Project Number: JYP-0902

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

A Major Qualifying Project report submitted to the Faculty of

Worcester Polytechnic Institute

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

By

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February 22, 2010

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1. Water
2. Sanitation
3. Greywater

Abstract

The informal settlement of Monwabisi Park in Cape Town, South Africa lacks water and sanitation services. The lack of proper facilities has led to the spread of diarrheal diseases and prevented further redevelopment in the area. The goal of this project was to design a facility with sanitation services and clean water access. The design, which includes dry composting toilets, washing stations, and greywater management, is intended for modification and replication throughout the park.

Acknowledgements

I would like to thank my advisors, Jeanine Plummer and Scott Jiusto for their guidance and encouragement throughout this project. I would also like to recognize my Cape Town project partners Melanie Donahue, Joshua Matte, and Blake Kelly for all of their hard work and well documented research. Special thanks also go to our sponsors, Garnett Jefferies and Jaco Muller, as well as Professor Kevin Winter of the University of Cape Town, and Di Womersley of the Shaster Foundation. Thank you for your wealth of knowledge and support throughout the course of this project.

This project report is part of an ongoing research program by students of the WPI Cape Town Project Centre to explore and develop options for sustainable community development in the informal settlements of Cape Town, South Africa. For more information, please go to: http://www.wpi-capetown.org/

The full project report for this work has been implemented as a website available at: http://wpi-capetown.org/projects/2009/water-sanitation/

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Executive Summary

Problem Statement

Across the globe, there is a water and sanitation crisis. There are nearly 1.1 billion people without improved water supplies and 2.4 billion with no access to improved sanitation services (World Health Organization, 2009). South Africa is no exception to this epidemic. After the Apartheid era, natives with newly earned rights migrated to urban areas in search of job opportunities. Many cities did not have the infrastructure to support this increased population, so people began setting up camps outside the city limits. These "squatter camps" were intended to be temporary while the cities worked on new housing developments. As the camps expanded, cities abandoned their efforts to supply appropriate infrastructure, causing the informal settlements to become permanent residences with little or no access to roadways, water supplies, and sanitation services (Granfone *et al.,* 2008). Although great efforts have been made in recent years, many informal settlements remain without basic water and sanitation services.

Background

The post-apartheid Bill of Rights declared that the people of South Africa were guaranteed "the rights of access to basic water supply and basic sanitation" (Republic of South Africa, 1996). These rights were further clarified by water and sanitation service ladder policies which define categories of service from inadequate to full (see Appendix I). After passage of the Bill of Rights, cities such as Cape Town were faced with an unprecedented demand for the installation of clean water supplies and sanitation services. Monwabisi Park, an informal settlement with roughly 21,000 residents in the Khayelitsha Township was outfitted with "pour-flush" toilet systems along the most accessible roadways. C Section, which is home to over 6,600 residents, was given 92 pour-flush toilets between 2006 and 2008. However, by October 2008, over three quarters of them were non-functional (Granfone *et al.*, 2008). Therefore, residents of Monwabisi Park must resort to homemade pit latrines, or open defecation. Both methods can lead to the contamination of soil and ground water and the transmission of diarrheal disease. In addition to being unsanitary and unsustainable, foul odors are a problem. As an alternative, the City of Cape Town offers "black bucket" service to all townships. Monwabisi Park residents refused this primitive service that requires defecation in a 20-27 litre bucket that is collected and serviced by city workers. This area of Khayelitsha thus remains in the lowest bracket of sanitation services as defined by the City (Muller, 2002). The Water and Sanitation Department has also installed municipal taps throughout the settlement to supply clean drinking water. These taps, however, are often vandalized and poorly maintained. As of December 2008, 11 of the original 27 taps in Monwabisi Park were rendered inoperable (Granfone *et al.*, 2008). This can lead to the overuse of functional taps causing standing water surrounding the taps. In addition to the hygiene concerns related to the taps, the water supply is a rapidly decreasing resource expected to be scarce by 2015 (Muller, 2002).

Because of water shortages in the City of Cape Town, greywater management is also a concern. This is water created by household activities such as dish washing and laundry. There is ongoing research on the treatment of greywater for reuse without extensive use of technology or electricity (Winter, 2008). The current conditions in the park, however, do not allow for the

proper disposal or reuse of greywater; it is simply dumped on the ground creating problems with standing water.

