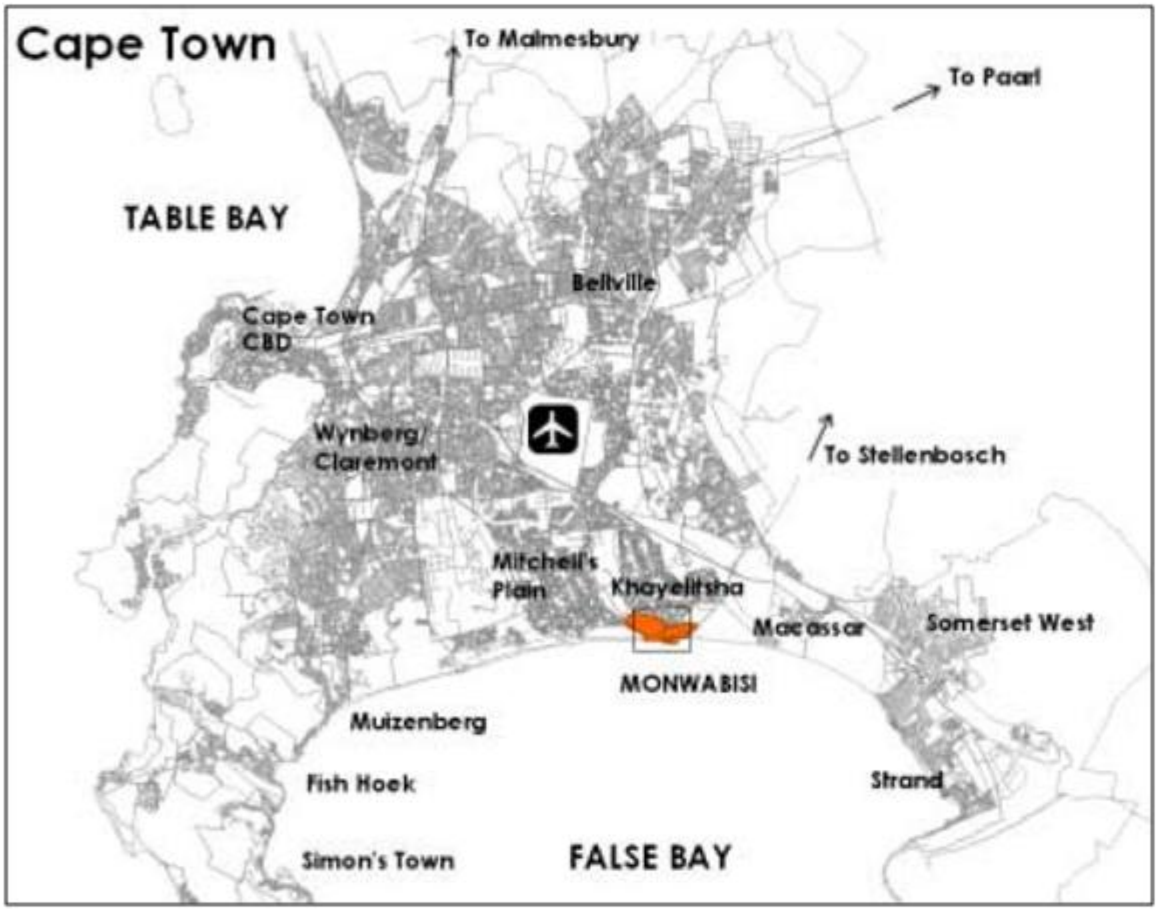

Figure 4: Map of Cape Town and Khayelitsha (Berner *et al*., 2004)

The population of Khayelitsha is about 90% Black African and 10% Coloured (those with sub-Saharan ancestry). The principal language used in the township is Xhosa. Khayelitsha, which means "Our new home" in Xhosa, is a "formerly disadvantaged area that still struggles with enormous social and economic problems" (Berner *et al*., 2004). In recent years, progress has been made in providing services in Khayelitsha. The city of Cape Town provides water taps and electricity to a portion of the community. However, poverty, unemployment, and gang activity are widespread in Khayelitsha. The township accounts for "more than 50% of [Cape Town's] unemployment population" (BuaNews, 2004) even though only one-third of Cape Town's population resides there. Khayelitsha is "one of the most dangerous places in the country, with the highest murder rate" in South Africa (BuaNews, 2004).

Most residents of Khayelitsha "live in corrugated iron shacks and […] are often unable to acquire basic needs such as food and clothing. This condition is further exacerbated by environmental factors such as the lack of proper toilet facilities" (Ndingaye, 2005). As the population of Khayelitsha has grown, the water and sanitation services provided to the settlements have not increased. The percentage of Khayelitsha residents with water piped to their dwelling or yard decreased from 73% in 1996 to 62% in 2001. Figure 5 shows the percentage decrease in people who have water piped to their homes. Figure 6 shows the percentage decrease in people who have basic on-site sanitation services (Information and Knowledge Management Department, 2005).

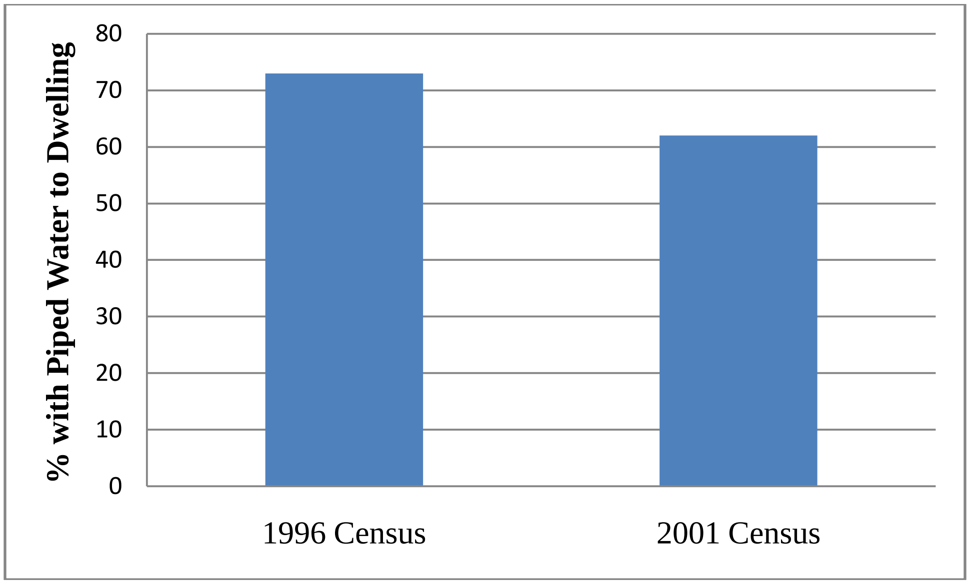

Figure 5: Percentage of Khayelitsha Residents with Water Piped to their Dwelling (Information and Knowledge Management Department, 2005)

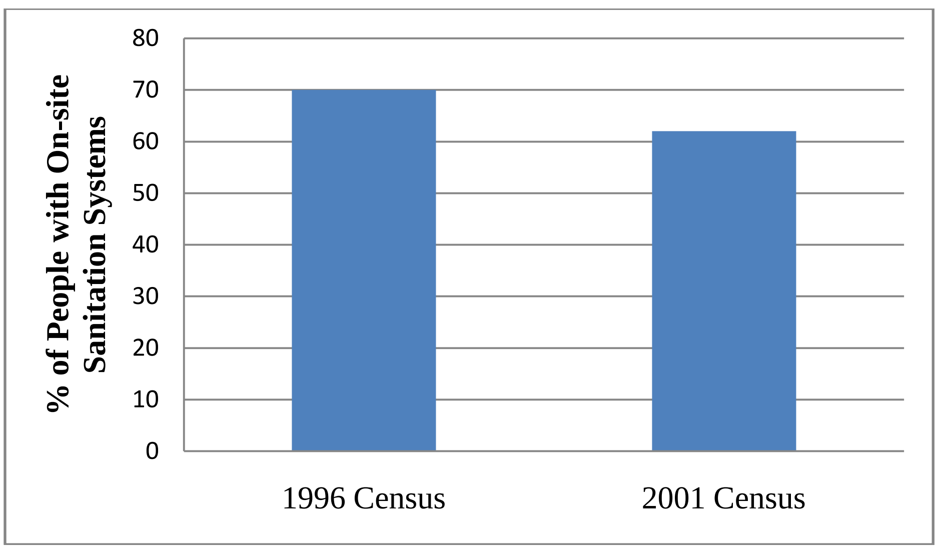

Figure 6: Percentage of People with Basic On-site Sanitation Services (Information and Knowledge Management Department, 2005)

2.5.1 Cultural Expectations

The City of Cape Town must communicate and work with the informal settlements in order to begin to solve the water and sanitation problems. According to the city's Water and Sanitation Service Standard (2008), "Community participation is identified as a key requirement for the success of the implementation programme." The Water and Sanitation Service Standard (2008) further explains that projects in informal settlements will be more successful if they are installed according to demand and then carried out by the community members themselves. Allowing the community to build their own sanitation facilities not only provides jobs, but also a sense of ownership. This sense of ownership and the ability to maintain the facility themselves will result in a more successful solution because community members will be unable to rely on outside contractors for maintenance due to the high costs (City of Cape Town, 2008).

According to an article written by an anonymous Khayelitsha resident, one major step forward for informal settlements could be the transfer of ownership of the land to the community members themselves (City Visiting Informal Settlements at Khayelitsha, 2008). As of 2008, anyone living in an informal settlement is a squatter and is living there illegally. Transfer of ownership would make them permanent residents, and they would no longer be prone to relocation. Mzonke Poni (2008), another resident of Khayelitsha, explains that many of these families have been here for decades and relocation upsets their livelihoods and creates even more poverty. With ownership of the land, community members could have a reason to invest in their own homes, thus improving their standard of living. Residents could make their own personal property development choices rather than being subject to decisions made by city officials. The community could also build their own houses providing even more jobs (Poni, 2008).

As stated above, the city recognizes that community participation is important, yet this has not always been put into practice. Residents of informal settlements are now demanding to be heard. On October 21, 2008, 300 residents from 10 informal settlements of Khayelitsha marched to local municipality offices to deliver a memorandum to the City of Cape Town (Nkuna, 2008). The first major point of the memorandum was that the city make decisions according to the community's needs. The second demand was recognition of people living in informal settlements as legal residents. Thirdly, the residents demanded water, sanitation, and electrical services. This march and memorandum was organized by Abahlali baseMjondolo of the Western Cape, also known as the South African shackdwellers' movement (Abahlali baseMjondolo of the Western Cape, 2008).

2.6 Monwabisi Park

Within Khayelitsha, there are several informal villages "earmarked for development, like Monwabisi Park" (Berner *et al*., 2004). Monwabisi is a two-kilometer long area of Khayelitsha on the False Bay coast. The Monwabisi area "consists of the southern coastline with calcrete cliffs and sandy areas of primary dunes […], a big part of it covered by low-bush vegetation" (Berner *et al*., 2004). The low-bush vegetation is primarily Dune Fynbos, a tough, woody, bush native to the Cape Town area.

Founded in 1997 on the Wolfgat Nature Reserve, this informal settlement is now the home for an estimated 20,000 people, most of whom speak the language Xhosa. Of the 5,785 shacks in Monwabisi Park, 73% of the shacks have heat, yet only 33% of the houses are accessible by emergency vehicles. There was one community center for the entire area, the Indlovu Center, which was constructed in 2007. The Indlovu Center provided the community with a daycare, youth center, health clinic, soup kitchen, community hall and a school (Envisioning Endlovini, 2008). However, on November 30, 2008, a fire swept through Monwabisi Park, destroying the community center, clinic, soup kitchen, laundry facility, travelers lodge and the crèche. Twenty-five houses were also destroyed in the devastating fire. Although the fire caused significant damage, the community has been working together to rebuild what was lost.

With an employment rate between 55% and 77%, Monwabisi Park is a particularly impoverished area within Khayelitsha. There are four political sections in Monwabisi Park: A, B, C and M. These sections are further divided into subsections. Figure 7 shows the different sections of Monwabisi Park. There are 5785 shacks in Monwabisi Park, 510 of which are in C Section. "Subsections A1, B1, C1 and M1 have direct access to electricity but have no toilet facilities. Subsections M2, C2, B2, and A2 have no direct access to electricity, but are provided with toilet facilities by the city" (Envisioning Endlovini, 2008).

Figure 7: Division of Monwabisi Park Sections (Envisioning Endlovini, 2008)

Since Monwabisi Park was established in 1997, the population has grown quickly. During a period of growth from 1997 to 2003, people started to build further away from the main roads and formed pathways to access their homes. The population has remained stable since 2003.

2.6.1.1 The Shaster Foundation

One group working for betterment of the Monwabisi Community is the Shaster Foundation. The Shaster Foundation was established in 1993 by Dianne (Di) Womersley with a mission "To create a holistic way for communities to work together for a better life and enable them to support the most vulnerable members of society – orphans, […] revive a sense of pride in traditional and indigenous culture amongst the precious youth of Africa, [… and] link this cultural revival to economic development and much needed job creation" (Shaster Foundation, 2008). In their efforts, the Shaster Foundation strongly advocates for sustainability, through the idea of permaculture. Permaculture, an idea unique to communities that rely on alternative farming, can be defined as "a set of ethics that suggest [people] think and act responsibly in relation to each other and the earth" (Green Building, 2007).

One of the Shaster Foundation's projects was to develop plans for an "Eco-Cottage" to replace the shacks that dominate Khayelitsha, especially in Monwabisi Park. Using sandbags and eco-beams to form the walls, which are then covered in plaster, the eco-cottages "use no water except for in the plasterwork; they are fireproof, bullet proof and very well insulated" (Shaster Foundation, 2008). Other Shaster Foundation projects include water conservation efforts and sustainable, alternative energy initiatives.

As detailed in this chapter, water and sanitation services are currently at an inadequate level in Cape Town, South Africa. This problem is particularly pronounced in informal settlements surrounding the city. Seeing an opportunity for improvement, a group of students traveled to Monwabisi Park in October to December 2008 to quantify the problem. Their research is described in Chapter 3.

3 Current Conditions in Monwabisi Park

A team of students and faculty members (Marcella Granfone, Christopher Lizewski, Dan Olecki, Advisor Scott Jiusto, PhD, and Advisor Robert Hersh) from Worcester Polytechnic Institute (WPI) traveled to Cape Town, South Africa from October to December 2008 and completed a study of current water and sanitation services in the C Section of Monwabisi Park. The study was part of an Interactive Qualifying Project (IQP), and was sponsored by the Shaster Foundation and the City of Cape Town Water and Sanitation Department. Granfone *et al.* (2008) used interviews and field observations to ascertain the severity of the water and sanitation problems in Monwabisi Park. They took an inventory of the conditions of all water taps and toilets in C Section and mapped their locations. The team also assessed the costs, benefits, and problems associated with these services based on social, health, and cultural perspectives. They then used various analytical methods to deduce the shortfall in services.

Once the level of water and sanitation services was determined, Granfone *et al*. (2008) worked to develop a concept for a "replicable public water and sanitation system that upholds the principles of permaculture and sustainability." The team worked with City of Cape Town Water and Sanitation Department (CTWSD) officials and the Shaster Foundation to gather information regarding the community dynamic and previous efforts to alleviate the water and sanitation problems in the city. They also interviewed representatives from the Sustainability Institute and companies that manufacture toilet options that may be appropriate for Monwabisi Park.

Upon completion of the study, Granfone *et al.* (2008) published a report detailing their findings. The report included recommendations for the development of a communal water and sanitation facility for installation in Monwabisi Park. The following sections summarize the contents of the report.

3.1 Current Water Conditions

Granfone *et al.* (2008) concluded that the people of Monwabisi Park suffer from poor water service conditions. Not only are there an insufficient number of taps, but many of the taps are not fully functional. The following section summarizes the current water conditions and how these conditions are affecting the public health of the community.

Currently in C Section there are 27 water taps, seven of which are fully functional and eleven that are not functioning. The remaining nine taps possess problems such as missing handles and nozzles, broken piping, and leaks. As shown in Figure 8, the taps in better condition (shown in green) are located along the main roads surrounding C Section, whereas the taps in the center of the settlement are in poor condition (shown in red). The taps along the road are in better physical condition because of their close proximity to pour-flush toilets, which are more frequently maintained by the city. The residents also assist in the maintenance of the taps because without water their toilets do not function (Granfone *et al.*, 2008).

