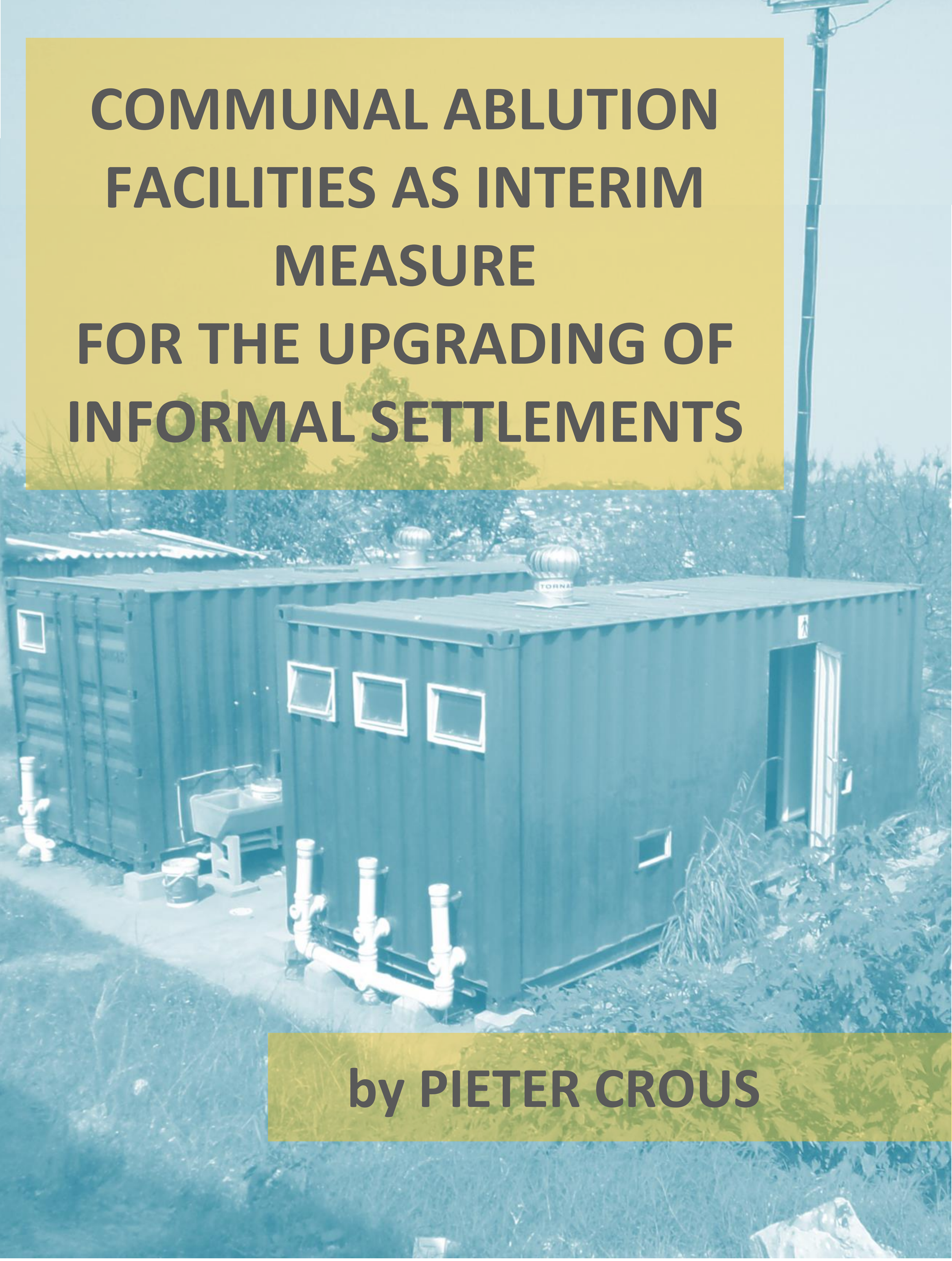
COMMUNAL ABLUTION FACILITIES AS INTERIM MEASURE FOR THE UPGRADING OF INFORMAL SETTLEMENTS



by PIETER CROUS

UNIVERSITY OF JOHANNESBURG
UNIVERSITY OF KWAZULU-NATAL
NRF National Research Foundation

COMMUNAL ABLUTION FACILITIES AS INTERIM MEASURE FOR THE UPGRADING OF INFORMAL SETTLEMENTS

by

PIETER ANDRIES CROUS

THESIS

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Abstract

The thesis investigates the whole life cycle of the community ablution facilities in the eThekwini municipality, and aimed to identify the technical success factors in rolling out communal ablution facilities as an interim measure in the upgrading of informal settlements throughout South Africa. The eThekwini municipality is based on the east coast of South Africa. Approximately 12% of the 3.4 million inhabitants of eThekwini are housing informally in one of the 420 informal settlements scattered around the urban and peri-urban areas. The municipality is responsible for the provision of basic interim services to these informal settlements within their jurisdiction and is in the process of rolling out containerised ablution facilities to all informal settlements as an interim measure. They have successfully provided 302 communal ablution blocks from 2009.

The findings of this thesis were based on the rollout of these communal ablution blocks. The thesis is structured in the life cycle of the community ablution blocks. The thesis required a broad set of data from a number of stakeholders in order to understand each stage in the life cycle, using a number of different data sources, such as (i) interviews with the municipality, professional service providers, and the caretakers, (ii) municipal and project related documentation and data, (iii) surveys of the existing community ablution blocks, and (iv) data logging of the water meters at the community ablution blocks.

The pre-implementation stages of the community ablution blocks investigated the planning, design and construction stages of the project. In the planning stage, the municipality prioritised each settlement based on a set of technical criteria, such as location to existing infrastructure, transport routes, bulk water and sanitation services, social infrastructure, the population of the settlement; to ensure that all interim infrastructure are considered within an integrated framework in order to reduce fruitless capital expenditure. Each settlement required community buy-in for both the placement and provision of the ablution facility and the selection of the caretaker. The design stage deals with the hydraulic design of the water supply and sewerage pipes as these were unknown parameters. The ablution structure and the sanitary fittings were discussed, but these were not significant in the design due to the space constraints within the containerised ablution facilities. There were significant delays found in the construction phase, which increased the initial estimated time required for construction by a factor of approximately three, which not only places a burden on the municipality to maintain the momentum of the project at scale but also increases the budget required for construction.

The post-implementation stages were not found to function as intended. The key success factors in the post-implementation stages were dependent on the quality of the caretaker and the quality of the support given to the caretaker. Furthermore, all maintenance work has to be performed rapidly to ensure that the caretakers remain proactive in ensuring the facility remains operational. The consequence of poor operation and maintenance has detrimental effects on the community, who have to resort to open defecation and other unimproved forms of sanitation.

The thesis adds to the shared water and sanitation body of knowledge. The thesis provides both quantitative and qualitative data on the post-implementation stage of the community ablution blocks, an area which is often neglected in practice and although this is often stated in literature, the

data is not readily available in literature. Furthermore, the thesis provided quantitative data on the water consumption characteristics and wastewater generated from the community ablution blocks.

The content of this thesis aligns directly with the national development goals of South Africa. The sanitation backlog characterising informal settlements means that the provision of communal ablution facilities will become a necessary interim solution to meet the basic needs of the community. However, the rollout and sustained use of the facilities is precarious and require sufficient pre-implementation management to ensure the rollout of the facilities can occur at scale and the interim infrastructure can dovetail with the long-term infrastructure development plans. In this research it was found that the current quality of hardware was insufficient in the face of the high usage rates (and vandalism). Furthermore, the current management arrangements for the post-implementation stages were inadequate to ensure the sustained operation of the facilities. Although communal sanitation has often been seen as the only means of providing informal settlements with improved water and sanitation infrastructure, the lack of adequate post-implementation management arrangements in place, shared water and sanitation facilities should be considered unimproved sanitation technologies due to the detrimental effects poor sanitation has on the community and the environment.

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Abbreviations

ABR	Anaerobic baffled reactor
CAB	Community Ablution Block
CLO	Community liaison officer
DEWATS	Decentralised Wastewater Treatment
DHS	Department of Human Settlements
DWA	Department of Water Affairs
EIA	Environmental Impact Assessment
EWS	eThekwini Water and Sanitation Unit
FBS	Free Basic Services
FBW	Free Basic Water
IDP	Integrated Development Plan
ℓ	litre
kℓ	kilolitre
ℓ/hh/d	litre per household per day
ℓ/c/d	litre per capita per day
KZN	KwaZulu-Natal
MDG	Millennium Development Goal
MEC	Mayoral Electoral Committee
MIG	Municipal Infrastructure Grant
NHBRC	National Home Builder Registration Council
PTO	Permission to occupy
RDP	Reconstruction and Development Programme
SALGA	South African Local Government Association
UD	Urine Diversion toilet
UISP	Upgrading of informal settlement programme
USDG	Urban Settlement Development Grant
VIDP	Ventilated Improved Double Pit latrine
VIP	Ventilated Improved Pit latrine
WSA	Water Service Authority
WSDP	Water Services Development Plan

Introduction

Informal settlements are a challenge in the majority of urban environments in the developing world. These settlements are characterised by a lack of basic services, such as water supply and sanitation, poor and crowded housing conditions, and poor public and environmental health. Although not very successful, local authorities have often tacitly ignored informal settlements from strategic planning and service delivery in order to discourage the settlement from growing. Yet, informal settlements have become a permanent part of the urban landscape of developing countries. This is evident in South Africa, where approximately 24% of the urban population is housed informally. The South African national government has mandated the upgrading of informal settlements through the provision of basic interim services. These basic services are provided free of charge to the informal settlement dwellers. This is not the status quo in the rest of the developing world, where residents have to either completely provide their own services or else partially pay for the services. The provision of these basic services in South Africa is the sole responsibility of the local government. The interim services include communal water and sanitation facilities, roads and stormwater drainage, refuse removal, and electrification. These interim services are intended to mitigate the direct risks associated with poor access to services and to form part of the long-term upgrading of the settlement, in order to provide formal services to each household.

The provision of communal water and sanitation services forms the first step in the provision of interim services. However, sanitation provision to informal settlements is a significant challenge. eThekwini municipality has realised this national mandate of interim water and sanitation services through the rollout of community ablution blocks throughout the municipal area. The ablution blocks in eThekwini are manufactured from prefabricated shipping containers which enables the rapid placement and rollout of these facilities. As of August 2012, 302 CABs had been constructed in rapid rollout project since 2009. There are approximately 3.4 million people residing in eThekwini, where 12% are housed informally. There are two main factors contributing to the selection of the eThekwini municipality as an appropriate case study. Firstly, the eThekwini municipality has strong institutional capacity and the eThekwini Water and Sanitation Unit has international recognition as a world class water service authority. Secondly, the municipality was the first in South Africa to implement the informal settlement upgrading policy at scale throughout their jurisdiction, providing the most extensive dataset from which to investigate the factors for successful implementation and sustained use of the facilities.

This research has a direct application to the development goals of South Africa. Although the rollout of communal water and sanitation facilities to informal settlements is a national priority, the expertise and knowledge regarding the factors for success have not yet been established. This research will play a significant role in assisting local government in decision making and in successful implementation of service delivery in order to actually improve the lives of informal settlement dwellers. Internationally, the research is also important, as communal sanitation has been perceived as an unimproved form of sanitation. The author agrees with this sentiment where there is poor management of the facility after the facility is handed over to the community. However, communal sanitation has often been identified as the only practical means of sanitation provision to densely populated informal settlement areas where household waterborne services cannot be provided without first formalising the dwelling unit. This formalisation takes time and requires some interim sanitation measures to meet the immediate needs of the community. It is important to note that this thesis differentiates between public and communal facilities. Public facilities are designed to meet the needs of any persons who are in the nearby vicinity – such as is found in a shopping mall, while communal facilities are designed to meet the needs of a specific community.

The aim of the research was threefold, (i) to collate and synthesise all of the information relevant to the rollout and sustained use of communal ablution facilities in eThekwini, (ii) to identify how well these facilities function, and (iii) to identify key success factors. As such, this research provides a holistic perspective of communal sanitation to informal settlements and provides an important perspective on the challenge of sanitation provision in informal settlements using eThekwini as a case study. Furthermore, in South Africa where there is political pressure to rollout communal water and sanitation facilities at scale, this research provides an academic analysis of the success factors within the entire lifecycle. To reach the aims, a number of research questions were identified and answered throughout this thesis. The methods used to answer the research questions required a broad range of techniques, which required both qualitative and quantitative research methods. The research questions are deconstructed in each section of the thesis, and are broadly encompassed in the following four questions:

1. What factors affect the planning and rollout of communal ablution facilities?
2. What factors are necessary to design for communal ablution facilities?
3. What factors negatively affect the sustained use of communal ablution facilities?
4. What are the lifecycle costs associated with the rollout of communal ablution facilities?

The thesis commences with an introduction to informal settlements in Chapter 1. It provides an overview of the nature of informal settlements and their role and prevalence in the urban environment, not only in South Africa but also in the rest of the world. Chapter 2 introduces the need for sanitation and provides an overview of the available technologies and the strategies that have been used to deliver basic sanitation services to informal settlements. The eThekwini municipality is then introduced in Chapter 3, which provides the demographics and the current institutional framework for water and sanitation provision to all within the eThekwini municipal area and briefly describes the history of water and sanitation provision to informal settlements and introduces the community ablution blocks (CABs) which are the current method used by the municipality to provide interim services. Chapter 4 contains the methodology using for the data analysis. This chapter also provides background information of where all of the data were sourced from. This was required as the data was sourced from a number of different stakeholders.

The second part of the thesis investigates the CABs in more detail, and investigates each project stage individually, which includes the planning stage (Chapter 5), the design stage (Chapter 6), the construction stage (Chapter 7), the operation stage (Chapter 8), and the maintenance stage (Chapter 9). Each chapter has a number of recommendations at the end of the chapter. These recommendations are based on the lessons learnt from the author's own experience. The thesis has removed any associated costs from each of these project stages and has placed them together (Chapter 10) as costs typically date rapidly and vary based on local conditions and market prices. This separation of the costs allows the majority of the results from the life cycle of the CABs to remain intact. The conclusions are presented in Chapter 11, and the recommendations for the successful rollout of communal water and sanitation facilities are consolidated in Chapter 12. Chapter 12 includes a number of suggestions for future research concerning communal water and sanitation facilities.

Permanency of Informal Settlements

Chapter 1

1. Introduction

Most governments, at all levels, would agree that informal settlements are an indication of a failure of the public sector, the legislative framework and the economy to provide conditions through which the residents may be housed formally, whether this is through government programmes or through private means (Huchzermeyer et al. 2006). The evidence and prevalence of informal settlements further indicate the willingness of people to try get as close to sources of employment as they can - whether with or without formal state permission (Reintges 2001). This has led to the use of dramatic terms, such as "the urban crisis", which is associated with unemployment and underemployment; inadequate accommodation as a result of high rates of urbanisation; and a lack of both physical and social infrastructure like water supply, sewers, roads, electricity, health facilities, and social services. It is clear that there is insufficient management of the urban environment (Onibokun 1988). However, it has been argued that cities without informal settlements do not cater for the provision of accessible housing for the urban poor (Yap & Wandeler 2010). The evidence of this in South Africa is manifest in the widespread existence of informal settlements (Albertyn 2004). Informal settlements are neither a recent nor a local phenomenon. They have been a significant trademark of the urban landscape in most developing countries for at least half a century (Huchzermeyer & Karam 2006; Mahmud & Duyar-Kienast 2001; Onibokun 1988; Gulis et al. 2004). However, the issue of slums appeared on the global agenda in 1999 through a joint program by the World Bank and UN-HABITAT (Huchzermeyer and Karam 2006). Informal settlements and their growth have become critical issues throughout the developing world (Mahmud & Duyar-Kienast 2001). In fact, the expansion of informal settlements is associated with the expansion of the cities themselves and is especially true in sub-Saharan Africa (Huchzermeyer & Karam 2006; UNFPA 2007). This increase in informal settlements is propagated by the lack of sufficient jobs and housing, and increased rural-urban migration (Mahmud & Duyar-Kienast. 2001; Horn et al. 2001). The combination of economic stagnation and urban population growth has, in sub-Saharan Africa and the developing world, created these grave economic conditions reinforcing the growth of informal settlements (White 1988). This means that informal settlements are here to stay (Huchzermeyer 2011; Gordon n.d.). Still, informal settlements are at times negatively perceived by not only the formal city residents but also the informal residents themselves (Abbott 2004).

Informal settlements vary considerably from country to country and even within a city. They range from high-density, squalid city-centre tenements to spontaneous, peripheral settlements without legal tenure rights (Huchzermeyer & Karam 2006; Boaden & Taylor 2001). Informal dwellings can be found in freestanding informal settlements, backyards of formal households, or on serviced sites. Free standing informal settlements are the result of land invasion and are established without any infrastructure, services or legal rights (Landman & Napier 2010). Backyard shacks and vacant land invasion within townships occur in response to population increase from newly formed households and rural-urban migrants (Cross 2006). Many politicians and city planners have traditionally regarded informal settlements as temporary and have chosen not to intervene and provide services

(UNFPA 2007). Typically, informal settlements have detrimental effects on the community's quality of life, with overcrowded, dense populations; uncollected garbage; unsafe and limited water availability; poor drainage and open sewers characterising such settlements (Fotso 2006; Ali & Stevens 2009).

2. Growth of Cities

Urbanisation is not a new phenomenon, but has been taking place since the industrial revolution in the 18th century, nor is the development of poorly served areas, referred to as slums, which have been well documented in Europe during the 17th – 19th centuries (UNHSP 2003). Urbanisation and the growth of cities have been steadily increasing, especially in the developing world (Roberts 2006). The majority of this worldwide urban growth (48%) is happening in smaller cities (cities having less than half a million inhabitants), with megacities (cities having more than 10 million inhabitants) only accounting for 5% of worldwide urban growth (UNDP 2008). Urbanisation has significantly impacted human settlement in Africa, where the majority of the population was rural only a century ago (Garenne 2006). It is expected that most future urban growth will happen in the developing world (UNDP 2008). Urbanisation has both positive and negative effects though. Positively, the advances made during the industrial revolution would not have been possible without urbanisation. There is also a positive correlation, although not always directly, between per capita income and the level of urbanisation (UNDP 2008; Greene & Rojas 2010). However, the densification of populations into small areas requires adequate and sustainable services to ensure public and environmental health.

The two concepts, urban growth and urbanisation, are not the same although both conceptually discuss the growth of the urban environment within a country or area but they are driven by different processes. Broadly, urban growth is mainly attributed to natural population increase, while urbanisation is attributed to rural-urban migration (Goldstein 1983). These processes have made the growth of cities inevitable and unavoidable and are particularly evident in Africa and Asia. One distressing consideration is that the majority of the urban population of the future will be poor, within the developing world's cities, and rapid urbanisation will occur in smaller cities. Yet, these cities often lack the capacity to ensure adequate planning to accommodate the development (UNFPA 2007). It has also been argued that globalisation of markets and consumption patterns cause developing cities to increasingly resemble those of urban settlement patterns prescribed by the American dream, with urban sprawl and less densification. Urban sprawl is economically inevitable, as the periphery provides cheaper land and labour (UNFPA 2007). Sprawl places a detrimental economic burden on the cost of running the city, not only through high transport costs but also the high cost of supplying services to the distant suburbs (Greene & Rojas 2010; Moloi & Harrison 2011).

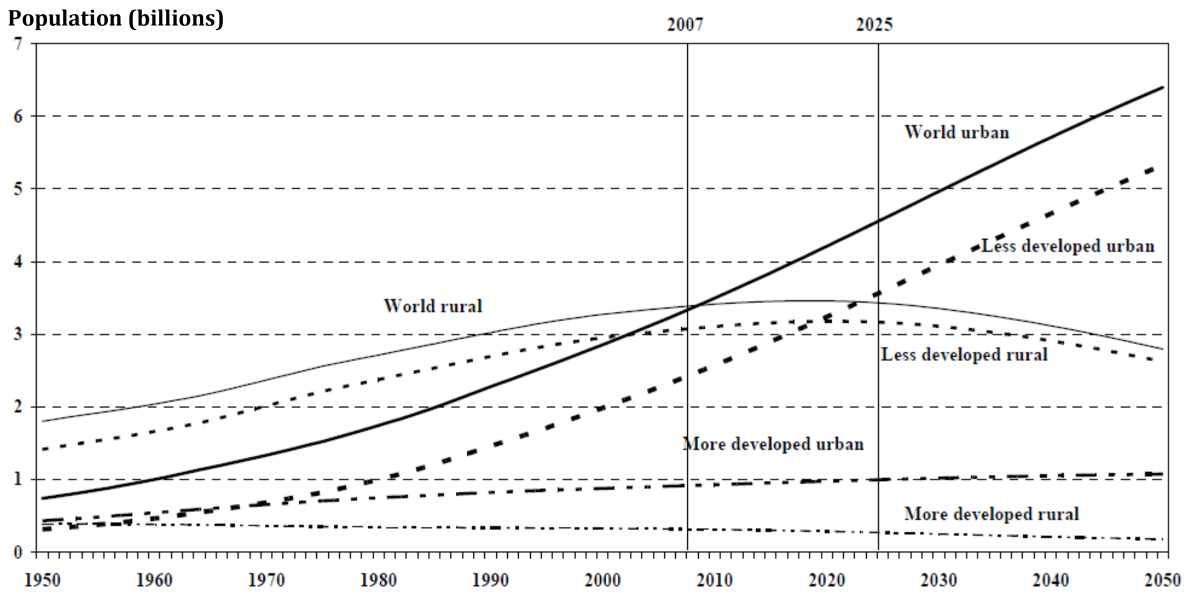

Figure 1: The rural and urban population variation between 1950 and 2050. This graph takes into account the total world population and also the more developed countries and the less developed countries (UNDP 2008)

The complex processes of urbanisation have resulted in more than half of the world's population now living in cities (UNFPA 2007; Vearey et al. 2010). This growth doesn't show signs of slowing down (Figure 1) and by 2030 the urban population is expected to almost reach 5 billion urban residents, with most of the growth happening predominantly in the developing world of Asia and Africa (UNFPA 2007). The world's rural population is expected to decrease by approximately 28 million between 2005 and 2030, while the urban population of the developed world is expected to grow by approximately 120 million (16%) (UNFPA 2007). Three stages of urbanisation have been proposed, with each stage of development affecting the demographics and economics of both the urban and rural environment (Roberts 2006).

1. Early stage: population is concentrated in rural areas and temporarily moves to cities as labour migrants.
2. Intermediate stage: where migration is more permanent and rural-urban migration produces rapid urbanisation.
3. Mature stage: the majority of the country is urban and migration becomes either intra- or inter-urban.

The earlier stages of urban development in developing countries are characterised by large scale rural-urban migration. These migrants essentially build major cities through a process of self-help - constructing housing, rudimentary infrastructure and jobs in an informal economy. Thus, the problems faced in this early stage of urbanisation are also solutions, solutions for both urban governments and urban inhabitants. The mature stage of urbanisation sees a decline in urban growth rates due to both the lower rural-urban migration and a decline in fertility rate due to access to education, contraception, male and female access to work, media influence, and higher urban living costs. But, the mature stage of urbanisation brings with it problems with which the informal economy cannot cope with and it tends toward an economy of survival, with fewer entrepreneurial opportunities as the main economic contribution in the mature stage of urbanisation is services. Services organise other sectors in the economy. The problems that come with the mature stage of urbanisation require concerted government action as the market, both formal and informal, alone cannot solve them even though the informal market worked in the earlier stages of urbanisation. Job creation is formed through trade liberalization and global production and service systems. Globalisation however has promoted high-productivity sectors, which do not stimulate job creation. Still, the effect of globalisation cannot be generalised in developing countries, as research has shown that the effect of globalisation has been ambiguous, contradictory and diverse (Roberts 2006).

Asia and Africa are urbanizing under low rates of economic growth and considerable export/import competition, yet there is no clear explanation for this (Roberts 2006; Kombe 2005; White 1988). Urbanisation in Africa is occurring without substantial industrialization or the development of a modern service economy (Roberts 2006). Africa's economic and social conditions started deteriorating in the 1970s, with the GDP declining every year between 1980 and 1988 (White 1988). In the 1980s, the annual rate of urban migration in sub-Saharan Africa was 4.7%, while the GDP dropped annually at 0.8% (Fotso 2006). This has meant that the provision of basic services and housing in the urban environment has been very difficult for local authorities and municipalities who are already strained (Fotso 2006; UN 2004). Therefore, the challenge for Africa is stabilizing population growth while also creating employment opportunities (Roberts 2006).

Despite being the least urbanized region in the world, sub-Saharan Africa has an urban population that is already as large as North America's (UNFPA 2007). South Africa's rate of urbanisation is much faster than other African countries, with 60% already urban dwellers, but the majority of this growth tends to be unplanned with inadequate housing opportunities, promoting informal settlements. In fact, urban growth in all of the developing world is directly linked to expanding informal settlements (Vearey et al. 2010).

Urban growth is associated with a number of drivers, which are dependent on the time at which urbanisation occurs and the degree of urbanisation within the country (Roberts 2006; White 1988). These drivers include population growth, rural-urban migration, natural causes like droughts, the slowdown of the global economy, the petroleum price (and the US dollar), the adverse trend in terms of trade for exporters of primary goods and urban biased policies (White 1988). In South Africa, both economic conditions and state policies will inevitably still continue to shape urbanisation (Mabin 2001). Over time, natural urban population growth becomes the greatest contributor of urban growth as countries become more urban, with lower numbers of possible rural-urban migrants (UNFPA 2007). Today generally, most urban growth stems from natural population increase rather than migration (mostly rural-urban migration), especially in large metropolises and in less developed countries (UNFPA 2007; Cerrutti & Bertoncello 2006; Roberts 2006; Zlotnik 2006; Goldstein 1983; UNDP 2008; UNHSP 2003). Yet, although studies identify rural-urban migration as the main factor affecting urbanisation, this typically is associated with the early stages of urbanisation (Garenne 2006). The actual extent of migration however is difficult to quantify as the definition of migration has not been standardized either within or between countries and people can be classified as migrants due to either residence time or migration distance (Goldstein 1983). Finally, urban growth is increased by the reclassification of rural areas to urban areas (UNFPA 2007; Roberts 2006).

Globally, the pace of urban growth has tapered off, reflecting slower economic growth and rates of natural population increase, as well as some return migration to their rural homes. This is evident in

Latin America where urbanisation has decreased, particularly among highly urbanised countries, and rural-urban migration flows have decreased in most countries, giving way to urban-urban migration as the dominant form of geographic mobility, which is much more difficult to measure (UNFPA 2007; Roberts 2006; Cerrutti & Bertoncello 2006).

3. Driven to the Cities

Migration is associated with pull and push factors. The political environment, including political instability or repression or wars, is a push factor promoting urbanisation (UNHSP 2003). Rural-urban migration is a prominent concern for governments globally (Goldstein 1983). It is fuelled by the attraction of urban areas and the associated economic difficulties experienced in the rural areas along with poor rural access to social services, education, health care and labour opportunities (Cerrutti & Bertoncello 2006; Garenne 2006; Horn et al. 2001; Goldstein 1983; UNHSP 2003). Poverty is a key push factor (Kombe 2005). Rural-urban migration in all Latin American countries occurs due to economic factors (Cerrutti & Bertoncello 2006). Some push factors include political disaster, economic disaster, health reasons, saturated population, unemployment and poor farming conditions in rural areas (Garenne 2006; Horn et al. 2001). A factor facilitating successful migration is social networks (Preston-Whyte et al. 2006). Rural migrants tend to be from disadvantaged families and some struggle to cope in the new urban area (Fotso 2006). Although migrants follow jobs, which are mostly concentrated in and around urban areas, very few developing country cities generate enough jobs to meet their growing populations (UNFPA 2007). The rapid growth of cities was not seen as an initial concern, as it was believed that the deteriorating living conditions would reverse, or at least reduce, rural-urban migration (White 1988). The fact that rural-urban migration continually occurring in the face of potential unemployment and lack of economic potential has been attributed to the 'bright light' syndrome, whereby cities have more potential to pioneer and develop a career than in the rural areas (UNHSP 2003). Urban migrants usually settle in the periphery of metropolitan areas, which increase spatial density and promote peripheral expansion (Cerrutti & Bertoncello 2006). These settlements are mostly unregulated and grow horizontally (Kombe 2005). In South Africa, Apartheid migration laws led to poor urban planning and sprawling peri-urban areas, which transformed the rural economy from an agrarian to cash based economy (Collinson et al. 2006; Davis 1986; Horn et al. 2001; Moloi & Harrison. 2011). Migration thus had a negative effect on the rural population (Collinson et al. 2006). The height of rural-urban migration that started in the late 1970s, ended by the time influx control was suspended in 1986 (Mabin 2001).

Governmental attempts to prevent rural-urban migration have been futile, counter-productive and, above all, wrong and are considered a violation of people's human rights (UNFPA 2007). Even restrictive immigration laws will not prevent immigration, as it is fuelled by the conditions of the global markets and not the political (Massey 2006). These anti-migration policies, either historical or recent, have rarely succeeded in reducing urban growth. However, considering that in the later stages of urbanisation, urban growth is driven mainly by natural increase not migration, policy should be directed toward reducing the fertility rate in order to reduce the rate of urban growth. These policies would need to focus on social and economic development, investments in affordable and quality health and education, the empowerment of women and better access to reproductive health services in both rural and urban areas (Goldstein 1983; UNFPA 2007; Mbuyi 1988). Thus, attempts to reduce urban growth should not restrict people's rights to migrate, but should rather focus on empowering people by enabling them to exercise their basic human rights, including the right to reproductive health (UNFPA 2007).

Circular migration, associated with those migrants who retain strong links with the household but reside there for less than six months, is strongly associated with the socio-economic status of the household left behind (Collinson et al. 2006). Thus, circular migration creates benefits for migrants' rural homelands by returning their income, knowledge and other urban benefits home (Goldstein 1983). The majority of circular migration is attributed to economic reasons, with migrant networks from the cities to the rural areas being an important factor facilitating migration to occur (Collinson et al. 2006). During Apartheid, circular migration was born because labour migration was closely regulated. However, circular migration has not changed in post-Apartheid South Africa. It has in fact expanded since the pass laws have been repealed (Collinson et al. 2006; Posel 2006). Most cross-border labour migration into South Africa is circular and has increased during the 1990s, as South Africa was the dominant regional economy, but the exact extent of cross border migration is not known in South Africa as it is in other parts of the developing world. For South Africa this has been unreliably estimated between 2 – 8 million people (Posel 2006; Massey 2006), and has been estimated at 8% of the total South African population (*Zlotnik 2006*). South Africa is a net importer of intra-continental migrants mainly from Lesotho, Swaziland, Botswana, Mozambique, Namibia, Zimbabwe, and distant counties such as the Democratic Republic of Congo, Malawi, Mauritius, Tanzania and Zambia (Massey 2006).

4. Informal Settlements

The high rate of urbanisation is associated with unemployment and under employment, inadequate housing, and a lack of both physical and social infrastructure to meet the needs of the growing urban population (Onibokun 1988). In South Africa, entrants into the urban environment are often forced to be housed in informal settlements, which are a shameful feature of poverty and inherited inequalities (Albertyn 2004). Yet, South Africa is not the only country experiencing a growth in informal settlements. Internationally, informal settlements are known by several different, interchangeable terms, i.e. slums*,* squatter housing*,* shantytowns*,* low-income communities, crowded communities, or informal settlements (UNFPA 2007; Fotso 2006; Mahmud & Duyar-Kienast 2001; Yap & Wandeler 2010). The term 'slum' was used during the 18^{th} century and its current definition is broad yet derogatory. It is used to define any densely populated low-income settlement with poor living conditions and substandard housing (UNHSP 2003). Slums, as formally defined by the United Nations in 2000, are characterized by the following six criteria, namely the lack of basic services, inadequate building structures, overcrowding, unhealthy and hazardous environmental conditions, insecure tenure, and poverty and exclusion (Huchzermeyer & Karam 2006). These characteristics were later redefined by UN-Habitat, where an urban slum is any area lacking either one or more of the following (UNFPA 2007; Yap & Wandeler 2010)

- durable housing
- sufficient living area
- access to improved water
- access to sanitation
- secure tenure

It is noted that in South Africa, informal settlements are associated with either informal (and illegal) tenure or the lack of appropriate housing structures, but the classification of informal settlements does not consider the settlements' access to basic services (DEA 2010). South African informal settlements are not typical of informal settlements in other African cities, but model the Latin American approach (as is typically found in Brazilian cities). In the Latin American model, informal settlements are typically surrounded by formal areas, where the formal areas form the major part of the city. The city of Durban in South Africa is an exception to this rule, having elements of both types of urban environments (Abbott 2004).

Although services such as roads, public transport, power and water supplies help to direct city growth (UNFPA 2007), their absence do not prevent informal settlement growth. Informal settlements develop irregularly over time (Kombe 2005). It has been shown that a free-standing informal settlement is developed over 10 - 15 years (Mahmud & Duyar-Kienask 2001). Initially, peripheral agricultural land is invaded and converted into a residential area, densifying over time until saturation (Kombe 2005). The spatial layout of the settlement is determined by the cultural, traditional, ritual, social, political and economic conditions (Mahmud & Duyar-Kienast 2001). Peripheral areas, in particular, are generally beyond or between legal and administrative boundaries of central cities. The government authorities' capacity to regulate occupation in these areas can be limited and poorly enforced. This indirectly enables unplanned, informal and illegal urbanisation processes (UNFPA 2007).

The growth rate and proliferation of informal settlements are indicators of skewed access to the formal economy and to public intervention, and is a visible sign of levels of inequality (Huchzermeyer et al. 2006). The majority of urban residents in the cities of the developing countries are marginalized from accessing land and housing through established legal or formal processes (Leduka 2004; Huchzermeyer & Karam 2006). They therefore step outside the law in order to gain access to land and housing, and build either on private or government land (Winayanti & Lang 2004; Mbuyi 1988). Informality has opened up the possibility for a large percentage of the urban population to survive (Huchzermeyer & Karam 2006). Although land invasions and illegal squatting are not legal, they are at least tacitly permitted (Mbuyi 1988). Governments react in one of three ways to land invasions, namely (Smith 2003)

- governments provide infrastructure and housing projects;
- governments relocates the settlements to nearby greenfield sites; or
- governments ignore the settlements, leaving them without rights and basic services

Informal settlement growth in South Africa is not only related to rural-urban migration but also results from natural population growth combined with the housing shortage, low wages and high unemployment (Crankshaw et al. 2001). Informal settlements around the Witwatersrand, the Western Cape and Durban grew rapidly in the late 1970s and early 1980s (Mabin 2001). This growth during the 1980s was evident in the economies of South Africa's largest cities, where approximately 2.5 million black South Africans (30 per cent of the labour force) in the late 1980s made their livelihoods in the informal economy (Rogerson 2001).

5. Characteristics of Informal Settlements

Informal settlements typically lack infrastructure, such as roads, stormwater drainage, garbage collection, solid waste disposal and sanitation facilities (Gulis et al. 2004). Free standing informal settlements are characterized by high densities. The available space between shacks is often 2 m or less (Gordon n.d.). Houses are generally constructed by the residents, not contractors (Mahmud & Duyar-Kienast 2001; Gordon n.d.). Housing materials for shacks are typically some form of recycled materials, varying from discarded corrugated iron, cardboard, timber or plastic sheeting, usually of a rectilinear or polygonal shape (Gordon n.d.). These materials cause the shacks to be too hot during the day and too cold during the night, with severe waterproofing problems, not only in the roof and walls but also from the floor due to inadequate foundations and inadequate or non-existent site drainage. This problem is exacerbated in low-lying areas by floods, which are common. Finally, the high density and the flammable construction material of the shacks make fires a common feature of informal settlements (Gordon n.d.). Although the images of informal settlements are traditionally negative, their culture and diversity have more recently made them very attractive tourist destinations around the world (Gordon n.d.). Informal settlements are often built on steep slopes, which have health benefits and do not use available farming land but strict building regulations have often prevented the formalisation of these houses (Gordon n.d.). Informal settlements are also found in precarious environments such as flood prone areas or on wetlands.

The expansion of informal settlements have created increasing intra-urban inequalities in the social determinants of urban health as informal settlements have characteristically poor health conditions (Vearey et al. 2010; Ali & Stevens 2009). This poor health is directly related to the poor environmental conditions, poverty and lack of nutritious food and poor access to health services (Garenne 2006). This is evident in the decline of the urban advantage in Africa since the 1950s, with very high infant mortality rates characteristically found in informal settlements (Garenne 2006). The inadequate level of basic services are hazardous to the environment due to direct pollution, which is exacerbated by increased growth in the settlements (Onibokun 1988). Thus, the provision of basic services such as water, refuse removal and sanitation have major impact on public health (Thomas 2006).

The youth make up a significant part of informal settlements and their integration into society is a human right imperative (UNFPA 2007). Yet, the standard of education in informal settlements is generally very poor compared to formal, urban schools, negating their urban advantage. This is one of the factors for poor school attendance, with between 20 – 50 per cent of young girls in informal settlements who do not attend school (UNFPA 2007). It is important to note that not all poor people live in informal settlements, and not all the informal settlement residents are poor (UNFPA 2007).

Informal settlements are characterised by lacking formal tenure rights (Huchzermeyer & Karam 2006; UNFPA 2007). Even though the situation within informal settlements is often considered to be temporary, i.e. that the settlement will either be relocated or formalised in-situ at a future date, the lack of interim forms of tenure to the residents violate the residents' rights (Albertyn 2004). However, securing tenure on its own may not prevent the devastating effects of the vicious cycles that deepen poverty in informal settlements (Huchzermeyer & Karam 2006). Other necessary improvements include improved access to water and sanitation and multi-sectorial approaches that combine economic, social and human development with effective political empowerment of the poor (Huchzermeyer & Karam 2006).

Available services in rapidly growing urban areas are almost immediately inadequate once commissioned (Onibokun 1988). This, along with the fact that governments tend to overlook informal settlements' service requirements means that the service provided rapidly become non-existent, rudimentary or inadequate. Sub-Saharan Africa, which includes South Africa, has both lower levels, and greater inequalities in access to essential services than the rest of the developing world (Collinson et al. 2006). Water supply has been argued to be the most crucial service requirement in urban areas (White 1988). However, without adequate disposal of the water, it can become a significant environmental problem, which is particularly important to informal settlements where households have either rudimentary or non-existent sanitation facilities (Gordon n.d.). Social services, such as adequate health, education and policing services are essential to community life. These services do not form part of the housing delivery project, but follow this once-off delivery, forming part of the 'operational' delivery (Cross 2006).

The housing requirements in South Africa's cities are enormous and ever increasing (Cross 2006). Housing is one of the central concerns of the South African government in its struggle against poverty alleviation and reducing the growth of informal settlements (Cross 2006). Not only does housing delivery promote access for the poor to services, but it also provides new households moving into the urban economy a platform from which to accumulate assets, allowing them to become functional citizens within the developed economy (Cross 2006). South Africa has three main sources of housing, from private sector, state, and self-help housing, which is shown in the Figure 2 (Landman & Napier 2010; Winayanti & Lang 2004).

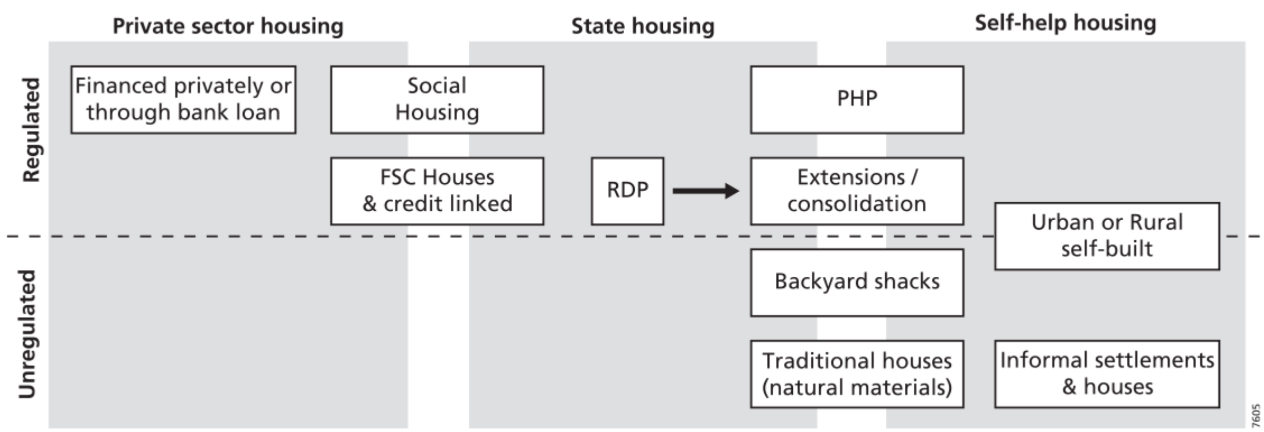

Figure 2: Range of housing delivery available in South Africa (Landman & Napier 2010)
FSC (Financial Services Charter) houses are credit-linked affordable housing options for the lower middle income households. RDP houses are government provided to those households earning less than R3 500 as part of the Reconstruction and Development Programme. PHP is the People's Housing Process whereby there is direct participation by the residents and is considered as aided self-help housing.

Private housing is only available to those who earn above R8 000 per month, resulting in 81 per cent of South Africa's population being excluded from this method of housing (Landman & Napier 2010). The state's RDP (Reconstruction and Development Programme) subsidy house consists of an individual free standing house of 30-40m^2 on plots of 250m^2. However, other alternative state subsidy housing scenarios have been recently developed (Landman & Napier 2010). Housing provided by the state is available to households whose incomes are lower than R3 500 per month, which includes 15.4 percent of the total housing in South Africa (Landman & Napier 2010). However, for those households earning between R3 500 and R8 000, renting a shack in an informal settlement is one of the limited alternatives. These households cannot benefit from state subsidies and do not have the means to rent a private house either (Landman & Napier 2010). It has been argued by Albertyn (2004) that "the housing programme must account for the needs of those who are most desperate and whose ability to enjoy all rights is most in peril if their situation is not addressed." It therefore was argued that owner-built entry-level houses, even if these are shacks, play a significant part in the process of housing delivery and should be placed within the delivery policy instead of being eliminated. This policy change would re-encourage the site and service delivery models, along with the upgrading of existing informal settlements (Cross 2006).

6. Quantifying Informal Settlements

Most (over 90%) informal settlements are found in the developing world, with the majority of such settlers residing in South Asia, then Eastern Asia, sub-Saharan Africa and Latin America (UNFPA 2007). In 1987 it was estimated that between 32 - 85% of the population in most cities in the developing world are housed in informal settlements (Kombe 2005). In some African cities informality was as high as 70% (Leduka 2004), and it was reported that informal settlement residents account for 72% of sub-Saharan Africa's urban population (UNFPA 2007). The sub-Saharan Africa informal settlement population in 2005 almost reached 200 million, which practically doubled within 15 years (UNFPA 2007). In 2005, 37% of the developing world's urban population lived in an informal settlement, which accounts for 840 million inhabitants, their main characteristics being lack of adequate sanitation and excessive overcrowding (UNDP 2008; Gordon, n.d.; UNFPA 2007 Gordon n.d.; UNFPA 2007).

Asia

In Bangladesh, 25% of the population lives in urban areas, with this urban population growth being double the national growth rate (Ali & Stevens 2009). The majority, 85% as estimated by UN-HABITAT, living in urban settlements live in the urban slums (Ali & Stevens 2009). The rise of informal settlements in Dhaka was seen in the wake of the aftermath of the war in 1971. There are estimated to be around 3 million out of a population of 7 million people (43%) in Dhaka who live in informal settlements (Mahmud & Duyar-Kienast 2001). These settlements are generally based on either government-owned or private land (Mahmud & Duyar-Kienast 2001). Informal housing is the only solution to housing low-income families with irregular salaries (Mahmud & Duyar-Kienast 2001). In Turkey, squatting illegally gives an assurance to dwellers that they will be landowners in the future and gives them the freedom to mould the physical landscape that they require (Mahmud & Duyar-Kienast 2001). Settling in informal settlements has been exacerbated by the limited access to legal land, the high cost of housing materials, and the high population growth in urban areas (due to rural-urban migration (Mahmud & Duyar-Kienast 2001). Over two million informal residents are expected in Istanbul, Ankara, and Izmir, with the majority (58.3%) of Ankara's population being housed informally (Mahmud & Duyar-Kienast 2001). The Bangkok Metropolitan Area in Thailand had an estimated population of around 10 million in 2005 (Yap & Wandeler 2010). In Bangkok, informal settlements are different to the rest of the world, as they generally house less than 200 houses in each settlement (Yap & Wandeler 2010). The slum areas still house over a million people in Bangkok (Yap & Wandeler 2010). Informal settlements in Jakarta, Indonesia, are illegally constructed and are characterized by substandard infrastructure, small plots of land, low quality of building structures

(Winayanti & Lang 2004; Yap & Wandeler 2010). Although constructed in hazardous environments, such as flood plains, the residents have come up with their own solutions (Winayanti & Lang 2004).

Africa

Africa is one of the least urbanised areas in the world, at around 40% in 2005. At the same time, Latin America and the Caribbean had an urban population of 78% (Zlotnik 2006). However, since the 1950s, the rate of urbanisation in Africa has increased rapidly, for example Eastern Africa experiencing an urban increase from 10% to 27% between 1970 and 2005. Southern Africa, in the same period, increased from 44% to 55%. The total urban population in Africa has increased more than fourfold over this period, from 83 million to 353 million (Zlotnik 2006). Urban population growth in Africa accounts for 62 per cent of total growth, while in southern Africa it exceeds total growth (127 per cent) due to rural decline (Zlotnik 2006). In Africa, the slum formation and urban migration are approximately the same (Schouten & Mathenge 2010). The rate of urbanisation in southern Africa has decreased from 3.0 per cent in 1970 to 1.5 per cent in 2005 (Zlotnik 2006). Overall in Africa, the rate of urbanisation has decreased during the same period from 4.7 to 3.6 per cent. At this current rate, the urban population in Africa will double every twenty years (Zlotnik 2006). The percentage of the urban population residing in informal settlements throughout Africa is estimated to range between 4-80 per cent, with the average around 50 per cent (Nyenje et al. 2010). The proportion of informal settlement dwellers is estimated to rise due to the current trends of rural-urban migration and poor economic growth (Nyenje et al. 2010).

In Tanzania, between 50 - 80% of the urban population live in informal settlements, with Dar es Salaam having over 2.4 million (over 70% of the city's population) people living in informal settlements (Kombe 2005). In 2007, Egypt has 1 300 informal settlements, housing 12-15 million of the country's 77 million people (UNFPA 2007).

South Africa

South Africa (Figure 3) had a population of 51.8 million people from the 2011 Census, with an urban population of 57.9% in 2005 (Zlotnik 2006) and 61-62% in 2010 (UNFPA 2010). Free standing informal settlements and backyard shacks account for 9% and 5% of the total South African population (StatsSA 2012). This is approximately 24 per cent of the urban population (StatsSA 2012). In the greater Durban area in KwaZulu-Natal, informal housing is the predominant form of housing delivery (Boaden & Taylor 2001).

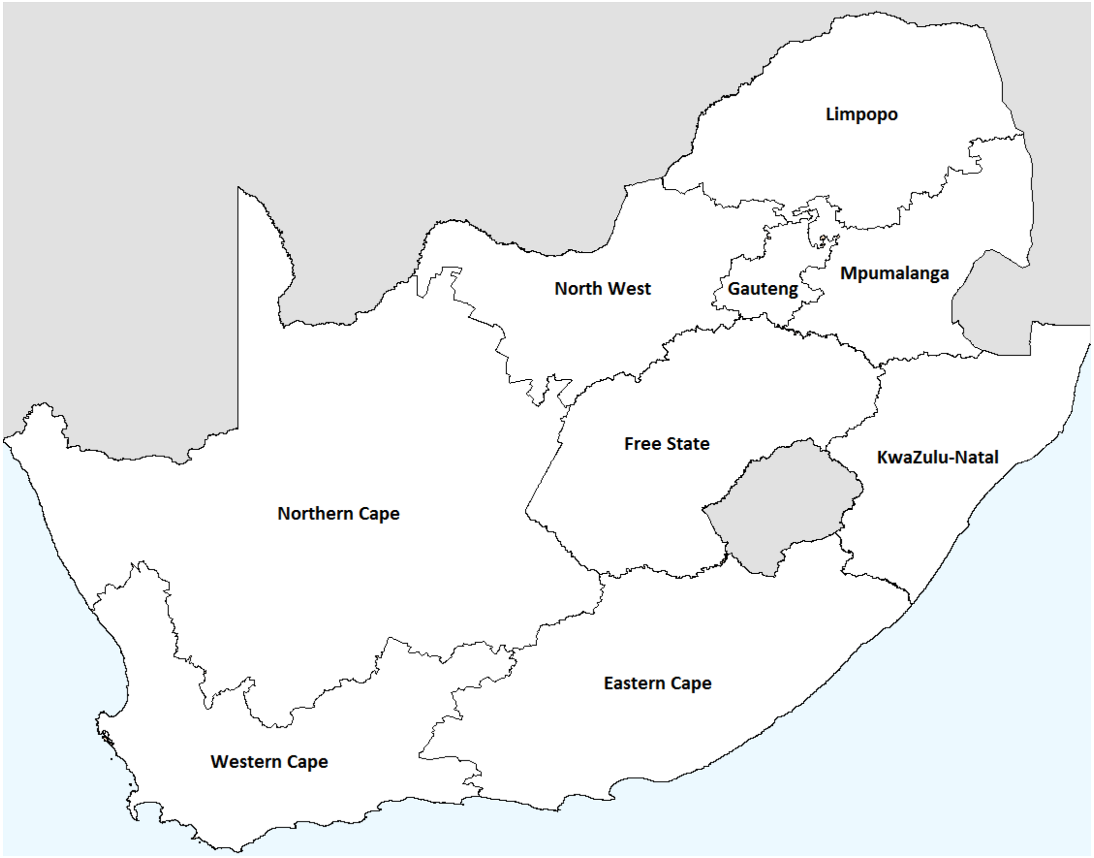

Figure 3: The provincial boundaries within South Africa (edited from MDB 2012)

Table 1 indicates the number of informal dwellings in South Africa, based on Census 2011 data. As already noted, these informal dwellings are defined differently from the UN definition of informal settlements (DEA 2010).

Table 1: Percentage of individuals residing in free standing informal dwellings (StatsSA 2012)

Province	Informal Dwellings (households)	Other Dwellings (households)	Informal Dwellings (%)
Eastern Cape	95 983	1 578 223	6%
Free State	80 355	736 414	10%
Gauteng	434 075	3 443 407	11%
KwaZulu-Natal	148 889	2 367 190	6%
Limpopo	41 434	1 370 866	3%
Mpumalanga	78 532	989 401	7%
North West	148 794	904 514	14%
Northern Cape	30 047	268 036	10%
Western Cape	191 668	1 428 508	12%
South Africa	**1 249 777**	**13 086 559**	**9%**

Most of the informal settlements in the City of Cape Town in the Western Cape were constructed post-Apartheid, with most of the migrants into these settlements originating from the Eastern Cape. Most residents see their informal dwellings as a temporary shelter and not permanent (Mels et al. 2009).

7. Informal Settlement Upgrading

Addressing the inevitable urban growth through realistic strategic plans has often fallen short as many authorities have previously either chosen to ignore the growing problems of overcrowding in hope that the cities will stop growing, or else masked this lack of strategic planning by an exhaustive master plan, which take years to draw up but is shelved soon after (UNFPA 2007). These strategic plans often exclude informal settlement dwellers as they have not always formed part of censuses, as if they 'don't exist' (Reintges 2001). The interventions proposed to address the challenge of informal settlements often fall short of reducing the challenge and may have contributed to their perpetuation rather than their reduction (Huchzermeyer et al. 2006). In Cuba for example, upgrading low-income settlements has been a *black hole* for public funds (Smith 2003). Still, service delivery to the urban and peri-urban informal settlements, especially those in small cities, should be the national priority of the developing world (UNDP 2008). While the provision of basic services can go a long way in improving the quality of life of informal settlement residents, there is also a need for these communities to gain access to a broader range of social services such as clinics, libraries, etc. (Thomas 2006). The challenge for urban planners and other policy-makers is not only providing services and houses to the growing urban populations, but also managing urban growth in such a way that it is not detrimental to the rural economy, the surrounding environment, and the urban system itself (White 1988; Vearey et al. 2010; Boaden & Taylor 2001). This requires proactive stances, based on a broader and longer-term vision, in order to enable access to the city for a rapidly growing number of people, of which a large majority are poor (UNFPA 2007).

Informal settlement upgrading is a highly political exercise, not only a technical challenge (Huchzermeyer et al. 2006). However, eradicating informal housing entirely is unrealistic when rural-urban migration and population growth continues, as government alone, using formal processes, cannot deliver houses fast enough, at scale and in appropriate locations. People need housing. A waiting list is not an option; neither is formal renting a solution for those without formal jobs. Thus, housing provision in South Africa cannot only be achieved through project-driven mass delivery approaches but must consider in-situ informal settlement upgrading, which provides the residents with more appropriate options (Cross 2006). A concept that has to be realised is that the upgrading of the settlement leads to the formalisation and subsequent commercialization of informal land. This invariably leads to the displacement of poor, low-income urban dwellers into further peripheral areas of the urban environment (Mahmud & Duyar-Kienast 2001; Yap & Wandeler 2010; Boaden & Taylor 2001; Reintges 2001). This occurs through the housing becoming more expensive and those who cannot afford the improvements have to move to peripheral areas or reduce their budgets on other items (Boaden & Taylor 2001). Peripheral expansion leads to significant transportation problems (Roberts 2006). It has been argued that transport accessibility would attract informal housing and guided informality could be achieved (Cross 2006).

7.1. Strategic upgrading policy in South Africa

Informal settlement upgrading is a prime development objective of the South African Government as its aim is to upgrade all informal settlements in the country by 2014/15 (DHS 2009). This has previously been communicated through provocative statements such as 'eradicating' informal settlements by 2014 (Landman & Napier 2010) and President Mbeki's vision in 2001 of attaining a shack-free country by 2016 (Huchzermeyer, 2004). Upgrading has many different meanings to different role players, but it goes beyond the provision of houses to providing improvements in the living conditions of the residents. This includes access to basic infrastructure, social infrastructure, legal tenure, improved spatial planning, and employment and entrepreneurial opportunities (Boaden & Taylor 2001). Upgrading should be done in an integrated, holistic approach which is suitable for the local conditions of each settlement. As such, the key to sustainable upgrading of services is community participation (DHS 2009). Informal settlement upgrading is not an arena for 'quick fixes' but needs the commitment and understanding of all involved in the complexity being addressed and requires an integrated approach from a number of sectors of government and of the economy (Huchzermeyer et al. 2006; Thomas 2006). Further, informal settlement upgrading should meet the broader social needs of the community by focusing on the promotion of social and economic integration and align with the strategic planning framework of the local government (DHS 2009). The upgrading of informal settlements falls within the Outcome 8 of the Presidential Outcomes, which aims to provide “Sustainable human settlements and improved quality of household life”, and is outlined in the following four Outputs from Outcome 8 (RSA 2010a)

1. Upgrading 400,000 units of accommodation within informal settlements
2. Improved access to basic services
3. Facilitate the provision of 600,000 accommodation units within the gap market for people earning between R3,500 and R12,800
4. Mobilisation of well-located public land for low income and affordable housing with increased densities on this land and in general

The motivation for upgrading is driven mainly by environmental and public health concerns, as most settlements are unplanned, with the primary drive of residents being to establish their dwelling unit. This leads to the unplanned and uncoordinated disposal of waste, which is a major threat to the spread of disease and environmental pollution. These effects can be mitigated through the provision of affordable and sustainable basic infrastructure that is amenable to the future expansion of the settlement (DHS 2009).

The South African government has specified incremental upgrading of informal settlements through the provision of interim services, where the settlement will be upgraded in-situ, or emergency (temporary) services, where the settlement will be relocated to a greenfields site (DHS 2009). Yet, this mandate has not been rolled out at scale throughout all municipalities.

Basic, interim municipal engineering services are provided to alleviate the immediate needs of the community, access to potable water, sanitation services and certain preventative measures to curtail the occurrence of disasters (DHS 2009). These interim services have to be provided in an integrated, long-term process whereby interim services form the first phase toward the provision of permanent services (DHS 2009). In-situ upgrading has been endorsed as most of the 2 700 informal settlements across South Africa are based on good locations where permanent residence is suitable (RSA 2010a). The first step in this incremental upgrading is the provision of communal water and sanitation services. The method in which this mandate is implemented is left to the local government, and no guidelines are provided as to how many people must be serviced by each facility, the size of the facility, or its location (DHS 2009).

Research has indicated that in-situ upgrading should be the first priority of all informal settlements (Cross 2006). In-situ upgrading requires local solutions through community participation with the informal settlement dwellers and buy-in from the local Councillors. However, the high rate of rural-urban migration (at 4% per year for the City of Cape Town for example) makes it difficult to aptly and appropriately facilitate upgrading and improvement negotiations with the residents, making the supply driven project route the only realistic choice (Cross 2006). Where in-situ upgrading is not possible, relocation of the settlement should be negotiated and must be approved by the community. Still, relocation can be detrimental to the community as it breaks down the social networks which are important for livelihood (Cross 2006). The relocation of informal settlement households with the provision of costly individual freehold titles often results in these households returning to informal settlements and (illegally) selling their title deeds to the formal market (Huchzermeyer & Karam 2006).

The upgrading of informal settlements requires both short-term and long-term integrated strategic planning. Even in situations where the residents are to be relocated, time is required to prepare an alternative site and there is the added risk of new land invasions once the settlement has been vacated. Alternatively, in situ upgrading takes up to several years for the settlement to be provided with a full level of service (DWAF 2007). The short-term focus must be set on the rapid provision of basic services such as water provision, communal wash areas and refuse removal (Thomas 2006). The most appropriate technical options depend on a number of factors beyond the issue of permanency of the services, including the economic and environmental state of the informal settlement (DWAF 2007). The environmental conditions of the informal settlements dictate whether or not the land is suitable for development. Poor environmental conditions may deter upgrading due to unsuitable soil conditions, topographical constraints and environmental impacts. However, in other cases, extensive land rehabilitation may be required before upgrading can be undertaken. The location of the settlement, whether in close proximity to employment opportunities or on the periphery of the urban environment, will further impact the feasibility and desirability of upgrading (DHS 2009). Security of tenure must be negotiated between local authorities and the residents and is achievable through a variety of tenure arrangements. This is essential, as the provision of water and sanitation services is challenging where the residents live on land without tenure rights (DWAF 2003). The Water Service Authority (WSA) should seek to promptly address these tenure issues and interim basic water and sanitation services should be provided as appropriate, affordable, and practical in accordance with a progressive plan that addresses both tenure rights and basic services (DWAF 2003). In the Upgrading Informal Settlement Program (UISP), residents receive access to land, basic municipal engineering services and social amenities and services (DHS 2009). The upgrading of the settlement requires an appropriate and sustainable trade-off between up-front capital costs, long-term maintenance and operating costs, settlement affordability levels, the need for environmental sustainability, social acceptability, human dignity and safety (DHS 2009). The evaluation of the sustainability of upgrading an informal settlement should be determined through investigating the

- willingness and ability to pay for services by the community;
- willingness and ability of government agencies to maintain and operate public infrastructure;
- monitoring the environmental impacts;
- progress in relation to the full upgrading of the settlement;
- in-migration rate of the settlement after upgrading;
- benefits of the upgrading on the community via post-implementation surveys.

7.2. Political framework for upgrading in South Africa

It has been argued that rapid urbanisation must encourage decentralisation of services (Muhairwe 2009). In South Africa decentralisation is achieved through local government being the responsible agency for the provision of basic services such as water, sanitation and refuse removal (see Figure 4) (Thomas 2006). This requires cooperative governance and inter-sectorial collaboration between numerous actors. This collaboration was promoted by the Local Government Municipal Systems Act number 32 of 2000 (Thomas 2006). Upgrading of informal settlements also falls within the responsibility of local government, through an integrated approach to the service delivery of water, sanitation, electricity and roads to the informal settlements (DWAF 2007). Local governments have to also proactively address and mitigate the expansion, re-invasion and in-migration of the upgraded informal settlements (DWAF 2007; DHS 2009). Upgrading is performed according to the municipal Integrated Development Plan (IDP) (DHS 2009). The municipality's IDP is the focal mechanism to achieve integrated planning and development. The IDP includes strategic plans, such as the Water Services Development Plan (WSDP) (DWAF 2007). The IDP should address issues of sustainable economic development of the municipality as a whole. The provision of secure tenure, housing and services without opportunities for economic growth is not sustainable and will lead to migration to more economically active areas and the possible establishment of new informal settlements.

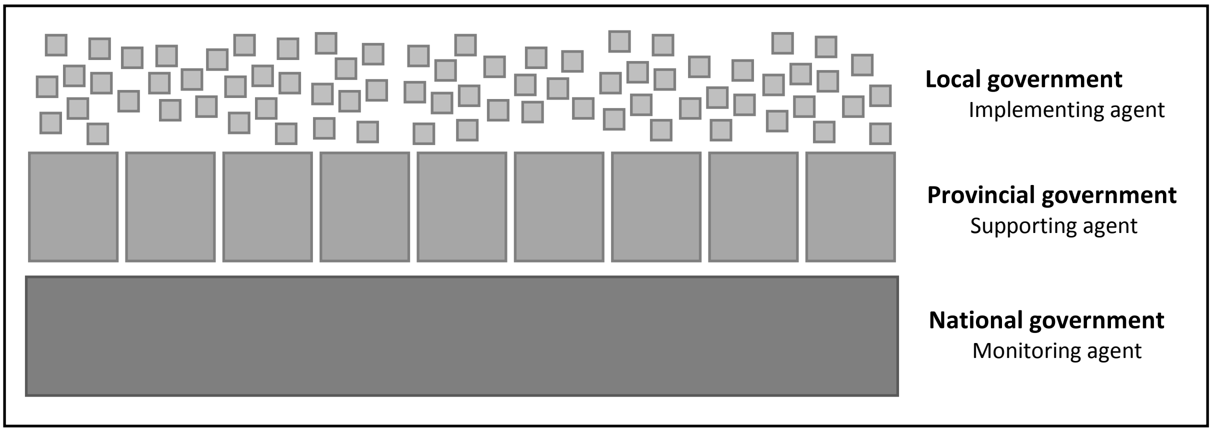

Figure 4: Decentralisation of service delivery and informal settlement upgrading in South Africa.
The local government is responsible for implementation the upgrading project. The local government must work within the provincial Strategic Housing Framework in the upgrading of informal settlements. The provincial department provides support to the local government and the national government is responsible for monitoring and evaluation and the allocation of funding for the upgrading of informal settlements.

The Provincial Department acts as a partner to the local government, facilitating funding and monitoring implementation of the upgrading (DHS 2009). Where the local government does not have sufficient capacity to perform this task, the Provincial Department must collaborate with local government to prepare a capacity building strategy to ensure the upgrading can be performed (DHS 2009). Finally, the National Department of Housing is responsible for monitoring the upgrading at a provincial level, negotiating the apportionment and allocation of funding, and providing assistance for the implementation of the upgrading (DHS 2009).

8. Conclusions

The emergence of informal settlements is a global phenomenon and have formed a permanent part of the urban landscape in the majority of the developing world cities through many decades. The high rates of urbanisation, through both rural-urban migration and natural population growth, is higher than the economic growth fuels the formation and proliferation of informal settlements. This is due to the fact that the city and the local authority are unable to provide houses, basic services or jobs for these new residents. It has been argued that informal settlements are the entry point into the city and that without informal settlements, the poor will be excluded from benefitting from the urban advantage. Approximately a billion people worldwide live in informal settlements. On average, approximately half of the urban residents throughout Africa are housed informally. The characteristics of these settlements have detrimental effects on public and environment health, which doesn't only affect the informal residents but also on the adjacent urban environment. They are typically characterized by the lack of basic services (such as roads, electricity, water, sanitation, stormwater drainage and refuse removal), inadequate and substandard housing, overcrowding, unhealthy and hazardous environmental conditions, insecure tenure, and poverty and exclusion.

South Africa is not exempt from these global challenges of urbanisation and the formation of informal settlements. Informal settlements are not a recent phenomenon that can be attributed to post-Apartheid policies in the 1990s, but have formed part of the South African urban landscape for many decades. Currently, approximately a quarter of South Africa's urban population is housed informally, accounting for approximately 12 million people. As such, the reality of informal settlements will remain a part of the urban environment of South Africa and the developing world for the following decades. Overcoming the backlog in basic services and upgrading informal settlements forms part of the strategic development goals of the South African government. But this will be an enormous task requiring not only urgent but sustained attention.

The South African informal settlement upgrading policy ensures accountability between the provincial and local governments such that upgrading is in line with the integrated development plan of both tiers of government. Strategically, there has been a significant policy shift in the upgrading of informal settlements in South Africa away from the mere provision of housing structures to the promotion of sustainable livelihoods through the provision of basic services, such as water and sanitation services, refuse removal, stormwater drainage, and roads and footpaths. These services are provided as interim measure to meet the immediate needs of the residents before formal houses are provided. This strategic shift to providing services not houses is critical in ensuring sustainable livelihoods, as the initial focus of informal settlement residents is to construct a dwelling unit and they neglect the importance of ensuring adequate infrastructure is in place to remove waste and pollution from the environment. But, the goal of 400 000 improved informal households by 2014 as set out in the Presidential Outcomes will only affect between 7 – 17 per cent of the informal settlement dwellers throughout South Africa, assuming 2.0 – 5.0 persons per household. Thus, the rollout of informal settlement upgrading will form part of the national development goals for many years to come.

The first step in the upgrading process is the provision of communal water and sanitation services as an interim measure for meeting the immediate needs of the community. However, the policy guidelines are very broad. Positively, this provides local authorities flexibility to select the most appropriate technologies. Negatively, the lack of rigid guidelines can make the implementation of such interim communal water and sanitation facilities problematic as the local authorities often lack capacity for selecting and implementing the program. This is evident in the poor rollout of interim communal water and sanitation services in South African informal settlements since publication of the upgrading program three years ago (2009). Thus, there is a need to understand the sanitation technologies available for communal applications in the process of upgrading informal settlements.

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Sanitation

Chapter 2

The Millennium Development Goals developed in 2000 by the United Nations (Target 7C) is to reduce the number of people without adequate water supply by half (UN n.d.). Sanitation was subsequently added at the Earth Summit in Johannesburg in 2002. The targeted global sanitation coverage is 75%. The UN target for achieving universal water supply and sanitation coverage (100%) is 2025. This means that 4 billion people have to be provided with sanitation services globally (WHO & JMP 2000). South Africa is a member state of the United Nations and as such has a commitment to providing improved water and sanitation services to all South African citizens.

This chapter investigates the benefits and the methods available to providing improved, basic sanitation services to unserved areas - mainly informal settlement areas. It further provides an overview of appropriate sanitation technologies available to these settlements within the framework of the South African government and the UN sanitation ladder, which is also discussed in detail. This chapter presents the available technologies for sanitation provision and wastewater treatment and discusses its application to communal sanitation.

1. The Benefit of Sanitation

Although not an engineer or health practitioner, Mahatma Ghandi is quoted for stating, "Sanitation is more important than independence." Over two million people, most of them children, die annually from diseases associated with lack of access to potable water, inadequate sanitation and poor hygiene (Paterson et al. 2007). Mafuta et al. (2011) argue that access to drinking water and sanitation is perhaps one of the most important Millennium Development Goals (MDGs) as it directly affects human health and productive employment. It is crucial for development, health and poverty reduction. It is estimated that the global MDG for sanitation will not be reached by 2015, when 2.6 million people will lack adequate sanitation facilities (WHO 2011).

Sanitation is a human right and a key component of primary prevention to ensure better health (WHO 2011). In South Africa, although sanitation is not explicitly defined in the constitution as a human right, it falls under the right to a safe environment (Section 24 a), human dignity (Section 10) and the right to adequate housing (Section 26). Local government has the responsibility of realising both of these rights (RSA 1996). Yet, South Africa is far from ensuring this right (Sali 2012). Although all of the national policy documents (white papers and strategies) relating to sanitation identify sanitation as a human right, Winnie Madikizela-Mandela, the chairperson of the Ministerial Sanitation Task Team, stated that South Africa has failed at sanitation provision (Sapa 2012e; Nombembe 2012b). Strategically sanitation provision falls under the Strategic Infrastructure Project (SIP 18). The Ministerial Sanitation Task Team concluded that sanitation is a basic requirement, even before roads or housing and will therefore play a pivotal role in the national infrastructure build programme (Sapa 2012d; Sapa 2012e).

1.1 Public Health

Sanitation services are essential to the health of a community which have ramifications on the potential for education and economic prosperity of the children and adults in unserved areas, such as informal settlements (Bartlett 2003). In fact, it has been estimated by the World Health Organisation (WHO) that the majority (80%) of all deaths in developing countries are related to water- and excreta-diseases (Petterson & Ashbolt 2002). Sanitation provision thus plays a significant part in improving public health and has been named the most significant medical advance since 1840 (WHO & JMP 2008). However, hygiene education has to form part of the sanitation provision program as the connection between health and sanitation is not always realised by the community (Bernhardt Dunstan & Associates 1998).

The modern sanitation revolution was inaugurated by Sir Edwin Chadwick, who released a report in 1842 recognizing that the absence of adequate water and sanitation in urban areas lead to widespread disease (Mara 2003 quoting Chadwick 1842). However, it is important to note that diarrhoeal disease is not only a waterborne disease, but is transmitted through poor hygiene behaviour by hands, food, etc. (Cairncross 2003). The benefits of this revolution are associated with three aspects of sanitation provision, namely the sanitation infrastructure, water supply, and hygienic behaviour, as shown in Figure 1. The benefit of improved sanitation can have a greater impact on health than water supply, especially for reducing diarrhoeal disease (Esrey et al. 1991; Prüss-Üstün et al. 2008; Bartlett 2003; Moraes et al. 2003). This is because most pathogens originate from domestic wastewater and are spread from hand to mouth or from hand to food to mouth rather than through drinking contaminated water, as shown in Figure 1 (Still et al. 2009). Cairncross et al. (2005) have argued that the main benefits are attributed to the change in hygiene behaviour. However, it has also been found that there are health benefits associated with sewerage connections (Moraes et al. 2003; Barreto et al. 2007). These associated health benefits of sanitation provision are independent of the type of toilet facility (Moraes et al. 2003) but the improved health effects have a positive economic impact on the users’ ability to work (Jewitt 2010).