The conditions in Monwabisi Park have drawn attention from organizations such as the Shaster Foundation for Community Development whose mission is to "improve the health and well-being of impoverished communities in a sustainable way" (Shaster Foundation, 2008). This group has piloted redevelopment efforts in the settlement with the creation of the Indlovu Project, a group of community buildings including a crèche, community centre, guesthouse, and soup kitchen (Shaster Foundation, 2008). WPI began their project-based partnership with the Shaster Foundation in 2007 with the construction of a community laundry centre. Since then, student project teams have worked with the foundation, the City of Cape Town, and the University of Cape Town to further document the conditions in Monwabisi Park and to develop potential solutions to the community's water and sanitation concerns.

Project Goal

The goal of this project was to design an integrated water and sanitation facility to improve services in Monwabisi Park. The facility was intended for construction adjacent to the Indlovu Project community centre, an area targeted for redevelopment. In addition, the facility could serve as a template for similar facilities elsewhere in the settlement.

Methodology

The first task was to review the current water and sanitation conditions within the park. Data on the number and location of taps and pour-flush toilets, as well as common alternatives used throughout the settlement were available from prior WPI research (Granfone *et al.*, 2008 and Carbonneau *et al*., 2009). This information was confirmed upon arrival in Cape Town and discussed with local city officials. The second task was to become familiar with case studies of parallel situations across the globe in order to understand sanitation and greywater management alternatives that have already been tested.

The third task was to define system parameters for the sanitation facility. Possible alternatives were categorized and ranked based on certain criteria. The sanitation systems were categorized as either dry compost systems or systems using water, and then evaluated based on spatial requirements, user capacity, financial investment, maintenance expectations, and health risks. The spatial requirements and user capacity were identified as the most crucial due to the dense population of the settlement and limited area for construction. Systems requiring a storage tank that could not be placed underneath the receptacles, or that could not accommodate at least 200 uses per day were disregarded. The maintenance expectations of the remaining systems were compared and it was determined that those requiring vehicle access were not ideal in all areas of the settlement due to the lack of roadways. The final systems were ranked based on sustainability. The highest ranking system was a urine divergent composting system.
The final task was to develop a site plan for the implementation of the water and sanitation facility. Details on the facility components are provided below.

Results

The proposed water and sanitation facility design is shown in Figure 1. The site area is approximately 9 m by 15 m situated between the existing community centre and proposed adjacent housing development. The sanitation system was positioned to allow the easiest user access, the most efficient odor control, and the best use of open space. The remaining area was divided into sections for laundry and hand washing stations, greywater biofilters, and compost pasteurization bins. The soil must be tested for ground water level in order to determine the precise location for the biofilters, which may alter the entire site plan. The final layout and construction method will be determined by the Shaster Foundation and Indlovu Project site manager.

Sanitation System

A urine divergent dry composting system was selected for the facility. The system is not dependant on a water source, may produce useable compost for the community, and has relatively simple working parts. The toilet facility and waste processing was designed to handle a 200 person user capacity based on the projected number of community centre visitors and residents of the proposed housing development. The daily expected waste quantities are 24 g of feces, 220 L of urine, and 3500 L of greywater (Muller, 2002). Each toilet stall will divert the urine into a septic tank buried beneath the system. This tank will be emptied by the city as needed until a method for reuse can be implemented. Five stalls measuring 0.9 m by 1.7 m are to be built side by side. Odor control within these stalls was a major design consideration. The collection containers are located in an airflow-controlled environment to ensure no foul odors advance into the stall. The airflow will also be controlled using electric fan powered vent pipes which will be attached to the adjacent building for further support. This will dissipate the odor above the second story.

Washing Stations

To encourage good hygiene around the toilet stalls, a hand washing station is included in the facility design. Three basins with pedal controlled faucets will be fixed to the facility's outer wall. These sinks will be volume-release controlled. One pump of the foot pedal will release 0.75 litres of water, resulting in a possible daily use of 300 litres assuming two pumps per use and 200 uses per day. This water will be collected along with the laundry station effluent in a shallow tank underneath the area. A four basin laundry washing structure was built in 2007 by WPI students, but was destroyed by a fire in 2008 that consumed the neighboring community centre which is now being rebuilt. This previously designed laundry system will be rebuilt to encourage residents to wash laundry on-site so the greywater may be collected and treated.

Greywater Management

Greywater will be collected from the on-site sinks, taps, and the laundry facility. The water will pass through a reed or grass bed gravel filter for treatment. The treated greywater will be piped into soakaways under nearby roads and footpaths for disposal. The expected daily greywater

production is 3500 litres and if feasible, water quality testing could be implemented in the future to determine if the filtered water could be used for irrigation or other reuse options.