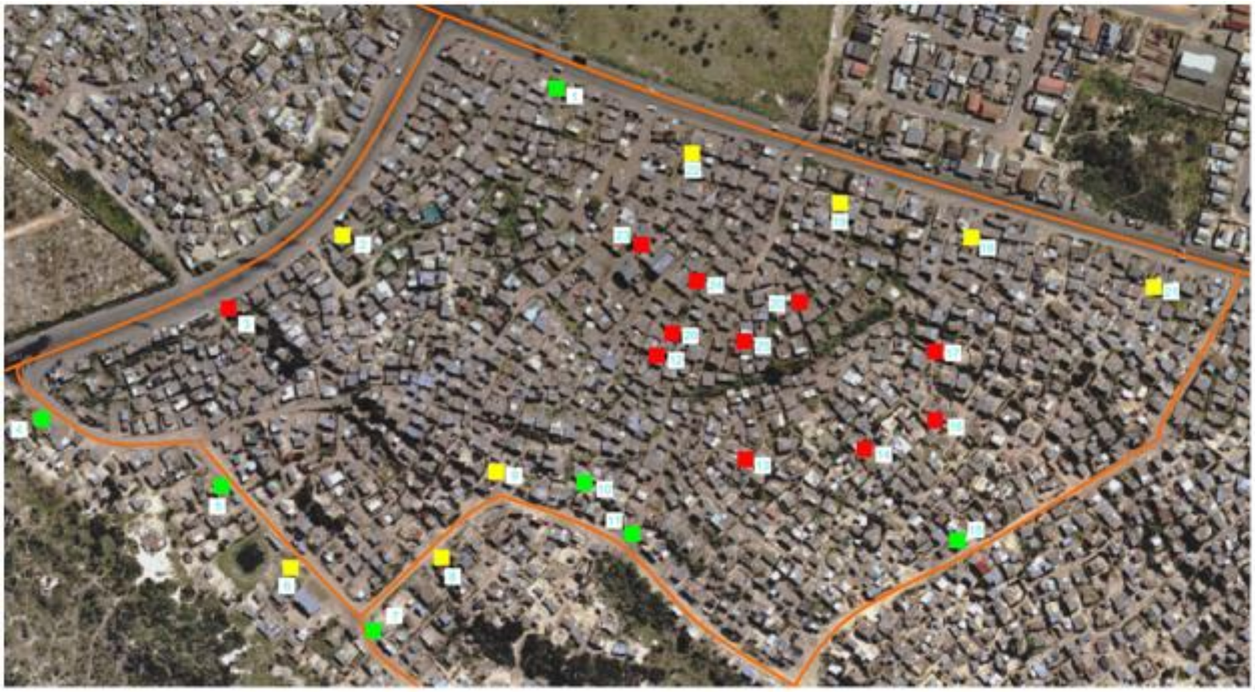

Figure 8: Location and Condition of Water Taps in C Section
(Granfone *et al.*, 2008)

There is a deficit in the number of taps needed for the population of C Section. As stated in Section 2.2.1, the national law requires that one water tap is provided for every 125 people. In C Section, if all 27 taps were in good working condition, the ratio would be 1:246. However, since eleven of these taps are non-functioning, the ratio of functioning taps to people is 1:442. Therefore, in order to legally provide water for everyone in C Section, 53 taps would need to be installed (Granfone *et al.*, 2008). Table 6 summarizes these results.

Table 6: Water Services in C Section (Granfone *et al.*, 2008)

Category	Number	Legally Required Ratio	Ratio if all 27 taps worked	Ratio of working taps to people	Number of taps needed
Population	6629	1:125	1:246	1:442	53
Households	1510	1:25	1:56	1:101	61

3.1.1 Water Use

Residents rely on water taps for all of their daily water needs. Granfone *et al.* (2008) estimated that a resident of Monwabisi uses 660 liters of water in one week, based on each individual using 33 20-liter buckets per week. Laundry, which is done twice a week, requires about 6 buckets of water, or 120 liters. Three buckets per day are required for bathing, cooking, and drinking (Granfone *et al.*, 2008).

The women of the household usually collect the water for daily chores. Since washing clothes and dishes requires such a large amount of water, these tasks are sometimes done at the tap. Because women spend time at the water taps, dishwashing and laundry can be an enjoyable social activity. In order to promote this socialization and to alleviate the manual labor needed to wash clothes, a laundry station was constructed by Alex *et al.* (2007) in 2007. The station proved to be a safe gathering place for women of the community. The station was designed with rainwater collection tanks and a drip irrigation system that watered the community garden. The laundry station was a success, but unfortunately it was destroyed in a fire one year later.

3.1.2 Conditions of Water Taps

The water taps are in poor condition for a number of different reasons. Misuse is a major contributor to water tap damage. With many people relying on a small number of taps, there is a physical burden on the structures themselves. For example, the faucets of the taps are at an inconvenient height. Subsequently, people hang their buckets from the nozzle to prevent spilling. When filled with water, the weight of the bucket stresses the piping of the nozzle causing it to bend, break, and leak. Figure 9 shows a bucket hanging from the nozzle of a tap. Residents also fill the cement drainage cylinder around the tap with sand, garbage, and rocks making it a resting place for the bucket. These materials prevent the water from properly draining (Granfone *et al.*, 2008).

Figure 9: Water Bucket Being Filled in C Section (Granfone *et al.*, 2008)

Poor drainage is major issue because it results in standing water, which directly affects the health of the community. As mentioned above, the water taps are installed above a cement cylinder intended to aid in proper drainage. The cylinder is filled with stone to allow for more rapid drainage into the ground. However, due to misunderstanding of the residents, these drainage cylinders get clogged with trash, food scraps, and sand. The failure of the drainage cylinder results in standing water in and around the taps, which becomes an area of high contamination as explained in Section 3.3. Additionally, food scraps are left in the cylinders, which attract flies and promote the growth of bacteria (Granfone *et al.*, 2008). Figure 10 is a picture of a tap in C Section surrounded by standing water.

Figure 10: Standing Water at a Water Tap in C Section (Granfone *et al.*, 2008)

The City of Cape Town attempted to facilitate drainage by installing irrigation systems next to the taps. However, these irrigation systems failed because fats and oils from dishwashing clogged the irrigation pipes.

Residents have also made failed attempts to eliminate standing water in the drainage cylinders. For example, residents have punctured holes in the drainage cylinders allowing water to drain out of the bottom preventing it from pooling at the top. However, this caused the water to flow into one area next to the cylinder, which also had poor drainage and caused erosion. Additionally, the constant overflow wears away the surrounding landscape causing damage to roads (Granfone *et al.*, 2008).

Leaks also contribute to the standing water issue. Misuse, theft, and vandalism all result in leaking water taps. These problems are easily noticed and corrected. However, leaks in the pipes underground often go undetected and therefore do not get fixed. Finding and fixing underground leaks is expensive and must be done by city workers or private contractors. These underground leaks can decrease the pressure of the water pipes, and thus decrease the effectiveness of the taps. Undetected underground leaks results in large amount of wasted water (Granfone *et al.*, 2008).

Another reason for poor tap conditions is theft and vandalism. It is easy for theft and vandalism to occur because the taps are infrequently maintained or supervised. Residents turn to stealing because of the harsh financial situation in Monwabisi Park. Components of the faucets or the piping are broken off and stolen so that the metal can be resold. When this occurs, the taps no longer function correctly resulting in leaks. Handles to turn the taps on and off are the most commonly stolen component and residents must find other ways to open the nozzle, such as pliers or homemade handles. When pipes are stolen the only way to prevent water from being wasted is to shut the tap off completely. However, these situations are rarely reported to the city officials and therefore the broken tap continues to waste water, which contributes to standing water pools (Granfone *et al.*, 2008).

Water use is not monitored in informal settlements and residents are not charged for their water usage. Therefore, people are often careless and do not conserve water. There is no incentive for people to reuse water or to use it in moderation. Often taps are left running constantly due to damages or user carelessness (Granfone *et al.*, 2008).

There are flow meters located near all of the taps in Monwabisi Park. However, these gauges are rarely checked and the City of Cape Town is unaware of the amount of water used in the informal settlements. The city has tried to reduce wasted water by installing pressure release valves. When water demand is lower, less water is pumped through the distribution system. This significantly decreases the water wasted due to underground leaks in the pipes (Granfone *et al.*, 2008).

3.2 Current Sanitation Conditions

The sanitation facilities in Monwabisi Park are inadequate for a safe and healthy community. During the investigation of the IQP team, findings indicated that there were not enough toilets to supply the community with what they need and desire. The problems are more pronounced in Monwabisi Park than other areas in Cape Town. While 65.1% of households in Khayelitsha have a flush or chemical toilet, more than 80% of households in Monwabisi Park do not have access to toilets (Knowledge Management Department, 2005). The following sections summarize the current sanitation conditions in Monwabisi Park as well as the problems associated with them and how they are affecting public health.

3.2.1 Available Toilets

In C Section of Monwabisi Park, 92 pour-flush toilets were installed by the City of Cape Town to help the community achieve a basic level of sanitation. There are ten clusters of toilets around the perimeter of C Section. Each group of toilets is 400 meters apart and contains approximately ten toilet stalls. Every cluster of ten toilets shares a communal septic tank, which needs to be serviced every two months by the Cape Town Water and Sanitation Department (CTWSD). Since the CTWSD trucks need to gain access to the toilets to remove the waste, the facilities are located along community roads on the border of each Monwabisi section. At each site, water taps are needed to flush the waste out of the toilets. The city installed one water tap at each cluster of toilets. Of the ten taps, eight remain in working condition. Because pour-flush toilets need water to flush, if the water taps are broken, the toilets become non-functional (Granfone *et al.*, 2008).

South African national law states that basic services require one toilet for every five families. To ensure the 1:5 ratio (City of Cape Town, 2008), every toilet is secured with a locking door and the city gives the keys to one toilet to five families. Ideally, these toilets result in healthier sanitation practices. However, the City of Cape Town and the community do not have the resources to properly maintain the facilities, resulting in the toilets falling into disrepair. Since these toilets are located in public areas and not everyone was issued a private toilet, people may break the locks to gain access to the facilities. When this occurs, the toilet effectively becomes a public restroom. This usually results in the toilets being destroyed, either by vandalism, overuse or misuse (Granfone *et al.*, 2008).

Poor toilet conditions often stem from misuse. Most people in the community are unaware of the proper practices for using the toilets. Since toilet paper is not readily available and expensive for the community members, magazines or other paper products are used as a substitute for toilet paper. This practice damages the system drains. Vandalism also contributes to the destruction of the toilets in Monwabisi Park. Because parts from the toilets can have monetary value, they may be stolen from the facilities and resold (Granfone *et al.*, 2008).

Once there is a problem with a sanitation system, it could take weeks for a representative from the city to fix the problem. While the community waits for the toilets to be maintained, citizens must continue using the toilets. Using the broken toilets damages them further, possibly to an irreparable state. It is estimated that 30% of the toilets fail because of these problems within the first six months after installation. These situations result in an actual ratio of working toilets to families to be one toilet to every 69 families (Granfone *et al.*, 2008). Figure 11 shows the conditions of sanitation systems in Monwabisi Park.

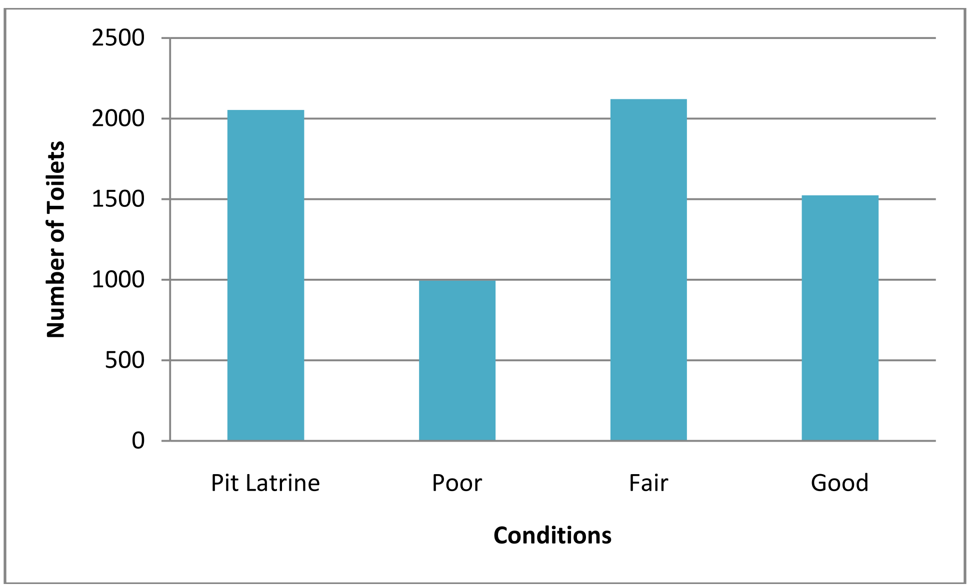

Figure 11: Conditions of Sanitation Systems (Granfone *et al.*, 2008)

Because toilet facilities are located around the perimeter of C section, people living in the center of C section must walk up to 2 km to access the closest toilet. The long distance, crime, and safety concerns discourage community members from using the city facilities. Instead, they build pit latrines in their yard or use the black bucket system, as described in Section 3.2.2.

3.2.2 Pit Latrines and Black Buckets

Pit latrines are private, homemade sanitation systems. Families dig a two to three meter hole in the ground and enclose the pit with a privacy structure. The families use this pit as a toilet facility. Once the pit is filled to capacity, it is sealed with sand and then a new latrine is constructed in a different area.

Safety concerns cause this type of sanitation system to be preferred by families living in the center of Monwabisi Park away from roads with no close access to toilets. Those with latrines take pride in their ownership of a private toilet. Families regularly maintain their latrines indicating the desire in the community to have a private sanitation system for every family. Although this is a preferred system for many people, these facilities cause many problems for the community. These latrines can harbor disease. Because the pits are not lined, waste seeps into the ground and can contaminate the ground water, especially when the water table is high.

Figure 12 illustrates the distribution of sanitation facilities across C Section in Monwabisi Park. The green markers indicate toilets in good condition, the yellow markers show toilets in fair condition, the red markers indicate pour-flush toilets in poor condition and the purple markers indicate pit latrines.

Figure 12: Sanitation Services in C Section (Granfone *et al.*, 2008)

For safety reasons, the black bucket system is used at night by those without pour-flush toilets and pit latrines. As described in Section 2.5, crime in Khayelitsha is high. Instead of walking to the closest toilet, some people prefer to use the black bucket as a toilet and dispose of the waste by dumping it on the ground. As just discussed, this causes ground water contamination, which leads to poor health conditions in the settlement.

3.3 Standing Water

The Monwabisi Park Community needs a basic level of water and sanitation services to ensure a healthy and safe lifestyle. Due to the lack of clean water and sanitation facilities within Monwabisi Park, disease from standing water is widespread. The people deposit their waste or excess water in the streets or neighboring yards, which causes pools of standing water to form. These sources of wastewater can pollute the soil, groundwater, or surface water into which they run (Granfone *et al.*, 2008). The lack of properly working drains in the area also results in wastewater collecting in the streets and standing for long periods of time. Untreated standing water harbors the growth of microorganisms (Disaster Mitigation for Sustainable Livelihoods Programme, 2006).

Young children are at risk for environmental health effects because they play in the water. During the winter, the amount of standing water increases with the amount of rainfall. Also, mosquitoes, which can carry malaria, use standing water to complete their life cycle. During summer months the stagnant water heats up, attracting flies. Residents suffer from diarrhea, cholera, and skin rashes as a result of the standing water in summer time. Informal settlements are also extremely prone to flooding due to the landscape and lack of drains. Floods not only add to the standing water, but also destroy homes (Disaster Mitigation for Sustainable Livelihoods Programme, 2006).

3.3.1 <u>Health Concerns</u>

Many of the diseases that affect people in Monwabisi Park are waterborne and are due to poor hygiene practices. Waterborne diseases are most common in areas which lack adequate water and sanitation services. The Indlovu Center clinic in Monwabisi Park is a facility to help treat diseases the community faces. Some of the more common diseases seen in this facility include cholera, malaria, and other diarrhea-causing ailments. The next sections discuss the severity of these diseases and how they affect the community of Monwabisi Park.