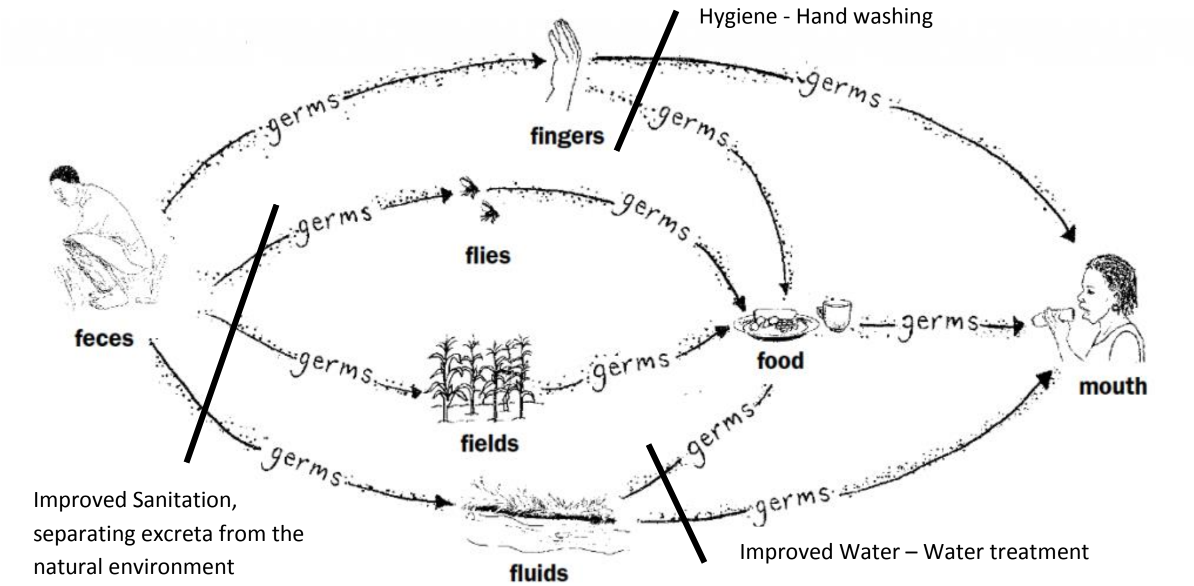

Figure 1: The faecal-oral transmission of disease, commonly referred to as the F-diagram (Conant 2005). Hygiene education and improved hygiene behaviour is a barrier between the finger-food and finger-mouth. An improved water supply is a barrier between fluids-food and fluids-mouth. Improved sanitation and excreta disposal is a barrier between faeces-flies, faeces-fields, and faeces-fluids.

Poor water and sanitation has been associated with increased risk of infection and malnutrition and stunted growth in children (Merchant et al. 2003; Checkley et al. 2004). In Africa, 115 people die every hour due to sanitation related diseases (WHO 2011). Unsafe water, sanitation and hygiene accounted for a global total disease burden of 6.3% in disability adjusted life years - DALY (WHO 2009; Murray & Lopez 1997). Diarrhoeal deaths are mainly (88%) caused by unsafe water, sanitation and hygiene, with 99% of those deaths occurring in the developing world (WHO 2009). To put this into perspective, more people are affected by poor sanitation related diseases than from war, terrorism and weapons of mass destruction combined (Bartram et al. 2005). As sanitation related diseases, such as diarrhoea, are preventable, sanitation interventions should be prioritised in all public health policies (Prüss et al. 2002; Bartram et al. 2005). Meeting the MDGs on water and sanitation would reduce diarrhoeal deaths by up to 10% (Bartram et al. 2005), and would be one of the most important contributions to health ever made (Mara 2003).

Although health is one of the most significant reasons for the promotion and provision of sanitation facilities, the users' reasons for choosing to improve poor sanitation facilities in rural Benin for example were found to be associated with prestige and not health (Jenkins & Curtis 2005). This impacts the way in which sanitation service promotion and education should be approached, not only to rural populations but also to informal settlements dwellers lacking sanitation.

1.2 Environmental Health

There are detrimental environmental health effects caused by untreated wastewater discharge. However, the actual extent of the problem is difficult to quantify, but the consensus is that the majority of wastewater throughout the developing world is discharged untreated into the surrounding environment. It has been reported that over 80 per cent of the wastewater is discharged untreated in the large cities of Sub-Saharan Africa (Nyenje et al. 2010). The figure for untreated wastewater disposal in the developing world has been reported as high as 90 per cent (Austin et al. 2005). The primary pollution from on-site sanitation is nitrate pollution, not pathogens (Fourie & van Ryneveld 1993).The total volume of wastewater produced in the urban environment is considerably higher when compared to the total precipitation entering these urban areas. Informal settlements produce and pollute the surrounding environment with extremely high nutrient loads, due to high population densities and the predominant usage of on-site sanitation facilities, if any at all. Eutrophication is a process by which lakes, rivers, and coastal waters become increasingly rich in plant biomass as a result of the enhanced input of nutrients, mainly nitrogen and phosphorus, and lead to the destruction of aquatic life. It is one of the most prevalent global problems of our era (Nyenje et al. 2010).

1.3 Economic Impact

The lack of sanitation has significant effects on the productive, economic livelihood of the individuals. WHO estimated that for every $1 invested in improving sanitation it would yield an average return of $9 (WHO 2011). Globally in 2012 the WHO determined that the return on invested of $1 on sanitation is $5.5 (World Bank 2013). The cost benefit ratio remains greater than one, even under less optimistic assumptions (Hutton et al. 2006). The economic benefits of water and sanitation outweigh the required investments and contributes significantly to poverty eradication (Sanctuary & Tropp 2008). Furthermore, the economic benefit of sanitation provision is greater than water supply (Sanctuary & Tropp 2008). A study of the economic impact of sanitation in 18 African countries indicated that US$5.5 billion is lost annually due to inadequate sanitation, which accounts for between 1 - 2.5 per cent of GDP of each country (WSP 2012a). The losses were attributed mainly to premature death of children under five years of age. In fact, child mortality rates are generally highly correlated with a lack of access to water and sanitation (Bartlett 2003). Other costs are associated with finding a discrete place for open defecation, health costs and productivity loss. Other economic losses are attributed to the water pollution, environmental losses (with regard to arable land) and tourism. However, the economic effects of a lack of sanitation have a disproportionate impact on the poor (Sanctuary & Tropp 2008; WSP 2012a). A similar study that was done by the Water and Sanitation Program (WSP 2008) in Southeast Asia found that the per capita economic losses associated with the lack of providing sanitation services are on average US$22 per annum. In India, the per capita economic losses are US$21 per annum, which accounts for 6.4 per cent of GDP (WSP 2010). The poorest 20 per cent of Indian urban residents have an estimated annual impact of US$37.5 per capita from inadequate sanitation.

2. Governmental Responsibility

Sanitation came under the political spotlight in the last municipal elections in South Africa (Reuters 2011). The lack of adequate sanitation, electricity and housing services in informal settlements has been the major factors in the increased service delivery protests around South Africa (Managa 2012; Staff reporter 2012; Davids 2012; Sali 2012; Phakathi 2012; Paton 2012), see for example cases in Gauteng

(Sapa 2012a; Sapa 2012c; Maliza 2012; Sapa 2011a; Seleka 2008; Mkani 2007), Western Cape (Sapa 2012b; Nombembe 2012a; Majuva 2011; Damba 2012), Mpumalanga (Mapumulo 2009), Free State (Seleka 2012; Sapa 2011b; Mbanjwa 2011), and the North West (Infrastructure News 2012).

The provision of sanitation falls under the responsibility of the local government departments, which include the Housing Department, Water and Sanitation Department and Health Department. The local government has the constitutional mandate to provide potable water and household sanitation services within its jurisdiction (RSA 1996; DWAF 1994). This has clearly been outlined in the Water Services Act (RSA 1997) and the Municipal Systems Act (RSA 2000). The local government is referred to as the water services authority (WSA). Constitutionally, WSAs are responsible for planning, ensuring access to, and regulating and provision of water services within their area of jurisdiction (DWAF 2003). WSAs have a responsibility to ensure that *all people* living within their jurisdiction are progressively provided with at least basic water services – the first rung on the water and sanitation ladder (DWAF 2003). All WSAs must produce an annual interim water services development plan (WSDP), which is updated every five years, to form a realistic, long-term plan for the prioritisation of providing basic water services, promoting economic development and sustainability (DWAF 2003). The WSDP must be integrated into the municipal Integrated Development Plan (IDP), and enables the WSA to carry out their mandate effectively and in line with the municipal strategy of providing services to all. The WSDP must show how the water services authority plans to meet this universal service obligation (DWAF 2003). Finally, appropriate asset maintenance and rehabilitation plans have to be developed and implemented by the WSA in order to reduce costs associated with the deterioration of assets (DWAF 2003).

Provincial and national government have the constitutional responsibility to support and strengthen the capacity of local government in the fulfilment of its functions, and to regulate local government to ensure effective performance of its duties (DWAF 2003). To this extent, the provincial departments could coordinate the construction of water and sanitation infrastructure on behalf of local departments. The national departments involved with sanitation provision include the Department of Water Affairs, Department of Human Settlements, Department of Health, and National Treasury. The role of national regulator of the water services is performed by the Department of Water Affairs (DWA), as per Section 155(7) of the Constitution. As such, DWA is the custodian of South Africa's water. DWA is not a water provider, but a sector leader, supporter and regulator (DWAF 2003). As the national regulator, DWA has legal recourse against non-compliance, as well as the ability to hand over water service responsibilities to different departments or spheres of government where required (Tissington 2011). In May 2009 the National Sanitation Programme Unit was relocated from DWA to the Department of Human Settlements (DHS), with DHS responsible for household sanitation infrastructure and DWA is responsible for bulk reticulation services (Tissington 2011). The National Upgrading Support Programme (NUSP) was initiated to support the DHS and the Cities Alliance in order to provide support to enable rapid rollout of informal settlement upgrading in the South African municipalities (NSUP 2010). The National Treasury's responsibility toward sanitation provision relates to the funding of the different departments and spheres of government, monitoring and regulating the finances of all public bodies (DWAF 2003). Due to the strong relationship between sanitation services and public health, the health sector must play a significant role in all aspects of sanitation, including policy creation, planning, implementation, and monitoring (DWAF 1994).

2.1 Sanitation Policy in South Africa

The policy documents relevant to sanitation provision in South Africa are stated in Appendix A. The national program for sanitation provision in South Africa was established in the wake of the new democratic government in 1994 and the Reconstruction and Development Programme (RDP). This gave birth to the first White Paper on Basic Water Supply and Sanitation (DWAF 1994). Household sanitation was readdressed in 2001, with the White Paper on Basic Household Sanitation (DWAF 2001), which encompasses most of the preceding White Paper (Tissington 2011). Although this document expressed the need to focus on basic household sanitation provision to communities in low density rural areas, and in informal settlements, there were little in terms of guidelines for sanitation provision in these areas (DWAF 2001; Mjoli 2009). In general, DWAF (2001) focuses on rural settlements, while DWAF (2003) focuses on urban areas. The main principles adopted in the White Paper identified that (DWAF 2001)

- sanitation encompasses not only the provision of infrastructure but also the environment and health;
- basic sanitation is a human right;
- the responsibility is on the local government to provide access to sanitation services ; and
- provincial and national government have a constitutional responsibility to support local government

These principles were built on the Water Services Act 108 of 1997, which explicitly indicated that everyone in South Africa has a right to access basic water supply and basic sanitation, and it is the onus of the water service authority, the local government, to ensure access to these water services (RSA 1997). The WSA is responsible for ensuring access to the water services. It further emphasised the provision of basic water and sanitation services to all of the municipal inhabitants instead of higher levels of sanitation to only a few (RSA 1997). This prioritisation of universal basic services is enshrined in the Municipal Systems Act 32 of 2000 (RSA 2000). To this extent, municipalities must develop an indigent policy that assists poor households with access to basic municipal services. The Act further requires municipalities to strategically plan for this through an annually updated IDP, which integrates and coordinates the municipal planning between different sectors (RSA 2000). The Strategic Framework for Water Services (DWAF 2003) provides a comprehensive review of policies, legislation and strategies with respect to the provision of water services in South Africa, seeking to align them and outline the changes in approach needed to achieve policy goals. This framework was developed with the South African Local Government Association (SALGA) and other key stakeholders (Tissington 2011). The main difference was that the strategy emphasised supply-driven sanitation provision (i.e. top-down approach), unlike the demand-driven sanitation provision (i.e. bottom-up approach) previously emphasised in the sanitation White Paper of 2001. Demand-driven sanitation provision was based on international best practice (DWAF 2001). This supply-driven approach is associated with the municipality being responsible for the sustained servicing of the sanitation services. The National Sanitation Strategy

(DWAF 2004) presented the responsibilities for sanitation delivery, i.e. planning, funding, implementation approaches, regulating the sanitation sector, and monitoring and evaluation (Tissington 2011). Yet, although the lack of poor sustainability of the sanitation services provided through top-down supply driven programs has been reported in literature (Winter et al. 2008, Still et al. 2009), the Free Basic Sanitation policy and the legacy of Apartheid has led to a sense of entitlement, in that the government is responsible for service delivery (Taing et al. 2013). Both the Strategic Framework for Water Services (DWAF 2003) and the National Sanitation Strategy (2004) strove to eliminate the household sanitation backlog by 2010; however, this target date has been moved to 2014, in line with the Department of Human Settlement's target date for universal access to housing by 2014. This target is however unachievable at the current rate of development (Dambusa 2012).

In 2000, the President announced the intention to provide poor households with access to what is known as Free Basic Services (FBS), which provides free basic water, electricity, sanitation and refuse removal to poor households. The free basic water policy was adopted in 2001, with free basic sanitation being adopted in 2009. The free basic sanitation policy is directly linked to the policies for infrastructure provision, as it is associated with the provision of sanitation facilities to poor households who lack any facilities (DWAF 2003). The Free Basic Sanitation Implementation Strategy (DWAF 2009) acknowledges the constitutional right to basic sanitation, and that poor households should not be denied access due to their inability to pay, emphasising implementation flexibility based on local conditions, such as geography, demographics, income distribution and institutional capacity (DWAF 2009). It also discussed the need for maintenance strategy plans for sanitation services within Water Service Development Plans (DWAF 2009). However, it has been argued that free basic sanitation is not a pro-poor policy, as most of the poorest households do not have access to waterborne sanitation connections and basic infrastructure (Mjoli 2009).

3. Sanitation Framework

An appropriate and sustainable sanitation system has to account for economic aspects, including affordability, financial capital investments and continued operation and maintenance; institutional aspects, including institutional capacity and opportunities for public–private partnership; environmental aspects, including environmental impact, health, minimising energy requirements, and resource recovery and reuse opportunities; and social aspects, including convenience, dignity, acceptability, and willingness to pay or operate (Zurbrügg & Tilley 2009). In the selection of an appropriate technology, a trade-off must be made between effectiveness, affordability, capacity to operate and maintain, life-cycle costs, consumer acceptability and environmental impact. Community participation should be conducted to educate users on all available technical options and related financial and operational implications. It is important that water and sanitation technologies be selected together, not in isolation (DWAF 2003; DWAF n.d.a).

The mere provision of water and sanitation facilities does not eradicate poor water and sanitation conditions. Yet, the sanitation backlog in South Africa has created an emphasis on eradication, through the provision of toilets and sanitation infrastructure. This affects both the pre- and post-provision of sanitation. Pre-provision includes the planning stage, which is constitutionally mandated to include community participation – Section 151(e) (RSA 1996). However, community participation is seldom associated with the construction of water and sanitation services (DWAF 2005; Boaden & Taylor 2001). Post-provision includes the operation and maintenance (O&M) which has been neglected, with neither quality assurance nor O&M plans in place (DWAF 2007). The purpose of O&M is broadly ensuring efficiency, effectiveness and sustainability of the water and sanitation facilities, with the general model for the sustainability of water and sanitation infrastructure shown in Figure 2 (Castro et al. 2009). The prevention of deteriorating and ageing infrastructure reduces fruitless expenditure and the rise of a 'new' backlog in water and sanitation services (CoGTA 2011).

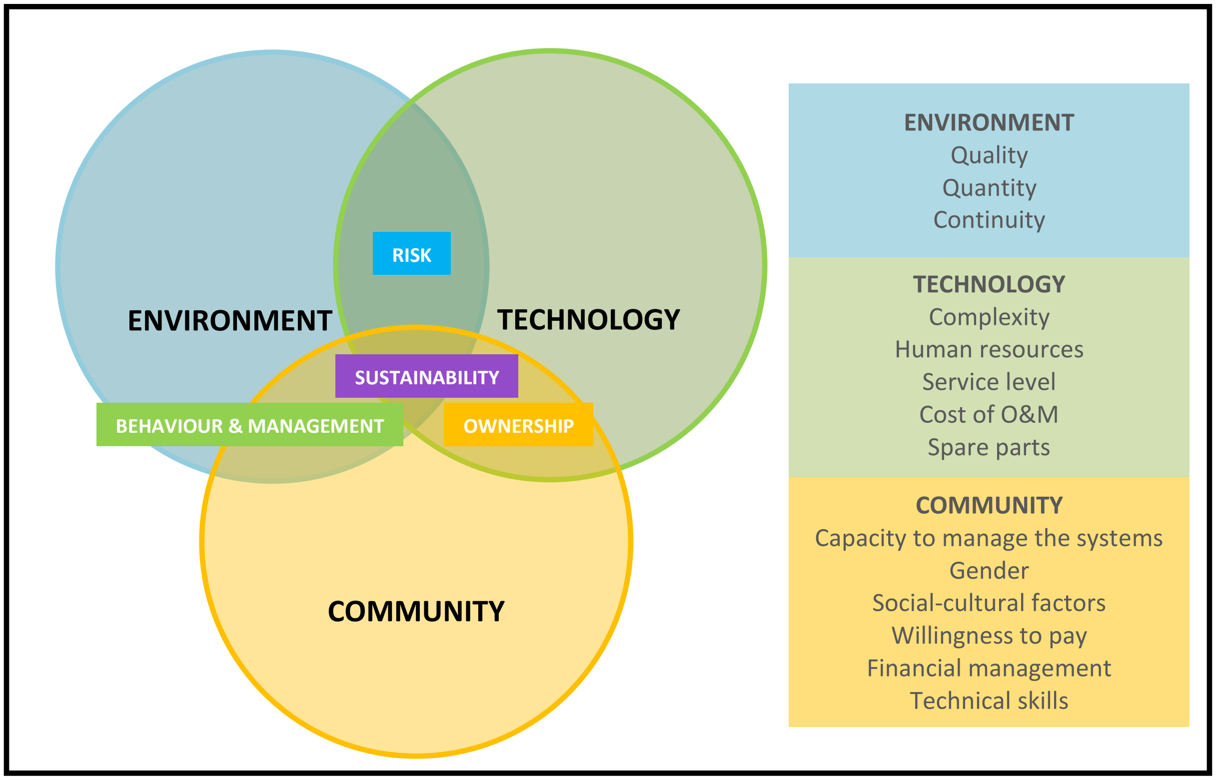

Figure 2: The sustainability nexus in the provision of water and sanitation services (adapted from Brikke 2000)

The input into any sanitation system can be separated into different sources, as shown in Figure 3. This study only investigates the wastewater from domestic sources, and does not account for municipal wastewater, which includes industrial wastewater sources.

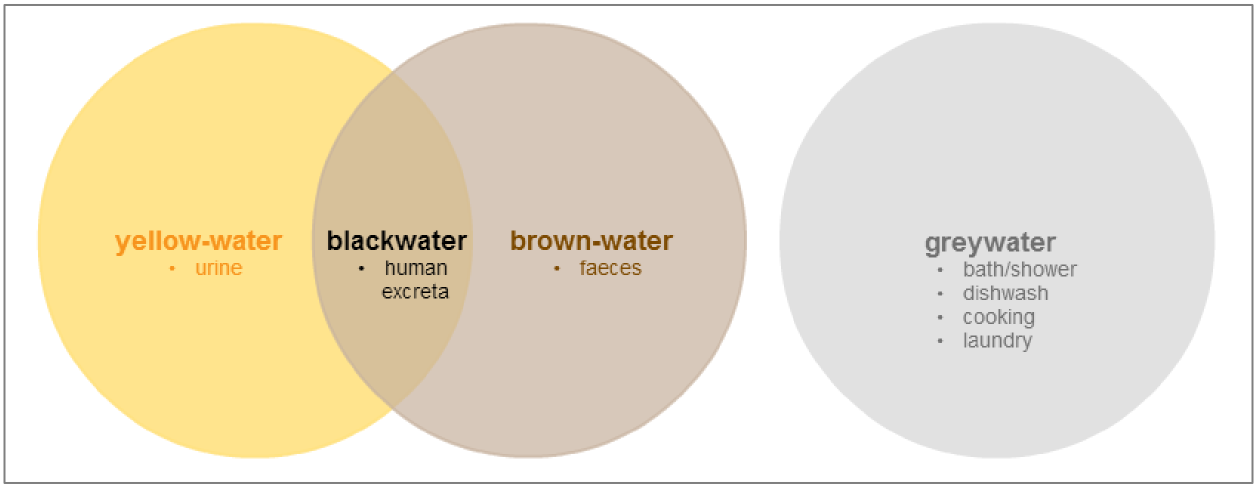

Figure 3: The separate wastewater streams from domestic wastewater
This study only includes the provision of sanitation services to households and as such only refers to domestic wastewater. The yellow-, black-, and brown-water includes the washing water used in the flushing of human excreta. The blackwater includes the water used for washing hands after defecation.

This study ties in with the United Nations Joint Monitoring Program's framework, the sanitation ladder (WHO & JMP 2008), which describes the different levels of sanitation provision (Figure 4). This broad framework was developed in 2008 and not only differentiates between different levels of sanitation but can be used as a practical tool for monitoring progress toward meeting the MDGs on sanitation provision. There are variations in the way in which the JMP figures are reported due to differences in indicator definitions (some countries report shared facilities as improved facilities), calculation methodologies and data sources (Konradsen et al. 2010). The main purpose of using the JMP sanitation ladder here is to determine the prevalence of shared sanitation facilities. The achievements in sanitation delivery in Africa are shown in Figure 5, with South Africa's progress shown in Figure 6. It is noted that although this framework has been criticised (Kvarnström et al. 2011) and does not account for hygiene behaviour such as hand washing (Konradsen et al. 2010), this framework is sufficient in this study as the research does not focus on a specific (or new) sanitation technology but investigates the implications of providing sustainable, shared sanitation facilities. Furthermore, the JMP sanitation ladder ties in with the sentiment of the South African government's goal of providing basic sanitation services to all, instead of providing a high level of sanitation to few (DWAF 2003), and the aim would be to move people up the ladder by first providing shared, yet improved, sanitation facilities before providing individual sanitation facilities for each household.

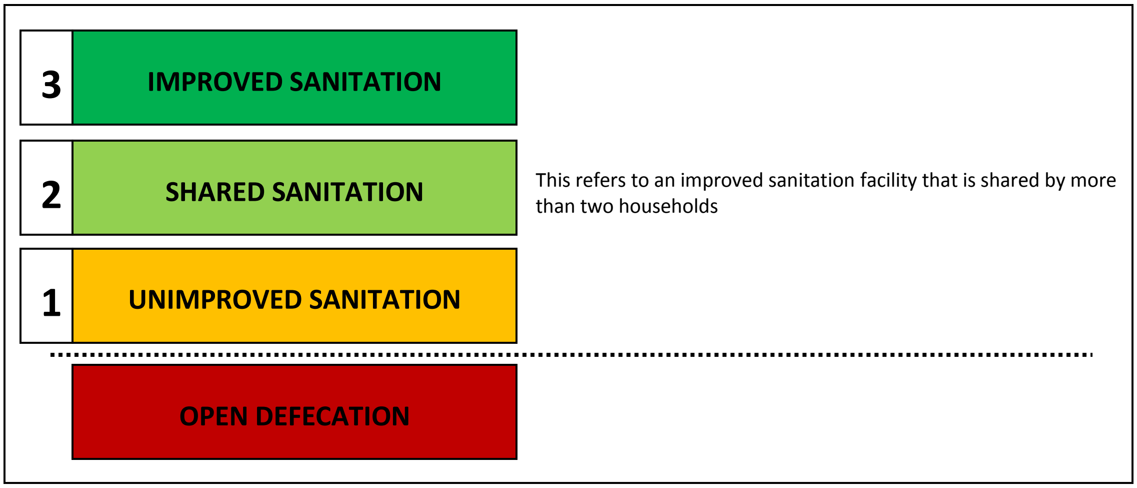

Figure 4: The sanitation ladder

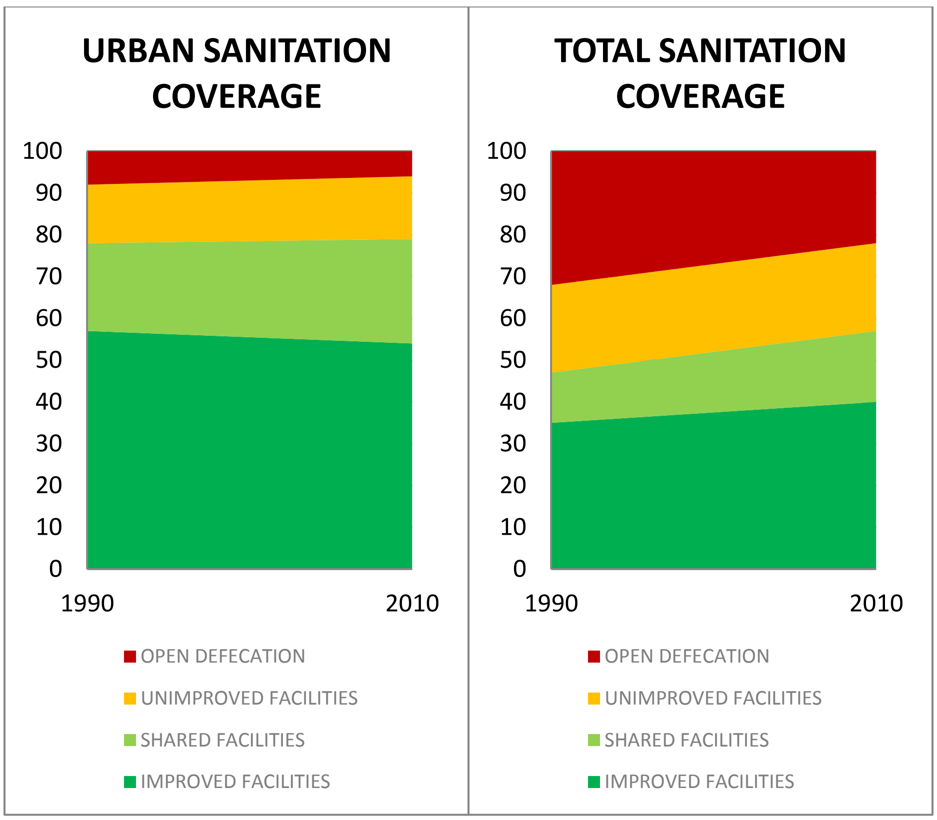

Figure 5: Progress toward the MDGs in Africa (AMCOW 2012)

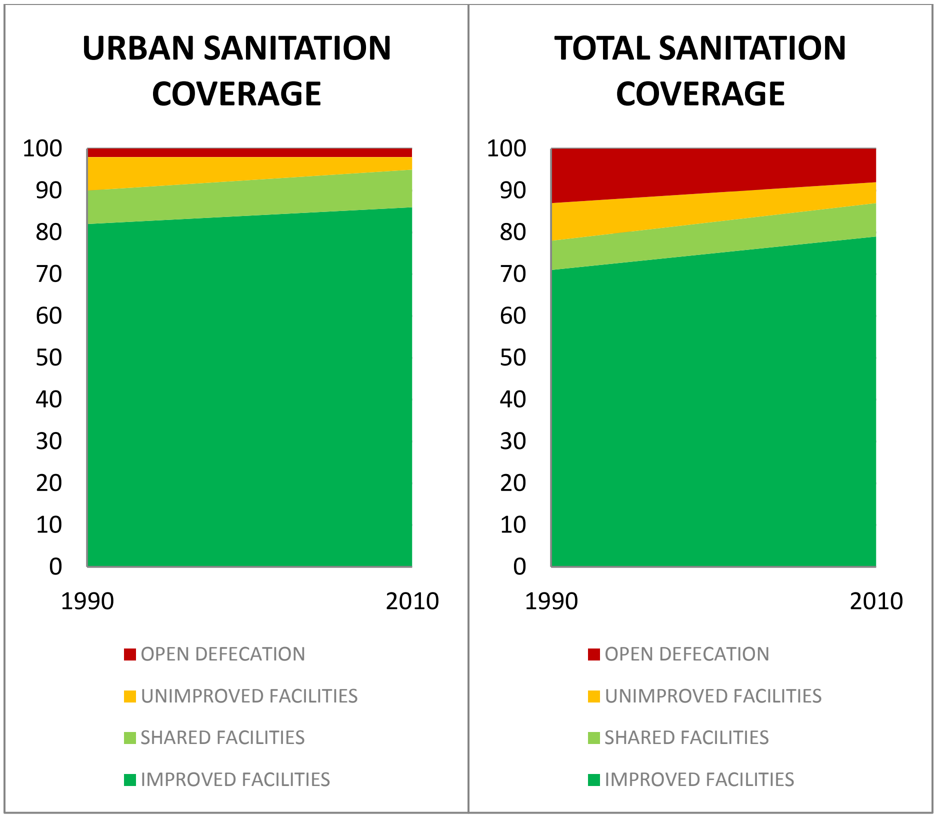

Figure 6: South Africa's progress on the MDGs (JMP 2012)

In the provision of sanitation services, the municipalities have to consider the following criteria in their selection of appropriate technology for the settlement (DWAF 2007)

- The availability of water services
- The proximity of sewer mains
- The suitability of the soil and geology for the different types of on-site services
- The availability of local materials and skills
- The actual funds available for the services or that can be sourced through grants and loans

The most appropriate sanitation technology for each informal settlement will depend on a range of factors - including financial, institutional, settlement permanency, environmental, and social issues. Planning and upgrading should be integrated into the municipality's broader development goals. Furthermore, the long-term plan for the settlement has to be considered, whether the settlement will be relocated or upgraded in-situ. To this extent, municipalities have three choices (DWAF 2007)

- Upgrade a settlement to a more formal settlement with permanent services appropriate to the economic and environmental conditions of the settlement;
- Install interim services until relocation;
- Move the settlement without the provision of services in the current location.

3.1 Sanitation Backlog

It is estimated that South Africa already reached the MDG target for sanitation in 2008, but that there has since been a drop in adequate sanitation due to poor operation and maintenance of the facilities. Nationally, the current backlog is 2.4 million households requiring sanitation services (Vawda 2012). The eradication of the water and sanitation backlog in South Africa by 2014 is directly linked to Outcome 8 (Sustainable human settlements and an improved quality of household life) and places the responsibility on local government in Output 9 (Responsive, accountable, effective and efficient local government system) of the Presidential Outcomes (RSA 2010a; RSA 2010b). The backlog does not only include the provision of sanitation services, but also refurbishment, extension and upgrading, and operation and maintenance of existing infrastructure (Dambuza 2012). The backlog is exacerbated by the local government's inadequate institutional capacity, poor planning and allocation of revenue, and lack of support from provincial and national government, with municipalities only spending 30% of the allocated capital budget for sanitation services in 2011 (Dambuza 2012; Vawda 2012). Furthermore, a national audit of sanitation services found that 28% of all government-funded sanitation services could fail within the short and medium term (Vawda 2012). Eradicating the sanitation backlog requires a holistic approach. Although the eradication of the sanitation backlog is quantified by the number of toilets provided, the sanitation backlog does not only refer to toilets. This is because sanitation protects both environmental and public health. As such, sanitation is a barrier, consisting of four discrete elements, namely,

- User interface –the toilet structure. This can either take the form of a sitting toilet or a squatting toilet.
- Conveyance – for waterborne systems, this is typically performed directly after toilet-use (by sewer networks). However, for on-site solutions, such as pit latrines, the conveyance happens once the pit is full and the sludge is transported either manually (by hand) or mechanically (by a truck or tanker).
- Treatment – decentralised treatment can either refer to on-site treatment, such as the pit (from the VIP), septic tanks, or DEWATS approaches; and centralised treatment refers to a centralised wastewater treatment plant.
- Reuse and resource recovery – this for example includes the reuse of nutrients in agriculture, the reuse of biogas for electricity use, and the reuse of greywater.

The estimated current water and sanitation backlog is shown at a Provincial level in Table 1, which translates into around 10 million people lacking sanitation services in South Africa (Etheridge 2012). The National Sanitation Task Team estimated that the total cost of R50 billion was needed to address the sanitation backlog of 2.5 million households (Dambusa 2012). Yet, official data from the 2011 Census reports the sanitation backlog in South Africa to be approximately four million households, which effectively means that the investment in sanitation should be in the order of R80 billion.

Table 1: Water and sanitation backlog in South Africa at a provincial level (StatsSA 2012). The data is based on a projection from the 2011 Census data. The sanitation backlog refers to households with no toilets, bucket toilets and unimproved pit latrines. The water backlog refers to households with no access to piped water and any piped water source greater than 200 m from the household.

Area	Sanitation backlog (hh)	Sanitation Backlog (%)	Water backlog (hh)	Water Backlog (%)
Eastern Cape	593 731	37%	540 838	32%
Free State	182 079	22%	39 165	5%
Gauteng	401 846	10%	180 473	5%
KwaZulu-Natal	727 888	30%	549 774	22%
Limpopo	860 534	62%	386 445	27%
Mpumalanga	441 522	42%	205 909	19%
Northern Cape	436 092	42%	173 856	16%
North West	68 544	23%	27 770	9%
Western Cape	120 271	7%	53 320	3%
South Africa	**3 986 727**	**26%**	**2 157 550**	**15%**

The provision of sanitation services to informal settlements faces very acute realities and as such, not all sanitation services are appropriate. The sanitation requirements in informal settlements throughout South Africa are shown in Table 2. Historically in South Africa, the provision of sanitation services to dense urban informal settlement areas has been problematic due to institutional problems, namely institutional capacity and the lack of governmental responsibility for sanitation provision. Other factors include the poor planning of the settlement and lack of available space within the settlement.

Table 2: Sanitation requirements for informal settlements in South Africa at a provincial level (StatsSA 2012) The data is based on a projection from the 2011 Census data. The sanitation backlog refers to households with no toilets, bucket toilets and unimproved pit latrines.

	Informal settlements without basic sanitation	Number of households without basic sanitation
Eastern Cape	71%	62 026
Free State	67%	51 510
Gauteng	59%	248 223
KwaZulu-Natal	55%	74 617
Limpopo	84%	32 785
Mpumalanga	58%	43 261
North West	71%	102 341
Northern Cape	72%	21 060
Western Cape	41%	74 690
South Africa	**60%**	**710 513**

Besides the physical provision or upgrading of the sanitation service, there are social and legal issues which discourage development. As a large proportion of informal settlement residents do not own their land and the landlords do not live within the settlement, the residents are unable to make adequate improvements to the lack of sanitation (Schaub-Jones 2005). Thus, strategies solely encouraging hygiene education can cause limited behavioural change as limited physical changes can occur to the sanitation facilities (Schaub-Jones 2005).

4. Unimproved Sanitation

Unimproved sanitation refers to any rudimentary sanitation option that has not been adequately engineered or planned for in order to ensure both human and environmental health. These can include a rudimentary pit or hanging latrine, or the bucket system toilets. Another form of unimproved sanitation is the flying toilet, which consists of defecation in a plastic bag and throwing the bag away from the house (Gulis et al. 2004). However, it is important to note that the most widespread form of defecation worldwide is not even on this rung of the ladder, with more than 2.6 billion people not having any form of toilet (Jewitt 2010). Open defecation is the reality for five per cent of South African households, affecting 2.7 million people (StatsSA 2012).

5. Improved Sanitation

Improved water and sanitation services are perceived by the users as promoting dignity, privacy, health, as well as increase security for women (Roma et al. 2010). A basic sanitation facility refers to any infrastructure necessary to provide safe, reliable, private, protected from the weather, ventilated, keeps smells to the minimum, is easy to keep clean, minimises the risk of the spread of sanitation-related diseases by facilitating the appropriate control of disease carrying flies and pests, enables safe and appropriate treatment and/or removal of human waste and wastewater in an environmentally sound manner, and the communication of good sanitation, hygiene and related practices (DWAF 2003). These minimum standards have been established by national government. From a health perspective, there is very little (if any) difference between correctly functioning on-site or off-site sanitation options (Parr et al. n.d.). The broad definition of basic sanitation provides guidelines but does not define the technology to be used. This choice is left to the WSA, as the appropriate technology is dependent on in-situ settlement conditions. This is seen as the key to success in providing free basic sanitation services in a sustainable manner (DWAF 2003). The capital and operating costs of a given technology may vary widely between locations - depending on locally available materials, construction method, extent of existing infrastructure, etc. (DWAF n.d.b).

The minimum standard for water supply is a standpipe at a maximum distance of 200 m from the household, providing a reliable water supply of 25 litres per person per day at a minimum flow of 10 litres per minute. In addition, the water must be available for at least 350 days per year and not interrupted for more than 48 consecutive hours (DWAF 2003). Although this distance-based approach has been argued to be absolute, not addressing the implications of carrying water from the standpipe due to in-situ topographic conditions (Majuru et al. 2011), this approach provides a baseline value for the provision of water services. The minimum standard for sanitation provision is a ventilated improved pit (VIP) or equivalent dry sanitation service.

There is a continuum of wastewater treatment from centralised treatment at a central wastewater treatment plant for the entire catchment to decentralised wastewater treatment plants, including on-site solutions, such as septic tanks or VIP latrines. There has been considerable debate surrounding the viability of each in the developing world where centralised sewer networks have not yet been developed. The consensus is that both are applicable and should be seen as complementary (Starkl et al. 2012). A staged development approach should be encouraged whereby decentralised systems meet the immediate need of the unserved areas such that the systems can be connected to centralised systems in the future. There are economies of scale with centralised systems. However, decentralised systems are more adaptable to local situations, including flat topography and low-density areas. Still, the operation, maintenance and risks associated with a few centralised treatment plants are more controllable, require less resources, and are more enforceable than a multitude of decentralised systems. Finally, the reuse of wastewater is often more easily achieved at a decentralised level due to domestic wastewater not co-digested with industrial effluent. Yet, reuse for agriculture and irrigation is possible at both centralised and decentralised scales (Starkl et al. 2012). It is important to note that as technological decentralisation increases, there must be an increased centralisation of regulating and managing these systems to ensure that the wastewater is adequately treated and the environment is not polluted.

A useful two-way classification system is often used for grouping the array of sanitation options. Systems are firstly grouped whether they are “waterborne” or “dry” (i.e. requiring water for flushing or not), and secondly whether the waste products are stored on site or removed. The resulting matrix of solutions is shown in Table 3 and is further discussed in this section. Although the MDGs place both waterborne sewers and VIP latrines on top of the sanitation ladder, the policy in South Africa has further ranked VIPs as the basic level of service and waterborne sewers as the highest level of service – based on the associated costs for these two technologies. This has caused on-site dry sanitation systems to be seen as inferior systems and waterborne sewers to become the aspiration of many informal settlement dwellers, independent of the affordability of this level of service (Roma & Buckley 2011; Howard et al. 2000; Bernhardt Dunstan & Associates 1998).

Table 3: The broad definition of sanitation technologies (CSIR 2005)

	Waterborne	**Dry**
On-site	Septic Tanks Aqua-privy Anaerobic Baffle Reactors	Ventilated Improved Pit Latrines Urine Diverting Toilets
Off-site	Conventional Sewers Simplified Sewers	Chemical Toilets Bucket Toilets

As a rule of thumb, urban areas should be provided with waterborne services, as waterborne sanitation is generally the most appropriate form of sanitation provision and should be regarded as a basic level of service. In rural areas, a water services authority must decide on an appropriate technology which is financially viable and sustainable (DWAF 2003). Informal settlements should be provided with waterborne services due to their location to the urban periphery and due to the high densities often found in these areas (Paterson et al. 2007).

The reuse potential of human excreta is briefly discussed in order to provide a holistic overview of the current state of the art in sanitation provision. This concept is referred to as ecological sanitation and has been a major focus in research and practice over the last three decades in order to promote the sustainable use of resources. However, ecological sanitation is an ancient practice, with evidence found in Roman, Chinese, Aztec and Inca cultures. The main goal of this approach is the reuse of nutrients and wastewater for applications to irrigation, agriculture and industry. This approach opposes the use of conventional sewerage networks as human excreta consist of approximately 500 litre urine and 50 litre faeces per capita per annum, which use in the order of 15 000 litres of clean water to flush away in the conventional sewerage network (Austin et al. 2005). However, most of the pathogens and health-risks are found in the faeces (Buckley et al. 2008b) while the majority of the nutrients are found in the urine (Austin et al. 2005). As such, this approach promotes source separation of faeces and urine. The simplest technology available for this approach is the urine-diversion (UD) toilet. Extensive research has been performed in South African relating to health aspects, acceptability and design of urine-diversion toilets (Buckley et al. 2008b; Buckley et al. 2008c; Austin et al. 2005; Austin 2007; Dunker et al. 2006). The main health risks associated with UD toilets are in the emptying and handling of the faeces, but can be readily managed (Buckley et al. 2008b; Buckley et al. 2008c).

5.1 On-Site Technologies

Dry sanitation

Dry sanitation refers to sanitation systems that do not require any water. Proprietary dry sanitation technologies exist which are beyond the scope of the thesis (Still et al. 2009). However, these systems require extensive operation and maintenance plans in order to prevent frequent blockages attributed to heavy use, incorrect use, or problems with the flushing mechanisms. In Cape Town, on-site systems include anaerobic toilets, pit liner toilets, bucket toilets, porta pottis and container toilets (Mels et al. 2010). The most common type of dry system is the ventilated improved pit (VIP) latrine. There are a number of different dry sanitation systems which are essentially variations of the VIP latrine *inter alia* the fossa alterna, the ventilated improved double-pit (VIDP) latrine, etc. (Tilley et al. 2009; van Nostrand & Wilson 1983; Bester & Austin 2000). The VIP system is the basic type of sanitation as required by the national standards (DWAF 2001). It has been used extensively in South Africa and throughout Africa. The VIP latrine (or equivalent dry system) is the City of Johannesburg's basic or lowest level of service (CoJ 2009). This technology has not only been implemented extensively, but has also been researched extensively. The World Bank design guidelines have been in place since the early 1980s, see Mara (1984). Buckley et al. (2008a) characterised the biological processes occurring within the pit. The current knowledge indicates that there is no benefit in adding pit additives into the pit to enhance the processes and extend the emptying period (Still et al. 2009; Buckley et al. 2008a). However, many local authorities in South Africa oppose non-waterborne services (including VIP latrines) based on public health and political grounds (Howard et al. 2000). Furthermore, the pit sludge has to be emptied on a regular basis. The pit is designed such that the sludge has to typically be emptied on a five year basis. The number of pits in need of emptying in South Africa is enormous, with at least a million full pits. The process of pit emptying, however, is problematic, especially in dense urban and peri-urban areas where mechanical emptying is not viable, as the tankers are unable to reach the pits (Still 2002). Manual emptying of VIPs can be detrimental to human health. Mechanical emptying may be more feasible in urban areas, especially if the pit is wet, as the procedure is essentially similar to the emptying of septic tanks. However where the pit is dry, mechanical emptying is not possible (Mara 1984). But, other low cost emptying solutions are under development for such applications (Still et al. 2012). Additionally, pit emptying strategies are severely hindered by the addition of solid waste in the pits. Therefore, on-site sanitation facilities require a functioning solid-waste collection strategy in order to enable effective emptying schemes and sustained sanitation services (DWAF n.d.c).

Currently, there are four options for emptying a full pit latrine (DWAF n.d.c; van Nostrand & Wilson 1983; Mara 1984).

- Do not empty the pit, but relocate the latrine over a new pit
- Extend the life of the existing pit, by increasing the design volume of the pit
- Empty the pit manually, ensuring that health risks are minimised
- Empty the pit mechanically, using desludging equipment

There are many different types of urine-diversion toilet arrangements. Generally, urine-diversion toilets are characterised by above ground faecal storage containers, usually two, and a pipe conveying urine into a soakaway. UD toilets are well suited to areas with a high groundwater table or rocky soils as the vaults are situated above ground. The faecal container capacity is based on 1 year retention time, after which the alternative chamber is used. The emptying of the faecal matter is the responsibility of the household. The problems associated with the emptying of VIP latrines led to UD toilets being implemented at scale by the eThekwini municipality and the abandonment of constructing new VIP latrines. There are over 75 000 UD toilets already constructed to those households that cannot be connected to a sewer network throughout the municipal area (Naranjo 2009). Although a success in peri-urban and rural areas, eThekwini municipality does not provide UD toilets to informal settlements. UDs have nonetheless been provided to informal settlements in both Johannesburg and Cape Town, but not at the scale of eThekwini.

Waterborne

Wastewater treatment is required where waterborne services are provided to a community. In areas where there are no sewers and there is adequate space, wastewater can be piped to a septic tank, a conservancy tank, or a small package wastewater treatment plant (Still et al. 2009; Okun & Ernst 1987). Other technologies include *inter alia* filters, constructed wetlands, anaerobic baffled reactors, and biogas plants (Zurbrügg & Tilley 2009). Decentralised wastewater treatment (DEWATS) uses the same technologies used for conventional centralised wastewater treatment, but have been modified to suit a variety of different locations (Gutterer et al. 2009). These systems have low operational and energy requirements. On-site treatment systems are often the only viable option where sewer networks are not economically viable, and are used by around 25% of all households in the USA (US EPA 1980). On-site treatment is not an inferior technology (Parr et al. n.d.) and should be given preference over off-site solutions, as on-site solutions are technically simple to implement (Grover 1993). In areas where full water supply is not available, pour-flush latrines can be implemented (Mara 1985). They use a nominal amount of water to flush, which is piped into a soakaway. They have been used extensively throughout the developing world, especially in Asia but have not found traction in South Africa.

Septic tanks have been used since the early 1900s and have been used extensively in the USA, with published design guidelines (US EPA 1980). Malan (1964) provided guidelines for septic tank use within South African conditions. They are used as primary treatment to remove solids and the biological load of the wastewater. They are designed for a minimum retention time of 24 hours, after which the effluent wastewater is disposed of in a soakaway, French drain, evapotranspiration field, or constructed wetland. The solids accumulate at the bottom of the tank which typically has a design life of two years before emptying is required. The anaerobic baffled reactor (ABR) is a modified septic tank with numerous smaller compartments. It has shown success in dense informal settlements, as it requires low-maintenance, no electricity, and produces very little sludge (Foxon et al. 2006). The compartments are constructed such that the liquid flows both upward and downward, enabling simultaneous anaerobic digestion of the wastewater within each of the compartments (Foxon et al. 2006). However, it also requires post-treatment to adequately remove nutrients and pathogens. The tanks have to be constructed such as to minimise frequent conveyance of on-site sludge by truck or tanker, as this increases the cost of transportation and can be significantly more expensive than a conventional gravity fed sewer system. A significant technological innovation in sanitation is the biogas digester, which can be implemented at centralised or decentralised wastewater treatment systems and has been used for informal settlement applications (Paterson et al. 2007). A biogas system consists of a bio-digester and a shallow pit or septic tank. The waste is digested anaerobically in the bio digester to produce methane gas, and then deposited into a pit or septic tank. The main use of the methane gas is for lighting, heating water or cooking (Schouten & Mathenge 2010).

5.2 Off-Site Technologies

On-site sanitation systems are common and viable options for low-density areas, typically found in rural areas (Mara 2008). Informal settlements are often found in peri-urban and urban areas and the use of on-site treatment is often infeasible due to high population densities, rapid in-migration, poor geological conditions and the risk of contaminating drinking water (Paterson et al. 2009). In Indonesia, for example, the maximum density for on-site sanitation is 250-300 people per hectare (Fang 1999; Mara 1984).

Waterborne sanitation makes use of sewerage to convey wastewater from the toilet facilities to a central wastewater treatment facility. Subsequently, the cost of waterborne sanitation stretches beyond the cost of the toilet and includes the cost of constructing, operating and maintaining the sewage disposal and treatment infrastructure (Naranjo 2009). The cost of waterborne sewers is much more expensive than water supply (Okun & Ernst 1987) and much more expensive than the treatment plant's capital expenditure (Gutterer et al. 2009). This is partly due to sewers requiring much larger diameter pipes and access for maintenance, such as manholes. Further, the introduction of waterborne sewers places a pronounced demand on the water supply, as sewers require more than 200 litres per capita per day in order to operate (Okun & Ernst 1987). Although waterborne sanitation may be seen as the standard for urban areas in South Africa where both potable water and sewer networks are available, globally, conventional sewerage and treatment systems drain 5 – 10 per cent of the total wastewater flow (Naranjo 2009). In the developing world, 95% of all sewage is discharged untreated into rivers, lakes or oceans (Jewitt 2010). It has been argued that conventional sewerage is an implicitly anti-poor technology due to the high costs and water requirements (Paterson et al. 2007; Schouten & Mathenge 2010; Naranjo 2009). However, in densely populated areas, off-site conveyance may be required where on-site disposal is not feasible (Okun & Ernst 1987). The additional two billion urban dwellers living in the developing world within approximately twenty years are likely to pose a significant threat to conventional waterborne sanitation systems, typically using 15,000 litres of water per capita per year, which poses a detrimental burden on water availability (Jewitt 2010; Paterson et al. 2007). Already water consumption has increased at twice the rate of population growth over the last century and is expected to increase by 50 per cent in the developing world by 2025 (Zabarenko 2011).

Paterson et al. (2007) argue that conventional sewerage is an anti-poor technology, due to its cost and water requirements which are lacking to poor residents. Simplified sewerage was conceptualised by Chadwick in 1852 and was first developed in north-east Brazil during the 1980s as an improvement over conventional sewerage (Mara 2003). Simplified sewerage has been argued to be the only sanitation technology that is technically feasible and economically appropriate for low-income, high-density urban areas (Paterson et al. 2007; Mara 2008). The system uses an on-site tank where solids are settled and removed from the effluent. This tank is emptied over time to ensure adequate removal of the solids. Thus, simplified sewers (also known as condominial sewerage in some cases or solids-free sewers) require smaller pipe diameters and less stringent gradients and depths than conventional sewerage, while maintaining sound physical design principles. The simplified sewer networks are flexible in layout and are appropriate for existing informal settlement upgrades (Mara 2008; Paterson et al. 2007). They are appropriate in high density urban areas, where on-site sanitation is not practical (Mara 1984). However, in South Africa, there is still a lack of national regulation on simplified sewerage (Eslick & Harrison 2004). Furthermore, there was a lack of planning and implementation of these systems on a social and institutional level, which further lead to poor level of success (Ashipala & Armitage 2011).

In post-apartheid South Africa there is an expectation that conventional waterborne sanitation should be extended to informal settlements, despite its cost and the resulting pressure on water supplies (Paterson et al. 2007). This perspective is shown by the City of Johannesburg, who's highest level of service (LOS3) is the flush toilet (CoJ 2009). Although informal settlements in the City of Cape Town are within close proximity to sewer networks, the required capital and expected operational costs due to implementation exceeded their available budget. The anal cleansing materials common in informal settlements include materials such as vegetable leaves, stones or hard paper, which pose significant threats to the operation of the sewers. Further, the City of Cape Town's treatment plants are in dire need of upgrading, as nearly 40% of the wastewater treatment plants were running at full capacity and most did not comply with effluent standards (Mels et al. 2010).

6. Shared Sanitation

Shared sanitation is not a new phenomenon but has been a part of civilization, with the most notable example dating back to the ancient Roman Empire's public wash baths and toilets (George 2008). Shared sanitation has been acknowledged as the only logical and appropriate sanitation solution for dense, unplanned informal settlement areas where land is not available and residents do not have tenure rights (Schouten & Mathenge 2010; Lüthi et al. 2011; Eales 2008). They are a reality for a large portion of the urban slums throughout the developing world. Yet, the published literature available on communal sanitation is sparse, and the available literature identifies different research areas related to CABs, such as institutional, technical, social areas of research. However, the literature does not address the entire lifecycle of such communal facilities. The focus of this section is thus to provide a background to the state of the art in communal sanitation to informal settlements.

The main success factors to communal sanitation were (i) that there is a clear definition of who the users will be, (ii) technical and institutional capacity, (iii) political will and, (iv) continued communication between the community and the institution responsible for the operation and maintenance – i.e. the local government (Cotton et al. 1995; Allison 2002). Although communal facilities are not a panacea, they are incremental improvements which could have long lasting benefits (Eales 2008). Yet, the Millennium Development Goal (MDG) indicator does not consider sanitation facilities shared between two or more households as "improved" facilities (WHO & JMP 2008). One of the critical issues regarding their sustainability is the question *who is responsible for the maintenance*? A study in Cape Town found that although the local government was responsible for the management of a communal facility, this was not the reality. Although clearly defined in the policy, the responsibility for maintenance was not clearly defined within the local government structures, and there were expectations that the maintenance would be performed in part by the community (Allison 2002). The Core Working Group on Post-2015 Global Sanitation Monitoring debated under which criteria shared sanitation facilities would be considered improved facilities and concluded that facilities shared by no more than five households or 30 people that is accessible at all times could be considered as an improved sanitation facility (WSP 2012b). Numerous reports describe the poor conditions typical of shared sanitation facilities, summarised below (Baken 2008; Naranjo 2009; Eales 2008; Cotton et al. 1995),

- Poor construction and planning
- Lack of operation and maintenance
- Lack of ownership
- Lack of safety (especially at night)
- Poor accessibility
- Lack of a reliable water supply
- Lack of hygiene (and hygiene education)

- Lack of cleanliness
- Poor lighting at night
- Overuse (due to increased in-migration)

Shared facilities can use dry, or on-site or off-site waterborne sanitation systems. In an urban slum in Kampala, Uganda, it was found that 75% of the population used a shared sanitation facility (Katukiza et al. 2010). Sulabh International in India has implemented over 7 500 public and communal toilet facilities that are maintained by caretakers. The organisation connected 190 of these facilities to biogas digesters which produce biogas for cooking, lighting and electricity generation (Sulabh n.d.). Furthermore, shared sanitation facilities have successfully been combined with a community hall which can be rented out for different functions to cross-subsidise the operational costs (Lüthi et al. 2011). In Indonesia, the three factors that encouraged sustainable use of shared communal sanitation facilities where (i) where there was no space for individual household toilets, (ii) where areas were prone to flooding or subsidence, and (ii) where there are a large number of tenants and/or casual users (Eales 2012).

It is important to differentiate between different types of shared facilities, not at a technological level, i.e. the type of sanitation service, but at a strategic level, i.e. who will benefit from the facilities and how many people will be serviced. Strategically, shared facilities can be separated into three broad categories, namely local, communal, and public facilities. Local facilities typically consist of a single toilet facility shared at a local level, between 2 – 10 households. These facilities are often locked with only those households having access to the facility. Montgomery et al. (2010) found that the health risks of trachoma were no different between household facilities and local facilities – shared by a maximum of nine households. Communal-facilities are the focus of this study. These facilities conceptually service between 10 – 150 households and are larger than the shared-facilities. Communal facilities can either be defined as latrine facilities – consisting of a number of toilets, or ablution facilities – consisting of toilets and washing facilities such as showers, wash hand basins, laundry facilities and showers. The community benefiting from communal facilities are typically identified during planning. In 2002, communal sanitation facilities were the *de facto* form of sanitation for densely populated, low income informal settlement areas throughout Ghana (Ayee & Crook 2003). Public facilities refer to those facilities provided in public areas and not confined to a predetermined residential area, typically found in shopping complexes, hospitals, bus stations, train stations, schools, offices, etc. It is noted that where public facilities are placed within a residential informal settlement, the system is referred to as a communal facility, not a public facility to differentiate between the two strategies. Pay-per-use communal and public facilities are found throughout the developing world, such as Kenya and India, and utilised to subsidise the operation and maintenance costs (Lüthi et al. 2011). However, even the smallest token amount is generally unaffordable for the poorer households who are forced to revert to open defecation (Allen et al. 2008; Baken 2008; Cotton et al. 1995).

It is conceptualised that for communal facilities, the capital and operational costs are inversely proportional as shown in Figure 7. In this figure, the operational costs are the costs associated with the local government (public cost), and the capital costs are associated with the cost to each household (private cost). Yet, the household’s willingness to pay for the facilities’ sustained use decreases as the facilities move from household facilities to shared facilities (Mulenga et al. 2004). All three of these strategies have been implemented in informal settlement areas throughout the developing world.

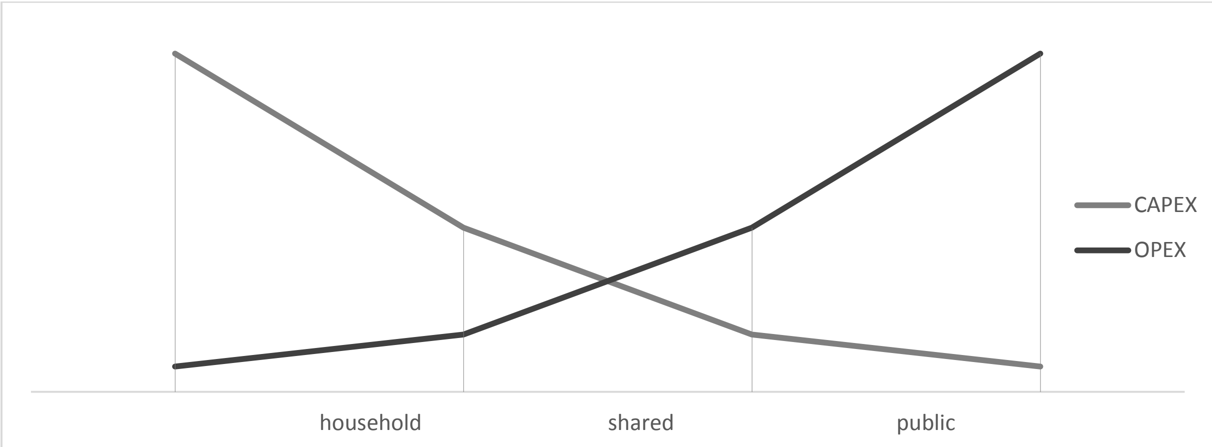

Figure 7: A conceptual model of the capital expenses (CAPEX) and operation and maintenance expenses (OPEX) related to the three strategies of sanitation provision in the developing world.
The capex costs refer to the cost to the local government (public cost), and the opex cost refers to the cost to the household(s) (private cost).

In the majority of cases the operation and maintenance of local facilities is the responsibility of the group of households. However, without a dedicated caretaker for the local, communal or public facilities, households are prone to disagree and argue over maintenance responsibilities. Further, the location of the shared toilets can cause restricted access to the households who could be using the facilities (Still et al. 2009). Shared sanitation services are often provided as temporary facilities. Yet, anecdotal evidence suggests that these facilities often remain as quasi-permanent facilities. For example, in Khayelitsha temporary porta-pottis have been in use for over 5 years (Damba 2010). Based on the sanitation backlog in Table 1 and the eThekwini communal sanitation guidelines for communal sanitation (one facility serves 75 households), it is estimated that on average it will take at least 27.7 years for each of the provinces to eliminate the backlog - at the current rate of 200 communal facilities per annum, as shown in Table 4. This will require not only coordinated planning but also extensive and detailed operation and maintenance plans and procedures in order to ensure the sustained use of these communal facilities.

Table 4: Time required to eliminate the sanitation backlog with communal facilities (Based on Table 1)
This table represents meeting the sanitation backlog within the entire province with the provision of communal facilities. It assumes the number of households served per communal facility is 75 households, at a rollout rate of 200 facilities per annum.

	Eastern Cape	Free State	Kwazulu-Natal	Gauteng	Limpopo	Mpuma langa	North West	Northern Cape	Western Cape
Number of communal facilities required	7 916	2 428	5 358	9 705	11 474	5 887	5 815	914	1 604
Years to achieve the backlog	40	12	27	49	57	29	29	5	8

Often the construction of the facilities are provided under the auspices of the local government, while the operation and maintenance is performed by the private sector. These defined responsibilities are at times detrimental to the community and the sustainability of the facility, due to poor discussion between the relevant stakeholders during planning (Allen et al. 2008).

6.1 Strategies

The predominant form of sanitation provision to informal settlements in South Africa is through shared or communal facilities. This is due to financial, space or land tenure issues (Naranjo 2009; Gutterer et al. 2009). The City of Cape Town's minimum level of service is one toilet shared between five households (Taing et al. 2013). The City of Cape Town offered nine different solutions to informal settlements, as shown in Table 5, with the dominant implemented solution being the container and flush toilets, servicing 40,8% and 26,1% households respectively (Naranjo 2009). It is evident that the majority of these solutions are shared, temporary facilities. Furthermore, the use of on-site dry sanitation and lack of sewer networks means that the facilities cannot be upgraded in the future to waterborne services but will require additional infrastructure to dispose of greywater, which is of public and environmental health concern (Carden et al. 2007). A feasibility assessment study of the City of Cape Town's informal settlements revealed that individual (household-based) solutions were not feasible for high density informal settlements and chemical toilets and container toilets were the only toilets that could be scaled up. Both toilet systems, however, have high service and maintenance costs (Mels et al. 2010). Although the planning of Khayelitsha's Island informal settlement adopted the framework of one toilet per five households, due to malfunctioning of the toilets and growth within the settlement, it is estimated that around 25 households share a toilet (Damba 2011). The City of Cape Town has piloted a communal dry sanitation system, called MobiSan®, to 500 residents in an informal settlement (Narajo 2009). Although successful in providing a sustained sanitation facility, the success is attributed to the appointment of a full-time caretaker. However, this model has since not been taken to scale in Cape Town.

Table 5: Sanitation options for informal settlements in the City of Cape Town (Mels et al. 2010)

Type of Toilet	Households Serviced	Required Emptying Rates	Constraints
Container Toilet	5	3 times per week	-
Flush Toilet	5	none	Frequent clogging
Chemical Toilet	5	3 times per week	High operational costs
Porta potti	1	2 times per week	Disposal distance (greater than 150m)
Bucket Toilet	1	2 times per week	-
Pit liner	5	-	-
Urine Diversion Toilets	5	Every 8 months	-
Anaerobic toilets	2	-	-

Although not indicative of the planning and the provision of services, a national audit in 2012 found that on average, one toilet was shared by 100 households in the Western Cape, and one toilet was shared by 10 households in Gauteng (Sapa 2012d). The lack of adequate sanitation was evident in one settlement in the North West Province where 1 000 people shared six toilets (Infrastructure News 2012).

6.2 Public Services

Public sanitation facilities are mandatory at public places throughout the first and third world. The facilities are provided at shopping complexes; public transport stations; schools and universities; parks, etc. These facilities are typically constructed as part of the initial design as per the relevant national regulations for public buildings. The maintenance of the facilities are then outsourced to a janitorial contractor who is responsible to ensure that the facilities are supplied with sufficient sanitary supplies and are kept clean at all times.

In the German railway stations, for example, Hering International are responsible for the construction, operation and maintenance of the public toilets (HI 2012). The company uses sanitary fittings that are traditionally used in jails where there are a high volume of users and the fittings are prone to vandalism. These fittings are constructed out of stainless steel, making the fittings robust and vandal proof. The walls of the toilet facilities are typically constructed out of reinforced concrete, allowing the sanitary fittings to be secured directly into the walls during fabrication. Although such design and construction specifications increase the capital costs associated with the facilities, it reduces the short-term maintenance requirements in replacing broken fittings, which are endemic of the current configuration at the eThekwini CAB facilities.

Figure 8: The Hering International public toilet facilities (HI 2012)
The photo on the left shows the internal configuration of the toilets, which only allows the user access the toilet pedestal, flush handle, and anal cleansing material. The photo on the right show the maintenance room which houses all of the mechanics of the public toilet facilities.

Hering International also perform the operation and maintenance tasks associated with the public toilets. Their facilities are constructed such that the users have limited access to the sanitary fittings, see Figure 8 for an example of users' toilet experience. All of water and drainage pipes, pumps, and toilet cisterns are removed from the user and are housed within an enclosed maintenance room which is only accessible by the Hering trained personnel.

Public toilets in shopping complexes typically do not have single toilets with cisterns, the toilets are typically fitted to a central supply and the flush water is pumped into the toilet bowl when the flush level is engaged. This typical configuration is shown in Figure 9.

Figure 9: Typical public toilet using a demand flush at the Aquaduct Racetrack Casino (Bestway64 2012)

6.3 Interim Services

The prevalence of shared facilities is not always directly asked in government surveys, for example the Census 2011. Yet, the high density within informal settlements throughout South Africa make individual sanitation provision to households primarily impractical. In the Housing Code of 2009 (DHS 2009), the national government mandated the provision of communal water and sanitation facilities to informal settlements in an attempt to rapidly provide a basic level of service to all unserved populations to reduce the burden of waterborne diseases. The provision of communal facilities as interim measure is effective, as sewer and water connections are centralised at specific locations (Eales 2008). The aim of providing communal water and sanitation facilities into an informal settlement is not only the provision of the communal facility now, but also the provision of bulk water and sewer connections which enables incremental future upgrading (as suggested by Lüthi et al. 2011). These facilities are not considered permanent facilities, but are an incremental step in the process of formalising the settlements and providing a full level of service to all households. Yet, as was shown in Table 4, the time required for meeting the backlog is on average 28 years. As such, these interim communal facilities will require strategic approaches in ensuring their sustained use and in realising the associated health benefits associated with the provision of water and sanitation facilities. DWAF (2004) previously discouraged the long-term provision of communal facilities due to the high operational cost associated with the systems. However, the current funding for both interim and permanent water and sanitation services are focused on capital costs (see for example the Municipal Infrastructure Grant) and there is significantly less funding available for the operation and maintenance of these facilities, as these are traditionally provided through municipal revenue and the Equitable Share grant, where the latter is often used for other purposes, such as salaries (Still et al. 2009). Thus, the provision of communal facilities, although interim, will require a dedicated funding stream for the operation and maintenance of these facilities, without which these facilities will become health risks to the communities who were meant to benefit from them.

7. Conclusions

The benefits of sanitation are indisputable and are well documented, associating improvements in sanitation with improved public and environmental health and economic benefits. There are a number of different sanitation technologies available for adequate removal of excreta from human contact. Each of the technologies are not suitable for all cities and environments, but the application is based on institutional capacity, financing, and the local conditions, both physical and social. Although dry and wet sanitation technologies are considered as improved sanitation technologies, the logistics of sustaining dry sanitation facilities, such as pit emptying, are often not considered during the planning stage, which leads to users reverting to unimproved sanitation practices. In South Africa, the legacy of Apartheid has caused dry sanitation to be seen as an inferior technology to waterborne sanitation. This sentiment is reflected in the national policy, where VIPs are the minimum level of service and waterborne sewerage is the highest level of service. In fact, waterborne sanitation is considered the gold standard to which all residents, formal and informal, aspire to. The promotion of waterborne sanitation will increase the burden on South African water resources, which are already constrained. This will require innovative water demand management initiatives at technical and social levels to reduce the increasing water demands.

Informal settlements are characterised by poor access to basic services, such as water and sanitation, and poor housing conditions. However, without adequate wastewater disposal, the construction of formal housing will not improve the poor environmental conditions typical within informal settlements. Thus, the provision of improved water and sanitation services should be considered the prime development objective in informal settlement upgrading. Globally, the provision of water and sanitation services to informal settlements has traditionally been problematic, due to the high densities and the lack of space within the settlement to provide individual services to each household. Shared facilities have become the *de facto* form of sanitation provision to informal settlements, where facilities are mostly shared by less than 10 households. There are acute problems associated with shared sanitation facilities. These problems have to be addressed in order for the operation of these facilities to be sustained. This is recognised in the United Nations defining shared sanitation facilities as an unimproved sanitation facilities.

In South Africa, the informal settlement upgrading policy has shifted from the provision of housing to the provision of services. The policy mandates the rollout of communal water and sanitation services as interim measure to meet the immediate needs of the community. This strategically ensures that every settlement is incrementally provided with a basic level of sanitation, from shared to household water and sanitation services. In order to reduce fruitless expenditure, these interim services must dovetail with the permanent, long-term service provision to the settlement, which excludes chemical toilets from being defined as interim sanitation services. Waterborne services are the most appropriate technologies in realising the political mandate of incremental upgrading, as the water and sewerage pipes that are extended to communal water and sanitation facilities forms an infrastructure backbone within the settlement that can later be extended to a household level. This is also based on the high population densities and lack of adequate water supply and wastewater disposal which are both characteristic of informal settlements. The management options for treating the wastewater is either through the conventional centralised treatment plants or decentralised wastewater treatment plants, such as septic tanks or package plant options.

The implementation of interim water and sanitation services in the incremental upgrading of informal settlements in South Africa is realised by the local Water Service Authority. From the eight metropolitan areas in South Africa, the eThekwini municipality was identified as the most appropriate case study for identifying the success factors for interim communal water and sanitation facilities. The eThekwini municipality has a strategic approach to informal settlement upgrading and over two years of experience in the rollout of communal ablution facilities at scale. These communal facilities use waterborne services, not dry sanitation services. This strategic decision is in line with the mandate to dovetail with the future, permanent services; the constraints of servicing (emptying) the pits in informal settlements; and their experience with the rollout and maintenance of both waterborne and dry sanitation services.

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The eThekwini Municipality

Chapter 3

1. Introduction

As the appropriate sanitation technology is determined at a local government level, the study investigated the sanitation intervention to informal settlements at the eThekwini municipality. The municipality was selected as an important case study due to the municipality's track record of innovation in water and sanitation and due to the political will to provide strategic services to meet the backlog throughout their jurisdiction. The eThekwini municipality has provided interim communal water and sanitation services to all the informal settlements within the urban edge since 2009.