Waste Collection and Treatment

Solid waste from each toilet will be collected in a container directly beneath the stall. A 200 litre drum, or similar container, will be located in the vault beneath the stalls, while urine will be diverted into a septic tank. This septic tank will be emptied by the city as needed until a location for on-site purification can be obtained. The solid waste collection drums will be moved as needed to the composting area. The method of composting chosen for this site is slow pasteurization. Collection drums will be placed into a shed and monitored until the temperature reaches 62°C. The proper carbon to nitrogen ratio can accelerate this process, and can be achieved by the addition of carbon rich material such as wood chips or dry reeds to the sludge. The length of time the compost must remain in the shed depends on the temperature. The United States Environmental Protection Agency developed the following equation to calculate the days required for composting based on temperature (T) in degrees Celsius (EPA, 2009):

$$D = (1.317*10^8) / [10^ (0.14*T)]$$

With proper composting, the solid waste may be returned to the community for use in flower or vegetable gardens.

Conclusions and Recommendations

A functional, sustainable, and socially acceptable sanitation centre was designed for the C Section community of Monwabisi Park. Physical construction remains to be implemented. Recommendations for continued work include:

1. *Waterborne "Flush Toilet" Systems*: Additional research on Anaerobic Baffled Reactors for on-site, closed loop wastewater treatment is needed to determine if these systems are appropriate for informal settlements.
2. *Waste Reuse Process:* After waste has been composted and tested for safety, it may be applied to local gardens as fertilizer. Initially, these gardens should contain only non-edible plants until testing can confirm the quality of compost required for edible plants. Any separated urine may be contained and tested, then diluted with water in a ratio of at least 1:8 (Germer, 2009) and used to fertilize gardens.
3. *Data and Testing:* This water and sanitation facility is designed as an experimental research facility. Collected data should be used to advance the sustainable design of the sanitation facility. Partnerships with students and faculty from the University of Cape Town, the City of Cape Town, and the Shaster Foundation should be continued.

References

Carbonneau, M., Elbag, M., & Krasinskas, J. (2009). *Cape Town Water and Sanitation Design* (Major Qualifying Project at Worcester Polytechnic Institute No. JYP-0804).

City of Cape Town. (2008). *Water and Sanitation Service Standard.* Cape Town, South Africa. Available online at: http://www.capetown.gov.za/en/Water/Documents/Water%20and%20Sanitation%20Service%20Standards.pdf

Environmental Protection Agency (EPA). *Wastes – Resource Conservation.* Retrieved November 2009 from: http://www.epa.gov/osw/conserve/rrr/composting/index.htm

Germer, J., Addai, S. & Sarpong, D. (2009). *Fertilization with Human Urine…in a nutshell*. Retrieved 12 November 2009. Informational Pamphlet Available online at: https://www.uni-hohenheim.de/respta/publications.php

Granfone, M., Lizewski, C., & Olecki, D. (2008). *Envisioning Endlovini: Water and Sanitation*. (Interactive Qualifying Project at Worcester Polytechnic Institute).

Muller, M. (2002). *The National Water and Sanitation Programme in South Africa: Turning the 'Right to Water' into Reality*. Available online at: http://www.wsp.org/UserFiles/file/3292007103257_afBGRightToWaterRealitySouthAfrica.pdf

Republic of South Africa (RSA). (1996). *The Constitution of the Republic of South Africa, 1996* (Act No. 108 of 1996). Available online at: http://www.info.gov.za/documents/constitution/1996/a108-96.pdf

Shaster Foundation. *The Shaster Foundation*. Retrieved 12 November 2009 from: http://www.shaster.org.za/old/index.htm

Winter, K., Armitage, N., Carden, K., & Spiegel, A. (2008). *Why Things Fail: Greywater Management in Informal Settlements, South Africa*. Available online at: http://www.waterinformation.co.za/literature/files/2008_081.pdf

World Health Organization. (2009). *World Health Statistics.* Retrieved 2 October 2009 from: http://www.who.int/en/

Appendix I: Water and Sanitation Service Ladders

Water Service Ladder (City of Cape Town, 2008)

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

Sanitation Service Ladder (City of Cape Town, 2008)