3.3.1.1 Hygiene

Educating the community about proper sanitation practices including hand washing and good personal hygiene is important for a healthy environment in Monwabisi Park. Some people find washing hands to be unnecessary, while others cannot afford soap due to their financial situation. Health education for the community has been ineffective due to lack of resources. Proper hygiene unawareness causes fecal-oral transmission of diseases to be very common in Monwabisi Park. People in the community use unwashed buckets to gather water from the standing pipes for daily household chores. In addition to using unsanitary buckets, the pipes are surrounded by standing water, which is contaminated with fecal matter. The water from the buckets is then carried home, the water is used and the diseases from fecal matter are ingested. Due to this lack of hygiene, diarrhea is a common symptom that affects the community. Each year in Khayelitsha, at least 80 children die from gastrointestinal diseases that cause diarrhea (Granfone *et al.*, 2008).

3.3.1.2 Waterborne Diseases

Cholera is a waterborne illness caused from the bacterium *Vibrio cholera* (WebMD, 2008). This infectious disease is transmitted from the ingestion of unhygienic water, usually water containing the feces of a person infected with the disease. Symptoms of cholera include diarrhea, leg cramps, dehydration and vomiting. Due to the intensity of the symptoms, this illness can be fatal if left untreated (Centers for Disease Control and Prevention, 2008).

Malaria is a mosquito-borne disease that is caused by the malaria parasite. Mosquitoes lay their eggs in standing water, which serve as breeding sites. The eggs develop into larvae, pupae and then grow into adulthood, a process which can take 9 – 12 days (Centers for Disease Control and Prevention, 2008). Those mosquitoes infected with the parasite transmit the disease when they bite their host. Because mosquitoes require stagnant water to complete their life cycle, the presence of such water increases mosquito populations and consequently increases the risk of malaria transmission. Symptoms of malaria include fever, sweats, and vomiting, and in severe cases can lead to death (Centers for Disease Control and Prevention, 2008). In South Africa, there were 77,854 malaria infections from 2000 to 2004, 875 of which were fatal (UNESCO, 2008).

3.4 Other Safety Concerns

As mentioned earlier, the laundry facility constructed by a team of WPI students was destroyed in a fire. The station was located next to the Indlovu Center, which used to house a community soup kitchen, pre-school, youth center, guest house, health clinic, and gardens. The fire, which took place in November 2008, destroyed the entire Indlovu Center and 25 surrounding shacks. Fires are not uncommon in Monwabisi Park. Many are started accidentally by paraffin stoves or candles, but some are the result of political unrest.

The destruction of the Indlovu Center and surrounding homes could have been lessened if the fire hydrants in Monwabisi Park were in better condition. Not only are there an insufficient number of hydrants, but when fires do occur, firefighters have difficulty finding them. Similar to the water taps, the markers used to locate hydrants are sometimes stolen and resold by Monwabisi Park residents to support their financial situation. Additionally, the hydrants are supplied water through plastic tubing. Because water taps are lacking, residents cut the plastic tubing and divert it to their homes to aid their water needs. This decreases the available pressure for fighting fires. When fires do occur, the low pressure water from the taps is not sufficient to properly extinguish the fire. Also, as mentioned above, less water is pumped to the informal settlements during the nighttime to reduce wasted water, lowering the water pressure in the system. Since most fires are caused by heating and lighting sources used primarily at night, the lower water pressure at these times is inadequate. In order to properly prevent fires in Monwabisi Park, the community needs more hydrants with proper pressure and markings to locate them.

In the areas surrounding the toilets and water taps, crime is not uncommon, especially where new toilet or tap facilities have been implemented. The structures used for building the toilets can have monetary value, which cause people to steal these materials and resell them. Also in these areas, rape is common, especially at night. People who walk long distances from their dwelling to the closet facility are targets for predators in these unlit and public toilet areas. Since the facilities are not monitored, people are discouraged from using the facilities due to these reasons and resort to the black bucket system or pit latrines.

3.5 Recommendations for Water and Sanitation Facility

To begin working toward a long-term water and sanitation solution, Granfone *et al.* (2008) recommended the construction of a "centralized water and sanitation facility." The facility would redevelop the current water services and hygiene practices for residents near the Indlovu Community Centre in Monwabisi Park. If successful, similar facilities would be installed across the informal settlement with the goal of eventually providing basic (or better) water and sanitation services to all residents of Monwabisi Park.

The report published by Granfone *et al.* (2008) listed key principles for ensuring the success of such a facility: water conservation, public health benefits, positive byproducts, an ability to be easily replicated, and awareness of safety, security, and accessibility concerns. The design they proposed focuses around these five principles.

The facility would give the community access to basic water and sanitation features including water taps, a laundry station, and toilets. It would also incorporate a hand washing station, a fire hydrant, and a set of shower stations. The water and sanitation facility would have a residence where a water and sanitation services specialist could live on-site. A plan view of the facility as recommended by Granfone *et al.* (2008) can be seen in Figure 13. The following sections describe the features of the facility in more depth.

3.5.1 Water Taps

Granfone *et al.* (2008) suggested the facility contain one water tap station with three individual water taps. The water taps would be operated by foot pedals. Currently, taps are often left running because people do not turn them off completely. A foot pedal would require a user to apply pressure to activate the tap, preventing waste of water. If no users were present, the tap would not run. The foot pedals would also reduce the transmission of disease because people would no longer need to touch the taps with their hands. The water tap stations would also have hooks or shelves so people could leave their buckets under the tap without having to hang them on the taps themselves. This should increase tap life. A sample image of the water tap station is shown in Figure 14.

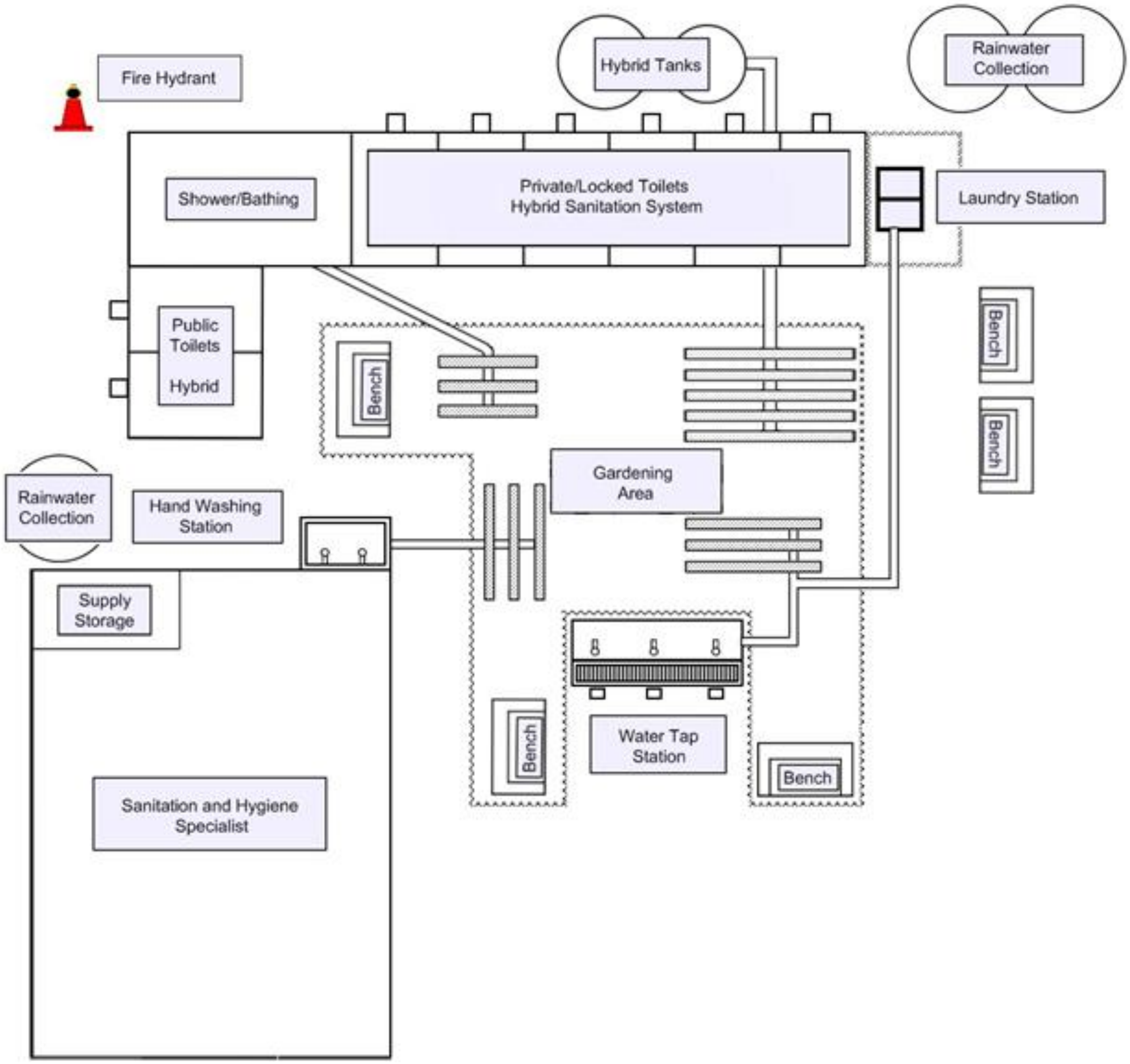

Figure 13: Proposed Water and Sanitation Facility (Granfone *et al.*, 2008)

3.5.2 Public Sinks

Public sinks would be part of the facility as well. Granfone *et al.* (2008) recommended the sinks use water primarily from rainwater collection tanks. Although the rainwater collection tanks are unlikely to supply sufficient water for full-time use, the strategy conserves water and reduces the demand on the municipal water system. Public sinks should encourage hand washing, especially if soap is provided. This would hopefully decrease the transmission of disease around the facility. Walking paths would lead people past the sinks as they exit the facility to further encourage hand washing. A sample hand washing station is shown in Figure 15.

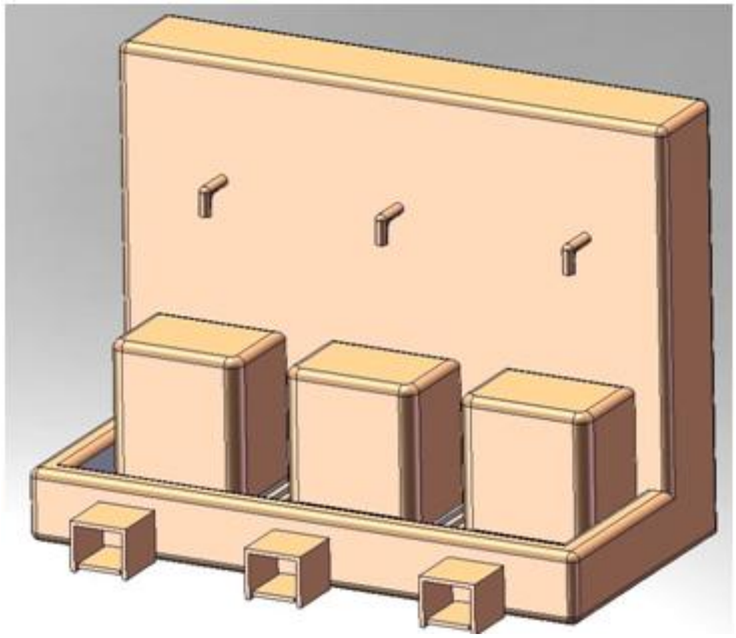

Figure 14: Proposed Water Tap Station (Granfone *et al.*, 2008)

Figure 15: Proposed Hand Washing Station (Granfone *et al.*, 2008)

3.5.3 Public Laundry Station

Another feature of the proposed facility is a laundry station. The community previously had a similar laundry facility, which was lost in a devastating fire. The laundry facility would include six individual laundry stations and primarily use water from rainwater collection tanks. As with the sinks, rainwater collection alone is insufficient to provide enough water for laundry year-round, but the option would conserve water and lessen the amount that needs to be pumped into the facility. Wastewater from the laundry station would be leached into a garden on the interior of the facility. Figure 16 shows a sample laundry station within the proposed facility.

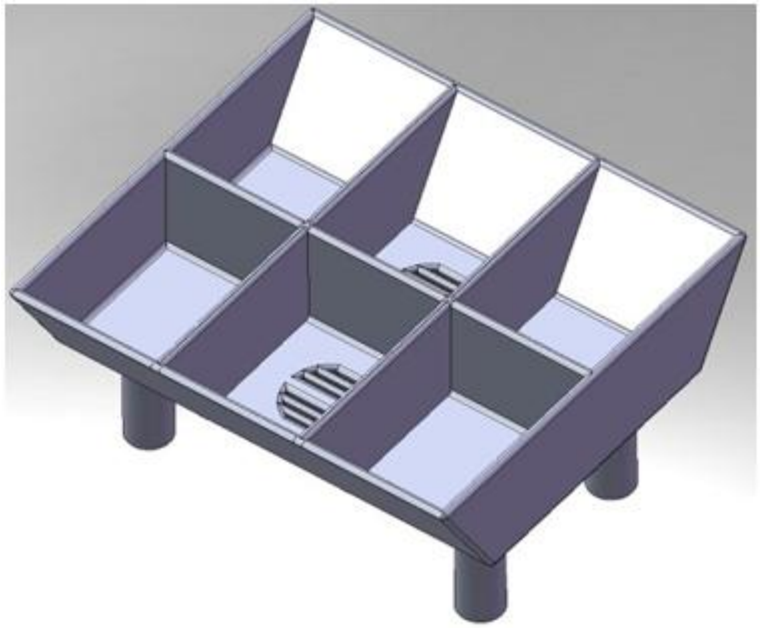

Figure 16: Proposed Laundry Facility (Granfone *et al.*, 2008)

3.5.4 Fire Hydrants

Since fire is a common problem in Monwabisi Park, Granfone *et al.* (2008) also recommended a fire hydrant be installed at the facility. The fire hydrant would be clearly marked or easily visible so the fire brigade could find it without delay in the case of emergency. The fire hydrant would be located in a public place as well to help deter vandalism.

3.5.5 Waterless Toilets

Perhaps the most important aspect of the water and sanitation facility would be the toilets. The report recommended two options for toilets. The Hybrid Vault Toilet System was recommended, but the Enviro Loo toilet system was listed as a viable alternative. These two particular toilets are described in greater detail in Section 4.1. Both systems require no water for flushing, making either a particularly good option where water is scarce. One option drains wastewater to a leaching field while the other dehydrates waste, producing compost. The toilets would be privately enclosed and locked. Each toilet would be shared by a few families. Each family would have a key to unlock the door to their toilet. One or two public toilets would also be on-site so passersby are less likely to break the locks off the private toilets. Furthermore, if friends with toilets in different locations choose to wash clothes together, a public toilet would allow the visitor to feel comfortable in the facility.

3.5.6 Site Layout

The proposed site layout by Granfone *et al.* (2008) is an L-shape as shown in Figure 17. The layout accomplishes many goals. Firstly, the L-shape provides for an open, community atmosphere that fosters community acceptance for good hygiene and sanitation. Inside the L-shape, a garden for growing crops has been proposed. Benches would be available in the garden area for people to rest while they wait to use the laundry station, water taps, or toilets. The L-shape would face the community center, and be partially fenced in to encourage pedestrian flow through one main entrance. Since all people must enter and exit the facility through one main access point, it would be easier to identify everyone entering the facility, hopefully decreasing vandalism. The site layout does not take space constraints for a particular site into account.

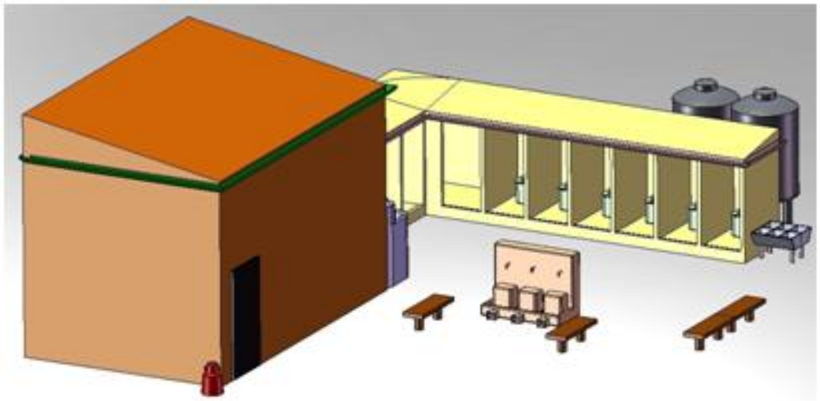

Figure 17: Proposed Site Layout (Granfone *et al.*, 2008)

3.5.7 Water Services Specialist

The design proposed by Granfone *et al.* (2008) also includes a residence for a Water Services Specialist to live on-site. This position would be filled by a trusted member of the community. The Water Services Specialist would be responsible for maintaining the Water and Sanitation Facility. He or she would clean the facility regularly, make any minor repairs, and educate people on how to use the facility and the importance of proper hygiene. Also, since the Water Services Specialist would almost always be on-site, he or she would serve as a crime deterrent and help ensure the safety of the facility.