South Africa is divided into 52 district municipal areas, of which eight are metropolitan municipalities, having more than 500 000 voters, and 44 are district municipalities, found in predominantly rural areas. District municipalities are divided into local municipalities, typically four to six local municipalities per district. There are 226 local municipalities in South Africa (ETU 2011). The eThekwini metropolitan municipality is based within the KwaZulu-Natal province on the eastern coast of South Africa, as shown in Figure 1 and Figure 2. The eThekwini municipal area comprises of Durban and 64 other smaller municipalities (Smith & Dedekind 2011). The municipal area stretches over 2 297 square kilometres and is divided into 103 wards (Gounden 2009). Every metropolitan and local municipality is divided into wards, as per the Municipal Structures Act 117 of 1998, in order to enable participatory democracy in local government. The wards should each have approximately the same number of voters and should be demarcated based on the population density, topography and other physical conditions (RSA 1998).

The official census statistics from 2011 indicated that eThekwini had a total population 3.4 million people comprising 946 000 households, with a gross density of 4.75 dwellings per hectare (StatsSA 2012; EH 2012). A total of 80% of the households were housed formally and 12% informally in a free standing informal settlements, with the remaining households being either traditional houses or backyard shacks (StatsSA 2012). The informal population of eThekwini was estimated between 800 000 to 1 400 000 residents, which accounts for a quarter to a third of the municipal population (EH 2012; Gounden 2011; Smith & Dedekind 2011; PPT 2010; EM 2012). Driven by continued urbanisation, the total municipal population is expected to reach 4.0 million by 2020 (EH 2012). The majority (86%) of the population in 2007 was urban (EH 2012).

Figure 1: The location of the eThekwini municipality within South Africa
The KwaZulu-Natal province is shown in yellow, and the eThekwini municipal area is highlighted in red.

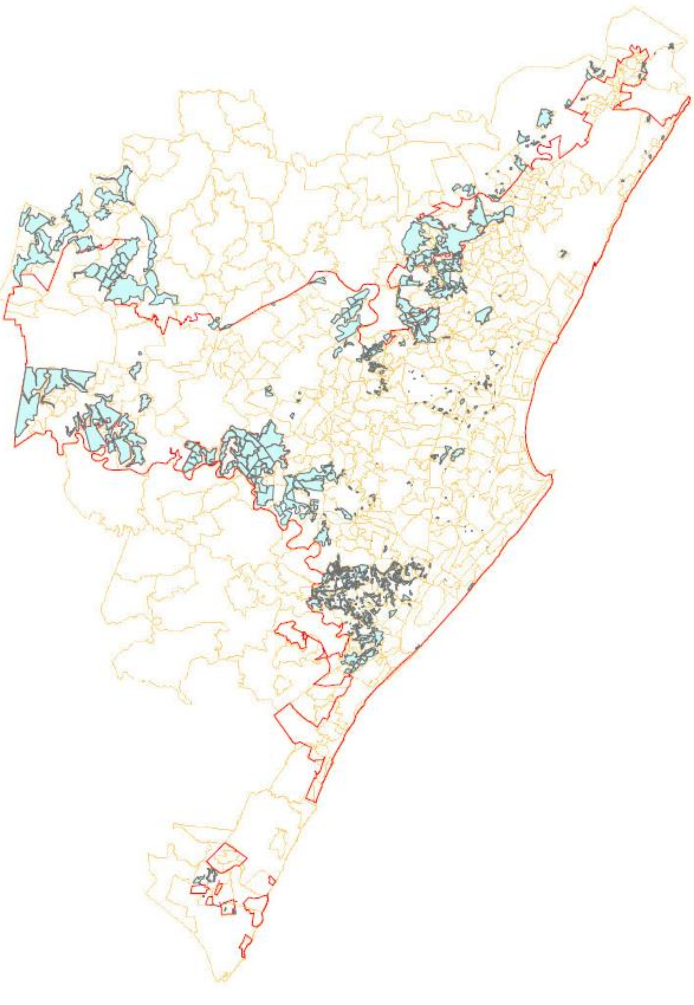

Figure 2: The eThekwini municipal area (Pietersen 2012).
The ward areas are delimited in yellow, with the location of the informal settlement areas indicated in light blue. The border of the urban edge line is shown with a red line. It is evident that the informal settlements predominantly follow the urban edge line, with the majority of these settlements located either within the urban or peri-urban areas.

Informal settlement housing of shacks, are defined by the eThekwini municipality as structures made of rudimentary materials without any approved building plans, often on illegally occupied land, having either basic or no services available. Rudimentary materials include wood, cardboard, metal sheets, mud, etc. (HDA 2012). The majority of statistics and data associated with informal settlements, not only within eThekwini but globally, are highly variable, due to the inherent nature and flux of informal settlements; and as such, the values are used to provide an indication of the state of informality in eThekwini. The municipal area is scattered with approximately 500 informal settlements, comprising approximately 239 000 informal settlement dwellings (HDA 2012). This accounts for approximately 78% of the entire informal population of KwaZulu-Natal. Of the 500 settlements, 80 have been approved for upgrading and 420 have either recently been approved or are waiting approval by the Provincial Department of Human Settlements. As already argued from the global perspective, informal settlements are here to stay. This is true in eThekwini. It was noted in 2007 that the majority of the informal settlement residents had been living there for an extended period of time, with 73% of the respondents remaining in the same settlement since 2001 (HDA 2012). Informal settlements in eThekwini tend to be either dense – as is typically found on inner city land or as infills within existing suburbs and townships having more than 60 dwelling units per hectare; or moderately dense – as is typically found on the urban periphery having between 30 – 60 dwelling units per hectare, as shown in Figure 3 (EH 2012; EM 2010a). The population densities in four eThekwini informal settlements were found to vary from 35 – 130 dwelling units per hectare (EM 2010b).

The definition of an informal settlement in KwaZulu-Natal stipulates that the settlement be located in urban or peri-urban areas (HDA 2012; Roma et al. 2010). Most of the informal settlements are located within this urban development line, also referred to as the waterborne edge - where waterborne sewerage is accessible. The urban development line defines the outer limit where development can occur around the urban areas within the municipal area. The majority (80%) of all new housing projects have been delivered within the urban development line (EH 2012). The urban development line is used to promote the compact city and curb urban sprawl. It was developed in terms of the municipality's Cost Surfaces Model. This model depicts the cost of bulk service provision across the entire municipality. The interior of the urban development line indicates sustainable areas for the provision of the full package of municipal services (EH 2012).

The Comprehensive Infrastructure Plan (CIP) in eThekwini distinguishes between three standards of services (EH 2012)

- Urban service standards: semi-pressure water house connections (whereby household water is provided through a roof tank), waterborne sanitation, electricity connection, and all weather surface roads;
- Rural service standards: One ground tank per household supplied with 300 ℓ per day, urine diversion toilets, electrification only of densely clustered pockets, all weather surface roads to all public transport routes and those communities having a density greater than 15 persons per hectare are provided with road infrastructure within the settlement; and
- Interim service standards: communal ablution blocks within 200 m of served households, high mast lighting for security, footpaths and emergency access roads for waste removal and emergency vehicles (EH 2012). The provision of roads and pedestrian footpaths is also

associated with stormwater management. Road access is a prerequisite for the provision of electrical infrastructure (PPT 2010).

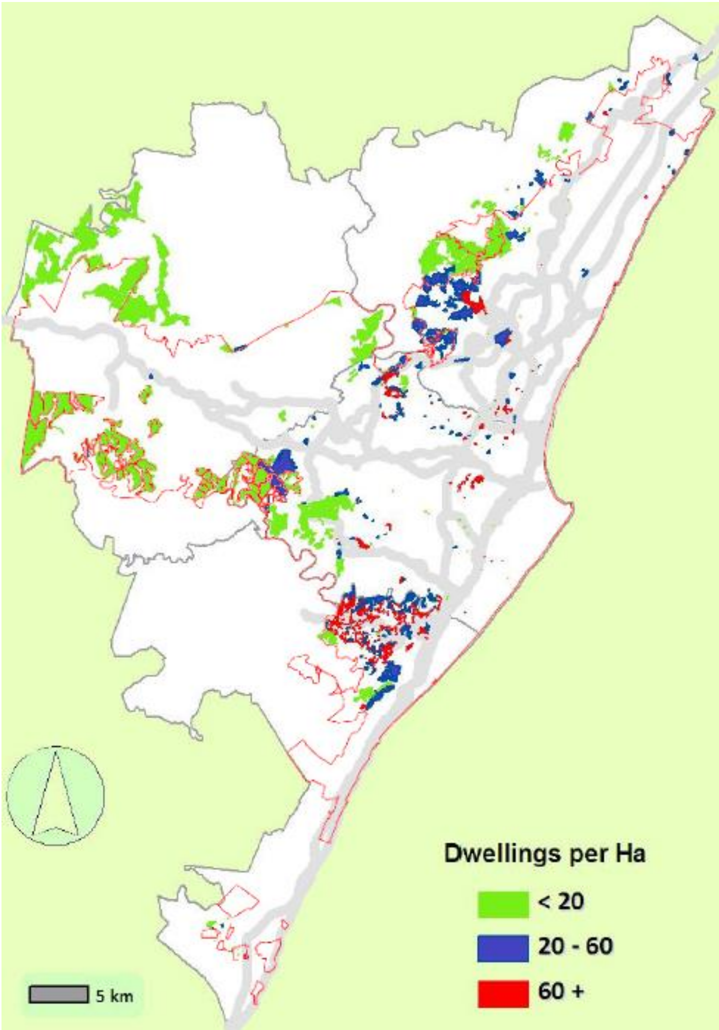

Figure 3: The informal settlement densities throughout eThekwini (EH 2012)

2. Housing Backlog

The planning and delivery of housing at scale in a metropolitan municipality is complex, requiring integrated planning between the different units in the municipality. As such, housing cannot be implemented in isolation by a single department (such as the eThekwini Housing Department). Such an integrated approach is achieved through the Housing Chapter, used in the municipal IDP, which is a 5-year plan that is annually reviewed. Additionally, the other external players such as the provincial authorities, land owners, the Housing Development Agency and social housing institutions must play their roles (EH 2012).

The formal housing market is not providing houses in sufficient quantity or quality or in well-located areas. This not only affects those households qualifying for a government provided house but also those who earn between R3 500 – R8 000 who do not qualify for a formal house, as previously discussed. Table 1 provides a summary of the water, sanitation and housing backlog in eThekwini municipality. Of the total housing backlog in eThekwini (as of July 2011) 61% were in informal settlements, 12% were in informal backyard shacks, and 27% were found in traditional dwellings (EH

2012). The current housing delivery program of eThekwini provides an average of 13 000 dwellings per annum, at a density of 20 dwellings per hectare (EH 2012). In order to meet the national government's targets for water and sanitation, the KZN Provincial government in 2010 would have had to scale up service delivery by 400% (CoGTA 2011).

Table 1: Housing, water and sanitation backlog in eThekwini as of December 2011
These time frames are municipal estimates based on the current rate of service delivery in eThekwini. It is important to note that these time frames are dependent on funding or subsidy allocations

Basic service	Backlog	Time
Housing*	410 020 hh	82 years
Water*	74 481 hh	37 years
Sanitation*	231 387 hh	14 years
Electricity*	323 000 hh	32 years
Roads*	1136 km	103 years
Stormwater**	751 properties	3 years
Sidewalks, bridges & footpaths**	R131 million	10 years

*data from EM (2012) **data from EM (2011)

The two main reasons cited for the delay in housing delivery in eThekwini are the requirements involved in completing an Environmental Impact Assessment (EIA) and the process of land acquisition, due to the land being expensive and being in high demand from the formal market for other uses. As such, the relocation of an informal settlement to a well-located greenfield site is discouraged. However, the majority of the informal settlements in eThekwini are based on well-located land. Yet, in-situ conditions, such as steep topography and adverse geological conditions increase the cost of servicing low cost housing developments. The informal settlements in eThekwini are characterised by at least one of the following (EH 2012; EM n.d.),

- Inadequate safety;
- Poor access to engineering services;
- Inadequate access to social services;
- Tenure insecurity;
- Poor top-structures posing safety risks e.g. of fire; and
- Inadequate urban management and regulation.

3. Water and Sanitation Provision

The driver for sanitation provision to eThekwini informal settlements was predominantly based on the health risks associated with the lack of basic water and sanitation services (Pfaff 2010), as access to formal sanitation services reduces the risk of disease and prevents health issues (Smith & Dedekind 2011). The eThekwini municipality is constitutionally responsible for water and sanitation provision, which is performed under the Water and Sanitation unit (EWS). EWS has internationally been recognised for its strong institutional capacity and has kept institutional continuity, with the water and sanitation manager being in the same position for 19.6 years, which is almost 6.5 times more than the average of 3.0 years (MDB 2012a). EWS has 28 registered professional engineers, which is three times more than the average for the eight metropolitan municipalities in South Africa (MDB 2012b).

Water service provision has to be done such that the services are equitable, affordable, environmentally effective and sustainable (Gounden 2011). However, this is challenging in the face of rapid in-migration and the formation of dense informal settlements (Gounden 2011). The minimum level of improved water supply and sanitation is accessible to 92.6% and 83.4% of households respectively in eThekwini (StatsSA 2012).

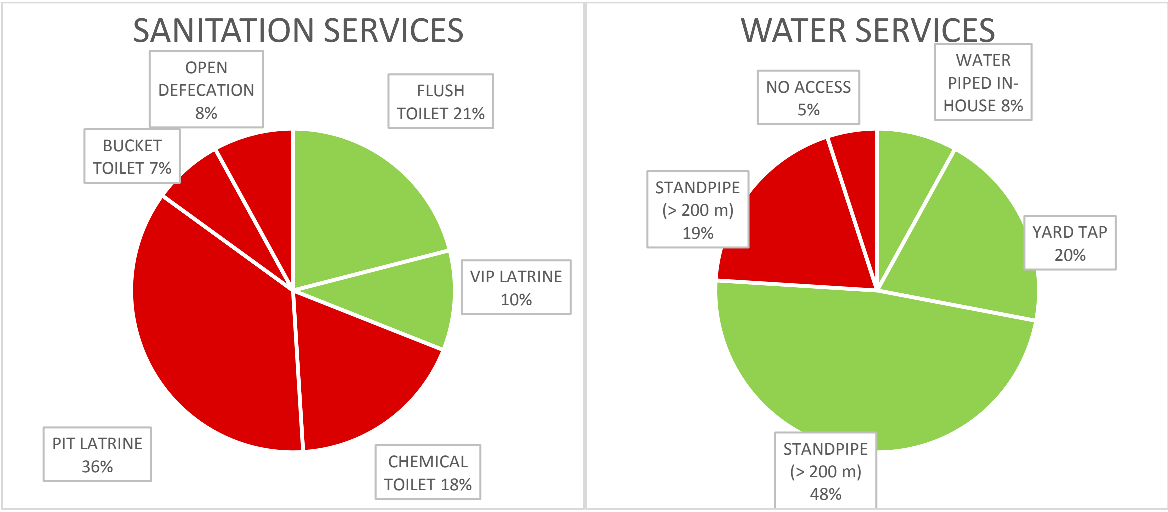

Figure 4: The water and sanitation level of service in the informal settlements of eThekwini (StatsSA 2012)
The statistics only indicated the technologies available to the households and did not indicate whether these services were shared or not. From the data, it is evident that 76 and 31 per cent of informal settlement households have access to improved water and sanitation services respectively, where improved services.

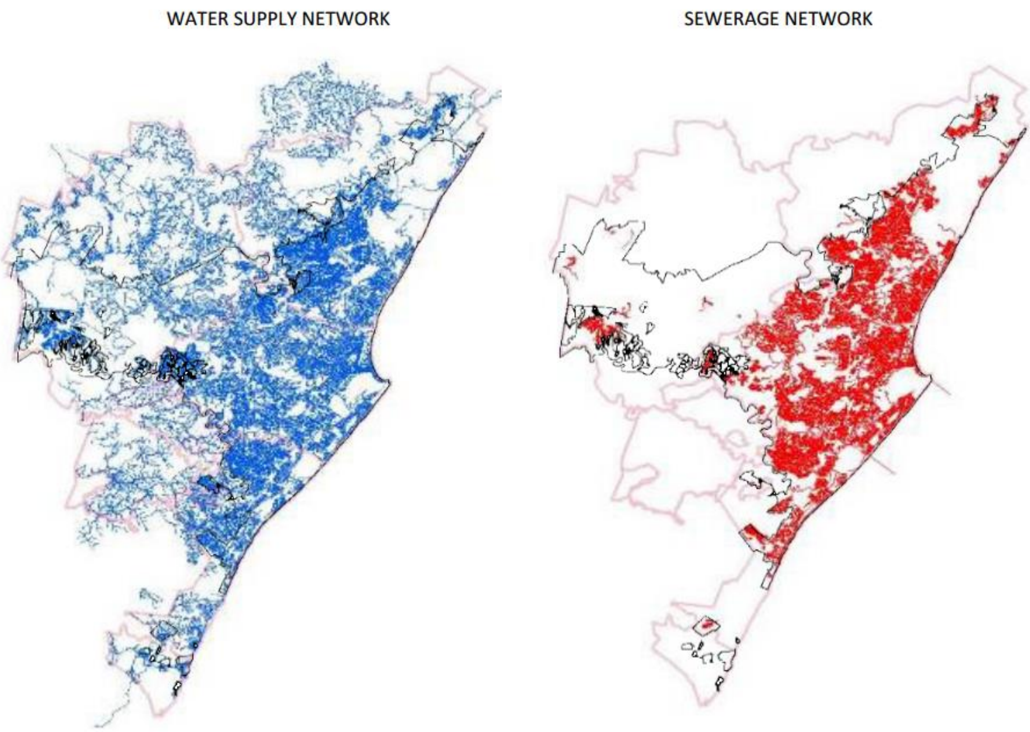

Figure 5: The location of water and sewerage infrastructure in eThekwini (EH 2012)
The urban development line, shown in black, is associated with the existence of the sewerage network.

The results from the 2011 Census are presented in Figure 4, indicating that informal households lack access to improved sanitation services. It is noted that the 2011 Census data does not distinguish between a shared or household level of service, which undoubtedly means that less than 31 per cent of informal households have access to improved sanitation facilities. The extent of the water and sewer network coverage in eThekwini is shown in Figure 5, where it is immediately evident how the urban development line (in Figure 2) is based on sewer coverage.

The eThekwini Municipality provides the first 9 kℓ of water per month free to all indigent residents, under its free basic water (FBW) program, as mandated by National Government. Similarly, the first 9 kℓ of sewage disposed is free of charge (EM n.d.). There are 487 062 households who rely solely on the FBW program (EM 2012). Groundwater tanks (semi-pressure water supply) is provided to 27 199 households and 178 228 households are serviced by standpipes or water dispensers (EH 2012). The current eThekwini water services include (EM n.d.):

- 900 Mℓ/day potable water is supplied from 8 Treatment works;
- 361 water reservoirs;
- 674 000 water connections;
- 477 Mℓ/day wastewater is treated in 28 wastewater treatment plants;
- 7 666 km of sewer mains;
- 86 000 urine diversion toilets; and
- 40 000 VIP pit latrines are being desludged

The basic level of sanitation provided in eThekwini during the 1980s and 1990s to peri-urban areas were VIPs, as shown in Figure 6. However, the subsequent emptying associated with VIPs was problematic. VIPs are appropriate in low-density areas, such as rural areas, as full pits could be relocated to a new pit; however, informal settlements lack adequate space and require sludge emptying, handling and disposal (Scruton 2009). Pit sludge emptying requires either manual or mechanical emptying. However, the pits are sometimes constructed in inaccessible locations, making manual emptying the only viable emptying method. It is important to note that the sludge is typically not homogeneous, consisting of sewage sludge and solid waste. These factors lead to high emptying costs (Scruton 2009).

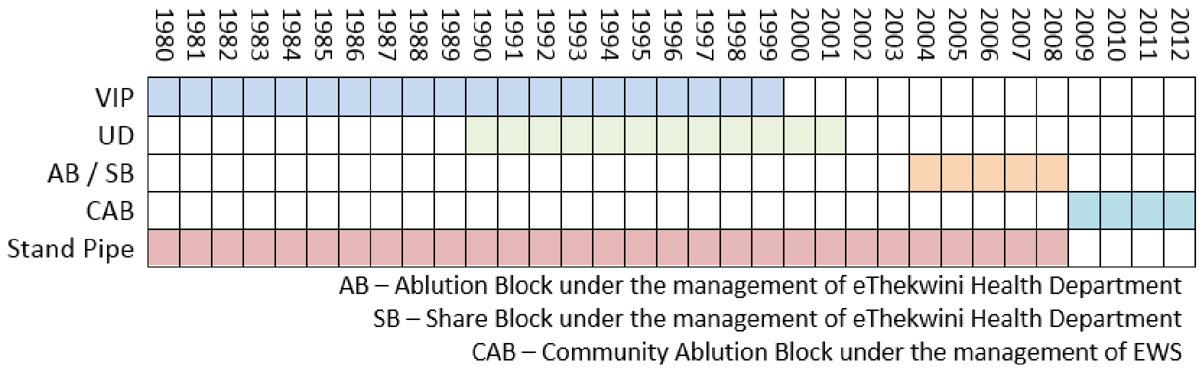

Figure 6: Water and Sanitation services provided to informal settlements in eThekwini

The provision of water and sanitation to informal settlements forms part of the municipal Informal Settlement Program which plans to incrementally upgrade informal settlements, and will be further discussed. Originally, the use of communal ablution facilities was implemented by the eThekwini Health Department. The use of communal facilities addressed the immediate needs of the informal settlement residents (Roma et al. 2010). The prioritisation for ablution provision was based on health criteria in order to reduce waterborne diseases and environmental pollution (as shown in Table 2). This was recorded by Environmental Health Practitioners working at settlement level by determining disease incidents at the local clinics (Nkici 2012; Smith & Dedekind 2011). The second driver associated with the provision of ablution blocks was to address the municipal backlog of services and making progress on the Millennium Goals. The third driver was to dovetail with the future (in-situ) upgrading of the informal settlements. Thus, the aim was to provide a basic, interim water and sanitation level to those settlements identified by the Housing Department for future upgrading (Smith & Dedekind 2011; Gounden 2011). This minimised fruitless capital expenditure, as the infrastructure would form part of the future reticulation within the formalised informal settlement and surrounding catchment areas (Dedekind 2010; Gounden 2011). Further, a number of supporting benefits are associated with the provision of CABs, including local economic stimulus through the large scale creation of labour opportunities, small local contractor development through the implementation of the Sub-Contractor Development Programme, and updating of EWS GIS and Asset Register (Smith & Dedekind 2011).

Table 2: The eThekwini Department of Health's selection criteria for ablution facilities, where different informal settlements could be compared to each other

Indicators	***The informal settlement names***					
Population size						
Infant Mortality rate						
Child Mortality rate						
No of Cholera cases						
No of diarrhoea cases						
No of worm infestation cases				. . .		
No of households with sanitation						
No of households with- portable water supply						
Rating						
Decision rating (1 to 5) 1-high priority - 5-low priority						

The eThekwini Health Department initially provided four different types of shared ablution facilities, namely (i) constructed and (ii) container ablution blocks where waterborne sanitation was available, and (iii) constructed urine diversion toilets and (iv) share blocks in areas beyond the urban development line (Scruton 2009; Gounden 2009). Share blocks were constructed during the period before 2008 on top of large conservancy tanks, able to hold 4-5 years of waste. Yet, none of these tanks have been emptied since construction (Nkici 2012; Roma et al. 2010).

The provision of Ablution Blocks, constructed from brick, was initiated in 2004 and 108 ablutions were constructed (Roma et al. 2010). It was a joint programme between the Housing, Architecture, Health, and Water and Sanitation Departments. However this program faced a number of challenges as the Health Department did not have the technical skills to manage the large scale rollout, and operation and maintenance of these facilities (Gounden 2011). Initially there was significant resistance to the provision of shared water and sanitation facilities, due to the fact that the communities were promised houses. However, a shift has occurred over time and the communities have become more positive toward the facilities (Nkici 2012). During this period, the community was responsible for the management of the facilities through voluntary caretakers, while the Health Department provided all consumables required for the operation of the facilities. However, the caretakers where not adequately motivated to maintain the facilities in light of community unrest and vandalism.

In 2009, the responsibility for the implementation of the project was handed over to the EWS and the ablutions were rapidly rolled out. The current institutional arrangement is shown in Figure 7. The Health Department was no longer responsible for the implementation of the services, but took on an advisory role in the planning. This shift happened because the EWS would have to approve any water and sanitation infrastructure within the eThekwini municipal area as they were responsible for the long term operation and maintenance of the water and sanitation services.

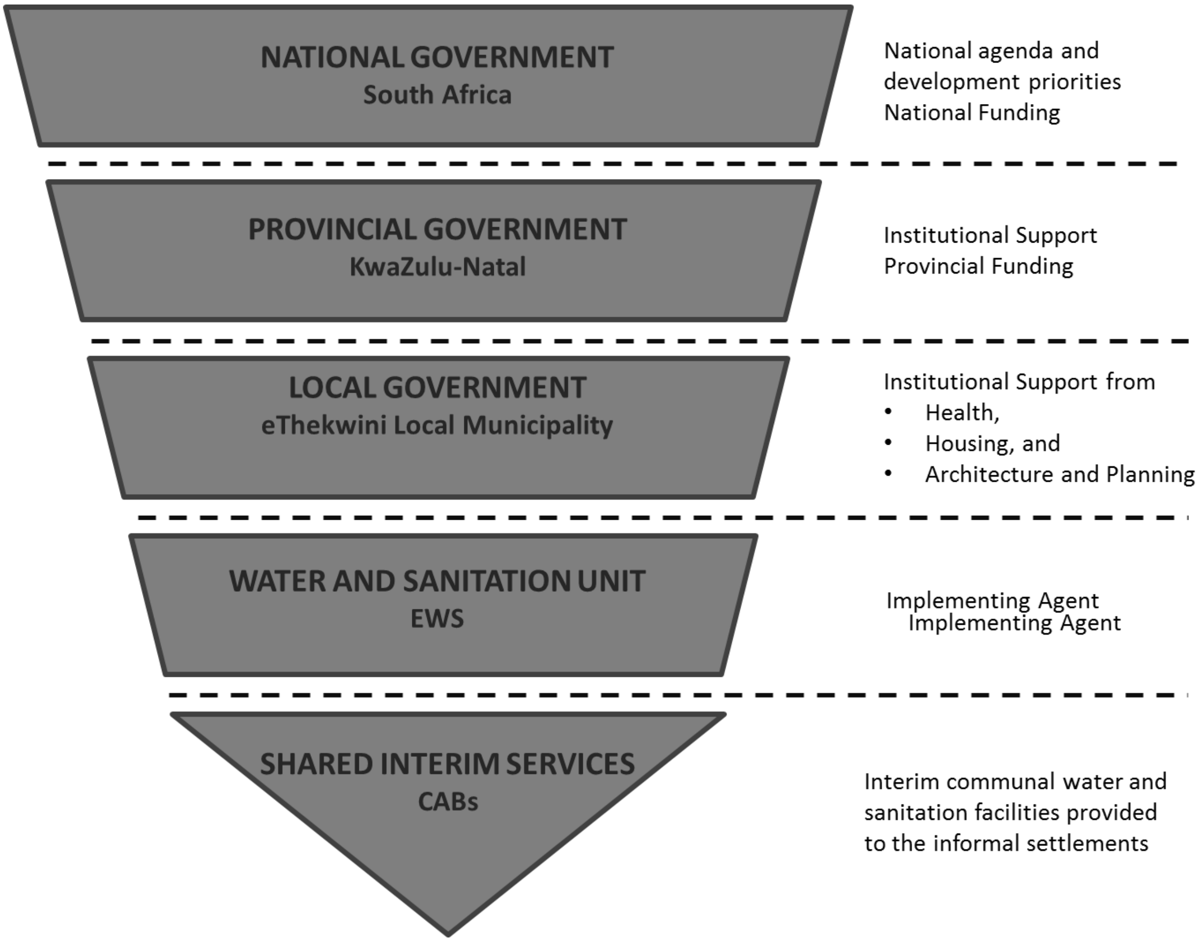

Figure 7: The current institutional arrangement for the rollout of communal ablution blocks in eThekwini
The eThekwini Water and Sanitation Unit is the implementing agent for the rollout of the CABs, with strategic development goals, funding and institutional support from national, provincial and local government.

This rapid rollout was achieved by the rapid placement of community ablution blocks (CABs) using modified shipping containers. EWS were further responsible for the employment of caretakers to manage the CABs and the provision of consumables, such as toilet paper and cleaning items (Gounden 2011). The design specifications for the CABs were based on minimum pipe diameters in the municipal guidelines, as there was no readily available quantitative data for the water demand of communal ablutions, especially not within eThekwini, from literature.

It is important to state that the focus of informal settlement upgrading shifted from the provision of toilets to the provision of infrastructure (bulk water and sewer infrastructure, roads, electricity) which would provide interim services for those settlements scheduled to be upgraded in-situ by the eThekwini Housing Department (Nkici 2012). The rollout of this infrastructure by the eThekwini Water and Sanitation Unit is implemented in collaboration with the eThekwini Housing Department, Architecture Department and Health Department in order to reduce fruitless expenditure. EWS remains the implementing agent and is the primary interface between these municipal services and the communities. For example, the expectations raised by the national government to provide housing to all informal settlement residents means that the Housing Department's role must be seen by the communities as secondary in order to minimise any negative sentiment in the rollout of these interim services and not primarily housing structures.

4. Interim Service Provision

Due to funding and other constraints, not all informal settlements can be provided with full services and housing in the short term. This requires both short- and long-term approaches for those settlements earmarked for future in-situ upgrading (PPT 2010). Those settlements which are not provided with full services within the short-term (within three years) but are earmarked for future full service upgrading in-situ in the Municipality's Housing Plan are provided with interim services (EM 2012). To this extent, informal settlements have been classified into four categories by the municipality (EH 2012)

- Category 1 - Imminent full upgrade;
- Category 2 - Incremental upgrading with interim services;
- Category 3 - Emergency Services only, as full upgrading is not possible; and
- Category 4 - Relocation

Short-term approaches provide immediate relief and incrementally dovetail with the long-term plan for full upgrading. Category 2 and Category 3 are currently not differentiated by the municipality, but are treated in the same fashion. Jointly these two categories apply to the majority of informal settlements in eThekwini. Long-term approaches include relocation to greenfield sites and full upgrading programs. To this extent, the municipality has implemented an Informal Settlement Program to upgrade informal settlements with basic, interim services wherever possible and only consider relocation for health, safety or technical reasons. The program is implemented for those settlements which will not be upgraded within the next three years (EH 2012). The intention of the interim services is to rapidly rollout a basic level of service to as many settlements as possible, instead of providing a high level of service to a few settlements (EM 2012).

Category 1 refers to those informal settlements that will be re-developed (at appropriate density) within three years. These settlements have to already have land secured, town planning applications approved and funding secured. Furthermore, the settlements have to meet the criteria for upgrading in terms of location, land assembly, bulk services, topography, environmental impact and geo-technical conditions. The de-densification may require partial relocation of the residents. This relocation forms part of the same project and should occur as close by as possible. Category 2 refers to those settlements that will be incrementally upgraded with basic, interim services. Interim services include communal ablution blocks, high mast lighting, and emergency access roads (EH 2012; PPT 2010). These informal settlements have to be earmarked for future upgrading. During this interim period, residents are typically not provided with formal tenure rights, but are protected from evictions. Category 3 refers to the provision of emergency services to settlements where future upgrading is not financially viable due to in-situ conditions. However, these settlements are not hazardous to the residents and cannot be relocated in the short-term. Emergency services include the provision of communal standpipes, communal ablution blocks, and footpaths for access. Category 4 refers to those settlements that will be relocated as they are located on land that cannot be upgraded due to financial viability and the settlement poses an immediate danger to the residents. These settlements are typically located in either floodplain areas or in areas prone to landslides. This category includes approximately 850 households in 12 informal settlements (EH 2012).

5. Conclusions

Cities throughout the developing world are faced with the growth of informal settlements, where the lack of basic services have detrimental effects on both environmental and public health. These development challenges are realities for most South African cities. It is especially evident in the eThekwini municipal area where 12 per cent of the households are housed informally, which is higher than the national average of nine per cent informal households in South Africa. There are approximately 420 informal settlements scattered within the urban and peri-urban areas of eThekwini, housing approximately a million people – almost a quarter of the total municipal population. The municipality is proactively addressing the problems associated with informal settlements through the provision of interim services.

The success of the informal settlement upgrading policy in South Africa has to be studied at the local government level. This is because the local authorities determine the most appropriate technologies to implement the political mandate and thus the implementation strategies and technologies will vary between local authorities in South Africa. The eThekwini metropolitan area was selected as the model case study for investigating the appropriateness of communal water and sanitation provision to informal settlements as the municipality has pioneered the rollout of community ablution blocks at scale since 2009 throughout its jurisdiction. This provides an exhaustive data set for understanding both the requirements of planning and construction of the facilities and the long-term sustainability of the facilities, through operating and maintaining these facilities. The implementing agent of these communal facilities remains the Water and Sanitation Unit of eThekwini. This is twofold, (i) the rollout of this infrastructure falls within the mandate and requires the approval of the Water and Sanitation Unit, and (ii) the operation and maintenance of these services will become their responsibility. In order to reduce fruitless expenditure, the eThekwini Water and Sanitation Unit does not implement this strategy in isolation, but collaborates with the eThekwini Housing Department, Architecture Department and Health Department.

The eThekwini municipality was also selected because the provision of water and sanitation services is managed by the eThekwini Water and Sanitation Unit, which has strong institutional capacity and has maintained institutional continuity. These factors facilitate the successful rollout of such projects at scale. The lessons learnt throughout this study can be used in the provision of interim services to informal settlements throughout South Africa, which is a national priority.

The provision of interim communal water and sanitation services in eThekwini is not a short term project, with the backlog in sanitation services being 231 387 households. This will require the provision of 220 community ablution blocks per annum, with a total of 3 085 ablution facilities throughout eThekwini, assuming that this backlog can be eradicated with communal ablution blocks within 14 years. Thus, the rollout of interim services cannot be provided on an ad hoc basis but must form part of the integrated planning for the formalisation of the informal settlement and the operation and maintenance of these facilities must be adequately planned for to ensure their sustainability.

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Data Sources and Acquisitions

Chapter 4

1. Motivation

This chapter provides the methodology used in the investigation of the CABs in eThekwini. This was not a simple task as the research did not only focus on one aspect of the CABs, but looked broader at the entire lifecycle of the rollout of CABs – from the planning, construction, operation requirements and user experience, and maintenance requirements. This meant that the information was gathered from a number of different sources - the project managers, the design consultants, different departments with the eThekwini Water and Sanitation Unit, site visits, and from water meter results. Collegial discussions were also had with key professionals and researchers within the water and sanitation field throughout the study. The thesis is laid out in the traditional format of project management. As such, the thesis is laid out to investigate in turn, the planning, design, construction, operation, and maintenance of the CABs by considering the effect that each of the parties have on the CABs. The lifecycle costs are separately presented in Chapter 10, as costs are variable, based on inflation, the performance of the economy, the supply and demand of different materials and skills, etc. Further, the funding programs for the implementation and sustained used of the facilities will vary over time, based on government priorities. As such, the cost implications of the CABs are detached from the static lifecycle typical of CABs.

A framework of all these parties is shown in Figure 1, and their roles in each of the lifecycle stages are described respectively throughout this chapter. This figure is repeated, where each of the affected parties in each stage are indicated in blue shading. The empirical research conducted by the author is indicated in black shading and red shading is used to indicate where the author relies entirely on secondary data.

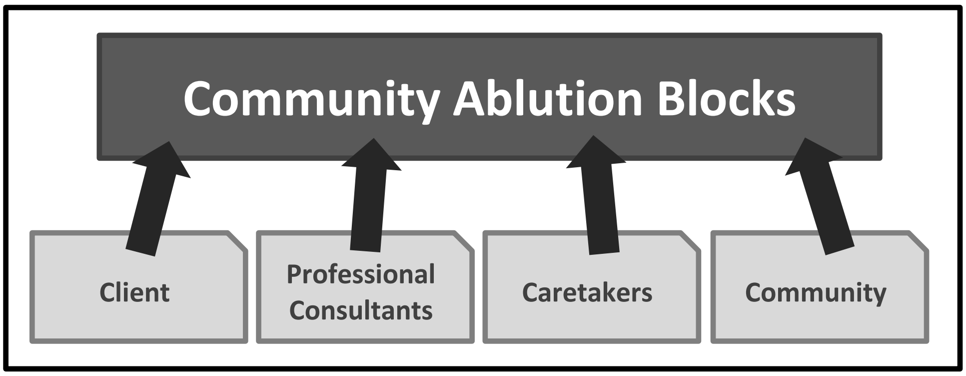

Figure 1: Schematic diagram of the affected parties within the lifecycle of the CABs
The client is the eThekwini Water and Sanitation Unit of the eThekwini municipality; the professional consultants include the project managers, design consultants and contractors; the caretakers are the caretakers appointed at each CAB facility; and the community is the community provided by the CAB facilities.

The thesis required a number of different data sources and datasets, which are summarised in Figure 2 and Table 1 in order to provide a holistic and transparent summary of the data used.

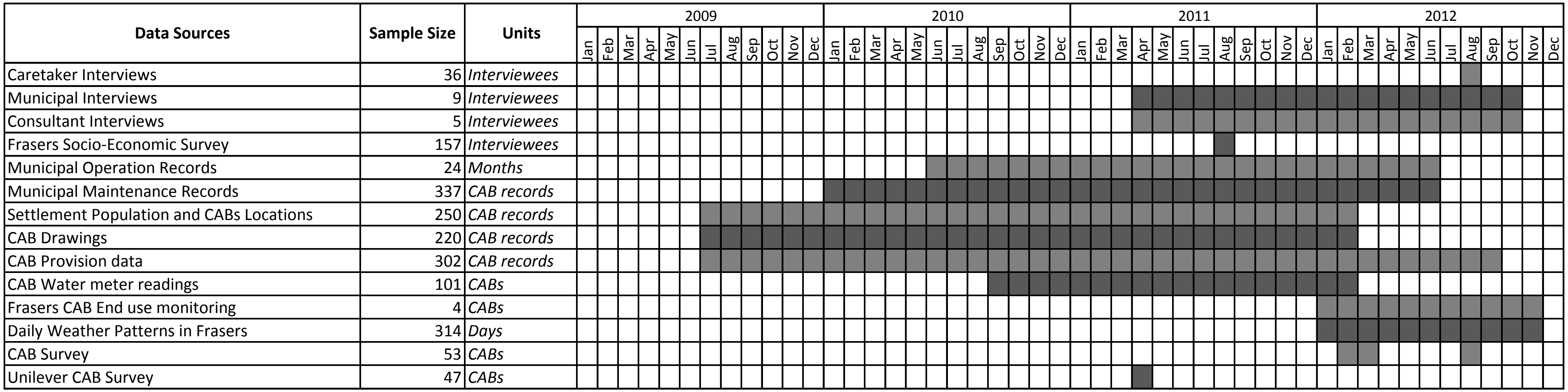

Figure 2: The timeline of the methodology gathered for this research

The graph indicates a timeline of when the different datasets were gathered.

Table 1: The summary of the different methods used to gather the data for each of the research questions

	Research Question	Project Stage	Data Source	Qty	Methodology	Type
1.1	How are informal settlements prioritised for the rollout of CABs?	Planning	Municipal interviews Consultant Interviews	2 5	Unstructured Interviews Unstructured Interviews	Qualitative Qualitative
1.2	How many households are served per CAB facility?	Planning	Municipal interviews Consultant Data	2 250	Unstructured Interviews Numerical Data	Qualitative Quantitative
1.3	What affects the caretakers' appointment?	Planning	Municipal interview	2	Unstructured Interviews	Qualitative
1.4	Which professional service providers are required in the planning stage?	Planning	Municipal interview Consultant Interviews	2 3	Unstructured Interviews Unstructured Interviews	Qualitative Qualitative
2.1	What are the best available sanitary fittings for CABs?	Design	CAB Survey	53	Observation	Qualitative
2.2	How does weather affect CAB usage?	Design	Temperatures per day Water Meter logging	314 4	Numerical Data Numerical Data	Quantitative Quantitative
2.3	What volume of water has to be supplied to CABs?	Design	Municipal Data Water Meter logging	101 4	Numerical Data Numerical Data	Quantitative Quantitative
2.4	How much wastewater is generated from the CABs?	Design	Water Meter logging	4	Numerical Data	Quantitative
3.1	How much time is required for the construction of the CABs?	Construction	Consultant Data	302	Numerical Data	Quantitative
3.2	Does the length of the water and sewerage pipelines connecting the CABs to the bulk infrastructure affect the time required for construction?	Construction	Consultant Data	302	Numerical Data	Quantitative
3.3	What factors impact the handover of the CABs to the community?	Construction	Municipal interview Consultant Interviews	2 5	Unstructured Interviews Unstructured Interviews	Qualitative Qualitative
4.1	Who is responsible for the operational management of the CABs?	Operation	Municipal interview	2	Unstructured Interviews	Qualitative
4.2	What are the caretakers' role in the operation and accessibility of the CABs?	Operation	Caretaker interview Municipal Interview	36 2	Unstructured Interviews Unstructured Interviews	Qualitative Qualitative
4.3	What effect does poor drainage and poor water supply have on the operation of the CABs?	Operation	CAB Survey	53	Observation	Qualitative
4.4	What are the sanitary consumable quantities for the CABs?	Operation	Municipal Data	24	Numerical Data	Quantitative
4.5	How are the sanitary consumables managed at the CABs?	Operation	CAB Survey	53	Observation	Qualitative
5.1	What are the official maintenance procedures and guidelines, and are they realised in practice?	Maintenance	Municipal interview Municipal Data	5 337	Unstructured Interviews Numerical Data	Qualitative Quantitative
5.2	What are the maintenance requirements for each of the CAB components?	Maintenance	Unilever Survey results CAB Survey	47 53	Observation Observation	Qualitative Qualitative
5.3	The CAB structure	Maintenance	Unilever Survey results CAB Survey	47 53	Observation Observation	Quantitative Quantitative
5.4	The CAB sanitary fittings, and	Maintenance	Unilever Survey results CAB Survey	47 53	Observation Observation	Quantitative Quantitative
5.5	Water supply and wastewater disposal	Maintenance	Unilever Survey results CAB Survey	47 53	Observation Observation	Quantitative Quantitative
6.1	What are the pre-implementation costs associated with CABs?	Life Cycle Costs	Consultant Data	249	Numerical Data	Quantitative
6.2	What are the post-implementation costs associated with CABs?	Life Cycle Costs	Maintenance records Operational records	337 24	Numerical Data Numerical Data	Quantitative Quantitative

2. Planning and Design of CABs

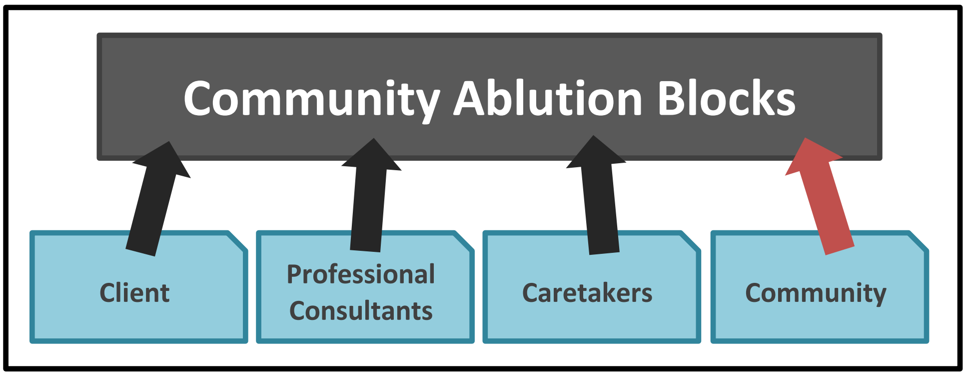

Figure 3: Schematic diagram of the affected parties within the planning and design of the CABs

2.1 Key Stakeholder Interviews

The research was conducted under the patronage of the eThekwini municipality, who were responsible for the rollout of the CABs. As such, the municipal officers were interviewed, using informal and formal, semi-structured interviews, in order to gain a first-hand understanding of the provision and the subsequent sustainability of CABs and the involvement from each department within the municipality's Water and Sanitation Unit. Two key stakeholders were interviewed from the Planning department. These individuals oversaw the planning and design of the CABs, which was outsourced to external Design Consultants and Project Managers. These interviews provided background to the planning and a rationale for the design, and provided supporting internal documentation.

The project managers were interviewed on three occasions, using semi-structured interviews. The interviews investigated both the planning of the CABs to different settlements and also to understand the critical project management functions that are required during this process. One of the four Design Consultants responsible for the planning and design of the CABs in one of the eThekwini project areas were interviewed in order to further understand the specific design requirements and standards for the CABs. Semi-structured interviews were conducted with two of their design engineers. A key stakeholder from the contractors responsible for the retrofitting of the shipping containers was also interviewed in September 2011. Finally, grey literature – including internal documents, presentations and policies associated with eThekwini municipality's approach to servicing informal settlements from 2008, were obtained from the municipality. The documents were used to determine the history of informal settlement sanitation provision and the evolution in the municipality's approach to providing these services.

2.2 Project Documentation

One of the crucial responsibilities of the project managers was documenting the progress in the rollout of the CABs. The current project managers have been involved with the project since its inception in 2009 and were contracted until 2014. They were responsible to keep records of where the CAB projects had been placed and whether the CAB projects were designed, constructed and handed over within the proposed time frame and within budget. The data they provided include the proposed budget and design and construction time periods for 302 CAB related projects (up to

3 September 2012) and the total cost of the assets that were provided in each of the CABs. These projects included containerised and prefabricated CABs to both informal settlements and transit camps throughout eThekwini. This data was used in order to determine both the costs associated with the provision of CABs, the required time period for the design and construction of the CABs, and the populations served by the CABs.

The project managers and design consultants further provided a detailed project design document which were generated for each settlement provided with CABs. Each of these documents provided the drawings and design standards required for construction and provided cost estimates of the projects before construction. These documents were interrogated in order to understand what information was required during the design stage of the planning process and where the relevant information could be obtained, such as demographics, aerial photography, the location of bulk infrastructure and the associated design standards required. Project drawings were also obtained for 220 CABs from the project managers in February 2012. The drawings were consulted where there were major discrepancies in either the cost or time periods in the construction of the CABs. Not all of these drawings were interrogated. The main benefit of these drawings were to identify the physical characteristics, i.e. length and diameter, of the water supply and sewer pipes, and also the environment within which these infrastructure were constructed, for example the topography and location of the CABs in relation to the layout of the settlement.

2.3 Water Demand Monitoring

The water requirements and subsequent wastewater discharges from CABs were investigated at two levels. Firstly, each of the CABs in eThekwini that was supplied with a bulk water meter was monitored. CABs are provided with water meters in order to account for municipal water and reduce the unaccounted for water losses throughout the municipal network. A list of CABs fitted with water meters was obtained from the Non-Revenue Water Department at EWS containing water consumption data between September 2010 and February 2012, with a total of 101 CABs having at least one month's water meter reading was analysed during this period. These water meters are typically read on a monthly basis (30 days); however, not all the data is always accurate. Each of the readings is logged and is reviewed where there are any uncertainties (either low-, high-, or estimated-readings). As of February 2012, 101 of the total CABs in eThekwini have water meters already connected (Fuller 2012). The inaccurate data, as described on the EWS database, was filtered from the data set and excluded from the analysis. The raw data was captured and statistically analysed using MS Excel. Secondly, the water requirements were investigated at an end-use level in four CABs in Frasers, a peri-urban informal settlement, shown in Figure 4. The settlement is geographically located between Tongaat and Ballito, in the northern section of eThekwini. Data surrounding the provision of CABs to Frasers were obtained from SBA and Aurecon. Aerial photographs were obtained from EWS in order to calculate population densities around each CAB site. The layout of the settlement was further investigated using Google Earth. The data provided a reasonable estimate of the settlement's population. However, it is noted that this data is limited, as it does not indicate how many households actually use the facility on a daily basis – even less accurately how many persons use the facility daily.

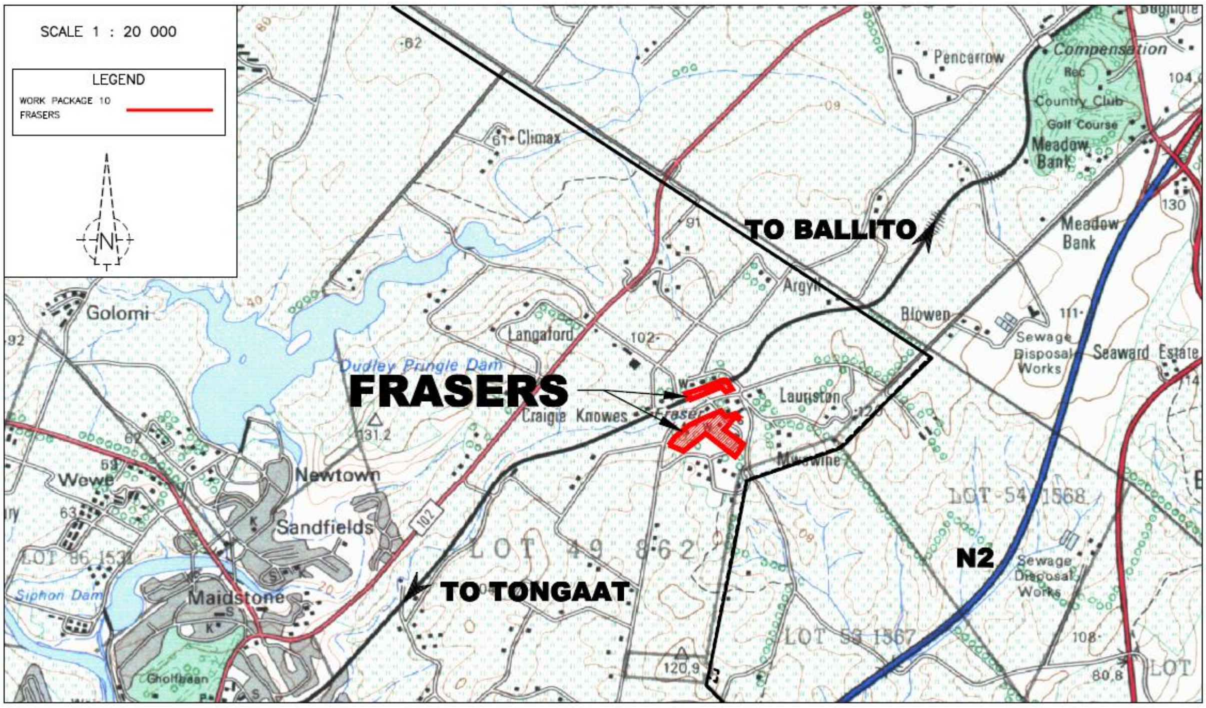

Figure 4: Geographical location of Frasers informal settlement in the north of eThekwini (SBA 2011)

One of the reasons motivating the use of the CAB facilities in Frasers informal settlement as a case study was because the facilities made use of septic tanks to dispose and treat the wastewater from the CABs. However, the stringent Environmental Impact Assessment (EIA) requirements meant that each of the septic tanks had to discharge less than 2 100 kℓ per annum. This was the first time that such on-site wastewater treatment facilities had been used in connection with CAB facilities in eThekwini, and there was a need to investigate the CAB water demands. A detailed study of the end-use water demand had not previously been conducted in eThekwini. The effect of on-site wastewater treatment at the CABs in Frasers was expected to be representative of the CABs conventionally connected to waterborne sewers, as the "flush and forget" behaviour typically prevails and users are not concerned about where the wastewater is discharged. Although the CABs in Frasers made use of water saving sanitary fittings to conserve water consumption, the data is expected to be representative of the CABs in eThekwini. Firstly, the number of sanitary fittings in the CABs in Frasers is identical to all CABs in eThekwini. This is due to the constrained area within the CAB container, as discussed in Chapter 6. Secondly, the CABs in Frasers were fitted with efficient water saving sanitary fittings of CABs, with all future CABs making use of such fittings and all existing CABs would be retrofit with similar water saving fittings upon repair.

2.3.1 End-Use Monitoring

The four CABs in Frasers were monitored by the author over the period from 20 January 2012 to 30 November 2012. The CABs were monitored using standard Class C domestic water meters and proprietary telemetric data loggers monitoring each type of fitting within the CAB, with a total of nine water meters and five data loggers per CAB, as shown in Figure 5 and is explained in more detail in Figure 6.[1]

[1] See Appendix B for more information on the water monitoring equipment.

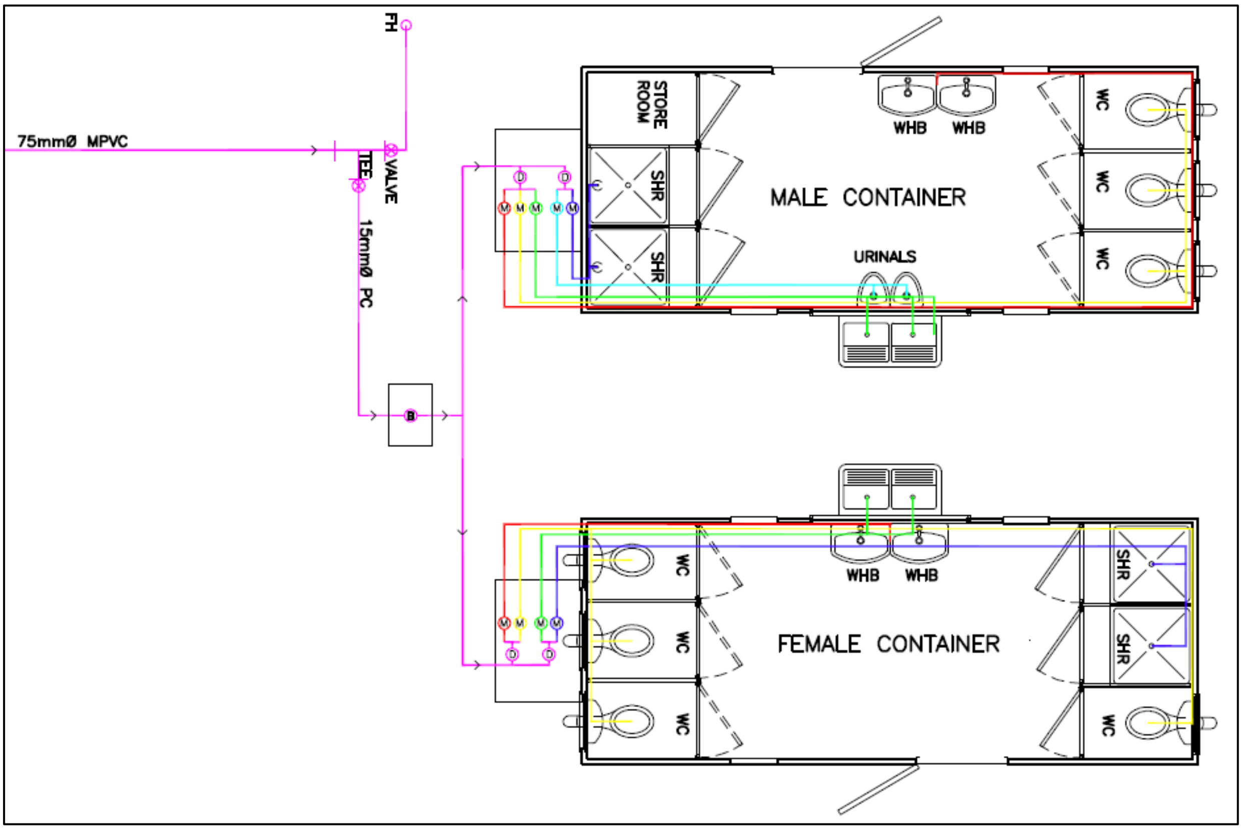

Figure 5: The schematic of the end-use water monitoring campaign in Frasers

From this figure, the water supply is provided with 75 mm diameter pipeline which supplies water to the CABs and also to a fire hydrant (FH on the figure). The water meters and data loggers are placed within an enclosure for protection, and the water supply is distributed from there to each fitting within the CAB.

These data loggers transmit the data to a secure server which can be accessed remotely via a website. The data loggers require an internal power source, i.e. batteries, in order to record and transmit the data, consequently having an economic value and a target for theft. The data loggers recorded the data on a 15-minute interval period and transmitted the data to a webserver on a daily basis. However, there were days on which there was no data recorded for some of the fittings. This was due to both broken fittings and broken data loggers. Further, leaking fittings were also discarded during the analysis of the water demands, for example the male basin in CAB 5 leaked for several days.

Female CAB		
Fixture	Water Meter	Logger
Laundry Tap 1	Female Laundry water meter	Data logger 1
Laundry Tap 2		
Attached Tap		
Shower 1	Female Showers water meter	
Shower 2		
Wash Basin 1	Female Basins water meter	
Wash Basin 2		
Toilet 1	Female Toilets water meter	Data logger 2
Toilet 2		
Toilet 3		
Toilet 4		

Male CAB		
Fixture	Water Meter	Logger
Laundry Tap 1	Male Laundry water meter	Data logger 3
Laundry Tap 2		
Attached Tap		
Shower 1	Male Shower water meter	
Shower 2		
Urinal	Urinal water meter	
Wash Basin 1	Male Basins water meter	Data logger 4
Wash Basin 2		
Toilet 1	Male Toilets water meter	
Toilet 2		
Toilet 3		

Figure 6: The data logging and end-use water monitoring setup in Frasers
There are nine water meters, namely one per female toilets (four toilets), female showers (three showers), female laundry facilities (two laundry taps and the attached tap), female hand wash basins (two basins), male toilets (three toilets), male urinals (two urinals), male showers (two showers), male laundry facilities (two laundry taps and the attached tap), and male hand wash basins (two basins). The male and female laundry facilities are identified as such for labelling purposes only, as the laundry facilities are outside the ablution blocks and can be used irrespective of gender.

Figure 7: The internal configuration of the data logging equipment at one of the male CABs in Frasers
The water meters are shown at the bottom of the figure, and the data loggers are elevated in order to ensure that they do suffer water damage during rain or due to leaks (Mohan 2012).

The monitoring equipment, both water meters and data loggers, were secured in a plastered-brick enclosure with a steel manhole cover (internal configuration shown in Figure 7) with a low economic-value steel manhole cover. This enables adequate access for maintenance, whilst ensuring safety from vandalism and theft.

The data from the CABs was cleaned using an algorithm across all of the data points, as there were days were data was missing (due to broken data loggers) and the data was invalid (due to broken fittings for example). Thus, where no data was recorded for the time interval, whether a 15-minute interval or an entire day, or the water demand for a particular day was equal to zero for a specific fitting, that day was replaced with either the previous or following week's data, indicated by the algorithm shown in Figure 8. Furthermore, where there was no data for a specific date the algorithm either made use of the previous or following week's water demand. When the previous week's water demand was estimated, the algorithm would use the following week's water demand. If both the water demands were estimated, then the algorithm made use of the previous week's estimated water demand. The leaks were determined by evaluating whether there was a constant, high flow rate for an extended period of time, more than six 15-minute intervals. Theseperiods when fittings were leaking were discarded for the analysis of the water demand, for example the male basin in CAB 5 leaked for several days. Where data could not be patched on a specific day, the data for a specific fitting were based on the water demand from one other CAB on that same day, where CAB 2 and CAB 5, and CAB 1 and CAB 3 shared data points.

The data loggers are remotely adjustable to the required logging intervals - as low as a minute and up to 24 hour intervals. However, the interval at which data are logged and sent to the web server determines the battery life of the data loggers. For peak flow design purposes, the data were recorded at 15-minute intervals.

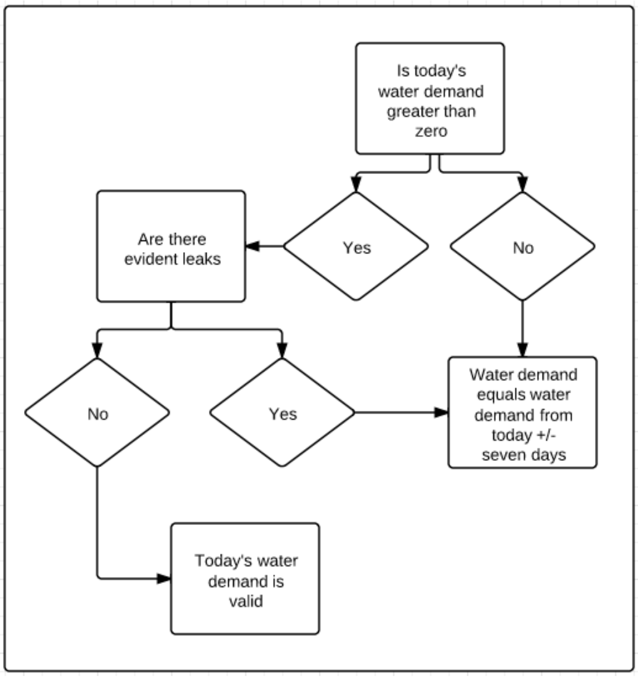

Figure 8: Flow diagram for the algorithm used for patching the end-use water demand data

Further, in order to characterise the hydraulic modelling of the CABs it was important to determine the operating hours of the CABs. From the analysis of CAB 5, it was evident that the operating hours of the CABs are from 05:30 am – 20:30 pm (15.5 hours). This is an appropriate estimation as none of the facilities have nocturnal lighting or electricity, and it is common for the caretakers to lock the facilities at night. There were no signs from the water monitoring that the facilities were locked at night. Reducing the data set to the water demands during the operating hours provides a better model of the water demands of a CAB, as the inclusion of water demands during non-operating hours would provide lower average water consumption over the entire day. The non-operational water demands were recorded as leaks; however, this was not used in the analysis of the peak and average water demands.

The data loggers provided 15-minute water consumption data from each fitting at each CAB (a total of 36 data points per time interval). The data was then concatenated into hourly and daily intervals in order to determine the average water demand from each fitting, the greywater demand, the blackwater demand, and the total water demand of the entire CAB. The average daily demand is essential for the hydraulic modelling of the water supply. The 1-hour average water supply was also considered for the hydraulic design of decentralised wastewater treatment facilities, such as anaerobic baffled reactors and septic tanks. The average demand was calculated by averaging the data over the operating period of the CAB (05:00 – 20:30). The hourly running water demands, not the static hourly water demands were calculated, as shown in Figure 9. However, this hourly data had to be converted into independent data so as to determine the *maximum independent* hourly water demands. Thus, the three data points preceding and succeeding the maximum hourly water demand were deleted in order to remove the confounding effects of the maximum hourly value.

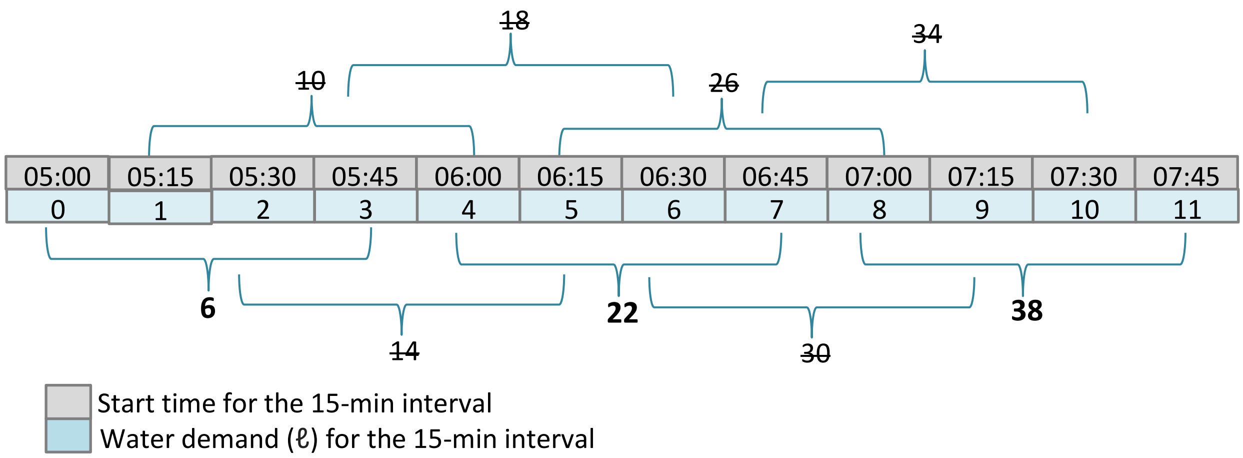

Figure 9: The algorithm used to determine the independent hourly data for the CABs from 15-minute data
This diagram indicates how the 15-minute interval data is summed up into hourly intervals. Once, the running 1-hour intervals have been determined, starting at the maximum 1-hour demand found for the interval from 07:00 – 07:45, the three preceding and succeeding data points are discarded and the independent hourly data is recorded. In this example, the independent hourly data is 6 ℓ, 22 ℓ and 38 ℓ.

The algorithms, shown in Figure 8 and Figure 9, to screen the dataset were implemented in MS Excel. The statistical methods used to analyse the screened data included the average, median, standard deviation, and the minimum and maximum values. The end-use data were used to determine the total water demand per day and the average and peak water demand per 15-minute intervals. The peak factors were then determined using Equation 1 where v_{peak} is the statistically significant peak volume and $v_{average}$ is the average volume over the specified interval, either 15-minute, 1-hour or 1-day.

$$Peak_{factor} = \frac{V_{peak}}{V_{average}} \qquad [1]$$

For each water demand measured over the different intervals (15 minutes, 1 hour or 1 day), a return period was assigned using the Weibull distribution, as shown in equation 2. The Weibull distribution is commonly used in hydrology to perform flood frequency analysis (Davie 2008). The distribution requires that the data be sorted in descending order, with each sorted value assigned with a rank value (R) of 1 … n from the maximum to the minimum value. The critical return period for design was considered to be one week. This means that the peak factor would be exceeded on average once every week. This is sufficient for water supply and wastewater management design, as failure is not catastrophic in water supply but only results in a loss in pressure throughout the network for that time period (van Zyl 1996; Booyens 2000).

$$Tr = \frac{n+1}{R} \quad [2]$$

where, Tr = return period
n = number of data points
R = rank value of each of the data points

The return period equation is the reciprocal of probability, P, given by

$$P = \frac{1}{Tr} \times 100\% \quad [3]$$

The average flow was determined for the 15-minute, 1-hour and 1-day intervals. This study interpreted the 15-minute peak factor as the "instantaneous peak factor" found in the Red Book (CSIR 2005). The Red Book's instantaneous peak factors are vaguely defined, with the peak factor being above 4 for high-density urban areas, and between 3 and 4 for low-density rural areas.

The effect of weather was investigated on the CAB usage as the CAB facilities are located away from the dwelling units. This was achieved by obtaining the daily high, low and average temperatures from the two weather stations closest to Frasers informal settlement, namely La Med and the Upper Tongaat weather stations. The weather stations did not provide quantitative daily rainfall patterns, but only indicated whether there was any occurrence of rain on the day. The data from these two weather stations were averaged in order to estimate the daily ambient temperature and whether any rainfall occurred in Frasers. The data was then compared to the water consumption found from the end use water monitoring.

2.4 Socio-Economic Survey in Frasers

A pre-implementation socio-economic survey was developed by the author, Roma and Tavener-Smith for a project independent of this thesis. The survey was administered in August 2011 in Frasers informal settlement by enumerators fluent in the local vernacular under the supervision of Roma and Tavener-Smith. A total of 157 of 397 households (40%) were surveyed. The scope of the investigation was to analyse the health, socio-economic and behavioural impacts brought by the installation of CABs. This was to be achieved through pre-implementation and post-implementation surveys. The results from the pre-implementation survey were analysed, without any pre-tests, by the author and used in this study for the purpose of understanding the demographics of the Frasers informal settlement, their socio-economic status and also to determine the prevalent water, sanitation and hygiene practices used before the CABs were constructed. The post-implementation study has not been conducted yet.

3. Operation

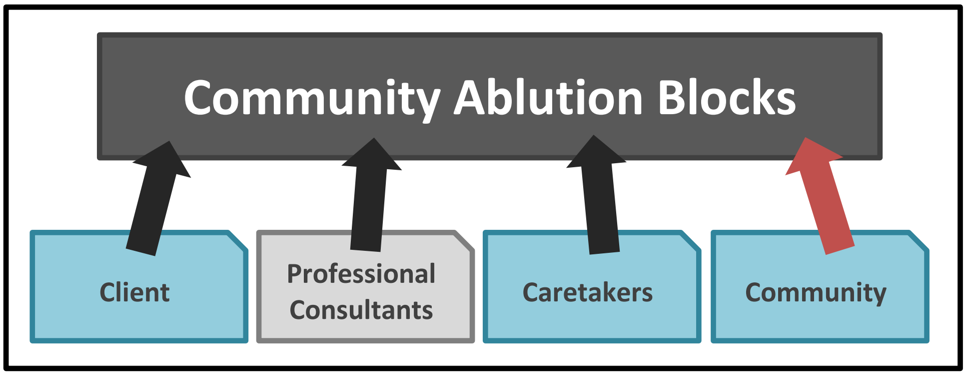

Figure 10: Schematic diagram of the affected parties within the operation of the CABs

3.1 Key Stakeholder Interviews

The key stakeholders from the Hygiene and Education Department of the Water and Sanitation Unit were interviewed. This department provided education on how to properly use the water and sanitation infrastructure and also promoted hygiene behaviour during the pre- and post-implementation of the development of all infrastructure. They used both posters and street plays to promote education. Furthermore, this department was responsible for the operation of the CABs and as such was directly responsible for the sanitary supplies to the CABs. The department was also responsible for the management of the caretaker supervisors, ensuring that the caretakers and supervisors were able to do their work and that all faults and repairs were performed within the required response time, and also for recording the maintenance and operation tasks performed.

The two key stakeholders from this department were interviewed on numerous occasions between June 2011 and October 2012. Available internal documentation presented at workshops, conferences or internal EWS meetings were gleaned for significant information regarding the provision of water and sanitation services to informal settlements.