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

Appendix II: Water and Sanitation Facility Drawings

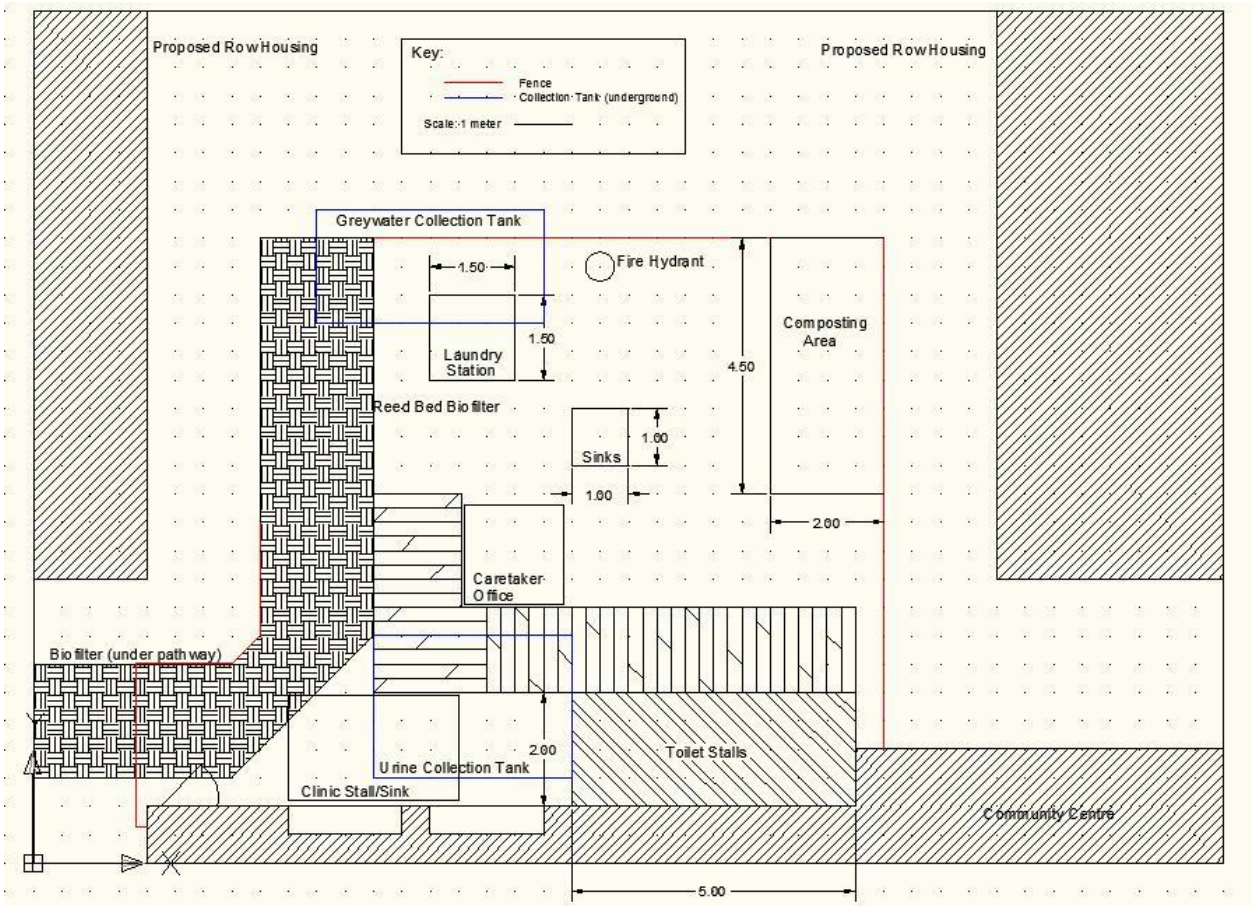

Figure 1: Water and Sanitation Facility Site Plan

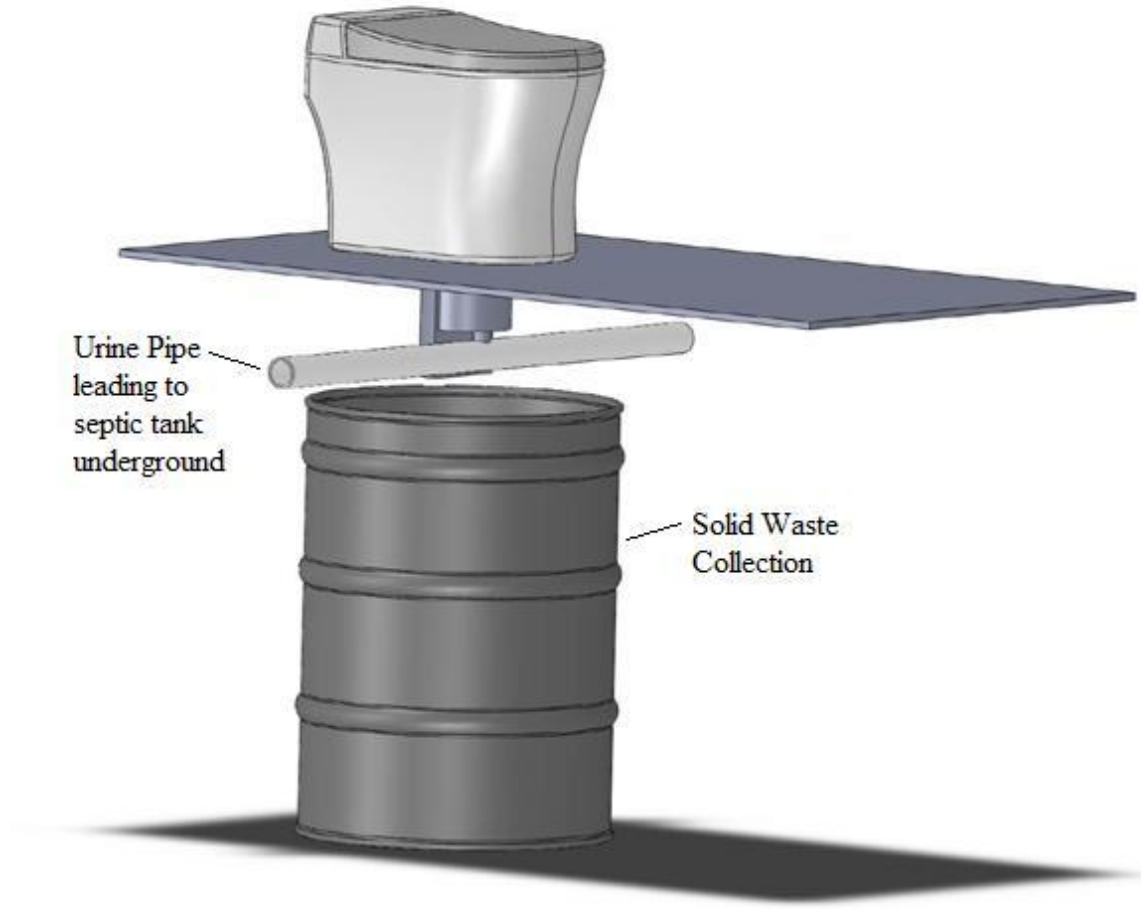

Figure 2: Waste Collection Design

Appendix III: Capstone Design Statement

The goal of this project was to design a sanitation facility for the residents of Monwabisi Park, an informal settlement in Cape Town, South Africa. While the South African government is responsible for providing basic water and sanitation services to all citizens, such services are lacking in Monwabisi Park. Specifically, limited functioning sanitation facilities, and the means to dispose of used and contaminated water, are significant factors in the spread of diarrheal disease and contributing to infant mortality.

This project focused on the water and sanitation practices of the residents surrounding the Indlovu Centre, a community services centre located in a political subdivision of the park designated as C Section. It was determined that most residents defecate openly or in poorly constructed pit latrines, while greywater is collected in dirty buckets then dumped onto the ground surrounding the homes. Alternatives to improve conditions were evaluated and a sanitation facility was planned. This project meets capstone design requirements as follows:

- *Analysis* of current waste and greywater disposal methods
  First, data collected in 2008 on the status of water and sanitation services available in the park was reviewed. Experts in the fields of wastewater treatment and sanitation within informal settlements were consulted.
- *Synthesis* of data
  A self-built urine divergent dry composting system was selected for collection and treatment of solid waste based on cost and overall sustainability potential. This provided an opportunity to explore different options for urine and greywater treatment including the use of septic tanks and biofilters.
- *Design* of a water and sanitation centre
  Plans for the sanitation centre were prepared including several options for biofilter and laundry centre placement. The final design is subject to change pending further soil and ground water testing in order to locate the most appropriate areas for the septic tanks and biofilters. Additional data on the safety and efficiency of the composting system is also needed.

This project included all eight ABET design considerations with particular emphasis on environmental design, social acceptability, and sustainability.