3.6 Summary of Current Conditions

It is clear from the study by Granfone *et al.* (2008) that water and sanitation services in C Section of Monwabisi Park are far below the basic level prescribed by South African national law. Table 7 summarizes the current water and sanitation services in comparison to the definition of basic services. Some people must walk more than 10 times the legally prescribed distance to reach a water tap. Also, 69 families must share one toilet. This is far more than the legally required 5 family maximum.

Table 7: Comparison of Basic and Current Services

Services	Basic Services	Current Services
Water	1 tap / 125 people	1 tap / 442 people
	25 liters / day	120 liters / day
	Within 200 meters	Within 2000 meters
Sanitation	1 toilet / 5 families	1 toilet / 69 families

To correct the water services shortfall across C Section, a minimum of 53 water taps is required. There are currently only 27 taps installed, 15 of which are functional. Thus, 38 more functional taps are needed to provide basic services. Similarly, there is a large shortage of toilets. A minimum of 266 toilets is required to provide basic services, but there are only 92 toilets installed. Therefore, about 175 more toilets are required to reach basic services.

Figure 18 displays the flow of water from the city distribution system to the home of a Monwabisi Park resident. In this figure, the black boxes represent water that has been used and contaminated. As shown by Figure 18, almost all of the water used by Monwabisi Park residents is wasted after it is used. This dirty water is disposed of in the streets and yards of residents, contributing to the high amounts of standing water that pose potential health risks. Current water use practices provide no means for used water to either be treated or reused.

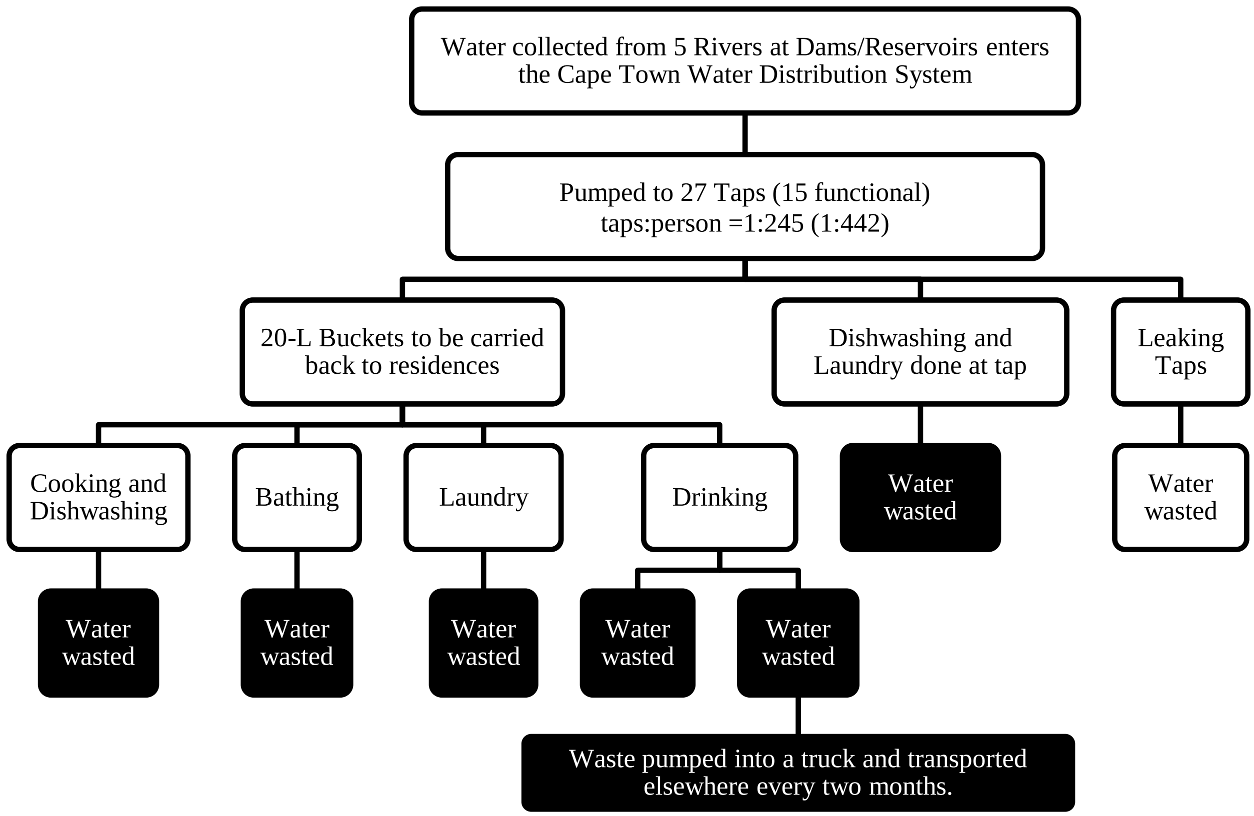

Figure 18: Water Flow through the Community

In conclusion, to improve current conditions in Monwabisi Park, not only must services be increased, but water treatment and reuse must also be implemented. Over time, these improved practices will conserve water and reduce standing water in the community.

4 Water and Sanitation Facility: Evaluation of Components

The focus of this Major Qualifying Project was to design an easily replicable water and sanitation facility for the C Section of Monwabisi Park. Targeting the problem of water and sanitation services at the local level, the facility should promote a healthy community and environment, embody the ideas of sustainability, and, most importantly, help satisfy the needs of the residents in that part of the community. The facility will not only include toilets and water taps, but showers, laundry and hand washing stations to further promote hygiene. If multiple facilities are installed across C Section, these local solutions should advance the level of water and sanitation services community-wide.

This chapter describes the methods used to analyze each component of the facility. Though each component was evaluated based on similar criteria and with similar goals, the toilet evaluation was done separately, through a direct comparison of the options available. Section 4.1 provides an in depth description of how each toilet treats the waste. The evaluation in which the final toilet option was chosen is explained in Section 4.2. Section 4.3 contains the evaluations for each of the other components found in the facility. These components were evaluated based on their benefits to the community, public health, and water conservation.

4.1 Toilet Options

One of the most important characteristics for the design of the water and sanitation facility was the type of treatment process employed to manage human waste. For that reason, many different types of toilets were considered. They include bio-digesting toilets, composting toilets, full flush toilets, the Afrisan Toilet system, the Biolytix Toilet system, the Hybrid Vault Toilet system, and the Enviro Loo toilet system. After initial consideration, several of these toilet options were ruled out because they were unsuitable to meet the needs of the community.

Bio-digesting toilets are designed to maximize methane capture from decomposing waste. Once the methane is captured, it can be burned as an energy source for cooking or heating water. Unfortunately, without the addition of animal wastes in addition to the human wastes in the bio-digester, insufficient methane is produced to make the bio-digesting toilet an economically feasible option. In addition, the concentrated methane would be an additional fire hazard in a community that has struggled with fire damage in the recent past. The insufficient methane production and possible safety hazards precluded the use of bio-digesting toilets in the water and sanitation facility.

Composting toilets treat waste through bacterial digestion. After digestion is complete, a nutrient-rich compost remains, which can be added to gardens to nourish crops. Composting toilets, however, require significant regular maintenance. After several uses, the vault below the toilet fills with compost and undigested human waste. This compost must be frequently removed, or the vault will overflow. Other nutrient-rich additives, such as food scraps, must be added on a daily basis to ensure proper composting. Because of the high level of required maintenance, the composting toilet was deemed an unsuitable option.

Afrisan toilets are waterless, dry composting toilets. Urine is diverted into a vault separate from solid waste. The urine is evaporated while the solid wastes are composted. The compost can be added to gardens to nourish crops. Like traditional composting toilets, Afrisan toilets require significant regular maintenance and additives such as peat moss to ensure proper composting. The Afrisan also has a low user capacity (one family per toilet). The considerable regular maintenance and minimal capacity make the Afrisan toilet an undesirable option for a community water and sanitation facility.

Full flush toilets use water to flush human waste away from the toilet to a community wastewater treatment plant. Flush toilets require significant water resources to operate. In addition, the wastewater must flow by gravity or be pumped to a municipal treatment plant. As mentioned above, water resources are limited in Monwabisi Park. Monwabisi Park is also in a low-lying area, so gravity flow to a treatment plant is not feasible. The wastewater would need to be pumped, requiring a significant and reliable source of electricity to operate the pumps. Furthermore, flush toilets require a sewer network to divert wastewater to a treatment plant. No such infrastructure currently exists in Monwabisi Park, and installation of a sewer network would be prohibitively expensive. Because of this, full flush toilets were not considered for the design of the water and sanitation facility.

After eliminating these toilet options, three choices remained to investigate further: the Enviro Loo toilet system, the Hybrid Toilet System, and the Biolytix toilet system. These three options mirrored the recommendations of Granfone *et al.* (2008). They recommended the Hybrid Toilet system and the Enviro Loo toilet system. Granfone *et al.* (2008) also suggested the Biolytix toilet system could be a cost-effective option in the future, but did not include the system in their final recommendations. These three toilet systems are discussed and compared in the following sections.

4.1.1 Enviro-Loo

The Enviro-Loo is a dry human sanitation system designed to treat waste in areas where water is scarce. Developed by Dr. Brian E. La Trobe in South Africa in the early 1990s, the Enviro-Loo has won several awards for its innovation and environmental awareness. Since 1993, 25,000 Enviro-Loos have been installed worldwide (Clean Up America, 2009). Unlike “conventional” water-based sanitation systems, the Enviro-Loo requires no water, making it a practical option for remote areas not connected to a municipal water source or lowland areas where pumping wastewater away is expensive.

The Enviro-Loo treats waste primarily through dehydration and low-temperature pasteurization. When urine and feces enter the toilet, they are separated by gravity. Solids fall onto a flapper, which casts solid wastes onto a drying plate. The liquid runs off the tray to the bottom of a 250-gallon vault. An external, wind-powered fan draws air through the vault, accelerating the drying of the solids and the evaporation of the liquid in the bottom of the vault. The vault is typically installed on the sunny side of the structure. The vault is painted black and faces the sun to maximize the capture of solar energy and increase the temperature in the vault. If the temperature in the vault is greater, the evaporation process is accelerated. Over time, the liquid portion evaporates, and the solid portion dries until it is less than 10% of its original volume.

The increased temperature in the vault from solar energy also serves to pasteurize bacteria and other organisms present in human waste. Pasteurization is the process of sterilizing a liquid by raising its temperature for a length of time. If temperatures are higher, the necessary time for sterilization is shorter. If the temperature is lower, the pasteurization process can still occur; however, a longer time is necessary. Figure 19 shows pasteurization effectiveness as a function of temperature and time. At temperatures over 65° Celsius, pasteurization can be achieved in less than one hour. Pasteurization is still effective at temperatures around 45° Celsius provided a one week sterilization time is provided.

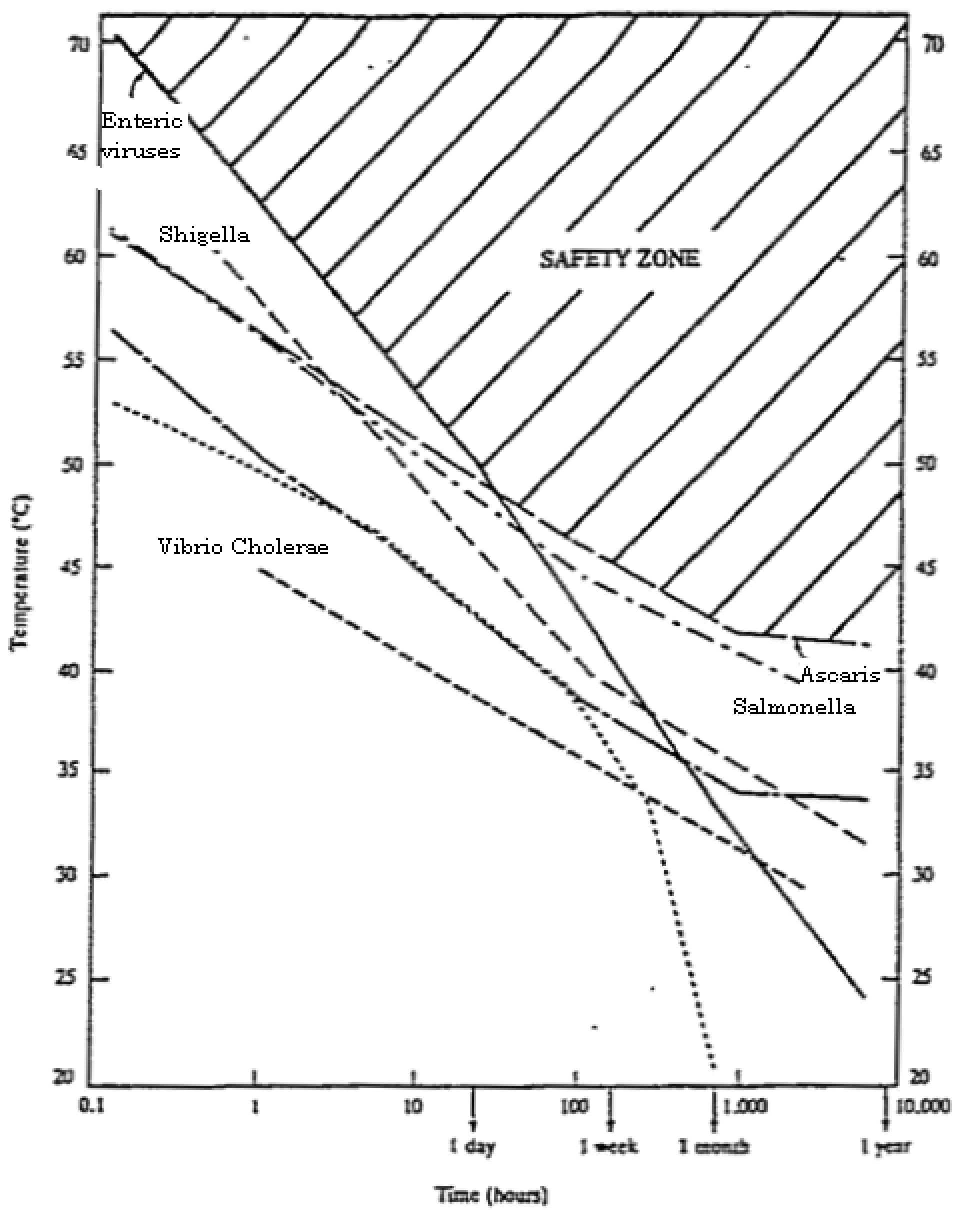

Figure 19: Temperature-Time Chart for Safe Water Pasteurization (Feachem *et al*., 1983)

There are many benefits of using the Enviro-Loo system. Because the system is waterless, it can be installed virtually anywhere and is independent of municipal water sources and wastewater treatment. The system significantly reduces the volume of waste, and thus the vault only needs to be emptied once every six months to three years, assuming twenty users per day. This minimizes the cost associated with managing the solids. Following evaporation, these solids can be added to a compost pile for three weeks to further digest. After digestion, these solids can be bagged and sold as compost. Routine maintenance only involves raking or scraping the drying plate, so minimal technical skill is required for regular operation. No maintenance trucks or other heavy equipment are required for scheduled maintenance.

There are few moving parts to this system, so it is unlikely to need repair. If installed outside, the system operates without electricity because the fan, which draws air through the vault, is completely wind-powered. The vault is made from polyethylene, a relatively inexpensive yet durable material. Because of the durability of the materials used, a lifetime of greater than 20 years can be expected. Additionally, odors are minimal due to one-directional air flow through the system and evaporation. The Enviro Loo is a low-cost sanitation alternative, with a cost of R5300 ($550).

Some drawbacks to the Enviro-Loo system may preclude its use in certain situations. For example, maintenance is required for proper operation. Every six months to three years, the remains on the drying plate need to be scraped or raked into a storage bag. This bag must then be removed every two or three years. The Enviro-Loo requires sunlight and wind to dehydrate waste most effectively, so it should be installed in a north-facing area with the vent chimney facing the prevailing wind. The facility should face north to maximize sun exposure in the Southern Hemisphere. The Enviro-Loo is also limited in its capacity. One Enviro-Loo toilet has a capacity of 60 uses (20 users) per day. However, multiple Enviro-Loo toilets can be placed side-by-side, allowing for a facility to service more people daily.