Finally, 36 caretakers were surveyed in a CAB survey during the period from 27 to 31 August 2012. The caretaker interviews formed part of the broader site survey investigating the maintenance requirements of CABs. The caretakers were interviewed through structured interviews designed by the author. These surveys were administered by the author and an environmental health practitioner who was fluent in the vernacular of the caretakers, as the majority of the caretakers did not speak English. The responses were recorded in the site survey and were statistically analysed in MS Excel.

3.2 Municipal Documentation

The official municipal records associated with the sanitary consumables were obtained from the Hygiene and Education Department over the period from June 2010 to June 2012. The sanitary consumables included PPE (personal protective equipment such as overalls, boots, gloves, masks); buckets, mops, and brooms; disinfectant; and toilet paper. The data was not recorded per site but for the total number of each consumable taken from the central EWS warehouse on a monthly basis. The data was analysed per site by extracting the dates on which each of the CABs were commissioned from the data obtained from the Project Managers. This meant that each type of consumable used per month was divided by the number of CABs that had been handed over to the community. Furthermore, the number of consumables used per month was evaluated by comparing the number of new CABs that became operational in order to determine which consumables were provided with the new CABs. Extracting useful data from the latter scenario required a number of assumptions to accurately estimate, as the caretaker may not have been provided with the consumables in the same month as the CABs become operational, but could have occurred either the month before or after the CABs become operational, depending on the time of the month that the CABs were handed over. All of the costs associated with each of the sanitary consumables were dated to April 2012. The data was captured and statistically analysed in MS Excel.

3.3 Unilever Project Findings Surveys

An unpublished project was conducted by Roma and Buckley for Unilever UK. The project investigated the potential role that Unilever could play in the provision of low cost high quality sanitations products to the communities provided with CABs. As such, the project performed a comprehensive baseline community survey to 47 CABs in 31 informal settlements. A total of 19 households were surveyed around each of the CABs, with a total of 900 valid household responses used for the analysis. The surveys explored the users' opinions and patterns of CAB use. It also investigated the CABs' level of cleanliness, presence of leakages and vandalism, provision and availability of sanitary consumables from the municipality (such as toilet papers) and status of operation and maintenance (Roma & Buckley 2011).

4. Maintenance

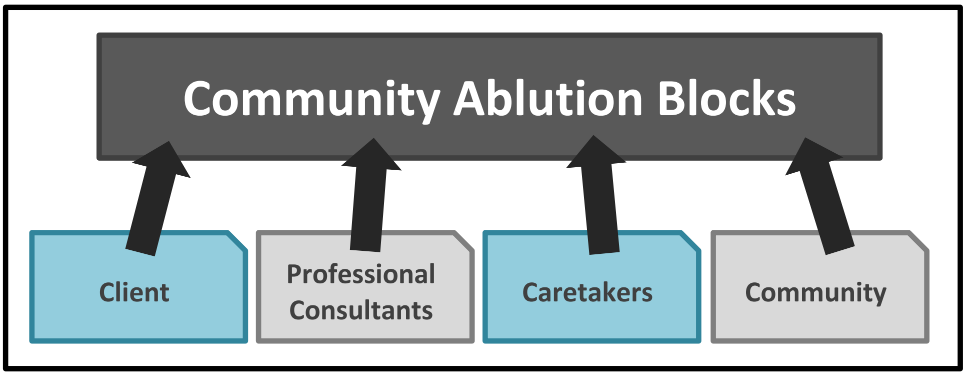

Figure 11: Schematic diagram of the affected parties within the maintenance of the CABs

4.1 Key Stakeholder Interviews

A semi-structured interview was arranged with two key stakeholders from the Wastewater Department at EWS, as this department was responsible for the maintenance of the CABs. The interview was also conducted with a number of plumbers who were present on 29 March 2012. The interview provided an important perspective on the maintenance requirements of the CABs that was unobtainable from written documents or either the caretakers or planners. The plumbers were able to air their frustrations and their insights into providing an improved CAB facility to the community. The author was perceived as a neutral party. It was apparent that the frustrations the plumbers experienced on site were often neglected by the other EWS departments, such as the planning department. This provided an unprecedented insight for the author into the mechanics of maintaining the CAB facilities.

4.2 Official Maintenance Records

The raw maintenance records were obtained from the Hygiene and Education Department. The records were provided from the period of January 2011 to July 2012 for all of the CABs. Predominantly the data only reported what the plumber repaired – either unblocking sewers, repairing leaks or replacing fittings. The costs associated with the maintenance were not readily available from these records. This was because the plumbers charged the municipality for all of the work performed during their shift and at times it did not only include the costs associated with the maintenance of the CABs. A total of 337 maintenance records were investigated in order to provide an estimate for the costs of replacing fittings, unblocking sewers, repairing leaks or repairing any structural damages on the CABs.

4.3 CAB Site Surveys

An extensive survey of 47 CABs was conducted in August 2011 as part of the Unilever funded project (Roma & Buckley 2011). A synthesis was made of the raw data and was presented to EWS and in the Unilever report. The raw data from the survey was obtained from the main author. Three more site visits were conducted during the period from February to August 2012. The first site visit was conducted on 22 February 2012, where four CAB sites were visited in two informal settlements. The site visits was not conducted with a structured survey. Photographic evidence of some issues around the CABs was captured. The sites were selected based on their location in the Central area and were preselected from a list of sites. Due to time constraints, only four sites were visited. However, the photographic evidence provided a further impetus to investigate the operational state of the CABs, as the sites visited were not entirely functional, which lead to two additional site visits where structured surveys were conducted.

On 28 March 2012 a total of 12 CAB site visits were conducted with an environmental health practitioner from EWS. These sites were located in two informal settlements in the North area of eThekwini. The aim of the site visits was to investigate the state of the CABs and the fittings, and as such the focus was not on interviewing the caretakers. The investigated sites were preselected from the North and Central areas and were required to have water meter readings from EWS and CAB construction cost data from Aurecon. Initially, 17 CAB sites in nine informal settlements were identified for the survey, yet due to time constraints only 12 sites were visited in the North project area of eThekwini. The site visits started at the furthest sites in the North area and worked back towards the Central area. As CAB construction costs are available per settlement, not per CAB site, it was determined that the surveys would have to investigate an entire settlement, not only a subset of CABs from within the settlement. The site visits were recorded both through a survey (Appendix C) and photographic evidence was recorded of each fitting and any structural defects in the CAB. The data from both the survey and the photographic evidence was captured and analysed in MS Excel.

A final round of site visits was conducted during the period from 27 to 31 August 2012 with an intern environmental health practitioner from EWS. A total of 37 CAB site visits were performed, and 36 caretakers were interviewed through structured interviews. The site visits were recorded both through a survey (Appendix D) and photographically recording each fitting in the CAB and all structural defects in the CAB. The aim of the site visits was to not only investigate the working state of the CABs, but also to determine the caretakers' experience ensuring the CABs are operational. The sites were selected based on available construction data, both cost data and the date when the CABs became operational. Appropriate sites were then selected from each of the four project areas. A list of 60 sites was short-listed. A total of 37 sites were finally visited based on time constraints and the environmental health practitioner's knowledge of the location of the various sites. The environmental health practitioner provided a list of caretaker numbers and where the caretakers were not present on site they were telephonically contacted to come to the respective site for an interview and where the caretakers were unable to else to have a telephonic interview. All data from the surveys and the photographic evidence was captured and analysed in MS Excel. The surveys represent a snapshot of the state of each CAB at that specific date and the data is expected to change at different dates. However, the 97 surveyed CAB sites from 2011 and 2012 provided sufficient data to develop a general condition of the CABs in eThekwini and to determine their success factors.

5. Limitations to data sources and acquisitions

This study acknowledges that there are limitations to the data. Firstly, the research was framed within the engineering lifecycle of the CABs, and focussed on the implementing and responsible stakeholders within this framework – the municipality and the professional service providers, namely the project managers and design consultants. The research does not provide primary data on the impact of the CABs on the communities, nor what effect the communities have on the CABs. These are major research questions which will require extensive research to answer, and was beyond the scope of work of this thesis. It is acknowledged that the community as pivotal to the success of any water and sanitation projects.

The responses from the key stakeholder interviews with the municipal officials, project managers and engineers can be considered as a combination of (i) what theoretically happens, (ii) what should happen, or (iii) what actually happens in the pre- and post-implementation of the CABs in eThekwini. These responses may have been affected by the researcher being perceived as a critical, external party to the project, yet the rollout of the CABs was internally perceived to be the best solution to curb the water and sanitation challenges in the informal settlements. The eThekwini municipality had also been recognised internationally by winning the IWA Development Award in 2011 for the rollout of CABs. Furthermore, although the interviews with the operational staff at the municipality, the plumbers and caretakers, provided hands on experience of the sustainability of the CABs, the researcher's cultural and language barriers may have limited the disclosure of some information.

The end use water consumption data provided from the case study, Frasers informal settlement, provided in depth analysis of the water consumption patterns of the CABs. However, it is noted that the data accuracy decreases as the detail of the population increases, i.e. the per capita consumption is more variable than per household consumption. This is because the population data is based on reasonable estimates from the municipal population figures and aerial photographs, not the actual, measured number of persons using the CABs per day. This was an adequate level of detail within the scope of the research. Furthermore, the water consumption of the CABs was quantified both at an end use level and from numerous CABs around the municipal area. However, the study did not quantify the volume of water obtained from additional water sources, such as stand pipes. This should be taken into account in future studies so as to provide a water balance for the entire settlement, as the additional water sources are expected to increase the daily water consumed within the settlement.Ethics Considerations

The fieldwork activities were submitted to and received the approval of the University of Johannesburg's Ethics Committee. All interviewees were made aware of the aims of the investigation before the interviews were conducted.

During all site visits, the caretakers and any community members engaging with the author were further made aware of the aims of the research and the author clearly defined his role as an academic and not a municipal representative, so as to not raise the expectations of either the caretakers or community in the possible outcomes of the research.

The author provided feedback on the findings to the municipality while the research was conducted, none of the findings were concealed from the relevant stakeholders in order to ensure that any remedial work could swiftly be implemented. A number of the findings and recommendations presented in the thesis were implemented both during and after the study was completed.

6. Conclusions

This thesis investigated the success factors in the provision of communal water and sanitation services service as interim measure in the upgrading of informal settlements. The study did not only look at one aspect of the service provision but investigated the life cycle of the CABs, from planning, design, construction, operation, and maintenance. The data were not readily available but required the collation of a number of documents from a number of sources, namely the design consultants, project managers, municipal officials, and CAB sites. The data were not readily available and had to be sourced from different informants within those organisations. The data was then scrutinised and verified to determine whether the information was relevant and which data were correct in contradicting documents. The data were both quantitative, such as the water demand and the information regarding the life cycle of the CABs, and qualitative, such as the data gleaned from the CAB surveys and anecdotal evidence found during the CAB site visits and structured interviews. The anecdotal evidence provides a deeper perception of the state of the CAB facilities and leads to a better understanding of the requirements for their sustained success.

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Planning

Chapter 5

1. Introduction

The mandate of upgrading informal settlements with *inter alia* communal water and sanitation facilities is placed on local governments. However, as previously discussed, the rollout of these services have to be planned strategically within the IDP of the local and provincial government. This requires some form of a prioritisation algorithm to determine which settlement should be upgraded first. Then, once the settlements have been prioritised, the needs of that specific settlement have to be determined, i.e. the number of facilities required in the settlement.

This chapter builds on the experience from eThekwini municipality's rollout of communal water and sanitation services. The chapter provides details of how the settlements are prioritised. It also provides details of the constraints associated with the placement of communal facilities within the settlements and the effect that distance has on the community. The water requirements and caretakers are briefly discussed here but are respectively discussed in detail in Chapter 6 (Design) and Chapter 8 (Operation). Finally, the chapter presents the means whereby the municipality was able to coordinate and manage the technical expertise and implement the rapid roll out the CABs throughout their jurisdiction. The research questions investigated include,

- How are informal settlements prioritised for the rollout of CABs?
- How many households are served per CAB facility?
- What affects the caretakers' appointment?
- Which professional service providers are required in the planning stage?

The post-Apartheid politically charged promise of housing for all has meant that the residents of informal settlements anticipate the government to provide houses to all. Yet, the provision of basic and emergency services is not only a paradigm shift for the local governments but also for the residents. Therefore, it is pivotal for the expectations of the residents to be managed. The community must understand that CABs are only the first step in an integrated approach to settlement upgrading and that the provision of CABs is in fact part of the process toward full household water and sanitation services. In an interview with key stakeholders from the EWS Planning Department and the Project Managers, it was indicated that community buy-in was essential in the long term maintenance, acceptance and usage of the CABs (Smith et al 2012).

2. Settlement Prioritisation

The selection of informal settlements for upgrading as per Part 3 of the Housing Code (DHS 2009) should,

- reach as many households as possible (rapid roll out of services) in order to upgrade all informal settlements by 2014, as per the national mandate;
- prioritise those settlements which have been the subject of a Court Judgement or threatened with eviction;
- primarily serve informal settlements which threaten health and safety;

- promote spatial restructuring and integration;
- avoid relocation;
- enable community participation.

Interim water and sanitation services are provided to those settlements earmarked (by the Housing Department) for in-situ upgrading in the short-, medium- and long-term, a process by which the informal settlements will be formalised in the future. Essentially, this includes settlements which will be upgraded within the next 5 – 15 years. This was determined through interviews (Smith et al. 2012), published documentation (Roma et al. 2010) and internal documentation (Dedekind 2010; Smith & Dedekind 2011; Scruton 2009; Pfaff 2010). The interviews further indicated a shift in this policy from December 2011, where the eThekwini Housing Department requested that CABs even be provided to those settlements with a scheduled upgrade time above 2 years (Smith et al. 2012). The backlog in services is staggering in eThekwini and the informal settlement upgrading program aims at providing interim services to all settlements instead of providing a full level of service to a few settlements. But, this rollout of services requires a sustainable plan of prioritising settlements for upgrading, i.e. which settlements will be upgraded first. This prioritisation plan is realised in eThekwini using an algorithm based primarily on location to existing infrastructure and services. This policy has been developed over the past decades and is the current policy in eThekwini for informal settlement upgrading. This location-based prioritisation criteria (EH 2012) require that the informal settlements

- are within the Urban Development Line;
- are within walking distance of public transport trunks;
- are based within existing urban settlements whose current densities promote sustainability;
- require low investments in new bulk infrastructure;
- are close to selected public transport interchanges;
- and are close to essential social facilities.

The first criterion distinguishes between rural and urban or peri-urban settlements, as rural settlements are not part of the Informal Settlement Program. Secondly, the settlements are prioritised based on proximity to public transport trunk routes. Settlements within proximity of 400 m or less are regarded as highly accessible, while settlements beyond 2 km are less accessible.

Thirdly, a comparison is made to the relative costs of providing bulk and local infrastructure for full services for every settlement. This is modelled through the municipal Cost Surfaces Model, as shown in Figure 1. This model provides a benchmark estimate of the costs, not an absolute estimate, as the sites are affected by in-situ conditions, such as topography. A benchmark cost is then provided for each settlement, where benchmark estimates of below R10 000 per household are regarded as economical, while benchmark estimates larger than R50 000 per household are uneconomical. The third and fourth criteria prioritise settlements according to their proximity to existing residential urban centres. These centres characteristically have densities over ten dwellings per hectare, high levels of available infrastructure and accessible to social facilities. The fifth criterion considers the settlements' proximity to selected public transport interchanges, where settlements within 1 km from the interchange are highly accessible. Finally, settlements are prioritised according to availability of social services, such as schools, libraries, clinics, sports fields, and basic recreation facilities (EH 2012).

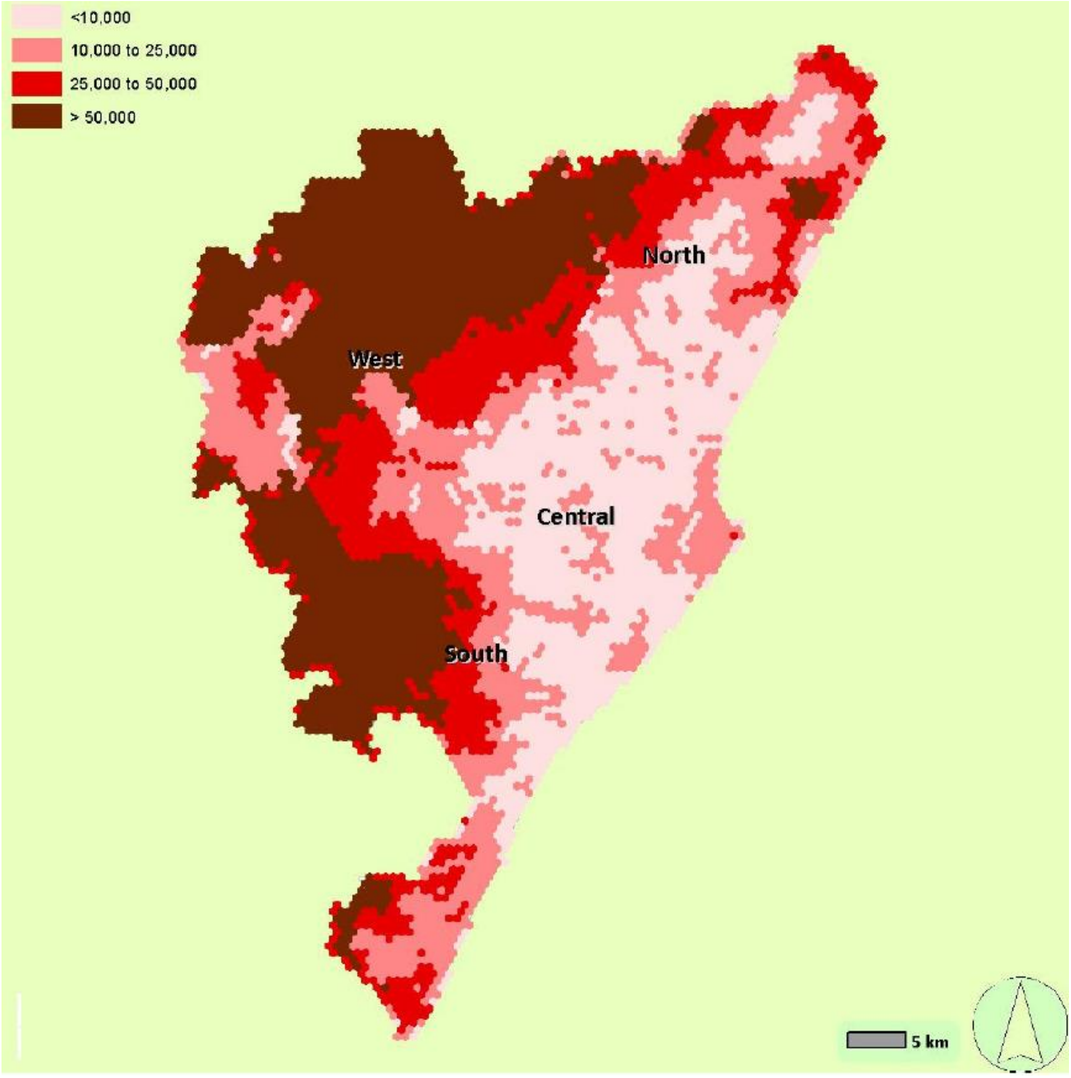

Figure 1: The cost of providing bulk water and sewer infrastructure (EH 2012)
The data is provided in the ZAR cost value of upgrading the water and sewer infrastructure per household.

Once the settlements have been prioritised and earmarked for in-situ upgrading by the Housing Department, the local government's responsibility includes the feasibility planning and design of the in situ upgrading by providing basic services, whereby communal water and sanitation services are the first phase of interim upgrading. And also planning for the long-term sustainability of these services by assuming ownership of the infrastructure through operation and maintenance of the infrastructure (DHS 2009).

The feasibility study includes the identification and verification of the number of residents within a settlement, the location of existing bulk water and sanitation infrastructure, the availability of access roads, and the availability of land for development. The availability of land in eThekwini is addressed through the bylaws which enable the municipality to gain permission to occupy the land, for interim water and sanitation services, without actually purchasing the land. This is stipulated in the Public Health Bylaws (Section 3 of P.N. 9/1949 found in Appendix E) (EM 2011). If the private land owners do not allow the municipality to provide the interim services, the bylaw stipulates that the land owners have 30 days within which to give the municipality access or else to provide the services themselves. In interview with the planning stakeholders indicated that after this notice period has expired, the municipality has to still provide the services, but provision is made at the cost of the land owner (Smith et al 2012). The other main job performed during feasibility is community participation to determine the community's requirements and where the services should be placed and, if required, where residents should be relocated. Once the feasibility study is complete, the EWS supervisor and the Design Consultant meet with the Ward Councillor to discuss the appropriate sites meeting the technical requirements. Once the placement of the CABs has been agreed upon, a public meeting is held with the residents to discuss the implementation of the CABs. Once the community has agreed upon the locations the detailed design commences.

3. Placement

The number of CABs required in each settlement is determined by the in situ conditions. The eThekwini guidelines dictating the number of CABs required per settlement are (Dedekind 2010; Smith & Dedekind 2011):

- Population density between 50 – 75 households per CAB
- Maximum walking distance of 200 m – 250 m from household to CAB
- Settlement must be located within the urban development line

The first design guideline, the population density, is normally the constraining factor due to the high population density in the eThekwini informal settlements. The minimum number of dwellings (50 households) is the criteria for the construction and provision of a CAB in an informal settlement. In practice, CABs can serve significantly more users (up to 200 dwellings – where there is an average of 5.5 people per household in informal settlements in eThekwini) than the designed value (Roma et al. 2010). This is due to the population flux and in-migration in the informal settlements in eThekwini. The population density from 250 CABs in 97 informal settlements was plotted (in Figure 2, Figure 3, and Figure 4) to determine the actual population density per CAB to the theoretical design population density per CAB of 75 households per CAB. The population data was gathered from the Housing Department and the number of CABs per settlement were obtained from the project managers. The CAB population density was determined by dividing the settlement population by the number of CABs provided. The results indicate that 21% (20) of the settlements had a density of less than 75 households per CAB. The majority (39%) of the settlements were provided with a single CAB and this could either be associated with legal disputes concerning the placement of the CABs, or due to the Housing Department and the project managers using different names for the settlements, causing the data to not be represented on the graph. It is noted that the roll out of CABs in eThekwini is not complete, but is an ongoing process.

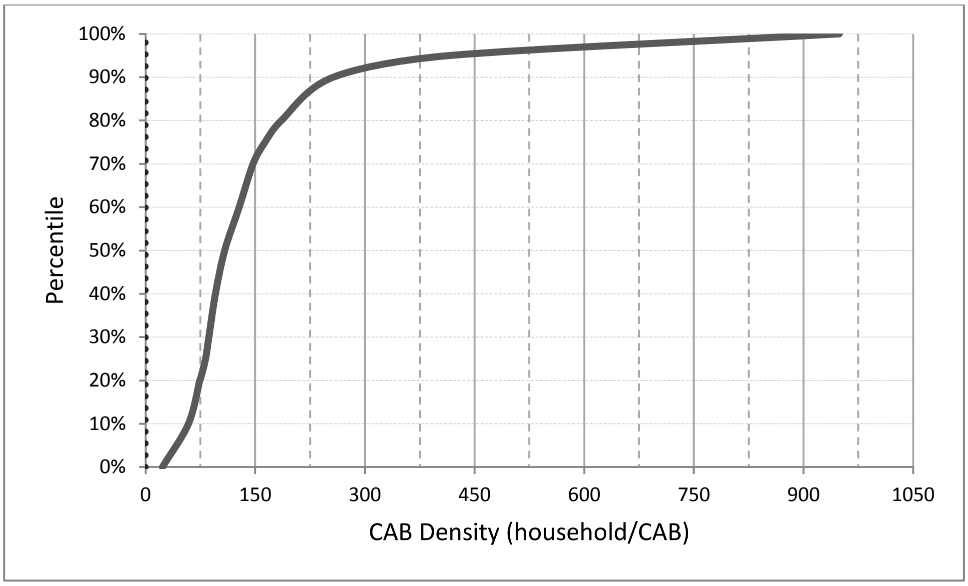

Figure 2: The probability graph for the actual number of households per CAB.

The figure is based on 250 CAB sites within 97 informal settlements. The data indicates that the mean density is 108.1 households per CAB, and only 20.4% of all the CABs are being used within the maximum design criteria of 75 households per CAB.

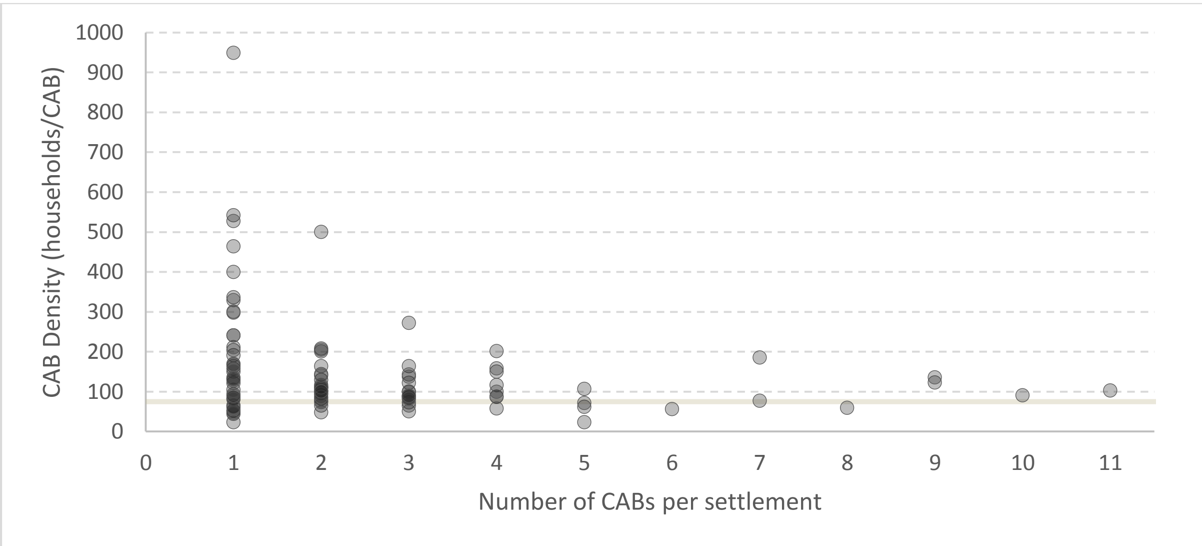

Figure 3: The relationship between the number of the CABs per settlement and the theoretical population density using each facility.

The graph shows the results of 250 CAB sites within 97 informal settlements. The CAB density is equal to the number of households per CAB. The maximum design value of 75 households per CAB is shown by the straight line. It is evident that the majority (79%) of the settlements have a density higher than the design value. Although it is noted that the provision of CABs is not complete but is an ongoing process.

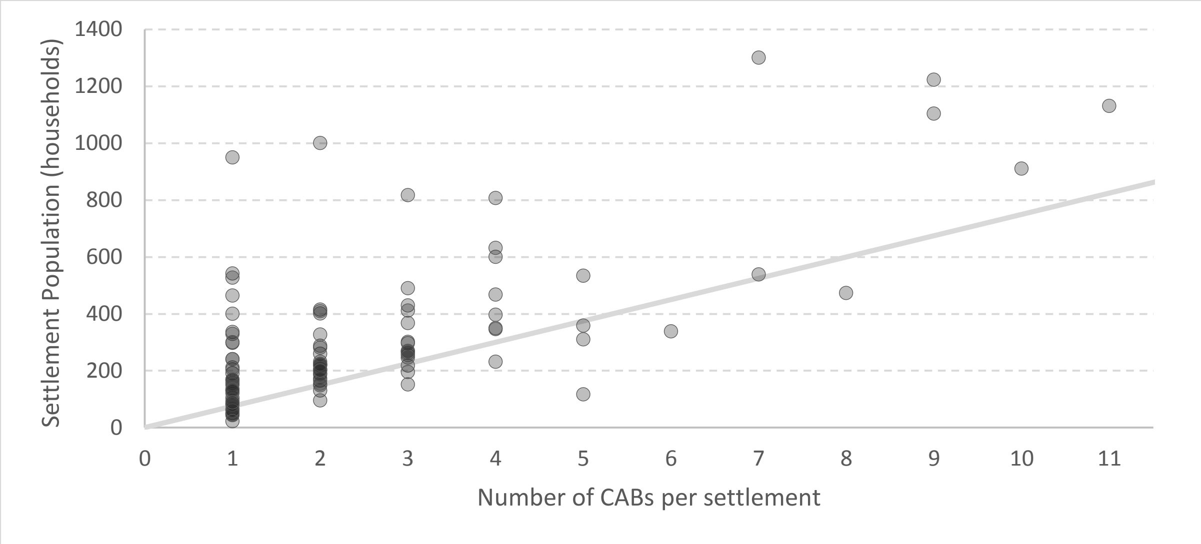

Figure 4: The relationship between the number of CABs and the population of the settlement.
The graph shows the results of 250 CAB sites within 97 informal settlements. The maximum design value of 75 households per CAB is shown by the straight line. The graph indicates that although the number of CABs generally increases with the population of the settlement, the majority of the settlements still have higher population usage per CAB than the design criteria.

Through interviews with the key stakeholders, CABs are placed, as far as possible, so as to be incorporated into the cadastral planning of the eThekwini Housing Department, and their future formal reticulation systems of the informal settlement and catchment areas (Smith & Dedekind 2011; Smith et al. 2012). Finally, those informal settlements beyond the urban development line, i.e. too rural and too far from bulk services, were initially not provided with interim CAB services. However, due to political pressure a pilot project was initiated using an on-site DEWATs treatment system. An interview highlighted the intention of the municipality was to promote these systems to other informal settlements beyond the urban development line (Smith et al. 2012).

The CABs are generally placed along the periphery of the settlements, due to the lack of available space within the settlement and the lack of access roads for both construction and for maintenance. The interview further indicated that there was another factor reinforcing the peripheral placement of CABs, namely the economic losses from the municipality due to illegal water connections. This means that where no water mains are available within the settlement, the CABs would make use of short water mains extensions on the periphery of the settlement, even when it meant that sewer extensions were much further (and more expensive) than the water supply infrastructure (Smith et al. 2012). Where existing water and sewerage mains crossed through a settlement, however, CABs would be placed at a suitably accessible location. However, where access was limited, EWS used pre-fabricated CABs as these can be carried along footpaths and assembled on site (Smith et al 2012). Six constraining factors have been identified in the placement of the CABs. These factors dictate the placement of the CABs within a settlement (as indicated by Gounden 2008; Roma et al. 2010; Scruton 2009; Gounden 2009; Smith et al. 2012)

- Topography
    - The average slope of the ground must be less than 1:3.
    - As the sewer forms part of the long-term infrastructure, the facilities should be placed around the low points of the catchment of the settlement
- Land availability

    - Land acquisition: where informal settlements are located on private land, a formal Permission to Occupy (PTO) has to be acquired from the landowner in order for the CAB to be placed on site.
    - Available Space: The CABs require a sufficient space on site (greater than 250 m^2).
    - Where no space is available, the relocation of dwellings is negotiated.
- Community participation
    - When the Ward Councillors or the community do not approve the proposed location of the CABs, new locations have to be screened and renegotiated and designed.
- Location of existing infrastructure
    - Access to existing sewerage infrastructure
    - Access to existing water supply infrastructure
- Environmental considerations
    - Water tables
    - Risk of groundwater pollution
- Site access
    - Access roads for construction vehicles during the construction period
    - Sufficient space for the placement of CABs
    - Access for the operation and maintenance of the CABs

These factors affect the placement of the CABs. Primarily the engineering factors are prioritised taking into consideration the environmental aspects, i.e. placement from existing infrastructure and placement of the CABs at low points for future upgrading to waterborne sanitation for all households. The PTO for land availability is negotiated after the preliminary design is conducted. This means that a significant amount of work has already been conducted in the preliminary design; however, acquiring the PTO can be a long process.

4. Distance

Distance plays a significant role in the provision of shared facilities. In eThekwini the maximum distance between a CAB and the household is 200 – 250 m. It was found that community acceptance and use of the CABs were mixed, with community residents living closer to the CABs being more satisfied with the facility. This is due to the shorter distances travelled to use the systems, i.e. carrying clothes, water buckets, etc. (Roma et al. 2010). The investigation of the findings from a recent comprehensive survey for Unilever investigating 900 households using CABs in 31 informal settlements in the eThekwini Municipality revealed that the distance between households and CABs was an important factor affecting the users' behaviour and patterns of use (Roma & Buckley 2011). Distance was one of the two main factors for non-use of CABs, with the second factor being closure of CABs at night and its effect on non-use is shown in Table 1 (Roma & Buckley 2011). Long distances especially limited the viability of using CABs for the elderly and disabled people as well as young children, the latter not using the CABs without parental supervision.

Table 1: The non-use of CAB facilities as a result of distance (Crous et al. 2012)
The first column refers to the proportion of non-users who do not use the CABs due to distance and the second column refers to the proportion of the total users who do not use the CABs due to distance.

	Proportion of non-use respondents	Total number of respondents
non-use of toilets due to distance	59.0%	11.3% (102)
non-use of water supply due to distance	46.4%	11.5% (104)
non-use of showers due to distance	60.9%	10.2% (92)
non-use at night due to distance	23.2%	13.3% (120)

The study provided qualitative evidence that distance had an effect on CAB usage. The findings from Roma & Buckley (2011) were further investigated by Crous et al. (2012) to explore the quantitative effect that distance has on shared water and sanitation services. The study surveyed 157 households, and all households and existing water infrastructure (communal standpipes) were recorded using a GPS. The study found that the major form of defecation was open defecation (over 85% of respondents). The survey investigated the users' perceptual distance to water and sanitation services by asking how far they walk to these services. The results are shown in Figure 5, which indicate that perceptually, the majority of the households felt that they had to travel more than four times the distance for defecation than for collecting water.

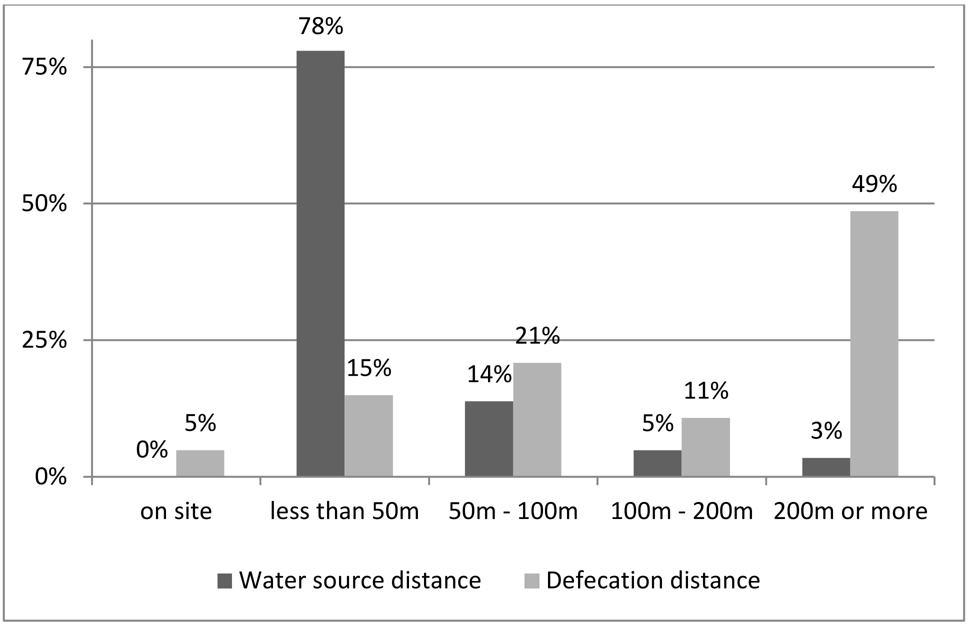

Figure 5: The perceived distance to existing water supply and defecation point (Crous et al. 2012)
This graph indicates the perception of the respondents in the pre-implementation survey. The responses were not necessarily the actual distance travelled, but the perceived distance. The graph clearly indicates the perception that the water supply is much closer (greater than four times closer) than where defecation takes place. (Data based on 144 respondents from the pre-implementation survey).

The findings from calculating the respondents' actual distance to water supply and the distance to the unconstructed CABs are shown in Figure 6. However, although no comparison can be made between the users' perceptual distance and the actual distance to water and sanitation services, the main finding is that communal water and sanitation interventions, such as engineered communal standpipes, can significantly reduce the time and distance in using unimproved water and sanitation facilities, such as open defecation.

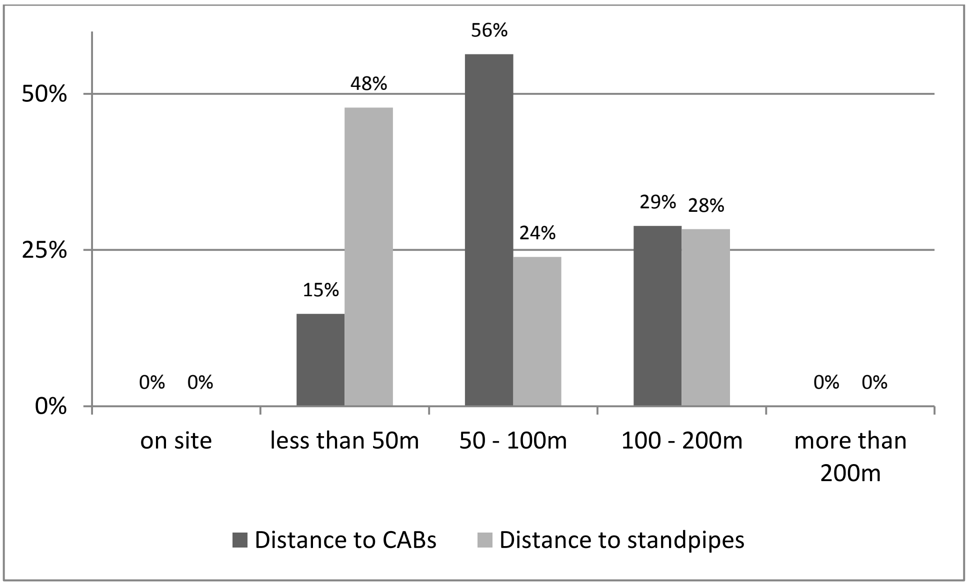

Figure 6: The calculated distance to water and sanitation services (Crous et al. 2012)
The graph shows the straight-line, shortest distance between the household and both the existing standpipe and future CABs, based on the GPS co-ordinates of the households from the surveyed respondents. The data indicates that standpipes are closer than CABs, as would be expected from the limitations associated with CAB placement. It is important to note that these results are based on the sample group and not all of the households in Frasers. (Data based on 145 respondents from the pre-implementation survey).

5. Water Supply

The provision of communal ablution facilities does not only consist of the facility structure, but also includes the provision of connector water and sewer networks to the CAB facilities from the bulk infrastructure as the facilities require water for washing facilities and for waterborne sanitation, and require adequate disposal of the generated wastewater. The water supply and sewer pipes are based on the standard guidelines from eThekwini. These guidelines are provided from the municipality in order to ensure that the infrastructure is strategically based on minimum standards. However, in order to reduce fruitless expenditure on these infrastructure extensions, the sewer pipes must accommodate the wastewater flow not only from the CAB facility, but from the entire catchment within the settlement. Furthermore, upgrading should not only focus on the extension of water and sewer networks into the informal settlement, but must also give attention to water demand management to ensure efficient and effective water services delivery (DWAF 2003). To this extent, the municipality has provided each facility with a bulk water meter, which monitors water demands on a monthly basis.

6. Appointment of Community Representatives

During the construction period, a Community Liaison Officer (CLO) is appointed in order to support the contractor in dealing with any issues that may arise between the contractor, the workers and the Ward Councillor. The CLO is responsible for sourcing the local labour for the construction of the infrastructure necessary for the CABs. Three CLO candidates are selected and shortlisted by the

Ward Councillor and then a formal interview is set up which includes the contractor, the design consultant and the EWS supervisor of that area. The CLO is appointed by the contractor (not the municipality) for the duration of the construction period.

The sustainability of the CAB facilities relies not only on the maintenance teams but more so on the caretakers as they are responsible for the daily cleaning of the facility and also reporting blockages, leaks and breakages within the facility. Therefore the appointment of a caretaker requires extensive interaction not only with the Ward Councillor but also with the community to ensure that the appointed caretaker is representative of the community. The selection and appointment of a caretaker is a sensitive process. Firstly, the appointment of a caretaker creates a job for a person within the settlement. Typically, jobs are a scarce commodity in an informal settlement and often beyond the settlement too. For example, Barcelona informal settlement in Cape Town had an unemployment rate of 51.8% (Taing et al. 2013). Thus, the caretaker position is a golden opportunity to generate an income without commuting to work beyond the settlement. Where insufficient public participation was done during the selection process, there has been anecdotal evidence of the community vandalising the CABs in order to disrupt the caretaker's job and cause the caretaker to look unprofessional in managing the CAB system. Thus, for the long term sustainability of the CABs, it is important that no shortcuts be taken in the selection of a caretaker and therefore caretakers should be selected with as much due diligence as is given to the planning of the physical CAB facility and its location. No evidence was gathered that indicates that increased due diligence will decrease the failure of the CAB. However, the selection process should not be taken lightly due to (i) the lack of available jobs within the settlement, (ii) the long-term interaction required from the caretaker to the municipality, and (iii) the competence and will of the caretaker to perform the required duties. These factors will have a fundamental impact on the eventual operational state of the CABs. A detailed discussion regarding the operation of the CABs and the caretakers' role is presented in Chapter 8 (Operation Stage).

7. Project Management

As previously discussed, the provision of interim services is performed by the Housing, Architecture, Health and Water and Sanitation Departments of the eThekwini municipality, where the Water and Sanitation Unit (EWS) is the Water Services Authority (WSA) responsible for providing services. Typically, municipal departments work in isolated silos. However, in informal settlement upgrading, the prioritisation will require coordination for open channels to be created so that information can be rapidly shared between the different departments. This is especially true for the Housing Department, who are responsible for prioritisation and the long-term formalisation of the settlements, and the Water and Sanitation Department, who are responsible for the planning of the CABs in each settlement, such that the settlements are all appropriately serviced, and that fruitless expenditure is minimised.

In order to provide services rapidly throughout the municipal area, the municipality was divided into four discrete project areas, as shown in Figure 7. Each of the four project areas has a project team which consists of design consultants, contractors and subcontractors. All of these four project teams are accountable to the project managers. The project managers are responsible for ensuring the projects are realised within the allocated budgets and time frames and that the rollout of CABs can continue on to the remaining settlements requiring interim services.

The design consultants are responsible for the technical design of the CABs and their placement within the settlement, and they monitor the quality of the construction work (Roma et al. 2010). The planning phase is documented by the design consultants in a Works Information document, as shown in Table 2, which includes the scope of work, schedule of quantities and construction drawings per site (Smith & Dedekind 2011). The roles and responsibilities associated with the project stage are detailed in Appendix F. An interview indicated that the Works Information is a generic template consisting of four stages that is produced for each CAB site. This template provides consistency across the four project teams and enables the rapid roll out of the CABs (Smith et al. 2012). The Works Information was initially completed at a settlement level. However, this is now completed at a site level, as delays at specific sites within the settlements inhibited the construction of the CABs at the other sites within the settlement. All risks are identified by the second stage whereby the necessary risk mitigation can be applied (Smith et al. 2012).

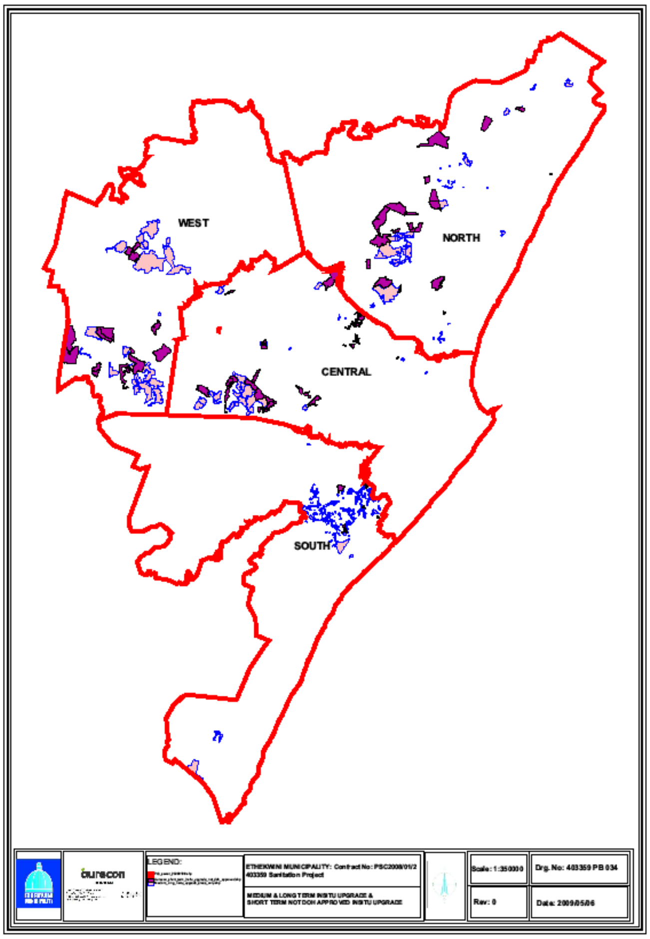

Figure 7: Location of the four project areas within the eThekwini municipal area (Dedekind 2010).
The project areas in eThekwini are referred to as the North, South, West and Central areas.

Table 2: Summary of the design stages performed by the design consultants, as included in the Works Information (Smith et al. 2012)

Stage 1 – Preparation Report	This is the feasibility study wherein all the risks are identified.
Stage 2 – Concept Report	This report builds on the previous study and provides the location of the ablution blocks in the settlement.
Stage 3 – Design Development Report	This report includes the detailed design and estimated pricing based on unit costs.
Stage 4 – Product Information	This is the capstone report of the design phase and consists of all of the previous reports and contains all construction drawings, layout plans, specifications, and detailed Bill of Quantities (BoQ) for the project. This document is referred to as the Works Information.

The interview with the project managers and the municipal stakeholders indicated that the design consultants are responsible for gathering all demographic and geographic data for the planning and are also responsible for ensuring the municipality as the legal right to place the CABs on private land, if required. The placement of the CABs is done by the design consultants. Initially, the design consultant is provided with GIS data (shape files) outlining the settlement and the number of households within the settlement from the Housing Department. However, this requires on-site validation as some settlements have arbitrary boundaries. Any changes to the definition of the settlement have to then be confirmed and signed off by the Housing Department (Smith et al. 2012). However, the settlement is expected to grow and change over time - expanding rather than shrinking. This validation process creates a fixed settlement population that is to be provided by water and sanitation services (Smith et al. 2012). Once the Housing Department has signed off the new definition of the settlement, the next step is to reassess the dwelling count in the settlement. This is done through the use of GIS data – through the use of aerial photography, etc., and a field count for verification, where required (Smith et al. 2012). The design consultant also identifies the current water and sanitation infrastructure available to the settlement, including the extent of bulk infrastructure (Smith & Dedekind 2011). Once both local demographics and infrastructure have been established, it is determined whether the settlement can be classified as appropriate to the scope of the municipality's project scope. Where settlements do not meet the requirements for upgrading with CABs, the settlements are still designed up to the second stage of the Works Information and are reassessed during subsequent phases of the CAB rollout project. Upon approval, possible CAB locations are investigated and appropriate CAB locations are determined. The design consultant then consults with municipal representatives from the Housing Department who go to site and investigate the appropriateness of the CAB locations. Once the site has been agreed upon, the municipal representative revisits the site with the Ward Councillor, who then consults with the community to get community buy-in. The planning phase is complete once the CAB site has been approved by the community, the municipality, and the design consultants and then the construction phase commences (Smith et al. 2012).

Once the Works Information is submitted and approved, the contractor is provided with an access date. This access date allows the project team to commence construction on a site (Smith & Dedekind 2011). Contractors and sub-contractors build new water and sewer pipeline extensions from existing infrastructure. They also construct the foundations and platforms for the CABs, connect the CABs to the new infrastructure and install ancillary works (Smith & Dedekind 2011). Sub-contractors receive 20% of contractors' budget, whilst local labour receives 10% of contractors' budget (Roma et al. 2010). An interview with the project managers indicated that the municipality was initially responsible for completing all ancillary works at the CABs. However, in order to streamline the construction phase and to ensure accountability, these responsibilities were handed over to the contractors (Fuller 2012). The construction phase is discussed in more detail in Chapter 7 (Construction Stage).

8. Case Study: Frasers

Frasers informal settlement is located in the northern section of eThekwini, geographically located between Tongaat and Ballito. This peri-urban informal settlement is beyond the urban edge and cannot economically be connected to a sewer network. The settlement has a population of 397 households. The number of households in the settlement was obtained from the eThekwini Housing Department's official Housing Department records. The settlement is separated by a railway line into a north and south area. From the aerial photograph, it was estimated that the north area includes 56 households, and the south area includes 341 households. Frasers informal settlement was initially planned to be provided with five CABs, as shown in Figure 8, with each CAB being located a maximum of 250 m from the households as the terrain is generally flat.

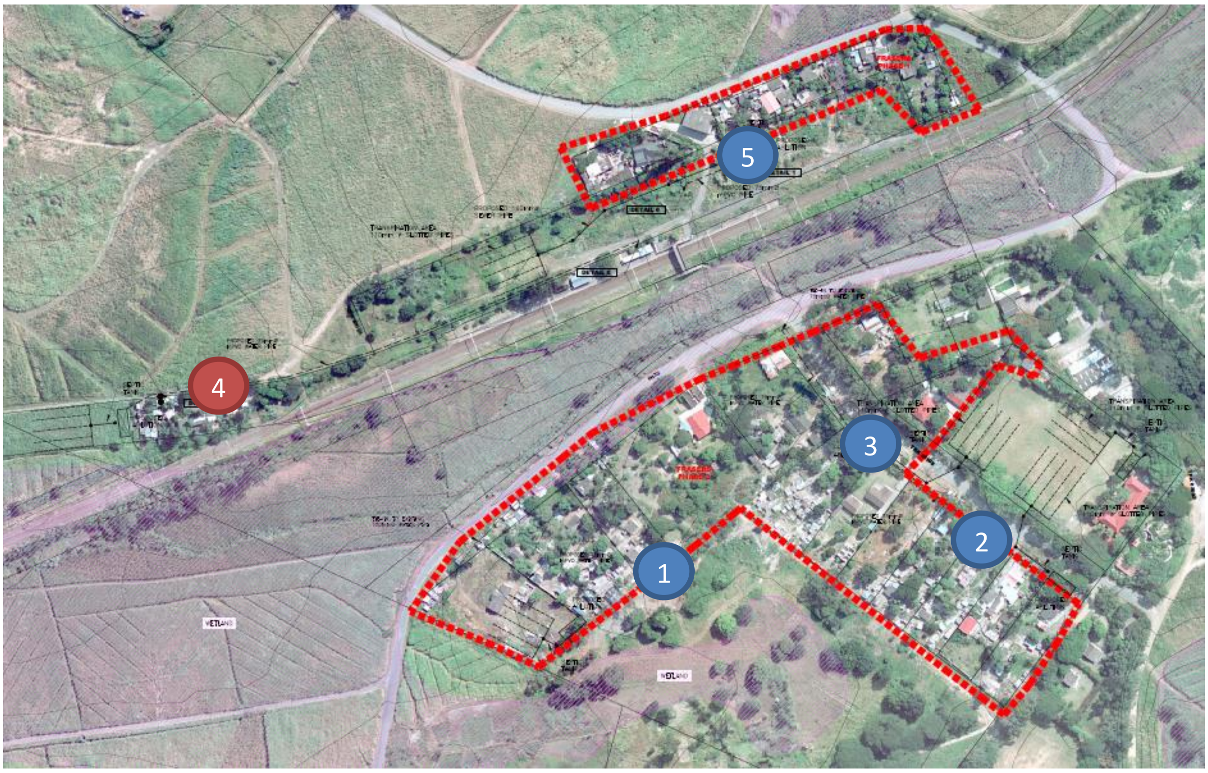

Figure 8: The layout of Frasers informal settlement.
The placement of the CABs provided during Phase 1 are shaded in blue and are numbered. Phase 2 is shaded in red, as this facility was not constructed and not monitored during the project. The figure further shows the location of the five evapotranspiration fields for the CABs and one for the school toilet (SBA 2011b).

The CAB effluent was designed to be treated by a combination of anaerobic baffled reactors (ABRs) or septic tanks (for primary-treatment) and soakaways (for secondary treatment). Because on-site wastewater treatment was employed, the design consultants had to submit the Ground Water

Protocol and EIA documentation for authorisation from the municipality. Legal approval had to also be obtained from the land owners for the placement of the soakaways, which were not only located on private land (Site 1, Site 4 and Site 5) but also on the school grounds (Site 2 and Site 3), which required permission from the Department of Education.

Initially, the project would have to be performed in two stages, due to problems pertaining to the access to land, with Site 5 and Site 4 being constructed in Phase 1 and the remaining three constructed in Phase 2. However, due to legal tenure disputes, Site 4 was not constructed during Phase 1, where Phase 1 became the provision of CABs to Site 1, Site 2, Site 3, and Site 5. Site 4 became part of Phase 2, which included another two additional CAB facilities constructed east and west of Frasers informal settlement. It was estimated that the total project time would require nine weeks for the Design Phase and eight weeks for the Construction Phase. As Frasers is located on a generally flat terrain, the distance between CAB facilities was increased to 500 m apart, the maximum distance between CAB facilities.

The risks identified in the Stage 1 report specific to this project included a lack of accurate GIS information for the settlement and permission to occupy (PTO) issues. This risk was adequately managed and did not hinder the progress of the project. Still, time was required to go on site and verify all pipe work (pipe diameters and pipe placement) and reconcile this information with the existing GIS files and then get the new files approved. The second issue was estimated to be managed by giving advanced notice to the eThekwini representative responsible for PTO. However, PTO was a barrier to the construction of the CABs in the settlement. The only two sites that did not have any legal issues were Site 2 and Site 5. The legal issues surrounding Site 4 were identified as early as 27 May 2011. On 12 August 2011 it was found that the land owner was planning to evict the squatters, but by 23 September 2011 no action had yet been taken. It was noted that if the land owner had not yet taken legal actions against the residents, then the owner would be served with a notice for the construction of the facilities. However, by 2 December 2011 it was noted that this site would form part of Phase 2 and would only be constructed in September 2012. There was also a delay in the PTO of Site 1, which was only granted in November 2011. Prior to this, no construction could take place. This was due to ownership issues of the land, where the wrong owner was consulted for PTO of the land. For Site 3, all of the water and sewer and wastewater treatment works were complete around the end of September 2011. However, there were disputes about the placement of the CAB, as it would be located in front of the cemetery and there were also informal dwellings which had to be relocated. It was found that the land owner was renting to three tenants, who were all compensated accordingly. The negotiations for the relocation of the dwellings was only resolved at the end of January 2012. These legal disputes delayed the construction and final handover of the facilities to the communities.

9. Conclusions

The planning phase is predominantly driven by engineers, specifically the design consultants, who determine the technical requirements of the settlements based on municipal standards and guidelines. The other stakeholder are the Housing, Health, Architecture, and Water and Sanitation municipal departments, contractors, project managers and the residents of the informal settlement. The aim of the planning stage is to provide communal ablution blocks at strategic places within those settlements earmarked for upgrading so as to meet the immediate needs of the community, promote sustainability, and reduce fruitless expenditure. An important by-product of the roll out of these interim CAB facilities is updating the municipal records for asset management.

The provision of basic interim services to all informal settlements within eThekwini is a long-term plan. This is a consequence of the large number of informal settlements around the eThekwini municipal area with their associated backlog in basic services. This requires a strategic plan and that each of the settlements be prioritised. This has been achieved in eThekwini by examining the long-term sustainability of the settlement within the municipal planning and the cost of providing services to the settlements. The current prioritisation has been well defined by the municipality, and is based on technical criteria developed for proper, long-term implementation of the informal settlement upgrading policy.

The CABs form the first step in the provision of interim services within the settlement. Thus, CABs form part of the larger upgrading of the settlement and requires long-term planning. To this extent it has often been stressed that the placement of the CAB within the settlement should be based on the extension of the water and sewer pipes into the settlement such that the infrastructure can later be extended to a household level. Still, short-term planning should emphasise appropriate access for the households to the CAB facilities. The eThekwini municipality has provided maximum distances between households and CABs and maximum population densities per CAB facilities. Although this promotes impartial provision of CABs to all of the settlements, the efficacy of these standards were not further investigated. It is hypothesised that reducing the number of people using each facility could reduce the operation and maintenance requirements. However, it was found that the majority (79 per cent) of the settlements had a population density higher than the municipal standard of 75 households per CAB, based on data from the eThekwini Housing Department.

The planning stage not only pertains to the physical CAB infrastructure, but also includes the selection of the caretaker in order to ensure that the CABs can be sustained after the facilities are handed over to the community. This selection process is delicate but very important. Thus, the selection process should include appropriate attention during the planning stage, as this appointment creates a job when there is a lack of available jobs within the settlement, and the sustained operation of the CABs will first and foremost fall on the caretaker.

The rapid rollout of interim, communal water and sanitation facilities has required optimisation in the documenting of the project implementation. Initially, the documentation was recorded haphazardly, but it became evident that there was a need for the project documentation to be recorded within a structured and generic template, the Works Information document, which facilitates consistency between the different project areas. One of the most significant changes in the project management was the change to site-level planning from settlement-level planning. This means that the settlement is divided into phases, with each phase consisting of strategic sites within the settlement. Once each phase has been planned for, the construction commences for that phase, while planning may still continue in the other sites in the settlement. This reduces delays in the planning phase, which are typically caused by legal disputes in the municipality obtaining permission to occupy the land at specific sites within the settlement. However, this can disrupt construction continuity within the entire settlement, which has negative effects on the proposed construction budget. The case study provided from Frasers informal settlement indicates the issues related to the municipality obtaining a permission to occupy from the relevant land owners. In fact, the issues surrounding ownership extended the project by no less than four months and essentially doubled the estimated time of the entire project. The settlement was initially separated into two phases in order to mitigate any delays caused by obtaining permission to occupy private land. However, three of the five sites had delays related to obtaining permission and the CABs were constructed on a per site basis.

The long-term sustainability of the CAB facilities pivots on community buy-in and community participation. Community participation is about acknowledging the community and taking their needs into account. This is achieved by raising awareness about the municipality's plans of providing basic services and making the community aware of any inconveniences that may be caused during the construction period. The community must be aware that the ownership of these facilities falls under the Water and Sanitation Department of the municipality, not other departments, such as the Housing Department, or external parties, such as the contractors or design consultants. The expectations of the community should be managed at all times and the community should be aware of who to contact at each stage of the project. The community should also be made aware of the selection process of the appropriate CAB placement and they should be given an opportunity to raise their concerns about the proposed CAB placement sites.

10. Recommendations

A number of general success factors were identified from the data collected from the different stakeholders involved in the planning stage. These are summarised in this section based on the author's own experience of the eThekwini municipality's rollout of CAB facilities.

- There needs to be an integration and open access of data between the municipal offices, namely the Housing Department and the Water and Sanitation Department in order to consolidate all the data surrounding the population estimates of each settlement and to ensure that the provision of the communal facilities dovetail with the long-term strategy of the housing provision strategies.
- Access and availability of land is scarce in informal settlements, and the settlements are often based on private land. This requires that By-laws are in place to ensure that communal water and sanitation facilities can be provided as interim measure on public or private land and that sufficient negotiations are done with the community to ensure that relocation of informal housing is minimised but that compensation is made for any relocations. Furthermore, it is important that the owner of the land be identified early in the project so that the municipality can get permission to occupy the land. The backlog of water and sanitation services in informal settlements throughout South Africa is extensive and thus it is important that all of the informal settlements within the local government's jurisdiction be prioritised rationally, based on an explicit set of criteria. The technical criteria for prioritisation have been developed in eThekwini over an extended period of time. The current policy ensures that long-term development is achieved within the municipal area. This prioritisation will ensure that services are provided in a logical and holistic manner to all settlements.
- The sustainability of the project relies on a functional caretaker who essentially takes ownership of the facility to ensure that the facilities are operational at all times. This is not a straightforward task and requires an open and non-discriminatory selection process for the

appointment of the caretakers. The community must understand that the municipality is the owner of the facilities and responsible for the sustained use of the facilities.

- Furthermore, in order to rollout interim services to all within the municipal area, there needs to be strong project management to ensure that the risks can be managed accordingly and that there is open communication between all stakeholders involved in the project. The scale of the project and the number of stakeholders involved requires that all documents be submitted according to a predetermined, generic template to ensure consistency. These documents should be stored at a central location, i.e. with the project managers, and be accessible to the municipality at all times.

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Design
Chapter 6

1. Introduction

The design stage of the CAB project can be separated into two distinct components, which are the physical structure and the supporting water supply and sewer infrastructure. The number of sanitary fittings available within the physical CAB is limited by the space available within the CAB structure. The size of the CABs and the number of fittings has been predetermined by the eThekwini Health Department and the eThekwini Water and Sanitation Unit, and this has become standard. The main unknown in the design of CABs is quantifying the water demand and the subsequent wastewater volumes generated from each CAB for the hydraulic design of the water supply and sewer infrastructure and wastewater treatment requirements. This chapter investigates the best practice for the physical CAB structure, the user interface, and provides quantitative data on the water and wastewater volumes associated with the CABs from Frasers informal settlement in order to provide guideline values for the water supply and sewer infrastructure required for CABs.

The research questions discussed in this chapter include,

- What are the best available sanitary fittings for CABs?
- What volume of water has to be supplied to CABs? How much wastewater is generated from the CABs?
- How does weather affect CAB usage?

2. Structural Design

CABs are constructed out of retrofitted shipping containers, as shown in Figure 1, with the internal space within the containers limited by the size of the shipping containers. The CABs are designed such that there are separate ablution facilities for males and females. Each CAB facility consists of male and female toilets, showers, wash basins, and laundry facilities (located on the outside of each container). The CABs also provide a store room for the caretaker to store cleaning equipment and the consumables, such as detergents and toilet paper. The CABs are provided with a water supply, but no geysers are provided to the facilities to heat the water for bathing – i.e. showering.

The use of containers allows for off-site prefabrication and rapid placement and installation of water and sanitation facilities with minimum time and labour on site. It further allows for future off-site refurbishment, or removal - once the settlement has been upgraded to individual, household water and sewer connections, and relocation of the container into other informal settlements (Smith & Dedekind 2011; Gounden 2011). It was stated by Neil Macleod, the head of EWS, that the design life of the CABs is estimated at 5 - 10 years, correlating to the date when formal housing is planned to be provided (da Silva Wells et al. 2008).

Figure 1: The CABs based in Frasers informal settlement.
Here the male and female CABs are placed parallel to one another, with openings to the male and female containers on opposite ends. The CAB configuration varies for each site. For this CAB, the laundry facilities are located between the two CABs.

The retrofitting of the CABs does not only include the installation of the sanitary fittings and pipework to the shipping containers, but also the addition of windows and sky lights; cubicle doors and separators within the CAB; ventilation on the walls; and placement of a new pedestrian door and welding the original container doors so as to prevent unwanted access. The sanitary fittings require the use of both water supply and wastewater pipes inside the containers which are then connected to the bulk water and sewer connections. The water supply pipes are specified to be 15 mm to each sanitary fitting, with the discharge pipes from the basins, showers and urinals are 100 mm and 150 mm from the toilets.

In eThekwini, the CABs are prefabricated by seven different manufacturers and are selected through an annual tender process (McKnight 2011; Smith & Dedekind 2011). This was confirmed in an interview with one of the CAB manufacturers (McKnight 2011). The interview further indicated that the internal configuration and the exact type of fittings vary considerably between the different manufacturers. The interviewed manufacturer was capable of retrofitting around 30 – 40 containers per month, depending on the demand from the municipality (McKnight 2011). The manufacturer further indicated that they were responsible for ensuring that the CABs were functional once they leave the workshop. This is achieved by pressure testing all fittings in the CABs at 5.5 - 6.2 bar before the CABs leave the yard in order to ensure none of the fittings are leaking and all the fittings are working (McKnight 2011). The transportation and the placement of the CABs on site is also the responsibility of the manufacturers, however they are not liable for any defects that occur during the transportation phase. There have been cases where the CABs are connected to the water and sewerage infrastructure on site and then some of the fittings do not work or leak. In such cases, it is not clear who is responsible for the reparation of the facilities? The municipality is in the process of restructuring the project such that the contractor is responsible for sourcing the CABs from the manufacturers and transporting the containers to site so that the contractors are responsible for the quality control of all infrastructure.

2.1 Fittings

The three main types of fittings in the CABs are toilets, taps and shower heads. The fittings used in the CABs throughout eThekwini are mainly selected based on durability, as the facilities are faced with a high degree of usage and vandalism. The durability of the fittings assists in minimising water losses. Secondly, the installed fittings should reduce the water consumption per use by adhering to water saving principles as discussed further throughout this section. In terms of operation and maintenance, the fittings should be easy to repair by plumbers. Where the fittings cannot be repaired, then they have to be replaced. The only standardisation that should be required for the fittings is that the replacement fittings are able to connect into the existing pipework within the CABs.

The CABs make use of conventional waterborne flush toilets, whereby each toilet bowl is provided with a cistern (Figure 2). This configuration is not typical of public bathrooms, whereby the flush water is supplied directly to the toilets when the flush lever is engaged. However, this configuration is not found within any of the current CAB configurations. Ablution facilities in the City of Cape Town used pour flush toilets, where the users had to manually pour water into the toilet bowl to flush the system. This was in an attempt to reduce wastewater generated. However, this system was unsuccessful due to poor community participation and user education and poor solid waste management (Ashipala & Armitage 2011).

The water consumed from the physical toilet (not the users' excreta) depends on the size of the cistern – the flush volume, and the structural integrity of the cistern. The durability refers to leaks associated with the connections between the water supply and the cistern and the connection between the cistern and the toilet bowl. The technological differences associated with toilets are a function of the cistern and the flushing mechanism and not the toilet bowl. Typical standard modern cisterns use a cistern volume of 6 ℓ per flush, with low-flush toilet cisterns having a flush volume of 4 – 4.5 ℓ per flush, with low-flush toilets being more economical in the life cycle cost (Still et al. 2008). Other types of water saving toilets include the dual flush for defecation and urination; the demand flush, where the cistern only discharges water when the flush level is held down; ultra-low flush cisterns, having a cistern volume of maximum 3 ℓ; vacuum toilets, which use 0.5 ℓ; and retrofit reduction in cistern volumes, using hippo bags or bricks etc. (Still et al. 2008). The use of low-flush toilets requires that toilet paper is provided such that blockages do not occur in the sewer infrastructure when other anal cleansing materials are used, such as sticks, stones, newspaper, etc.

Water losses also occur where the cisterns are leaking, something that none of these technologies address. The ultimate method of reducing water losses from the toilet is to make use of a waterless cistern, one in which the cistern is left void of water and only fills up once the flush lever is pushed down. This configuration has been referred to as a leak-free toilet and has proven to reduce domestic water consumption (Still et al. 2008). This method uses a variable amount of water, as the cistern discharges once the flush lever is disengaged; with the maximum volume of water discharged depending on the size of the cistern. This cistern technology saves water not only in reducing water losses, but also in the users customising their flush demands specific to their toilet usage, like the demand flush systems. However, it is stressed that community education is necessary to ensure that the toilets are properly used.

Figure 2: Typical toilet configurations found in the CABs (August 2012)
From left to right, a conventional flush toilet with a flush handle that discharges all the cistern water once engaged. A waterless cistern which fills up while the push button is engaged and discharges the cistern water once the user lets go of the button. A demand flush toilet which discharges water once the flush handle is pulled upward.

There are different types of urinals available to reduce water losses or water wastage. The standard communal urinal consists of a stainless steel backdrop and a collection trough for the discharge of the urine which could be used by more than one person at a time. However, these types of configurations use a considerable amount of water and have been banned in some cities within South Africa (Still et al. 2008). Therefore urinals typically consist of free standing, single user urinals. These urinals can either be of a waterless or a low flush configuration. Waterless urinals make use of a cartridge or a non-return valve to reduce the odours from the discharge pipe. There are numerous configurations, but some of the common configurations available in South Africa are shown in Figure 3. The cartridges are either oil-based or made of a curtain-like flap. Waterless urinals require replacement of the cartridge on average every two years, depending on use. And they can be retrofit into existing urinals. However, they require regular (monthly or weekly) maintenance, where the urinal bowls are wiped with a chemical to clean the bowls of any residual urine. These additional chemicals and annual (or biennial) replacement costs add to the cost of maintaining the urinals in the CABs and where waterless urinals are poorly maintained, the stagnant urine will develop a noxious odour in the male CAB facilities. Low-flush urinals are water based urinals and can either be hi-tech, with automatic discharges (requiring a sensor) or low-tech, with a manual flush mechanism (tap). These systems can be more cost effective as they do not require additional maintenance or chemicals. The CABs are typically fitting with a tap as shown in Figure 4. The use of a low-flush urinal system is more practical for the custodians of the communal ablutions in informal settlements, the eThekwini municipality. Firstly, water is already supplied to the CABs and is made available for the urinals during construction. Secondly, the chemicals are expensive and must be regulated to ensure that the chemicals are used properly within the ablutions. Finally, when the cleaning chemicals are unavailable, the ablution facilities will have a pungent urine smell which will significantly reduce the experience of the users at the CABs.