4.1.2 Hybrid Toilet

The Hybrid Toilet system was developed in Australia in the 1990's by Paul Turner and Mark Langford. The toilet was initially developed for Aboriginal communities that did not have access to a sufficient water supply. Because this lack of water made it impractical to use flush toilets in their community, there was a strong need for a non-flushing toilet. After researching different systems, the inventors designed the Hybrid Toilet, which is a design which combines aspects of a composting toilet and a septic system (Aussie Things, 2005). The Hybrid Toilet is similar to a composting toilet because it breaks down waste, inactivating pathogens, and then the waste percolates into the gravel bed, like a septic system (Gough Plastics, 2007).

The treatment process takes place in two different tanks before it is discharged into the ground. The primary tank is placed directly below the toilet so waste enters it immediately. Upon installation, the primary tank is filled with water. When waste enters, anaerobic bacteria break it down forming a sludge, which settles at the bottom of the tank. Anaerobic activity digests the solid waste to five percent of its original mass (SA Biotech, 2008). Optimum conditions for anaerobic activity are a pH of 6-8 and a temperature of 30-37° Celsius. There is no mixing within the tank; therefore, a steady gradient of decreasing oxygen levels exists with the highest concentration of oxygen at the top. As new waste enters, displacement forces water out of the primary tank into the separation chamber. Since gas is formed during the anaerobic activity, solids can sometimes be carried to the top of the primary tank. However, the separation chamber is specially designed with thin slots so that larger solids cannot pass through.

After passing through the separation chamber, liquid enters the secondary tank. The secondary tank contains a series of baffles made of a plastic media on which microorganisms grow. The microorganisms degrade any remaining organic material in the liquid. The baffle walls increase the travel distance of the water through the tank, thus increasing the retention time in the tank. This increased retention time increases surface contact with the plastic media, thus resulting in more opportunities for microbial degradation and a higher quality effluent. Aeration is provided through tank ventilation, supplied by either a standard rotary ventilator or a fan that can be run by solar power or a 12-volt DC adapter. After treatment in the secondary tank, the effluent is discharged directly into the ground where it percolates through the soil for greater purification. If the system is used correctly, then one liter of liquid will be discharged per person per day.

The effluent from one Hybrid Toilet in Townsville, Queensland, Australia was tested in 1998. The results of the test are summarized in Table 8. The table shows the Hybrid Toilet can produce a much cleaner effluent quality when compared to septic systems, pit latrines, or sewage treatment plants. One major advantage is the low levels of *E. coli* in the discharge. The Hybrid Toilet had an average of 32 organisms per 100 mL, while the septic system, pit latrine, and sewage treatment plant averaged 600,000, 1,000,000, and 1,000 organisms per 100 mL, respectively. Other test results included biological oxygen demand (BOD), which averaged 13 mg/L, volatile suspended solids (VSS), which averaged 12.2 mg/L, and a negligible amount of pathogens.

Table 8: Comparison of Waste Water Treatment Systems (Perks, 2009)

Characteristics	Septic System (to ground)	Hybrid Toilet (to ground)	Pit Toilet (to ground)	Sewage Treatment Plant
Persons	10	10	10	Variable
Avg. Water Use (L/day)	200	0	0	Variable
Avg. Effluent Discharge (L/day)	200	11	12	Variable
Avg. *E. coli* (organisms/100 mL)	600,000	32	1,000,000	1,000
Avg. BOD (mg/L)	250	13	Very High	20
Avg. VSS (mg/L)	250	12.2	Very High	30
Treatment Period	2-5 days	140 days	0	6-8 hours
Health Risk to Receiving Waters	High	Negligible	High	Negligible

The Hybrid Toilet has several advantages in addition to having a high effluent quality. The Hybrid Toilet is especially advantageous in terms of maintenance. For instance, the sludge needs to be removed only once every four to seven years. Because this is done so infrequently, it would be feasible for the city to travel to informal settlements to complete this task. Additionally, the system has no moving parts and therefore requires no mechanical maintenance. Other advantages of the system are that it is odorless, does not clog, and requires no additives. The system is closed, and therefore people are protected from contact with the waste. With respect to climate conditions, the system is resistant to floods and high water tables; contaminants cannot be released during a flood occurrence. Lastly, the system can handle isolated cases of overloads, so if it is overused there will still be a high effluent quality. However, if the system is continually overloaded, effluent quality may decrease.

One Hybrid toilet can service 25 people. However, two toilets can be placed above one primary tank. Additionally, three primary tanks can all discharge to one secondary tank. Therefore, six toilets with three primary tanks and one secondary tank can be installed to service 150 people. The average sizes of the primary and secondary tanks are 1.6 and 1.2 meters in diameter, respectively. Tank sizes vary according to projected use. The cost of one system, servicing 25 people, is 14,150 Rand. Thus, the cost per person is 566 Rand.

One disadvantage of the Hybrid Toilet is that effluent quality is not monitored. Since the effluent is discharging directly to the ground, if quality worsens it could contaminate the groundwater. Thus, the system must be regularly maintained to ensure that effluent quality remains high (Seeger & Strobes, 2008). One other disadvantage is that the anaerobic process is dependent upon temperature and pH. Both of these aspects could be difficult to regulate. However, under non-ideal conditions, digestion can still occur at a reduced rate. Since the sludge remains in the tank for four to seven years, this long retention time may compensate for reductions in process efficiency.

4.1.3 Biolytix

The Biolytix system is a natural household wastewater treatment system that uses living organisms to treat wastewater into reusable water. Using nature as inspiration, Dean Cameron, an ecologist, worked to develop a sanitation system that mimicked environmental processes for decomposing organic matter. After four years and an investment of $4 million, Cameron designed a natural sanitation system that was cost efficient and low maintenance: the Biolytix system. This system has won many awards over the years, including the Australian Academy of Technological Sciences and Engineering Clunies Ross Award for Science Innovation (Australia's most prestigious science innovation award), the Asian Innovation Award 2007, the EPA's Sustainable Industries Award, and the Green Plumber's National Award.

The Biolytix system uses organisms (worms and microbes) to break down the solid waste into humus, which cleans the wastewater like a filter. This effluent can later be used to irrigate gardens. The Biolytix system consists of three filtration processes. The first process begins once the waste from the flushing toilets is dumped into the first layer. The top layer performs like a filter and is formed of coarse mesh bags filled with plastic media. This media acts as a soil ecosystem for the organisms. The organisms break down the waste into humus and the remaining organic matter filters through organism-made humus tunnels onto the next layer. The second layer consists of humus and coco-peat compost, which is "90% water by weight, yet has a high cation and anion exchange capacity" (Biolytix, 2009). This layer behaves as another ecosystem for the organisms. These organisms form a natural filter system by making tunnels and aeration pores in the humus. Because of its ion exchange ability, this layer removes all odors, making this an odorless system, as well as removing the bacteria and toxins in the waste, which are later consumed by the beetles and worms.

The effluent from the second layer then travels through to the final layer, the Geofabric filter, where all particles greater than 90 microns are removed. The water is then fed into the sump, which acts as a settling tank. The clean water is pumped up through the center of the filter and released underground through an irrigation system, to reduce any health risks. This irrigation system is designed to allow the effluent to evenly distribute in the soil slowly. The three filter process of the Biolytix is shown in Figure 20.

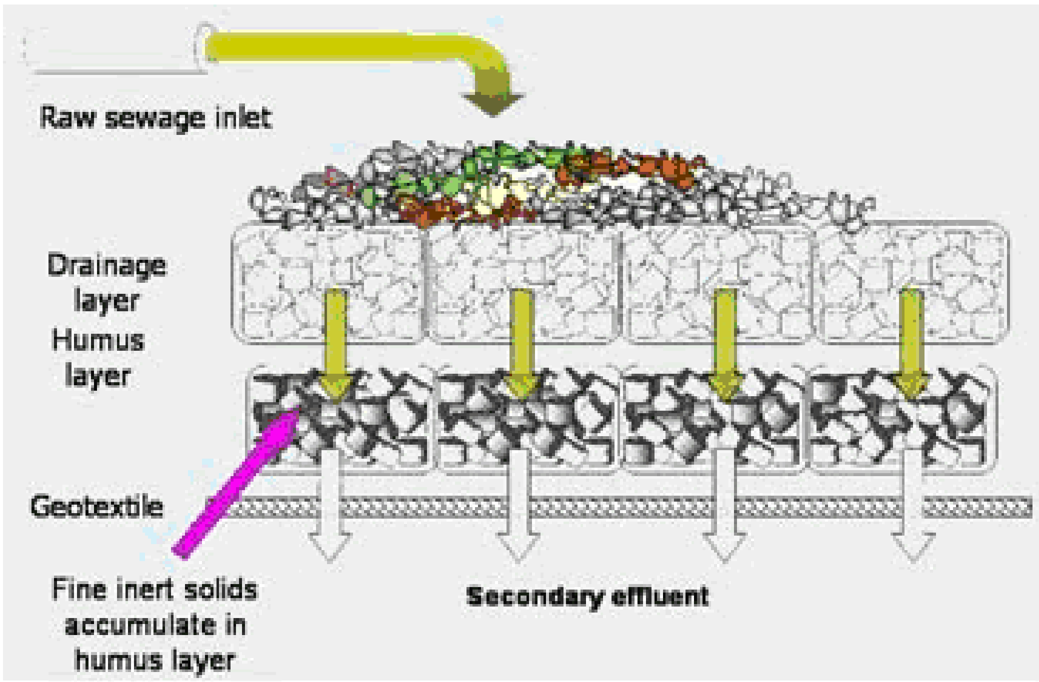

Figure 20: The Filter Process of the Biolytix System (Biolytix, 2009)

The filters that comprise the Biolytix system are contained in a 3000-liter polymer tank. The system needs 40 watts/day of electricity to support the industrial strength pump and air pump to bring the water to the irrigation system. Figure 21 shows the design of the tank (Biolytix, 2009). Each tank can treat 2200 liters of wastewater per day and results in a “3-4 log reduction in thermotolerant coliforms” (Biolytix, 2009).

The Biolytix system is a preferred choice in South Africa. These systems can be found in areas where low maintenance and quiet systems are desired. At the Onguma Safari Camps in Etosha, Namibia, 38 Biolytix systems are already installed over the 20,000 hectare Onguma Nature Reserve. The Bushmans Kloof Wilderness Reserve in Western Cape, South Africa uses the effluent from the wastewater to irrigate the landscape, as does the World Wildlife Fund Guesthouse, in Stellenbosch, Western Cape, South Africa (Biolytix, 2009).

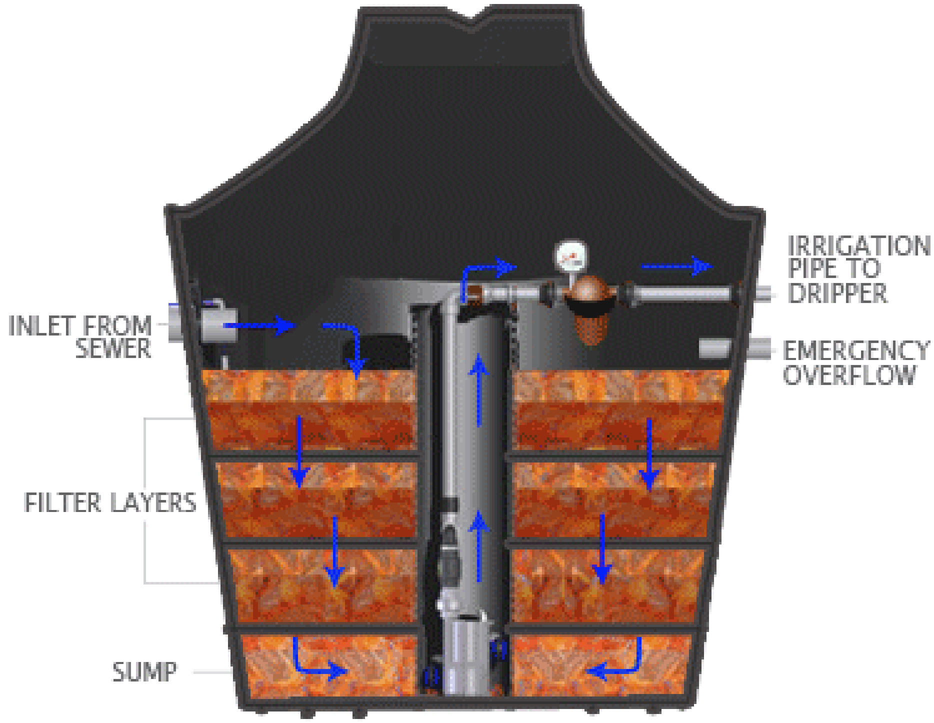

Figure 21: The Biolytix Design (Biolytix, 2009)

Not only does the Biolytix system offer an odorless and low maintenance sanitation system, the Biolytix uses natural resources to treat wastewater. Because it recirculates water, it is a sustainable alternative to other sanitation systems. However, the pump uses electricity and may require maintenance if broken.

4.2 Evaluation

Both the Enviro Loo and the Hybrid Toilet were analyzed against the list of criteria in Table 9 to identify the type of toilet most suitable for the water and sanitation facility in Monwabisi Park. The Biolytix system was not included in this ranking. The Biolytix Company stated that the company will not install their product in informal settlements at this time, which made the Biolytix system no longer a viable option for the water and sanitation facility (Hawke, 2009).

Both the Enviro Loo and Hybrid toilet achieved satisfactory removal of pathogens, thus meeting public health concerns. These systems also accommodate the maximum users per day to meet government-defined basic sanitation services levels (5 families per toilet). Both options do not produce any energy and have a high estimated lifetime. Because both systems meet the necessary conditions for these standards, these criteria do not affect toilet selection. The following sections discuss criteria in which the two systems differ.

Table 9: Toilet Evaluation Criteria

Category	Criteria	Enviro Loo	Hybrid
Efficiency	Pathogen inactivation	High	High
Operation & Maintenance	Frequency of maintenance	Medium (6 months - 3 years)	Low (5-7 years)
	Technical skill required for maintenance	Low	Low
	Operation Requirements	Medium	Low
	Water requirements	None	Low (Installation)
	Road Access required	No	Yes
Byproducts	Energy production	No	No
	Compost production	Yes	No
	Sludge production	None	Low
	Effluent	None	Low
Energy Demand	External Energy Requirements	Yes (sunlight/wind)	None
Design Parameters	Number of Users per Day (people)	High (20)	High (25)
	Estimated Lifetime	High	High
	Size of Unit (meters)	Low (0.93 x 2.36)	Medium (1.6 x 2.8)
	Space Demand (meters)	Medium (1.37 x 3.63)	Medium (1.6 x 4.07)
Cost	Product Cost (Rand)	5,300[1]	14,150[2]
Community	Community involvement	Medium	Low
Case Studies	Study Feedback	High	Medium

[1]Excludes: toilet cubicle, VAT, transportation, installation, drying bag (optional) (R135.00)
Includes: anchor device and overflow connector
[2] Excludes toilet cubicle, VAT, transportation, installation

4.2.1 Operation and Maintenance

The Hybrid toilet requires little maintenance involving the use of City of Cape Town trucks to remove the waste every five to seven years. The sludge from the Hybrid toilets needs to be pumped out at the expense of the city since the community does not have the means to do this task themselves. In addition to maintenance needed from the City, the effluent from Hybrid toilet also needs to be closely monitored to ensure clean effluent is being released into the ground. The other toilet option, the Enviro Loo, requires on-site maintenance from the community only once every six months. The toilet uses a dehydration process to dry out the waste into useable compost. This waste needs to be raked every so often to expedite the dehydration process. Both toilet options can handle the occasional foreign object in the system. It is very easy for the object to be identified and removed from the facility when the system is maintained.

The toilet would preferably be maintained on-site, without the use of city trucks and workers. It takes city employees longer than community members to address problems with sanitation facilities. Trucks cannot access a facility that is not located along a main road. Therefore, the Hybrid system, which requires trucks to pump out waste, is not a viable option for facilities without road access. The facility must either be built along a main road, or it must use a technology that does not require trucks or other heavy equipment to maintain. The Enviro Loo does not require the use of road access, since it can be easily maintained on-site.

Maintenance is not necessarily a drawback to a technology. A system that requires some maintenance encourages community involvement. Therefore, the families would take ownership of their facility and would be more likely to take proper care of it.

It is also necessary that the toilets can be easily installed in the facility. Both systems require ground excavation. The Enviro Loo toilet comes with a pre-fabricated tank, making it easily implementable. The Enviro Loo Company also trains the users how to install the toilet and shows them how to properly use the toilet. The Hybrid toilet requires water upon installation. Due to the scarcity of water, waterless toilets are a practical option. Not including Hybrid installation, both systems are waterless. The high water table prevents large amounts of water from easily infiltrating into the ground, so systems that require less water disposal are favorable.

4.2.2 Byproducts

The Enviro Loo is a waterless system that produces compost. After being dehydrated within the system, the waste is removed to complete the composting process. It can then can be sold for profit or be used on a garden. The Hybrid system does not produce compost, but does discharge effluent into the ground. Because of past case studies, as mentioned in Section 4.1.2, this effluent needs to be closely monitored to ensure groundwater contamination is not occurring. In addition to effluent discharge, the Hybrid system produces sludge. Although sludge can provide nutrients and can act as a fertilizer, this sludge requires the use of City Trucks to pump out the waste, and therefore the facilities must be located along main roads.

4.2.3 Energy Required

Both the Enviro Loo and the Hybrid toilets do not require the use of electricity to run the systems. The Enviro Loo is the only toilet that requires energy to function. Sunlight is necessary for the Enviro Loo to complete the dehydration process for the compost. Wind energy is also needed to power the fan, which also aids in the dehydration process by drawing air through the vault.

4.2.4 Facility Size

Constraints such as space demand and estimated lifetime were analyzed when identifying the more suitable toilet for the community. If the toilet required little space, more toilet facilities could be implemented in the limited area for the facility. The Enviro Loo toilet required less space than the Hybrid Toilet. The Enviro Loo unit required an area of 0.93 by 2.36 meters, while the Hybrid Toilet needed 1.6 x 2 meters. When including the structure around the toilet, the area required for each facility increased. The total space demand for the Enviro Loo is 1.37 x 3.63 meters, while the Hybrid needed an area of 1.6 x 4.07 meters.

4.2.5 Facility Cost

Cost was also taken into consideration, but to a lesser degree. It was deemed more important to have a facility that would be certain to work for several years (or decades), even if the cost were slightly higher. The cost of the Enviro Loo is R5300. This includes an anchor device and an overflow connector. The cost for a Hybrid is almost triple that of an Enviro Loo. The price of a Hybrid is R14150. Both these prices do not include toilet cubicle, VAT, transportation or installation.

4.2.6 Case Studies

A study was done in 2008 in Tasmania's Narawntapu National Parks, which monitored the effluent quality of three different Hybrid Toilet systems. The report concluded that two out of the three systems effectively treated the waste. However, the third system was discharging a low quality effluent. The effluent contained low levels of fecal coliforms, but high levels of total suspended solids and BOD. The problem occurred due to improper installation. The results of this report reiterate that the system must be regularly maintained and monitored to ensure that the effluent is not contaminating the groundwater (Seeger & Strobes, 2008).

The Enviro Loo has already been implemented successfully in many areas across South Africa and around the world. Enviro Loos have been installed at schools, conference centers, national parks, and informal settlements in South Africa. Figure 22 shows multiple Enviro Loos installed in close proximity in another informal settlement in South Africa. They have been installed in the United States at Boy Scout Camps and Golf Courses. Enviro Loo toilets can also be found in France, Australia, Dubai, and Namibia. Each of these case studies reported positive feedback; the Enviro Loo effectively treated the waste (Belzak, 2009).

Figure 22: Enviro Loo Toilets at an Informal Settlement (Clean up America, 2009)

4.3 Evaluation of Remaining Components

The primary goals in designing a water and sanitation facility are to provide a sustainable solution that improves public health and to satisfy the needs of the community. To ensure that these goals are met, additional amenities were considered for inclusion in the facility. These amenities include rainwater collection tanks, a dishwashing station, water taps, a laundry station, hand washing sinks, showers, a garden, the Water and Sanitation Specialist, and other various safety features.

These components of the water and sanitation facility were evaluated to determine whether or not they are suitable and necessary for Monwabisi Park. Each component was evaluated based on its contribution to improving current practices and its impact on the community. These two considerations are expanded in Table 10. Current practices in Monwabisi Park that must be improved are water usage (decreasing the amount wasted), decreasing standing water, improving public hygiene, and reducing the vandalism, theft, and misuse of public property. However, the foremost priority is to provide safer, healthier, and more convenient access to water. A component can be considered as having a positive impact on the community if it will be accepted by the public and if it promotes positive interaction between residents.

Table 10: List of Evaluation Considerations

Current Practices	Reduces Water Usage
	Removes Standing Water
	Improves Public Hygiene
	Reduces Vandalism/Theft/Misuse
Community	Public Acceptance
	Promotes Interaction

Potential components were also evaluated based on water use. The volume of water being used under current practices was compared to estimated consumption rates if the different components of the facility are utilized. All water consumption rates were estimated with the help of Dianne Womersley, founder of the Shaster Foundation, and interviews with residents conducted by Granfone *et al.* in 2008.

4.3.1.1 Taps

Water taps at the water and sanitation facility can reduce standing water, improve public hygiene, and reduce theft, vandalism, and misuse. Currently, water taps are being damaged through misuse or vandalism. To prevent this from occurring at the water and sanitation facility, steps are needed to make taps easier to use and better supervised. The two most common ways taps are misused are hanging buckets off the taps and leaving water running. To remedy the first issue, shelves are recommended below the taps, so that buckets can rest on the shelf while being filled. Also, operation of the taps using foot pedals can prevent the water from being left running, which in turn prevents pools of standing water from forming around the tap. In addition, the foot pedal can reduce the transmission of disease at the water tap, since no one would need to touch the taps with their hands. The taps would also be supervised by a water and sanitation specialist, which can discourage vandalism. Two water taps are recommended for the facility to ensure basic service requirements are met. With two taps, 250 people could be serviced by the facility. If fewer than 125 people are serviced by the facility, the second tap would offer some redundancy in case one tap is broken.

4.3.1.2 Rainwater Collection Tanks

Rainwater collection tanks can reduce the amount of water needed from the city distribution system. Water for the dishwashing station, laundry station, and showers can be supplemented by a rainwater collection tank. Gutters on all of the toilet enclosures and the on-site residence can collect runoff from the roofs and redirect it to the tanks. If there is not enough rain water, water can be pumped through a hose from the tap nearby to refill the tank. Based on these considerations, rainwater collection tanks are recommended for the facility.

4.3.1.3 Dishwashing station

Providing sinks at the water and sanitation facility that can be used for washing dishes can improve current water use practices, reduce standing water, and promote community interaction. Currently in Monwabisi Park, dishes are either washed in the home or at the water taps. In either case, food scraps are washed away with the water used. These scraps can become breeding grounds for insects and disease if the water is dumped outside in the streets. If dishes are washed at nearby water taps, the scraps can eventually clog up the drainage area beneath them.

As a solution to these problems, dishwashing stations are recommended for the new water and sanitation facility. Upon arrival at the facility, food scraps can be scraped into a composting box and then brought to the sinks to be washed. Each sink would have a screen on the drain to ensure smaller chunks of food do not get into the drainage system. The sinks would include stoppers to allow filling of the sinks to conserve water. Water for the dishwashing station can be supplemented by the rainwater collection tanks. Waste water from the dishwashing sinks would infiltrate to the garden instead of contributing to standing water in the streets. In order for water from the dishwashing station to be used for irrigation, biodegradable soap must be used. Like the laundry station that once serviced the Indlovu Center, the dishwashing sinks would promote community interaction.

Currently, residents require about one bucket, or 20 liters, of water a day to wash dishes. However, if dishes are washed at the tap, the water will most likely be left running and therefore be wasted. However, the sink stoppers would ensure water is not left running, and thus be conserved. It is estimated that 19 liters of water would be used to wash dishes at the facility. Additionally, all of this water will be appropriately discharged instead of being left in the streets.

The dishwashing station can also be used to wash water collection buckets. Currently, residents transport their water from the tap back to their home using buckets. These buckets are often dirty and contaminate the water. Providing a quick and easy means to clean water buckets could improve drinking water quality and thus, public health.

4.3.1.4 Laundry

Having a laundry station at the facility can improve current water practices, reduce standing water, and promote community integration. A laundry facility previously built near the Indlovu Center was successful (Alex *et al.,* 2007). It became a community gathering place and helped the residents of the area to do their laundry in an efficient manner. The water and sanitation facility similarly focuses on creating a community atmosphere, particularly through a communal laundry facility. Six laundry sinks are included the design. The previous laundry station, which has since been destroyed by fire, contained four sinks. The six sink design can further encourage use of the laundry stations and community development. The sinks would include stoppers to allow filling of the sinks to conserve water. The laundry sinks would drain to an on-site leaching field described in Section 4.3.1.7, which requires the detergent to be biodegradable. The previous facility used a detergent known as Triple Orange (Alex *et al.,* 2007). Sinks would also have screens over the drains to prevent the leaching field pipes from clogging.

Current laundry practices require about 6 buckets of water per family, or 120 liters, two days a week for a total of 240 liters per week. Assuming that residents would still be doing laundry twice a week, it is estimated that this amount of water would decrease to 100 liters per day, or 200 liters per week, to reflect the amount of water that would not be wasted if residents use the laundry station at the facility. All of the water used would be discharged appropriately.

4.3.1.5 Sinks

Hand washing sinks are recommended for the facility to encourage cleanliness and increased hygiene in the community. Hand washing sinks placed by the exit of the facility force people to pass them as they move to their next activity. The location should serve to promote hand washing not only by convenience, but it should also remind people who have not made hand washing a habit. Soap for the sinks would be provided through the Shaster Foundation. The soap used is biodegradable and should not interrupt plant growth. To prevent the likelihood of theft, the soap would be in liquid form, dispensed from a fixture on the wall. Water from the sinks would drain to an on-site leaching field described in Section 4.3.1.7. The sinks would have drain covers to prevent large items from flowing into and clogging the pipes in the leaching field.

Since hand washing is not part of the current daily practices of many Monwabisi Park residents, adding this feature to the facility would require additional water. It is estimated that hand washing would require about 8 liters of water per day per person. This water increase would be largely outweighed by the public benefit it will provide. Hand washing sinks have the potential to greatly reduce the fecal-oral transmission that many residents are frequently exposed to.

4.3.1.6 Shower facility

Current washing practices in Monwabisi Park are usually limited to a sponge bath several times a week. To avoid making frequent trips back and forth to the water taps, water is shared by members of the household. Once everyone has used the water for bathing, it is disposed of in the streets. To encourage progress toward more complete hygiene practices including regular showering, two shower stalls are recommended in the water and sanitation facility design. The showers could be used by anyone who normally visited the facility. The showers would be supplied water by rainwater collection tanks. Water would drain into a garden leaching field as described in Section 4.3.1.7.

Currently, one household uses about 20 liters of water per day for sponge bathing. At the facility, it is estimated that a five minute shower would use about 40 liters of water per person. Therefore, having showers in the facility would increase the consumption of water. However, controlling the discharge would greatly reduce the amount of standing water. Additionally, changing practices from sponge bathing to shower would improve public health, hygiene, and standard of living in the community.

4.3.1.7 Garden Leaching Field

After water drains from the laundry, dishwashing, and hand washing sinks and from the showers, it would flow into a series of buried pipes which would drain into a leaching field. The pipes would have holes which allow water to infiltrate the soil. Above the pipes, a garden would be planted with a two-fold purpose. The garden would allow the community an area to grow crops. The plants absorb some of the wastewater from the facility, limiting the amount of land needed to leach the water away. The garden would be cared for by a specialist described in Section 4.3.1.8. The pipes would be installed underground in side-by-side 0.75 meter wide trenches 0.75 meters below the garden area. The bed of the trench would be layered with gravel to help accelerate infiltration. If the garden area is not sufficiently large to leach all of the wastewater from the facility, additional trenches would be constructed under the public paths near the water and sanitation facility to expand the size of the leaching field.

To find the necessary size of the leaching field, the following procedure was used. First, the amount of wastewater discharged by the facility was estimated using the summation of the water consumption rates of each component. These rates are summarized later in Table 12. The estimated total wastewater flow for an average day was 5,830 gallons (22,000 liters) per week. Estimated future peak flows totaled 12,400 gallons (46,900 liters) per week. With these water loads, the leaching field required a trench measuring 120 feet (36 m) in length. Calculations can be found in Appendix A.

4.3.1.8 Water and Sanitation Specialist

The position of water and sanitation specialist (WSS) would be filled by a respected member of the community. He or she must go through an interview process conducted by the Shaster Foundation before being hired. After obtaining the position, the specialist must be trained on proper hygiene by the City of Cape Town and the Shaster Foundation. The specialist would also be trained by Enviro Loo representatives on maintenance and use of the Enviro Loo toilet when they are installed.

The specialist would live in a house on-site and act as a liaison between the community members and the City of Cape Town. Any water or sanitation issue would be addressed to the specialist. Living on-site would increase the security and safety of the facility. The person in this position would have the authority to remove any unwanted visitors who may be vandalizing or misusing the facility. Additional duties of the specialist would include: monitoring and raking of the waste in the Enviro Loo toilets, managing the community garden, keeping all areas of the facility tidy and properly working, and distributing water buckets. This specialist would have a supply of toilet paper, hand washing soap, and laundry detergent readily available for the community members. He or she could also provide medicine to treat diarrhea. Responsibilities of the WSS also include refilling the water tanks for the showers, sinks, and laundry facility. The specialist would be in charge of instructing residents the proper use of each service. He or she should also promote the use of the hand washing sinks to improve hygiene.

It is not the job of the specialist to clean private toilet stalls. This should be done by the families that have been granted access to the restrooms. If families are not keeping up with the maintenance, then the specialist should notify them of this and instruct them in proper cleaning techniques.

The salary of the specialist (18,000 Rand per year) would be paid by the Shaster Foundation. This salary is an average full time salary for settlement residents. Compensation for the position would include living arrangements and an annual salary. Additionally, produce from the garden can be sold to the community at a reduced price or donated to the soup kitchen. Profit from the garden should be either donated to the Shaster Foundation, or saved for any improvements that need to be made to the facility such as a solar water heater.

Table 11 shows a cost analysis for the addition of the position of Water and Sanitation Specialist. It is more cost efficient to have a specialist on-site maintaining the toilets than to have unattended pour flush toilets in the community. On average, only 70% of the unattended pour flush toilets remain useable six months after installation (Granfone *et al.*, 2008). Since 30% of the toilets are unusable, the cost to install these non-functioning pour flush toilets is wasted and more money is needed to replace or fix these toilets.   The specialist attending to the toilets would prevent vandalism, theft, and misuse to the toilets, causing the Enviro Loos to have a much longer lifespan and less money spent annually on replacing or maintaining the toilets.

Table 11: Cost Analysis for Water and Sanitation Specialist

Toilet Type	**Pour Flush[1]**	**Enviro Loo[2]**
Supervision	Unattended	Attended
Price per Toilet (R)	8,500	5,296
Estimated Lifespan	4 years	50 years
Annual Capital Cost (R)	2,125	106
Maintenance Cost (R)	1,176	0
Attendant Salary per Toilet (R)	0	2,250
Annual Cost per Toilet (R)	3,301	2,356
Annual Cost per Family (R)	660.2	471.2
Toilets Functional after 6 months	70%	100%
Cost Spent on Non-Functioning Toilets (R)	990	0

[1](Granfone *et al.*, 2008)
[2](Parsons, 2009)

4.3.1.9 Safety Features

The supervision by the WSS should deter crime and vandalism, but other additions to the facility can be made to increase safety. Granfone *et al.* (2008) proposed a fire hydrant. This hydrant should be easily accessible by the specialist, firefighters, and the rest of the community. It should not be connected to the distribution system by plastic tubing as it has in the past. Proper piping should be used because in the past the tubing was cut and redirected, rendering the hydrant useless. Another safety feature is lighting. Outdoor spot lights should be on during the night to prevent vandalism and crime. Fences should also enclose the entire facility so that residents can only enter and exit through the specified area. This would allow the specialist to monitor everyone that enters the facility. Providing other services, including laundry stations and gardening, also socializes the facility and reduces problems.