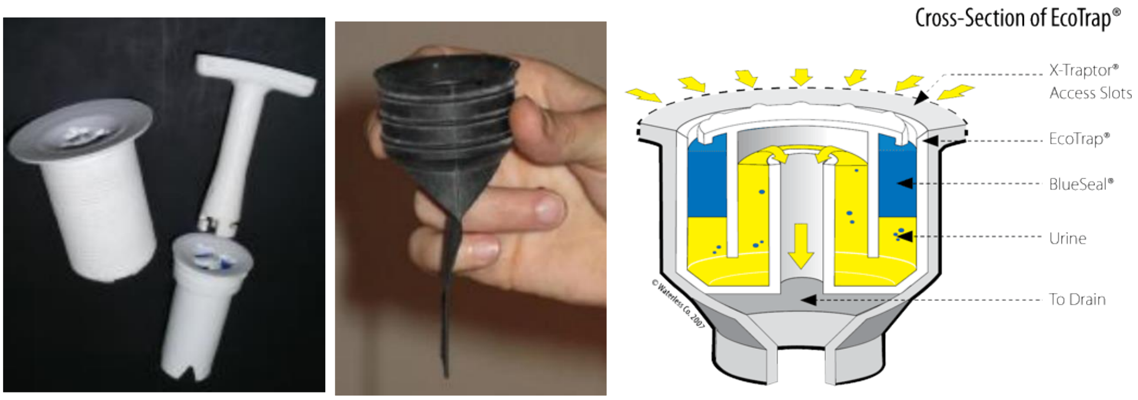

Figure 3: The different types of non-return valves used in waterless urinals
The middle photo (von Münch 2009) is the curtain valve which fits inside the cartridge on the left (Dahm 2011). This cartridge can be easily removed. The photo on the right (Waterless Co. 2012) uses an oil-based cartridge which forms a layer on top of the urine to prevent the urine smell.

Figure 4: Typical urinal configuration in the CABs in eThekwini (August 2012)
The left photo shows a demand tap for each urinal, while the right photo shows a tap that is turned which when engaged discharges water into both urinals.

The CAB requires taps for the hand wash basins, the laundry basins and the showers. These configurations require different types of taps, depending on the application. The main types of taps found in CABs are manufactured from either plastic or chrome-plated bronze (see Figure 5 for a number of examples of taps found in the CABs). It has been recommended that plastic taps have less resell value and thus are less prone to being stolen (Still et al. 2008). The main requirement of a tap is to ensure that the tap does not waste water unnecessarily (i.e. through leaks). The tap can either make use of a conventional tap which discharges water when the tap is opened. The second type of tap is referred to as a demand tap, which only releases water when the tap button is engaged (pushed down). The third type of tap is the metering tap, which discharges water for a specific period (60 – 90 seconds depending on the available water pressure) once the button has been pressed. The laundry basins are typically suited to the conventional taps, as the basins are filled up on a regular basis for washing either clothes or dishes or for filling up containers for off-site water usage. The hand basins are well suited to demand taps, as they are only used for washing hands, face, or brushing teeth. Although it was hypothesised that shower taps would be well suited to a metering tap configuration in order to minimise shower water demand the installation of this configuration in four CABs was found to not be ideal. The main advantage was that the water would not run continuously, but the users could wet their bodies, with a single push, then apply soap while the water is off, and then rinse their bodies with a second push. The main reason for not recommending this configuration was that the capital cost of the metered taps is high, yet the plumbers did not have the necessary spare parts to repair the taps on site, resulting in the taps having to be replaced. This means that the metered tap have a higher capital cost and a shorter life cycle than other taps. Furthermore, where the self-closing mechanism is not functioning properly, the showers either do not delivery any water or else the taps discharge water for the majority of the day, which eliminates the advantages of using the metered tap. Thus, either conventional taps or demand taps are appropriate for the showers.

Figure 5: The different shower taps available in the CABs
The photo on the left is a metered tap, which once pushed discharges water for 60 – 90 seconds depending on the water pressure. The middle photo is a typical brass tap and the photo on the right has a chrome-plated brass tap.

For water demand management, there is unanimous consensus that showers make use of water saving shower heads. There are a number of available products in the South African market, available as either plastic or chrome-plated shower heads. Shower heads can be more water efficient by making use of aerators and/or pressure compensated flow-control devices (Still et al. 2008). The typical guideline shower flow is around 10 ℓ per minute, however, the range of shower flows has been classified by the WHO and is shown in Table 1.

Table 1: Shower head classification, where flow rate is given in litres per minute (WHO 2006)

Classification	Very Good	Good	Reasonable	Fair	Poor and wasteful
Flow rate (ℓ/min)	6 – 8	8 – 12	12 – 18	18 – 24	> 24

2.2 Structural Limitations

The CAB facilities are limited by the internal space within the CABs. The design of the CABs was rationalised by the eThekwini Health Department. The Department went through numerous iterations and finally concluded that six cubicles is the maximum number of cubicles that can be practically fitted within the containers, as shown in Figure 6. The rational design for the number of fittings per CAB is based on the fact that there has to be more than one fitting per CAB, as it is a public facility.

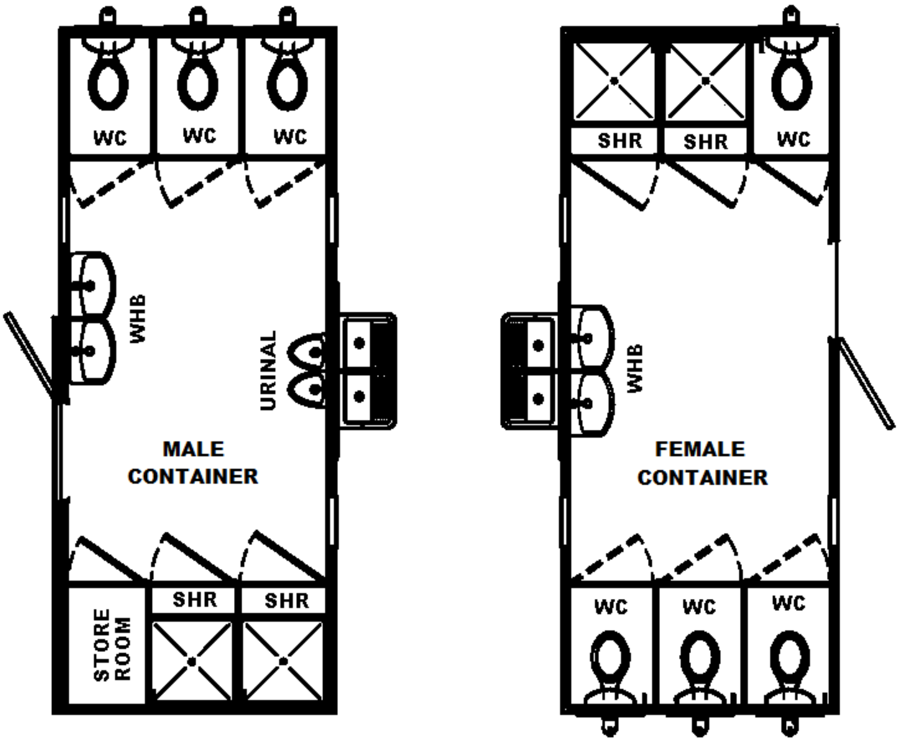

Figure 6: The internal CAB configuration (edited from SBA 2011)
The male container has three toilets and two urinals and the female container has four toilets for defecation. The male and female containers both have two showers and two wash hand basins inside the containers and two external laundry basins. The caretakers are provided with a storeroom in the male container where their equipment is stored.

The main factor that has to be considered in the sizing of the toilet cubicles is not only the width, but also the length to ensure that there is sufficient leg room when the user is seated. The toilet cubicles are typically 1.1 m in length, which provide a distance of 0.83 m between the cubicle door and the back of the toilet seat. Using the dimensions of Leonardo da Vinci's Vitruvian Man in his work The Proportions of Man, it is found that this cubicle length provides at least 100 mm buffer between the cubicle door and the user where the users have a height of 1.86 m or less.

The male container has three toilets and two urinals, while the female container has four toilets. The *spare* cubicle in the male container is used for the caretakers to keep their equipment and sanitary consumables. The municipality has promoted the storage facility as an essential component of the CABs. Without such a storeroom facility, the caretakers would have to store the sanitary consumables and equipment in their own house, which can be burdensome for smaller house structures. The usage of the storeroom is discussed in more detail in Chapter 8, which indicates that in practice there is poor utilisation of this storeroom.

The main limitation in the use of a shipping container is the mounting of the fittings to the container. This is because the fittings are retrofit to the metal container, which is relatively thin – with the walls being no more than 5 mm thick. If the connections are not done properly in a robust manner, then it can cause the fittings to be flimsy, disconnect, and leak. The two main fittings which are prone to leaks are the wash hand basins and the toilets. These are discussed in more detail in the Chapter 9 (Maintenance).

3. Water supply

The CABs are the interim water and sanitation infrastructure, and as such require a constant water supply (Roma et al. 2010). The majority of the informal settlements earmarked for future upgrading in eThekwini are based within the waterborne edge where current water and sewerage infrastructure can be economically extended into the settlement (Roma et al. 2010). The CABs are said to be an improved water source over the earlier communal standpipes, as the sewerage provides for greywater (and blackwater) disposal. This theoretically reduces on-site greywater accumulation, which has been a significant challenge in unserved areas in the past (Scruton 2009; Gounden 2009). In areas where sewerage is not economically viable, the municipality has piloted on-site wastewater treatment, using the DEWATS approach. For design purposes, the water supply pipes from the bulk water connections are 75 mm and the sewer pipes are 160 mm. These are based on the minimum standards from eThekwini guideline values. The water supply is based on the minimum diameter for water supplied to fire hydrants (Rosseau 2012). Furthermore, the CABs are all designed with bulk water meters in order for EWS to monitor the water demand of the CABs. This enables the monitoring of leaks and excessive demands caused by illegal connections. It also reduces the non-revenue or unaccounted water within the municipal area (Smith & Dedekind 2011). The cost of the water supply is carried by the municipality.

Literature indicates that there is an increase in water usage as the distance between the source and the household decreases. In South Africa, the guideline daily water demand increases from 12 - 15 ℓ/c/d for a communal standpipe within 200 m from the household, to 45 – 55 ℓ/c/d for a yard tap with a flush toilet, to 50 – 70 ℓ/c/d for low-income in-house water connection (SANS 2010). However, there are no guidelines for CAB facilities with not only a single tap and toilet, but also showers, wash hand basins and laundry facilities (Crous et al. 2012). There is a need to understand the water demand from CABs both for water and wastewater management. The water demand is essential for the design of the water supply network, as this forms the basis of providing adequate and reliable water to the community (which is a requirement of Water Service Act 1997). Further, the Water Service Authority (WSA) has to account for the free basic water provided to the CABs. In terms of the Water Service Act (1997), all municipality customers are provided with 6 kℓ free basic water per month (RSA 1997; DWAF 2002). As of July 2010, the free basic water policy in eThekwini increased to 9 kℓ per month. Similarly, there are no charges for the disposal of use of the first 9 kℓ of water per month (EWS 2012; Roma et al. 2010). For CABs, the free basic water amounts to 450 – 675 kℓ per month per CAB. However, an understanding of the actual water demand at the CABs enables more efficient planning for the life cycle costs associated with the provision of CABs. The water demand also affect the design of on-site wastewater treatment facilities, as too large a design is uneconomical and too small a design reduces the treatment efficiency of the on-site wastewater treatment systems. Where off-site treatment is available, waterborne sewers are required and the design requires informed data on the sizing of the sewers for economical provision of services. It further has an effect on the amount of wastewater that will ultimately be treated by the wastewater treatment plant and the treatment plant's capacity to treat the additional wastewater. Water consumption at CABs was previously estimated at around 35-40 ℓ per capita per day (Roma et al. 2010). The water demand from 72 CABs around eThekwini between September 2010 and February 2012 are shown in Figure 7. The results indicate that the water demand is highly variable, with the median monthly water meter reading being 270 kℓ/month. Assuming that the CABs are used by the design population (50 – 75 households) and that there are on average 2.89 persons per household, as found in a survey of 1 012 households in 31 informal settlements with CAB facilities around eThekwini (Roma & Buckley 2011), it is estimated that the total daily CAB water demand is between 41.5 - 62.2 ℓ/c/d. It is noted that Figure 7 only presents 30% of the total water meter reading dataset, the other 70% of the data was excluded from the analysis as the data was flagged by the municipality for potential inaccuracies.

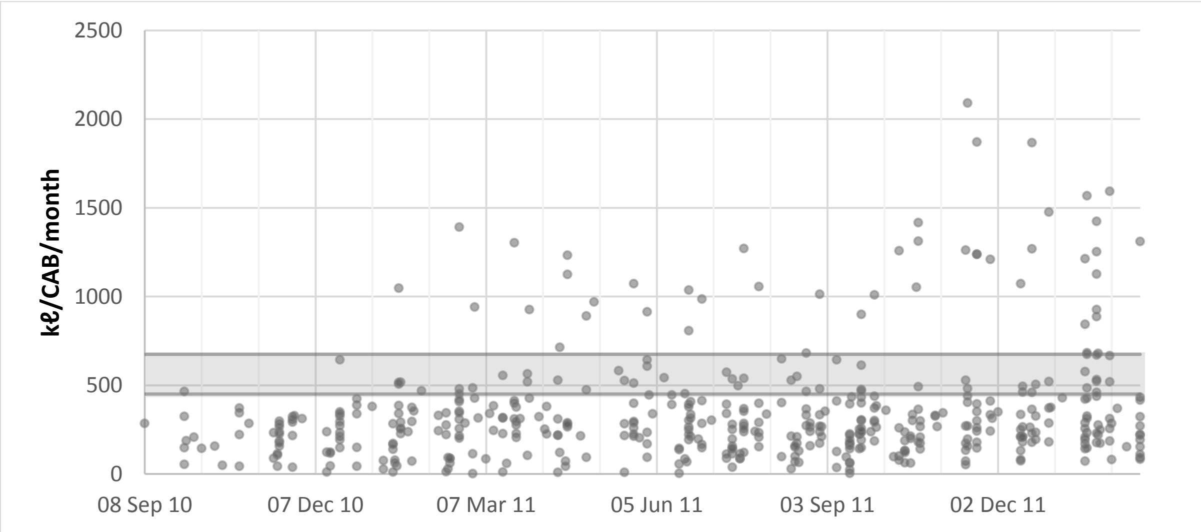

Figure 7: The monthly water meter readings from 72 CABs around eThekwini
The figure indicates the boundary free basic water volumes for the CABs per month of450 – 675 kℓ/CAB/month. However, the figure indicates that 3.5% of the monthly CAB water meter readings lie within these boundary values and 3.1% lie above and 93.4% lie below the free basic water boundary values for CABs.

Domestic water demand and the subsequent wastewater flow within municipal networks are characteristically unsteady within diurnal periods, weekly periods, and seasonal periods, see Figure 8 for example (Haestad et al. 2004; van Zyl 1996; Fair et al. 1966). Day to day variations in water consumption is mainly determined by household and industrial or commercial activity – i.e. domestically, Sunday is traditionally used for rest and Mondays for laundry washing. The water demand can be defined within the minimum (during the morning hours) and maximum (in the morning and early afternoon) water demand during a diurnal period (Trifunovi 2006; Fair et al. 1966).

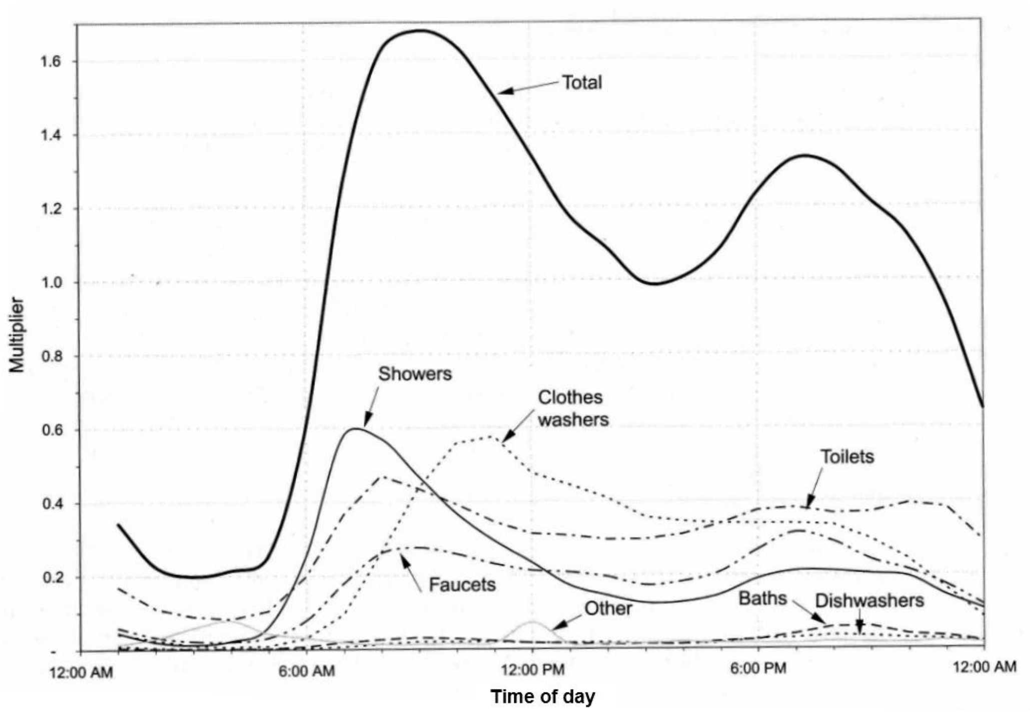

Figure 8: Example of how domestic water consumption varies over a diurnal period (Haestad et al. 2004)

End-use monitoring provides accurate, detailed design of water supply, sewer and wastewater treatment design (Jacobs 2004). It determines the water demand at the lowest points within the system at very short time-intervals (Haestad et al. 2004; Jacobs & Haarhoff 2004). In this study end-use monitoring refers to the water demand from each type of fitting within the CAB, namely toilets, showers, hand wash and laundry wash basins. However, to date no end-use demand loads have been readily available from literature for communal ablution or sanitation facilities, especially not from the CABs constructed in eThekwini. The hydraulic parameters required for the design of water and sanitation infrastructure are (DeOreo & Hayden 2008),

- the average daily demand (ℓ),
- the average monthly demand (kℓ),
- the instantaneous peak factor,
- the hourly peak factor, and
- the daily peak factor.

Monthly water demand patterns provide the Water Service Authority (WSA) a design value when determining the required water supply quantity for an area and the cost of the water provision. Seasonal variations can further be used to determine the maximum water demand on the maximum day, but such an absolute peak water demand is not statistically significant in the design of the CABs. The hydraulic sizing of water and wastewater infrastructure is based on peak volumes (Johnson 1999; Haestad et al. 2004; 2006 Trifunovi). Peak volumes are calculated as steady-state based on average flows although water demand is highly variable (Haestad et al. 2004). The annual average daily demand (AADD) and the instantaneous peak factor is used to determine the maximum loading capacity of the pipes of water supply using the following equations (CSIR 2005; van Zyl 1996),

$$Q_{peak} = PF \times Q_{average} \quad [1]$$

$$PF = \frac{V_{peak}}{V_{average}} \quad [2]$$

More generally, peak flows are expressed as a function of average flow and is given by a peak factor, at the required interval (hourly, daily, weekly, monthly, annually). The instantaneous peak factor is the starting point for building a model of the water patterns of any distribution area (Trifunovi 2006). However, the shorter the flow interval, the higher the peak factor should be (Fair et al. 1966; Booyens 2000). It is important that peak factors are not based on the absolute peak flow during the recorded time period, as these values occur infrequently and are not statistically significant for hydraulic design (Tessendorff 1972; Aquacraft n.d.). The peak flow was determined using the Weibull distribution (Davie 2008). This was also used by Booyens (2000) to determine peak factors in water demand.

The maximum capacity of the water supply pipe system will have an effect on the water supplied to the CABs. However, when the water demand at a CAB exceeds this capacity, the *failure* is not catastrophic (Johnson 1999; van Zyl 1996). The *failure* causes a reduction in pressure within that specific period where the design has been exceeded (Booyens 2000). Therefore, the design of the water supply to the CABs should not be based on the absolute maximum water demand over the entire period.

The analysis of literature based peak factors found that most of the graphs, such as the Hunter curve developed in 1940, are outdated and very conservative due to limited accurate available data (Haestad et al. 2004; DeOreo 2011). The South African water supply guidelines (CSIR 2005), although providing guideline peak factors, stress that the selected peak factor should be determined by the designer. Booyens (2000) indicated that the Red Book graphs are very conservative and have not been updated since first print (over 30 years ago). The municipal guideline peak factor in eThekwini is 4.0 for sub-main and lateral sewers (Rosseau 2012).

The degree of utilisation is the inverse of the peak factor and directly provides both an economic, hygienic and a technical perspective to the peak factor as it indicates the utilisation of the water distribution network (Tessendorff 1972; Johnson 1999). This is typically used for performing a cost benefit analysis in the selection of the peak factor in practice (Trifunovi 2006). Tessendorff (1972) suggests the ideal time-interval for determining the degree of utilisation within a distribution system is an hour, with typical values found between 30% - 50% in a water distribution system (Tessendorff 1972). The degree of utilisation is calculated as follows,

$$\boldsymbol{U = \frac{1}{PF} \times 100}\% \quad [3]$$

where, U = degree of utilisation
PF = peak factor

The degree of utilisation is primarily of economic importance for the design of the system. Low values indicate that the system has to maintain excess capacity for short peak intervals which is uneconomic (Tessendorff 1972). Thus, it is important to have a probabilistic understanding of the return period within which the peak event will recur and what the implications of increasing the degree of utilisation (lowering the peak factors) are on the system's design.

4. Wastewater volume

Sewers must be designed to adequately function throughout the range of flows, from peak flow (allowing for sufficient capacity to discharge the waste), to extreme minimum (to ensure adequate velocities to transport solid particle so they do not settle and block the sewerage) (ASCE & WPCF 1972; Haestad et al. 2004). The hydraulic design of sewers is based on the average daily and hourly flow volumes and the hourly peak factor. This data is incorporated into the hydraulic design in order to predict (Haestad et al. 2004),

- Present and future wastewater discharge in the infrastructure life,
- Diurnal wastewater volumes, and
- Seasonal variation.

Domestic wastewater flows are typically less than water demand due to domestic irrigation and gardening, leaks, etc. (ASCE & WPCF 1972). It has been estimated that 60% - 70% of the total domestic water supplied is discharged as wastewater (Fair et al. 1966). Water consumption monitoring is based on actual water demand at the required interval – individual fitting, household, suburb, etc. However, wastewater monitoring is not as straightforward due to the issues associated with the monitoring setup. Thus, wastewater is commonly estimated.

For on-site wastewater treatment facilities, such as septic tanks and anaerobic baffled reactors (ABRs) it is important to know the peak daily wastewater volume, as both of these treatment facilities present hydraulic retention time in terms of days, typically between 1 – 2 days. The design of the ABR requires peak hourly wastewater volume in order to ensure that the upflow rate meets the requirements for appropriate treatment – with acceptable design upflow velocities around 0.27 m/h (Foxon et al. 2006) and an upper limit of 1.0 m/h (Gutterer et al. 2009).

5. Case Study: Frasers

The CABs in Frasers informal settlement were provided with water efficient sanitary fittings. The toilets made use of waterless cisterns having a demand flush mechanism, and the showers made use of a water efficient shower head and a metered tap. The flow rate of the shower heads from Site 5 in Frasers was investigated by measuring the volume of water discharged over a minute interval. The average of 12 trials found that the flow rate was 5.8 ℓ/min, which is classified as very water efficient (Table 1). The same trails were conducted for the wash hand basins and laundry basins and the average flow rates were found to be 7.9 ℓ/min and 14.3 ℓ/min respectively, which is considered very reasonable for ablutions (at the wash hand basin) and for washing clothes and collecting water for domestic use (at the laundry basin).

In Frasers, the minimum and maximum water pressure for the area was between 2 – 6 bar. The minimum pipe diameters were 75 mm and 160 mm for the water and sewer infrastructure, as stipulated by the eThekwini regulations. The sewers also adhered to the eThekwini regulation for minimum gradient of 1:150. The facilities required a total of 430 m for the sewer pipeline to connect to the on-site wastewater treatment facilities and 420 m for the water pipeline. The wastewater treatment facilities consisted of ABRs or septic tanks for primary treatment and soakaways for post-treatment. The soakaways were constructed using 110 mm slotted pipes, with a total length of

1 050 m for the four soakaways. The design of the ABRs and septic tanks was based on previous in-house guidelines; however, there is no national water demand guideline for CAB effluent volumes, as CABs do not fit any of the scenarios presented in the SANS 10400 guidelines (SANS 2010).

The CABs in Frasers informal settlement are representative of the typical CAB installations around eThekwini, in terms of water pressure and supply, and the number of sanitary fittings within the CABs. The use of efficient sanitary fittings forms part of the water conservation and water demand management strategies within eThekwini in order to reduce the increasing demand on water resources, which is a national priority (DWA 2013).

The data from the end-use monitoring of the four CABs in Frasers informal settlement was collected over the period from 20 January 2012 to 30 November 2012. The number of days without data per fitting is recorded in Table 2 and Table 3. The excluded data was patched using an algorithm for all the CABs over the whole period.

Table 2: Monitoring period for the CABs

This table presents the total monitoring days and the associated dates for which CABs were monitored. The monitoring period started in the middle of summer and ended in the beginning of summer. The patched data refers to data that was patched based on the patching algorithm. The estimated data refers to data that were sourced from another CAB on that specific day, as the data could not be patched from one week prior to or following.

	CAB 1	CAB 2	CAB 3	CAB 5
Start Date	10 April 2012	1 March 2012	10 April 2012	20 January 2012
End Date	30 November 2012	31 May 2012	30 November 2012	30 November 2012
Total Days	244	92	244	314
Data Patched	16%	42%	39%	30%
Data Estimated	21%	30%	3%	0%

Table 3: The extent of data correcting for each CAB fitting

The table presents the percentage of data that was patched, estimated, or left unedited per fitting over the entire monitoring period.

CAB No.	DAYS		MALE SHOWER	MALE LAUNDRY	MALE BASIN	MALE TOILET	URINAL	FEMALE LAUNDRY	FEMALE SHOWER	FEMALE BASIN	FEMALE TOILET
1	244	unedited	4%	81%	7%	82%	74%	76%	74%	93%	70%
		patched	14%	15%	7%	14%	23%	20%	23%	3%	26%
		estimated	82%	4%	86%	4%	3%	4%	3%	4%	4%
2	92	unedited	3%	3%	3%	35%	35%	79%	21%	72%	0%
		patched	40%	40%	40%	65%	65%	21%	77%	28%	0%
		estimated	57%	57%	57%	0%	0%	0%	2%	0%	100%
3	244	unedited	64%	93%	93%	70%	50%	14%	36%	41%	58%
		patched	33%	3%	4%	26%	50%	81%	61%	56%	38%
		estimated	4%	4%	4%	4%	0%	5%	3%	3%	4%
5	314	unedited	75%	77%	87%	89%	63%	74%	71%	74%	17%
		patched	25%	23%	13%	11%	37%	26%	29%	26%	83%
		estimated	0%	0%	0%	0%	0%	0%	0%	0%	0%

5.1 Water supply

The parameters required for hydraulic design of the water supply is the average daily water demand of the CABs and the instantaneous peak factor. The average daily water demand from the four CABs in Frasers are presented in Table 4 and the supporting statistical information for each CAB is presented in Table 5. The contribution from each fitting in the CAB is shown in Figure 9. The number of households at each CAB presented in Table 4 has previously been discussed and the estimated water demand was found to be approximately 103 ℓ/hh/d (Crous et al. 2012; Crous et al. 2013). From the socio-economic survey conducted in the settlement in August 2011 it was found that there are on average 2.2 persons per household (Okem et al. 2012). The average water demand is approximately 80.6 ℓ/hh/d, and translates into a monthly household consumption of 2.4 kℓ, which is significantly lower (73%) than the free basic water allowance of 9 kℓ/hh/month. This is equivalent to a daily water demand of 36.6 ℓ/c/d from the CABs. This value is consistent with the CAB water demand of 35 – 40 ℓ/c/d (Roma et al. 2010). Yet, the CAB water demand is lower than the national guideline of 45 – 55 ℓ/c/d for a yard tap and a flush toilet per household (SANS 2010).

Table 4: The average daily water demand for the four CABs in Frasers.

	Daily Water Demand (ℓ/CAB/d)	**Households per CAB**	**Daily Water Demand** (ℓ/hh/d)
CAB 1	12 000	227	82.2
CAB 3	6 650		
CAB 2	9 320	114	81.7
CAB 5	4 370	56	78.0
AVERAGE	-	-	80.6

Table 5: The statistically relevant information for the daily water demand for the four CABs in Frasers.
The water demand is presented in ℓ per household per day. The maximum and minimum daily water demand is the respective value for the seven day return period.

	Median	**Standard Deviation**	**Maximum**	**Minimum**
CAB 1 and CAB 3	75.4	34.9	119	49.3
CAB 2	81.2	27.8	114	43.6
CAB 5	71.6	26.8	109	52.5
Average	76.1	29.8	114	48.5

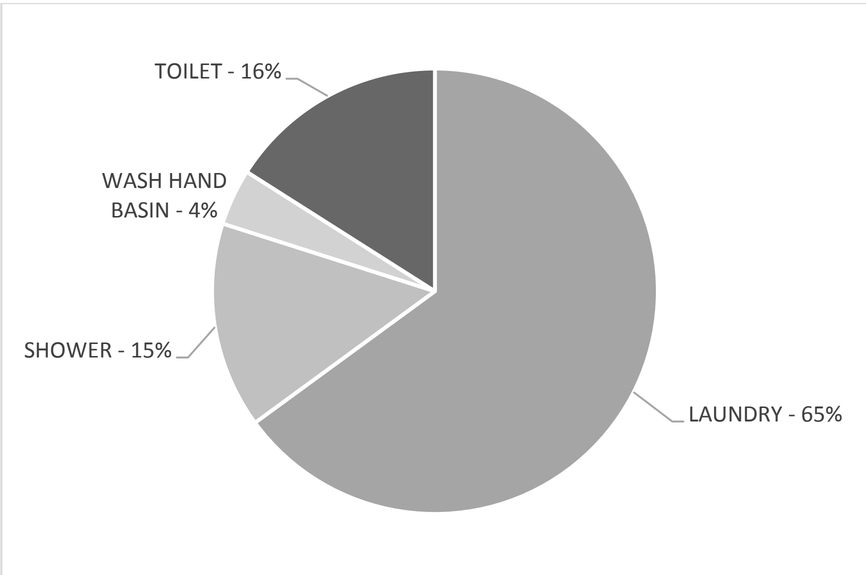

Figure 9: The distribution of the CAB water per sanitary fitting.
This figure provides the water demand for the male and female CAB fittings combined. The main fitting used in the CAB is the laundry water, which accounts for 65% of the CAB water demand. In contrast, the blackwater accounts for 16% of the water used in the CAB.

The socio-economic study found that 66% and 34% of the respondents from 147 households surveyed in Frasers were male and female respectively. The male and female facilities were analysed in order to compare the usage behaviour of the CABs for each gender. This comparison excludes the water sourced externally, as this water can be accessed by either male or female users. The comparison of the male and female CABs indicates that from the average for the four CABs, the male facilities were used more than the female facilities, with the male toilets, wash hand basins, and showers being used 2.8, 3.4, and 2.9 times more than the respective female facilities. This comparison of the male and female containers indicated that more males used the ablutions than females, or that the males used more water than the females, or a combination of both. The cause of this disparity was not further investigated in this study.

The hydraulic design of the water supply requires the instantaneous peak factor for the water demand of the entire CAB. The average instantaneous peak factor for all four CABs was found to be 5.2, with the instantaneous peak factors for CAB 1, CAB 2, CAB 3, and CAB 5 being 5.4, 3.9, 6.7, and 4.6 respectively. This is higher than the eThekwini municipal peak factor of 4.0 (Rosseau 2012). From the peak factor, the degree of utilisation was found to be on average 19%, with the degree of utilisation varying between 15 – 25% for the four CABs.

The CABs form part of the interim water and sanitation service provision in Frasers, which also had five standpipes already operational in Frasers. There were discussions within the municipality to decommission the standpipes from Frasers due to the poor drainage provided for the standpipes and the associated problems associated with the stagnant greywater. Although this was never implemented, the quantity of additional water sourced from these existing standpipes was not accounted for in this study due to a lack of available data. Previous estimates indicated that the additional water sourced from the existing standpipes around Frasers are approximately 17 ℓ/hh/d. The assumptions are presented in Crous et al. (2012) for the CABs in eThekwini, based on an extensive survey of 1 021 households who use CABs around eThekwini (Roma & Buckley 2011). Based on this assumption, the total average daily water demand for the CABs is 97.6 ℓ/hh/d.

The effect of weather was investigated on the CAB usage as the CAB facilities are located away from the dwelling units. This was achieved by averaging the daily average temperatures from the La Med and the Upper Tongaat weather stations to estimate the ambient temperature in Frasers. It is important to note that the effects of the weather on the use of the CABs was not further investigated to determine the root causes of such correlation, but only to provide a broad analysis of the CABs in relation to the environment. No qualitative research, i.e. questionnaires, was conducted.

From the four CABs in Frasers, it was found that the average correlation factors between ambient temperature and the male toilets, showers, wash hand basins, and laundry facilities were 0.22, 0.48, 0.28, and 0.29, while the female sanitary fittings had correlation factors that were on average half of the correlation factors for the male sanitary fittings. The low correlation between temperature and female usage of the CABs indicates that the two parameters are independent, i.e. that female usage is not dependent on temperature. This result is expected, as it is a factor of the different social perceptions and physical differences in female and male defecation and hygiene practices. Although there is graphical evidence of temperature having an effect on the toilets (Figure 10) and the showers (Figure 11), the contribution of these fittings does not have a significant effect on the total wastewater generated from the CABs. Figure 10 indicates the correlation between temperature and usage of the male toilets in CAB 5. This CAB was the only CAB located north of the railway. The CAB had the highest correlation between the average temperature and toilet usage, with a correlation factor of 0.48, which was approximately double the correlation factor for the average from all of the male toilets. It is hypothesised that pre-CAB defecation practices, for example unimproved pits or open defecation, were used when the weather hindered the use of CABs. This is because these pre-CAB defecation practices are typically located within closer proximity to the household than the CAB.

The showers indicated a significantly higher correlation to average ambient temperature than any of the other fittings in the male CABs, as shown in Figure 11. This result is expected, as the showers are fitted with only cold water supplies and further, the effect of the lack of employment could also affect the motivation of male users to adhere to regular bathing practices.

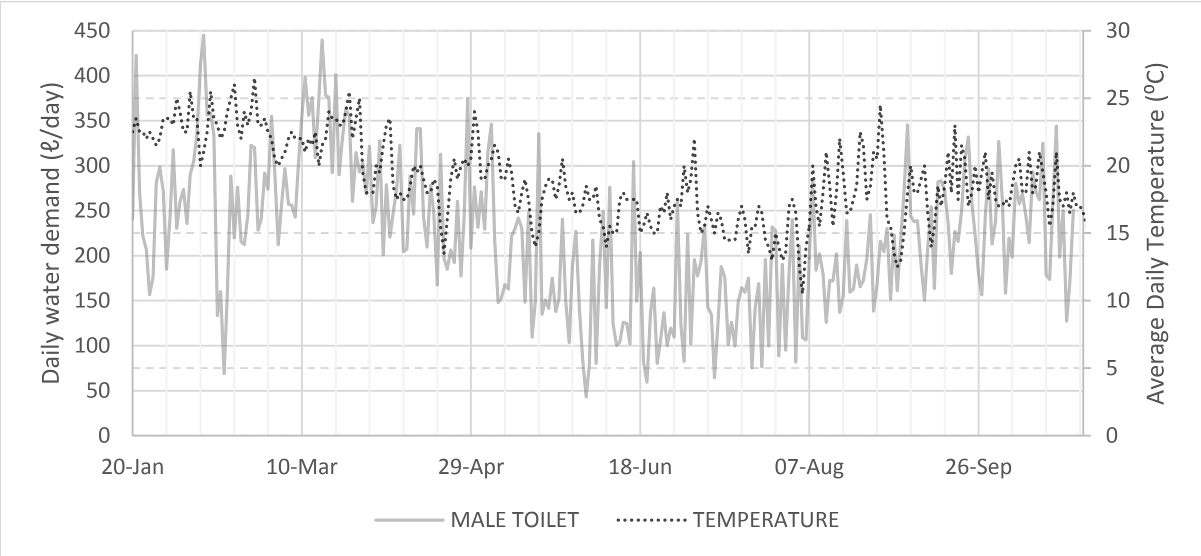

Figure 10: The effect of weather on the usage of the male toilet in CAB 5
The correlation factor for the ambient temperature and the male toilet wastewater generatedis 0.48 for the period from 20 January to 27 October 2012.

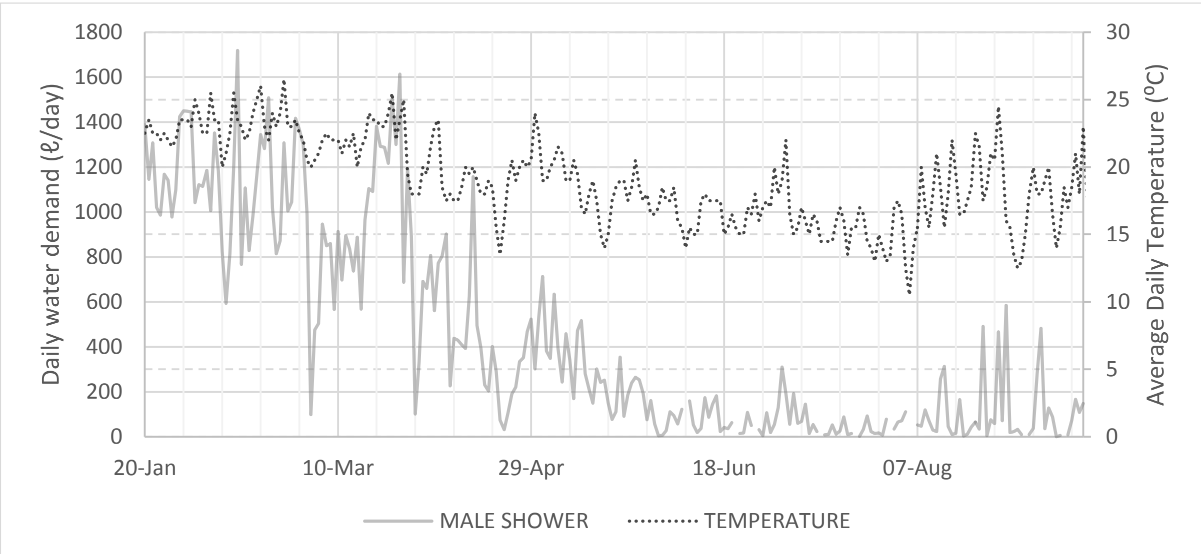

Figure 11: The effect of weather on the usage of the male shower in CAB 5
The correlation factor I for the ambient temperature and the male shower wastewater generatedis 0.77 for the period from 20 January to 19 September 2012.

The presence of a geyser for heating the water, namely for bathing, has been discouraged by the eThekwini municipality in order to reduce the cost of the CAB facilities and to ensure the rapid rollout of at least a basic water and sanitation services to all. Yet, the data from Frasers informal settlement, with subtropical temperatures, still had a high correlation between average temperature and showering.

5.2 Wastewater Volumes

The wastewater generated per household for CAB 1 and CAB 3, CAB 2, and CAB 5 are shown in Figure 12, Figure 13 and Figure 14 over the entire monitoring period. These figures indicate that the blackwater was a very small fraction of the total CAB wastewater generated, being 18%, 21% and 10% for CAB 1 and CAB 3, CAB 2 and CAB 5 respectively. The blackwater for CAB 1 and CAB 3 combined, for CAB 2, and for CAB 5 was 18%, 11% and 10% of the total wastewater generated respectively. This is considerably lower than the average percentage of blackwater for domestic households, which is typically around 40% (Jacobs 2004). The toilets in Frasers use demand flush mechanisms and waterless cisterns. The toilet cistern fills up once the flush mechanism is engaged, and the cistern discharges once the flush mechanism is disengaged. Thus, the flush water volume is highly variable for flushing, based on the users' needs. Based on the average daily toilet flush water, the daily per capita toilet flush volume is around 2 ℓ/c/d. This flush volume is based on the total population around the CABs and assumes that all the users use the facility once per day.

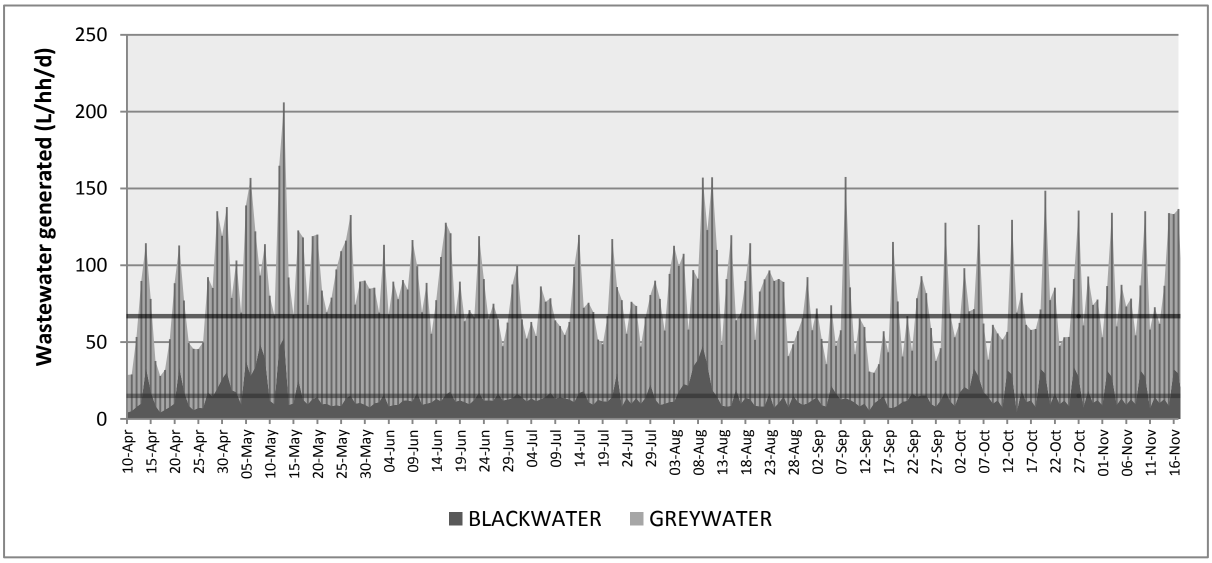

Figure 12: Daily household wastewater generated for CAB 1 and CAB 3 combined.
The total average daily CAB wastewater generated was 82.2 ℓ/hh/d, with the average daily blackwater was 15.1 ℓ/hh/d and the average daily greywater was 67.0 ℓ/hh/d.

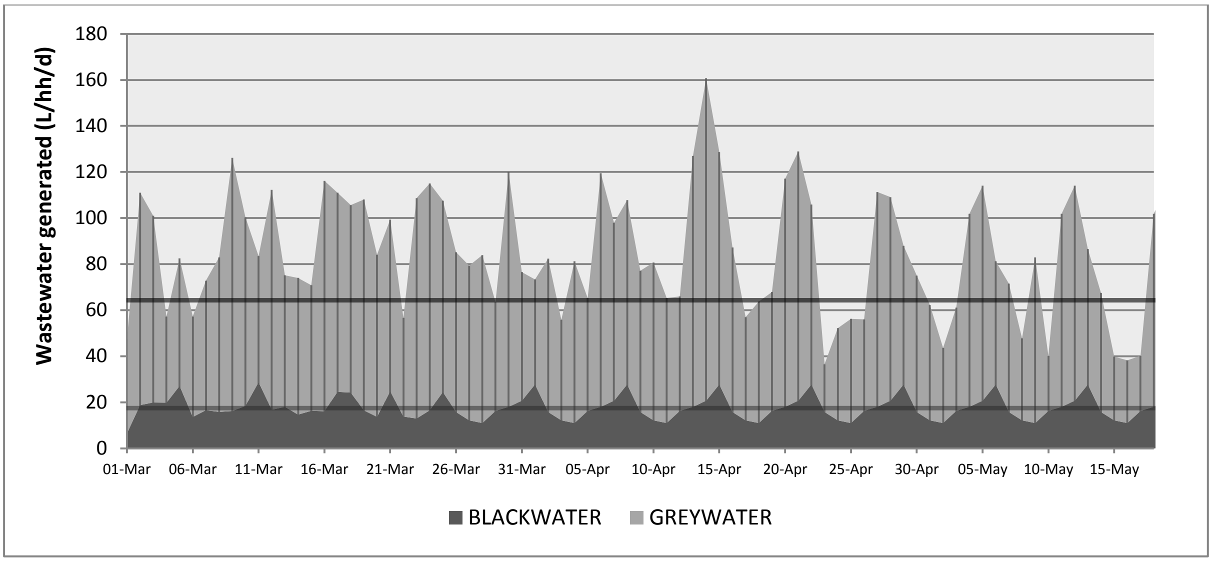

Figure 13: Daily household wastewater generated for CAB 2.
The total average daily CAB wastewater generated was 81.7 ℓ/hh/d, with the average daily blackwater was 17.4 ℓ/hh/d and the average daily greywater was 64.2 ℓ/hh/d.

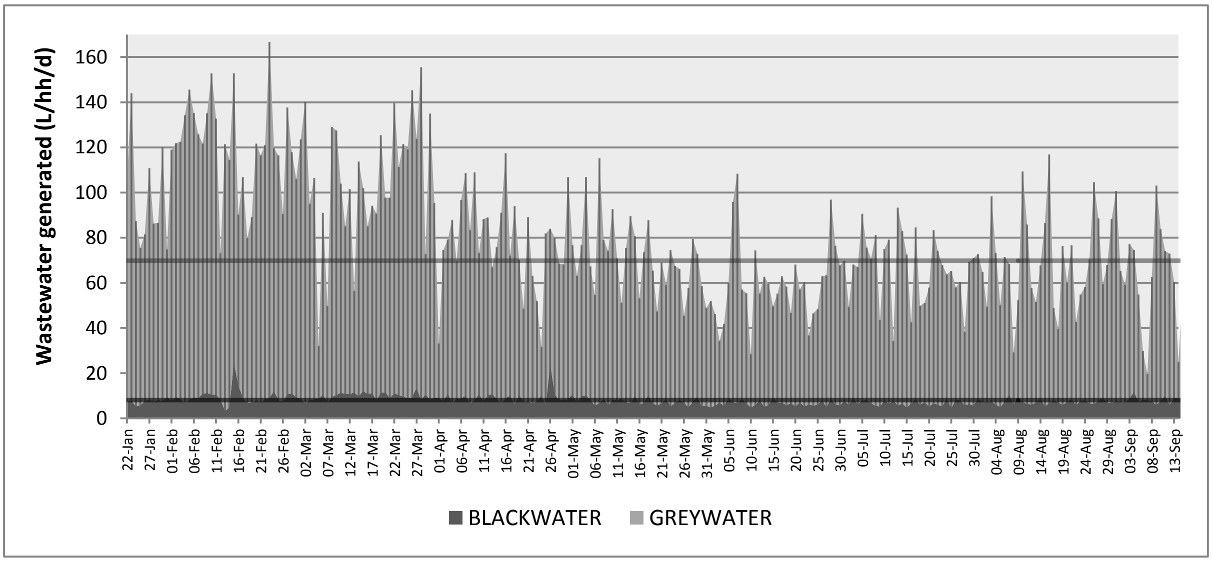

Figure 14: Daily household wastewater generated for CAB 5.
The total average daily CAB wastewater generated was 78.0 ℓ/hh/d, with the average daily blackwater was 8.12 ℓ/hh/d and the average daily greywater was 69.9 ℓ/hh/d.

For the CABs, internally a factor of 1.0 can be assumed, i.e. the wastewater volume generated is the sum of all of the water supplied to the showers, toilets, and wash hand basins. However, externally this relationship does not hold, as the users often carry water away from the CAB for household consumption, such as washing, cleaning, and laundry. This water does not get discharged into the sewerage and safe disposal of this wastewater has to be designed for in order to minimise the hazards associated with stagnant water. It was found that approximately 19% of the CAB wastewater (20 ℓ per household) does not get disposed and treated (Crous et al. 2012). The amount of water not discharged into the sewer was not monitored, but was based on the assumption that each household on average carries one 20 ℓ container away from the CAB container for domestic uses. This assumption was based on the fact that the container size of 20 ℓ is a standard size and is commonly used for collecting water from standpipes. Furthermore, this volume of water is within the free basic water (25 ℓ/c/d) allocated for domestic purposes to indigent households in South

Africa (DWAF 2002). Anecdotal evidence of external water uses is shown in Figure 15. This water that is not disposed or treated and accounts for approximately 25% of the total water supplied to the CABs.

Figure 15: The external CAB water behaviours based on site visits performed in August 2012 (August 2012). The figure on the left indicates how users collect water in a 20 ℓ container from the laundry basins for domestic purposes. The figure on the right indicates how users perform laundry washing duties next to the laundry basins. This is practice is implemented as the laundry basins are in use by other users. The wastewater from such practices are typically discharged into the surrounding environment not the sewers.

The relevant hydraulic design parameters for the wastewater disposal and treatment are presented in Table 6. The total greywater presented in Table 6 includes the proportion of the greywater that is assumed to be discharged, and not the total daily greywater generated. The results indicate that the daily peak factor for greywater and blackwater is consistent at around 1.5 for both types of fittings. However, the hourly blackwater generated for CAB 1 and CAB 3 is nearly 1.5 times higher than the other two CABs. This is because CAB 3 had highly variable hourly blackwater volumes, which was previously reported to have a peak factor as high as 8.6 (Crous et al. 2012).

Table 6: The design parameters for the wastewater treatment from the CABs.
The daily greywater generated is the total amount of greywater that is discharged into the sewers. The percentage of blackwater refers to the amount of blackwater that is discharged into the sewers and treated.

	Daily Greywater (ℓ/hh/d)	Daily Greywater Peak Factor	Hourly Greywater Peak Factor	Daily Blackwater (ℓ/hh/d)	Daily Blackwater Peak Factor	Hourly Blackwater Peak Factor	% Blackwater
CAB 1 and CAB 3	47.0	1.4	3.6	15.1	1.7	4.6	24%
CAB 2	44.2	1.5	3.9	17.4	1.4	3.3	28%
CAB 5	49.9	1.4	3.5	8.12	1.3	3.4	14%
Average	47.0	1.4	3.7	13.5	1.5	3.8	22%

6. Conclusions

The physical layout and design of CAB structure and fittings have been determined by the eThekwini municipality. The use of prefabricated shipping containers enables the rapid placement of the facilities on site and reduces the amount of work required on site to construct the facility. The use of retrofit shipping containers also constrains the amount of fittings that can be placed within the CAB. The sanitary fittings used within the CABs should use water conservatively such that unnecessary water losses are minimised. The main requirement is that they are of a high quality in order to withstand a high rate of usage and vandalism. The facilities make use of low-flush waterborne toilets, which require a constant water supply and the use of toilet paper to reduce blockages within the sewerage network. The use of waterless urinals should be discouraged as there are no contingency plans when the waterless urinal system fails, which will impact the integrity of the entire CAB facility.

The monitoring of the water demand at the four CABs in Frasers has provided detailed, quantitative data for the hydraulic design of the CABs. The quantitative data on the water demand and wastewater generated from these four CABs in Frasers informal settlement indicated that the average daily water demand was 97.6 ℓ/hh/d, or 44.4 ℓ/c/d based on an average of 2.2 persons per household. This water demand is representative of the CABs within eThekwini, as it falls within the range of water demand values estimated from the 72 CABs around eThekwini, which had an average water demand between 41.5 – 62.2 ℓ/c/d. The instantaneous peak factor was found to be approximately 5.0 on average, which is higher than the eThekwini guideline peak factor of 4.0. The weather did not have a considerable effect on the total water demand of the CAB, but had the most significant effect on the male shower and male toilet water consumption.

It was found that approximately 25% of the water used at the CAB facilities does not get disposed of or treated. This has to be improved in order to reduce the effects of poor drainage. The wastewater discharged into the sewer consists of approximately 22% blackwater and 78% greywater. This is significantly lower than the typical domestic blackwater concentrations. The peak factors for the wastewater are approximately 1.5 and 4.0 for the daily and hourly intervals respectively. The hydraulic design of the water and sewer pipes is important as the pipe networks form part of the long-term infrastructure development within the settlements. It also provides for reliable municipal planning for water demand management and estimating wastewater treatment capacity.

7. Recommendations

The main requirements for the design of the CABs have been addressed in this study. There are a number of recommendations that are made from the data and from the site visits in order to promote the sustained operation of the CABs once they have been commissioned. Physical CAB structure

- Although the manufacturers install a minimum quantity of fittings within the CAB, as per the municipal specification, the type of fitting is left to the manufacturers. However, as EWS are responsible for the long term maintenance of the CABs, the selection of the fittings should be selected based on municipal standards, such that the fittings are South African bureau of Standards (SABS) or JASWIC[1] approved sanitary fittings. This will ensure that there is a high quality standard for the fittings. However, standards should be developed for the CAB sanitary fittings, as these fittings are used more extensively within CABs than within typical domestic environments.
- There should be clear responsibilities for who is responsible for the CABs directly after the CABs have been placed on site such that any construction defects can be dealt with swiftly. It

[1] JASWIC is the Joint Acceptance Scheme for Water Services Installation Components. Its objective is to assist in establishing and upholding national standards for water supply and sanitation at a municipal level (JASWIC 2008)

is recommended that the contractors be responsible for the supply chain of the CAB, from sourcing the manufacturers of the CABs, ensuring the fittings adhere to the required standards, and the transportation and placement of the facilities on site. The design consultants should be responsible to ensure the water supply and sewer pipeline designs are properly constructed. The water service authority, in this case EWS, should be responsible for the long-term operation and maintenance of the CABs. The three role players should all be present at the handover of responsibilities to ensure that the work has been implemented to a high standard.

- Physically within the CAB, the toilet cubicles should be sized to a length of at least 1.2 m in order to accommodate users of a height up to 2.1 m. This recommendation is based on the current location of the toilet within the cubicle.
- Future research should investigate the appropriate technologies that can be used to provide a cost effective heating system to the CABs that will promote the use of the facilities even for lower temperatures. In other provinces in South Africa where the winter temperatures are significantly lower than in Durban, communal water and sanitation services must implement a geyser system for the showers facilities.

The appropriateness of a shared cistern for the entire CAB should be further investigated. This could be achieved in the CABs by fitting the toilets to a central water cistern (no less than 20 ℓ in volume) fastened either to the wall or located on top of the male and female container roof.Water and wastewater management

- Although EWS have implemented water demand management of the CABs by providing awater meter for each CAB facility, the data available from the municipality in February indicated that only about 30% of the water meter readings were valid. The effect of adequate data management has to be addressed in order to ensure that data is being collected, i.e. the water meters are being read, and that accurate data is stored on the municipal database. Without such practices, the water demand management strategies will be fruitless and the associated benefits of supplying water meters to the CABs will be lost.It was estimated that approximately 25% of the total CAB water is not disposed of in the sewer, but is released into the adjacent environment. The effects of poor wastewater management are detrimental to public and environmental health. There should be appropriate means for the disposal of wastewater into the sewers. This will require both user education to promote proper disposal of wastewater and physical infrastructure, which could take the form of drains next to the CAB facilities where users can dispose of any greywater. The actual volume of water not discharged into the CAB sewerage has to be quantified through further research.
- The on-site wastewater treatment infrastructure should account not only for the wastewater generated from the CABs, which was found to be in the order of 40 – 60 ℓ/c/d, but should also account for the additional water increase when the settlement is provided with in-house water and sanitation services. The guideline value for low-income households is 50 - 70 ℓ/c/d. This will mean that either the on-site treatment facility should be able to adequately manage the future wastewater volumes, or that the settlement has sufficient available space for additional on-site wastewater treatment facilities to be constructed.

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Construction

Chapter 7

The construction phase starts once the planning has been approved by the project managers. The contractors are then given an access date for construction to commence. This chapter provides an overview of the construction phase and provides detailed analysis of the available data from the eThekwini municipality. The chapter aims to answer the following three research questions in the rollout and future planning of such communal ablution facilities in informal settlements. These questions are,

- How much time is required for the construction of CABs?
- Does the length of the water and sewerage pipelines connecting the CABs to the bulk infrastructure affect the time required for construction?
- What factors impact the handover of the CABs to the communities?

These questions have to be addressed as these have a direct impact on municipal resources, both in terms of securing and spending funding, and in planning for the rollout of such infrastructure.

1. Time Requirements

The time required for construction is estimated during the initial planning stages of the project, this is known as the programmed construction period. Once the planning phase is complete and the Works Information has been submitted, the project managers provide the contractors an official access date onto site to start construction. The contractors then provide an updated time estimate for completing the construction based on the updated specifications of the design consultants and the current capacity of the contractors. The actual construction period is the period between the access date and the date of completion. The construction completion date is the date on which the contractors and the design consultants signed off the work. This is the recorded date on which the construction period is officially finished. These three recorded construction dates vary considerably and the results from 302 CAB related projects are provided in Figure 1 and Table 1.

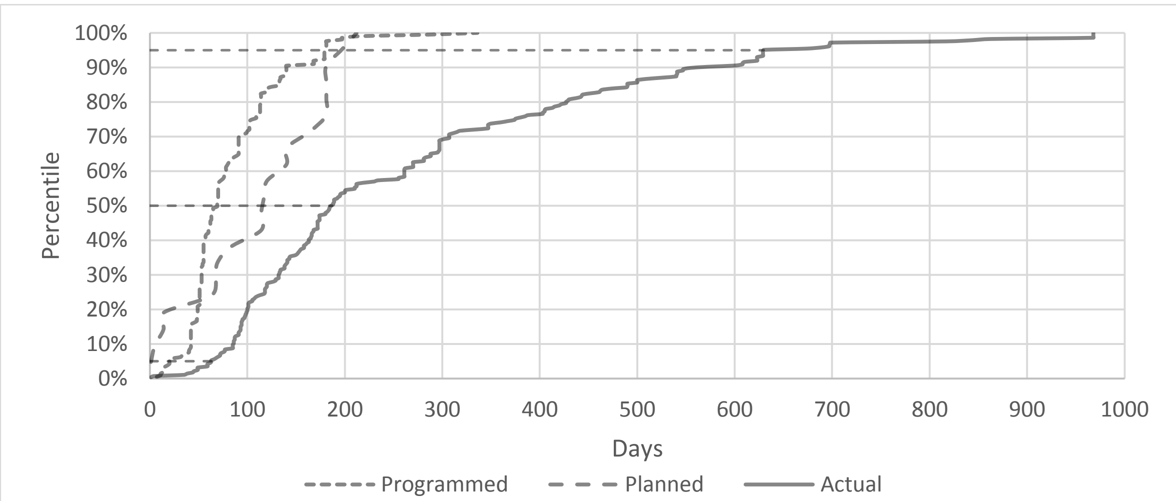

Figure 1: The construction period for the CAB projects in eThekwini
The data indicate that the median time required for the actual construction period is approximately three times more than the initial programmed time estimated for construction.

The results in Table 1 are only presented for those projects which had valid data for all three construction periods. It was calculated that there was less than 10% difference in the median of all the data points and only those sites with data for each recorded construction period. The median of the actual construction period from 286 CAB projects was 174 days. The results from Table 1 indicate that on average, the initial feasibility construction period is nearly 50% shorter than the contractors planned construction period and the actual time required for construction is 2.4 times longer than the initial estimated programmed construction period.

Table 1: The construction period for the CAB projects in eThekwini
The absolute maximum and minimum construction periods are not provided as these values are not statistically relevant. All values are presented in calendar days, not work days.

	Programmed Construction Period	Planned Construction Period	Actual Construction Period
Average	81.9	112.3	196.4
Median	65	117	174
Maximum (95th percentile)	197	197	415
Minimum (5th percentile)	14	5	4
Standard Deviation	71.0	67.4	197,3
Available data points	21	21	21

The median for each of the four project areas in eThekwini are further provided in Table 2 in order to differentiate between different areas. Excluding the West project area, it was found that the actual construction time period was approximately three times longer than the programmed construction period.

Table 2: The median construction period for the CAB projects in the four project areas of eThekwini
All values are presented in calendar days, not work days. The value N represents the number of data points for each project area.

	Programmed Construction Period	N	Planned Construction Period	N	Actual Construction Period	N
North	114	52	181	7	288	71
South	55	115	130	8	163	145
West	11	2	-	0	168	21
Central	57	42	65	6	172	49
Total	69	211	117	21	187	286

2. Connecting Infrastructure

One of the main factors that have to be considered during the construction of the CABs is the construction of the water and sewer pipes. The actual construction periods were thus further investigated based on the lengths of both the water and sewer connections to the CAB facilities and is shown in Figure 2. However, the results indicate that there is not a significant correlation between the construction periods and either the water or sewer the pipe lengths, as the trend lines indicate that the pipe length almost remains constant between different construction periods. Therefore, there is no direct association between the proximity of the CABs to bulk water and sewer infrastructure and the time requirements on site.

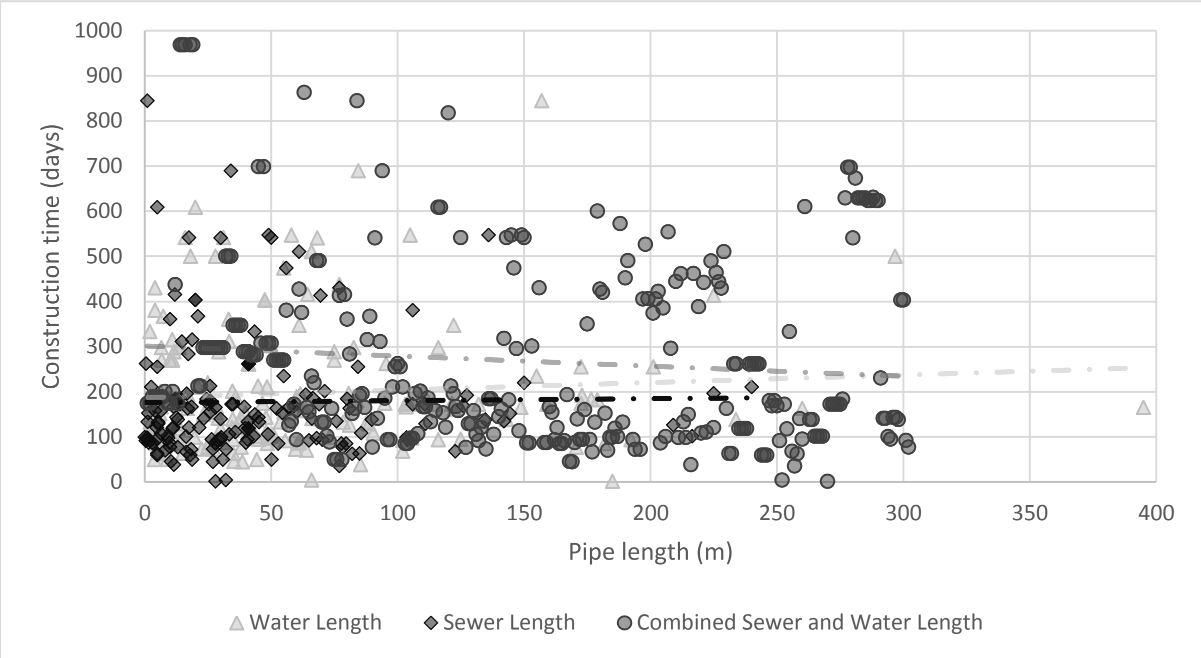

Figure 2: The actual construction time as a function of the water and sewer pipe lengths
The results are based on 186 water pipe lengths, 166 sewer pipe lengths and 156 combined water and sewer pipe lengths. The trendlines indicate that the construction time either remains constant or decreases as the pipe length increases. This result indicates that the construction time is not a direct function of the pipe length.

However, evaluating the costs associated with the entire water and sewer asset associated with each site there is a positive correlation between the construction time and the cost of the infrastructure, as shown in Figure 3. The cost does not only include the cost of the pipes, but also includes the civil works, i.e. the excavation and backfill.

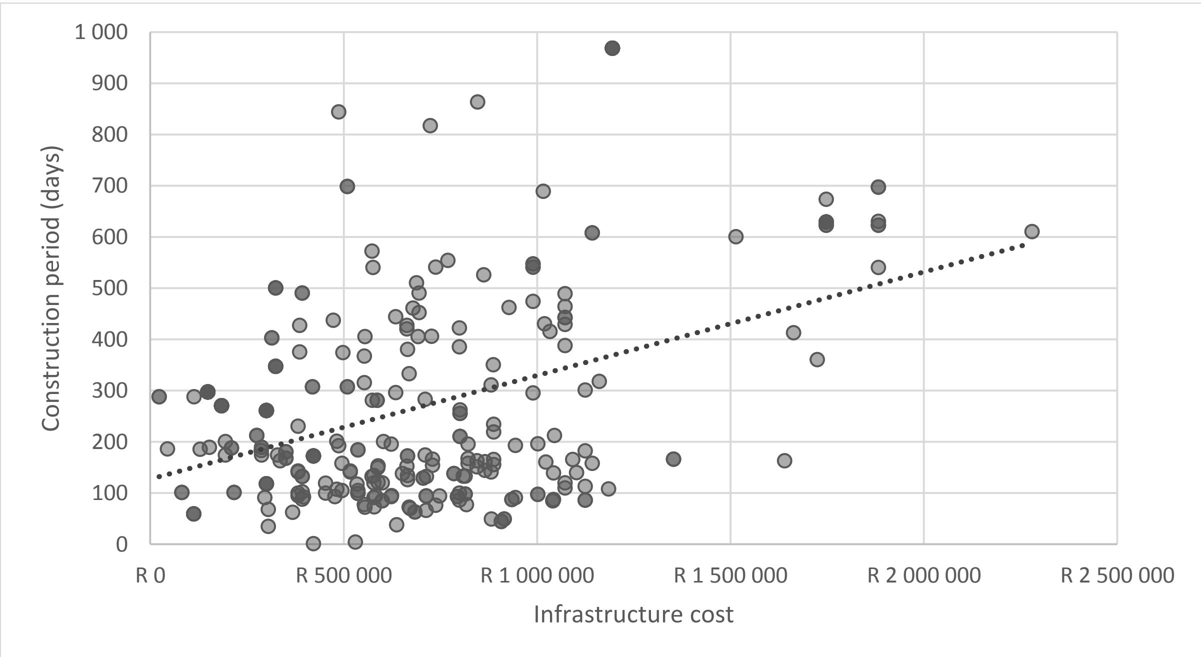

Figure 3: The actual construction time as a function of the cost of the infrastructure
The infrastructure includes the cost of all civil works and the cost of the sewer and water supply pipes. As expected, there is a positive correlation between the construction period and the cost of the construction period because as the construction time increases, the cost of the construction will also increase.

3. Additional Issues

Although there is a positive correlation between the time required for construction and the costs associated with construction, these two factors are dependent on each other. This is due to the fact that the cost of the civil works accounts for the time spent on site. For this reason it was important to identify other factors that can occur during the construction period which can also lead to the additional costs of the project (Crous et al. 2012). An interview with the project managers indicated that these factors are variable and are not only dependent on the physical conditions within the settlement but are factors relating to project management. These major factors increasing project costs include (Fuller 2012):

- Delays
  - Due to lack of available materials
  - Due to the community or the Councillors
  - Labour strikes
  - Due to the time required for the permission to occupy the land
- Relocation
  - Relocation of existing water and sanitation infrastructure
  - Relocation of dwellings
  - Relocation of crops
- Provision of Temporary Infrastructure
  - Chemical toilets
  - Site access
- Provision of security

Delays in the project increase the overheads of the contractors, as the contractor has to pay for the labour costs and the standing time of rented equipment. These delays affects not only the cost of construction, but the entire CAB provision to the settlement, as approximately 60% of all costs are dependent on the construction period time (Crous et al. 2012). The delays can be due to the lack of available materials – for example the shortage of bitumen in South Africa at the end of 2011 due to shortages as a result of complications at local refineries (Venter 2011). This factor delayed the CAB projects where services were installed over road crossings. The project managers further indicated that construction delays are also caused near the end of a project, where the local labourers are dissatisfied with the end of their employment contract and strike. The contractors are required to employ local labour in each settlement. The local labour accounts for 10% of the contractor's contract. However, these local labourers are only employed during the construction of the infrastructure to the CAB facility. Further delays can be caused in the acquisition of land for the CAB and the water supply and sewer infrastructure. This process can take much longer than initially expected, due to difficulties in finding the rightful owners of the land. Although this should be resolved during the planning phase of the project, the delay at one site can have knock-on effects on the contractor's capacity to implement other projects. Finally, unresolved community's or Councillor's expectations may also result in the construction being delayed (Fuller 2012).

At times, water and sewer infrastructure is constructed over existing sanitation services, such as VIP latrines. These are subsequently removed and have to be replaced with temporary chemical toilets and removed once the CAB is handed over to the community. However, the cost of these toilets increases with delays in the construction of the CABs and in some settlements, the community does not want the temporary facilities to be removed, which also increases the cost of the CAB project. Temporary access has to also be provided to some settlements such that trucks can delivery supplies and the physical CAB containers. In such cases the contractors either have to construct an access road or else a crane has to be hired to deliver the CAB on site. The relocation of dwellings for the placement of the CAB site or the placement of water and sewerage connections also increases the construction cost. Each of the relocated households are compensated. However, some dwellings consist of more than one household which means that each household within that dwelling has to be paid the compensation. The project manager interviews further indicated that at times, the households also resist relocation and although they have been compensated and have agreed to move, they do not actually move and have to be paid the compensation again (Fuller 2012). Households are also provided with acrop compensation where there is a loss in crop harvest incurred by the construction. Security has to also be provided in some areas, such as the South area especially, to protect not only the personnel but also the construction equipment and supplies. This requires the employment of a full time security guard. The delays caused during construction will have an effect on the total cost of the security services (Fuller 2012). These effects can be seen on the difference between the actual costs of construction and the programmed construction costs – as proposed during the planning phase, as shown in Figure 4.