4.4 Water Usage

The facility has been designed to accommodate 200 people, or about 40 families. This number of families would serve as its maximum capacity. Using the estimated water flow rates stated above for each component, the water flow through the facility was calculated for maximum and projected use. These results are shown in Table 12. According to Table 12, when the facility is being used to its maximum capacity, 58,000 liters are being used per week. Additionally, 47,000 liters are being discharged to the garden each week. The remainder of the water that is used is consumed through cooking or drinking. If the amount of water discharged exceeds the capacity of the garden, more piping can be placed in nearby pathways. When the facility is being used to maximum capacity, it is assumed that no laundry or dishwashing is done at the home, and therefore there is no water being discharged elsewhere in the community.

Table 12: Maximum Capacity Water Flow Rates

Service	Rate	Days/week	Total Water (L/wk)
Laundry	100 L/day	2	8,000
Shower	37.85 L/ 5 min	3	22,710
Dish-washing	18.92 L/load	7	5,298
Hand washing	7.75 L/day	7	10,850
Cooking/Drinking	40 L/day	7	11,200
		Total Water Used:	58,058
		Total Water Discharged to Garden:	46,858
		Total Water Discharged Elsewhere[1]:	0

[1]Does not include leftover water from cooking

However, it is assumed that when the facility first opens, it will not be utilized to its full capacity. Therefore, estimates have been made to determine the water flow rates for when components of the facility are not being fully utilized. It was estimated that only a small portion of the community members would use the shower facilities and dishwashing stations. These results are shown in Table 13. As shown, the total water used at the facility is 41,000 liters per week. This total includes the water that is taken from the taps in the facility and transported back to the home for various tasks. The total water discharged to the garden is 22,000 liters per week. The total water discharged elsewhere is 7,800 liters per week. This water may contribute to standing water. However, this is a dramatic decrease when compared to current practices, in which almost all of the water used is discharged to the streets.

Table 13: Projected Water Flow Rates

Service	Rate	Days/week	Total Water (L/wk)
Laundry	100 L/day	2	8,000
Shower at site	37.85 L/ 5 min	1	1,893
Dishwashing at site	18.92 L/load	7	1,324
Hand washing	7.75 L/day	7	10,850
Cooking/Drinking	40 L/day	7	11,200
Sponge Bathing	20 L/day	6	3,600
Dishwashing at home	20 L/load	7	4,200
		Total Water Used:	41,067
		Total Water Discharged to Garden:	22,067
		Total Water Discharged Elsewhere[3]:	7,800

[3]Does not include leftover water from cooking

As shown by Table 12 and Table 13, the total water used during maximum capacity conditions is higher than the total for the projected use. This increase can be mainly attributed to showering at the facility. When residents sponge bathe at home, water is often shared between members of the family. However, when the showers are used at the facility, each person is able to bathe in clean, fresh water. Although the showers would use more water, using them would result in better hygiene, a higher standard of living, and no standing water.

The flow of water through the facility under maximum capacity is shown in Figure 23. As shown, nearly all of the water is being treated and reused in the garden. The flow of water during the projected use of the facility is shown in Figure 24. In both figures the black boxes represent used or contaminated water. Most of the water is being treated and reused, yet some is still being improperly discharged.

By comparing Figure 23 and Figure 24 to Figure 18 in Section 3.6, it can be concluded that the facility would greatly decrease the amount of water that is wasted within the community. When water is wasted, it contributes to standing water, thus exposing the residents to public health risks. When water is treated in the facility, it is recycled and reused to water the garden. Additionally, any water that infiltrates through the garden or additional leach field would be naturally treated and thus would not be contaminating groundwater. Most importantly, water would be delivered to the community safely and reliably.

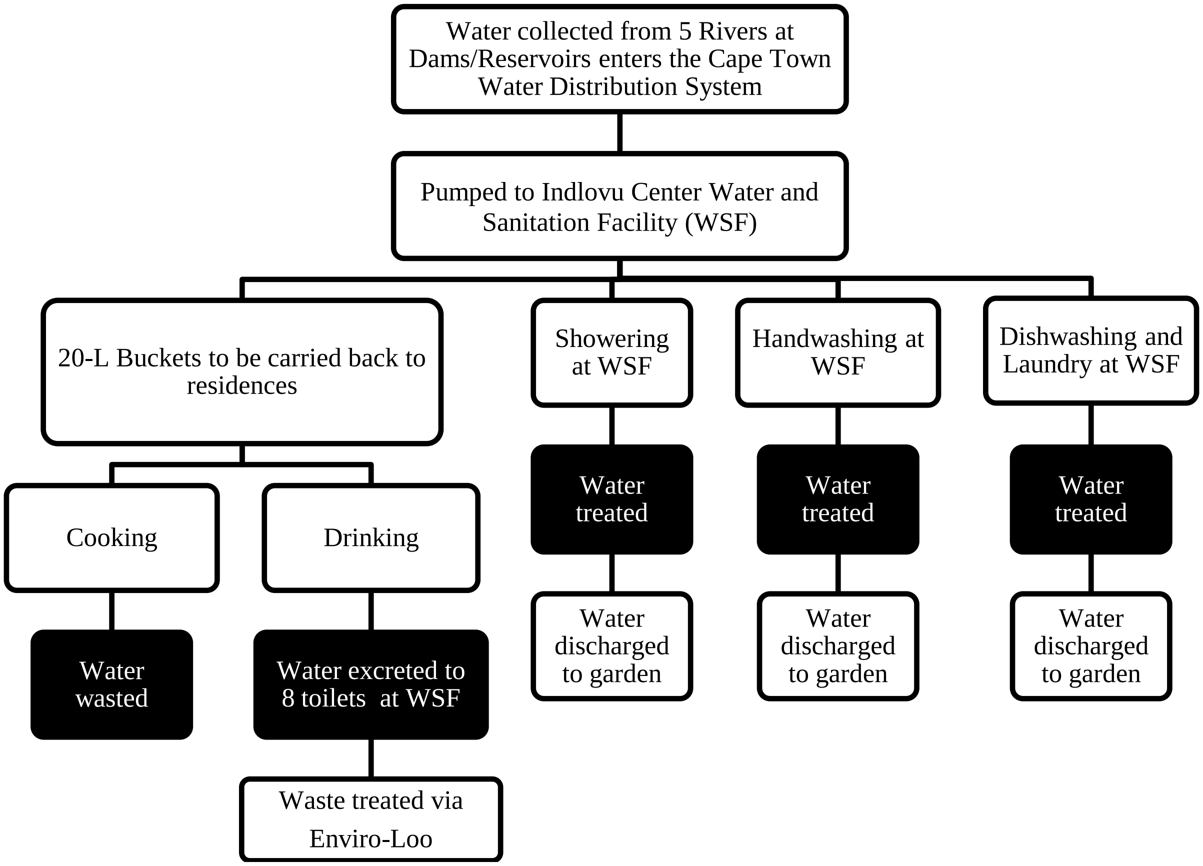

Figure 23: Water Flow under Maximum Capacity Conditions

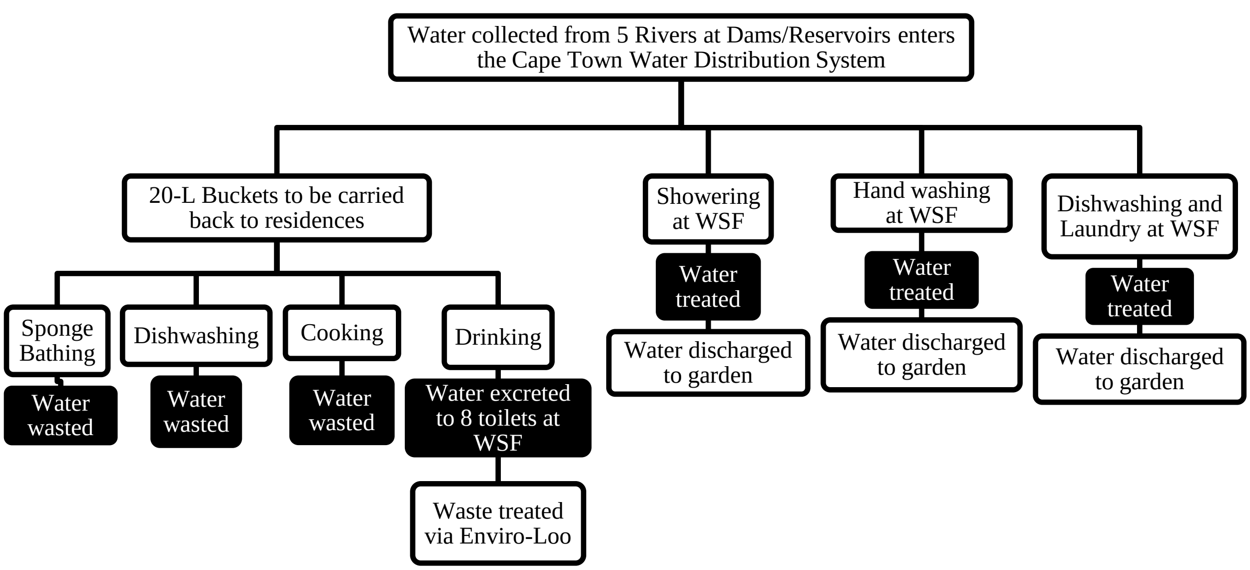

Figure 24: Water Flow under Projected Use Conditions

5 Final Design

As stated in Chapter 3, to achieve basic services in Monwabisi Park, 38 more taps must be installed along with 175 more toilets. The number of water and sanitation facilities needed to achieve or exceed basic services in Monwabisi Park is dependent on the number of families per toilet. As the ratio of families to toilets increases, more people are serviced and fewer stations are required for C Section. Although basic levels of service are achieved with a 1:5 family to toilet ratio, members of the community have indicated that they would like to have a ratio close to 1:1; a 1:3 ratio might be acceptable if the facility is tightly controlled and managed (Granfone et al., 2008).

Table 14 provides information on the user ratios required to achieve various levels of service across C Section of Monwabisi Park. For example, if up to 200 users are desired per facility, 33 facilities need to be constructed to achieve basic services. However, if more facilities are constructed, then basic services will be exceeded because fewer people will need to be serviced by each facility. If it is desired that only 120 people would be serviced by one facility, 55 facilities must be constructed. Then, the toilet to family ratio would be 1:3, while the tap to people ratio would be 1:60.

Table 14: Services Provided by Water and Sanitation Facility

Water		Sanitation			Total Results	
Number of Taps	**Tap: People Ratio**	**Number of Toilets**	**People per Toilet**	**Toilet: Family Ratio**	**People Serviced**	**Number of Stations**
2	1:48	8	12	1:2.5	96	69
2	1:60	8	15	1:3	120	55
2	1:80	8	20	1:4	160	42
2	1:100	8	25	1:5	200	33
Legal Ratio	1:125		**Legal Ratio**	1:5		

The final design of the water and sanitation facility incorporates the recommendations made in Chapter 4. The following sections present the detailed design, including a blueprint of the facility intended for the Indlovu Center. Variations to this design that can be implemented in other areas of C Section are also provided.

5.1 Indlovu Seed Build

As stated in Section 2.6, a devastating fire in November 2008 destroyed the Indlovu Center and many surrounding homes. Currently, members of the community and the Shaster Foundation are working to rebuild and redevelop the area around the Indlovu Center. The community has identified a plot of land where they would like to build a communal water and sanitation facility. The land is located directly behind the Indlovu Center, pending the relocation of one family. A water and sanitation facility has been designed based on the physical constraints of the site as well as the needs and desires of the community it will be servicing. This facility would be the seed build in C Section of Monwabisi Park. It is intended that this seed build can be replicated in other areas of the community so that all residents of C Section may have access to adequate water and sanitation in the future.

5.1.1 Design Constraints and Limitations

There are building and design constraints that apply to most plots of land in C Section. These constraints must be taken into consideration before building a water and sanitation facility. The constraints common to each site are described in this subsection.

The first major constraint is space. When planning for redevelopment, it is desirable to relocate as few families as possible. Across Monwabisi Park, most single-family house lots are approximately ten meters wide by twelve meters long. Therefore, any water and sanitation facility must be confined by these parameters to ensure that only one family would be relocated for each new facility.

Possible building locations are also constricted by the amount of sunlight they receive because the Enviro Loo toilets rely on heat from the sun to function. Therefore, it is necessary that the site not be shaded by surrounding buildings or trees. Additionally, the toilets should be placed in the area of the site that faces north to maximize sun exposure in the Southern Hemisphere.

Another major constraint for most building lots in C Section is the high water table. Some areas of Monwabisi Park are prone to flooding during the winter months. Gray water from the laundry and dishwashing station, the hand washing sinks, and the showers needs to be discharged. Because of the high water table, the amount of water that can be discharged without saturating the soil is limited.

5.1.2 Indlovu Center Facility Design

The Indlovu Center water and sanitation facility has been designed to fit in the 10 meter wide by 12 meter long plot of land behind the community center.

The design includes the following:

- 8 SC240 Enviro Loo toilets and individual restroom stalls
- 2 water taps
- 2 hand washing sinks
- 6 laundry basins
- 4 dishwashing sinks
- 2 showers
- 2-1,000 liter rainwater collection tanks
- A 23 square meter community garden
- Storage and living space for the WSS

An AutoCAD drawing of the facility is shown in Figure 25. The footprints of the bathroom stalls are outlined in blue. The Enviro Loo units are located directly below and behind the stalls; they are drawn in light blue and labeled. In order to install the Enviro Loo units, 34 cubic meters of excavation will be required. This space is outlined in red and labeled.

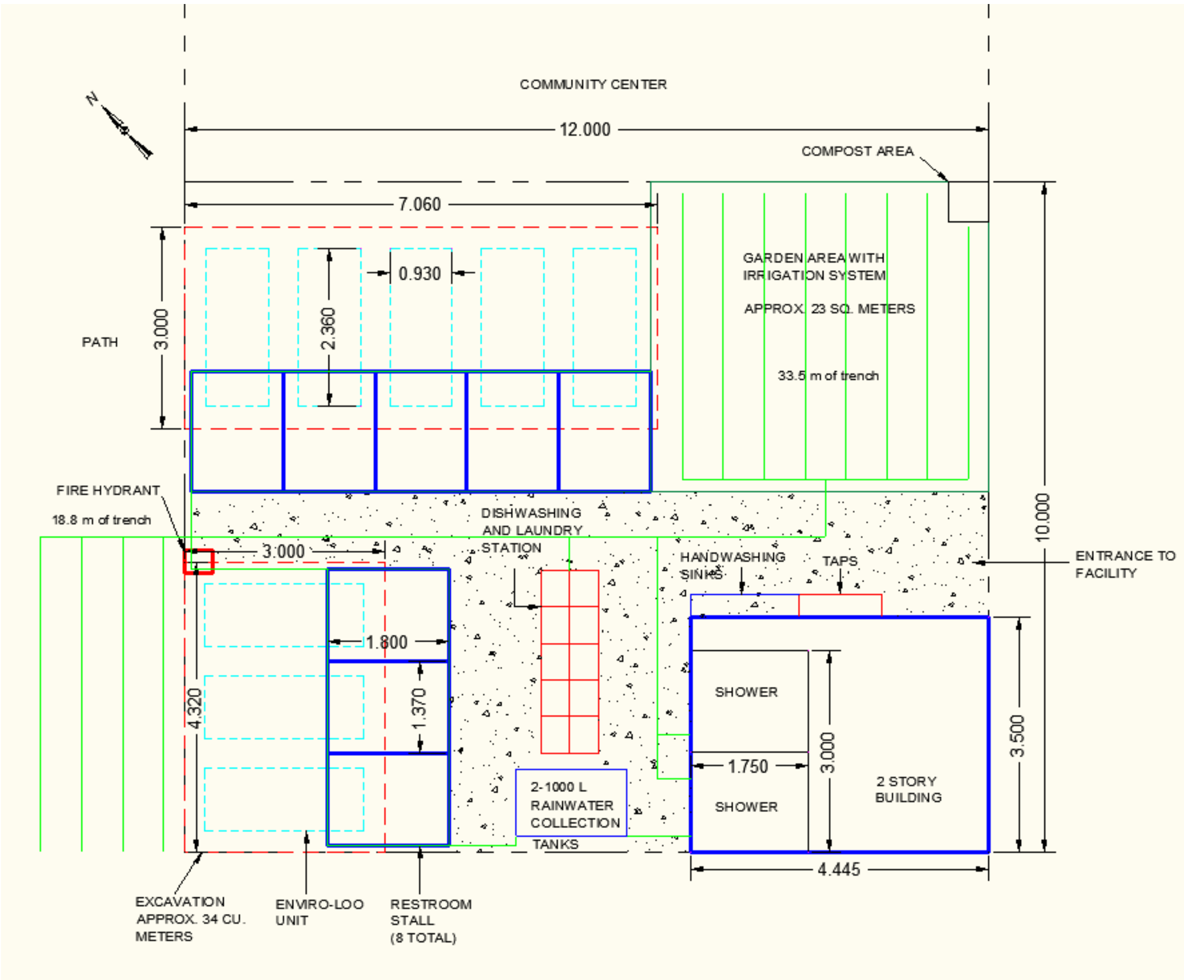

Figure 25: Indlovu Center Design

As shown by Figure 25, the community center is located on the northeast side of the water and sanitation facility. The community center is a two story building, and will thus block some of the incoming sunlight needed for the toilets to operate efficiently. Therefore, the Enviro Loo units have been placed as close as possible to the corner of the lot facing north. Additionally, the community center building abuts the water and sanitation facility lot lines. To accommodate this, one meter of walking space has been left behind the Enviro Loo units so that they can be accessed for maintenance. The units on the northwest side of the lot can be accessed from the pathway that runs adjacent to the facility.