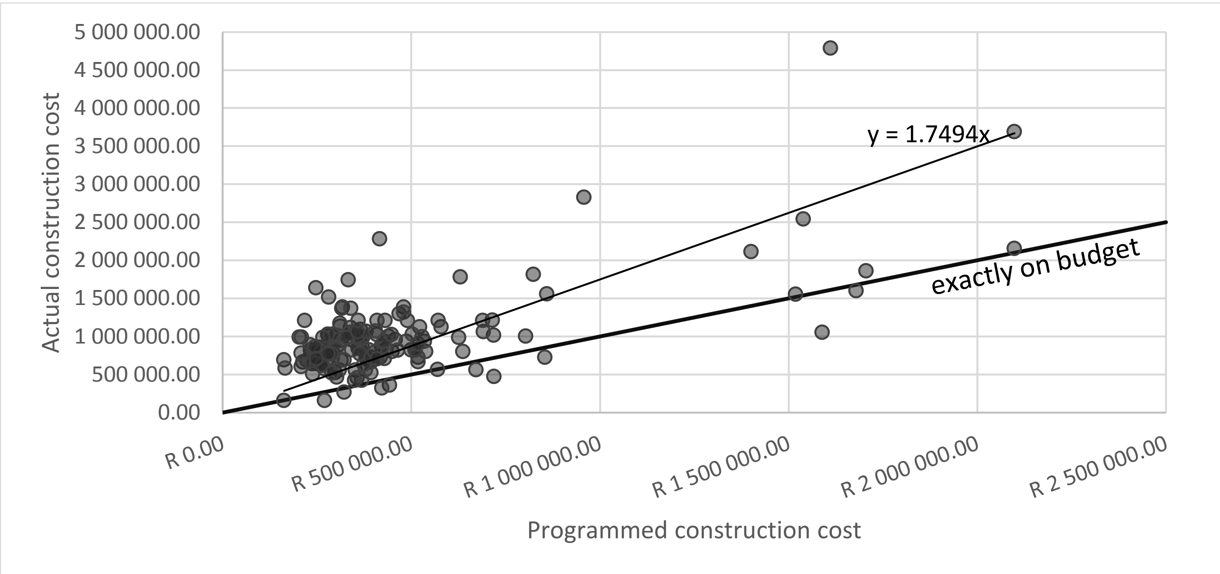

Figure 4: Programmed construction costs versus the actual construction costs.
The results are drawn from 152 CAB related projects. The graph indicates that the majority (93%) of these projects were under budgeted, with the actual cost being on average 247% of the programmed construction cost. Also, the linear trend line (R^2 = 0.2) indicates that the actual cost was 1.7 times the target cost.

4. CAB Handover

Once the construction has completed, which is a date signed off by both the design consultants and the contractors, the construction is assessed through a mutual inspection by the relevant parties, including EWS, the design consultants and the contractors. All faults, if any, are recorded and have to be corrected within 42 days. After the mutual inspection, the CABs are handed over by the project managers to EWS, who then handover the facility to the councillors, who then identify a suitable date for handover to the community. It was noted that the handover to the community can be very political (Smith et al. 2012).

An interview conducted with the project managers and a representative from EWS indicated that initially, the CABs were only handed over once the whole settlement was provided with CABs, however, delays (environmental, PTO, etc.) hindered the completion of the entire settlement's CABs. This caused frustration within the community and could (at times) increase vandalism. It was subsequently decided that the handover of the CABs would be done per site, not per settlement. One month after the handover date, a second mutual inspection is done, where the EWS Wastewater department's operation and maintenance managers assess how the CABs are operating and identify any snags. However, the availability of the relevant EWS representatives becomes a problem around bottleneck periods, such as the end of the calendar and financial years. This can cause the inspection process to take longer than a month (Smith et al. 2012).

5. Case Study: Frasers

The Frasers informal settlement case study is different to most other settlements, as these CAB facilities made use of on-site treatment facilities, namely septic tanks and anaerobic baffled reactors. This meant that additional excavation had to be performed for the soakaways and the ABR and septic tanks. The provision of CABs to Frasers informal settlement was scheduled to commence in the second week of May 2011 and complete 51 calendar days later, in the last week of July 2011. However, the construction for the four CABs in Frasers is shown in Table 3. The delays in initiating the construction period were due to PTO issues which were already discussed in the previous chapter. During the construction period there were incidences of rain in June and July which also caused delays in the excavation and construction.

Table 3: The construction period for the CABs in Frasers informal settlement
The days are presented as calendar days, not work days.

Site name	Actual construction access date	Total construction period (days)	Actual construction time relative to target time
Site 1	19-Sep-11	165	324%
Site 2	12-Jul-11	155	304%
Site 3	12-Jul-11	234	459%
Site 5	09-May-11	219	429%

The construction of Site 5 started off with the excavation of the sewerage infrastructure and the excavation for the anaerobic baffled reactor. The main delay in this project was the delay in delivering the actual containers to site, which took place approximately three months to get the containers on site and connected to the water and sewerage infrastructure. This was because the containers were non-conventional, using water-saving fittings not the typical sanitary fittings, and the pipework was also unconventional as these CABs needed to be monitored with water meters connected to each fitting. It was also found that the ABR at the site, constructed from brick and mortar, was permeable and had to be retrofit with insulating materials. The final delay was in the procurement of the data loggers and water meters, which delayed the construction period for approximately a month. Although Site 2 and Site 5 were completed on 14 December 2011, the facilities were only formally handed over to the communities by the Ward Councillors on 22 January 2012. Although Site 5 was kept locked until the facilities were formally handed over, Site 2 was in use from the time that the facilities were handed over from the project managers to EWS on 20 December 2012.

Twenty-two labourers had been employed during the peak of the construction period. Yet, labour strikes at the beginning of November 2011 disrupted the construction period during November and December. These strikes had been reported elsewhere too and were common where the project was closing and the contracted local labourers would again be unemployed. A total of 10 labourers were retained to perform the construction tasks during and after this period. The second problem that was faced was that the construction period would have to restart in January 2012. This was anticipated to be problematic, due to the fact that some of the labourers may not return for work the following year. This was not the case in Frasers. However, the Community Liaison Officer did not return to work after the December break and a new person had to urgently be employed.

6. Conclusions

The analysis of the data from the project managers responsible for the rollout of the CABs found that there was a large discrepancy between the initially estimated time required for construction and the actual construction time, with the actual construction time being approximately three times longer than the estimated construction time. However, it was found that the time required for construction was independent of the length of the connecting water and sewerage infrastructure.

For local government, the increased construction time affects both planning and budgeting, as the eThekwini municipality has to motivate for funding from provincial and national government in order to upgrade informal settlements and commit to spending that budget within the financial year. Furthermore, the negative sentiment of the communities can be exacerbated toward local governments by this slow service delivery, which can impact the sustainable operation of the CAB facilities. Ultimately there are no benefits to these construction delays as they affect all parties. The local government, contractors, project managers, and the design engineers all have to allocate resources (either/both human or capital resources) during the construction period to ensure that the services are provided to the community. The community is also affected, as they have to make use of rudimentary, unimproved sanitation services and are also negatively affected by the conditions present during construction for prolonged periods.

Informal settlements are not ideal construction sites and there are many delays that can arise from within the settlements' characteristics, namely delays in obtaining permission to occupy (PTO) the land from private land owners and relocating the residents and local labour strikes near the end of the construction period. It was found that the time of the construction period was not dependent on the length of the water and sewerage infrastructure and was dependent on other factors. As was indicated in the Frasers case study, the PTO was a major issue which can delay the construction and even postpone the construction of the facilities – as was the case with Site 4. Thus, these delays are not primarily caused by the physical settlement conditions wherein the construction occurs or due to highly complex construction methods, but are issues that require intensive project management risk mitigation strategies during the planning stages of the project.

As three of the sites in Frasers had delays in obtaining the PTO, the CABs were constructed on a per site basis, not per settlement. Although per site construction fast-tracks the time when the contractor can gain access to the site, the outstanding PTOs can cause extended delays in the construction period and incur additional costs to the contractor.

The reasons for the inconsistency in the actual construction time have been hypothesised by the author based on the available data, but it is noted that there are other factors that could also affect the construction stage. These other factors that encourage construction delays could be attributed to incomplete planning and design documents, which can cause delays in the correct implementation of the design specifications by the contractors, or due to inadequate project management during either the planning stage or the construction stage of the project, or due to insufficient capacity of the contractors to perform the construction within the proposed timeframe. These factors were not investigated in this study, but are highlighted here to provide a comprehensive overview of some other factors that could also affect the construction period. Future research should investigate these in more detail in order to fully understand the extent to which all of these different factors affect the actual time required for construction.

7. Recommendations

A number of issues were identified from the construction stage data collected mainly from the project managers. This section provides the author's recommendations for ensuring realistic planning can be performed during the initial planning stages and are summarised in this section based on the author's own experience of the eThekwini municipality's rollout of CAB facilities.

- All the required designs and PTOs should be in place for each settlement before construction commences. This will require more resources and time for the responsible parties, in this case the design consultants and the municipality, to follow up with the relevant private landowners and acquire the PTO.
- The expected construction period estimated during the planning stage should be increased by a factor of three to account for potential delays in obtaining PTOs, labour strikes and the procurement of materials as these delays have cost implications for the contractors and also have an effect on the contractors' capacity to start the construction in other settlements.
- Dividing the settlement into different construction phases is important in promoting a continuation of the work by the contractors within their project area and in the strategic planning of the construction within that specific settlement. However, the delays in obtaining PTOs may still affect the contractors' capacity to start work in the other construction phases within the settlement. Thus at the beginning of the construction period, the contractor should only obtain materials and employ any local labourers and subcontractors for those sites that have already been provided with an access date for construction in order to reduce costs incurred by delays in the construction period, as the other sites within the settlement may not be ready for construction once the work within that specific phase has been completed.

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1. Introduction

The long-term sustainability of any water and sanitation service is dependent on the operation and maintenance (O&M) of the facilities. This is also consistent with CABs and their sustained use (Roma et al. 2010). There is global evidence for the deterioration of water and sanitation infrastructure once the project involving the provision of the facilities has terminated, as operation and maintenance are often neglected (Dillon n.d.). However, there is a recognition of the need for holistic planning, emphasising not only service delivery (design and construction), but also the post-construction activities of operation and maintenance (Brikke 2000). The operation and maintenance of CABs is critical as failure of the CAB system affects a large population not only a single household. Therefore, the operation and maintenance must be monitored continuously to ensure that the community does not have to revert to unimproved means of sanitation, such as open defecation. The operation and maintenance model that was presented in Chapter 2 was adapted for the CABs and is presented in Figure 1.

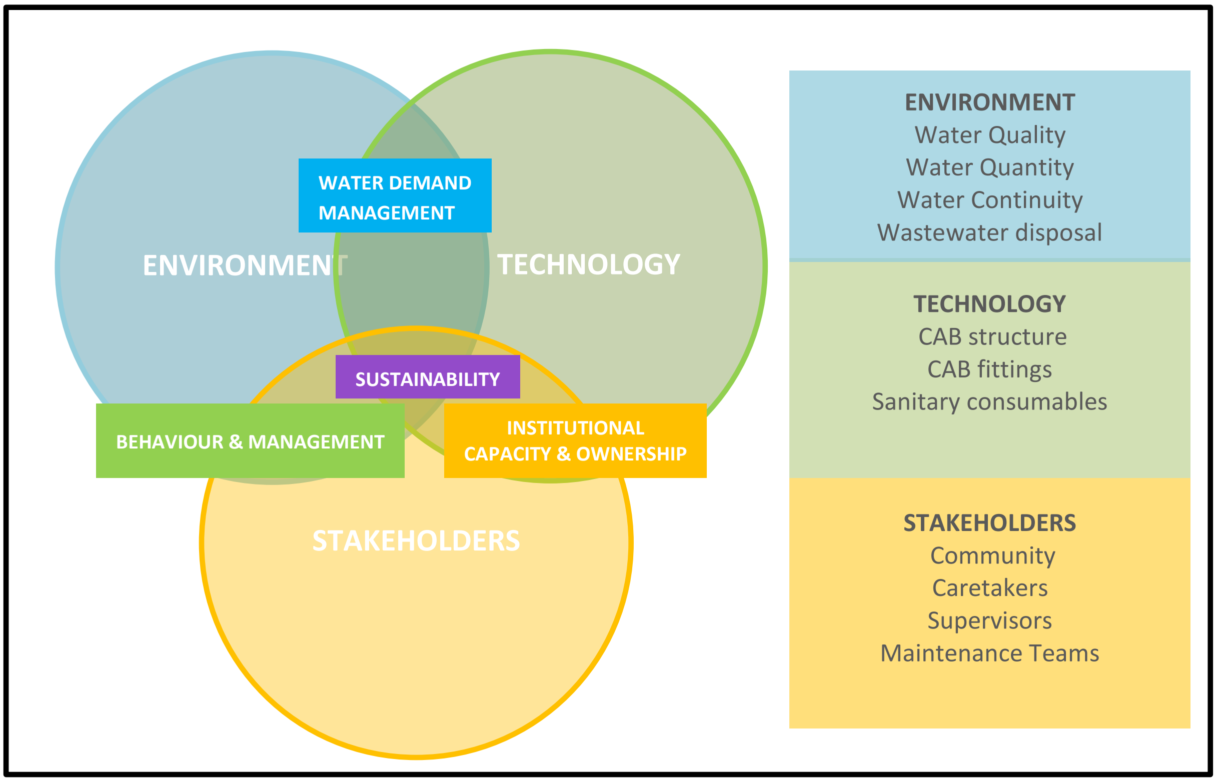

Figure 1: The sustainability nexus in the operation of CABs (adapted from Brikke 2000)

Although O&M have typically been grouped as they both deal with the facilities after they have been provided, they are two separate tasks that should be managed separately. In this study, the operation and maintenance have been separated. Operational aspects are directly related with the operation of the system, e.g. the activities of any operational staff (e.g. caretakers), the reporting of faults and defects, and the materials required for sustained operation of the system (e.g. toilet paper, disinfectant, water supply, etc.) (Carter 2009). The operation of interim water and sanitation services should be undertaken in accordance with the principles of the Expanded Public Works Programme to maximise job creation (DHS 2009). The four main aspects associated with the operation of CABs includes,

- The appointment of caretakers,
- Provision of caretaker cleaning materials,
- Proper reporting system,
- Provision of toilet paper,
- Provision of a safe, reliable water supply.

The research questions include,

- Who is responsible for the operational management of the CABs?
- What are the caretakers' role in the operation and accessibility of the CABs?
- What effect does poor drainage and poor water supply have on the operation of the CABs?
- What are the sanitary consumable quantities for the CABs?
- How are the sanitary consumables managed at the CABs?

2. Role Players

An interview with a researcher of communal sanitation facilities in Indonesia highlighted that although the post-implementation responsibility of water and sanitation services in South Africa falls on the local government, this is not typical of all developing world countries, especially in South East Asia where the government does not maintain facilities after construction (Eales 2012). Based on the South African context, the eThekwini municipality is responsible for the operation of all the CABs provided within the municipal area. This is achieved with the appointment of caretakers, responsible for the daily activities at the CAB. The caretakers report to supervisors who ensure the CABs are operational and all problems are addressed. The maintenance is attended to by a repair team and is discussed in more detail in Chapter 9 (Maintenance). The role players associated with the operation of the CABs includes caretakers, who are stationed on site; supervisors, who liaison with the caretakers and coordinate all maintenance; repair teams, who are contracted to make repairs; and financial officers, who log all operation and maintenance costs at the municipal office. The activities of the role players are shown in Table 1 and the institutional requirements for the CABs are shown in Table 2.

Table 1: The proposed operational activities that should be implemented at the CABs (based on Brikke 2000)

ACTIVITY	FREQUENCY	RESPONSIBLE PERSONS	TOOLS AND EQUIPMENT
Clean toilet seats and mop the CAB internally	At least twice daily	Caretaker	Disinfectant, mop, bucket, toilet brush
Report any operational defects	As required, minimum of weekly	Caretaker	Telephone – typically a cellular phone
Log all defects	Once reported	Supervisor	CAB fault database
Repair any defects	Within 48 hours of the report	Maintenance team	pipes, taps, toilet seats
Log all repairs	Once repair is complete	Supervisor	CAB fault database
Report all repair costs	Once repair is complete	Financial officer	CAB cost database

Table 2: The institutional requirements for the monitoring of the operation of CABs

ACTIVITY
Log faults – blockages, leakages, or structural damages
Log response time – the time required to repair the leaks once reported
Log repair frequencies
Log maintenance costs
Flag unresponded maintenance requests
Log and manage caretaker supply requests from the central warehouse

3. Water Supply and Sewage Disposal

The water requirements for CABs were extensively covered in Chapter 4 (Planning) and is mentioned here to present the operational requirements for CABs in its entirety. As stated before, CABs require a constant water supply and an adequate method of wastewater disposal. Without the water source, the CABs cannot function as all of the sanitary fittings, including the toilets, are reliant on water. Yet, without an operational disposal system, the wastewater, either greywater or blackwater, will discharge into the CAB and cause the CAB to be non-operational. This typically occurs when the sewer is blocked due to either illegal connections or due to the disposal of foreign objects into the sewer. Foreign objects include materials other than toilet paper used for anal cleansing or where the refuse collection system is poor in the settlement and solid waste is discharged into the sewer.

Poor water and wastewater management and appropriate disposal into sewers, both internally and externally, will promote the spread of waterborne diseases. The increased greywater around the CABs also reduces the access to the facilities and inadvertently creates barriers for use and can cause the users to not take care of the facilities. One of the frequent problems associated with the CABs is leaks, both from the water supply and from leaking effluent pipes on the interior and exterior of the CABs. From the study in August 2012, it was found that 20 of the CABs (80%) had greywater around the exterior CAB platform and surrounding environment, as shown in Figure 2. The reason for the poor drainage of CABs is partly due to the leaking of the laundry wastewater pipes and partly due to the washing practices of the community – as clothes are washed in buckets next to the basins and then emptied into the surrounding environment. The problem is also exacerbated when the sewers are blocked and the wastewater is discharged around the CABs. Internally, poor drainage is problematic as the facilities do not allow for drainage from the CAB floor, only from each of the fittings. The only method of removing water from the inside of the CAB is through the CAB door, which is not practical due to the burden of greywater already found externally around the CAB. The main reasons for poor internal discharge are blocked shower drain pipes and the leaking toilet drainage pipes, as shown in Figure 3. The studies in March and August 2012 revealed that 33 of the male and 25 of the female CABs (75% and 66% respectively) had more than one leaking toilet drainage pipe. This is caused both during transport, where the drainage pipes attached to the toilets move away from the toilet bowl structure, and cause an opening from which leaks can arise, and during use, where the toilet moves during daily use – from users sitting down and getting up from the toilet seat. The most critical drainage problem is the toilet leaks as this possess a significant health risk to the users, especially the vulnerable within the settlement.

Figure 2: Poor drainage externally in the CABs
The top photos show the poor drainage associated around the laundry facilities and the bottom photos are associated with poor drainage around the CAB environment.

Figure 3: Poor drainage internally in the CABs
The top two photos show the problems associated with poor drainage within the CABs. The top-right photo clearly indicates the internal leak is associated with poor drainage from the showers. The bottom-right photo shows a caretaker providing an interim measure with dealing with the leaks from the toilet wastewater pipe. The bottom-left photo shows a detached wastewater pipe from the basin, which discharges into the CAB.

Finally, the water pressure also plays a role in the operation of the CABs. Low pressures can occur not only due to poor water network design and planning, but also due to illegal connections from the surrounding settlement. Illegal connections are common in informal settlements around eThekwini and they form part of the municipal non-revenue water losses. The effects of low water pressure mainly affect the showers, as they are used real-time. The laundry facilities and the toilets will be affected during peak periods, where there are large numbers of people using the facilities, but will be functional during the entire period. High water pressures can be experienced where the CABs are located at a low-point in the distribution network, such as a valley for example. High water pressures can cause the fittings to malfunction, such as the toilet flush mechanism especially. Alternatively it can cause the connections between the pipes and the taps, or other fittings, to burst, causing a continuous leak inside the CABs.

4. Caretaker

The provision of CABs is accompanied with the appointment of a caretaker who was responsible for the operation of the CAB system and reporting defects, such as leaking or broken fittings or blocked sewers. The CABs were locked and opened at the discretion of the caretakers, who were employed by eThekwini municipality to work 4 hours per day (Roma & Buckley 2011). The lack of safety and prevalence of crime episodes in the settlement at night were also factors inhibiting the use of CABs at night (Roma & Buckley 2011).

An interview with the key stakeholder at EWS identified that there were currently 294 caretakers employed within the 350 CAB sites under the management of EWS (Sibiya 2012). The appointment and management of caretakers was considered to be important in the reduction of vandalism and abuse (Moodliar n.d.). The interview highlighted that supervisors were appointed to ensure the caretakers manage the CABs correctly, one supervisor for each of the four eThekwini areas, as divided in the project - North, South, West and Central (Sibiya 2012). The supervisors reported back to EWS management on issues found on site, to ensure all necessary actions can be taken (Smith & Dedekind 2011). When caretakers identify malfunctioning CABs, they then report the faults to the supervisors. The fault reporting flowchart is shown in Figure 4.

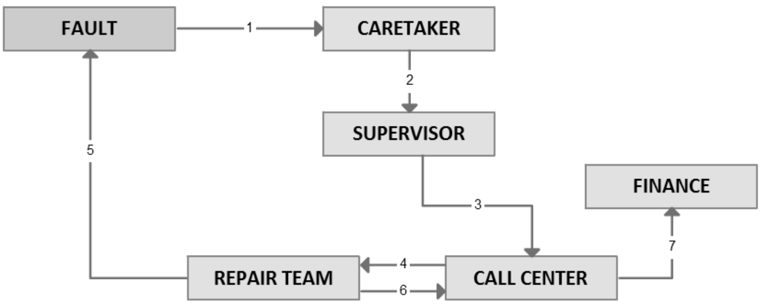

Figure 4: The schematic diagram of the fault reporting of CABs in eThekwini
The first step is the caretaker identifying a problem in the system and then reporting it to their supervisor. The supervisor then logs the fault with the call centre who then appoints the appropriate repair team to go through to the CAB to perform the repairs. Once the fault has been repaired, the repair team then logs the repair with the call centre who then sends the repair invoice to the EWS finance department.

Initially, when the ablutions were provided by the Health Department, the caretakers were selected and paid by the local community (Scruton 2009; Gounden 2009). Although the presence of a caretaker should have had a positive effect on the operating conditions of the CABs, this was not realised as the management and payment of the caretakers from within the local community did not work effectively. Once EWS took responsibility for the provision of CABs, they also became responsible for the management of the caretakers and the caretakers were selected and appointed by EWS (Roma et al. 2010; Smith & Dedekind 2011).

The EWS supervisor who works in that area ensures that a caretaker has been appointed by the time the CAB is handed over from the project manager to EWS. The selection of the caretaker was discussed with the key stakeholder from EWS. This selection process formed part of the responsibility of the Ward Councillor. The selection of the caretaker followed the same procedure as was used in the appointment of Community Liaison Officers in the R1.6 billion AC pipe replacement project in which 1 600 km of water pipes were replaced between 2007 and 2010 (EWS n.d.). It was stated that the Councillor would approach the local structures of the settlement and would select three unemployed candidates who are in need of an income and would be appropriate to perform the duties of the caretaker. These candidates did not need any skills and require at least a Grade 6 or Grade 7 education in order to ensure that they could read and write, as they have to fill in register forms each day stating what time of day they worked (Sibiya 2012). Although the majority of people in informal settlements have access to a cellular phone, it is not required that the caretaker own a cellular phone as this could exclude people who are unemployed and need an income. There was no discrimination between male or female candidates, but they had to be between 18 – 65 years of age. An interview with the key stakeholder indicated that although there was no gender discrimination, marginally, the majority of the caretakers were women as they were more readily available than men (Sibiya 2012).The candidates should be located close to the settlement, within 200 m from the proposed CAB site (Sibiya 2012). After the screening process, formal interviews were then undertaken with the three candidates. The interview was conducted by the EWS supervisor for the area and the Human Resources representative from EWS. The interview seeks to determine whether the candidates are able to work with people and are able to perform the necessary tasks of the caretaker. The answers are scored and the candidate with the highest score is selected. The selected caretaker then signs a one-year contract and is employed by EWS (Sibiya 2012). This caretaker undergoes training on the responsibilities of their employment and general health issues (Smith & Dedekind 2011).

The caretaker was generally responsible for a single CAB facility. However, if two facilities were located within close proximity, then the caretaker was also required to look after that facility too. However, in such cases, the renumeration to the caretakers was the same, although the workload essentially doubled. Caretakers were employed to work four hours per day, with the hours being worked during the entire day, logging their hours and reporting back to their supervisors. The responsibilities of the caretakers were not investigated in the structured interviews, but typical responsibilities include (Roma et al. 2010):

- Cleaning of the facility,
- Ensuring there is sufficient toilet paper and sanitary consumables available,
- Reporting leaks, blockages, or broken fittings,
- Ensuring the community have access to the facility while on duty.

It was found from the survey in August 2012 that 27 of the caretakers (82%) locked the CAB facilities at night. The caretakers who did not lock the CABs at night preferred to lock it, but were unable to do so as they had either lost their keys (12%) or the locks were broken and needed to be replaced (6%). The average open hours for the CABs was 05:57 – 19:15 (13.3 hours), with the longest reported open period being from 04:00 – 21:30 (17.5 hours) and the shortest from 07:30 - 16:00 (8.5 hours). This means that the community have to use alternative toilet facilities at night, as the majority of CABs are not used at night. This requires some form of hygienic disposal of the night soil, as the CABs are not accessible at night.

The caretakers were not provided with a dedicated space where they could bestationed during the day in order to oversee the operation of the CABs. Therefore, some of the caretakers locked the facilities when they were not present, in order to prevent misuse and vandalism. In such situations when the caretaker was not present, the community would have to go to the caretaker’s house either to get the key for the CAB or to get the caretaker to open the facility. As already discussed, the current CAB configurationdoes not provide adequate space where the caretakers can constantly watch over the facilities while on duty.

5. Caretaker Supplies

The appointment of a caretaker is associated with the provision of sanitary consumables to ensure the caretaker can adequately maintain the CAB facilities (Moodliar n.d.; Roma et al. 2010; Smith & Dedekind 2011). The EWS stakeholder interview further indicated that the caretakers were provided with a caretaker starter-pack upon appointment. This includes personal protective equipment (PPE) - including protective shoes, an overall, mask and gloves; mops; brooms; buckets; disinfectants; and toilet paper.

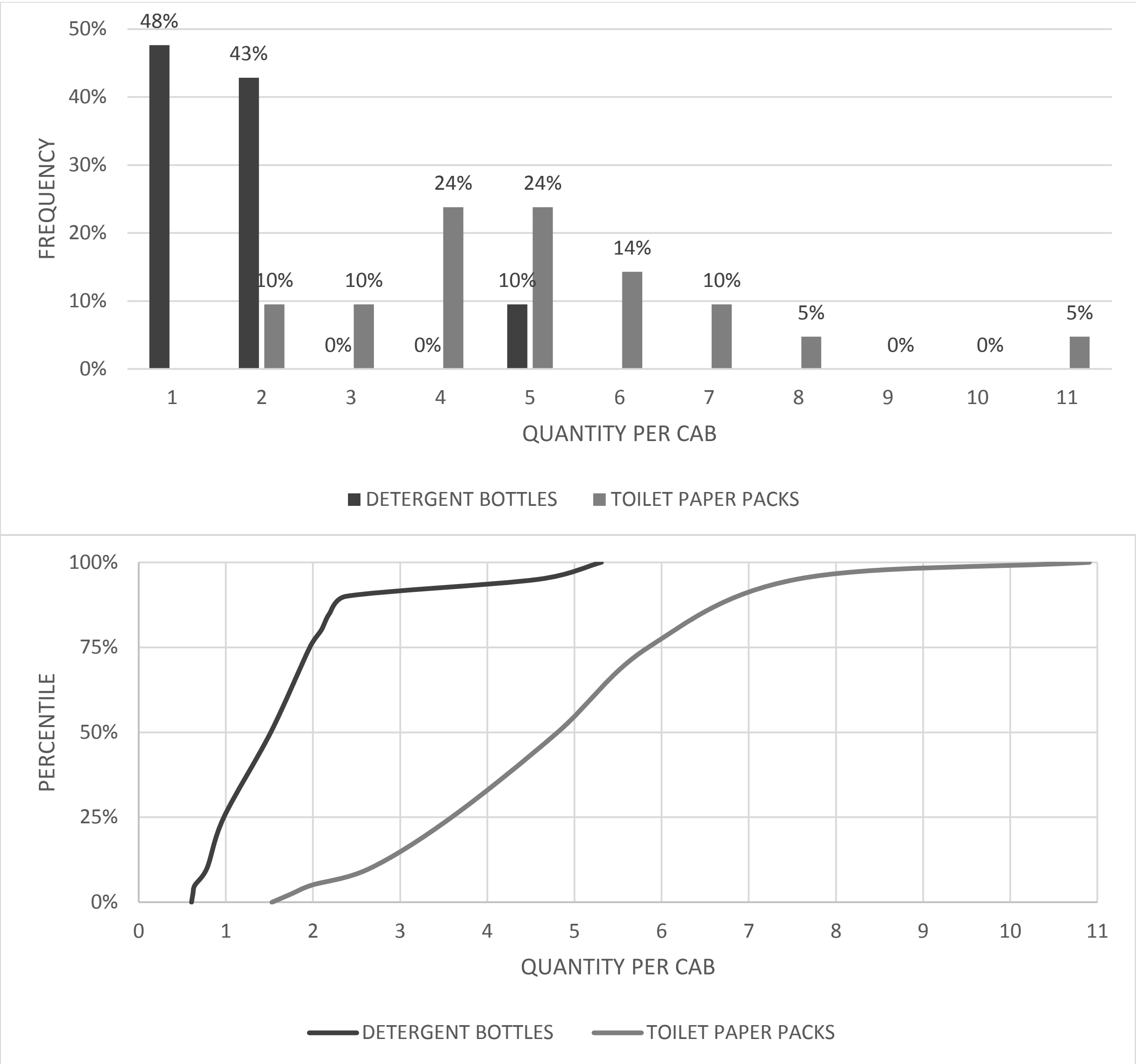

Figure 5: Histogram and cumulative frequency graph for the sanitary consumables used per CAB per month
The data was provided on monthly intervals for all of the CABs. The data is based on the official number of CABs handed over to the community between August 2010 and June 2012 (20 months), as provided by the project managers, and the official number of sanitary consumables provided by the Water and Sanitation Unit of the eThekwini municipality. Toilet paper had data for 21 months and refers to the number of toilet paper packs, each containing 48 toilet paper rolls. The detergent had data for 21 months and refers to a 5 ℓ bottle of cleaning detergent. On average, each CAB used 4.9 packs of toilet paper per month (235.2 rolls of toilet paper) and 1.7 bottles (5 ℓ) of detergent.

The caretaker starter-pack was reissued every 4 – 5 months, depending on usage patterns of the caretakers (Sibiya 2012). For the remaining period of appointment, the major monthly costs are associated with the toilet paper and detergents. Toilet paper was provided in a pre-emptive effort to prevent blockages caused by the use of other means of anal cleansing – such as newspaper, sticks or magazines (Moodliar n.d.; Taing et al. 2011a; Taing et al. 2011b). On average, over the period from October 2010 to June 2012, each CAB facility used 4.9 packs of toilet paper per month and 1.0 bottles of detergent. This is shown over time in Figure 5, whereby the quantity the consumable is the quantity drawn from the store room over a month period. The data was provided on a monthly basis for the total sanitary consumables taken from the municipal storehouse.

Figure 6: Methods of distributing the toilet paper within the CABs
The most common method for toilet paper distribution is to tear the toilet paper into reams and place them in the bag within which the toilet paper was delivered (bottom). Alternatively, toilet paper can be distributed from a box, either placed on the wash basin (left) or placed elsewhere in the CAB (right).

The caretakers were responsible for distributing the toilet paper to the users. Although all of the toilet cubicles had made provision for toilet roll holders, only one of the CABs in a study of 38 CABs in August 2012 made use of these toilet holders. The caretakers rather placed the toilet paper in a bag or a box within the CAB, as shown in Figure 6.

It is typically found that the caretakers pre-cut the toilet paper for convenience and did not leave the toilet paper in the rolls. The final method of toilet paper distribution was providing each household served by the CAB with two rolls of toilet paper per month. This method was implemented where the CAB was located near a train station and the caretaker noticed commuters taking the toilet paper away from the CABs. However, where no toilet paper was evident within the CABs there is evidence of newspaper, which potentially increases sewer blockages. The study of 38 CABs revealed that 58% and 21% of the CABs showed evidence of toilet paper and newspaper in or around the toilet bowls.

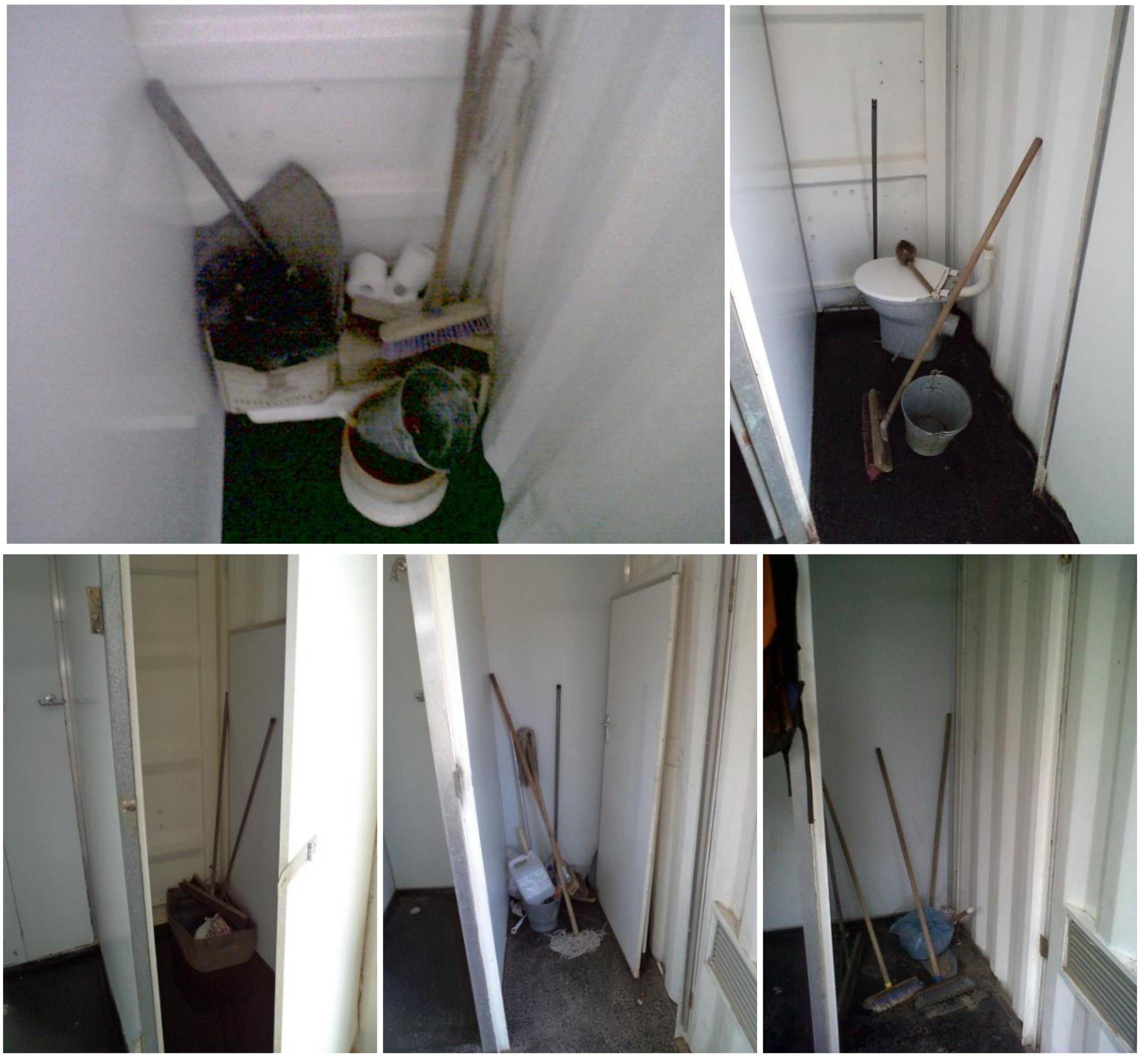

Figure 7: Typical content found in the caretaker store room
The caretaker store room was found to be empty for the majority (73%) of the CABs visited. However, the typical caretaker supplies stored are brooms, mops, brushes and buckets. Toilet paper was found in only one of the store rooms. Broken fittings (such as the toilet in the top right) can be placed in the store room until they are repaired by the EWS maintenance team.

Each CAB facility was provided with a storage room for the caretakers. The storage room is the same size as the typical toilet cubicle. The store room was typically located next to the male showers, as shown in Figure 7. Of the 38 CAB sites visited in August 2012, photographic evidence recorded from 33 CABs revealed that only 10 of the store rooms (30%) were being used by the caretakers. This means that the majority of the caretakers stored the supplies in their house, not the CABs.

Two of the caretakers had locked the store room with a padlock, while 15 CABs (45%) did not have a door for the storeroom, as the door was either missing or broken, yet three of these store rooms (20%) without doors were still being used to house the brooms, mops or buckets. The typical door used for the store room was exactly the same as the doors used for the cubicle doors of the showers and toilets, with a space between the ceiling and the top of the door and a space open between the floor and the bottom of the door. This is not secure and can encourage theft or vandalism of the caretakers' property. One of the caretaker respondents indicated that he was encouraged to store the supplies in his house rather than at the CAB site due to theft. There is photographic evidence that the 13 CABs which did store supplies in the provided store room, 8% stored toilet paper; 77% stored brooms, brushes or mops; 46% stored buckets; 31% stored the disinfectant. Further, the location of the store room next to the showers is not ideal, as the showers are often blocked and discharge water into the CABs (as can be seen in Figure 8). This affects the possibility of dry storage in the store room, for example the storage of toilet paper.

Figure 8: Examples of cubicle doors in the CABs
The evidence shows that the storage room cubicle doors are exactly the same as the cubicle doors for the rest of the CAB. Not only are the door hinges prone to breaking, but the doors further have gaps between the door and the ceiling and the door and the floor, which can promote theft of smaller supplies, such as detergents and toilet paper.

The act of washing hands with soap can reduce diarrhoeal disease by 42 – 47% (Curtis & Cairncross 2003). Yet, despite these health benefits, the provision of soap by the municipality for hand washing had been problematic in the rollout of CABs. From the municipal stakeholders' perception, soap was seen to not only be used for hand washing but also for showering or washing clothes and had traditionally been avoided in the sanitary consumables provided to CABs. As such, no CABs are provided with soap for hand washing. Still, the benefits of hand washing cannot be ignored, and the distribution of soap should be creatively investigated with extensive community participation.

6. Case Study: Frasers

The four CABs constructed in Frasers informal settlement were operated by three caretakers, where one caretaker was responsible for the operation of Site 2 and Site 3. There were two female caretakers (Site 1 and Site 5) and one male caretaker. From the survey conducted in August 2012, it was found that the facilities were all locked at night, being operational between 05:00 and 20:00 on average. There was evidence of toilet paper in all of the facilities, with Site 1 and Site 5 pre-cutting the toilet paper for the users and placing the toilet paper in a box (Site 5) and a plastic bag (Site 1) for the users to collect inside the CAB. The caretaker for Site 2 and Site 3 found that the facilities (mainly Site 3) were being used by railway commuters and the toilet paper would often be stolen. To prevent this, the caretaker distributed the toilet paper to the community instead of leaving the toilet paper in the CABs. However, there was no evidence of newspaper for anal cleansing in both of these sites, which could lead to blocked sewers.

The caretaker storerooms were empty for Site 1 and Site 5. The caretaker for Site 2 and Site 3 kept the brooms, mops, buckets, plunger and toilet brush in the storeroom of Site 2, with the other storeroom left empty. Finally, all of the sites had poor external drainage, with stagnant greywater found around the CAB laundry facilities. Internally, there was no stagnant wastewater for Site 1 and Site 5, while Site 2 and Site 3 had wastewater originating from the male toilets, and the female showers in Site 2. To mitigate the discharge of toilet wastewater into the CAB, the caretaker placed an interim bucket underneath the discharge pipe (as shown in the bottom right photo in Figure 6).

7. Conclusions

The delivery of water and sanitation services, which includes communal facilities, is often considered to be complete once the infrastructure has been constructed. This is often seen as the end of the project, the engineered project, yet this should be considered the beginning of the life cycle of the project, whereby operation and maintenance are critical in the success of the sustained use of the facilities and enable continued asset management. This chapter investigated the operational aspects associated with the provision of CABs throughout eThekwini. To this extent, the chapter interrogated this aspect of the project quantitatively through site visits and internal documents of the eThekwini Water and Sanitation Unit. However, although this does not qualitatively measure the use, or non-use, of the facilities by the communities the quantitative data provides a general understanding into the mechanics of operating communal water and sanitation services.

In eThekwini, the responsible persons for the operation of the CAB facilities were the caretakers, at a local level; the supervisors, at a district level; and the finance officers and maintenance teams at a municipal level. The key success factor in the sustained use of CABs lies in the quality of the caretaker and the quality of the support provided to the caretaker. Thus, coordination between the different role players is essential to ensure that the facilities remain operational at all times. One of the main problems in the communication between the caretakers and the supervisors is reporting which fittings are broken.

The caretakers are appointed annually by the municipality to ensure that the CAB facilities are operational. The selection process of the caretakers should be done with care to ensure that the community is aware of the process and approves of the selected person. Without the community buy-in, the community can smear the caretaker’s reputation by wilfully vandalising and breaking the facilities in an attempt to remove that person from the caretaker position. The key factors attributed to a good caretaker lies in a fair caretaker selection process, adequate training to perform their daily tasks, and adequate support from the supervisor to address the needs of the caretaker. The caretakers’ tasks included distributing toilet paper and cleaning the facilities. To this extent, the caretakers were appointed to work four hours a day, seven days a week, whereby the municipality reported that the caretakers would unlock and clean the facilities in the morning, clean the facilities in the afternoon and lock the facilities at night. However, although these working hours are sufficient for cleaning purposes, they do not address the issues that arise from vandalism. Furthermore, some of the caretakers locked the facilities when they are not present, which reduces the accessibility of the CABs. The majority of the caretakers locked the facilities at night and the communities require alternative points for defecation.

Although there is no supporting data from this study, common sense would suggest that the presence of a full time caretaker, one that is always on-site, would prevent vandalism or misuse of the CAB facilities. A full-time caretaker would enable the facilities to be open at all times of the day, and that the caretaker would be present at all times to ensure that their reputation is not smeared. Where vandalism does occur, the caretaker should be able to take legal recourse by laying criminal charges against the offenders. It is noted that this hypothesis oversimplifies what is likely to be a very nuanced and delicate balance of social dynamics and that this issue requires further detailed studies.

The operation of the CABs is also dependent on a constant water supply and appropriate disposal of wastewater. Constant water supply has to be managed by ensuring that there is adequate capacity at the water source and adequate water pressure to the facilities. The water pressure can be reduced by illegal water connections from the supply pipelines and these have to be minimised. This effect is noticed directly by the use of the showers. It will also affect toilets and basins during peak periods. Lack of appropriate disposal into sewers, both internally and externally, negatively affects public health by promoting the spread of waterborne diseases. This is directly affected by toilet wastewater spilling within the CABs. Increased greywater around the CABs also reduces the access to the facilities and inadvertently creates barriers for use and can motivate users to not take care of the facilities.

The caretakers are provided with sanitary consumables on a monthly basis to encourage proper use of the facilities, i.e. to reduce sewer blockages. The main sanitary consumables included toilet paper and detergents, which required one 5 ℓ detergent bottle and 235.2 rolls of toilet paper on average per CAB. The caretakers unsystematically distributed the toilet paper to the CABs using their preferred techniques, one of which is by pre-cutting the toilet paper and placing these in a box or bag within each male and female CAB. The caretakers were also provided with mops, brooms, cloths, and Personal Protective Equipment to enable them to perform their caretaker duties. There were currently no methods of distributing soap to the CAB users for hand washing in spite of the extensive research surrounding the benefit of providing soap for hand washing, which cannot be ignored. Creative ways have to be considered to realise these associated health benefits.

8. Recommendations

The key to sustained use of communal ablution facilities lies in appropriate operational capacity. The key success factors to address this issue have already been stated, but there are a number of key points that the author recommends in order to promote sustained use of the facilities. These recommendations are based on the author’s experience in the field and the current body of knowledge.

- The impartial selection of the caretakers is essential to the sustained use of the facilities. This selection process is currently driven by the design engineers and is implemented by the Ward Councillors. The positions should be advertised publicly, whether with posters, flyers, etc., to ensure that all community members have an equal opportunity to apply for the caretaker position as the opportunity of being employed within the settlement is very desirous.
- An interview with the plumbers responsible for the maintenance of the CABs indicated that the use of a full time caretaker would minimise vandalism and misuse (EWS Plumbers 2012). To implement this, it is recommended that a caretaker be appointed on a shift basis, i.e. three caretakers each working 8-hour shifts. This will ensure that the community has continuous access to the facilities and it is hypothesised that this will reduce maintenance costs caused by vandalism and misuse. The increased cost of hiring additional caretakers should not only be compared to the direct maintenance costs because there are other positive consequences of improved conditions within the ablution facilities such as the reduction in open defecation, which has both health and economic benefits to the community. Further research is required to confirm this hypothesis. The cost of a fulltime caretaker is up to six times the cost of the current caretaker arrangement, which is significant. This cost is comparable to the current budget allocated for both operation and maintenance, as discussed further in Chapter 10.
- Although there is a need for caretakers to store the bigger supplies (such as buckets, mops and brooms) and any broken fittings somewhere on-site, the current storeroom setup is not functioning as intended. This could either be achieved through a dedicated room for the caretaker to store the equipment or through providing a more secure enclosed area within the CAB for storage. The dedicated caretaker room could be used for housing the caretaker while on duty.
- The previous two points could be addressed by providing a CAB site that consists of a fence around the entire perimeter with a single entrance and a standalone 4 – 6 m^2 caretaker room positioned at the entrance of the CAB site. This room can be prefabricated, for example, out of wood (wooden hut) or a retrofit container. The caretaker room can be used for storage of the cleaning equipment and also provides a place where the caretaker can be positioned during their shift to ensure that any misuse or vandalism can be dealt with as it occurs. This setup is shown in Figure 9.

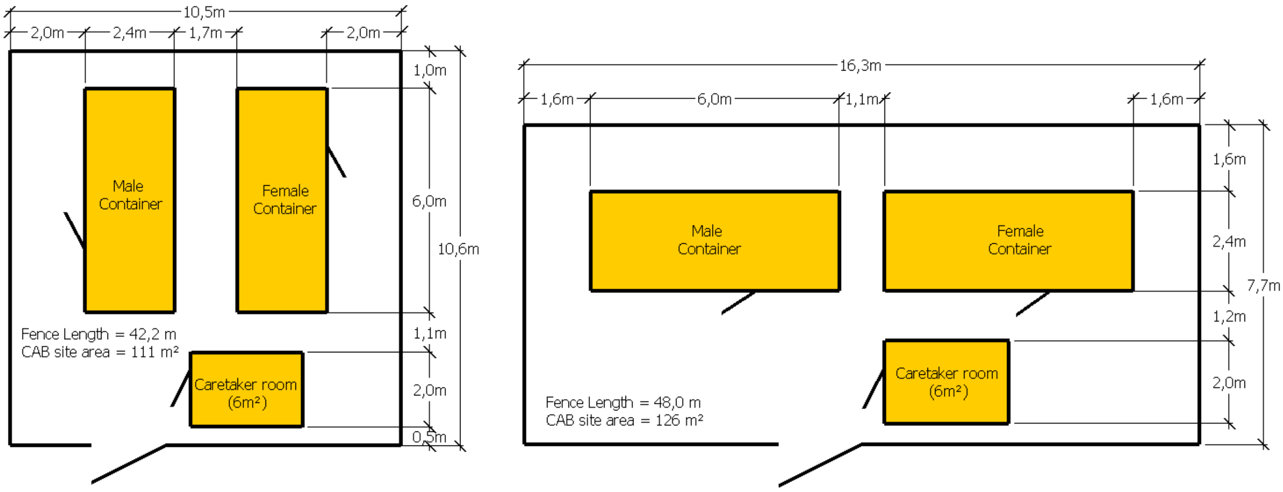

Figure 9: The proposed CAB site setup
The figure indicates two main types of CAB sites that are found around the eThekwini municipal area

- The predominant arrangement of toilet paper distribution was by the caretakers pre-cutting the toilet paper and leaving it within the CABs. It is recommended that this be the encouraged over the distribution of toilet paper to each household.
- The municipality must investigate procuring the toilet paper pre-cut as per the current caretaker arrangement, in order to standardise the distribution of toilet paper. This must be possible due to the magnitude of the toilet paper requirements at the CABs, as the municipality is on average currently purchasing in the order of 50 000 toilet paper rolls per month. At the end of the project, with approximately 3 500 CABs in operation, the municipality will require in the order of 500 000 toilet paper rolls to be issued per month to all of the CABs.
- Soap should be made available to the CAB users for hygiene. However, this should be monitored by the caretaker to ensure that the soap does not get stolen. This could use the MobiSan® approach in Cape Town (Naranjo 2009), where the soap is placed in a stocking and fastened outside the window of the caretaker room.
- Sufficient stormwater drainage with an associated soakaway should be provided external to the CABs, near the laundry facilities to ensure that all greywater can be absorbed into the environment and not remain stagnant next to the CABs. Internal drainage should also be provided to ensure all wastewater be removed from within the CAB. This could be achieved by providing drainage pipes at strategic places within the CAB, i.e. at each corner where there are toilets and under the wash hand basins. These drains should be provided with a steel grid to ensure that no foreign objects are deposited into the sewer
- The effect that the caretakers' gender has on the sustained use of the CABs have to be further investigated. This issue was beyond the scope of the study.
- The poor reporting between the caretakers and the supervisors of which fittings require repair could be addressed by providing basic training to the caretakers to ensure that they, and all role players, use a standard vocabulary for reporting faults.
- Where users cannot use the CAB facilities at night, the CABs should provide a night soil disposal chamber. This chamber could be mixed with the CAB greywater, such as the shower and laundry wastewater, before entering into the sewer network.

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Maintenance

Chapter 9

1. Introduction

This chapter provides an overview of the official maintenance procedures and responsibilities, based on municipal documents and interviews. The maintenance of the CABs is divided into three separate sections, namely maintenance for the CAB structure, the CAB sanitary fittings, and the water supply and wastewater disposal. The three components associated with the CABs are inherently separate tasks requiring different skills and equipment to perform the repairs.

The research questions for this chapter were,

1. What are the official maintenance procedures and guidelines, and are they realised in practice?
2. What are maintenance requirements for each of the CAB components?
    a. The CAB structure,
    b. the CAB sanitary fittings, and
    c. the water supply and wastewater disposal?

2. Background

After two years of experience with the CABs, the EWS implemented a centralised, standard procedure through which maintenance was performed. This need arose from the vast number of CABs and the maintenance requirements associated with each CAB. The maintenance and repairs of CABs was the responsibility of Wastewater Department at EWS, as the CAB essentially becomes their asset (Smith & Dedekind 2011; Sibiya 2012). Through a semi-structured interview with the key stakeholders in the EWS Wastewater Department, including a number of plumbers who make the repairs, it was found that the Wastewater Department inherited the maintenance role from the Construction Department and took ownership of the maintenance of the CABs after the World Cup in 2010 (EWS Plumbers 2012). A previous interview indicated that the maintenance is done by the relevant plumbers, and the work is signed off by the caretaker on site once repaired (Sibiya 2012), this was confirmed by the review of the maintenance records. The official repair time for the CABs is within 48 hours after the fault has been reported. However, in an interview with one of the EWS operation stakeholders, it was stated that at times the plumbers may go out to site for a repair and find that there are other faults on site but do not necessarily have the appropriate spare parts on hand, but will then have to go back to site again at a later stage (Gounden 2012). Furthermore, the maintenance records indicated that there was poor coordination between what the caretakers report as broken and what the plumbers actually repair. This means that the caretakers are at times unequipped to repair the CABs on-site with the necessary fittings as they do not carry stock at all times. The Wastewater Department verbally indicated that this is further compounded due to the fact that the plumbers contracted to the Wastewater Department are employed on a tendered roster basis from a large database of plumbers. Yet, they do not necessarily carry stock of the domestic plumbing fittings and have to go to the hardware stores and supply three quotes which will be tendered, which extends the repair time (EWS Plumbers 2012). The qualitative results from a survey are shown in Figure 1 and the response time from the official maintenance records is shown in Figure 2. The results indicate that the caretakers believe that the municipality take twice as long as the official records state. It is however noted that only 55% of the official maintenance records had accurate data, i.e. the maintenance records had a date on which the fault was reported and the date of repair.

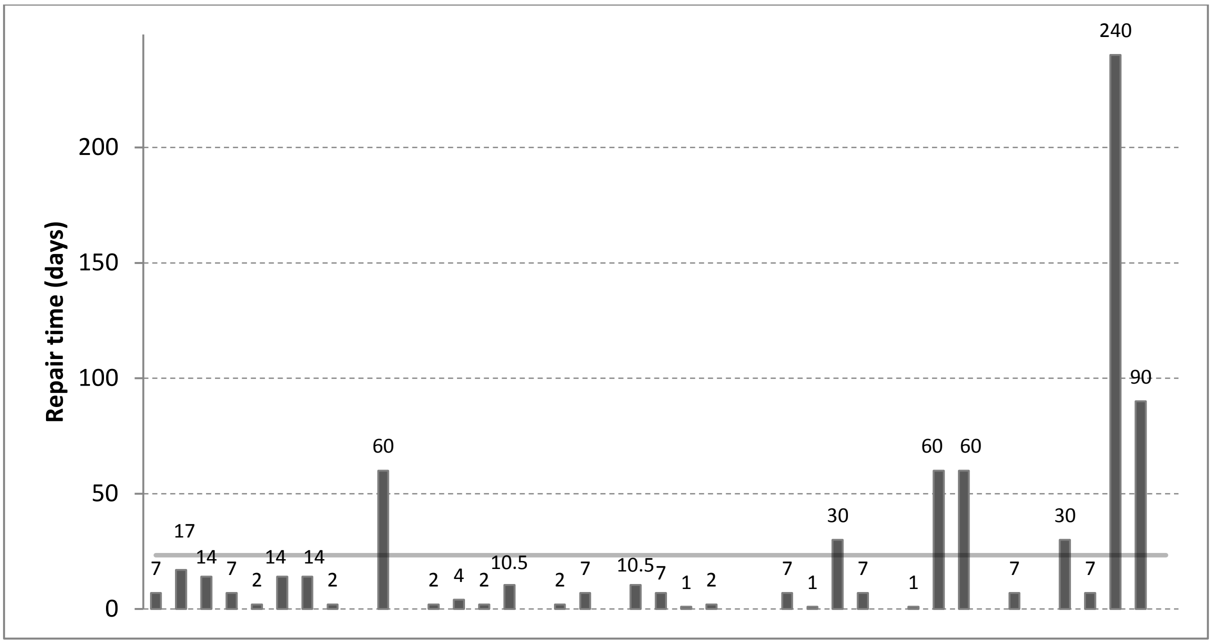

Figure 1: The repair time from 31 CAB sites in August 2012
The average reported repair time was 23.4 days. The results were found from surveys conducted in August 2012, where each of the caretakers were asked how long it typically takes the maintenance team to come out to site once the fault has been reported with the supervisor.

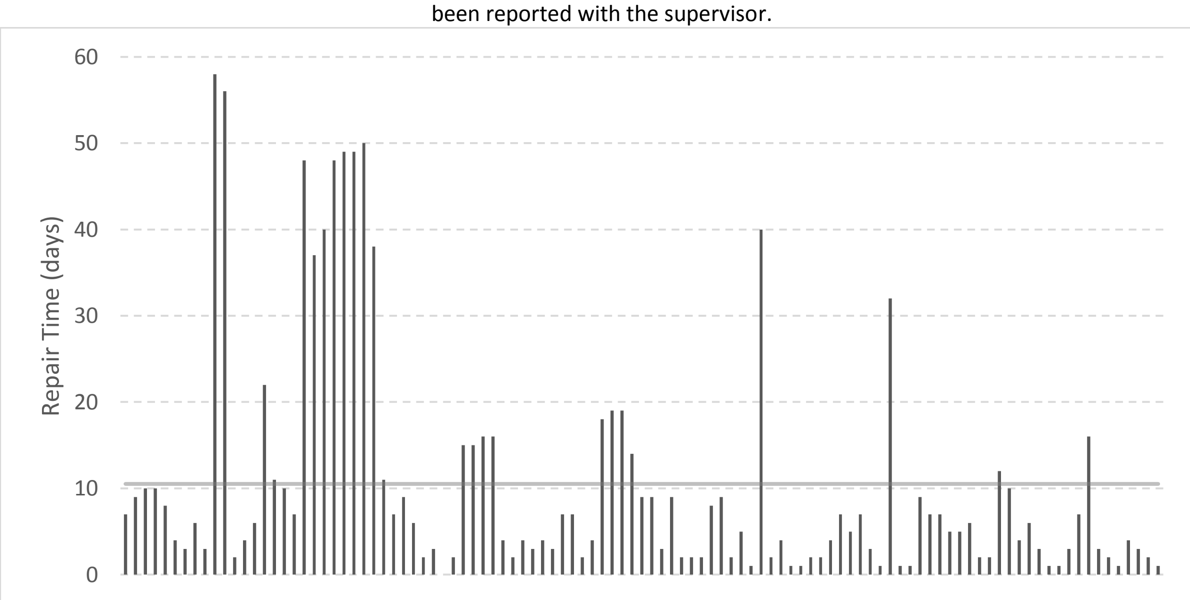

Figure 2: The repair time from 105 maintenance incidences in eThekwini between March '11 and August '12
The average repair time was 10.5 days. It was found that 74% of the incidents took longer than the official response time of 48 hours.

An interview with one of the operational stakeholders indicated that all reporting is traditionally achieved by the caretaker phoning the supervisor to report the faults. However, it was stated that as the month gets to an end, the caretakers do not have airtime to contact the supervisor and subsequently leave the reporting till the next month (Sibiya 2012). Although the municipality has a toll free call centre number where faults can be logged, this is only free from a Telkom telephone line, which is practically non-existent in informal settlements. The interview further indicated that the municipality is in the process of rolling out a toll free call centre number which is free for Cell C cellular phone customers (Sibiya 2012). This would be more accessible for the caretakers who would log the faults to the call centre and not to the supervisors. This would also centralise all maintenance reporting.

The maintenance records are completed by hand and filed at the municipality. However, the majority of the records were found to be incomplete, missing the proper identification for the CABs. Therefore no comment can be made on the extent of maintenance required at each CAB, i.e. how many times the CABs have been repaired in the last year. This should be better managed to ensure that the municipality can identify sites with high risk of failure and can manage these risks properly.

The first issue that has to be addressed is the community's response to the CAB facilities. The interview with the Wastewater Department stakeholders indicated that often when communities have a disagreement within the settlement, the community take their frustrations out on the CABs. Similarly, when the community doesn't want a caretaker to look after a certain facility, the community took their frustrations out physically on the CAB, not the caretaker (EWS Plumbers 2012). Furthermore, in the interview it was evident that an anecdotal perception was that the further away from the settlement the CABs were located, the more the community would vandalise these systems (EWS Plumbers 2012). In such cases, failure has occurred in the planning stage, as the community participation may not have articulated the constraints to placing the CABs closer, further the needs and expectations of the community were not managed. The plumbers indicated that they felt the Ward councillors were responsible, stating "the Ward councillors are to blame, as they had the final say in where the facilities should've been placed" (EWS Plumbers 2012).

The interview highlighted the main aspects that affect the sustained use of CABs include misuse, materials and construction, and blockages and leaks. Firstly, it was stated that the misuse of the CABs was associated with vandalism and theft. Often, where vents have been removed, children will throw sticks and stones into the CABs (EWS Plumbers 2012). It was stated that at times, community members will stole the fittings and used them for personal use. As such, they remove the fittings, take them home, and bring them back to shower with them (for example) when they use the CABs (EWS Plumbers 2012). Secondly, there has to be specific responsibilities assigned to the repair of construction defects. Yet, there was no specific responsibility for correcting this. This causes the facilities to be locked and not handed over to the community for an extended period after the construction is complete. Blockages and leaks were not only found in the sewer pipe from the CAB, but also in the wastewater pipes from the fittings, especially the showers. There are also leaks associated with the wastewater pipes, especially from the toilets and the urinals, which have detrimental health implications.

The maintenance of a water supply infrastructure has been categorised into three distinct forms of maintenance, namely preventive, corrective or reactive (Castro et al. 2009). This type of approach can be applied to the maintenance of CABs. Preventive maintenance is regularly performed to ensure the infrastructure remains in a working condition. This includes water and sewer network inspection, and the cleaning and replacement of sanitary fittings that these routine inspections have identified. Corrective maintenance deals with repairing or changing a poorly designed system. This could either refer to the addition of pumps to a low-pressure water supply or the replacement of faulty pumps. Finally, reactive maintenance occurs in response to a crisis or public complaints. This is the typical form of maintenance taking place for CABs. This form of maintenance includes pipe breaks, blockages or the malfunctioning or leaking of sanitary fittings at the CABs.

This chapter presents a comprehensive overview of the maintenance requirements for the CABs. The results are based on a synthesis of the four site visits conducted in 2011 and 2012 at a total of 97 CAB sites and the maintenance repair records of 337 CABs from the municipality. The maintenance is categorised into a framework consisting of three distinctly independent tasks, as shown in Figure 3. It is noted that although the post-implementation stage (O&M) is critical in the long-term sustained use of the CABs, this is often neglected in practice in typical water and sanitation related projects globally.

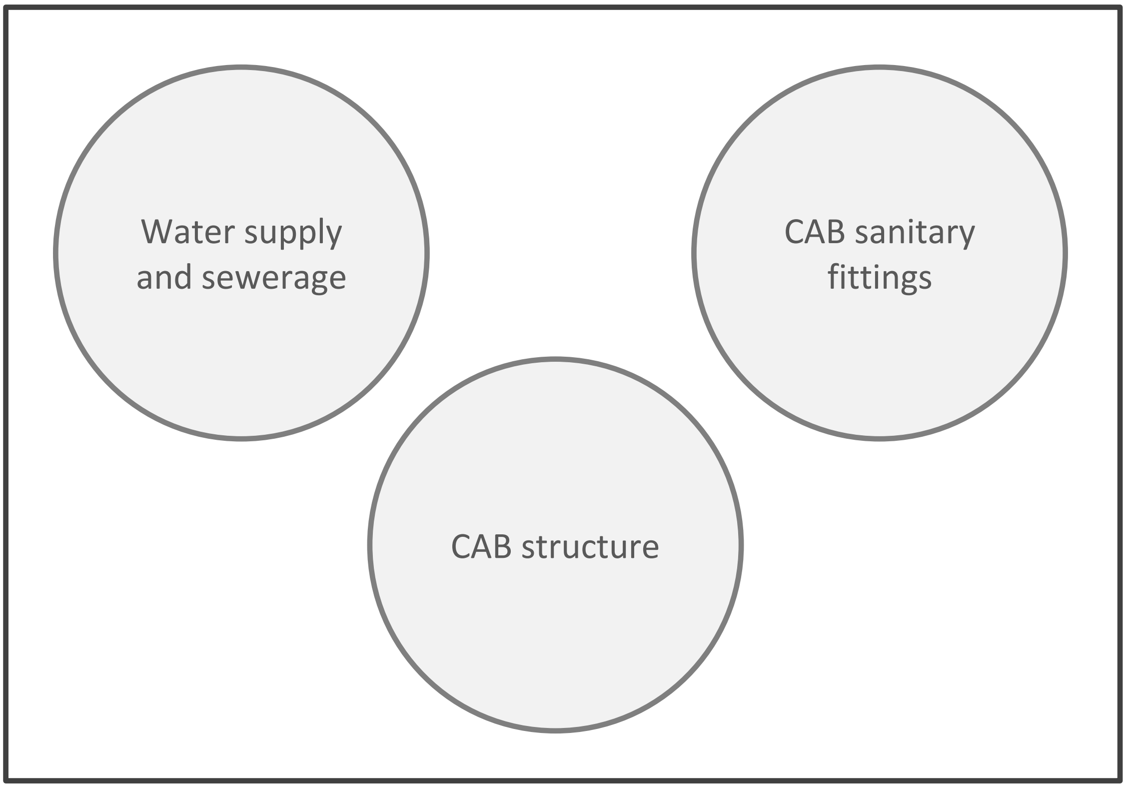

Figure 3: The framework of CAB maintenance
This framework refers to the physical CAB structure and all bulk infrastructure.

Finally, the issue of standardisation is briefly addressed in order to understand how it can be applied to CABs. Standardisation is separated into different categories, as standardisation can be used within institutional policies, institutional capacity, the physical CAB structure and the sanitary fittings. Each of the aspects are addressed independently. This chapter therefore provides not only an understanding of the maintenance requirements of the physical structure but also provides an institutional framework required to ensure the sustained use of the CABs.

Taking the CABs to scale in eThekwini would mean that there would be a significant number of sanitary fittings and other structural fittings that would need to be maintained within the municipal area. This is shown in Table 1, with Table 2 indicating the current requirements for the 290 CABs already constructed within eThekwini.

Table 1: The theoretical number of fittings for the 2 916 CABs in eThekwini at scale

Sanitary fitting		Structural fitting	
Taps	23 328	Windows	37 908
Toilets	20 412	Cubicle doors	34 992
Shower heads	11 664	Whirly birds	5 832
Urinals	5 832	CAB doors	5 832

Table 2: The current number of fittings in use for the 290 CABs constructed in eThekwini

Sanitary fitting		Structural fitting	
Taps	2 320	Windows	3 770
Toilets	2 030	Cubicle doors	3 480
Showers	1 160	Whirly birds	580
Urinals	580	CAB doors	580

The data in Table 1 and Table 2 indicate that a dedicated strategy for procuring, storing and distributing these fittings has to be implemented, with the required staff to realise this process and deliver the necessary fittings. This is a significant task to achieve at scale. For example, assuming that each type of sanitary fitting requires one replacement per month at scale (Table 1), the eThekwini municipality will have to distribute on average 347.9 sanitary fittings per hour, or 2 783.5 sanitary fittings per day, or 13 917.3 sanitary fittings per week. Based on the data from the site surveys, these figures presented above are very conservative, and the actual number of fittings required for CAB maintenance is expected to be significantly higher.

3. CAB Structure

The CAB structural refers to structural aspects of the CAB facility such as the windows, the air vents, the whirly bird, the cubicle doors, the paint, and the CAB door. The interview with the Wastewater Department indicated that one of the main problems associated with the maintenance of the CAB structure arise from vandalism and due to poor construction and materials (EWS Plumbers 2012). Each of these are categorised in Table 3.

Table 3: The categorisation of the problems associated with the CABs
These are either dependent on vandalism or misuse, or due to the limitations of the structure.

Item	Vandalism or Misuse	Physical Limitations
CAB door	✔	
CAB Windows	✔	
Air vents	✔	
Whirly bird	✔	✔
Cubicle door	✔	✔
Paint		✔

The CAB door refers not only to the door breaking or missing but also to the door not working properly, see Figure 5 for examples. This is caused by either the lock breaking or the keys being lost by the caretaker. The results (Figure 4) indicate that a total of 17 CAB sites having at least one unhinged door, whether the door was on site or missing (14%). Where the keys have either been lost or the locks are broken, the CABs either remain unlocked or locked for 24-hours of the day. The consequence of an unlocked CAB is that the caretakers have less control over misuse or vandalism of the CABs. This impacts the caretakers' ability to manage the system adequately. The fact that CABs are locked requires that all the CAB keys be located at a central location which is accessible to the repair teams and managed within the operation and maintenance database associated with the CABs. Yet, although the caretakers reported that the plumbers would repair leaks and blockages, six caretakers reported that the CABs have at times been locked for more than a month. Thus, there seems to be a poor coordination between the plumbers and the municipal authority responsible for the keys and locks.

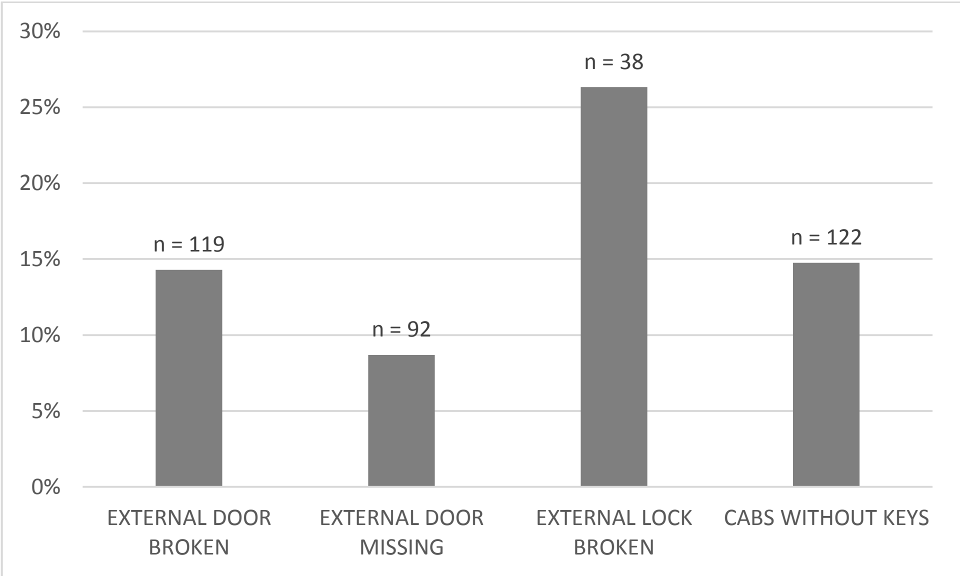

Figure 4: The maintenance associated with the external CAB doors
The sample size (n) of each parameter is shown above the parameter

Where the CABs were not operational due to the facilities being locked for an extended time period – either due to the caretaker having lost the key or the lock being broken, or due to the CAB being locked due to blockages or low-pressure water supply. On average, the CABs that were locked had 3.8 and 2.8 broken windows in the male and female CABs, while in those CABs that were open had on average 1.1 broken windows in the male and female CABs. There was a higher percentage of broken windows (41%) in the locked CABs than in the operational CABs (29%).