The residence for the WSS is located in the lower right hand corner of the site. Because of spatial constraints, a two story building is required. The first floor contains two showers, which can be accessed by the walkway on the northwest side of the building. The rest of the downstairs will is used as storage and working space for the WSS. This space provides storage for clean water buckets, gardening tools, cleaning supplies, and maintenance tools. The second floor provides 15.5 square meters of living space for the WSS. The entrance of the house is located between the water taps and the entrance to the facility. This allows the WSS to monitor people entering and exiting the facility.

The community garden is located in the east corner of the site. An area in the corner of the garden has been reserved for a small structure where waste from the Enviro-Loo can be held for further composting. The garden would be irrigated from the gray water discharged by the laundry and dishwashing station, the hand washing sinks, and the two showers. Drip irrigation would be provided from burial grade PVC piping buried 0.75 meters deep. In order to prevent clogging of the irrigation system and accelerate infiltration, the trenches should be lined with gravel before the pipes are laid. The garden area alone provides enough space for 33.5 meters of irrigation pipes. It was projected that 36 meters of trenches would be needed to allow all water to seep into the ground. These calculations are shown in Appendix A. The garden has almost enough space to accommodate for the projected amount of discharge. To provide excess space for leaching, additional piping can be laid out in the pathway adjacent to the facility.

Figure 25 also shows laundry and dishwashing stations located between the bathroom stalls and the WSS residence. The hand washing sinks and taps are placed alongside the WSS house, close to the entrance of the facility. Placing the hand washing sinks in this area reminds bathroom users to wash their hands when leaving the facility, promoting good hygiene. Having the water taps close to the entrance also provides convenience for users only entering the facility for water. The laundry, dishwashing, and hand washing sinks can all be purchased from JoJo tanks or an equivalent dealer.

The rainwater collection tanks can be purchased from JoJo tanks or an equivalent dealer. Rainwater is collected and transported from the roofs of the buildings using a gutter system. Approximately 36 meters of gutter are required.

A fire hydrant has been placed on the northwest side of the lot. Because it is placed along the pathway, it can not only service the facility, but the surrounding community as well. This location can be easily identified by firefighters.

In addition to the fire hydrant, other safety features have been proposed as well. One of these is lighting. The facility would be constantly lit with outdoor spot lights to discourage crime at night. Additionally, the facility would be enclosed with a fence. The fence ensures that users only use the intended entrance and exit, making it easier for the WSS to monitor activity. The fence can be bought from the Eco-beam distributor; it is also made of recycled material. It is called Eco-fence.

5.1.2.1 Implementation

With the exception of the Enviro Loo units, the facility is designed to be built by the community. All building structures can be built using Eco-beams and sandbags. The filling and sewing of sandbags can provide jobs for local residents. All other materials that are purchased, such as the sinks, tanks, and fence, can still be installed by community members with training and support from the Shaster Foundation and the Worcester Polytechnic Institute students and faculty. The walkways and irrigation systems can also be constructed by community members. The only construction services required by the City of Cape Town would be the water piping connection to the distribution pipes.

When the Enviro Loo units are installed, the manufacturer would provide training for the WSS and community members. Two to three months later, further training would be provided on how to correctly maintain the toilets(Parsons, 2009). All other necessary training for the WSS will be provided by the Shaster Foundation and the City of Cape Town.

5.1.2.2 Indlovu Center Cost Estimation

Funding for this project will be sought through cooperation with the Shaster Foundation, Worcester Polytechnic Institute, and other partners. The facility design is intended to be low cost. It is expected that each water and sanitation facility would cost approximately 180,000 Rand (US $19,000) for materials and construction. A detailed cost analysis can be found in Appendix B.

5.1.3 Possible Variations to the Design

It is understood that not all areas in C Section would have the same design needs as the Indlovu Center site. One constraint driving the design of any facility is sun exposure. The Enviro Loo toilets should always be placed in the area of the lot that is facing north. Another constraint for the facility is space. Figure 26 shows a 3-dimentional rendering of the facility. Because excess space is unavailable, the facility is compact and thus changes to the design are limited.

Figure 26: Facility Variation

A sample variation of the design is provided in Figure 27. As shown, the top of the drawing is facing north and therefore the toilets have been placed on that side of the facility. This design provides the same number of toilets, laundry and dishwashing sinks, hand washing sinks, and taps, and the WSS residence is the same size. The garden has one square foot less of area. The rainwater collection tanks have been increased to 2,250 liters each. There could also be a roof covering the laundry and dishwashing station for protection from rain and sun.

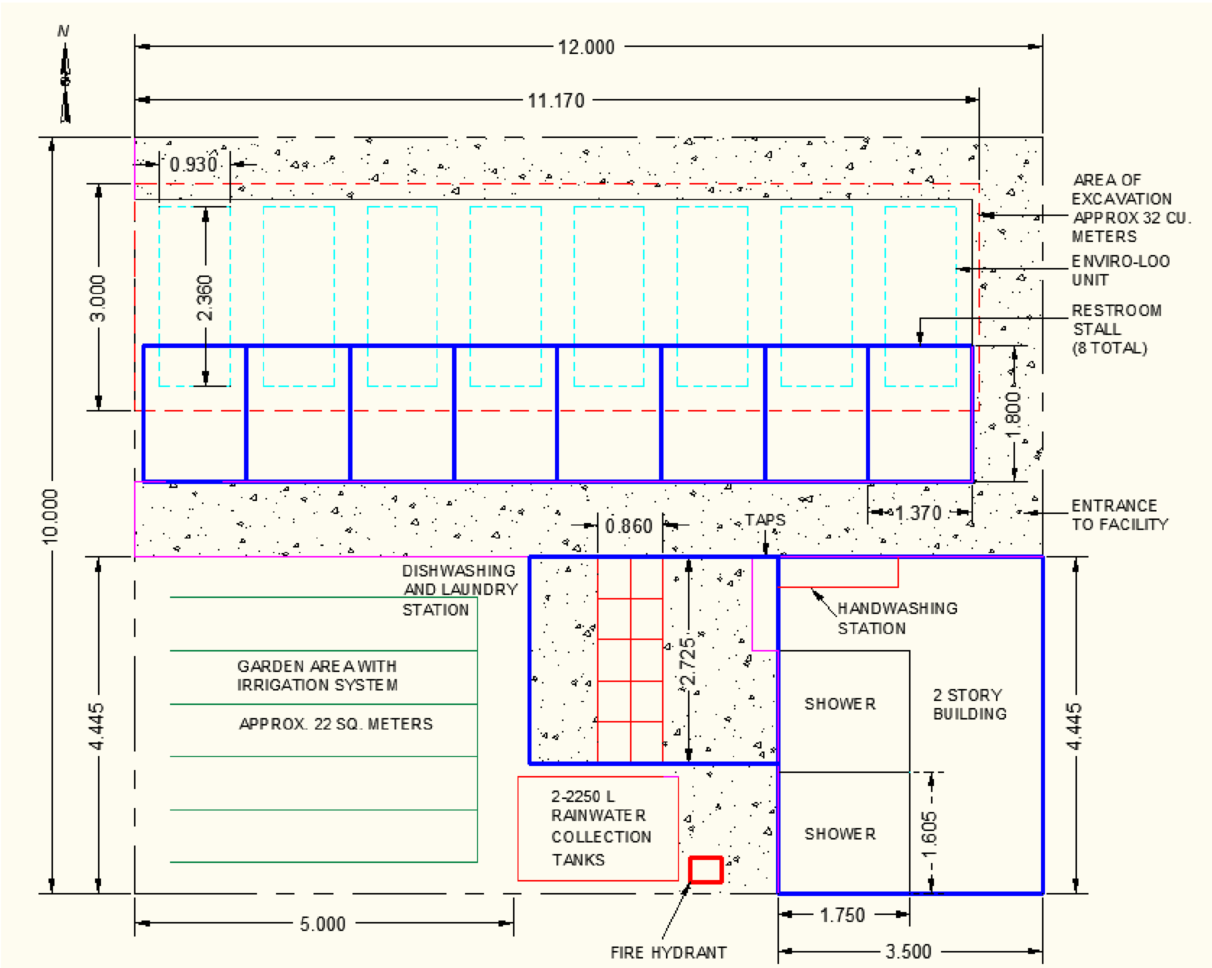

Figure 27: Alternative Layout for Water and Sanitation Facility

Other variations can be made to the facility design. For instance, if a community decides that they dislike the showers, they can be either removed or replaced by a sponge bathing area. Conversely, if the community plans on using the showers more frequently, more drainage area may be needed to accommodate the increase in the water discharge. This can be done by placing additional piping under the walkways. If additional drainage area is needed, space may need to be acquired from abutting lots or public paths.

5.2 Future Construction

The water and sanitation facility should help to alleviate the water and sanitation deficiencies in Monwabisi Park, Cape Town, South Africa. If multiple facilities are installed across the informal settlement, the goal of providing basic water and sanitation services is attainable. If 40 families are serviced by each water and sanitation facility, C Section in Monwabisi Park can be fully serviced by 33 facilities. Before this can happen however, the seed facility near the Indlovu Center still needs to be constructed and re-evaluated. Modifications can be made to increase the success of future facilities before they are installed. Chapter 6 provides recommendations for continuing the work to implement the Indlovu Center Facility and other future facilities in Monwabisi Park.

6 Recommendations

This chapter contains recommendations for work to continue this project. There is much more to accomplish to remedy the shortfall of water and sanitation services in Monwabisi Park beyond the scope of this single facility and the small portion of the community it will service. The recommendations are intended to ensure the success of the facility installed near the Indlovu Center, and also to eventually provide complete water and sanitation services across Monwabisi Park.

No soil percolation tests were completed during the design process because of resource constraints. The only information available during the design process was an observation that the soil was “sandy.” Because of this, conservative values for infiltration rates for an average “sandy” soil were used. However, soils are highly variable and thus it is critical that soil percolation tests are done to confirm the minimum area required for the leaching field size, especially under winter saturation conditions.

In the past, no public toilets have been available for use by passersby or other visitors to the facility. If people without key access needed to use a toilet facility, they were unable to. Some would break the locks off existing toilets to gain access. If a toilet were available, it is less likely that a passerby would break the locks off the toilet stalls. Furthermore, if a friend from another part of the township accompanied someone who had toilet access to do laundry, they would both be able to use toilets. A public toilet should therefore be available at every facility.

Currently, there is no method of heating hot water for use in the facility, especially for showering. One option for this is to run an electricity services line to the facility to run an electric heater. A second option is to add a propane or liquefied natural gas burner to heat the water. A third option is to install solar panels on the roof of the building to capture energy, which could be used to heat the water. Of these options, solar heating may be the best solution in the long-term, but solar panels can have a high upfront cost. Additionally, solar panels will not work as well in cloudy weather and may need to be supplemented by gas heating. An evaluation of these three methods (and perhaps other methods) should be completed to choose the best solution for heating the water.

Lighting for the facility could ensure greater safety for residents who use the facility at night. At the very least, people are likely to feel safer if they can see the environment around them as they walk to, around, and from the facility. The water and sanitation facility would not be as effective in improving public health if people are uncomfortable or unwilling to frequent it after dark. If lighting were installed, people may consider using the facility at night that otherwise would not have used it. This, of course, would require a source of electricity, which is available at the Indlovu Center. If the water heating source could be combined with the source of electricity used to provide light, it may prove cost efficient to light the facility.

These water and sanitation facilities include new technologies and promote new hygiene practices. Understanding how to use and maintain the new or unfamiliar features like the showers in the facility can promote their use. Knowledge of each feature can also prevent misuse, which could damage the apparatus. Because of this, an education program should be available for community members to learn about their new water and sanitation facility.

Lastly, and perhaps most importantly, this facility was designed to be replicable and installed multiple times across Monwabisi Park. After the seed facility is built, it will be important to study what has worked well and what aspects of the facility need improvements to meet community needs. Modifying the facility design based on feedback from Monwabisi Park residence before another facility is installed will ensure community-wide success for the water and sanitation development plan.

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Appendix A: Leaching Field Percolation Calculations

Q_{inf} = Flow rate of infiltration
I_r = Infiltration rate (ft/day)
A = Area of Trench (W*L)
W = Width of Trench
L = Required Length of Trench

Assume: $Q_{inf} = I_r * A \Rightarrow A = Q_{inf} / I_r$
$A = W*L \Rightarrow L = Q_{inf} / I_r / W$

Expected Flow Scenario

	Q_{inf}		I_r		W		L	
Expected Soil Case	5830	gal/wk	0.6	in/hr				
	833	gal/day						
	111	cfd	1.2	ft/day	2	feet	46	feet

	Q_{inf}		I_r		W		L	
Best Soil Case	5830	gal/wk	1	in/hr				
	833	gal/day						
	111	cfd	2	ft/day	2	feet	28	feet

	Q_{inf}		I_r		W		L	
Worst Soil Case	5830	gal/wk	0.2	in/hr				
	833	gal/day						
	111	cfd	0.4	ft/day	2	feet	139	feet

Maximum Flow Scenario

	Q_{inf}		I_r		W		L	
	12380	gal/wk	0.6	in/hr				
Expected Soil Case	1769	gal/day						
	236	cfd	1.2	ft/day	2	feet	99	feet

	Q_{inf}		I_r		W		L	
Best Soil Case	12380	gal/wk	1	in/hr				
	1769	gal/day						
	236	cfd	2	ft/day	2	feet	59	feet

	Q_{inf}		I_r		W		L	
Worst Soil Case	12380	gal/wk	0.2	in/hr				
	1769	gal/day						
	236	cfd	0.4	ft/day	2	feet	296	feet

Appendix B: Facility Cost Analysis

The following table shows a preliminary cost analysis for the water and sanitation facility. There are no operation and maintenance fees.

Item	Number of Items	Price/Item(Rand)	Total (Rand)	Total (US)
Enviro Loo Toilet[1]	8	5,170	41,360	4,362
Enviro Loo Accessories[2]	8	125	1,000	105
Tanks[3]	2	3,000	6,000	633
Shower[4]	2	3,414	6,827	720
Double Basin Sinks[5]	12	1,000	12,000	1,266
Taps[6]	2	900	1,800	190
Pipes[7]	6	332	1,992	210
Water and Sanitation House[8]	1	90,860	90,860	9,582
		Capital Cost:	**161,839**	**17,068**

Attendant Yearly Salary[9]	1	18,000	18,000	1,898
		Annual Facility Price[10]	**26,092**	**2,752**
		Annual Price per Family[11]	**652**	**69**

[1] (Parsons, 2009)
[2] Includes Anchoring Device and Overflow Connector
[3] Price Estimated from 2500 L Horizontal Tank (R4712) from Jojo Tanks
[4] Price Estimated from American Shower and Bath ® Entry Shower Kit (American Shower & Bath® Corner Entry Shower Kit (401060)
[5] For Hand washing, Laundry and Dishwashing Station (Alex *et al.*, 2007)
[6] (Muller, 2009)
[7] Price Estimated from 64' American PVC Piping (Central Vacuum PVC Pipe)
[8] Price for 2 Floor Eco Beam House (54 m^2); Includes Living Room, Kitchen, Bath, 2 Bedrooms, Balcony (FitzPatrick, 2004)
[9] (Granfone, Lizewski, & Olecki, 2008)
[10] Assume a 20-year facility lifespan
[11] Assume 40 families use facilities