Figure 5: Evidence of the type of broken door handles for the CABs

The evidence of broken windows (Figure 6) indicates that vandalism was the major cause of broken windows, as the windows were purposefully broken. The prevalence of broken windows is shown in Figure 7, indicating the percentage of CAB facilities having broken windows. The CAB sites had varying number of windows broken at the facilities, from none to all of the windows. There were a total of 13 windows at each site, six for the male and seven for the female container. Each male and female container had two roof windows for additional lighting in the CABs. A total of 25 CAB sites had broken windows, which on average had 1.8 and 2.0 broken windows in the male and female facilities respectively.

Figure 6: Evidence of the type of broken windows found at the CAB sites

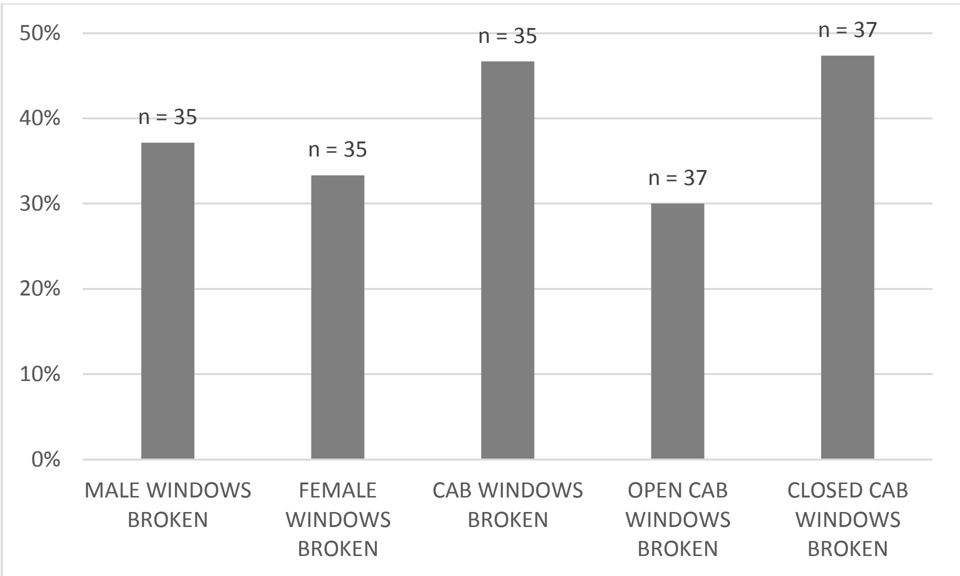

Figure 7: The percentage of CAB windows broken
The data is based on the site visits conducted in August 2012. The site visits conducted in 2011 reported one site had windows broken, however, it was not directly assessed in the site visit. The sample size (n) of each parameter is shown above the parameter.

The air vents in the CABs were used to provide ventilation within the CABs. The air vents were located approximately 500 mm from floor level. The type of air vents (and lack of air vents) found in CABs is shown in Figure 8. However, 12 of the CABs (27%) had missing air vents. As with the windows, 18% of the locked CABs had missing air vents, while in the operational CABs 15% of the air vents were missing. The lack of air vents encourages vandalism, where foreign objects such as sticks, stones, or other such materials were found within the CABs, shown in Figure 9. The lack of an air vent further reduces privacy and impacts the dignity of the CAB users.

Figure 8: Types of air vents found in the CAB facilities

Figure 9: The vandalism associated with missing air vents in the CABs

Improved ventilation within the CAB is provided by both the air vents and the whirly bird. Although missing air vents do not reduce the ventilation in the CAB, the lack of a whirly bird does reduce the flow of air through the CAB. A total of 33 of the CABs (87%) visited in August 2012 had non-working whirly birds. The majority of these were broken not missing, with only two CAB sites having missing whirly birds. A typical example of a broken whirly bird is shown in Figure 10. Where the whirly birds are broken but on-site, the whirly bird can be adjusted back to the working position. This can be performed either by climbing onto the CAB roof or else by using a long stick (such as a broom or mop) to readjust the whirly bird back into position, where the latter is easier to perform. Although this function could be performed by a caretaker, the caretakers need to be educated to perform this task.

Figure 10: Example of a non-functional whirly bird

Broken whirly birds are immediately identifiable as they are not turning and are in a slanted, off centre position

The cubicle doors were typically constructed out of chipboard. The photographic evidence of broken and missing cubicle doors is shown in Figure 11. The lack of cubicle doors has a direct link to privacy and providing a dignified facility for showering and defecation. Furthermore, the storage of caretaker equipment is not secure or safe where the cubicle door at the caretaker storeroom has broken. The results from the surveys associated with broken or missing cubicle doors are shown in Figure 12. The data from 14 CABs which had broken cubicle doors indicated that the male toilet cubicle doors were broken 1.3 times more of the time than the female toilet cubicles. Although this was not investigated, this fact could be associated with the males using the CABs more than the females, or else due to males being taller than the females – causing them to inadvertently push against the cubicle doors.

Figure 11: Photographic evidence of the broken and missing cubicle doors

Figure 11 also shows evidence of water damage to the cubicle doors. Yet, the main reason for the cubicle door failure is due to poor hinge materials. It was found that once the cubicle doors had broken off, the cubicle doors were stored within the CABs, on top of either the shower or toilet cubicles, as shown in Figure 13.

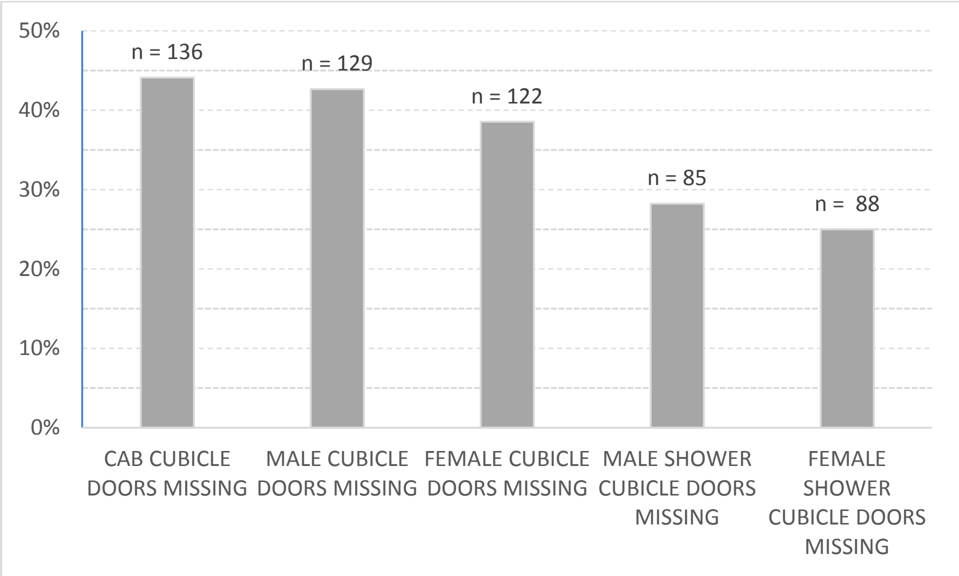

Figure 12: Results for broken and missing cubicle doors in the CABs

Figure 13: Photographic evidence of the storage of the cubicle doors

The final maintenance issue associated with CAB structure is the painting of the facility. The CABs were painted internally and externally. Although this was not directly assessed in the surveys, the photographic evidence (Figure 14 and Figure 15 and also evident on Figure 13) indicates that the CABs would require to be repainted every 1.8 years (663.6 days) on average. This is based on the time interval between the handover of the CAB to the community and the time of the site visit. This value is therefore an underestimation and it is recommended that the CABs be monitored annually to investigate whether the facilities need to be repainted, both externally and internally. This is a preventative maintenance measure. It is hypothesised that the paint wears over time due to the expansion and contraction of the shipping container during the different seasons of the year. Furthermore, the CABs are damp, due to leaks inside the CAB, which also affects the lifetime of the paint, internally and externally. The typical requirements for repainting the CAB would include the scraping off of the old paint and then repainting in order to promote the preservation of the aesthetics of the CAB.

Figure 14: The paint chipping off on the inside of a CAB

Figure 15: Photographic evidence of external paint requiring repair

4. CAB Sanitary Fittings

The maintenance of sanitary fittings can conceptually be broken down as shown in Figure 16. Here, the maintenance can be due to the leaks or breakage of the water supplied to the fitting, structural damage to the sanitary fitting; and leakage and breakage of the wastewater discharge pipes. It is important that all three of these components are accessible for repair after installation.

Figure 16: Conceptualising the three areas that can break at each type of sanitary fitting
Here the sanitary fitting refers to either the toilets, showers, basins or urinals.

In terms of the sanitary fitting, there is a need for standards to be in place in order to ensure that no substandard hardware is installed, as the current hardware was often found to be inferior for the high usage demands typical of CABs. The relevant standards that are currently available in South

Africa include the South African Bureau of Standards (SABS) and JASWIC, as previously recommended in Chapter 6. In the German public toilet facilities, as discussed in Chapter 2, the sanitary fittings are of the same high standard as is used in jails, where there are a high volume of users and the fittings are prone to vandalism. These fittings are constructed out of stainless steel, making the fittings robust and vandal proof. The walls of the toilet facilities are typically constructed out of reinforced concrete, allowing the sanitary fittings to be secured directly into the walls during fabrication. Although such design and construction specifications increase the capital costs associated with the facilities, it reduces the short-term maintenance requirements in replacing broken fittings, which are endemic of the current configuration at the CAB facilities.

4.1 Showers

Showers consisted of two distinct fittings, the shower head and the shower tap, which together enable the shower to function properly, with the tap being more critical to the functionality of the shower than the shower head. However, depending on the installation of the shower plumbing, the loss of a shower head reduced the functionality of the shower for the user but did not stop the shower from being functional, as shown in Figure 17.

Figure 17: The typical configuration of a shower without a shower head
Typically, the pipe on which the shower head is mounted protrudes through the wall and the community is able to use the shower without the shower head.

The synthesis of the survey studies in Figure 18 indicated that the majority of the shower cubicle doors were missing. And that the shower taps were more commonly broken than the shower heads. The loss of either of these fittings was independent of each other, as is shown in more detail in Table 4.

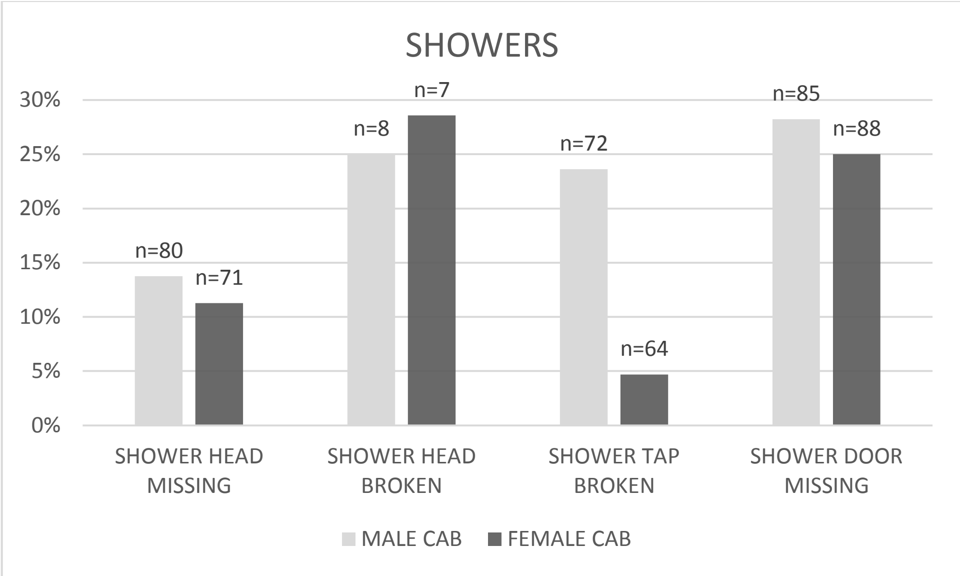

Figure 18: Configuration of showers in the male and female CABs

Table 4: The relationship between shower heads and shower taps in the CABs

The table indicates the relationship between the number of shower heads present in the CABs and the number of shower taps present in the CABs, both of which have a maximum of two per male and female facility. The table indicates that there is no correlation between the two aspects of the shower facility.

FEMALE CAB

Shower taps \ Shower heads	0	1	2
2	0%	0%	71%
1	0%	0%	2%
0	22%	0%	5%

MALE CAB

Shower taps \ Shower heads	0	1	2
2	0%	3%	79%
1	0%	5%	3%
0	8%	0%	3%

The plumbers present during the interview with the Wastewater Department stated emphatically that the showers were one of the main sanitary fixtures that were repeatedly blocked. This was mainly due to poor construction – where the drainage pipe should have a minimum diameter of 50 mm, but often has been reported to be 40 mm. This decreased diameter encourages blockages. Blockages associated with the showers were very difficult to repair due to poor access for the plumbers to the discharge pipes. This was because the only method of accessing the plumbing associated with the showers was through the back of the showers, on the side of the containers. However, this was originally accessible as this area was fitted with doors, but these have been welded shut in order to reduce vandalism. The plumbers gave anecdotal evidence of one site having approximately three blockages per month that have to be repaired constantly. The process of unblocking the fittings could be simplified by providing the caretakers with unblocking products (such as Burnout) and educating them on how to use perform the task of unblocking the drains (EWS Plumbers 2012).

4.2 Hand Wash Basins

The taps were typically attached and secured to the basin itself. Yet, one of the main issues associated with the basins was that the taps were prone to coming loose, which caused the whole tap to turn when the user opens or closes the tap. It was found that 37 of the 132 taps (28%) inspected in August 2012 were not secured and caused the whole tap to turn (Figure 19). This was because the basins were constructed out of plastic and were very thin, preventing the taps from easily being fastened and secured onto the basins. A more successful method of securing the taps and preventing them from turning is to secure the taps directly onto the CAB walls, as shown in Figure 20. This was also stated in the interview (EWS Plumbers 2012). However, the mounting of the taps directly onto the wall requires that the mounting be secure and it is suggested that demand taps, the push-type taps, not be used for this configuration.

Figure 19: The wash hand basin taps turning

Although not always evident in the photos, these taps are loose from the basin and turn when the tap is turned by the user. It is especially difficult to use the plastic taps as these discharge very close to the rim of the basin and inevitably cause the taps to discharge water onto the floor. The turning taps impedes the functionality and comfortability of the system as users.

Figure 20: The wash hand basin taps fasted to the walls of the CAB

4.3 Toilets and Urinals

The toilets were prone to malfunction in two ways, either due to the toilet breaking or leaking. Leakages occurred from the water supply where either washers were broken and the water leaked from the pipes onto the CAB floor or leaked from the cistern into the toilet bowl. The connection between the toilet and the discharge pipe was commonly prone to leaking (Figure 21) which can cause a significant health risk where the wastewater is not removed from the CAB. The plumbers stated that discharge pipe leaks were associated with the seal breaking both from the toilet pedestal moving during transportation of the CAB facility to site and movement of the pedestal from daily use (EWS Plumbers 2012). This movement was caused by the pedestal not being sufficiently secured to the floor of the CAB.

Figure 21: Leaks from the toilet discharge pipe

The toilet discharge pipes leak where the toilet is connected with the discharge pipe (right). The toilet discharge pipes are typically repaired by gluing the two pipes together with an epoxy sealant (left). Where this has not yet been done, one caretaker used a plastic container (right) to catch leaking water from the discharge pipe and would empty the containers on a regular basis.

The toilet breakage was due to either the flush mechanism breaking (Figure 22), preventing adequate pressure to build up to allow for flushing, or due to the toilet seat breaking (Figure 23), with the results shown in Figure 24. Missing or broken toilet seats can be expected from the number of people who use the facilities. Although the toilet seat is not associated with catastrophic failure of the toilet, it affects the user experience.

Figure 22: The broken flush mechanism from the CAB toilet cisterns (August 2012)
In the left and middle photos, the flush mechanism has broken off from the flush handle and the users have to flush the toilet by manually lifting the flush mechanism. On the right, the flush mechanism and flush handle have both broken and the caretaker closed of the water to the cistern by clamping the pipe within a plastic bottle to prevent the water from continuously leaking into the toilet bowl.

Figure 23: Missing and broken toilet seats (August 2012)

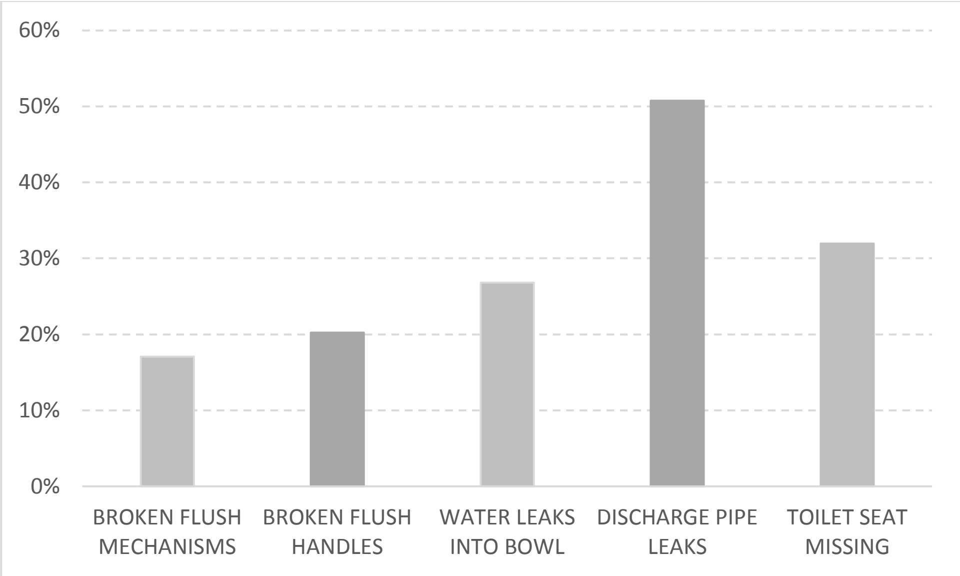

Figure 24: The characteristics of the toilets facilities
The results are based on a total of 491 toilets in both the male and female facilities of 70 CABs. The variation between the data from the male and female facilities were negligible.

Urinals consisted of two parts, namely the urinal bowl and the flush mechanism. The main part of the urinal that malfunctioned was the flush mechanism, either the piping to the urinal or the flush mechanism itself, as shown in Figure 25. Typically each urinal was provided with its own flush mechanism. From the survey in August 2012, it was found that 60% of the flush mechanisms were conventional taps, i.e. they had to be turned to be engaged, and 24% were demand taps, i.e. they had to be pushed to be engaged (from 34 CAB sites). Both urinals were also found (12% of the time) to be provided with a shared flush mechanism, such that when the flush is engaged both urinals are flushed. In three (4%) of the urinals there was no flush mechanisms that were working, which increases noxious odours from the stagnant urine. Continuous leaking into the urinal bowl was only recorded for 5% of the CAB facilities.

Figure 25: Different urinal configurations found in the CABs (August 2012)
The top photos show the urinals sharing a conventional tap for the flushing mechanism. The bottom left photo shows the urinals each with their own demand tap. The bottom right photo shows how the water supply to the urinals has been vandalised and does not work.

4.4 Laundry Facilities

The laundry facilities are the most susceptible to vandalism as they are located externally to the CABs and cannot be locked at night or when there is no caretaker supervision. The user behaviour at the laundry facilities is shown in Figure 26 and the problems associated with laundry facilities are shown in Figure 27 and Figure 28. Figure 29 provides the statistics from the surveys conducted in 2011 and August 2012. The poor drainage from the laundry facilities (Figure 29) although mostly associated with the leaking discharge pipes could also be associated with users performing laundry washing in a bucket next to the CAB facility and discharging the wastewater into the surrounding environment. This was however not formally investigated, but there was anecdotal evidence of washing being performed in buckets as the basins were occupied by other users.

Figure 26: The user habits at the laundry facilities

The top photos show that the laundry facilities are also used as a water supply point where water can be collected and carried off site for domestic purposes. The bottom left photo indicates how the basins are used for washing laundry. It is evident that the basins are filled with water and soap and the clothes are left to soak and are then washed. The bottom right photo indicates how the caretaker has put locks on the taps to ensure that unauthorised people do not use the laundry facilities. It can be seen from the bottom photos that the basins have been fastened with an epoxy to prevent the basin coming loose from the wall of the container.

Figure 27: The problems associated with the laundry facility structures

The photo on the right shows that the laundry basin has been removed from site, but that the users are still using the taps as a water source for collecting water. This is evident from the concrete block which helps to elevate the water bucket or tank. The photo on the left shows a laundry basin where the taps have been vandalised and stolen. Although the taps no longer provide direct water into the basins, the basins are at times still used for laundry purposes by transporting water from the other laundry basin or a nearby standpipe into this *dry* basin.

Figure 28: The problems associated with the wastewater discharged from the laundry facilities
The top photos show how the discharge pipes from the laundry facilities have loosened from the basin and discharges water directly into the surrounding environment. The facility in the top left photo is dry due to the water being turned off at the CAB facility due to other broken sanitary fittings. The bottom photos indicate the greywater discharges into the environment due to poor drainage of the laundry facilities. Although not directly investigated, this poor drainage could also be due to the users performing washing in buckets and discharging the wastewater next to the basins.

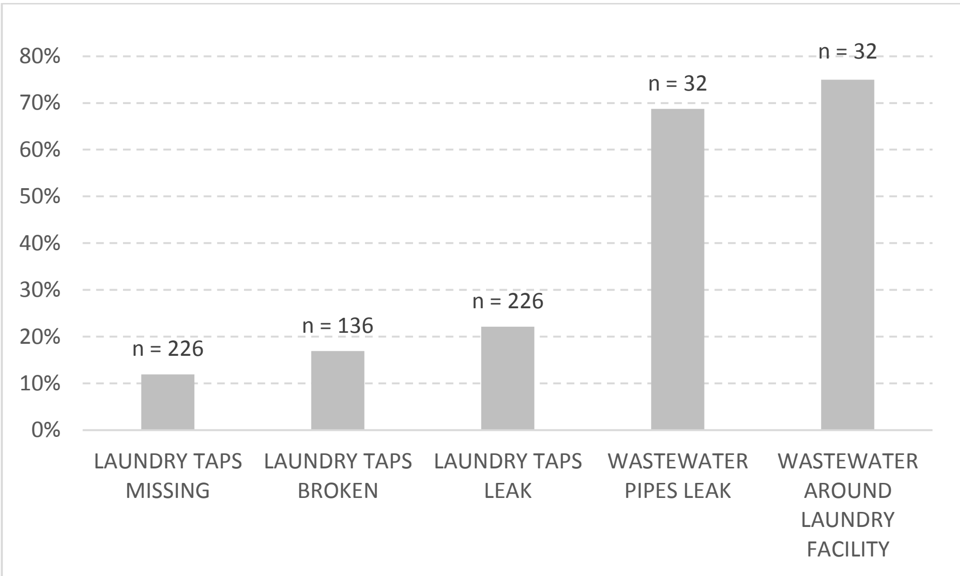

Figure 29: The statistics associated with the maintenance of the laundry facilities
The results were found from both the surveys conducted in 2011 and in August 2012. The results indicate that there is poor drainage of the greywater discharged from the laundry facilities and that there is a high percentage of greywater around the laundry facilities.

The comparison between plastic and non-plastic taps used at the laundry facilities is shown in Figure 30. The results were based on the data from a survey that investigated 47 CABs in 2011. The results indicated that non-plastic taps were twice as prone to breaking as plastic taps, where non-plastic taps refer to brass or chrome-plated brass taps.

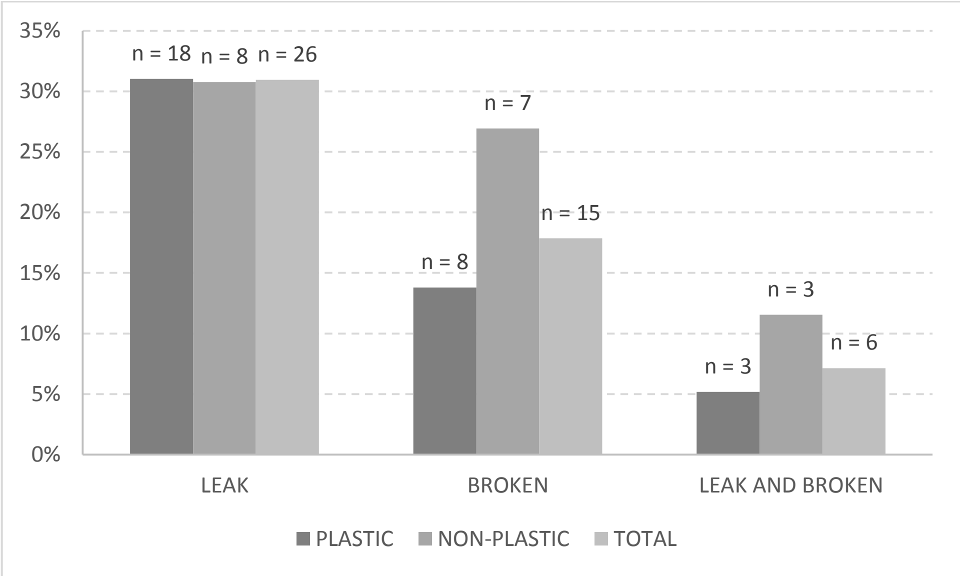

Figure 30: Comparison between plastic and non-plastic taps at the laundry facilities
The results are based on 84 taps from the survey of 47 CABs conducted in 2011. The results indicate that there is no difference between the leaks of plastic and non-plastic taps. The results however indicate that non-plastic taps are approximately twice more susceptible to breaking, and breaking and leaking than plastic taps.

5. Water Supply and Wastewater Disposal

The final aspect that has to be considered is the water supply and wastewater disposal. The water supply can fail due to low water pressures in the CAB which mean that the facility cannot operate. This is said to be caused due to illegal water connections. In such cases, the water pipes have to be inspected and adequate measures be taken to restore the water supply to the facilities. This was not a common phenomenon, but was found at one of the 38 sites visited in August 2012.

The wastewater disposal can be inhibited where the sewers are blocked. This is caused due to misuse of the toilets, where materials other than toilet paper are used for anal cleansing, such as newspaper, papers or tissues. From the survey of 47 CABs in 2011, it was found that 13% of male and 9% of female toilets had evidence of other anal cleansing materials and in August 2012 from 33 CABs it was found that 30% of male and 15% of female CABs had evidence of other anal cleansing materials. The results from 183 maintenance records indicated that 28% (51) of the time the maintenance teams had to unblock the sewers. Where sewers are completely blocked, the CAB disposes all of the water around the CAB, internally and externally. This causes the toilets to be full of excrement and cause the surrounding environment to be contaminated with polluted water. The results of a blocked sewer are shown in Figure 31.

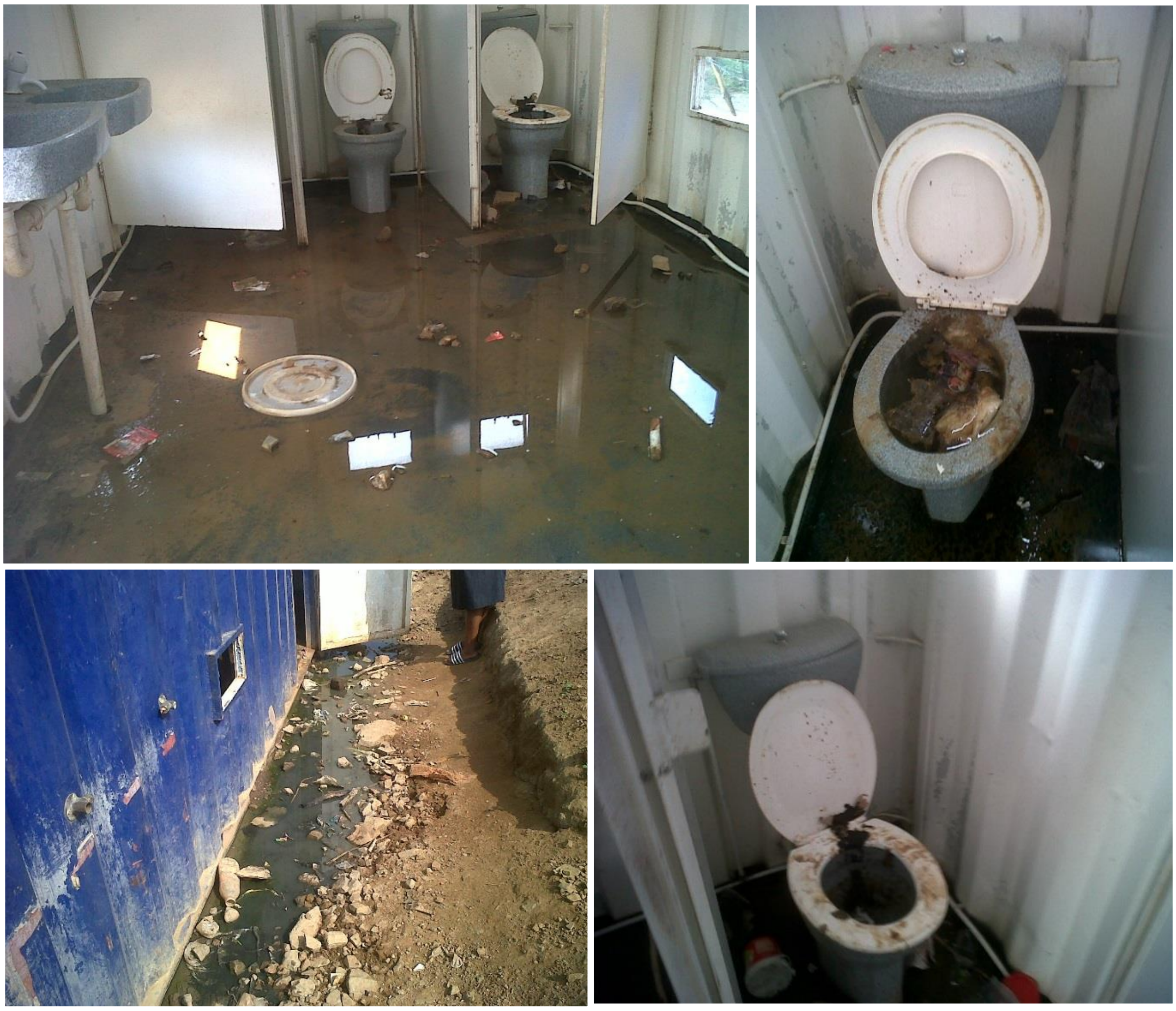

Figure 31: The consequence of blocked sewers within the CAB facility

From the study in August 2012, it was found that 20% of the 32 reported CAB facilities had broken external wastewater pipes, as shown in Figure 32. This not only exposes the users to human excreta, but will also expose the environment to the excreta in situations where the sewers become blocked and the wastewater runs out of these broken pipes.

Figure 32: Vandalism of the discharge pipes
The wastewater discharge pipes are all found external to the CABs and are easy to vandalise by breaking the pipe (top left). The top right photo shows a rodding eye, which is used for routine sewer inspection, has been broken. The bottom left photo shows a discharge pipe with faeces in it. The bottom right shows a wash hand basin discharge pipe which has been broken and the water greywater is discharging directly into the environment.

6. Summary of Results

The chapter provided insight into the maintenance requirements associated with CABs. This section synthesises the results in an attempt to rank the main issues to address in providing sustained CAB facilities. The three areas associated with the CAB maintenance, which includes sanitary fittings, CAB structure, and water supply, are all defined and then ranked systematically. The toilets and showers are characterised by all three of these maintenance areas, as they have a sanitary fitting (such as the toilet structure), CAB structure (the cubicle door) and drainage issues (blocked sewer or leaking drainage pipe). The parameters are defined in Table 5 and each of these parameters are ranked in Table 6. Ranking of the fittings is based on the municipality's responsibility to maintain the CAB facilities, i.e. synthesising how often each component fails and what effect it has on the community. The percentages used in Table 6 are based on failure frequency. The rubric used in this analysis was conceptualised and clearly defined before the parameters were ranked in order to remove the author's bias from the ranking of the parameters.

Table 5: The definitions used to rank the parameters associated with the maintenance of CABs
The parameters are each identified according to the origin of the maintenance, whether due to the fitting, CAB structure, or drainage. This indicates the responsibilities that have to be performed by the maintenance teams. Missing fittings and broken fittings are both referred to in this table as broken fittings for economical use of words.

Type of Fitting	Type of Problem	Affects Health	Affects Use	Affects Dignity	Affects Comfort	Promote Misuse
Toilets	F S D	Toilet leaks in discharge pipe and toilet does not work. Sewer blocked	Toilet mechanism or handle broken	Cubicle door broken. Sewer blocked	Toilet seat broken	No toilet paper. Sewer blocked
Showers	F S D	Wastewater inside CAB. Sewer blocked	Tap broken	Cubicle door broken	Shower head broken	Shower head or tap broken
Laundry	F D	Wastewater around CAB	Tap or basin broken	Tap or basin broken	Wastewater around CAB	Wastewater around CAB
Basins	F D	Basin does not work	Basin does not work		Tap turns or leaks	Tap turns or leaks
Cubicle Doors	S			Broken doors	Broken doors	Broken doors
Windows	S			Broken windows	Broken windows	Broken windows
Paint	S				Peeling paint	Peeling paint
CAB Doors	S	CABs locked or keys missing		CAB door/ handle/lock broken	CAB door/ handle/lock broken	CAB door/ handle/lock broken
Air Vents	S			Broken vents	Broken vents	Broken vents
Whirly Birds	S				Broken whirly	

F = Maintenance required due to the CAB sanitary fittings
S = Maintenance required due to the CAB structure
D = Maintenance required due to the water supply and sewerage (drainage)

It may be argued that toilets should be of primary importance to the maintenance teams as the provision of sanitation is often seen as the provision of a toilet. However, sanitation does not only include the toilet structure, but considers the sanitation system, which emphasises the user interface (toilet structure), wastewater disposal, and treatment. The results from ranking the parameters indicate that the major concern should be the reparation of the drainage of the laundry facilities, which has an effect on the environmental and public health. However, this is complicated by the fact that the evidence of poor drainage is not only due to the laundry drainage pipes breaking, but also due to the community performing laundry washing in buckets next to the wash basins. This water is often discharged next to the CABs, which results in stagnant water around the CAB facilities. Thus, the reparation should not only address the sanitary fitting, but should also address the need of wastewater disposal from other water sources through providing an additional drain and providing relevant education to the community and the caretaker.

Table 6: The ranking of the maintenance issues
The maintenance issues are ranked based on the sum of the occurrence of each of the parameters.

Rank	Fittings	Type of Problem	Affects Health	Affects Use	Affects Dignity	Affects Comfort	Promote misuse	∑
1	**Laundry**	**F D**	75%	29%	17%	75%		196%
2	**Toilets**	**F S D**	44%	20%	28%	32%	33%	157%
3	**Windows**	**S**			47%	47%	47%	140%
4	**Basins**	**F D**	36%	36%		30%	30%	132%
5	**Cubicle Doors**	**S**			42%	42%	42%	125%
6	**Showers**	**F S D**	6%	14%	27%	27%	26%	99%
7	**Paint**	**S**				46%	46%	92%
8	**CAB Doors**	**S**	15%		21%	29%	21%	86%
9	**Air Vents**	**S**			27%	27%	27%	82%
10	**Whirly Birds**	**S**				34%		34%

F = Maintenance required due to the CAB sanitary fittings
S = Maintenance required due to the CAB structure
D = Maintenance required due to the water supply and sewerage (drainage)

It is important to stress that the maintenance of the CABs does not only involve the repair or replacement of sanitary fittings, such as replacing taps or unblocking drains. There are maintenance issues concerning the CAB structure, such as the cubicle doors, that have a significant effect on the use of the facilities.

7. Case Study: Frasers

The four CABs in Frasers informal settlement were included in the survey conducted in August 2012. All three of the caretakers were present during the survey. It was determined that the caretakers last reported a fault in June (Site 5), July (Site 2 and Site 3) and the beginning of August (Site 1). The most common sanitary fittings that breaks and leaks were unanimously said to be the toilets. The caretakers reported that the repair response time being two days Site 5 and Site 1, and 14 days for Site 2 and Site 3.

Structurally, the CABs were in working condition, with no broken windows or discharge pipes, or missing vents or cubicle doors. Yet, Site 2 and Site 5 had non-functional whirly birds. There was water internally in three of the CABs which originated from the toilet discharge pipes. The caretaker at one of the sites had temporarily solved the problem by placing a bucket under the leaking discharge pipe (see Figure 21). Site 2, Site 1 and Site 5 all had at least one toilet seat missing. Site 1, which had been repaired two weeks prior to the survey, had two toilets which did not have flush handles or working flush mechanisms. The laundry facilities and showers were all in working condition but the wash hand basins were not working in Site 3. The wash hand basins in Site 5 had been replaced with plastic tap and the shower taps were replaced at Site 5 and Site 3. There was greywater around all of the laundry facilities of all four sites. This should not be a maintenance issue, as it is a consequence of inferior design or construction that should be reconsidered in future CAB designs in order to reduce the known health risks associated with stagnant water.

From these four sites it is evident that maintenance is essential in sustaining the facilities. Although the oldest facility (Site 5) was commissioned less than eight months prior to the survey, the female shower taps and male wash hand basins had already been replaced. The shower taps were replaced due to the metered taps malfunctioning. None of the replacement fittings were specifically water efficient but they are expected to be durable against high use, which will ultimately reduce leaks.

8. Conclusions

The chapter has highlighted the post-implementation state of the CABs and although some of the issues can be classified as issues relating to pre-implementation stages, due to inferior design of the CAB facility and poor material quality, maintaining these defects becomes the liability of the maintenance teams and require institutional structures in place to monitor, report and repair these defects. Successful maintenance strategies require appropriate user education, quality hardware, and minimum time to attend to the maintenance issues. This chapter has shown that there are some major issues that have to be addressed for the sustained implementation of CABs in eThekwini. Essentially, the current state of the CABs is inadequate to meet the needs of the communities.

Although the maintenance of the CAB facilities is pivotal to the sustained use of the facilities, it was found that the maintenance is not currently implemented as is theoretically intended. Officially, the maximum time between the repair has been reported and the maintenance team goes out to site is 2 days, but in practice, the average time is 10.5 days, with the caretakers qualitatively estimating the average repair time to be 23.4 days. This lack of immediate and urgent response from the maintenance teams promotes not only vandalism and misuse but potentially negates hygiene education initiatives conducted in the settlement. It also promotes open defecation and also reduces the caretakers' urgency to make the telephone call to their supervisor and report the faults in the first place, which perpetuates poor maintenance and leads to the CABs being in a derelict state. There also needs to be a consistent vocabulary between all the role players associated with maintenance to minimise miscommunication, such that the defects can rapidly be repaired.

The use of a shipping container is theoretically very advantageous in the rapid placement and rollout of the ablution facilities on-site, as these can be prefabricated off-site, the containers can easily be relocated off-site for refurbishment, and the containers can be removed once the settlement is upgraded with a full level of service. However, all of the hardware is retrofit into the thin metal walls of the container, which leads to flimsy joints between the hardware and the container itself. Here the hardware refers to the sanitary fittings, air vents, cubicle doors, windows, and water and drainage pipes which are retrofit within the CAB facilities. This means that the repairs of communal facilities are not only plumbing related. These three independent maintenance tasks require that the maintenance teams either have a wide training to deal with all of these areas or else that three different maintenance teams be instated to deal with each dimension independently.

Communal sanitation facilities are able to provide a basic service to a large community and are seen as the only solution where household sanitation services are not appropriate due to financial and physical limitations within the settlement. However, when these facilities are non-operational, they affect a large community which is a significant environmental and public health concern. Thus, the motivation to provide state of the art support for the maintenance of these facilities is imperative in providing improved sanitation services to all. The scale of the project in eThekwini, which is expected to reach in the order of 3 000 CAB facilities over the next 14 years, will mean that there will have to be a streamlined process between all the role players involved in the process. Furthermore, the large number of sanitary fittings, such as approximately 20 000 toilets, and structural components, such as approximately 35 000 cubicle doors, means that the municipality will have to have adequately stocked storage facilities which are strategically placed throughout the municipal area such that the dedicated maintenance teams can effectively perform the repair tasks.

9. Recommendations

It is important that all reported defects from the caretakers be dealt with rapidly. Failure to address these requests from the caretaker can have a number of knock-on effects, such as resentment between the community and the municipality; lack of rapid reporting from the caretaker to the supervisor; negative impact on any hygiene education conducted within the settlement, etc. Thus, it is important that the official response time be upheld at all times and that this be monitored regularly.

In order for there to be a responsive maintenance plan there is to be an open and accessible channel through which the faults can be logged at each CAB. It is recommended that toll free numbers not only be made available to the caretakers but to everyone in the community. This would provide a "community voice" whereby the community can report faults if the caretaker is not proactively reporting the faults. To this extent, stickers should be stuck internally and externally on each CAB such that it is visible to all.

The poor reporting of repairs could be mitigated by providing the caretakers with an assembly drawing for the entire CAB, where each part is labelled with a code. Assembly drawings are frequently used for car maintenance (see Figure 33 for example) and repairs and simplify the communication between the factory or stockyard and the reseller. The assembly drawing booklet for the CABs could be provided to each caretaker who would simply have to relay the quantity and code for each fault back to the call centre and the maintenance team would be able to be properly equipped to make the necessary repairs without having to go back to site at a later date with the appropriate materials.

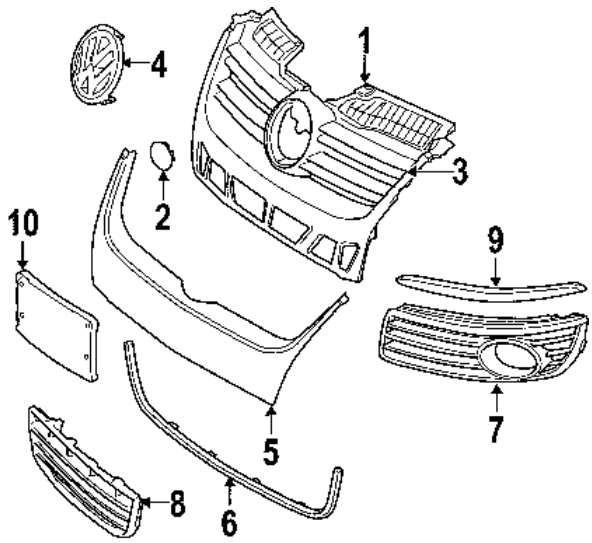

Figure 33: An example of an assembly drawing used in the replacement of car parts (VWvortex 2012)

A proposed maintenance schedule for the CAB structure is given in Table 7. The replacement equipment for each part of the CAB structure should be kept in a central location which is accessible to the maintenance team. The required skills, not only plumbing related, should be included with the training of the maintenance teams.

Table 7: The maintenance schedule for the CAB structure

	EFFECT OF FAULT	REPAIR EQUIPMENT AND MATERIALS	REQUIRED SKILLS
CAB DOOR	Hinge breaks	Screw driver, hinge	Handyman
	Door missing (stolen/broken)	New door and hinge	Carpenter
WINDOWS	Glass breaks	Glass cut to size and putty	Glass fitter
AIR VENTS	Vent missing	New vent (steel mesh) and screws or welding equipment	Welder
WHIRLY BIRD	Whirly bird not working	Long stick (broom) to nudge it back in place	Caretaker
	Whirly bird stolen	New whirly bird	Handy Man
CUBICLE DOORS	Hinge breaks	Screw driver, hinge	Handy Man
	Door missing (stolen/broken)	New door and hinge	Carpenter
PAINT	Paint peels off	Paint, paint brush, scraper	Painter

Adequate access must be provided for any repairs to all of the sanitary fittings. Furthermore, valves should be in place to ensure that where sanitary fittings are leaking or broken, the caretaker can turn off the water serving that fitting to ensure that minimum water losses occur until the fitting is repaired.

It was indicated by the plumbers that for the showers, the main problem was blockages (EWS Plumbers 2012). Therefore, it is recommended that the drainage pipes should be increased in diameter in order to reduce any blockages that occur. The proposed minimum diameter is 120 mm. Furthermore, the caretaker should also be provided with the required materials to unblock the drains and should not have to rely on the maintenance teams.

The hand wash basins should be provided with either demand or conventional taps, however, the placement of the taps should depend on the type of taps selected. To this extent, demand taps should preferably be attached to the basins and conventional taps preferably attached to the container wall.

The toilets should ideally be provided with adequate measures to prevent any wastewater discharging internally into the CAB as this is a significant health hazard. To this extent, the toilet discharge pipe and the toilet pedestal should be fastened with an epoxy resin once the CABs are delivered on site.

Standardisation is necessary to ensure that the maintenance can be performed continuously and prevent any snags in the repair of the CAB facilities. The sanitary fittings themselves do not have to be standardised, as they are typically replaced by the available fittings in the EWS warehouse when they are broken. The non-standardisation of the sanitary fittings ensures that there can be flexibility in the implementation of new and more durable types of sanitary fittings. It is recommended that the fitting types be monitored to determine their appropriateness and durability. Structurally, each CAB is provided with standard window, door and vent openings in the retrofit shipping container. The sizing of the cubicle doors are standardised through the containers being the same size. Therefore, the CAB is sufficiently standardised in the physical structure of the containers and the sanitary fittings. Where other types of CAB containers are used, i.e. prefabricated dry-wood containers used in dense settlements, there have to be sufficient materials available to maintain the facilities. In general, the different types of facilities provided throughout the municipal level should be minimised. There is a need for standardisation to be implemented at an institutional level. This includes the reporting of faults to a central location where records can be logged digitally. The responsible supervisors should be notified on the progress of all repairs from a centralised location. The maintenance teams should be trained accordingly and the responsible teams must promptly be notified of all repairs required at the CABs. It is recommended that the maintenance records be completed electronically to ensure that all of the information is recorded, as the manually recorded sheets were often incomplete. This would enable the municipality to identify problematic areas where additional interventions, such as community education programmes for example, can be implemented.

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CAB Costs and Funding

Chapter 10

1. Introduction

The aim of this chapter is to understand the cost implications associated with the rollout of these facilities, both in the pre-implementation and post-implementation stages of the CAB lifecycle. Costs have purposefully been excluded from the preceding chapters because costs are inherently bound to a specific time and quickly become outdated. In order to prevent the thesis from being outdated, the costs have been condensed into this (single) chapter. This chapter does not go into the detailed costs of each stage in the project but provides an estimate of the average costs based on available data. A number of detailed costs that are excluded from this analysis, such as the professional fees, i.e. the cost of the project managers and design consultants in the design and construction stages. The National Housing code stipulates the project management costs cannot exceed 8% of the total cost of the works (DHS 2009). The project management and the design consultants' fees for the provision of communal ablution blocks in eThekwini were predicted to be in the order of 2% and 11% respectively of the total cost of the works (Dedekind 2010). Furthermore, a number of the operational and maintenance costs were excluded from the lifecycle cost analysis, such as

- the employment of the caretaker supervisors,
- supporting staff,
- where required, the cost of buying the land from private landowners,

However, although these costs affect the life cycle cost of the CABs, this chapter provides sufficient information to plan and budget for similar communal water and sanitation facilities similar to those being implemented by the eThekwini municipality.

This chapter provides average household costs based on the design population density per CAB, i.e. 50 – 75 households, although it was found in practice that the mean population served by CABs is 108.1 households. The motivation for documenting the costs at the design population density throughout this chapter is because this is the density for which the CAB rollout programme plans to provide services throughout eThekwini and this is the budget which the municipality uses to budget and plan for the provision of the CAB facilities.

The funding available for informal settlement upgrading in South Africa are different to those in other parts of the developing world, where the residents have to rely on their own resources to improve their water and sanitation conditions. In South Africa, government funds (grants) are dependent on the current national priorities and these grants will vary over time. This chapter introduces the current funding environment for informal settlement upgrading in South Africa through government grants. The chapter also provides data, where available, of the costs associated with each stage in the rollout of CABs throughout the eThekwini municipality.

2. Government funding for sanitation provision in South Africa

The funding available to reach the sanitation backlog in South Africa has always been inadequate. This is seen through the required capital costs for sanitation provision increasing significantly from

R4.5 billion (US $0.70 billion[1]) in 2004 (DWAF 2004) to R13.5 billion (US $1.7 billion) in 2012 (Vawda 2012) to reach the goal of universal sanitation access within the proposed date set out by national government. Thus, the capital investments required to meet the sanitation backlog are immense and cannot be done in isolation or ad-hoc, based on available funds at a local level, but must be implemented in an integrated and strategic approach for long-term sustainability, as has already been stressed in Chapter 2. This is because sanitation is not only about the provision of toilets, but requires continuous operation and maintenance which has to adequately be planned for. This long-term development strategy is based on the local government's Integrated Development Plan (IDP) which forms the basis for all development planning within the municipal area, encompassing the Water and Sanitation Development Programme (WSDP). It is important that the local government's IDP aligns with the provincial government's strategic plans (DWAF 2004). The IDP is the main tool for funding and allocation of resources.

In the mid-2000s, there were three main sources of basic sanitation funding in South Africa, namely the Municipal Infrastructure Grant (MIG) for capital costs of infrastructure development, the Equitable Share (ES) for operation and maintenance costs, and internal municipal revenue and cross-subsidisation. Two additional grants, which are administered through the Department of Human Settlements have recently been implemented, namely the Urban Settlements Development Grant (USDG) and the Rural Household Infrastructure Grant (RHIG) (Tissington 2011). The available funding for the local government to provide basic services in the upgrading of informal settlements are available from (PPT 2010a; PPT 2011),

- Upgrading of Informal Settlements Programme (UISP),
- Urban Settlements Development Grant (USDG),
- Project Linked Subsidy grant (PLS),
- Municipal infrastructure Grant (MIG),
- Emergency Housing Grant, and
- Integrated Residential Suburbs Programme (IRDP).

The funding for the provision of interim and permanent services make allowance for the capital costs associated with service delivery, which includes community participation, land acquisition and rehabilitation, planning and design, and the capital cost and installation of the services, whether interim or permanent (NUSP 2010; DHS 2009). The funding places a cap on the project management fees at eight per cent of the total project cost, in order to focus on the provision of the infrastructure (DHS 2009).

The UISP fund can be used in those settlements earmarked for in-situ upgrading in the Integrated Development Plan (IDP) for the provision of interim and permanent services and potentially for emergency services and is contained in the National Housing Code of 2009 and is founded on Section 3(4)(g) of the Housing Act (PPT 2011; DHS 2009). The USDG has replaced the MIG cities grant and its main objective is providing basic services to poor households through the provision of bulk, connector and internal infrastructure. The USDG can be used for interim and emergency basic infrastructure (PPT 2011). This grant has been used extensively in the provision of Community Ablution Blocks in eThekwini. The USDG is administered by the Department of Human Settlements

[1] All US dollar values based on an average exchange rate of the year (X-Rates 2013). See Appendix G for the average annual exchange rates.

to assist accredited metropolitan municipalities to provide bulk water and sanitation services to well-located areas near social and economic facilities and opportunities. The grant integrates the release of land in well-located areas to the function of planning and funding of the built environment. The grant is directly aligned with Outcome 8 of the presidential service delivery (Tissington 2011). The USDG is only available to accredited municipalities (PPT 2010b). The current accredited municipalities for the 2011/2012 Urban Settlements Development Grant include (Sibanda 2011),

- The City of Johannesburg,
- eThekwini Municipality,
- The City of Cape Town,
- The City of Tshwane, and
- Nelson Mandela Bay Municipality.

The Emergency Housing grant can be used for emergency housing and basic infrastructure (PPT 2011). The IRDP grant is used where informal settlements are upgraded, but do not make use of incremental upgrading – such as using emergency services or interim basic services (PPT 2010a). The MIG was first introduced in the 2005/2006 financial year and was a ring-fenced, conditional grant funding the capital cost of basic infrastructure to poor households, and could be used to provide funding for waterborne sanitation in informal settlements, where it was shown that the sanitation backlog within the jurisdiction is being addressed in their IDP or WDSP (Mjoli 2009; DWAF 2007a; DWAF 2004). The maximum allowable MIG grant value in 2012 for the VIP was R7 400 (US $900) and for waterborne sanitation was R21 300 (US $2 600) per household, assuming an annual increase of eight per cent (DWAF 2007b).

The funding is released based on the municipalities' IDP strategies. The UISP funding is released on an annual basis to the Provincial Departments from National Government in terms of the provisions of the Division of Revenue Acts. It is administered by the Provincial Housing Department and the National Department of Human Settlements (PPT 2010a). Although the UISP grant requires a minimum of 10% co-financing for the capital costs of the entire upgrading process, this grant should not exclude those municipalities who can demonstrate that they are unable to source the required co-funding (DHS 2009). The UISP further places the responsibility of the O&M of all infrastructure on the municipality, including social, community, economic and municipal infrastructure facilities. These O&M costs should be sourced from non-housing sources in the municipality (DHS 2009).

The O&M costs are sourced from the ES grant and municipal revenue from tariffs and cross-subsidisation from the high income users to low income users. The ES grant is an unconditional grant meant for O&M but it can be used at the municipality's discretion, and in practice is often spent on overhead costs, such as salaries, and the eradication of the sanitation backlog (Still et al. 2009; Mjoli 2009). It is transferred from National Treasury to municipalities through CoGTA. The grant is based on the number of indigent households within its jurisdiction. Cross-subsidisation works where the high income population is able to subsidise the costs of the indigent population. But, this is not always the case where there are a high proportion of rural areas within the municipal jurisdiction. Careful analysis of costs and tariffs are required at a local government level to ensure that this cross-subsidisation is sustainable and the O&M of all services can be implemented.

3. Planning stage – Estimated costs

In order to plan efficiently, it is important to have guideline cost estimates for the provision of interim services in order to secure grant funding and to manage internal resources. These projects are substantial and for eThekwini, where interim service delivery is a very high priority project, the 2011/2012 financial year was estimated to benefit 9 500 informal settlement households at a budgeted cost of R190 million (US $26 million), which is equivalent to R20 000 (US $2 800) per household. Yet, the rate at which these services can be provided is dependent on funding and institutional capacity (EH 2012). Table 1 provides an overview of which funding mechanisms can be used for upgrading an informal settlement for the different categories, as defined by the eThekwini municipality in Chapter 3.

Table 1: Funding available to the different components in the upgrading of informal settlements

Category	Purchasing Land	Permanent Services	Interim Services	Emergency Services	Top-Structures	Relocation
1	USDG / IRDP	USDG / IRDP	n.a.	n.a.	IRDP	Partly RG
2	UISP	n.a.	USDG	n.a.	UISP	Partly RG
3	n.a.	n.a.	n.a.	USDG / EH	n.a.	RG
4	n.a.	n.a.	n.a.	EH	EH	RG

USDG Urban Sustainable Development Program
IRDP Integrated Residential Development Program
RG Relocation Grant
UISP Upgrading of Informal Settlement Program
EH Emergency Housing Assistance Program
n.a. not applicable

The cost of providing water and sanitation services is dependent on the location and density of the settlement. The estimated unit cost of providing a medium sized water scheme to 5 000 households in South Africa is in the order of R8 000 (US $1 100) per household. This unit cost can double for the same scheme located in deep rural areas of KwaZulu-Natal (CoGTA 2011). Although these factors affect the unit cost estimates, a baseline household cost estimate is provided in Table 2. It is important to note that where the provision of interim services requires existing households to be relocated, the households are each compensated with R2 500 (US $300).

Table 2: Average estimated household costs of the provision of interim services, with costs based on the South African Rand in 2010 (PPT 2010b)

Interim service	Household costs	eThekwini contribution	External Funding
Road & footpaths (primary & tertiary roads only with footpaths & stormwater controls)	R5 000	R5 000	R0
Communal ablution blocks	R4 946	R4 946	R0
Bulk water and sewer connectors	R4 386	R4 386	R0
Household electricity connections	R5 000	R0	R5 000
Total	**R19 932** ***US $2 700***	**R14 832** ***US $2 000***	**R5 000** ***US $690***

4. Construction stage – Actual costs

The data from the 302 CAB related projects from the project managers were cleaned, and a total of 249 CABs were found to be applicable for the cost analysis of the construction stage, i.e. the CABs had a construction cost greater than zero. The actual cost for the construction of these 249 CAB sites in 96 informal settlements throughout eThekwini is presented in Figure 1 and Figure 2. There was a poor correlation between the constructed CAB infrastructure and the population size of the settlement in Figure 1. This was hypothesised to be due to delays experienced in the construction period and also the physical conditions of the settlement, such as the distance to existing water and sewerage infrastructure and the topographic conditions. There seemed to be a better correlation between the number of CABs per settlement and the unit cost of providing CABs, as shown in Figure 2. Counter-intuitively, the trend indicated that the unit cost of providing CABs to a settlement increased as the number of CABs within the settlement increased. The one exception was the provision ofseven CABs to a settlement, which had a higher unit cost than providing eight CABs to another settlement. This exception was assumed to be due to the lack of available data points for settlements having more than five CAB facilities.

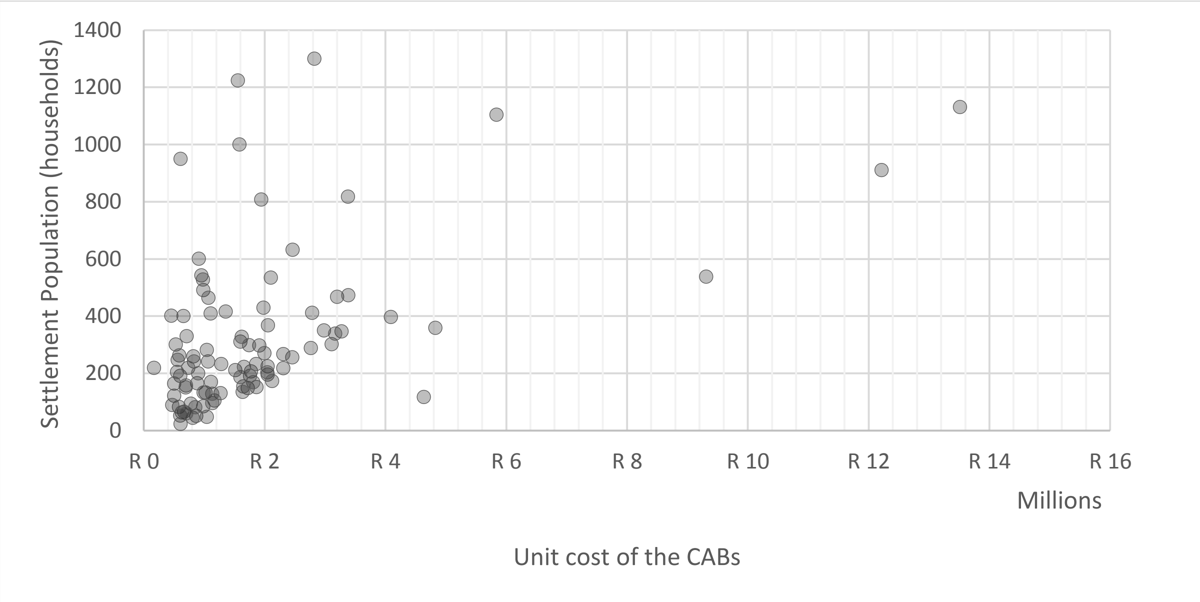

Figure 1: The relationship between the population and the cost of the CABs per settlement
The unit cost of the CABs was calculated based on the total cost of the CABs and the connecting infrastructure for the entire settlement divided by the number of CAB facilities per settlement. This graph is based on 249 CAB sites in 96 informal settlements. It indicates that there is poor correlation between the population size of the settlement and the cost of the infrastructure to the settlement. This is expected as the infrastructure is not only dependent on the number of facilities to be constructed, but also on the distance to the existing infrastructure and delays in the construction period.

The increased unit cost of the CABs with increased CABs per settlement was based on the fact that the CABs did not only include the cost of the containers, but also the cost of extending the water and sewerage infrastructure to the CABs from the bulk pipelines. The majority of the CABs required individual extension pipelines from the bulk pipelines and did not share the cost of these extensions between CABs.

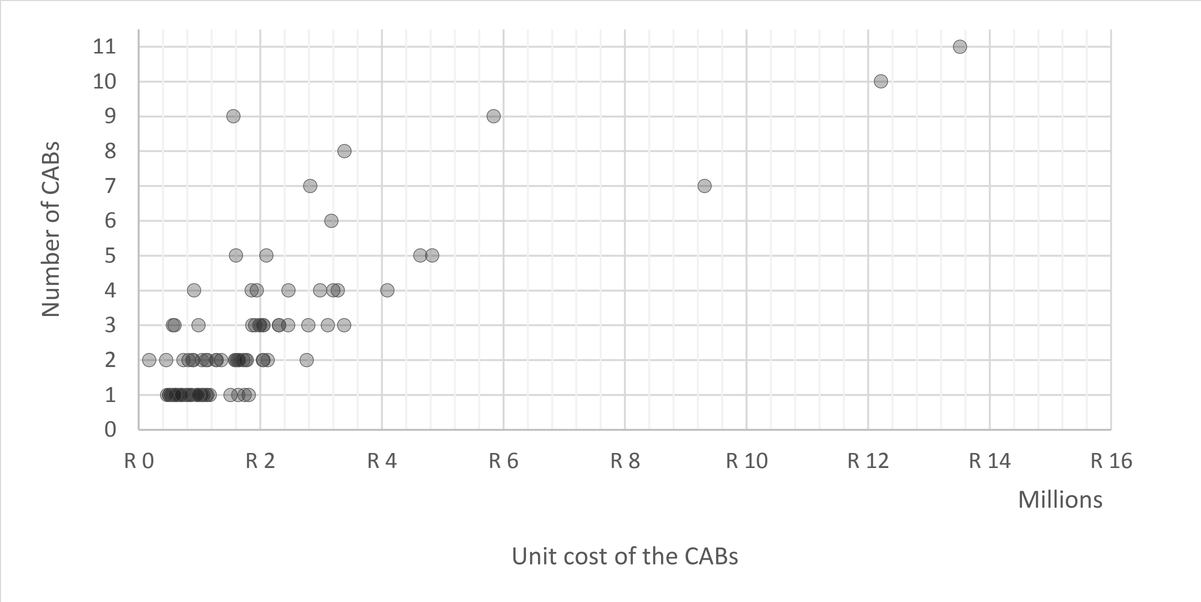

Figure 2: The relationship between the number of CABs and the cost of the services per settlement
This graph is based on 249 CAB sites in 96 informal settlements. It indicates that although the trend is that the cost of the CABs does increase with the increased number of CABs per settlement, there is a large spread between the costs for each unit CAB.

The CAB costs were analysed by dividing the total construction cost by the number of CABs per settlement. The results are shown in Table 3, which indicated that the median household cost per CAB for 50 – 75 households is between R9 400 – R14 000 (US $1 100 - $1 700) for the capital costs.

Table 3: The cost of providing the CAB facilities
The results are based on the unit cost of CABs per settlement (column 1) and then dividing the costs for a design value of 50 - 75 households (column 2 and column 3). The results are based on 249 CAB sites in 96 informal settlements.

	per CAB	**per 50 households**	**per 75 households**
Average	R764 512.60 *US $93 000.00*	R15 290.25 *US $1 900.00*	R10 193.50 *US $1 200.00*
Median	R707 791.87	R14 155.84	R9 437.22
Standard Deviation	R331 256.73	R6 625.13	R4 416.76
Minimum (5th percentile)	R228 109.78	R4 562.20	R3 041.46
Maximum (95th percentile)	R1 343 768.57	R26 875.37	R17 916.91

The cost of the prefabricated CAB container was R75 000 (US $9 100), or R150 000 (US $18 000) for the male and female container. The median cost can thus be divided into two categories, the bulk water and sewer connectors and the prefabricated container, as shown in Table 4.

Table 4: The median capital cost of providing the CAB facilities

	per CAB	**per 50 households**	**per 75 households**
Prefabricated container	R150 000.00	R3 000.00	R2 000.00
Bulk water and sewer connectors	R557 791.87	R11 155.84	R7 437.22
Total Capital Cost	R707 791.87 *US $86 000.00*	R14 155.84 *US $1 700.00*	R9 437.22 *US $1 100.00*

5. Post-implementation stages

Although it has been stressed that the post-implementation stages of water and sanitation provision is crucial for sustained use of the infrastructure, most sanitation business plans do not have adequate operation and maintenance strategies in place (DWAF 2004). The funding for operation and maintenance are not accessible through the capital grants, such as the USDG and the MIG and this has to be funded through the Equitable Share grant as well as the municipality's own revenue sources. The successful implementation of communal ablution facilities will require that the local governments have not only defined roles and responsibilities for all the stakeholders and support, but also adequate funding streams to manage the operation and maintenance of the facilities. The eThekwini Water and Sanitation Unit estimated the average cost of operation and maintenance per CAB to be in the order of R12 000 (US $1 500) (Gounden 2012). Furthermore, the operation and maintenance has to perform adequate asset management to deal with the challenge of ageing infrastructure, which can affect the local government's water and sanitation delivery programme (CoGTA 2011).

5.1 Operation stage

The three main components associated with the operational costs of the CABs included the cost of employing a caretaker, providing cleaning materials, and providing toilet paper to each of the CABs. The operating cost for the CABs was carried by the eThekwini municipality and the households were not charged for the use or sustainability of the facilities. There were additional costs that were not included in this cost analysis, such as the employment of the caretaker supervisors and supporting staff, and where required, the cost of buying the land from private landowners. This study only investigated the direct costs associated with the operation of the CABs.

As of February 2012, the caretakers were employed to work an average of four hours per day (1 460 hours per annum) and were paid R1 800 (US $220) per month (R21 600, US $2 600, per annum). The eThekwini municipality was able to secure funding from the Extended Public Works Programme Incentive Grant (EPWP) to pay the caretaker salaries (EM 2011). The caretaker salary was an unconditional salary, and the caretakers were paid whether the CABs were operational or not. This unconditional payment arrangement is not ideal, as it does not incentivise the sustained use of the facilities. But such incentivisation strategies may be detrimental to the health of the community as it may, for example, cause the caretakers to lock the facilities when there are no caretakers at the CAB. This practice was already evident at some of the CAB sites.

The caretakers were provided with an initial caretaker starter-pack, which includes mops, brooms, brushes, buckets, personal protective equipment, disinfectants and toilet paper. This amounted to an annual cost of approximately R600 (US $73) (Sibiya 2012). Once the CABs were operational, the only recurring monthly cost was the cost of the toilet paper and the disinfectant. The toilet paper was provided in a pack of 48 rolls – costing R119.04 per pack and the disinfectant (Germatol) was available in 5 ℓ bottles at R44.50 (US $5.42) (Sibiya 2012).

The final cost that formed part of the operation of the system included the monthly tariff for the water supply and wastewater disposal. This varies for each municipal area. In eThekwini, the water is supplied by Umgeni Water, who charged R4.63/kℓ incl-VAT (US $0.56/kℓ) for the 2012/2013 financial year. The revenue the municipality makes from domestic water supply is charged on a sliding scale, based on the amount of water used and the wastewater disposed into a sewer. This is shown in Table 5.

Table 5: The tariff charged for domestic water consumption and wastewater discharge into a sewer (EM 2012)
This table is based on the eThekwini water tariffs for 2012/2013. VAT in South Africa is 14%.

Domestic water consumption and wastewater discharged	Charges per kℓ water consumed (incl-VAT)	Charge per kℓ wastewater discharged (incl-VAT)
Consumption below 9 kℓ/month	NIL	NIL
Consumption 9 – 25 kℓ/month	R8.71	R3.60
Consumption 25 – 30 kℓ/month	R11.94	R4.94
Consumption 30 – 45 kℓ/month	R26.28	R10.88
Consumption above 45 kℓ/month	R28.91	R11.98

The total cost for the operation of the CABs is presented in Table 6. The results are presented at different time intervals, which provide the monthly, annual, and decennial costs associated with the operation of the CABs. The decennial costs are provided as this is the time required before formal upgrading within the settlement is expected to occur. The results indicated that the majority of the costs in this stage of the project (44%) were used for paying the caretaker salaries, followed by the cost of supplying water and disposing of the wastewater (37%), and then the cost of providing toilet paper (14%). The decennial costs assume a compound annual increase of 6.25% based on the average inflation rate from 1993 – 2012 (inflation.eu 2012). This increase aims to account for annual increases that are expected to occur. Finally, the results provide a cost estimate for the households, based on the design population of 50 – 75 households.

Table 6: The total costs associated with the operation of the CABs in eThekwini
The monthly cost estimate is based on the first month of operation, where the caretaker starter-pack is given to the caretaker. This starter-pack is reissued ever 4 – 5 months. The 10 year cost estimate is the cost of operating the CAB over a 10 year period, based on an annual increase of 6.25%.

Item	Monthly Cost Estimate	Annual Cost Estimate	Decennial Cost Estimate
Water supply*	R1 161.84	R13 942.09	R185 939.66
Sewer discharge (treatment)**	R370.36	R4 444.33	R59 272.15
Caretaker	R1 800.00	R21 600.00	R288 069.96
Consumables (starter-pack)	R664.36	R1 526.27	R20 355.17
Consumables (monthly)	R658.95	R7 907.35	R105 456.97
Total Cost per CAB	**R4 118.34** ***US $500***	**R49 420.04** ***US $6 000.***	**R659 093.90** ***US $80 000.00***
Total Cost per Household***	**R54.91 – R82.37** ***US $7 - $10***	**R658.93 – R988.40** ***US $80 - $120***	**R8 787.92 – R13 181.88** ***US $1 100 - $1 600***

*Assuming 110 ℓ/hh/d * 75 household * 365 days / 12 months / 1000 ℓ per kℓ * R4.63
** Assuming 85 ℓ/hh/d * 75 households * 365 days / 12 months / 1000 ℓ per kℓ * R1.91
***Assuming 50 - 75 households per CAB

5.2 Maintenance stage

The maintenance relates to the repair and replacement of the sanitary fittings, such as taps, shower heads, toilets; structural components, such as windows, external and internal doors, whirly birds; and unblocking sewers. These costs were acquired for the repairs of the sanitary fittings and the unblocking of sewers by the maintenance team over a two week period, from 26 July 2012 to

9 August 2012, where 27 CAB sites were repaired, and 11 of these (41%) had to be repaired and the sewers had to be unblocked. The average time spent at each site was 5.1 ± 0.1 hours, where the average cost for each site was R1 199.59 (US $150).

Based on the site visits and surveys, it was estimated that each CAB site required regular maintenance to be performed on a monthly basis. Although no costs were available for the structural repair work, these costs were assumed to be in the same order as the costs associated with the repair of the sanitary fittings and sewer unblocking. Estimating, conservatively, that on average all of the cubicle doors, windows and the external doors have to be repaired or replaced once per annum, and the CABs have to be repainted once every 22 months, the average monthly cost of repairing the CAB structure was found to be in the order of R5 000.00 (US $610). This estimate was made, based on the site visits, as this data was not recorded by the eThekwini municipality. This estimate of R5 000 (US $610) for maintenance thus provides an approximation of the costs required to maintain the CAB facilities. This meant that the estimated household maintenance costs is in the order of R66.67 – R100.00 (US $8 - $12) per month for the design population of 50 – 75 households per CAB facility.

It is noted that the combined operation and maintenance cost estimated from the available data amounts to R9 118.34. This is in the order of the monthly operation and maintenance cost of R12 000.00 estimated by the municipality (Gounden 2012).

6. Discussions

The funding required for each project stage is summarised in the following tables, with Table 7 presenting the costs per CAB facility, and Table 8 and Table 9 presenting the costs for a design population of 50 – 75 households per CAB facility.

Table 7: Average cost of a single CAB facility

	Capital Investment	**Monthly Cost**	**Annual Cost**	**Decennial Cost**
Capital Cost	R 707 791.87			
Operation Cost		R4 118.34	R49 420.04	R659 093.90
Maintenance Cost	`	R5 000.00	R60 000.00	R 800 194.34
Total O&M Cost		R9 118.34	R109 420.00	R1 459 288.20
		US $1 100	US $13 000	US $180 000

Table 8: Average household cost of a single CAB facility shared by 50 households

	Capital Investment	**Monthly Cost**	**Annual Cost**	**Decennial Cost**
Capital Cost	R 14 155.84			
Operation Cost		R82.37	R988.40	R13 181.88
Maintenance Cost		R100.00	R1 200.00	R16 003.89
Total O&M Cost		R182.37	R2 188.40	R29 185.77
		US $22	US $270	US $3 600

Table 9: Average household cost of a single CAB facility shared by 75 households

	Capital Investment	Monthly Cost	Annual Cost	Decennial Cost
Capital Cost	R 9 437.22			
Operation Cost		R54.91	R658.93	R8 787.92
Maintenance Cost		R66.67	R800.00	R10 669.26
Total O&M Cost		R121.58	R1 458.93	R19 457.18
		US $15	US $178	US $2 400

The results from Table 8 and Table 9 indicated that the capital investment is more expensive than the funding available for VIP toilets (R7 400, US $900), but less expensive than full household waterborne sanitation services (R21 300, US $2 600). However, the median capital investment for the CABs was between R9 400 – R14 000 (US $1 100 – $1 700) depending on the number of households served by each facility, which was more than the planned cost of R9 300 (US $1 100) for the provision of CABs.

The annual operation and maintenance costs were between R1 500 – R2 200 (US $180 - $270) per household for the CABs. This O&M cost is ten times larger than the O&M cost of a dry sanitation system, such as a VIP toilet, which was R180 (US $22) per annum assuming the pit will be emptied every eight years, and is higher than the O&M cost of an in-house flush toilet with waterborne sewers, which is R1 200 (US $150) (DWAF 2007b).

7. Conclusions

The provision of basic interim services requires sufficient funding to design and construct the infrastructure and then to maintain and operate the facilities for sustained use. In South Africa, contrary to the majority of the developing world, the responsibility is on the local government to provide and ensure the sustained use of all interim water and sanitation services.

The results from the rollout of CABs throughout eThekwini indicated that the household capital costs were in the order of R9 400 – R14 000 (US $1 100 – $1 700) per household for 50 - 75 households per CAB facility. The major component of the capital investment (79%) was used for extending the water and sewer pipelines into the informal settlement, which will form part of the long-term infrastructure.

The cost of operating and maintaining the CAB facilities was higher than that of a dry sanitation option, such as a VIP toilet, and a domestic waterborne sewer connection. The major cost of operation (44%) was paying for the caretaker's salaries, followed by the cost of supplying water and disposing of the wastewater (37%), and the cost of providing toilet paper (14%). It is important to note that the cost of operating the CABs in eThekwini is equal to the initial capital investment within 5 years of implementation. And thus, sufficient planning must be performed during the planning stage in order to ensure that the municipality has sufficient funding that will keep the facilities operational once the facilities have been handed over to the community. Although there are a number of government grants available for the capital costs, the O&M of water and sanitation services has often been neglected throughout South Africa. The O&M has to be covered by the municipal revenue, cross-subsidisation and the Equitable Share grant.

This chapter provided an initial estimate of the costs involved in the provision of communal ablution facilities as interim measure in the upgrading of informal settlement. The additional costs not included in this study included the cost of professional service providers, such as project managers, design engineers, environmental management protocols; purchasing of land where required; hygiene and education; and supporting staff for the coordination of the operation and maintenance, such as caretaker supervisors. These costs have to be considered in order to ensure that sufficient funding is available to ensure the sustained use of the facilities.

8. Recommendations

The main recommendation is ensuring that sufficient funds are available to perform the required operation and maintenance of the facilities. It is not recommended that grant funding be made available for the maintenance of the facilities, as the availability of funds may have a detrimental effect on the sustainability of the facilities, as it may inadvertently promote vandalism and misuse. However, it is suggested that funding be made available for the operation of these facilities, especial in those municipal areas where internal funding is limited. This would include subsidies for the caretakers, sanitary consumables, and water supply and wastewater discharge into the sewer, as these components are fundamental to the sustained use of the facilities. Based on limited data, the maintenance costs were estimated to be in the order of R70 – R100 (US $8 - $12) per household per month. However, with proper community buy-in, education and more durable, higher quality sanitary fittings, it is hypothesised that this cost could be reduced. Where there is a willingness to pay for improved facilities, i.e. facilities that work, the municipality could negotiate with the community to carry the cost of the maintenance themselves through a pay-per-use or a monthly fee per household.[2]

In Chapter 8 it was identified that the use of a full time caretaker could potentially reduce the incidence of vandalism and misuse, which would reduce the required maintenance costs. The cost of employing a caretaker for 24 hours, 365 days a year would require a salary of R10 800 (US $1 300) per month. Although this is approximately the total current budget for both operation and maintenance, this could make use of external grants, such as the Extended Public Works Programme Incentives Grant as the provision of a caretaker promotes job creation within the informal settlement.

[2] The pay-per-use should be between R0.20 – R0.50 per use for settlements with on average 2 – 5 persons per household, assuming three trips to the CAB facility per day. The monthly fee would then equate to between R18 – R46 per person.

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Conclusions

Chapter 11

1. Background

The desktop study of the occurrence of informal settlements in Chapter 1 indicated that South Africa is not isolated in the prevalence of informal settlements. Informal settlements are a global phenomenon and are a permanent part of the urban landscape in the majority of the developing world cities. In Africa, it has been estimated that half of the urban population is housed informally and in South Africa this accounts for approximately 12 million people – a quarter of the urban population. Informal settlements are often seen as a blight on the urban environment by local governments and formal and informal residents. However, these settlements are often the only entry point into the city. And it has been argued that without informal settlements, the poor would be excluded from the potential benefits associated with living in an urban environment. But informal settlements have typical characteristics, such as a lack of basic services (such as roads, electricity, water, sanitation, stormwater drainage and refuse removal), inadequate and substandard housing, overcrowding, unhealthy and hazardous environmental conditions, insecure tenure, and poverty and exclusion. There are a number of factors which lead to their occurrence, but the consequence of their existence is characterised by poor public and environmental health. This has an effect not only on the informal residents but also on the surrounding urban population.

Due to the large prevalence of such poor settlements, it is considered that informal settlements will remain a part of the urban environment of South Africa and the developing world for the following decades. The process of upgrading informal settlements cannot be solved with quick fix solutions but must form part of the immediate and sustained long-term strategic development goals of all developing world governments, including South Africa. The South African government has had a significant policy shift, from the provision of housing to the provision of basic services. The government has an informal upgrading policy in place which aims to upgrade informal settlements through a process of incremental upgrading. This is achieved through the rollout of interim basic services to the settlement that meet the immediate needs of the community before the rollout of formal housing. These interim services are to dovetail with the formal household services to reduce fruitless expenditure on infrastructure. This policy shift is very important, as the majority of informal residents' aim is to provide shelter whether or not basic services are available or able to be implemented. This upgrading policy further promotes accountability between the provincial and local governments such that upgrading is in line with the integrated development plan of both tiers of government to ensure that the development of land is strategically implemented.

The provision of formal housing without adequate wastewater disposal does not improve the poor environmental conditions typical within informal settlements. Thus, the provision of improved water and sanitation services is considered the prime development objective in informal settlement upgrading, as acknowledged in the upgrading policy, where communal water and sanitation provision forms the first step in the upgrading process. However, the policy guidelines are very broadly defined, providing local authorities flexibility in the selection of appropriate technologies. Yet there has been a poor rollout of these interim communal water and sanitation services throughout South African informal settlements since publication of the upgrading policy three years ago (2009). This could either be (i) due to poor institutional capacity and coordination or (ii) lack of understanding of the appropriate technologies available for communal use in informal settlements. Sanitation provision to informal settlements has globally been a challenge due to high densities and the lack of available space within the settlement to provide individual services to each household which has led to shared, or communal, facilities becoming the *de facto* form of sanitation provision to informal settlements, in spite of shared facilities still considered as unimproved facilities by the United Nations Joint Monitoring Programme. Sanitation was broadly discussed in Chapter 2 in order to provide a holistic background to sanitation provision. The benefits of sanitation are indisputable and are well documented, associating improvements in sanitation with improved public and environmental health and economic benefits. The most appropriate sanitation technology must be based on the local institutional capacity, financing options, and the local physical and social conditions. The provision of these communal water and sanitation services in South Africa is realised by the local Water Service Authority.

Although both dry and wet sanitation technologies are improved sanitation technologies, the legacy of Apartheid has caused dry sanitation to be seen as an inferior technology to waterborne sanitation in South Africa. In fact, waterborne sanitation is considered the gold standard to which all residents, formal and informal, aspire to. Waterborne services are also considered the most appropriate technologies in realising the mandate of incremental upgrading as the interim water and sewerage infrastructure forms part of the waterborne backbone that can later be extended to a household level.

The success of the informal settlement upgrading policy in South Africa has to be studied at the local government level. This is because the local authorities determine the most appropriate technologies to implement the political mandate and thus the implementation strategies and technologies will vary between local authorities in South Africa. From the eight metropolitan areas in South Africa, the eThekwini municipality was identified as the most appropriate case study for identifying the success factors for interim communal water and sanitation facilities as the municipality was proactively addressing the problems associated with informal settlements through the provision of interim services and has over two years of experience in the rollout of communal ablution blocks (CABs) at scale. The eThekwini municipality was also selected because the provision of water and sanitation services was managed by the eThekwini Water and Sanitation Unit. They were internationally recognised to have strong institutional capacity and have maintained institutional continuity, which facilitates the successful rollout of such projects at scale. The eThekwini municipal area had approximately 420 informal settlements, housing around 114 000 informal households. This accounts for 12 per cent of the households, which was higher than the national average of nine per cent informal households in South Africa.

There is a need to investigate and understand the success factors in providing these interim facilities, as the provision of such interim communal water and sanitation services in eThekwini is not a short-term project. Based on the municipal figures, the backlog in sanitation services (231 387 households) will require the provision of 220 community ablution blocks per annum, with a total of 3 085 ablution facilities throughout eThekwini, assuming that this backlog can be eradicated with communal ablution blocks within 14 years. The rollout of interim services cannot be provided on an ad hoc basis but must form part of the integrated planning for the formalisation of the informal settlement and the operation and maintenance of these facilities must be adequately planned for to ensure their sustainability over the entire life of the facilities (around 15 years).

This investigation of the municipality's success in the implementation of this project required the collation of data from a number of sources, namely the design consultants, project managers, municipal officials, and site visits. The data were not readily available and had to be sourced from different informants within those organisations. The data were both quantitative, such as the water demand, and qualitative, such as the data gleaned from surveys and anecdotal evidence found during the site visits. The anecdotal evidence provided a deeper perception of the state of the communal facilities and led to a better understanding of the requirements for their sustained success.

2. Community Ablution Blocks

The provision of CABs was reported in the typical project management stages, from planning and design and construction (pre-implementation stages) to operation and maintenance (post-implementation stages). The thesis did not explicitly investigate the implementation stage, the user acceptability. This was reported throughout the project stages, but for a more detailed analysis it will require extensive research to determine the behaviour patterns of the CAB users. The eThekwini municipality has successfully created the momentum required to rollout the CABs at scale, incorporating the appropriate stakeholders and securing the required funding. There were some problems that still need to be further investigated to determine how the construction stage can better be planned for. The post-implementation stages were not as successful, which needs to still be addressed to ensure the CABs remain operational. Ensuring the sustained use of the facilities is critical because the CABs are the primary method of water and sanitation provision to informal settlements. Without adequate post-implementation management arrangements in place, communal ablution facilities should be considered an unimproved sanitation technologies due to the detrimental effects poor sanitation has on the community.

2.1. Pre-implementation stages

There are a number of stakeholders involved during the planning stage, which requires that the project documentation be recorded within a structured and generic template to facilitate consistency. The planning stage is predominantly driven by engineers, the design consultants, who determine the technical requirements of the settlements based on municipal standards and guidelines. The aim of the planning stage is to ensure that the settlements within eThekwini are all strategically upgraded and that the CABs are placed strategically within those settlements earmarked for upgrading so as to meet the immediate needs of the community, promote sustainability, and reduce fruitless expenditure. This should also provide appropriate access for the households to the CAB facilities. The eThekwini municipality has provided maximum distances between households and CABs and maximum population densities per CAB facilities. Although the efficacy of these standards were not further investigated it was found that the majority (79 per cent) of the settlements had a theoretical population density higher than the municipal standard of 75 households per CAB. These increased population densities will reduce the potential lifespan of the sanitary fittings.

The long-term sustainability of the CAB facilities pivots on community buy-in and community participation, which occurs during the planning stage. Community participation is about acknowledging the community and taking their needs into account. This is achieved by raising awareness about the municipality's plans of providing basic services and making the community aware of any inconveniences that may be caused during the construction period. The expectations of the community should be managed at all times and the community should be aware of who to contact at each stage of the project. The community should also be made aware of the selection process of the appropriate CAB placement and they should be given an opportunity to raise their concerns about the proposed CAB placement sites. Finally, the planning stage also includes the selection of the caretaker in order to ensure that the CABs can be sustained after the facilities are handed over to the community.

The design stage includes the physical design of the CAB container and the water and sewerage infrastructure. The physical design of CAB structure and fittings are determined by the eThekwini municipality, who has specified the use of retrofit prefabricated containers that can rapidly be placed on site. The main requirement of the sanitary fittings is that they are of a high quality in order to withstand a high rate of usage and vandalism. The hydraulic design parameters for the connecting infrastructure was expected to fall within the range of 41.5 – 62.2 ℓ/c/d, and the average instantaneous peak factor was found to be 5.2. From the end-use monitoring of four CAB facilities in Frasers, the CAB water demand was found to be 97.6 ℓ/hh/d, or 44.4 ℓ/c/d based on an average of 2.2 persons per household.

The analysis of the construction stage indicated that the actual construction time for the CAB projects was approximately three times more than the estimated construction time. The construction time was not dependent on the length of the water and sewerage pipes, but the reasons for this large disparity are complex. They are hypothesised to arise from a combination of poor project management; poor project estimation by the quantity surveyor; or poor on site conditions, such as delays in obtaining permission to occupy (PTO) the land from private land owners, relocating the residents, and local labour strikes near the end of the construction period. The effects of delays associated with PTOs was highlighted in the provision of CABs to Frasers, where the delays in obtaining PTOs essentially doubled the entire project. It was decided that the CABs be constructed per site within the settlement (site-level planning) in order to fast-track the construction. From a project management perspective, the change to site-level planning from settlement-level planning has been one of the most significant changes in the pre-implementation stages and has occurred in a number of settlements. However, this means that the contractor has to employ local labourers and subcontractors per site, and not per settlements, as the delays in the planning stage can potentially also cause delays in the construction stage too, which negatively affects the proposed construction budget.

2.2. Post-implementation stages

The scale of the project in eThekwini, which is expected to reach in the order of 3 000 CAB facilities over the next 14 years, will mean that there will have to be a streamlined process between all the role players involved in the operation and maintenance stages and that the municipality has adequately stocked storage facilities which are strategically placed throughout the municipal area such that the dedicated maintenance teams can effectively perform the repair tasks such that the CAB facilities remain functional.

There is however a misconception in the delivery of water and sanitation services which implies that once the infrastructure has been handed over to the community that the project is complete, and the post-implementation is often neglected. The post-implementation responsibilities have to be defined and necessary role players have to be appointed to ensure adequate operation and maintenance of water and sanitation services is performed. In eThekwini, the responsible persons for the operation of the CAB facilities were the caretakers, at a local level; the supervisors, at a district level; and the finance officers and maintenance teams at a municipal level. The key success factor in the operation of CABs lies in the quality of the caretaker and the quality of the support provided to the caretaker. The coordination between the different role players is essential. Officially, the maximum time for the repair to be performed after it has been logged is 2 days, but in practice, the average time is 10.5 days, with the caretakers qualitatively estimating the average repair time to be 23.4 days. This lack of immediate and urgent response from the maintenance teams promotes not only vandalism and misuse but also promotes open defecation and also reduces the caretakers' urgency to make the telephone call to their supervisor and report the faults in the future, perpetuating poor maintenance and leading to the CABs being in a derelict state. Successful maintenance strategies require appropriate user education, quality hardware, and minimum time to attend to the maintenance issues.

Communal sanitation facilities are able to provide a basic service to a large community and are seen as the only solution where household sanitation services are not appropriate due to financial and physical limitations within the settlement. However, when these facilities are non-operational, they affect that large community which is a significant environmental and public health concern. Thus, the motivation to provide state of the art support for the maintenance of these facilities is imperative in providing improved sanitation services to all. But the current state of the CABs is inadequate to meet the needs of the communities. Although the maintenance of the CAB facilities is pivotal to the sustained use of the facilities, the maintenance is not currently implemented as is theoretically intended. The maintenance issues are a function of the CAB usage rates, vandalism, and the quality of the sanitary fittings and the CAB structure.

The key factors attributed to a good caretaker lies in a fair caretaker selection process, adequate training to perform their daily tasks, and adequate support from the supervisor to address the needs of the caretaker. The caretakers are appointed annually by the municipality. The selection of the caretaker should be done carefully to ensure that the community is aware of the process and approves of the selected person. If this is not ensured, the community can smear the caretaker's reputation by vandalising the facility in an attempt to remove the caretaker from their position. The caretakers' tasks include distributing toilet paper and cleaning the facilities. To this extent, the caretakers are currently appointed to work four hours every day of the year. However, although these working hours are sufficient for cleaning purposes, they do not address the issues, such as vandalism, that arise when caretakers are not present. The provision of a fulltime caretaker is expected to prevent vandalism or misuse of the CAB facilities.

The municipality provides the caretakers with sanitary consumables on a monthly basis to encourage proper use of the facilities, i.e. to reduce sewer blockages. The main sanitary consumables include toilet paper and detergents, which required one 5 ℓ detergent bottle and 235.2 rolls of toilet paper on average per CAB. There is no systematic method for distributing the toilet paper and this could be improved. Currently, the municipality does not distribute soap to the CABs for hand washing in spite of the extensive research surrounding the benefit of providing soap for hand washing. Creative ways have to be considered to realise these associated health benefits.

The maintenance stage has highlighted the fact that although shipping container are advantageous for rapid placement of the ablution facilities on-site and future relocation or refurbishment, the hardware (sanitary fittings, air vents, cubicle doors. Windows. And water and drainage pipes) are all retrofit into the thin metal walls of the container. This retrofit leads to flimsy joints between the hardware and the container itself. This means that the maintenance requirements are not only plumbing related and require that maintenance teams either have a wide training to make all the repairs or else that three different maintenance teams be instated to deal with each dimension independently, namely the sanitary fittings, the CAB structure, and the water supply and sewerage. There is a need for communal water and sanitation standards for the hardware in order to ensure that no substandard hardware is installed, as the current hardware was often found to be inferior for the high usage demands typical of CABs. The relevant standards that are currently available in South Africa include the South African Bureau of Standards (SABS) and JASWIC, as previously recommended in Chapter 6. In the German railway stations, for example, Hering International uses sanitary fittings that are traditionally used in jails where there are a high volume of users and the fittings are prone to vandalism. These fittings are constructed out of stainless steel, making the fittings robust and vandal proof. The walls of the toilet facilities are typically constructed out of reinforced concrete, allowing the sanitary fittings to be secured directly into the walls during fabrication. Although such design and construction specifications increase the capital costs associated with the facilities, it reduces the short-term maintenance requirements in replacing broken fittings, which are endemic of the current configuration at the CAB facilities.

2.3. CAB costs

The provision of basic interim services in South Africa is the responsibility of local government. Thus, there has to be sufficient funding available for the pre- and post-implementation of the project. The cost analysis of the CABs in this thesis has excluded the cost of professional services, such as project managers, design engineers, environmental management protocols; purchasing of land where required; hygiene and education; and supporting staff for the coordination of the operation and maintenance, such as caretaker supervisors. These costs have to be considered in order to ensure that sufficient funding is available to ensure the sustained use of the facilities. The results from the rollout of CABs throughout eThekwini indicate that the capital costs are in the order of R9 400 – R14 000 per household for 50 – 75 households per CAB facility. The major component of the capital investment (79%) is used for extending the water and sewer pipelines into the informal settlement, which will form part of the long-term infrastructure once the settlement is provided with formal housing.

The cost of operating and maintaining the CAB facilities is higher than that of a dry sanitation option, such as a VIP toilet, and a domestic waterborne sewer connection. The major cost of operation (44%) is paying for the caretaker’s salaries, followed by the cost of supplying water and disposing of the wastewater (37%), and the cost of providing toilet paper (14%). It is important to note that the cost of operating the CABs in eThekwini is equal to the initial capital investment within 5 years of implementation. And thus, sufficient funding must be secured during the planning stage in order to ensure that the municipality can keep the facilities operational once the facilities have been handed over to the community. The funding available for the operation and maintenance of the CABs is sourced from municipal revenue, cross-subsidisation and the Equitable Share grant.

Recommendations and Future Research

Chapter 12

A number of general success factors were identified from the data collected from the different stakeholders involved in each stage of the CAB rollout. This chapter repeats the collated recommendations from each of the results chapters in order to consolidate the recommendations from the research. These are made based on the research findings and the author's own experience from the eThekwini municipality.

1. Planning stage

- It is important that all of the informal settlements within the local government's jurisdiction are prioritised, based on technical criteria specific to the municipal upgrading policy. This prioritisation will ensure that services are provided in a logical and holistic manner to all settlements so to reduce fruitless expenditure and to dovetail with the strategic development planning of the local and provincial government.
- Where a settlement is earmarked for upgrading but is located on private land, municipal by-laws have to be in place to ensure that the interim communal water and sanitation facilities can be provided to meet the immediate needs of the community. It is important that the private land owner be identified early in the project so that the municipality has sufficient time to get permission to occupy the land. There has to be sufficient negotiations with the community to ensure that any informal housing relocation is minimised but that compensation is made for these relocations.
- All the required designs and PTOs should be in place before construction commences, either for site-level planning or settlement-level planning, in order to minimise any delays which could increase the construction costs.
- Due to the extent of the project, there needs to be strong project management to ensure that the risks can be managed accordingly and that there is open communication between all stakeholders involved in the project. All documents should be submitted according to a predetermined template. These documents should be stored at a central location, i.e. with the project managers, and be accessible to the municipality at all times.
- There has to be open access of data between the different municipal offices responsible for informal settlement upgrading, namely the Housing Department and the Water and Sanitation Department, in order to consolidate all population estimates and settlement information.
- The impartial selection of the caretakers is essential to the sustained use of the facilities. This selection process is currently driven by the design engineers and is implemented by the Ward Councillors. The positions should be advertised publicly, whether with posters, flyers, etc., to ensure that all community members have an equal opportunity to apply for the caretaker position as the opportunity of being employed within the settlement is very desirous. This will have long term ramifications on the sustainability of the facility, as the caretaker essentially ensures that the facilities are operational at all times.

2. Design stage

2.1. Physical CAB structure

- There should be clear responsibilities for the CABs directly after the CABs have been placed on site such that any construction defects can be dealt with swiftly. It is recommended that the contractors be responsible for supply chain of the CAB, from sourcing the manufacturers of the CABs, ensuring the fittings adhere to the required standards, and the transportation and placement of the facilities on site. The design consultants should be responsible to ensure the water supply and sewer pipeline designs are properly constructed. The water service authority, in this case EWS, should be responsible for the long-term operation and maintenance of the CABs. The three role players should all be present at the handover of responsibilities to ensure that the work has been implemented to a high standard.
- The selection of the sanitary fittings should be selected based on municipal standards, such that the fittings are South African bureau of Standards (SABS) or JASWIC approved. This will ensure that there is a high quality standard for the fittings. However, standards should be developed for the CAB sanitary fittings, as these fittings are used more extensively within CABs than within typical domestic environments.
- Physically within the CAB, the toilet cubicles should be sized to a length of at least 1.2 m in order to accommodate users of a height up to 2.1 m. This recommendation is based on the current location of the toilet within the cubicle.
- The presence of a geyser for heating the shower water should be investigated such that the hot water will promote the use of the facilities even for lower temperatures. This is especially true for other provinces within South Africa where winter temperatures are significantly lower than in Durban.
- The appropriateness of a shared cistern for the entire CAB should be further investigated. This could be achieved in the CABs by fitting the toilets to a central water cistern (no less than 20 ℓ in volume) fastened either to the wall or located on top of the male and female container roof.

2.2. Water and wastewater management

- Although EWS have implemented water demand management of the CABs by providing a water meter for each CAB facility, the data available from the municipality in February indicated that only about 30% of the water meter readings were valid. The effect of adequate data management has to be addressed in order to ensure that data is being collected, i.e. the water meters are being read, and that accurate data is stored on the municipal database. Without such practices, the water demand management strategies will be fruitless and the associated benefits of supplying water meters to the CABs will be lost.
- The effects of poor wastewater management at the CABs are detrimental to public and environmental health. This should be rectified through both user education to promote proper disposal of wastewater and physical infrastructure, which could take the form of drains next to the CAB facilities where users can dispose of any greywater. Where users do not want to use the CAB facilities at night, due to safety reasons for example, the CABs should provide a night soil disposal chamber. This chamber could be mixed with the CAB

greywater, such as the shower and laundry wastewater, before entering into the sewer network.

- The on-site wastewater treatment infrastructure should account not only for the wastewater generated from the CABs, which was found to be in the order of 40 – 60 ℓ/c/d, but should also account for the additional water increase when the settlement is provided with in-house water and sanitation services. The guideline value for low-income households is 50 - 70 ℓ/c/d. This will mean that either the on-site treatment facility should be able to adequately manage the future wastewater volumes, or that the settlement has sufficient available space for additional on-site wastewater treatment facilities to be constructed.

3. Construction stage

- There has to be better estimating of the construction period as under estimating the construction time increases the actual construction costs. If the current project setup remains unchanged, the expected construction period estimated during the planning stage should be increased by a factor of three to account for potential delays in the construction, inter alia obtaining PTOs, labour strikes and the procurement of materials.
- Dividing the settlement into different construction phases is important in promoting a continuation of the work by the contractors within their project area and in the strategic planning of the construction within that specific settlement. However, the delays in obtaining PTOs may still affect the contractors' capacity to start work in the other construction phases within the settlement. Thus at the beginning of the construction period, the contractor should only obtain materials and employ local labourers and subcontractors for those sites that have already been approved for construction in order to reduce costs incurred by delays in the construction period.

4. Operation stage

- Vandalism and misuse is expected to occur where the caretaker is not present. To prevent this, a caretaker should be appointed on a shift basis, i.e. three caretakers each working 8-hour shifts for example. The caretakers should be provided with a place to sit while on duty, as shown in Figure 1. This will ensure that the community has continuous access to the facilities. It is hypothesised that this will reduce maintenance costs caused by vandalism and misuse. The increased cost of hiring fulltime caretakers is approximately equivalent to the current monthly cost for operation and maintenance. However, this cost should not only be compared to the direct maintenance costs because there are other positive consequences of improved conditions within the ablution facilities such as the reduction in open defecation, which has both health and economic benefits to the community. Further research is required to confirm this hypothesis.
- The caretaker must be able to take legal recourse where vandalism does occur by laying criminal charges against the offenders. It is noted that this hypothesis oversimplifies what is likely to be a very nuanced and delicate balance of social dynamics and that this issue requires further detailed studies.
- Although there is a need for caretakers to store the bigger supplies (such as buckets, mops and brooms) and any broken fittings somewhere on-site, the current storeroom setup is not

functioning as intended. This could either be rectified by using a dedicated storeroom for the caretaker to store the equipment, as shown in Figure 1.

- For increased safety and minimised vandalism and misuse, the CAB site should be enclosed off with a fence around the entire perimeter with a single entrance and a standalone 4 - 6 m^2 caretaker room positioned at the entrance of the CAB site, as shown in Figure 1. This room can be prefabricated, for example, out of wood (wooden hut) or a retrofit container.

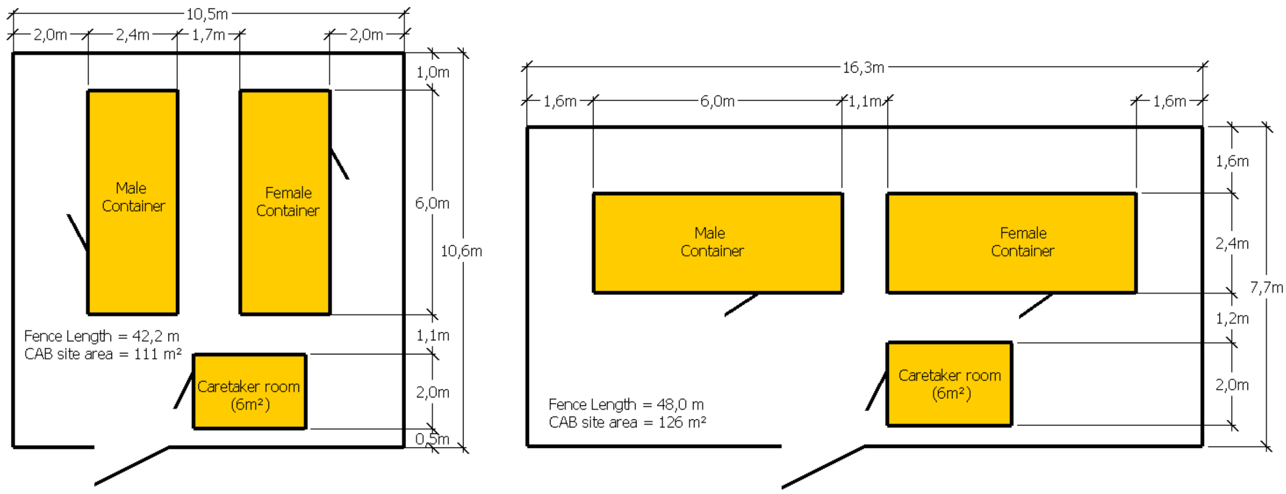


Figure 1: The proposed CAB site setup (see Chapter 8)
The figure indicates two main types of CAB sites that are found around the eThekwini municipal area.

- The municipality must investigate procuring the toilet paper pre-cut, as per the current caretaker arrangement, in order to standardise and simplify the distribution of toilet paper. This must be possible due to the magnitude of the toilet paper required at the CABs, as the municipality is currently purchasing in the order of 50 000 toilet paper rolls per month and this amount will increase to in the order of 500 000 toilet paper rolls per month at the end of the project.
- Soap should be made available to the CAB users for hygiene. However, this should be monitored by the caretaker to ensure that the soap does not get stolen. This could use the MobiSan® approach in Cape Town (Naranjo 2009), where the soap is placed in a stocking and fastened outside the window of the caretaker room.
- Sufficient stormwater drainage with an associated soakaway should be provided external to the CABs, near the laundry facilities to ensure that all greywater can be absorbed into the environment and not remain stagnant next to the CABs. Internal drainage should also be provided to ensure all wastewater be removed from within the CAB. This could be achieved by providing drainage pipes at strategic places within the CAB, i.e. at each corner where there are toilets and under the wash hand basins. These drains should be provided with a steel grid to ensure that no foreign objects are deposited into the sewer

5. Maintenance stage

- The toll free number telephone number of the municipal call centre should be viewable internally and externally on the CABs. This arrangement will provide a “community voice”, ensuring that the community and the caretakers can both report faults of the CAB facility to the municipality. The number should be free of charge from a mobile telephone as landline phones are practically non-existent within informal settlements.

- It is important that all reported defects from the caretakers be dealt with rapidly. Failure to address these requests from the caretaker can have a number of knock-on effects, such as resentment between the community and the municipality; lack of rapid reporting from the caretaker to the supervisor; negative impact on any hygiene education conducted within the settlement, etc. Thus, it is important that the official response time be upheld at all times and that this be monitored regularly.
- The poor communication of faults between the caretakers and the plumbers could be mitigated by providing the caretakers with an assembly drawing for the entire CAB, where each part is labelled with a code, see for example the assembly drawing for a car shown in Figure 2. The assembly drawing booklet for the CABs could be provided to each caretaker who would simply have to relay the quantity and code for each fault back to the call centre and the maintenance team would be able to be properly equipped to make the necessary repairs.

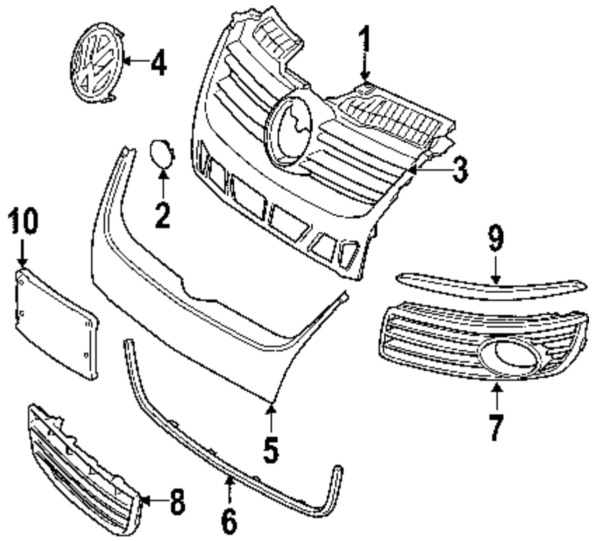


Figure 2: An example of an assembly drawing used in the replacement of car parts (see Chapter 9)

- The drainage pipes of the showers should be increased in diameter to 120 mm in order to reduce any blockages that occur. The caretaker should also be provided with the required materials to unblock the drains. The hand wash basins should be provided with demand taps should be used where the taps are attached to the basins and conventional taps should be used where the taps are attached to the wall of the container. The toilet discharge pipe and the toilet pedestal should be fastened with an epoxy resin once the CABs are delivered on site to reduce blackwater from leaking internally in the CAB. Alternative to single toilets with cisterns, the toilets should each be fitted to a central water cistern (no less than 20 ℓ in volume), which is fastened either to the container wall or located on top of the container roof. A demand flush mechanism can then be attached to each toilet, such as is found in conventional public toilets in shopping centres (Figure 3).

Figure 3: Typical public toilet using a demand flush at the Aquaduct Racetrack Casino (see Chapter 9)

- Valves should be in place to ensure that where sanitary fittings are leaking or broken, the caretaker can turn off the water serving that fitting to ensure that minimum water losses occur until the fitting is repaired.
- The maintenance of the CAB structure was not occurring. A proposed maintenance schedule for the CAB structure is given in Table 1. The replacement equipment for each part of the CAB structure should be kept in a central location which is accessible to the maintenance team. The required skills, not only plumbing related, should be included with the training of the maintenance teams.

Table 1: The maintenance schedule for the CAB structure

	EFFECT OF FAULT	**REPAIR EQUIPMENT AND MATERIALS**	**REQUIRED SKILLS**
CAB DOOR	Hinge breaks	Screw driver, hinge	Handyman
	Door missing (stolen/broken)	New door and hinge	Carpenter
WINDOWS	Glass breaks	Glass cut to size and putty	Glass fitter
AIR VENTS	Vent missing	New vent (steel mesh) and screws or welding equipment	Welder
WHIRLY BIRD	Whirly bird not working	Long stick (broom) to nudge it back in place	Caretaker
	Whirly bird stolen	New whirly bird	Handy Man
CUBICLE DOORS	Hinge breaks	Screw driver, hinge	Handy Man
	Door missing (stolen/broken)	New door and hinge	Carpenter
PAINT	Paint peels off	Paint, paint brush, scraper	Painter

6. CAB costs

- As the provision of interim services to informal settlements is a national priority there is direct funding from the National Treasury available for the capital costs. The main recommendation is that the municipality ensures that there is sufficient funding available to perform the required operation and maintenance of the facilities.

- Grant funding should not be made available for the maintenance of the facilities, as the availability of funds may have a detrimental effect on the sustainability of the facilities, as it may inadvertently promote vandalism and misuse. However, it is suggested that funding be made available for the operation of these facilities, especial in those municipal areas where internal funding is limited. This would include subsidies for the caretakers, sanitary consumables, and water supply and wastewater discharge into the sewer, as these components are fundamental to the sustained use of the facilities. Funding for the caretakers could make use of external grants, such as the Extended Public Works Programme Incentives Grant, as the provision of a caretaker promotes job creation within the informal settlement.
- Based on limited data, the maintenance costs were estimated to be in the order of R70 – R100 (US $8 - $12) per household per month. However, with proper community buy-in, education and more durable, higher quality sanitary fittings this cost could be reduced. Where there is a willingness to pay for improved facilities, the municipality could negotiate with the community to carry the cost of the maintenance themselves through a pay-per-use or a monthly fee per household.

7. Future Research

The thesis investigated the success factors associated with the rollout of communal water and sanitation facilities. Although these facilities are classified as interim facilities, there will be a need for similar research comparing both the pre-implementation and post-implementation from different local governments throughout South Africa. Communal sanitation is often the only practical means of sanitation provision in dense informal settlements that lack formal housing but there is a significant amount of research that has to be conducted, both nationally and globally, in order to better understand the success factors for communal sanitation facilities. The study found that the majority of the future research should focus on the *soft* topics associated with water sanitation provision, and not the technical topics. Although there are numerous aspects that have to be addressed in the successful implementation of communal sanitation facilities this chapter proposes a few research questions that would direct future research toward a thorough understanding of communal sanitation facilities.

7.1. Social Studies

The first step in understanding the day-to-day operation communal ablution facilities will require having an understanding of the communities' perception of the facilities and the factors which influence use and non-use. At a community level, this will require a number of social sciences to understand not only the relationship between the community, the communal facility, the caretakers, and the supporting municipal staff. Future research should seek to answer the following questions,

- What is the community perception of the communal facilities?
- What effect do heterogeneous communities have on a communal facility?
- What factors affect the use of the facility at night and during the day?
- To what extent does the provision of a communal facility prevent open defecation?
- What is the community perception of the caretaker and the maintenance teams?
- What additional skills, education, or tools do the caretakers require in order to perform their duties and minimise the involvement of the supporting maintenance staff?

- What factors have to be present for the ideal selection of the caretaker?
- What effect would a full time caretaker have on the operation of the communal facility?

7.2. Technical Studies

The technical research should aim to promote the rapid provision of the facilities and their sustained use. To this extent, the research should address the issues of construction delay in more detail and should also develop a deeper level of understanding on the life cycle costs of communal facilities and modelling what effect different CAB structures, such as prefabricated concrete ablutions, or different quality hardware, or different wastewater management strategies have on the life cycle costs.

- What factors most affect the delays in the construction period?
- What are the actual life cycle costs associated with communal facilities?
- What effect does each stage in the rollout of the communal facility have on the life cycle costs?
- What are the best management options for the O&M of the communal facility?
- What standards are available for sanitation fittings used in communal or public facilities? Are these standards applied and adhered to?
- What is the most appropriate geyser for heating the shower water within an informal settlement environment?
- What faecal sludge management practices are best suited to the resource recovery from communal facilities in urban and peri-urban areas?

7.3. Institutional Studies

Institutional research should focus on the local government and all the related institutions involved in the rollout of CABs as part of the informal settlement upgrading programme, investigating issues such as,

- What are the institutional roles and relationships within local government that are involved in the CAB role out and sustainability, and how can these best be facilitated?
- What is the regulatory context surrounding CABs?
- What are the financial requirements and the skills required to best sustain the CABs, and where within the local government structures does capacity have to be developed?

7.4. Conclusions

There is a need for communal sanitation facilities, such as the community ablution blocks constructed throughout eThekwini, not only in South Africa but also in the rest of the developing world. The backlog of basic services in informal settlements will require such shared technologies to be implemented, even if only for an interim period, in order to meet the immediate needs of the community. The research on communal sanitation facilities is extensive and there are a number of questions that have to be answered to ensure their sustained operation. The questions suggested in this chapter are presented are not comprehensive, but are presented so as to indicate what the current research needs are, based on the author’s experience of community ablution blocks in eThekwini.

Appendix A

Sanitation Policy Documents in South Africa

The policy documents associated with sanitation provision in South Africa can be grouped in three distinct categories (DWAF 2003; Mjoli 2009),

1. Legislation
    1.1. The Constitution of the Republic of South Africa Act 108 of 1996
    1.2. Water Services Act 108 of 1997
    1.3. The National Water Act 36 of 1998
    1.4. Housing Act of 1994
    1.5. The Local Government: Municipal Systems Act 32 of 2000
2. White Papers
    2.1. White Paper on Basic Water Supply and Sanitation Policy - DWAF, White Paper on Water Supply and Sanitation Policy (November 1994)
    2.2. National Sanitation Policy (October 1996) – DWAF
    2.3. White Paper on Basic Household Sanitation (2001) – DWAF
    2.4. Policy framework for the Introduction of the Municipal Infrastructure Grant (2004) – DPLG
    2.5. The MIG – Basic levels of services and unit costs: A guide for municipalities (2007) – DPLG
    2.6. DPLG Guidelines – Sustainable municipal infrastructure provision and service delivery (2007) - DPLG
3. Strategies
    3.1. Strategic Framework for Water Services - DWAF, Strategic Framework for Water Services: Water is Life, Sanitation is Dignity (2003)
    3.2. National Sanitation Strategy (2004)
    3.3. National Sanitation Strategy for Informal Settlements (2007)
    3.4. Free Basic Sanitation (FBSan) Implementation Strategy (2009)

Appendix B

End-use monitoring equipment specifications

Cautions

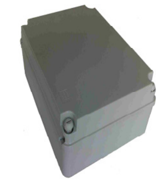
- In order to avoid personal injury or damage to the BeyondCom Unit, only specialised personnel may work on or open the unit.
- Ensure that the supplied voltage matches and does not exceed the values specified on the BeyondCom Unit.
- Ensure the unit is placed in a location where there is adequate ventilation.
- Avoid placing the unit in direct sunlight, near heat or heating devices, where the humidity is high, or where it may come into contact with liquids or dust.
- Avoid subjecting the unit to vibrations.
- When there is lightning, unplug the unit from the AC outlet immediately. Never touch the antenna when there is a lightning storm.
- RF signals from this unit and antenna may cause interference with other equipment. Move this unit far away from other equipment should there be a risk of interference.
- In order to limit interference to inputs, keep sensor cables well away from power cables.
- Keep antenna well away from the unit and other power sources such as electric motors, power cables etc.
- Do not clean the unit with chemicals or strong detergents. Use a clean soft cloth.
- If the unit is to be used near medical devices, ensure that those devices are sufficiently protected against any RF and / or interference which may be emitted from this unit.

Technical specifications

Enclosure:	IP66 rated polyesther
Dimensions (W x H x D):	150 x 80 x 105mm
Weight:	1.8 kg
Operating Temperature:	5 deg.C – 45 deg.C
Relative Humidity:	20 - 90% RH (non-condensing)
Power Supply:	AC 220 V, 50 Hz

Note:
Specifications are subject to change without notice.
Weight and dimensions are approximate.

P O Box 382, Bassonia, 2061, South Africa



BeyondCom™ Remote Monitoring Station.
Model: BCLP200

Installation Manual

Document Number OPS.BCU.010W (Rev 0)

Before connecting or operating this product, please read these instructions completely. Please keep this manual for future reference.

These basic set-up instructions will guide you through the process of installing the BeyondCom Unit. Use of the system including setting alarm conditions, users, SMS's and accessing information through the internet are contained in the BeyondTelematic instruction manual.

There are no serviceable parts and the only maintenance required is that of changing the backup battery which should be done at least every 2 years. This should only be done by Beyond Wireless Technology (Pty) Ltd or one of its designated agents.

Conditions of use

For safety reasons the BeyondCom Unit must be installed and used in accordance with the instructions provided in this Installation Manual and the BeyondTelematic User Manual.

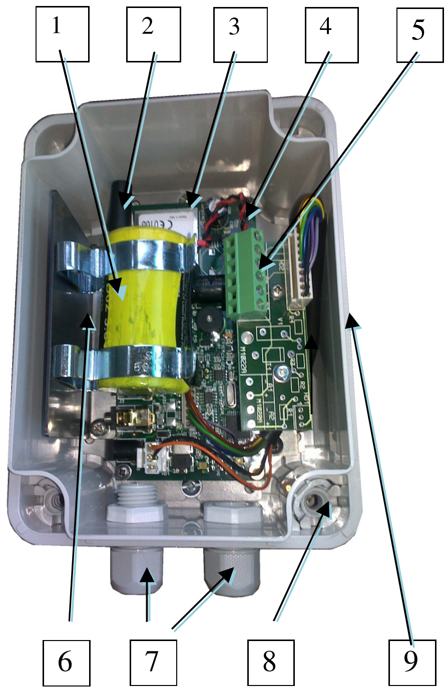
The device must be used only for the purposes for which it was designed.

Use of this device implies acceptance of the Beyond Wireless Technology (Pty) Ltd standard terms and conditions, which may change from time to time.

www.beyondwireless.co.za

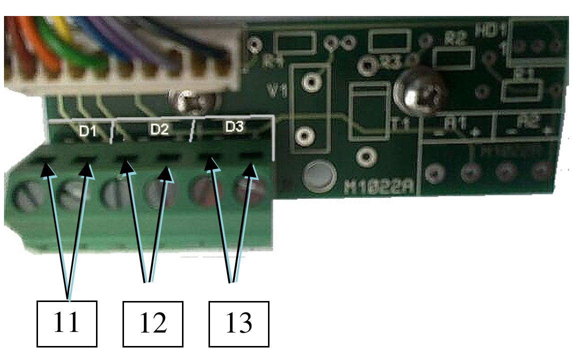
Controls and Connections:

Enclosure components



1 Lithium battery
2 Antenna(SMA conn.)
3 Motherboard
4 Battery connector
5 Connection board (see details below)
6 Power [Red] LED,
GSM [Yellow] LED,
Status [Green]LED
7 Compression glands
8 Mounting hole
9 Enclosure
10 Lid (not shown)
11 Digital input channel D1(+/-)
12 Digital input channel D2(+/-)
13 Digital input channel D3(+/-)

Connections



Installation:

Connecting / mounting BeyondCom™ Unit:

1. Connect antenna by screwing the antenna plug into the SMA plug 2. Should an external antenna be required, run the cable through one of the compression glands 7 and screw the plug in 2.Only use an antenna which is compatible with the BeyondCom Unit.
2. Connect inputs to the terminal blocks 5, for the respective inputs 11, 12 and 13 taking note of the polarity. Where digital inputs are potential free, the polarity is not important, but the polarity must be observed for open collector inputs.
3. Connect the battery by plugging the battery connector plug into the plug on the motherboard 4. Note that the plug can only go in in the correct orientation and will "click" into position.
4. Mount the box with the Compression glands 7 facing downward. The mounting holes 8 are accessed by removing the plastic clips in the four corners.
5. Ensure the lid is closed securely to ensure weatherproof.

⚠ **Do NOT connect the battery without the antennae connected.**

⚠ **BeyondCom unit must be kept away from machinery and items which may cause interference such as power cables, electric motors etc.**

⚠ **The unit must not be placed in an environment exceeding the rating of the enclosure, or used at operating temperatures outside the allowed levels for the BeyondCom unit.**

Disconnecting the BeyondCom™ Unit:

1. Unplug the battery plug 4.

⚠ **The BeyondCom unit MUST be off before the antenna is disconnected.**

2. Disconnect Antennae by loosening the nut and removing the antennae plug.
3. Remove all other connections.

220C

Volumetric Meter Composite Body
Protected Dial – Class C
Reed and HRI AMR pre-equipment

Main Features

DN15, PN16

Ultra light and easy to handle

Accuracy better than class C requirements

Conforms to the latest OIML standard

Pre-equipped as standard for both Reed and HRI AMR interfaces

Tamperproof design

Designed for tropical installation conditions

Extreme resistance to water hammer

Application

The 220C meter has been specially designed for operators anxious to improve the reliability and meter efficiency of their networks. The 220C piston meter benefits from Sensus' long experience in the manufacture of high-performance meters.

The 220C design meets particularly the requirements of markets with high expectations. Theft of the meter is discouraged by its design without a brass body. Its tamperproof design assures at any time the correct reading of the actual water consumption and its super strong composite body makes its installation safe, even in a tropical environment.

The dial is housed in a case filled with lubricant which means it is protected from any impurities in the network. It can be read perfectly under all conditions and is not affected by fogging or the build up of algae.

Through its dual AMR pre-equipment, with both Reed and HRI interfaces, the 220C can be used in any network where a reliable and cost effective AMR system is required. Both AMR solutions are retrofittable and can be added at any time after the meter has been installed.

Options Available

HRI electronic sensor (Data Unit, Pulse Unit, Sensus((S))cout)

Reed switch

Connectors

Non-return valve

UK & Ireland Enquiries
Sensus Metering Systems
11 The Quadrangle, Abbey Park,
Romsey, Hampshire SO51 9DL UK
T: +44 (0) 1794 526100
F: +44 (0) 1794 526101
Email: info.gb@sensus.com

www.sensus.com

International Enquiries
Sensus Metering Systems GmbH Ludwigshafen
Industriestraße 16,
67063 Ludwigshafen Germany
T: +49 (0) 621-6904-0
F: +49 (0) 621-6904-1409
Email: info.int@sensus.com

www.sensus.com

SENSUS METERING SYSTEMS

Meter Design

The 220C body, made of a composite material based on a polymer with glass fibres, provides exceptional strength and weathering behaviour.

Special attention has been paid to the strength of the threads ensuring that the meter may be installed in existing installations without the danger of thread damage.

Reliability

Thanks the use of the composite body with generous wall thickness the 220C meter offers high protection against weathering, water hammer and accidental heat exposure. The meter will retain all its mechanical properties irrespective of the installation environment. The internal components, made of high-grade polymers, have been designed to preserve the initial performance of the meter for many years of operation. All materials are suitable for potable water and won't affect the organoleptic properties of drinking water.

Register

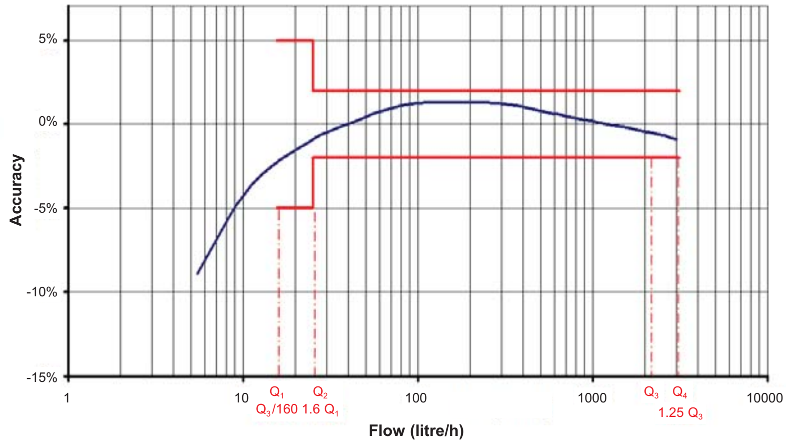
The register's roller counter is immersed in a lubricant, ensuring optimum operation and protection. This technique prevents any condensation and enables perfect legibility of the counter under all conditions, irrespective of the water quality.
The counter is protected by a very thick polymer dial face designed to withstand environmental influences without cracking or discolouring.

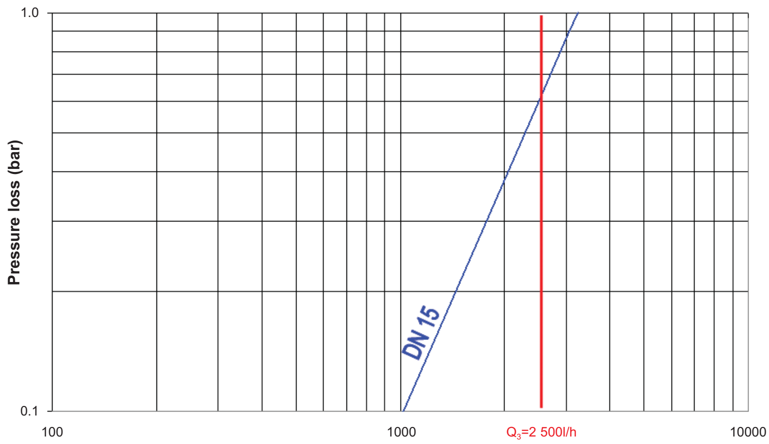
Tampering protection

A key requirement in the design of the 220C meter was to produce a tamper-proof meter:

- Having no magnetic transmission, the meter is not affected by external magnets placed near the meter.
- The use of a robust composite body combined with a thick polycarbonate window prevents any mechanical tampering (commonly through the use of a screw-clamp or a hot needle).
- Meter sealing is achieved by means of a non-removable plastic seal. Provision is made for an optional wire and lead seal.

Accuracy Curve





Typical Head loss Curve

Compliance

The 220C already complies with the new International Organisation of Legal Metrology (OIML) recommendation 49/1 - 3 (2006 revision).

The 220C DN15 meter has a permanent flow rate (Q_3) of 2 500 l/h and a metrological ratio Q_3 / Q_1 of 160 which is the equivalent of a class C meter as defined by the old ISO 4064 metrological standards.

Installation and Maintenance Instructions

(refer to installation instructions MD 1001 for more detailed information)

1. The meter may be installed horizontally, vertically or at an any angle without loss of accuracy
2. The installation of upstream and downstream valves is recommended to facilitate maintenance of the meter
3. Flush the pipe work thoroughly to clear all impurities
4. Remove the two caps protecting the threads and place washers with connectors (not supplied) on the two ends
5. Check the direction of flow through the meter by the arrow on the body. Ensure that the meter is installed appropriately
6. First tighten the inlet nut on the meter by hand
7. Fit and tighten by hand the nut on the outlet. Tighten both nuts with a spanner using minimal force
8. Open the upstream stop-valve slowly and then completely; then draw water at intervals
9. Check for flow through the meter and check for leakage at the connections

Performance Data

Metrological Characteristics (OIML Recommendation R49/ 1 to 3 (2006)

Nominal size	**DN**	**mm**	**15**
Permanent flowrate	Q_3	m^3/h	2.5
Ratio Q_3 / Q_1			160
Overload flowrate	Q_4	m^3/h	3.125
Minimum flowrate (tolerance ±5%)	Q_1	l/h	15.6
Transitional flowrate (tolerance ±2%)	Q_2	l/h	25.0

Operational Characteristics (manufacturer's data)

Nominal size	**DN**	**mm**	**15**
Starting flowrate		l/h	3
Minimum flowrate		l/h	6
Transitional flowrate		l/h	15
Maximum registration		m^3	10^4
Lowest resolution		l	0.02
Pressure loss at Q_3		bar	0.6
Pressure Class	PN	bar	16

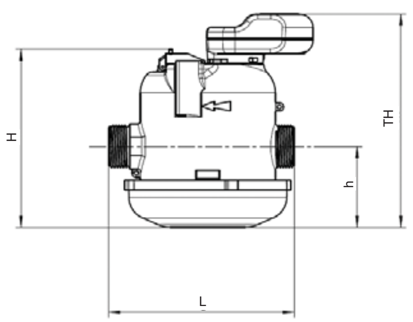
Dimensions and Weights

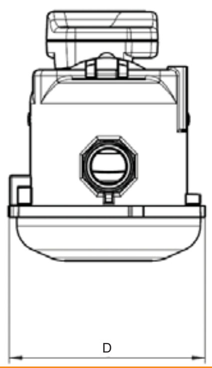
Dimensional characteristics

Nominal size	**DN**	**mm**	**15**
Length	L	mm	115[1]
Width	W	mm	105
Total height	H	mm	110.5
Total height with assembled HRI	TH	mm	132.3
Height to pipe axis	h	mm	50.0
Piping dimension		inch	½
Tail		inch	G¾"B
piece	Diameter	mm	26.44
thread	Pitch		1.814
Weight		kg	0.5

(1) For other dimensions contact your sales office

Dimensions and Weights





AMR Options

The 220C meter can be equipped with either a reed switch and/or with the Sensus advanced HRI modules. Both interfaces can be fitted in the field on already installed water meters or ordered factory fitted to the meter.

The Reed switch guarantees a cost effective pulse output with a pulse resolution of 2 pulses/litre.

For more advanced applications the 220C can be equipped with a HRI module. Some of the advantages of the HRI module are:

- Detection of reverse flow and therefore exact remote duplication of the counter reading.
- The inductive interface does not suffer from reed switch bounce and, unlike a reed switch; the pulse output is not affected by magnets placed near the meter.
- The pulse value is programmable.

Different modules with integrated functions are available:

1. HRI Pulse Unit (A-version)

The litre pointer activates the HRI allowing a basic resolution of one litre per pulse. The output pulse value can be factory set using the divisor D (e.g. D = 100 means 1 pulse per 100 litres).

The possible pulse output D values are (amongst others):

1 / 10 / 100 / 1000 / 2.5 / 25 / 250

2. HRI Data Unit (B-version)

The HRI Data Unit is a data interface which provides an accurate meter reading as well as the serial or customer ID. The pulse output as described above is also included.

The HRI Data Unit can be connected to a M-Bus network for remote read or a MiniPad for mobile inductive read (MiniBus), both in accordance with the IEC 870.

HRI Data Unit with Sensus protocol can also be supplied on request.

3. Sensus((S))cout Radio Unit

The integrated Sensus((S))cout radio module in conjunction with the reliable HRI sensing technology provides the option of an easy and quick remote reading capability through a mobile or fixed radio network.

For any additional information about the HRI, please refer to the data sheets LS 8100 and LS 3300.

LD 1660 INT / 001-0108 • Subject to change without notice

SENSUS METERING SYSTEMS

Appendix C

The CAB survey used for 12 CAB sites

22 March 2012

Compiled by Crous PA, University of Johannesburg

Community Ablution Block Assessment

Settlement Name: ____________________ **GPS coordinate:** ________ S ________ E **Date:** __________ Time: __________

CAB Environment

CAB identification (Male | Female signs)	Yes	No
CAB TD Number	Yes	No
Stagnant greywater on CAB platform	Yes	No
Door handles work	Yes	No

External Fixtures

Laundry	INT	**Attached Tap**	INT
Taps Leak	INT	Taps Leak	INT
Pipes Leak	INT	Pipes Leak	INT
Taps Missing	INT	Taps Missing	INT

Caretaker Questionnaire

Care taker present — Yes No

When last did you report a broken fitting — Date

When last did EWS Maintenance come out — Date

What did they fix

toilets INT basins INT Showers INT Laundry INT

blockage Yes No

Does the community use the facility? Yes No (INT)

Male CAB

Windows on Roof INT | **Windows on walls** INT

Standing water in CAB Comment

from Toilet	INT	from basins	INT	from showers	INT	from urinal	INT

Internal Fixtures

Toilet	INT	**Basins**	INT	**Showers**	INT	**Urinals**	INT
Pipework Missing	INT	Pipework Missing	INT	Pipework Missing	INT	Pipework Missing	INT
Continuous Leak in bowl	INT	Taps Leaking	INT	Shower head missing	INT	Type of valve	INT
Flush Handle Missing	INT	Taps Missing	INT	Taps Missing	INT	Continuous flow	
Flush mechanism broken	INT	Continuous flow	INT	Continuous flow	INT		
Toilet leak on bown outlet	INT	(taps can't turn off)		(taps can't turn off)			

Blockages Comment

Water Pressure High Average Low

Female CAB

Windows on Roof INT **Windows on walls** INT

Standing water in CAB Comment

from Toilet	INT	from basins	INT	from showers	INT

Internal Fixtures

Toilet	INT	**Basins**	INT	**Showers**	INT
Pipework Missing	INT	Pipework Missing	INT	Pipework Missing	INT
Continuous Leak in bowl	INT	Taps Leaking	INT	Shower head missing	INT
Flush Handle Missing	INT	Taps Missing	INT	Taps Missing	INT
Flush mechanism broken	INT	Continuous flow	INT	Continuous flow	INT
Toilet leak on bown outlet	INT	(taps can't turn off)		(taps can't turn off)	

Blockages Comment

Water Pressure High Average Low

Caretaker Signature ____________________

EWS Signature ____________________

UJ Signature ____________________

Appendix D

The CAB survey used for 37 CAB sites

27 to 31 August 2012

Compiled by Crous PA, University of Johannesburg

Community Ablution Block Assessment form

Compiled 24 August 2012

CAB Environment						
M | F Signs	Y	N	Doors	0	1	2
TD Number	Y	N	Door handles	0	1	2
GW on Platform	Y	N	GW around CAB	Y		N

Laundry Facilities											
Taps	0	1	2	3	4	WW basin pipe leak	0	1	2	3	4
Taps Work	0	1	2	3	4	WW pipe leak	0	1	2		
Taps Leak	0	1	2	3	4	Water on platform	N	M	F		
N = none. M = male. F = Female.											

Time		Date	August 2012		
Settlement Name					
GPS Coordinates					
TB Number					
Caretaker Present	Yes	No			
How many people use the CAB?					
You have keys for CAB? Yes / No	Do you lock it at night?	Yes	No		
When last did you report a fault?					
How long did it take to repair CAB?					
When last did EWS repair CAB?					
What commonly breaks?	T	B	S	U	L
What commonly leaks?	T	B	S	U	L

Male CAB

Male CAB			**Locked**		**Open**		
Wall Windows		Roof Windows		Broken Windows			
Broken external toilet ww pipes	0	1	2	3	4		
Water in CAB	N	T	B	S	U		
Anal Cleansing	TP	NP	O	TP = toilet paper. NP = newspaper. O = other			
N = none. T = toilet. B = basin. S = shower. U = urinal							
Toilets	**0**	**1**	**2**	**3**	Toilet seat	0 | 1 | 2	3
Flush Mech Works	0	1	2	3	**Urinal**	**0 | 1**	**2**
Flush Handle	0	1	2	3	Flush Mech Works	0 | 1	2
Cont Leak in Bowl	0	1	2	3	Valve type	T | P	N
WW Pipe leak	0	1	2	3	Cont Leak in Bowl	0 | 1	2
T = tap. P = Push. N = none.							

Basins	**0**	**1**	**2**	**Showers**	**0**	**1**	**2**
Water pipes connect	0	1	2	WW Blocked	0	1	2
WW pipes leak	0	1	2	Shower heads	0	1	2
Taps leaking	0	1	2	Taps leaking	0	1	2
Taps	0	1	2	Taps	0	1	2
Type of tap	P	C		Type of taps	P	C	B
WW leaking	0	1	2	Tap cont leak	0	1	2
Water Pressure	High		Average		Low		

Female CAB

Female CAB			**Locked**		**Open**				
Wall Windows		Roof Windows		Broken Windows					
Broken external toilet ww pipes	0	1	2	3	4				
Water in CAB	N	T	B	S	U				
Anal Cleansing	TP	NP	O	TP = toilet paper. NP = newspaper. O = other.					
N = none. T = toilet. B = basin. S = shower. U = urinal									
Toilets	**0**	**1**	**2**	**3**	**4**	Toilet seat	0 | 1 | 2	3	4
Flush Mech Works	0	1	2	3	4				
Flush Handle	0	1	2	3	4				
Cont Leak in Bowl	0	1	2	3	4				
WW Pipe leak	0	1	2	3	4				

Basins	**0**	**1**	**2**	**Showers**	**0**	**1**	**2**
Water pipes connect	0	1	2	WW Blocked	0	1	2
WW pipes leak	0	1	2	Shower heads	0	1	2
Taps leaking	0	1	2	Taps leaking	0	1	2
Taps	0	1	2	Taps	0	1	2
Type of tap	P	C		Type of taps	P	C	B
WW leaking	0	1	2	Tap cont leak	0	1	2
Water Pressure	High		Average		Low		

Appendix E

eThekwini Municipality Public Health Bylaws

P.N. 225/1911 (as amended) SECTION D.1

3. (*bis*) (a) Whenever, in the opinion of the Council, any premises are not provided with a permanent or sufficient supply of wholesome water for drinking or domestic purposes, it may cause notice to be served upon the owner thereof requiring him to take water from the Council and, for that purpose, to provide the necessary piping and fittings for connection to any pipeline of the Council situated within a reasonable distance from the premises.

(b) In such notice the Council may prescribe the points upon the premises at which such water supply should be made available to the occupier thereof to constitute a sufficient supply in its opinion.

(c) If the owner of the premises fails, within a period of one month from the date upon which such notice is served upon him, to comply therewith, he shall be guilty of an offence, and the Council shall be entitled by its officers and servants to enter upon the premises and carry out the works required by the notice and to recover the cost thereof from the owner.

(d) For the purpose of this By-law, "the Council" shall include any Committee of the Council to whom the Council may delegate the matters referred to herein pursuant to Section 8 of Ordinance No. 11 of 1934.

(P.N. 9/1949)

Appendix F

CAB Project roles and responsibilities

		eThekwini Water and Sanitation Unit	eThekwini Health Department	Design Consultant	Contractor	eThekwini Housing Department	Ward Councillor	Community
Stage 1	**Preparation Report**							
	Identify settlement demographics					x		
	Identify settlement topographics					x		
	Identify existing water and sanitation services	x		x				
	Identify CAB site locations			x				
	Estimate the required water and sanitation services to be designed for			x				
	Identify all risks			x				
Stage 2	**Concept Stage**							
	Appropriate design standards	x						
	Proving existing WATSAN services			x	x			
	Approval of CAB site locations	x	x	x		x	x	x
	Appointment of Community Liaison Officer	x		x				
	Community Participation		x				x	
	Relocation of Houses		x					
	Costing Estimate			x				
Stage 3	**Design Development**							
	Design details and layouts			x				
	Information on Surveys			x				
	Environmental Management Plan	x						
	Encroachment appliations	x		x		x		
	Health and Safety requirements		x					
Stage 4	**Product Information Stage**							
	Detailed construction drawings			x				
	Layout plans			x				
	specification	x						
	procedures			x				
	Bill of Quantities			x	x			
	Contarctor's target cost				x			
Stage 5	**Construction**							
	Implementation of the contract				x			
	Quality control			x				
	Risk mitigation			x	x			
	As-built drawings	x		x				
Stage 6	**Post Practical Completion Stage**							
	Site inspection	x		x	x			
	Community handover	x					x	

Appendix G

Rand Dollar average annual exchange rates

Year	Rand per US Dollar
2003	7.5474
2004	6.438329
2005	6.36084
2006	6.76525
2007	7.06574
2008	8.36675
2009	8.40756
2010	7.29294
2011	7.25002
2012	8.20638
2013	9.22607

All data based on X-Rates.com (2013) *Monthly Average*. X-Rates.com. Available from: http://www.x-rates.com/average/?from=USD&to=ZAR (Accessed July 2013)

Appendix H

Research outputs

Date	Details
07/2013	Crous P, Haarhoff J & Buckley CA (2013) Can shared facilities be sustainable? Experience from communal ablution blocks in eThekwini, South Africa. WEDC 36th International Conference. 1 – 5 July 2013
06/2013	Crous P, Haarhoff J & Buckley CA (2013) Water demand characteristics of shared water and sanitation facilities: Experiences from community ablution blocks in eThekwini Municipality, South Africa. WaterSA 39 (3). p. 361 - 367
10/2012	Crous P, Buckley CA & Haarhoff J (2012) Designing decentralised wastewater treatment for communal facilities: Preliminary Results from eThekwini's Community Ablution Blocks. Conference on Decentralised Wastewater Management in Asia. Nagpur, India (paper accepted). 20 – 23 November 2012
06/2012	Crous P, Haarhoff J & Buckley CA (2012) Unaccounted Costs And Delays In The Planning Of Interim Water And Sanitation Services In Informal Settlements – Experience From Ethekwini Municipality. Water Research Showcase. Wits University, Johannesburg. 22 June 2012
05/2012	Crous P & Buckley CA (2012) What are the costs associated with the provision of Communal Ablution Blocks? Workshop on Towards an Understanding of the Dynamics of Communal Ablution Blocks in order to Explore Commercial Opportunities for Sanitation Delivery. UKZN, Durban. 23 May 2012
05/2012	Crous P, Haarhoff J, Buckley C, Tavener-Smith L & Roma E (2012) Towards understanding the effect of distance on shared water and sanitation provision. WISA Biennial Conference. CTICC, Cape Town. 6 – 10 May 2012
05/2012	Crous P, Haarhoff J & Buckley C (2012) Determining the water requirements for Community Ablution Blocks: Preliminary Results from a Pilot Project in Frasers Informal Settlement. WISA Biennial Conference. CTICC, Cape Town. 6 – 10 May 2012
08/2011	Crous P (2011) Improving sanitation in informal settlements - Moving from conceptualisation to implementation. Workshop on Exploring The Content And The Nature Of The Right To Basic Sanitation. Constitution Hill, Johannesburg. 12 August 2011

The candidate investigated the critical problem of low sanitation coverage in informal settlements. The focus was on the provision of community ablution blocks, a promising vehicle for rapid sanitation delivery and being piloted in the eThekwini metropolitan area. This option was evaluated throughout its life cycle, covering planning, design, construction, operation and maintenance. A broad array of inputs had to be used and integrated – evaluation of existing units, on-line monitoring of new units, technical interviews and community surveys. The thesis is a comprehensive, authoritative contribution to guide sanitation planners and engineers all over the world.